論文集 Proceedings

第17回世界湖沼会議
17th World Lake Conference

（いばらき霞ヶ浦2018）
(Lake Kasumigaura, Ibaraki, Japan 2018)



人と湖沼の共生
ー持続可能な生態系サービスを目指してー

Harmonious Coexistence of Humans and Lakes
-Toward Sustainable Ecosystem Services-













平成30年

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Tsukuba International Congress Center

主催 茨城県
Host Organizations
Ibaraki Prefectural Government

公益財団法人 国際湖沼環境委員会（ILEC）
The International Lake Environment Committee Foundation (ILEC)

共催 国土交通省，環境省，農林水産省，土浦市，つくば市，かすみがうら市，鉾田市，茨城町，水戸市，霞ヶ浦問題協議会，ラムサール条約登録湿地ひぬまの会

Co-Hosts
Ministry of Land, Infrastructure, Transport and Tourism (MLIT) , Ministry of the Environment (MOE) , Ministry of Agriculture, Forestry and Fisheries (MAFF) , Tsuchiura City , Tsukuba City , Kasumigaura City , Hokota City , Ibaraki Town , Mito City , Council to Resolve Pollution Problem in Lake Kasumigaura , The Association of Lake Hinuma, Registered Ramsar Site

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基調講演

地球環境の変動と湖沼の未来



三村 信男
茨城大学学長

私達にとって身近な自然である湖沼は、周辺からの汚濁流入などと最近顕在化してきた地球温暖化の影響という2つの圧力にさらされています。人と湖沼が共生する、望ましい未来を生み出すために、私達は何をすべきでしょうか。この講演では、湖沼自身のもつ環境適応力を活かすことや、豊かな食材や美しい景観といったトータルな湖沼環境の活用の大切さについて考えます。

Curriculum Vitae

1979年、東京大学大学院工学系研究科博士課程修了（工学博士）。専門分野は地球環境工学、海岸工学。日本とアジア・太平洋諸国における気候変動の影響評価と適応策に関する研究プロジェクトを推進。1992年以降、国連の「気候変動に関する政府間パネル（IPCC）」に専門家として参加し、第2次～第5次評価報告書の主執筆者、総括主執筆者を務めた。国内では、文科省、環境省、国土交通省、外務省、茨城県などの委員を務めた。

職歴

1979年4月	東京大学工学部土木工学科助手
1983年1月	東京大学工学部土木工学科助教授
1984年4月	茨城大学工学部建設工学科助教授
1987年～1988年	カリフォルニア工科大学研究員
1995年4月	茨城大学工学部都市システム工学科教授
1997年～2000年	東京大学大学院工学系研究科教授（併任）
1997年5月	茨城大学広域水圏環境科学教育研究センター教授
2004年9月	茨城大学学長特別補佐
2006年5月	茨城大学地球変動適応科学研究機関機関長
2014年4月	茨城大学副学長
2014年9月	茨城大学学長

Keynote Speech

Future of Lakes under Global Environmental Change



Nobuo Mimura
President, Ibaraki University

Lakes are exposed to two pressures recently; human-induced pressure such as pollution loads discharged from the surrounding areas, and impacts of global warming. What should we do to create desirable future where humans and lakes can coexist harmoniously? In this lecture, I will discuss the way to activate the lake's ability to adapt to the environmental changes, and importance to utilize the ecosystem services fully including rich and varied food and landscape resources.

Curriculum Vitae

Completed the doctoral course in engineering, School of Engineering, the University of Tokyo in 1979 (Doctor of Engineering). Specializing in earth environmental engineering and coastal engineering. Promoting the research project on climate change impact assessment and adaptation in Japan and Asia-Pacific countries. Participated in the UN Intergovernmental Panel on Climate Change (IPCC) as an expert from 1992 and served as a coordinating lead author (CLA) and lead author (LA) for IPCC Assessment Reports (2nd Report to 5th Report). Domestically served as a ministerial committee member for Ministry of Education, Culture, Sports, Science and Technology, Ministry of the Environment, Ministry of Land, Infrastructure, Transport and Tourism, Ministry of Foreign Affairs as well as a prefectural committee member for Ibaraki Prefecture.

Career

April 1979	Research Assistant, Department of Civil Engineering, Faculty of Engineering, the University of Tokyo
January 1983	Associate Professor, Department of Civil Engineering, Faculty of Engineering, the University of Tokyo
April 1984	Associate Professor, Department of Urban and Civil Engineering, College of Engineering, Ibaraki University
1987 to 1988	Research Associate, California Institute of Technology
April 1995	Professor, Department of Urban and Civil Engineering, College of Engineering, Ibaraki University
1997 to 2000	Doubled as Professor, Graduate School of Engineering, the University of Tokyo
May 1997	Professor, Center for Water Environment Studies, Ibaraki University
September 2004	Vice President Extraordinary, Ibaraki University
May 2006	Director, Institute for Global Change Adaptation Science, Ibaraki University
April 2014	Vice President, Ibaraki University
September 2014	President, Ibaraki University

政策フォーラム

ディスカッションの概要

松井 三郎

世界湖沼会議企画推進委員会委員長

湖沼環境保全のためには，住民，農林漁業者，事業者，研究者，行政など湖沼に関わりを持つ全ての人々が，それぞれの立場で役割を果たすことが必要であり，とりわけ，政策責任者は，湖沼環境保全施策の立案・推進を行う役割を担っています。

政策フォーラムでは，国内外の政策責任者による発表と討議を通し，今後の湖沼環境保全施策の方向性について総括していきたいと考えています。

まず，開催地を代表して茨城県知事から霞ヶ浦の現状や新たな取組についてご報告いただくほか，国土交通省，環境省，農林水産省の政策責任者には，各省の立場から水質浄化や生態系保全の取組についてご意見やご議論をいただく予定です。

また，国際連合環境計画から地球規模の幅広い視点でのご意見や，第3回世界湖沼会議の開催地であるハンガリーのバラトン湖開発評議委員会から，霞ヶ浦と似た浅い湖であるバラトン湖の取組や今後の課題等についてご報告いただけるものと期待しています。

Policy Forum

OVERVIEW OF DISCUSSION

Saburo Matsui

Chairperson, 17th World Lake Conference Project Promotion Committee

In order to conserve lake environment, it is necessary for everybody involved in lakes, such as residents, agriculture, forestry and fishermen, business operators, researchers, government administrators, play a role in their respective positions. In particular, the policy directors are responsible for the planning and promotion of lake conservation measures.

In the policy forum, we hope to summarize the direction of future lake conservation measures through the presentations and discussion made by domestic and foreign policy makers.

First of all, on behalf of the venue, Ibaraki prefecture Governor will report about the current state of Kasumigaura and new initiatives. In addition, the Ministry of Land, Infrastructure, Transport and Tourism, the Ministry of the Environment, and tbe Ministry of Agriculture, Forestry and Fisheries Policy Officers plan to give opinions and discuss water quality remediation and ecosystem conservation efforts from the positions of each ministry.

Also, we expect to receive a wide range of global viewpoints opinions from the United Nations Environment Programme. We also expect reports on efforts and future issues from the Balaton Lake Development Council of Hungary, the venue for the 3rd World Lake Conference, where Lake Balaton, is a lake shallow similar to Lake Kasumigaura.

湖沼セッション（国外湖沼）：事例発表

湖沼および湿地の管理に関する課題

Colin Maxwell Finlayson[1,2]

[1]チャールズ・スタート大学土地・水・社会研究所, [2]IHEデルフト水教育研究所

湖沼および湿地の生態学的状況は、地球規模で悪化し続けてきた。これは、このような生態系の悪化を食い止め、回復させるための政策が多くの国々で定められたにもかかわらず生じてきた。このような政策の大半は、湖沼および湿地を含むさまざまな水界生態系を網羅する政府間条約であるラムサール条約を通じて下された決定に応えるものであった。湖沼および湿地の損失と劣化を食い止めることはもちろんのこと、回復することもできなかったということは、ラムサール条約で下された決定が必要とされていたものではなかったか、あるいは、各国政府が行った上記の決定が適切に実行されてこなかったことを意味するだろう。ラムサール条約では2018年に初めて、「世界湿地概況」が公表された。これは、湿地の状況の概要を示し、変化の推進力を特定し、現在進行中の当該生態系の悪化を食い止めるための対応について概要をまとめたものである。今回の発表では、湖沼および湿地がもたらす生態系サービスの損失の影響を重視しつつ、これらの生態系の生物多様性が維持される場合に限って生態系サービスが利用できるということを念頭に置きながら、湿地の状況および悪化の原因に関する情報についてさらに詳しく検証する。次に、国連の持続可能な開発目標を実行するための取り組みという観点からこの情報を考える。本論文の結論には、これらの生態系サービスの価値は損失を食い止めるには不十分であったという認識を含む。このことは、持続可能な開発目標のターゲットを達成する各国の能力に関して疑問を生じさせる。

ケニアが抱える湖沼の管理上の難問の解決

Daniel Olago[1], Jackson Raini[2], Obiero Ong'ang'a[3], Walter Rast[4], Masahisa Nakamura[4]

[1]ナイロビ大学気候変動・適応研究所（ICCA）および地質学科, [2]FlamingoNet, [3]OSIENALA（フレンズ・オブ・レイク・ビクトリア）, [4]公益財団法人国際湖沼環境委員会（ILEC）

ケニアには完全に国内にある湖沼と国境をまたぐ湖沼の両方があり、湖沼及びその流域における人為的利用と活動によって、強烈な圧力下に置かれている。気候変動によって、これらの湖沼の水質、機能、生態系の健全性に関する圧力が高まっている。しかし、ケニアには湖沼管理に包括的かつ持続的に取り組むための具体的な政策や、法制、ガバナンス体制は存在しない。本論文では、この隔たりを取り上げると同時に、保全と開発との均衡を保つ観点から、持続可能な湖沼管理を保証し、自然インフラと建設インフラを支えるために、統合的静水－流水流域管理（ILLBM）方法を適用できる（制度、政策、参加、技術、情報、財政）枠組みを提案する。

Keyword: ILLBM, ガバナンス, 管理, 湖沼

メキシコのレルマ・チャパラ盆地の統合管理の課題

Alejandro Juárez Aguilar

コラソン・ディ・ラ・ティエラ理事長

レルマ・チャパラ盆地はメキシコ中西部にあり、52,320km^{2}の表面積を有する。19の小さな盆地から構成されており、それぞれに主要な川や湖があり、その全体が複雑なプロセスでつながることによって一連の生態系サービスが生じ、1,600万人の人々に恩恵をもたらしている。この盆地は、さまざまな生態系、生産活動、文化がある複雑な地域である。この地域では、主に放牧、作物栽培、工業、商業がGDPの12%を占めているが、水不足が進んでいる。環境サービスフレームワークの観点では、重要な側面に関する情報が少なく、意思決定者と一般住民がこのような情報に十分にアクセスできないことが大きな課題となっている。これを改善するために、1) 主要なデータを充実させる、2) 一般住民がもっと盆地の情報にアクセスできるようにする、3) このプロセスを拡大するためにパートナーシップを構築・強化する、という3つの戦略が推進された。これらのアプローチの一環として、メキシコおよび外国の機関との共同作業で、主にチャパラ湖の小盆地と別の小盆地において、合計94のプロジェクトが完了した。このプロセスの指針とした強力なツールは、湖水盆地統合管理プラットフォームである。依然として困難な問題が残っているが、強力な共同作業であるレルマ・チャパラ盆地の統合管理に利害関係者を関与させるために、この論文では、この戦略の成果、プロセスの困難さとそれに対応した方法を取り上げる。

Keyword: 環境サービスフレームワーク, ILBM, パートナーシップ, 生活

湖沼セッション（国外湖沼）：パネルディスカッション

ディスカッションの概要

中村 正久
（公財）国際湖沼環境委員会副理事長

湖沼セッション（世界の湖沼）では、アジア・オセアニアの湿地・湖沼群、アフリカ大地溝帯の湖沼群、メキシコの大湖沼及びその流入河川流域などに関する事例を報告し、湖沼流域管理をめぐる世界の取組の現状と今後の課題の一端について議論します。事例報告には、湖沼流域における人為活動が引き起こす様々なストレスによる湖沼生態系機能の劣化とその影響、地史学的スケールの湖沼環境の変遷、流域の産官学住民の連携による水質や生態系機能の回復を目指す様々な取組などが含まれます。またパネルディスカッションでは、上記の報告を受け、湖沼と流域の生態系機能の回復にむけた幅広く継続的な取組や、生態系サービス概念を反映した流域ガバナンスの向上、さらにはこういった新しい課題を追求する上で重要な国際連携などの幅広い課題群について、会場からの参加を交えて議論します。

Lakes Session (World Lakes Session): Case Study Presentation

Global challenges for valuing, assessing and monitoring lakes and wetlands

Colin Maxwell Finlayson[1,2]

[1]Institute for Land, Water & Society, Charles Sturt University, [2]UNESCO-IHE, Institute for Water Education, Delft

The status and trends of lakes and wetlands are examined using indicators that illustrate the despite considerable conservation effort over the past 4-5 decades they are in continuing decline. Similar trends are evident for ecosystems and species populations with a few exceptions. These declines have occurred despite the high value of the ecosystem services that lakes and wetlands provide for people. Total economic valuation of lakes and wetlands shows that they are worth more than many other biomes yet pressures from increasing human populations and economic development are still resulting in ongoing declines. This situation is not new ? it has been described on many occasions and in many parts of the world. It is exacerbated as recent data for the area of lakes and wetlands has led to an increase in the total economic value of these ecosystems in comparison to others. More recent efforts to promote the UN Sustainable Development Goals as a way forward for humankind offer renewed hope for lakes and wetlands. This is particularly the case as lakes and wetlands are central to achieving many of the targets that have been agreed under these goals. For the Sustainable Development Goals to be successful there needs to be a concerted effort across sectors and across all ecosystem services. Single attention to particular goals or targets or ecosystem services is unlikely to halt and reverse the declines in lakes and wetlands that we have experienced for many decades. Our challenge is to find a way forward that recognises multiple values and the vital role that lakes and wetlands play in sustaining our landscapes and our future.

UNTANGLING THE MANAGEMENT CONUNDRUM OF KENYAN LAKES

Daniel Olago[1], Jackson Raini[2], Obiero Ong'ang'a[3], Walter Rast[4], Masahisa Nakamura[4]

[1]Professor, University of Nairobi, [2]FlamingoNet, [3]OSIENALA (Friends of Lake Victoria), [4]International Lake Environment Committee Foundation (ILEC)

Kenya has both fully internal and transboundary lakes that have come under intense pressures from anthropogenic uses and activities within the lakes themselves and their catchments. Climate changes are compounding the pressures of the quantity, quality, function and ecosystem health of these lakes. There is, however, no specific policy, legislative and governance regime to address the lakes management in a holistic and sustainable manner. This paper addresses this gap and provides a framework within which an Integrated Lentic-Lotic Basin Management (ILLBM) approach can be applied (institutions, policies, participation, technology, information, and finance) to ensure the sustainable management of the lakes and their supporting natural and built infrastructure in the context of balancing conservation and development.

Keyword: ILLBM, Governance, Management, Lakes

CHALLENGES OF INTEGRATED MANAGEMENT OF THE LERMA-CHAPALA BASIN, MEXICO

Alejandro Juárez Aguilar

Director General, Corazón de la Tierra

Lerma-Chapala basin is allocated in Central-Western Mexico, with a surface of 52,320 km2. It's composed by 19 sub-basins, each one with a main river and/or lake, altogether linked in a convoluted process which generates a series of ecosystem services, benefiting 16 million people. This basin is a complex territory with a variety of ecosystems, productive activities and cultural manifestations, which generates 12% of GDP, mainly by ranching, crop cultivation, industry and commerce, all of this in an area with increasing water scarcity. From the perspective of the Environmental Services Framework this generates strong challenges, due to low generation of information about key aspects, besides the deficient access of decision-makers and general population to such knowledge. In an effort to improve this, three strategies have been fostered to improve such tendency: 1) improvement of key data, 2) increasing access to information of the basin for general public and 3) creation-strengthening of partnerships, in order to escalate the process. As part of these approaches, a total of 94 projects have been completed, mostly in the Lake Chapala sub-basin but also in another sub-basins, in a collaborative effort with institutions from Mexico and from abroad. A powerful tool to guide this process is the Integrated Lake Basin Management Platform. This paper reviews outcomes of such strategies, the difficulties of the process and how they were dealt with, in order to involve stakeholders into the integrated management of Lerma-Chapala basin, a strong collaborative effort with still a defiant way ahead.

Keyword: Environmental Services Framework, ILBM, partnerships, livelihood

Lakes Session (World Lakes Session): Panel Discussion

OVERVIEW OF DISCUSSION

Masahisa Nakamura

Vice President, ILEC

In the World's Lakes Session, each of the three panelists will report on the wetlands and lakes in Asia and Oceania, on the lakes in the African Rift Valley region, and on the largest lake in Mexico and its river basins, and will attempt to give the audience a glimpse of the world's efforts on lake basin management experiences and challenges faced today and in future. The case study presentations will include the deterioration and its impacts on lake ecosystem functions caused by various stresses originating from anthropogenic activities in the lake basin, the environmental changes taking place in reference to the geo-historical time scale, and the collaborative activities for restoration of water quality and ecosystem functions involving government, industry, scientific institutions and lake basin residents. The panel discussion following the above presentations will address the need for wide-ranging and continuous efforts to restore the ecosystem functions in lakes and watersheds, for improvement of basin governance reflecting the concept of ecosystem services, and for international collaboration to pursue emerging and related issues, with participation from the audience.

湖沼セッション（国内湖沼）：事例発表

第４回涸沼環境フェスティバル-ラムサールシンポジウムinひぬま-

谷萩 八重子
第17回世界湖沼会議サテライトひぬま実行委員会副委員長

茨城町は，茨城県のほぼ中央に位置し，汽水湖「涸沼」をはじめとする水と緑の豊かな自然環境と，うるおいある生活環境に恵まれた都市近郊の田園都市です。

茨城町のシンボルである涸沼は，関東で唯一の汽水湖であり，涸沼の名を冠する「ヒヌマイトトンボ」をはじめとして，渡り鳥であるスズガモや，希少種のオオワシ，オオセッカなど，多種多様な動植物の命を育む湖沼です。平成27年5月にはラムサール条約の登録湿地となりました。

しかしながら昭和時代に入ると，流域人口の増加や，経済の発展，護岸整備や干拓工事等の涸沼を取り巻く環境の変化により，水質の汚濁が進行し，本来の涸沼の美しさが損なわれた経緯があります。サテライト会場茨城町では，涸沼の豊かな自然環境を守りつつ，その恵みを持続的に享受するために必要なことを議論するため，第４回涸沼環境フェスティバル-ラムサールシンポジウムinひぬま-を開催しました。

水戸市環境フェア2018　～千波湖のめぐみ～

櫻場 誠二
水戸市環境フェア実行委員会世界湖沼会議サテライト専門部会副部会長

水戸市は、東京から約100キロメートルの距離に位置し，人口約27万人の県庁所在地です。市のほぼ中心に，日本三公園の一つである偕楽園と千波湖があり，梅まつりには多くの観光客が訪れるほか，黄門様で知られる徳川光圀公や最後の将軍慶喜公がいた歴史ある町です。

千波湖は，周辺に多くの自然を残す市民の憩いの場であり，水戸市のシンボルとなっていますが，湖に流入する水量が少ないため，夏季のアオコ発生が問題となっており，これまで行政と市民が連携して，アオコの対策に取り組んできました。

水戸市環境フェアでは，千波湖のめぐみをテーマに，この豊かな自然を未来に引き継ぐためにはどうしたらいいか，市民と取り組んできたビオトープづくりや外来種フィッシングなどの事業を取り入れ，体験を通して学ぶことができるイベントづくりをしました。また，シンポジウムでは，子供と大人で議論を交わし，環境保全の大切さについて認識を深めました。

若者のチカラを～大学生と多様なセクターによる外来水生植物除去活動～

尾﨑 昂希
NPO法人国際ボランティア学生協会（IVUSA）琵琶湖オオバナミズキンバイ対策チーム長

琵琶湖では、2009年に外来水草オオバナミズキンバイが発見された。約7年間で30万㎡まで増殖する強い繁殖力により、2014年に特定外来生物に指定された。2013年当時、オオバナの認知度は低く、除去活動をしていたのは高齢である漁師が中心で、水草除去は重労働であった。この問題に対して、「学生の力で琵琶湖を守りたい」と本協会の学生の想いから活動が始まった。

本協会では、2013年からオオバナ除去活動を企画し、NPO、行政、漁師などと連携して計40回、述べ参加人数9543人により約320tの除去活動を行ってきた。主な取り組みとして、定期的な除去活動や、夏季休暇には3日間、大学生約400人が琵琶湖に集まって除去活動を行っている。さらに、認知度・危機意識向上のために、子どもへの環境学習やフォーラム等で啓発活動も行なっている。これらの活動を通して、外来水草の早期発見・早期除去のできる体制をつくり、完全除去を目指している。

印旛沼流域における水循環健全化を目指した超学際の取り組み

近藤 昭彦
千葉大学環境リモートセンシング研究センター教授

印旛沼は東京大都市圏に位置する閉鎖性水域であり、千葉県の水瓶として機能している。この沼の水質を改善し、水害に強く、活力がある地域を創成するために、千葉県は2001年に印旛沼流域水循環健全化会議を立ち上げ、市民の意見を取り入れながら、2013年に印旛沼流域水循環健全化計画を策定した。この計画の実施に当たっては、複数の課題を流域の視点で総合的に捉え、流域特性を活かしながら、連携による「みためし」手法（順応的管理）により計画を推進してきた。それにも関わらず、沼の水質は改善の兆しを見せていない。一方で多くの流域住民は印旛沼との関係性を意識することは少ない。そこで、様々なステークホルダーが緩くつながる印旛沼流域圏交流会を2014年に結成し、健全化の目的を共有する枠組みを構築した。同じ目的の達成を共有するステークホルダーが超学際を実現し、印旛沼の価値を高め、より良い地域を創ろうとする試みを紹介する。

湖沼セッション（国内湖沼）：事例発表

日立の環境経営と環境保全に寄与する水処理システム

大西 真人
（株）日立製作所水ビジネスユニット水事業部CTO

2015年に国連が定めた持続可能な開発目標，いわゆるSDGsが様々な場面で注目される時代となった。ESG(環境，社会，ガバナンス)は企業価値を評価する指標として重要視され，企業活動においても環境への配慮が極めて大事なものとなっている。日立製作所は社会イノベーション事業を通じて，社会や顧客の課題解決とともに，環境保全にも取り組んでいる。

本発表では，低炭素社会，高度循環社会，自然共生社会の実現に向けた日立の環境経営の枠組みと，環境保全に寄与する窒素，リン除去システムについて紹介する。

琵琶湖における水環境保全の歴史と新たな取組について

小松 直樹
滋賀県理事

琵琶湖再生への取り組みは、1970年代後半、赤潮の発生など水質悪化が見られる中、主婦層を中心とした、リンを含む合成洗剤を石鹸に切り替えようという住民運動に始まる。この運動を受けて、行政も一緒になって取り組み、リンを含む合成洗剤の使用等を禁止する富栄養化防止条例の制定に至った。併せて、下水道の整備や工場排水の規制などを行うことにより、水質改善については一定の成果が見られた。一方で、在来魚の減少と外来魚の増加、水草の大量繁茂など、琵琶湖本来の生態系が失われていることが大きな課題となっている。滋賀県は、2011年に改定した琵琶湖総合保全整備計画（マザーレイク21計画）に基づき、行政、住民、NPO、研究者、企業など様々な主体と協働して、これらの課題に取り組んでいる。さらには、生態系に配慮した水質管理を行うため、全有機物が把握できるTOC（全有機炭素）の導入に向けて、調査研究を進めている。

田沢湖再生に係る取組み～クニマスの里帰りに向けて～

小田野 直光
秋田県仙北市地方創生・総合戦略統括監

田沢湖では、1930年代まで漁業が盛んに行われ、田沢湖の固有種であったクニマスが生息していた。しかし、1940年に、灌漑用水の確保及び電源開発のために、玉川酸性水（上流の玉川温泉のpHは1.2）を田沢湖に導入したことにより、田沢湖の環境は激変し、クニマスの他、多くの生物種が死滅した。クニマスは絶滅したと考えられていたが2010年に山梨県西湖で発見された。これを契機に仙北市では「田沢湖再生クニマス里帰りプロジェクト」を立ち上げ、田沢湖の環境を再生するための活動を行っている。2017年には、クニマスの生態展示の他、田沢湖の歴史、文化、未来へのメッセージを発信する田沢湖クニマス未来館が開館し、環境学習の場として多くの児童・生徒に活用していただいている。今後は、田沢湖を灌漑や発電に利用しつつ、クニマスが田沢湖で再び泳ぐことができる環境を取り戻す動きを加速させることが課題である。

下水由来資源を活用したユーグレナ培養技術の構築

出雲 充
（株）ユーグレナ代表取締役社長CEO

当社はミドリムシの屋外大量培養に世界で初めて成功したベンチャー企業であり、食料問題、環境問題の新たな解決法の創出に挑戦している。ミドリムシを活用した多角的な事業展開に取り組んでおり、健康食品や化粧品事業を収益の柱としている。また、ミドリムシは、体内の葉緑体によって光合成を行う単細胞生物（微細藻類）であり、その光合成の効率が優れている特性を応用し、二酸化炭素の排出削減への活用やバイオ燃料開発、飼料化に関しても研究を進めている。

B-DASHプロジェクトでは、これまで活用されていなかった下水処理場で発生するCO2、リン、窒素を活用してミドリムシを培養し、培養したミドリムシを飼料や肥料に活用できるかを検証した。本プロジェクトで培養したミドリムシを販売するには、関連する法規上の課題を精査し、安全性試験などの検証を行う必要がある。しかし、下水処理場の未利用資源で培養したミドリムシがより付加価値の高い製品に生まれ変われば、持続可能な社会を実現する可能性を広げるだろうと信じている。

湖沼セッション（国内湖沼）：パネルディスカッション

ディスカッションの概要

福島 武彦

茨城県霞ケ浦環境科学センター長

湖沼セッションのパネルディスカッションは、国内湖沼を対象に持続可能な生態系サービスの持続的な利用を目指して、流域内及び流域間連携を推進するために各主体がどう連携してゆくべきかを討議することが目的です。まず、国外湖沼セッションのまとめ役である中村氏から世界湖沼の抱えている環境問題、今後の課題を紹介してもらいます。次に、環境省、国土交通省の担当者が新たな施策や取組状況を説明し、また研究者が湖沼流域の保全に向けての連携・協働の例や生態系を含めた新たな指標を概説してくれます。それらをベースに、1) 日本・世界の湖沼が抱える、抱えるであろう問題は何か、2) 生態系サービスの持続的な活用方法はあるか、3) これらのためにどのような流域内外の連携が必要か、を議論します。

湖沼における生態系保全を考慮した新たな水環境の指標について

熊谷 和哉

環境省水・大気環境局水環境課長

国内湖沼の水質は、湖沼計画等に基づき陸域からの流入負荷量を削減してきたものの、水質環境基準の達成率が５割程度と横這い傾向となっていることに加え、湖底の貧酸素化や水草の繁茂、在来魚介類の減少といった課題もあり、従来の環境基準の達成状況だけでは水環境の現状が国民に伝わりづらいとの指摘があった。

このような状況を改善し、湖沼水環境の目標や評価を国民にわかりやすいものとするため、環境省では、2016年３月に生態系保全の観点を取り入れた新たな水環境の指標（底層溶存酸素量及び沿岸透明度）を導入した。

底層溶存酸素量は、魚介類等が生息できる底層溶存酸素を確保する観点から、生活環境項目環境基準として、沿岸透明度は、水生植物及び親水利用の保全の観点から、地域の合意形成により設定する地域環境目標として設定した。

新たな指標を活用した施策が浸透し、各地の湖沼で望ましい水環境が実現されるよう、引き続き取組を行っていきたい。

国土交通省における湖沼環境保全の取組

岩井 聖

国土交通省水管理・国土保全局河川環境課企画専門官

日本では、高度経済成長期に工業化や都市化の進展に伴い河川や湖沼の水質が悪化し、生態系へも影響を及ぼした。国土交通省では、水質の悪化が著しい河川、湖沼において、河川管理者、下水道管理者や市町村等の関係機関が連携して改善の取組を進めてきた。その結果、河川や湖沼における水質は少しずつ改善しつつある。

また、河川や湖沼は、森林や農地、都市などを連続した空間として結びつける、国土の生態系ネットワークの重要な基軸である。国土交通省では、河川が本来有している生物の生息・生育・繁殖環境等の保全・創出するための「多自然川づくり」に取り組んでいる。現在では、川の中を主とした「多自然川づくり」だけでなく、流域へと視点を広げ、多様な主体とも連携しながら生物多様性の保全を通じ魅力的で活力ある地域づくりを推進しており、これらの取組を紹介する。

国内湖沼における流域内連携の実態

井手 慎司

滋賀県立大学環境科学部教授

国内湖沼の保全に関する流域内連携の実態を把握するために，特定湖沼に係る保全計画を有する全国の地方自治体に対して，同計画内で実施された行政と行政以外の主体とによる連携事業の有無と事業内容を尋ねる調査を2018年に実施した．その結果，連携事業における連携の形態は大きく「STEP1:不特定多数の個人・団体との連携（25事例）」「STEP2：協議会等との連携（35事例）」「STEP3:財政・広報支援（15事例）」「STEP4：共同企画・運営（14事例）」「STEP5：役割分担あり（26事例）」の５つに分類できることがわかった．また，連携の形態は，それぞれの湖沼が抱える問題が多様になるにつれ，多様化する傾向がみられた．

湖沼セッション（国内湖沼）：パネルディスカッション

社会-生態システムの健全性を指標とした流域ガバナンス

奥田 昇
総合地球環境学研究所准教授

急速な経済成長に伴う水辺環境の劣化や水文化に対する関心の低下は、アジアの流域社会が抱える共通の問題と位置づけられる。他方、流域社会を構成する集落は、地域固有の社会的課題を抱える。地域と流域の社会・環境問題をともに解決するには、社会-生態システムの健全性を志向する価値の転換と社会協働のしくみが必要である。演者が提案する流域ガバナンスは、健全性を「生物多様性」「栄養循環」「しあわせ（Well-being）」の３つの指標で評価する。また、流域社会の多様な主体の協働を促すには、行政や科学者が主導する従来の流域管理に地域住民主導の文化的アプローチを組み込むことが有効である。パネルでは、インフラ型流域社会のモデルである琵琶湖と高負荷型流域社会のモデルであるフィリピン・ラグナ湖を対象として、身近な水辺環境の文化的価値に気づき、保全・継承する活動を通して、地域の環境やしあわせを向上するアクションリサーチの実践例を紹介する。

Lakes Session (Japanese Lakes Session): Case Study Presentation

THE FOURTH HINUMA ENVIRONMENT FESTIVAL RAMSAR SYMPOSIUM IN HINUMA

Yaeko Yahagi

Vice chair, Executive Committee of 17th World Lake Conference Satellite Hinuma

Ibaraki Town, located at the center of Ibaraki Prefecture, is a rural city with the peaceful living atmosphere that is blessed with a rich natural environment of water and greenery, such as “Hinuma Lake.” Hinuma, the symbol of Ibaraki Town, is the only brackish water lake in the Kanto region of Japan (Tokyo metropolitan area). Represented by “Hinuma Ito-Tombo (Mortonagrion hirosei)” which is named after the lake, it provides habitats for the wide variety of wild species such as the migratory scaup “Suzugamo,” “O-washi (Steller’ s Sea Eagle),” “Osekka (Marsh grassbird)” and many other flora and fauna. It was designated of the Ramsar Convention (Convention on Wetlands of International Importance especially as Waterfowl Habitat) in May 2015.

However, after entering the Showa era (after 1925), once Hinuma’s water quality was deteriorated, and the original beauty has been impaired, due to the changes in the environment such as the increase of population of the river basin, economic growth, revetment maintenance, and reclamation project. On September 30th, the Ibaraki Town, as one of the satellite venue, we have hosted the fourth Hinuma Environment Festival: Ramsar Symposium in Hinuma. We discussed our required action for conservation of the rich natural environment of Hinuma and for receiving the bounty of its natural resource sustainably.

MITO CITY ENVIRONMENTAL FAIR 2018 ～GIFTS OF SENBA LAKE～

Seiji Sakuraba

Vice Chair, World Lake Conference Satellite Working Group, Executive Committee of Mito City Environmental Fair 2018

Mito City is the prefectural capital located at a distance of about 100 kilometers from Tokyo with a population of about 270,000 people. Roughly in the center of the city is Kairakuen Park, which is one of the three great gardens of Japan, and Senba Lake. Mito City is a historical city where Mitsukuni Tokugawa, who is known as Mito Komon, and Yoshinobu Tokugawa, who was the last shogun, lived and many tourists visit its plum festival.

Senba Lake is a place where people can relax surrounded by nature and symbol of Mito City, however, because of the little water flowing into the lake, the outbreak of blue-green algae is an issue during summer months and the government and public have been engaged in measures against blue-green algae together.

For the Mito City Environmental Fair, a biotope challenging the public what to do to take over the responsibility for this rich nature in the future and events incorporating programs including fishing of non-native species and allowing the public to learn from experience were created. For the symposium, grown-ups and youths also had an earnest discussion and increased their awareness of the importance of environmental conservation.

THE COOPERATION WITH VARIOUS ORGANIZATIONS BY UNIVERSITY STUDENTS IN REMOVING ACTIVITY OF INVASIVE ALIEN AQUATIC WEED IN LAKE BIWA, JAPAN

Koki Ozaki

Invasive Alien Aquatic Weed Removal Management Team Manager, Nonprofit Organization International Volunteer University Student Association(IVUSA)

In Lake Biwa, Water primrose Ludwigia grandiflora was first found in 2009. It reached 300,000 square meters within 7 years. Because of an amazing ability to propagate, it was designated as a specific alien species in 2014. In 2013, almost all people don’t know the problem, commercial fishermen who were elderly were mainly engaged in removal activities, and removal of aquatic plants was a heavy work.Against these problems, the activities began with the desire of student to save Lake Biwa by the power of young university students.

We,IVUSA (International Volunteer University Student Association), started activities from 2013. We have carried out 40 removal events in which a total of 9,543 persons were paricipated including administrative officers, regional environmental organizations, commercial fishermen, and local residents. As much as 320 tons of water primrose was successfully removed. As a main activity, we regularly conduct removal activities and we organized large scale removal events by more than 1,000 students for 3 days every summer vacation.Also we have tried to raise regional awareness and crisis consciousness of this problem by carrying out an education for children and exhibitions for stakeholders.Through these activities, we are aiming for complete removal by establishing an organization that can detect and remove it at an early stage.

Lakes Session (Japanese Lakes Session): Case Study Presentation

TRANSDISCIPLINARITY AIMED AT SOUND HYDROLOGIC CYCLE IN INBANUMA WATERSHED

Akihiko Kondoh

Professor, Center for Environmental Remote Sensing, Chiba University

Inbanuma (Inba Lake) is a closed lake located in Tokyo metropolitan area, and serves as a water resources of Chiba Prefecture. To improve water quality and to create a safety in flood, vigorous and comfortable region to live in, Chiba Prefecture founded a council for sound hydrologic cycle in Inbanuma watershed in 2001. Taking opinions of citizens, action plan for improving the environment in Inbanuma watershed was decided in 2013. The activity includes collaborations among different sectors, such as "MITAMESHI Activity"(adaptive management), with the holistic viewpoint subsuming multiple subjects in the watershed. Despite all the effort, water quality in Inbanuma did not show the signs of improvement. On the other hand, most of the residents in the watershed do not notice the relationship to Inbanuma. So, the exchange meeting of Inbanuma watershed was established in 2014 to loosely connect all the stakeholders who share the achievement of the objectives for sound hydrologic cycle and regional creation in Inbanuma watershed. This is a trial for the realization of transdisciplinarity that has been targeted in SDGs(Sustainable Development Goals) and Future Earth(scientific framework to establish SDGs).

HITACHI ENVIRONMENTAL MANAGEMENT AND WATER TREATMENT SYSTEM FOR CONTRIBUTING TO ENVIRONMENTAL CONSERVATION

Makoto Onishi

Chief Technology Officer, Water Solutions Division, Water Business Unit, Hitachi, Ltd.

It became the times when sustainable development goals, so-called SDGs which the United Nations set in 2015, attracted attentions in various scenes. ESG (environment, society, governance) is regarded as important for an index to evaluate a corporate value, and consideration for the environment becomes extremely important in the corporate activity. Hitachi, Ltd. promotes resolutions of social/ customer issues through our social innovation business and works on environmental conservation.

In this presentation, I introduce the new framework for Hitachi environmental management which realizes low-carbon, resource efficiency, and natural harmonizing society. Furthermore I introduce the nitrogen and phosphorus removal system from the sewage or lakes water for contributing to environmental conservation.

THE HISTORY OF LAKE BIWA'S WATER ENVIRONMENT CONSERVATION AND SHIGA'S NEW INITIATIVES

Naoki Komatsu

Director General, Shiga Prefectural Government

The initial push toward restoring the water quality of Lake Biwa came from housewives who took a leading role in initiating a public movement to make the switch from synthetic detergents to organic soap in the late 1970s, when fresh water red tides were observed. In response to the movement, the Shiga Prefectural Government established an ordinance prohibiting the use of synthetic detergents. It also improved sewers and created regulations on industrial waste water, improving water quality to a certain level. However, there are still many problems regarding loss of ecosystems, such as the decrease in endemic species, the increase in invasive species, and the overgrowth of waterweed. Based on the Lake Biwa Comprehensive Conservation Plan (Mother Lake 21 Plan), which was revised in 2011, the Shiga Prefectural Government has promoted initiatives to address these problems in collaboration with various parties such as governments, citizens, NPOs, researchers and companies. In addition, Shiga is conducting investigations and research toward introducing the use of TOC (or Total Organic Carbon), with which all organic matter can be measured, in order to manage water quality and preserve the ecosystem.

Lakes Session (Japanese Lakes Session): Case Study Presentation

ACTIVITIES FOR ENVIRONMENTAL RESTORATION OF LAKE TAZAWA -TOWARDS HOMECOMING OF KUNIMASU-

Naoteru Odano

Director-General for Regional Revitalization and Comprehensive Strategy, Semboku City, Akita Prefecture

In Lake Tazawa, fishing has been actively carried out until 1930's and the endemic species in Lake Tazawa, Oncorhynchus kawamurae (common name "Kunimasu trout"), inhabited. However, most of the species inhabited in Lake Tazawa, including Kunimasu, died after introduction of highly acidified water of Tamagawa river to Lake Tazawa for irrigation and electric-power generation in 1940. In 2010, it was confirmed that Kunimasu, which had been believed to be extinct, are living in Lake Saiko, Yamanashi Prefecture. On this occasion, Semboku city has started "Restoration of Lake Tazawa and Kunimasu Homecoming Project" and has been carried out activities for environmental restoration of Lake Tazawa. In 2017, a facility to display Kunimasu and dispatch information of history and culture of Lake Tazawa and messages to future was opened. The facility is also utilizing as a place of environmental study for children and students. One of future issues is to accelerate activities for restore environment that Kunimasu may swim in Lake Tazawa again continuing utilization of Lake Tazawa for irrigation and electric-power generation.

WASTEWATER AS A RESOURCE: MICROALGAE CULTIVATION IN A SEWAGE TREATMENT CENTER

Mitsuru Izumo

CEO, euglena Co.ltd.,

We, euglena Co., Ltd. is a venture company which had reached the world's first successful outdoor mass culture of edible microalgae Euglena. We are trying to create new solutions for global food issues and environmental problems with it. We have been working on multifaceted business development primarily in healthy food and cosmetics areas. At the same time, as Euglena is a single-celled organism that photosynthesizes highly efficiently, we have been studying for addressing CO2 emissions reduction as well as for utilizing Euglena in biofuel and feed.

The B-DASH Project in Saga prefecture was conducted to test if unused resources in sewage treatment such as CO2, Nitrogen and Phosphorus can be used for Euglena cultivation. Then we investigated whether such Euglena can be used for feed or fertilizer as high valued products. In order to sell such Euglena in feed or fertilizer markets, it is necessary to pass safety tests which are required by legal authorities. Once we reach the realization of value-adding utilization of unused resources in wastewater, it will broaden opportunities of environmental businesses for a sustainable society.

Lakes Session (Japanese Lakes Session): Panel Discussion

OVERVIEW OF DISCUSSION

Takehiko Fukushima

Director, Ibaraki Kasumigaura Environmental Science Center

"Lake Session (Japanese lakes)" is held to discuss within-basin and between-basin cooperation activities for sustainably utilizing the blessings of ecosystem services from Japanese lakes. At first, Dr. Masahisa Nakamura, vice President of ILEC, will introduce the present and future environmental problems in world lakes. Next, the government officers from ME and MLIT show new policies and programs in lake management, and the researchers explain the examples of cooperation activities and new indices for ecosystem service. Based on these information, we shall discuss 1) what problems Japanese and foreign lakes are facing or will face? 2) how do we utilize ecosystem services sustainably? and 3) what types of within-basin and between-basin cooperation activities are needed for it?

NEW INDEXES OF WATER ENVIRONMENTS CONSIDERING ECOSYSTEM CONSERVATION IN LAKES

Kazuya Kumagai

Director Water Environment Division, Environmental Manegement Bureau, Ministry of the Environment

Although there has been reduction in inflow load from land based on the lake plan, the achievement ratio of water environmental quality standards of domestic lakes has been stagnant at approximately 50%. There are also problems of poor oxygen water mass in bottom layer, overgrowth of aquatic plants, and decrease in native aquatic life, and there are indications that there is difficulty in conveying the current situation of water environment only using achievement ratio of past environmental quality standards.

In order to improve the situation and make the goals and evaluation of lake water environment easier to understand for the public, the Ministry of the Environment implemented new water environment indexes (amount of bottom layer dissolved oxygen and Littoral water transparency) in 2016 March.

Amount of bottom layer dissolved oxygen was set as living environmental standard in terms of securing dissolved oxygen for inhabiting aquatic life, and Littoral water transparency was set as a regional environmental objective in terms of recreational use and conservation of aquatic plants.

We will continue approaches to penetrate measures utilizing new indexes and to achieve favorable water environment in various lakes.

ENVIRONMENTAL CONSERVATION EFFORTS IN LAKES BY THE MINISTRY OF LAND, INFRASTRUCTURE, TRANSPORT AND TOURISM

Masashi Iwai

Senior Deputy Director, River Environment Division, Water and Disaster Management Bureau, Ministry of Land, Infrastructure, Transport and Tourism

During the period of high economic growth in Japan, the quality of the water in rivers and lakes has worsened with the progress of industrialization and urbanization, and this has influenced ecosystems. In cooperation with the relevant organizations such as sewer managers, local governments and river administrators, MLIT has worked to improve water quality in the rivers and lakes where the worsening of the water quality has been remarkable. As a result, the quality of the water in rivers and lakes has been gradually improving.

Rivers and lakes are vital components of the nation's land ecological networks that connect forests, farmlands and cities as integrated areas. MLIT is working to "nature-oriented river works" in order to conserve and create such things as the habitat, growth and breeding environments for living things that are naturally living in the rivers. Currently, in cooperation with diverse entities, MLIT has expanded its viewpoint from not only "nature-oriented river works", which mainly focused on rivers, to promoting the creation of attractive and dynamic river basin areas through the conservation of biodiversity, and introducing such initiatives.

Lakes Session (Japanese Lakes Session): Panel Discussion

LAKE WATERSHED COLLABORATION IN JAPAN

Shinji Ide

Professor, School of Environmental Science, the University of Shiga Prefecture

To understand the current situation of watershed collaboration for lake conservation in Japan, the authors conducted questionnaire survey in 2018. In the survey, we asked local governments having a conservation plan for a specific lake if there were any collaborative projects with citizens or citizen groups carried out within the plans and, if any, what kinds of projects were they? As a result of the survey, it was revealed that types of collaboration in those projects could be classified into five steps, namely, Step 1: collaboration with unspecified number of individuals and groups (25 cases), Step 2: one with council-type organizations (35 cases), Step 3: financial and public relations support (15 cases), Step 4: joint planning and implementation (14 cases), and Step 5: division of roles (26 cases). It was also suggested that types of collaboration tend to be more diverse and varied as the problems facing respective lakes become diversified.

WATERSHED GOVERNANCE TO ENHANCE SOCIAL-ECOLOGICAL HEALTH

Noboru Okuda

Associate Professor, Research Institute for Humanity & Nature

Degradation of aquatic environments and loss of interests in aquatic culture are considered environmental issues common in watersheds of economically growing Asia. Within the watershed, each of local communities has a site-specific social issue. Toward the solution of both social and environmental issues, we need transformation of values oriented to social-ecological health of watershed system through social involvement in environmental governance. Here I propose the watershed governance to enhance the social-ecological health, which is assessed by three indices, biodiversity, nutrient cycling and well-being. For diverse stakeholders to be involved in this governance, it is effective to incorporate community-based cultural approach into the science-based watershed management. For this purpose, my project practices action research to empower local communities for conservation of the familiar nature of wetlands through sharing their indigenous cultural values among community members, especially between generations, which results in enhancement of the above three indices at the local scale. In my talk, I introduce case studies in Lake Biwa of Japan and Laguna de Bay of the Philippines, which are considered a model for infrastructure-oriented and high-loading societies, respectively, in order to discuss applicability of this governance approach to a variety of watersheds in Asia.

霞ヶ浦セッション：事例発表①

霞ヶ浦の水環境保全についての茨城県の取組み

桑名 美恵子

茨城県県民生活環境部次長

霞ヶ浦は，茨城県の南東部に位置し，豊かな水と多様な自然環境を有しており，北西にそびえる筑波山とともに，茨城県を代表する美しい景観を形づくっている。また，水道用水，農業用水，工業用水を供給するとともに，豊かな水産資源にも恵まれている。

一方で，霞ヶ浦は，流域に100万人近い人々が住み，農業や畜産などの産業も盛んであることなどから，富栄養化の原因物質である窒素やりんなどが流入し，水質汚濁が進行しやすい湖である。霞ヶ浦の水質改善のため，茨城県では，湖沼水質保全計画を定め，生活排水対策や，農地・畜産対策などによる汚濁負荷量の削減や，情報発信・環境学習・啓発活動などを推進している。さらに，計画に定める事項を確実に実施するため，霞ケ浦水質保全条例を制定して，流域すべての人々が生活と生産あらゆる面で水質保全に取り組むことを規定するとともに，森林湖沼環境税を導入し，取組みを加速するための財源として活用している。

霞ヶ浦における水環境改善の取り組みについて

辰野 剛志

国土交通省関東地方整備局霞ヶ浦河川事務所長

霞ヶ浦の水環境は私たちに多様な恩恵をもたらしています。霞ヶ浦流域は、かつては洪水被害や塩害が頻発していました。そのため、治水事業により地域の安全・安心を高め、利水事業によって安定した水利用を可能としてきました。流域の都市化や社会基盤整備が進む一方で、水質の汚濁、湖岸植生帯の減少及び湖水浴場の消失など、水環境の課題が顕在化しました。これらの課題に対応するため、霞ヶ浦河川事務所では、「霞ヶ浦河川整備計画」、「霞ヶ浦に係る湖沼水質保全計画（第７期）」を踏まえ、霞ヶ浦の水環境がもたらす多様な恩恵を今後も持続的に享受し、未来の子供達に引き継ぐため、水質改善対策、自然環境の保全と再生、人と河川との豊かなふれあいの確保、景観の保全・形成、環境教育の推進、流域全体を視野に入れた総合的な河川管理を地域住民・流域が一体となり、連携・協働しながら進めていきます。

霞ヶ浦の生態系サービスとその経済評価

江幡 一弘

茨城県霞ケ浦環境科学センター副センター長

多くの人々は霞ヶ浦から多様な恩恵（生態系サービス）を受けています。将来にわたり霞ヶ浦の生態系サービスを持続的に利用していくためには，どのようなサービスをどのくらい受けているのかを把握し，湖沼管理に結びつける必要があります。そこで，霞ヶ浦の生態系サービスの項目を整理し，サービスの享受量の変遷及び現在の経済的な価値を検討しました。その結果，享受量は水利用などの人間活動を豊かにする項目が増加し，魚や水生植物などの生物に関する項目が減少していることが明らかとなりました。また，ある生態系サービスの価値を上げようとすると、別の生態系サービスの価値が下がることも明らかとなりました。人と湖沼が共生していくための課題を解決するために，霞ヶ浦に関わるすべての関係者が集まって議論していくことが重要です。

霞ヶ浦セッション：事例発表②

これからも『霞ヶ浦の恵み』を皆さんにお届けします－霞ヶ浦の漁業を将来へ－

伊藤 一郎

霞ヶ浦漁業協同組合霞ヶ浦水産研究会会長

古くから霞ヶ浦ではワカサギ，シラウオ，川エビなどを対象とした漁業が盛んに行われ，漁業者は『霞ヶ浦からの恵み』と共に暮らしてきました。

一方で霞ヶ浦は様々な社会活動を支えるための水源地としてその姿を大きく変え，魚介類の生息場所となる水生植物帯の減少など漁場環境も大きく変化したことにより，漁業を安定して経営していくことが厳しくなってきています。

そこで，今ある環境の中で漁業を継続し，霞ヶ浦の恵みを次世代に引き継いでいけるよう，私たち漁業者は資源状況に応じて操業時間などのルールを決め，資源の適切な利用に努めています。また，霞ヶ浦の代表魚であるワカサギを増やすための人工ふ化事業や，水生植物帯の保全活動など漁場環境の改善にも取り組んでいます。

これからも霞ヶ浦の恵みが将来にわたり持続し，その美味しさを皆さんに届けることができるよう努めていきますので，ご理解とご協力をよろしくお願いします。

霞ヶ浦の恵みを活かしたレンコン生産

飯田 公巳

JA土浦蓮根本部会

レンコンは縁起物として，正月や節句を中心に需要がある作物です。レンコンは，栽培するにあたって，豊富な水資源と有機物に富んだ豊かな土壌が必要不可欠です。そのため，日本国内におけるレンコンの産地は非常に限られています。

茨城県の霞ヶ浦周辺の低湿地帯においては，土浦市，かすみがうら市を中心として，豊富な水資源と豊かな土壌を活かして，日本一のレンコン産地が形成されています。

今回は霞ヶ浦の恵みを活かしたレンコン生産について，生産者の目線から，産地の実態や，生産現場における取り組みについてご紹介します。

霞ヶ浦の水と鹿島製鐵所のかかわり

但田 賢哉

新日鐵住金（株）鹿島製鐵所安全環境防災部環境防災室室長

- 新日鐵住金は、3つのエコ、すなわちエコプロセス（つくるときからエコ）、エコプロダクツ（つくるものがエコ）、エコソリューション（世界へ広げるエコ）を推進していくことで、持続可能な社会の構築に貢献していく考えです。
- 鹿島製鐵所は薄板や厚板、鋼管、H形鋼を製造しており、年間700万トンを超える粗鋼生産能力があります。
- 鉄は鉄鉱石を高炉で溶かして連続鋳造機で固めた後に熱間圧延機で延ばして作られます。その製造過程で水は欠かせないものであり、高温の鉄から設備を守る冷却用の役割や鉄の品質を高めるために鉄の表面を直接洗浄する役割などがあります。
- 水は1日約260万トン使用しています。高温の鉄の冷却や洗浄により蒸発してしまう水もありますが、残りは殆ど回収し水資源の有効活用をしており、そのリサイクル率は90％以上です。蒸発などのロス分を補充するための新たな水は、霞ヶ浦から1日約23万トン供給されています。

霞ヶ浦沿いのサイクリングロードを活用した地域活性化事業について

今野 浩紹

（株）かすみがうら未来づくりカンパニー代表取締役

地域の人口減少や産業衰退などの社会問題が注目されるなか、地方創生策として各自治体でさまざまな取り組みが実施されています。茨城県かすみがうら市では、霞ヶ浦湖岸沿いの自転車道「つくば霞ヶ浦りんりんロード」に多くの人が訪れることに着目。継続的な交流人口の拡大を目指し、株式会社JTB関東、株式会社博報堂、株式会社ステッチの3社にて、地域資源を活用したサイクリングプログラムの開発が行われました。プログラムの開発を経て、事業を推進していくために、かすみがうら市、株式会社筑波銀行、株式会社ステッチが出資し、2016年4月に「株式会社かすみがうら未来づくりカンパニー」が設立されました。

地域を巡るサイクリングプログラム「かすみがうらライドクエスト」の運営を主軸としながら、地産地消レストラン「かすみキッチン」、地産品を販売する「かすみマルシェ」の3事業を通し、かすみがうら市の魅力を体験できる取り組みを目指しています。

霞ヶ浦セッション：事例発表②

生活学校で取り組んだ水質浄化の実践報告（生活者の視点からの提案）

藤原 正子
茨城県生活学校連絡会会長

昭和49年に潮来市に移り住み，地下水からくみ出された水道水の美味しさに感動しました。現在の霞ケ浦の水質の改善をし，以前のような美味しい水を飲みたいと考え，実践してきました。

「事例1」洗剤も使わず細かい汚れもきれいに落とすアクリルたわし作り。イベント開催時に配布し，PRを行っています。

「事例2」風呂の残り湯の再利用の実践。各種のイベントでも呼びかけています。

「事例3」廃油と凝固剤だけで使ったエコキャンドル作り。潮来市やつくば市等で実践
しています。

「事例4」「食のライフスタイルチェックをしよう」の意識調査や「捨ててしまった簿」
の結果報告。

一人ひとりがわずかでも無駄を減らし，もったいない気持ちを大切にする事が，霞ケ浦の水質改善につながると信じています。私達人間は、地球環境と切り離せないと思うからです。

霞ヶ浦セッション：事例発表③

世界湖沼会議に参加する市民の活動

滝下 利男
世界湖沼会議市民の会'18副会長

前回の第6回世界湖沼会議の際、市民グループが連携して対応し、大会の成功に寄与しその後の環境保全や地域活動を活発化させ、また相互に知り合うきっかけとなった。この市民グループ連携の重要性に鑑み、第17回世界湖沼会議の開催を機に世界湖沼会議市民の会'18として結成した。市民の立場から世界湖沼会議に協力するとともに、会員相互の連携と協力により、茨城県内各地で世界湖沼会議に関連する諸活動を展開し、成功に導こうとするものである。ここでは市民グループが中心となって企画・実施したイベント、また日頃実施している活動を紹介する。

霞ヶ浦の恩恵を未来に引き継ぐために　私たちのパートナーシップ

阿部 彰
（一社）霞ヶ浦市民協会第17回世界湖沼会議サテライトつちうら実行委員会委員長

サテライトつちうらは、第1弾として泳げる霞ヶ浦フェスティバル、第2弾として霞ケ浦環境科学センター夏まつり、そして本会議開催直前に第3弾としてメイン大会を開催した。第1弾は、前回の世界湖沼会議を契機に市民などにより毎年開催されており、今年は6校の高校生により霞ヶ浦やその流域の将来像について検討を行った。第2弾では、前回の世界湖沼会議を契機に設立された霞ケ浦環境科学センターを舞台に、特別講演及び漁業者・農業者・林業従事者・里山保全のNPO及び大学生が、霞ヶ浦の魅力や保全、そして未来を語り、霞ヶ浦の将来像について検討するとともに，子ども向けのクイズ大会も行った。第3弾では、霞ヶ浦に関わる多くの市民団体、事業者や行政関係者などがこれまでの活動を共有し、認識し、各団体が共通して目指せる「霞ヶ浦の将来像」について話し合いを行った。引き続き，いつまでも全ての人々に愛される霞ヶ浦になることを目指していく。

霞ヶ浦の魚食文化の再構築からの新たな人間と自然との共生システム

千葉 隆司
かすみがうら市歴史博物館係長（学芸員）

人間と自然との共生関係について考えるにあたり、霞ヶ浦において重要なキーワードとなるのが漁業と魚食文化である。これらは霞ヶ浦の自然環境と密接な関係で結ばれているが、人間社会の発展により、その関係に変化が生じてきている。かすみがうら市では、漁業と魚食文化など民俗文化から新たな「霞ヶ浦と人間」との共生関係を考えるための事業を歴史博物館を中心に実施してきた。本年のサテライトかすみがうら事業もその流れを受けるもので、帆引き船フェスタ2018with世界湖沼会議、帆引き船講演会＆帆引き船シンポジウム「帆引き船と霞ヶ浦の魚食文化」、特別展「日本漁業史の中の帆引き船」を開催した。観光帆引き船をシンボルに、霞ヶ浦の魚食のブランディングを図り、鮮魚販売、名産品・郷土料理の開発、帆引き船観光ツアーなどになどによる漁業と魚食文化の再構築が、霞ヶ浦の豊かな生態系と人類の共存、その持続的な環境づくりにつながっていくものと考えた。

自然と共に歩むまち ～鉾田～

大木 繁夫
鉾田市まちづくり推進会議自然環境部会部会長

鉾田市は、鹿島灘や北浦、涸沼に代表される水辺や広大な田畑、洪積台地の里山に囲まれた豊かな自然を有し、農業を主要産業としています。かつて水運の中継地として栄えた歴史があり、湖沼・湿地と人々の居住地域が近いことも特徴です。市では、第二次総合計画及び環境基本計画において自然資源保全活用を重要項目の一つに位置づけ、その一環として流入河川の水質向上などに取り組んでいます。また、市民団体においても、貴重な自然環境を保全・再生するとともに、生態系サービスとして経済活動に活用するための取り組みを実践しています。今回の鉾田市世界湖沼会議サテライト会場では、そういった活動や現地の様子を鉾田市内や茨城県内、国内外の方々に知っていただくために様々なイベントを企画し、成功裏に終了しました。今後も、『自然と共に歩むまち』を目指して、官民協働で様々な課題に取り組んで参ります。

霞ヶ浦セッション：事例発表③

宍塚の谷津田における古代米づくりと淡水プランクトンの季節的変動

助川 太一

茨城県立竹園高等学校高校生

霞ヶ浦流域にある土浦市宍塚大池周辺の里山で谷津田を開墾し，無農薬無肥料の自然農法による古代米づくりに取り組んだ。宍塚の里山は2015年に生物多様性保全上重要な里地里山として選定されている。地下水の涵養能力をもつ谷津田は，大型の流入河川が少ない霞ヶ浦では重要な水源地であり，野生生物にとっても重要な生息地となっている。谷津田は耕作がしにくいことに加えて，農家の減少，都市化の進行，農業従事者の高齢化などを背景として耕作放棄地が急速に広がり，多数の生物がすみかを失うと，里山全体の生態系のバランスが崩れていく。荒れ地を開墾し米づくりをすることは里山の環境保全活動につながり，生物の多様性を維持することにつながる。古代米づくりに取り組みながら水質調査も併行して実施し，谷津田に発生するプランクトンについて，発生する種類が季節的にどのように変動し，稲作とどのように関連しているかを調べている。

霞ヶ浦セッション: パネルディスカッション

ディスカッションの概要

福島 武彦

茨城県霞ケ浦環境科学センター長

霞ケ浦セッションのパネルディスカッションは、霞ケ浦の現状把握を行った上で、未来像の設定やその実現に向けての取り組みを検討し、具体的な行動の方向性を示すことが目的です。まず、行政担当者やポスターセッションでの事例発表をもとに霞ケ浦の現状把握、将来の課題などを整理します。次に、各主体の代表者の事例発表をベースとして、霞ケ浦の未来像をパネリストとともに議論します。最後に、市民団体、若い世代の代表者やサテライト会場の意見集約結果をベースに、未来像達成に向けての各種主体の責任と必要な取り組みを提案します。特に、霞ケ浦の恵みである、生態系サービスを将来にわたって持続的に享受するための工夫を考えます。

Lake Kasumigaura Session: Case Study Presentation 1

IBARAKI PREFECTURAL GOVERNMENT'S EFFORTS TO IMPROVE WATER QUALITY IN LAKE KASUMIGAURA

Mieko Kuwana

Executive Director, Department of Residential and Environmental Affairs, Ibaraki prefectural Government

Lake Kasumigaura, located in the southeastern part of Ibaraki Prefecture, is a vast waterscape and part of a diverse natural environment. Along with the towering Mt. Tsukuba on its northwestern side, it is a beautiful sight to behold representing Ibaraki Prefecture. The lake water is also used for domestic, agricultural, and industrial uses; and the lake is blessed with an abundance of aquatic resources.

However, since nearly one million people live in the watershed, and industries such as agriculture and livestock are also popular around the region, nitrogen and phosphorus, which are the causative agents of eutrophication, flow into the lake, thus making it easily polluted. In order to improve the quality of Lake Kasumigaura, Ibaraki Prefectural Government has established a Water Quality Conservation Plan, and is promoting domestic wastewater management. The government also seeks to reduce pollutant loads via agricultural land- and livestock-related countermeasures; and is promoting information dissemination, environmental learning, as well as awareness raising activities. Furthermore, in order to implement the plan fully, the Kasumigaura Water Quality Conservation Ordinance was enacted to regulate that the people in the basin ensure water conservation in all aspects of everyday life and production. The government also introduced a local tax called 'Forest and Lake Environment Conservation Tax,' and uses it as a financial resource to accelerate the efforts.

WATER ENVIRONMENTAL IMPROVEMENT IN LAKE KASUMIGAURA

Tsuyoshi Tatsuno

General Manager, Kasumigaura River Office, Kanto Regional Development Bureau, MLIT

The water environment of Lake Kasumigaura brings diverse benefits to us. In the Kasumigaura basin, flood damage and salt damage frequently occurred in the past. As a result, the flood control plant has been raising the safety and security of the area, making it possible to use water stably in the Tokyo metropolitan areas by the water utilization project. While urbanization of river basins and development of social infrastructure have been progressing, problems of water environment such as water pollution, loss of lake shore vegetation zone and loss of lake water bathing spots have become apparent. In order to respond to these issues, the Kasumigaura River Office will continue to provide diverse benefits of the environment of Lake Kasumigaura water based on the "Lake Kasumigaura River Development Project" and "Lake Water Quality Conservation Plan for Lake Kasumigaura (Seventh Phase)". In order to sustainably enjoy and take the benefits over to the children of the future, the people in the basin are unitedly taking efforts to improve water quality, conserve and restore the natural environment, maintain good mutual relation between the river and the people, preserve and form landscape, promote environmental education and carry out basin- wide comprehensive river management.

ECOSYSTEM SERVICES OF LAKE KASUMIGAURA AND THE ECONOMIC EVALUATION THEREOF

Kazuhiro Ebata

Vice President, Ibaraki Kasumigaura Environmental Science Center

People receive diverse benefits (ecosystem services) from Lake Kasumigaura; for these to continue to be available in the future, it is necessary to the nature and magnitude of the services received and link them to lake management. Therefore, we organized the components of ecosystem services of Lake Kasumigaura and examined the changing of the amount of enjoyment of services and the current economic value. It was revealed that items enriching human activities, such as water use, increased, and items related to flora and fauna, such as fish and aquatic plants, decreased. It also became clear that trying to raise the value of one ecosystem service lowers the value of another ecosystem service. To resolve this problem and to enable people to coexist with the lakes, collaboration and discussion among all stakeholders concerned with Lake Kasumigaura is important.

Lake Kasumigaura Session: Case Study Presentation 2

DELIVERING THE RICHES OF LAKE KASUMIGAURA TO FUTURE GENERATIONS: THE FUTURE OF THE FISHING INDUSTRY IN LAKE KASUMIGAURA

Ichiro Ito

Group Director, Kasumigaura Marine Products Research Group, Kasumigaura Fishermen's Association

The fishing industry has long prospered alongside Lake Kasumigaura, in particular the pond smelt, icefish and river prawn industries.

However, changes in the lake's usage as a water source and a decrease in the aquatic plants that provide a habitat for fish have resulted considerable changes in fishing grounds and increasing instability in the fishing industry.

In order to maintain the fishing industry and pass the riches of Kasumigaura on to future generations, we, Local fishermen, have decided on rules such as limiting fishing time in response to the state of environmental resources and are working towards using resources in an appropriate way. Furthermore, in order to increase the pond smelt that Kasumigaura is known for, we have introduced an artificial hatching programme as well as environmental improvement projects such as reed bed conservation.

We hope to maintain the riches of Lake Kasumigaura for the future so that everyone has the chance to savor Kasumigaura fish. We also hope that you will join us in understanding and cooperating with this project.

PRODUCTION OF LOTUS ROOT HARNESSING THE BOUNTY OF LAKE KASUMIGAURA

Masami Iida

Section of lotus root in Japan Agriclutural Cooperatives Tsuchiura

Lotus root is crop that is mainly in demand at New Year's and seasonal festivals as a lucky charm. Abundant water resources and organically-rich soil is essential for growing lotus root. For this reason, the number of areas where lotus root can be produced in Japan is incredibly limited.

Japan's largest lotus root production area has been formed in areas with the morass around Lake Kasumigaura in Ibaraki Prefecture, centered around Tsuchiura City and Kasumigaura City, where the area's abundant water resources and rich soil can be used.

Here, we will introduce the actual conditions of production areas and initiatives taken at production sites from the perspective of producers on lotus root production that utilizes the bounty of Lake Kasumigaura.

KASHIMA WORKS RELATIONSHIP WITH WATER FROM KASUMIGAURA

Kenya Tada

Director, Nippon Steel & Sumitomo Metal Corporation KASHIMA WORKS, Safety,Environment & Plant Safety Division

- Nippon Steel and Sumitomo Metal will contribute to the creation of a sustainable society by promoting the "three ecos," namely: Eco Process (The way we manufacture is eco-friendly), Eco Products (The goods we produce are eco-friendly) and Eco Solution (The sharing of our eco-solutions).
- Kashima Works manufactures steel sheets, steel plates, pipes and tubes and H-section steel. Its crude steel production capacity is over 7 million tons a year.
- Steel is produced by melting iron ore in the blast furnace, solidifying it in the continuous casting machine and rolling it in the hot-rolling mill. In the manufacturing process, water is essential. Water cools facilities for protection from high temperature steel and directly washes off the steel surface to improve steel quality.
- About 2.6 million tons of water are used in a day. Some water is vaporized due to the cooling of high temperature steel or washing off the steel. Most of the remaining water is recovered for effective use of water resources. The recycling rate is 90% or more. To replenish the loss from vaporizing, about 230,000 tons of new water are supplied in a day from Kasumigaura.

Lake Kasumigaura Session: Case Study Presentation 2

REGIONAL REVITALIZATION PROJECT USING CYCLING ROAD ALONG KASUMIGAURA

Hirotsugu Konno

Kasumigaura Mirai Creation Company

As social problems such as the declining population of the region and industrial decline attract attention, various efforts are being implemented in each local government as a regional creation plan. In Kasumigaura City, Ibaraki Prefecture, paying attention to the fact that many people visit the "Tsukuba Kasumigaura Rin Lin Road" bike path along the Lake Kasumigaura. Aiming for continuous exchange population expansion, JTB Kanto Co., Ltd., Hakuhodo Co., Ltd. and Stitch Co., Ltd. have developed a cycling program utilizing regional resources. Kasumigaura, Tsukuba Bank, Ltd. and Stitch Co., Ltd. contributed through the development of the program, and in order to promote the business, "Kasumigaura Future Creation Co., Ltd." was established in April 2016.

Through the three projects of Kasumigaura City's local cycling program "Kasumigaura Ride Quest", the local production area disappearance restaurant "Kasumi Kitchen" and local product "Kasumi Marche" to undertake efforts to experience the charm of Kasumigaura I aim for it.

THE REPORT ON THE PRACTICE OF WATER PURIFICATION METHODS BY "WOMEN'S GROUP FOR LIFESTYLE SOLUTION"

Masako Fujiwara

President, Ibaraki Life School Liaison Committee

I was very impressed by the taste of the Itako city tap water, I moved in 1974. I remember it tasting very good.
Since then, I have implemented many methods to purify the water in Kasumigaura Lake for many years. For example:

Action 1: Distributing handmade acrylic scourer for diminishing the discharge of detergent and sewage water into Kasumigaura Lake.
Action 2: Reusing water at home, mainly from bathtub.
Action 3: Reusing cooking oil to produce oil candles.
Action 4: Surveying dietary habits and listing food waste.

If everyone reduced waste with even a little sense of regret, we will revive the "Mottainai" spirit, and achieve real improvement in the water purification at Kasumigaura Lake. I believe we should be more concerned with the environmental issues our planet is currently facing.

Lake Kasumigaura Session: Case Study Presentation 3

CITIZENS ACTIVITIES PARTICIPATING IN WORLD LAKE CONFERENCE

Toshio Takishita

Vice President, 2018 Citizens'Association that works closely with the World Lake Conference

During the 6th World Lake Conference, the citizen group worked together to contribute to the success of the event, activated environmental conservation and regional activities, and got to know each other.

Consideration the importance of this citizen group collaboration, we formed the World Lake Conference Citizens' Association '18 in 2016.

In cooperation with the World Lake Conference from the citizen's point of view, we will accomplish various activities related to the World Lake Conference in various places in Ibaraki Prefecture, and will lead to success by partnership and cooperating with each other.

Here, we will introduce the events that citizen groups mainly planned and implemented, and the activities they are usually practicing.

PARTNERSHIP FOR TAKE OVER THE ECOSYSTEM SERVICE OF LAKE KASUMIGAURA TO THE FUTURE

Akira Abe

Chair, Kasumigaura Citizens'Association

Executive Committee of Satellite Tsuchiura has held three events related to Lake Kasumigaura. The first one is 'The Citizen's Festival for Swimmable Lake Kasumigaura'. This annually held event has been organized by citizens since 6th World Lake Conference. This year six high school students debated the future vision of lakes and watershed. The second one is 'Summer Festival in Kasumigaura Environmental Science Center.' In this event, presenters including the special lecture, workers for fishery, farming and forestry, NPO members (Satoyama conservation) and university students dialogued the future vision of lakes and watershed, then talked about charm and conservation of Lake Kasumigaura. Additionally, quiz event for children was held. The third one is 'Satellite Tsuchiura Main Events'. In this event, many participants including civic groups, businesses and administrators working for Lake Kasumigaura discussed common goals for 'future vision of Lake Kasumigaura' after sharing and understanding what they have done. We are aiming for whole generations keep loving Lake Kasumigaura.

TOWARD A "SYMBIOTIC" SYSTEM BETWEEN HUMAN AND NATURE BASED ON A RECONSTRUCTION OF CULTURE OF EATING FISH IN LAKE KASUMIGARUA

Takashi Chiba

Chief clerk (Curator), Kasumigaura city museum of history

When considering the relationship between human and natural environment in the Lake Kasumigaura region, the two important factors are fishing and culture of eating fish. As the human society develops, the nature of relationship between human and natural environment changes. In Kasumigaura City, we at the Kasumigaura Municipal Museum of History organized a series of activities to consider the symbiotic relationship between human and Lake Kasumigaura from the standpoint of local folk culture, such as fishing and fish consumption. This year, we have organized the "Fishing Sailboat Festival 2018" in connection with the World Lake Conference, a series of lectures and symposia entitled "Fishing Sailboats and Fish Consumption Culture in Lake Kasumigaura," and special exhibition "Fishing Sailboats in the History of Fishing in Japan." Now, we use fishing sailboats as the symbol of local sightseeing and intend to promote fish in Lake Kasumigaura as a local brand. It is our hope to reconstruct fishing and culture of fish consumption by sales of fresh local fish and other local products and by sightseeing using fishing sailboats. We believe that such reconstruction will eventually lead us to the environmentally sustainable society and symbiotic relationship between human society and the rich ecosystem of Lake Kasumigaura.

Lake Kasumigaura Session: Case Study Presentation 3

HOKOTA, A TOWN LIVING IN HARMONY WITH NATURE

Shigeo Oki

Hokota Regional Promotion Conference, Natural Environment Section, Section Leader

Hokota City is located amid rich nature surrounded by waters including the Kashima Sea and Lakes Kitaura and Hinuma, vast farmlands and village forests in a diluvial upland, and it mainly depends on agriculture. Because Hokota was once a prosperous water transport hub, it is also characterized by lakes/wetland and residential areas in close proximity. The city positions the preservation and utilization of natural resources as an important item in the Second Comprehensive Plan and the Basic Environmental Plan and is trying to improve the water quality of inflowing rivers within this context. Also Civic groups, in addition to trying to preserve and revive the precious natural environment, are going ahead with the idea of utilizing it in economic activities as part of an ecosystem service. In order to make such activities and the local mood known to those in the city, in Ibaraki Prefecture, in Japan, and outside Japan, we successfully hosted various events in the Hokota City satellite venue for the World Lake Conference. We are going to address various issues through public and private cooperation to be committed to “a town living in harmony with nature.”

GROWING THE ANCIENT RICE AT "YATSUDA" IN SHISHIZUKA AND THE SEASONAL CHANGE IN THE FRESHWATER PLANKTON

Taichi Sukegawa

Student, Ibaraki Prefectural Takezono High School

In 2015, the United Nations set 17 Sustainable Development Goals (SDGs). We have “Life on Hand”; protect, restore and promote sustainable use of terrestrial ecosystems, sustainability manages forests, combat desertification, and halt and reverse land degradation and halt biodiversity loss. We cultivated a rice field, have grown ancient rice using the natural firming method; organic and non-fertilizer in the local forest area called Shishizuka.

Shishizuka was selected as Satoyama of importance to save biological diversity in 2015. Satoyama is undeveloped woodland near populated area.

Shishizuka is used both for animal habitant and for water source because there are not enough big feeder rivers to the lake of Kasumigaura. In these days, it is difficult to maintain paddy field of Yatsuda. Yatsuda is with the situation of decreasing the number of farmers, urbanization and aging farmers. As a result, the abandoned field is spreading rapidly. Also, due to losing animal habitant, ecosystem of whole Satoyama will be destroyed. Cultivating the field leads to the environment conservation activity maintaining biological diversity.

We also investigate water quality and find out what kind of plankton exist in Shishizuka, and the relation with our farming.

Lake Kasumigaura Session: Panel Discussion

OVERVIEW OF DISCUSSION

Takehiko Fukushima

Director, Ibaraki Kasumigaura Environmental Science Center

"Kasumigaura Session" is held 1) to summarize the present and future states of Lake Kasumigaura, 2) to set the goal images of Lake Kasumigaura in future, and 3) to discuss the concrete measures for leading to the goals. At first, we will discuss and summarize the states and problems of natural and social environments in Lake Kasumigaura based on the presentations by government officers and in the poster session. Next, the goal images of Lake Kasumigaura will be argued with panelists based on the case reports by individual stakeholders. Finally, we shall propose the lists of individual responsibilities and concrete measures necessary for attaining the goals based on the opinions of citizens' group and young generation as well as the summary reports from the respective satellite sessions. In this session, the ways are discussed to sustainably utilize the blessings of ecosystem services from Lake Kasumigaura.

KP-1

参加者に求められる水環境学習を目指して

長手　勇樹[1], 永峯　弘規[1], 小松﨑　佑介[1], 藤原　隆司[1], 中山　知之[1], 満行　和博[1],
内藤　正弘[1], 水田　和広[1],
[1]土浦市市民生活部環境保全課

キーワード:市民参加, 水辺ふれあい, 人材育成

抄録

土浦市では, 霞ヶ浦をはじめとする地域の豊かな自然の保全・継承のため, 地域の歴史や自然に触れるなどの体験をとおして地域への愛着を育む環境学習が最も重要であると捉え, 小学生向けに様々な環境学習の機会を提供しています。また, 市内にある茨城県霞ケ浦環境科学センターなどにおいても, 様々な水環境学習イベントが実施されています。これらのイベントは主催団体により, 広報の方法が異なることから, これまで小学生やその保護者が全ての環境学習の機会を認知することは困難でした。そのため, 土浦市では, 2015 年からこれらの情報を一元的にその対象となる小学生(保護者)にメール配信し, さらに, 申込みの代行を行う『つちまるエコキッズクラブ』事業を開始し, 環境学習に参加しやすい環境づくりを行っています。3 年間の当事業の概要や申込者が多い水環境学習イベントを紹介します。

1. はじめに

土浦市は, 日本で 2 番目に広い面積を有する霞ヶ浦(西浦)の上流部にあたる西に位置し, 霞ヶ浦に流入する河川の中で最も大きな桜川の河口の低地に中心市街地を有しています。

霞ヶ浦には 1960 年代までは湖水浴場が点在し, 市内にも神林(現:湖北), 大岩田などにありました。これらの湖水浴場では, 小学校の授業や町内会の行事などで湖水浴を実施したり, 遠浅の砂浜ではカラス貝などの淡貝を採取するなど, 霞ヶ浦は子どもたちの生活空間の一部となっていました。

しかしながら, 霞ヶ浦は, 1970 年代に水質が急激に悪化してアオコが大量発生するとともに治水, 利水を目的として護岸のコンクリート化, 築堤などが行われ親水性が失われてしまい, 霞ヶ浦は「汚い」, 「くさい」, 「危険」な場所となり, 子どもたちの生活空間から霞ヶ浦が切り離されてしまいました。

土浦市では, 2000 年3月に制定した土浦市環境基本条例の制定を契機に, 霞ヶ浦をはじめとする地域の豊かな自然の保全・継承のため, 地域の歴史や自然に触れるなどの体験をとおして地域への愛着を育むことが最も重要であると捉え, 環境学習事業を開始しました。

また, 第6回世界湖沼会議を契機として設置された茨城県霞ケ浦環境科学センター(2005 年開館, 土浦市沖宿町)においても体験型学習の機会や場を提供することが役割の 1 つとして位置づけられており, 多くの環境学習事業を展開しています。

この他にも桜川探検隊連絡協議会(事務局:一般社団法人霞ヶ浦市民協会)や霞ヶ浦水辺ふれあい事業実行委員会(事務局:茨城県霞ケ浦環境科学センター)により地域の子どもたちに環境学習の機会が提供されています。

これらのイベントは主催団体により, 広報の方法が異なることから, 小学生やその保護者が全ての水環境学習を認知することは困難でした。そのため, 土浦市では, 2015 年からこれらのイベントの情報を一元的にその対象となる小学生(保護者)にメール配信し, さらに, 申し込みの代行を行う『つちまるエコキッズクラブ』事業を開始し, 環境学習に参加しやすい環境づくりを行っています。なお, 「つちまる」(図 1)は, 土浦市のイメージキャラクターで, 市内の子どもたちにとても人気があります。



図 1　土浦市イメージキャラクター「つちまる」

2. つちまるエコキッズクラブ

(1)事業スキーム

①募集　年度当初に市内小学校に募集チラシと応募用紙を配布し, 新規会員募集を行うとともに, 市ホームページの会員登録フォームからいつでも会員登録が可能となっています。登録の際には, 環境学習イベントの申込みに必要な住所, 氏名, 学年, 電話番号と情報提供媒体となるメールアドレス(PC,携帯, タブレット)を登録することとしています。

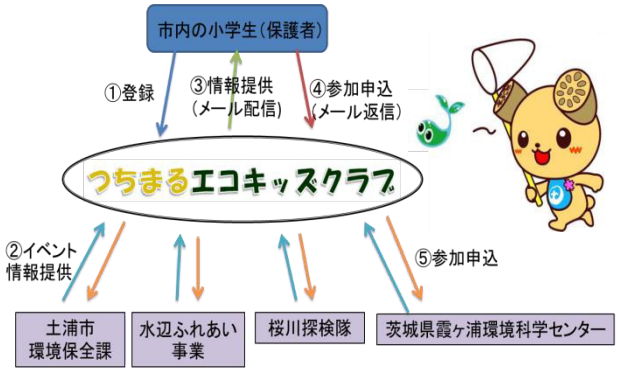

図 2 つちまるエコキッズクラブの事業スキーム

②情報提供　土浦市周辺で実施される環境学習事業等(行政が主催団体として関係しているもの)の情報を収集し，速やかに会員に情報提供(メール配信)を行っています。初年度(2015 年度)は，週 1 回配信している市政全般のメールマガジン「つちまるファンクラブメールマガジン」の一部に組み込んで配信し，2016 年度からは専用メールマガジンとして，随時，配信しています。なお，環境学習イベントの告知は，当メール配信のほか，ホームページ，市広報紙などの媒体により周知しています。

③申込　情報提供メールに参加の意思を返信してもらい，その意思に基づいて会員情報を主催者に伝え，申し込みの代行を行います。

(2)実績など

2015 年度からの実績を表に示します。会員数は年々増加し，申込代行の数も増えています。中でも，自然を体験できるイベント(川遊び，タモ網での魚とり，魚釣り，ゴムボート・カヌー体験など)には参加申込代行者数が多い傾向があります。また，2016 年度から環境学習に特化したメールマガジンになると申込者が増えています。つちまるエコキッズクラブ事業をとおして市内の小学生が，環境学習に参加しやすい環境になりつつあると感じています。今後もつちまるエコキッズクラブの認知度・活用性を向上させ，環境学習の参加者の増加を図っていきたい。

表 1　つちまるエコキッズクラブの実績

	2015 年度	2016 年度	2017 年度
会員数	217 名	390 名	518 名
メール配信数 (申し込み代行件数)	18 件 (23 件)	24 件 (16 件)	22 件 (16 件)
申込代行者数	22 名	66 名	92 名

※2017 年度は 2018 年2月現在

表 2　2017 年度に参加募集を行った環境学習

月　日	行事名	主催
6月3日	霞ヶ浦水辺ふれあい事業～タモ網で霞ヶ浦の生き物を捕まえよう～	水ふ
6月3日	身近な水環境の全国一斉調査～土浦の河川～	市
7月 22 日	夏休み！霞ヶ浦わくわくキッズボートで霞ヶ浦と触れ合おう	霞 C
7月9日	霞ヶ浦水辺ふれあい事業～ゴムボートに乗って霞ヶ浦湖岸で遊ぼう～	水ふ
7月 29 日	夏休み！霞ヶ浦わくわくキッズセンターに住む昆虫を観察しよう	霞 C
8月1日 8月7日 8月 11 日	桜川エコアドベンチャーツアー(川遊び，カヌー体験)	市
8月8日	第1回桜川探検隊～霞ヶ浦の漁業と森～	桜探
8月 18 日	夏休み！こども環境教室	市
10 月 14 日	帆引き船模型工作教室	霞 C
10 月 14 日	秋の水路で魚釣り＆センター企画展ツアー	霞 C
10 月 28 日	第 3 回桜川探検隊	桜探
10 月 29 日	霞ヶ浦水辺ふれあい事業～霞ヶ浦ｸﾙｰｼﾞﾝｸﾞ＆自分だけのﾎﾞﾄﾙｱｸｱﾘｳﾑを作ろう！～	水ふ
11 月4日	霞ヶ浦流入河川水質一斉調査～土浦の河川～	市
12 月9日	親子で行く「エコプロ 2017」	市
1月 27 日	サイエンスラボ　まりものがたり	霞 C
2月 17 日	サイエンスラボ　塩の不思議	霞 C

※水ふ：霞ヶ浦水辺ふれあい事業実行委員会，市：土浦市環境保全課，霞 C：茨城県霞ケ浦環境科学センター，桜探：桜川探検隊連絡協議会

3.　申込者数の多い環境学習の一例

【桜川エコアドベンチャーツアー】

この環境学習事業は，市内中心部を流れる桜川の上流，中流そして霞ヶ浦を訪れ，それぞれの水の様子(透視度，パックテスト)，周囲の自然や生き物を観察しながら人と水とのかかわり方，水と自然の関係を体験し，子どもたちに水質浄化，自然環境保全の意識啓発を目的とした事業です。2017 年は，夏休み期間中に計 3 回計画し，定員は合計 80 名でした。申込者数は定員を超える応募があり，つちまるエコキッズクラブをとおして申込みを行った参加者は 40 名(内，29 人が子ども)で，最も申込者数の多い事業です。

①上流での活動

山裾から山道を片道 30 分程度歩き，桜川の源流の 1 つである湧水の散策を行います。散策過程では，ため

池や田んぼなどで水が使われている様子を学びます。

湧水の場所では水質調査や沢の生き物（沢カニ，ヤゴなど）観察などを行い，緑のダムである山林がきれいな水を生み出し，生き物が繋がっているという生態系について学びます。



図 3　上流での活動の様子（山裾から湧水を目指す）

②中流での活動

河口から 7.5 ㎞ほどの桜川中流で水質調査のほか，桜川漁業協同組合の方々の協力をいただき，昔の桜川の様子や川遊びの話を聞き，投網によって捕獲した魚の観察を行います。また，ターザンロープやカヌーなどを用いて川遊びを行います。初めは，川の中に入ることをためらっていた子どもたちもすぐに全身を水につけて遊び，歓声が上がります。直接川で遊ぶことをとおして，地域の川や湖への愛着を育むことができる貴重な機会となっています。

また，高学年のみが参加する開催日では，カヌーに乗り約 4 キロの川下りを行います。川下りを行いながら，農業用の取水施設や雨水の排水施設など，市街地までの河岸の様子を観察します。川下りの途中では魚がカヌーに飛び込んでくるというハプニングもあり，生物が豊富な河川であることを体感することができます。

③霞ヶ浦での活動

霞ヶ浦では，水質調査を実施し，透視度やパックテストだけでなく，水の色や温度，臭いの違いについても観察します。最後に，上流，中流，霞ヶ浦での活動を振り返り，人と水とのかかわり方，水と自然の関係を復習し，子どもたちに水質浄化と自然環境保全の意識啓発を行います。

④市民ボランティアとの協働など

この事業には，中流での桜川漁業協同組合のご協力だけでなく，昼食時に土浦市環境基本計画推進協議会の委員の皆様にボランティアとして参加していただいております。夏休み期間中は高温多湿のため，お弁当を持参し半日持ち歩くことは食中毒の恐れがあることから，ボランティアの皆さんに冷たい「そうめん」と「スイカ」を提供していただいています。

このように，当該事業は，地域の多くの方々の協力をいただき，子どもたちに楽しい夏の思い出とともに，かけがえのない水と，水を生み出す自然を大切にする気持ちを育んでもらい，参加者から好評を得ています。



図 4　中流での活動の様子
（上：川遊び，下：カヌーでの川下り）

4.　まとめ

・つちまるエコキッズクラブは，環境学習にターゲットを絞り，メールマガジンを配信することで，環境学習に関心の高い子ども（保護者）のファンを獲得することができ，募集媒体としてとても有効な方法となっています。

・茨城県霞ケ浦環境科学センターの環境学習事業も含めて，地域の子どもたちがそれぞれの興味に従って，霞ヶ浦をはじめとする地域の自然に触れる機会が増えています。

・子ども（保護者）は，日ごろ体験できない水辺で自然や生物に触れる機会を求めていることから，さらに子供たちに求められる事業にしていきたい。

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KP-2

観光資源としての霞ヶ浦

土浦市商工観光課

キーワード:観光，地域活性化，

抄録

土浦市は，日本第2位の湖面積を誇る霞ヶ浦の西端に位置し，茨城県南の政治・経済・文化の中心都市として発展してきました。水郷筑波国定公園の豊富な観光資源を有しており，霞ヶ浦は土浦ならではの観光資源であるといえます。他都市にはない付加価値の高い霞ヶ浦観光の拠点づくり，水辺の交流空間づくりを進めています。土浦ならではの観光資源を紹介します。

1. はじめに

土浦市は，東京から約60km，県都の水戸から45kmに位置し，北には筑波山麓，南東には霞ヶ浦と接し，県南地域の交通の要衝にあります。首都圏からも1時間程度でアクセスできる立地状況でありながら，豊かな自然環境を持つ地域です。なかでも霞ヶ浦は，土浦市の観光資源として代表的なものであるといえます。

霞ヶ浦を活かした観光の取り組みにはどのようなものがあるか，具体的に示します。

2. 霞ヶ浦を中心とした観光資源

①霞ケ浦総合公園

霞ヶ浦湖畔の広大なレジャー施設「霞ヶ浦総合公園」は，体育館をはじめ，テニスコート，プール，ネイチャーセンターなど，霞ヶ浦湖畔を楽しむための施設が充実しています。

公園内は，親子連れで遊ぶ方やランニング，ウォーキングを楽しむ方が多数訪れています。

また，ネイチャーセンターには，4月～5月は，約3万本のチューリップを楽しむことができます。11月～2月はウインターイルミネーションを行っています。



図 1　霞ヶ浦総合公園

②つくば霞ヶ浦りんりんロード

霞ヶ浦沿岸に展開するサイクリングロード「つくば霞ヶ浦りんりんロード」は，平坦な地形が続くことを活かした，全長約180kmにも及ぶ，国内有数のサイクリングロードです。湖岸を自転車で走り，霞ヶ浦を満喫してもらうため，サイクリストが訪れやすい仕組みづくりを行っています。JR常磐線土浦駅ビル内にサイクリング施設「りんりんスクエア土浦」がオープンするなど，サイクリストを迎える施設整備をしています。

③霞ヶ浦観光帆曳船及び遊覧船

霞ヶ浦では，毎年7月から10月にかけて観光帆曳船の操業を行っており，霞ヶ浦観光の目玉となっています。観光遊覧船によるクルージングでは，帆曳船の見学を楽しむことができ，多くの観光客で賑わいます。観光遊覧船は，JR 土浦駅からの徒歩圏内で 2 社が運航しています。



図 2　帆曳船



図　3　観光遊覧船

④茨城県霞ケ浦環境科学センター

茨城県霞ケ浦環境科学センターでは，霞ヶ浦の歴史や，水環境から地球環境まで楽しく学べる展示のほか，自然観察会や講演会なども開催され，霞ヶ浦について学ぶことができます。

⑤霞ヶ浦広域観光ルート促進協議会

霞ヶ浦周辺の土浦市，鹿嶋市，潮来市，神栖市，行方市，美浦村，阿見町，稲敷市，かすみがうら市で構成する霞ヶ浦広域観光ルート促進協議会をはじめとする，広域的団体として，霞ヶ浦を含む地域を広域的にPRするため，イベントなどでのパンフレット配布等の取り組みも積極的に行っています。

⑥筑波山地域ジオパーク

霞ヶ浦を含む筑波山地域ジオパークでは，平成28年9月に日本ジオパークとしての認定を受けました。土浦市，つくば市，石岡市，笠間市，桜川市，かすみがうら市の6市からなる筑波山地域ジオパークは，住む人が地域の価値を再発見して愛着を持ち，訪れる方々にその価値を理解してもらい，地域活性化につなげることを目指しています。

3.　入込客数

平坦な地形を活かしたつくば霞ヶ浦りんりんロードでは，サイクリングを楽しむ人が増えており，観光入込客数も近年増加しています。また，観光帆曳船を目的とした観光客も訪れています。そのほか，霞ヶ浦では釣りやヨットなどのレジャーも盛んで，活気に溢れています。

4.　考察

つくば霞ヶ浦りんりんロードは，サイクリストをはじめとした観光客等を呼び寄せる好材料となっていると考えられます。また，霞ヶ浦を訪れる観光客も多数いることから，霞ヶ浦は観光素材として魅力あるものであるということができます。



図　4　筑波山地域ジオパークのゾーニング

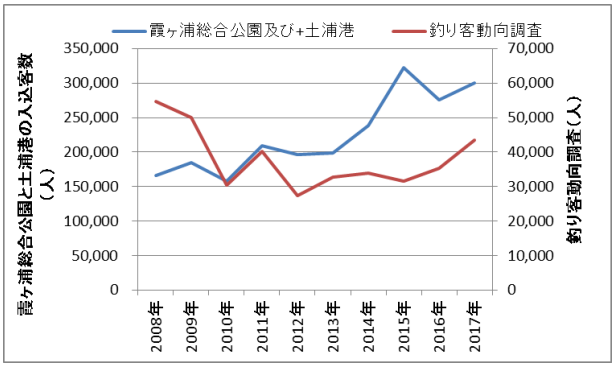

図　5　霞ヶ浦総合公園と土浦港における入込客数の推移と釣り客数

5.　結論

霞ヶ浦の豊かな自然を活かした各種の観光施設は魅力的であり，多くの観光客を呼び寄せることができるものです。今後も水辺体験メニューやイベントの充実をはかり，霞ヶ浦湖岸で楽しむ体験型観光の積極的なPRの推進に努めます。

KP-3

霞ヶ浦を活かしたシティプロモーション

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[1] 土浦市広報広聴課シティプロモーション室

キーワード:まちづくり, 地域活性化, シティプロモーション

抄録

土浦市は, 日本第2位の湖面積を誇る霞ケ浦の西端に位置し, 茨城県南の中核都市として発展してきました。気候は年間を通して比較的温暖であり, 霞ヶ浦から筑波山麓に至る豊かな自然環境に恵まれています。本市ではこのような地域資源の持つ魅力を掘り起こし, 磨き上げることで, まちの魅力を強化して発信するシティプロモーション事業を推進し, 市の認知度向上を図っています。本稿では, 特に本市と歴史的, 環境的に関係の深い地域資源である「霞ケ浦」を活用したシティプロモーションの取組について紹介します。

1. はじめに

土浦市は, 日本第2位の湖面積を誇る霞ヶ浦の西端, 首都東京から約 60km, 茨城空港から約 20km, 成田国際空港から約 40km に位置し, 茨城県南の中核都市として発展してきました。気候は年間を通して比較的温暖であり, 霞ヶ浦から筑波山麓に至る水辺と山並みを有した豊かな自然環境に恵まれています。

この知における人と霞ヶ浦の関わりは古く, 市内にある上高津貝塚は約四千年から三千年前の縄文時代の遺跡で, 当時入り江だった霞ヶ浦から得られた豊富な魚介類や塩, 周辺の動植物などを採取し生活していたムラのあとが残っています。

江戸時代には, 土浦から霞ヶ浦, 北浦を経て利根川に入り, 江戸湾に至る水路が形成され, 年貢米や醤油, 油, 木材などが運ばれ, 水戸街道の拠点であったことと相まって, 人・ものが行き交う水陸交通の拠点として, にぎわいました。日々の漁場や物流の拠点でなくなった現在でも,観光やレジャーなど様々な目的で多くの方が霞ヶ浦を訪れています。

このように土浦の魅力ある地域資源である霞ヶ浦を活かしたプロモーションにより, 市内外のより多くの人にその魅力を知っていただき, 本市の認知度向上に取り組んでいます。

ここで,具体的な取組内容について紹介します。

2. 方法

土浦市では, 学習, 体験, イベントなど霞ヶ浦を活かした様々な事業を行っています。

市内の小学生に対し, 霞ヶ浦をはじめとする地域の豊かな自然の保全・継承のため, 地域の歴史や自然に触れるなどの体験を通して地域への愛着を育む環境学習を行っています。

また, 土浦市は, つくば市・石岡市・笠間市・桜川市・かすみがうら市の 6 市からなる「筑波山地域ジオパーク」としての認定を受けています。多くの方が豊かな自然にふれあえる体験型のジオツアーに参加することで, 地域の価値を理解し, 愛着を持つことにつなげています。



図１．ジオ資源としての霞ヶ浦

次に, 霞ヶ浦沿岸に展開するサイクリングロード「つくば霞ヶ浦サイクリングロード」は, 平坦な地形が続くことを活かした全長 180km にも及ぶ国内有数のサイクリングロードです。誰でも気軽にサイクリングが楽しめるよう広域型のレンタサイクルを実施するとともに, 平成 30 年 3 月には土浦駅直結の本格的サイクリング施設がオープンし, 多くのサイクリストが訪れています。



図２．つくば霞ヶ浦りんりんロード

3 番目に霞ヶ浦を活かしたイベントとしては，全国有数の希望を誇る市民マラソン大会であるかすみがうらマラソン兼国際盲人マラソンを開催しています。かすみがうらマラソンは「蘇れ，霞ヶ浦　水はスポーツの源」をメインテーマにしています。また，霞ヶ浦マラソン兼国際盲人マラソンと同時開催しているかすみがうらウォーキングは，湖畔の風景を楽しめる霞ヶ浦の湖岸堤防を歩くコースとなっております。なお，参加費の一部を水質浄化運動基金として徴収し活用しています。

また，今大会においては，ランナーの皆さんやモール505 で同時開催しているランナーズヴィレッジの様子など SNS で市内外に発信しました。



図３．かすみがうらマラソン



図４．ランナーズヴィレッジ

土浦市のシティプロモーションを進めるにあたり，行ったアンケートでは豊かな自然が市内外で魅力度の高い地域資源となっています。主な地域資源としてレンコン，霞ヶ浦特産品，観光遊覧船や帆曳船など霞ヶ浦に関するものが上位を占めます。また，日本一の生産量を誇るレンコン，米，工芸作物，畜産など農林畜水産物の資源を活用した都市と農村の交流と加工品の開発を進め，地域の農林水産業を活性化することで，交流人口の増，まちの賑わい創出を図る「土浦ブランドアッププロジェクト推進事業」に取り組んでいます。



図５．土浦ブランドが生まれる大地

3.　結果

霞ヶ浦をはじめとする地域の豊かな自然の保全・継承のため，地域の歴史や自然に触れるなどの体験を通して地域への愛着を育む環境学習においては，2015 年から「つちまるエコキッズクラブ」事業を開始し，土浦市周辺で実施される環境学習事業等の情報を収集し，速やかに会員に情報提供することにより，環境学習に参加しやすい環境づくりを行っています。2015 年に 215 名の会員数が 2018 年には 518 名の増となるなど，市民の CIVIC PRIDE の醸成を図っています。

平成 3 年に約 4700 人の参加からはじまったかすみがうらマラソン兼国際盲人マラソンは回を重ねるごとに参加者が増え,今ではエントリー数 2 万 5 千人を超える大規模な大会へと成長しました。参加費の一部は霞ヶ浦水質浄化運動基金と盲導犬育成助成金として使われています。具体的な使い道として,水質浄化啓発広告塔の設置など，霞ヶ浦の水質浄化に取り組んでいます。

サイクリングロードは昨年整備が進み，旧筑波鉄道の廃線跡を利用したつくばりんりんロードと霞ヶ浦湖岸を走る霞ヶ浦自転車道が土浦市内においてつながり，「つくば霞ヶ浦りんりんロード」として多くの方に利用していただき，サイクリングの楽しさと風景を含めた環境の素晴らしさを感じていただいています。

「土浦ブランドアッププロジェクト推進事業」では，本市の農林畜水産物や加工品 21 点の応募の中から，「レンコン」，「霞ヶ浦産　白魚煮干」，「小えび佃煮」など 18 点を土浦ブランドとして認定し，更なる土浦の魅力を市内外に発信し，認知度向上を図っています。

二年に一度実施している市民満足度調査[1]では，住みごごちについて，住みよい，どちらかといえば住みよいをあわせると 41.1%になり，定住意向についても，住み続けたい，どちらかといえば住み続けたいをあわせると 66.2%と高い割合になっています。いずれも前回調査をうわまわっております。また，空気のきれいな良好な環境の保全という項目が前回調査より満足度があがっています。

また，毎年調査が行われている住みよさランキング[2]においても，2016 年 150 位から 2017 年 100 位へと大幅にあがっています。

4.　考察

霞ヶ浦マラソン兼国際盲人マラソンは土浦市民にとっても，土浦市の誇りとして幅広い世代に認識されています。今後は，開催時以外にも多くの人々が訪れていただけるような取り組みが必要ではないかと考えられます。

サイクリングロードや遊歩道の整備が進んでいますが，まだ認知度という点において市内外においても十分であるとはいえません。今後更なるサイクリング環境の整備を進めるとともに，認知度の向上を図る必要があります。

「筑波山地域ジオパーク」や「土浦ブランド」についても，今後更なる認知度の向上を図る必要があります。

土浦市の魅力の発信において，霞ヶ浦を活用することはイメージアップに大いに貢献できることがわかりました。

身近に自然を感じられることは市の魅力として感じてもらうことができることは，とても重要な地域資源であると考えます。

5. 結論

土浦市のシティプローモーション事業を展開していく上で，地域資源として霞ヶ浦はとても重要であることがわかりました。

大きく育ったイベントや，霞ヶ浦地域の賑わいを創出し,水辺に親しむ環境を整備し，あらゆるメディアや機会を活用した情報発信を徹底して行い，霞ケ浦の魅力の発信を強化することで，土浦市の更なるイメージアップを図ることができると考えています。

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KP-4

土浦市の高度処理型浄化槽設置及び転換促進へ向けた取組み

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キーワード:生活排水対策, 高度処理型(合併処理)浄化槽, 浄化槽設置整備事業

抄録

土浦市は霞ヶ浦の西方に位置し, 霞ヶ浦の水を生活用水として古くから利用してきた。1965 年代になると霞ヶ浦の流域人口の増加や社会経済活動の進展に伴い水質汚濁が進み, 湖から発する異臭や漁獲量の減少など, その利用に障害を生じるようになった。霞ヶ浦の水質汚濁は家庭から出る生活排水が原因の一つとなっており, 生活排水を処理する方法の一つとして浄化槽がある。1987 年以降, 国と茨城県は水環境保全のために, し尿及び生活雑排水を同時に処理できる浄化槽(合併処理浄化槽)の設置費用を補助する市町村に対し, その費用の一部を負担する事業を開始し, 本市も当該事業に取組んできた。そして現在までに, 土浦市は補助金額に対して独自の上乗せを行い, また, 国と茨城県が補助の対象とする浄化槽よりも高性能な浄化槽のみを補助の対象とするようになった。

1. はじめに

土浦市は, 茨城県の南部に位置し, 関東の名峰「筑波山」を背に, 日本第二の湖, 霞ケ浦の西岸に位置している。霞ヶ浦は大小 56 の河川・水路が流入しており, 最大水深は約 7m, 平均水深約 4m と非常に浅いため水質汚濁が進行しやすく, 1965 年代半ば以降, 流域人口の増加や社会経済活動の進展に伴い富栄養化による水質汚濁が進行し, 利水や環境保全の面で様々な障害を生じた。水質汚濁の原因の 1 つである生活排水の処理には下水道事業, 農業集落排水事業, 浄化槽, くみ取り便所などがある。

2. 浄化槽の種類

浄化槽は一般的に, トイレからのし尿だけを処理する単独処理浄化槽と, トイレからのし尿と併せて台所排水などを処理する合併処理浄化槽に分けられる。さらに現在では, 窒素やリンの除去ができる高度処理型(合併処理)浄化槽がある。高度処理型(合併処理)浄化槽には窒素を除去する機能を持つ浄化槽(N 型)と窒素及びリンの両方を除去する機能を持つ浄化槽(NP 型)の二種類ある。霞ヶ浦の富栄養化を防止するためには, 高度処理型(合併処理)浄化槽の普及が重要と考えられている。

3. 生活排水の処理方法と関連法の変遷

生活排水とは日常生活を通じて発生する排水のことで, トイレからのし尿とそれ以外の生活雑排水(台所, 洗濯, 風呂など)から成っている。し尿は戦前, 重要な肥料資源として活用されていたが, 戦後は, 主に伝染病予防の観点から,「廃棄物の処理及び清掃に関する法律」により, 衛生上問題のないよう処理することが義務づけられた。そのため,「くみ取り」によりし尿処理場で処理することとなり, さらに, 生活の近代化により, 下水道未普及地域では主に単独処理浄化槽によるトイレの水洗化が進んだ。そして 1983 年, 浄化槽法が公布され, その設置や利用についての規制が進められた。しかし, 当時の浄化槽法は生活雑排水を未処理のまま放流する単独浄化槽の設置を認めていたので, 水質保全面から問題となった。そこで 1987 年, 合併処理浄化槽の普及を目的に後述する補助事業が国と県と市により開始された。さらに土浦市では, 霞ヶ浦と本市が「湖沼水質保全特別措置法」に基づく指定湖沼と指定地域に指定されたことを受けて, 1990 年から新築に伴い浄化槽を設置する場合は独自に合併処理浄化槽の設置を促していた。そして 2001 年, 浄化槽法における浄化槽の定義から単独処理浄化槽が削除され, 下水道処理予定区域を除き, 合併処理浄化槽の設置が義務づけられた。そして, 既に設置されている単独処理浄化槽(みなし浄化槽)については合併処理浄化槽への転換の努力義務が明文化された。

一方茨城県は, 2007 年 10 月から施行されている「茨城県霞ケ浦水質保全条例」の中で, 霞ヶ浦流域内において生活排水を排出する者が浄化槽を設置する際には高度処理型(合併処理)浄化槽の設置義務を規定するなど, 生活排水対策の強化を図っている。

故に, 現在の土浦市では, 生活排水を処理するため

に新たに浄化槽を設置しようとした場合，高度処理型（合併処理）浄化槽の設置が義務となっている。しかし，義務化以前に設置された単独処理浄化槽がまだ残されており，新設が原則禁止となった 2001 年度には，約 7,000 人以上の利用者が土浦市内に存在していた。

単独処理浄化槽は管理状態がよい場合でも，生物化学的酸素要求量（BOD）の除去率が約 65%と低く，生活排水は未処理で放流されることから，BOD の全負荷量は約 32g/人・日と，同じく未処理で放流するくみ取りの場合（27 g/人・日）よりも多くなっている[1]。そこで，国と茨城県では，1987 年に開始した補助事業を拡充させて，既存の単独処理浄化槽の転換の促進を図っており，本市も当該事業に独自の変更を加えて取組んでいる。以下，補助事業について詳述する。

4. 国と茨城県の補助事業

1987 年，厚生省（現：環境省）により，合併処理浄化槽設置整備事業（現：浄化槽設置整備事業）が創設された。これは，浄化槽の設置者に対し補助事業を行っている市町村に対して一定の条件を満たしている場合に国がその費用の一部を助成する事業である。助成金は標準的な設置費の 4 割程度を基準額に設定し，原則として補助基準額の 1/3 ずつを国，都道府県，市町村が負担する。さらに，2006 年度には浄化槽の設置にともなう単独処理浄化槽の撤去費が助成の対象とされ，その後，2010 年度からは使用年数の制限が撤廃された。

なお，これらの事業は，2005 年度より創設された「循環型社会形成推進交付金」や「汚水処理施設整備交付金」の対象として実施している。

茨城県でも，1987 年度から家庭用の合併処理浄化槽の設置に対する助成制度を設けており，1999 年度には国費補助に合わせて高度処理型浄化槽（N 型）を補助対象とし，霞ヶ浦流域については，2003 年度から，富栄養化防止のため窒素及びリンが除去できる高度処理型浄化槽（NP 型）も補助対象としている。さらに，2008 年度から 5 年間限定で導入した「森林湖沼環境税」を活用し，高度処理型浄化槽設置補助の強化を実施している。現在，2 度の延長により 2018 年度から 3 期目に突入している。

5. 土浦市の補助事業

本市においても，国と茨城県の取組みを受けて，生活排水による公共用水域の水質汚濁を防止するため，1987 年に「土浦市合併処理浄化槽設置事業費補助金交付要綱」を定め，合併処理浄化槽を設置する事業を行う者に対する補助を開始した。当初は名称のとおり合併処理浄化槽を補助の対象としていたが，2000 年に「土浦市高度処理型合併処理浄化槽設置事業費補助金交付要綱」と改称し，補助対象を高度処理型（合併処理）浄化槽に限定した。2006 年には国と茨城県が補助の対象とする浄化槽の放流水の基準値（表 1 上段）より高性能な浄化槽（表 1 下段）を補助の対象とするようになった。そして 2007 年からは単独処理浄化槽から高度処理型（合併処理）浄化槽へ転換する場合に撤去に要する費用として，9 万円を限度として加算している。

表1　茨城県及び土浦市の補助事業対象高度処理型（合併処理）浄化槽の放流水の水質基準

実施主体	補助事業対象 高度処理型 （合併処理）浄化槽※1	水質項目※2	
		BOD （mg/L）	総窒素濃度 （mg/L）
国 茨城県	N型	20mg/L以下	20mg/L以下
	NP型	10mg/L以下	10mg/L以下
土浦市	N型	**10mg/L以下**	**10mg/L以下**
	NP型		

※1 国・茨城県については土浦市において補助を利用できるものを抜粋している
※2 BOD の除去率と総リン濃度については県と市とで違いは無いので省略している

補助金額については 1987 年から増加しており，2014 年からは県の上乗せ補助の見直しにより，単独処理浄化槽やくみ取り便所から高度処理型浄化槽への転換促進のため，転換（建築確認を伴わない新規浄化槽への入れ替え）の場合は新築の場合より補助額が手厚くなった。

補助率については，当初は国・茨城県・土浦市の三者で同率の負担であったが，現在までに茨城県と土浦市でそれぞれ上乗せ補助を行っている。補助金の内訳イメージを図 1 に，2018 年 4 月 1 日現在の補助限度額及び市上乗せ分の内訳を表 2 に示す。

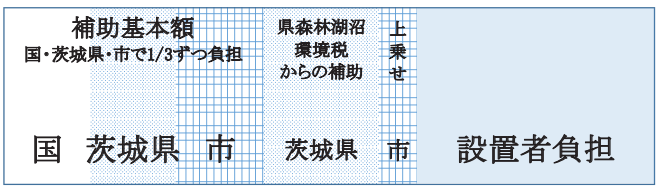

図 1　補助金の内訳イメージ（5 人槽 N 型転換ありの場合）

表 2 土浦市の高度処理型（合併処理）浄化槽設置補助事業の補助限度額及び市上乗せ分内訳

補助対象人槽	補助限度額（単位：千円）			左欄の市上乗せ金額内訳（単位：千円）
5人槽	N型	転換あり	705	60
		転換なし	593	
	NP型	転換あり	1,159	
		転換なし	1,047	
6～7人槽	N型	転換あり	897	125
		転換なし	769	
	NP型	転換あり	1,600	
		転換なし	1,472	
8～10人槽	N型	転換あり	1,122	165
		転換なし	950	
	NP型	転換あり	2,226	
		転換なし	2,054	
単独処理浄化槽から転換する場合の撤去費用			90	0

補助を開始してからこれまでの補助件数は約 600 基（2017 年度末現在）となっている。また，近年の補助基数の推移を表 3 に示す。

表 3 土浦市における補助基数の推移（単位：基）

区分	2013年度（平成25年度）	2014年度（平成26年度）	2015年度（平成27年度）	2016年度（平成28年度）	2017年度（平成29年度）
5人槽	11	8	17	11	13
6～7人槽	10	12	5	4	7(1)
8～10人槽	0	1	1	3	1

※（）は，窒素及びリン除去能力を有する高度処理型浄化槽（NP 型）

6. 今後の課題

単独処理浄化槽の利用者人口は 2016 年で約 3,500 人となっており，引続き高度処理型浄化槽などへの転換を促す対策が必要である。また，くみ取り便所については約 6,400 人おり，同様に対策が求められる。

市が補助対象としている N 型及び NP 型高度処理型（合併処理）浄化槽のうち，霞ヶ浦の水質汚濁防止の観点からすれば，富栄養化の原因となる窒素及びリンの両方を除去する NP 型の方が窒素だけの N 型よりも望ましい。しかし，表 3 に示すとおり，過去 5 年の間に NP 型高度処理型（合併処理）浄化槽に対する補助を実施したのは 1 基のみであった。故に今後は，NP 型高度処理型（合併処理）浄化槽の普及に向けた取組みも必要である。

茨城県では，2018 年度から，くみ取り便所や浄化槽から下水道に切り替える工事への補助金について，一定の要件を満たす霞ヶ浦流域の高齢者・子育て世帯を対象に，自己負担が実質ゼロになるよう制度を大幅に拡充している。環境負荷の少ない排水処理施設への転換が今後も期待されている。

表 4 土浦市の浄化槽設置事業費補助事業に係る主な出来事

西暦（元号）	出来事
1987（昭和 62）	国・茨城県・市において助成制度創設 「土浦市合併処理浄化槽設置事業費補助金交付要綱」制定
2000（平成 12）	名称を「土浦市高度処理型合併処理浄化槽設置事業費補助金交付要綱」に改称 市における補助対象を高度処理型合併処理浄化槽に限定
2002（平成 14）	要綱を要項に変更
2005（平成 17）	環境省関係浄化槽法施行規則の一部を改正する省令公布 浄化槽からの放流水の水質基準が BOD20mg/L 以下及び BOD 除去率 90%以上と規定される
2006（平成 18）	補助事業対象高度処理型（合併処理）浄化槽の放流水の水質基準変更（表 1 参照）
2007（平成 19）	茨城県条例「茨城県霞ケ浦水質保全条例」施行（10 月） 国・茨城県の制度を活用して単独処理浄化槽の撤去費補助開始
2008（平成 20）	茨城県において森林湖沼環境税の導入 高度処理型合併処理浄化槽の呼称を高度処理型浄化槽に変更
2014（平成 26）	県の上乗せ補助の見直しにより，転換を伴うかどうかで補助額に差を設けるように改正
2018（平成 30）	茨城県の森林湖沼環境税（個人の場合）の課税期間を平成 33 年度まで延長

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KP-5

土浦市における生活排水対策の効果

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キーワード:生活排水対策, 点源及び面源汚染

抄録

土浦市(旧新治村域を除く)は, 1991 年(平成3年)に茨城県で初めて水質汚濁防止法に基づく生活排水対策重点地域の指定を受け, 1992 年(平成4年)3月に「土浦市生活排水対策推進計画」, 2009 年(平成 21 年)5 月には「第二期土浦市生活排水対策推進計画」を策定し, 下水道や農業集落排水施設のインフラ整備や一定水準の処理性能を満たした浄化槽の設置者に対して補助制度を設け, 生活排水対策を積極的に推進してきた。計画策定前の 1990 年(平成2年)度末と 2016 年(平成 28 年)度末の生活排水処理形態の人口割合は, 汲み取りが 32.2%から 6.2%に, 単独処理浄化槽が 14.3%から 2.5%にそれぞれ減少し, その一方で, 下水道が 35.2%から 81.3%に増加した。さらに農業集落排水施設が新たに4施設に増え, 2.8%をカバーしている。その結果, 人口が 6,414 人増加しているものの BOD 負荷量は 1,888.1 kg/日から 326.4 kg/日となり, 82.7%削減したと推計され, 市内を流れる河川の水質の改善に寄与した。

1. はじめに

土浦市は, 日本で 2 番目に広い面積を有する霞ヶ浦(西浦)の上流部にあたる西に位置し, 市内全域が霞ヶ浦の流域となっている。土浦市は, 古くから漁業や農業など霞ヶ浦の恩恵を受けて, 人々が生活していたが, 水戸街道の開通(1604 年)から江戸中期(1700 年代)までに本格的なまちづくりが進み, 城下町としての形態が整い, さらに江戸中期から明治期は, 江戸に大量の物資を運ぶ水運交通の要衝, 物資の集散地として栄えた。大正期以降は鉄道の開通などにより, 茨城県南部の中心都市として発達し[1)], 人口は1974 年(昭和 49 年)には10 万人を超え, 2009 年(平成 21 年)10 月に 144,534 人で最多となった。

このように土浦市は, 古くから漁業や農業, 水運などで霞ヶ浦から経済的な恩恵を受けるとともに, 夏季には湖水浴場が開設されるなどレジャーの場としても恩恵を受けてきた。しかしながら, 生活様式や産業活動の近代化, 流域人口増加の影響を受け, 1960 年代(昭和 40 年代)頃から霞ヶ浦の水質は急激に悪化し, アオコの大量発生に伴う悪臭や水道水のかび臭などに悩まされるようになった。

土浦市では, 水質汚濁原因の 1 つである生活排水対策として, 1979 年(昭和 54 年)1 月に土浦市湖北に霞ヶ浦湖北流域下水道霞ケ浦浄化センター(以下, 湖北流域浄化センター)が供用開始となり, 公共下水道管(一部合流式)の整備が行われてきた。また, 1987 年(昭和 62 年)からは家庭用の合併処理浄化槽の設置費用に対して補助制度を設け, 生活排水対策を積極的に推進してきた。しかしながら, 市内を流れる河川の水質改善はなかなか進まなかったことから, 土浦市(旧新治村域を除く。以下, 土浦市という。)は, 1991 年(平成3年)に茨

表 1 土浦市が講じた生活排水対策(1991～2016)

Year	講じた施策・状況
1991 年	下水道の接続人口が5万人を超える。
1992 年	西部地区農業集落排水施設(780 人槽)供用開始。
1993 年	虫掛地区に生活排水路浄化施設を設置。
1995 年	北部地区農業集落排水施設(950 人槽)供用開始。
1997 年	沖宿地区生活排水路浄化施設を設置。
1999 年	東部地区農業集落排水施設(1,770 人槽)供用開始。
2000 年	下水道の計画区域に市街化調整区域を加える。 高度処理型浄化槽のみを補助対象とする。
2003 年	下水道の接続人口が 10 万人を超える。
2008 年	西根地区農業集落排水施設(690 人槽)供用開始。
2009 年	第二期土浦市生活排水対策推進計画策定。
2016 年	下水道の合流改善事業が完成。

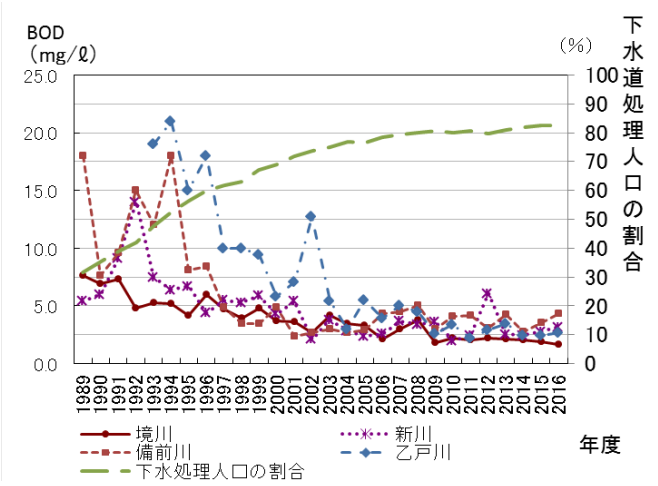

図 1　土浦市内の河川水質と下水処理人口の割合

城県で初めて水質汚濁防止法に基づく生活排水対策重点地域の指定を受け，1992 年(平成4年)3月に「土浦市生活排水対策推進計画」(以下，第一期計画という。)を策定し，表1に示すとおり下水道，農業集落排水施設及び合併処理浄化槽などの対策を講じてきた。その結果，図 1 に示すとおり，下水処理人口の割合が高くなるとともに土浦市内が流域となっている主な河川の水質は大幅に改善している。

第二期土浦市生活排水対策推進計画(2009 年策定)は，2018 年(平成 30 年)に最終年度となることから，第一期計画の策定前の 1990 年(平成 2 年)度と現在の土浦市から発生する生活排水由来の汚濁負荷量について推計した。

なお，推計にあたっては，生活排水路浄化施設及び合流改善事業による汚濁負荷量の削減については考慮しなかった。

2.　方法

(1)汚濁負荷量の算定と処理形態別人口

生活排水による汚濁負荷量の算定は，生活排水の処理形態別に次の式に従って算出し，その合計を求めた。1990 年(平成 2 年)度末及び 2016 年(平成 28 年)度末の処理形態別人口を表2に示す。

(処理形態別の汚濁負荷量の算定)

原単位(g/日・人)×人口(人)＝汚濁負荷量(g/日)

(2)処理形態別の原単位

処理形態別の原単位は，次の方法で設定した。設定した原単位を表3に示す。

①下水道

湖北流域浄化センターの対象年度の処理実績[2](処理水量，処理水質，工場系率)から排出負荷量を求め，水洗化人口で除して，排出原単位とした。

②農業集落排水施設処理場ごとの実績(処理水量，処理水質)から排出負荷量を求め，水洗化人口で除して，排出原単位とした。

③浄化槽及び生活雑排水

浄化槽及び生活雑排水の原単位は，既報[3]の原単位を用いた。単独処理浄化槽については，単独処理浄化槽の排出原単位と生活雑排水原単位の合計を単独処理浄化槽利用者の原単位とした。

表 2 生活排水の処理形態別人口

(人)

処理形態＼年度	1990 年	2016 年
下水道	45,080 (35.2%)	113,137 (81.3%)
集団住宅排水施設	22,349 (17.5%)	0
農業集落排水施設	0	2,433 (2.8%)
高度処理型浄化槽※	0	3,257 (2.0%)
合併処理浄化槽	966 (0.8%)	7,043 (5.2%)
単独処理浄化槽	18,361 (14.3%)	3,199 (2.5%)
汲み取り	41,280 (32.2%)	5,381 (6.2%)
合計	128,036	134,450

※　窒素やりんを除去する機能を有する合併処理浄化槽

表 3 生活排水処理形態別の原単位

(g/日・人)

処理形態＼項目		COD	BOD
下水道	1990 年	2.16	0.33
	2016 年	1.83	0.29
農業集落排水施設(2016 年)		1.32	0.49
高度処理型浄化槽		3.22	2.30
合併処理浄化槽		4.14	3.68
単独処理浄化槽		3.20	3.15
汲み取り		0.09	0.01
生活雑排水		13.0	29.0

なお，集団住宅排水施設については，合併処理浄化槽の原単位を用いた。

④汲み取り

土浦市内の汲み取りし尿は，し尿処理場で処理され，1986 年（昭和 61 年）度からは希釈後下水道に放流され，湖北流域浄化センターで再処理されている。1990 年の処理実績（処理水量，希釈倍率）の記録が残されていないことから，一人 1 日当たりのし尿受入量は 1～2L（下水排水量の 100 分の1未満）で最大 5 倍希釈されることを考慮し，大きく見積もって下水道利用者の負荷量の 20 分の 1 とした。汲み取り利用者の原単位は，汲み取りの負荷量に生活雑排水原単位を合わせた値とした。

3. 結果

（1）COD 負荷量

COD 負荷量の算定結果を図2左に示す。1990 年の COD 負荷量は，合計で 1,027.8 kg/日となり，汲み取り利用者と単独処理浄化槽利用者の割合が，それぞれ 52%，29%と多かった。一方で2016 年の COD 負荷量は，合計で 371.8 kg/日となり，1990 年に比べ 63.8%減少した。下水道利用者が 51%で最も高い割合となり，次いで汲み取り利用者と単独処理浄化槽利用者の割合が，それぞれ 19%，14%だった。

（2）BOD 負荷量

BOD 負荷量の算定結果を図2右に示す。1990 年の BOD 負荷量は，1,888.1kg/日となり，汲み取り利用者と単独処理浄化槽利用者の割合が，それぞれ 63%，31%と多かった。2016 年の BOD 負荷量は，326.4kg/日となり，82.7%削減された。2016 年の内訳は，汲み取り利用者と単独処理浄化槽利用者の割合が，それぞれ 48%，32%で，依然として生活雑排水未処理の割合が高かった。

4. 考察

・土浦市内の生活排水の処理形態は，2016 年現在で，下水道が81%を占めている。しかし，未だに生活雑排水未処理（汲み取り，単独浄化槽）人口が 8.7%を占めており，適正な生活排水処理への移行が課題となっている。

・原単位を比較すると，集合処理である下水道や農業集落排水施設と浄化槽を比べると高度処理型浄化槽であっても COD,BOD の両方の原単位とも集合処理の方が低いことから，新たに集合処理（下水道，農業集落排水施設）の区域になった際には，高度処理型浄化槽が設置されていても速やかに集合処理に変更することが水質浄化に寄与する。

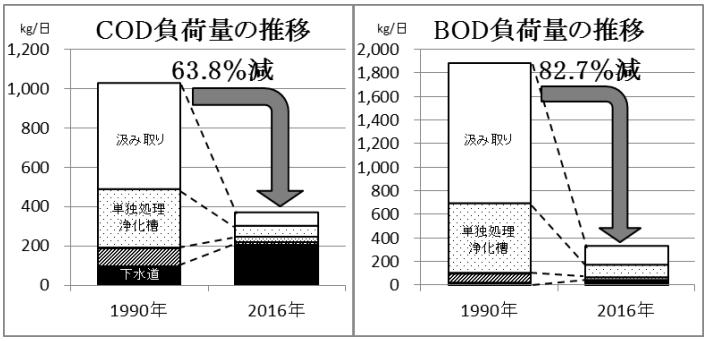

図 2　生活排水由来の汚濁負荷量の削減状況

・BOD 負荷量は，生活雑排水未処理に由来する割合が多く，生活雑排水の垂れ流しがなくなった場合，さらに 75%以上の削減を見込むことができると考えられる。一方で，COD の場合，生活雑排水の垂れ流しがなくなった場合でも 30%程度の削減にとどまる。

・下水道処理水は，霞ヶ浦に直接放流されることから，河川への負荷量のみを比較すると COD で 82%，BOD で 84%削減された。

・湖北流域浄化センターでは，近隣の自治体からの流入もあり，全処理人口が 2016 年度は 236,554 人となっている。さらに事業場からの流入もあるため，湖北流域浄化センターからの COD 負荷量の総量は，504 kg/日となる。この値は，土浦市内から発生するその他の生活排水処理形態の負荷量の約 3.3 倍となる。湖北流域浄化センターにおける処理性能が霞ヶ浦の水質浄化に与える影響は大きいと考えることができる。

5. 結論

・生活排水対策の推進により，霞ヶ浦への COD，BOD の負荷量が 1990 年と比べ 2016 年にはそれぞれ 63.8%，82.7%減少した。

・河川への COD，BOD の負荷量（下水道負荷量を除く）は 1990 年と比べ 2016 年にはそれぞれ 82%，84 減少し，市内河川，水路の水質浄化に大きく寄与している。

・今後，生活雑排水の垂れ流しがなくなることにより，更なる水質改善が図られる。

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備前川における生活排水路水質調査

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内藤　正弘[1], 水田　和広[1], 中山　洋一[2]

[1]土浦市市民生活部環境保全課, [2]土浦市建設部下水道課

キーワード:生活排水対策, 水質改善

抄録

備前川は, 1 級河川利根川水系霞ヶ浦に流入する河川であり, その流域は, 土浦市の市街地として急速に宅地化が進んだ地域である。宅地化に伴う生活排水等の流入により, 水質汚濁が進行し, 1992 年度には, BOD は 24 mg/L(75%値, 旧環境庁発表)と国内ワースト 3 位を記録した。現状の備前川の BOD は, 2016 年度において, 3.7 mg/L(75%値, 茨城県調査)であり, 水質は大幅に改善している。備前川の水質改善については, 1994 年に計画された, 備前川における「水環境改善緊急行動計画(清流ルネッサンス21)」にて, 様々な立場の人々が水質改善の取り組みを行ったことが功を奏していると考えられる。本報では, 計画策定時に実施された流入水路の水質調査について, 現況調査した結果を報告する。

1. はじめに

(1)備前川の概要と水質

備前川は, 霞ヶ浦に流入する河川の 1 つであり, 河床勾配が緩やかで, 下流部の河床が深く, 霞ヶ浦の背水の影響を強く受けることから, 河川水の停滞による水質汚濁が進行しやすい河川である(**表 1**)。上流部から下流部にかけて宅地が広がり, 下流部には一部畑が残っているものの, その流域の大部分は宅地である。

表 1 備前川の概要

河川名	備前川
河川延長	3.8km
流域面積	4.1km^2
環境基準地点	小松橋
指定区間	全川
類型指定	A類型　(BOD 2mg/L以下)
指定年度	昭和48年度

備前川の水質は, 流域の急速な宅地化による生活排水等の流入により汚濁が進行し, 1992 年には, 小松橋地点の BOD が国内ワースト 3 位の 24.0 mg/L(75%値, 旧環境庁発表)を観測し, 悪臭やアオコが発生するなど河川環境が著しく損なわれていた(**図 1**)。このような状況のなか, 1993 年に, 旧建設省による「水環境改善緊急行動計画(清流ルネッサンス21)」における第 1 次計画河川等に選定され, 種々の水質浄化対策が実施された結果, 2016 年度現在の BOD は, 3.7 mg/L(75%値, 茨城県調査)であり, 河川水質は大幅に改善している。

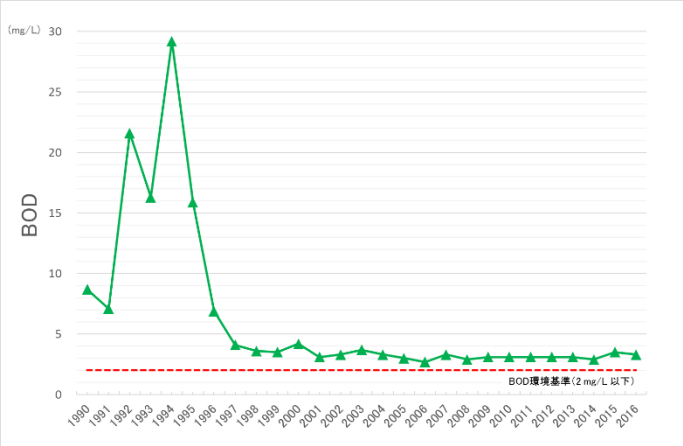

図 1　備前川における BOD 経年変化(年平均, 茨城県調査)

※測定地点:1998 年以前は小松橋, 1999 年以降は備前川橋

(2)水環境改善緊急行動計画(清流ルネッサンス21)

当計画は, 水質汚濁の著しい河川, 湖沼等のうち, 地元公共団体や地域住民が中心となって良好な水環境を創出する様々な取り組みがなされている河川などを対象にして, 2000 年までに良好な水環境の復活を目指し, 地元と河川管理者, 下水道管理者及び関係機関が一体となって水環境の改善事業を総合的, 緊急的かつ重

点的に実施することを目的として計画された。備前川は，1993 年に，旧建設省により第 1 次計画河川等の 1 つに選定され，これを受け，茨城県は，地元住民や土浦市を含む行政機関からなる「備前川清流ルネッサンス推進協議会」を設置し，翌年度，「備前川水環境改善緊急行動計画」を策定した。当計画は，目標水質を 2000 年までに BOD（75%値）を 4 mg/L，SS を 20 mg/L と定めており，目標を達成するための主な施策の 1 つとして，下水道の普及や合併処理浄化槽の設置等の生活排水対策が位置づけられていた。

(3) 流入水路の実態調査

計画策定時（1993 年）の備前川流域の下水道普及率は 58%，水洗化率は 69%であり，公共下水道への排水は実質 40%にとどまり，残りの多くは生活雑排水が未処理のまま水路を通して備前川に流入していたと考えられる。そのため，当時(1992 年)の備前川における BOD 汚濁負荷量の状況は，し尿（5%）と雑排水（74%）を合わせた生活系の負荷量が全体の 79%であり，生活系からの汚濁負荷量が大半を占めていた。計画策定にあたって，1994 年2月4日に，備前川の上流 0.5km 地点から急激に川幅が広がる常磐線陸橋手前の約 2km の区間に流入する 10 水路を対象に水質調査が行われている。調査項目は，流量，透視度，水温，pH，EC，濁度，BOD，SS であった。今回は，現況を把握するために，当時と同様の調査を実施した。

2. 方法

調査地点は，計画策定時の調査地点と同一の地点を基本とし，10 地点選定した。一部の水路は，流量が極めて少なくなっていたことから，調査地点から除外し，比較的流量の多い地点を調査地点に追加した（N1，N2）。

また，採水日は，前回調査と同様に，3 日間降雨がない日（2018 年3月 14 日）に実施し，採水時間についても前回と同様の午前 10 時から午後3時に行った。



図 2 調査地点の例 （地点番号③，⑩）

現地では，流量，水温，透視度を測定し，その他の項目については，サンプルを環境計量事業所に持ち込み，分析を依頼した。分析項目は，pH，COD，BOD，SS，T-N，T-P とした。

3. 結果及び考察

今回の調査結果と計画策定時との比較を**表 2** に，今回の調査結果（その他の項目）を**表 3** に示す。さらに，BOD の比較図を**図 3** に示す。

計画策定時の調査結果と今回の調査結果を比較すると，全地点において，BOD，SS，透視度が改善していることが確認された。さらに，BOD 及び SS について，各水路の結果の加重平均を算出すると，BOD については 97.4%，SS については 81.2%削減されたことが確認された。

表 2 計画策定時との比較

調査	流量(L/sec)		水温(℃)		透視度(cm)		pH(－)		BOD (mg/L)		SS (mg/L)	
地点	1994年	2018年	1994年	2018年	1994年	2018年	1994年	2018年	1994年	2018年	1994年	2018年
①	1.74	-	11.0	-	5.2	-	7.19	-	377.14	-	860.00	-
②	0.13	-	8.2	-	24.8	-	7.16	-	311.60	-	32.00	-
③	0.36	0.46	7.8	14.5	11.3	50以上	7.66	9.2	58.98	2.2	41.00	1.0
④	1.42	0.21	9.5	11.5	23.2	50以上	7.53	9.4	5.55	4.4	24.00	4.6
N1	-	0.26	-	10.5	-	50以上	-	7.7	-	1.1	-	1.0
⑤	0.52	0.6	6.5	11.0	30以上	50以上	7.4	7.7	69.19	1.7	10.00	2.4
⑥	0.41	0.3	6.0	11.0	19.0	50	7.38	7.3	86.11	13.0	13.33	6.4
N2	-	0.48	-	11.0	-	50以上	-	7.6	-	3.0	-	8.2
⑦	15.63	11.68	7.2	12.8	16.0	22	7.42	7.9	99.60	4.6	36.00	23.0
⑧	2.38	0.65	12.8	21.0	13.2	50以上	9.99	7.8	174.09	13.0	20.00	6.8
⑨	1.09	2.45	6.9	10.6	9.1	50以上	7.53	7.5	222.90	0.5	16.00	2.0
⑩	2.59	0.81	8.9	10.0	14.0	50以上	7.94	7.5	419.08	1.8	25.00	2.0
加重平均	–	–	–	–	–	–	–	–	155.9	4.1	85.7	16.1

表 3 その他の調査結果

地点番号	COD (mg/L)	SS (mg/L)	T-N (mg/L)	T-P (mg/L)
①	–	–	–	–
②	–	–	–	–
③	4.1	1.0	3.5	0.12
④	4.4	4.6	3.4	0.03
N1	2.9	1.0	5.1	0.09
⑤	3.5	2.4	2.4	0.06
⑥	13	6.4	0.97	0.14
N2	6.0	8.2	3.1	0.18
⑦	7.0	23	1.6	0.12
⑧	11	6.8	1.5	0.24
⑨	4.4	2.0	2.5	0.09
⑩	2.4	2.0	1.0	0.06

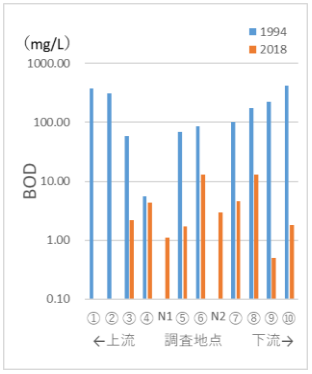

図 3 BOD 結果比較

今回の調査では，透視度は，調査地点⑦を除き，すべて 50cm 以上であった。これは，調査地点⑦の水路は，ため池からの流入水があることから，プランクトンの増殖により，透視度が低下したと考えられる。

BOD は，調査地点⑥，⑧が比較的に高い値であった。調査地点⑥の水路では，生活排水臭が強かったことから，未処理の生活雑排水及び浄化槽排水が原因であると考えられる。一方で，調査地点⑧の水路は，水温が 21 ℃であり，生活排水臭が感じられなかったことから，

事業場排水が原因であると考えられる。

4. 結論

備前川水環境改善緊急行動計画が策定され，24 年余りが経過し，様々な立場の人々が，水質浄化対策を着実に進めた結果，河川環境基準（BOD 2.0mg/L 以下）は未達成なものの，備前川の水質は大幅に改善している。

生活排水対策に着目すると，備前川流域のほぼ全区域に下水道が整備され，インフラ整備はほぼ完了している（図 4，図 5）。

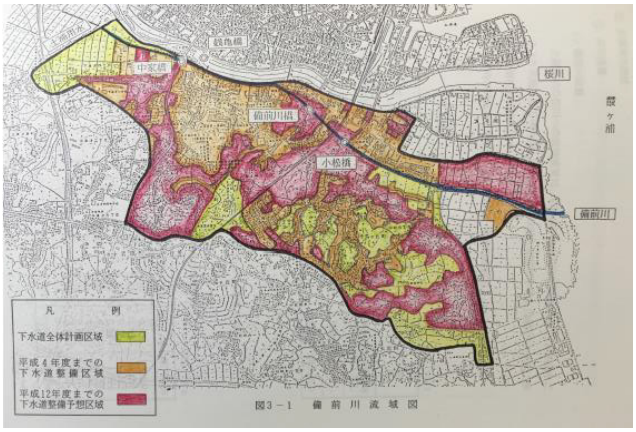

図 4 備前川流域の下水道普及状況（計画策定時，1994）

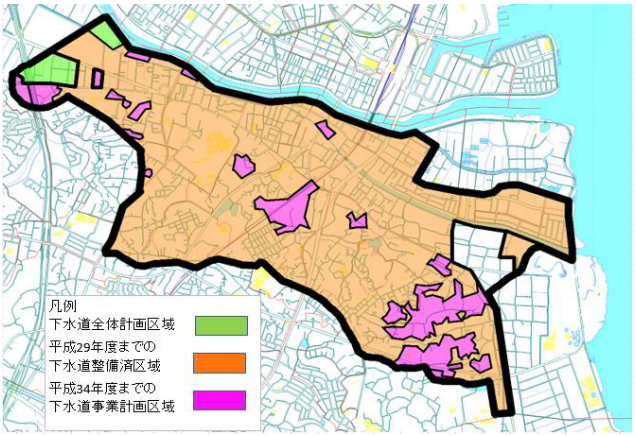

図 5 備前川流域の下水道普及状況（2018 年3月 31 日現在）

今回の流入水路調査の結果と計画策定時の結果を比較すると，BOD は大幅に改善している。しかしながら，一部の流入水路において，下水道未接続等により，計画目標値（BOD 4.0mg/L）に達していない箇所が見受けられる。

土浦市内全域に目を広げると，生活排水の処理形態は，2016 年3月 31 日現在で，下水道が 82.5%を占めているが，未だに生活雑排水未処理（汲み取り，単独浄化槽）人口が 6.9%を占めており，適正な生活排水処理への移行が課題となっている。

下水道への接続については，茨城県においても，霞ヶ浦に係る湖沼水質保全計画（第7期）のなかで，下水道への接続促進を掲げている。本市としても，垂れ流し 0%に向けて，適正な生活排水処理への移行についての啓発，指導を強化して参りたい。



図 6 調査地点⑩の水路に直接流入する生活雑排水（2018 年3月 14 日撮影）

5. 参考文献

[1] 備前川清流ルネッサンス21推進協議会:利根川水系備前川水環境改善緊急行動計画（清流ルネッサンス21），1994.11

[2] 備前川清流ルネッサンス21推進協議会:利根川水系備前川水環境改善緊急行動計画（清流ルネッサンス21）参考資料，1994.11

[3] 茨城県・栃木県・千葉県:霞ヶ浦に係る湖沼水質保全計画（第7期），2017.3

[4] 土浦市:第２期土浦市生活排水対策推進計画，2014.3

KP-7

土浦市における工場・事業場排水対策の取組み

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キーワード:排水規制

抄録

土浦市は，日本で2番目に広い面積を有する霞ヶ浦（西浦）の西岸に位置し，霞ヶ浦の恩恵を受けながら発展してきた。霞ヶ浦の水質は，経済活動の活発化に伴い，1960 年代頃から急激に悪化し，その対策のために，市内の工場・事業場には水質汚濁防止法や茨城県条例などの水質関係法令等に基づく排水基準が定められている。事業者は，これらの水質関係法令等に定められる排水基準の遵守する義務があり，その遵守状況について茨城県が立入調査・指導を行っている。市では，県を補助する立場として，1972 年から継続して市内の工場・事業場の排水調査を行っており，本報では，市における工場・事業場排水対策の取組みの一つである，工場・事業場排水調査について報告する。

1. はじめに

土浦市は，日本で 2 番目に広い面積を有する霞ヶ浦（西浦）の西岸に位置し，霞ヶ浦の恩恵を受けながら発展してきた。霞ヶ浦は，湖水浴を楽しめる自然豊かな湖であったが，生活様式や産業活動の近代化，流域人口増加等の影響を受け， 1960 年代頃から水質が急激に悪化した。茨城県環境局（当時）による，1975 年における霞ヶ浦への流入汚濁負荷量の推計[1]では，工場排水の割合は 21.3 %とされ，その割合は決して低くはなかった。（**図1**）土浦市内の工場・事業場には，国の法律や県条例等による排水基準が定められており，これら法令等の遵守状況を確認するために，県による立入調査，指導が行われている。市においても，県を補助する立場として，1972 年から継続して工場・事業場の排水調査を実施している。

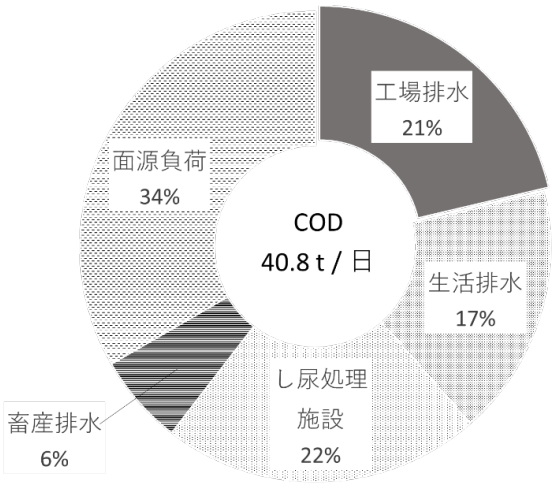

図1 霞ヶ浦に流入する汚濁負荷の割合（1975）
※西浦・北浦・常陸利根川の合計

2. 土浦市の産業構造

土浦市の産業構造は，第三次産業の比率が高く，商業・業務都市としての特性と工業都市としての性格を併せ持っている。[2]本市は，1963 年に，首都圏整備法による都市開発区域の指定を受け，首都圏の衛星都市として首都圏整備計画に基づき開発が行われ，工業団地，住宅団地の造成及び関連都市施設の整備が進み，従来の商業都市に加えて，工業都市としても発展するようになった。[3]（**図2**）

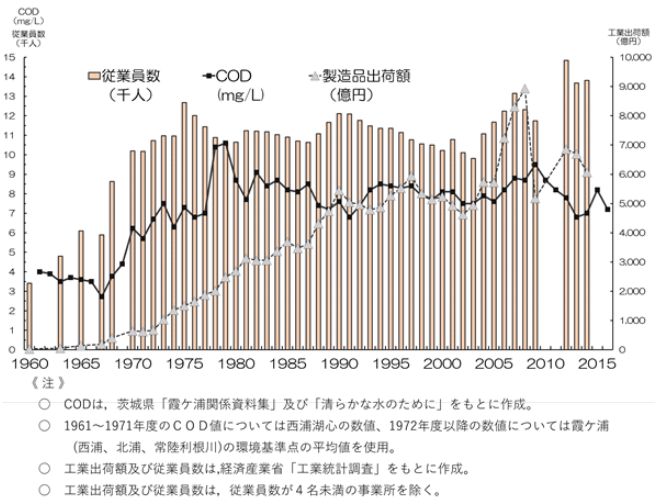

図２ 霞ヶ浦の COD 経年変化と土浦市の製造品出荷額及び従業員数の推移

市内の工業団地は， 1968 年に日本住宅公団による土浦・千代田工業団地（土浦市内 127.2ha，旧千代田村内 40.8ha，計 168ha）の整備が完了し，続いて 1997 年に都市基盤整備公団による土浦北工業団地（41.7ha ）の整備が完了した。2000 年には，おおつ野ヒルズ(41ha)の

整備完了し，2006 年の新治村との合併に伴い，東筑波新治工業団地(35.5ha)が加わり，おおつ野ヒルズを除く3つの工業団地において分譲が完了している。

3. 土浦市内の工場・事業場排水基準の変遷

市内の工場・事業場に対しては，国の法律や県・市条例，あるいは公害防止協定による排水基準の遵守が義務付けられており，その変遷等について**表1**に示す。霞ヶ浦の水質汚濁の対策のために，市内の工場・事業場に対しては，幾度となく排水基準が改正されており，国の一律排水基準より厳しい排水基準の遵守が義務付けられている。

表1 市内の工場・事業場排水基準の変遷等

法令・条例等	年 月 日	概 要
県公害防止条例	1966.12.10 公布	霞ヶ浦水域をＡ水域とし，公害防止基準を定める。BOD・COD:30 mg/L
公害対策基本法	1967. 8. 3 公布	公害問題の根本的な解決のための施策の理念と方向を明らかにし，総合的，計画的な公害対策実施への道筋を示す。
水質汚濁防止法	1970.12.25 公布	法に定める特定施設を有する事業場からの排出水について，排水基準以下の濃度で排水することを義務付け。
公害防止協定	1971. 4. 1 締結	土浦市，旧千代田村と土浦・千代田工業団地進出企業において公害防止協定を締結する。 以降，土浦・千代田工業団地進出企業に限らず，締結を進める。
水質汚濁に係る環境基準 (環境庁告示第 59 号)	1971.12.28 告示	公害対策基本法第9条に基づき，水質汚濁に係る環境基準が告示される。
排水基準を定める総理府令	1971. 6.21 公布	水濁法に基づき，国の一律排水基準を定める。 BOD・COD:120 mg/L 排水量:50m^3/日以上の事業場を対象 ※業種により暫定基準あり。 BOD・COD:200 mg/L～16,000 mg/L
県公害防止条例全面改正	1971.10.18 公布	水濁法の上乗せ排水基準を定める。 霞ヶ浦水域:BOD・COD:30 mg/L 排水量:50m^3/日以上の事業場を対象 県独自に，畜舎・石材加工などの汚水に係る特定施設を定める。
市公害防止条例	1972. 4. 1 公布	他の地方公共団地との相互協力や国・県への措置要請，公害防止協定の締結等について定める。 県公害防止条例の規模要件未満の畜舎を汚水に係る特定施設として定める。
霞ヶ浦の水質環境基準類型指定(湖)	1972.11. 6 公布	公害対策基本法に基づき，国が湖内Ａ類型(COD:3 mg/L)に指定する。
霞ヶ浦の水質環境基準類型指定 (流入河川)	1973. 9. 3 公布	公害対策基本法に基づき，県が流入河川Ａ類型(BOD:2 mg/L)に指定する。
県公害防止条例一部改正	1973.11. 1 公布	水濁法上乗せ排水基準を改定する。 新設の特定移設等(公布日から適用) BOD・COD:10 mg/L，排水量 20m^3/日以上の事業場 既設の特定移設等(施行日から適用) BOD・COD:20 mg/L，排水量 50m^3/日以上の事業場
県公害防止条例	1974. 8. 1	北浦，常陸利根川水域における水濁
一部改正	公布	法上乗せ排水基準を定める。(霞ヶ浦水域と同水準)
県公害防止条例一部改正	1975.10. 7 公布	霞ヶ浦流域の特定事業場に自己監視及び報告が義務化される。
公害防止協定見直し	1977. 4, 1 ～ 締結・改定	社会情勢を踏まえ，公害防止協定の全面改定。 公害防止細目協定において，排水量の区分に応じた排水基準や自己監視及び報告等を定める。
県霞ケ浦の富栄養化の防止に関する条例	1981.12.21 公布	国の一律排水基準に先駆け，窒素・りんの排水規制が導入される。
湖沼水質保全特別措置法	1984. 7.27 公布	指定湖沼，指定地域を定める。 みなし指定地域特定施設の排水規制 指定施設等の構造・使用方法の規制
水質汚濁防止法施行令改正	1985. 5.17 公布	国の一律排水基準に，窒素・りんが導入される。 窒素:60 mg/L 以下，りん:8 mg/L 以下
県霞ケ浦の富栄養化の防止に関する条例 改正	1985. 7.13 公布	窒素・りんの上乗せ条例として位置づけ。
湖沼法に基づく指定湖沼及び指定地域に係る告示	1985.12.16 公布	霞ケ浦(北浦及び常陸利根川を含む)が指定湖沼となる。
公害対策基本法に基づく霞ヶ浦の水質環境基準類型指定(湖)	1986. 4. 5 公布	公害対策基本法に基づき，国が湖沼Ⅲ類型(窒素 0.4 mg/L，りん 0.03 mg/L)に指定する。
湖沼水質保全特別措置法 改正	1987. 7. 2 公布	汚濁負荷量規制(COD)の制定 湖沼特定事業場(排水量 50m^3/日以上)
湖沼水質保全特別措置法 改正	1992. 9. 1 公布	汚濁負荷量規制(窒素・りん)の制定 湖沼特定事業場(排水量 50m^3/日以上)
環境基本法	1993.11.19 公布	環境基本法制定に伴い，公害対策基本法が廃止される。
県水質汚濁防止法に基づき排水基準を定める条例	2005. 3.24 公布	県公害防止条例を全改定 水濁法特定施設の上乗せ排水基準(BOD・COD・SS 他)を定める。
県生活環境の保全等に関する条例	2005. 3 24 公布	県公害防止条例を全改定 独自の排水特定施設及びその排水基準(BOD・COD・SS 他)を定める。
湖沼水質保全特別措置法 改正	2005. 6.22 公布	湖沼特定施設範囲の見直し (汚水処理施設等を負荷量規制の対象とする) 既設の事業場に対する汚濁負荷量規制基準の追加
県霞ケ浦水質保全条例	2007. 3.27 公布	県富栄養化防止条例を全改定，改称 ①水濁法特定施設の排水基準(窒素・りん)を定める。 ②排水指定施設及びその排水基準(窒素・りん)を定める。 ・一部排水指定施設において，従前より小規模な施設を対象とする。 ・新たに，51 人槽以上の浄化槽を排水指定施設に追加。 ③規制対象の排水量の裾下げ ・20 m^3/日以上→10 m^3/日以上 ④既設，新設区分の廃止 (旧条例の既設扱いの事業場は，施行後3年間猶予) ⑤排水規制が適用されない事業所を小規模事業所として排水基準(BOD・COD・SS ・窒素・りん)を定める。
県生活環境の保全等に関する条例 一部改定	2007. 3.27 公布	県霞条例に併せて，排水特定施設の規模要件，排水基準等について改定。
公害防止協定見直し	2008. 4. 1 ～ 締結・改定	環境関係法令等の整備を踏まえ，順次，公害防止協定及び細目協定の締結・改定を進める。

4. 土浦市における工場・事業場排水調査

市では，1972 年から工場・事業場の排水調査を開始し，調査の初年度は茨城大学農学部に分析を委託，その結果を受けて排水処理施設の整備改善指導を実施した。現在は以下の①から④のステップで実施しており，分析は環境計量事業所に委託している。

①市職員による採水

②分析結果及び基準遵守状況の通知

③基準超過に対する注意喚起又は改善計画書提出の指示

④必要に応じて，改善のためのヒアリング

2017 年度の調査では，調査対象を市内 54 工場・事業場とした。対象の選定は，公共下水道へ接続されていない工場・事業場のなかで，水質汚濁防止法，湖沼水質保全特別措置法，茨城県生活環境の保全等に関する条例及び茨城県霞ケ浦水質保全条例に規定する特定施設等を設置する工場・事業場のうち，排水量が 10 m^3/日以上の工場・事業場及び環境影響のリスクが高い電気メッキ施設を有する工場・事業場とした。

5. 土浦市内の工場・事業場における遵守状況

近年の排水基準遵守状況を**図3**に示す。不適合率（水質関係法令・条例又は公害防止協定に定められる排水基準を超過した工場・事業場の割合）は，概ね 20 % から 40 % の間を推移しており，基準超過が常態化している工場・事業場も見受けられる。基準超過の主な原因は，次の3点が挙げられる。

①工場・事業場が立地されてから 40～50 年が経過し，排水処理施設が老朽化していること

②度重なる法令等の改正に対して，排水処理施設の対応が追い付いていないこと

③団塊の世代の退職に伴い，排水処理施設の維持管理のノウハウが不足していること

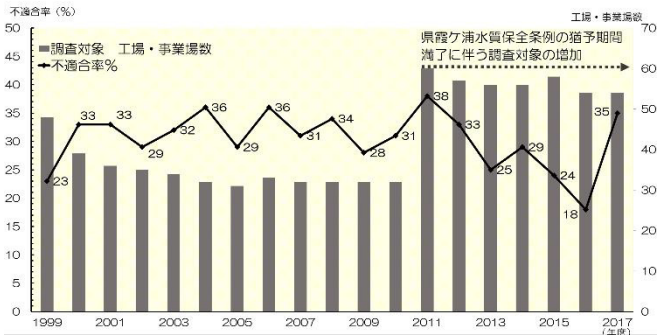

図 3 土浦市内の工場・事業場における排水基準の遵守状況

6. 総括

土浦市では，工場・事業場排水対策の取組みとして，工場・事業場排水調査を約 50 年継続して実施している。調査結果の一例として，食品製造業の排水調査の結果（COD）に着目すると，調査開始当時(1972)と 2017 年の調査では大幅な改善が見られる（**表2**）。

表2 食品製造業における COD（mg/L）の調査結果

工場・事業場	1972 最小	1972 最大	1972 平均	2017 最小	2017 最大	2017 平均
A	42.72	101.48	77.5 (n=6)	2.0	7.6	4.2 (n=3)
B	12.5	52.6	28.3 (n=6)	5.0	5.6	5.3 (n=2)
C	37.6	250.13	102.1 (n=6)	5.7	9.4	7.3 (n=3)
D	33.13	71.42	42.5 (n=4)	6.6	12	9.2 (n=3)

※調査開始当時から継続して操業している工場・事業場を抽出
※調査回数は工場・事業場によって異なる。

また，霞ヶ浦に流入する汚濁負荷量（COD）[4]に着目すると，2015 年における工場排水の負荷量（COD）は，西浦では 0.7 t/日 ，北浦で 0.1 t/日 であり，1975 年の推計値の 8.7 t/日（西浦・北浦・常陸利根川の合計）と単純に比較すれば，およそ 92 % 削減している。

他方で，土浦市内の工場・事業場における排水基準の遵守状況は，概ね 60 % から 80 % に留まっており，排水基準遵守の徹底には至っていない。現行の排水基準を定常的に遵守するためには，事業者自身が各々の工場・事業場の特性を熟知し，相応の投資を行いながら，排水処理施設を適切に維持管理することが肝要である。

土浦市では，第8次土浦市総合計画において，基準超過事業場割合を0%にすることを目標に掲げている。今後も，茨城県等の関係機関の協力を得ながら，粘り強く事業者と向き合い，現場に一番近い地方公共団体として，目標達成に努めて参りたい。

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KP-8

市民による霞ヶ浦流入河川水質調査について

伊藤　良子[1], 宮本　清[1], 中川　清[1]

[1]霞ヶ浦問題協議会

キーワード: 市民参加, 簡易検査, 意識啓発

抄録

本事業は霞ケ浦に流入する 56 河川の水質調査をとおして「流域住民の水質浄化意識の高揚」を目的とするもので，本年度で第 17 回を迎える。調査方法は市民や子供たちと一緒に地元の川に行き，川の様子を観察し所定の記録用紙に記入する。その後，川の水を採水し，学校・市役所等に持ち帰り簡易検査により水質測定を行うものである。

調査結果は専門機関で解析し報告書として取りまとめ，関係者に配布するほか，平成 28 年度は概要版を作成し関係者・参加者等に配布した。

本調査は簡易測定であるが経年変化をみると各項目とも低濃度帯の占める割合が年々増加しており，改善傾向が認められる。また汚濁原因は依然として生活排水及び農業・畜産排水が考えられる。

霞ヶ浦の浄化は行政のみで成し得るものではなく，流域住民の協力なくして達成できるものではない。今後とも本事業をとおして住民の霞ヶ浦や流入河川の水質浄化意識の高揚を図ってまいりたい。

1）はじめに

霞ヶ浦問題協議会は昭和 48 年夏におけるアオコの大発生や養殖コイの大量へい死を契機として，流域市町村長の呼び掛けにより同年 9 月に発足した団体である。その後，加入市町村の増加や市町村合併を経て，現在 21 市町村長を構成メンバーとしている。

また，構成市町村では家庭排水浄化推進協議会を組織し，その会員が地域のリーダーとなって，粉石けん運動，霞ヶ浦・北浦地域清掃大作戦，廃油回収，浄化キャンペーン，流入河川水質調査など住民主体の霞ヶ浦浄化運動を展開している。

今回発表テーマとした「霞ヶ浦流入河川水質調査」は平成 13 年度から行っている霞ヶ浦問題協議会の主要事業の 1 つである。

霞ケ浦には 56 本の河川が流入しているが，その水質改善は霞ヶ浦の水質と同様に流域住民にとって大きな課題となっている。本事業は汚濁が進んでいると思われる河川（河口部は全 56 か所）を対象として，「霞ヶ浦に流入する河川において，流域住民の参加による水質調査を実施し，‘河川は私たちのもの’との認識をより一層高めることにより，流域住民の水質浄化意識の高揚を図る」ことを目的として実施しているものである。

かつて，川は子供たちにとって，魚釣りや夏休みの川遊びを通して身近な存在であったが，水質の汚濁や学校の指導により，現在では子供たちが川と接する機会はほとんどない状況である。これは近隣住民にとっても同様である。川と疎遠になったことが川の水質改善や環境保全の重要性について認識されない大きな要因と考えます。

そこで，流域住民や子供たちが川に足を運び，川と触れ合い，水質調査をとおして水質の状況や周辺環境など，川の現状を認識することで浄化意識の高揚が図れるものと考え，この事業が始まった。

なお，同様の事業として平成 16 年度から全国レベルの取組みとして「身近な水環境の全国一斉調査」が行われている。

2）方法

サンプリング日時の影響を少なくするため，毎年 10 月最終土曜日を基準日としている。実施に際しては構成 21 市町村が住民や学校に呼びかけ参加者を募集し，環

境担当職員が指導者となって実施している。

調査方法は川の様子（水の色，臭い，川底・護岸・周囲の動植物）を観察し，所定の記録用紙に記入する。採水は生活排水の影響が表れやすい，午前中に行うことを原則としている。

その後，サンプルを学校・市役所等公共施設に持ち帰り，簡易検査（パックテスト）により水質調査を行う。

調査項目は以下の理由によりCOD，pH，アンモニア態窒素，リン酸態リン，透視度としている。

COD：有機物汚濁の代表的指標であり，簡易測定でも比較的高精度の測定が可能であること。

アンモニア態窒素：生活排水に多く含まれ，生活排水による汚濁について評価可能であること。

リン酸態リン：生活排水や農業排水に含まれ，簡易測定が可能なこと。

3）結果

これらの調査結果については本協議会が 21 市町村分の記録を集計し，専門機関に委託し，報告書として取りまとめている。平成 28 年度実績としては全 56 河川，285 地点について測定し，参加者数は 270 人と多くの方にご参加いただいている。項目別の濃度分布は図 1～3 のとおりであり，低濃度帯の占める割合が年々増加し，水質の改善傾向が認められる。

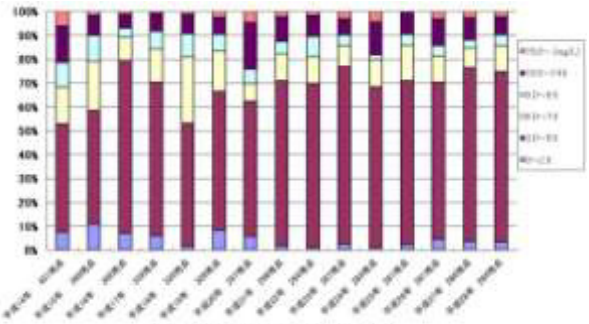

図1 全調査地点のCOD値の割合

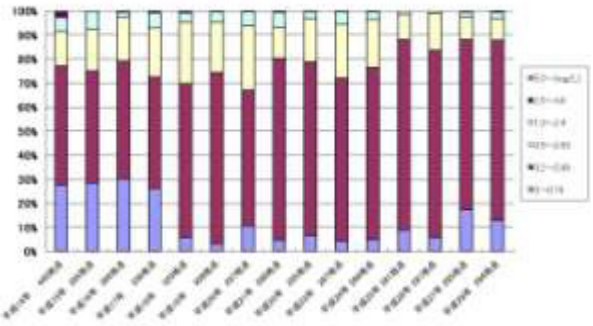

図2 全調査地点のNH_4－N 値の割合

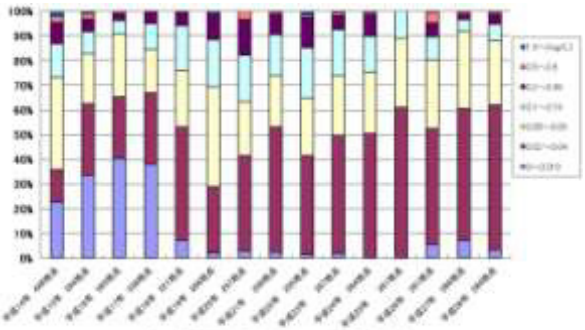

図3 全調査地点のPO_4－P値の割合

なお，アンモニア態窒素とリン酸態リンについて平成 17 年度と平成 18 年度でパターンが異なるが，これはメーカーの都合で濃度読取用カラーチャートの区分が変更となったことによるものです。

本事業は簡易測定による年 1 回の測定であり，その河川の水質を代表するものではないが，流域全体でほぼ同時期に，かつ同様の方法で測定し，上下流の変化，他河川との比較，経年変化を見ることは有効であると考えている。

調査結果については報告書として取りまとめ，関係者に配布するほか，平成 28 年度は測定地点や測定項目ごとの検査結果を濃度分布ごとに色別の円で表し，地図にプロットしたマップ様の概要版を作成し，関係者・参加者等に配布した。（図 4～6）

また，平成 28 年度は茨城県霞ケ浦環境科学センターの協力により，公定法による全窒素，全リンの測定を行い，簡易検査との相関を検討した。

4）考察

本調査は簡易測定であり，数値での評価は困難であるが，経年変化をみると各項目とも低濃度帯の占める割合が年々増加しており，水質の改善傾向が認められる。相対的に北浦エリア，新利根川流域の汚濁が顕著であり，早急な対策が必要である。

しかし，霞ケ浦の環境基準と比較すると依然として高濃度であり，一層の改善対策が求められる状況にある。

今回の調査結果を概要版の色別のマップから推察すると，流入河川の汚濁の要因は依然として生活排水及び農業・畜産排水によるものと考えられる。

前述のとおり，下水道，農業集落排水施設の整備により，総体的には若干の改善傾向は見られるものの，下水道等未整備地区やその接続率が低いと思われる地域では水質汚濁が顕著であった。



図 4　CODの濃度分布



図 5　アンモニア態窒素の濃度分布



図 6　リン酸態リンの濃度分布

また，簡易測定と公定法による窒素，リンの測定結果を比較したが，特に窒素は測定結果のオーダーが異なっているなど，両項目とも明確な相関は認められなかった。

また，公定法による全窒素，全リンの調査結果においても簡易測定と同様に生活排水処理率の低い地域での汚濁が認められた。

5）結論

本調査は地元市町村職員の指導のもと，流域住民と子供たちが主体となって行っている事業である。図 7 のとおり一時期より減少したものの参加者は 300 名前後，調査ポイントは 280 地点を維持している。

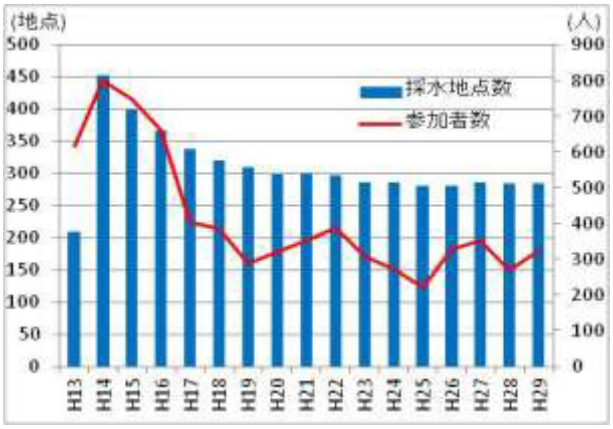

図7　参加者及びポイント数

一部市町村では小学校の授業とタイアップして，小学生や教師が実際に川に行き，本調査をとおして，普段意識することの少ない地元の自然や川をあらためて認識する機会となっている。また，家に帰って学校での様子を保護者と会話することで，昔の川の様子を学んだり，保護者も川について再認識する機会ともなっている。 さらに本調査には各市町村の家庭排水浄化推進協議会メンバーも参加しているが，メンバーであっても普段の生活では川を見る機会は少ないと思われ，この調査が今後の活動の意識づけとなっている。

事業の目的とする「流域住民の水質浄化意識の高揚」を図るには一人でも多くの方に参加していただくことが重要である。私たちが毎日飲んでいる「命の水」を守るため，概要版の活用等あらゆる機会をとおして，これまでの調査結果等を広く周知し，参加者の増に努め，今後とも継続して実施することが肝要と考えている。

また，調査結果から総体的には水質の改善傾向が認められますが，考察に記したとおり，下水道や農業集落排水施設の未整備地区における生活排水による汚濁が大きな要因と考えられることから，接続促進や高度処理浄化槽の普及及び適正な維持管理についてもPRしてまいりたい。

KP-9

霞ヶ浦・北浦地域清掃大作戦について

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[1]霞ヶ浦問題協議会

キーワード: 市民参加, 意識啓発

抄録

「霞ヶ浦・北浦地域清掃大作戦」は霞ヶ浦問題協議会発足当初から行っている主要事業の１つで，春・夏の年２回実施しており，本年３月に第89回を迎えた。本事業への参加人数は毎年10万人を上回り，流域人口96万人の１割を超え，一時期程ではないものの近年増加傾向にある。一方，ゴミ回収量については10年前の約半分となっている。

参加者が常に流域人口の 1 割を超えており，本事業が住民に深く認識され，住民の霞ヶ浦の環境保全に対する意識向上が伺えるが，未だ十分とは言い難い状況である。今後も，この取組みを継続して実施し，霞ケ浦や河川の環境保全に努めてまいりたい。

また，本事業をとおして子供たちや住民が湖岸・河川敷に足を運び，周辺環境や水質の現状を自らの目で感じることで，私たちの「命の水」の源である霞ヶ浦や河川の水質浄化の必要性やそれらが私たちにとって大切なものであることを再認識してもらえるよう努めてまいりたい。

1）はじめに

霞ヶ浦問題協議会は昭和 48 年夏におけるアオコの大発生や養殖コイの大量へい死を契機として，流域市町村長の呼び掛けにより同年 9 月に発足した団体である。その後，加入市町村の増加や市町村合併を経て，現在 21 市町村長を構成メンバーとしている。

構成市町村ではそれぞれ家庭排水浄化推進協議会が組織されており，その会員が地域のリーダーとなって生活排水対策を主とする様々な霞ケ浦水質浄化運動を展開している。

今回発表テーマとした「霞ヶ浦・北浦地域清掃大作戦」は霞ヶ浦問題協議会の発足当初から行っている主要事業の 1 つで，春・夏の年 2 回実施しており，本年 3 月に第 89 回を迎えた。

特に春期分については毎年 3 月第 1 日曜日を「霞ヶ浦清掃の日」と定め，流域 21 市町村が一斉に実施しているもので，毎年多くの住民や企業・団体の方に参加いただき，大きな成果を上げている。今回は世界湖沼会議開催の年に当たることから記念大会とした。

2）方法

本事業は昭和48年度から継続して実施しているため，地元住民にとっても年中行事として捉えていただいている状況となっている。また，企業・団体にとっても同様で多くの企業・団体に毎年参加いただいている。

夏期分については市町村ごとに独自の方法で実施しているが，春期分については霞ヶ浦流域の 21 市町村が一斉に実施していることが特徴である。これほど広範囲かつ，一斉に清掃している事例は稀であると思われる。

実施方法は以下のとおりである。

①開催案内，参加要請

本事業の案内については，流域住民には市町村が窓口となり，各戸 1 人の参加を原則として市町村HPや広報紙によって周知・要請している。

毎年参加いただいている企業・団体に対しては本協議会から要請文を送付している。

②開会式

協議会の構成 21 市町村を 4 ブロックに分け，持回りで拠点となる市町村を設定し，拠点会場において開会式を行っている。

開会式は本協議会や地元市町村，大好きいばらき県民会議，茨城県企業公社が主催し，国・県等関係機関の出席をいただき，地元住民や企業等約500～600人の

参加により実施している。また，開会式ではIBS（ラジオ：茨城放送）に依頼し，インタビュー放送をとおして，広く霞ケ浦浄化を訴えている。





開会式の様子

上：H30.3.4　拠点会場の鹿嶋市津賀城址公園

下：会長あいさつ

③清掃活動

拠点地区では開会式の後，市町村職員の先導により，参加者全員が湖岸等に移動し，清掃作業を行う。作業時間は約 1 時間としている。

また，全国で水中クリーンアップ活動を行っている団体の協力により，地元漁業協同組合の承諾を得たうえで，プロのダイバーによる湖内の清掃も実施している。



作業終了後，開会式会場において参加企業に提供頂いた飲物等を受取り，解散となる。





上，下：清掃活動の様子

拠点地区以外では地元市町村や地区長の呼び掛けにより，住民や市町村職員が中心となって清掃活動を行っている。一部市町村では地元企業の参加を得ている。

ゴミの処分は地元市町村にお願いしており，回収量は市町村ごとに計測し，本協議会で集計・報告している。

なお，春期分については（一社）関東地域づくり協会の支援を頂いている。

3）結果

最近の参加者数，ゴミ回収量は表 1 のとおりである。

表 1 参加者数及びゴミ回収量



表に示すとおり毎年大勢の参加により，大きな成果となっている。参加人数では夏期は増加傾向にあるものの，春期については約8～10万人となっている。合計の参加者は10万人を上回り，流域人口96万人の1割を超えており，一時期ほどではないものの近年は増加傾向にある。ゴミ回収量については10年前の約半分となっているが，湖岸，河川がきれいになったとは言い難い状況である。

4）考察

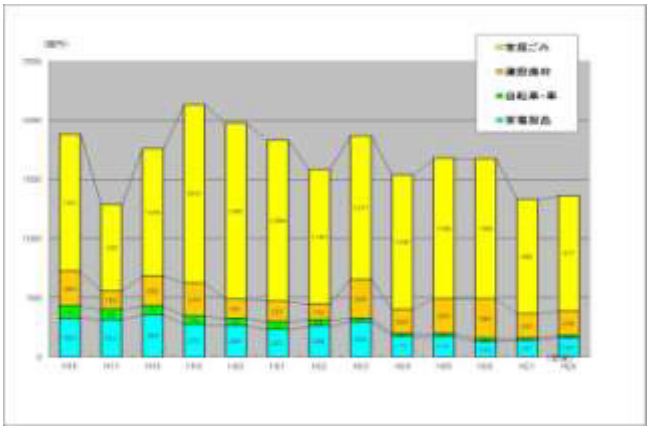
霞ヶ浦のゴミ問題は流域市町村において様々な対策がなされており，本事業のほかにも市町村独自の清掃や各種団体による清掃活動も活発に行われており，回収量減少に繋がっているものと思われる。

本事業は表1に示したとおり，毎年多くの方に参加いただいており，本事業が住民に深く認識され，そして住民の霞ヶ浦の環境保全に対する意識が向上していることや本事業自体が年中行事として根付いていることが伺える。また，ゴミ回収量は一時期に比べ減少しているものの，相当量に上り，まだまだ十分といえる状況にはない。継続した実施が必要と考える。

また，国土交通省霞ヶ浦河川事務所では湖岸巡視の際に確認したゴミの不法投棄の状況を表2のとおり[1]「霞ヶ浦ゴミマップ」として公表しているが，不法投棄件数は減少傾向にあるものの，ゴミの量は依然として高止まりで，湖岸のいたるところに不法投棄がなされている。一人ひとりの意識改革が必要と考える。

また，近年はCSR運動の一環として企業から参加要望が多い状況にある。このような状況を有効に活用し，流域に住む全ての人たちの触れあいの場としても本事業を活用してまいりたい。

表2 湖岸不法投棄ゴミの推移



5）結論

考察に述べたとおり，本事業におけるゴミ回収量は減少しているが，湖岸・河川敷がきれいになったと言えるものではなく，場所によっては拾った次の日にはゴミが捨てられている。本協議会会長が言っているように，「何事も地道に粘り強く」実施していくことが肝要と考えます。

近年，霞ケ浦湖岸等において，様々な主体，手法により清掃活動が活発に行われているが，本事業は霞ヶ浦流域の10万人が一斉に清掃活動を行うという霞ヶ浦環境保全事業を代表するものであることから，今後とも皆様方の協力の下，継続して実施してまいりたい。さらに一人でも多くの方に参加頂けるよう努めてまいりたい。

霞ヶ浦や河川の水質浄化は研究者や行政のみで出来るものではありません。そこに住んでいる住民の協力が不可欠である。

かつて，霞ケ浦や河川は子供たちにとっては魚釣りや夏休みの遊び場であり，近隣住民にとっても生活の一部であった。しかし，近年，霞ケ浦や河川を見たり，触れたりするのは漁業者や釣り愛好家，マリンスポーツ愛好家のみであり，子供たちや近隣の住民でさえ，霞ケ浦等に接する機会は少なく，霞ヶ浦等の環境や水質の状態を自分の目で実感することは少なくなっている。

霞ヶ浦や河川は子供たちや近隣住民の意識から遠い存在となっている。疎遠であることが環境保全や水質浄化について考える機会を喪失させ，無関心な人が多くなっている原因の一つと考えます。

よって，本協議会としては本事業を始めとして，あらゆる機会を捉えて捉え，子供たちや近隣住民が湖岸や河川敷に足を運び，周辺環境や水質の状態を実感として感じることで，私たちの「命の水」の源である霞ヶ浦や河川の環境保全や水質浄化の必要性やそれらが私たちにとって非常に大切なものであること再認識してもらえるよう努めてまいりたい。

引用文献

[1] 国土交通所霞ヶ浦河川事務所平成28年度「霞ヶ浦ゴミマップ」

KP-10

恋瀬川探検隊事業について

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矢部　利夫[1]，長谷川忠徳[1]，真家　功[1]，秋永　吉隆[1]，荻沼　宏樹[1]，廣原　正則[1]
[1]恋瀬川探検隊連絡会議

キーワード：市民参加，意識啓発，環境教育

抄録

恋瀬川探検隊は恋瀬川の上流から下流まですべての住民が相互に連携して，恋瀬川や霞ヶ浦の水質浄化に取り組む気運の醸成を図ることを目的とし，石岡市，かすみがうら市，小美玉市及び3市内の環境団体，関係行政機関を構成メンバーとして平成15年に設立された。

設立以降これまでの15年間に54回の事業を開催し，地元の子供たちを中心に多くの方に参加いただき活発な活動を展開している。

事業内容は地域特性に合わせて，様々な観点から郷土の自然や歴史が学べるよう山関連・水関連・歴史関連と多様な内容としており，霞ケ浦浄化や環境保全の重要性，地元の歴史を認識する契機となっている。今後とも事業内容を十分に精査し，より多くの参加が得られるよう努めてまいりたい。

また，霞ヶ浦流域では恋瀬川探検隊同様の5つの探検隊があり，独特の事業も行われていることから，探検隊相互の交流等新たな事業展開についても検討し事業の活性化に努めてまいりたい。

1.はじめに

霞ケ浦は広くて浅いという特性に加え，流入河川が56本と多数あるにもかかわらず，出口は1本であることから，元来，汚濁しやすい湖であり，かつて，アオコが大発生するなど水質汚濁が問題となっており，行政ばかりでなく，市民団体や環境団体等により様々な水質浄化活動が行われてきた。

その活動の一環として，流入河川や霞ヶ浦の水質浄化，環境保全を目的として，霞ケ浦に流入する代表的な河川ごとに5つの探検隊組織が組織されており，本題の恋瀬川探検隊もその1つとして平成15年に発足した。

恋瀬川探検隊連絡会議の構成メンバーは恋瀬川流域の石岡市，かすみがうら市，小美玉市及び3市内の環境団体，関係行政機関とし，その目的は恋瀬川流域や霞ヶ浦の水辺，動植物，風土，文化と直接触れ合うことを通じて，流域の子供たちや住民の水環境への関心を高め，上流から下流に至るまで相互に連携して，恋瀬川流域や霞ヶ浦の水質浄化に取り組む気運の醸成を図ることとしている。

設立以降これまで15年間に計54回の事業を開催し，地元の子供たちを中心に多くの方に参加いただいている。さらに，事業実施に際しては関連団体のご協力を頂いている。

なお，開会式では環境保全の観点から以下の合言葉を全員で唱和している。

「持ち帰っていいものは思い出だけ，残していいものは足跡だけ，とっていいものは写真だけ」

また，子供たちが主役の事業であることから，合言葉に続いて「3つのし　まむし，うるし，けむしに気を付けよう」を復唱し，安全第一をモットーとして事業を行っている。

２．方法

恋瀬川は石岡市北部の吾国山を源流とし，霞ケ浦に流入する延長27.85ｋｍの１級河川で，常陸国風土記にも登場する歴史ある河川で，森林環境，水環境ばかりでなく歴史・文化にも触れることのできる絶好の自然学習フィールドである。恋瀬川

探検隊は恋瀬川の上流から下流までの流域全体を活動エリアとしている。

恋瀬川探検隊の活動状況としては，現在，3 市合同での全体事業を年 1 回，市ごとの地域事業を各年 1 回の年 4 回の事業を実施している。

全体事業については 3 市持ち回りで担当市を決め，上流部では山関連事業として森林環境や水源の状況，下流部では水関連事業として河口部の自然観察，魚とり，投網体験など地域に即した事業内容としている。併せて歴史関連事業も取り入れている。

更に，3 市の協力により恋瀬川の上・中・下流部の河川水を用意し，パックテストを用いた水質検査を行っている。その際，講師の先生から上流から下流に至る汚れの変化やその原因，汚さない工夫について学んでいる。



間伐体験の様子



川に入って魚とり



水質調査で透視度測定

地域事業については 3 市の特性に合わせた事業内容としているが，自分の地域に関することばかりでなく，上流（水源）の様子や下流部に及ぼす影響，霞ケ浦の様子等流域全体にわたる知識が得られるよう工夫している。

実施までの流れとしては，年度当初に恋瀬川探検隊連絡会議において事業計画を定め，各市の広報紙や学校への参加要請を行い，参加者を募集している。

3．結果

これまでの 15 年間に 54 回の事業を開催し，地元の子供たちを中心に多くの方に参加いただいている。

具体的な事業内容は表 1 のとおりであり，地域特性に合わせて多様な内容となっており，様々な観点から幅広い体験を通して，郷土の自然環境・歴史について学んでいる。

表 1　恋瀬川探検隊事業一覧

山関連事業	植物観察，間伐体験
	枝打ち見学，木工体験
水関連事業	湖岸・ハス田見学，水質調査
	野鳥観察，植物観察，魚とり
	霞ケ浦湖上体験，投網体験
歴史関連事業	古墳・遺跡見学
	郷土資料館見学

また，事業実施に際しては森林組合やレンコン農家等の関連団体のご協力をお願いしているほか，地元婦人団体からカレー，トン汁，スイカなどのおもてなし協力を頂き，楽しみを加味した事業としている。

年度ごとの参加人数は図 1 のとおりであり，事業内容により募集人数が異なり，全体的な傾向はつかめないが，合計で 54 回の開催で述べ 3550 人，1 回平均 65 人の参加となっており，全体事業に限っては概ね 100 人以上の参加となっている。

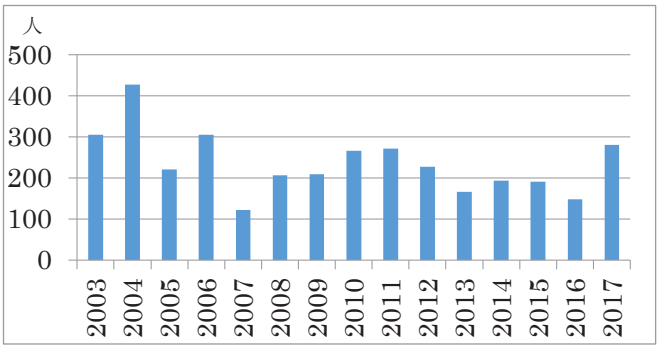

図 1　参加人数経年グラフ

4．考察

毎年多くの子供たちが参加し，活発な事業展開が図られている。山から川そして霞ヶ浦へ流れる水の動きを中心として，上流・中流・下流の子供たちが互いに他エリアの自然環境や水質状況について学び，環境保全や水質浄化の重要性を認識する契機となっているものと思われる。

歴史・文化に関する事業においては郷土の歴史・文化に興味を持つ契機となっているものと思われる。

参加状況を見ると研修や見学のみの事業より，子供たちが実際に体を動かす「体験型」の事業が人気となっていることが伺える。今の子供たちも自分の体を動かしての自然体験が大好きなのである。そして，その体験を通して，多くのことを身に付けて欲しいと思っている。

間伐，木工，水遊び，魚とり等を行っている子供たちは生き生きとしており，常に予定時間をオーバーしている状況である。今後とも体験型の事業を積極的に取り入れ，より多くの参加が得られるよう事業の活性化に努めてまいりたい。

5．結論

茨城県の調査によれば霞ヶ浦の汚濁負荷原因として，依然として生活排水の占める割合が大きい。COD，T－N については約 20%パーセント，T－P については約 50 パーセントが生活排水によるものとなっており，生活排水対策が霞ケ浦浄化の重要課題となっている。

霞ケ浦は流域市町村の水道水源となっているばかりでなく，農業・工業用水など様々な水源として利用されており，茨城県では水質保全計画を策定するなど長年にわたり浄化対策を進めている。

しかし，霞ケ浦の水質浄化，特に生活排水対策は行政のみで達成できるものではなく，そこに住んでいる住民の協力が不可欠である。

そして，それは一部地域の活動だけで達成できるものではなく，流域全体が一体となって取り組まなければならないものである。

その意味からも一つの河川に注目し，上流から下流までの全ての住民・子供を対象とし，水質問題を流域全体の問題として捉え，自分の取るべき対策を考えることができる本事業は極めて有意義なものであると考える。

さらに，霞ヶ浦流域では恋瀬川探検隊と同様に桜川探検隊，巴川探検隊等 5 つの探検隊があり，独特の事業も行われていることから，探検隊相互の交流等新たな事業展開についても検討し，設立の目的である上・下流が連携した水質浄化気運の醸成に努めてまいりたい。

また，霞ケ浦は各種水源としての利活用ばかりでなく，漁業やマリンスポーツの場等幅広い分野において多くの恵みをもたらしてくれる我々茨城県の貴重な財産である。

今回の世界湖沼会議のテーマである「持続可能な生態系サービスを目指して」を達成させるため，恋瀬川探検隊連絡会議としても一層の事業の活性化を図ってまいりたい。

KP-11

題名：園部川における生物多様性保全活動

加藤　章一, 羽生　勇, 斎藤　祐依
横浜ゴム(株)茨城工場

キーワード：生物多様性,霞ヶ浦,水生生物,特定外来種

抄録

横浜ゴム（株）茨城工場では、工場で使用した水を浄化した上で工場近隣を流れる園部川に排出している。 園部川は霞ヶ浦へと流入する河川の一つであるとともに地域の農家にとっての重要な水源となっている。

そこで私たちは工場排水が園部川にどのように影響しているのかを定量的に分析するために 2013 年から生物多様性保全活動を開始した。 活動では園部川の水質調査、水生生物調査、鳥類調査、植生調査を行いデータを取得している。 水質調査のデータからは工場排水の水質が常に園部川の水質より優れていること、水生生物調査からはモロコが一番多く生育していること、鳥類調査からはヒヨドリが多く生息していること、植生調査からはカナムグラが多く生育する環境であることが判明している。 今後も継続的に調査を実施しデータを蓄積していく。

1. はじめに

横浜ゴム（株）茨城工場では、工場で使用した水を浄化した上で工場近隣を流れる園部川に排出している。園部川は霞ヶ浦へと流入する河川の一つであるとともに地域の農家にとっての重要な水源となっている。

そこで私たちは工場排水が園部川にどのように影響しているのかを定量的に分析するために 2013 年から生物多様性保全活動を開始した。

2. 方法

生物多様性保全活動は年に 3 回、5 月、7 月、10 月に実施している。 活動内容は水質調査、水生生物調査、園部川流域の鳥類調査、植生調査、工場敷地内の鳥類調査を工場内有志の参加メンバーで行っている。



図 1　活動の様子

3. 園部川の水質

水質調査は、①透明度　②伝導率を測定して行っている。 それぞれのデータを園部川本流と支流で測定・記録している。 今までのデータを図1に示す。

測定データはまだ少なく水量や天候の影響を受け明確な傾向を読み取るまでには至っていないが、弊社から放流している水は概ね 150 μ /cm 前後、園部川本流では 200～250 μ /cm、園部川支流では 200～300 μ /cm であり弊社より放流している水は常に園部川より電気伝導度が低く高い水質の水であることと、園部川の電気伝導度が上昇傾向であることがデータからは読み取れる。今後

もデータ取得を継続して水質をウオッチングしていく。

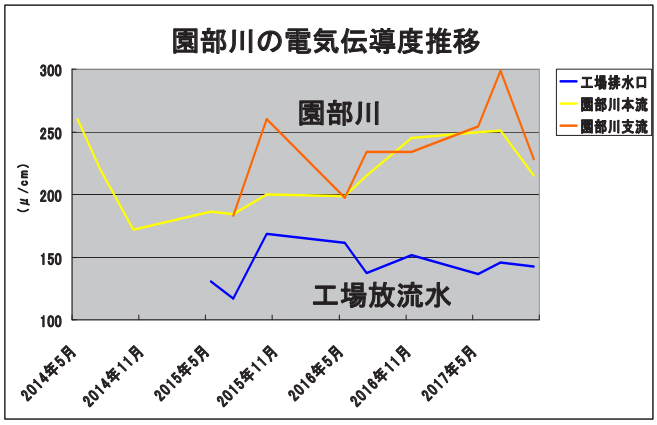

図 2　園部川の電気伝導度推移

4.　園部川の水生生物

水生生物の調査は小美玉生物の会の皆様にご指導をいただきながらメンバーが網を持ち水中で捕らえた水生生物の種類と量を調査してデータを記録して行っている。

2014 年から 2017 年の 4 年間のデータから園部川本流で一番見られる水生生物はモロコであった。続いてハグロトンボのヤゴ、カワムツ、モツゴ、メダカの順で多い。合計 33 種類の多様な水生生物が見られた。表1に園部川本流で見られる水生生物トップ 10 を示す。

表 1　園部川本流で見られる生物　トップ 10

No	種　　名	2014～2017年合計
1	モロコ	45
2	ハグロトンボ（ヤゴ）	32
3	カワムツ	25
4	モツゴ	22
5	メダカ	15
6	スジエビ	14
7	アメリカザリガニ	12
8	ドジョウ	11
9	ヌマチチブ	8
10	クロダハゼ類(トウヨシノボリ)	8

なお、アメリカザリガニやタイワンシジミ等の外来生物は在来種保護のため捕獲後に再び川に戻さずに処分している。

5.　園部川流域の鳥類

鳥類の観測は日本野鳥の会茨城県の皆様にご指導をいただきながらメンバーが双眼鏡を持ち行い、見つけた鳥の種類と数を記録している。2014 年から 2017 年の 4 年間のデータから園部川流域で一番見られる鳥はヒヨドリであった。特に 2017 年の 10 月にはヒヨドリの 200 羽もの大群が観測されたことが大きく影響している。これは渡り鳥の移動時期であることと小雨が降っており、オオタカやハヤブサ等大型の鳥が飛んでいない安全な日であったことが要因として考えられる。続いてムクドリ、スズメ、ハシボソガラス、ツバメの順で多く 合計 42 種類の多様な鳥が観測されている。 表 2 に園部川流域で見られる鳥のトップ 10 を示す。

表 2　園部川流域で見られる鳥　トップ 10

No	種名	2014～2017年合計
1	ヒヨドリ	256
2	ムクドリ	78
3	スズメ	77
4	ハシボソガラス	72
5	ツバメ	50
6	カルガモ	42
7	ハシブトガラス	35
8	ハト（レース用）	30
9	ヒバリ	27
10	カケス	26

6.　園部川流域の植生

園部川流域周辺の植物の生育の調査は小美玉生物の会の皆様にご指導をいただきながら行い、植物の種類とそれぞれの占有率を測定しデータ記録を行っている。

2014 年から 2017 年までのデータから年間を通じて占有率が高い植物はカナムグラでトータルで 22.1%の占有率であった。ただしデータには季節による変動があり 5 月の測定結果ではスギナ（ツクシ）がトップの占有率となる。　冬季は自治体で流域の雑草類の刈り取りを行っており、スギナ等春に生育する植物と以降の夏にかけて活発に生育していく植物との差がデータに現れている。

また活動の一環でセイタカアワダチソウの抜根を行っている。2015 年 5 月より 2017 年 5 月までの 3 年間でトータル 2792 本の抜根を行った。その結果抜根を実施した場所ではセイタカアワダチソウの生育が見られなくなった。今後も抜根の範囲を広げていきたいと考えている。



図 3　セイタカアワダチソウ抜根の様子



図 4　セイタカアワダチソウ抜根後の様子

表 3　園部川流域で見られる植物　トップ 10

順位	種名	2014年～2017年 占有率(%)
1	カナムグラ	22.1%
2	クサヨシ	9.3%
3	スギナ(ツクシ)	6.9%
4	イヌビユ	5.7%
5	オランダミミナグサ	4.3%
6	メヒシバ	4.3%
7	イヌムギ	4.2%
8	ツユクサ	4.0%
9	ネズミムギ	3.9%
10	ヨモギ	3.9%

7.　地域住民への PR 活動

この生物多様性活動の調査結果は年に 1 回、毎年 4 月に地域住民の皆様、区長様、水利組合様、小美玉市の環境課、ご指導いただいている日本野鳥の会や小美玉生物の会の先生方等を招いて報告会で報告している。また参加いただいた方には工場見学もしていただいている。今年は 4 月 14 日 (土)に実施し、20 名の方に参加いただいた。地域の皆様からは、工場排水が川の水より高い水質であることを始め、工場の環境活動に対し高い評価を頂いている。



図 5　活動報告会で住民の皆さんと記念撮影

8.　今後の課題

以上が弊社茨城工場での生物多様性活動の状況であるが、今後は調査を継続して長期的にそれぞれがどのような傾向を示すかを把握していくことが重要であると考えている。活動を継続していき工場内の活動参加者のレベルアップをはかり社内に「生き物博士」的人材が育成されることを期待している。

横浜ゴム茨城工場は地域あってこそ事業活動が持続できる存在であり、今後もこの活動を通じ地域に少しでも貢献できればと考え活動を継続していきたい。

引用文献:なし

KP-12

水を基軸とした認定 NPO 法人宍塚の自然と歴史の会による里山保全活動

及川　ひろみ, 阿部　きよ子, 菊地　敏夫, 佐々木　哲美, 福井　正人, 森本　信生
認定 NPO 法人宍塚の自然と歴史の会

キーワード:里山, 湿地保全, 溜め池, 水田耕作, 雑木林, 市民参加

抄録

□霞ヶ浦の保全は, 流域の里山の保全が重要な役割を果たす。土浦市宍塚とそれに隣接する里山は, 生物多様性や埋蔵文化財に恵まれた, 関東平野で有数の里山である。その魅力に魅せられた近隣住民は宍塚の自然と歴史の会を 1989 年に発足させ, 里山の保全活動を 30 年間継続してきた。水を基軸にした活動に絞っても, 溜め池, 小川, 谷津の田や湿原の保全のための様々なとりくみ、水源である雑木林での植生管理などが行われてきた。現時点では地元自治体のこの地域の将来設計は市街地開発と保全の両論併記の形に留まっているが, この地域で展開されている諸活動を活かした策が, 行政や地権者, 農業従事者, 市民による知恵の集結により施されることが望まれる。

1. はじめに　霞ヶ浦流域における里山の役割

里山は, 多様な生物の生息・生育環境として, また, 食料や木材など自然資源の供給, 良好な景観, 水源かん養や国土保全, 文化の伝承等の役割を果たしている。里山に降った雨は土壌に貯えられ濾過され, きれいな水となって川、湖沼に流れ込む。水資源の循環機能としての森林と土壌の果たす役割は重要である。

特に深山幽谷が少ない霞ヶ浦流域では、面積(2,157 ㎢)の大部分が市街地と里山であり、41%の面積を占める里山の山林部分が果たす役割は重要で、その保全活動が環境保全、水質保全に欠かせないことを認識しなければならない。

2. 宍塚の里山の状況

茨城県土浦市にある「宍塚の里山」は土浦市宍塚側が 100ha, 隣接するつくば側を含めると, 約 200ha の里山環境が残され, 環境省「生物多様性保全上重要な里地里山(重要里地里山)」に選定され, ほぼ中央に存在する宍塚大池は, 約 3.3ha の農業用溜め池で,「ため池百選」(農林水産省)に指定されている。また, 国指定の遺跡を含む, 旧石器時代から近代までの遺跡が多く存在する。

この地域に魅力を感じた市民が, 1989 年に「宍塚の自然と歴史の会」を発足させ, 30 年間様々な活動をおこなってきた。本稿では, 霞ヶ浦の保全のうえで重要であると考えられる「水」に関連する保全活動の報告をする。

3. 湿地における保全活動

① 溜め池

宍塚大池は三本の谷津を堰きとめて作られた面積 3.3 ha の溜池で, 上空から見ると「大」字形をしている。水源は池の周囲の林からの湧水で, 流入河川はない。池の周囲は堤防以外, 護岸工事が行われていないために, アシ, マコモ, フトイ, ウキヤガラといった抽水植物が生育し, その先の林へと緑が連なり, 2016 年の調査で、国, 県が絶滅危惧種として扱っている水生植物が 9 種類確認されている。トンボなどの水生昆虫、水鳥なども豊かで、筑波山から霞ヶ浦との位置関係からも、生物の多様性にとって重要な池である。

しかし 1990 年頃から, 次々と生物相に影響を与える事態が発生した。野生のハスが大量に繁茂したための開放水面の著しい減少、ブラックバス、ブルーギルといった外来魚の急増、水位低下を契機におこったアメリカザリガニの大量発生とそれによる水生植物の激減、トンボの減少、昨年からのヒシの繁茂などである。会では池の開放水面確保, 絶滅危惧種オニバスを保全することを目的に, ハスの葉を人力で刈り取る作業を 1990 年から開始し, 2013 年までに池の中央 1ha 以上開水面を確保した。また、オニバス、ジュンサイなどを池以外で保全する活動を継続している。また、2006 年には環境省による「いきづく湖沼ふれあいモデル事業」を受託して, 池の総合調査を行い、その後外来魚等外来生物の駆除を年間 80 日以上行ったり水質を調査するなど、さまざまな試みを行い、生態系の回復に努めている。

② 小川

昔ながらの土水路である小川があり, 備前川, 霞ヶ浦へと続いている。数種類の淡水貝、ヨシノボリ, ドジョウな

どの魚，その他のさまざまな生き物が見られる。しかし、川底に落ち葉が溜まると腐敗し、酸欠で貝類などが死亡する。地元の人たちが，大池の水を田に水を引く直前，小川掃除である「ミイザライ」を行っていたことにならい、毎年春先，落ち葉を掻き出している。小川は，子ども達の大切な生き物との触れ合いの場ともなっている。

③　谷津

宍塚の里山は宍塚大池，森林，谷津，草地，竹林，小川，植林地など多様な環境で成り立っている。中でも谷津は森林としての台地，斜面林，低湿地から成り，重要な環境要素になっている。谷津の先端から絶えず水が湧き出すシミズがあり，サワガニ，トンボ類が生息している。またカヤネズミなど絶滅危惧種が生息している谷津では，草刈りは冬季に行うなどの保全をおこなっている。ヨシやスゲを刈った後はフクロウ，サシバなどの採餌場となっている。

4. 水田における保全活動

①　宍塚米オーナー制　谷津田耕作農家の支援活動

里山の谷津田は生き物の生息域としても重要で，サシバの生息環境を守ろうと始めた宍塚米オーナー制度も 20 年目を迎えた。宍塚米オーナー制度は経済的に不利な谷津田の耕作を続けるには，里山のもつ公益的な機能の恩恵を受けている都市市民がお金や労力を提供する必要があると考え，農家に谷津田の耕作を続けてもらうために，谷津田の保全に賛同する一般市民がオーナーとなって，経済的な支援をしようという制度である。仕組みはオーナーが 1 口幾らかの定額を出資して稲作の経費を負担し，その見返りとして収穫された米を受け取るという形態である。1999 年の開始当初は取り組みの内容が珍しくもあり，新聞やテレビにも取り上げられ，県内はもちろん全国から応募があり，あっという間に予定した募集数の 150 口（精米5kg/口）に達した。その後，申込者が増えて取扱量が2トン位までに達したが，2011 年福島原発事故の影響で6割程度まで減少した。県内の申込者は増加しているものの県外の減少に追いつかない状況である。ただ，県外からは米は要らないが寄付はするサポート会員が 3 倍に増えるなど支援は広がっている。オーナーには年 3 回ほどの「オーナーだより」を送って行事案内や田んぼの近況を報告している。この制度の実行にあたり，精米，米の発送，通信事務その他の作業で大勢の会員がボランティアで参加している。米オーナー会員，耕作農家，支援ボランティアの3者の協力で里山の水田は維持されている。

②　地元農家との協働による保全活動

会では地元農家との協働活動として，農地・水・環境保全会（愛称：田んぼさわやか隊）を地元農家と共に立ち上げ，里山内の谷津田および里山周辺の水田地帯での水路の整備，水田畦畔および休耕田の草刈などの活動を行っている。

会の活動の中で，貴重な宍塚の里山を守るために，里山に隣接する水田地帯を保全することは重要であり，また高齢化が進み，後継者が不足している農家にとっても，非農家が作業に加わることで省力化を図ることができる。いわゆる Win-Win の関係を構築することで，地元が会の活動に理解を示す上でも重要な役割を果たしている。

里山内の谷津田はもちろん，里山周辺の水田地帯も水路は土水路が保たれており，生物の生息地として重要である。都市部の水田地帯でこれほどの長さの土水路が残されているところは珍しく，今後も土水路として残すことが環境保全にとって重要である。農家の代表者も「土水路をコンクリートU字溝にすれば，管理は楽になるがU字溝には蓋が付くことになるだろうし，道も広がるため，一般車両が通行するようになる。手間は掛かるが，いまのままの土水路のままが良い。また除草剤は生物だけでなく，人の身体にも良くないから使いたくない」と考えており，土水路の形状を今後も維持するために，この活動を継続することがますます重要になってくる。

最近では草刈や水路の整備に加えて，休耕田を「田んぼさわやか隊」の田んぼとして復田する活動に取り組み，保全にプラスして会員自ら作る楽しみを得られる活動に拡大してきており，活動参加者も増え，これからの発展が期待される。

③　自然農田んぼ塾　有機農業を通じての保全活動

「宍塚オーナー米」の発足と同時に「田んぼ塾」を開始し、谷津の耕作放棄田を再生し，カエルやトンボ，水生昆虫などの生物を育む場所にする活動を続けてきた。

当初は地元農家の助けを借り，代掻き、畦つくりを行っていた。農薬や化学肥料は使用せず，除草は田車を使用した。谷津田での作業はぬかるみに足を取られ重労働だった。その後，岩澤信夫氏の「冬季湛水不耕起栽培」を経て，川口由一氏の「無施肥　耕さず　虫や草

を敵としない」自然農法に出会い，谷津田に適した農法であるという認識のもと，「自然農田んぼ塾」と改称し、現在に至っている。田の周囲に溝を掘り，田の表面には枯草を敷き，溝によって排水が容易となり，ぬかるみだった所が固くしまり作業が楽になった。また必要に応じて溝に水を入れることで，全面に水を張る必要がなくなり節水型の農法となっている。田に敷いた枯草はやがて分解されて肥料となる。自然界の森林や林の自然のサイクルが田の中で行われている。最近では SRI（稲強化法：System of the Rice Intencification） 乳苗植え付け，間断灌漑）と自然農の組み合わせ，直播栽培に取り組んでいる。メンバーは 20 名弱（コアメンバー5~6 名）で 1,800 ㎡の田んぼに 9 品種の稲を育てている。

④ 環境教育、食農教育とあわせた谷津田の保全

1995 年から始めた田んぼ塾には子どもたちも参加していたが，自然農田んぼ塾で新たな農法の研究と実践を始めたのに伴い，2012 年から子ども中心の通年制の田んぼの学校を開設した。この「学校」では，機械化以前の標準に近い農法での稲作と，稲作に伴う伝統行事，環境学習（生き物調べなど）にとりくんでいる。小さな 3 枚の田約 220 ㎡を用い，冬水田んぼ，不耕起，無農薬で生き物の多様性保持に努めている。

毎年，20 前後の家族が参加し，苗代への種まきから脱穀作業，もちつきまで，保護者も子どもと一緒に作業する。毎回，短時間の学習もし，各自日誌をつける。さなぶり（田植え終了を祝う伝統行事の昼食会），案山子作り，案山子送り（かかしを燃やす昼間のキャンプファイヤーのような行事），ならせ餅（地元の伝統行事，餅つきをし，ナラの枝にもちを付けて持ち帰る）などの行事は，準備から片づけまで，参加者が分担しながら行っている。親子ともに稲作りの作業に泥んこになって奮闘し，溜池，用水路，田，地下水（ポンプ井戸を使用）という水環境，谷津田をとりまく環境の季節ごとの変化，多様な生き物たちと触れ合う中で，子どもたちは大きな成長を見せており，親子ともに里山の環境への理解が深まっている。

⑤ 高校生の谷津田での活動

2017 年冬より竹園高校の JRC 部（Japan Red Cross：日本赤十字）が，谷津の耕作放棄地で開墾と米づくり（古代米プロジェクト）を実施している。これは世界湖沼会議に関わる高校生の活動の一環でもある。これは，竹園高校卒業生で里山の活動を世界湖沼会議プレ会議で発表した学生と担当教諭が前任の筑波高校で関わった「つくばね学」で畑が実習先になった縁がきっかけとなった。竹園高校の学生と教諭は，慣れない作業に戸惑いながら鎌と鍬，レーキで開墾作業を行い里山の保全には人の関わりが欠かせないことを肌で感じ取っている。今後，種まきから田植え，草取り，生育調査を通して稲と自らの成長を重ね合わせていくことが期待されている。

5. 林地における保全活動

かっての里山は薪炭林や肥料など資源の供給に欠かせない場所であったが，近年はエネルギー需要の変化で必要とされず，樹木の伐採や下草刈りなどが成されず荒れるにまかされてきた。多様な恵みや機能に着目した里山を重視して保全活動を行ってきた。

里山保全を実践する里山さわやか隊は雑木林の下草刈り，観察路の草刈り，ハス刈り，ゴミ拾いなど従来行ってきた実践活動を組織化して，1998 年に発足した。月に 2，3回のペースで活動し，毎回10人前後の参加者がいる。2013 年から林野庁の森林・山村多面的機能発揮対策交付金事業の助成を受け，森林の整備活動が強化された。それに伴い作業の危険度も増してきたことから刈払機，チェーンソーの資格講習を実施するなど参加者の技量のレベルアップも図ってきた。近年，地元の方や来訪者に気持ちよく散策が出来るようになったとの声も聞かれる。また、近年著しいマダケ、孟宗竹の広がりが、土壌の劣化、里山の保水力の低下をもたらすことがわかってきた。竹林の拡大阻止のため、伐採をすすめている。また、地元中学の科学部が当会と協力してこの地で竹の研究をすすめ、竹伐りを継続しておこなっている。

6. 結論

農業と暮らしに欠かせなかった里山の存在価値が，いったん失われたかのように考えられたが，今，また新たにその値打ちが見出され始めている。そのなかで，当会の活動は，楽しみながら保全に貢献するという形で約30年間継続し，成果を上げてきた。

しかし，土浦市第 7 次総合計画では，宍塚地区の市街地開発と保全の両論併記がなされており，必ずしも保全の方向に向かっている状態ではない。今後，この地域で展開されている諸活動を活かした策が，行政や地権者，農業従事者，市民による知恵の集結により施されることが望まれる。

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題名：霞ヶ浦における市民参加型モニタリングと淡水魚保全活動

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キーワード：市民参加型モニタリング、淡水魚保全、普及啓発活動、タナゴ類、イシガイ科二枚貝

抄録

土浦の自然を守る会では、タナゴ類を中心とする霞ヶ浦に生息する淡水魚保全を目的として、市民参加型イベント「一日漁師体験」による魚類相モニタリング、霞ヶ浦流域におけるタナゴ類およびイシガイ科二枚貝の生息状況調査、ゼニタナゴ等在来タナゴ類の生息域外保全、シンポジウム等による普及啓発活動を実施してきた。魚類相モニタリングでは、2006 年以降おおよそ月に 1 回の頻度でモニタリングを実施し、合計 48 種が確認され、ダントウボウなどの新たに定着した外来種も確認されている。また、タナゴ類やイシガイ科二枚貝の生息状況調査では、在来タナゴ類は減少しているものの、広域にイシガイ科二枚貝が残っていることが確認された。生息域外保全では、ゼニタナゴの増殖に成功し、利根川流域の他の環境保全団体等へ分譲も実施している。これらの活動の成果についてはシンポジウムや書籍・文献にて普及啓発を実施している。

1. はじめに

霞ヶ浦は、約 100 種の魚類が生息しており、東日本の中で最も種多様性が高い地域のひとつである。内水面漁業においても、ニホンウナギ *Anguilla japonica* やワカサギ *Hypomesus nipponensis* などが漁獲され、衰退しつつあるものの内水面漁業が維持され続けている地域であり、生物多様性、生態系サービスの観点から日本国内における重要な淡水域のひとつである。このことから、多くの研究の場となっているほか、国立環境研究所によりプランクトンや魚類等のモニタリングも実施されている。しかしながら、魚類については、流域が広域であることもあり、湖内については情報があるものの、流入河川、農業水路等も含めると調査、モニタリングは少ない状況である[1]、[2]。

霞ヶ浦においては、かつてはレッドリスト記載種であるニホンウナギやタナゴ類などが数多く生息していたものの、近年は、特に在来タナゴ類は減少が著しく、ゼニタナゴ *Acheilognathus typus* は 2001 年以降記録が無いなど、魚類の生息状況の把握および一部の種については保全の必要性が非常に高くなっている。

一方で、オオクチバス *Micropterus salmoides* やチャネルキャットフィッシュ *Ictalurus punctatus* をはじめとする魚食性外来魚が侵入しているほか[3]、近年は特定外来生物に指定されたばかりのオオタナゴ *Acheilognathus macropterus*[4]やコウライギギ *Tachysurus fulvidraco*[5]など多くの国外外来魚が侵入、定着している。加えて、タモロコ *Gnathopogon elongatus* やゲンゴロウブナ *Carassius cuvieri* など国内外来魚も侵入、定着している種が多い。さらに、富栄養化など生息環境の悪化も進行している。このため、在来種の保全を目的とした、保全活動やモニタリングが必要不可欠である。

このような状況のため、市民団体である土浦の自然を守る会では、魚類の生息状況を把握し、保全活動に生かすための基礎データの収集および普及啓発を目的として、市民参加型の活動を行ってきた。活動としては、定置網による魚類相のモニタリング、タナゴ類・イシガイ科二枚貝の生息状況調査、ゼニタナゴ等在来タナゴ類の生息域外保全、シンポジウムや書籍・文献（例えば[6]）による保全のための普及啓発活動などである。本稿では以上の活動について概要を報告する。

2. 方法

魚類相把握を目的としたモニタリングは、江戸崎市の小野川河口において市民参加型のイベント「一日漁師体験」として実施した。一日漁師体験は、2006 年 4 月から現在までおおよそ月に 1 回程度の頻度で実施した。漁師の定置網で採集されたすべての魚類を調査対象とし、使用した定置網は誘導網の長さが約 80m で、沖合側の先端部に返しの付いたメッシュサイズ 4mm の捕獲用網罠が 3 つ接続されているものである。定置網の設置時間は約 24 時間とした。

採集した魚類は、一般市民の参加者により種別に仕分けし、魚種ごとに採捕個体数および重量を測定した。なお、モツゴ *Pseudorasbora parva* やタモロコなど小型かつ、採集個体数が 1,000 個体を超えるような場合には、一部をサンプリングし、個体数と重量の比率を算出した

のち、全重量に比率をかけることで、全採集個体数を求めた。

タナゴ類やイシガイ科二枚貝の生息状況調査は不定期に実施し、本稿では特に重点的に実施したイシガイ科二枚貝調査について報告する。イシガイ科二枚貝の調査は、湖岸、河川、農業水路を主な対象とし、104 地点で調査を実施した。イシガイ科二枚貝は 1 地点あたり 2〜4 名で、約 30 分間手による採集を行った。採集した個体は同定後、種別に殻長の測定し、記録した。

ゼニタナゴおよびアカヒレタビラ *Acheilognathus tabira erythropterus*、タナゴ *Acheilognathus melanogaster* の生息域外保全については、水田跡地を掘削したため池にて増殖、系統保存を実施している。ゼニタナゴは霞ヶ浦で地域個体群が絶滅したと考えられるため、霞ヶ浦産の個体を琵琶湖博物館より分譲を受けた。アカヒレタビラとタナゴについては、霞ヶ浦流域で採集した個体を用い、増殖を試みている。ゼニタナゴについては、2012 年に約 5m 四方のため池を掘削し、ゼニタナゴとドブガイ類 *Sinanodonta* spp.、イシガイ *Unio douglasiae* ともに放流した。また、アカヒレタビラ、タナゴについても 2014 年に新たに約 5m 四方のため池を掘削し、増殖を開始した。

3. 結果

一日漁師体験では、2006 年から 2017 年までに、48 種の魚類が確認された。レッドリスト記載種では、アカヒレタビラやタナゴなどの在来タナゴ類などが少数確認されている。また、国外外来種については、オオクチバスやブルーギル *Lepomis macrochirus* の減少傾向が捉えられているほか、コウライギギやダントウボウ *Megalobrama amblycephala* といった新規外来種も採集された。

11 年間のモニタリングを実施することで、種ごとの増減が確認されていることもモニタリング結果の大きな特徴であった。例えば、2011 年以降それまで少なかったワカサギの採捕数が大きく増えた一方で、2009 年までは多く採捕されていたアユ *Plecoglossus altivelis* が激減し、その後ほぼ採捕されなくなるといったことも確認された。また、国外外来種であるペヘレイ *Odontesthes bonariensis* も 2010 年以降確認されなくなるなど、外来種でもほとんど確認されなくなった種も見られた。

イシガイ科二枚貝の調査では、104 地点を調査の結果、ドブガイ類が 59 地点、イシガイが 54 地点、マツカサガイ *Pronodularia japanensis* が 18 地点、ヨコハマシジラガイ *Inversiunio jokohamensis* が 6 地点、フネドブガイ *Anemina arcaeformis* が 2 地点で確認された。ドブガイ類、イシガイは、霞ヶ浦周辺の広い範囲で確認され、環境も湖内、河川、農業水路と幅広かった。また、マツカサガイは、確認地点数は少ないものの広域で確認された。一方で、ヨコハマシジラガイは確認される場所が限定的であった。マツカサガイ、ヨコハマシジラガイともに、採集された環境は小河川および農業水路のみであった。

生息域外保全については、2013 年以降ゼニタナゴは順調に増殖し、個体数も増加したため、現在では利根川流域の環境保全団体等へ危険分散のため分譲し、さらなる増殖を進めている。また、アカヒレタビラ、タナゴについては、大きく増加しているわけではないものの池において一定数を維持している。

上記の調査や保全活動の結果を広く普及するため、シンポジウムや文献等により一般に広く公開し、霞ヶ浦の魚類の生息状況を報告してきた。シンポジウムでは、全国タナゴサミットなどのシンポジウムを実施した。また、霞ヶ浦の魚類の図鑑として、[6]を出版したほか、個別の事例については、外来種の確認事例などを論文等として報告してきた（例えば[4]）。

4. 考察

市民活動によるモニタリングと生息状況調査のいずれにおいても、専門家の助言により適切な手法を用いることにより、現状を評価可能なデータが収集できることが示された。加えて、市民活動により収集されたデータの一部が、オオタナゴやコウライギギの特定外来種への指定にもつながり、社会貢献へと至った事は大きな成果であると考えられる。

また、生息域外保全についても、活動にかけられる労力が限られており、小規模であるといった課題があるものの、継続的に実施できている状況である。その結果、生息域外におけるゼニタナゴの増殖が進み、周辺の保全団体等との連携が強化されるなど、活動の幅も広がっている。加えて、シンポジウムや書籍・文献等による情報発信により、市民活動の成果が行政施策等へ生かされつつある。

一方で、市民活動での成果を生かした具体的な保全活動は、タナゴ類の生息域外保全が中心であり、地域住民や行政と連携した保全活動や外来種対策につなげるという観点では、十分とはいえない。さらに、いずれの活動においても助成金の獲得のための労力や作業労力が限られていることから、継続的に活動を実施することに苦労している。また、霞ヶ浦流域は広域であることから、他の市民団体や行政、研究者との連携が必要不可欠で

あるが、広域で活動を展開するには至っていないといった課題もある。

5. 結論

市民活動により、魚類相や年変動の把握およびタナゴ類やイシガイ科二枚貝の生息状況の一端が明らかになった。また、ゼニタナゴ等保全が必要な在来タナゴ類の生息域外保全や普及活動による市民団体、研究者、行政の連携も進みつつある。課題もまだまだ残されているものの、持続可能な市民活動につなげるためにさらなる連携の強化、とくに行政との連携や共同での保全活動等に展開していく必要があると考えられる。その上で、将来的には行政、市民団体、研究者の協働による持続可能な保全活動につなげていきたい。

なお、一日漁師体験は茨城県森林湖沼環境税を活用して行った。

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2000 年以降に霞ヶ浦流域で確認された外来魚オオタナゴ（コイ科）、コウライギギ（ギギ科）、ダントウボウ（コイ科）、カダヤシ（カダヤシ科）

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キーワード：国外外来魚，定着，在来生態系，早期防止対策

抄録

水産業振興等により，様々な魚種が自然分布域外に移動された結果，日本の淡水域には 44 種類の国外外来魚，50 種類の国内外来魚の定着が確認されている．霞ヶ浦では 30 種以上の国外外来魚が確認され，少なくとも 12 種が定着しており，一部は在来生態系を変化させ経済的に価値のある魚種にまで影響を与えている．筆者らは 2001 年以降霞ヶ浦流域においてオオタナゴ *Acheilognathus macropterus*，コウライギギ *Pseudobagrus fulvidraco*，ダントウボウ *Megalobrama amblycephala* およびカダヤシ *Gambusia affinis* を確認した．これら 4 種の国外外来魚が確認、同定された経緯を記述し，移入経路と対策について考察した．前 3 者は飼育魚の遺棄あるいは養殖魚の逸出の可能性が考えられた一方，カダヤシは薬剤を使わないカの防除法として，我が国でも積極的に放流されていたことが侵入の要因であると考えられた．4 種の国外外来魚については，行政、漁業関係者、自然保護団体等関係者への周知等の啓発，増殖と拡散の早期防止対策と共に，継続したモニタリングが必要と考えられる．

1. はじめに

水産業振興，あるいは遊漁目的等により，様々な魚種が自然分布域外に移動された結果，日本の淡水域には 44 種類の国外外来魚，50 種類の国内外来魚の定着が確認されている（中井 2002）．国外外来魚のうち，オオクチバス *Micropterus salmoides*，ブルーギル *Lepomis macrochirus*，チャネルキャットフィッシュ *Ictalurus punctatus* ，カダヤシ *Gambusia affinis* などは，捕食等により在来生物群集へ深刻な影響を及ぼしていることから「特定外来生物による生態系等に係る被害の防止に関する法律」により特定外来生物に指定されている（環境省 2016a）．霞ヶ浦では 30 種以上の国外外来魚が確認され，少なくとも 12 種が定着している（萩原・熊谷 2007，野内ほか 2008）．2000 年前後に急増したチャネルキャットフィッシュは，霞ヶ浦の在来生態系を変化させ経済的に価値のある魚種にまで影響を与えている（Matsuzaki et al. 2011）．

筆者らは 2001 年 12 月に霞ヶ浦の江戸崎入りの漁師諸岡清志氏の営む定置網に入網した大量のオオタナゴ *Acheilognathus macropterus* を確認した．2010 年 9 月にはこの定置網にてコウライギギ *Pseudobagrus fulvidraco* を確認した．2009 年 4 月にはこの定置網にてダントウボウ *Megalobrama amblycephala*，を初めて確認し，その後 2012 年，2014 年に相次いで入網した．茨城県におけるカダヤシの生息は利根川に沿って確認されているが，詳細は不明である（環境省 2016a）．筆者らは 2002～2016 年に古河市，稲敷市，美浦村，守谷市でカダヤシを確認した．本稿では，2000～2010 年という短期間に，4 種の国外外来魚が確認、同定された経緯を既存の研究や文献をもとに記述し，移入経路と対策について考察する．

2. 方法

オオタナゴ，コウライギギおよびダントウボウは，小野川河口部で漁業を営む川魚漁師が新古渡橋上流に設置した定置網（set net ，霞ヶ浦では張網）により採集された．定置網は陸から直角に約 80 m 沖側に延長した垣網に 3 つの袋状の網が接続された構造で，これにより小野川に遡上した魚類と共に，降下する魚類も誘導される仕組みとなっている．定置網はほぼ毎日 1 回回収されるため，魚の誘導時間は 24 時間であった．入網した魚類の一部を漁師から提供を受け、試料とした．カダヤシは霞ヶ浦と利根川に接続した幅約 1 m 未満の流れの弱い水路でタモ網により採集した．試料を自宅に持ち帰り，生体のまま，あるいは 10 %フォルマリン固定後，外部形態，計数・計測形質を観察・測定した．

3. 結果と考察

3 ．1 オオタナゴ

漁師が見慣れないタナゴ類として 2001 年 9 月から 12 月までに定置網に入網し蓄養していた 64 個体の試料を入手した. 観察の結果, 得られた標本の背鰭と尻鰭軟条数と, 非常に短い口ひげという特徴から, 本種をオオタナゴと同定した(萩原 2002). タナゴ類は生きた二枚貝に産卵する特徴があり, その後本種についての産卵生態の研究が進められた. 2006〜2008 年の 3 年間にわたり産卵管長, 卵巣・精巣重量を計測した結果, 産卵期は 4 月中旬〜7 月中旬であり, 霞ヶ浦に生息する在来タナゴ類であるアカヒレタビラ *Acheilognathus tabira erythropterus* , タナゴ *Acheilognathus melanogaster*, ヤリタナゴ *Tanakia lanceolata* と重複することが示された. また, 産卵期には 80 mm 以上の長い産卵管を有することで, 産卵利用貝において他種に比べて広い産卵スペースが利用可能ということが明らかとなった(萩原 2011). タナゴ類においては卵形が種・系統群を反映することがある. そのため, 2009〜2010 年の産卵時期に 77 個体の親魚から 1506 個の卵を得て, 長径(L), 短径(S)から長径・短径比率(L/S), 容積を計算した. 本種の卵形は動物極側に偏長した電球状であり, L/S は親魚の体サイズに依存せず固有の値を示したが, 卵容積は親魚サイズに依存した. これらから, 卵形と L/S は系統を反映している一方, 容積は個体レベルで親魚サイズなどその時々の環境条件に対して, 子孫を最大に残せるように可塑的に適応しているものと考えられた(萩原 2013).

3.2 コウライギギ

筆者らは 2010 年 9 月定置網に入網した小形のギギ科と思われる個体を, また 2011 年 6 月この付近の余郷入り干拓地の導水路にて釣獲により同種と思われる個体を得た. 体長が 32 mm と小形で, ギギ科の特徴である短い髭が上顎に 2 本あることや大きな脂鰭があることなどでナマズ科の魚と区別された. 本種について, 筆者らの試料も含めて霞ケ浦で採捕, 保管していた計 8 個体について形態学、遺伝学的に調査・研究された結果、コウライギギであることが明らかとなった(荒山ほか 2012). 体の地色がやや黄色く, 暗色域が地色をいくつかに分けるような模様がある, 尾鰭の上葉と下葉の中央を走る黒色帯がある, 胸鰭棘鋸歯が棘前部のほぼ全面にやや外に向いて密生する, という形質および頭部形状や体高などの体型的特徴から, コウライギギと同定された(荒山ほか 2012). その後, 渡良瀬遊水地で得られた標本の DNA は霞ヶ浦で報告されたものと一致し, 渡良瀬遊水地で採集されたコウライギギの起源は同一であることが示唆された(新田ほか 2017). また, 渡良瀬遊水地の魚図鑑(関根 2009)に記載されたギギ科の稚魚の写真は体の模様と尾鰭の上葉と下葉の中央を走る黒色帯が認められ, コウライギギに酷似していた. さらに 2017 年には手賀沼, 2018 年には渡良瀬遊水地巴波川(うずまがわ)支流においても本種の稚魚が採取されており(萩原ほか, 未発表), 利根川中, 下流域に定着していることが明らかとなった.

オオタナゴとコウライギギは、前述のような情報に基づき、2016 年 8 月 15 日に閣議決定された「特定外来生物による生態系等に係る被害の防止に関する法律施行令の一部を改正する政令」により, 特定外来生物に追加指定され 10 月より, 飼養, 保管, 運搬, 放出, 輸入等の規制が開始された(環境省 2016b).

3.3 ダントウボウ

2009 年 4 月, 前述の漁師の定置網に大型の強く側偏したコイ科魚類が入網した. 体型はゲンゴロウブナ *Carassius cuvieri* に似るが, 黒ずんで鱗が細かく小さな背鰭や腹部のキールは, ワタカ *Ischikauia steenackeri* と似た形態を示していた. その後, 同種と思われる個体が 2012 年, 2014 年と時間をおいて採集され, 2016〜2017 年に若魚や成魚が相次いで採集された. 採集された 7 個体について計数, 計測形質を測定した結果, 腹鰭を起点とした側線下鱗数が 7〜9, 標準体長 60.3 mm の標本を除いて標準体長／体高が 2.5 以下, 同属他種の脊椎骨数が 42 以下に対して 42〜44 と多く, 体側の鱗の基部が白く, 両端が黒く, これらが重なることで体側の前部から後部にかけて数条の縦縞が形成されている, という特徴からダントウボウと同定された(萩原 2017). インターネット情報によると 2015 年に古渡橋近傍で, 標本の親魚世代と考えられる体長の個体の釣獲記録が掲載されている. また 2017 年には桜川下流および霞ヶ浦流域で, 標本と兄弟世代と考えられる体長の個体の釣獲記録が掲載されており

(https://choka-jiman.com/choka/ibaraki/choka-12751.html, 参照 17-08-2017), 江戸崎入り奥部古渡橋周辺ではすでに定着している可能性が考えられた.

3.4 カダヤシ

2002 年1月 5 日に古河市北山田の大川用排水路, 2011 年 6 月 4 日に稲敷市六角の六角導水路, 2012 年 5 月 27 日に稲敷郡美浦村大谷の余郷入導水路, 2016 年 9 月 10 日に守谷市高野の五反田川において, 多数のカダヤシを確認した. 外観と大きさが類似するミナミメダカ *Oryzias latipes* の尻鰭は体に沿って長いのに対し, カダヤシは体と接する部分が比較的少なく, オスの尻鰭は変形して交接脚と呼ばれる器官となっている. ミナミメダカ

の尾鰭は直線的であるのに対して，カダヤシでは後縁が丸くなっている．妊娠したカダヤシの雌は腹部に濃紺色の円斑が出現する．頭部背面は，ミナミメダカほど扁平ではない．ミナミメダカでは眼の上半分が青色を帯びるが，ない点からカダヤシと同定された．

4. まとめ

タナゴ類は美しいオスの婚姻色により，観賞魚として中国，韓国，台湾などから多数の個体が輸入されており，婚姻色の目立たないオオタナゴは，これらに混じって輸入され，投棄された可能性がある（萩原 2002）．また，産卵母貝であるイシガイ科二枚貝類の移動に伴って，貝中に寄生した状態で随伴移入される可能性もあり，オオタナゴの場合は真珠養殖母貝を中国から輸入した際に，持ち込まれたかもしれない（萩原 2002）．コウライギギは国内で稀に観賞魚として流通していることや中国では一般的な養殖魚であることなどから，飼育魚の遺棄あるいは養殖魚の逸出の可能性が考えられる（荒山ほか2012）．ダントウボウは中国では重要な養殖魚であり，我が国における養殖魚研究用として持ち込まれたものや，稀にゲームフィッシュとして持ち込まれたものが逸出した可能性がある（萩原 2017）．カダヤシ（蚊絶やし）は英名 Mosquitofish にあるように，カの幼虫であるボウフラを捕食することから，薬剤を使わないカの防除法として，我が国でも積極的に放流された(いはらき新聞 1989)．県内でも取手市が 1989 年に徳島市からの 300 個体を譲り受け，市内の用水路に放流した（いはらき新聞 1989）．オオタナゴ，コウライギギ，ダントウボウは経済のグローバル化に伴って養殖，観賞魚，ゲームフィッシュとして我が国に持ち込まれたものが，逸出した可能性が高いと考えられる一方，カダヤシはカの防除を目的に積極的に我が国に持ち込まれ，放流されたことで，前 3 者とは移入の経緯が異なっている．カダヤシは，ハブや *Protobothrops flavoviridis* ネズミ駆除のために持ち込まれたフイリマングース（*Herpestes auropunctatus*）の例に似ている．カダヤシもフイリマングースもカやハブに対する駆除効果は不明な一方，我が国の在来生態系に悪影響を与えている（環境省 2016）．地域固有の生態系は歴史上の産物であり，新たな種を人為的に持ち込めば，競争排除や捕食などを通して時に外来種の大増殖を引き起こし、生態系の変化の結果，在来種の生息を圧迫する恐れがある．外来種の積極的な導入には慎重になるべきであろう．

利根川流域には，ギギ科のギバチ *Pseudobagrus tokiensis* をはじめ多くの絶滅が危惧される淡水魚が生息している．4 種の国外外来魚は，近縁種間の競争排除や捕食などの影響も懸念されるため，関係者への侵入，定着状況の周知等の啓発，増殖と拡散の早期防止対策と共に，継続した個体数および分布状況のモニタリングが必要と考えられる．

本調査では，諸岡清志・初江（故人）夫妻，諸岡やすし氏には定置網漁でたいへんお世話になった．熊谷正裕氏，荒井聡氏，松間健一郎氏，中村栄氏，稲葉修氏には調査に協力いただいた．ここに記して感謝する．

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KP-15

市民参加による実践型の霞ヶ浦水質浄化啓発事業について

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キーワード:市民参加, 協働, 意識啓発, コミュニケーション, 水辺ふれあい

抄録

霞ヶ浦の水質汚濁については様々な原因があり, 大きな原因の一つは家庭からの生活排水である。この生活排水対策については, 住民一人ひとりが, 霞ヶ浦の水質浄化を自らの課題として認識することが重要であることから, 霞ヶ浦水辺ふれあい事業実行委員会においては, 1998 年(平成 10 年)からヨシの植栽, 霞ヶ浦に住む動植物の観察, 湖岸清掃活動等の流域住民・市民参加による実践型の浄化啓発事業を実施し, 流域住民の水質浄化に対する意識の高揚を図っている。今後は, 事業の効果について, より具体的な検証方法を検討し, さらなる事業の充実を図るものとする。

1. はじめに

茨城県, 栃木県及び千葉県の一部を流域とする霞ヶ浦は, 湖面積約 220 ㎢(西浦:168.22 ㎢, 北浦:35.04 ㎢, 常陸利根川:15.33 ㎢)に及ぶ我が国第 2 の湖沼であるが, 湖面積が広いうえに水深が浅く, また湖水の交換日数が約 200 日かかることなどから, 元来水質が汚濁しやすい湖である[1]。

霞ヶ浦の水質汚濁の原因は, 大きく 2 つに分けることができる。ひとつは, 河川などを通じて直接, 有機物質や窒素, りんが霞ヶ浦に流れ込むもので, 汚れの発生源は, 流域内の約 96 万人の生活排水や工場・事業場, 牛・豚などの畜産, 農地, 市街地, 湖内のコイ養殖などのほか, 自然由来の森林からの負荷や湖面への降雨である。もうひとつは, 霞ヶ浦の湖底に堆積している底泥(ドロ)から窒素やりんが湖水に溶け出すものである[2]。

水質汚濁の大きな原因の一つは家庭からの生活排水であり, 汚れの発生源ごとの汚濁負荷割合のうち生活排水を原因とするものはそれぞれ, COD:22%, 全窒素:20%, 全りん:46%である[3] (図 1)。台所などから何気なく流してしまう排水が霞ヶ浦を汚すことに繋がるため, 洗剤や石鹸の使用量は適量にする, 食用油は使い切る, 食器を洗う前には油汚れを拭き取るなど[4], 流域住民一人ひとりが汚れをそのまま流さない生活を心がける必要がある。

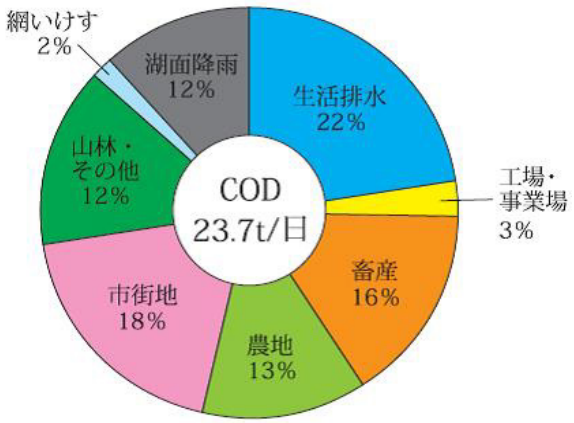

図 1 汚濁負荷(COD)の割合(2015 年度(平成 27 年度))

2. 方法

生活排水対策については, 住民一人ひとりが水環境にやさしくしようという意識を持つとともに, 霞ヶ浦の水質浄化を自らの課題として認識し, 日常生活において水質浄化に向けた積極的な取組を行うことが重要である[4]。

このため, 霞ヶ浦水辺ふれあい事業実行委員会(市民団体, 行政機関等で構成(表 1))においては, 1998 年 (平成 10 年) から, ヨシの植栽, 霞ヶ浦に住む動植物の観察, 湖岸清掃活動等の流域住民・市民参加による実践型の浄化啓発事業を実施し, 流域住民の水質浄化に対する意識の高揚を図っている。

事業の実績としては, 過去 20 年間で 83 回の事業を実施し, 近年では毎年 800 人前後の参加がある(図 2)。

表 1 霞ヶ浦水辺ふれあい事業実行委員会構成団体

項番	名称	備考
1	一般社団法人霞ヶ浦市民協会	地域住民
2	一般社団法人土浦青年会議所	地域住民
3	有限会社ワールドバスソサエティ	地域住民
4	土浦暮らしの会	地域住民
5	NPO 法人水辺基盤協会	NPO
6	霞ヶ浦問題協議会	行政
7	霞ヶ浦グラウンドワーク	地域住民
8	国土交通省霞ヶ浦河川事務所	行政
9	独立行政法人水資源機構利根川下流総合管理所	行政
10	土浦市	行政
11	かすみがうら市	行政
12	茨城県霞ケ浦環境科学センター	行政



図 2 霞ヶ浦水辺ふれあい事業参加人数

3. これまでの事業実績

(1) 水生植物とのふれあい事業

水生植物とのふれあいを通じて自然の大切さを体感し，霞ヶ浦浄化意識の向上を図るため，1998 年度（平成 10 年度）以降，ヨシやマコモの植栽，霞ヶ浦に住む植物の観察，工作教室などを行っており，トータルで 2,856 人が参加した。2017 年度（平成 29 年度）は 58 人が参加し，ヨシ舟・ヨシ笛づくり，ゴムボート乗船体験，救命胴衣体験及びネイチャーゲームを行った(図 3)。



図 3 水生植物とのふれあい事業風景

(2) さかなとのふれあい事業

さかなとのふれあいを通じて水と動植物とのつながりについて学び，霞ヶ浦浄化意識の向上を図るため，1998 年度（平成 10 年度）以降，毎年「泳げる霞ヶ浦市民フェスティバル」に参加し，キャスティングゲーム（フィッシングゲーム）を行っている。トータルで 7,672 人が参加し，2017 年度（平成 29 年度）は 270 人が参加した。

(3) 人と人とのふれあい事業

霞ヶ浦の水辺での人と人とのふれあいを通じて霞ヶ浦への見識を深めるとともに，霞ヶ浦浄化意識の向上を図るため，1999 年度（平成 11 年度）以降釣りマナー向上研修会，ヨシの紙漉き体験，生活排水対策講座などを行っており，トータルで 5,120 人が参加した。2017 年度(平成 29 年度)は 273 人が参加し，霞ヶ浦の湖岸清掃を行った。

(4) 水生生物とのふれあい事業

水生生物とのふれあいを通じて自然の大切さを体感し，霞ヶ浦浄化意識の向上を図るため，2010 年度（平成 22 年度）以降，田植え，メダカの放流式，二枚貝の浄化実験などを行っており，トータルで 619 人が参加した。2017 年度(平成 29 年度)は 55 人が参加し，ヨシ，シジミなどの霞ヶ浦に住む植物や野鳥の観察等を行った(図 4)。







図 4 水生生物とのふれあい事業風景

(5) その他の事業

湖上体験をとおし，霞ヶ浦の豊かな恵みを体感するとともに，様々な視点から霞ヶ浦の将来像を考える契機とするため，2014 年度（平成 26 年度）以降，ろ過装置づくり，スマホ顕微鏡づくりなどを行っており，トータルで 209 人が参加した。2017 年度(平成 29 年度)は 77 人が参加し，遊覧船乗船体験，メダカの観察及びボトルアクアリウム体験を行った(図 5)。





図 5 その他の事業風景

4. 参加者の感想

霞ヶ浦の水が汚いので，きれいになったら泳ぎたい。

霞ヶ浦やメダカについて楽しく学ぶことができた。

環境のことがよく分かった。

湖の中のごみ拾いをできるだけ多くの人でやりたい。

霞ヶ浦の水質がとても心配になった。

5. 考察

1998 年（平成 10 年）に発足して以来，20 年にわたり年 600 人以上が参加する事業を実施している。参加者の感想から，各事業が霞ヶ浦の水質汚濁について認識し，水質保全を意識する契機となったことが伺えるため，引き続き各事業を実施していくことが重要である。今後は，各事業が流域住民の水質浄化に対する意識の高揚に及ぼす効果について，より具体的な検証方法を検討し，それらの結果を踏まえながら，より効果的な事業の充実を図る必要があるとものと考察する。

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KP-16

霞ケ浦湖心におけるバクテリア生産動態と炭素収支

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キーワード:バクテリア生産, 霞ケ浦, 炭素収支

抄録

水圏生態系におけるバクテリアは溶存態有機物を懸濁態化させ, 微生物ループを通して生食食物連鎖以外に高次の栄養段階に物質を輸送する重要な役割を果たしている. 本研究では霞ケ浦湖心におけるバクテリア生産動態と炭素収支を明らかにするため, 2012 年から 2016 年において安定同位体を使用した ^{15}N-デオキシアデノシン法を用いてバクテリア生産速度(BP)を測定し, 一次生産量(PP)と比較を行った. BP は 0.01 gC m^{-2} d^{-1} (12 月) ~ 0.80 gC m^{-2} d^{-1} (8 月) の範囲を変動し, 水温と有意な正の相関を示した. PP に対する BP の比率は冬 (0.11±0.08) に低く, 秋 (0.22±0.20) に高くなる傾向を示した. バクテリア炭素要求量(BCD;BP+バクテリア呼吸量)は 0.14~2.92 gC m^{-2} d^{-1} と見積もられ, BCD/PP 比は秋に 0.97 を示し, PP に相当する有機炭素量をバクテリアが消費することが明らかとなった. 一方, 冬から夏にかけて BCD/PP 比は 0.48~0.58 を示し, 水柱の植物プランクトンによる有機物生産量は BCD を満たしていることが示唆された.

1. はじめに

水圏生態系におけるバクテリアは, 溶存態有機物を起点とした微生物ループを駆動させる主体者として, 生食食物連鎖以外に高次の栄養段階に物質を輸送する重要な役割を果たしている[1] . 通常, バクテリア生産量 (BP) は放射性同位体で標識されたチミジンやロイシンの取り込み速度を測定し, それを細胞増殖量及び炭素量に変換することで求められる. しかしながら, 放射性同位体の使用には, 我が国では多くの制限があり, BP の実測例は限られている.

霞ケ浦は首都圏における重要な水資源であり, 栄養塩・有機物の流入負荷が大きいため, 水質保全・管理を目的としたモニタリングが 1976 年より実施され, 湖内外物質循環の定量が進められてきた. しかし, 系外からの有機物負荷が湖内物質循環にどの程度組み込まれ, 寄与するのかといった問いに対しては, 溶存態有機物を粒状態化する役割を果たす BP の実測なくして定量的な回答は困難である. そこで本研究では, 霞ケ浦湖心における BP の季節変動を明らかにすることを目的とした. さらに, 一次生産量 (PP) との比較を行い, 低次栄養段階生物群集の炭素収支を見積もった.

2. 方法

調査は 2012 年 3 月~2016 年 3 月の期間, 霞ケ浦湖心において毎月実施した. BP は放射性同位体を使用しない ^{15}N-dA 法[2]を用いて測定した. 測定手順(i~iv)を以下に示した.

i. 湖水に [$^{15}N_5$]-2'-deoxyadenosine (15N-dA, CIL Inc.) を添加し, 現場水温に設定した恒温槽で培養した. 培養終了後, 孔径 0.2 μm PTFE メンブレンフィルター (JGWP, Millipore) に濾過し, 冷凍保存した.

ii. DNA 抽出キット (Extrap Soil DNA Kit Plus ver.2, 日鉄環境エンジニアリング) を用いてバクテリア DNA を抽出した.

iii. 抽出 DNA 試料に Nuclease P1 (Wako), Phosphodiesterase I (Worthington), Alkaline phosphatase (Promega) を加え, ヌクレオシドまで加水分解した[3].

iv. 液体クロマトグラフィー・質量分析計 LC-MS (LCMS-8040, Shimadzu) によって, 15N-dA 量を定量し, 取込速度を測定した.

^{15}N-dA 取り込み速度は, 霞ケ浦において実施した ^{3}H-ロイシン法[4]との比較実験によって得られたコンバージョンファクターによって[^{3}H]-Leu 取り込み速度に変換し, 3.1 kg C mol^{-1} leucine[5]によって炭素生産量を求めた.

PP はデータペーパ[6]より引用した. BP は深度積算 (5.5~6.9m)し, 水柱当たりの生産量で示した. 本研究では水温によって各季節を定義し, 春を 4 月~5 月(11.8 ~ 23.4℃), 夏を 7 月~9 月(23.8 ~ 30.2℃), 秋を 10 月~11

月(14.0 ~ 22.4℃), 冬を 12 月~3 月(4.0 ~ 10.4℃)とした.

3. 結果と考察

BP は 0.01 gC m^{-2} d^{-1} (12 月) ~ 0.80 gC m^{-2} d^{-1} (8 月) の範囲を変動した(図 1). 季節別には, 春は 0.23±0.20, 夏は 0.35±0.24, 秋は 0.24±0.21, 冬は 0.12±0.07 を示し, 夏に高く, 冬に低下する傾向を示した. BP と水温の間には有意な正の相関関係が見られたが(R^2=0.24; 図 2), 決定係数は比較的低く, 水温以外による変動要因の存在が示唆された.

PP は春は 2.05±0.80, 夏は 3.19±2.13, 秋は 1.17±0.53, 冬 は 1.18±0.65 gC m^{-2} d^{-1} を示し, 春から夏にかけて高くなり, 秋と冬は同程度の値を示した. PP に対する BP の比率 (BP/PP 比) は冬 (0.11±0.08) に低く, 秋 (0.22±0.20) に高くなる傾向を示した.

ここで, バクテリア呼吸量 (BR) を経験式 (log BR = 0.66 × log BP + 0.68 [7]) から求めると, バクテリア炭素要求量 (BCD = BP + BR) は 0.14~2.92 gC m^{-2} d^{-1} と見積もられた. PP に対する BCD の比(BCD/PP 比) は, 秋には 0.97 を示すことから, バクテリアは水柱の植物プランクトン生産に相当する量の有機炭素を消費していると考えられ, この季節は系外からの有機物負荷が湖内バクテリア生産を支えるために必要であることが示唆された. 秋は水温が比較的高く, バクテリアの活性が高く維持されているものの, 日射量の低下に起因すると考えられる PP の低下により BCD/PP 比が高くなったものと考えられる. 一方, 冬から夏にかけての BCD/PP 比は 0.48~0.58 を示し, 水柱の植物プランクトンによる有機物生産はバクテリアによる炭素要求量を満たしていることが示唆された.

4. 結論

霞ケ浦湖心におけるバクテリア生産は水温と正の相関を示したものの, 特に高水温時における BP のばらつきは大きく, 水温以外の変動要因存在が示唆された. 富栄養湖においては基質よりもむしろ捕食者やウイルスなどによる制限の相対的重要性が高まることが示唆されており[8, 9], 今後 BP の変動要因の解析が霞ケ浦のバクテリア生産動態の解明に重要である.

炭素収支においては, 秋を除いて, 水柱の一次生産量は BCD を満たすことが示唆され, 霞ケ浦では湖外や底泥からの高い栄養塩負荷により, PP が高く維持されていたためと考えられる. 一方, 秋においては系外からの有機物負荷が湖内バクテリア生産を支えるために必要なことが示唆されたことから, 湖内外の炭素循環を明らかにする上で, これらの起源及び寄与度の推定が今後必要であると考えられる.

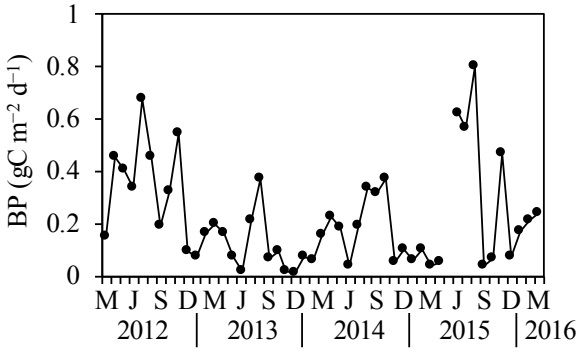

図 1 バクテリア生産量(BP)の季節変動.

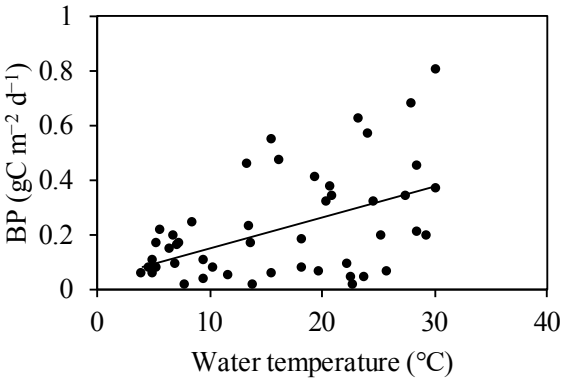

図 2 水温と BP の関係. 回帰直線は[BP] = 0.011×[水温] + 0.039 (n = 48, R^2 = 0.24, p < 0.001)を示す.

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KP-17

霞ヶ浦(西浦)におけるユスリカ群集の長期変遷

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キーワード:ユスリカ幼虫, 優占種の交代, 捕食者, 利用可能な餌資源

抄録

霞ヶ浦の西浦において 31 年間にわたりユスリカ群集の長期変遷を調べた。霞ヶ浦で優占するユスリカ幼虫はオオユスリカ *Chironomus plumosus*, アカムシユスリカ *Propsilocerus akamusi*, スギヤマヒラアシユスリカ *Clinotanypus sugiyamai* およびオオカスリモンユスリカ *Tanypus nakazatoi* の 4 種であったが, これらの個体数密度は 1980 年代から 2010 年代にかけて大きく変化していた。1980 年代はアカムシユスリカが最優占種であったが, 1990 年以降激減し, 2000 年代はほとんど採集されなかった。オオカスリモンユスリカは 1995 年以降に急増し, 2000 年代後半からは霞ヶ浦で最も優占するユスリカ種となっていた。これらの優占種の交代を引き起こしたと考えられる要因や優占種の交代機構, および幼虫密度の低下が捕食者であるテナガエビの現存量の変動におよぼす影響について考察した。

1. はじめに

ハエ目ユスリカ科の昆虫類であるユスリカ幼虫は湖沼の底生動物群集の主要構成員であり, 貧毛類と並んで個体数・現存量ともに優占する生物群となる。霞ヶ浦のユスリカ幼虫については, 1990 年代以降に個体数密度の低下や種組成の変化が報告されている[1]。底生性のユスリカ幼虫は主に植物プランクトンを餌資源として成長する一方で, 魚などの捕食者の重要な食物源として利用される[2], [3]。したがって, 湖沼におけるユスリカ幼虫の個体数や現存量は, 餌となる植物プランクトンの種組成の差異や現存量の多寡, あるいは魚類による捕食者圧の強弱に大きく影響されると考えられる[4]。

最も富栄養化が進行し, アオコの大発生が問題となった 1980 年代の霞ヶ浦の深底帯では, オオユスリカ *Chironomus plumosus* とアカムシユスリカ *Propsilocerus akamusi* 幼虫の 2 種が高密度に生息し, その成虫が湖岸に大量に飛来したため, 迷惑虫として問題となった。しかし 1980 年代後半以降, これらのユスリカ種は減少傾向にある[5]。

霞ケ浦(北浦)の湖畔にある茨城大学広域水圏環境科学教育研究センターの霞ヶ浦定期観測グループが, 茨城県霞ケ浦環境科学センターと共同で実施した霞ヶ浦 100 地点全域調査の結果, 2009 年 3 月時点でのユスリカ幼虫全体の現存量は 1982 年のそれのわずか 1.6%であることが明らかとなった[6]。特にアカムシユスリカ幼虫の場合は, 約 30 年前の 100 分の 1 にまで激減していたが, 当該ユスリカ種の激減理由については不明である。

さらに興味深いことに, 霞ヶ浦ではアカムシユスリカのように激減したユスリカ種がいる一方で, オオカスリモンユスリカ *Tanypus nakazatoi* のように近年増加している種の存在が知られている[1]。しかしながら, 現在までの霞ヶ浦のユスリカ群集については, 長期にわたる定点観測データに基づいてユスリカ種組成や幼虫密度の変遷について議論した研究例は少ない。さらには, いつ頃ユスリカ優占種の交代が起きたのか, またその優占種の交代のメカニズムについては明らかにされていない。

これらのことを明らかにするには, 霞ヶ浦の底生動物群集に関するモニタリングを継続し, かつ既存のユスリカ幼虫に関する調査データを整理すること。さらに, そのようなユスリカ幼虫の動態に影響する要因については, 水温や溶存酸素量などの環境要因, 国立環境研究所などが報告している植物プランクトンに関する情報, 農林水産省統計情報部が発行している水産統計報告などの一次生産者や魚類などの高次栄養段階の生物の変化に

関する知見を集約して総合的に解析する必要がある。

加えて，霞ヶ浦におけるユスリカ幼虫の種組成や個体数密度の減少がユスリカ幼虫を主要な餌資源とする捕食者の動態におよぼす影響を評価することも重要である。例えば，ユスリカ幼虫は 1980 年以降に漁獲量が減少傾向にあるハゼ科魚類やテナガエビ *Macrobrachium nipponense* の重要な餌資源になることが知られている[7], [3], [4]。オオユスリカやアカムシユスリカ成虫の羽化量に及ぼす魚類の捕食圧については定量的な研究がなされている[8]。しかしながら，魚類によるユスリカ幼虫への直接的な摂食量の評価やテナガエビによるユスリカ幼虫の捕食量を定量的に評価した研究は極めて少ない。これらの研究結果に基づいて近年のアカムシユスリカの激減などに見られるユスリカ幼虫の密度や種組成の変化が餌生物群集の動態に及ぼす影響を考察することは，霞ヶ浦の生態系サービス向上の一環として，有用魚種の資源保護や健全な霞ヶ浦の生物環境を保全・回復させる上でも貴重な知見をあたえるであろう。

そこで本研究では，(1)これまで霞ヶ浦(西浦)で実施されてきた 31 年間におよぶ定点観測データを整理することで霞ヶ浦におけるユスリカ群集の長期変遷から見えてくる優占種の交代パターンを明らかにすること，(2)これらの優占種の交代を引き起こしたと考えられる要因を抽出し，近年の霞ヶ浦におけるユスリカ幼虫優占種の交代メカニズムの解明をすること，そして(3) ユスリカ幼虫とその捕食であるテナガエビを用いた室内実験から，幼虫密度の低下が当該捕食の現存量に及ぼす影響を評価すること，を目的とした。

2. 方法

霞ヶ浦(西浦)におけるユスリカ群集の現状把握とその長期変遷を明らかにするため，霞ヶ浦の複数の定点で野外調査を実施するとともに，過去から現在までの 31 年間に収集された試料の再同定とデータ整理を行った。また霞ヶ浦のユスリカ幼虫密度の減少がそれらを餌資源とする捕食者に及ぼす影響評価に資するデータを得るために，霞ヶ浦で優占するユスリカ幼虫 3 種に対する異なる水温環境下でのテナガエビの捕食圧を調べる複数の実験をした。

3. 結果と考察

霞ヶ浦で優占するユスリカ幼虫はオオユスリカ，アカムシユスリカ，スギヤマヒラアシユスリカ *Clinotanypus sugiyamai* およびオオカスリモンユスリカの 4 種であったが，これらの個体数密度は 1980 年代から 2010 年代にかけて大きく変化していた(図1)。

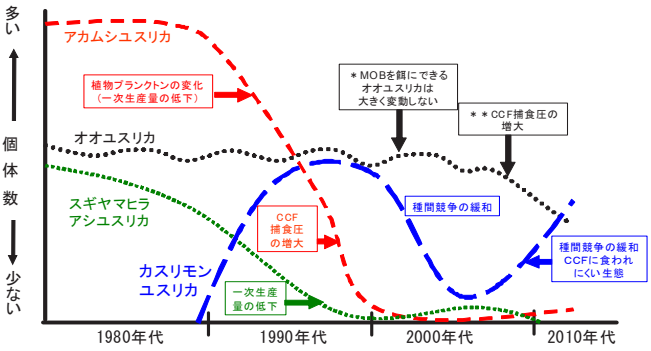

図1 霞ヶ浦のユスリカにみられる優占種の交代とその要因についての模式図．*MOB はメタン酸化細菌，**CCF はチャネルキャットフィッシュ．

1980 年代はアカムシユスリカが最優占種であったが，1990 年以降激減し，2000 年代はほとんど採集されなかった。これには植物プランクトンの質的・量的変化とチャネルキャットフィッシュによる捕食圧の増加が影響していると考えられた。

オオユスリカの場合，極端な密度の低下や上昇のような変化は見られず，ほぼ一定の密度を保っていた。これは当該幼虫が植物プランクトンおよびメタン資化細菌の 2 つを餌資源として利用できるため[8]と考えられた。

オオカスリモンユスリカは 1995 年以降に急増し，2000 年代後半からは霞ヶ浦で最も優占するユスリカ種となっていた。これには他のユスリカ種が減少することに伴う種間競争の緩和とチャネルキャットフィッシュに捕食されにくい特異な生態が関係しているためと推測された。

異なる水温環境下で実施した各種ユスリカ幼虫に対するテナガエビの捕食実験から，このエビは水温の低い時期でも積極的にユスリカ幼虫を捕食することが分かった。従って冬場にのみ底泥表面に生息するアカムシユスリカの激減は，それを重要な餌アイテムとしている捕食者の現存量にも大きな負の影響をおよぼすと推測された。

5. 結論

物質循環におけるユスリカの役割は，2012 年現在とアカムシユスリカが高密度に存在していた 1980 年代とでは大きく異なることが予想されるため，現在の霞ヶ浦におけるユスリカ類の役割を再評価し，モニタリングの継続による霞ヶ浦の生物群集の変化を追跡し続けることが今後も重要である。

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KP-18

Water Quality and Microbial Community in Bottom Sediment Corresponding to a Depth Level in Lake Kasumigaura

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Keywords: closed water body, eutrophication, nutrients leached from sediment, microbial community analysis

ABSTRACT

Dissolution tests were conducted at 30°C under aerobic and anaerobic condition by using sediment from 3 different sampling points in Lake Kasumigaura and microbial community analysis in the bottom sediment was conducted corresponding to a position in a depth direction in order to understand the relevant behavior of materials and lake water quality. In the result of dissolution tests, the behavior of dissolution from bottom sediment was largely different between samples points in the lake. Also, in the results of microbial community analysis, the detection rate of each bacterium was largely changed among samples, especially in the surface of bottom sediment nearby inflowed river. The different of microbial community in the bottom sediment in lake would effect on lake water quality.

1. INTRODUCTION

Lake Kasumigaura has known as eutrophic lake since the 1970's. Generally, the causes of lake eutrophication are principally divided into external loads[1] such as rainfall or inflow of nutrient and internal loads[2] such as nitrogen, phosphorus, and trace metals dissolved from bottom sediments. Since eluted nutrients and metals play significant roles in the occurrence of lake algal blooms[3], estimating the dissolution of nutrients and metals is important. In addition, bacteria in sediment also play important roles in the elution of nitrogen and phosphorus compounds[4]. However, not much is available on the bacterial community in sediment at different sampling sites and different environmental conditions in the intralake[5]. In this study, focusing on Lake Kasumigaura, we investigated the microbial communities in bottom sediments to understand the relevant behavior of materials and environmental conditions since bottom sediments have generally been treated as a 'black box'.

2. METHOD

2.1 Sampling

Bottom sediment samples were taken at three locations (**Fig. 1**): St. 1 off Tsuchiura Port (36° 04' 35" N and 140° 13' 42" E), which is roughly 900 m from Sakura River estuary, St. 2 at Kakeumaoki (36° 03' 03" N and 140° 15' 00" E), and St. 3 at the center of the lake (36° 02' 06" N and 140° 24' 27" E). Samples were taken in August of 2015. The sampling of bottom sediments was conducted in two ways: to serve for the dissolution test and microbial community analysis. To be specific, a diver took a core sample from a depth of about 30 cm from the surface of the bottom sediments. Four samples were taken per sampling point for the dissolution test, using an acrylic column of 20 cm in internal diameter. The samples for microbial community analysis were taken with an acrylic column of 5 cm internal diameter, and immediately put into cold storage and taken to a laboratory for analysis. At laboratory, the sediment sample was cut and divided into 1-cm layers.

2.2 Dissolution test

The bottom sediments sampled with an acrylic column of 20 cm internal diameter were transported to the laboratory with minimal disturbance of the sediments. After the water was drained from the column, the locally sampled water filtered through the GF/B filter was gently fed into the column. Dissolution tests were conducted under aerobic conditions and anaerobic conditions, according to the

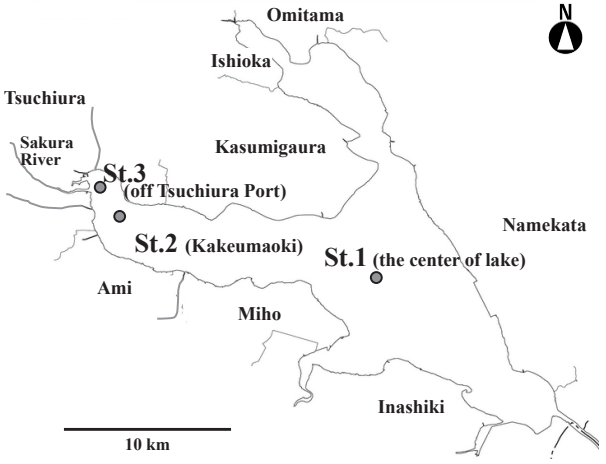

Fig. 1 – Sampling points and rivers flowing into Lake Kasumigaura

sediment testing and investigation manual[6]. Each dissolution test was conducted for 20 days, in a dark location, at a steady temperature of 30°C. Aeration with air was performed until the DO level reached about 8.0 mg/L under aerobic conditions; and aeration with nitrogen was performed to reduce the DO level to or below 1.0 mg/L under anaerobic conditions (n = 2).

2.3 Microbial community analysis

DNA was extracted from sediment samples. Extrap Soil DNA Kit Plus ver. 2 (Nippon Steel & Sumikin Eco-Tech Co. LTD, Tokyo, Japan) was used to extract the DNA. The amplicon PCR was conducted by using primers targeting the 16S rRNA gene region of eubacteria of 341 and 785 as *E. Coli* position, targeting for the V3-V4 region. The following PCR protocol was used: initial denaturation was conducted at 95°C for 3 min, followed by 25 cycles of 95°C/30 sec, 55°C/30 sec, and 72°C/30 sec. The PCR amplification products were purified with an AMPure XP kit (Beckman Coulter Genomics Inc., Brea, CA, USA). Sequence analysis was conducted for of the 16S rRNA gene, using MiSeq (Illumina Inc., San Diego, CA, USA) with the MiSeq reagent Kit v3 (600 cycle). A chimera check of the determined sequences of each lead obtained from the analysis was performed with USEARCH v6.1[7], and operational taxonomic unit (OTU)-picking and cluster analysis were performed with QIIME 1.9[8]. Identification of the OTUs was performed using the Greengenes database (ver. 13_8)[9] as a reference.

3. RESULTS AND DISCUSSION

The results of dissolution tests show in Fig. 2. The dissolution rate of NO_3^- under aerobic condition and NH_4^+ under anaerobic condition from the sediment of St. 1 is the largest among other dissolution rates from the sediment of St. 2 and St. 3. While, the dissolution of NH_4^+ was not observed from the sediment from St. 3 under both of anaerobic condition and aerobic condition. This difference is presumably due to the amount of nitrifying bacteria and denitrifying bacteria exist in the surface of the bottom sediment. Supposing that nitrifying bacteria are enriched at St. 1 and St. 2, they convert ammonium to nitrite and nitrate, then the dissolution of ammonium would be observed under anaerobic condition and the dissolution of nitrate would be observed under aerobic condition. In the same way, supposing that anammox bacteria exist at St. 3, they convert ammonium and nitrite to nitrogen gas under anaerobic condition, then the dissolution of ammonium would not observed under anaerobic condition. Consequently, Mn was not eluted from the bottom sediment of St. 3, whereas the significant dissolution was

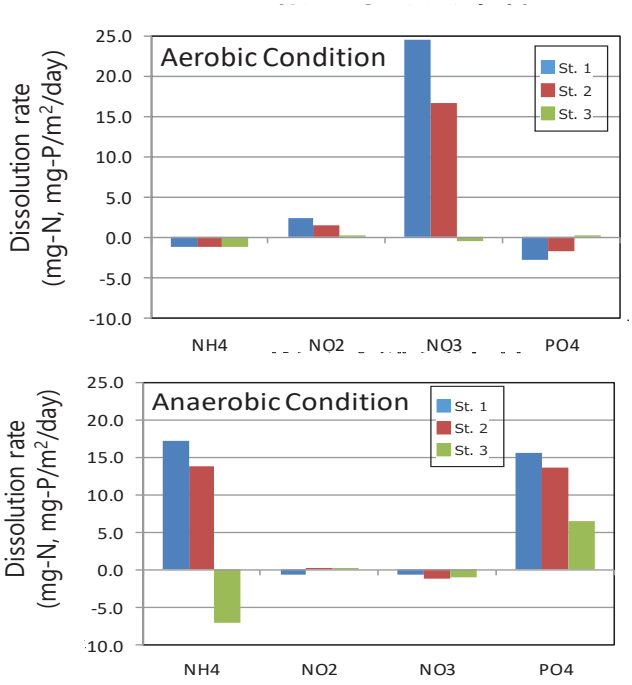

Fig. 2 – Dissolution rate of nutrients from bottom sediment

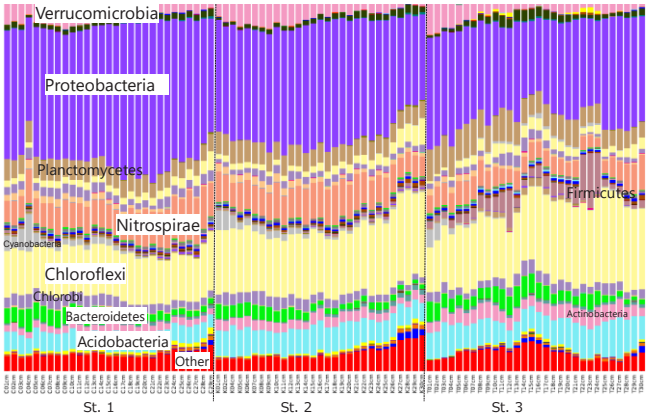

Fig. 3 – Microbial profile of phylum level in bottom sediment in each depth

observed from the bottom sediment from St. 1 and St. 2 (data not shown).

The result of microbial community analysis shows in Fig. 3. In the result of sequence analysis, approximately 10,000 leads were obtained and categorized into 921 OTU and identified to their closely related species. The basic composition of the microbial community was almost the same at every depth and sampling point. Proteobacteria (mainly Deltaproteobacteria, Gammaproteobacteria, and Betaproteobacteria), Nitrospirae, Chloroflexi Firmicutes, Verrucomicrobia and so on were detected in common. The detection rate of Cyanobacteria causing algal bloom was low, but they were relatively highly detected in the surface of bottom sediment from St.1 and St.2. Nitrospirae including nitrite oxidizing bacteria were detected at 8.2%

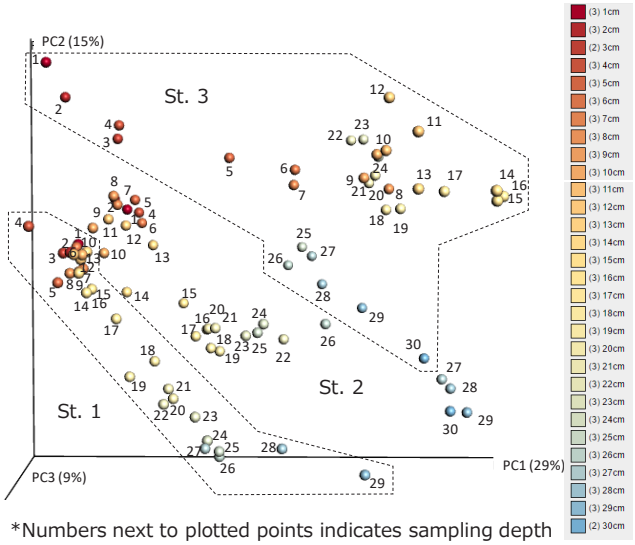

Fig. 4 – PCoA analysis of microbial communities

(±2.1% SD) at St.1 and at 7.9% (±1.5% SD) at St.2, whereas at the sediment form St.3, the detection rate was relatively lower at 5.1% (±2.1% SD). In dissolution test of the bottom sediment from St. 3, though nitrate was not detected under aerobic condition, this would be most probably because the detection rate of Nitospirae causing nitrifying was low.

The result of principal coordinates analysis based on the resemblance of the microbial community in each sample is shown in Fig. 4. The distance of each plotted point indicates the degree of similarity. The microbial community in each sampling point was similar each other as shown by area surrounded by plotted line. In terms of depth direction, microbial community was shifted with same trend in regardless of sampling points. In addition, the microbial community of St. 1 and St. 2 was relatively closed, compared to St. 3. In St. 3, the diversity of the microbial community was comparatively high, especially in sediments at a depth of 0-10 cm, but the microbial community became homogeneous in sediments at a depth below 10 cm. Judging from plotted points upper than 24 cm of St. 3, the bottom sediment was presumed to be resuspended by strong wind. In addition, in the vicinity of surface in the bottom sediment, the microbial community was largely changed by accumulation of suspended solid carried from inflowed river. Therefore, the microbial community of surface layer (1 to ca.13) at St. 1 and St. 2 is similar.

4. CONCLUSION

In this study, dissolution tests were conducted at 30°C under aerobic and anaerobic conditions by using bottom sediment from 3 different sampling points in Lake Kasumigaura. Additionally, microbial community analysis in the sediment was conducted corresponding to a position in a depth direction. As a result, the behavior of dissolution from bottom sediment was different between samples taken from nearby inflowed river and center of lake. Microbial community also largely changed, especially in the surface layer of bottom sediment from the sampling point nearby inflowed river. The different of microbial community in the bottom sediment in lake would effect on lake water quality.

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KP-19

硝酸イオンの窒素(δ ^{15}N)・酸素(δ ^{18}O, Δ ^{17}O)安定同位体を指標とした霞ケ浦用水を灌漑水源とする森林－水田集水域における窒素動態評価

中島泰弘 [1]，鵜野光 [1]，箭田佐衣子 1，伊藤優子 2，小林政広 2，板橋直 13，吉川省子 1，朝田景 1，堀尾剛 1，稲生圭哉 1，江口定夫 1

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キーワード:脱窒，地下水，森林，水田，窒素降下物

抄録

筑波山の森林域および筑波山および霞ケ浦用水を灌漑水源とする水田を主とする農耕地を含む集水域を対象とし、林内雨、土壌水、渓流水、農業用水、農業排水、河川水を採取し、硝酸イオンの濃度および窒素(δ^{15}N)・酸素(δ^{18}O、Δ^{17}O)安定同位体自然存在比を測定することにより、対象地域に流入・流出する硝酸態窒素の起源を明らかにした。

筑波山森林集水域では林外雨および林内雨で δ $^{18}O_{NO3}$ (64.78～70.80)と Δ$^{17}O_{NO3}$(16.16～21.07)が観測され、降下物由来 NO_3^-と推察された。これらはリター層を通過し土壌水、渓流水へと至る間に急激な低下が生じていた。

逆川流域においては生活排水由来と思われる比較的高い δ $^{15}N_{NO3}$ 値(10.50)を持つ硝酸イオンが排水で観測された。また Δ$^{17}O_{NO3}$ と δ $^{18}O_{NO3}$ のプロットからある程度の脱窒が生じている δ $^{18}O_{NO3}$ 値のシフトが観察された。

1. はじめに

霞ケ浦は人口増加や農業、産業活動の進展などによる水質の汚濁の対策として霞ヶ浦に係る水質保全計画(第 7 期)(平成 28～32 年)を策定し、取り組みを続けているが、現在のところ劇的な改善は見られていない。その原因の一つとして、生活排水や農業・畜産排水、降下物等負荷源が複数存在し、その寄与の程度が不明であることが考えられる[1]。

そこで本研究では霞ケ浦用水を灌漑水源とする森林－水田集水域を対象とし、硝酸イオンの安定同位体を指標として対象地域に流入・流出する硝酸態窒素の起源を明らかにするための調査を行った。対象地域では霞ケ浦用水をはじめとして、生活排水、降水、肥料等に由来する複数の窒素負荷源が存在するが、これらはそれぞれ安定同位体比のプロファイルが異なるため、流出河川水等の安定同位体比を測定することにより硝酸態窒素の起源とその寄与を明らかにすることが可能である。さらには脱窒によって窒素濃度が減少する際には同位体比が変動するため、そのシグナルも捉えることが可能となる。

2. 方法

筑波山の森林を主とする集水域(0.038 km^2)および南麓に位置する逆川流域 (9.9 km^2)を対象とし、森林においては林外雨、林内雨、リター層通過水、土壌水(10－200 ㎝) 、地下水、渓流水を、また逆川流域においては山腹渓流水、山麓水、水田灌漑水、水田排水、逆川本流河川水、降水、霞ケ浦用水、地下水を定期的に採取した(図1)。水試料中の NO_3^-濃度はイオンクロマトグラ

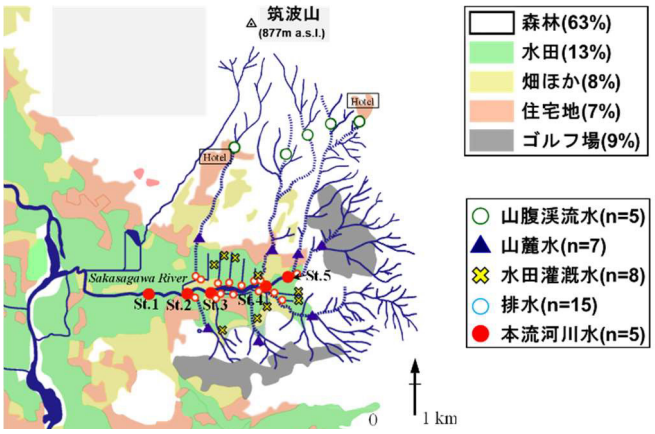

図 1 逆川流域の土地利用と採水地点

フ法で測定し、$\delta^{15}N_{NO3}$、$\delta^{18}O_{NO3}$ および $\delta^{18}O_{NO3}$ 値は脱窒菌法により求めた[2]。

3. 結果および考察

・筑波山森林集水域における硝酸イオンの安定同位体比プロファイル

筑波山森林集水域の硝酸イオンの安定同位体比プロファイルを図 2 に示す。$\delta^{15}N_{NO3}$ は林外雨および林内雨からリター層通過水を経て土壌水、渓流水に至るまで-6.61 から 2.30 の範囲にあり、大きな変化は見られなかった。その一方で、$\delta^{18}O_{NO3}$ および $\Delta^{17}O_{NO3}$ は林外雨および林内雨ではそれぞれ 64.78 から 70.80、16.16 から 21.07 の範囲にあり、リター層通過水では $^{15}N_{NO3}$、$\delta^{18}O_{NO3}$、$\Delta^{17}O_{NO3}$ がそれぞれ-6.61 から 1.58、-2.43 から 53.39、-1.95 から 11.29 と急激に低下し、土壌水および渓流水ではそれぞれ-2.12 から 13.20、-3.06 から 4.54 となった。高い $\Delta^{17}O_{NO3}$ と $\delta^{18}O_{NO3}$ は降下物由来 NO_3^- に特徴的なプロファイルを示し、また 0 付近の値は土壌中で生成された NO_3^- に特徴的なプロファイルであることから[3]、降下物によって供給された窒素がリター層を通過する際に窒素の内部循環サイクルに取り込まれ、硝化によって大気中あるいは水中の酸素によって混合・置換されていることが観察された。筑波山森林集水域では 1980 年代から窒素飽和状態にあり、森林生態系内には多量の NO_3^- が蓄積していると考えられるため[4]、森林を主とする集水域からの窒素流出および逆川流域への森林由来の窒素負荷が 1 年を通じて生じていると考えられる。

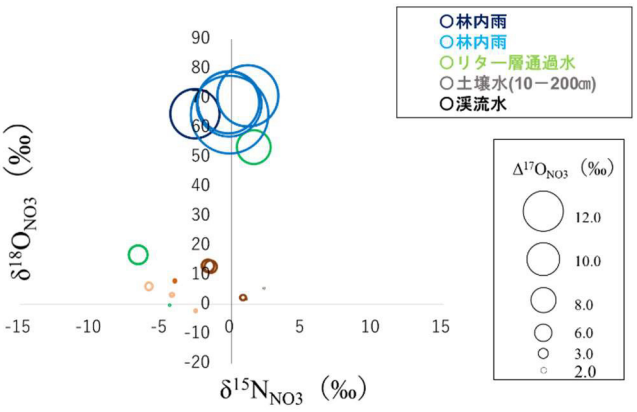

図 2 筑波山試験地における硝酸イオン安定同位体比の $\delta^{15}N_{NO3}$— $\delta^{18}O_{NO3}$ プロット

脱窒によって $\delta^{18}O_{NO3}$ は上昇する一方、$\Delta^{17}O_{NO3}$ には影響を及ぼさないため、原点と降下物由来 NO_3^- プロファイルを結ぶ直線上から上方にシフトする傾向がある。筑波山森林集水域における硝酸イオンの $\delta^{18}O_{NO3}$ と $\Delta^{17}O_{NO3}$ は高い相関があった(図 3)。そのため、$\delta^{18}O_{NO3}$ の変動には脱窒は大きく関与していないと考えられる。

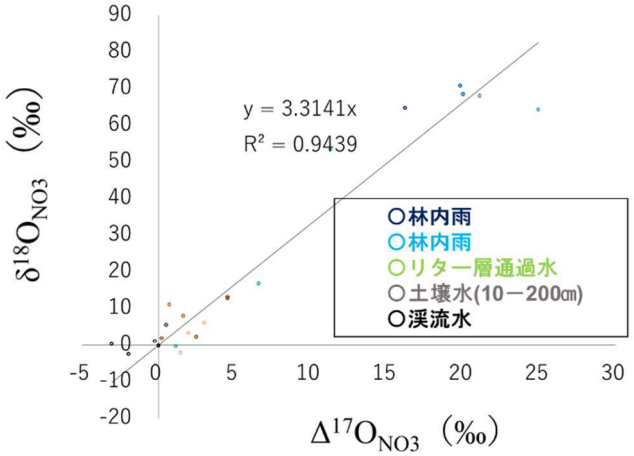

図 3 筑波山試験地における硝酸イオン安定同位体比の $\Delta^{17}O_{NO3}$— $\delta^{18}O_{NO3}$ プロット

・逆川流域における硝酸イオンの安定同位体比プロファイル

逆川流域における硝酸イオンの安定同位体比プロファイルを図 4 に示す。$\delta^{15}N_{NO3}$ は-8.11 から 10.50 の範囲にあり、筑波山森林集水域よりも概ね高くなる傾向にあった。$\delta^{18}O_{NO3}$ および $\Delta^{17}O_{NO3}$ はそれぞれ-0.44 から 7.59、-0.46 から 3.59 の範囲にあった。$\delta^{15}N_{NO3}$ と $\delta^{18}O_{NO3}$ の相関は乏しく、これのみで脱窒の傾向は観察されなかった。高い $\delta^{15}N_{NO3}$ を持つ硝

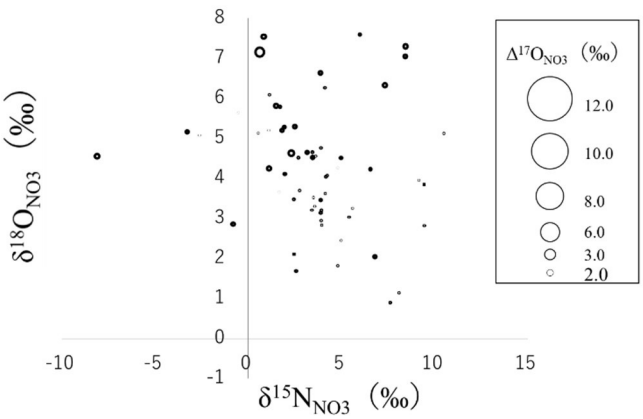

図 4 逆川流域における硝酸イオン安定同位体比の $\delta^{15}N_{NO3}$— $\delta^{18}O_{NO3}$ プロット

酸イオンは主に排水を中心に観測されており、主として生活排水由来であると考えられる。

逆川流域における硝酸イオンの $\delta^{18}O_{NO3}$ と $\Delta^{17}O_{NO3}$ の関係を図 5 に示す。図中の直線は図 3 で示した原点と降下物由来 NO_3^-プロファイルを結ぶ直線と同一である。逆川流域においては筑波山森林集水域と異なり直線上から上方にシフトするプロットが多く見られた。またこれらの多くは $\delta^{15}N_{NO3}$ 値も比較的高い傾向にあり、$\delta^{15}N_{NO3}$ と $\delta^{18}O_{NO3}$ の相関がみられないものの、ある程度の脱窒が生じていることが推察された。

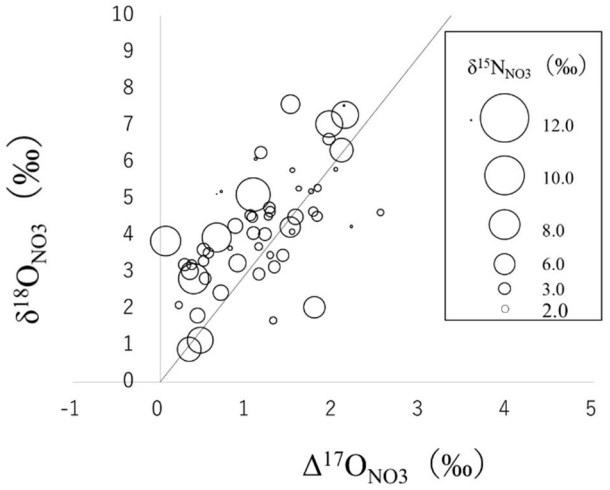

図 5 逆川流域における硝酸イオン安定同位体比の $\Delta^{17}O_{NO3}$—$\delta^{18}O_{NO3}$ プロット

4. 結論

筑波山森林集水域および筑波山を水源とする水田を主とする農耕地を含む逆川流域の硝酸イオンの安定同位体を測定することにより硝酸態窒素の起源とその寄与を明らかにした。

筑波山森林集水域においては林外雨および林内雨で降下物由来 NO_3^-に特徴的な高い $\delta^{18}O_{NO3}$ と $\Delta^{17}O_{NO3}$ 値をもつプロファイルが観測され、リター層を通過し土壌水、渓流水へと至る間に急激な低下が生じていた。

逆川流域においては生活排水由来と思われる比較的高い $\delta^{15}N_{NO3}$ 値を持つ硝酸イオンが排水で観測された。また $\delta^{18}O_{NO3}$ と $\Delta^{17}O_{NO3}$ のプロットからある程度の脱窒が生じている $\delta^{18}O_{NO3}$ 値のシフトが観察された。

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KP-20

浚渫土を有効利用した前浜造成について

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キーワード:前浜、浚渫土、有効利用、土壌シードバンク、湖岸植生復元

抄録

かつての霞ヶ浦においては、ヨシ等をはじめとする抽水植物をはじめ、多様な植生が湖岸帯に存在したが、霞ヶ浦開発事業による湖岸堤築造により湖岸帯の植生が消失したほか、平成 8 年 4 月の管理開始以降も植生帯面積の微減が続いている。これら湖岸植生帯面積の減少について、独立行政法人水資源機構(以下「水機構」という。)では、維持管理の一環として実施する浚渫工事で発生する浚渫土を、平成 14 年度から養浜材として有効活用した前浜を造成することで湖岸植生帯の復元に取り組み、ヨシ等抽水植物の自然発生、生育を確認した。また、新たな試みとして浅瀬として整備した前浜については、沈水植物を含む湖岸植生、水生生物の生育場としての有効性を確認する事ができた。

1.　はじめに

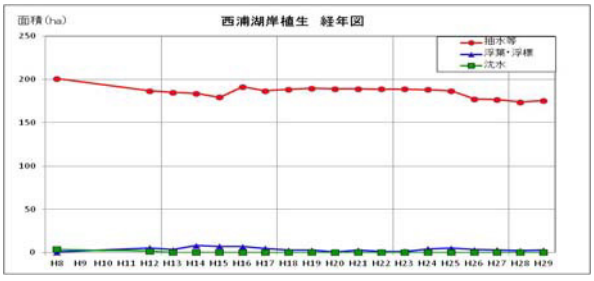
霞ヶ浦開発事業(以下「開発事業」という。)は、湖周辺の洪水被害の軽減と、茨城県をはじめ千葉県、東京都の水需要に対する新規利水の供給を目的として計画され、昭和 46 年 3 月末に当時の建設省より事業継承され、25 年の歳月を経て平成 8 年 3 月に完成した。

開発事業では、無堤区間約 78km に天端高 Y.P.+3.00m の堤防を新築、既設堤防区間約 103km の堤防補強のほか、霞ヶ浦に流入する 52 河川について、流入河川工事(護岸補強等)や、既設の諸施設(樋管・樋門、漁港・舟溜等)の補償工事を実施した。

管理開始以降、西浦では平成 8 年から平成 15 年にかけて、もともと生育していた湖岸植生の減少が確認された。また、北浦を含め浮葉・浮標植物や沈水植物についても少ない状況が続いている。図－1、2に西浦及び北浦の湖岸植生帯面積の変遷を示す。

一方、管理開始以降、維持管理の一環として、霞ヶ浦内の施設(漁港・舟溜、揚水樋管・樋門)の機能維持のため浚渫を実施しているが、浚渫土を仮置きした際に、ヨシをはじめとして様々な植物が自然発生していることを確認している。これは、風や波浪等の影響により湖底に沈殿した水生植物の種子(土壌シードバンク)が、浚渫を実施し仮置きする事で、発芽、育成に適した環境条件となり自然発生したものと考えられる。

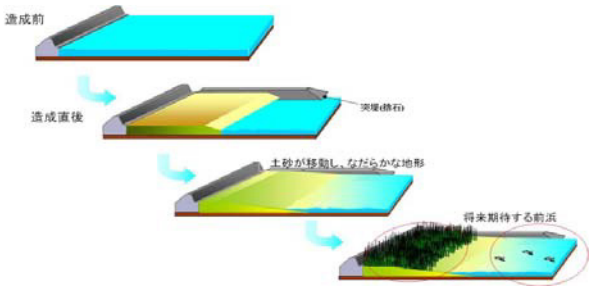
このため、水機構では、平成 14 年度より湖岸の植生帯がない箇所に、浚渫土を有効活用した前浜を造成することで、湖岸植生の自然発生を促し、復元を図ることとした。前浜造成により期待する効果を図－3、湖岸植生種類を図－4に示す。



図－1　湖岸植生面積　経年図(西浦)



図－2　湖岸植生面積　経年図(北浦)



図－3　前浜造成により期待する効果



図－4　湖岸植生（水辺）の種類

2.　前浜造成の設計

2.1　湖岸植生帯の連続性を期待した前浜造成

図-3，4に示すような湖岸植生が連続的に生育することを期待した前浜を設計するにあたって、以下に示す考え方により設計を行った。

土砂は、ある水深以下では移動しなくなる。その移動限界水深hiは式(1)[1]で表すことができる。また、前浜の安定断面は式(2)[2]で算定できる。

$$\left(\frac{H}{H_0}\right)^{-1}\sinh\frac{2\pi h_i}{L}=\alpha\left(\frac{H_0}{L_0}\right)\left(\frac{L_0}{d}\right)^{n} \qquad \text{式(1)}$$

ここに、H、L　：移動限界水深における波高、波長

H_0、L_0：沖波における波高、波長

d　：養浜材の粒径

$$h=Ax^{2/3} \qquad \text{式(2)}$$

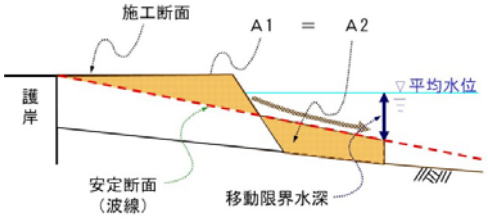
$$A=2.25\times\left(w_s^2/g\right)^{1/3}$$

ここに、w_s：沈降速度

g：重力加速度

$$w_s=\sqrt{\frac{2}{3}\left(\frac{\sigma}{\rho}-1\right)gd+\frac{36\nu^2}{d^2}}-\frac{6\nu}{d}\quad\text{（Rubeyの式）}$$

上記により求めた安定断面に対して、施工性を考慮することとし、図－5 に示す施工断面を造成することにより土砂の移動で最終的に安定断面に落ち着くことを期待した。



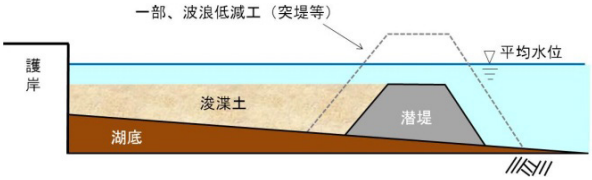
図－5　前浜造成の概念図

また、波浪等による浚渫土（植生基盤）の流出防止のため、護岸から湖方向に突堤を設置した。形状は直線を基本とするが、現地状況により横堤を配置しT 型、L 型とした。材料については、当初、景観、経済性より木杭を使用したが、木杭の腐食、魚類等の生育場（割ぐり石の空隙）、植生回復（空隙に堆積した漂砂による植生基盤生成）も考慮し、捨石工に変更した。

2.2 沈水・浮葉植物等を期待した前浜（浅瀬）造成

理由は後述によるが、平成 27 年度以降は、沈水・浮葉植物等を期待した前浜（浅瀬）を造成した。

2.1 との違いは、図-6に示すように、湖側に流水の連続性及び波浪抑制を確保するため、潜堤及び突堤等を設置し、その内側に浅瀬（水深 50 ㎝程度）となるよう浚渫土を置土した前浜を造成した。



図－６　前浜（浅瀬）の概念図

3.　前浜の整備状況とモニタリング調査

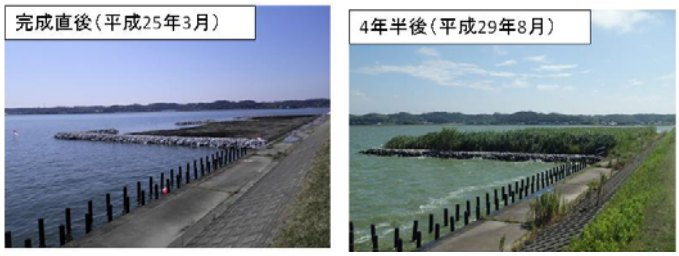
水機構が平成 14 年度から平成 29 年度までに完成させた前浜造成箇所（計22地区約 18ha）を図－7に示す。これらの前浜造成地区の内、抽水植物等を想定した前浜は、21 地区（小袖ヶ浜地区の一部は浅瀬として造成）であり、浅瀬として造成した前浜は串挽地区が完成し、現在、帆津倉地区を造成中である（平成 32 年度完成予定）。



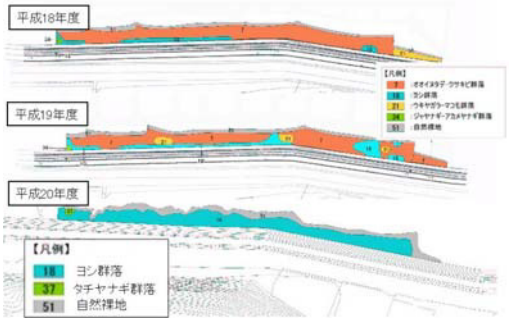
図－7　前浜造成位置図

2．1により造成した前浜については、地形、波浪等の影響により、一部浚渫土の流出等が確認された地区もあるものの、前浜を造成後、概ね半年程度で抽水植物、陸生植物の定着が確認され、その後は、抽水植物に遷移していくことを確認することができた（平成 20 年度時点の馬掛地区の確認植生：35 科 90 種）。図－8に自然植生の事例、図－9に植生モニタリング調査結果を示す。

一方で、沈水植物については継続した発生が確認されなかったため、水機構では沈水植物復元試験[3]を平成 21～24 年度にかけ実施した結果、現在の霞ヶ浦の水



図－8　植生復元の事例（北浦：宇崎地区）



図－9　植生の変遷（西浦：馬掛地区）

質における沈水植物の生育には、水深（50 cm程度）、波浪抑制の他、浅瀬上に堆積する浮泥を除去する必要があることが判明したため、突堤内部に浅瀬（50 cm程度）を造成するとともに、沖側に湖水の出入口（潜堤）と波浪抑制工（突堤等）を造成することで、沈水植物等に加え、水生生物の生息場となることを期待した。

浅瀬として造成した前浜のうち、小袖ヶ浜地区（平成22 年造成後、平成 26 年度に突堤改築）では、平成 29 年7月に実施した植物調査において、36 科 87 種の植生と期待した沈水植物としてマツモ（図－10）を確認した。

なお、重要種はマツモを含む4種、特定外来植物は、ミズヒマワリ等 2 種が確認されている。



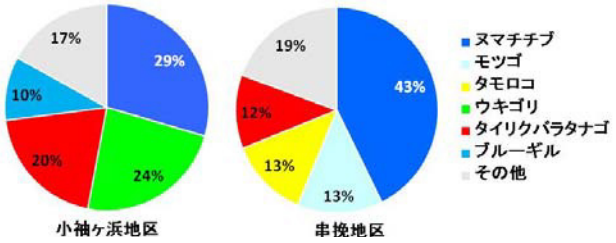
図－10　調査風景と沈水植物の確認
（西浦：小袖ヶ浜地区）

一方、浅瀬として平成 28 年度に造成した串挽地区では、25 科 66 種の植生が確認されたものの、浚渫土がシルト分を多く含んでいたこともあり、沈水植物は確認されなかった。なお、重要種は、カワヂシャを含む3種、特定外来種は、アレチウリ1種を確認している。

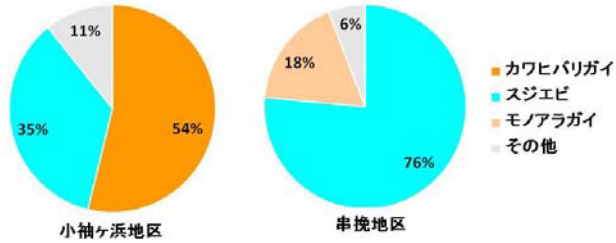
また、両地区において平成 29 年7月に実施した魚介類調査（刺網：20,50mm、投網 12,18mm、魚カゴ、セルビン等）では、魚類3目5科 14 種、貝類4目5科5種、エビ類1目1科2種を確認したほか、串挽地区では、石積突堤に魚卵（ヌマチチブと推測）を確認した（図－11）。それぞれの地区における魚類の優占種を図－12 に、貝類・エビ類の優占種を図－13 に示す。



図－11　確認された魚卵（北浦：串挽地区）



図－12　魚類の優占種



図－13　貝類、エビ類の優占種

4.　まとめ

水機構が管理事業の一環として実施する浚渫工事により発生する浚渫土の置場について、霞ヶ浦の湖岸植生や魚類等の水生生物の生育場として配慮した前浜として造成することにより、霞ヶ浦の自然環境の復元に寄与できたものと考えている。

また、新たな試みとして浅瀬として造成した前浜においても、多種多様な湖岸植生、水生生物の生育の場として良好であることが確認できた。

一方で、特に植生については、浚渫土の土質状況により影響を受けたことが想定されたことから、今後、時間経過による環境変化を確認するとともに、更なる自然環境への配慮を行っていく予定である。

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KP-21

モニタリングデータが語る霞ヶ浦の水質変化

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キーワード: 霞ヶ浦, モニタリング, 環境因子と生態系機能, FRRF 法(Fast Repetition Rate Fluorometry)

抄録

1976 年に開始された国立公害研究所(現:国立環境研究所)による霞ヶ浦モニタリングは今年で 42 年目を迎えた。本報告では, そのうち筆者自身もその取得に関わった 2000 年代以降の一部のデータに焦点を絞り, 近年の霞ヶ浦における水質変化について論じる。霞ヶ浦ではアオコ問題が 2009 年に生起し, 2011 年には 13 年ぶりの大発生で社会問題化するなど, 事態が深刻化した。なぜ突然アオコが大発生したのか?その原因は明らかとなっていないが, 我々は湖水柱・底泥の環境因子と生態系機能の連動関係にその要因があるのではないかと想定した。本報告では, これまで蓄積したモニタリングデータを俯瞰しながら, アオコ再発生に至る水質・底質変化について概説したい。

1. はじめに

1976 年に開始された国立公害研究所(現:国立環境研究所)による霞ヶ浦モニタリングは 1996 年以降, UNEP の実施する GEMS/Water 事業のトレンドステーションとして位置づけられ, 現在でも継続されている。また 2006 年には日本長期生態学研究ネットワーク(JaLTER; Japan Long-Term Ecological Research Network)のコアサイトにも登録された。

本モニタリングの最も特徴的な点は, 研究者が直接的に携わっていることにある。つまり単に事業を継続するだけではなく, それぞれの年代を反映する研究ニーズを盛り込んだ調査が推進されている。例えば 2000 年代以降は, 代表的な流入河川の調査が追加的に行われており, 底泥調査も 2003 年から開始されている(現在, 河川調査は継続中。底泥調査は規模を縮小しながら継続中)。これまで数多くの研究者の努力によりモニタリング事業が継承され, 今年で 42 年目を迎えた。国内外を見渡してもなかなか例を見ない長期間のモニタリングとなり, 膨大なデータが蓄えられている。

本報告では, それらのうち筆者自身もその取得に関わった 2000 年代以降の一部のデータに焦点を絞り, 近年の霞ヶ浦における水質変化について論じる。霞ヶ浦では, アオコ問題が 2009 年に生起し, 2011 年には 13 年ぶりの大発生で社会問題化するなど, 事態が深刻化した。流域発生源対策が着実に進められていながら, なぜ突然アオコが大発生したのか?その原因は明らかとなっていないが, 我々は湖水柱・底泥の環境因子と生態系機能の連動関係にその要因があるのではないかとの仮説を設定し, 検証を行うこととした。

2. 方法

2.1. 調査方法

調査地点と緯度経度の情報を図 1 と表 1 に示した。調査地点は St.1～12 の西浦における 10 地点である(St.5 と St.10 は欠番)。代表地点の湖心は St.9 であり, 高浜入りでの代表地点は St.3, 土浦入りでの代表地点は St.7 である。採水頻度は毎月 1 回, 悪天候時を除き概ね各月の 10 日に近い水曜日に実施して

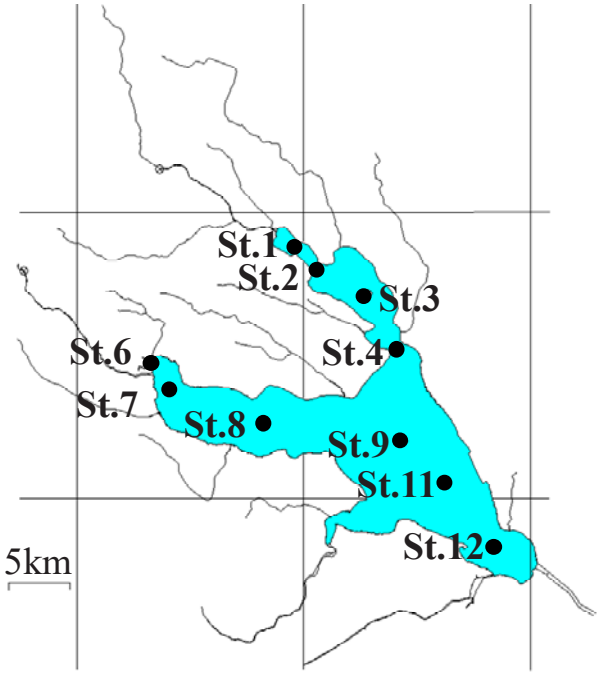

図 1 : 採水地点

表 1：採水地点の緯度と経度[1]

地点	St.1	St.2	St.3	St.4	St.6
北緯	36° 08.952'	36° 08.262'	36° 07.302'	36° 05.352'	36° 04.912'
東経	140° 19.492'	140° 20.422'	140° 22.652'	140° 23.892'	140° 13.223'
地点	St.7	St.8	St.9	St.11	St.12
北緯	36° 03.902'	36° 02.722'	36° 02.142'	36° 00.503'	35° 58.593'
東経	140° 13.993'	140° 17.972'	140° 24.222'	140° 26.152'	140° 28.332'

いる。各調査地点では水質センサーを用いた水温，溶存酸素，pH，光量子等の現場測定，2m カラム採水器やプランクトンネットを用いた試料採取を行っている。得られた試料は実験室に持ち帰り，各種測定を行っている。また 2004 年以降，限定的ながら St.3，St.7，St.9 において底泥コア採取も実施した。

2.2. 測定方法

現場測定項目等の水質・生物項目については，そのデータと共に測定方法を国立環境研究所のウェブサイト[1]で公開している。底泥試料については今井[2]の報告に準じて前処理等を行い，測定に供した。FRRF 法(Fast Repetition Rate Fluorometry)による一次生産速度の測定は小松ら[3] の手法に準じた。

3. 結果

2000 年代当初の霞ヶ浦では全域において白濁現象が見られた。図 2 と図 3 に示す通り，これは透明度の減少と懸濁物質濃度(SS: Suspended Solids)の増加としてモニタリングデータに反映されている。2006 年 4 月には本モニタリング開始以来，最大の SS 濃度(66.8mg/L)と最小の透明度(30cm)を同時に記録した。なお SS のうち，有機態炭素(POC: Particulate Organic Carbon)及び窒素(PON: Particulate Organic Nitrogen)は白濁が確認された時期であっても濃度上昇が見られなかった。

各藻類の細胞数密度について変化に着目すると，白濁のピーク時である 2006 年，珪藻類の急激な増加が見られた(図 4)。2006 年 3 月にはモニタリング開始以来の最大値を示している。その後，少しのタイムラグを経て 2007 年夏季から藍藻類の細胞数密度が増え始めており，2011 年のアオコ大発生もデータに反映されている。

4. 考察

白濁が観測された 2000 年代当初には SS の増加が見られた一方，POC や PON 濃度には大きな変化がなかった。これらの結果から白濁の原因となる成分は無機物であると考えられる。宇田川ら[4]は X 線回折等の結果より，白濁の原因成分をカルシウムと結論づけているが，その

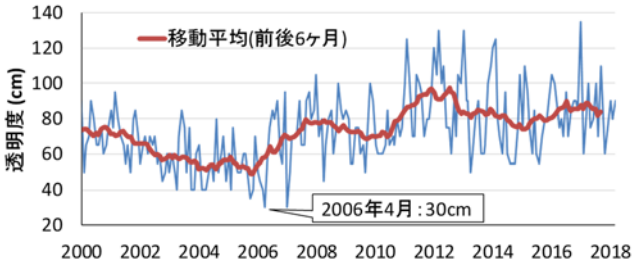

図 2：透明度の経年変化（St. 9，湖心）

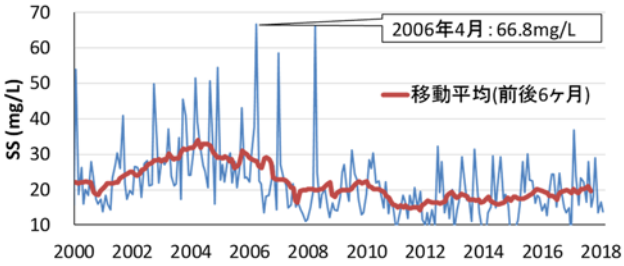

図 3：SS の経年変化(St. 9，湖心)

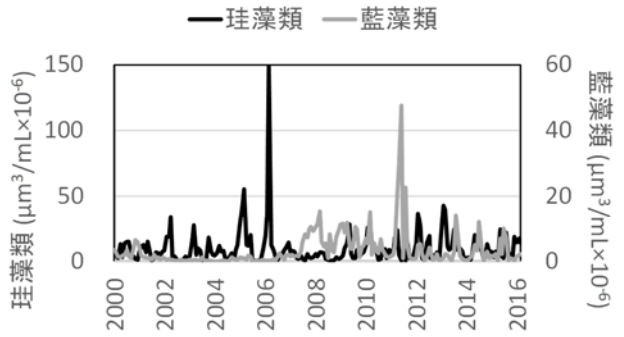

図 4：藍藻類と珪藻類の細胞数密度
(St. 9，湖心)

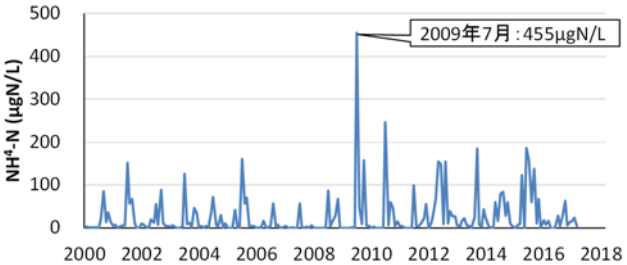

図 5：NH_4-N の経年変化(St. 9，湖心)

起源等，明確なことは現在でも明らかになっていない。

2011 年には藍藻類の増加に伴う大規模なアオコが見られた。この要因として様々に考えられるが，その一つに透明度の上昇が考えられる。図 2 に示す通り 2007 年以降，霞ヶ浦では急激な透明度上昇が見られた。Tomioka et al. [5] も藻類増殖における光環境の重要性を指摘している。

もう一つの要因として重要と考えられるのが，2009 年以降，湖水柱で観測されたアンモニア性窒素(NH_4-N)濃度の急激な上昇である。2009 年 7 月には，本モニタリング開始以来，最大の NH_4-N 濃度(図 5: 455 μ gN/L)を示

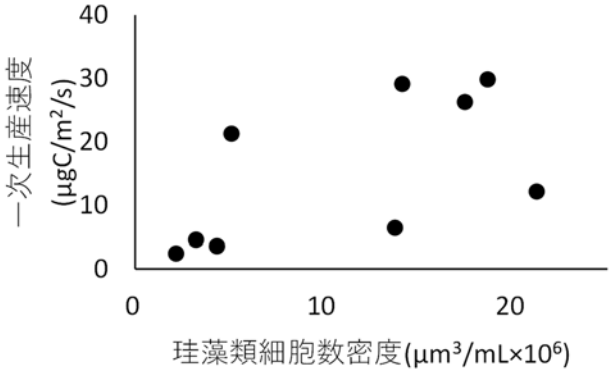

図 6：一次生産速度と珪藻類濃度の関係
（2015 年 7 月～2016 年 3 月，St. 9，湖心）

していた。また底泥直上における NH_4-N も同時期に急激な濃度上昇を示しており，全溶存態窒素濃度の約 50%が NH_4-N だった(それ以前は約 30%)。2009 年以降，NH_4-N の溶出フラックスが大きかったと考えられる。

底泥環境に着目すると，その間隙水中では溶存有機物（DOM: Dissolved organic matter）と栄養塩類（NH_4-N とリン酸態リン PO_4-P）の濃度が 2006 年頃から顕著に増加していた。また，間隙水 DOM の高分子画分と溶存炭水化物の濃度がいずれも間隙水全層において著しく減少しており，底泥環境の急激な変化をうかがうことができる[6]。さらに 2007 年 8 月，間隙水 NH_4-N の突然の濃度上昇と，底泥細菌群集での Firmicutes 門 Bacillus 属の突然の優占化が，明白に観察された[7]。同 Bacillus 属が持つ npr 遺伝子によるタンパク質分解が活性化して，間隙水中 NH_4-N の濃度上昇を加速化したと示唆された。底泥におけるそうした生態系機能（溶出等）が，アンモニア性窒素濃度の上昇等に見られるような湖水柱の環境変化をもたらし，最終的にはアオコの発生に至ったのではないかと推察される。

また，その逆として湖水柱での生態系機能が底泥環境に及ぼす影響も様々に考えられる。例えば上記の底泥環境の変化は，2006 年 3 月に見られた珪藻類の急激な増加が関連している可能性が高い。そこで我々は湖水柱での生態系機能の基礎的項目として一次生産に着目した。現場で瞬時に定量できるようにするため，蛍光法の一種である FRRF 法 (Fast Repetition Rate Fluorometry)を適用し，2015 年 7 月～2017 年 6 月に計測を行った。その結果，2.4～57.0(μ g/m^2/s)と変動幅が大きく，明確な季節変動は見られなかった。しかし珪藻類細胞数密度数と比較すると，図 6 に示す通り正の相関(R^2=0.60)が見られたのに対し，藍藻類細胞数とは負の相関(R^2=－0.40)を示していた。これは湖心だけでなく高浜入りの St.3 でも同様であった。つまり霞ヶ浦における湖水柱での生産は，珪藻の存在量に強く影響を受けていることが分かる。2007 年 8 月に見られた底泥環境の変化は，その前年に起きた珪藻類の急激な増加（湖水柱での生産とその沈降）によりもたらされた可能性がある。

5. 結論

日本第 2 位の面積を誇る霞ヶ浦であるが，平均水深は 4m と他湖沼と比較して浅いため，実は蓄えている水量で比較すると国内第 13 位に陥落する。しかしポジティブに言えば霞ヶ浦は「日本を代表する『浅い湖』」として位置づけることができる。

「浅い湖」と「深い湖」の違いには様々考えられるが，水質での相違を考えると，底泥の影響を受けやすいかどうかが重要なポイントになる。2006～2007 年，霞ヶ浦では底泥と言う見えない場所で，大変重要な変化が起きていた。そしてそれは徐々に湖水柱の水質にも影響していくこととなり，5 年後の 2011 年，その影響はアオコの大発生と言う形で発現した。こうした事実は底泥モニタリングを行っていなければ明らかにならなかったものである。2000 年代当初より綿密に調査計画をたて，底泥調査を開始していた先人達の慧眼に敬意を表しつつ，今後も霞ヶ浦ならではの水質問題に取り組んでいきたい。

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KP-22

Influence of light wavelength and intensity on geosmin production of *Streptomyces coelicolor* A3(2)

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Keywords: musty odor problem, lake sediment light condition, Actinomycetes, geosmin

ABSTRACT

The occurrence of musty odor concerns originated from microorganisms in freshwater environments has been reported in all over the world. Actinomycetes are known one of the causal microorganisms to produce musty odor substances in fresh water environments. Light is one of the most important factors for metabolic response of actinomycetes. Previous studies have reported that *Streptomyces coelicolor* A3(2) produced carotenoid when exposed at blue light, but didn't produce at red light. Both carotenoid and geosmin are terpenoids. Furthermore, isopentenylpyrophosphate is common precursor of geosmin and carotenoid. In this study, we conducted plate culture experiments under different LED light intensity (0, 1, 10, 20 and 30 μmol m^{-2} s^{-1}) of white, blue (470 nm), green (525 nm), and red (660 nm) light to elucidate the factors that influence on geosmin production. Geosmin production of *S. coelicolor* A3(2) gradually increased under blue and white light condition between 2.5 and 20 μmol m^{-2} s^{-1} light intensity, but the production tended to decrease above 20 μmol m^{-2} s^{-1}. This result suggested geosmin production of *S. coelicolor* A3(2) increased when exposed short wavelengths light, but decreased at light intensity above specific level.

1. INTRODUCTION

In recent years, the occurrence of musty odor concerns originated from microorganisms in freshwater environments like as lakes (including Lake Kasumigaura), rivers, and reservoirs has been reported in all over the world[1]. Actinomycetes are known one of the causal microorganisms to produce geosmin and 2-methylisoborneol (2-MIB), both are responsible for musty odor in fresh waters. Waterworks are strongly interested in when geosmin production occurs in the reservoir, because musty odor compounds can be perceived by human being at very low concentration level (ng/L)[2], and it is ineffective to remove by conventional water supply treatment processes such as coagulation, sedimentation, filtration and chlorination[3]. Establishment of effective removal methods is essential for reservoirs in situ, but it is still unclear what environmental factors control the production of these compounds in aquatic environments.

Geosmin biosynthesis by *Streptomyces coelicolor* A3(2), a strain whose genome has been fully sequenced[4], is studied[5]. But the biosynthesis trigger of geosmin production is still unclear. Light is one of the important trigger factors for metabolic response of actinomycetes; as have reported that *S. coelicolor* A3(2) produced carotenoids when exposed under blue light (2.4 μmol m^{-2} s^{-1}), but didn't produce under red light (2.4 μmol m^{-2} s^{-1}) [6,7]. Both of carotenoid and geosmin are terpenoids. Furthermore, isopentenylpyrophosphate (IPP) is common precursor of geosmin and carotenoid. Therefore, it is assumed that light influences on geosmin production by actinomycetes. Based on these backgrounds, we have studied what kind of environmental factors influence on geosmin production of actinomycetes. Here, we reported that the results of plate culture experiments under different light irradiation conditions (wavelengths and intensities) to elucidate the factors that influence on

geosmin production of *S. coelicolor* A3(2).

2. METHODS

S. coelicolor A3(2) was pre-cultured at 28°C for 2 days in 100 mL YMPD medium (2.0 g yeast extract, 2.2 g meat extract, 4.0 g Bacto peptone, 2.0 g NaCl, 1.0 g $MgSO_4 \cdot 7H_2O$, 1.0 g glucose, pH 7.2, per litter) in a 300 mL baffled Erlenmeyer flask, and incubated with shaking at 120 rpm under dark condition. All medium pH were adjusted with NaOH solution before autoclaving. Cells from each 1 mL of cultured medium were harvested by centrifugation (5,000 × g, 5 min) and were washed twice with BS medium without carbon source (BS negative; 2.0 g $(NH_4)_2SO_4$, 2.0 g NaCl, 1.0 g $MgSO_4 \cdot 7H_2O$, 0.5 g K_2HPO_4, 0.05 g $FeSO_4 \cdot 7H_2O$, pH 8.0, per litter). After homogenized weakly by 1 mm glass beads with 1 mL of sterilized distillated water using Fast Prep system (Thermo Savent), cell suspension at a final concentration of 1×10^5 CFU/mL were spread on SFM agar plate (20 g soybean flour, 20 g mannitol, 15 g ager, pH 8.0, per litter). All plates were cultured at 28°C for 7 days under specified light conditions or dark condition. Under light condition, we used white, blue (470 nm), green (525 nm), and red (660 nm) LED light equipment for illuminating at 1, 10, 20, 30 μmol m^{-2} s^{-1} onto the plates respectively. After 7 days cultivation, 5.0 mL of methanol was directly added to each plate for geosmin extraction, and then the plates were kept at room temperature for 30 min. 1.0 mL of methanol geosmin extracts was collected in glass tube and added 2.0 mL of n-hexane. After that, these tubes were stirred for 30 min and then centrifuged at 800 × g for 30 min to separate the n-hexane and methanol layer. The n-hexane layer was carefully collected and filtered through in a Pasteur pipette packed by Na_2SO_4 for dehydration[8]. The extracts were analyzed by GC-MS QP2010 plus (Shimadzu Co Ltd. Japan) with AOC-20is series autosampler (Shimadzu Co Ltd. Japan) for measuring geosmin concentration.

3. RESULTS AND DISCUSSION

After 7 days cultivation, all plate surface of light or dark condition were filled with *S. coelicolor* A3(2) mycelia. On the other hand, geosmin concentration in the plate was increased under light (white, blue, green, red) conditions compared with dark condition. Furthermore, geosmin concentration was gradually increased under blue and white light condition between 10 and 20 μmol m^{-2} s^{-1} light intensity. But the concentration tended to decrease above 20 μmol m^{-2} s^{-1}. These results strongly suggested that the lights played a key role in the induction of geosmin production activity by *S. coelicolor* A3(2). Especially short wavelength light such as blue influenced potently to producing geosmin by *S. coelicolor* A3(2). Also the production respondency might have threshold level of light intensity.

From the previous studies, carotenoid production of *S. coelicolor* A3(2) is induced by irradiating of blue light (2.4 μmol m^{-2} s^{-1}) but isn't induced when irradiated with red light (2.4 μmol m^{-2} s^{-1}) [6,7]. In this study, on the other hand, geosmin was produced by *S. coelicolor* A3(2) under green and red light irradiation conditions. Because metabolic pathway of carotenoid and geosmin has different parts, we suggested that carotenoid and geosmin production could be affected by different factors under long wavelengths light irradiation. In conclusion, it was indicated that various wavelengths light irradiation would induce geosmin production of *S. coelicolor* A3(2).

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KP-23

高度化した水循環機構下にある霞ヶ浦流入河川・桜川流域の水環境
－ 多地点電気伝導率観測による水質実態の可視化 －

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キーワード:栄養塩動態, 河川環境, 水循環機構, 多地点電気伝導率観測, 利根川水系桜川

抄録

桜川流域には下流の霞ヶ浦を水源とする用水路網が張り巡らされ, 農地の灌漑に利用されている. 一方, 農地からの排水は流域の河川に流出し, 再び水源である霞ヶ浦へと還流する. このような人工の水循環系の一端を担う河川の流水は, 質・量の両面で農地(農業)の影響を強く受けていることが予想される. 本研究では, 測定が容易な電気伝導率を指標とし, 流域内多地点で複数回観測することにより水質実態の可視化を試み, その上で湖水循環流域の水環境の現状と課題について考察することとした.

1. はじめに

1) 桜川流域の概要

利根川水系桜川は, 茨城県西南地域の桜川市, 筑西市, つくば市, 土浦市の 4 市に跨る指定延長 63.41km（流路延長約 55km), 流域面積 350.3km^2 の一級河川（県管理）である（図-2). 桜川市の鍬柄山（274m に端を発し, 筑波山地（主峰 : 筑波山 877m）西方の平野部を南流, 土浦市中心市街地付近で霞ヶ浦の西浦（以下, 霞ヶ浦）へと注いでいる. 霞ヶ浦流入河川の中では最大規模（延長・面積）の河川である[1].

2) 高度化した水循環機構

今日, 流域の平野部は一大農業地域を形成しているが, これは古くからの河川水, 地下水の灌漑利用に加え, 下流の霞ヶ浦を水源（ダム）とする「霞ヶ浦用水（1994 年完成)」の管路網整備による, 安定的な大規模灌漑機能に支えられている[2]. 一方で地域からの排水機能は, 流域の河川が担っており, 流出した水と物質は河川を介して霞ヶ浦へと還流する. その水質は良好とは言い難いのが現状であり, 霞ヶ浦の汚濁負荷要因の一つとされている[3]. 更に還流した水と物質の一部は再び霞ヶ浦から揚水されるという, 複雑かつ高度な人工水文循環が, 閉鎖的な水域内で繰り返されている点が最大の特徴である（図-3). 桜川に代表される霞ヶ浦圏域の河川流域は, 流域下流に「ダム湖」を持つという全国的にみても特異な水循環機構を有していると言える[3].

3) 研究目的

以上の背景から, 排水機能を担う桜川水系の河川水は, 質・量の両面において, 農地（農業）由来の影響を強く受けている事が予想される. しかし, 流域の



1) 筑波山と水田地帯



2) 中・下流部(田土部)



3) 河口(土浦市街)

図-1 桜川の景観

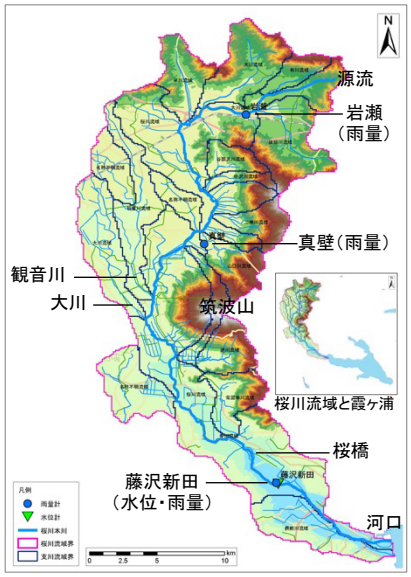

図-2 桜川流域と主要水文観測所

地図データ出典:国土数値情報,主要水系調査, 他

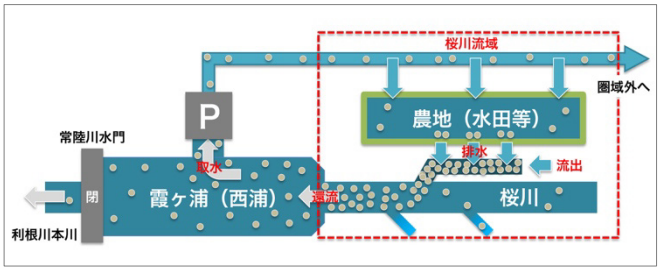

図-3 桜川流域を取り巻く人工水循環のイメージ

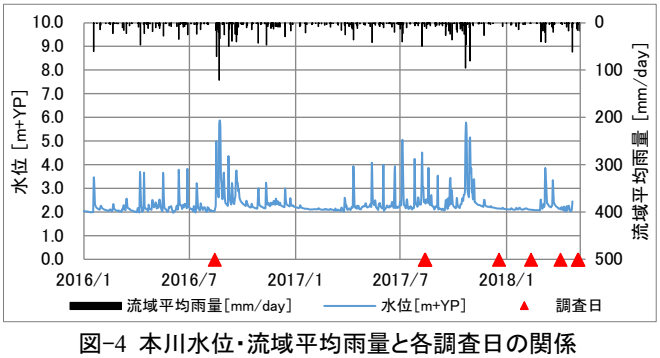

図-4 本川水位・流域平均雨量と各調査日の関係

水位:藤沢新田, 雨量:岩瀬・真壁・藤沢新田(データ出典:水文水質 DB)

水文・水質に関する広域的・定期的なデータが不足している点，本研究の先行研究[4]で提起された，本川下流桜橋付近（地先レベル）での水質改善，という課題検討の点から，本川及び流域全体の水質実態について，現地調査によりその傾向を捉えることとした．

2．調査方法

現地調査における水質項目として，河川水（地表水）の起源を評価したい点，測定が容易（多地点調査が可能）な点，日変動性が低い点から，電気伝導率（以下，EC）を主な指標とすることとした．なお，茨城県の公共用水域調査の水質項目に EC は無く，流域の EC のデータは特に不足している．

調査地点は，本川を軸に，流入する一次・二次支川と用排水路の上下流，その他の水域（溜池等）を対象に，現地状況を勘案して 110 地点設定した．調査項目は，全地点でポータブル pH／導電率計（東亜 DKK, WM-32EP）を用いて水温，EC，NaCl，pH，ORP（別途，気温）を測定，一部で透視度，パックテストにより COD，NO_2^--N，NH_4^+-N，NO_3^--N，PO_4^{3-}-P を測定した．代表地点ではイオン分析のためのサンプリングを実施し，コンパクトイオン分析計（HORIBA，LAQUA twin シリーズ）を用いて Ca^{2+}，Na^+，K^+，NO_3^- を簡易測定した後，本分析のため 0.45μm のシリンジフィルターにより濾過しストックした．

現地調査は，2017/8/13～14（夏季・農繁期・12 時間通水期*），12/18～19（冬季・農閑期），2018/5/4～5（春季・農繁期・24 時間通水期*）の 3 回，それぞれ連続 2 日間に渡り実施した．また，本川に限定した調査を，2016/8/15, 2018/2/10, 4/4 の 3 回実施した（**表-1**）．**図-4** に現地調査時期と本川水位（下流 8.8K・藤沢新田地点），流域平均雨量（上流・岩瀬，中流・真壁，下流・藤沢新田 3 地点を平均）の関係を示す．

3．結果と考察

1）流域全体の EC の空間分布と傾向

本稿では EC の結果について扱う．調査地点の空間分布と EC の測定結果を**図-5** に，EC の値の分布を**図-6** に示す．全体の傾向として，西側の平野部の水域（本川を含む）と，東側の筑波山地山麓部及び本川源流部の水域で明確な差異が認められた．

全データを平野と山麓の 2 グループに分け（測定地点の周辺地形から判断），それぞれ中央値をみてみると，平野部は，夏季 22.3mS/m，冬季 24.3mS/m，春季 21.4mS/m であるのに対し，山麓・源流部は，夏季

表-1 各調査回の位置付けと諸条件

調査回	2016年8月（フレ）	2017年8月	2017年12月	2018年2月	2018年4月	2018年5月	2018年春～夏季（予定）
対象	本川のみ ①	流域全体 ①	流域全体 ②	本川のみ ②	本川のみ ③	流域全体 ③	本川のみ ④
季節	夏季	夏季	冬季	冬季	春季	春季	春～夏季
流況	渇水	豊水	低水	低水	平水	豊水	高水？
藤沢新田水位*1	2.0m +YP	2.3m +YP	2.1m +YP	2.1m +YP	2.1m +YP	欠測	－
藤沢新田EC*2	29.6 mS/m	22.8 mS/m	23.9 mS/m	23.8 mS/m	23.1 mS/m	28.0 mS/m	－
霞ヶ浦湖心水位*3	1.0m +YP	1.1m +YP	1.2m +YP	1.3m +YP	1.0m +YP	1.1m +YP	－
霞ヶ浦湖心EC*4	35.6 mS/m	34.3 mS/m	23.5 mS/m	23.0 mS/m	28.1 mS/m	21.8 mS/m	－
備考	・少雨，渇水傾向	・小規模出水時，低減中			・農繁期前	・農繁期（24時間通水）	・大規模出水時

藤沢新田水位，湖心水位・EC データ出典：水文水質 DB

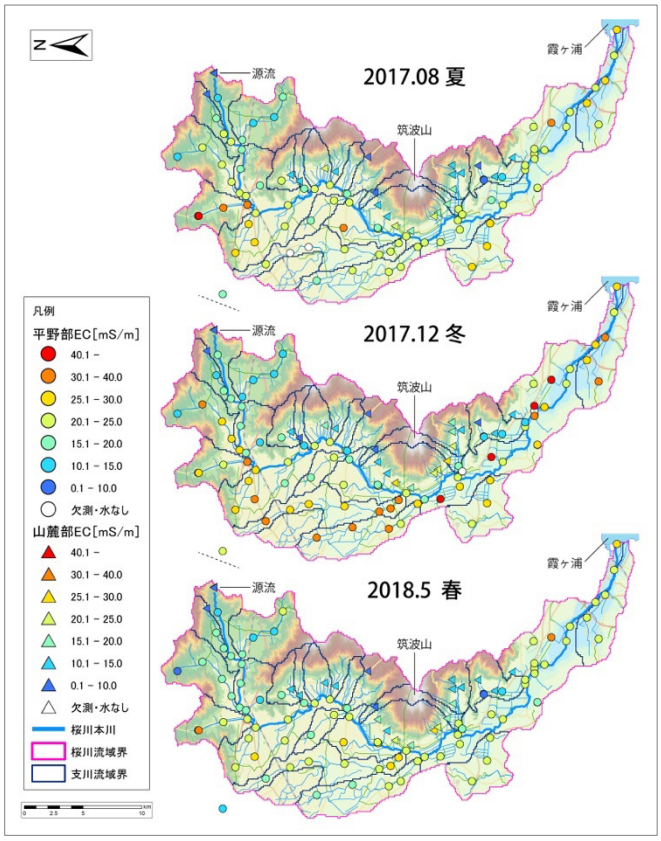

図-5 調査地点の空間分布と EC（○が平野，△が山麓地点）

地図データ出典：国土数値情報，主要水系調査，他

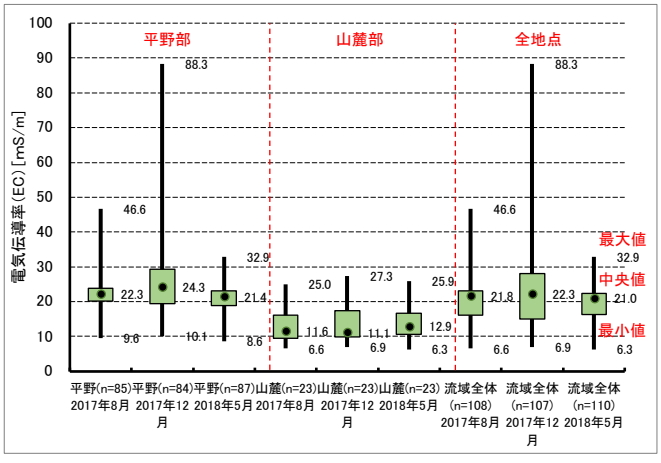

図-6 桜川流域の EC の値の分布

11.63mS/m，冬季 11.14mS/m，春季 12.9mS/m と，平野と山麓で 10mS/m 程の開きがあることが分かった．

山麓部は変動幅が平野に比べて小さく，安定的である．流水についても，豊富とは言えない（流域面積的に妥当）が，春・夏・冬季を通して見られた．これらの起源は，山地湧水が高い割合を占めていたと考えられる．

一方，平野部は変動幅が大きく，特に山付きでない本川右岸側の支川（観音川，大川流域等）の EC が相対的に高い傾向にある．流水については，春・夏季は見られたが，冬季は非常に少なく，またこの時の EC は春・夏季と比較して更に高いことから，流水・水質共に季節変動性が大きいことも分かった．平野部の支川は，山麓部と異なり流水を安定的に供給する湧水等の水源が乏しい，或いはほとんど無い地域であり，春・夏季に見られた流水の起源は，農地等からの排水等が高い割合を占めていたと考えられる．

更に，全データ（3 回分）の最小値は 6.3 mS/m（春季），最大値は 88.3 mS/m（冬季）と大きな開きがある．最小値は山麓部の源流の値であり，これは風化花崗岩地帯の山地湧水と位置付けられ，同じ花崗岩地帯での EC の測定結果 [5]に照らしても妥当な結果と言える．一方，最大値は平野部の水田地帯中の幹線排水路の値であり，土壌等から溶出した水が冬季で流水のほとんど無くなった水路内で濃縮したと推測される（当該地点は毎回高い傾向にある）．

2） 本川縦断における EC の変化

本川縦断における EC の変化を**図-7** に示す．図中には，本川の左右岸から流入する一次支川・排水路等の最下流地点の EC をプロットした．本川の EC は，源流部の直下流から急上昇するが，45.0K より下流の区間に入ると河口付近までほぼ平行である．またその変動は，全体が上下にスライドする形になっている．中流部にみられる本川よりも低い値の流入水は，筑波山地山麓側（左岸）からのものであり，本川の EC に対して希釈効果をもたらしていると考えられる．

なお，同じ夏季（8 月中旬）であっても，2016 年と 2017 年で傾向が大きく異なっている．直前の降雨と当日の水位を参照すると諸条件が異なっており，2016 年は，調査直前の降雨が少なく，水位約 0.98m と渇水傾向．2017 年は調査直前にまとまった雨があり，水位は約 1.35m と豊水傾向にあり，これらが水質に影響したと考えられる．2017 年は雨水流入によって，河川水全体の希釈が働き，2016 年より低い結果になったと推測される．

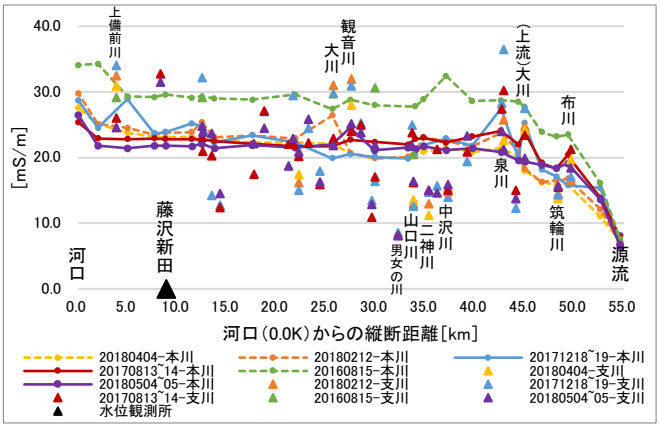

図-7 桜川本川縦断における EC の変化と流入支川の EC

＊ 縦断距離は茨城県資料 [1] からの引用又は Google Earth を用いて測定．

4．まとめと今後の課題

現地調査から，桜川本川と流域全体の EC の傾向を捉えることができた．今後，EC と水文データ，時期（灌漑・非灌漑期*）の 3 つから，桜川においてその時どのような起源の水が支配的であるかを推定し得る可能性が示唆された．

今後の課題として，①水質と地質，土地利用，用水配水エリアとの関係等，水質形成要因の検討，②多雨期，台風等による出水中等，異なる状況・流況時の調査から，水質の季節変動性の検討，③河川水サンプルのイオン分析結果の精査等が挙げられる．

＊ 灌漑期（通水期）：霞ヶ浦用水の水田通水の期間は 4/21～8/31．4/21～5/10 は 24 時間通水，5/11～8/31 は 12 時間（日中のみ）通水 [6]．

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霞ヶ浦湖底堆積物に見られる津波・洪水記録

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キーワード：湖底堆積物，津波，洪水

抄録

霞ケ浦湖心部において湖底表層堆積物を採取し、採取試料約 78 cmについて 1 cm間隔で粒度測定および全炭素・全窒素・全硫黄濃度を測定した。堆積物には 1707 年噴火の富士宝永テフラ（火山灰）と 1783 年噴火の浅間 A テフラが確認された。また、コア下部にはヤマトシジミ密集層があり、その年代は AD1270～AD1298 であった。湖底堆積物中には粒度の極大値が示すイベント層と全炭素濃度の極大値が示すイベント層がある。それらの年代をテフラ層の深度を基にした重量堆積速度で求めたところ、粒度の極大値は歴史的な津波イベントとの対応が、全炭素濃度の極大値は歴史的洪水イベントとの対応がみられた。津波堆積物は利根川筋を通じて太平洋側からもたらされたものであり、1960 年の常陸川水門竣工以降は観察されない。洪水堆積物は利根川および鬼怒川を通じてもたらされたと考えられ、上流域に位置する日光湯ノ湖の湖底堆積物にも見られる劇的洪水のいくつかの年代に対応する。

1. はじめに

2011 年に発生した東北地方太平洋沖地震およびそれに伴う津波による被害発生以降、津波発生メカニズムや発生頻度に関する関心が高まっている。今回は茨城県南部地方の災害史を明らかにする目的で、霞ケ浦の湖底堆積物に残された災害記録を明らかにするための調査を行った。

霞ケ浦は約 1 万年前に地球規模の海水面上昇に伴って誕生し、その長い歴史の大部分を海湾の一部として経過してきた。風土記の時代には「流れ海」という名が示すように大量の海水が潮の干満に伴って湖内に流入していた。現在の霞ケ浦は利根川の川筋を経由して太平洋と連絡しているが、江戸時代初期に利根川の流路が江戸湾から太平洋へと付け替えられる前には、主として鬼怒川の流路となっていた。霞ケ浦は、このような地理的な位置にあることから、歴史的な事件としての津波や劇的な洪水の影響を受けてきた。今回はこのような自然災害の記録が霞ケ浦の湖底堆積物に残っているのではないかと考え、湖底堆積物の調査を行った。

2. 方法

今回、試料を採取した地点は霞ケ浦の湖心、北緯 36° 01’20”、東経 140° 24’40”、 水深約 6m の水域である。柱状試料の採取には、産総研の吉川氏製作の「押し込み式柱状採泥器」を用いた。採取長約 78cm の柱状試料を 0.5cm 間隔に切り分け、粒度分析と有機元素分析用とした。

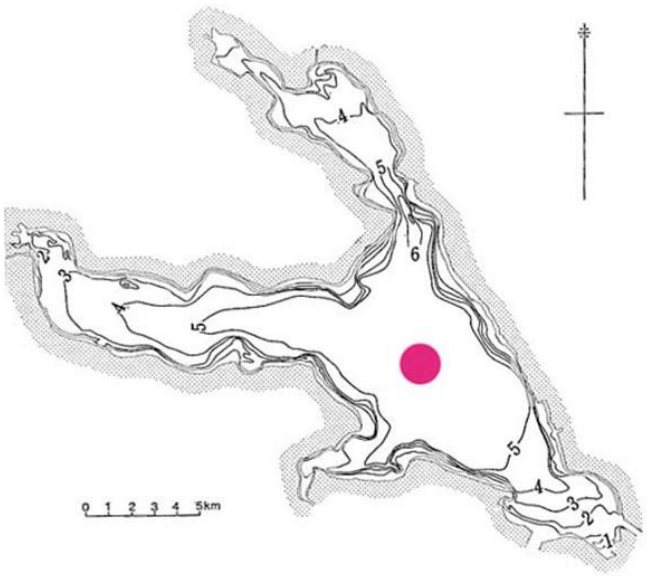

図 1 調査地点

0.5cm 間隔に切り分けた計 156 個の湿試料について、レーザー回折散乱法により粒度分析を行った。試料は、10%の過酸化水素水を用いて有機物分解処理を行い、測定前には分散剤として、10%のヘキサメタリン酸ナトリウムを加え、超音波で 5 分間撹拌した。測定には Cilas 社製の Cilas 1064 を使用し、中央粒径値を求めた。同様の分析を同一地点で採取した柱状試料について 1 cm間隔で粒度測定を行った。測定

には Malvern Panalytical 社製の Mastersizer2000 を用いた。2 試料の粒度測定の結果は 1 ㎝毎に表現し、深度ごとの平均値を用いることとした。粒度測定後の試料について、試験篩を用いて泥サイズの粒子を洗い流し、砂粒子観察用試料とした。砂粒子をシャーレに広げ、双眼実体顕微鏡を用いて構成粒子を観察し、火山灰の層準を特定した。

1cm 間隔で採取した計 78 個の乾燥試料について、ガスクロマトグラフ法により全有機炭素（TOC）、全窒素（TN）、全硫黄（TS）濃度の分析を行った。試料は粉砕し、約 10mg を銀製カプセル中に秤量した。1 規定の塩酸処理を用いて無機炭素を除去したのち、銀製カプセルを錫製カプセルに入れ、キューブ状に成形した。測定には Thermo Fisher Scientific 社製の FLASH 2000 を使用し、検出されたピークの面積から各元素の濃度を求めた。

3. 結果

柱状試料の肉眼観察および砂粒子の観察結果から深度 42.5 ㎝および 48.5 ㎝に浅間 A テフラ（1783 年噴出）および富士宝永テフラ（1707 年噴出）の密集層が確認された。柱状試料の最下部付近の深度 67 ㎝・71 ㎝・73 ㎝にはヤマトシジミの貝殻が複数観察され、炭素 14 を用いた年代測定の結果、AD1270～AD1298 の年代値が得られた。

3.1 中央粒径

平均粒径は 3～6 μm であり、テフラ層準はそれをはるかに上回る値であった。深度―粒度グラフにおいて、10 個以上の極大値を示した。

3.2 全硫黄濃度(TS)

全硫黄濃度は柱状試料最下部から富士宝永テフラの層準に向かって低下する。富士宝永テフラの前後で一時的に濃度が上昇したのち、浅間 A テフラ以浅で一旦わずかに上昇したのち濃度が低下して表層に至っている。

3.3 全有機炭素濃度(TOC)

全有機炭素の濃度は、下部から浅間 A テフラのやや上位までほぼ一定の値で推移するが、浅間 A テフラの層準よりやや上位で急増したのち、小さな極大値をいくつか伴いながらほぼ一定の値で推移した。

3.4 全窒素濃度(TN)

全窒素濃度は全有機炭素濃度のほぼ 10 分の 1 の値を示すが、全有機炭素濃度の変化にほぼ似た変化を示した。

4. 考察

全硫黄濃度の変化に示されるように、今回採取した試料は、ヤマトシジミが棲める汽水環境から霞ケ浦が現在のような淡水湖の環境へと変化した過程を示していると考えられる。堆積物の粒度プロファイルや全炭素濃度プロファイルに見られる極大値が示す意味を明らかにする目的で、それぞれのイベントのおよその年代を求めた。採取した試料の深度を年代に変換するために、表層―浅間 A テフラ間の堆積物の単位面積当たりの乾燥重量をもとに重量堆積速度を求め、内挿法で深度を年代に変換した。同様に、浅間 A テフラ―富士宝永テフラ間の重量堆積速度を求め、深度を年代に変換した。その結果、中央粒径プロファイルでみられた極大値の堆積年代の多くは歴史的な津波イベントの時期に対応する可能性が高いことが示された。一方、全炭素濃度プロファイルでみられた極大値の多くは日光湯ノ湖の湖底堆積物で推定された 50 年に一度程度の「劇的洪水」の年代と一致する可能性が高いことが示された。湯ノ湖は利根川と鬼怒川双方の水源地の一つである金精峠の東側にあり、利根川や鬼怒川の下流域で大洪水が発生した時に対応するイベント堆積物が識別されている。

霞ケ浦のように、海岸から 40 ㎞以上離れた湖沼で津波のイベントを示す堆積物が報告された例はない。このことについて検討する。近年の津波災害で「河川津波」という言葉に注目が集まり始めている（2018 年 3 月 NHK 番組）。これは、河川を通じて遡上した津波が平地における津波の侵入に先行して到達するため、住民の避難を妨げる可能性を指摘したものである。霞ケ浦で考えられるイベントが津波の痕跡であるとすれば、霞ケ浦は河川津波を記録している珍しい例と考えられる。河川を遡上した津波が狭い流路から広い霞ケ浦に広がった場合にそのような痕跡を残しうるものかどうか、さらなる検討が必要であるが、それが実際のものであったとするならば、かなり大きな津波であったことになる。

5. まとめ

霞ケ浦の湖心域において採取長約 78 ㎝の柱状試料を採取し、粒度分析および全有機炭素濃度などの元素濃度測定を行った。噴火年代既知の広域テフラ（火山灰などの火山噴出物）の深度と堆積物の単位面積当たりの積算乾燥重量を基に、イベント層準の堆積年代を推定した。その結果、歴史的な津波記録に対応する可能性の高い津波イベント及び歴史的劇的洪水に対応する可能性の高い洪水イベントを識別した。

KP-25

霞ヶ浦研究会の歩みと役割:霞ヶ浦に関わる情報交流の場の展望

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キーワード:霞ヶ浦、環境情報、保全と改善、情報交換、啓発活動

抄録

霞ヶ浦研究会は、霞ヶ浦を考える研究者や市民の団体として1991年12月に設立され、霞ヶ浦の保全と改善に関する研究、情報交換、啓発活動を続けて来た。1991 年は、アオコ発生が大きな社会問題となり市民、行政、研究者が富栄養化に取り組んでいた。霞ヶ浦研究会の活動は1995年に霞ヶ浦で開かれた第6回世界湖沼会議の開催を支え、その後の様々な環境問題についても取り上げて来た。活動を反映し、生物多様性や生態系関係の内容を含む冊子や会報の出版も続けている。

2005 年、茨城県霞ケ浦環境科学センターが開設され、「調査研究・技術開発」、「環境学習」、「市民活動との連携・支援」、「情報・交流」を進めている。講座や観察会が開かれ、市民が熱心に参加している。霞ヶ浦研究会の手がけて来たことは、センターに引き継がれているとも言える。一方、自由に情報交換し、科学的に論議する場、生物生態系情報の共有の場として霞ヶ浦研究会の存在の意味は無くならない。

1. はじめに

霞ヶ浦研究会は、霞ヶ浦を考える研究者や市民の団体として1991年12月に設立され、霞ヶ浦の保全と改善に関する研究、情報交換、啓発活動を続けて来た。当初の精力的な活動は、1995年に霞ヶ浦で開かれた第6回世界湖沼会議を支えもした。その歩みを振り返り、果たした役割とこれからを考え、合わせて霞ヶ浦に関わる情報交流の場の展望を考察する。

筆者は、1978 年土浦の自然を守る会に入会し、霞ヶ浦を良くする市民活動に関わるようになった。世界湖沼会議'95に向けて発足した世界湖沼会議市民の会や霞ヶ浦研究会にも入会し、シンポジウムなどに参加した。やがて霞ヶ浦研究会運営委員となり、霞ヶ浦研究会報 7 号(2004)より編集を担当し、18 号(2016)まで発行した。霞ヶ浦研究会報その他の出版物から、会の活動を振り返る。

2. 霞ヶ浦研究会の発足

霞ヶ浦研究会設立趣意書(1991.7)は、「霞ヶ浦総合開発工事の終了を迎え、霞ヶ浦研究に関する情報交換と調査研究の場としての霞ヶ浦研究会への参加」を研究者に呼びかけている。1993年会員数は77人、多くが研究者である。

12 月 7 日(土)の設立総会では、霞ヶ浦にどう取り組むのかのパネルディスカッションが持たれた。13 人のパネリストから持続可能な発展、住民・研究者・行政の結集、発生源対策、生き物を守る、水門、地域性、条例と法に基づく県の基本・保全・水源地整備3計画、建設省霞ヶ浦工事事務所の建設事業と水質浄化事業、水質目標値、農業負荷、アオコ現存量と流域の汚濁物質、環境デザイン、行政とマスコミ、情報と意識共有の必要性について報告・提起された。続く総会で規約と事業計画が決まり、会の発足となった。

会の目的と性格は、規約に以下のように定められた。

・第2条(目的)本会は、霞ヶ浦を中心とした環境資源の保全・改善並びに持続的発展に関する研究・調査、情報の交換・収集及び広報・啓発活動等を目的とする。

・第3条(性格)本会は、上記目的に賛同する国・公立研究機関、大学、自治体、企業及び住民団体の個人及び団体が広く横断的に参加できる開かれた研究会とする。

3. 当初の活動

発足から1年4ヶ月(1991・1992 年度)の活動は、まことに精力的であった。

・例会8回:3名程度の話題提供方式で進められた。各回のテーマは、霞ヶ浦に対する社会的要求と将来設計、ヨシ・土地利用・環境保全のための社会システム、霞ヶ浦の生き物たち、霞ヶ浦の環境容量と新管理手法、水田の水質浄化機能・流域の自浄作用、霞ヶ浦水産業の現状と将来、霞ヶ浦と流域に関連した県の試験研究、霞ヶ浦の歴史と環境変遷と、多岐にわたっていた。

・第1回シンポジウム:霞ヶ浦再発見ー人と生き物の共生をめざしてー 9 月 19 日に土浦市民会館で開催され、200 人の参加者があり、景観、谷津田、豊かな生き物(ワンド構築提案)についての講演に聞き入った。この記録は、冊子にまとめられた(1993.3.25)。

・ワークショップ(1):景観「湖岸景観」について 15 人の参加。湖岸自然環境調査、景観調査、住民意識調査(霞ヶ浦工事事務所からの委託研究)など。見た目アオコ指標シートを作成した。

・ワークショップ(2):新川「下水処理水を利用した新川の親水公園化」10 課題(河川環境管理財団助成)

・行政担当者との意見交換会:霞ヶ浦工事事務所、茨城県環境局霞ヶ浦対策課の事業説明と意見交換(2 月)

この間のニュース発行 22 号ということからも、会員相互の情報交流の熱意が伝わる。

4. 世界湖沼会議'95 の翌年 1996 年まで

1993 年度からは、ワークショップの展開を特徴としつつ、例会3回、シンポジウム、行政担当者と意見交換会を毎年開き、年報他の出版を重ねている。これらへの市民参加も多く、湖沼会議'95 に結びつくものであった。地元紙常陽新聞に「貢献度が大きい」と紹介されている(1995.10.21)。世界湖沼会議'95 への参加者は 8,200 人。市民、行政、企業が多く参加し、それまでに無い盛り上がりを見せた。

この間の活動の概略は以下の通りである。

＜1993 年度＞例会3回:シアノバクテリアの増殖・遺伝・カビ臭(6月)、植物を使った水の浄化と霞ヶ浦(10 月)、湖沼をめぐる有害物質の諸問題(1月)。第2回シンポジウム:限りある霞ヶ浦ー開発と自然の接点を探るー川ガキ、ワカサギ、田んぼ、水道、逆水門、環境教育の立場から(9月、土浦水郷文化体育館、参加 80 人)。ワークショップ:景観(湖岸景観・植生浄化など)、新川(下水処理水を利用した親水公園化研究)。行政担当者との意見交換会:新川について(2月)。出版:1991～1992 年度年報、霞ヶ浦関連文献目録、第2回シンポジウム記録「限りある霞ヶ浦」。

＜1994 年度＞例会3回:ハス田と霞ヶ浦(6月)、漁業と霞ヶ浦(10 月)、霞ヶ浦流域の畜産(12 月)。第3回シンポジウム:霞ヶ浦を語る9報告(1月、土浦 国民宿舎「水郷」、参加 70 人)。ワークショップ:土浦港浄化実験(水耕生物濾過法による植生浄化実験)。行政担当者との意見交換会:農業・畜産・水産系生産活動による COD、窒素及びリンの発生負荷削減対策について(3月)。出版:1993 年度年報、「わたしたちの霞ヶ浦ーひとと湖のかかわり」STEP, 1994(25 人の分担執筆、167 頁)。

＜1995 年度＞例会2回:資源リサイクル型地域エコシステム(7月)、霞ヶ浦は今(9月)。ワークショップ:土浦ビオパーク、11 月ビオパーク友の会設立により活動を移行。シンポジウム:世界湖沼会議市民の会と共催、世界湖沼会議'95 を終えて(12 月、土浦 国民宿舎「水郷」参加 100 人)。行政担当者との意見交換会:霞ヶ浦の新たな水位管理について(3月)。総会シンポジウム:ジャーナリストから見た世界湖沼会議とその周辺(3月)。出版:1994 年度年報。

＜1996 年度＞ワークショップ:地域エコシステム(地理情報システムを使った市町村レベルでの環境管理ー阿見町の例)。フィールド観察「建設省の土浦入りにおける湖岸施設を視る・霞ヶ浦名産を味わう」(10 月)。シンポジウム:霞ヶ浦環境センター(仮称)構想を考える(11 月、土浦 国民宿舎「水郷」、参加 50 人)。第2回研究発表会:発表者 11 人(2月、土浦 国民宿舎「水郷」、参加 70 人)。土浦ビオパークの存続決定。

5. 霞ケ浦環境科学センター開設 2005 年まで

ほぼ1年経った 1998 年度から、湖沼会議'95 で県知事が表明した霞ケ浦環境科学センターの開設 2005 年までの活動について述べる。

年2～4回の例会・観察会を実施。ワークショップは 1998 年より環境教育について行い、2000～2003 年には環境教育講座を実施しテキストを検討した。研究発表会は、3 月の総会時に特別講演を含めて行う形が定まった。2003 年 3 月には特別講演「霞ケ浦環境科学センターを考える」を実施している。

2002 年 10 月、シンポジウム「霞ヶ浦の自然再生を考えるー湖岸帯の植生と修復ー」を土浦市で実施した。2000～2001 年度に緊急対策費 34 億円で霞ヶ浦湖岸 11 カ所で実施された湖岸植生帯復元アサザ再生事業について 7 人が討論した。190 人の参加者があり、関心の高さを伺わせた。発案者からは市民型公共事業とされたが、十分な説明責任を担いきれない未熟さを見せたというまとめを、このとき司会をした筆者は霞ヶ浦研究会報7号に寄せた[1]。

会報7号は、このシンポジウム記録と前6号に続く 1999～

2002 年の活動記録として発行した(2004.2)。会報8号は、「霞ヶ浦の白濁現象」を特集し、2003・2004 年活動記録を収めた(2005.3)。この号には、2002 年 12 月から 2004 年 3 月までに開かれた霞ヶ浦意見交換会(霞ヶ浦工事事務所主催)における会員意見の記録も収録している。以降、特集・研究報告・研究発表要旨・意見論考・例会報告要旨・ワークショップ・活動報告の会報内容が定まった。

2005 年 3 月総会の特別講演は「コイヘルペスウィルスについて」内水面試験場長からの講演だった。2005 年 5 月に霞ケ浦環境科学センターが開設された。

この間の例会テーマを年次別にあげる。

＜1998 年度＞霞ヶ浦の植物プランクトンとヨシ帯はどのように変わったか(7 月)・霞ヶ浦の動物たちは今(10 月)・流域から見た霞ヶ浦(11 月)・漁業再生への道を探る(2 月)

＜1999 年度＞硝酸態窒素の汚染と面源(6 月)・アオコの毒素について(9 月)・霞ヶ浦の溶存有機物(2 月)

＜2000 年度＞湖の底質(6 月)・霞ヶ浦の流域管理(12 月)

＜2001 年度＞霞ヶ浦湖岸の植生の現状と修復(6 月)・湖岸の物質循環の構造と機能(9 月)・霞ヶ浦湖岸帯の修復手法と課題(1 月)

＜2002 年度＞霞ヶ浦湖岸の野鳥を守る(5 月)・霞ヶ浦湖岸工事の現地見学会(7 月)・北浦沿岸帯の動物群集(7 月)

＜2003 年度＞農業から見た霞ヶ浦(6 月)・地理学から見た霞ヶ浦(7 月)・漁業から見た霞ヶ浦(10 月)

＜2004 年度＞霞ヶ浦の濁度上昇(8 月)・地域農業と環境保全(11 月)・砂浜と底質ー生物と機能(12 月)

＜2005 年度＞産業と多面的機能(7 月)・湖沼法改正(10 月)・冬期湛水水田(12 月)

6. 2006 年度から 2016 年度まで

総会時の特別講演と研究発表、年 2〜5 回の例会を実施し、その内容を翌年度の会報にまとめることを続けた。2006 年会報9号では、筆者は「順応的管理」について論述した[2]。自然再生推進法施行(2003.1)以降耳にし出したが、事前の環境影響評価をせず事業先行となる課題を記した。2011 年3月の東日本大震災後は、例会で現状報告を受け、2014年会報 14 号に特集した。放射能汚染についての特集を 15、16、17 号と継続した。以下に 8 号以下の特集テーマを記す。

8 号 2005:霞ヶ浦の白濁現象(2005.3.27 発行)

9 号 2006:霞ヶ浦の湖岸帯(2006.3.22)

10 号 2007:霞ヶ浦の構造と機能(2007.3.23)

11 号 2008:霞ヶ浦再生に向けた新たなアプローチ(2008.9.28)

12 号 2009:霞ヶ浦と人間活動(自然再生、開発影響)(2009.9.26)

13 号 2010:霞ヶ浦と人間活動(漁業、水産の現場から)(2010.12.25)

14 号 2011:東日本大震災と霞ヶ浦(2011.12.25)

15 号 2012:東日本大震災後の環境と霞ヶ浦(2013.5.31)

16 号 2013:東日本大震災後の霞ヶ浦・逆水門論考(2014.7.31)

17 号 2014:東日本大震災後の霞ヶ浦と流域(2015.8.31)

18 号 2015・2016:霞ヶ浦の水質(2016.9.30)

7. 振り返りと今後の展望

霞ヶ浦研究会が設立された 1991 年は、霞ヶ浦でのアオコ大発生コイの大量斃死(1973)以降、アオコ発生が大きな社会問題となり市民、行政、研究者が富栄養化に取り組んでいた。霞ヶ浦研究会を含む多くの活動が 1995 年の第 6 回世界湖沼会議の開催を支えた。その後の様々な環境問題についても、霞ヶ浦研究会は例会等で取り上げて来た。その多くは、会員研究者たちの手弁当で持たれた。

2005 年、茨城県霞ケ浦環境科学センターが開設され、「調査研究・技術開発」「環境学習」「市民活動との連携・支援」「情報・交流」の4機能を、市民、研究者、企業及び行政の4者のパートナーシップのもと、効果的に発揮できる運営を目指すとしている。講座や観察会が開かれ、市民が熱心に参加している。霞ヶ浦研究会の手がけて来たことは、センターに引き継がれているとも言える。これに自然環境部門の調査研究・技術開発機能が加われば万全である。

一方、自由に情報交換し、科学的に討議する場、生物生態系情報の共有の場として霞ヶ浦研究会の存在の意味は無くならない。流域では、太陽光発電事業による平地林減少問題もある。組織の高齢化は厳しい現実だが、今後の在り方を探りたいと筆者は考えている。

引用文献

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[2] 山根幸美: 順応的管理についての一考察, 霞ヶ浦研究会報, 9 号, pp. 97-98, 2006.

KP-26

利根川水系桜川の水質改善に向けた水環境の現状と課題

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キーワード:水質汚濁, 河川環境, 現地調査, 水循環機構, 利根川水系桜川

抄録

関東平野の湖沼である霞ヶ浦への流入河川の一つである, 利根川水系桜川について取り上げ, この流域を中心に観察・調査を行い, その結果から河川の水質改善について考察する. 水質・周辺環境について 2015 年 4 月から 2018 年 4 月にわたり現地調査を行い, 桜川が流入する霞ヶ浦との関係も調査し, 季節変化の実態の一端を明らかにした.

1. はじめに

1-1. 利根川水系桜川の概要

利根川水系桜川は, 桜川市, つくば市, 土浦市の広い平野の田園地帯を流れる, 指定延長 63.41 km, 流域面積 350.3 km^2 の一級河川である[1]. 桜川市山口にある鏡ヶ池を水源とし, 国内第 2 位の湖面積をもつ霞ヶ浦の西浦に流入する(**図-1**). 古鬼怒川が作った広い平坦地の中を流れ, 霞ヶ浦流入河川の中では最大規模(延長・面積)の河川である(**図-3**).

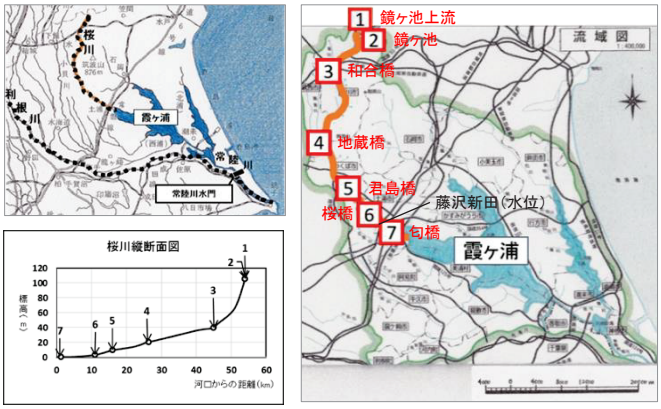
1-2. 研究背景

この研究は, 著者が 2016 年度自由学園最高学部卒業研究としてまとめた「自然と人のかかわり—利根川水系桜川について—」[2]を土台とし, その後継続して行った調査結果を付け加え再構成したものである.

桜川は, 著者の郷里(茨城県つくば市周辺)を流れている. 桜川下流に位置する桜橋周辺で幼少期から見てきたが, いつ見ても深緑色に濁っており, きれいな川にしたいという思いが桜川を研究対象とするきっかけになった. 現在の桜川の水質は, 良好とは言い難い状況にあるが, 地域でのヒアリング調査から, 昔(1960 年代)の桜川はきれいだったという証言を得た. 茨城県公共用水域測定結果の内, 比較的長期のデータが存在する桜川河口・銭亀橋の DO(溶存酸素量), COD(化学的酸素要求量), BOD(生物化学的酸素要求量)のデータを見ても, 1960 年代後半は低値であった(**図-4**).

1-3. 研究目的

そこで, 桜川下流桜橋付近(以下, 栗原地先)の水質改善を目指し, 桜川の上下流及び霞ヶ浦等, 周辺水域の水質実態の把握を目的とした調査を行うこととした.



【左上】図-1 利根川流域図
(『流域をたどる歴史関東編』[3]利根川流域概要図に加筆)
【左下】図-2 桜川河道縦断図(原図)
(縦断距離を 25,000 分の 1 の地形図上をマップメジャーで測定, 標高を国土地理院の「地理院地図」で測定して作成)
【右】図-3 霞ヶ浦流域と調査地点
(霞ヶ浦・常陸利根川管内図[4]に加筆)

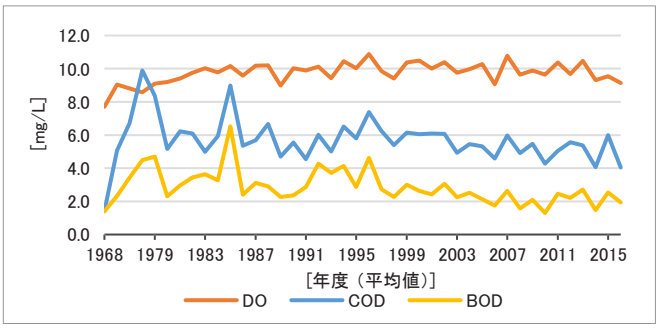


図-4 桜川・銭亀橋の水質経年変化(1968～2016 年度)
(年平均, データ出典:茨城県公共用水域測定結果)

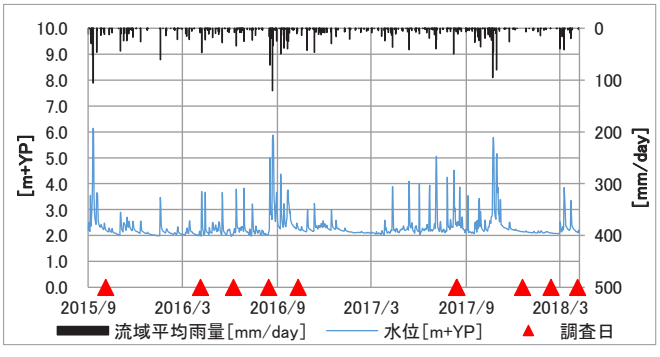


図-5 桜川の水位・雨量と調査日(2015.9.1～2018.4.7)
(データ出典:水文水質データベース)

2. 調査方法

2015 年 4 月から 2018 年 4 月にかけて，桜川本流全域の水質・環境調査，霞ヶ浦及び利根川水系常陸川と常陸川水門，霞ヶ浦を水源とし桜川流域を含む地域一帯に水を供給している霞ヶ浦用水についての現地視察を行った．更に桜川流域で保全活動を行っている団体のヒアリング調査や文献調査を行った．

桜川の水質・周辺環境調査地点は，茨城県の水位観測所設置地点，市の水質調査地点を参考にし，また調査のし易さなども考慮して 7 地点(**図-3**)を選んだ．水質調査項目は，2015 年は気温，水温，透視度，COD，pH（水素イオン指数）を測定した．2016 年からは，亜硝酸態窒素（NO_2^--N），アンモニウム態窒素（NH_4^+-N），5 月と 8 月のみ一般細菌，大腸菌群，6 月のみ DO を，2017 年からは，硝酸態窒素（NO_3^--N），りん酸態りん（PO_4^{3-}-P）を加えた．COD，NO_2^--N，NH_4^+-N，NO_3^--N，PO_4^{3-}-P はパックテストで測定し，pH は計測器とパックテストで測定した．採水，透視度，パックテストの調査は，2015，2016，2017 年の 6 月に参加した「身近な水環境の全国一斉調査」[5]とほぼ同一の方法で行った．

3. 結果と考察

3-1. 桜川全域の水質・環境調査

桜川全域の水質・周辺環境調査から得られたデータの内，本稿ではパックテストによる水質項目と透視度の結果を**図-7～12** に示す．NO_3^--N は河口に向かって上昇傾向，PO_4^{3-}-P，透視度は河口に向かって低下する傾向が顕著に捉えられた．その他の項目はバラツキが大きいため，平均値を取った結果を**図-6** に示す．源流の鏡ヶ池上流はいずれの項目も良好であるが，平野部を流下するに連れて悪化する傾向が見られる．COD についても下流部にかけて上昇している．

また，現地状況からは，5 月の田植えからの農繁期に，濁水が流入するなど水質が悪化し，流れも少なくなることが確認された．石原ら(2006)[6]には，この時期に桜川の河川水中の除草剤成分の最高濃度が検出されたことも報告されている．

また，主に農業地帯を流れる桜川の生物相は，上流には在来種の生物が多く，下流には外来種が多い傾向がみられた．魚類などの動物も下流域に外来種がみら

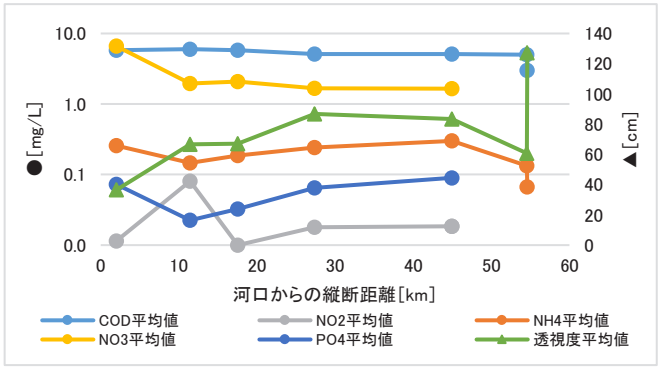


図-6 水質項目別の平均値(2015.10～2018.4)

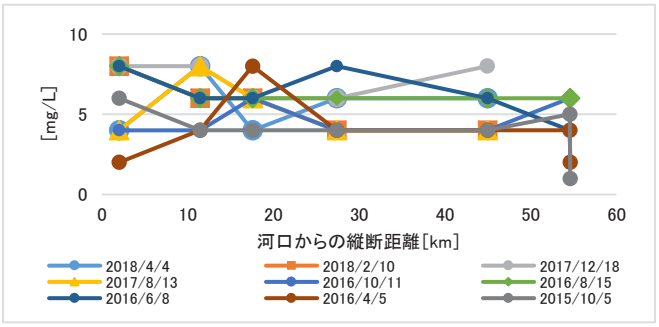


図-7 COD の縦断変化(2015.10～2018.4)

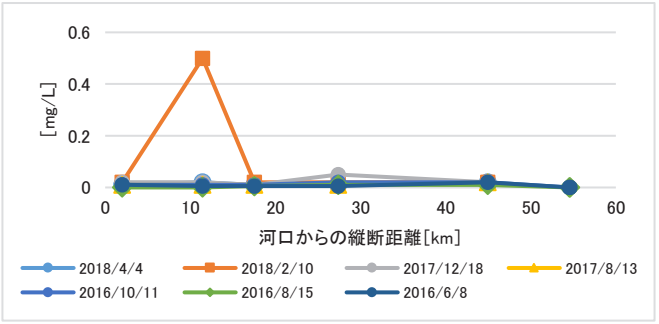


図-8 NO_2^--N の縦断変化(2016.6～2018.4)

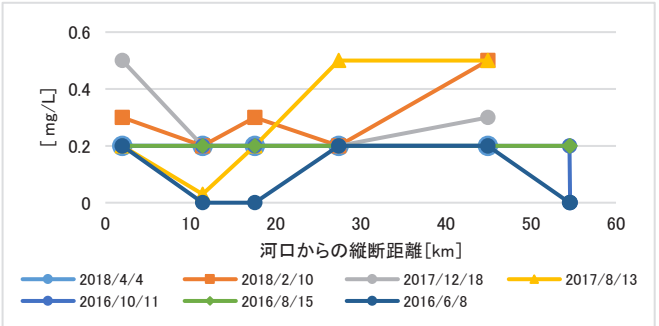


図-9 NH_4^+-N の縦断変化(2016.6～2018.4)

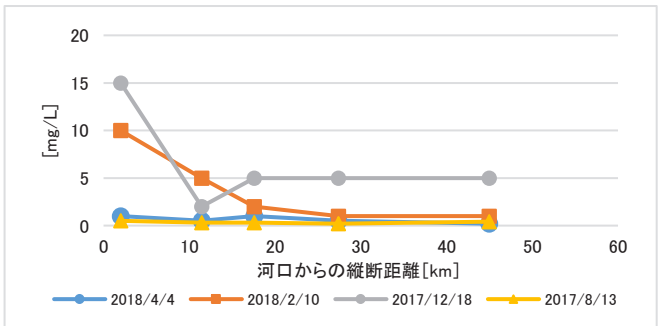


図-10 NO_3^--N の縦断変化(2017.8～2018.4)

れた．特に桜橋周辺では外来種のアカミミガメが見られ，2015 年 10 月から 2018 年 4 月までの調査で，アカミミガメかどうか判別できないカメも含め，冬季を除き，毎回数個体以上見られた．

3-2. 霞ヶ浦および常陸利根川の現地調査

桜川から霞ヶ浦（西浦）へと流入した水は，常陸利根川に流れるが，利根川本川との合流点に設けられた常陸川水門は，洪水時以外完全に閉めきられている．これは，霞ヶ浦の水位を一定に保ち淡水のダム湖化とするためであり，その霞ヶ浦の水は霞ヶ浦用水（1994 年通水開始）として汲み上げられ農業・水道・工業用水として利用される．農業用水については，耕作に利用された後，農業排水として桜川に入っており，またその水が霞ヶ浦に流入するという特徴的な水循環を形成していることが分かった（図-13）．

4. まとめと今後の課題

以上の調査から，研究対象である桜川の栗原地先は，このような水循環の一部分に当たり，地先での水質改善を進めるためには，桜川流域からの汚濁負荷の低減だけでなく，霞ヶ浦の水質改善が極めて重要であることが分かった．

2016 年 8 月には茨城大学公開臨湖実習に参加して霞ヶ浦の水質や生息する生物について学んだ．また，他大学の学生と霞ヶ浦の水質改善についてのディスカッションを行い，「農業排水の処理を考えることが一番の近道である」とまとめた．霞ヶ浦の課題は桜川の課題でもある．よって，桜川の栗原地先の水質改善には，農業排水の処理を考えることが一番の近道であると考える．今後，県や市の協力のもと桜川流域の農業排水処理方法の改善が必要であると考える．また，継続的に栗原地先を中心に水質調査を行い，結果を周知し，流域住民も桜川に関心を持てるような活動を行っていくことも水質改善への一助となると考える．

謝辞

茨城大学広域水圏環境科学教育研究センターには卒業論文共同利用研究としてご指導いただいた．関係諸機関より資料の提供，地域の方々にはヒアリング調査等でご協力をいただいた．感謝申し上げる．

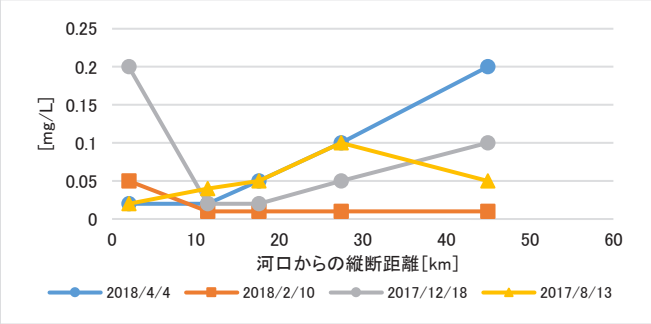


図-11 PO_4^{3-}-P の縦断変化（2017.8～2018.4）

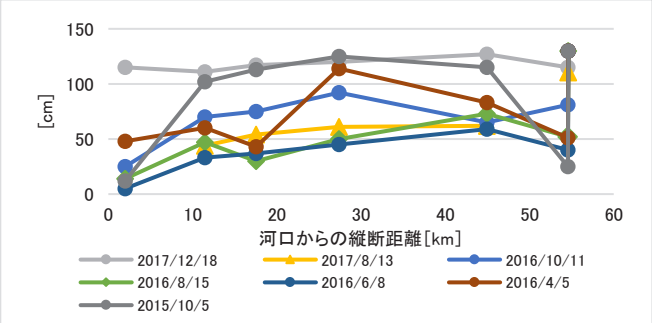


図-12 透視度の縦断変化（2015.10～2017.12）

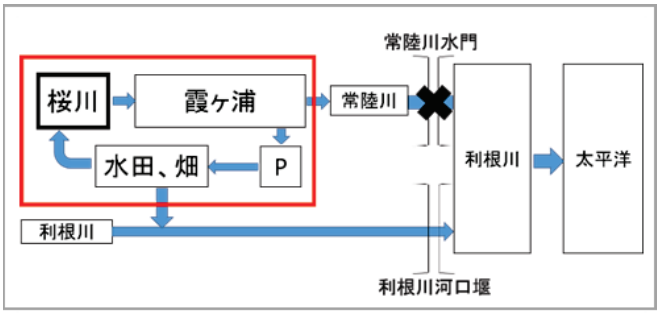


図-13 桜川の水循環のイメージ

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KP-27

筑波研究学園都市の成長による近隣湖沼への雨水流出負担の変化

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キーワード:筑波研究学園都市, 人口重心の移動, 土地利用の変遷,

抄録

本稿では、筑波研究学園都市と周辺湖沼との関係を考察する。つくば地域の上下水利用の状況について資料調査により概観した。さらに、都市化の影響の中で人口定着・重心の動向と土地利用の変化という観点から都市と湖沼との関係の変容を確認した。とくに、雨水排水流末湖沼としての牛久沼への排水負荷の比重が高まってきたことを明らかにし、現状と課題について述べた。

1. はじめに

筑波山と霞ヶ浦は、雄大な地形地物要素であり地域を代表するランドマークである。有史以来つくば地域と霞ヶ浦が結びついた記録・著述も多く存在するが、研究学園都市建設地の決定時にも、豊富な水瓶として霞ヶ浦の存在が決め手のひとつであったとの記録(文献[1])もみられるように、つくば地域と霞ヶ浦の関係は深い。本研究では、閣議決定による計画決定から 50 年経過し、都市としての成熟期を迎えた筑波研究学園都市近隣に存在する霞ヶ浦及び牛久沼との関係性を概観し、特に、雨水流出に着目し市街地開発に伴う流末への影響を述べる。

2. 方法

本研究では、都市化の影響の中で人口定着・重心の動向と土地利用の変化という観点から研究学園都市と湖沼との関係を捉える。

(1) つくば地域の上下水利用の概観(資料調査)

表1:資料調査概要

種別	対象用水道等
上水	水道用水:県南広域水道用水 工業用水:県西広域工業用水道
農業用水	霞ヶ浦用水
下水	霞ヶ浦常南流域下水道 小貝川東部流域下水道

(2)人口の変化

1970 年代以降の研究学園都市の建設に伴う都市化及び人口定着の状況を、国勢調査人口メッシュデータを利用し人口重心の動きを把握する。

(3)牛久沼流域の土地利用の変化の把握

筑波研究学園都市がほぼ流域を包含する牛久沼の流域について、国土地理院土地利用図の変遷(1976 年、1997 年、2016 年)により、都市化状況を概観する。



図1:筑波研究学園都市(つくば市)と周辺湖沼の位置

3. つくば地域の上下水利用の概観(資料調査)

現在、つくば市では上水として、霞ヶ浦を水源とする水道利水が 22,562,173 m³(2016 年度)で 99.41%を占める。農業用水としての利水もあり、この市内受益面積は 3,106ha である。生活者の目線からみれば、汚水・雨水の排水よりも、直接口にする上水の利水に着目される向きが多いのは当然のことであり、研究学園都市と関係が深い湖沼は霞ヶ浦であると、これまで一般的に考えられてきた。なお、研究学園地区の建設後に霞ヶ浦から上水が供給された(供給開始:1977 年)が、その以前は、旧町村の一部に簡易水道事業が設けられており、地下水利用がなされていた。とはいえ、利水に関しては大部分を霞ヶ浦に依存している。一方、公共下水道(汚水)については市域北西の一部地域を除き、利根町の終末処理場を介し利根川に配水され、湖沼を流末とはしていない。他方、公共下水道(雨水)に関しては、研究学園都市の建設時以降、河川に排水する都市下水路が整備されたが、この流域は河川に依存することから、後述の河川の

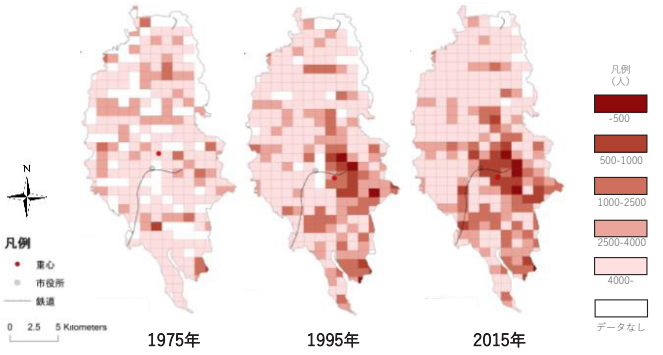

図 2：つくば市における人口変化

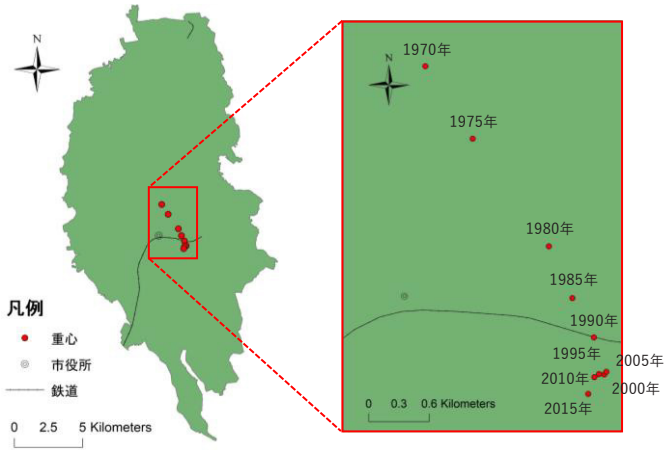

図 3：つくば市における人口重心の移動

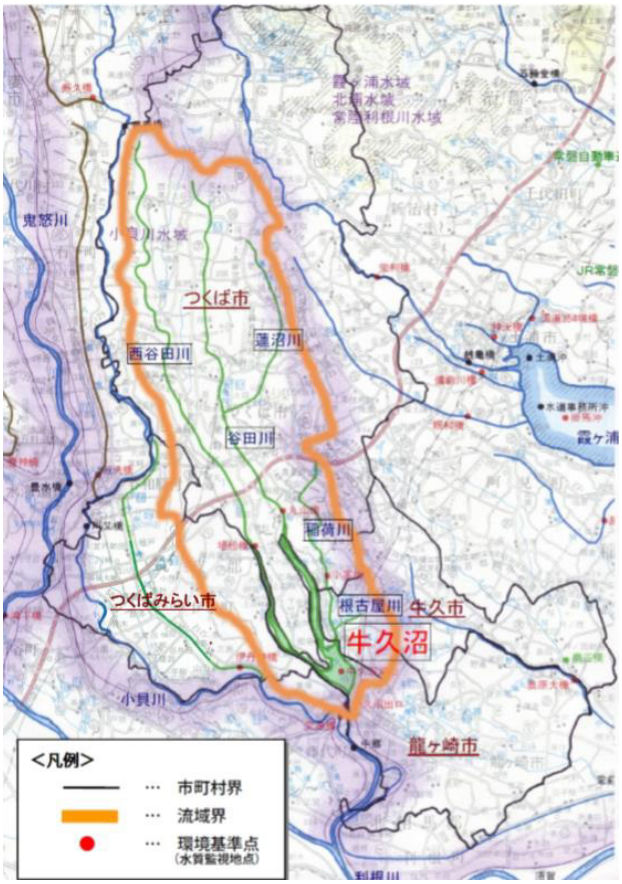

図 4：牛久沼流域図．文献[7]による

いずれに接続するかにより霞ヶ浦か牛久沼のどちらかの水系に属することになる。なお、研究学園都市建設により整備された研究学園地区（つくばセンターの南北に伸びる市街地）に沿って、霞ヶ浦水系と牛久沼水系の分水嶺が縦走している。この分水嶺近辺を水源とする河川は、花室川、小野川（以上、霞ヶ浦水系）、蓮沼川、谷田川、稲荷川（以上、牛久沼水系）である。

4. 筑波研究学園都市内での人口重心の変動

この計画都市の区域はつくば市域と一致しているため、この都市の建設に伴う人口定着は、市域人口で捉えることができる。なお、同市は筑波町、大穂町、豊里町、谷田部町、茎崎町、桜村の 6 ヶ町村の合併で成立したため、旧町村の中心をなす集落・市街地に旧役場が置かれ、それぞれが地域の拠点となっていた。つまり、同市は旧町村それぞれの中心市街地と周辺に遍在する集落による旧来の市街地と、研究学園地区、さらにつくばエクスプレス（以下、TX）沿線開発により形成された市街地というように大きく 3 つの性質の異なる地区を有している（図 1）。なお、研究学園都市建設にかかる用地買収では、地元との妥協からこれら拠点地域や優良農地を避け、山林が切り開かれることとなったが、まさに市街化された旧山林に霞ヶ浦と牛久沼の分水嶺が位置している。

人口重心については、国勢調査地域メッシュの人口データに基づき算出した。1970 年以降 5 年毎に人口重心の動きをみると、1970 年（国土地理院所在地近傍）から 2005 年までの 35 年間で南東方向に約 3.6km 移動した。TX 開通は 2005 年であり、その後の 10 年は南西へ方向を変え、約 300m 移動した。これは鉄道開業前は 100m/年で南東方向（研究学園都市の都市軸に沿う）、鉄道開業後は 30m/年で南西方向（TX 路線方向に沿う）へ重心が移動していることになる（現在はつくば市立葛城小学校近傍に重心が移動した）。この重心移動は、つくば市域における人口偏在の重みが北部から南西部へ移動していることを示す。

5.牛久沼流域の土地利用の変化の把握

土地利用図（図 5、文献[3]データ図化による。）のメッシュ面積割合に基づき、牛久沼流域の土地利用状況の変遷を確認した（図 6、文献[3]データ図化による。）。これによると、1976 年以降の 40 年間で、約 25%を占めた樹林地が減少し約 10%となった反面、市街地は一貫して増加し、約 10%から約 30%となったことが把握できる。

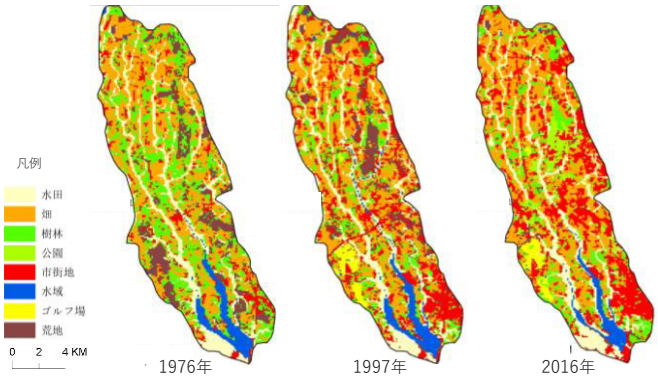

図 5:牛久沼流域の土地利用の変化(土地利用図)

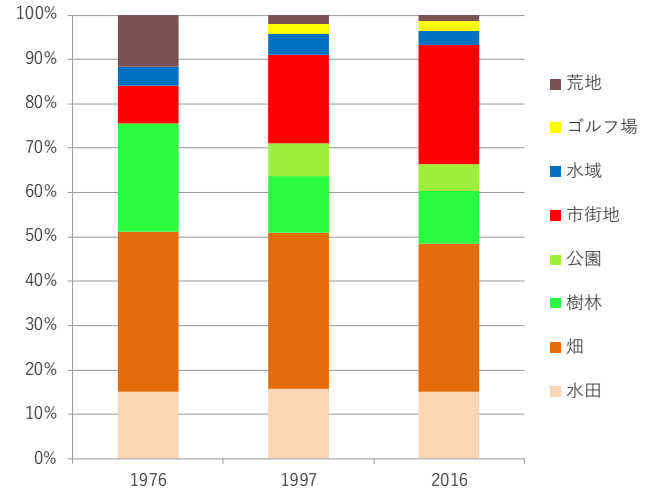

図 6:牛久沼流域の土地利用の変化(用途別割合)

6. 考察

人口重心の移動はつくば市域南部の牽引の力が大きいが、市域北部、南部それぞれの地区を流路に含む河川の流末は霞ヶ浦、牛久沼と流域が異なる。特に TX 開通後は沿線開発による影響があることから、及ぼす影響(雨水排水)が近年増しているのは牛久沼であり、筑波研究学園都市と湖沼の関係性も、流末への影響という観点からは牛久沼へ排水負荷の比重が高まっている。

7. おわりに

本稿では市街地の拡大、都市化の進行によって、特に雨水処理流域の比重が変化することを示した。

都市基盤として上下水道が普及する以前は、生活面では、井戸水などの地下水、農工業では近隣の河川・溜池などを利用していた。そもそも水資源の供給力は現代にくらべ劣ることもあり家庭からの汚水排水自体少ない上、都市的土地利用が進む以前は舗装面が少なく、雨水については宅地・田畑・山林それぞれにおいて地表面での雨水浸透の処理がなされてきた。つまり、地域毎に処理される水循環システムであった。現代において、つくば地域では水瓶は霞ヶ浦に依存しつつも、汚水排水は遠隔の利根川へ行われていることは1で記述の通り

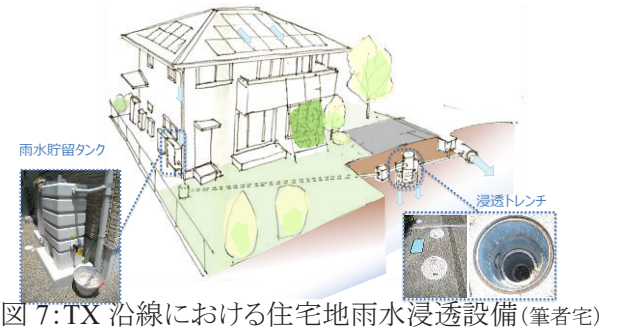

図 7:TX 沿線における住宅地雨水浸透設備(筆者宅)

である。利水や排水といった水循環が地域内で完結していた仕組みが、現在は広域化し上水取水/汚水排水が異なる遠隔地(かつ水系が異なる)で行われている。しかし、各地に降る雨の雨水排水は各降雨地近傍の河川に排水となる。このように上下水利用に関して自然水系とは乖離したシステムが形成されている。

TX 沿線で急速な都市化が進むなか、牛久沼流域に改めて目を向けることが重要である。先述の雨水処理に関しては自然の水系に近い処理がなされるという点でいえば、TX 沿線において、各宅地内での雨水浸透を促進する設備の導入が進められていることは注目すべきことではある(図 7)。しかしながら、この設備導入の意義や牛久沼そのものに対する一般住民の関心や市街化による流末への影響への認知は拡大・深化はしていないものと思われる。都市生活利便を享受する住民自身にとって、その生活の基盤となる都市が開発されることに伴って流域流末に与える負荷について認知を広めるなどの啓蒙を図ることも重要といえる。

補足ではあるが、霞ヶ浦・牛久沼をはじめとした湖沼は多くの自治体に接するため、広域自治体連携による対策が肝要となる。多主体による環境保全への多様な取組みを期待したいところである。

なお、今回は検討対象流域において牛久沼をはじめとした下流域に実際にどれだけの流量の変化がみられているのかの実数値の検証はできていない。今後の検討課題である。

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KP-28

Birds Belonging to the Family Charadriformes on the shore of Lake Kasumigaura

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Municipal Official

Keywords: alluvial lowland, plover, Lake Kasumigaura

ABSTRACT

There are a lot of alluvial lowlands on the shore of Lake Kasumigaura-the second largest lake in Japan. The alluvial lowlands, which are used for lotus fields, rice paddies as well as residences, form the habitat for shorebirds, in particular, birds belonging to the family charadriformes.7species of the family have been observed in the lowlands for 11years.

1. INTRODUCTION

There extend alluvial lowlands along the embankment all around Lake Kasumigaura. The lowlands are used for lotus fields, rice paddies as well as residences (Figure.1), forming habitats of birds belonging to the family Charadriformes (hereafter"plover"). In this paper, the result of observations on birds of the family in the lowlands is to be introduced.



Figure.1 The lowlands and the Embankment of Lake Kasumigaura; In the left side of the embankment, there extend rice paddies and a lotus field.

2. METHOD

(1) Method of observations

A. By driving a small car, so-called "k-car" through narrow trucks among the fields in order to seek birds more thoroughly.

B. By using binoculars to seek them and a digital camera with a 500mm telephoto lens to judge the kinds of species.

(2) Target area

The alluvial lowlands on the shore of Lake Kasumigaura.

(3) Term of observations

From 11 Nov 2007 to 31 Mar 2018. Times of observations are over 250.

3. RESULTS

7 Species of plovers as follows were observed. According to "Check-List of Japanese Birds 7th Revised Edition", there are 15species of plovers in Japan, it means that there are 47% of Japanese species of plovers in this area.

A. Northern Lapwing

They are common winter resident, staying alone, with several individuals or in a large flock. They sometimes form a flock of over 100 individuals (Figure2).



Fugure.2 A flock of Northern Lapwings flying on 14 Dec 2008; In this picture, 102 individuals are photographed.

B. Grey-headed Lapwing

They would be accidental in the target area, appearing alone or with several individuals (Figure.3).



Figure.3 Grey-headed Lapwings on 30 Dec 2014

C. Pacific Golden Plover

They are common migratory in the target area. Though they stay in a flock of tens of individuals in rice paddies, they stay in lotus fields alone or with several individuals. Though it is said that they are generally migratory in Japan, they stayed in Dec 2010 (Figure.4).



Figure.4 Pacific Golden Plovers in non-breeding plumage on 5 Dec 2010.

D. Ringed Plover

They are common winter resident in the target area, instead of being said that they are rare in Japan. They stay with several individuals or alone (Figure.5).



Figure.5 A Ringed Plover on 20 Dec 2015

E. Long-Billed Ringed Plover

They are uncommon resident in the target area, appearing alone or with several individuals (Figure.6).



Figure.6 A Long-Billed Plover on 31 Dec 2016

F. Little Ringed Plover

They are common resident in the target area, though they are generally summer resident in Japan. Breeding of them were seen in Jun and Jul, while they wintered (figure.7).



Figure.7 A Little Ringed Plover in Snowfall on 11 Feb 2011

G. Oriental Plover

They are accidental in the target area as they are said to be accidental in Japan. A flock of 10 individuals stayed at the end of Sep 2011.



Figure.8 An Oriental Plover on Sep 2011

4. DISCUSSION

Kentish Plovers and Mongolian Plovers were not seen, however, they may have been observed somewhere in the target area, because they generally inhabit in the coastal area such as the Kasimanada coast in the vicinity of Lake Kasumigaura.

5. CONCLUSION

7 species of plovers were observed in the alluvial lowlands and the vicinity on the shore of Lake Kasumigaura. Most of them wintered.

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KP-29

ハス田における防鳥ネット管理方法とカモ類の侵入状況および食害との関係

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キーワード:レンコン, 鳥害, カモ

抄録

本研究では, 地域の野鳥の保全とレンコン生産の向上とが両立可能な農作業体系について検討することを目的として, 防鳥ネットの利用と水鳥の侵入状況調査および食害に関する検討を行った。その結果, 防鳥ネット除去圃場においては, カモ類がマガモ, コガモ, ハシビロガモ, ヒドリガモ, サギ類がコサギ, ゴイサギが確認でき合計で 80 羽の飛来が認められた。これに対し, 防鳥ネット完全閉鎖圃場においては, 主にバン類のバンが確認でき合計で 17 羽の飛来が認められた。これらの圃場レンコンを採取した結果, 2 アールの収穫面積に対し, 防鳥ネット除去圃場からは, 鳥類の採餌活動によって食害を受けたもの 52 本など合計 55 本の食害があるとされるレンコンを回収し, そのうち食害レンコンの重量が 100g 以上 200g 未満のものが多かった。これに対し防鳥ネット完全閉鎖圃場では食害レンコンは採取されなかった。

1. はじめに

平成 27 年度の野生鳥獣による農作物の被害金額は5億5千万円余で, ここ数年は5億円前後で推移している。26年度の約5億9千万円と比較すると約6パーセント減少した。鳥類では, 茨城県南・鹿行地域においてカモ類によるレンコンへの被害が多く, 鳥類全体の約9割, 鳥獣全体の約7割を占めている。(茨城県, 2017)。これらのレンコン田に対し, 鳥類の食害を防止するために, レンコン田のかなりの面積に, 防鳥ネットが張られ, 冬期には, カモ科マガモ属のコガモ, ヒドリガモやクイナ科のオオバンなどを中心に多数の野鳥が羅網して落鳥する事態が続いている(渡辺ほか 2012). 本研究では, 地域の野鳥の保全とレンコン生産の向上とが両立可能な農作業体系について検討することを目的として, 防鳥ネットの利用と水鳥の侵入状況調査および食害に関する検討を行った。

2. 方法

平成 29 年 2 月に防鳥ネットの設置作業を土浦市田村地区内において実施した。圃場面積は 18m×54m で約 10a とした。設置した防鳥ネットは, 側面ネット:5 ㎝目合, 上面ネット:15 ㎝目合とした。また, 周囲柱, 中間柱およびサポート柱を設置し, エクセル線を設置した。また, 出入口のカーテンを設置し開閉できるようにした。防鳥ネット除去の圃場については, 防鳥ネット完全閉鎖圃場を管理する農家に提供を依頼し, 直線距離にして 60m ほどの圃場を選択した。圃場面積は 18m×54m で約 10a, 周囲柱, 中間柱およびサポート柱のみで防鳥ネットが張られていない。よって 2 圃場は同じ農家管理を実施した。

この両圃場において鳥類の飛来侵入状況を確認するために, 防鳥ネット完全閉鎖圃場および防鳥ネット除去圃場に関して平成 29 年 10 月 1 日からセンサーカメラを設置した。

平成 30 年 1 月 20 日に防鳥ネット除去の圃場の食害調査を実施した。平成 30 年 2 月 1 日に防鳥ネット完全閉鎖圃場の食害調査を実施した。調査方法は掘り取り量は 2a として, ハス田に入り収穫する農家の後ろについて食害があるとされるレンコンを回収した。回収されたレンコンは写真を撮り重量および食害範囲を測定した。



図1 防鳥ネット設置なしレンコン圃場におけるカモ類の転倒採餌。2018 年 1 月 16 日午前 1 時撮影

3. 結果

田村地区における防鳥ネット除去圃場および防鳥ネット完全閉鎖圃場の間には鳥類の飛来状況，飛来数や飛来鳥種に違いが認められた。防鳥ネット除去圃場においては，カモ類がマガモ，コガモ，ハシビロガモ，ヒドリガモ，サギ類がコサギ，ゴイサギが確認でき合計で 80 羽の飛来が認められた。特にカモ類の飛来数が多く，全体の 9 割を占めていることがわかり，バン類に関しては 1 羽も確認されていない。防鳥ネット完全閉鎖圃場においては，主にバン類のバンが確認でき合計で 17 羽の飛来が認められた。確認されたバンはすべて成鳥ではなく幼鳥のバンであった。またカモ類サギ類に関しては確認されていない。飛来状況について防鳥ネット除去圃場は，11 月下旬からカモ類の飛来が確認できるようになり，その後 12 月の中旬以降はほぼ毎日，日の入り後から日の出までの間で，特に 0 時から日の出の前までの間の時間帯に飛来する傾向があった（図 2）。サギ類の飛来数は少ないが日の出後から日の入りの間に飛来している。防鳥ネット完全閉鎖圃場は，11 月上旬にバンの幼鳥が日の出後から日の入り前までの間のみ確認できた。その後 11 月 21 日の飛来確認以降，飛来が認められていない。

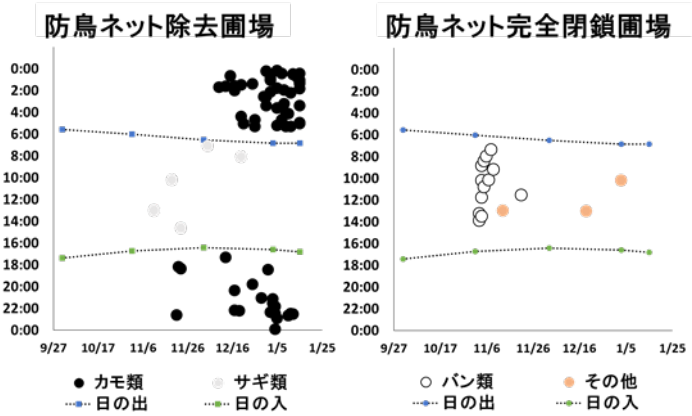

図 2 防鳥ネット管理の違いによる鳥類飛来侵入状況

食害調査について，防鳥ネット除去圃場からは，鳥類の採餌活動によって食害を受けたもの 52 本，鳥類をはじめとする動物の嘴や足指，爪などによって傷がついたもの 2 本，原因不明 1 本，合計 55 本の食害があるとされるレンコンを回収し，そのうち食害レンコンの重量が 100g 以上 200g 未満のものが 20 本と最も多かった。回収された食害レンコンは，食害範囲平均横 4.4cm，縦 5.8cm，平均重量 274.9g，合計重量 15.1kg であった。これに対し防鳥ネット完全閉鎖圃場では食害レンコンは採取されなかった。

表 1 防鳥ネットの有無とレンコンの収量および食害

	防鳥ネット	
	除去	完全閉鎖
2a 収量(kg)	420	480
被害量(kg)	15.1	0
被害率(%)	3.6	0

4. 考察

レンコン田での防鳥ネットへの羅網被害について，根本ら（2017）は 50 圃場を調査した結果，121 羽の羅網被害が確認されたが防鳥ネットを完全閉鎖管理圃場では，羅網被害リスクを 10 分の1に低減できることを明らかとしている。また，本研究では防鳥ネット完全閉鎖管理によってレンコンの食害被害を低減できることを明らかとした。農家が防鳥ネットを適正に管理する取り組みをおこなうことで，羅網被害を低減し，レンコンへの食害を低減できることを明らかとなった。

5. 結論

防鳥ネット除去圃場では，多数のカモ類が飛来し，かつこれらのカモ類が採餌活動を行うことで，レンコンへの直接的あるいは間接的に被害を及ぼしていた。これに対し，防鳥ネットの完全閉鎖処理は，オオバンなどの幼鳥などの侵入が認められたが，カモ類の侵入は認められず，かつレンコンの食害が認められなかったことから防鳥ネットの完全閉鎖管理の有効性が認められた。

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KP-30

題名:蓮田の野鳥羅網被害を考える

～ラムサール条約登録湿地になれない理由の考察～

Damage to wild birds caused by nets on lotus fields.
～The reason why Lake Kasumigaura cannot become a Ramsar site～

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[1]日本野鳥の会　[2]ＮＰＯ金田台の生態系を守る会
キーワード:霞ヶ浦　防鳥ネット　ラムサール　レンコン　羅網

抄録

霞ケ浦は国内有数の水鳥の生息地である。今，防鳥ネットが蓮田を覆っている。2004 年から県の補助金を受けて，霞ケ浦周辺の蓮田に野鳥除けとしての防鳥ネットが設置されている。水鳥を中心に，猛禽など希少種を含めた野鳥が命を落とす状況になっており「野鳥の会茨城県」の資料によると 2014～2018 年の 5 年間で 7,000 羽強の野鳥の網死が確認されている，この度写真による現状調査を実施した．蓮田農家の網の管理が十分とは言えない事態が依然としてあり，またこの間耐用年数を過ぎた網の撤去などあったものの被害の減少に繋がったとは言えず，今も野鳥が命を落とし続けている。もがき苦しむカモ等が垂れ下がった中を子供たちが通学している，大地は自然の恵みであり，野鳥も私たち人も共存して行くことが大事と考える。今の深刻な状況を写真等の活用で広く認知して頂き，解決への方策を求めラムサール条約登録湿地につなげたいと考える。

Lake Kasumigaura is one of major habitats of aquatic birds in Japan. In spite of that, the surrounding lotus fields *hasuda* are now covered with anti-bird nets. Since 2004, using prefectural subsidies, anti-bird netting has been set up on the lotus fields around Kasumigaura in order to protect them from wild birds. Wild birds - mostly aquatic birds but also rare species such as birds of prey – die because of the nets. According to the data from Wild Bird Society of Ibaraki, in the 5 years from 2014 to 2018 more than 7000 birds lost their life in the nets. We conducted a photographic survey to assess the current situation. We found out that the management of the nets by lotus root farmers is still insufficient and the situation has not improved. Some nets that were past their service life have been removed, but this did not lead to the reduction of damage to the birds, which continue to lose their life in the nets. Children on their way to school walk past the fields with ducks tangled in nets, struggling for their life. We believe that it's important for humans to coexist with wild birds and share the blessings of nature. Our aim is to use photographic and other evidence to gain wide recognition of this serious issue and to call for measures to solve it, and eventually achieve protected status by registration of the site under Ramsar Convention.

1. はじめに

霞ヶ浦は冬鳥が多く飛来する湖であり，湖とその周辺を取り巻く広大な蓮田には野鳥が数万羽集まる野鳥の楽園であった。 ところが蓮田に 2004 年頃から防鳥ネットが設置され[1]，2005 年頃から殆どの蓮田に拡大して行った。日野鳥の会茨城県の 2009 年，2010 年の1月末に行う羅網被害調査によると，一年で約 2000 羽[2]のカモ類・猛禽類・その他各種の野鳥類が網にかかったことが報告されている[2]。 この悲惨な状況の解決方法を探る基礎として

観察結果を報告する。

2.方法

巡回観察は，2007 年ごろから 2018 年現在まで毎年冬季 9 月末から翌年4月末までの間は週に 5 日程度，自転車で土浦地区の蓮田周辺約20キロ余りを午後の 3～4時間パトロールして(図 1)，羅網している野鳥を救出したり，指定病院に運んだり(図 6)，県環境政策課や農協に通報して救出依頼しながら観察した(図 1)。

巡回中の救出前や救出不能だった羅網により死亡した被害野鳥の様子を，カメラ(キャノン(1Ds マークⅡ及びニコンCOOLPIxB700)で撮影記録した。

時々は，ネットを張った蓮田で作業者に生産状況等の様子を聞いた。

3. 結果

撮影した写真は1日平均5枚，11年間で 3000 枚近くに達した。 野鳥の会茨城県で調査した羅網した鳥の数は，の霞ヶ浦周囲 250km の1日調査では，約 2000 羽であった。巡回した延長 20～30kmでは，羅網した鳥がいない日はなく最低300羽，多い時には500～600羽に達していた。中には，救出できる鳥がない日もあるが，平均して 3～4羽で，多い時は10羽以上救出した。救出は農道や畔道に近い手の届くネットでしかできなかった(図 2)。

時によっては，カモ類を狙って2次羅網したオオタカ(図 3)やチュウヒ，ハヤブサなどの貴重なワシタカ類，サンカノゴイ(図 4)等(図 5･7･8)の死骸もあった。

4. 考察

防鳥ネットは、農家が収穫を終えた後も外さない。一度張ると劣化し破損するまで放置するなどした結果，網の外側と内側から鳥の種類を選ばず，水鳥･希少種など引っかかり，犠牲になっていることが確かめられた。

羅網は蓮根の鴨類による食害を防ぐためとの設置理由であるが，カモが収穫前のレンコンを食べることについての明確な調査証拠はない。[3]。

5. 結論

防鳥ネットは2004年頃より，カモがレンコンを食害しているという根拠のない理由の下，農水補助金により設置され、ほとんどの蓮田に拡大した。著者らが観察した2008年から 10 年経過しても羅網は減少していない。防鳥ネットの新たな設置の停止と，風化･劣化した防鳥網を撤去しない限り痛ましい羅網は防げない。農業団体･行政･保護団体の調査と協議を十分にすることが希少種をはじめとした自然の命を保護するのに必要と思われた。霞ヶ浦をラムサール条約登録湿地にして人と野鳥が共存をはかるべきである。

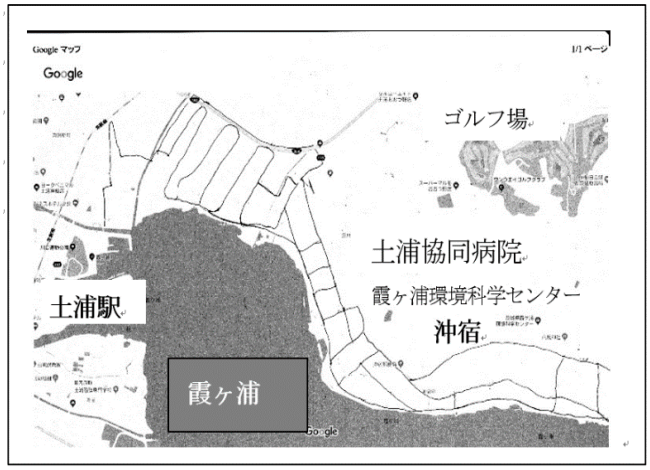

図 1 調査コース



図 2 天井ネットでもがくマガモ(土浦市田村)



図 3 網にかかったオオバンを食べるオオタカ(沖宿)



図 4　網にかかって死んだ絶滅危惧種サンカノゴイ（沖宿）



図 5　翼を絡めとられ，死亡後間もないオナガガモ（田村）



図 6　沖宿で救出し動物病院に搬送したコミミズク



図 7　足を絡めとられ，死亡した若いゴイサギ（田村）



図 8　冬の蓮田風景:防鳥網で死んでいるオオバン等多数

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KP-31

The per capita runoff change analysis in a watershed—an example of Lake Kasumigaura basin

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Keywords: land use/cover changes, comprehensive runoff coefficient, per capita runoff, Lake Kasumigaura basin

ABSTRACT

This research took Lake Kasumigaura Basin as an example and discussed the effect of land use/cover changes (LUCC) on per capita runoff change through the spatial analysis. The results showed that: 1) Land Use/Cover types have changed enormously in Lake Kasumigaura Basin in the past 40 years; 2) LUCC influenced the runoff change which can be described by the increase of comprehensive runoff coefficient from the year 1976 to 2014; 3) Per capita runoff kept stability, but people would share more rainwater runoff in the future.

1. INRODUCTION

The earth's topography and landforms are the results of mountain-river-lake-sea interaction. The most active and the shortest cycle interaction is river-lake. The energy exchanged day and night, which fully demonstrated the life characteristics of rivers and lakes. With the rapid development of Tsukuba city after the high economic growth period of Japan, land use/cover types have a great change in Kasumigaura basin. Even though Japanese government had published a very scientific master plan on constructing of Tsukuba city, also the natural river channels were deepened, widened and leveed during the urbanization process; local natural environment has deeply changed. Both history and reality showed that lake play a key role in the flood control of the middle and downstream [1], while natural lakes have irreplaceable advantages compared with artificial flood control projects. Lake Kasumigaura is the extreme end of the watered and has been strongly influenced by the mainstream for a long time. In addition, the Lake Kasumigaura development project was implemented from 1970 to 1995, and large-scale construction also mass maintenance was carried out. As watered is a complex and open regional system, its development was effected by many factors nowadays by the concept of World-Basin-Urban [2] (Table 1). At the same time, the population has begun to decline and the proportion of people of working age continues to decrease. The birthrate is well below replacement level. Japanese people are aging fast.This research took Kasumigaura basin as an example and discussed the effect of land use/cover changes (LUCC) in upstream and the changes of comprehensive runoff coefficient, which can provide a basis for keeping basin healthy and sustainable development [3].

Table 1 Concept of World-Basin-Urban

Scale	Description
Global	Extreme weather and climate events, storm surge caused by sea level rise, salt water intrusion, etc.
Basin	Unreasonable land use, excessive deforestation, water and soil erosion, river way transformation, deterioration of river water quality, natural and geographic conditions and hydrological location characteristics of a city, etc.
Urban	Impervious area increases, forest and green space decrease, wetland decrease, drainage pipe laying, river way artificialization, drainage system aging, highly intensive population and wealth, etc.

2. METHODS AND MATERIALS

In this research, land use/cover data was obtained from National Land Numerical Information Service Download System and then transferred into raster data by the software of ArcGIS for Desktop V10.3, which was used to analyze the spatial relationship among each element in the Kasumigaura basin. The basin boundary was extracted by the mesh data from Geospatial Information Authority of Japan and verified by the paper map from Ibaraki Kasumigaura Environmental Science Center. Population data was supported by Company of

Infonica.

Weighted average method was used to calculate the comprehensive runoff coefficient change with the suggestion of Notification No. 521 from Ministry of Land, Infrastructure and Transport (Table 2). The expression is as follows:

$$\sum_{i=1}^{n} w = \frac{a_i}{n} \times q_i$$

Where, w is the sum of runoff coefficient, a_i is the area of the land use type i, n is the total area of the basin, q_i is the runoff coefficient land use type i.

Per capita runoff calculation is assumed that precipitation does not change too much over years, which the expression can be described as follows:

$$\bar{d} = \frac{w}{s} \times p$$

Where, $\bar{d}$ is per capita runoff, s is total population in the region, p is the precipitation as a constant.

Table 2 Runoff coefficient Standard

Land use/cover	Runoff coefficient (q)
Water	1
Urban area	0.9
Golf	0.5
Dry farming field	0.3
Paddy field	0.2
Forest	0.2
Uncultivated land	0.2

3. RESULTS

According to the former research [4, 5], we generalized the land use into 7 types of past 40 years (Figure 1). From the figure 1 we can clearly see that the land use was changed. Especially in the upstream area, which named Tsukuba City and Tsuchiura City, urban areas have obviously increased while forest area decreased, uncultivated land was effectively used and golf courses was developed in the downstream area over time. Fortunately, the lake area has not changed much.

Then we calculated by the generalization, land use type change is shown in figure 2, while runoff coefficients change and population change is shown in figure 3.

From figure 2 we can understand that the urban area increased by 2.4 times from 1976, while the forest area decreased by 0.69 times as before. A large number of golf courses developed in the 1990s, which accords for 1.61% of the basin.

And from figure 3 there is no doubt the comprehensive runoff coefficient has huge changed as a value of 0.61(1976 was 0.46), this means a large number of rainwater need to be discharged downstream than before, this increased not only the pressure of the lake in downstream area, but also a great waste of water resources. While population showed the same trend with comprehensive runoff coefficient. But population is illustrating a downward trend over time, and this means

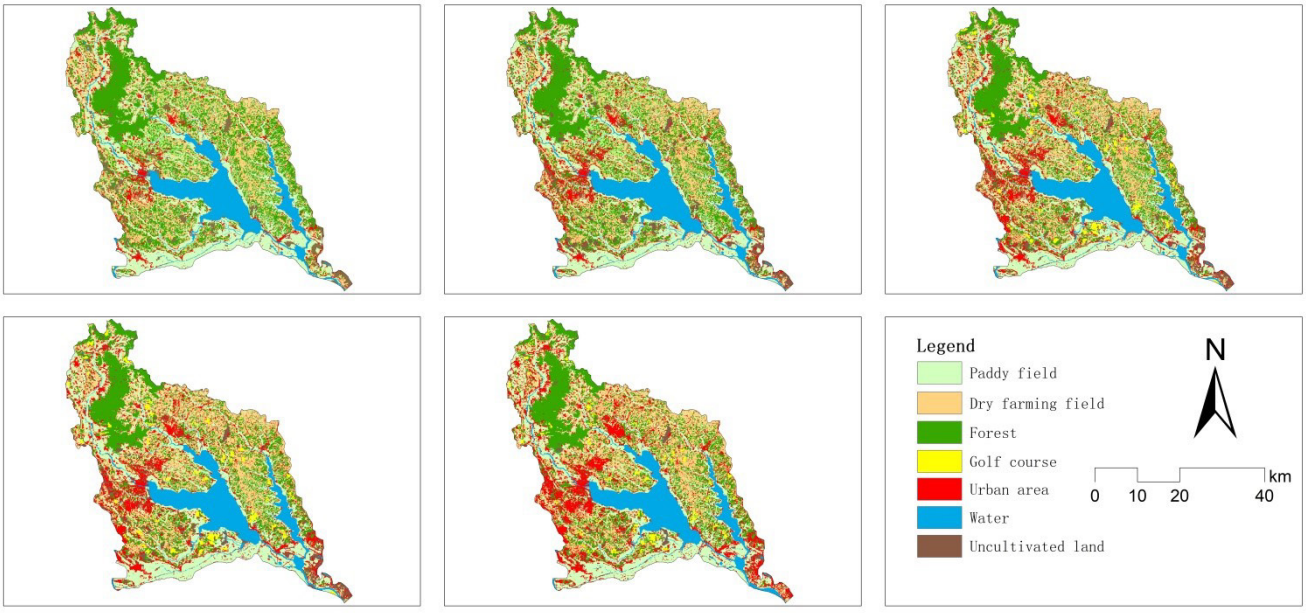

Figure 1 Land use changes of Lake Kasumigaura Basin from 70' to 10'. From the left they are successively the year of 1976, 1987, 1997, 2006, 2014.

stable per capita runoff in the area will change based on the function of section 2.

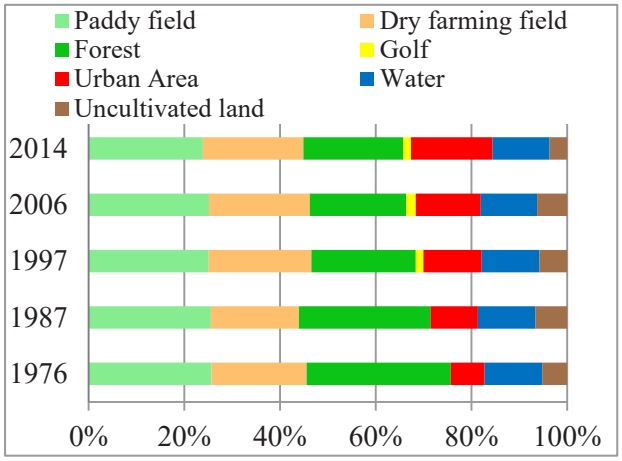

Figure 2 Comparison of land use changes in Lake Kasumigaura Basin

According to government estimates there are 8 million residences in Japan with no one living in them. But these abandoned houses will stay there for a long time until management. This means that people need to share more rain risks even flooding losses, in another word, the value of per capita runoff will increase.

Urban area would expose more risk under extreme rainfall without the timely drainage, because there are more people and wealth concentrated in the city. At the same time, the channels between the Lake Kasumigaura and River Tone River have a high risk if there is a flooding. Water intrusion is possible based on historical data, even if we did not make such a simulation in this research. From the year of 1997 the comprehensive runoff coefficient stayed stable, even in 2006 it showed a little low value we can sill considered there is no rising trend, because the social structure of Kasumigaura has reached saturation.

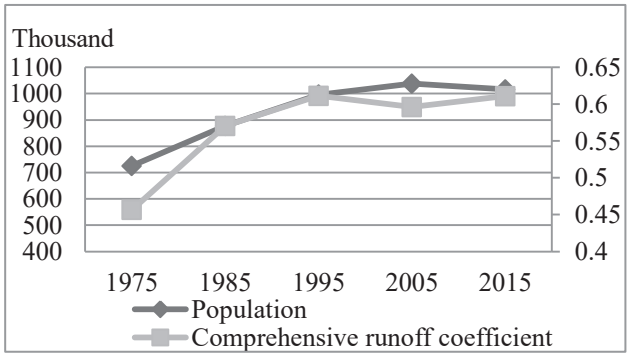

Figure 3 Comprehensive runoff coefficient change and population change in Lake Kasumigaura Basin

4. Conclusions

1) Land Use/Cover types have changed enormously in Kasumigaura basin, i.e. urban area expanded from 2.4 times during the past 40 years;

2) Both the comprehensive runoff coefficient and the population of the basin increased nearly 1.5 times from 1975 to 2015;

3). Per capita runoff in the area kept stably.

This study warns that the lakes in the downstream are suffering much more flood pressure than before even there are less flooding disaster happened recently. Once the flood comes, the losses are still large will be inestimable. From the result the comprehensive runoff coefficient is being stable and has no rising trend, and per capita runoff in the area kept stably, which means the social structure of Kasumigaura basin has reached saturation. To promote regional development, it is necessary for government to make reasonable and scientific policies, keep maintenance even evolution with the background of that the population has begun to decline, local people in the area also should protect the environment themselves strictly.

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KP-32

霞ケ浦(北浦)におけるユスリカ幼虫密度の長期変化

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キーワード:北浦, 底生動物, ユスリカ幼虫, 長期変遷

抄録

1999 年から 2016 年の間, 霞ヶ浦の北浦に生息するユスリカ幼虫組成とその密度の変化を調べた。北浦の湖心部(1 定点)での定期調査は 1999 年から, また北浦の南北を縦断するように 5 つの調査地点を設けた複数の定点調査は, 2007 年から 2016 年まで実施した。その結果, 北浦の軟泥部で優占するユスリカ幼虫は, オオユスリカ *Chironomus plumosus*, アカムシユスリカ *Propsilocerus akamusi*, オオカスリモンユスリカ *Tanypus nakazatoi*, およびスギヤマヒラアシユスリカ *Clinotanypus sugiyamai* の 4 種であった。北浦の湖心部(水深約 6.5m)における幼虫密度の長期変遷を見ると, オオユスリカ幼虫の密度には大きな変化が見られなかった。アカムシユスリカは 2001 年～2007 年の間はほぼ採集されなかったが, 2008 年以降は個体数の回復傾向がみられた。オオカスリモンユスリカとスギヤマヒラアシユスリカは 2008 年以降, 湖心部ではほとんど採集されなかった。北浦の幼虫密度の長期変遷やその変化をもたらす要因について議論した。

1. はじめに

霞ヶ浦の環境問題として, 水質悪化と並んで重要と考えられるのは生物群集に関わる環境問題である。特に水草帯の減少, 有用魚種の減少, 外来生物の増加, 極近年では東京電力福島第一原発事故による放射能汚染やそれによる水産魚種の出荷規制など多岐にわたっている。このような霞ヶ浦における現在生じている, あるいはこれから新たに起こるであろう生物環境問題を抽出し, それらの解決方法を探るためには, 霞ヶ浦の生物群集の変化を追跡できる地道なモニタリングが重要である。

ハエ目ユスリカ科の昆虫であるユスリカ幼虫は湖沼の底生動物群集の主要構成員であり, 貧毛類と並んで個体数・現存量ともに優占する生物群であり, その種も国内で約 2,000 種, 世界では約 15,000 種が知られている。底生性のユスリカ幼虫は主に植物プランクトンを餌資源として成長する一方で, 魚などの捕食者の重要な食物源として利用される。そのため, ユスリカ幼虫の個体数や現存量の増減や種組成の変化などを長期間追跡し, それらの動態に影響する要因を知ることは, 霞ヶ浦の一次生産者である植物プランクトン組成の変化が高次栄養段階の生物に及ぼす影響評価, 近年の霞ヶ浦有用魚種の減少理由, 外来魚が湖沼生態系に及ぼす影響評価などを解明する上で, 重要な手がかりになるかもしれない。

このユスリカ幼虫について, 霞ヶ浦水域において最も広い面積を有する西浦においては, 国立環境研究所による 30 年以上のモニタリング実績がある。一方で, 北浦のユスリカ幼虫についてはこれまで単発的な研究が多く, 連続した長期データに基づいて, 個体群動態やそれに影響する要因について議論できるようなデータはほとんどなかった。中里ら[1]は 1929 年から 2002 年までに報告された文献のデータを整理し, それら 35 年分のデータを用いて北浦のユスリカ幼虫の長期変遷についてまとめている。ただし, この解析に用いられた過去の文献の多くは種別ではなくユスリカ幼虫全体の個体数のみであったり, 種の情報がある文献の場合でも, その種同定が十分にされていないものが多く, 大型で比較的同定が容易なオオユスリカ *Chironomus plumosus* とアカムシユスリカ *Propsilocerus akamusi* の 2 種についてのみの報告が多かった。そのため, 中里ら[1]では, オオユスリカとアカムシユスリカ幼虫の長期変遷やそれに影響する要因については考察をしているものの, それ以外の種については情報不足によりほとんど議論されていない。その中里ら[1]では 2000 年の北浦全域分布調査(60 地点)の結果から, 13 種のユスリカ幼虫が生息していること, さらに, これまで霞ヶ浦の西浦と北浦からは報告例が無かった *Tanypus nakazatoi** が, 北浦ユスリカの優占種の 1 種であることを明らかにした。また, 北浦の幼虫密度は 1980 年初頭がピーク

であり，その後減少傾向にあることも報告している。

1999 年以降，北浦のユスリカ幼虫については，北浦湖畔に位置する茨城大学広域水圏環境科学教育研究センター (CWES) の霞ヶ浦定期観測グループが途中の一時的な中断はあるものの，北浦の湖心部での調査を継続してきた。さらに 2007 年以降は北浦の南北の 5 定点でユスリカ幼虫のモニタリングを継続している。また 2009 年 3 月には北浦の 40 地点で全域分布調査をした。

今回の発表では，1999 年から現在までの調査データを解析し，北浦におけるユスリカ幼虫の個体群動態とそれに影響する要因について考察する。また 2009 年の全域分布調査と 2000 年 2 月の全域分布調査の結果を比較することで，ユスリカ相の変化や個体数の増減について議論する。

※中里ら[1]の論文中では *T. punctipennis* とされているが，その後同種は *T. nakazatoi* として新種記載された。

2. 方法

北浦について

北浦は茨城県の南東部，西浦の東側に位置する南北に長い湖で(図１)，周囲長 64km，面積 35.2km^2，平均水深 4.5m の浅い富栄養湖である。一般的に霞ヶ浦というときは面積の大きい西浦を指すことが多いが，正式には北浦，西浦，北利根川，常陸川，鰐川および外浪逆浦をあわせた総称である。北浦は潮来市，行方市，鉾田市，鹿嶋市などの市町村に囲まれ，約 20 万人がその北浦周辺に居住している。霞ヶ浦の水質は近年の傾向として全窒素・全リン濃度が西浦ではほぼ横ばいであるのに対し，この北浦では上昇傾向にあり，北浦の水質悪化は西浦以上に深刻な問題となっている。

調査地点と幼虫の採集方法

調査地点は北浦のほぼ北端にあたる高田沖に St.K1 を取り，そこから南に向かって合計 5 定点を設けた(図 1)。ユスリカ幼虫はエクマンバージ採泥器を用いて各地点 3〜5 サンプルずつ採集し，344μm メッシュのサーバネットで捕集した。採集と同時に環境要因として透明度，水温，溶存酸素量を測定した。

1999 年から 2007 年 3 月までは St.K7 で，2007 年以降は St.K1〜K10 の 5 定点で調査をした。その他に 2009 年 2 月には北浦の 40 地点で分布調査を実施した。幼虫の採集方法は定期観測と同様の方法でおこなった。環境要因として水温，溶存酸素のほか，採取した堆積物の強熱減量と含砂率を測定した。

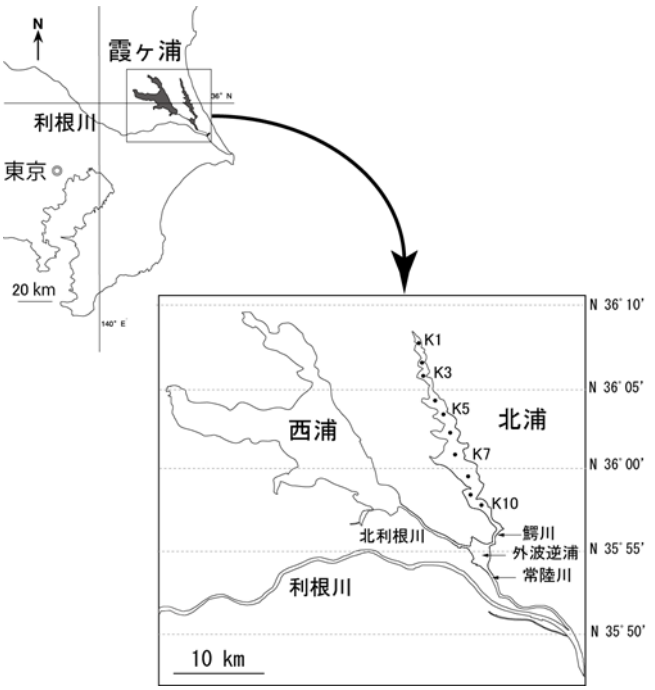

図 1 北浦の位置と調査定点(St.K1〜K10)

3. 結果と考察

調査期間を通して北浦から合計 15 種のユスリカ幼虫が採集された。その内訳はモンユスリカ亜科のスギヤマヒラアシユスリカ *Clinotanypus sugiyamai*，カユスリカ属 *Procladius* sp.，カスリモンユスリカ *Tanypus kraatzi*，オオカスリモンユスリカ，エリユスリカ亜科のコガタエリユスリカ属 *Hydrobaenus* sp.，コガタエリユスリカ属 *Nanocladius* sp. アカムシユスリカ，そしてユスリカ亜科がオオユスリカ，ナガコブナシユスリカ属 *Cladopelma* sp.，カマガタユスリカ属 *Cryptochironomus* sp.，スジカマガタユスリカ属 *Demicryptochironomus* sp.，ハイイロユスリカ *Glyptotendipes tokunagai*，コブナシユスリカ属 *Harnischia* sp. オオミドリユスリカ *Lipiniella moderata*，コガタユスリカ属 *Microchironomus* sp.，ハモンユスリカ属 *Polypedilum* spp.，およびヒゲユスリカ属 *Tanytarsus* sp. であった。これらの中で北浦の軟泥部の底質からの出現頻度が高かった種はオオユスリカ，アカムシユスリカ，オオカスリモンユスリカ，スギヤマヒラアシユスリカの 4 種であった。

図 2 に 2007 年 3 月から 2014 年 8 月までの湖心部

（St. K7, 水深約 6m）における優占 4 種ユスリカ幼虫の個体数変動を示した。また表 1 には St. K7 の 1999 年から 2016 年の冬季における個体数密度の長期変遷を示した。

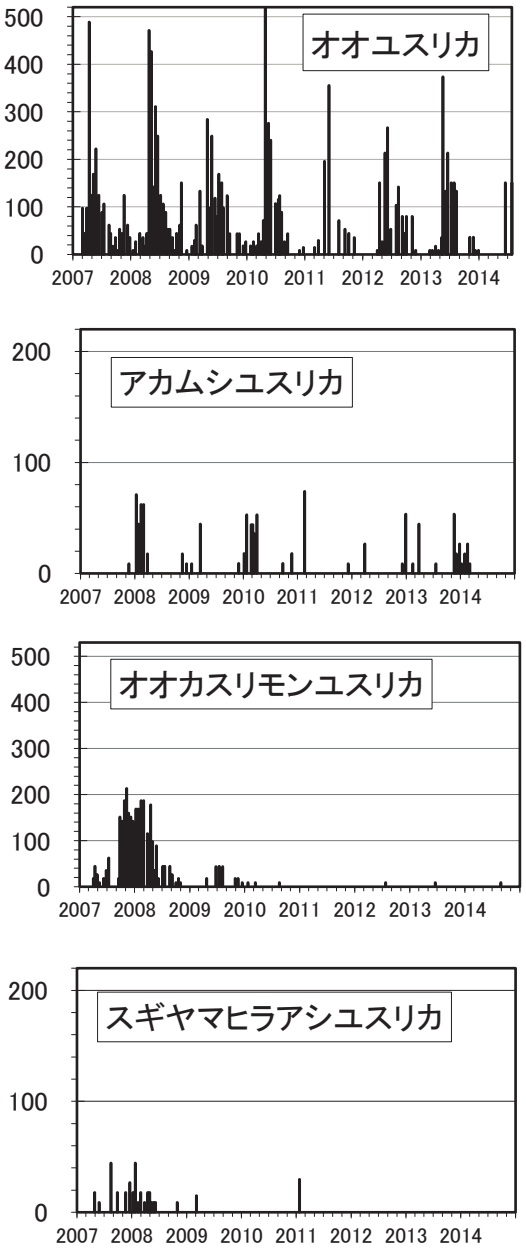

図 2 北浦の湖心部（St.K7）で優占する 4 種のユスリカ（オオカスリモンユスリカ, アカムシユスリカ, オオカスリモンユスリカおよびスギヤマヒラアシユスリカ）幼虫密度の経年変化

2007 年～2014 年までの幼虫密度の変化を見ると, オオユスリカの場合は 1 年間の中で 5－6 月に密度のピークを持ちながら一定の増減を繰り返して密度が推移したが, 大きな経年変化は見られなかった。冬季に限定した幼虫の長期変遷をみると, 2010 年以降ほとんど採集されていない（表 1）。アカムシユスリカの場合は, 冬季に限定して採取されており（4 月～10 月までは底泥の深い深度にいるためエクマンバージ採泥器では採取不可能）, その密度は 100 個体/m^2以下であった。 またその長期変遷を見ると 2001 年～2007 年の間はほぼ採集されなかったが, 2008 年以降は個体数の回復傾向がみられており, 2016 年には 1999 年に次いで高密度となっていた。オオカスリモンユスリカについては, 2008 年に密度のピークがあるもののそれ以降減少している。ただし, 北浦最北端の深度の浅い St.K1(水深約 1.5m)での調査結果では, 2013 年, 14 年も密度が高かったので, これは湖心部（St.K7）だけの現象かもしれない。スギヤマヒラアシユスリカは 2005 年以降湖心部ではほとんど採集されなかった。

表 1 St.K7 における優占ユスリカ種の密度（個体数/m^2）の長期変遷. 表中の ”－” はサンプル分析中を意味する。

Year, month	オオユスリカ *Chironomus plumosus*	アカムシユスリカ *Propsilocerus akamusi*	スギヤマヒラアシユスリカ *Clinotanypus sugiyamai*	オオカスリモンユスリカ *Tanypus nakazatoi*
1999, Jan	119	758	380	7
2000, Feb	27	96	90	71
2001, Jan	163	69	158	59
2001, Dec	15	15	148	0
2003, Jan	15	15	533	0
2004, Feb	-	-	-	-
2005, Apr	15	0	15	0
2006, Mar	178	0	0	98
2007, Mar	98	0	0	18
2008, Feb	27	62	18	187
2009, Feb	18	0	0	0
2010, Feb	18	44	0	0
2011, Feb	0	74	0	0
2012, Feb	0	0	0	0
2013, Feb	0	9	0	0
2014, Feb	0	27	0	0
2015, Jan	18	27	0	0
2016, Feb	0	524	0	0

謝辞

本発表に使用したデータの多くは茨城大学広域水圏センター霞ヶ浦定期観測グループによって得られたものである。この場を借りてお礼申し上げる。

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KP-33

鉾田地域における地下水中の硝酸態窒素濃度と土地利用及び畜産関連施設との関係

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キーワード:硝酸態窒素、地下水、土地利用、QGIS、空中写真

抄録

農畜産業が盛んな鉾田地域を対象に、地下水中の硝酸態窒素濃度に及ぼす土地利用及び畜産活動の影響を調査した。採水井戸から異なる半径の範囲を対象に、土地利用別面積率及び畜産関連施設を空中写真を用いた地理情報システム（GIS）解析により求め、さらに堆肥置き場の周囲を堆肥散布の多い領域とみなして他と区別した。これらを独立変数、硝酸態窒素濃度を従属変数として赤池情報量基準（AIC）に基づき最適重回帰モデルを選定した結果、井戸からの半径 500 m を GIS 解析範囲、堆肥置き場からの半径 150 m を堆肥多散布領域としたときに最小 AIC の最適モデルが導出され、地下水中の硝酸態窒素濃度の地域内分布を説明するための土地利用及び畜産活動に関わる変数とその空間的範囲が特定された。選定された独立変数の一つである水田面積率は負の偏回帰係数を有し、水田からの地下浸透水が硝酸態窒素による地下水汚染を軽減する効果を持つことが示唆された。

1. はじめに

霞ヶ浦の北浦に注ぐ鉾田川は、硝酸態窒素濃度が高く、環境基準（硝酸態窒素及び亜硝酸態窒素）である 10 mg N/L を超えることがあるため、原因の解明が求められている。鉾田地域は畑作が卓越し、露地畑ではニンジンや甘藷、施設畑ではメロンや葉菜類が多く栽培されている。また、台地上には地下水を灌漑する水田が多く分布する。さらに、畜産業も盛んに行われており、1 ㎢ あたり約 1800 頭の豚が飼養されている。これまで、鉾田川流域の河川水中の窒素を対象とした研究報告は多いが、河川水の主要な供給源の一つである地下水を対象とした研究はほとんど行われていない。

本研究では、地下水中の硝酸態窒素濃度に着目し、農畜産業がその濃度の空間的分布に与える影響を把握するため、採水井戸周辺の土地利用および畜産関連施設との関係について調べた。

2. 方法

鉾田地域を対象に、2014～2017 年に計 70 か所の井戸で地下水を採取し、硝酸態窒素濃度等を測定した。採水井戸から半径 100, 300, 500 及び 700 m 以内の範囲において、井戸ごとに土地利用別面積率を算出し、硝酸態窒素濃度との関係（統計的に有意な相関関係の有無）を調べると共に、どの半径で土地利用面積率を算出すると、硝酸態窒素濃度と有意な相関関係を示す土地利用が増えるかを調べた。土地利用別面積率の算出には、空中写真（2003 年 10~12 月、撮影縮尺 2 万分の 1）から目視判断で水田、露地畑、施設畑、森林、樹園地、荒地、建物用地、パドック（畜舎に隣接した家畜用運動場）等を分類して自作した土地利用図を使用した。また、空中写真から畜舎の屋根面積（家畜飼養規模の指標）の計算、堆肥置き場（堆肥散布量が多い領域の指標）の目視同定等を行った。GIS データ作成・解析には、フリーソフトである QGIS を用いた。

さらに、上記 4 つの半径の集計範囲を対象に、地下水中の硝酸態窒素濃度を従属変数、土地利用別面積率及び畜舎の屋根面積を独立変数として、様々な組合せで重回帰分析を行い、赤池情報量基準（AIC）が最小となる独立変数の組合せを選定して最適重回帰モデルとした。これらの結果、後述するように、半径 500 m を集計範囲としたときに AIC が最小となる重回帰モデルが得られたことから、以降の GIS データ解析は、採水井戸から半径 500 m を対象とした。

次に、集計範囲内にある堆肥置き場の周囲を『範囲 M』として、それ以外の範囲よりも堆肥散布量の多い領域と仮定した。すなわち、『範囲 M』とそれ以

外の範囲を区別して土地利用面積率を算出することで、堆肥による窒素負荷が地下水中の硝酸態窒素濃度に与える影響を表現できると考えた。なお、パドックと建物用地については、堆肥を散布しないと考えて『範囲 M』には含めなかった。硝酸態窒素濃度を従属変数、『範囲 M』及びそれ以外の範囲の土地利用別面積率、『畜舎の屋根面積』を独立変数として、AIC が最小となる独立変数の組合せを選定し、『範囲 M』を考慮した最適重回帰モデルとした。なお、『範囲 M』としては、堆肥置き場から半径 100, 150, 200, 250 及び 300 m の 5 通りの領域を検討し、AIC を基準として重回帰モデルの選定を行った。これにより、『範囲 M』をどの半径で設定すると最も AIC の低い重回帰モデルが得られるかを特定した。

3. 結果と考察

今回の調査では、地下水中の硝酸態窒素濃度は全体（70 地点）の 41%で環境基準を超過した。採水井戸からの 4 通りの範囲（半径 100, 300, 500 及び 700 m）について、硝酸態窒素濃度と土地利用別面積率の相関係数を見ると、500 m のときに、水田と露地畑の 2 種類の土地利用で有意な相関となることが示された（図 1）。さらに、これら 4 通りの範囲内で様々な組合せで重回帰分析を行った。そのうち、それぞれの範囲内で AIC が最小となった重回帰モデルの AIC と井戸からの半径の関係を図 2 に示す。いずれのモデルも、井戸からの半径が 500 m 付近で AIC が最小となる傾向があった。その中でも最も AIC が小さかった重回帰モデルの独立変数は、水田面積率、パドック面積率及び『畜舎の屋根面積』であり、水田面積率の偏回帰係数のみ負の値を示した。また、切片の値は 9.7 mg N/L であり、地下水汚染が地域全体に広がっていることが示唆された。

これらのことから、井戸から半径 500 m を集計範囲としたときに、最も、土地利用面積率及び畜産関連施設と地下水中の硝酸態窒素濃度の関係がより密になることが示された。また、図 1 では、露地畑面積率が正の相関（5%有意）を示すのに対し、施設畑面積率との相関は見られなかったが、これは露地畑のほうが施設畑よりも降雨による硝酸態窒素の溶脱が生じやすいためと考えられる。

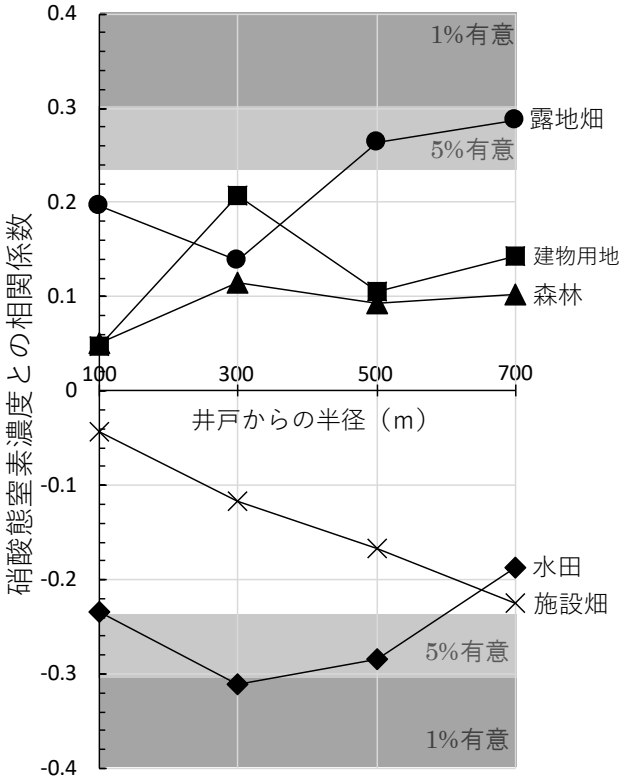

図 1　それぞれの範囲における硝酸態窒素濃度と土地利用別面積率の相関係数

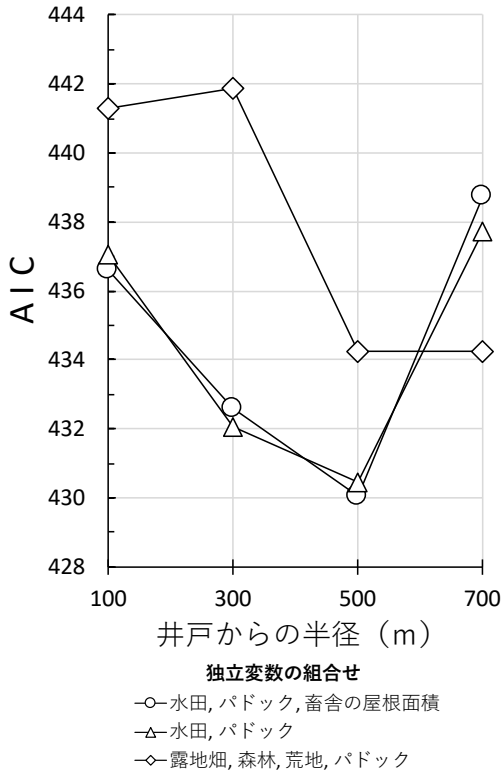

図 2　４通りの範囲における重回帰モデルの AIC

次に、井戸から半径 500 m の範囲内を対象として、『範囲 M』の半径を 5 通り（100, 150, 200, 250 及び 300 m）設定して、様々な独立変数の組み合わせで重回帰分析を行った。それぞれの領域内において、最小AICが得られた重回帰モデルのAICと『範囲M』の半径との関係を図 3 に示す。多くのモデルが半径 150 m のときに AIC が最小値を示す傾向にあったが、中には、半径 300 m のときに最小 AIC を示すモデルもあった。これらの中で最も AIC が小さい重回帰モデルは、半径 150 m のときに得られ、独立変数としては、『範囲 M』内の水田、樹園地及び荒地の各面積率と、それ以外の樹園地及びパドックの各面積率が選択され、『範囲 M』内の水田面積率とそれ以外の樹園地面積率の偏回帰係数が負の値を示した。また、切片の値は 9.1 mg N/L であった。また、全体的に、堆肥を多く散布する領域として『範囲 M』を考慮した場合（図 3）は、『範囲 M』を考慮せずに重回帰分析を行った場合（図 2）よりも、AIC が大きく低下することが示された。

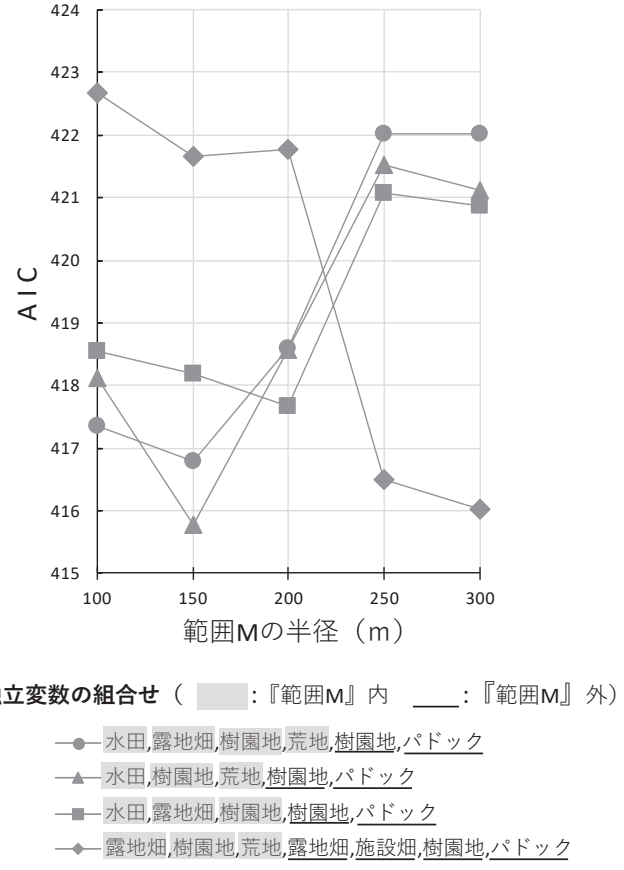

図 3　『範囲 M』の半径の違いによる重回帰モデルの AIC の変化

4. 結論

鉾田地域における地下水中の硝酸態窒素濃度と採水井戸周囲の土地利用及び畜産関連施設の間の関係を、空中写真に基づくGISデータを用いて解析した結果、地下水中の硝酸態窒素濃度の地域内分布は、採水井戸から半径 500 m の範囲内の土地利用及び畜産関連施設の影響を受けていること、堆肥置き場から半径 150 m の領域内では、他の領域よりも多くの窒素負荷が生じていることが示唆された。AIC を基準として選定された多くの重回帰モデルの切片は、9 mg N/L 以上であり、土地利用にかかわらず硝酸態窒素による地下水汚染が地域全体に広がっていることが示唆された。一方、水田は硝酸態窒素濃度に対して負の効果を有しており、水田からの地下浸透水は、汚染軽減に役立っていると考えられる。以上より、土地利用別面積率だけでなく、畜産活動に関係する複数の指標を用いた GIS データ解析により、地下水中硝酸態窒素濃度に影響する空間的範囲とその主な要因が示され、具体的な地下水汚染発生及び軽減の特徴を把握することが可能となった。

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全球湖沼流域気候 Web アプリケーション:CGLB で どこまで霞ヶ浦の情報を取得できるか

How much information about Lake Kasumigaura can we obtain using a Web application of Climates of Global Lake Basins: CGLB?

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[1] 気象研究所

キーワード: Climates of global Lake Basins, 全世界, 湖沼流域, 気候, データベース

抄録

霞ヶ浦は、日本の湖沼のうち 2 番目に広い水面を持ち、水資源、漁業、観光など多目的に用いられており、日本人には、馴染みの深い湖沼の一つである。日本語を解さない人が、霞ヶ浦を科学的側面から調べたい時に利用価値の高い情報となるのは、全世界をカバーする湖沼データベースである。本稿では、そうした湖沼データベースアプリケーションの一つである Climates of Global Lake Basins (CGLB)で、霞ヶ浦の情報がどの程度まで取得可能かを調べた結果を報告する。霞ヶ浦の水文学的湖沼情報は、水面積、流域面積、湖岸長、平均水深、最大水深などが得られる他、気象庁による月平均気温・降水気候値、人工衛星観測による水位変動などが容易に得られた。また、オンデマンドで、地上気象の値を、1 点での時間変化折れ線グラフまたは領域の分布図として描画することができる。

1. はじめに

霞ヶ浦は、日本の湖沼のうちで2番目に広い水面を持ち、水資源、漁業、観光など多目的に利用されている。流域面積は、2156.7km^2 で、河川流域で比較すると、鹿児島県に源流を持ち、宮崎県宮崎市を通って日向灘に注ぐ大淀川に次いで、第 30 位相当である。霞ヶ浦を水源とする自治体は、茨城県(37.23m^3/s)、千葉県(4.19m^3/s)、東京都(1.50m^3/s)の 3 都県で、合計 42.92m^3/s となっている。また、流域の殆どが平地で、多くが農業利用されているため、里山環境でみられる生態系が発達している。

霞ヶ浦の詳細な情報は、インターネットが発達した現在、容易に取得することができる。主立った Web サイトとして、以下のサイトが挙げられる。

- かすみがうら*ネット
- 国土交通省関東地方整備局霞ヶ浦河川事務所
- 独立行政法人水資源機構
  - ✓ 利根川下流総合管理所 霞ヶ浦開発
  - ✓ 霞ヶ浦用水管理所
- 茨城県霞ケ浦環境科学センター

これらのサイトから、情報を収集し、分析して、例えば、学校教育や自由研究、市民活動や行政機関の文書を作成する際などに、大いに役立つことが考えられる。

これらの Web サイトは、日本人向けで、日本語での情報提供が殆どを占める。Google によるキーワード検索では、「霞ヶ浦」のヒット件数が、360 万件であるのに対して、「Kasumigaura」は 30.5 万件(「Kasumiga-ura は 1650 件」)と 1/10 程度で、観光旅行者向けの Web サイトが上位を占める。日本語を解さない人が、霞ヶ浦を科学的側面から調べたい時、最初にアクセスするのは、国際湖沼委員会が提供する World Lake DataBase (WLDB) [1].などの世界を対象とした湖沼データベース[2]であろう。本研究では、そうしたデータベースの一つである全球湖沼流域気候を提供する Web アプリケーション(Climates of Global Lake basins; CGLB)[3]を利用して、どこまで、霞ヶ浦の情報を取得できるかについて、調査を行った。

2. CGLB

CGLB[3]は、全世界の湖沼を対象にしたデータベースである。最初の頭文字 C(limate)が示す通り、気候情報が他のデータベースに比べて充実していることが特徴である。湖沼の情報は、水文学的視点情報は HydroLAKES[4]から得ている。CGLB に収録されている湖沼数は、HydroLAKES に収録されている湖沼で、100 万以上を数える。

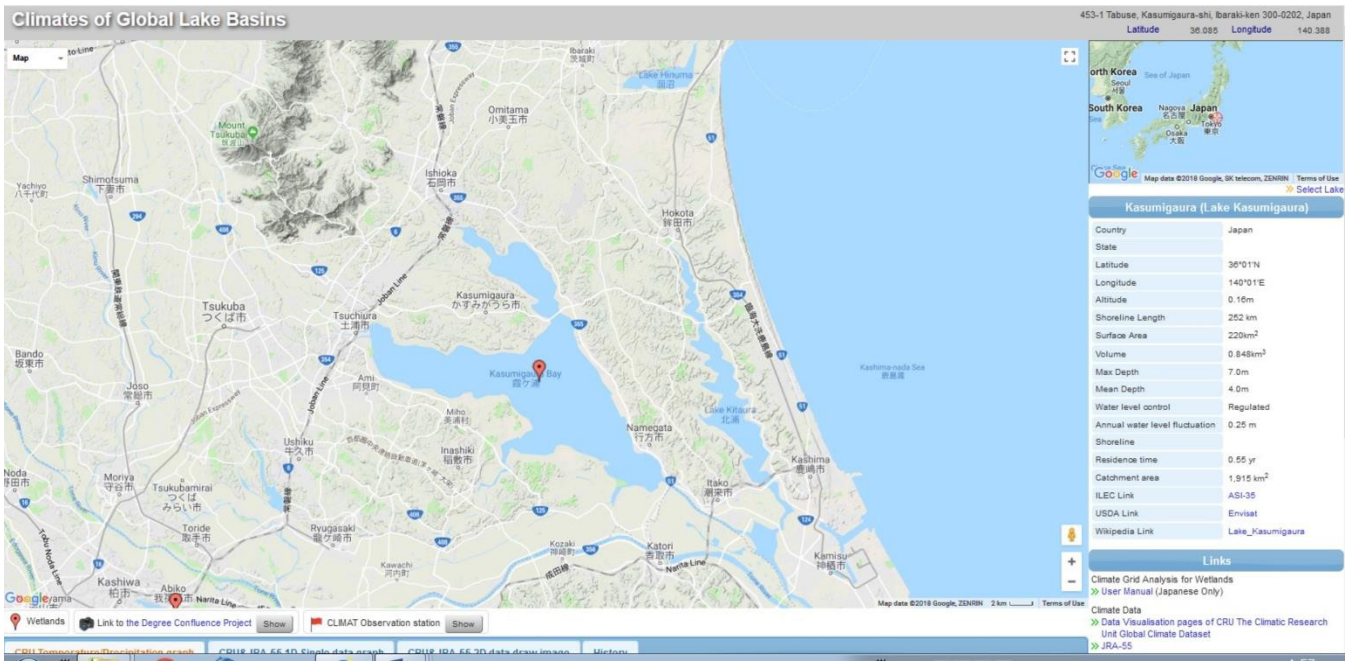


図 1. 霞ヶ浦を CGLB で表示した場合のスクリーンショット (http://hydro.iis.u-tokyo.ac.jp/CGLB/)

Fig.1 Screenshot of CGLB for Lake Kasumigaura.

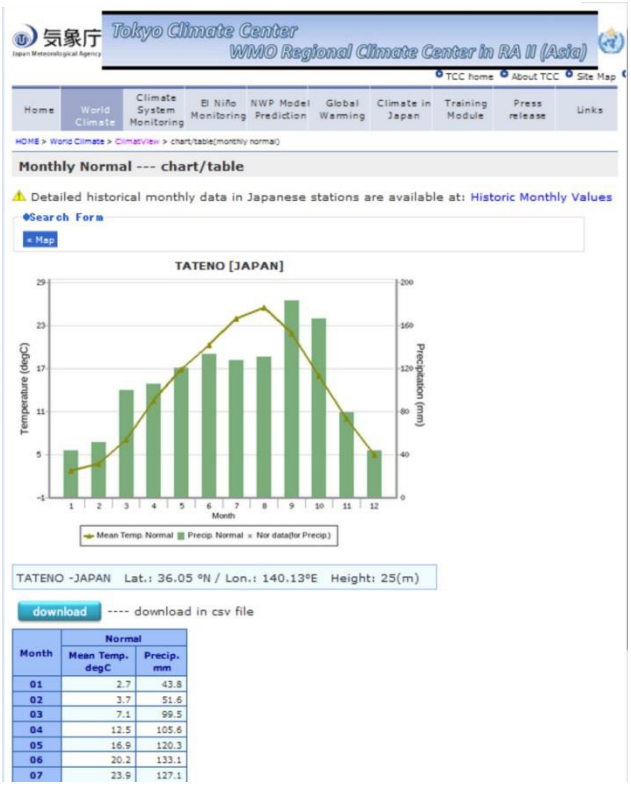
気候の情報については、ユーザーが興味のある湖沼付近の気温、降水量などの観測値を、1 点の時系列、または領域の分布の時系列として、オンデマンドで描画する機能がある。

その他の情報については、外部サイトへのリンクとして提供しており、人工衛星観測による水位情報は米国農業省のサイトへの、湖沼の水質、生態系などの情報は、WLDB のサイトから取得可能である。また、Wikipedia へのサイトへもリンクが張られている。

これらの情報は、ある特定の湖沼の情報を収集したものではなく、全世界の情報を収集したものである。以下では、これらの情報のうちに、どれだけ霞ヶ浦に関して、情報が存在するかを中心にして調査する。また、全世界の情報という特徴を活用して、霞ヶ浦の特徴付けを行う。

3. 結果と考察

図1に、CGLB で霞ヶ浦を表示したスクリーンショットを示す。右側にあるリスト表示ボタンをクリックし、リストから霞ヶ浦を選択すると、Google Maps 上に、霞ヶ浦を中心とした範囲が表示される。リスト表示ボタンの下には、霞ヶ浦の水文学的情報（面積、流域面積、湖岸長、平均水深、最大水深など）が表示される。Google Maps 上には、各国の気象・水文局が観測した情報を、世界気象機関(WMO)が収集し、全世界に向けて配信している CLIMAT 情報[5]の登録地点を表示することができ、その



Month	Normal	
	Mean Temp. degC	Precip. mm
01	2.7	43.8
02	3.7	51.6
03	7.1	99.5
04	12.5	105.6
05	16.9	120.3
06	20.2	133.1
07	23.9	127.1

図 2. 気象庁の ClimatView による最近傍観測点(立野)の月平均気温と降水量の気候値

http://ds.data.jma.go.jp/gmd/tcc/tcc/products/climate/climatview/

Fig. 2 Screenshot of climatological monthly mean surface air temperature and precipitation at Tateno on ClimatView developed by Japan Meteorological Agency

マーカーをクリックすると、気象庁が提供する ClimateView を通して、その地点の月平均気温と降水量の気候値を見ることができるし、値も表にまとめられている(図 2;観測地点は立野)。図 1 の範囲無いには、3 つの登録観測地点が表示されるが、実際にデータが存在するのは立野(つくば市)のみである。このような、登録はされているが、データがオンラインで描画されない観測地点は、全世界をカバーするデータには数多く存在している。容易には取得できないものの、観測地点が存在するという情報は、オフラインであれば入手可能である可能性を示唆しており、意味のある情報である。

CGBL のオンデマンド機能で、描画した月平均降水気候値の分布図を図 3 に示す。Google Maps 上で表示されている範囲を描くようになっている。全世界のデータのため、解像度が 0.5°(50km 程度)と粗く、表示範囲では、詳細な地域分布は表示できないものの、それでも地域差、季節変化は明瞭に見ることができる。降水等、合わせて 9 種類の気象情報を描画することができる。

霞ヶ浦の場合、CBLB から、米国農業省の人工衛星による水位観測サイトへリンクが張られており(図 4)、水位変動も調査することができる。また、情報量は少ないものの、英語版 Wikipedia へのリンクも張られている。

4. まとめ

本稿では、全世界を対象とした湖沼データベースアプリケーション Climates of Global Lake Basins(CGLB)を利用して、霞ヶ浦の情報をどこまで取得できるかについて調査した。多様な情報を取得できた一方で、深く掘り下げた調査には、まだ必要な情報が多数ある。今後、より CGLB を充実させる上で、何が必要か、より多くの人と対話を通して、検討を重ねたい。

謝辞

本稿は、学術振興会科研費特別推進研究 16H06291 の支援の下、行われました。

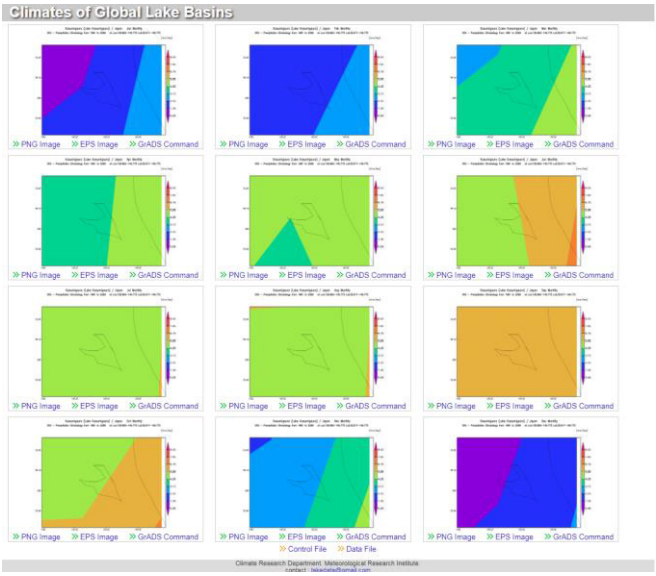


図 3. CGLB による月平均気候値の霞ヶ浦周辺分布

http://hydro.iis.u-tokyo.ac.jp/CGLB/#

Fig. 3 Screenshot of height variations of Lake Kasumigaura observed from ENVISAT.

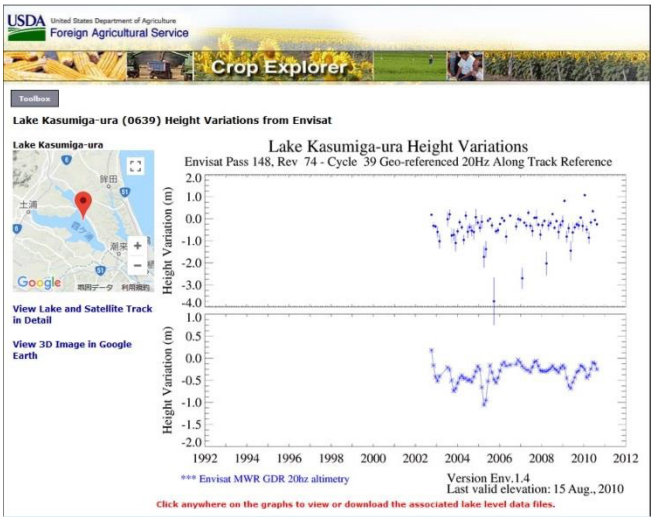


図 4. 米国農業省人工衛星が提供する ENVISAT による霞ヶ浦の水位変

https://ipad.fas.usda.gov/cropexplorer/global_reservoir/

Fig. 4 Screenshot of height variations of Lake Kasumigaura observed from ENVISAT.

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霞ヶ浦の環境に関する取り組みへの各種地理空間情報の整備・提供

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キーワード:湖沼データ, 数値データ, 湖沼画像データ

抄録

国土交通省国土地理院は, 湖沼データ「霞ヶ浦」をはじめとして霞ヶ浦に関連する各種地理空間情報を提供しています. これらの地理空間情報を活用することで, 国, 自治体を初めとする関係機関により進められている霞ヶ浦の環境保全, 再生や自然共生などの取り組みがより詳細かつ定量的あるいは視覚的に行うことを可能にし, 有用な地理空間情報を提供する立場からの貢献ができるものと考えています.

1. はじめに

霞ヶ浦の環境保全, 再生や自然共生などの取り組みには, 霞ヶ浦の湖底地形や霞ヶ浦周辺の変遷や景観が分かる各種地理空間情報は大変有用なものであると考えています. 国土交通省国土地理院が整備・提供する霞ヶ浦に関連した各種地理空間情報はこれに相応しく, ウェブや GIS の最新技術を駆使し, 霞ヶ浦をいろいろな視点から詳細かつ定量的あるいは視覚的に見ることをできます.

2. 方法

国土交通省国土地理院が整備・提供する霞ヶ浦関連の各種地理空間情報には, 以下のものがあります.

○湖沼データ

湖沼データ「霞ヶ浦」は湖沼調査の結果を取りまとめた1万分1湖沼図「霞ヶ浦」を数値化したもので, 「数値データ」と「湖沼画像データ」から構成されます.

湖沼データは, 以下に示す国土地理院のウェブサイトで湖沼データの無償ダウンロード提供を行っています.

http://www.gsi.go.jp/kankyochiri/lakedatalist.html

また, 以下に示すウェブ地図の「地理院地図」でも, 「地理院タイル(湖沼データ)」として湖沼データを閲覧できます.

https://maps.gsi.go.jp/#5/36.104611/140.084556/&base=std&ls=std&disp=1&vs=c1j0h0k0l0u0t0z0r0s0f1

○2 万 5 千分 1 地形図

2 万 5 千分 1 地形図は繰り返し修正・改測されてきました. 修正・改測された各時期の 2 万 5 千分 1 地形図は国土地理院のウェブサイトの「地図・空中写真閲覧サービス」上で閲覧できます.

http://mapps.gsi.go.jp/maplibSearch.do#1

○地理院地図のベースマップ(標準地図)

既述の「地理院地図」上で「ベースマップ(標準地図)」を表示すれば, 最も基本となる地図である「電子地形図(タイル)」を閲覧できます.

○空中写真

空中写真もこれまでに繰り返し撮影されています。測量用航空機から撮影された各撮影時期の空中写真は数値化され, 地理院地図や地図・空中写真閲覧サービスで閲覧できます.

○正射画像・衛星画像

地理院地図では, 空中写真を正射変換した正射画像や広域の衛星画像も閲覧できます.

3. 結果

○湖沼データ(数値データ)

数値データは等深線等を表し, 霞ヶ浦の湖底地形を詳細, 立体的に把握できます. また, 水生植物や底質からの霞ヶ浦の性質の把握にも役立ちます.

○湖沼データ(湖沼画像データ)

湖沼画像データは1万分1の地図形式で, 多色で表示されています. 湖沼部は深さに応じて段彩表示され, 湖岸の陸地は最新の電子地形図(タイル)で表しています. 段彩表示を行ったことで, 非常に視覚的で見やすいものになっています.(図1)

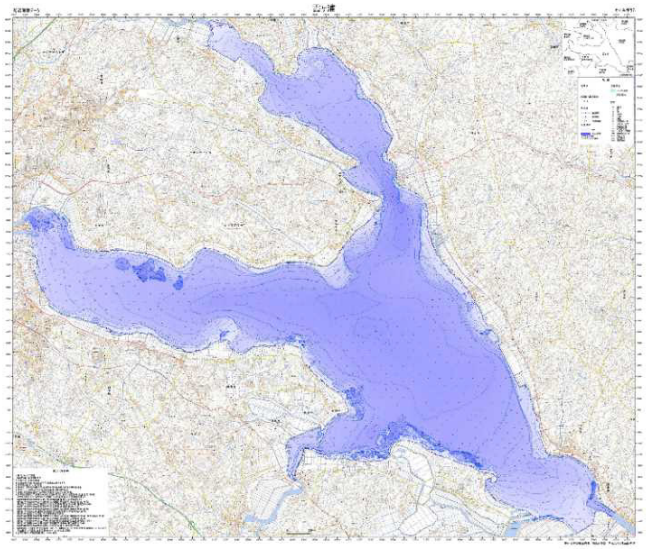

図 1　湖沼画像データ「霞ヶ浦」

○2 万 5 千分 1 地形図・空中写真

土浦市付近の霞ヶ浦の湖岸域では昭和 40 年代以降に埋め立て，整地や宅地化などの大きな人工改変があったことが分かりました．そこで，昭和 40 年以降の 2 万 5 千分 1 地形図や空中写真をそれぞれ並べて見たところ，湖岸域におけるこれらの変遷を非常に明確に把握できました．湖岸域の変遷は湖沼環境の変化を見るときに重要です．（図3及び図4）

○電子地形図（タイル）・正射画像・衛星画像

霞ヶ浦周辺を含めた広域的な影響や景観の把握も重要ですが，これには電子地形図（タイル），航空機で撮影した空中写真を歪みのない画像に変換して正しい位置情報を付与した正射画像や衛星画像の活用が効果的です．地理院地図上で 3D 表示することで，いっそう臨場感が得られます．（図2）

4.　考察

上述の各種地理空間情報はウェブや GIS で扱え，定量的，視覚的あるいは階層的に扱うのに便利です．

湖沼データで見ると，霞ヶ浦は最深部でも 10m 程度でさほど深くはありません．また，浚渫などで凹地状に窪んだところがありますが，全体的に平坦な湖底地形になっていることが分かります．湖沼データを活用すれば更に詳細に解析でき，土砂流入・堆積のシミュレーションやアオコなどの発生箇所の解析などにも有効です．（図1）

更に地域一帯の変遷を見ることが湖沼環境の変化を見る上で重要であり，時系列の 2 万 5 千分 1 地形図や空中写真が非常に有効であることが分かりました．

修正・改測時期の異なる複数の 2 万 5 千分 1 地形図や撮影時期の異なる複数の空中写真を使って湖岸域の変遷を見たところ，土浦市付近では土浦駅北東の湖北地区や駅東側の港町地区において昭和 40 年代から 60 年代にかけて埋め立て，整地や宅地化などがあったことが分かりました．このことから，この地域では既に昭和年代に埋め立てなどの大規模改変があったことが分かりました．（図3及び図4）

このような変遷とこの付近の霞ヶ浦の水質や植生の変化の相関を考察する際，空間，時間の両軸でこのような地理空間情報を参照するは非常に有効的です．

5.　結論

湖沼データ「霞ヶ浦」の他，2 万 5 千分 1 地形図，空中写真などの各種地理空間情報が，霞ヶ浦の環境保全，再生や自然共生などの取り組みに対して効果的なものと考えています．国，自治体を初めとする関係機関が進める種々の取り組みに対して貢献できれば幸いです．



図 2　土浦市付近の正射画像の 3D 表示



図３　２万５千分１地形図「土浦」



図４　土浦市付近の空中写真

TS1-1

Native Japanese strain of the common carp (*Cyprinus carpio*): a precious natural heritage remaining in Lake Biwa

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Keywords: Lake Biwa, common carp, native Japanese strain, subspecies

ABSTRACT

Wild common carp (*Cyprinus carpio*) are suffering worldwide because of the invasion of conspecific domesticated strains, and the native Japanese strain is no exception. A survey of mitochondrial (mt) DNA sequences from 11 localities in Japan revealed that roughly half of the haplotypes found at all 11 localities were those of introduced Eurasian strains, indicating that the native Japanese strain is suffering as a result of the invasion of Eurasian strains. However, an intensive mtDNA survey of the Lake Biwa population, the largest freshwater body in Japan, demonstrated that about 80% of the individuals in its deep off-shore waters (30–70 m depths) had native Japanese haplotypes. Moreover, a population genetic analysis of nuclear single nucleotide polymorphisms (SNPs) revealed that Lake Biwa harbored a relatively pure native population in its deep waters. Morphological analyses of the Lake Biwa and introduced Eurasian carp using genetic hybrid indices based on the SNPs showed that the typical native Japanese carp surviving in the lake differed from the introduced Eurasian carp in a body-shape trait, some internal features, and some meristic and morphometric characters used for carp taxonomy. A metadata comparison of the last characters between the native Japanese and native Eurasian carp indicated that the native Japanese carp deserves at least subspecific status. In addition, the native Japanese strain was located in a relatively basal position in the molecular phylogenetic tree of the common carp. Therefore, the native Japanese strain surviving in Lake Biwa has world conservation priority, to preserve genetic and taxonomic diversity of the species.

1. INTRODUCTION

Freshwater ecosystems are experiencing greater declines in biodiversity than those in the most affected terrestrial ecosystems, and invasion by exotic species is one of the five major threats to global freshwater biodiversity[1]. (The remaining four are overexploitation, water pollution, flow modification, and habitat destruction or degradation.) The extent and impact of such invasions, however, are probably underestimated because of the presence of cryptic invaders; *i.e.*, the invasion of a community by a species (or a formerly allopatric population) that is morphologically similar to a resident species will likely be undetected. Molecular techniques are leading to breakthroughs in the detection of cryptic invaders, and in describing the genetic structure of alien and source populations[2]. For adequate protection of freshwater biodiversity, molecular analyses are now indispensable.

In this proceeding, I briefly review recent molecular studies of the Japanese common carp, *Cyprinus carpio* L. 1758 (*sensu lato*). The common carp is one of the most frequently cultured fish species worldwide. While it has now been introduced to all continents, except for Antarctica, anthropogenically, its natural range was originally restricted to temperate Eurasia, from Europe to East and South-east Asia. Although the origin of the Japanese common carp had long been controversial, a recent molecular study including individuals from various parts of its natural range revealed that both the native Japanese and alien Eurasian strains occur in Japanese freshwaters, such that there is an unexpected conservation problem with this very familiar fish. Subsequent studies demonstrated that Lake Biwa, the largest freshwater body in Japan, harbors a relatively pure native population in its deep waters, and that the typical native Japanese carp surviving in the lake is morphologically different from Eurasian subspecies.

By presenting case studies of the Japanese common carp, I hope to demonstrate the importance of

geographically wide-range molecular (and morphological) analyses to fully understand a local conservation problem.

2. MITOCHONDRIAL DNA SURVEY OF NATURAL POPULATIONS IN JAPAN

A large survey of mitochondrial DNA sequences (the complete D-loop region) from 11 localities in Japan was conducted[3]. From 166 individuals, 28 haplotypes were detected, fitting into six divergent clades. One of the six clades included 19 closely related haplotypes with moderate nucleotide differences, while the remaining five clades each included either a single haplotype or two almost identical haplotypes. Further phylogenetic analysis, together with the published Eurasian haplotypes, demonstrated that the five monotypic clades were sisters to various Eurasian lineages, whereas the 19 related haplotypes formed a monophyletic group distinct from the Eurasian clade. Given their monophyly and genetic diversity, the 19 related haplotypes were thought to originate from the Japanese native strain. Conversely, the nine haplotypes of the five monotypic clades were considered domesticated strains introduced from Eurasia, judging from their phylogenetic affinity to Eurasian lineages and unnaturally low genetic diversity.

Among the 166 individuals sequenced, almost half of the individuals in all 11 locations had Eurasian haplotypes, which indicated that the native populations were widely endangered in Japan by the introduction of domesticated Eurasian strains.

3. MITOCHONDRIAL DNA SURVEY OF LAKE BIWA POPULATIONS

An intensive mitochondrial DNA survey[4] was conducted to examine the populations in Lake Biwa, the largest freshwater body in Japan. Lake Biwa is an ancient lake harboring over ten endemic fish species/subspecies. The lake consists of the large deep “North Basin” and smaller shallow “South Basin”. From 40 locations in the lake, 856 common carp were collected. For each specimen, the mitochondrial cytochrome *b* gene was genotyped (native Japanese or non-native Eurasian haplotypes) by PCR using allele-specific primers[5]. Analysis of the haplotype frequencies showed that the native Japanese haplotype was significantly more frequent in deep (30–70 m) off-shore waters and waters along the steep northern coast of the North Basin (about 80% on average) than in shallow coastal waters in the South Basin and waters along the eastern coast of the North Basin (less than 50% on average).

These results suggested that the deep waters of the lake contain a relatively pure native population. To test this hypothesis, nuclear single nucleotide polymorphism (SNP) markers[6] were developed, and confirmed the hypothesis in a yet-to-be-published study. Other than in the deep off-shore water of Lake Biwa, no population has been found that matches the population of that habitat in the high frequency of native Japanese haplotypes.

4. MORPHOLOGICAL ANALYSIS USING THE GENETIC HYBRID INDEX

Morphological analyses of 183 specimens of Japanese common carp (171 from Lake Biwa and 12 from nursery ponds) were conducted[7]. To account for the effects of hybridization with Eurasian domesticated strains (introduced strains), the extent of hybridization (expressed by the hybrid index, HI, where 0 corresponds to the pure introduced strain and 1 to the pure native strain) was assessed for each specimen using nuclear SNP markers[6]. The relationship between the value of HI and various morphological traits was then evaluated using correlation or regression analysis. The traits that showed significantly positive or negative correlations with HI were considered to be those that distinguish the native and introduced strains. The results showed that the typical native Japanese carp has a more elongated body, more branched dorsal-fin rays, fewer and shorter gill rakers, a more developed pneumatic bulb, a more coiled pneumatic duct, a longer posterior swim bladder, and shorter intestine than the typical introduced strain.

To review the taxonomic status of the native Japanese strain, predicted trait values of taxonomically important

meristic characters for the typical native Japanese strain were compared with the metadata values published by Baruš *et al*.[8] for the Eurasian subspecies. Baruš *et al*. classified the wild strain of the common carp into the following three subspecies based on morphology: *Cyprinus carpio carpio*, distributed in Europe and Central Asia; *C. c. haematopterus* Temminck & Schlegel 1846, found in East Asia; and *C. c. viridiviolaceus* Lacépède 1803, found in southern China and Vietnam. Of the three nominal subspecies, the typical native Japanese strain most closely resembled *C. c. viridiviolaceus*. However, the native strain differed from the southern China and Vietnam subspecies in having more lateral-line scales and slightly more branched dorsal-fin rays, which indicated that the native Japanese carp deserves at least subspecific status.

5. CONCLUSION

By including the published Eurasian haplotypes, molecular analysis of common carp from Japanese freshwaters first revealed the possibility that the native strain remains in Japan, although it is widely endangered by the introduction of domesticated Eurasian strains. Intensive mtDNA and nuclear SNP surveys of Lake Biwa populations demonstrated that the deep waters of the lake actually contain a relatively pure native population, which is exceptional among Japanese freshwaters. The morphological features of the typical native strain were reconstructed using the HI based on nuclear SNP markers, and a metadata comparison of the taxonomically important meristic characters with Eurasian subspecies indicated that the native Japanese strain deserves at least subspecific status. In the mtDNA phylogeny described above, however, the native Japanese strain was sister to the remaining lineages of the species. Therefore, we can conclude that the native Japanese strain surviving in Lake Biwa has world conservation priority, to preserve the genetic and taxonomic diversity of this species.

In recent publications, such as the online Catalog of Fishes[9], the subspecies *Cyprinus carpio carpio* is elevated to species rank as *Cyprinus carpio* (*sensu stricto*), which is restricted to the Black, Caspian, and Aral Sea basins, and the subspecies *C. c. haematopterus* and *C. c. viridiviolaceus* are listed as synonyms of *Cyprinus rubrofuscus* Lacépède 1803, found in eastern Asia. Based on these taxonomic ranks, the native Japanese strain deserves specific status.

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TS1-2

Current status of and future research on biodiversity assessment and ecosystem conservation in Japanese lakes

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Keywords: Lake Kasumigaura, biodiversity, ecosystem service, long-term ecosystem research, sustainability

ABSTRACT

In Japanese lakes, about 28% of the freshwater fish species and 31% of the aquatic plant species have disappeared from historical to current (since 2000) time period [6, 7]. This decrease in the number of emerging species can be regarded as one important signal indicating the current state of biodiversity deterioration of Japanese lakes. Further, Matsuzaki & Kadoya (2015) [8] estimates of catch per unit effort (CPUE) of fishery resources revealed that the CPUEs declined in most lakes, and the functional group richness of exotic piscivores was the most important predictor of changes in the CPUE among several drivers. This suggests a substantial decline in ecosystem services. To mitigate further degradation of biodiversity and ecosystem services, and to continue to enjoy the benefits of freshwater areas and their adjacent ecosystems, we have started analyzing the relationships among multiple ecosystem services in the Lake Kasumigaura Basin. Our dataset includes biological monitoring of plankton and benthos in Lake Kasumigaura accumulated for about 40 years along with the water quality monitoring since the 1970s [10-13]. This research seeks to make use of such long-term data for evaluation and conservation of biodiversity and ecosystems, in addition to developing new monitoring methods and tools (e.g., environmental DNA).

1. INTRODUCTION

Vertebrate populations in freshwaters are more degraded than those on land and in the sea [1], but the assessment of their biodiversity is limited owing to high numbers of species, their uneven distribution, and the difficulty of investigation [2]. Freshwater conservation activities might be more effective at the regional or basin scale.

In Japanese lakes, rapid eutrophication and water quality deterioration occurred during the 1960s and 1970s with increasing economic growth, along with the construction of weirs or gates and the lining of shorelines with concrete banks to develop water resources and control floods. Since the 1980s, invasive alien species have spread out and increased in abundance [3]. All of these anthropogenic factors have degraded the biodiversity of Japanese lakes. Biodiversity losses can cause declines of ecosystem services through the degradation of ecosystem functioning [4]. A high reported willingness to pay for the ecosystem services of lakes [5] suggests that people recognize the importance of lakes. To maintain the health of lakes, therefore, we should continue pursuing their wise use, appropriate management, rehabilitation, and conservation.

In this presentation, we first show the current state and trends of lake biodiversity in Japan. Next, focusing on Lake Kasumigaura and its catchment, we describe research to identify links within the pelagic food chain using long-term biological monitoring data and to evaluate the ecosystem services of the catchment. Finally, we discuss perspectives for future studies to support lake conservation.

2. BIODIVERSITY ASSESSMENT OF JAPANESE LAKES

Broad-scale biodiversity assessment was advanced in the 2011–2015 research program (S9) sponsored by the Ministry of the Environment, Japan; N. Takamura led the research group for the assessment of freshwaters. We

compiled records of both strictly freshwater fish and aquatic vascular plants (floating-leaved and submerged macrophytes) in Japanese lakes (N=45 and 52, respectively), and revealed that about 28% of the freshwater fish species and 31% of the aquatic plant species have disappeared from historical to current (since 2000) time period [6, 7]. The main driver for the loss of fish was the richness of exotic piscivores. Those for the loss of aquatic plants were eutrophication and grass carp invasion. These changes in native species richness can be regarded important signals indicating the loss of biodiversity in Japanese lakes.

Matsuzaki and Kadoya [8] compiled long-term data on the annual catch, fishing effort, and fishing power of 23 Japanese lakes dating back to the 1950s, and showed using Bayesian state-space models that the catch per unit effort (CPUE) has declined in most lakes. The richness of exotic piscivores was the most important predictor of changes in the CPUE among several drivers, and it destabilized CPUE. The results clearly suggest that it would be highly desirable to prevent further invasions by exotic piscivores.

We prioritized lakes for species conservation by scoring- and complementarity-based approaches using compiled data on the fauna and flora of Japanese lakes [9].

3. LONG-TERM ECOLOGICAL RESEARCH IN LAKE KASUMIGAURA

Lake Kasumigaura is regarded as an important water resource for industry, agriculture, and drinking. Fisheries thrived in this lake until water resource development began in 1959, with gate construction downstream in 1959–1963 to prevent seawater inflow and the construction of concrete dikes around the whole shoreline during 1970–1995 to secure water resources. The use of the lake expanded during the 1960s, including for tap water in 1961 and for pen culture of carp in 1963. Overuse of the lake eventually caused massive cyanobacterial blooms and extensive carp mortality because of low levels of nighttime dissolved oxygen in the 1970s [3].

NIES began monthly monitoring in Lake Kasumigaura (Nishi-ura) in 1976. Our dataset covers plankton [10–13] and benthos, along with water quality. Since 1996, when the water level of the lake was raised by 30 cm, no additional strong anthropogenic alterations have occurred. However, maintaining good water quality still conflicts with pursuing high-level fisheries and agricultural production, so it is necessary to continue gathering data for wise use of this lake.

Recently, we quantified the strength and direction of the causal relationships among environmental variables, primary production, and the abundances of five functional zooplankton groups (large cladocerans, small cladocerans, rotifers, calanoids, and cyclopoids) in the lake from 1996 to 2015 by using convergent cross-mapping, a non-linear causality test [14]. Primary production was causally influenced only by NO_3-N. Rotifers and cyclopoids were limited by primary production, and cyclopoids were further influenced by rotifers. In addition, the relative abundance of pond smelt—the most important commercial fish in the lake—was significantly and positively correlated with the abundance of rotifers and cyclopoids. Therefore, the bottom-up linkages between nutrients, primary production, and zooplankton might be key mechanisms supporting high planktivore abundance in Lake Kasumigaura.

4. EVALUATION OF ECOSYSTEM SERVICES IN THE LAKE KASUMIGAURA CATCHMENT

Catchment management is key to lake conservation. The NIES research team [15] (led by S.S. Matsuzaki) is evaluating ecosystem services of the catchment of Lake Kasumigaura for the period 2015 to 2019. We divided the basin into 50 subcatchments and clarified spatial synergies and tradeoffs in each subcatchment among fish species richness (an indicator of biodiversity) and 10 ecosystem services: two supporting (net primary production, habitat diversification), three provisioning (crops, rice, livestock), four regulating (water purification, climate regulation, carbon storage, flood regulation), and one cultural (spiritual and religious values). The fish fauna was evaluated by using environmental DNA.

Factor analysis showed that the two supporting and three of the four regulating services (climate regulation, carbon storage, flood regulation) showed spatial synergies, and two of the provisioning services (crops, livestock) showed a tradeoff relationship with a regulating service (water purification). Although we treated each service as equivalent, forested areas should be given priority because they have multiple ecosystem services; and countermeasures such as suppressing nutrient flows from fields into rivers would be worth investing in to alleviate the tradeoff relationship.

5. CONCLUSIONS AND PERSPECTIVES

Our studies reveal that biodiversity in Japanese lakes has clearly decreased since 2000, and therefore restoring it is a priority. The extirpation of exotic piscivores might be

effective for conservation of native fish species. The high rate of loss of aquatic plant species should be addressed in lake restoration.

Ecosystem services vary by regions, so regional characteristics should be evaluated. Our research in the Lake Kasumigaura catchment began by visualizing the natural services of each subcatchment; this could provide a useful and easy-to-grasp tool for building consensus about methods for improving the overall services of a region.

Analyzing long-term monitoring data by using a newly developed test to distinguish causality allowed us to reveal the food-web linkage controlling Lake Kasumigaura. New monitoring techniques using environmental DNA, rapid species identification through DNA barcoding, and unmanned aerial vehicles have advanced. As comprehensive ecosystem monitoring is important for lake management, scientists should be involved in lake conservation, such by improving techniques for measurement, analysis, and evaluation.

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O1-1

Vertical Distribution of Phytoplankton and Their Relationship with Water Quality in Mae Kuang Reservoir, Chiang Mai, Thailand

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Keywords: Vertical distribution, Phytoplankton, Water quality, Mae Kuang Reservoir

ABSTRACT

This study aims to investigate the vertical distribution of phytoplankton and their relationship with the water quality in Mae Kunag Reservoir, the large important irrigation and water supply in Chiang Mai-Lamphun Basin. The sampling was carried out from 2014-2015. Every five meters deep from surface were investigated at deepest point of the reservoir. The samples were collected in summer, rainy and cool-dry seasons. One hundred and one species of phytoplankton in 37 genera and 6 divisions were found. The highest number of phytoplankton species were found in Division Chlorophyta (56 species) followed by Division Euglenophyta (17 species) Division Cyanophyta (11 species) Division Chrysophyta (6 species), Division Bacillariophyta (6 species) and Division Pyrrhophyta (5 species) respectively. The dominant species were *Cosmarium* sp, *Staurodesmus* sp., *Staurastrum limneticum*, *Pseudanabaena* sp. and *Trachelmonas acanthostoma*. The overall water quality of Mae Kuang Reservoir was classified to the level 2nd when compared to the standard surface water of Thailand. It means that the water was appropriated to using for household consumption by passing the standard treatment.

1. INTRODUCTION

The Mae Kuang Udomtara reservoir is situated in the Doi Saket district, Chiang Mai province, approximately 30 km North-east of Chiang Mai city. It was constructed in 1991 to irrigate 280 km^2 of agricultural area of three districts of Chiang Mai and Lamphun province. The reservoir also supplies drinking water to villages by the water line irrigated to the local and regional water works station in Chiang Mai. In addition, the reservoir is used for fishery and recreational activities. Therefore, the maintenance of an ecological balance and suitable water quality in the reservoir is extremely important. Continuous physical, chemical and biological monitoring of the water quality are necessary to meet required standards.

2. METHOD

The study site

The Mae Kuang reservoir was created in 1991 and more than 150,000 people lived in communities inundated by this reservoir. The Mae Kuang Reservoir has been short of water from many past years. Declining water yield from the watershed was reflected in low reservoir levels except the wet and flooding years in 2011

Physcio-chemical parameters studied

Secchi depth was measured with a black and white disk. pH and temperature were measured in the field using a pH meter. Conductivity of water was measured in the field by a conductivity meter (WTW Company). Chemical analyses of the water followed APHA, AWWA, and WPCF [4]. The quantity of dissolved oxygen in the individual samples was measured using the azide modification method (to avoid interference from high nitrate and iron concentrations). Alkalinity was measured in the laboratory by endpoint titration with an indicator (Methyl-orange). Nitrite nitrogen was measured by a colorimetric method using sulfanilamide, nitrate nitrogen by the cadmium reduction method, ammonium nitrogen by the phenate method, soluble reactive phosphorus and total phosphorus (after acid hydrolysis) by the ascorbic acid method and total iron by the atomic absorption method. For colorimetric detections by the spectrophotometer, “Generys 5” of Spectronic Instrument, USA was used.

The samples collected

The samples were collected in the deepest point of Mae Kuang reservoir. At the deepest point, every 5 meter depth were collected from surface to bottom. Before sampling at each site, the sampling equipment (a net, bucket, and plastic jar) was washed to remove any organisms and other matter left from the previous site. Quantitative samples were collected by water sampler for total volume of 10 L. The 10 L of water collected was filtered slowly through a plankton net (mesh size of 10 μm) to avoid any overflow. When the water volume remaining in the net was about 100 mL, the water was transferred to a plastic jar (250 ml volume). The samples were immediately fixed in the field with Lugal's solution [5].

Laboratories works

The phytoplankton species and details of larger species were examined on a microscope slide under a compound microscope at a magnification of 100 – 400 x. All individuals collected were counted and identified to the species level of taxonomy.

3. RESULTS

The investigation of diversity and distribution of phytoplankton in Mae Kuang reservoir found that 101 species of phytoplankton in 37 genera and 6 divisions were found. The major group was Division Chlorophyta (56 species) followed by Division Euglenophyta (17 species) Division Cyanophyta (11 species) Division Chrysophyta (6 species), Division Bacillariophyta (6 species) and Division Pyrrhophyta (5 species) respectively. The dominant species were desmid group as *Cosmarium* sp, *Staurodesmus* sp., *Staurastrum limneticum*, *Pseudanabaena* sp., and the euglenoid as *Trachlomonas acanthostoma* (Table 1). On the other hand, the evenness index investigation was revealed that not significantly difference through the sampling year (Table 2).

4. DISCUSSION

The study on distribution in depth distribution profiles of phytoplankton in Mae Kuang Reservoir were investigate from surface to deepest point in each sampling time. The distribution in each sampling time had a similar distribution pattern. The number of phytoplanktonn was higher on the epilimnion zone (surface and 5 meter depth.). Although, the phytoplankton could not have mobility but some of them usually had a gas vacuole in their cell and living along the epilimnion area [1]. This area also had a high light intensity and more nutrient than metalimnion and hypolimnion [2], therefore, it leads to have more distribution of growing factors.

The number of abundance indicated that, the density of phytoplankton will be decrease in deeper sampling. This was also strongly related to the diversity and evenness. Moreover, the results showed that, the distribution of phytoplankton in each sampled was significantly related to the changing of water condition in each seasons. In this work the high number of phytoplankton were found in the upper layer, epilimnion zone. However, the highest number of phytoplankton was not found in the surface but in the 5 meter deeper. The

Table 1 The dominant species of phytoplankton in different season and depth

Depth	winter	summer	Rainy
0 meter	*Cosmarium pseudarctoum*	*Sturodesmus* sp.	*Sturodesmus* sp.
	Sturastrum smithii	*Cosmarium* sp.	*Staurastrum longbrachiatum*
	Trachelomonas volvocina	*Staurastrum longbrachiatum*	*Trachlomonas acanthostoma*
5 meter	*Pseudanabaena* sp.	*Staurastrum. longbrachiatum*	*Staurastrum longbrachiatum*
	Cosmarium sp.	*Staurastrum protectum*	*Stauodesmus curvatus*
	Eudorina elegans	*Tetraedron incus*	*Trachelomonas volvocinopsis*
10 meter	*Cosmarium* sp.	*Staurastrum longbrachiatum*	*Cosmarium* sp.
	Pseudanabaena sp.	*Staurastrum protectum*	*Sturodesmus* sp.
	Staurastrum schmidle	*Botryococcus braunii*	*Staurastrum paradoxum*
15 meter			*Cosmarium* sp.
			Trachlomonas acanthostoma
			Peridinium sp.

Table 2 The diversity index, evenness index and number of species of phytoplankton in Mae Kuang Reservoir. (December 2014, April and June 2015)

Sampling time	Site	Number of species	Evenness index	Diversity Index
Dec-14	MK 1	31	0.642*	0.9325
(Winter)	MK 2	48**	0.3525	0.8603
	MK 3	35	0.4994	0.906*
Apr-15	MK 1	23	0.7211	0.6884
(Summer)	MK 2	17	0.678	0.8922
	MK 3	18	0.5944	0.8676
	MK 1	25	0.7262	0.9334**
Jun-15	MK 2	29	0.6245	0.929
(Rainy)	MK 3	21	0.7976**	0.929
	MK 4	16*	0.7483	0.8956

Remark: **highest value, *lowest value

strong sunlight and high temperature of surface was influenced factor in the water column [6]. Thus, the highest abundance of living organism was not in the surface but higher at the underneath layer. However, the photic zone was limiting factor to the primary producer activities in the standing water [7]. On the other hands, the distribution revealed that some of them were found in all conditions but many of them were specifically grown in the different sampling depth and seasons, that were directly related to their microhabitat and environment. From this relationship, we could be use a phytoplankton as a bio-monitor index to assess water quality, at lease the changing of annual water conditions [8]. Moreover, the dominant species of phytoplankton were used to find the relationship in both single parameters and overall water quality (including conductivity, alkalinity, nitrate nitrogen, ammonium nitrogen and soluble reactive phosphorus). However, the Multivariate Statistical of dominant species distribution and ecological data should study. The relation and calculation will lead to the biotic indices the including the species score. Each dominant species will have a different individual index that depends on the correlation level to the water quality [9].

5.CONCLUSION

The study aims to investigate the vertical distribution of phytoplankton and their relationship with the water quality in Mae Kunag Reservoir was carried out from 2014-2015. The 101 species of phytoplankton in 37 genera and 6 divisions were found. The phytoplankton abundances found as a moderate compared to the other Thailand reservoirs and the major group was a Chlorophyta. The water quality compared to the standard surface water of Thailand was classified to the level 2nd, it means that the water quality was appropriate to using for household consumption by passing the standard treatment.

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O1-2

Relationship between Phytoplankton Community Structure and Water Quality in the Lake Gold Coast, North Jakarta

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Keywords: artificial lake, Lake Gold Coast, microalgae, nutrient, and water quality

ABSTRACT

The input of organic materials into aquatic environment has potential to become nutrients that could be utilized by phytoplankton. Nutrient utilization by phytoplankton may affect plankton community structure in environment. This study aimed to determine the relationship between phytoplankton community structure and water quality in the Lake Gold Coast. This study was conducted from January to December 2016 in five observation sites. Physical water quality parameters (depth, transparency, turbidity, temperature, pH, salinity, and dissolved oxygen, chemical parameters (ammonia, nitrite, nitrate, and orthophosphate) and biological parameters (phytoplankton) was analyzed. Group of phytoplankton found were Bacillariophyceae, Chlorophyceae, Cyanophyceae, and Euglenophyceae. Bacillariophyceae has the highest abundance during observations. Based on water quality, there were three groups of site. This grouping was used to conduct the further analysis. PCA analysis result showed that phytoplankton abundance was in close position to orthophosphate. This was strengthened by Pearson correlation test that showed high correlation between abundance of phytoplankton with orthophosphate.

1. INTRODUCTION

Lake Gold Coast is an artificial ornamental lake located in Pantai Indah Kapuk, North Jakarta. Lake Gold Coast has shallow depth ranged from 0.32 to 0.45 m. Main function of this lake is as aesthetic additional value in luxurious residential area. It is also functioned as rain catchment to prevent flood and wastewater shelter of domestic activity surrounds the lake. However, this is not proper condition since wastewater contains organic matter that could decrease water quality. Based on previous research, Lake Gold Coast has already polluted by organic matter in medium level [1].

Organic matter has potency as source of nutrients that could be utilized by phytoplankton. Nutrient is one of variables controlling phytoplankton community structure and biomass[2,3]. Nutrients utilization of phytoplankton could influence plankton community structure in the lake. Based on that condition, this research was aimed to analyze the relationship between phytoplankton community structure and water quality in Lake Gold Coast.

2. METHOD

This research was conducted in Lake Gold Coast in twelve months (January to December 2016) with a month time interval. There were 5 sites that represent lake condition. Site 1 is close to Sewage Treatment Plant and Pump Station. Site 2 is located before Sewage Treatment Plant. Site 3 is the deepest area of lake. Site 4 is area that receives input from Bukit Golf Mediterania interconnection. Site 5 is located in the corner of lake.



Fig. **1** Lake Gold Coast, North Jakarta

Physical and chemical parameter (depth, transparency, turbidity, temperature, pH, salinity, and dissolved oxygen) measurement was conducted *in situ*. Other chemical parameter such as BOD, COD, ammonia, nitrite, nitrate, and orthophosphate was analyzed in laboratory. Analysis was conducted based on standard method [4].

Biological parameter, phytoplankton, was sampled using plankton net with 30 μm mesh size and preserved by Lugol solution.

Plankton was observed and counted using Sedgewick Rafter Cell under compound microscope. Morphological identification was conducted based on identification book [5]. Abundance of phytoplankton was calculated using

standard method formula[4]. Data analysis was conducted using Canberra Index[6], Diversity Index[7], Principal Component Analysis (PCA)[8], and Pearson correlation.

3. RESULTS

The highest taxa number of phytoplankton was found in January and September, and the lowest is December. The highest abundance of phytoplankton was found in June and the lowest was in December (Fig. 2).

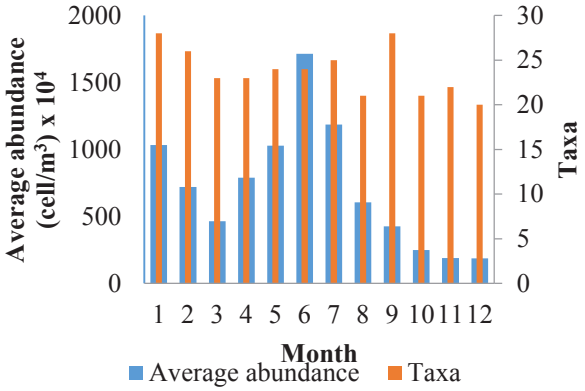

Fig. **2** Average abundance of phytoplankton

Chlorophyceae has the highest taxa proportion of and it was occured every month (Fig. 3), while the abundance proportion was fluctuated every month (Fig 4).

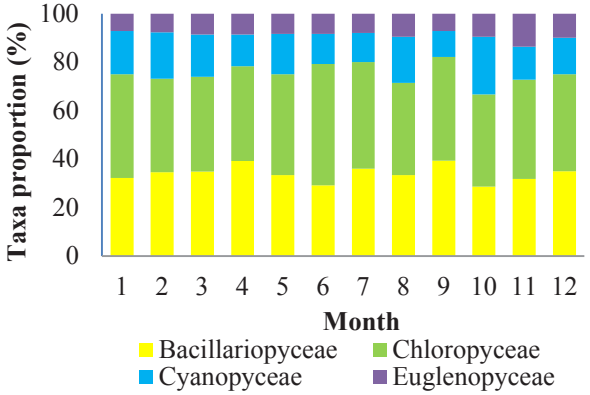

Fig. **3** Taxa proportion of phytoplankton

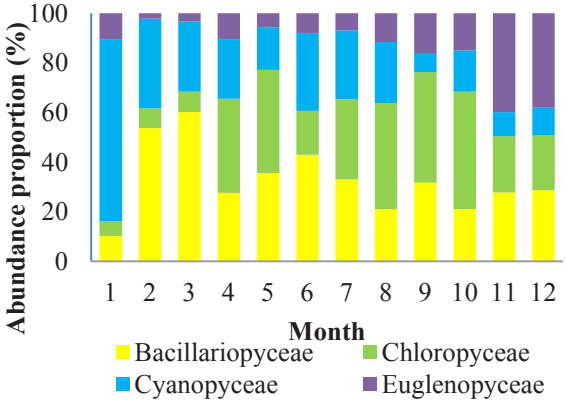

Fig. **4** Taxa proportion of phytoplankton

Based on water quality, there were three groups, Group I (Site 2 & 4), Group 2 (Site 1 & 3), and Group III (Site 5) (Fig. 5). Nutrient concentration was fluctuated during observation (Fig. 6).

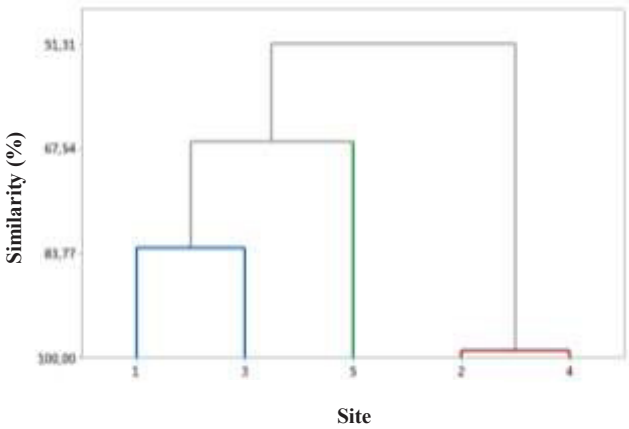

Fig. **5** Dendrogram of site grouping based on water quality

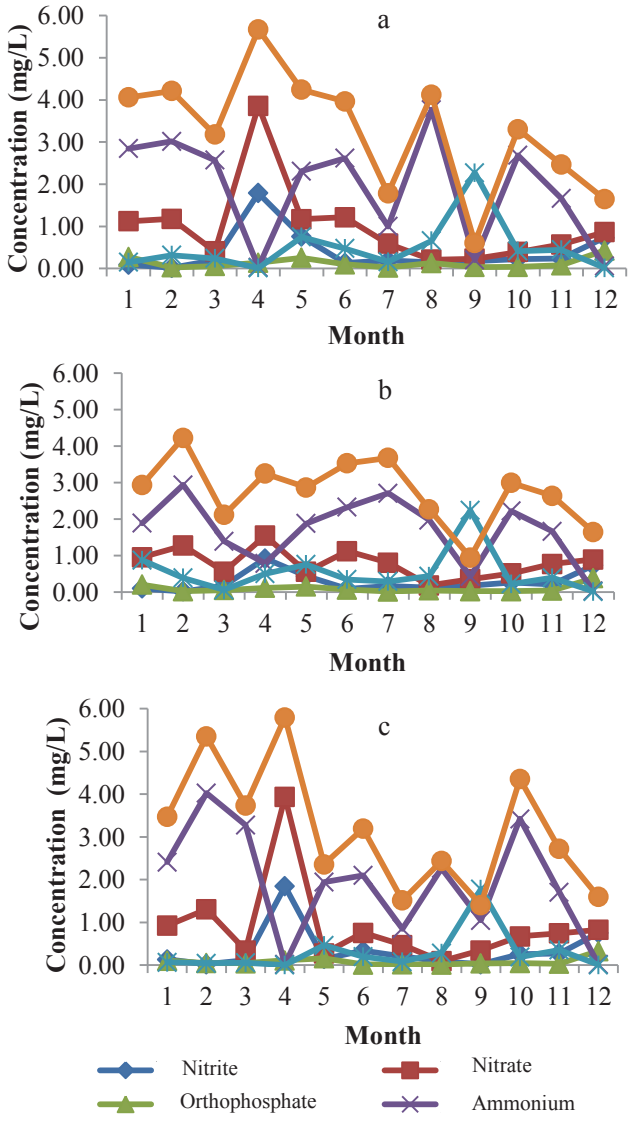

Fig. **6** Nutrient characteristic (nitrite, nitrate, orthophosphate, ammonium, free ammonia, DIN) (a) Group I (b) Group II (c) Group III

Relationship between phytoplankton abundance and water quality is illustrated in Fig. 7.

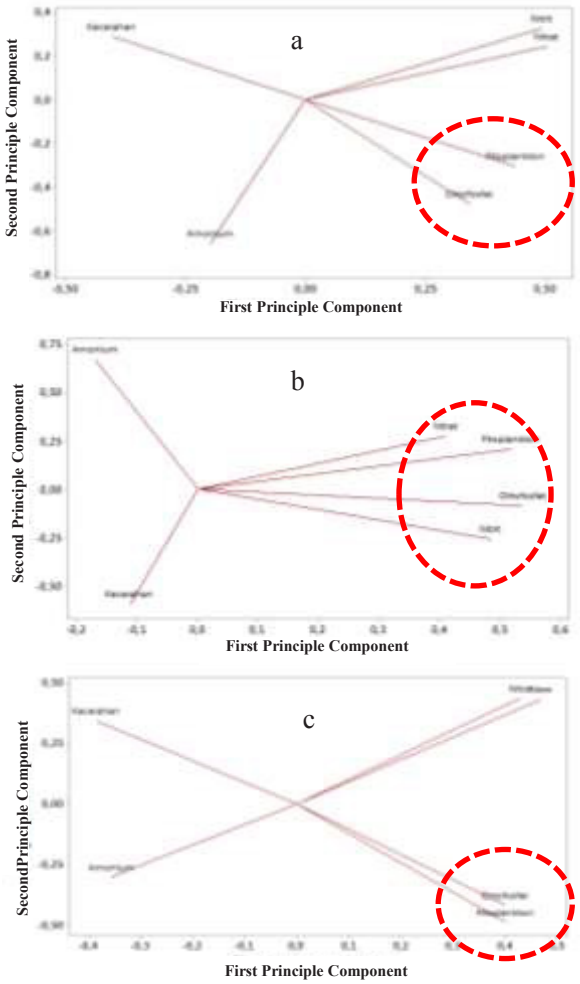

Fig. 7 Biplot phytoplankton abundance and water quality a) Group I, b) Group II, and c) Group III

4. DISCUSSION

Bacillariophyceae has the highest abundance and Chlorophyceae has the highest taxa proportion. The high abundance of Bacillariophyceae was presumed influenced by the high N:P ratio (58:1). Class Bacillariophyceae will have high abundance in N:P ratio condition = 20:1[9].

Dendrogram in similarity level of 75% formed 3 groups based on water quality characteristics. Site 2 and 4, was formed into one group, presumably since it has the highest turbidity, Site 1 and 3 has the highest nitrite, nitrate, and orthophosphate, and site 5 has the lowest turbidity and the highest salinity.

Diversity and dominance index in 3 groups were relatively low, and similarity index was moderate. PCA biplot showed the relationship between phytoplankton and water quality. Nitrate, nitrite, and orthophosphate were close to phytoplankton. Correlation test result between phytoplankton and water quality in 3 groups showed that phytoplankton has positive correlation with orthophosphate. This because of lower value of orthophosphate was followed by lower abundance of phytoplankton. Orthophosphate is inorganic nutrients which dissolved in water and could directly utilized by phytoplankton[10].

Scendesmus, Oscillatoria, Microcystis, Navicula, Nitzschia, and *Euglena* are phytoplankton that usually found in waters polluted by organic matter. These genera were found in Lake Gold Coast. It supports the previous research that showed Lake Gold Coast has already polluted by organic matter. The main source of organic matter is domestic activity surround the lake. Therefore, management is needed to prevent water quality degradation of lake[11].

5. CONCLUSION

Group of phytoplankton found in Lake Gold Coast were Bacillariophyceae, Chlorophyceae, Cyanophyceae, dan Euglenophyceae. The highest abundance was group Bacillariophyceae. The abundance of phytoplankton was influenced by orthophosphate.

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O1-3

Littoral Phytoplankton Community in Lake Lananao Along Marawi City, Philippines

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Keywords: Lake Lanao, phytoplankton community, Marawi City

ABSTRACT

Being an effective biological indicator, phytoplankton diversity can determine productivity of and physicochemical status of any bodies of water. This study was performed to explore the diversity of phytoplankton in the littoral zone of Lake Lanao along Marawi city, LDS, Philippines. Freshwater samples were collected on the months of November 2016 and February 2017 following oblique towing using a planktonet with a mesh size of 23 microns. A total of 27 species, including one unidentified, representing 24 genera belonging to the divisions Bacillariophyta, Chlorophyta, Cyanophyta, Charophyta, and Dinophyta were recorded. The identified genera are as follows: *Anabaena, Ankistrodesmus, Coelosphaerum, Coscinudiscus, Cyclotella, Cymbella, Cylindrocystis, Diatoma, Dictyosphaerum, Eudorina, Golenkinia, Lyngbya, Melosira, Microcystis, Navicula, Nitzschia, Oedogonium, Pandorina, Peridinium, Rhizosolenia, Rhopalodia, Staurastrum, Synedra* and an unidentified genus. Result showed that the unidentified species was the most abundant with relative abundance of 71.58% and 64.27% and the Shannon's Index of Diversity was 0.99 and 1.06 for the November 2016 and Febraury 2017 samples, respectively.

1. INTRODUCTION

Phytoplankton is an important primary producer and the base of the food chain in aquatic ecosystems[1]. It is highly sensitive to even slight fluctuations in water quality. Even slight disruptions result in disequilibrium of community structure and absence of some species from the system[2]. As a result, species composition of phytoplankton community is efficient bio-indicator for water quality. The last phytoplankton study in Lake Lanao that was published was by Lewis[3] in the year 1978. This study reassessed the current composition and diversity of phytoplankton in the chosen area. The result of the study can help assess the current ecological status of the Lake Lanao in Marawi City, Philippines, to somehow provide a point of reference for future related researches in the lake, to serve as a source of realization for the people dwelling near the lake of the importance and need to preserve the Lake.

2. METHODS

This study has the research design of being purposive. Lake Lanao, the second largest lake in the Philippines, is geographically located in the province of Lanao del Sur, Central Mindanao[3]. The most populated and developed area then among all localities surrounding Lake Lanao was Marawi City. The study was conducted along the littoral zone of Lake Lanao along Marawi City Three sub-sites were established to serve as replicates, with coordinates as follows, 07°59.714 N and 124°17.276 E, 07°59.626 N and 124°17.330 E, 07°59.614 N and 124°17.433 E.

Vertical towing was done using a planktonet with a mesh size of 23 microns. The collected water samples were strained to remove water and was replaced with equivalent amount of 5% formalin into a plastic bottle for fixation and immediately treated with Logul's iodine for staining and preservation. Each sampling container was sealed and labeled accordingly. This was done thrice for every substation.

Physico-Chemical such as temperature, Secchi disk transparency, pH level, conductivity, Dissolved Oxygen and the depth parameters were taken.

The phytoplankton samples were observed at the Department of Biology, College of Natural Sciences and Mathematics, Mindanao State University, Marawi City. An 1ml aliquot of the sample was examined drop by drop using an improvised counting chamber with a mounting area of 1.8x1.8 cm^2 and a depth of 0.5 mm using a Euromex I-scope microscope under 400x magnification. The phytoplankton was counted

following the right hand rule method with the aid of an advanced tally counter android application [4]. Distilled water was used to wash the improvised counting chambers before using it for the next counting to avoid retention of any plankton. The species observed were then photographed using an Iphone. In the identification of phytoplankton species, references include the works of (Bellinger & Sigee, 2010)[5], (Botes, 2003)[6], (Van Vuuren, Taylor, Van Ginkel, & Gerber, 2005)[7].

The following formulas were used to compute the abundance and diversity of the Phytoplankton;

Abundance:

$$x = \frac{\text{total no. of organisms counted}}{\text{volume} of\ sample\ \text{(ml)}} \times dilution\ volume \times \frac{1}{AVWF}$$

Where: AVWF (Actual Volume of Water Filtered) = mouth area of plankton net × distance towed

Relative Abundance (%)

$$RA = \frac{\text{abundance of individualspecies}}{totalabundance\ of\ species\ present} \times 100$$

Shannon's Index of Diversity

$$H' = -\sum(\text{Pi}\ \log \text{Pi})$$

3. RESULTS

There were a total of 27 species of phytoplankton belonging to 24 genera, including one unidentified species. Table 1 shows the relative abundance of phytoplankton species for the two sampling periods.

The unidentified species showed a high value of relative abundance for both sampling periods. The least abundant species is the *Coscinudiscus Spp*. The calculated Shannon's Index of Diversity were 0.99 and 1.06, for the first and second sampling, respectively.

Relatively, the overall species diversity of Phytoplankton in Lake Lanao along Marawi city was quite low. The sampling sites contained also a large number of *Anabaen*a, a genus that is known to release neurotoxic substances which mean that the water is not potable. Furthermore, there is a huge amount of *Oedogonium* present in the area which may indicate algal blooms, this could explain the bluish-green look of the water in the area. Several other species that are also known to cause bloom can be observed in the area, such genera as *Peridinium* and *Staurastrum* that accounts for a taste and odour problem for the drinking water supplies [8].

Table 1. Relative Abundance of Phytoplankton for the 1st and 2nd sampling.

SPECIES	RELATIVE ABUNDANCE	
	1st Sampling	2nd Sampling
Bacillariophyta		
Coscinudiscus sp.	0.01%	0.04%
Cyclotella sp.	0.06%	0.04%
Cymbella sp.	0.26%	0.08%
Diatoma sp.	Not Observed	0.10%
Melosira sp. 1	0.12%	0.02%
Melosira sp. 2	0.51%	0.22%
Navicula sp.	0.31%	0.05%
Nitzschia sp. 1	0.73%	0.09%
Nitzschia sp. 2	0.18%	2.70%
Rhizosolenia sp.	0.09%	0.00%
Rhopalodia sp.	0.06%	0.00%
Synedra sp.	0.08%	2.14%
Chlorophyta		
Ankistrodesmus sp.	0.03%	Not observed
Dictyosphaerium sp.	0.07%	0.20%
Eudorina sp.	0.02%	0.02%
Golenkinia sp.	0.15%	0.06%
Oedogonium sp.	20.01%	26.39%
Pandorina sp.	0.75%	0.18%
Staurastrum gracile	0.17%	0.10%
Cyanophyta		
Anabaena sp.	0.77%	0.42%
Coelosphaerum sp.	0.13%	0.05%
Lyngbya sp.	0.04%	0.01%
Microcystis sp.	0.13%	0.36%
Charophyta		
Cylindrocystis sp.	2.92%	1.04%
Dinophyta		
Peridinium sp.	0.59%	0.13%
Unidentified		
Unidentified sp.	71.58%	64.27%

Table 2. Some Physico-Chemical Measures

Measure	Sampling 1	Sampling 2
Secchi Depth	3.45	3.18
Temp (^{0}C)	27.10	25.10
Conductivity (µS/cm)	0.15	0.13
pH	8.88	7.49
Dissolved Oxygen (mg/l)	6.03	5.98

4. DISCUSSION

Stressed environment are known to have lower number of species, with only one or two species having significantly greater individuals than the other species[9]. In this study, there was only two relatively very abundant species which is the Unidentified species and a chlorophyta *Oedogonium* species.

The Shannon's Index of Diversity of 0.99 and 1.06, for the first and second sampling, respectively, showed very little difference.

Some physico-chemical characteristics were measured (*Table 2*). Temperature does not significantly different due to the relatively uniform temperature that prevails all throughout the year in tropical countries. Water communities in the tropics do not exhibit extreme seasonal fluctuation as it does in the land. Change due occur but with little fluctuations[10].Suspended particulates including organic matter can make the water turbid and also traps light penetrating the surface, also the phytoplankton trap more light in their cells thereby contributing to more turbid water. Thus turbidity can cause an increase in phytoplankton abundance[11]. Specific conductivity can be utilized as a rapid measurement of dissolved solids, increased conductivity value decreases the diversity of the phytoplankton [12]. This seems to coincide with the pattern of the study. There was a Shannon index of 0.99 in the first sampling in which the conductivity value is 0.15 and then 1.06 with the decreased conductivity value of 0.13 in the 2nd sampling, diversity of phytoplankton increased.

5. CONCLUSION

In this study, there was only two relatively very abundant species which is the Unidentified species and a chlorophyta *Oedogonium* species.The total Shannon's Index of diversity of all of the observed phytoplankton is 0.97 for the littoral zone of November 2016 and 1.06 for the same zone of January 2017, the values were relatively not far from each other, mean that the species number in the site is poor.

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O1-4

The typology and taxonomic diversity of the Abkhazia Republic lakes and rivers (Caucasus)

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Keywords: lakes, rivers, Caucasus, Abkhazia, phytoplankton, zooplankton, zoobenthos, typology, biodiversity

ABSTRACT

The Republic of Abkhazia (the Western Caucasus) has a significant number of water objects - plains and mountain lakes and rivers. Many of them are associated with karst processes and caves. According to the inventory, 28 flat lakes and at least 70 lakes of mountain origin are identified. Lakes are very different on genesis, area, depth, water regime, mineralization and composition of hydrobionts. The largest lakes in the plain are lakes Inkit (40 ha), Skurcha (140 ha), Bibisiri (76 ha), Sukhumskoe (27 ha) and a lake near Ochamchira city (74 ha). The most famous mountain lakes are Lake Big Ritsa (127 ha) and Small Ritsa (10 ha) of the National Ritsinsky Park, as well as Amtkel Lake (58 ha) and Mzi Lake (15 ha). Researches of the Kazan Federal University (Russia) and the Institute of Ecology of the Academy of Sciences of Abkhazia in 2007-2017 revealed the typology and biodiversity of river and lakes, rare and endemic species. Thus the diversity of types of water bodies causes a high biodiversity of lakes and rivers of Abkhazia.

1. INTRODUCTION

Abkhazia is located in the northwestern part of Transcaucasia between the rivers Psou and Ingur, in the south-west it is washed by the Black Sea (Fig. 1). The coast, more than 210 km long, is not very indented, there are often wide pebble beaches. The sea spaces, subtropical vegetation, turbulent rivers and mountain peaks of the Greater Caucasus give Abkhazia exceptional picturesqueness. The fame of Abkhazia is attached to mountain ranges, numerous caves, clear rivers and mountain lakes.



Fig. 2 Map of the Republic of Abkhazia

The number of water bodies in Abkhazia is not known from the literature. Mountain rivers of Abkhazia have dozens of tributaries and hundreds of streams, the total amount is very difficult to establish.

Up to now, no more than 10 large lakes have been described and investigated with respect to the lakes (Big Ritsa, Small Ritsa, Blue, Skurcha, Inkit, etc.). Mostly these are studies from the 2000s of employees of the Kazan (Volga region) Federal University and of the Institute of Ecology of the Abkhazia Academy of Sciences[1]. Taking into account that fresh and salt lakes are found among lakes, small and large in size, with different water regime, the problem of lakes typification with the use of different classifications arises[2].

The purpose of the research is to identify various types of lakes in Abkhazia and their biodiversity.

2. METHOD

More than 120 water bodies of Abkhazia (including 15 lakes, 80 rivers, as well as streams, waterfalls and cave lakes) were surveyed during the Russian-Abkhazian expeditions of 2007-2017 for the purpose of hydrological, hydrochemical, hydrobiological and ichthyological studies. Studies were conducted by traditional methods [3]. The physic-chemical and hydrological measurements, water sampling for chemical and hydrobiological analyzes and ichthyological fishing was made during field investigations. The water samples were analyzed in the Abkhaz State Center for Environmental Monitoring. Hydrobiological and ichthyological samples were analyzed in Kazan Federal University.

The Google Earth, SAS.Planet and QGis programs were used to determine the number of water bodies and hydrographic parameters.

3. RESULTS

Number and types of water bodies

The territory of Abkhazia is characterized by a well-developed river network, including a large number of watercourses belonging to the Black Sea basin. The hydrographic network of Abkhazia is represented by a large number of watercourses and lakes, which is a consequence of excessive moistening of the territory. Many rivers originate from glaciers of the Main Caucasian Range and flow along the plain to the Black Sea. Large deviations in the terrain are determined by the rapid flow of rivers and the large coefficient of tortuosity of their riverbed. According to research conducted in the 1970s, 4049 watercourses with a total length of 8,256 km were identified for 26 main rivers of Abkhazia, taking into account their river basins[4].

According to the analysis of maps, space images and field studies, we identified 61 rivers and 6 streams flowing into the Black Sea, with a total length of more than 1100 km. The typology of rivers flowing into the Black Sea is shown in Table 1.

Table 1 Typology of the Abkhazia rivers

1.	Length of the rivers, flowing into the sea, km	
	More 100	2 (River Bzyb, Kodor)
	50-70	4 (River Kelasur, Galidzga, Okoum, Mokva)
	10-50	22
	3-10	23
	1-2	10
	Less 1,0	6 (streams)
2.	Nature of the current	
	Plain	Mountain-plain
	29	32 (3 with an underground channel – Reprua, Psyrtsha, Maanikvara)

Many of them have a well-developed river network with dozens and hundreds of tributaries (permanent and temporary). Thus, the mountain river Bzyb, flowing from a height of 2310 m above sea level, has a length of 113.8 km, a coefficient of tortuosity of 1.39; the river has 284 tributaries. The total number of all rivers and tributaries of Abkhazia is estimated previously at 4977 objects, including temporary watercourses; the total length is probably about 10 thousand km.

Based on the results of the study of maps and space images, 28 lakes of Abkhazia located on the plain and at least 70 lakes of mountain origin have been identified. The largest lakes in the plain are Lake Inkit (40 ha), Skurcha (140 ha), Bibisiri (76 ha), Sukhumskoe (27 ha) and the lake east of Ochamchira (74 ha). The total area of lowland lakes is about 440 ha. The largest mountain lake is Lake Big Ritsa, with an area of 127 ha. Tectonic lakes predominate among the mountain lakes.

Hydrobiological characteristics

Phytoplankton. Phytoplankton of Abkhazia water objects is very diverse. Over the years of research there were identified 256 species of 8 departments with a predominance of diatoms. The brackish Skurcha Lake researchers found 119 species (59 diatoms), Inkit Lake - 98 (32), Big Ritsa Lake - 90 (44), Blue Lake - 40 (27) of 7-8 divisions. In rivers, the number of species is less: Kodor River - 35 species (27), Auadhara River - 31 (20) of 4 divisions; in small rivers and streams met 5-20 species. The caves found 40 species of 7 divisions.

Zooplankton. Zooplankton of water objects of Abkhazia is represented by 46 species (22 rotifers, 24 - crustaceans). The greatest number of species is found in lakes; rivers and lakes in caves are characterized by extremely low species abundance of zooplankton. Quantitative indicators of zooplankton are low. 27 species of zooplankton were identified in fresh lakes, in saline - 22. The greatest number of species was found in samples from the freshwater lake Mzy - 22 species, in other lakes there are 3-9 species. Among salt lakes, the most species were found in the Lake Scurcha (20).

The highest values of zooplankton abundance were recorded in freshwater lakes (up to 260 000 ex./m3 in Lake Big Ritsa) and in the salt Lake Inkit (14 000 ex./m3). In cave lakes and salt lakes, the abundance of zooplankton was extremely low. The biomass of zooplankton in most cases did not exceed 0.4 g/m3, while water objects tentatively belonged to the α-oligotrophic type. The highest biomass of zooplankton was recorded in freshwater lakes. Vertically, zooplankton is distributed unevenly. In the Lake Big Ritsa the highest density of zooplankton was observed in the epi- and metalimnion, and biomass in the epilimnion (0-4 m). In the lakes Small Ritsa and Amtkel the greatest density was in the hypolimnion. In the salt Lake Scurcha zooplankton is concentrated in the surface layers of water, which is associated with a deficit of oxygen (25-30%) in the water column and the presence of hydrogen sulphide.

Zoobenthos. In the species composition of the zoobenthos of the water bodies of Abkhazia 287 taxa (species) were identified, belonging to 3 types, 6 classes, 25 orders, 103 families and 187 genera. The occurrence of species in water bodies varies greatly. The greatest number of species is recorded in the littoral of lakes and rivers with a calm current. 88 species (32% of all known species) were identified in the water bodies of the Kodorosko-Skurchi system (Lake Skurcha, the Kodor River), which belong to 3 types, 6 classes, 19 orders, 48 families and 64 genera (Table 2).

Table 2 Taxonomic diversity of the zoobenthos

Water object	Types / Classes	Orders / Families	Genera / Species
River Codor	1/1	4/16	19/21
Lake Akuna	3/4	9/10	10/11
Lake Scurcha	3/6	13/29	40/55
Total	3/6	19/48	64/88

The variety of types of water bodies leads to

high biological diversity, rare species and endemic species are encountered. In the cave waters there are crustaceans Diacyclops bicuspidatus (Copepoda), endemic gammarus Niphargus alasonius, endemic freshwater shrimp Troglocaris anophthalamus (white in the absence of illumination). Crustaceans (amphipods), living in the mountain-plain rivers, provide a fodder base for ichthyofauna. In Abkhazia, there is an old fish farm for the reproduction of trout on the river Mchishta. This river has an underground channel, comes out from under the rock with a lot of suspensions, and here in mass numbers live the amphipods, which feed on fish.

Ichthyofauna. Ichthyofauna of water bodies of Abkhazia is represented by 23 species of fish for estuaries of rivers and 26 species for lakes. Most diverse the Cypriniformes order (13 species). The background species are *Alburnoides bipunctatus* and *Gambusia affinis*, often occur *Alburnus charusini*, *Leucaspius delineatus* and *Phoxinus phoxinus.* According to the confinement to the salinity regime in estuarine river areas and on lakes, freshwater species predominate (57% and 54%). By type of food, most species are identified as benthophags (52% in rivers and 46% in lakes). By the ratio of faunal groups, most species belong to the Ponto-Caspian freshwater complex. According to the indices of the species diversity, the highest values were obtained for the rivers Gudou, Pshap, Gumista, Bzyb, Mchishta, Maanikvara and Lake Skurcha. The most similar in species composition of ichthyocenosis are the Maanikvara, Kodor and Bzyb rivers, and lakes Akuna and Bebesiri (the coefficient of generality was 0.33).

4. DISCUSSION

Types of water bodies in Abkhazia are very diverse. Water objects are represented by mountain fresh-water karst and tectonic lakes; plains brackish-water lakes (lagoon); mountain and plain freshwater rivers, freshwater lakes and streams in karst caves, brackish streams. There are rivers with a double riverbed (surface and underground), disappearing in the rocks. The river Reprua is the shortest river in the world, its length on the surface is only 18 m, at the same time its main stream flows from the largest cave of the world - the cave Voron'a-Krubera about 2 km high. Many mountain lakes of Abkhazia are unique, they are the standards of clean waters of the planet. Of particular interest here are the cave lakes and their inhabitants.

A variety of types causes a variety of habitat conditions. In terms of chemical composition, the water bodies of Abkhazia are very diverse. Here, there are ultra-fresh waters with very little mineralization (Lake Bolshaya Ritsa, mountain lakes). Mountain rivers and mountain-plains predominantly belong to fresh water with a small mineralization. Plain rivers are characterized by waters of high mineralization. Plain lakes are brackish or saline.

A variety of types causes a variety of habitat conditions. In terms of chemical composition, the water bodies of Abkhazia are very diverse. Here, there are ultra-fresh waters with very little mineralization (Lake Bolshaya Ritsa, many mountain lakes). Mountain rivers and mountain-plains predominantly belong to fresh water with a small mineralization. Plain rivers are characterized by waters of high mineralization. Plain lakes are brackish or saline.

Of the great number of water bodies of Abkhazia (more than 5000), we studied 120 rivers, lakes and streams that correspond to certain types, including 40 major rivers in estuaries and the largest lakes. Based on these studies, a high biological and taxonomic diversity of rivers and lakes of Abkhazia was revealed: 256 species of microscopic algae, 46 - of zooplankton, 287 - of zoobenthos and 26 species of ichthyofauna. Many species are rare.

The rivers and lakes of Abkhazia are also experiencing anthropogenic impact, especially in cities in post-war conditions. Urban rivers are polluted by sewage. Plain small lakes and rivers are very vulnerable to anthropogenic impact, especially grazing and watering on them. To preserve the water bodies of Abkhazia, it is necessary to observe the regime of water protection zones, prohibit the grazing and watering of livestock on them, and constantly monitoring their condition. Mountain lakes of Ritsinsky National Park are actively used for recreational purposes, for them it is necessary to reduce the recreational load.

5. CONCLUSION

The Republic of Abkhazia is well provided with water resources, this is a strategic resource for the development of the country. The high diversity of types of water bodies in Abkhazia (the Caucasus) generates biological diversity, the presence of rare species. It is necessary to take measures to preserve the prosperous ecological state of rivers.

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O1-5

DNA Barcoding Reveal The Current Status Unevaluated Species Of *Rasbora Sp* (Cyprinidae) From Beratan Lake, Bali

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Keywords: Beratan Lake, Dna Barcoding, *Rasbora sp,*

ABSTRACT

One of the fish species that is a living resource found in Beratan lake is *Rasbora sp*. *Rasbora sp* contained in Beratan lake has unique characteristics that have not been much studied yet either morphometric or genetic. DNA barcoding can be used to determine the status of *Rasbora sp* contained in Beratan lake. From the results of the research, it is known that *Rasbora sp* species in Beratan lake is a complex species that cannot be clearly identified because the species is identical to the species *Rasbora lateristriata* and *Rasbora baliensis* based on barcoding DNA. The grouping of rasbora species based on their living areas also occurs due to geographic isolation such as waters, thus affecting the genetic diversity of *Rasbora sp* into low. In addition, data on conservation status, population trends and trade status of *Rasbora lateristriata* and *Rasbora baliensis* species are not available adequately. This data is important for the management of the species on *Rasbora sp* found in Beratan lake.

1. INTRODUCTION

One type of fish that is a biological resource in Beratan lake is *Rasbora sp*. This fish is an endemic species that can only be found in Beratan lake. This fish is alive and active in surface water and included in fish group active during the day (diurnal). Their living is by colony and never aloof, their habitat is commonly found living in clear water, where it is not too swift. These fish are often located near plants water[26]. To know the specific characteristics of this fish and its taxonomy, only done by Identification method, based on the morphological character of *Rasbora sp*[6].

Molecular identification with the deoxyribonucleic acid (DNA) barcoding technique can be used in the identification of an organism from species to subspecies accurately to a variety of species that are difficult to distinguish morphologically[35]. This technique is widely developed to identify species, because it is relatively easy to do comparison to other techniques[38]. DNA has an important role in taxonomy to identify and define species[34]. Mitochondrial DNA markers (mt DNA) is one of getting more attention, because of their potential to study species evolution, maternal inheritance and high mutation rates[2].COI gene of mitochondrial genome is a standard gene that is often used as a marker gene in animal identification[13]. COI gene is a COI Gene with two advantages. First, the universal primers of this gene are so solid that they are able to recognize the 5 'end of most animal groups. Second, COI gene has the highest molecular evolution compared to other mitochondrial genes, thus having low intraspecific variation, but interspecific high divergence between adjacent taxa[15].

A combination of phylogenetic systems with conservation genetics, provides an important framework for understanding diversity[11] and predicts the extent of fish exploitation[32]. The efficiency of this method depends on the degree of genetic divergence between species and intra-species level identification[37]. Therefore, barcode DNA is important for identifying fish species in conservation and biodiversity survey efforts, based on the diversity of sequences produced[14][24]. DNA barcoding also has an advantage on the higher accuracy of the results in identifying animal or fish species when compared with morphological observation identification technique. This has been successfully done on various types of marine and freshwater organisms[19][22][27][30].

Currently there is a decrease in the population of *Rasbora sp* in Beratan lake. This is caused by several factors such as habitat destruction and changes in lake waters quality, overfishing, and introduction of other fish species from outside Beratan lake such as the introduction of Zebra fish[31]. Understanding the existing fish species in a region is the first step in conserving aquatic biodiversity and promoting a sustainable fishery concept. The goal of the study is to use a DNA barcode approach to identifying The Current status of *Rasbora sp* based on mitochondrial DNA (COI)

2. METHOD

A total of 48 *Rasbora sp* specimens were collected in the Beratan lake in june - july 2017. fish caught using gill nets and fish traps (bubu) captured in waters of Beratan lake

Observations were made on several key factors the fish's body. Based on the modification of Jordan[12] there are 15 morphometric characters observed in fish, among others: total length (TL), standart length (SL), forked length (FL), Pre dorsal length (PDL), Pre pectoral length (PPL), Pre pelvic length (PVL), pre anal length (PAL), eye diameters (ED), dorsal length (DL), Pectoral length (PL), Pelvic length (PLL), anal length (AL), caudal length (CL) , Body depth (BD), head length (HL). Morphometrics characteristic compared with data from www.fishbase.org [7]. and analysed the similarity by PAST 3.1 software based on bray curtis index.

For barcoding analysis, 1gram of fish muscle tissue was taken using sterile scissors to avoid the contamination. The tissue is placed on a 2 ml tube and preserved using 96% ethanol until the dna extraction process. The dna samples extraction was performed by using chelex method[36]

Samples were amplified at COI (Cythochrom Oxydase Sub Unit I) locus using PCR (Polymerase Chain Reaction) method[28] Mixed reagents used in the PCR process for each sample and the PCR process is carried out with temperature optimization. The successfully amplified product was then sent to the UC Berkeley sequencing facility for the sequence read from the sample. The sequencing method used is the Sanger method

The basic sequence of DNA sequencing results is verified by the similarity to the COI skuen present in the gene bank (http: //blast.ncbi.nlm.nih.-gov) using the Basic Local Alignment Search Tool (BLAST) method[25] (NCBI). The sequencing results were then aligned using Clustal W to determine whether the homologous sequence results with others. Phylogenetic trees were made using MEGA 6 software, with neighbor-joining based on Kimura2 Parameters method and bootstrap 1000 replication[29]. Phylogenetic trees were used to see the kinship of *rasbora sp*.

A review of the conservation status and population trend of each species was determined using IUCN (International Union for Conservation of Nature and Natural Resources) [10]. The trade status of identified species was determined using CITES (Convention on International Trade in Endangered Species).

3. RESULTS AND DISCUSSION

3.1 Morphometric analysis

Measurement results of morphometric characters on *Rasbora sp* contained in the Beratan lake are made in percentage of head length and standard length compared with the morphometric character of two species of rasbora species found at www.fishbase.org that is *Rasbora baliensis* and *Rasbora lateristriata*.

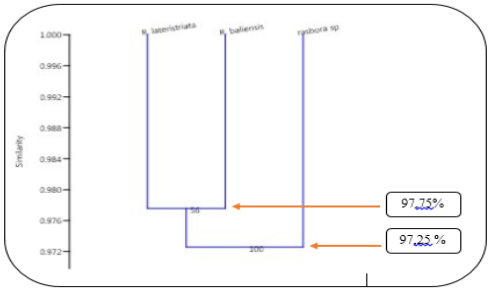

Fig 1. Dendogram Similarity Of *Rasbora Sp* With *Rasbora Lateristriata* And *Rasbora baliensis* Based On Morphometric Characters

The morphometric character values are then grouped based on similarity of morphometric characters using UPGMA clustering analysis in PAST 3.1 software based on Curtis bray index. From the grouping results based on the similarity of morphometric characteristics, it is found that *Rasbora sp* in the Beratan lake forming a group of isolated and non-clumped species to one species, both in *Rasbora lateristriata* species and *Rasbora baliensis*. From the analysis results obtained that morphometric character, *Rasbora* sp in Beratan lake has 97.02% similarity level to *Rasbora lateristriata* and 97.4% to *Rasbora baliensis*. For *Rasbora baliensis* and *Rasbora lateristriata* themselves have a similarity of 97.7% (figure 1). although clustering of *Rasbora sp* in Beratan lake is not clustered to *Rasbora lateristriata* or *Rasbora baliensis*, but the morfometric value of *Rasbora sp* in Beratan lake is relatively closer to *Rasbora baliensis*.

3.2 Barcoding Analysis

Application PCR gene COI by using JGLCO Primer and JGHCO primer successfully performed well. Phylogenic analysis and genetic distances were performed using COI gene scuens from *Rasbora sp* samples in Beratan lake and some sequences of data from GenBank [3][17][19]. Genetic distance analysis was performed using the neighbour joining tree method based on Kimura 2 Parameter (K2P) Analysis with bootstrapping 1000x replication. The phylogenetic tree is a method to determine the rate of evolution and kinship of a species. The phylogeny tree shows that the *Rasbora sp* squen in the Beratan lake forms a large clade with the *Rasbora lateristriata* and *Rasbora baliensis* scuen found on Bali Island with a bootstrap value of 56%. While the *Rasbora lateristriata* and *Rasbora baliensis* squen form a separate clade according to the area in which the sample was found, including clade *Rasbora lateristriata* from Eastern Java, clade *Rasbora baliensis* from eastern Java clade *Rasbora lateristriata* from central java and *Rasbora agyrotaenia.*

The mean genetic distance between *Rasbora sp* scores in the lake was associated with the *Rasbora lateristriata* and *Rasbora baliensis* scores found in the bank gene is 2.41%.

This value indicates that from the length of 650 bp squence there are 16 different nucleotides between the squences. Genetic distance is one indication of an individual with another individual having close or distant kinship relationship

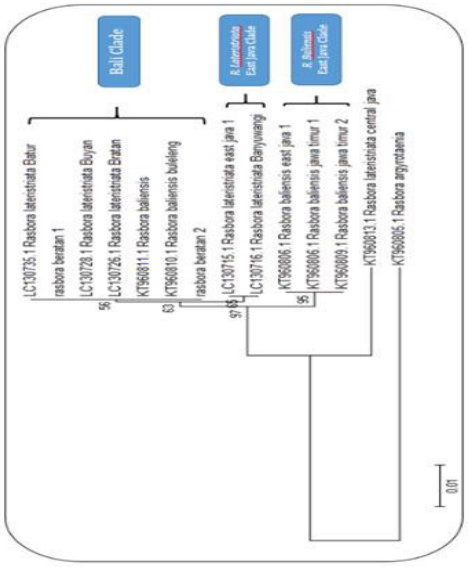

Fig. 4. Neighbor-Joining Tree Of *Rasbora Sp* In Beratan Lake Based On Kimura 2 Parameter With Bootstrap1000 Replication

. The result of the genetic distance analysis found that the closest genetic distance is known between the squamous species of *Rasbora sp* in the Beratan lake with *Rasbora baliensis* KT960811.1, *Rasbora lateristriata* Batur LC130735.1, *Rasbora lateristriata* Buyan LC130728 and *Rasbora lateristriata* Bratan LC130726.1 with a value of 0%. This is consistent statement that genetic distance is based on COI gene sequences with values more than 0.02 is classified into different species[37].

The value of haplotype diversity (Hd) of *Rasbora sp* scores found in Beratan lake is found to be 0, this means that the value of haplotype diversity *Rasbora sp* in Beratan lake is in very low. When compared to some other freshwater fish species such as *catla catla, Pelteobagrus fulvidraco* and *Channa striata*, this Hd value *Rasbora sp* in Beratan lake is the lowest [4] [8] [20]. The results of this analysis indicate that the classification of a species based on genetics can occur due to the influence of isolation from each geographical state. In addition, geographic isolation in waters in a particular region will also affect the genetic diversity of the species living in it. Isolation of the geographic region will cause the species to have a smaller migration opportunity which results in a low chance of crossing this species with other species or strains outside the region[1].

3.3 Status Conservation, Population Trends and Trade Status

The status of Conservation and Population trends by IUCN as well as trading status by CITES. Based on the IUCN category the species of asboras studied are categorized as vulnerable and not evaluated. Population trends of both species of rasboras are also unknown. In addition, all the species identified in this study have not been evaluated by CITES to know its status. Lack of data contained in the IUCN and CITES will certainly have implications for fish management in Beratan lake especially for species *Rasbora sp* considering this fish spesies is one of the species that are targeted by fishermen catching fish in Beratan lake. Basic information on the genetic variations resulting from this study will be useful for devising an effective strategy for the conservation and rehabilitation of this endangered species of rasbora sp.

4. CONCLUSION

Morphometric analysis, phylogenetic trees and genetic distance from all samples of *Rasbora sp* in Beratan lake indicate that this species is still a very complex species to be clearly identified both morphologically and genetically whether the species can be grouped into species *Rasbora laterisetriata* or *Rasbora baliensis*.

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O1-6

Development of Specific Markers for Monitoring Distribution of Spotted Barb (*Barbodes binotatus*) using eDNA Analysis

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Keywords: eDNA, spotted barb, specific primer design, fish distribution

ABSTRACT

Indonesia has numerous lakes and rivers inhabited by many native and endemic fishes. It has been reported that many of Indonesian native fishes are declining because of overexploitation, habitat degradation, and pollution. Better management and conservation of Indonesian fish resources are needed for the sustainable utilization of the fishes. However, long term monitoring using traditional methods is time consuming and laborious. Currently, the environmental DNA (eDNA) approaches have been proposed as alternative tools to detect and monitor species in aquatic ecosystems. Primer design and test is an important step when targeting a particular species. The study aimed to develop specific primers for monitoring distribution of spotted barb in of Lake Maninjau and Lake Toba using eDNA approach. In this study, the design primers were tested in silico and in vitro. Our designed primer seemed to be specific for *B. binotatus* from Lake Maninjau and Lake Toba. However, further test should be conducted to increase the specificity of the primers. Moreover, newly designed primers will be developed from another segment of mitochondrial DNA.

1. INTRODUCTION

Indonesia has numerous lakes and rivers inhabited by many native and endemic fishes. The total number of freshwater fishes in Indonesia is approximately 1218, including 630 endemic species [1]. According to published reports, some of Indonesian native fishes are threatened to become extinct, due to overfishing and other human activities such as habitat degradation and water pollution. Some population of consumed native fishes that live in the lakes in Sumatera such as Lake Toba and Maninjau and the rivers surround are declining in the wild and becoming rare in the local market [2].

Management and conservation efforts which include biota and habitat management are important to achieve sustainable utilization of fish resources. Long-term monitoring is required to asses fish distribution and abundance. However, the conventional methods for such monitoring are costly and labour intensive [3–5]. Moreover, the conventional monitoring requires people with taxonomic knowledge that can identify fish morphology and the sampling procedure can be invasive on species or ecosystem [6].

Currently, analysis of environmental DNA (eDNA) can be used to monitor fish species by detecting their DNA in water samples. Fishes discard slimes, scales, epidermal cells, and faeces, which contains DNA that remains preserved in water for a certain time [7]. Many studies on fish have conducted eDNA analysis in the river and lake [8–10]. These studies show that the eDNA has higher detection power and lower cost compared to the conventional methods and therefore it allows more effective population management program.

A barcode sequence which is specific to the species should be determined for fish identification and recognizing eDNA signal from the water sample. Primer design and test is an important step when targeting a particular species. The primers can be designed by eye or using a software. The designed primers should be tested for their specificity bioinformatically or in silico and in vitro [6]. The in silico test is conducted by subjecting the designed primers to a software and see if the primers bind only to the target or also to non-target [6]. The in vitro test is performed by testing the primers against the extracted DNA of fish tissue[6].

2. METHOD

Spotted barb was selected as the target fish because the fish is economically valuable for the local people in West and North Sumatra, nevertheless spotted barb population in Lake Maninjau and Lake Toba is declining. Moreover, spotted barb lives in clear water, their presence and absence may relate to environmental changes due to

anthropogenic activities. Tissue samples of *Barbodes binotatus* were obtained from two lakes (Lake Maninjau in West Sumatra and Lake Toba in North Sumatra) and the rivers surrounding them, and preserved in 96% ethanol. The specimens were photographed, labelled and fixated in 4% formaldehyde followed by preservation in 70% ethanol for morphological identification. The morphological characterization was conducted in the Research Center for Biology-Zoology Department LIPI.

DNA extraction was conducted from the muscle tissue or fin following the procedure for purification of mammalian and rodentia (GeneJet Thermo Fisher Scientific). Total DNA concentration of different samples was measured by Thermo Scientific NanoDropTMOne. A 650 bp barcode region of Cytochrome Oxidase 1 (CO1) was amplified following[11,12] and performed using C1000 Thermal Cycler (Biorad). The primers used are Fish F1: TCAACCAACCACAAAGACATTGGCAC (forward) and Fish R1: TAGACTTCTGGGTGGCCAAAGAATCA (reverse)[12,13].

The PCR products were run on 1.5% agarose gel for 20 minutes and then visualized using Gel Doc imager (Bio-Rad). The amplicons were bidirectionally sequenced in 1st BASE Pte ltd, Malaysia. The sequencing results and sequences obtained from Genbank were aligned using SeaView to develop specific primers for *B. binotatus*. The specific primers were tested in silico by submitting the specific primers in Primer Blast NCBI and in vitro by PCR using templates from target and non-target species. The annealing temperature for the specific primers was adjusted using Tm calculator (ThermoFisher scientific). The non-target templates were species which are closely related and those potentially lived in the study field. The target samples from Lake Maninjau and Lake Toba were coded with SU and P, respectively. Non target samples were *Barbodes gonionotus* (TA1), *Barbonymus schwanenfeldii* (TK1), *Barbonymus balleroides* (LA1), *Tor* sp. (GA1), *Osteochilus waandersii* (L1-5), and *Neolissochilus* sp.(I1). Positive result of the specific primers was indicated by visible DNA band in a particular size.

3. RESULTS AND DISCUSSION

The combination of designed specific primers (Table 1) amplified 147 nt COI segment of *B. binotatus*. The *in silico* test showed that the primers combination of 150F.1 and 297R may hit one species of non-target fish with some mismatches pair, two mismatches in the forward region and one mismatch in the reverse region.

Table 1 Designed specific primers

No.	Name of primers	Sequence (5'-3')
1	150F.1 (forward)	GCCGCTAATGATTGGGGCYC
2	297R (reverse)	GGGCCAGGTTACCCGCG

We continued the test to amplify the target and non-target sequences using primers 150F.1-297R with annealing temperature of 58^{0}C. A visible band was detected in non-target fish (*Osteochilus waandersii,* well no. 11) (Fig 4A). Similar result was shown when the test was repeated with annealing temperature increased by 60^{0}C (Figure is not shown).

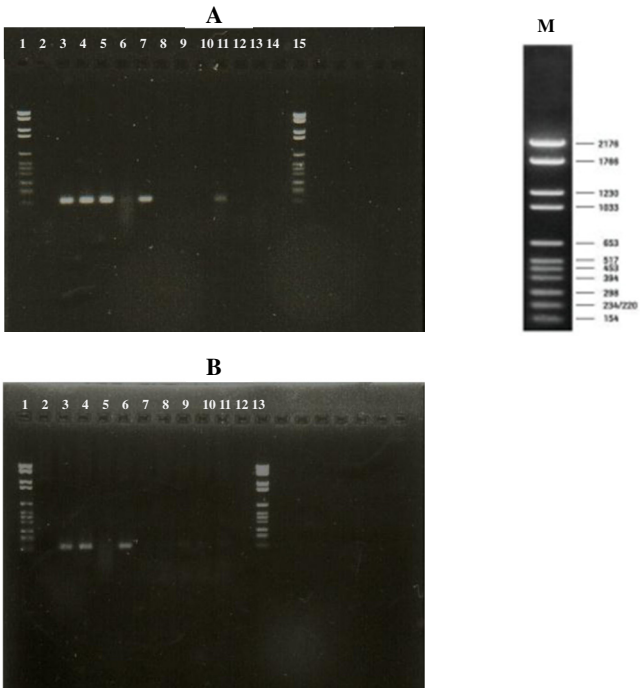

Fig 1. Amplification of target and non target gene by primer pair 150F.1-297R. A: 1= marker, 2= negative control (PCR reagents without DNA template), 3= SU1, 4= SU2, 5= SU4, 6= P7, 7= P10, 8= TA1, 9= TK1, 10= LA1, 11= GA1, 12= L1, 13= I1, 14= Negative control, 15= marker. B: 1= Marker, 2= negative control, 3=SU1, 4= P10, 5= P8, 6= P14, 7= L1, 8= L2, 9= L3, 10= L4, 11= L5,12= negative control, 13= marker.

There should be no visible band detected in *O. waandersii* template because *O. waandersii* and *B. binotatus* are not closely related. A contamination might happen during sample preparation before amplification in the PCR machine. Therefore, we repeated the test and included all individual samples of *O. waandersii*. The

result showed visible bands in the target templates and none in samples L1 (the one used previously in Fig 4A) and L2. However, three samples of *O. waandersii* (L3-L5) exhibited very faint bands. It was posible that the faint bands are artifacts from the primer dimers.

Target templates of P7 (Fig 4A) and P8 (Fig 4B) did not show any detected DNA bands. When analyzed using phylogenetic tree, P7 and P8 were not in the same group with other target samples (figure will be shown during the conference). That could explain why the two samples were not amplified. Further analysis should be conducted for the two samples whether there was a contamination during the pre PCR step or misidentification in the morphology.

4. CONCLUSION

Our designed primer seemed to be specific for *B. binotatus* from Lake Maninjau and Lake Toba. However, further test should be conducted to increase the specificity of the primers, such as optimizing the annealing temperature and to include the positive control which is samples of *B. binotatus* DNA template from Java. Furthermore, newly designed primers will be developed from another segment of mitochondrial gene such as cytochrome b.

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O1-7

Predicting climate change impact on zooplankton community structure based on thermally polluted lakes

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Keywords: biodiversity, COI, *Daphnia*, global warming, heated lakes

ABSTRACT

Thermal pollution of freshwater basins is an increasing problem related to power plants activity. Change in thermal regime of lakes can have far-reaching negative consequences as a source of environmental disturbance, posing a risk of local extinctions and supporting establishment of invasive species. On the other hand, heated lakes and reservoirs can be used as a large scale experiment for testing global warming related predictions. In order to address the question, how increased temperature will impact genetic diversity and structure of local community, we used a system of five lakes heated by lignite combusting power plant in Poland. Due to warm water discharge these lakes are ca. 3-4°C warmer than non-heated control lakes nearby. We checked how five decades of temperature elevation affected genetic diversity of *Daphnia* community, and compared genetic structure of *Daphnia* community inhabiting heated lakes with control lakes community. Furthermore, we genotyped resting eggs extracted from sediments, produced by *Daphnia* in heated lake before warm water discharge and afterwards, to check how the community changed through the time after temperature elevation. Collected data provide an evidence for significant impact of thermal regime on structure and genetic diversity of local *Daphnia* community. Adaptation to climate warming will likely induce such changes in lake communities worldwide, as they might be inevitable for community functioning in new environmental conditions.

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1. INTRODUCTION

Currently, one of the most concerning issues in ecology and environmental protection is global warming. According to Intergovernmental Panel on Climate Change the average Earth's temperature is now ca. 0.8°C higher comparing to the beginning of XX century, and it is expected to be even 3-4°C warmer[1]. Such changes in environmental conditions are expected to cause drastic alterations in biocenoses all over the world, including shifts in phenology, migrations, biological invasions and extinctions[2–4]. However, current approaches in studying responses of organisms to future climate change are limited, as they either rely on investigation of habitats in different climate zones, historical records covering only about 0.5°C difference, or experimental surveys of one up to several species with relatively short-term temperature elevation. Therefore, the question of how species will respond to global warming remains open.

Here, we use lakes heated by power plant and warmed up in significant rate as a simulation of climate change scenario. We investigated genetic structure of *Daphnia* community in heated lakes and compared it to the control (non-heated) lakes population, to check whether increase in temperature triggers any significant change in *Daphnia* community structure and biodiversity of heated lakes.

2. METHODS

Five heated (Goslawskie, Patnowskie, Lichenskie, Mikorzynskie and Slesinskie) and four control lakes (Goplo, Skulskie, Skulska Wies, Budzislawskie) were investigated for 3 years (2014-2016) in monthly intervals. *Daphnia* samples were collected and physical-chemical parameters (temperature, oxygen concentration, TDS, conductivity, pH, secchi disc visibility) were monitored at the same time. *Daphnia* were collected with plankton net (100µm) in lakes deepest part, and preserved in ethanol 96%. DNA of some of the collected *Daphnia* was isolated using DNeasy Blood & Tissue Kit (Qiagen) and daphnids from heated and control lakes were genotyped on Cytochrome C oxidase subunit I (COI) barcode. Obtained sequences were analyzed by constructing phylogenetic tree using Neighbor-Joining method. For reference, we used several sequences of COI of *Daphnia galeata* (G.O. Sars, 1864), *D. longispina* (O.F. Müller, 1776) and *D. cucullata* (G.O. Sars, 1862) published in NCBI GenBank.

Furthermore, we obtained sediments from heated Mikorzynskie lake, conducted the dating with Cs137 isotope and isolated resting eggs of *Daphnia* from layers representing past *Daphnia* community in the lake. We counted and measured ephippia (structure covering resting eggs) and genotyped resting eggs using 16 microsatellite markers. We further analyzed genetic data with DAPC analysis.–

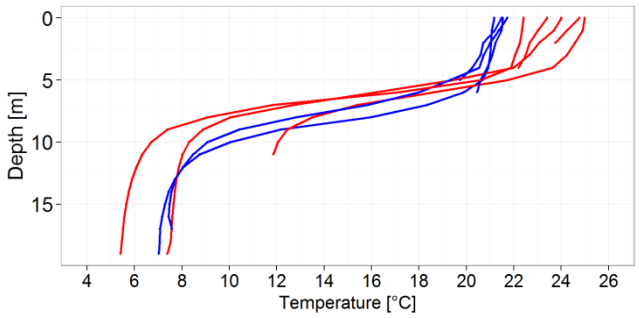

Fig. 1 Temperature of heated (red lines) and control (blue lines) lakes measured every meter from the surface to 20m depth. Lines represent summer average for 3 years when measurements were conducted.

3. RESULTS

The temperature measurements revealed strong difference in thermal conditions between heated and control lakes, especially in epilimnion. Heated lakes are 1-4°C warmer either in entire water column or in epilimnion zone, depending on whether they are stratified or not (Fig. 1). Such rate of temperature increase corresponds to what is

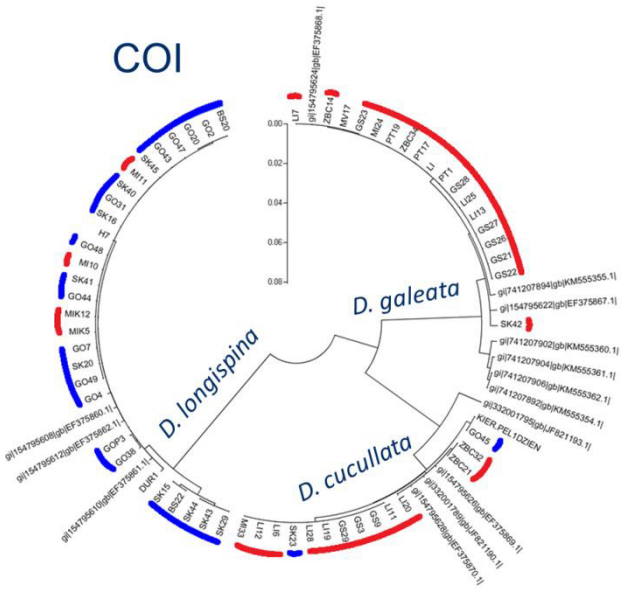

Fig. 2 Phylogenetic tree of COI sequences, constructed with Neighbor-Joining method. Red lines indicate clones from heated lakes, blue lines indicate clones from control lakes. Species name indicated on each branch is based on reference genotypes from NCBI GenBank.

expected in next 100 years by IPCC[1].

Phylogenetic tree showed significant difference in community structure of zooplankton. In heated lakes we detected mostly *Daphnia galeata and D. cucullata*, whereas in control lakes there was mainly *D. longispina* (Fig. 2).

Fossil data also showed significant alteration in heated lake after warm water discharge.

4. DISCUSSION

Clear difference in epilimnion temperature corresponds with what is expected as a result of climate change[2]. Therefore, we assume the system of heated lakes is a good model for investigation of climate change in freshwater ecosystems. The rate of temperature difference is similar to what scientists use in artificial experiments [5–7], but the size of the experiment in case of heated lakes is spanned onto entire ecosystem. Moreover, the duration of temperature increase is way longer than what any experiment reached so far, and selection conditions for organisms are more natural.

Genetic analyses of *Daphnia* community indicate that temperature increase triggered selection on *Daphnia* and caused shifts in species composition. It is known, that *D. galeata* is more pronounced on the south of the Alps, whereas *D. longispina* (former *D. hyalina*) occurs more frequently in northern Europe[8].

Daphnia from heated lakes are also significantly larger and cope way better in presence of filamentous

cyanobacteria[9], which indicates, that thermal selection and change in community composition of *Daphnia* in heated lakes was adaptive. It has former been confirmed, that long-term exposition to elevated temperature triggers selection and adaptation to elevated temperature[6,7,10]. It is also known, that such adaptation requires former change in population/community genetic structure[5,11,12]. Moreover, it has been observed that due to change in thermal regime local communities might undergo significant change in species structure[13]. Therefore we claim that European lakes undergoing global warming might become dominated by *Daphnia galeata*, which takes advantage over *D. longispina* in warmer environment.

5. CONCLUSION

Our study confirms significant impact of temperature increase on structure of freshwater communities. We conclude, that further temperature elevation will cause shifts in European *Daphnia* communities towards domination of *D. galeata* and small *D. cucullata*, whereas occurrence *D. longispina* might be limited. Alterations in community structure due to change in temperature regime are also confirmed by fossil data.

Climate change is a phenomenon that currently acquires a lot of attention. Ecological hazard that temperature increase is expected to pose is investigated with various approaches, but all of them have some important limitations. Here we show that aquatic ecosystems altered by power plants might be useful climate-change simulation in entire ecosystem. The temperature increase in investigated heated lakes corresponds to climate change forecasts and the character of response of *Daphnia* community to higher temperature looks reliable in comparison to former experimental studies.

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O1-8

Zooplankton abundance and biomass size spectra in shallow urban lakes : Analysis using laser optical plankton counter

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Keywords: Zooplankton size spectra, urban lakes, Laser Optical Plankton Counter, NBSS

ABSTRACT

A laser optical plankton counter was used to examine zooplankton size structure in seven urban lakes across the Swan Coastal Plain (SCP), Western Australia. Based on the zooplankton abundance and biomass of equivalent spherical diameter ESD in 32 bins for every 0.1 mm between 0.3 and 2.5 mm, zooplankton normalised biomass size spectra (nbss) were constructed to display community structure. Nbss parameters slope and intercepts were used to classify the zooplankton community size spectra. Zooplankton size distribution varies across the lakes. Based the LOPC measurement, small-sized zooplankton (<1.0 mm ESD) was dominant in most lakes which contributed to >50% of the total abundance. However, the contribution of large-sized zooplankton (1 – 2.5 mm ESD) toward total biomass was significant in Lake Yangebup, Little Rush, Bibra and Herdsman Lake. Small-sized zooplankton (0.3-1.0 mm ESD) biomass, on the other hand, was evident in Lake Monger, Joondalup and Yonderup. A Bray-Curtis Analysis using the nbss parameters classified the zooplankton communities into three groups. A group with a lower slope was observed only for Lake Yonderup (slope= –0.471) which indicates the dominance of small-sized zooplankton. Lower slope was caused by the dominant of small copepod (0.5-1.0 mm ESD) which contribute to >80% of the total biomass. Group 2 and group 3 have a steeper slope closer to the theoretical value of -1 which indicate a significant contribution of large-sized zooplankton toward total biomass. >50% of the total biomass was constructed by larger-sized zooplankton (1.0–2.5mm ESD) for this group.

1. INTRODUCTION

Zooplankton are key ecological indicator in aquatic ecosystems because of their quick response to environmental changes such as land-use, water quality, nutrient concentration `[1], and hydrological regimes [2, 3]. They are also key elements in the aquatic food webs and trophic structure as they respond to phytoplankton community and fish predation [4]. Planktonic communities may include a variety of taxonomic and functional group. Zooplankton abundance and biomass, for example, often scale with body size, with smaller-sized generally more abundant than larger size and biomass generally increased with size ([5].

A shift in the size structure of zooplankton community may indicate the changes in the functioning of the lake. As such, the size structure of zooplankton community can be used to display community structure and trophic interaction as a response to both bottom-up and top-down factors [6]. Normalised biomass size spectra (nbss) is a measure of total abundance or biomass in logarithmically equal of each size classes. Nbss approach has been widely used to describe planktonic community structure in marine and lakes ecosystem while the nbss parameters (slope and intercepts of the nbss) are used to classify zooplankton community and their response to environmental variables [7, 8].

Studies on zooplankton size structure in urban lakes are rare [9]. In particular, little attention has been paid to the zooplankton community structure in lakes within the Swan Coastal Plains (SCP) areas in Western Australia, although the ecological importance of the habitats is recognised [10]. The SCP is an important bioregion in Western Australia situated at the foot of the Darling Ranges facing the Indian Ocean in the South-West of Western Australia with two main waterways, the Swan and the Canning Rivers. The wetlands of the SCP support a diverse range of terrestrial and aquatic biota. However, growing urban, agricultural and industrial development over the past century has significantly reduced the number of wetlands that once existed on the SCP. Less than 25% of the remaining wetland continues to face direct threats due to urbanisation and indirect threats through land clearing and nutrient enrichment and pollutant contamination.

This study aimed to examine the spatial distribution of the zooplankton size spectra (abundance and biomass) in seven urban lakes across the Swan Coastal Plain. A laser optical plankton counter was used to extract zooplankton abundance and biomass data and size spectra information. Normalised biomass size spectra approach was used to display zooplankton community structure, and nbss parameters (slope and intercept) were used to classify the zooplankton size spectra.

2. METHOD

Zooplankton samples were collected from six lakes across the Swan Coastal Plain, Western Australia by horizontal tow using a 56 um mesh net with a mouth of 25 cm diameter from a 3-meter distance at a constant speed of ~0.5 $m.s^{-1}$. Size composition was classified into five size fractions, 0.3 – 0.5 mm, 0.5 – 0.75 mm, 0.75 – 1.0 mm, 1.0 – 1.5 mm, and 1.5–2.5 mm Equivalent Spherical Diameter (ESD). Although the LOPC measures zooplankton from 0.1 to 3.5 mm ESD, we analysed abundance and biomass only

for zooplankton size range between 0.3 and 2.5 mm ESD. We used these size range as we found that air bubbles in the lab circulator LOPC prevented accurate counts for particle size >0.3mm and extremely low density for zooplankton larger than 0.25mm ESD. The zooplankton within size range 0.3 – 2.5 mm includes small copepod and larger cladocerans, but may not include microzooplankton, such as copepod nauplii and rotifers, and larger-sized zooplankton such as *Mysis* and *Leptodora* [11].

The size spectrum of zooplankton display a measure of total abundance or biomass in the logarithmically equal interval of body size [12]. The normalised biomass size spectrum (nbss) plots the normalised biomass of the zooplankton community against the log-biomass of the zooplankton in each size classes. The slopes and intercepts of the nbss regression lines are then compared between lakes using one-way ANOVA test for multiple comparisons followed by applying Fisher's LSD post hoc test to identify differences within each pair of slopes. The nbss was organised for zooplankton within the range of 0.3 – 2.5 mm ESD.

3. RESULT

The <0.5 mm size fraction was composed of small cladocerans such as juvenile cladocerans and ceriodaphnia, and copepodite of both calanoid and cyclopoid groups. The >0.5mm was mainly composed of large cladocerans and adult calanoid. Large cladocerans were represented by *Daphnia carinata* and *Daphnia lumholtzhi.* The small-size fractions (0.15–0.3 mm ESD) were mainly composed of rotifers and small copepodid and nauplii and were excluded from the analysis due to coincident count by the LOPC.

Zooplankton size distribution shows similarity for all sampling site where the abundance peak was observed for the 0.3–0.5 mm size classes. The abundance of the 0.3–0.5 mm size fraction represented, on average, 40–80% of the total zooplankton abundance Larger-sized zooplankton (>1.0mm ESD fraction) represented, on average, 1–12% of the total zooplankton abundance.

Zooplankton biomass ranged from 2.26 mg.L^{-1} (Lake Joondalup) to 16.20 mg.L^{-1} (Lake Yangebup). Larger-sized zooplankton (size 0.10–0.25mm ESD) represented a significant contribution toward total biomass in Lake Yangebup, Little Rush, Bibra and Herdsman. Size 0.10–0.25mm ESD accounted for > 50% of the total biomass in these lakes (Fig.1). The figure was slightly different for Lake Monger, Joondalup and Yonderup where larger-sized contributed less than 25% to the total biomass.

The normalised biomass size spectra (nbss) parameters (slope and intercept) showed significant linearity in all sampling sites (One-way ANOVA, $p<0.05$, r2 = 0.63 to 0.84) except for Lake Yonderup which indicates an increased biomass with size. The nbss for lake Yonderup showed weak linearity ($r^2 = 0.30$) with higher intercept and lower slope which corresponded to a lower proportion of large-sized zooplankton towards biomass. The slope value in all sampling sites combined ranged from -0.47 to -1.02 with the intercept ranged from 1.6 to 3.22.

Cluster analysis based on nbss parameter classified, the lakes into three groups (Figure 2). Group 1 represents Lake Yonderup; group 2 represents Lake Joondalup, Bibra, Monger and Lake Little Rush; group 3 represents Lake Yangebup and Lake Herdsman. Group 1 represented lake within low urban density area. Lake Yonderup situated in the national park with relatively low urban density. Group 2 and 3, on the other hand, are situated within the highly urbanised area, thus higher urban stressor (e.g. nutrient loading).

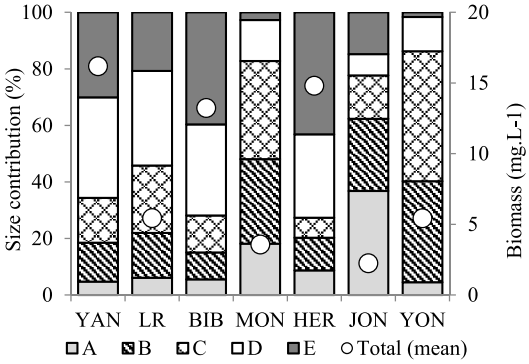

Fig. 1 Mean total biomass and the relative contribution of each size classes toward total biomass in all sampling sites (A=0.3–0.5mm ESD; B=0.5–0.75mm; C=0.75–1.0mm; D=1.0–1.5mm; E=1.5–2.5mm ESD)

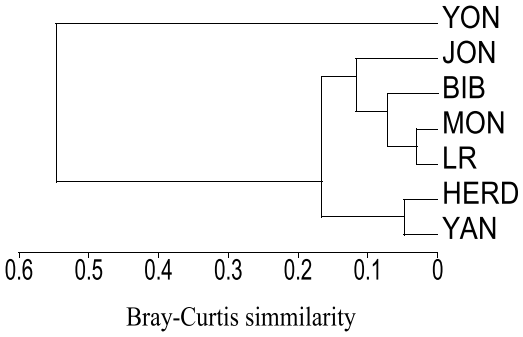

Fig. 2 Bray-Curtis cluster analysis by nbss slopes and intercepts

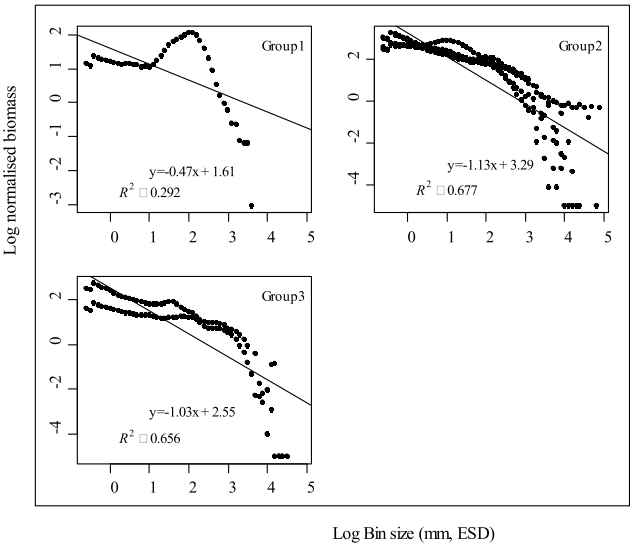

Fig. 3 Normalised biomass size spectra in different lakes. Group 1, Yonderup Lake; Group 2, Lake Joondalup, Bibra, Monger and Little Rush; Group 3, Herdsman and Yangebup.

4. DISCUSSION

Zooplankton nbss variation can be used to display zooplankton community structure in urban lakes. A relatively flat slope (more negative) reflect the higher contribution of larger-sized organisms toward biomass and the increased biomass with size. The intercept of the nbss reflects the abundance of organisms and the ecosystem productivity. Higher intercept correspondence with higher organisms abundance and productivity [13]. Zooplankton size spectra in the SCP lakes and wetlands showed distinct spatial patterns. Group 1 was observed only in a lake in the area of the north of Perth Metropolitan areas located in the national park and characterised by low productivity and relatively low nutrient input. Group 2 and 3 are urban lakes situated in highly urbanised areas characterised by high nutrient content.

The slope of the nbss for group 2 and 3 (–1.03 and –1.13) were within the similar result with the previous study on zooplankton size spectra analysis in a freshwater ecosystems. Sprules and Munawar [14] found the slope of –0.90 to –1.03 for inland water while Gaedke [15] revealed nbss slope of –0.94 to –1.16 for Lake Constance.

Higher intercept value in group 2 and 3 indicating higher zooplankton abundance and productivity there. This was corresponded with a higher values of Chlorophyll a (35.56 to 53 $mg.L^{-1}$ during summer). The high proportion of the small-size fraction and its contribution toward total biomass in Lake Yonderup indicate that the zooplankton community in this lakes is characterised by small-sized zooplankton.

Zooplankton BSS variation in different lakes indicates that the different bottom-up and top-down factors could regulate the zooplankton differently. Eutrophic water could support high phytoplankton production and may interfere with zooplankton filter feeding ability which coincides with the absence of large filter feeding zooplankton such as Daphnia [16]. High concentration of surface Chlo-a in Lake Monger, Yangebup, Little Rush, and Lake Bibra were observed in field investigation and by the study of Sinang, et al. [17]. High nutrient input can support high phytoplankton production and abundance and even induce phytoplankton bloom and affect the size structure of zooplankton.

5. CONCLUSION

From this analysis, we can display zooplankton community structure based on the composition of each size classes and the corresponding biomass. Through the LOPC analysis, the zooplankton size spectra in urban lakes in The Swan Coastal Plain were separated into 3 groups. One group has a lower slope (–0.47) which caused by the dominant of small-sized contribution towards total biomass. Two groups have a steeper slope (–1.03 and –1.13) which were close to the theoretical value (–1) caused by the dominance of large-sized zooplankton contribution towards total biomass.

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O1-9

Zooplankton in Assessing of the Water Quality in Urban Areas

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Keywords: zooplankton, urban territories, water ecosystem, water quality

ABSTRACT

The results of studying the zooplankton communities of various water bodies located in the urbanized areas of the Middle Volga Region (Russia) are presented. The aim of the research was to assess biodiversity, characterize the structure of zooplankton communities and identify the factors that have the greatest impact on zooplankton. The studied reservoirs were divided into 4 groups: lakes located in floodplains of rivers and urban forest parks; small shallow-water lakes in residential micro-districts; ponds located on rivers flowing through the city and careers on rivers; small shallow-water lakes where rehabilitation measures were carried out. As a result of the studies, 180 species of zooplankton were identified. The greatest number of species was in lakes located in parks and in residential areas. It has been established that in urbanized areas, pollution and eutrophication processes have the greatest negative impact on zooplankton communities. Negative correlations of quantitative indices of taxonomic groups of zooplankton with water content of copper, iron, manganese, lead, zinc, permanganate oxidation were revealed.

1. INTRODUCTION

The ecological consequences of economic anthropogenic activity are most pronounced in urbanized areas. Anthropogenic impact on water objects of urban areas is very diverse. Small lakes and ponds are a special type of aquatic ecosystem, differ in many respects from large systems such as reservoirs and large lakes. As habitats of hydrobionts, they are more susceptible to weather and various anthropogenic factors, including those related to the nature of land use. A distinctive feature of lakes located in urbanized areas is their involvement in the urban environment. Due to the peculiarities of the hydrological characteristics, such as low depth, absence of stratification, an unpredictable regime of mixing and rapid response to changes in environmental conditions are typical for small lakes[1]. However, they play a vital role in preserving the biodiversity of aquatic organisms within highly transformed urban areas. They often maintain a higher biodiversity of aquatic invertebrates than, for example, in rivers[2, 3]. In this sense, the importance of small lakes in urban areas has not been adequately studied, since they can have high local species richness, contain rare and endemic species not found in other lakes and rivers, and also contribute to regional differences, due to their high variability over time and space[4]. These features of urban lakes are important to know when developing a strategy for managing water resources in cities. In addition, such studies are necessary to understand the impact of anthropogenic impact of various species on aquatic ecosystems in general and on the state of aquatic communities in particular. Small shallow lakes can act as models for studying the main anthropogenic stressors on communities of aquatic organisms and, in particular, on zooplankton[4].

The aim of the research is to assess biodiversity, characterize the structure of zooplankton communities, identify the factors that have the greatest impact on zooplankton of small lakes in urban areas.

2. METHOD

Studies were carried out on 61 different water bodies located in the cities: Kazan, Ulyanovsk, Bugulma, Almetyevsk (Russia).

All the studied water bodies we divided into 4 groups.

1) Lakes located in the forest park zone of Kazan, in the floodplains of the Volga, Kazanka and Sviyaga rivers (11 lakes). Lakes are little transformed in comparison with other water bodies studied, their characteristics are close to natural ones.

2) Small shallow-water lakes in Kazan, located in residential micro-districts with different population density. The catchment area of these lakes is heavily transformed, usually asphalted and built up. Most lakes are man-made derivatives. They were formed as a result of unloading of high-lying groundwater and accumulation of surface runoff in pits or in depressions in the territories of former wetland complexes (40 lakes).

3) Ponds located on the rivers flowing through the cities of Bugulma and Almetyevsk, as well as quarries formed after the extraction of sand in the channel of the river.

Sviyaga in the city of Ulyanovsk (8 reservoirs).

4) Small shallow-water lakes, where rehabilitation measures were carried out (2 lakes). As a consequence, in one of the lakes the hydrological regime and the type of water changed (Lake Lebyazhie, Kazan), and the other was artificially restored at the site of the reservoir previously covered for building (Lake Chishmale, Kazan). Zooplankton of lakes was studied during the period from 1992 to 2016. The frequency of sampling at water bodies was different. On 2-3 lakes from each selected group (except for ponds) studies were carried out during 1-3 vegetative periods. The remaining water bodies were surveyed 1-3 times in June-August. Most of the small lakes in Kazan were studied in the course of work on the inventory of water bodies carried out in 2007 [5].

In shallow-water lakes, samples were taken by straining 50 liters of water through the Apshtein network (mesh size - 100 microns). From ponds and quarries, samples were taken in the central, deepest part by pulling the Jedi net from the bottom to the surface. Cameral processing included the determination of species composition of zooplankton, calculation of abundance and biomass in accordance with generally accepted hydrobiological methods[6]. In total, more than 280 quantitative samples of zooplankton were selected and processed during the study period.

3. RESULTS

Morphometric parameters of the studied reservoirs vary. The surface area of the lakes was from 0.07 to 80 ha, the average depth from 0.12 to 4 m, the maximum depth from 0.6 to 10.1 m (Table 1). The smallest in terms of area and depth of water bodies were groups of lakes in residential areas and restored lakes. The average depths of water bodies in these groups are less than 1 m, and the maximum depths are less than 2.5 m, the area - up to 2 hectares.

The physical and chemical characteristics of the water of the studied water bodies varied in a rather wide range. Transparency of water in most cases was low and in terms of the magnitude of the trophic state index (ITS) the water bodies are eutrophic. PH values characterize the environment in the lakes as neutral. The oxygen content in the surface layers of water usually exceeded 100%, but in the near-bottom, oxygen deficiency was often observed, even in lakes with shallow depths. A fairly high content of ammonium ions was noted in water bodies. High content of nitrites (on the average 0,63 ± 0,48 mg / l) and phosphates (0,58 ± 0,05 mg / l) was noted in ponds.

180 species of zooplankton have been identified in the study of water bodies of urban areas, of them Rotifera - 83 (46%), Cladocera - 54 (30%), Copepoda - 43 (24%). In general, the small lakes of urbanized areas are characterized by rather high species richness.

Most often in the lakes there were *Chydorus sphaericus* (O.F.Muller, 1785) (82% of lakes), *Keratella quadrata* (Muller, 1786) (59%), *Mesocyclops leuckarti* (Claus, 1857) (57%), *Euchlanis dilatata* Ehrenberg, 1832 (44%), *Bosmina (B.) longirostris* (O.F.Muller, 1785) (44%), *Lecane (s.str.) luna* (Muller, 1776), *Simocephalus vetulus* (O.F.Muller, 1776) and *Eucyclops serrulatus* (Fischer, 1851) (in 39%).

If we consider the species richness of zooplankton separately for the selected types of water bodies, then the largest number of species (132), as expected, was found in the little transformed lakes located in the parks. In the samples from these water bodies, the greatest number of species (15.6 ± 1.1) was encountered. Fewer species (118) were found in anthropogenically derived lakes located in residential areas, but samples from these lakes were poor, compared to other groups of water bodies, an average of 9.1 ± 0.6 species.

The quantitative indicators of zooplankton in small water bodies of urbanized areas were relatively low. The largest average summer abundance (285.26 ± 98.71 thousand ind / m^3) were in lakes located in parks. The highest values of biomass (1.47 ± 0.31 g / m^3) were in lakes located in residential areas. The lowest values of quantitative indicators were in the restored lakes and in ponds.

Rotifers prevailed in ponds in abundance, in other water bodies - copepods. According to biomass rotifers prevailed in ponds on rivers, Cladocera - in lakes located in parks and dwellings in massifs and Copepoda - in restored lakes[7].

Rotifers prevailed in ponds in numbers, in other water bodies - copepods.

4. DISCUSSION

Biodiversity is one of the most important indicators characterizing the sustainability of ecosystems. Reducing the species richness of plants and animals is observed with pollution, which is especially characteristic of aquatic ecosystems located in the territories of large cities. Our research has shown that the water bodies of urbanized areas, despite the low quality of water in them, are characterized by a rather high species richness (180 species). The variety of types of water bodies and biotopes within them supports the diversity of zooplankton. Shallow-water lakes, as a rule, overgrow with macrophytes, creating additional shelters for zooplankton. Thus, a high diversity of zooplankton

species is maintained within a small area.

The greatest species of wealth was the lake of natural origin, located in parks and floodplains of rivers, as well as small lakes in residential areas. In the latter, the number of species in each individual water body could be low, but the composition of species is different. There are no species found in all water bodies and only three species - *C.sphaericus*, *K. quadrata* and *M. leuckarti* are found in more than 50% of the investigated lakes.

Studies have revealed low quantitative indicators of zooplankton, which, in our opinion, is a consequence of the impact on zooplankton of pollutants and other unfavorable factors. This also explains the high proportion of cyclops in the juvenile stages.

The indicators characterizing the structure of the zooplankton communities differ for lakes of different types. The average individual mass of the zooplankter (w) was small, in the restored lakes it corresponded to the polytrophic, in the other reservoirs it was highly trophic. The ratio of the number of eutrophic species to oligotrophic (E / O) characterizes the studied water bodies as eutrophic[8]. The same species are resistant to the effects of adverse environmental factors and are most often found also in contaminated lakes.

The calculation of the Pearson correlation coefficients revealed significant ($p < 0.05$) negative dependences of the quantitative indicators of zooplankton-the total abundance, abundance and biomass of many Rotifera and some Cladocera and Copepoda with copper, iron, manganese, lead, zinc in water, permanganate oxidizability. This proves that the increased content of pollutants in water reduces the quantitative indicators of zooplankton and changes the structure of communities.

During the multivariate analysis performed by the main component method, it was found that the quantitative indicators of zooplankton are negatively correlated with the indices of the integrated water quality assessment (TSI, water pollution index and average ranking index). This suggests that in water bodies of urban areas the greatest impact on the development of zooplankton communities is caused by water pollution, as well as the parallel process of eutrophication.

CONCLUSION

Studies have shown that small reservoirs of urbanized areas have a fairly high species richness of zooplankton. The quantitative indicators of zooplankton in small water bodies of urbanized areas were relatively low. Due to pollution and eutrophication, structural characteristics of zooplankton communities change, quantitative indicators (numbers and biomass) are reduced.

Negative correlations of quantitative indices of zooplankton with copper, iron, manganese, lead, zinc, and permanganate oxidation in water have been revealed. To a lesser extent, the effect of eutrophication and pollution is manifested in lakes with conditions close to natural (lakes located in parks) and in larger ones in transformed lakes and ponds.

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O1-10

Zooplankton communities in Lake Nasser under current flood regime before the implications of Grand Ethiopian Renaissance Dam (GERD) construction.

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Keywords: Zooplankton, Flood, Lake Nasser

ABSTRACT

Lake Nasser is a subtropical monomictic, mesotrophic lake and it is the main Nile water reservoir in Egypt. The Nile flood comes once a year in late August and has a direct effect on the Lake ecosystem. This study investigates and documents the effect of Nile flood (the current regime) on zooplankton communities in Lake Nasser as a large artificial water body before filling of Grand Ethiopian Renaissance Dam (GERD). Zooplankton sampling was performed during flood (August 2016), post-flood (December 2016) and pre-flood (May 2017). Five sectors were selected as sampling locations covering the whole lake. zooplankton populations at the studied area composed of four main groups, *Copepoda*, *Cladocera*, *Rotifera* and *Protozoa* in addition to *meroplankton*. The standing crop of the total zooplankton was higher during flood season with an average density of 117803 Org. m^{-3}, while it decreased to more than the half during post-flood and pre-flood seasons with averages densities of 31602 and 31828, respectively. The study concluded that, flood is an important factor that affects zooplankton composition and density in Lake Nasser and any future change in flood regime will have its impact on zooplankton communities in Lake Nasser.

1. INTRODUCTION

Lake Nasser is a subtropical monomictic, mesotrophic lake [1] which is the second largest human-made lake in the world after Lake Volta (Ghana); it was formed due to the construction of Aswan High Dam for the purpose of flood control and water storage. The Nile flood comes once a year in late August originating from the Ethiopian highlands continuing to late November [2]. The ecosystem of Lake Nasser mainly affected by the yearly flood of the Nile, which in turn may affect abundance and compositions of organisms like phytoplankton and zooplanktons and others [3].

The Grand Ethiopian Renaissance Dam (GERD), which is being constructed on the Blue Nile at the Ethiopian border with Sudan, would have a direct effect on the net annual discharge downstream. The negative hydrological impacts of GERD will increase by increasing the height of its spillway dam and increasing the storage capacity may affect the strategic storage for the reservoirs in Sudan and Egypt [4]. Moreover, the filling period of GERD reservoir will be accompanied by an impact on Egypt and reservoir impounding of this size over 6 years will cause annually decrease inevitably Nile flow to Lake Nasser by about 12 BCM, which represents approximately 23% of Egypt's annual share of Nile water. The adverse impacts on Egypt during and after filling of GERD reservoir will increase especially during periods of low flood, [5].

Thus, this study investigates and documents the effect of Nile flood (the current regime) on zooplankton communities in Lake Nasser before filling of GERD to represent a reference point for any future impact on zooplankton communities as result of flood regime change.

2. METHOD

Site Description

Lake Nasser has an area of about 5248 km^2, a mean depth of 21.5 – 25.5 m (maximum 90 m) and the maximum width is about 60 km, the average width is 8 km. Lake Nasser extends between 22º 31′to 23° 45′N and 31° 30′ to 33° 15′E and filled during late 1970s [6].

Sampling program

Sampling was performed during flood (August 2016), post-flood (December 2016) and pre-flood (May 2017). Five sectors were selected as sampling locations covering the whole lake (Fig.1). At each sector, water samples were collected from three sites (eastern bank, middle of the lake and western bank). The average densities of zooplankton at the three sites were expressed as the density of

zooplankton at each sector.

Samples were vertically hauled from upper 5 meters by plankton net 55 µ mesh size, 30 cm diameter and 80 cm length. The collected samples were transferred to a labeled clean bottle and immediately fixed with 4 % formaldehyde. Three subsamples were examined under a binocular research microscope with magnification varied from 100X to 400X. Zooplankton species were identified according to many publications and taxonomic references. Zooplankton population density was expressed as the number of individuals per cubic meter.

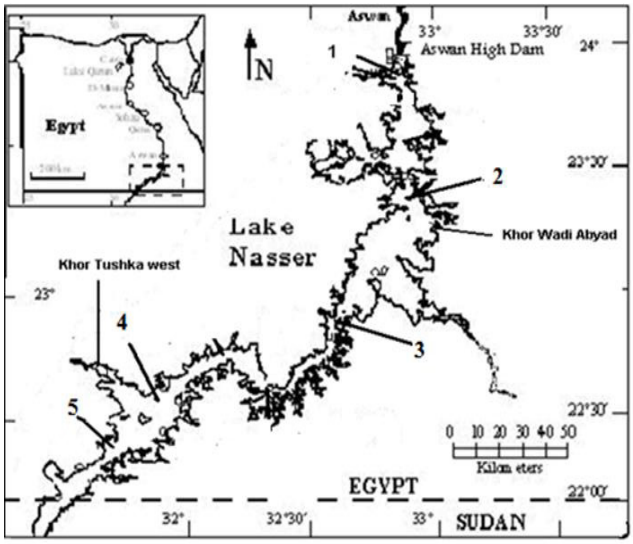

Fig. 1 Map of Lake Nasser showing the selected sectors at the main channel

Data analysis

The diversity indices including species richness, evenness and Shannon-Wiener index were calculated using Primer 7 software. Spatial variations of zooplankton data were represented on study area using ArcGIS 10.5 software.

3. RESULTS

Distribution of total zooplankton

The standing crop of the total zooplankton was higher during flood season with an average density of 117803 Org. m^{-3}, while it decreased to more than the half during post-flood and pre-flood seasons with averages densities of 31602 and 31828, respectively (Fig.2). The zooplankton populations at the studied area composed of four main groups *Copepoda*, *Cladocera*, *Rotifera* and *Protozoa* in addition to *meroplankton*.

Figures 3, 4 and 5 show that, *Copepoda* was the dominant zooplankton group at all sectors along the main channel of the lake during the three seasons except sector 1 during post-flood season and sector 5 during pre-flood season, where *Rotifera* and *Cladocera* were the dominants, respectively.

Copepoda was represented by three adult species; *Thermodiaptomus galebi*, *Mesocyclops ogunnus* and *Thermocyclops neglectus*, in addition to larval stages. Nauplius larvae consisted the main bulk of *Copepoda* with averages densities of 48167, 11395 and 8196 Org. m^{-3} during flood, post-flood and pre-flood, respectively. *Thermocyclops neglectus* was the dominant adult copepod species with averages densities of 6886, 1377 Org. m^{-3} during flood and post-flood, while *Thermodiaptomus galebi* was the most abundant during pre-flood with an average of 4698 Org. m^{-3}.

Twenty-one rotifer species (16 during flood, 14 during post-flood and 4 during pre-flood seasons) were dominated by *Keratella tropica* during flood season while, *Keratella cochlearis* was the dominant one during post-flood and pre-flood seasons.

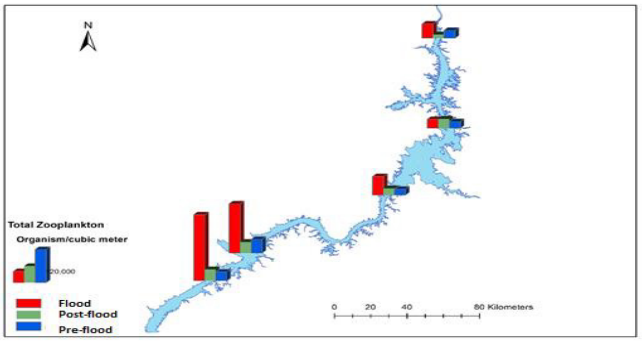

Fig. 2 The distribution of total zooplankton along the main channel of Lake Nasser during the three seasons.

Zooplankton composition

Cladocera was represented by 6 species during the study period. *Diaphanosoma mongolianum* was the most abundant species during flood and post-flood with averages densities of 15376, 943 Org. m^{-3}, respectively. During pre-flood season, *Ceriodaphnia dubia* was the dominant cladoceran species with an average density of 6792 Org. m^{-3}.

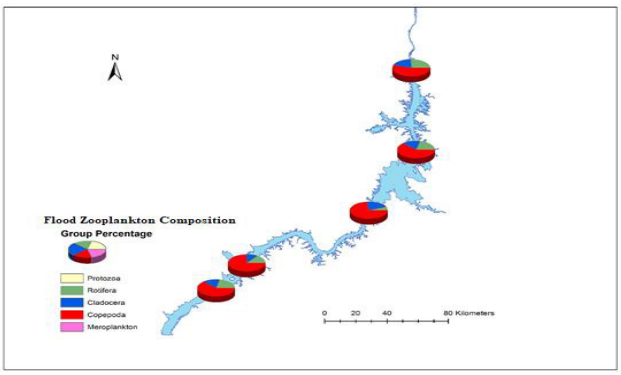

Fig.3 zooplankton composition along the main channel of Lake Nasser during flood season.

Generally, the highest species number (34 species) was recorded during pre-flood season, while the lowest species number (18 species) recorded during post-flood season. The richness index was nearly equal (2.82 and 2.89) during pre-flood and flood seasons, but it decreased to 1.64 during post-flood season. However, the evenness index (0.74) was higher during post-flood season compared to that reported during pre-flood and flood seasons. The shanone values reported during this study were 1.98, 2.07 and 2.13 during pre-flood, flood and post-flood seasons respectively.

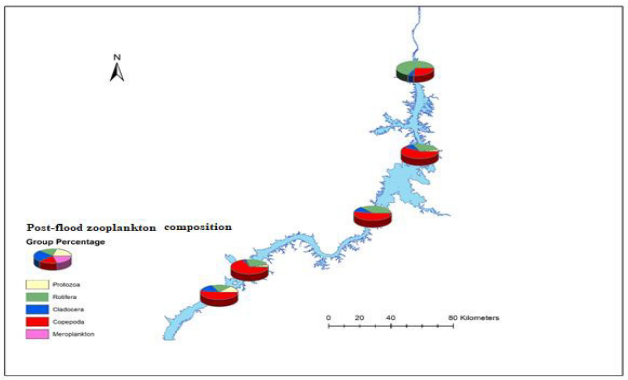

Fig.4. zooplankton composition along the main channel of Lake Nasser during post-flood season.

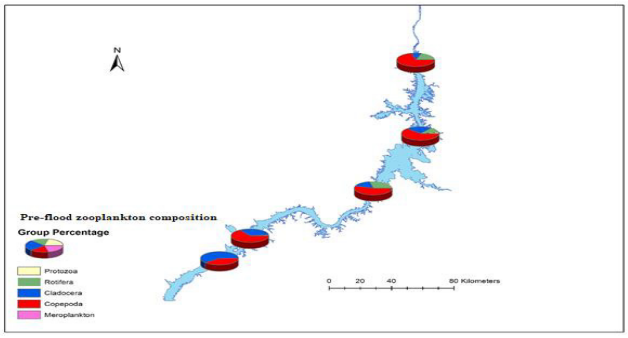

Fig.5. zooplankton composition along the main channel of Lake Nasser during pre-flood season.

4. DISCUSSION

In the current study, the increasing of zooplankton during flood season is associated to increasing of larval stages of *Copepoda* which feed mainly on phytoplankton [7]. The highest density of phytoplankton in the lake was recorded during autumn season [8], where the flood samples of the present study were collected during late of August (autumn season). Moreover, the total zooplankton density was increased at southern part of the lake especially during flood season which agrees with previous studies [1, 9], which concludes that the southern part (upstream) is richer in zooplankton than the northern one (downstream).

Generally, the changes of zooplankton density in Lake Nasser always accompanied by the fluctuation of phytoplankton abundance [10, 11]. *Copepoda* was the most dominant group during the three seasons. This is due to the abundance of nauplius larvae which mainly feed on phytoplankton [7, 12]. The dominate adult copepods, *T. galebi, T. neglectus* and *M. ogunnus* are a cosmopolitan species which show typical limnetic habit and avoiding grossly polluted waters. The increasing of the rotifer percentage at sector 1 during post-flood season and cladoceran percentage at sector 5 during pre-flood season is accompanied with the decreasing of copepod percentage during the same time and at these sectors.

5. CONCLUSION

Flood is an important factor that affects zooplankton composition and density in Lake Nasser. Many studies were carried out on Lake Nasser from different aspects due to its importance for the Egyptian people. However, more future studies should be conducted to monitoring the expected changes in the lake ecosystem by the construction of the Renaissance Dam in Ethiopia.

AKNOWLEDGEMENT

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O1-11

Status of some Wetlands from South Western Maharashtra-India with special reference to Floristic Diversity, Ecosystem benefits, Threats and Management strategies

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Keywords : Wetlands, South Western Maharashtra-India, Floristic Diversity, Ecosystem benefits, Management strategies

ABSTRACT

India has a wealth of wetland ecosystems that support unique habitats with large diversity of biota representing almost all taxonomic groups. As per the National Wetland Atlas 2011, India has about 757.06 thousand wetlands with a total wetland area of 15.3 m ha, accounting for nearly 4.7% of the total geographical area of the country[20]. Out of these, only 26 wetlands have been designated as Ramsar Sites[21]. Upon recognizing the ecological significance of the wetland habitats, an extensive and intensive survey was undertaken during 2012-2016 to document floristic diversity of 20 wetlands from South Western Maharashtra. The floristic diversity survey revealed that about 263 plant species belonging to 210 genera of 63 families inhabiting in the study area. Of these 263 species, 191 are dicotyledons belonging to 162 genera of 51 families and 72 species are monocotyledons belonging to 48 genera of 12 families. To highlight the environmental and geographical significance mapping of these 20 wetlands have been completed with the help of GPS. This paper reviews the wetland wealth of South Western Maharashtra, India in terms of floristic diversity, their geographic distribution and ecosystem benefits. The paper also discusses threats, priority area and management strategies for conservation of these fragile ecosystems.

1. INTRODUCTION

The Convention on Wetlands of International Importance especially as Waterfowl Habitat was adopted at Ramsar in 1971 (www.ramsar.org). The Convention was focused at the fundamental ecological functions of wetlands as regulators of water regimes and the value of wetlands in economic, cultural, scientific, and recreational terms. Wetlands play an important role in maintaining ecological balance through their biotic and abiotic components. These are important ecosystems and forms life support systems for flora, fauna and fisheries. India is having 58.4 million ha area covered by wetlands[11]. These wetlands plays significant role in protecting and conserving biological resources occurred in them. Extensive studies on wetlands have been carried out in different geographic areas. These include ecosystem studies, food and feeding habits of birds and population studies.

The biodiversity value and high biological productivity of wetlands are well recognized[14]. Biswas and Calder[1] described 115 species including lower groups for the wetlands of British India and Burma. Subramanyam[2] has made major contribution to the wealth of aquatic plants of India by providing key for identification of aquatic flowering plants. CDK Cook et.al.[3] has made taxonomic overview of fresh water aquatic plants. The Indian subcontinent harbors about 470 aquatic species of flowering plants[7]. CDK Cook[12] in his book has recorded 485 species of aquatic and semiaquatic flowering plants with key for identification, description and illustration. Karthikeyan et.al. [5] have contributed to the aquatic plant diversity of India. The total numbers of aquatic plant species exceed 1200 and they provide a valuable source of foo, especially to waterfowl[18]. A directory of Asian wetland[6], Indian Wetlands, Handbook of Wetland Management[7] are the important sources of information on wetlands of national importance.

This study is an attempt to identify the composition of plant species diversity present in 20 wetlands from Satara, Solapur, Kolhapur and Ratnagiri districts of South Western Maharashtra-India. Identifying the plant species composition of these wetland habitats will provide better understanding of the ecosystem and its functioning and will offer a better perceptive regarding the stability of ecosystem.

2. METHOD

During 2012-2016, an extensive and intensive survey throughout the study area was undertaken periodically. All the collected specimens were identified and processed as per the conventional methods of drying, poisoning, mounting and labelling[4],[8]. The collected specimens were identified by referring various floras[9], [10], [13], [16], [17], [19] The identified specimens were then confirmed with the help of authentic specimens available in SUK and BSI Herbaria. The nomenclature of plants has been adapted and updated applying ICBN[15] and referring to latest taxonomic literature from online nomenclatural database (www.theplantlist.org). The processed herbarium specimens were deposited in the herbarium at Post Graduate Center of Botany, Krishna Mahavidyalaya, Rethare Bk., M.S. India. Mapping of 20 selected wetlands has been completed with latitude, longitude and altitude with the GPS (Garmin model e-trex). Imageries are developed with the help of Garmin software and internet.

3. RESULTS

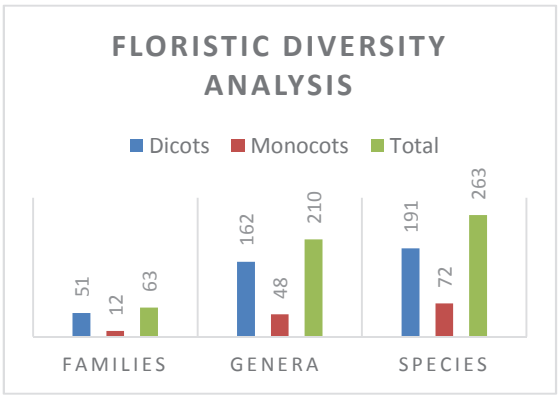
In the present work, a total of 263 plant species, belonging to 210 genera and 63 families of dicots and monocots have been collected and documented. Dicotyledons are represented by 191species belonging to 162 genera and 51 families while monocotyledons are with 72 species belonging to 48 genera and 12 families.

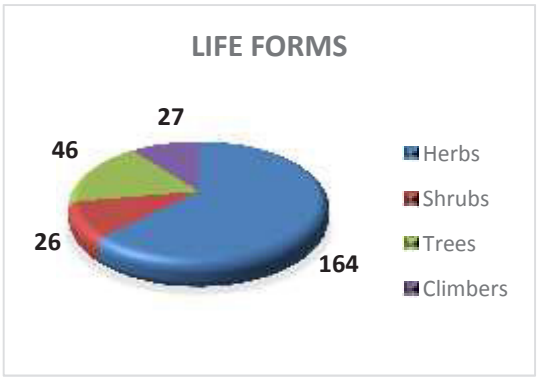
The 263 reported species includes 164 herbs, 26 shrubs, 46 trees and 27 climbers. The family Poaceae is dominant with maximum number of species (42) followed by Asteraceae (21 species), Fabaceae (19 species), Cyperarceae (14 species) and Euphorbiaceae (13 species). Twenty four families were represented each by single species.



Fig.1. Map showing the location of Mayni Bird habitat, Maharashtra

Regarding the life forms, about 164 species are Herbs followed by trees (46), lianas (27) and shrubs (26). *Cyathocline manilaliana* an endemic threatened plant were recorded form the area.





4. DISCUSSION

Wetlands provide numerous products and services to humanity like multiple uses of water services, flood control, carbon sequestration, biodiversity conservation and fisheries. They provide a refuge for migratory birds. Mayni and Yeralwadi wetlands are the best bird habitats.

Urbanization influences major threat to wetlands. Pollution, poor management, demands for water, agricultural runoffs, wastewater discharges are the severe threats.

Separate legal provisions for protection of water quality and protection of biodiversity of wetlands are the urgent need to save these fragile ecosystems. Besides national legislation a majority of wetlands are ignored in the policy process. It is essential to identify ecologically important and sensitive wetlands which greatly help in making conservation strategies. Regular water monitoring plan is essential to prevent them from getting polluted. It helps in maintaining their biota, hydrology and ecological integrity.

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O1-12

Fisherman's Willingness to Pay for Sustainable Ecosystem Management of Jaffna Lagoon

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Keywords:Choice Modeling, Lagoon, Sustainable Ecosystem Management, Willingness to Pay

ABSTRACT

The economy of the fishing community along the Jaffna lagoon is heavily dependent on fishing activities, but overfishing and overexploitation of lagoon ecosystem is a significant challenge for the Sri Lankan government to support sustainable lagoon ecosystem.The purpose of this study is to analyze the fisherman choices, preferences and willingness to pay for different sustainable lagoon ecosystem management practices. Choice modeling approach was used to estimate the willingness to pay different lagoon ecosystem management. Along the lagoon, 65 fishermen from four densely populated town fishing communities and 53 fishermen from two less densely populated village fishing communities are randomly selected for this survey. Conditional logit model was estimated for the selection of choices of fishing communities. Results show that fishermen from town communities are willing to pay for less for increase the number of mangroves and develop the tourist facilities when compared to village fishing communities as there are high competitions for land along the lagoon shore in townfor fishing activities, anchoring fishing boats and housing. As fishing is the major source of income for both communities, they are not willing to support for banning inappropriate fishing gears. Establishing fishing harbour facilities, properly planned multistory housing units, increasing the awareness of negative impact of inappropriate fishing gears and developing alternative sources of income for fishermenwould increase their support for the sustainable lagoon ecosystem management.

1. INTRODUCTION

Coastal lagoons support a range of natural services that are highly valued by society including fisheries, storm protection, controlling soil erosion and flood, climate regulation, ecotourism, anchorage, recreation etc (Gonenc and Wolflin, 2005).Coastal lagoons are highly productive ecosystems. They contribute to the overall productivity of coastal waters by supporting a variety of habitats, including salt marshes, seagrasses, and mangroves. They also provide essential habitat for many fish and shellfish species. Because of high nutrient availability, coastal lagoons can foster high rates of primary production, thereby supporting high rates of secondary production compared to other aquatic ecosystems (Nixon, 1995). Protection and the sustainable use of coastal ecosystem is a major concern of many international institutions.Jaffna lagoon is the largest lagoon system in the country. The economy of the fishing community along this lagoon is heavily dependent on fishing activities, but overfishing and overexploitation of lagoon ecosystem is a significant challenge for the Sri Lankan government to support sustainable lagoon ecosystem (Katupotha,J. Silva, E.I.L. 2013).

Although various programs have been launched to control overfishing and overexploitation of lagoon ecosystem, fishermen are still hesitant to implement mitigation practices due to economic and environmental uncertainty. Therefore,the government should design a cost effective policy to adopt the needs of fishermen and promote sustainable lagoon ecosystem. The purpose of this study is to analyze the fisherman choices, preferences and willingness to pay for different sustainable lagoon ecosystem management practices.

2. METHODOLOGY

Choice modeling is increasingly being formulated in a random utility framework, which allows measurement of the values of non-market goods and services. The Utility function (U) is a function of an observable component (indirect utility function) and an unobservable error component.

$$U = V + \varepsilon \quad (1)$$

Where V is the indirect utility function and ε is the stochastic error term. We assume that the indirect utility is a linear form,

$$V_i = \beta_i X_{ki} + \alpha y = \beta_1 + \beta_2 x_{2i} + \beta_3 x_{3i} + \ldots + \beta_k x_{ki} + \alpha_i y_i \quad (2)$$

Where $X_{ki}(=\{x_1, x_2, \ldots, x_k\})$ is a vector of k attributes associated with alternative i, β is a coefficient vector, y_i is income for a respondent choosing the alternative i bundle, and α is the coefficient vector of income. If the stochastic error term is logistically Gumbel distributed (Type I extreme value distributed), the choice probability for alternative i is given by,

$$\Pr(i) = \frac{\exp(\rho V_i)}{\sum_{j \in C}^{J} \exp(\rho V_i)} \quad (3)$$

Where ρa positive scale parameter and C is the choice set for an individual. For convenience we generally make the assumption ρ =1.To estimate the welfare impacts, i.e., willingness to pay, for a change from the status quo state of the world to the chosen state, the following formula is used:

$$V_i(X_i, y) + \varepsilon_i = V_j(X_j, y - CV) + \varepsilon_j \quad (4)$$

Where V_i and V_j represent utility before and after the change and CV is compensating variation, the amount of money that makes the respondent indifferent between

the status quo and the proposed scenario.Conditional logit model can be applied to estimate the welfare measure in equation (4). Equation (4) can be restated as:

$\beta_i X_{ki} + \alpha_i y + \varepsilon_i = \beta_j X_{kj} + \alpha_j (y - CV) + \varepsilon_j$ (5)

$\alpha_i$andα_j are assumed to be equal if marginal utility of income for a respondent is constant. In conditional logit model, coefficient of k attributes across the all alternatives are the same, and $\beta_i = \beta_j$; only the attribute levels differ across the alternatives, Under this condition, welfare change is estimated by the following:

$CV = -\frac{1}{\alpha}\left[\left(\beta(X_{ki} - X_{kj}\right) + (\varepsilon_i - \varepsilon_j)\right]$ (6)

The conditional logit model (equation 6) is used to estimate welfare changes in lagoon ecosystemmanagement, since the impact of the attributes of lagoon ecosystem management is assumed to remain the same across all choice alternatives.In the choice questions, respondents were asked to select an option they favoured the most out of the three alternatives provided. Each option contains the three attributes and the cost to the household with various levels of attribute combinations. Respondents were asked to answer similar types of choice questions sets multiple times. There are two levels for fishing method attributes, three levels for number of mangroves attributes, two levels for tourism attributes and six levels in the cost to household.Here we assume interaction effects between attributes are insignificant.Unrealistic options were excluded. 21 choices were selected. “No change” in the current attributes levels (Option C) was included in the each choice set. Along the lagoon, 65 fishermen from four densely populated town fishing communities and 53 fishermen from two less densely populated villagefishing communities are randomly selected for this survey. Conditional logit model was estimated for the selection of choices.

Table 1. Definitions of selected lagoon ecosystem managementattributes

Attributes	levels	Definitions
Fishing Method	Banning inappropriate Fishing gears (BIFG)	Implementing full ban on inappropriate fishing gears
	No change	No change in the current Fishing gears
Number of Mangroves	Big increase (BIM)	50% increase in number of mangroves
	Small increase (SIM)	20% increase in number of mangroves
	No change	Maintain current number of mangroves
Tourism	Improving tourist Facilities (ITF)	Developing tourist spots with boatingfacilities
Cost to Household	0, 50,100,200,400,800	Annual payment to regional office

3. RESULTS

Table 2: Choice Modeling and Willingness to Pay

Attributes level	Coefficent		Village (WTP)	Town (WTP)
BIFG	-.083	(0.108)		
SIM	.182*	(0.042)	444	
BIM	.330*	(0.000)	804	335
ITF	.592*	(0.000)	1442	557
Cost	-.0008*	(0.000)		
Town*BIFG	.037	(0.589)		
Town*SIM	-.145	(0.221)		
Town*BIM	-.192*	(0.055)		
Town*ITF	-.363*	(0.000)		
No of Observations	3,540			
Likelihood Ratio (x^2)	241.08			

*- significant at 5% level, P value in parenthesis

The results of choice modeling and willingness to pay are shown in Table 2. Big increase in number of mangroves and improving tourist facilities variables are significant at 5% level and Banning inappropriate fishing gears is not significant at 5% level in both fishing communities. Coefficient of cost is negative as expected and significant at 5% level.Results show that village fishermen are willing to pay Rs 804 and Rs 1442 per year and town fishermen are willing to pay Rs 335 and Rs 557 per year for big increase in number of mangroves and developing tourist facilities respectively.

4. DISCUSSION

Coefficient of big increase in number of mangroves and improving tourist facilities show relatively large magnitudes in village fishing communities.As there are high competitions for land along the lagoon shore in town for fishing activities, anchoring boats and housing, fishermen from town communities are willing to pay for less for increase the number of mangroves and develop the tourist facilities when compared to village fishing communities. Since fishing is the major source of income for both communities, they are not willing to support for banning inappropriate fishing gears. Their low education level is also another reason to understand the impact of inappropriate fishing gears on fish growth in the lagoon. As village fishing communities have an additional source of income from coconut plantation, they are less sensitive to the cost of choice of lagoon ecosystem management compared to fishermen from town.

5. CONCLUSION

Establishing fishing harbour facilities to accommodate more fishing boats and properly planned multistory housing units to make available land for planting mangroves, developing tourist spots and increasing the awareness of negative impact of inappropriate fishing gears for the sustainability of fishing stocks and developing alternative sources of income for fishermenwould increase their support for the sustainable lagoon ecosystem management.

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O1-13

Can scientific evidence to depict the ecosystem services effectively resolve the conflict between the protected area managers and the local dependent community? Nalabana bird sanctuary; Chilika Lake a wetland of international importance, India; a case study.

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Key Words: ecosystem services, lake ecosystem, protected area, scientific evidence, spawning, nursery

ABSTRACT

Chilika Lake is the most significant coastal wetland along the east coast of India and a Ramsar site. The highly productive lake eco-system with its rich fishery resources sustains the livelihood of more than 0.2 million fishers. Chilka is a vital wintering ground for the migratory bird of Asiatic subcontinent. Nalabana island within the lake, spread over 15.53 sq. Km, designated as a bird sanctuary in 1973. Nalabana was known for highly productive capture fishing ground till 1973. The ban on fishing clamped after notification led to conflict between the local fishers and the protected area managers. Interestingly, after the designation of protected area the fishers have been getting a good harvest from the trap they lay outside the sanctuary boundary. However, the ecosystem services, contributed by the sanctuary quietly has been gone unnoticed by the local fishers. For the ecosystem service paradigm to be relevant to resource-dependent communities, it is essential to generate awareness and their perception of it. The study carried out during July 2011 to June 2014, by the authors, attempted to establish through scientific evidence, the ecosystem services provided by the sanctuary in the form of potential nursery and spawning ground for fish. The outcome of the study conclusively demonstrated that sanctuary is serving as feeding and nursery for 45 spawning of 11 resident species, contributing significantly to the lake fishery. The outcome of the study changed the perception of local fishers about the sanctuary and ecosystem services it provides, also in resolving longstanding conflict.

1. INTRODUCTION

Nalabana bird sanctuary spread over 15.53 km^2, within Chilika lake (Fig-1) is a protected area designated as a sanctuary in the year 1973 under Wild Life (Protection)Act since from 1973. Fishing activities have been prohibited in the sanctuary since from 1973. Historically, Nalabana was the largest traditional Jano fishery ground, a form of traditional capture fishery. The local fishers practice this traditional fishery until it became a protected area in 1973. Fishers have been objecting to such prohibition within the sanctuary area, leading to a conflicting situation between the protected area managers and the local fishers. More than 0.4 million migratory bird congregate in the sanctuary during winter every year. The droppings of these birds in the form of guano triggers the abundant growth of phytoplankton and zooplankton.

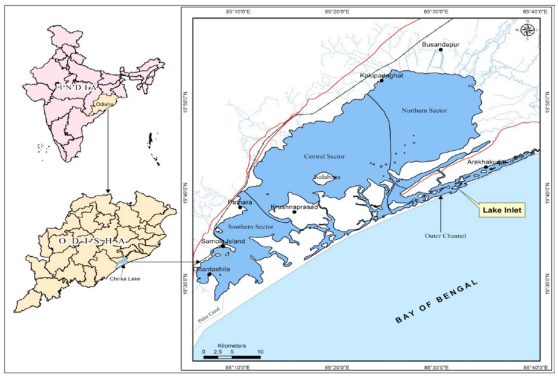

Fig-1 Chilika Lake along the east coast of India and the Nalabana Sanctuary the study area located in the central sector.

This attracts many commercial finfish for feeding and spawning. Interestingly after the ban on fishing within the sanctuary, now the fishers lay their box-net traps outside the sanctuary at proximity to sanctuary boundary and get a bumper harvest.

The ecosystem services sanctuary provides, apparently remained unnoticed by the local communities. For sustainable management of the sanctuary, the awareness and perception of local fishers about the ecosystem services is crucial. This necessitated the present study to establish the flow of ecosystem services from the sanctuary as a potential nursery and spawning ground for finfish and shellfish based on scientific the local fishermen. The objective of the study has been to generate awareness about the supporting and regulatory ecosystem services, from the sanctuary in the form of spawning, feeding and nursery ground for important fish species. Also, to change the understanding of local fishers, about, how the undisturbed sanctuary area is the lake fishery, benefiting the fishermen in the long run. The study was initiated in July 2011 for three years. The outcome of the study demonstrated convincingly to the local fishers, how the undisturbed conservation area is serving as a sanctuary for fish, maintaining the ecosystem resilience and flow of ecosystem services.

2. METHOD

The study site (Fig 2) is within Nalabana sanctuary area of 15.53 km^2 with core zone of 6.72 km^2 and buffer zone of 8.81 km^2 in Chilika lake. For the study, the sanctuary was divided into four sectors by using GPS (Garmin-Model:72H). In each sector, one sampling station (N-1, N-2, N-3 & N-4) has been fixed. Four control stations outside the sanctuary area (C-1, C-2, C-3 & C-4) are set as the control for comparison. Regular sampling carried out in 4 stations within Sanctuary and four control stations at an interval of 30 days. During each campaign, the water quality, macrobenthos, phytoplankton, zooplankton, macrophytes, postlarvae of finfish and shellfish and spawners and juveniles were studied. The sieved material collected in the glass bucket tied to the tail end of the tow net was collected in the rectangular enamel trays. The post-fry were collected after removing the debris, and the materials were segregated into fry and post- larvae of different species. The segregated specimen was measured, photographed and preserved in plastic bottles for transport to the laboratory for further investigation.

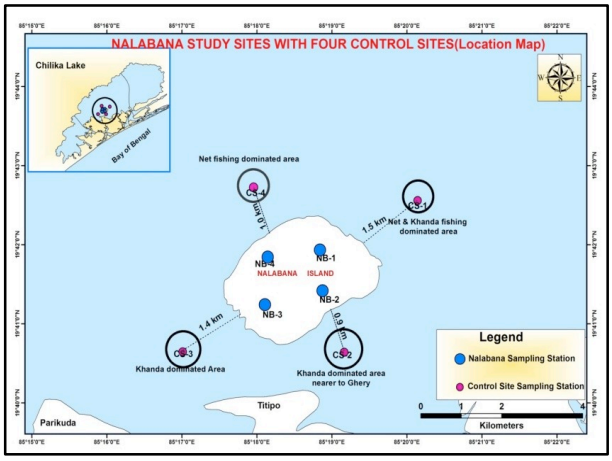

Fig-2 The study site (Nalabana sanctuary in Chilika lake) with four stations inside Nalabana sanctuary area and four control stations outside sanctuary area

For the sampling of adult and juvenile fishes, a nylon dragnet of thirty feet long and three feet height with 15mm mesh size was used. Spawners, particularly, females with ripe ovary and juvenile fishes were collected from dragnet and were segregated. The females were dissected to expose mature ovaries and preserved in 10% buffered formalin. Developing fish eggs collected from each sampling station were studied under a microscope for identification.

3. RESULT

The study results for ecological parameters, i.e. water quality variables, phytoplankton and zooplankton abundance, macro-zoobenthos status, and nutrient status, macrophyte biomass and diversity etc.) indicated that the overall ecological conditions of Nalabana sanctuary are very conducive for productive fish habitat. Nalabana sanctuary as a potential fish habitat is rich in available natural food elements, i.e. zooplankton, benthic organisms and general bottom biota, benthic filamentous algae, organic detritus etc. Macroalgae and organic detritus are known to be the preferred food by mullets are abundantly found in the sanctuary. The abundant seagrass meadows of Halophila ovalis, provides the best shelter for juveniles of mud crab and shrimp which were abundantly found in the sanctuary area, testify the study area as a potential nursery ground for fish and shellfish.

The average values for zooplankton population density in Nalabana sanctuary area (25647± 18623.08 no/m^3) was not significantly higher ($p<0.068$) than the control stations (20833± 14931.19 no/m^3) as obtained from ANOVA test. The average zooplankton density for Nalabana sanctuary core area was also found to be higher than the average values for the central sector of the Chilika lake (22020 no/m^3) and main lake area (16959 no/m^3) during the study period. The zooplankton diversity of Nalabana sanctuary core area was more or less the same as the central sector of the lake. The main zooplankton groups were copepods, amphipods, cladocera, gastropod veligers, bivalve veligers, copepod nauplii, cirripede nauplii and hydrozoans.The zooplankton diversity was dominated by copepods at both Nalabana sanctuary area and control stations.

The gut content of 10 commercially important species revealed that the food elements encountered matched with the available food materials in the sanctuary. The gut content of above species has been, gastropods, bivalves, polychaetes, amphipods, filamentous algae, diatoms, organic detritus and seagrass leaves.

4. DISCUSSION

The outcome of the study carried out for three years confirmed that 11 resident fish species of Chilika lake breed in Nalabana sanctuary area. Survey on juvenile fish abundance in sanctuary area indicated that more than 45 species of juveniles of finfish and shellfish species are frequenting sanctuary area for feeding purposes throughout the year. The pooled average data of the operation of tow net hauls of 10 minutes' duration to study the early juvenile fish and prawn frequenting for feeding purpose (nursery ground) are recorded and analysed. The study confirmed that 45 species of finfish and shellfish (prawns) are utilizing Nalabana area as a potential feeding/nursery ground.

Variation in the abundance of different species studied from tow net collections is recorded. In general, food elements traced from the guts of 10 economic fishes i.e. M.gulio, E. suratensis, N.nasus, M. cephalus, L.macrolepis, G.setifer, H.limbatus, R. sarba, E.tetradactylum & Arius arius, matched with the available natural food materials from Sanctuary. Above findings indicated that the juvenile fishes are attracted to the study area because of abundant availability of food materials. No evidence of spawning of finfish and shellfish and potential nursery ground for juvenile fishes and shellfishes from control stations (outside sanctuary area) could be gathered during the study period in respect of the species recorded from the sanctuary.

5. CONCLUSION

Awareness about the ecosystem services flowing from the sanctuary was low. The fishers were ignorant about the regulating and supporting services provided by sanctuary. This has resulted in a conflicting situation. The present study with scientific evidence demonstrated that Nalabana sanctuary significantly contributes to lake fishery. The rich seagrass meadows provide an excellent nursery ground for the finfish and shellfish. The scientific evidence from this participatory research resolved the long-standing conflict between the fishers and the protected area managers.

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O1-14

霞ヶ浦の生態系サービスの経済評価と評価手法の課題

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キーワード:生態系サービス, 代替法, コンジョイント分析

抄録

霞ヶ浦の多様な生態系サービスについて整理し, 代替法とコンジョイント分析を用いて経済評価を行った。その結果, 代替法では供給サービスと調整サービスが大きく, その中でも洪水調節が最も大きかった。一方, 基盤サービスは算出できなかった。また, コンジョイント分析では水質改善に最も重きをおいていることが明らかとなった。評価の課題として, 水質汚濁と生態系のトレードオフを考慮した価値の算出の必要性や, 供給サービスと文化的サービスのダブルカウント等が考えられた。また, 今回評価した項目以外にも評価できる項目があった可能性があり, 今後はこれらの課題の解決を図りながら, 霞ヶ浦がどうあるべきなのか, 多様なステークホルダーが議論する為の基礎資料として利用したい。

1. はじめに

霞ヶ浦は茨城県の南部に位置する湖であり, 湖面積は 220km^{2}と日本で 2 番目に大きい湖である(図 1)。現在, 霞ヶ浦流域には約 96 万人が生活している。また, 霞ヶ浦周辺は水田やハス田, 畑地が広く分布し, 鹿島臨海工業地帯もあることから農業や工業も盛んである。これらの生活や経済活動の多くは霞ヶ浦の水が用いられている。さらに, 霞ヶ浦湖内ではワカサギ等の漁獲やコイ等の養殖など水産業も盛んであり, 佃煮の生産や帆引き船の操業等の伝統を残すとともに観光資源としても利用されている。また, 霞ヶ浦はコンクリート護岸に覆われ, 常陸川水門によって水位が操作され, 農業や工業などの利水の他に, 大雨時の洪水を調整する治水の役割も担っている。このように, 多くの人々は霞ヶ浦から多様な恩恵(生態系サービス)を受けている。今後も人々が霞ヶ浦の生態系サービスを持続的に利用していくためにはどのようなサービスをどのくらい受けているのかを把握し, 湖沼・流域管理に結びつける必要がある。

2016 年に環境省は生物多様性及び生態系サービスの総合評価(JBO2)を実施し, 生態系サービスの内容や変化に与える要因等についてまとめている[1]。また, 2010 年に生物多様性条約の第 10 回締約国会議において「生態系と生物多様性の経済学(The Economics of Ecosystems and Biodiversity, TEEB)」報告書が公表されており, そこでは適切な管理のためには計測し定量化できる指標が必要であることが記載されている[2]。これらのことから, 霞ヶ浦の生態系サービスを分かりやすく認識するためにサービスの内容を整理し, 経済的な価値(貨幣価値)に置き換え可視化することが重要である。

そこで, 本研究では JBO2 に準じて霞ヶ浦の生態系サービスの内容を把握し, 経済学的手法を用いて生態系サービスの経済的な価値を評価するとともに, 評価手法の課題について検討した。

2. 評価対象および評価手法

評価対象は霞ヶ浦(湖沼部分)のみとし, 生態系サー

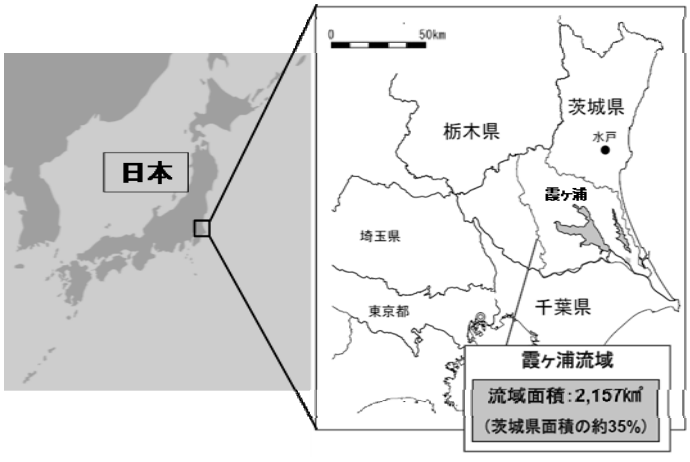

図1　霞ヶ浦とその流域

ビスの経済評価については現在の価値を評価することとした。評価項目及び評価指標については JBO2 で用いられている項目や指標を参考にし，供給サービス，調整サービス，文化的サービス，基盤サービスの4つに分類し，さらに中項目，小項目に細分化し評価指標を設定した（表 1）。経済評価手法は，代替法および選択型実験（コンジョイント分析）とした。

2-1. 代替法

評価する年代は現在とし，直近の既存の統計資料等から，実際に市場に流通しているものについては市場価格で代替し，それ以外の指標については主に代替となる原単位を設定し，物量をかけることで算出した。

2-2. コンジョイント分析

コンジョイント分析はウェブアンケート調査によって全国の 20 歳以上の成人を対象に実施し，有効サンプル数は 1,181 データであった。アンケートの内容として，まず霞ヶ浦の仮想的状況として以下の説明を行った。

『ここでは仮に，今後，対策をしないと，2040 年頃には様々な霞ヶ浦の恵みを受け取れなくなる恐れがあるとします。しかし，霞ヶ浦を現在より良い水環境にするための対策を実施することで，現在の恵みを維持，またはより多くの霞ヶ浦の恵みを受け取れるようになるとお考え下さい。そこで，霞ヶ浦の水環境をより良くするための基金を設置して，広く一般の方から寄付をつのり，お金をかけていくつかの対策を実施することにしました。つまり，あなたが今回この基金に募金をすることで，2040 年においても望ましい霞ヶ浦の恵みを維持し，守っていくことができるとします。ここでは，先の説明で述べた「水質」，「全国的に希少とされている魚類」，「漁獲量」，「湖岸植生帯」の４つの要素で霞ヶ浦の状態を考えることにします。その上で，以下に示す各要素についての将来生じうるレベルをご覧ください。』

この説明文に続き，各要素のレベルを示した選択肢を各アンケート票の中で 7 問提示し,回答者には各質問につき 1 個ずつ最も望ましい対策を選択させた。この結果から４つの要素を各生態系サービスとして設定し，1単位変化することによる一人当たりの支払意思額を算出した。そして，その支払意思額に湖沼の現状から最も良い状態に改善した場合の改善量と調査対象とした人口をかけることで各生態系サービスの価値として算出した。設定した単位や湖沼の現状と最も良い状態については表 2 のとおりである。

表1 霞ヶ浦の生態系サービスの評価項目及び指標

項目	中項目	小項目	指標
供給	食糧・原材料	水産物（漁業）	漁穫量
		水産物（養殖）	淡水真珠
			コイ，その他魚類
	水供給	取水量	農業用水
			工業用水
			水道用水
調整	水の調整	地下水涵養量	地下水涵養量
		水質浄化	脱窒量
	気候の調整	潜熱効果	蒸発散量
	自然災害の防護	洪水調節	治水容量
文化	宗教・祭り	水神の数	
	教育	霞ヶ浦を利用した体験学習，霞ヶ浦を題材とした環境教育	
	景観，観光・レクリエーション	レクリエーション利用者数	帆引き船利用者数
			釣り利用者数
			水遊び人数
	伝統芸能・伝統工芸	伝統的建造物（茅葺屋根の原材料）	妙岐の鼻地区カモノハシ・ヨシ群落面積（茅葺に利用される群落）
		伝統的水産加工品	佃煮生産量（わかさぎ・はぜ・アミ・えび・ふな等）
基盤	多様性	生物多様性	

表 2 単位及び湖沼の現状と最も良い状態

項目	単位及び湖沼の状態
供給	漁獲量が 1t 増えること。 ＜現状:900 t，最も良い状態:17,500 t＞
調整	湖岸植生帯が1％増えること。 ＜現状:13.2%，最も良い状態:90.0%＞
文化	CODが 1 mg/L 下がること。 ＜現状:8 mg/L，最も良い状態:5 mg/L＞
基盤	稀少な種（魚類）が 1 種増加すること。 ＜現状:3 種，最も良い状態:6 種＞

ただし，現状は2018年とし，改善を目指す年は2040年としたことから，得られた金額を22で除することで1年当たりの金額とした。

3. 経済評価結果及び評価の課題

代替法では供給サービスが329億円/年，調整サービスが751億円/年，文化的サービスは2億円/年と見積もられた。基盤サービスは評価することができなかった。項目としては洪水調節が最も大きかった。コンジョイント分析では供給サービスが0.09億円/年，調整サービスが22億円/年，文化的サービスは279億円/年，基盤サービスは 165 億円/年と見積もられた。文化的サービス（水質改善）が最も大きくなり，水質改善に重きをおいていることが明らかとなった。

本研究において霞ヶ浦の生態系サービスの経済評価が明らかとなったが，評価方法についての課題も明らかとなった。課題について以下にまとめた。

（1）水質浄化（脱窒量）の価値の算出方法は，単位除去量当たりの下水処理場の建設費と維持管理費を原単位として，それに実際の脱窒量をかけることによって算出した。脱窒は微生物の代謝によって起きるが，硝酸濃度が高いと脱窒量が増えることが報告されている[3]。つまり，霞ヶ浦の窒素濃度が高い（汚濁が進む）ほど水質浄化の価値が高くなり，霞ヶ浦の価値も高くなるという霞ヶ浦の価値の評価として矛盾してしまう。窒素濃度が高いと別の価値が減少する等のトレードオフの関係を検討する必要がある。

（2）水道用水の価値の算出方法は，水道用水の単価から水処理として利用される活性炭の使用単価を引いた値を原単位とし，実際の取水量をかけることで算出した。しかし，水道用水の水処理は活性炭のみならず，微生物による分解やオゾン処理がされている浄水場もあり，より詳細に検討する必要がある。

（3）漁獲と伝統水産工芸品の佃煮がダブルカウントの可能性がある。供給サービスと文化的サービスがダブルカウントになりやすい。

（4）生物や植物の種の多様性（基盤サービス）等は市場で取引されていないため代替法では評価することができない。

（5）コンジョイント分析では特定の行為を各生態系サービスとして設定したが，他のサービスと関連する可能性がある。

4. 結論

本研究によって霞ヶ浦の生態系サービスの経済評価について明らかにするとともに評価手法の課題を整理した。詳細は以下のとおりである。

・代替法では供給サービスや調整サービスで大きく，その中で洪水調節が最も大きかった。コンジョイント分析では文化的サービス（水質改善）や基盤サービスが大きく，特に水質改善に重きをおいていることが明らかとなった。

・経済評価の課題として，水質汚濁と生態系のトレードオフを考慮した価値の算出の必要性や供給サービスと文化的サービスのダブルカウントなどが明らかとなった。

本研究によって霞ヶ浦の生態系サービスの経済的な価値が明らかとなったが，課題も多かった。また，今回評価した項目以外にも評価できる項目があった可能性がある。今後はこれらの課題の解決を図りながら，霞ヶ浦がどうあるべきなのか，いろいろな当事者が議論する為の基礎資料として利用したい。

謝辞

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O1-15

Terminalia arjuna as a Riparian Species to the Protection along the Lake, Tank and Catchment Areas in Sri Lanka

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Key Words: Riparian species, *Terminalia arjuna*, Diameter at breast height

ABSTRACT

Terminalia arjuna is a characteristic component of dry riparian forests in Sri Lanka which helps to control erosion, acts as a natural bio filter and protects the wet land areas. The current, field-based approaches for estimation of volume in tree species are laborious and expensive process due to destructive harvesting of more trees. Therefore, to protect the riparian species, we require accurate, flexible and valid common equation to do predictions of volume estimation. This research mainly focuses on evaluation of volume of *Terminalia arjuna* trees in order to make suitable management decisions regarding biodiversity and biological resource services in riparian areas.

For the current study, the secondary data was taken from Moragahakanda area in Sri Lanka. 400 observations for *Terminalia arjuna* were considered for constructing final volume estimation. All possible combinations of linear equations were developed with the relationship of total volume (V) with diameter at breast height (DBH), Total height (Ht) and basal area (BA). The most appropriate model was selected considering the higher adjusted coefficient of determination (Adj R^2), low root mean square error (RMSE) and other parameters used for model adequacy checking such as Durbin-Watson statistics (Dw), Anderson-Darling normality test etc. Overall result indicates that *Terminalia arjuna* is a higher value timber species which needed to introduce to conserve riparian areas and timber volume can be estimated without uprooting the trees by using the below equation.

$$In\ (V) = -1.50 + 0.572\, ln(D) + 1.06\, ln(H) + 1.11 BA^2$$

INTRODUCTION

Natural rivers associated with riparian habitats are considered as one of the most diverse, dynamic and complex ecosystems in the world. The river margin communities are highly influenced by the changes in hydrology and flow patterns. As a result, riparian communities are considered as good indicators of the environmental changes caused by long-term river flow regulations. One of the most important functions of riparian vegetation is its ability to control erosion, acts as a natural biofilter that helps reduce pollution in surface runoff and shallow groundwater[1].

Terminalia arjuna is well-known as Kumbuk in Sinhala, Arjun tree or tropical almond in English and Marudha marum in Tamil. This tree is a water loving plant and it occurs naturally along the rivers, banks of streams and seasonally dry water resources at low elevation and mostly available in dry tropical riparian forests in, Sri Lanka, Bangladesh and South and central India[2]. This species can be identified by its superficial, shallow root system spreads radially along stream banks. Thus, *Terminalia Arjuna* is classified as "Luxury Grade" by Sri Lanka Timber Corporation.

Stem volume is one of the vital variable measurement in tree management. Volume can be easily measured using variables such as diameter and total height of the tree[4]. Volume equations shoud be the acceptably, accurate, easy, cheap and effective tool for estimating the individual tree volume which was developed for management purposes[3;7]. But it is difficult to measure due to laborious, destructive and time consuming. If we uproot the valuable riparian tree species, it will adversely affect for the riparian eco system.

Therefore, the present study was conducted with the objectives of constructing a volume prediction models for *Terminalia arjuna* using multiple linear regressions technique and it leads to making suitable management decisions of *Terminalia arjuna* with their dbh, total height and tree volume. In addition, timber valuation[5] can be done without uprooting trees by using this equation. Such information can be useful in implementation of conservation practices to restore riparian plant communities along the river banks in the future.

METHODOLOGY

This study was conducted in sites across the area of Moragahakanda which govern by State Forest Department in Sri Lanka in North Central Province. This

area was located in Dry Zone of Sri Lanka. Less than 1750m annual rainfall with elevation range between 151m -175m can be expected from this area. The mean annual temperature fluctuated between 26.5 °C to 28.5 °C while RH varied between 64.7% and 87.6%. Reddish brown earths (nonlateritic loamy soils) is the major soil type and the other important soil type is the Alluvials that occur along the lower courses of rivers[6].

Secondary data (Table 1) of *Terminalia arjuna* were collected from inventories (Enumeration and Way Side Deport Registers) of State Timber Corporation in Moragahakanda. Merchantable height, individual tree diameter (over bark) at breast height (1.3m above ground: DBH) were recorded as before felling the trees and number of logs, mid girth and log lengths of each log were recorded as just after felling the trees. Merchantable height was defined as the height to the first live branch of tree species.

Table 1. Statistical summary for diameter at breast height (DBH) and merchantable height (Ht), basal area (BA) and merchantable volume (V) of sample trees

Variables	Mean	Min.	Max.	SD	Variables	Mean	Min.	Max.	SD
DBH (m)	0.88	0.20	2.94	0.55	Height (m)	12.45	1.20	50.20	7.50
Basal area (m^2)	0.36	0.017	2.30	0.28	volume (m^3)	5.14	0.08	27.08	5.05

(Source : STC, 2016)

Field measurements were entered and tabulated. The volume (V) (m3) of each individual stem was calculated by dividing it into sections of different length (L) (m) and measured the mid diameter (D) (m). Finally, Huber's formula was used to calculate volume of each log (Rawat *et al*., 2003). $V = \frac{\pi D^2 L}{4}$. By using above information, volume for each log were calculated starting at the base and ending at the top of the tree (cumulative values) and then added to get the total merchantable volume *Terminalia arjuna* separately.

Below procedure was used in testing the overall significance of the regression equation. The regression coefficients should be significant at 95% confidence limit ($p<0.05$) and check out the multicollinearity effect of variables with Variance Inflation Factor (VIF<10). The coefficient of determination (R^2) measures the proportion of variation in the dependent variable that is explained by the behavior of the independent variables. In order for the model to be accepted, the adjusted R^2 value must be high i.e >50%[8]. The each model was selected by examining p-values of Anderson-Darling statistic (the data is normal at p-value > 0.05) to determine the normality of residuals and Durbin-Watson statistic (Dw) which assists to detect autocorrelation in the residuals. Finally the best models were validated by using residual plots (predicted versus residuals), correlation between measured versus predicted volumes (r), MAPE (Mean Absolute Percentage Error) values and RMSE. The Root Mean Square Error (RMSE) must be relatively samll for the model to be acceptable for volume estimation[9].

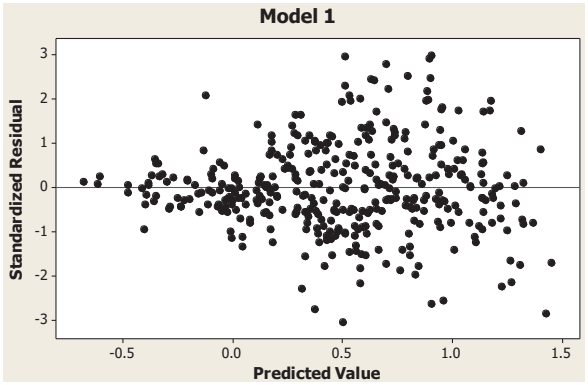
RESULTS AND DISCUSSION

Various linear regression volume equations were developed for *Terminalia arjuna* (Kumbuk) hence the models were assessed and validated to ensure their adequacy for the prediction of merchantable volume of tree species.

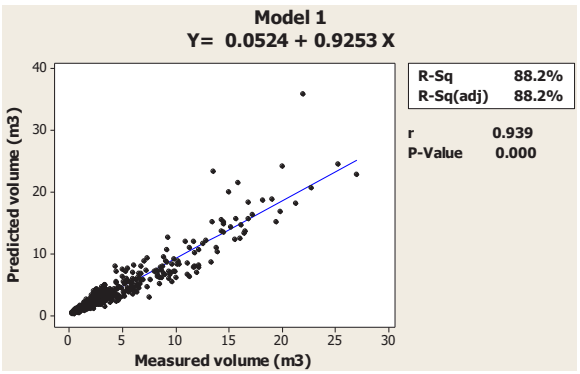
The best fitted two models were selected by consideration of the higher adjusted coefficient of determination (R^2_{adj}). Insignificant variables were not selected and developed models contained variables with significant parameters and significance of the regression coefficients ($p<0.05$) at 5% level. The calculated variance inflation factor (VIF) is less than 10 implied about absence of multicollinearity. Durbin-Watson (DW) statistic for the resulted equation around 2. Anderson-darlin normality test show in Figure 1 (c) and normal distribution of residuals due to p value is more than 0.05. Some tree modeling studies observed that, not normal distribution of residuals and it was explained as an inevitable phenomenon for forest population due to the nature of the growth process[11;12;13]. The models could be validated by the residual plots, correlation between predicted versus measured values (r), MAPE values and RMSE. Root Mean Square Error (RMSE), MAPE, and correlation between measured versus predicted were used to determine the accuracy of the developed models and RMSE, MAPE values were very low for developed equations. This was eleborated by the report of[9] who explained that RMSE estimation is a common measure of model fitting in regression models and low values indicating better fit. Simillar parameters were used by[5]and[10] to select the best fitted models to estimate the wood volume. Standard residuals of the fitted models for *Terminalia arjuna was* plotted against predicted values in Figure 1(a). Except few points, almost majority of the values were in between -2 to +2 and referring to that there are only very few unusual data points. The residual plots of predicted versus residuals was elaborated the best volume model performances and it shows the random distribution or no pattern of the residuals. The predicted values of *Terminalia arjuna* was plotted against measured volume and Figure 1(b). According to that, the higher correlation coefficient was recorded for all develop models. It suggested that the developed model had a good fit for tree species.

Table 2. Developed equation and the evaluation criteria for *Terminalia arjuna* (kumbuk)

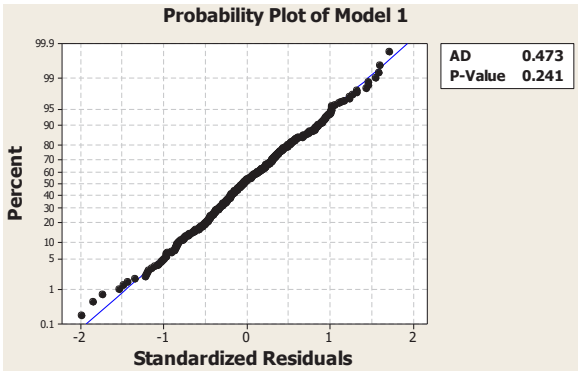
Developed equations	Model No	R^2	Adj R^2	DW	P value of Anderson-Darlin Normality Test	RMSE	MAPE %
ln V =-1.50+0.572 ln (D)+1.06 ln (H)+1.1 $(BA)^2$	1	90.3%	90.3%	1.931	0.256	0.100	0.26
ln V = - 0.87 + 1.04 ln (D) + 0.908 ln (Ht)	2	83.1%	83.1%	1.768	0.085	0.180	1.63



(a)



(b)



(c)

Figure 1 (a) The plot of Predicted versus Residual value (b) The plot of Measured versus Predicted volume (c)The probability plot (Anderson-Darlin Normality test) of *Terminalia arjuna* for best fitted model 1

CONCLUSION

Model 1 is the best fitted developed model for volume estimation for *Terminalia arjuna* (Kumbuk) and that equation can be applied with relative ease under applications

$$In\ (V) = -1.50 + 0.572\ ln(D) + 1.06\ ln(H) + 1.11BA^2$$

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O1-16

霞ヶ浦における湖岸植生帯の現状について

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キーワード: 自然再生, 湖岸植生, 養浜, 樹林化, 生態系機能

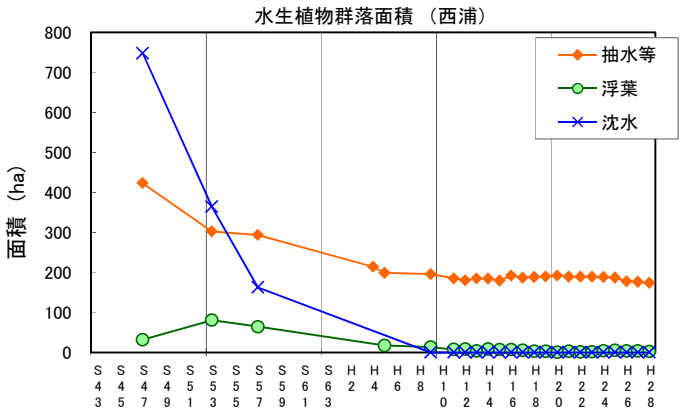
抄録

霞ヶ浦の湖岸植生帯は, 昭和 40 年代からの水質悪化や湖岸堤の整備等により, 平成 9 年頃にかけて大幅に減少したことから, 消波施設や養浜の整備等, 様々な保全対策を行ってきたところである。しかし, ヨシ等の抽水植物は, その後も現在に至る約 20 年間において減少傾向が続いている。このため本研究では, 霞ヶ浦(西浦)を対象とし, 最近の約 20 年間の植生図を用いて, 湖岸植生帯の面積や群落構成の変化, 特徴などについて整理し, その要因について考察した。その結果, 西浦では全体として湖岸植生が減少, 樹林化が進行している傾向が見られ, 植生面積は, 保全対策箇所は維持されているが, 未対策箇所では減少しているなど, 箇所毎の状況にもいくつか特徴が見られた。今後は, これまでに得られた成果を踏まえ, 減少傾向を解消しつつ良好な水辺環境を創造, 維持するための手法を導き, さらに保全対策を推進していく必要があると考えられる。

1. はじめに

霞ヶ浦の湖岸には, かつて抽水植物, 浮葉植物, 沈水植物など多様な植生帯が形成されていたが, 昭和 40 年代からの流域の人口増加に伴う水質悪化や霞ヶ浦開発事業(H8 年 3 月完成)による湖岸堤築造等により, S47 年から H9 年の 25 年間で, 沈水・浮葉植物はほぼ消滅し, 抽水植物は約半分程度まで減少した(図1)。

また, 植生帯面積は, H8 年からの霞ヶ浦開発事業の管理開始に伴う水位運用後も減少が確認されたため, 各機関では消波施設整備や前浜造成などによって植生帯を復元し, 保全対策を継続的に行っているところである(表 1, 図 2)。しかし, 抽水植物は H8 年から現在にかけても約 29ha と少しずつであるが減少傾向が続いている(図1)。



注)1 昭和47年、53年の値は、妙岐の鼻地点の抽水植物を幅50mとして算出。
注)2 抽水等:抽水植物等(沈水・浮葉を除く主に抽水状体の堤外地植物群落)、浮葉:浮葉植物群落、沈水:沈水植物群落

図 1. 霞ヶ浦(西浦)の湖岸植生面積の変化

表 1. 湖岸植生帯の主な保全対策施設 （西浦）

対策手法		整備内容・地区数（完成年度）	整備事例
国土交通省	波浪対策	・治水対策として石積や篭による消波施設の整備 ・25 地区（H3-H26）	
	湖岸植生緊急保全対策	・粗朶や石積による消波施設, 養浜による多様な湿地環境整備 ・8 地区（H10-H23）	
	植生保全対策	・粗朶, 篭, 袋詰め根固めによる消波施設の整備 ・12 地区（H11-H24）	
水資源機構	前浜造成	・浚渫土による前浜の造成, 突堤の整備 ・15 地区（H14-H24）	
茨城県	水生植物帯造成	・消波施設の設置と養浜による静穏な浅場造成 ・5 地区（H14-H23）	

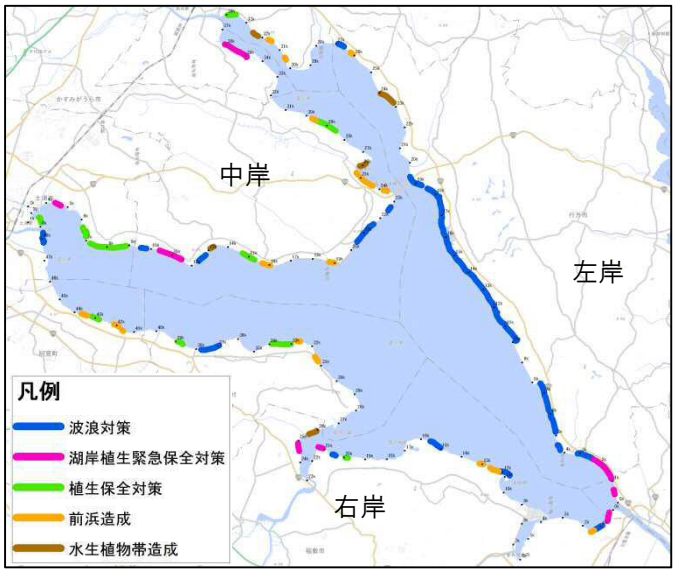


図 2. 対策施設の位置図（西浦）

本検討では今後の霞ヶ浦の湖岸植生帯の保全・再生のあり方を検討するための基礎資料とすることを目的に，H8 年から H28 年までを対象に，蓄積された植生図，水位や波浪等のデータから，霞ヶ浦全体の植生変化の現状とその特性を捉えることを主眼に整理を行った。

2. 方法

対象地区は霞ヶ浦の西浦とし，航空写真の判読により群落区分を行った植生図を用いて湖岸植生の面積を計測した。本検討で整理対象とした植生は，植生図のうち湖岸堤の護岸前面から沖側の範囲（Y.P.+1.5m 以下）とした（図 3）。

植生面積は，霞ヶ浦の距離標を基準に 1km 区間ごとに整理した上で，前述の保全対策施設（表 1，図 2）の有無で区分した（図 4）。

なお，植物群落のうち，航空写真の撮影時期等により精度が大きく異なる可能性がある浮葉・浮遊植生は整理対象外とした。

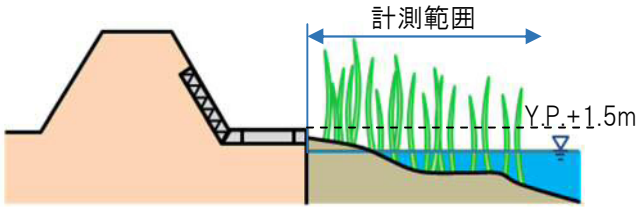


図 3. 植生面積の計測範囲（横断面）



図 4. 植生面積の計測方法（平面イメージ）

3. 結果

3.1 西浦における植生面積の変化

H8 年から H28 年の約 20 年間における変化量について，以下のとおり整理した。

(1)ヨシ等抽水植生について（図 5）

西浦全体では，H8 年が約 112.3ha であったが H28 年は約 82.9ha となり，約 74%にまで（約 29ha）減少した。

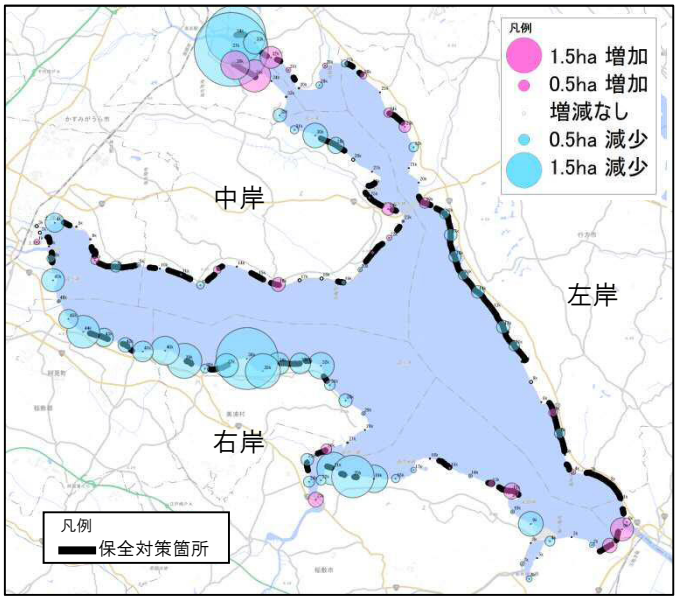


図 5. ヨシ等抽水植生の面積変化

箇所別では，主に右岸側や中岸湾奥部の対策施設がない区間において減少量が比較的多かった。一方，対策施設が連続的にある左岸側では，減少量は比較的少なかった。また，養浜等の保全対策により増加している区間も見られた。

(2)低木・亜高木について（図 6）

西浦全体では，H8 年が約 5.6ha であったが H28 年は約 18.4ha となり，約 327%にまで（約 13ha）増加した。

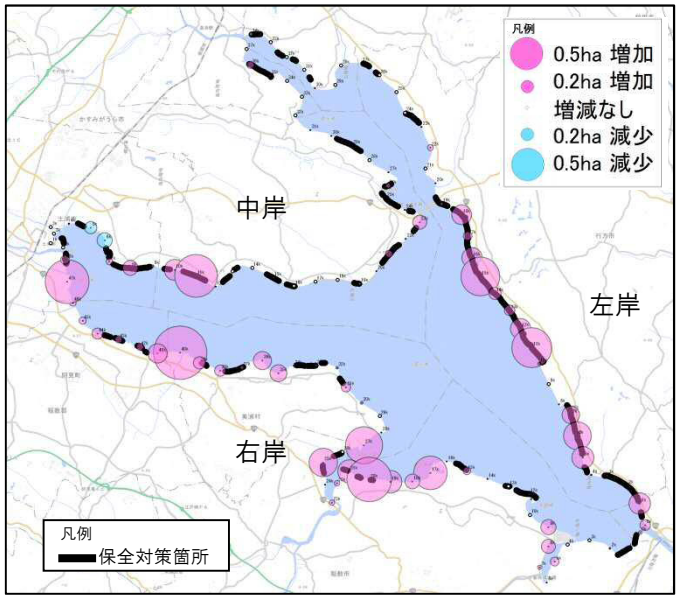


図 6. 低木・亜高木の面積変化

箇所別にみると，低木・亜高木は対策施設の有無に係らず，維持または増加している区間が多く，減少している区間はほとんどなかった。

3.2 対策手法別の植生変化

図 7 に対策手法別の植生面積の増減状況を示す。

波浪対策は，主に離岸堤による波浪対策を実施した箇所であるが，全体として植生面積は増加傾向であった。ただし，ヨシ等抽水植生が減少し，20 年間で低木・亜高木の面積が約 10 倍にまで増加しており，樹林化が著しかった。

湖岸植生緊急保全対策では，養浜などにより H8 から H18 で主にヨシ等抽水植生が大きく増加したが，その後，一部で樹林化が進行した。

消波施設を施工した植生保全対策では，植生面積（主にヨシ等抽水植生）が減少している。

前浜造成，水生植物帯造成は，養浜等によりヨシ等抽水植生は増加傾向で，樹林化も比較的進んでいない。

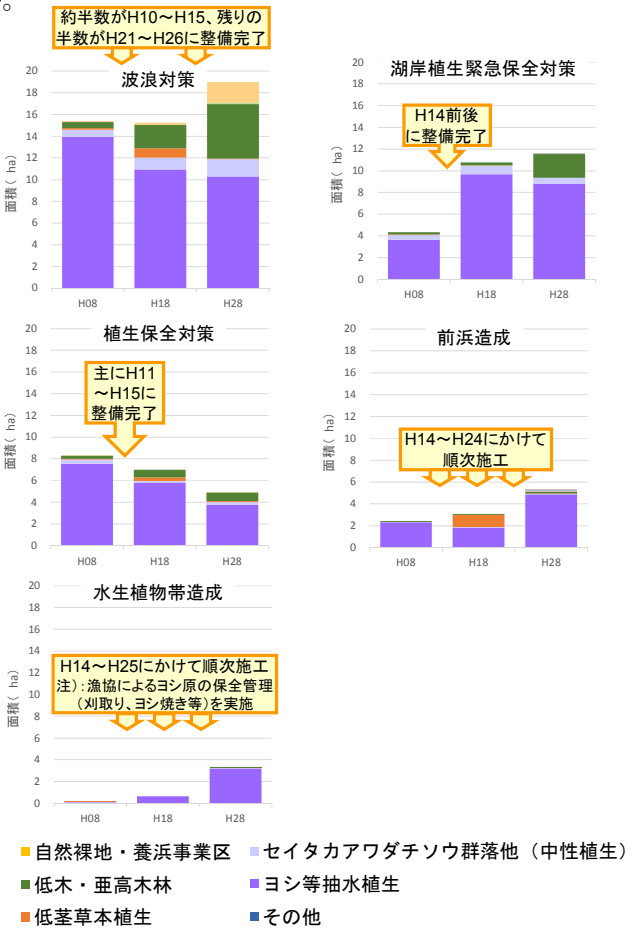


図 7. 対策手法別の植生変化（西浦）

4. 考察

4.1 西浦における湖岸植生の変化

近年の西浦では，保全対策によりヨシ等抽水植生が増加している箇所も見られ，一定の効果は発現していると考えられるが，対策施設が施工されていない区間では減少量が比較的多く，樹林化は対策施設の有無に係らず，左右岸で進行している。

また，対策施設のタイプにより植生の変遷が異なり，「前浜造成」「植生帯造成」ではヨシ等抽水植生の増加が見られたが，「植生保全対策工」では植生面積が減少し，「波浪対策工」では樹林化の進行が著しかった。

4.2 湖岸植生の変化要因

H8 年からの水位運用前後の水位を比べてみると，西浦では，S51～H7 年度の平均水位（各年度の 11-3 月の平均水位の平均値）は Y.P.+1.014m であるのに対し，H8～H22 年度（水位運用を休止していた H12-H15 年度除く）では Y.P.+1.178m と，約 16cm 上昇している。これを踏まえると近年約 20 年間では，以下のような事が変化要因の一つとして推定される。

- 「施設なし区間」では，水位上昇による冠水深の増大，波高の増大およびそれに伴う生育基盤の侵食により，ヨシ等抽水植生が減少。
- このようなヨシ等抽水植生の衰退箇所への樹木の侵入や，経年的な遷移などにより低木・亜高木が増加。
- 緊急保全対策箇所を代表とする「施設あり区間」では，水位上昇により冠水深が増大するが，施工直後は消波施設により波高が減少するとともに，生育基盤の造成等により，ヨシ等抽水植生が増加。
- その後，造成地盤の裸地などに侵入した樹木が，消波施設による陸域の安定化の影響もあり，生長・拡大し，ヨシ等抽水植生を被圧。

5. 今後の方向性

今回，西浦の植生変化について，約 20 年の時間スケールでの全体的な傾向について概ね把握することができた。

今後は，施設の有無と植生の増減との関連性等について代表的箇所を選定し，より詳細に要因分析を進める必要がある。併せて，現在の霞ヶ浦の水位や波浪等の環境特性を踏まえた上で，抽水植物の減少傾向を解消しつつ良好な水辺環境を創造，維持するための具体的な手法の検討，及び将来的な霞ヶ浦の自然再生のあり方や方向性についてもとりまとめていく予定である。

多種多様な生物の生息基盤となる湖岸植生帯は，霞ヶ浦の生態系サービス（基盤サービス）として非常に重要な存在であるので，引き続き関係機関とも連携・情報共有し，保全に努めていきたい。

O1-17

題名：琵琶湖における冬季の水位と沈水植物群落の変遷に関する考察

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キーワード：琵琶湖開発事業，水位管理，沈水植物，冬季の水位低下，生物多様性評価

抄録

水資源機構は，琵琶湖総合開発事業の一環として，水資源開発と琵琶湖沿岸及び下流淀川の治水を目的に琵琶湖開発事業を実施し，1992 年 4 月より管理を開始した。これによる水位変動が沈水植物の生育などへ与える影響を把握することを目的として，1997 年から毎年，湖北の早崎，湖西の安曇川，湖南の赤野井の 3 測線で潜水目視観察等の調査を行っている。本稿では，2002 年の秋季から冬季にかけての水位低下以降，クロモとセンニンモの平均被度の優先順位に変化がみられたことに着目して考察を行った。その結果、秋季から冬季の水位低下が南湖に生育するセンニンモの平均被度に影響を与えたことが推察できた。

*B.S.L.±0.0m＝T.P.（東京湾平均海面）＋84.371m

1. はじめに

琵琶湖における水資源開発と治水を目的に実施された「琵琶湖開発事業」が 1992 年 3 月に終了し 4 月から管理に移行したことにより，国土交通省（当時「建設省」）による瀬田川洗堰のルール化した操作（図1）が開始された。水資源機構（当時「水資源開発公団」）では，事業の実施による琵琶湖沿岸生態系への影響を把握するため，1997 年から毎年，早崎，安曇川，赤野井の 3 測線において，潜水目視観察により，植被率，種別被度階級，群落高などの沈水植物調査（以下「定期調査」という。）のほか，節目調査として，約 6 年に 1 回の頻度で「沈水植物季節変化調査」を実施している。本稿では，2002 年の秋季から冬季にかけての水位低下以降，クロモとセンニンモの平均被度の優先順位に変化がみられたことに着目して考察するものである。

2. 琵琶湖の水位低下の状況

琵琶湖の水位は 1874 年より観測されているが，管理開始以降に発生した渇水のうち，1994 年 9 月に観測史上最低水位となる B.S.L.（琵琶湖基準水位）−1.23m を記録したほか，2000 年 9 月には史上第 5 位となる B.S.L.−0.97m を記録した。これらは沈水植物の生育が著しい夏季に発生していることから，第 9 回世界湖沼会議において「夏渇水による琵琶湖の水環境への影響」と題して報告されている[1]。その後に発生した記録的な渇水として，2002 年 10 月に史上第 2 位の B.S.L.−0.99m が挙げられる。この渇水は秋季から冬季にかけて発生したものであり，図 1 に示すように長期間に渡って水位が低い状態が続く傾向が見られた。また，1994 年の水位は，最低値を記録後，一時的に上昇しているが，再度，冬季に低下していることから，1995 年にまで影響していることが考えられた。これらを踏まえ、管理開始以降の水位低下の状況を表 1 にとりまとめた。なお,秋季から冬季にかけて琵琶湖水位が B.S.L.−0.8m 以下で長期間続く時期の沈水植物に与える影響が,これまで取り上げられていなかったことから，表 1 の「日数」は B.S.L.−0.8m 以下の日を対象として算出した。その結果、これまで着目されていなかった秋季から冬季にかけて約 50 日から 100 日間，水位が低い時期があることを整理した。

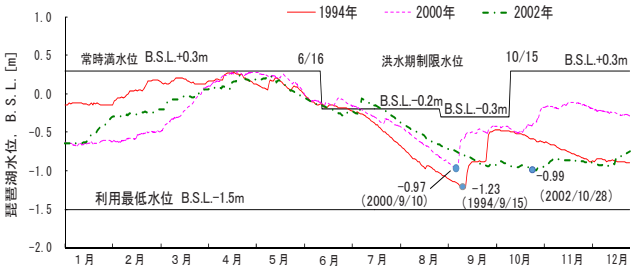

図 1 管理開始以降に発生した渇水時の琵琶湖水位

表 1 管理開始以降の水位低下状況

西暦	最低水位（B.S.L.m）	B.S.L.−0.8m以下の期間	日数	時期
1994年	−1.23	1994/08/11 ～ 1994/09/29	50日間	夏季～秋季
1995年	−0.90	1994/11/26 ～ 1995/01/13	49日間	秋季～冬季
1996年	−0.94	1995/10/31 ～ 1996/01/14	76日間	秋季～冬季
2000年	−0.97	2000/08/29 ～ 2000/09/11	14日間	夏季～秋季
2002年	−0.99	2002/09/15 ～ 2002/12/26	103日間	秋季～冬季

3. 調査方法

3.1 定期調査(沈水植物調査)

図 2 に示す琵琶湖の三大ヨシ帯の 3 測線(北湖 2、南湖 1)を設定した。沈水植物調査は，毎年 8～9 月に各調査測線において、水際線から幅 2m、長さ 10m のベルトトランセクト法による潜水目視観察を実施した。調査範囲は、北湖の早崎・安曇川測線においては群落生育下限までとし，南湖の赤野井測線においては群落生育下限に達しないため対岸までとした。潜水目視観察により、植被率，種別被度階級、群落高を調査した。また併せて水深、底質の計測を行った。

3.2 沈水植物季節変化調査

1999 年，2005 年，2011 年，2017 年には，定期調査の 3 測線を含む 12 測線(図 2)において，沈水植物の季節的な生育状況の変化等を把握することを目的として，定期調査と同様に潜水目視観察調査(植被率，種別被度階級、群落高)及び、水深、底質の計測を行った。各年 8 月の定期調査以外に年 3～5 回実施した。

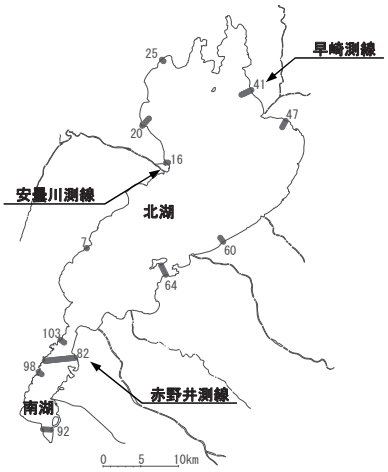

図 2 調査測線位置図(定期，季節変化)

4. 結果

4.1 定期調査(沈水植物調査)の結果

1997 年から 2018 年まで実施した調査結果のうち，表 1 に示す秋季から冬季にかけての水位低下と気象や水質データなどを水植物の生育状況と比較するために 2007 年までの調査結果を対象とした。平均植被率(測線上の同水位帯における植被率の合計を調査区画数で除した値)を図 3～5 に示す。各測線とも、水深帯別の植被率では、水位変動の大きい B.S.L.-2.0m 以浅に比べて B.S.L.-2.0m から B.S.L.-5.0m の植被率が高い。また、植被率の変動については、2003 年は 3 測線ともに低下したが，2 年後以内に回復しているほか，赤野井測線の B.S.L.-2.0m 以浅は、1999 年から 2007 年まで，常に増加を示している。

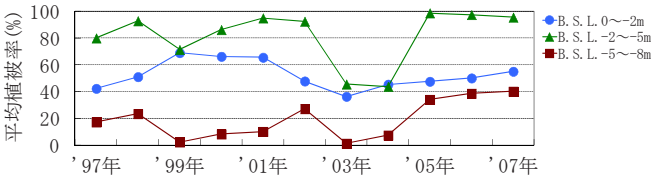

図 3 安曇川測線における水深帯別平均植被率

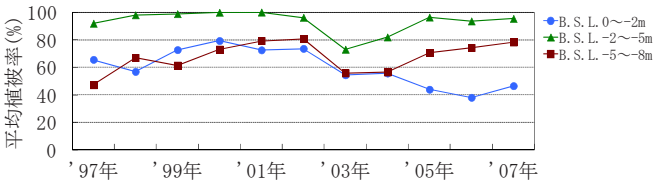

図 4 早崎測線における水深帯別平均植被率

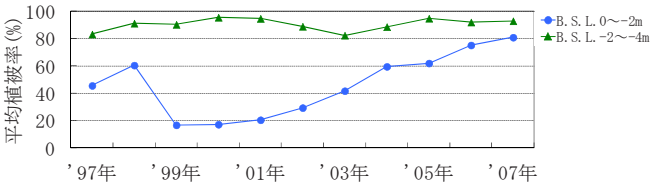

図 5 赤野井測線における水深帯別平均植被率

4.2 沈水植物季節変化調査の結果

沈水植物の季節変化を，冬季に植物体（地下部分除く）が見られたか否かとういう調査結果と，繁茂する時期などの生育情報を基に 4 群に区分とした。(表 2) また，季節ごとの植被率に群落高を乗じて求めた体積により群落占有体積図(図 6)を作成した。

表 2 沈水植物の季節変化類型区分

区分	季節変化の特徴	種名
・在来種Ⅰ群	冬に植物体がほとんどみられず，夏から秋に繁茂	・クロモ ・コウガイモ ・ネジレモ ・ササバモ ・ヒロハノエビモ ・オオササエビモ ・イバラモ ・オオトリゲモ
・在来種Ⅱ群 ・外来種Ⅱ群	冬でも植物体がみられ，夏から秋に繁茂	・センニンモ ・サンネンモ ・ヒロハノセンニンモ ・マツモ ・ホザキノフサモ
		・オオカナダモ（外来種）
・在来種Ⅲ群	冬に植物体がほとんどみられず，春に繁茂	・ホソバミズヒキモ ・エビモ
・外来種Ⅰ群	冬でも植物体がみられ，初夏に繁茂	・コカナダモ（外来種）

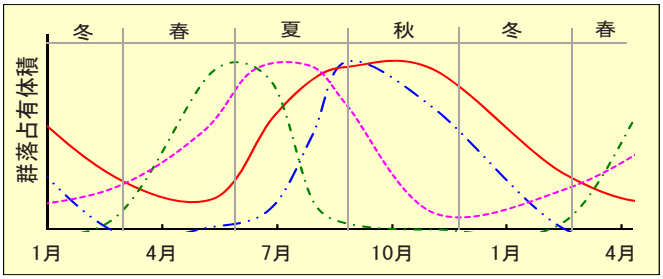

図 6 季節ごとの群落占有体積図

5. 考察

考察に先立ち，琵琶湖水位，日照，水質のほか，「在

来種Ⅰ群」のクロモと「在来種Ⅱ群」のセンニンモの平均被度（測線上の同水位帯における各種ごとの被度の合計を調査区画数で除した値）などを比較するため図7を整理した。

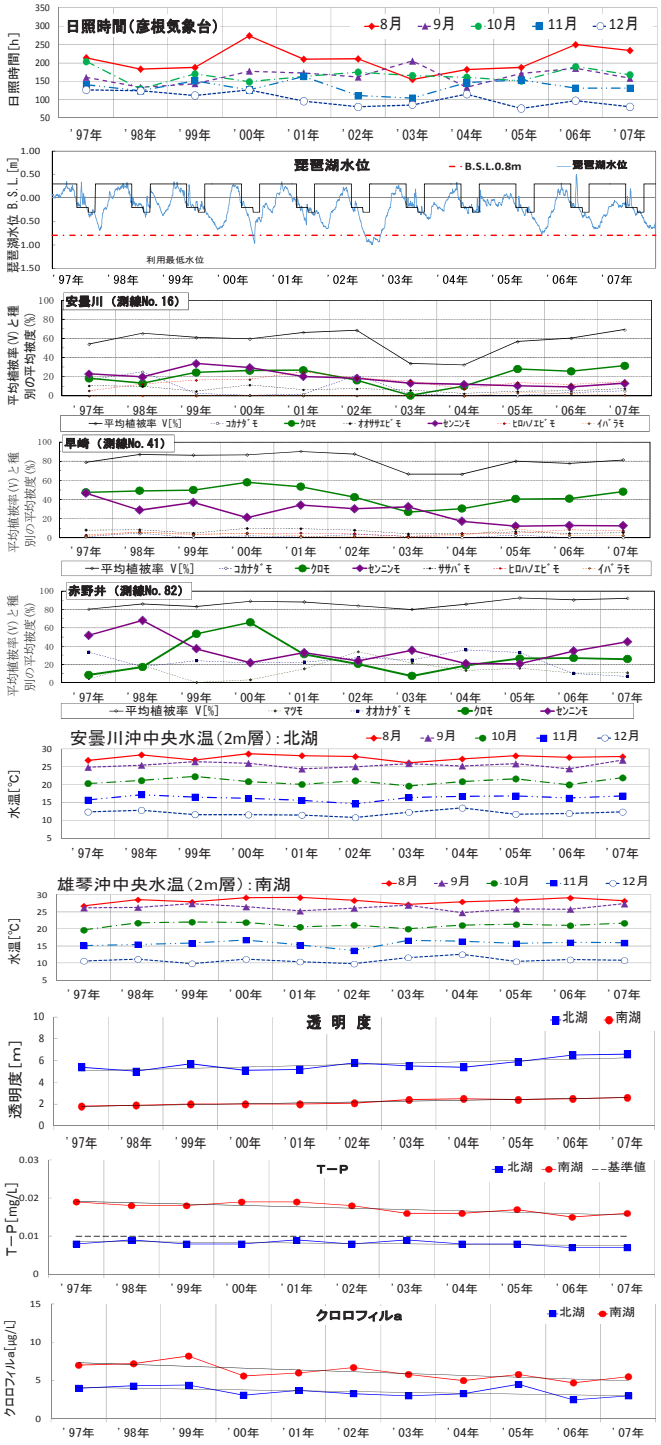

図 7 琵琶湖水位と定期調結果・日照・水質との比較

冬季に植物体が枯れるクロモは 8～9 月に現存量が最大に達し、冬季に植物体が枯れない常緑のセンニンモでは 8～11 月に現存量が最大に達する[3]といわれていること，2002 年の水位低下は 12 月まで続いたことを考慮し，日照時間と水温は 8 月から 12 月の 5 ヶ月間のデータを採用した。また，比較する対象期間は，秋季から冬季にかけて水位が低下した 2002 年の前後 5 年間（1997 年から 2007 年）とした。

光，水温特性についてクロモとセンニンモを比較すると，高水温（23～29℃），強光下ではクロモの成長速度が速く，低水温（11～17℃），弱光下ではセンニンモの成長速度が速くなることが実験により確かめられている[3]。2002 年 9 月から 12 月にかけて水位が低下した時の日照時間を見ると、11 月，12 月が，それ以前の年よりも短くなっている傾向がうかがえる。また，2003 年は冷夏であったことから，8 月の日照時間が短くなっている。これ以降の南湖（赤野井）では，クロモの減少に対してセンニンモが徐々に増加している。よって，南湖は，2002 年の水位低下で，低水温・弱光下が長期間継続されたこと，翌年が冷夏だったなどからセンニンモが生育しやすい環境になったと推察される。北湖（安曇川，早崎）でも 2003 年付近でクロモと，センニンモの平均被度が逆転しているが，これは，南湖（赤野井）と反対の現象を示している。安曇川沖中央の 11 月，12 月水温が，13～15℃あり,北湖は透明度も高いことから，クロモの生育が多く確認されている沿岸部の水深 6m 以浅は，クロモの生育にとって好条件となっていることが推察される。また，水質では,富栄養化の改善による透明度の上昇，植物プランクトンの減少により，栄養塩の競合が有利になったことなどが,複合的に影響していると考えられる。

6. 結論

本稿では，2002 年の秋季から冬季にかけての水位低下以降，クロモとセンニンモの平均被度の優先順位に変化がみられたことに着目して考察を行った。その結果、秋季から冬季の水位低下が南湖に生育するセンニンモの平均被度に影響を与えたことが推察できた。水資源機構では，事業の実施による琵琶湖沿岸生態系への影響を把握するため,これからも琵琶湖沿岸域環境調査を継続する。今後、これらの調査結果が，事業影響評価のためだけではなく，学術的な基礎資料としても活用され，琵琶湖の環境保全に役立つことを願う。

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O1-18

On Inhabitation of Birds Belonging to the Family Charadriformes and Scolopacidae in Lotus Fields on the Shore of Lake Kasumigaura

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Municipal Official

Keywords: Endangered Species, Lotus Fields, Plover, Sandpiper

ABSTRACT

Birds which belong to the family Charadriformes and Scolopacidae inhabit depending on shores, in particular mudflats. On the other hand, there are a lot of lotus fields, which provide mudflats, in the alluvial lowlands on the shore of Lake Kasumigaura. It got confirmed by observations for 11years that 28 species of the families including ones registered on the Red List of Japan's Ministry of the Environment inhabit in the lotus fields, and most of them were observed there through almost a year except June and July or several months.

1. INTRODUCTION

The alluvial lowland along a part of the shore of Lake Kasumigaura - the second largest lake in Japan, of which length is about 20km from the west end to the east end, mainly consists of lotus fields (figure.1). The lotus fields provide mudflats suitable for the habitat of birds belonging to the Charadriforms –hereafter "Plover", Scolopacidae –hereafter "Sandpiper"(figure.2).

Concerning this area, observations on these birds have been conducted by members of the Wild Bird Society of Japan. However, the times of the observation are twice par a year, that is to say, the end of Apr and Aug, so that their inhabitation through a year was not obvious.

Therefore, in order to clarify what kinds of plovers and sandpipers inhabit there throughout a year and that the lotus fields provide good habitats for them, I have conducted multiple observations par a year for 11 years.



Figure.1 Target Area; In the area surrounded by a yellow line, green patches are lotus fields, white ones are rice paddies.



Figure.2 A mudflat in a lotus field on 20 Aug 2017

2. METHOD

(1) Method of observations

A. By driving a small car, so-called "k-car" through narrow trucks among the fields in order to seek birds more thoroughly.

B. By using binoculars to seek them and a digital camera with a 500mm telephoto lens to judge the kinds of species.

C. Seeking in some parts of the area or the whole area par an observation.

(2) Times of observations

The first observation was on 11 Nov 2007 and the last one was on 31 Mar 2018. The times of observations reaches 226 times including the first and last one.

(3) Target Fields

The lotus fields. Though I observed not only in the lotus fields but also in other lands such as rice paddies in this area, I don't discuss the results in this paper.

3. RESULTS

(1) Overview (table.1)

A. 6species of plovers, 22species of sandpipers have been observed. According to "Check-List of Japanese Birds 7th Revised Edition", there inhabit 15species of plovers and 58species of sandpipers in Japan. It means that 40% of Japanese species of plovers and 38% of those of sandpipers have been observed in the lotus fields in the area.

B. There were 5species registered on the Red List of Japan's Ministry of the Environment - hereafter "the Red List". That is to say, the wood sandpiper, the spotted redshank and the common redshank are registered in the rank of "VU" (vulnerable), the Dunlin is in "NT" (near threatened)

And the Grey-headed Lapwing is “DD” (data deficient). “VU” is the category, which is considered that it will be shifted to the category of "endangered " species in the near future ,if the stress factors that have brought the present state continue to work

C. Some species were observed almost through a year except Jun and Jul (Type.1). This category includes the wood sandpiper, the ruff as well as the little ringed plover. Others were observed mainly in winter (Type.2). This category includes the ringed plover, the terminck’s stint, the long-toed stint as well as the snipe. Others are migratory such as the pacific golden plover, Rufous-necked Stint (Type3). The others are accidental such as the bar-tailed godwit (Type.4).

D. 18species were observed in winter. The lotus fields probably provide the environment suitable for wintering of plovers and sandpipers.

Table.1 Times observed of each species par each months

	month			Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
	observations in the month			32	20	11	23	13	1	1	29	27	16	27	26
Type.1	Little Ringed Plover	p		22	11	5	19	7			24	21	13	16	15
	Marsh Sandpiper		s	3	1		1	1			2	9	6	5	1
5sp	Wood Sandpiper 【VU】		s	20	16	6	14	5			13	15	15	16	14
	Common Sandpiper		s	15	6		11	4			22	19	7	6	7
	Ruff		s	5	4	2	3	3			1	3	2	2	6
Type.2	Northern Lapwing	P		19	11	4							1	9	19
	Ringed Plover	p		7	7	2						2	2	5	4
9sp	Long-billed Plover	p		6	4						6	1	1	2	2
	Snipe		s	19	14	8	18	5				13	9	12	18
	Long-billed Dowitcher		s	5	2		2						1	4	3
	Green Sandpiper		s	20	6	4					19	18	9	16	8
	Terminck's Stint		s	21	14	4	6				2	5	7	12	11
	Long-toed Stint		s	4	1	1					2	3	3	2	1
	Dunlin 【NT】		s	25	11	3	4					1	4	10	12
Type.3	Pacific Golden Plover	p					5	1			1	1			
	Black-tailed Godwit		s									4	4	4	
7sp	Spotted Redshank 【VU】		s				1	1				3	1		1
	Common Greenshank		s				1				4	7	1	2	
	Rufous-necked Stint		s			1		1			4	16	5	2	1
	Little Stint		s	7							1	1	1	1	
	Sharp-tailed Sandpiper		s				1	1					4	3	
Type.4	Grey-headed Lapwing【DD】	p		1											
	Bar-tailed Godwit		s										1		
7sp	Eurasian (or Eastern)Curlew		s									1			
	Common Redshank 【VU】		s									1			
	Terek Sandpiper		s								2	2			
	Ruddy Turnstone		s				1								
	Great Knot		s								1	1			
	p; plovers, s; sandpipers	6	22												

(2) Noticeable Species (Table.2)

A. Little Ringed Plover; Though it is said that they are generally summer residents in Japan, they usually wintered in this area.

B. Marsh Sandpiper; Though it is said that they are generally migratory, several of them sometimes wintered.

C. Wood Sandpiper; They are very common in the lotus fields in this area, instead of their being registered in the rank "VU" in the Red List.

D. Ruff; Though it is said that they are generally migratory, a few of them sometimes stayed through winter.

E. Ringed Plover; Though it is said that they are rare in Japan, a few of them usually stayed mainly in winter.

F. Long-toed Stint; Though it is said that they are migratory in Japan's main islands, a few of them often stayed in this area in winter.

G. Dunlin; Though they are registered in the Red List, they stay in this area by large flocks mainly in winter. The average of individuals of the dunlin observed par an observation dominates obviously among those of the other species.

H. Pacific Golden Plover; Though they stayed in a flock consisting of tens of individuals in rice paddies in this area, they stayed alone in the lotus field.

Table.2 The Average of Individuals Observed par an Observation

	month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec
Type.1	Little Ringed Plover	2.5	3.0	6.8	2.3	2.3			6.2	13.1	7.9	5.8	4.5
	Marsh Sandpiper	1.3	1.0		2.0	2.0			2.0	1.8	8.2	2.2	1.0
	Wood Sandpiper	2.5	2.6	4.3	5.0	1.2			6.1	8.1	8.3	6.9	4.5
	Ruff	1.8	2.0	3.5	1.3	1.3			1.0	1.0	2.0	1.0	3.0
Type.2	Ringed Plover	1.4	2.0	2.5						1.0	3.0	2.8	2.3
	Long-toed stint	1.0	3.0	3.0					1.0	1.3	1.3	1.5	1.0
	Dunlin	36.8	57.9	51.0	42.3					1.0	6.5	61.3	71.8
Type.3	Pacific Golden Plover				1.0	1.0			1.0	1.0			

3. DISCUSSION

Further researches would be required as follows, in order to clarify the value of lotus fields as the habitat of plovers and sandpipers.

(1) Researching trends in the number of the species and individuals over the longer term

The observations were conducted within continuous 11years. However, it is not long enough to confirm the trends in the number of species and individuals of plovers and sandpipers. The further long-term observation is required.

(2) Researching influences of the environmental change in the lotus fields on the number of the species and individuals

Nets to prevent birds damaging crops began to be installed in the lotus fields around 2002, and a new method to water the fields began to be adopted mainly in spring and winter. Gaining the data before the events is required in order to clarify the influences of the events on plovers and sandpipers.

4. CONCLUSION

Facts as follows show that the lotus fields provide habitats suitable for plovers and sandpipers. Remaining the lotus fields suitable for their habitat is required.

A. 28species have been observed.

B. 3species of them are rather rare species registered in the rank "VU" which is just lower than the rank "Endangered" species in the Red List.

C. 18species were observed in winter.

D. Most were observed through almost a year except June and July or several months.

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O1-19

Species Richness and Endemism of Vertebrate Fauna In and Around Four Lakes in Agusan del Sur, Philippines

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Keywords: bat, birds, diversity, herpetofauna, wetlands

ABSTRACT

Lakes are important wetlands that provide critical habitats for vertebrates. In this study, species richness and endemism of vertebrates were assessed in four lakes of Agusan del Sur. Cruising, mist netting, and McKinnon's List methods were employed to document vertebrates in the area. Forty-eight vertebrate species comprising 38 birds, three bats, and seven herpetofauna (three anurans and four reptiles) were recorded in the four lakes of Agusan del Sur. A low endemism of 29% was documented consisting of 10 species of birds, one bat, and three herpetofauna. Two Philippine endemic species have vulnerable status, namely, *Anas luzonica* (Philippine duck) which was only recorded in Oromica Lake and *Oreophryne anulata* (Mindanao Cross Frog) which was only found in Nato Lake. The endemic bat species, *Ptenochirus jagori* (Greater Musky Fruit Bat) was the only bat species found in all lakes sampled. A high species diversity with even distribution of species was recorded in the lakes of Agusan del Sur where Nato Lake had the highest vertebrate species richness (S=41) and diversity (H'=3.714). Bray-Curtis cluster analysis showed that Lakes Oromica, Nato, and Los Arcos had high similarity percentage in terms of birds while Lakes Himbang and Nato had high similarity percentage of herpetofauna. Lakes Oromica and Nato were more similar in bat composition. Conversion of forest surrounding the lake into agricultural purposes was observed as threat to the vertebrate fauna in the area. The presence of three vulnerable species indicates the need for conservation of the four lakes in this study.

1. INTRODUCTION

The Philippines, a tropical country, is one of the most biologically rich regions in the world[1]. The country's biodiversity includes at least 206 species of mammals of which 117 (57%) are endemic [2]; 102 amphibian species[3] with 78 endemic [4]; 258 reptile species with 170 (66%) endemic[4], and 695 species of bird species with 241 endemic[5]. However, with the discovery that several subcenters of endemism exist within islands and that species have varied patterns and range of distribution, there is still a need to conduct more surveys in many areas and on different habitat types[6] and one of these habitats is lakes. Lakes are among the most important of wetlands[7] that provide critical habitat for an amazing array of animals including amphibians, reptiles, birds and mammals[8]. Yet, lakes have been subjected to various pressures resulting from the increasing need of people and communities for food, fuel, water, and many other products and services. Thus, surveys on vertebrate fauna in lakes are needed to be able to assess the status of distribution and conservation of species. This study was conducted to determine the species richness and endemism of vertebrate fauna in and around the lakes of Agusan del Sur.

2. METHOD

Sampling Area

This research was conducted in the selected lakes of Agusan del Sur, the seventh largest province of the Philippines with a land area of 8,568 square kilometers located in the Caraga region of Mindanao[9] on November to December 2016. Four sampling sites were surveyed in lakes situated in the municipalities of Esperanza and Prosperidad.

Collection of Samples, Processing, and Identification

The birds and bats were sampled by mist netting. McKinnon's List was used to supplement mist netting data on birds. Morphological measurements were recorded and photographs were taken. Birds were identified using Kennedy *et al.*[10] and Fisher and Hicks[11] while Ingle and Heaney[12] for bats. For herpetofauna, modified cruising method was done and morphometrics were recorded. Identification was based on Alcala and Brown[13], Brown *et al.*[14], Nuñeza[15]. The conservation status of the vertebrates was determined based on the IUCN Red List of Threatened Species[16].

3. RESULTS

Forty-eight vertebrate species of which 14 species are Philippine endemic (10 birds, one bat and three herpetofauna) with 29% endemism were recorded in the four lakes of Agusan del Sur (Table 1). The 48 species comprised 38 species of birds, three bats, and seven herpetofauna (three anurans and four reptiles).

Table 1 Vertebrate fauna recorded in and around four lakes in Agusan del Sur

Vertebrate Fauna	Sampling Sites				Total
	1	2	3	4	
Birds	36	20	24	26	38
Bats	3	1	3	2	3
Herpetofauna					
Amphibians	2	1	2	1	3
Reptiles	1	1	2	3	4
No. of Vertebrate Species: 48					
No. of Endemic Vertebrate Species: 14					
No. of Threatened Vertebrate Species: 3					

Legend: 1-Nato Lake; 2-Himbang Lake; 3-Oromica Lake; 4-Los Arcos Lake

The Philippine endemic species with vulnerable status, *Anas luzonica* (Philippine duck) was only recorded in Oromica Lake while *Oreophyne anulata* (Mindanao Cross Frog) was only found in Nato Lake. The Philippine coucal (*Centropus viridis)* was observed to be in pairs perching on a tree branch on the side on Lake Nato. In addition, the rarely seen wading birds such as the Grey heron (*Ardea cinerea*) and the Great-billed heron (*Ardea sumatrana*) were also recorded in Lake Nato.

Three bat species namely, *Cynopterus brachyotis* (Lesser Short-nosed Fruit Bat), *Eonycteris spelaea* (Common Nectar Bat), and *Ptenochirus jagori* (Greater Musky Fruit Bat) belonging to one order and one family were recorded in the four lake sites of Agusan del Sur. The endemic bat species, *Ptenochirus jagori* (Greater Musky Fruit Bat) was the only bat species found in all lakes sampled.

For herpetofauna, *Rhinella marina* (Cane Toad) and *Eutropis multicarinata* (Northern Two-striped Mabuya) were the most distributed herpetofauna species found in all sampled sites. The Philippine endemic and vulnerable species *Oreophryne anulata* (Mindanao Cross Frog) and *Hydrosaurus pustulatus* (Sailfin Water Lizard) were only present in Nato and Los Arcos Lakes, respectively.

Table 2 shows that the lakes of Agusan del Sur had a high number of vertebrate species with high species diversity and even distribution. Among the sampled sites Nato Lake had the highest number of vertebrate species.

Table 2 Biodiversity Indices of the four lakes in Agusan del Sur

Indices	Sampling Sites			
	1	2	3	4
Taxa (S=48)	41	23	32	31
Dominance	0.02439	0.04348	0.03125	0.03226
Shannon H’	3.714	3.135	3.466	3.434
Evenness	1	1	1	1

Legend: 1-Nato Lake; 2-Himbang Lake; 3-Oromica Lake; 4-Los Arcos Lake

Of the four lakes in Agusan del Sur, Lakes Oromica, Nato and Los Arcos had high similarity percentage (>78%) in terms of birds. Lakes Oromica and Nato had high similarity percentage in bat composition (>96% similarity), while Lakes Himbang and Nato are more similar in terms of herpetofauna.

4. DISCUSSION

The species richness and diversity in and around lakes of Agusan del Sur could be attributed to the varied vegetation types of area and the presence of the food availability for vertebrate species. According to Jones *et al.*[17] vegetation type, temperature, humidity, rainfall, latitude, and altitude, as well as food availability are factors which may contribute to the presence of the species in an area. The presence of endemic species and threatened species in the lakes of Agusan del Sur indicates that lakes are important habitats for the vertebrate fauna. The Philippine endemic and vulnerable *A. luzonica* thrives in Lake Oromica since it has larger land area with patches of vegetation cover allowing bird species to disperse. Additionally, plant species and vegetation structure (density and coverage) provide an explanation for bird species dispersal and richness[18, 19]. In addition, *A. luzonica* frequents most freshwater and saltwater habitats, including mangroves, open sea, and watercourses inside forest[20] thus implying that this species favors areas that are larger with widely open patches. Meanwhile, the recorded Philippine endemic species with vulnerable

status, *O. anulata* (Mindanao Cross Frog) and *H. pustulatus* (Sailfin Water Lizard) in Nato Lake showed that this lake is an important habitat for herpetofauna species despite the conversion of the surrounding land area into agricultural fields. The similarity of sites in terms of faunal composition was seen to be due to the presence of fruiting trees or food sources, microhabitats, and breeding sites which meet the requirements of the species.

5. CONCLUSION

The four lakes surveyed in Agusan del Sur have a relatively high species richness and species diversity. Among the sampled sites, Nato Lake had the highest vertebrate species richness (S=41) and diversity (H'=3.714). Two Philippine endemic species with vulnerable status, *Anas luzonica* (Philippine duck) and *Oreophyne anulata* (Mindanao Cross Frog) were notable species recorded. The presence of endemic species and three threatened species indicates that the lake ecosystem provides favorable habitats for vertebrates. Conversion of forest into agriculture was observed as threat to the vertebrate fauna in the area.

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O1-20

霞ヶ浦における淡水二枚貝類の生息状況と遷移

鈴木　興道

キーワード:ドブガイ、イシガイ、イケチョウガイ

抄録

霞ヶ浦（西浦・北浦）の湖内およびその周辺の流入河川において、1994 年以降、二枚貝類を採取し、生息状況の遷移を調査してきた。結果として湖内では、ドブガイ、マルドブガイ、イシガイ、イケチョウガイ、マシジミ、カワヒバリガイの6種類が確認され、流入河川では上記の他に、カラスガイ、ヨコハマシジラガイ、ヒレイケチョウガイの 3 種類が確認され、計 9 種類となった。 イケチョウガイは 2009 年まで断続的に 9 個体確認されてきたが、それ以降は確認されていない。ヒレイケチョウガイは真珠生産の母貝として養殖されているが、2011 年に桜川中流で 1 個体の成貝が確認され、自然繁殖の可能性が示唆される。カラスガイは湖内では確認されず、2013 年に恋瀬川上流の釣り堀から大量の老貝と 2018 年に桜川で成貝 1 個体が確認された。ヨコハマシジラガイは湖内では確認されず、川尻川で少数ながら生息している。総じてカワヒバリガイや肉食魚類など外来種の繁殖と食害が続き、在来種の生息量が低減している。

1. はじめに

霞ヶ浦には古来より豊かな水環境と生態系が有った。著者は 1995 年開催「第 6 回世界湖沼会議」にて、霞ヶ浦の魚種組成の遷移を下記のように報告(1)した。

“湖内:1885 年以降 34 種 80 種→1973 年以降 21 科 51 種。流入河川（花室川）:1991 年以降 7 科 29 種”。

しかし、その後も在来魚類の生息種数および現存量は低下傾向が続き、特に外来肉食魚のバス、ブルーギル、ナマズ類の増加に相反して、二枚貝類の産卵床となるチチブ、ヨシノボリ、ウキゴリなど在来の小型魚類が捕食され低減している。貝類も同様な傾向が著しい。

2. 方法

貝類の調査範囲は、霞ヶ浦の湖岸及びその流入河川である花室川や川尻川などであった。湖底は砂泥質で歩きやすく、湖岸沿いに水深 1m程度の沖合を素足で探りながら歩き、足裏に貝殻の感触がある所をタモ網で掬い取るラインセンサスを行った。流入河川では貝採り器（目合 5mm）を用いた。採取した貝類は、殻長、殻高、殻幅、質量を測定し記録した。調査頻度は冬期を除き各年2～3日であった。1999～2001 年は調査を休止した。

3. 結果

1993 年の調査当初は貝類の生息密度が高く、写真1に示すように多くの個体が採取された。湖内では、写真2に示すイケチョウガイ *Hyriopsis schlegeli* (Martens)とドブガイ *Anodonta woodiana*(Lea)、写真3に示すマルドブガイ *Anodonta calipygos* Kobelt、写真 4 に示すイシガイ *Unio douglasiae nipponesis Martens*、マシジミ *Corbicula leana Prim*e、写真5に示すカワヒバリガイ *Limnoperna fortune* (Dunker)の6種類が確認された。

流入河川では上記貝類の他に、写真2に示すカラスガイ *Cristaria plicata plicata (Leach)*とヒレイケチョウガイ *Hyriopsis cumingi* [Unionidae]、写真4に示すヨコハマシジラガイ *Inversiuno jokobamensis* (Ihering)の 3 種類が確認され、合計9種類であった。

図1に主な貝類の各年の測定個体数と国交省霞ヶ浦河川事務所が管理する湖心水質自動監視所における年間の上層平均水温の遷移を示した。変動範囲は15.5～17.3℃で弱い上昇傾向にあるが、貝類への影響はない。しかし、現実には貝類の測定個体数に大きな増減が認められ、特に 2013 年以降の減少が危惧される。

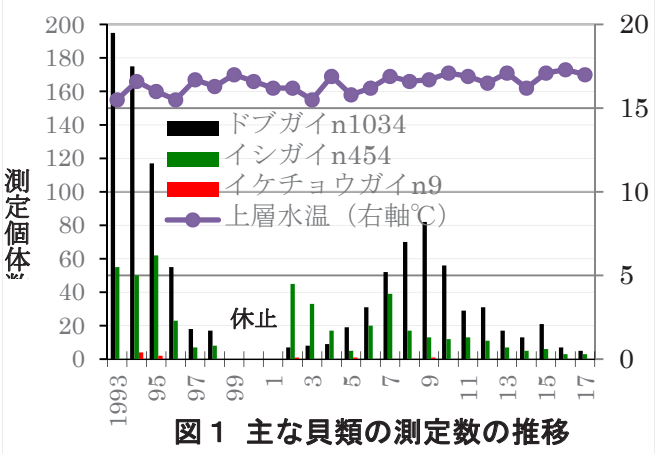

図１ 主な貝類の測定数の推移



写真1　霞ヶ浦西浦（土浦市石田地区）の採取状況(1994.7.6)。イケチョウガイ（写真下の大2個体）、ドブガイ（左～上側の中粒）、イシガイ（右側の細粒）。イケチョウガイは桜川の河口で 6 個体が確認された。



写真3　マルドブガイ。沖合の一部に生息が認められた。殻長に対する殻幅が厚く、殻幅比の上限領域が 0.55（ドブガイは 0.50）程度まである。ドブガイに比較して形態がボール状に丸みを帯び殻頂部の発達が著しい。



写真5　カワヒバリガイ（殻長 20～30mm）。足糸で瓦礫や排水管に強力に密着群生する。水質汚濁にも強い。



写真2　左上：イケチョウガイ(殻長 235mm)。左中：ヒレイケチョウガイ(240)。左下：カラスガイ(262)。右上：マルドブガイ(175)。右中：ドブガイ型(186)、下がヌマガイ型(164)。右下4個体：タガイ型(46～90)。



写真4　左側 5 個体：イシガイ(殻長 72～26mm) 。中央 5 個体：ヨコハマシジラガイ(64～35)。右側上 4 個体：マシジミ(34～19)。右側下2個体：タイワンシジミ。

4.　考察

・　ドブガイは湖内及び流入河川に広く生息分布している。図2に殻長に対する殻高と殻幅、図 3 に質量の関係を示した。当種には歯がない。殻高が高く卵円形のものをヌマガイ型、殻高が低く卵形のものをドブガイ型、田の側溝等に群生し長卵形小型のものをタガイ型と呼

ばれる。しかし、この3型の間には中間的な形態のものが極めて多く、殻長に対する殻高の割合及び殻幅の割合はいずれも漸移・重複して3型を区別する境界は生じず、3 型の呼び名は典型的なものにしかあてはまらない。

- マルドブガイは、全体がボールのように丸く膨らみ、殻頂部が著しく発達して蝶番線から突出する。霞ヶ浦の当種は、琵琶湖や木曽川のものと比較すると、殻長に対する殻高、殻幅、質量の分布は全く重複分布する。霞ヶ浦では湖内では採取されたが、流入河川では確認されなかった。
- イケチョウガイは、1930 年代初めに琵琶湖から霞ヶ浦に移入繁殖した。2009 年まで断続的に 9 個体が確認されてきたが、それ以降は確認されず、今日では絶滅したと思われる。なお 1966 年に霞ヶ浦から青森県の姉沼へ移入した当種は、今日最大の繁殖集団となっており、著者はこれを再び霞ヶ浦へ80個体試験放流した。1～2年後には全て死滅したことから、当種復活の可能性は低い。ヒレイケチョウガイは真珠の母貝として養殖されているが、2011 年に桜川中流で 1 個体の成貝が確認され、自然繁殖の可能性が示唆される。
- カラスガイは 1994 年の沼沢氏の調査[(2)]でも確認されなかった。しかし当種は 2013 年に恋瀬川の川又川上流に在る釣り堀から多数の老貝と、2018 年に桜川で成貝 1 個体が確認されており、流入河川の溜池に生息している可能性が示唆される。
- イシガイは湖内及び流入河川で広く確認された。ヨコハマシジラガイは湖内では確認されず、川尻川など里山の流入河川で少数ながら生息している。

- **表1 霞ヶ浦における二枚貝類の調査結果**

種類	霞ヶ浦湖内	流入河川
ドブガイ	全域に生息	
マルドブガイ	生息	なし
カラスガイ	なし	一部に生息
イケチョウガイ	2009 年まで確認	なし
ヒレイケチョウガイ	生息(養殖)	一部に生息
ヨコハマシジラガイ	なし	一部に生息
イシガイ	全域に生息	
シジミ類	マシジミの他に外来種が繁殖	
カワヒバリガイ	全域に繁殖	

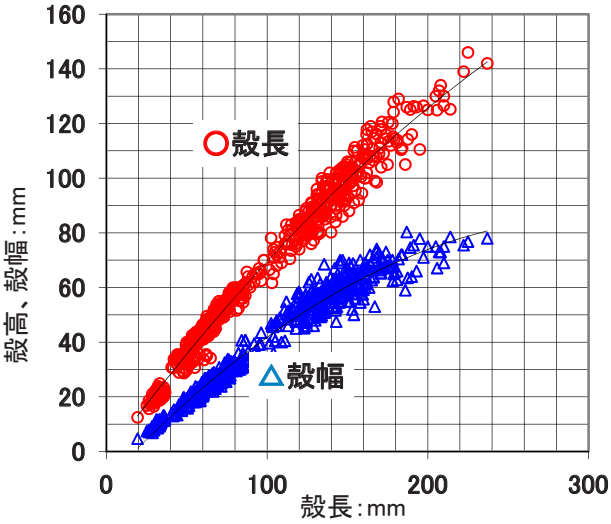

図2 ドブガイの殻長に対する殻高と殻幅

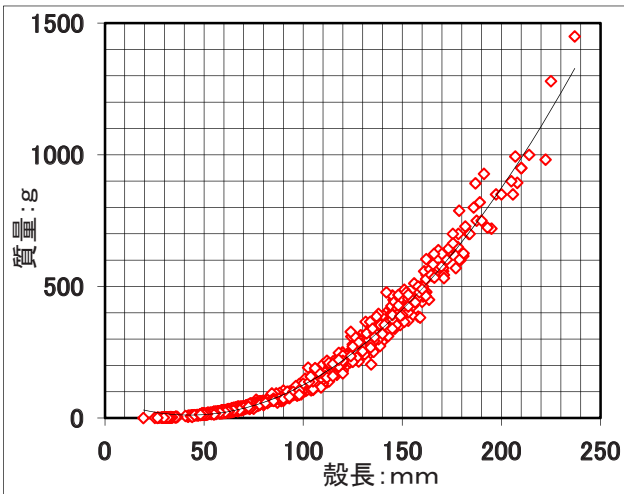

図3 ドブガイの殻長と質量の関係

5 結論

- 水温は弱い上昇傾向にあるが貝類への影響はない。底泥の堆積は少ないが、2013 年以降、貝類の確認量の減少が続いており、畜産排水が危惧される。
- 近年、タイワンシジミや朝鮮シジミ、カワヒバリガイの外来種が繁殖し、種の攪乱が進行している。
- ナマズ類の外来種魚類が繁殖し、在来種が減少している。特にヨシノボリ等の小型魚が捕食されている。彼らの生息域となる葦原の復元が望まれる。
-

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O1-21

Spatial Analysis of Macrophytes Diversity and Distribution in a few Selected Lakes and Reservoirs in Southeast Asia; with Special Reference to Malaysia, Indonesia and Myanmar

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Keywords: Biodiversity evaluation, ecosystem functions, invasive alien species

ABSTRACT

Southeast Asian inland lakes and reservoirs are important ecosystem which functioning in both ecological and economical services. The primary factor that distinguishes wetlands from other land forms is the characteristic vegetation of aquatic macrophytes, adapted to the unique hydric habitat. Therefore, the objective of this study is to analyze the macrophytes diversity and distribution represented in a few selected lakes and reservoirs of Malaysia, Indonesia and Myanmar. The field survey were carried out from February 2015 until April 2018 in eight selected lakes, namely Chini Lake, Bera Lake, Chenderoh Reservoir, Temengor Reservoir (Malaysia), Tempe Lake, Jatiluhur Reservoir, Saguling Reservoir (Indonesia) and Inle Lake (Myanmar). There were four natural lakes and four man-made reservoirs. All of them play multi-functional roles including as a source of fisheries and tourism, power plant, as well as water sources for irrigation. In Malaysia, there are four consecutive reservoirs along Perak River, whereas in Indonesia, there are three consecutive reservoirs along Citarum River. The result showed relatively high in diversity of macrophytes in natural lake compared to man-made reservoir. Subsequently, the characteristics of the lakes are the most important aspect for macrophytes distribution. A better understanding of spatial patterns of macrophytes diversity and distribution would help to improve conservation efforts as well as for the invasive alien species monitoring program because prevention is the most effective method to control the invasive species.

1. INTRODUCTION

Aquatic macrophytes plays vital role in a healthy wetland ecosystem. They serves as primary producers of oxygen through photosynthesis, provides substrates for algae and shelters for many invertebrates, sediment nutrient cycling and helps in stabilizing river and stream banks. Aquatic macrophytes are also a good bio-indicator for water quality monitoring. By its nature, eutrophication could results in a progressive change of species composition and a loss of species diversity.

Climate changes and human activities would lead to a devastating effect on aquatic macrophytes community. According to Seshavatharam (1990), human activities would lead to an uncontrolled growth of aquatic vegetation. Anthropogenic pressure such as sewage inputs and agriculture run off could cause significant changes in abundance and composition of macrophytes (Lind and Cottam, 1969). Meanwhile, climate change will affect aquatic systems by warming the water temperatures, altering stream flows pattern, and increasing storm events (Poff *et al*., 2002). These changes are expected to have profound effects on the distribution and phenology of species and the productivity of aquatic ecosystems (Parmesan, 2006).

Several studies were conducted to examine the relationships between macrophytes and environmental factors. The following studies were carried out to determine the relationships between macrophytes and chemistry of water variables (Heegard *et al.,* 2001; Meerhoff *et al*., 2003; Capers *et al.,* 2010; Akasaka and Takamura, 2011; O'Hare *et al.,* 2012). In addition, macrophytes community composition and distinct in distribution with hydrology, climate, substrate type and nutrient availability (Cronk and Fennessy, 2001) and can be affected by geology, water, land use and sediment chemistry (Koch, 2001; Lougheed *et al*., 2001; Hansel-Welch *et al*., 2003; del Pozo *et al*., 2011).

Characteristics of sediments such as chemical compound and physical properties have important role in aquatic vegetation distribution (Misra, 1938). Aspects that influenced the growth and distribution of macrophytes have long been interested by ecologist (Pearsall, 1920; Misra, 1938; Moyle, 1945; Peltier and Welch, 1970; Barko *et al.,* 1986).

This study will be focusing on providing a better understanding of macrophytes diversity and distribution represented in a few selected lakes and reservoirs of

Southeast Asian region. A better understanding of spatial patterns of macrophytes diversity and distribution would help to improve conservation efforts as well as for the invasive alien species monitoring program because prevention is the most effective method to control the invasive species.

2. METHOD

The field survey were carried out from February 2015 until April 2018 in eight selected lakes, namely Chini Lake, Bera Lake, Chenderoh Reservoir, Temengor Reservoir (Malaysia), Tempe Lake, Jatiluhur Reservoir, Saguling Reservoir (Indonesia) and Inle Lake (Myanmar)(Table 1). The characteristics of sampling sites are as being explained in Table 2.

Table 1. The lists of sampling sites for macrophytes diversity and distribution

Site/ criteria	Location	Impoundment
Chenderoh	Perak, Malaysia	Man-made; Perak River (1930)
Temengor	Perak, Malaysia	Man-made; Perak River (1978)
Chini Lake	Pahang, Malaysia	Natural, Floodplain
Bera Lake	Pahang, Malaysia	Natural, Floodplain
Jatiluhur	West Java, Indonesia	Man-made; Citarum River (1967)
Saguling	West Java, Indonesia	Man-made; Citarum River (1981)
Tempe Lake	Sulawesi, Indonesia	Natural, Floodplain
Inle lake	Shan State, Myanmar	Natural, Solution

Table 2. The characteristics of sampling sites for macrophytes diversity and distribution

Site	Surf. area (km2)	Elev. (m)	Max. Depth (m)	Human impact	Fish industry
Chenderoh	25	45	25	Domestic waste	Yes
Temengor	152	245	100	-	Yes
Chini Lake	2.02	11.9	4	Domestic waste	Yes
Bera Lake	61.5	43.9	7	Domestic waste	Yes
Jatiluhur	83	107	90	Domestic waste	Yes
Saguling	56	650.5	92	Domestic waste	Yes
Tempe Lake	130	5	5	Domestic waste	Yes
Inle lake	47	1000	7	Domestic waste	Yes

The diversity and distribution of macrophytes is being analyzed by using the geographical information system. The diversity of species in distinct subunits within a study area (known as *alpha* diversity) is the principal subject of the spatial analysis of diversity. The most direct measurement of *alpha* diversity results from counting the number of observed diversity units (the number of species).

In the process of selecting areas for conservation, emphasis is most often placed on conserving the highest number of species (Petit et al. 1998). It is, however, important to realize that focusing conservation only on those sites with the highest levels of diversity may lead to a failure to identify threatened species found only at sites with generally low levels of diversity (e.g. high mountain ecosystems which reveal a low number of species, but where such species are unique and not found in other ecosystems).

3. RESULTS

The result showed relatively high in diversity of macrophytes in natural lake compared to man-made reservoir. Subsequently, the characteristics of the lakes are the most important aspect for macrophytes distribution.

4. CONCLUSION

A better understanding of spatial patterns of macrophytes diversity and distribution would help to improve conservation efforts as well as for the invasive alien species monitoring program because prevention is the most effective method to control the invasive species.

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O1-22

Habitat conditions and structures of rare riverside grassland plant communities on the Tenryu-gawa River system in the Nagano Prefecture, Japan

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Keywords: endangered species, invasive alien species, floodplain vegetation, semi-natural grassland

ABSTRACT

Recently, populations of river-specific plants and herbaceous perennial species in Japan have decreased and extinct. However, in a preliminary investigation, we confirmed the presence of rare plant communities in the Tenryu-gawa River system. And, alien plants such as *Coreopsis lanceolate* and *Robinia pseudoacacia* invaded and established in the natural grassland in Tenryu-gawa River system. Therefore, the purpose of this study was to explore the habitat conditions and structures of these rare plant communities on the riverside grassland vegetation in this area to conserve these endangered species. Vegetation and environmental conditions of the riverside communities were investigated in the summer of 2017.All investigation plots were 28, and the area of one quadrat was 2m×2m. Five types of communities were distinguished by a TWINSPAN classification. These were primarily classified into three high-water channel site types and two low-water channel site types. The endangered herbaceous perennials, such as *Cynanchum paniculatum* or *Ixeris chinensis* subsp. *strigosa*, appeared in high-water channel site types, whereas the river-specific plants, such as *Potentilla chinensis* or *Artemisia capillaris*, dominated in low-water channel site types. On the other hand, alien plants such as *Coreopsis lanceolate* invaded in all types. It was thought that many alien plants had a negative influence on the growth of the rare plant communities.

1. INTRODUCTION

Recently, it becomes the problem that river-specific plant and herbaceous perennial plants decreased and extinct in Japan [1]. And, alien plants established semi-natural grassland communities in the river side [2]. Also, alien plants such as *Corepsis lonceolata* and *Buddleja davidii* invaded and established in the southern part of Nagano prefecture [3] [4]. However, the rare plant communities such as *Ixeris tamagawaensis* and *Orostachys japonicas* were comfermed [5] [6]. So, the riverside and semi-natural grassland communities have remained in the southern part of Nagano prefecture. In preliminary investigation, we were able to confirm those rare plant communities in the Tenryu-gawa River system. And, alien plants such as *Coreopsis lanceolate* and *Robinia pseudoacacia* invaded and established in the natural grassland in Tenryu-gawa River system. Therefore, the purpose of this study was to explore the habitat conditions and structures of these rare plant communities on the riverside grassland vegetation in this area to conserve these endangered species.

2. METHOD

The present study was conducted on the river side and semi-natural grassland on Tenryu-gawa river system in Nagano prefecture, Japan. Vegetation and environmental conditions of the riverside communities were investigated in the summer of 2017. All number of investigation plots were 28 (high water channel; n=22 , low water channel; n=6), and the area of one quadrat was 4 ㎡(2m×2m). For the vegetation survey（Braun-Blanquet 1964) , plot cover and maximum high of each species were recorded in each plot. To explore environmental conditions, we recorded RPPFD(Sep.), soil hardness(Sep.) and grain ingredient of sand(Nov.).

Statistical analyses

TWINSPAN classification was used as species composition and structure of communities. Furthermore, a detrended correspondence analysis (DCA) was performed with the species incidence matrix.

3. RESULTS

The number of appearance species was 72. To know the species composition and structure of communities, all plots were analyzed by TWINSPAN. And, appearance species were classified by TWINSPAN, too. So, five type communities were distinguished by TWINSPAN classification. And mainly, all plots were classified in the group of 3 high water channel site types and 2 low water

channel site types. *Corepsis lonceolata* was common species in all types. *Z.japonica, I.pseudo-tinctoria, R.lucia* was common species in high water channel. *Cynonchum ponlculatum* dominated in Cp-Zj type. The endangered plants such as *Orostachys japonicas* or *Ixeis chinensis*, *Lespedeza tomentosa* appeared in Ic-Lt Rp type. The herbaceous perennial plants such as *Cymbopogon tortilis* or *Dianthus superbus* constituted grassland vegetation in Ds-Ct type. *Artemisia princeps* and *Artemisia capillaris* were common species in low water channel. *Artemisia capillaris* dominated in Ac-Pj type. And *Lespedeza tomentosa* appeared too. *Potentilla chinensis* and *Robinia pseudoacacia* dominated in Pc- Rp type.

Environmental conditions

In Cp-Zj type, the soil hardness and community height were lower than other. Community height and RPPFD of Ic-Lt-Rp type were highest. The ratio of alien plants of the communities on low water channel site was higher than others.

DCA ordination of the river side grassland community

The same date of TWINSPAN was utilized by DCA ordination. The all plots were arranged high water channel site types and low water channel site types.

4. DISCUSSION

The river specific plants and herbaceous perennial plants appeared in high water channel. So, these were grassland vegetation indigenous to river side. Cerepsis lonceolata dominated in Cp-Zj type. We thought that Cerepsis lonceolata impacted on other herbaceous plants. And, it seemed that dominance of Robinia pseudoacacia impacted on herbaceous plants in Ic-Lt-Rp type. We thought that grassland communites were decreased by dominated Amorpho futiacasia in Ds-Ct type. For this reason, the problem of high water channel were dominace of Cerepsis lonceolata and alien plants such as Robinia pseudoacacia or Amorpho futiacasia impacted on herbaceous plants and decreased grassland. The river-specific plants such as Potentilla chinensis or Artemisia capillaris and Lespedeza tomentosa appeared low water channel. So, it was thought that the disturbance with the river was necessary for conservation of the low water channel grassland communities. Robinia pseudoacacia dominated in Pc-Rp type. In this type, the rare river-specific plants and R. pseudoacacia were maintained under the same condition by the disturbance of the river. For this reason, the ratio of alien plants of the communities on low water channel site was higher than others.

5. CONCLUSION

It was thought that many alien plants had a negative influence on the growth of the rare plant communities. We thought that immediately, it was necessary to exterminate of the alien plants to conserve rare plants.

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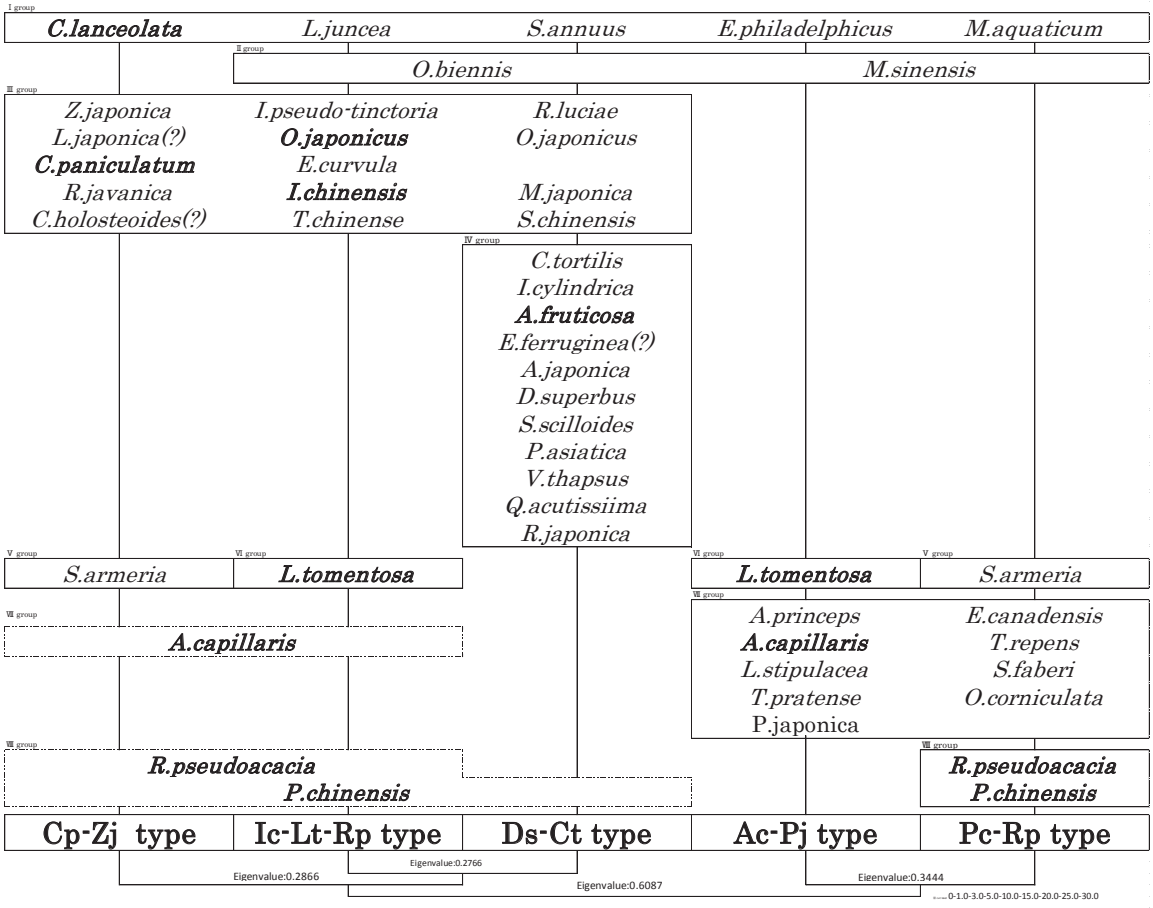

Fig.1 Species composition and structure of communities by TWINSPAN

Table 1. Environmental conditions

	type	Cp-Zj type	Ic-Lt-Rp type	Ds-Ct type	Ac-Pj type	Pc-Rp type
Plot cover(%)	mean	70.56	64.00	66.25	76.67	60.00
	SD	14.02	12.45	11.26	2.89	10.00
Number of species	mean	10.67	19.00	18.50	16.67	12.00
	SD	2.693	1.732	2.619	0.577	1.732
High of community(cm)	mean	74.90	153.80	109.00	94.33	114.00
	SD	17.62	101.13	27.96	12.50	39.85
Alien plants percentage(%)	mean	19.84	23.00	21.37	44.00	46.97
	SD	6.60	4.63	8.25	2.95	2.62
Soil hardness(mm)	mean	11.67	13.04	13.17	18.60	17.47
	SD	4.39	4.31	5.45	5.51	4.73
RPPFD(%)	mean	53.62	31.75	46.35	48.43	65.10
	SD	16.02	22.25	10.28	10.94	14.24

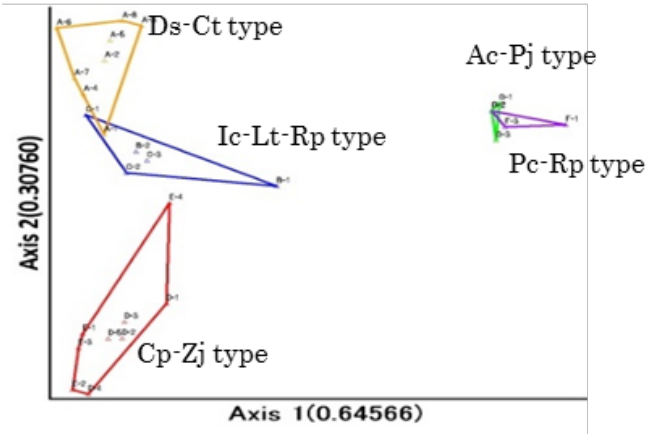

Fig.2 DCA ordination of the river side grassland communities

O1-23

急拡大する侵略的外来水生植物オオバナミズキンバイ等への対策：琵琶湖における取組事例

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キーワード：侵略的外来植物、オオバナミズキンバイ、外来種対策、琵琶湖、霞ヶ浦

抄録

琵琶湖では2009年に初確認されたオオバナミズキンバイは，先行して琵琶湖に侵入・定着していたナガエツルノゲイトウに置き換わるように分布範囲と生育面積を急速に拡大し，生態系への影響や漁業被害，航行障害などが懸念され，2013 年度から本格的な対策事業が始まり，2014 年度からは建設機械や水草刈取り船など機械力を導入した大規模駆除が行われている。一旦はリバウンドを経験しながらも，駆除に際しては機械駆除と人力駆除を併用できるだけ取り残しがないようにし，駆除済みの区域における巡回・監視を徹底して群落の再生を抑えることで，年度末の水域全体の生育面積は過去2カ年減少傾向を続けることができた。本発表では，琵琶湖で試行錯誤を重ねて確立された駆除方法を中心に，駆除個体の処分には過大な手間暇と経費がかかることなど対策の概要について紹介する。本種は近年，関東地方の霞ヶ浦，手賀沼，印旛沼への侵入が確認され早期対応が求められる。

1.　はじめに：琵琶湖での対策の始まり

オオバナミズキンバイ（写真①：以下「オオバナ」と略記。）*Ludwigia grandiflora* とナガエツルノゲイトウ（写真②：以下「ナガエ」と略記。）*Alternanthera philoxeroides* は，わが国ではともに外来生物法の特定外来生物に指定されている侵略性の高い外来植物である。近年，オオバナとナガエ（以下，「オオバナ等」と略記。）は，琵琶湖をはじめ日本の複数水域への侵入・定着が確認されつつある。


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琵琶湖では，まずナガエが 2004 年時点で北湖東岸の内湖への侵入が確認され，その後，北湖南部から南湖にかけて分布範囲を拡大し，一部の内湖や河川，琵琶湖の内湾などでは大規模な群落を形成し始めた。続いて，2009 年に南湖北部の東岸でオオバナが確認され，南湖全域の湖岸へ急速に拡大し，先行したナガエに置き換わる形で大増殖するに至った。

オオバナとナガエはともに水陸両生の抽水植物であり，葉や茎の断片から発根するという栄養繁殖または種子繁殖（オオバナのみ）により分散するため，分布域は水際線沿いにときに急速に拡大する。オオバナ等は生育面積が水際から沖合いに向けて大規模に拡大するため（写真③），希少種を含む在来他種の植物を競争的に排除し，大規模に水面を覆う群落下では特に高水温期に著しい酸素欠乏が予測されるなど，在来の動植物の生息・生育に対して深刻な影響を与えるものと考えられる。また，大規模な群落の生育状態は，漁業の操業への支障や船舶の航行の阻害となるほか（写真④），琵琶湖から下流域への分布拡大や，琵琶湖周辺の農地への侵入など，数々の懸念は次第に現実化しつつある。


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滋賀県では，2013 年度からオオバナを対象とした本格的な駆除事業を開始したが，この年度は外来種調査を主課題とした緊急雇用対策事業（エイリアン・ウォッチャー事業）による対応であったため，内湖の一部において人力による駆除が年度を通して実施された。その結果，オオバナの生育規模と増殖速度を考えると，オオバナ等への対策は機械力を用いないと対応不能な状態に陥っていることが

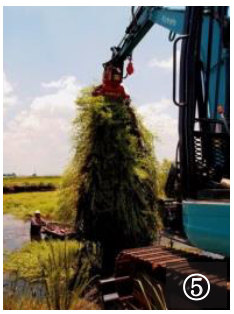
明白となった。そこで，2013 年度末には滋賀県は関係市や団体とともに「琵琶湖外来水生植物対策協議会」を結成し，2014 年度から環境省の交付金と県からの補助金により，機械力を駆使したオオバナ等の大規模な駆除事業に着手することとした。

2. 琵琶湖における大規模駆除事業の展開

(1) 2014 年度：大規模機械駆除の開始

2013 年度末の時点で，琵琶湖および周辺水域におけるオオバナ等の生育面積は合わせて約 78,000 ㎡（うちオオバナ約 65,000 ㎡。以下，同じ。）に達していた。2014 年度を迎え初めての機械力を導入した大規模駆除を実施するに当たり，駆除作業で大量の植物片が発生し，それらが栄養繁殖して広域分散する原因となる可能性を憂慮する専門家からの意見もあり，その一方でオオバナ等の生育面積は増加を続けていることが確実であることから，県議会の 9 月定例議会で補正予算を確保し，駆除事業は年度後半からの実施となった。

まず，オオバナ等を掴み取ることができる特殊な林業用の建設機械，スイングヤーダ（写真⑤）を用いた駆除事業は 10 月末から始まった。続いて，琵琶湖の沈水植物の刈り取りに用いられてきたハーベスター形式の水草刈取り船（写真⑥）も操作方法を工夫することでオオバナ等の駆除にも使用可能であると確認されたため，年末からは水草刈取り船による駆除事業も始まった。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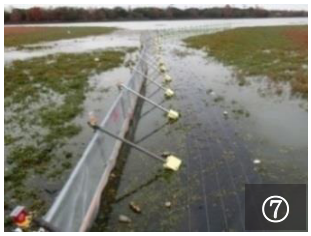
岸から沖合いに向けて広がる大規模なオオバナの純群落の大部分を完全に除去する方針として駆除を進めた結果，年度内には最大約 176,00 ㎡（157,000 ㎡）に達したオオバナ等の生育面積は，年度末には約 62,000 ㎡（46,000 ㎡）にまで縮減させ，初めて前年度末の値よりも減らすことができた。

(2) 2015 年度：大規模リバウンドと分布拡大

2015 年度は，前年度に補正予算まで投入し大規模な駆除が実施されたことから当初予算は潤沢ではなかったが，前年度に機械駆除を実施した箇所では，その後地元の漁協や NPO が巡回・監視を行うことで，群落の再生がほぼ抑えられている区域も確保され，駆除後の丁寧な巡回・監視が有効であることが明らかとなった。しかし，その一方で，夏以降，特に秋になってから群落が想定を超える規模で再生した区域もあり，その原因として駆除せず残存した他の抽水植物群落の中に混生して残存したオオバナ等からの再生が示唆された。そこで，同年度の駆除事業においては，機械による大規模な駆除と人力による取り残しのない丁寧な駆除を併用し，駆除実施後の箇所では巡回・監視により群落の再生を抑えることを試行した。その結果，全体としては生育面積が大規模にリバウンドして最大約 306,000 ㎡（271,000 ㎡）に達し，年度末にも約 229,000 ㎡（200,000 ㎡）が残存する結果となった。さらに，この年度には，これまでオオバナが確認されていなかった琵琶湖の北湖周辺水域においても 4 箇所で相次いで小規模なオオバナ群落が確認されたが，北湖ではオオバナの生育しない状態の復元・維持を目標として緊急の駆除を行った。

(3) 2016～2017 年度：丁寧な駆除と巡回監視の徹底

2016 年度は，過去最大規模の当初予算を確保し，「できるだけ取り残しのない丁寧な駆除」と「駆除後の巡回・監視の徹底による再発防止」を基本方針とし，巡回・監視は当該事業による駆除が済んだ区域だけでなく，過去に駆除をした周辺区域にも拡大して，群落の成長開始に先んじて年度開始直後から駆除事業に着手した。しかし，年度当初の生育面積が膨大で，シミュレーションを行った結果，当初予算による駆除事業だけでは年度末に残存する生育面積から次年度の群落の成長速度が既存の事業者による駆除能力を上回り「制御不能な状態」になると予測されたため，県議会 9 月定例会議での補正予算を確保し当初予算と合わせて 3 億円を超える規模での駆除が実施されることとなった。なお，事業は上記の基本方針に沿って行うものとし，分散拡大のリスクや保全の必要性に応じた優先度を評価し，優先順位の高い箇所から順に駆除事業の対象とした。その結果，大規模群落のなかには優先順位が高くないと判定され，「順番待ち」となる群落も出てきたことから，その一部には群落の辺縁部から離脱が起こらないよう，拡大防止のためのフェンスの設置も試みられた。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このようにリスクや必要性に応じた優先順位に基づいた大規模かつ丁寧な駆除を実施した結果，年度内の最大生育面積が過去最大の約 348,000 ㎡（299,000 ㎡）に到達すると推定されたものの，年度末の残存生育面積は約 156,000 ㎡（131,000 ㎡）にまで減少させることができた（図 1）。

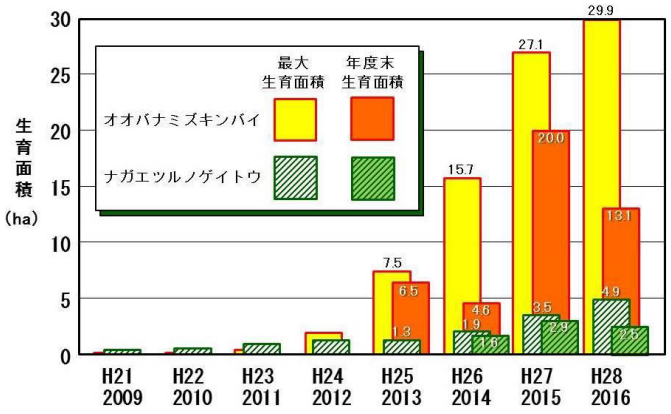

図1. 琵琶湖および周辺水域におけるオオバナ等の年度内最大生育面積と年度末残存面積の経年的変化.

2018 年度も前年度の枠組みを継承して取組を進めており，年度末の残存生育面積は本要旨の投稿時点では 100,000 ㎡程度となる見通しとなっており，その後の進捗については，発表の際に追加するものとする。

3. 対策を進めるうえでの課題

(1) 駆除から処分に至る過程の効率化・円滑化

現場から除去したオオバナ等は，その瞬間から生きた状態の特定外来生物であることに加えて，事業系一般廃棄物となるため，その適切な処分に至るまでは外来生物法だけでなく廃掃法の適用も受けることになる。現時点では，オオバナ等は焼却処分または埋設処分をする必要があるため，除去作業を行った基礎自治体において仮置きする場の確保し，除去したオオバナ等の軽量化や乾燥を行ってから，処分場へと運搬して処理を行っている。すなわち，オオバナ等の駆除事業には，現場での除去作業に加えて，その後の過程にも相当な労力と経費を要しており，その効率化・円滑化を図ることが必要である。また，処分方法を抜本的に改める新たな処理技術の開発にも期待が寄せられている。

(2) 難駆除群落に対する対策手法の確立

駆除の優先順位の高い箇所は水際から沖合いへ向かって群落が成長している箇所であるが，オオバナ等は水陸両生の植物であり，かつての高水位時に漂着したり，水際から陸上へ伸長したりして陸域にも生育している。これらは分散・拡大等のリスクが比較的低いとはいえ，石組み護岸の間や土中深くに根を張り，取り残しのない除去を行うことがきわめて難しい状況にある。こうした難駆除の群落に対しても，順次駆除を進めていくことが必要であり，新たな対策手法の検討・開発が求められている。

(3) 駆除後の管理体制の確立と継続

事業の進展により，駆除済みの箇所が増加することは，巡回・監視を行う必要のある地域の拡大を意味する。駆除跡地での巡回・監視に必要な労力と経費は，駆除の実施直後から継続して実施することで次第に縮減できるものと予測されるが，一方で，当面の間，その努力を継続させる必要のあることも確実なことである。そのための効果的かつ持続可能な巡回・監視の手法と体制を確立することが必要である。

4. 他の水域への警鐘

琵琶湖および周辺水域では現在，年度当初に機械駆除を必要とする大規模群落が存在しない「管理可能な状態」にその全域を置くことを当面の目標として対策事業を進めており，2 年連続で年度末の残存面積を縮減させることができ，諸課題が残されているとはいえ，やっとその目標の実現に向けての道筋が付けられたところである。これまでの経緯を振り返ると，対策がこれまでの規模となってしまった背景としては，行政施策的には十分とは言えないまでもかなり順応的な対処が採られてきたとはいえ，特にオオバナは素性のよくわからない新たな植物でもあったことから，結果として対策が後手に回ってしまい，分布範囲と生育規模の著しい拡大を許容してしまったことが挙げられる。

本会議の開催地である茨城県霞ヶ浦をはじめとする関東地方の水域ではすでにナガエが侵入しており，うち一部の水域では生育規模に拡大し，被害対策も採られてきている。近年，霞ヶ浦と千葉県の印旛沼，手賀沼において新たにオオバナが確認された。これらの水域においては，琵琶湖では先行して生育していたナガエの群落が次々にオオバナに置き換わり，はるかに大規模な群落へと成長したことを，ぜひとも教訓としてもらいたい。オオバナの発見箇所では，それぞれ緊急の対応が試みられたが，たまたま確認された見つけやすい箇所以外にもすでに群落が拡大していることを想定し，大規模な拡大を招くことのないよう，できるだけ先手を打つ対応が採られることを願ってやまない。

O1-24

霞ヶ浦周辺地域における特定外来生物カワヒバリガイの現状と対策

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キーワード:外来種, 分布拡大, 水利施設

抄録

カワヒバリガイ *Limnoperna fortunei* は中国・朝鮮半島を原産とする淡水二枚貝であり、現在はアジア各国と南米に広く分布している。本種は固い基質に固着する性質を持ち、水利施設の配管等に付着してその運用に悪影響を及ぼす。茨城県の霞ヶ浦とその周辺地域でカワヒバリガイの生息状況の調査を行ったところ、霞ヶ浦では 2006 年から 2012 年までの間に湖岸の 46%から 83%まで分布を拡大し、採集個体数は約 3.8 倍に増加した。霞ヶ浦から取水する水利施設(水路・貯水池)とその流入河川においてカワヒバリガイの生息が確認され、分布データと遺伝解析の結果から、これら侵入の少なくとも一部は水利施設を経由したものと推察された。霞ヶ浦から取水する水利施設の管理組織では，貯水池や水路等のモニタリング調査や落水による駆除などを通じ，水利施設を経由したカワヒバリガイの分布拡大と被害抑制の試みを進めている。

1. はじめに

カワヒバリガイ *Limnoperna fortunei* は中国・朝鮮半島を原産とする淡水性二枚貝であり、現在はアジア各国と南米に広く分布している[1-4](図 1). 本種は繊維状の分泌物である足糸により岩などの基質に固着する性質を持ち、水利施設の配管内部に付着して水の流れを妨げるなど施設の運用に悪影響を与えることが知られている[5]. また、本種の侵入によって、侵入先の在来生態系に大きな変化が生じることが報告されている[6]。



図 1 貯水池のバースクリーンに付着したカワヒバリガイ

霞ヶ浦は日本で二番目に大きい湖であり、その水は飲料水や農業用水・工業用水など、様々な目的の水源として使われている。2005 年以降、霞ヶ浦ではカワヒバリガイの生息が確認されており、自然環境への影響や水利施設での被害が懸念されている。

本稿では、霞ヶ浦とその周辺地域におけるカワヒバリガイの現状を概観すると共に、その分布拡大と被害対策の取り組みについて述べる。

2. 方法

霞ヶ浦におけるカワヒバリガイの分布状況を明らかにするために、湖岸の全域を対象にカワヒバリガイの目視調査を 2006 年と 2012 年に行った。調査では、水深の浅い湖岸を主な対象として、調査員1人が 10 分間当たりに採集できた個体数を密度の指標として記録した。得られた分布データを元に、霞ヶ浦湖岸における本種の分布拡大速度の推定と将来予測を行った。

カワヒバリガイの分布拡大経路を検討するために、霞ヶ浦の周辺河川と、霞ヶ浦から取水している水利施設を対象とした生息状況の調査を行った。また、一部の貯水池では落水(水抜き)を行い、カワヒバリガイの侵入状況の調査をおこなった。

3. 結果

2006 年から 2012 年までの間に、カワヒバリガイは霞ヶ浦湖岸の 46%から 83%まで分布を拡大し、採集個体数は平均で 3.8 倍に増加した(図 2)。解析の結果、2012 年における霞ヶ浦湖岸における生息の有無は、2006 年における生息地点からの距離によって最もよく説明されることが示された。この生息分布マップを元に霞ヶ浦におけるカワヒバリガイの分布拡大速度を推定したところ、6 年間に約 11km の速度で分布拡大が進行していることが明らかになった(定着確率が 50%を越える距離を拡大距

離として推定)。この拡大速度を元にすると、霞ヶ浦では遅くとも 2018 年には湖岸全体にカワヒバリガイが生息するようになると推定された[7]。

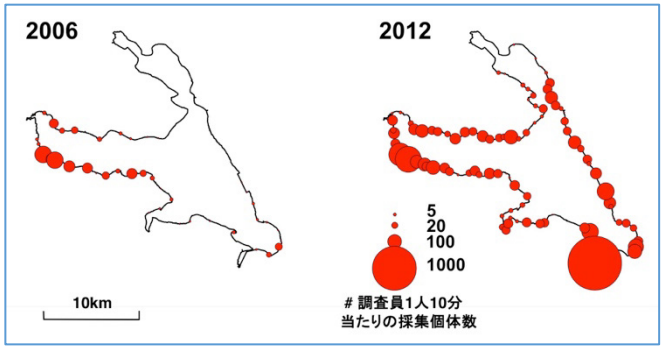

図 2 霞ヶ浦におけるカワヒバリガイの分布拡大(伊藤・瀧本 2013 より作図)

小貝川は関東平野を流れる全長 118km の一級河川であり、2008 年以降カワヒバリガイの生息が確認されている。分布調査の結果、小貝川では、カワヒバリガイは霞ヶ浦から取水している水利施設の分水工(水を分ける施設)よりも下流でのみ採集された(図 3) [8]。この水利施設(霞ヶ浦を水源として 1988 年以降一部通水・1994 年から本格通水を開始)では、2006 年から施設の中でカワヒバリガイの生息が確認され [9]、水路や貯水池の水からはカワヒバリガイの浮遊幼生が確認された。遺伝子解析の結果、小貝川で採集されたカワヒバリガイには、霞ヶ浦から採集されたカワヒバリガイと共通するハプロタイプが高頻度で含まれていた[10]。

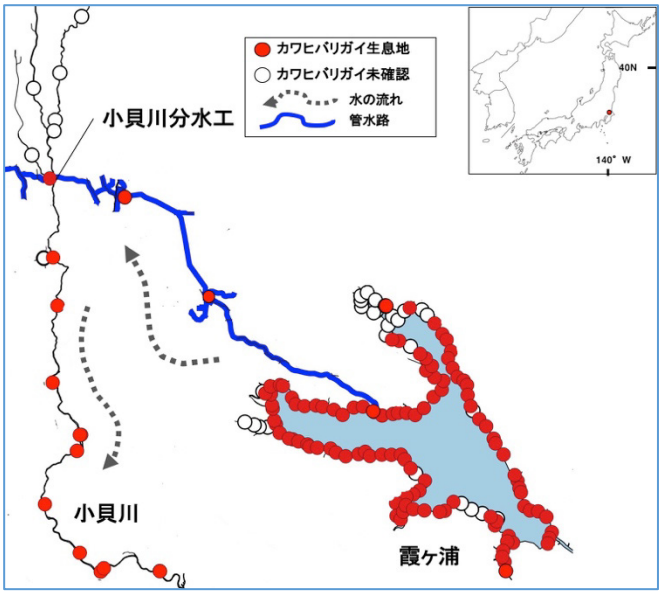

図 3 小貝川と霞ヶ浦、水利施設(管水路・貯水池)におけるカワヒバリガイの分布(Ito 2015 より作図)

利根川水系に隣接する那珂川水系では、2009 年から 2013 年までの調査ではカワヒバリガイの生息が確認されていなかった[11]。しかし、2014 年以降、那珂川水系内の霞ヶ浦から取水している貯水池において、新たにカワヒバリガイの生息が確認されるようになった(図 4)。カワヒバリガイの駆除を目的として貯水池の落水を行ったところ、カワヒバリガイは貯水池の約半分の範囲から採集され、特に流入口と取水口に近い部分で密度が高い傾向を示した。採集個体のサイズと過去に報告された成長データから、この貯水池には遅くとも 2013 年にはカワヒバリガイが侵入していたと推察された[12]。那珂川水系全体では、カワヒバリガイの生息が確認された地点はごく限られており、侵入の段階としてはまだ初期の状態である可能性が高いと推察された。

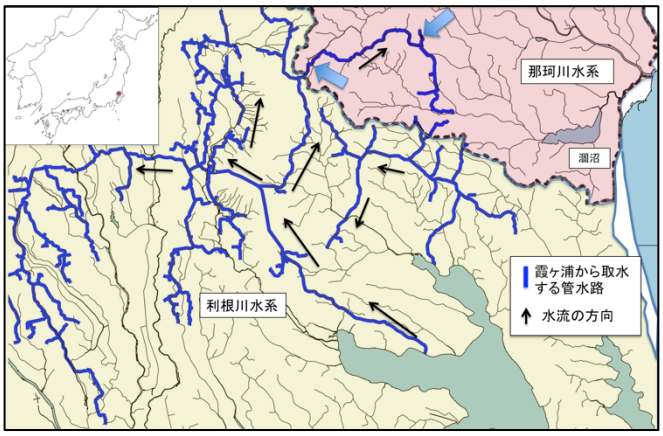

図 4 霞ヶ浦から取水している水利施設(管水路)と、那珂川水系内でカワヒバリガイの発見された貯水池(青矢印)の位置関係(伊藤 2016 より作図)

4. 考察

調査の結果、霞ヶ浦ではカワヒバリガイの分布拡大と密度の増加が進行しつつあることが示された。近年、霞ヶ浦から取水する一部の水利施設ではバースクリーンの閉塞や死貝の堆積などによる通水障害が発生しており[9]、今後霞ヶ浦から流出する河川や、そこから取水する水利施設では、カワヒバリガイが侵入・定着することを想定する必要があるだろう。

小貝川と水利施設に生息するカワヒバリガイの分布データ(図 3)、並びに遺伝解析の結果は、小貝川に生息するカワヒバリガイの少なくとも一部が、水路や貯水地を経由して霞ヶ浦から分布を拡大したことを示している。現在明らかになっている那珂川水系内のカワヒバリガイの生息地点も、霞ヶ浦から取水する水利施設とその周辺、もしくはその下流に限られている [12]。水路や導水路を経由したカワヒバリガイの分布拡大を示唆するデータは日本国内の複数の地域で明らかになっており[8,13]、水利施設を経由する

本種の拡大は国内でもごく一般的に生じているものと推察される。霞ヶ浦の水は茨城県南部を中心に広い範囲で利用されており(図 4)、その中には調査の行われていない河川や水利施設が数多く含まれている。今後、これらの地域でも新たにカワヒバリガイの侵入が確認される可能性は高いと考えられる。

那珂川水系でカワヒバリガイの生息が確認されている貯水池は涸沼(2015 年ラムサール条約登録)に流入する河川の上流部に位置しており、この地域での対策は生物多様性保全を考える上でも重要である。現在、水利施設の管理組織では通水障害への対策に加え、貯水池や水路、周辺河川でのモニタリング調査や非灌漑期に行う貯水池の落水などを通じて，用水を経由したカワヒバリガイの新たな分布拡大と被害を抑制する試みを進めている(図 5)。

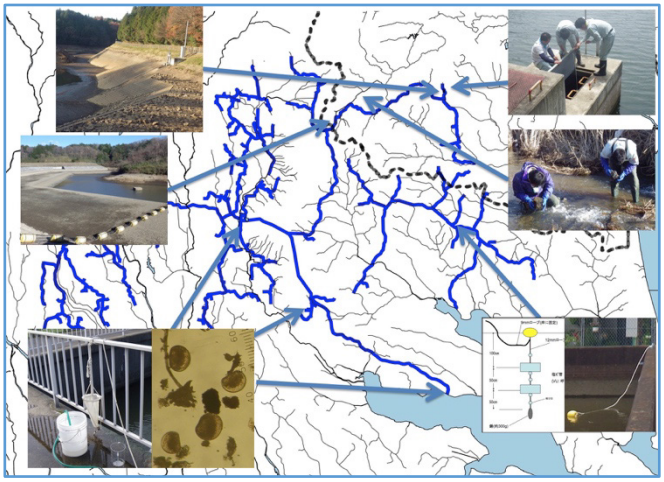

図 5 霞ヶ浦から取水する水利施設の管理組織によるカワヒバリガイ対策:左上:貯水池の落水による駆除，左下:浮遊幼生調査，右: トラップと目視観察によるモニタリング調査

5. 結論

カワヒバリガイの浮遊幼生は 100-200μm と小さく[14]、本種の発生した水源の水を大量に利用することを前提とした侵入防止は極めて困難である。当面はモニタリング調査を通じてカワヒバリガイが発生した地点を明らかにするとともに、その地域の水利施設の管理や駆除を積極的に行うことで被害の拡大や未侵入地域への移動を減らしていく必要があるだろう。水路を経由した外来種の意図せぬ分布拡大は、様々な分類群で報告がある[15,16]。今後，水利整備事業の運営や開発を行う上で，これら外来種の問題への配慮が求められるだろう。

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O1-25

Trophic status of *Chitala ornata* (Osteichthyes; Notopteridae), an invasive fish species in Sri Lanka and impacts of its invasion on Fish diversity in tributaries of Bentota River

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Key words: Invasive, *Chitala ornata*, Stomach contents, Biodiversity, Bio volume.

ABSTRACT

Fish were sampled using gill nets, seine nets, cast nets and some were also collected from fishermen's catches at the tributaries of the Benthota River in Katapola, Ganegoda, Avitthawa, Yagirala and Galatara from August to December 2016. To investigate the potential threats from *Chitala ornata*, its stomach contents were analyzed and quantified using the Point method based on the percentage of bio volume per food category. Ten species of fish were recorded from all five sites, including two endemic species, *Clarias brachysoma, Channa orientalis*. Some indigenous species such as *Puntius vittatus* (n=371), *Rasbora daniconius* (n=120), *Puntius dorsalis* (n=33) and *Trichogaster pectoralis* (n=52) were also caught in reasonable number. Parts of fish (scales, fins and flesh), mollusks, adult insects, insects larvae, macrophytes and digested/detritus matters were observed in the stomach. Among the stomach contents of *C. ornata* larger than 15 cm, highest bio volume (72%) comprised of parts of fish which was significantly higher ($p < 0.05$) than other food categories. Macrophytes accounted for the lowest biovolume (6.5%) which was significantly lower ($p < 0.05$) than the other food categories. However gut contents of *C. ornata* smaller than 10 cm comprised of a higher percentage of algae and plant materials (60%). Remains of fins of *Channa orientalis*, and *Rasbora daniconius* and some invertebrates observed in stomach contents of *C. ornata*, indicated its negative impacts on biodiversity in study sites. Therefore urgent attention should be paid to population control of *C.ornata* and to prevent its further invasion into new habitats.

1. INTRODUCTION

Invasive Alien Species (IAS) are species, native to one area or region, that have been introduced into an area outside their normal distribution, either by accident or on purpose, and which have colonized or invaded their new home, threatening biological diversity, ecosystems and habitats, and human well-being. *Chitala ornata* is one of the major IAS in Sri Lanka, a primarily carnivorous species and hence threatening biodiversity. At present, IAS introduction is considered as one of the major direct driver of erosion or devastation of the biodiversity in freshwater ecosystems[1] [2].

It is believed that the introduction of *C. ornata* (Family: Notopteridae), which is native to the Mekong basin in Laos, Thailand, Cambodia and Viet Nam[3] was through a negligence of aquarists and ornamental fish traders[4]. This species is now found in the Diyawanna Oya and the Bolgoda Lake in the western province of the country as well as in Bentota River of Sri Lanka.

Stomach content analysis is a better tool to predict possible predation, competition and feeding habit of particular species. A stomach content analysis of an endangered clown knife fish *C. ornata* from different wild population indicated that this species was primarily predatory and carnivorous in nature, indicating differences in the diet in different wild populations[5]

However, so far no detail ecological and biological studies on possible impacts assessments of *C. ornata* in freshwater bodies of southern region of Sri Lanka has been carried out, but some studies on ecological, biological and reproductive studies had been carried out in western province of Sri Lanka[6].

Present study was carried out mainly to investigate the possible competition for food among the *Chitala* spp. and other indigenous fish species inhabiting Bentota River and to investigate ontogenetic diet shift in *C. ornata* as a sub objective.

2. MATERIALS AND METHODS

Five sampling sites i.e. Katapola, Ganegoda, Avitthawa. Galatara and Yagirala associated with tributaries of Bentota river were selected in the suburbs of Elpitiya area in Sri Lanka. Fish were sampled using gill nets,

seine nets, and cast nets. In addition some *C. ornata* were collected from fishermen.

Maximum number of 10 individual belonged to different length classes of each fish species caught were preserved in formalin in order to carry out gut content analysis. Fishes larger than 10 cm were preserved by injecting 10% formalin into the body cavity immediately after capture to prevent deterioration of stomach contents and then were put in formalin bath. Prior to the gut content analysis total length and body weight of each individual were measured. For gut content analysis the point method based on the percentage of bio volume per food category was used[7]. Gut contents were analyzed according to different length classes i.e. below 15 cm, 15-30 cm and larger than 30 cm, in order to assess ontogenetic diet shift.

Diet overlaps were calculated on the basis of the gut contents of species concerned. Diet overlap (S) between each pair of species was determined using Schoener's (1970) formula;

$$S = 1 - 0.5 \left(\Sigma_{ai=1}^{n} \left| P_{xi} - P_{yi} \right|\right)$$

Where S= the dietary overlap coefficient of fish species x and y.

Pxi = proportion of food category "i" in the diet of species "x"

Pyi = proportion of food category "i" in the diet of species "y"

n = number of food categories

The values for this similarity index ranged from 0.00 to 1.00, with 1.00 indicating complete overlap and 0.00 indicating no overlap.

The diet/niche breadth was calculated for each fish species using the niche breadth coefficient, Bi[8].

$$B_i = -\Sigma^{n}_{j=1} P_j * \log P_j$$

Where Pj = the proportion of food category "j" consumed by species "i".

Bi = the niche breadth coefficient of a fish species "i"

n = the number of resource states available

For the data that exhibited normal distribution, One-way ANOVA was carried out to check the significantly different food items among and between the different size classes of fish using SPSS ver 17 statistical package.

3. RESULT AND DISCUSSION.

Fish species richness was reasonably high in all selected five sites. Ten fish species were collected from three sites out of five sites sampled and included some endemic species such as *Clarias brachysoma, Channa orientalis.* Some indigenous species such as *Puntius vittatus* (n=371), *Rasbora daniconius* (n=120), *Puntius dorsalis* (n=33) and *Trichogaster pectoralis* (n=52) were also caught in reasonable numbers. Highest abundance of *Chitala ornata* was recorded in Katapola site. Length of the smallest *Chitala ornata* recorded is 7.2 cm while the largest one measured 42 cm when pooled together irrespective to the sites.

Results of the gut content analysis of *C. ornata* are shown in Table 1. The main food items recorded in *C. ornata* irrespective to sites are parts of the fish (flesh, scales, parts of fins and bones), mollusk, adult insects, insects larvae, macrophytes, and digested/detritus matters.

Table 1: Gut contents of *Chitala ornata* per different size classes irrespective to the sampling sites.

Food item	Size classes (cm)		
	0-10	10-15	> 15
Parts of the fish	05	32*	72*
Mollusk	04	18	07
Adult insects	17	12	04
Insects larvae	02	09	03
Macrophytes	60*	15	6.5
digested/detritus matters	12	14	7.5

Small *Chitala ornata* (less than 10 cm) mainly depended on macrophytes and adult insects, but when they attained to the large size (more than 15 cm) their food habits shifted to carnivory from herbivory, by feeding mainly on parts of fish and mollusks. Consumption of adult insects gradually decreased with increasing body size. These data clearly reveals ontogenic diet shift. Some fresh fish remains that are not digested were identified as small cyprinids like *Puntius vittatus, Rasbora daniconius* and endemic fish *Channa orientalis.*

Results of the one way ANOVA reveals significant difference ($P < 0.05$) of food items such as parts of the

fish and macrophytes among different size classes. Shirantha (2016) recorded same situation in research carried on Size-dependent dietary shifts in *Chitala ornata* in Bolgoda Lake, Western province, Sri Lanka [9]. Their research outcomes revealed clear ontogenetic variations of relative abundance of different food categories based on stomach content analysis. It showed strong ontogenetic diet shifts from omnivory in 30-35 cm fish to carnivory in fish larger than 35 cm and exclusively piscivory when it was larger than 50 cm.

Diet/niche overlap values for possible fish species pairs are given in Table 2.

Table 2: Diet/niche overlap values for possible fish species.

Fish species	CO	PV	RD	PD	TP	OG	CHO
CO	-	0.15	0.24	0.37	0.29	0.19	***0.812***
	PV	-	0.37	0.41	0.49	***0.56***	0.165
		RD	-	***0.62***	***0.68***	0.36	0.418
			PD	-	***0.53***	0.32	0.472
				TP	-	***0.57***	0.359
					OG	-	0.204
						CHO	-

Note: CO- *Chitala ornate* PV- *Puntius vitatus* RD- *Rasbora daniconus* PD- *Puntius dorsalis* TP- *Trichogaster pectoralis* OG- *Osporonemus goramy* CH0- *Channa orientalis*

High diet/niche overlap value was exhibited by fish species pair CO-CHO. This revealed high competition for food among *Chitala ornata* and *Channa orientalis*, an endemic species.

The diet/niche breadth values of the species considered in this research are shown in table 3.

Table 3: Diet/niche breadth values of fish species considered.

Fish species	Overall
Chitala ornata	2.67
Puntius vitatus	2.88
Rasbora daniconus	***4.02***
Puntius dorsalis	***4.93***
Trichogaster pectoralis	***4.73***
Osporonemus goramy	3.18
Channa orientalis	2.96

Rasbora daniconus, Puntius dorsalis and *Trichogaster pectoralis* showed a relatively large niche breadth based on food resources used and thus are more generalised feeders. In contrast, *Chitala ornata* recorded a narrow niche breadth value ($B_i < 2.75$) indicating specialised feeder. *Puntius vitatus, Osporonemus goramy* and *Channa orientalis* are moderately specialised feeders.

4. CONCLUSION

Remains of body parts of *C. orientalis*, which is an endemic fish species found in guts of *C. ornata* indicates threats to the endemic fauna of Sri Lanka. Presence of flesh and parts of fins of *R. daniconius* and some invertebrates in the gut contents of *C. ornata*, indicates the negative impacts on native fish as well as on other aquatic fauna. Size distribution of *C. ornata* ranging from 8 cm to 42 cm indicates reproduction within the introduce habitat and successful colonizing nature. Therefore urgent attention should be paid to population control of *C.ornata* and to prevent its further invasion.

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O1-26

Are Japanese Rice Fields threatened by the New Invasive Alien Species of Tadpole Shrimp (*Triops strenuus* Wolf, 1911) from Western Australia?

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Keywords: invasive alien species (IAS), rice fields, ecosystem management, consensus building, nature conservation

ABSTRACT

Three species of tadpole shrimp, i.e., *Triops sinensis* (Uéno, 1925) (resurrected by Naganawa in 2018, previously synonymized erroneously in Japan with *Triops granarius* (Lucas, 1864)), *Triops longicaudatus* (LeConte, 1846) and *Triops cancriformis* (Bosc, 1801-1802), have been known from Japan. The author described a fourth *Triops* species (= *Triops strenuus* Wolf, 1911) living in the rice fields of Shirahama and adjacent area of Wakayama Prefecture (a southern area of Honshu, the largest of the four main islands of Japan). This species was probably endemic to the Australian continent, and no habitat distribution outside of Australia has been reported so far. The impact on the existing ecosystem of Japan is quite unknown, and therefore, it is necessary to announce this intrusion into Japan in order to clarify the invasion route, habitat ecology, and the future measures against this new alien species. This invasion is considered to be caused by the resting eggs brought together with silica sand (imported from Western Australia into Japan for the large-scale beach improvement). There are two possible routes of dispersal from the coastal sand to the rice fields where *T. strenuus* had been found in Japan: (1) windborne dispersal and (2) dispersal by human activities (i.e., tourism) and/or animal vectors (e.g., water birds and crows). The results presented here also describe the phylogenetic relationship with all the Australian species described so far, but also all the known *Triops* species of the world, based on the nucleotide sequences of mitochondrial DNA.

1. INTRODUCTION

About 50 living tadpole shrimp species are known from the world, all belonging to the single family Triopsidae Keilhack, 1909. They are subdivided in two genera (*Lepidurus* Leach, 1819 and *Triops* Schrank, 1803) and are around the recent world except Antarctica. Tadpole shrimp are limnophilous crustaceans that adapted their way of life to natural temporary waters; however, we can find them in Japan in rice fields only. The first discovery of a tadpole shrimp in Japan was by Professor Chiyomatsu Ishikawa (Tokyo Imperial University) in August of 1916, from the locality of Kagawa Prefecture of Shikoku, the smallest of the four main islands of Japan. Yatsu stated in 1916 [1] that tadpole shrimp inhabited Japan, and then Kawamura also referred to it in brief [2]. Later, Uéno reported on Japanese and Chinese tadpole shrimps in detail, entitled "*Apus* from eastern Asia" [3]. This was the first academic description on tadpole shrimp published in Japan.

As for tadpole shrimp at present, four species, i.e., (1) *Triops sinensis* (Uéno, 1925), called "Tairiku Kabuto-ebi" in Japanese (formerly "Asia Kabuto-ebi"); (2) *Triops longicaudatus* (LeConte, 1846), "America Kabuto-ebi"; (3) *Triops cancriformis* (Bosc, 1801-1802), "Europe Kabuto-ebi"; and (4) *Triops strenuus* Wolf, 1911, "Shirahama-Australia Kabuto-ebi" (**Fig. 1**) have been reported from three main islands of Japan, except Hokkaido [4-6]. This report is an updated version of the author's paper published in *Crustaceana* in February of this year [7].

2. METHODS

Newly collected samples from Japan, Siberia and Mongolia, and also ethanol-fixed specimens on loan from the Western Australian Museum were used to sequence 658 bp of mitochondrial cytochrome *c* oxidase gene subunit I (COI), following the methods described in Naganawa [7]. The sequences were compared with ones retrieved from GenBank in a phylogenetic analysis. All newly generated sequences were deposited in GenBank.

3. RESULTS & DISCUSSION

The most important facts are as follows. First, silica sand of Australian origin has been imported into Japan for beach improvement about 25 years ago. Second, the present author found the resting egg of *Triops* from the coastal sand of the area in Japan. And third, the *Triops* specimens collected from Japanese rice fields in the area, cluster within Australian *Triops* in the phylogenetic analyses (DNA barcoding approach). The individuals from Japan add a fifth hitherto unknown lineage to *T. strenuus*. On the one hand, this result shows that the

genetic diversity in Australia is even greater than shown by Meusel & Schwentner [8], but unfortunately, also does not allow verifying the precise source population genetically. In addition, unrecognized Australian *Triops* populations may have been present in between the coastal area and the rice fields, may work as potential dispersal agents. Formerly recognized Japanese tadpole shrimp as "Asia Kabuto-ebi" are all to be *T. sinensis* correctly.



Fig. 1 New invasive alien tadpole shrimp of Australian origin, *Triops strenuus* Wolf, 1911 [7] (∗ in Fig. 2)

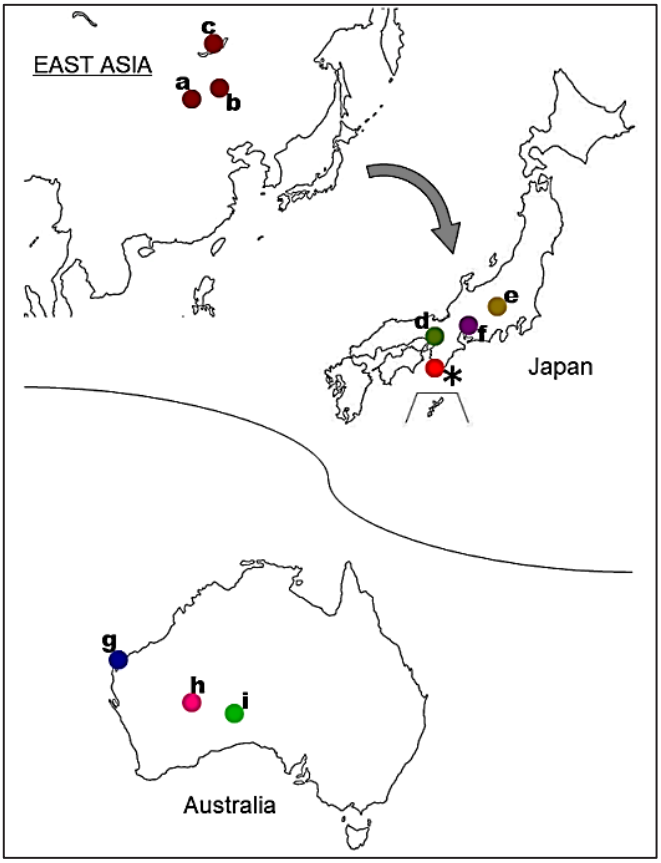

Fig. 2 Distribution map of newly recognized *Triops* [7]

The author's findings are listed below, under trying to describe each as new formal species, except one (*Triops sinensis* (Uéno, 1925)). At least, *Triops* sp. Learmonth could be a new species; *Triops* sp. Mistake Creek and *Triops* sp. Great Victoria Desert are newly recognized Australian lineages (see also **Fig. 2**).

(a) *Triops* sp. Mandalgobi (Gobi, Mongolia)

(b) *Triops* sp. Choir (Gobi, Mongolia)

(c) *Triops* sp. Baikal Olkhon Is. (Siberia, Russia)

(d) *Triops sinensis* (Uéno, 1925) (western Japan)

(**non *Triops granarius* (Lucas, 1864), misidentified**)

(e) *Triops* sp. Shigeno (Nagano Prefecture, Japan)

(f) *Triops* sp. Kakigase (Gifu Prefecture, Japan)

(g) *Triops* sp. Learmonth (Western Australia)

(h) *Triops* sp. Mistake Creek (Western Australia)

(i) *Triops* sp. Great Victoria Desert (Western Australia)

4. CONCLUSION

The scope of this article is to report the occurrence of an Australian *Triops* in Japan. Additionally, it provides nine new COI sequences, some of which coincidently suggest the presence of new genetic lineages.

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カブトエビ

豪州産が紀南に定着

京大の長縄さん　国内で初確認

流れに逆らって泳ぐシラハマオーストラリアカブトエビ（白浜町才野で）

白浜町にある京都大学瀬戸臨海実験所の長縄秀俊さん（54）＝京大大学院理学研究科動物学教室＝は、同町や上富田町の水田で、オーストラリア原産のカブトエビが生息していることを確認した。国内で豪州産が確認されたのは初めて。今後、生息域が広がる可能性があるという。シラハマオーストラリアカブトエビと命名。研究成果は近く、甲殻類研究の国際誌に掲載される。

カブトエビは、全長2～4センチほどになる小形の甲殻類。「トリオプス」や「生きた化石」などとも呼ばれ、飼育セットが販売されている。国内では、アメリカ、アジア、ヨーロッパの3種が知られている。

長縄さんは3年前、白浜町の水田や周辺の水路で、既知種と色や形の違ったカブトエビを確認。その正体を解明するため、世界各地からカブトエビのサンプルを集めるなどして研究を続けてきた。顕微鏡による形態観察やDNA解析などから、豪州大陸の固有種である可能性が高いことを突き止めた。

1905年に豪州中部のウルル（エアーズロック）付近から発見され、11年に報告のあった種と共通の祖先を持ち、約3400万年前に枝分かれしていた。ただ、ウルルのカブトエビは雌雄があるが、白浜の種は雌だけで増えている。その繁殖のメカニズムや進化の過程は分かっていない部分が多いという。

白良浜の養浜事業か　日本への侵入経路

生態系への影響などを考えるため、日本への侵入経路の究明にも取り組んできた。侵入経路は1989年から数年間行われた白良浜の養浜事業が有力とみている。カブトエビの卵は直径0・3～0・4ミリほどで、乾燥した状態だと50年以上生き続けられる。西オーストラリア州から日本へ輸入された白砂に卵が紛れ込んで白良浜に持ち込まれ、風や人の移動によって拡散した可能性が考えられるという。

2016年の調査で、白良浜から卵の殻と思われるものも見つけている。

長縄さんは「今後はオーストラリアの研究者らと共同で、今回のものも含めカブトエビの進化についてさらに詳しい調査を展開していきたい」と話している。

カブトエビ

南極大陸を除く世界各地から約50種が知られている。これらのほとんどが絶滅の危機にひんしている。日本でカブトエビが初めて発見されたのは1916年。降雨や雪解けの後に一時的にできる天然の水たまりが主な生息地だが、日本では水田やその周辺以外から発見されたことがない。

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Appendix 1 Article on this invasive alien species (IAS) problem reported on Kii Minpo news, Japan

O1-27

The widespread of the redclaw, *Cherax quadricarinatus* in Indonesia

Jiří Patoka[1]*, Yusli Wardiatno[2], Ali Mashar[2], Yonvitner[2], Daisy Wowor[3], Rikho Jerikho[2], Muhammad Takdir[4], Lora Purnamasari[5], Miloslav Petrtýl[1], Lukáš Kalous[1], Antonín Kouba[6], Martin Bláha[6]

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Keywords: Redclaw; biological invasion; non-indigenous species; Parastacidae; aquaculture; pet trade

ABSTRACT

Redclaw (*Cherax quadricarinatus*, von Martens) is a crayfish native to north-eastern Australia and southern New Guinea, being found for the first time west of the Wallace Line in Java in 2016. Following introductions for aquaculture purposes, it escaped from culturing facilities, exhibiting invasive habits in various tropical and subtropical countries. Based on climate matching, its further spreading within Indonesian territory was predicted. We surveyed selected localities within Indonesian territory to check the species occurrence. Redclaw crayfish were found in numerous rivers, lakes, ponds and reservoirs in Batam and Bintan Islands, Java, Sulawesi, and Sumatra. Some stocks were apparently well established, providing a food source for locals and sustaining catching for pet trade purposes. Since there are no effective regulations of this crayfish introductions and exploitation in Indonesia, its further dissemination and spread to new localities is expected. This will lead to the devastating consequences toward often endemic freshwater biota in this prominent biodiversity hotspot. Increased attention to this issue, especially at the level of wildlife management and national environmental policy, is urgently needed.

1. INTRODUCTION

In Indonesia, *Cherax quadricarinatus* is native only to the Papua province but it was previously recorded as non-indigenous and established at two localities west of the Wallace Line in Java[1]. The lobster is increasing in popularity for human consumption in Indonesia[2]. Moreover, this country was previously identified as one of the leading exporters of ornamental crayfish, especially of the genus *Cherax*[3]. The production of *C. quadricarinatus* for ornamental purposes was also recorded there[1]. Nevertheless, information about the method of farming and harvesting in this region are just anecdotal[2] and detailed monitoring is lacking.

Based on climate matching between the native range and entire Indonesian territory, it was predicted that this species has a high potential to become established when introduced[1]. *Cherax quadricarinatus* is a relatively large and highly fecund species[4], known to be a successful invader in warm climatic conditions. Its spread may have devastating consequences to numerous Indonesian endemic crustaceans including shrimps, crabs and other freshwater biota, potentially affecting the functioning of entire ecosystems. This assumption is supported by a recent event in the Lido Lake, Java: *C. quadricarinatus* together with the invasive shrimp *Macrobrachium lanchesteri* (de Man) caused a dramatic decline of the native shrimp *M. sintangense* (de Man) leading to its extinction at this locality (Aprila, Wowor and Farajallah, unpublished data). Since there are no effective legislative measures of non-native crayfish introductions in Indonesia, the further spread of *C. quadricarinatus* to new localities was expected. This is the highly alarming scenario, given that the region is a prominent global biodiversity hotspot[5].

2. METHODS

During June 2016 – August 2017 we surveyed selected localities within Indonesian territory to ascertain *C. quadricarinatus* presence. Crayfish were collected at each locality during one-night sampling with use of bamboo or foldable net traps baited with fish and gastropod meat. We found populations of *C. quadricarinatus* in various waterbodies including natural lakes, artificial ponds and reservoirs, and also rivers in Batam and Bintan Islands, Java, Sulawesi, and Sumatra (Fig. 1). Identification of captured crayfish was based on morphological characteristics according to Holthuis[6] and Souty-Grosset et al.[7]. If ovigerous females are observed in a population, the population is considered established.

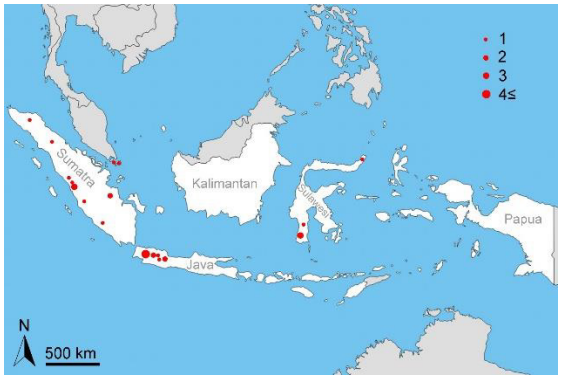

Fig. 1 Map of Indonesia with localities where *Cherax quadricarinatus* was recorded, localities indicated by red circles of different sizes indicating number of sites.

3. RESULTS AND DISCUSSION

C. quadricarinatus was imported into Indonesia in 2003 for the establishment of aquaculture industries[2]. But based on information obtained from local people, the crayfish in Kemang Lake were produced for the pet trade in net cages in 2002 (Fig. 2), escaping from the facility the same year. Currently, crayfish are captured by local hunters using bamboo traps in the lake. We assume that this was the starting point for the dissemination of the species in the entire Indonesia.



Fig 2. Net cages used for culture of ornamental fish and crayfish in Kemang Lake, West Java – Indonesia.

Cherax quadricarinatus was also recorded to be commonly advertised for trade as an ornamental animal in local pet shops in Jakarta and Bogor, Java, being offered under the general local name "lobster air tawar" (freshwater crayfish) and in one case under misnomer C. albertisii. Based on information from pet shop owners, the traded crayfish originated from Kemang Lake.

In addition to previous records in Cilala and Lido Lakes, Java[1], we report 32 additional established populations of *C. quadricarinatus* widespread within Indonesian territory outside its native range (Table 1). The only national regulation of non-native species in Indonesia is Regulation No. 41/PERMEN-KP/2014 banning the import of 152 selected non-native fish. In this law, fishes are defined as "all types of organism in which all or part of its life cycle is in an aquatic environment". There are only four crayfish listed and banned: *Faxonius rusticus* (Girard), *F. virilis* (Hagen), *Pacifastacus leniusculus* (Dana), and *Procambarus clarkii* (Girard). Generic names were updated according to the recent taxonomic revision (Crandall and De Grave 2017).

Table 1. Established populations of *Cherax quadricarinatus* in Indonesia: locality name; type: artificial (pond, reservoir), natural (lake), river; island; GPS coordinates. Localities marked by an asterisk were adopted from the previous study[1]

Locality	Type	Island
Sei Ladi Reservoir	artificial	Batam Island
Buaya River	river	Bintan Island
Bagendit Lake	natural	Java
Borcess Lake	natural	Java
Burung Lake	natural	Java
Cilala Lake*	natural	Java
Ciburuy Lake	natural	Java
Cirata Reservoir	artificial	Java
Darma Reservoir	artificial	Java
Gede Lake	natural	Java
Kemang Lake	natural	Java
Kemuning Lake	natural	Java
Lengkong Lake	natural	Java
Lido Lake*	natural	Java
Panjang Lake	natural	Java
Saguling Reservoir	artificial	Java
Tonjong Lake	natural	Java
Bantimurung Pond	artificial	Sulawesi
Bonto Jolong Pond	artificial	Sulawesi
Lekoala Pond	artificial	Sulawesi
Tondano Lake	natural	Sulawesi
Tempe Lake	natural	Sulawesi
Laut Tawar Lake	natural	Sumatra
Maninjau Lake	natural	Sumatra
Manna River	river	Sumatra
Teluk Lake	natural	Sumatra
Sipin Lake	natural	Sumatra
Kerinci Lake	natural	Sumatra
Atas Lake	natural	Sumatra
Bawah Lake	natural	Sumatra
Talang Lake	natural	Sumatra
Toba Lake	natural	Sumatra
Batang Lembang River	river	Sumatra
Batang Ombilin River	river	Sumatra

It is obvious, that *C. quadricarinatus* is popular for exploitation and, since release of this crayfish to the wild is not illegal in the country, we assume that more waterbodies are or will be used for its culture. In addition, more unintentional escapes might also be expected. Local people have very poor knowledge about risks related to invasive species (Patoka J., pers. observ. 2017) and since the eradication of established crayfish is impossible without dramatic disturbance of the whole ecosystem, further education of the general public seems to be crucial for prevention of new introductions. Therefore, we strongly recommend this situation to the attention of wildlife managers and national policymakers.

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O1-28

Ecological Barriers and Aquatic Ecosystem isolation – The effect on mosquito populations and their natural enemies in Chiang Mai City, Thailand

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Keywords: ecological fragmentation, population, mosquito born disease, predator-prey and habitat

ABSTRACT

Rapid urbanization is the main reason of habitat isolation and fragmentation in many city area of the world. Extinction, decreasing of biodiversity and balancing of community lost were the effect of habitat isolation. Mosquitos (Diptera: Culicidae) are the vector of many pathogen disease. Mosquito larva as prey in aquatic ecosystem could got some effect on unbalancing of community by Ecological Barriers and Aquatic Ecosystem isolation. There are many small wetland, freshwater Lakes and ponds in Chiang Mai, Thailand. Sixteen observation sites were selected by grid sampling method (3x3 km^2). The physicochemical data and biological data were analyzed and compared between every isolated area and main area. For the result, the newly created small canal, ponds that isolated from the main of larger habitat and ecological barriers as a water gate are inducing unbalancing of community, increasing number of mosquito larva and increasing pond breeding site of mostly *Culex* species mosquito. Result of physicochemical and biological parameters show dissolve oxygen (DO), Evenness of aquatic organism and percentage of predator were negative correlation between number of mosquito larva. Moreover, good water quality was positive correlation between number of predator. From the result, the biological barriers and aquatic environment isolation by human urbanization was indirect effect of the mosquito born disease in many countries of tropical zone. Therefore, every construction and city management have to concern with the biological barriers and isolation.

1. INTRODUCTION

Cities have emerged on the banks of rivers throughout history[1]. Rivers are multi-faceted ecological, cultural, economic, and political agents, providing resources such as food, water, irrigation, sanitation, and transportation. Urban growth is most rapid in the developing world, where cities gain an average of 5 million residents every month[2]. Man made construction such as pond, water gate, pipe line and rode are ecological barriers that isolated the habitat of aquatic organism. Population and community were got effect from ecological barriers. The role of barriers as "filters" structuring population and community in each environment[3].

Many mosquito larva species (Diptera: Culicidae) be as a prey in food chain[4]. One of the ecological barriers effects is community change. The reduction of predator in isolated area can be cause of increasing prey population[5]. Many species of mosquito are the pathogen of many vector borne disease. Dengue fever transmitted by *Aedes* mosquito, is one of the important vector born disease that occur in the city of tropical area[6]. The number and severity of dengue infections has been increasing since the Second World War, culminating in a 30-fold increase between 1960 and 2010. It is now 20 times more common than the flu[7]. Because of global warming, pesticide use, and the *Aedes* mosquito's preference for urban environments[8], the insect – and the virus it carries – are rapidly spreading around the world.

Mosquito Larva observation is the simple way to determine the mosquito population in environment. Before the 1940s, control actions had been directed specifically at the aquatic ecosystem. The focus was on eliminating larvae, and there was a growing interest in applying biological strategies to reduce mosquito populations at the breeding sites[9]. The mosquito larva predator was interested.

Over 3,520 mosquito species that recognized in the world and 459 species in Thailand[10]. There are many aquatic ecosystem isolations such as small wetland, freshwater

Lakes, ponds, retention areas and paddy field in Chiang Mai. In this study, we focus the effect of habitat isolation on the abundance of mosquito larvae in aquatic environment in Chiang Mai. The relation between main area and isolation area with predators and mosquito larva were analyzed. Moreover, water quality was estimated to find out the relation between the predator and mosquito larva.

2. METHOD

Study site

Sixteen observation sites around Chiang Mai city were chosen base on fresh water habitat applied from Williams and Feltmate 1994 [11] by using grid sampling method (3x3 km^2) (figure 1).

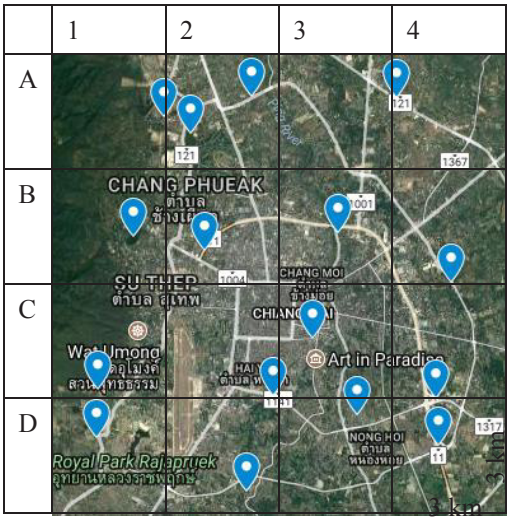

Fig. 1 Sixteen sampling area around Chiang Mai city

Data and sampling method

Samples were collected in dry season before the first rain conning in Chiang Mai (1st April 2018 – 30th April 2018). The physicochemical parameters in 8 parameter including water temperature, pH, ORP, Conductivity, Salinity, Total dissolve Solid, Dissolve oxygen and turbidity were measured using handheld HORIBA U52 equipment. Hydraulic characteristic water velocity was measured by measuring velocity meter. Light Intensity (Lux) was measure by using Lux meter. Riparian and habitat characteristic (stream bed, aquatic plant, deposits and stream bank) were scored follow by The National Institute of Water and Atmospheric Research (NIWA) New Zealand[12]. Macroinvertebrates were collected by kick and pick method[13] from several habitats of each sampling site. Samples were preserved in 70% ethanol prior to transport to laboratory. After the cleaning and sorting process, macroinvertebrate samples were identified to family level under stereomicroscope.

Analysis

The environment data were used to calculate Habitat score that applied from NIWA organization New Zealand. The macroinvertebrate and other mosquito predator were collected in qualitative sampling method. Macroinvertebrate were identified, and No. of individual predator and mosquito were count. The correlation in each factor and biological data were used PAST3

3. RESULTS AND DISCUSSION

From 16 study sites, 12 sites were found mosquito larvae. Ten sites were pond isolation. After analyzed with Mann-Whitney U test, mosquito abundance of isolation and main side were significantly different ($p<0.01$). The pond sites have higher mosquito abundance than the flow sites ($\bar{X}$=98.2±115.0, 12.9 ±20.3 respectively). Highly mosquito larvae abundance was presented in pond side because most of mosquito larvae prefer standing water or slow water flow.

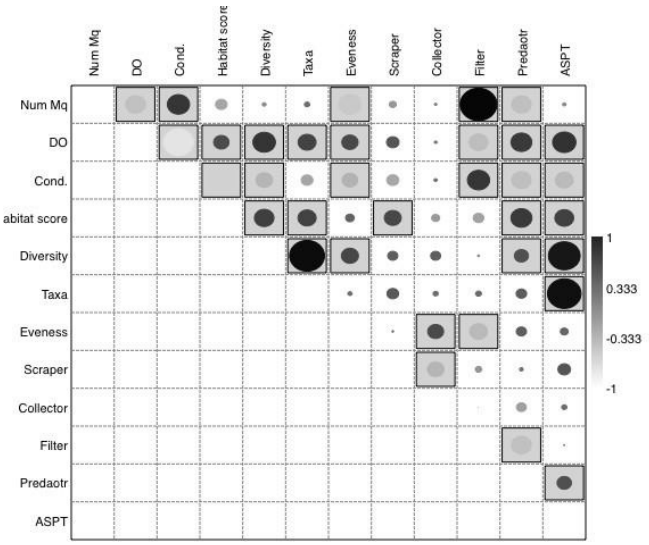

Fig.2 Correlation between mosquito larvae and factors

(Grey box showed p<0.05 significant)

Correlation between mosquito larvae and influent factor showed as figure 2 The mosquito larvae abundance showed significantly negative correlation with dissolved oxygen, predator ($p<0.01$) and evenness ($p<0.001$) and showed positive correlation with conductivity and functional feeding group of filter feeder ($p<0.001$). The water flow can increase the dissolved oxygen in the water. Thus, standing water (that mosquito lives in) have low oxygen. Moreover, ASPT score that higher for represent good water quality was show the positive correlation with diversity and percentage of predator.

4. CONCLUSION

Isolation of aquatic habitat have effected to the mosquito

population especially in larva stage. The stream that changed to standing water by human activity are suitable habitat for mosquito may increase the mosquito borne diseases in urban area. Therefore, every construction and city management should concern with the biological barriers and isolation.

5. ACKNOWLEDGEMENT

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O1-29

The state of Ghana's Aquaculture Production on the Volta Lake at a Glance

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Keywords: Volta Lake, Tilapia production, Nutrient discharge, Site selection, Carrying capacity

ABSTRACT

This present study was conducted to establish the number of tilapia farms on the Volta Lake, their farm size, employees experience in nutrient discharge and pollution control, annual production and feed used. Owners of 129 farms (83 small, 32 medium and 14 large scale) were interviewed using qualitative and quantitative questionnaires. The 129 farms employed 1,379 permanent and 1,200 causal workers with 3,392 cages (59% in used). The owners had no experience in tilapia farming and selected their sites based on physical characteristics without in-depth research. Only 3% had legal documents to operate on the Volta Lake. The 129 farms produced 18,632.27 metric tons of fish in 2015 and 14,711.82 metric tons in 2014. Fifty-Eight percent fed based on stock density, 20% used body weight while 16% used the age of the fish. Ninety five percent do not measure water quality parameters, engage in any kind of pollution control and know the amount of phosphorus being deposited in the lake. Ninety percent had no knowledge about the carrying capacity and zonation of the lake. All the farmers use between 70 and 90 bags (25kg per bag) of feed to produce 1 metric ton of fish. Based on that, the author estimated that about 31,674.74 metric tons of feed were used in 2015 and 25, 010.09 metric tons in 2014 with FCR of 1.7. The findings led to the conclusion that Ghana's aquaculture development on the Volta Lake needs to be better planned to prevent negative environmental impacts in the future

1. INTRODUCTION

The study was aimed to establish the number of tilapia farms operating on the Volta Lake, their locations, farm size, employees experience, annual production, feed used and workers knowledge on nutrient discharge, pollution control, carry capacity, disease and bacterial control.

2. STUDY AREA

Volta Lake is about 394,000 km2 and runs through six countries: Mali, Benin, Togo, Burkina Faso, Ivory Coast and Ghana. In Ghana, it covers 4% land area with a volume of 149 km3 and a depth of 19 m (MOFAD, 2016). It is divided into eight strata and surrounded by 1250 communities as shown in Figure 1.





Figure 1 B and B: Volta Lake view and the strata map.

3. APPROACH AND METHODOLOGY

Both qualitative and quantitative questionnaires were used to collect the needed data from the famers, chiefs', elders and the community members.



Figure 2: Retailers loading the fish for the market.

4. RESULTS AND DISCUSSIONS

A total of 129 tilapia cage farms were interviewed, 17% from the strata I - Afram River arm (Kwahu-Adowso), 57% in strata II - Lower section (Dzemeni,Akosombo) and 25% in strata III-Middle section (Kpando). Fourteen percent (14%) were established between 2001 and 2010, 5% in 2011, 16% in 2012, 18% in 2013, 24% in 2014 and 23% in 2015. This implies that interest in aquaculture farming continues to grow in Ghana each year with an

average growth rate of about 16% (Kassam, 2014). The increasing number of farms is very significant. As suggested by Asmah et al (2016), the increasing number of farms on the Volta Lake would contribute to food and nutrition security; create more jobs for unemployed youth and save Ghana an amount of US$ 200 million from fish importation per year. From the survey, majority of the farms were concentrated in strata II. This implies that there is more surface area for aquaculture development in other strata's. However, the water quality and aquaculture impact on communities around the strata II should be controlled to prevent conflict and health problems.

Of the 129 farm owners, 5% were females and 95% were males. Setboonsarng (2002), observed a low participation of women in aquaculture in some Asian countries. However, women not been owners, 92% women engaged in postharvest activities such as processing and marketing of aquaculture products as reported by Akrofi (2002). It could be said that, the number of female owners in current aquaculture production in Ghana is opposite of what were reported by Amsah (2008) and Chirindza (2010). Both Asmah (2008) and Chirindza (2010) focused on pond aquaculture as compared this study on cage aquaculture. The reason for the decline of women owners in aquaculture could be attributed to the introduction of cage culture in Ghana. The cage aquaculture farming is more intensive, expensive and is done in deeper. The annual production yields from the 5% female fall within the larger scale farm classification as confirmed by a similar study by Nandeesha and Heng (1994) in Cambodia ponds.

The age range was from 28 years to 85 years, 51% did not disclose their level of education, 10% had no basic education, 12% attended only Junior High School, 22% held bachelor degrees, and 5% had earned a master's degree. This could be suggested that in the future more youth and educated people would be interested to invest in aquaculture farming to enhance food security and focus on ecosystem approach (Soto et al, 2007).

The majority (80%) had no experience before starting their farms, 97% indicated did no research but based on advice from friends and expected high profit returns. This implies owners had various reasons for starting their aquaculture farms (Adeleke and Omoboyeje, 2016).

Only 3% had acquired legal documents to operate a fish farm on the Volta Lake.Most farms belong to associations. It implies that the farms could form one strong association to assist farmers to acquire permits, advocate for enabling policies and compile with responsible code of conduct.

Sixty-four percent (64%) small-scale, 25% medium-scale and 11% large-scale farms were recorded. Sixty-three percent (63%) purchased fingerlings or brood stock from other farms, 1% sourced from Water Research Centre, 22% produced own fingerlings and 14% got from their own farm and other farms. Out of 129 farms, only 9% farms measured and sorted fish every two weeks. The remaining 91% said they do not measure and sort, in order to avoid causing mortalities.

The total fish stock in cages and ponds of 108 farms was 2,667.296 metric tons. Ninety-four percent (94%) were table size and ready to be sold during the Christmas period, 4% were fingerlings, 1% fry and 1% brood stock.

The number of cages recorded was 3,392. Fifty-nine percent (59%) were in use, while 41% cages were in the river but empty. Two cage sizes were very standard: 5x5 and 6x6 meters. Only four farms had larger sized cages. It could be said, the size of cages used had contributed to the slow growth of aquaculture production in Ghana. This is because; the average stock density (fingerling per cage) for 5x5x5m was 10,000 as compared to 500,000 for 16 or 19 diameter cage.

The total fish production from 88 farms (68%) in 2015 was 18,632.27 metric tons while 14,711.82 metric tons was produced by 56 farms in 2014. Ghana have had higher aquaculture production yield of 44,610 tons (FAO, 2017) as compared to Tanzania, and Rwanda. Brummett et al. (2008) suggested that Ghana has the potential to produce more fish as Volta Lake has about 140 species of fish (Braimah, 2001).

Majority do not use feed conversion ratio (FCR). The farms used between 70-90 bags (25kg) feed to produce 1 metric ton of fish. It was estimated that approximately 31,674.74 and 25, 010.09 metric tons of feed were used in the upstream of the Volta Lake during 2015 and 2014.

Almost all do not know the amount of nitrogen and phosphorus that is being deposited in the lake. The average oxygen level in the Lake had dropped from 8.6 mg/L to 7.8 mg/L. Some farmers had measured oxygen levels of 0.4 mg/L inside the cages and 0.6 mg/L outside the cages in 2015, which falls below what Alabaster and Lloyd (1982) suggested as the suitable conditions for fish growth.

Figure 3 presents the some challenges faced by the aquaculture farmers on the Volta Lake.

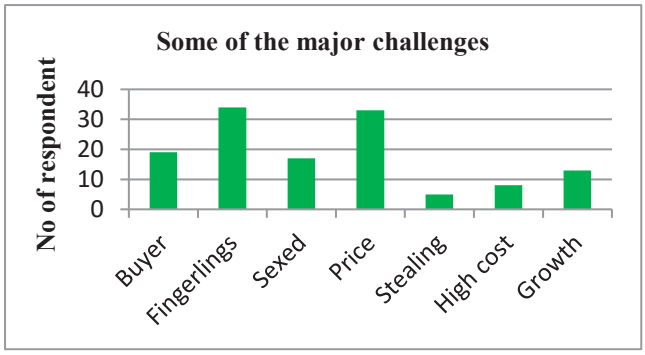

Figure 3: Some challenges faced by the aquaculture farmers on the Volta Lake.

5. CONCLUSION

The study revealed that there is an increasing trend of aquaculture farming activities on the Volta Lake mainly on strata II. The Ministry of fisheries and Aquaculture and Environmental protection agency are dialoguing with the farmers and the communities to develop responsible and sustainable ecosystem approach to ensure safe aquaculture production for human consumption, clean and quality water for community's members' living around the lake as well as easy passage for local canoe operators.

6. RECOMMENDATIONS

1. Farmers should move the cages to deeper waters to avoid massive mortalities during low oxygen periods (January-February and July, August to September).
2. There should be a peace dialogue to resolve the conflicts between the fish farmers, the communities, local fishermen and canoe operators on the user righ.
3. The farmers should be educated on feeding methods and feed conversion ratio to enable them maximize profits and minimize mortality rates.
4. Entrepreneurship, budgeting, marketing, productivity, human resource and cage management training should be organized for the farmers to see fish farming as a business. The small and medium farms workers should be taught in basic numeracy and literacy skills to enable them keep records
5. Government should support fish farmers to establish their own feed mill and provide them water and sediment quality equipment to enable the farmers to monitor water and sediment quality.
6. The farmers should form strong local Associations to enable them to collaborate for more success. For example, working together they could agree on a common price system, set-up sales outlets, cold stores and fingerlings production centers for farmers in all the regions.
7. Government (to include all ministries and agencies responsible for aquaculture production) should ensure and enforce a strict policy on importations of tilapia into Ghana to encourage local investors to increase production and create jobs for the youth in Ghana

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O1-30

Spatial and Temporal Variation of Length-Weight Parameters and Condition Factors of Commercial Fish Species in Lake Nasser, Egypt

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Keywords: Length-Weight parameters, Condition Factors, Spatial and temporal variation, Lake Nasser

ABSTRACT

Length and weight data of fish populations are necessary in stock assessment models and ecosystem modelling. Also, they could be used to spatially compare between different fish populations under different environmental conditions. This study provides an updated information on the length weight relationships and condition factors of six fish species in Lake Nasser, Egypt. It also investigates how these parameters are affected by variation in environmental characteristics of the Lake, therefore it presents the first reference on the spatial and temporal variation of these data in Lake Nasser. More than 13,000 fish were collected on monthly basis to cover different geographical zones and seasons of the lake. The values of the growth coefficient *b* obtained in this study were very close to the values recorded by previous studies with slight inconsistency while the average condition factors, *K,* were generally lower than that reported for 1984 - 2000. Moreover, results indicate overall statistically significant differences in seasons and locations for total length, total weight and condition factor means. The results obtained from this study are contributing to the knowledge of fish populations in Lake Nasser and highlighting the spatial and temporal variation of fisheries biological parameters in such large lake system. This variation should be considered by fisheries scientists and managers for future studies.

1. INTRODUCTION

Length and weight data of fish populations are useful for estimation of growth rates, length and age structures, and other components of fish population dynamics. This information is necessary in stock assessment models and ecosystem modelling approaches [1]. Moreover, length and weight data could be used to spatially compare between different fish populations under different environmental conditions [2] and temporally to track seasonal variations in fish growth [3]. The condition factor is used in order to compare the "condition", "fatness" or wellbeing of fish. It is strongly influenced by both biotic and abiotic environmental conditions and can be used as an index to assess the status of the aquatic ecosystem in which fish live [4].

Lake Nasser is a huge water body with a surface area of 5,237 km^2 at its highest water level (180 m above sea level) that now provides an important source of fish for Aswan governorate and the rest of Egypt [5]. Despite the importance of investigating the spatial and temporal variation of different biological parameters of fish populations in such a huge water body, which extends for 291.8 km from South to North, information about the spatial and temporal variation of length-weight parameters and condition factors of fish species in Lake Nasser is absent. All available information on these parameters are of the lake as whole without considering any variation in environmental conditions through different regions of the lake and over different seasons.

This study contributes to available length- weight and condition factor data for the most economically and ecologically important fish species inhabiting Lake Nasser. Also, this study investigates how these biological parameters are affected by variation in environmental characteristics of the Lake, therefore it presents the first reference on the spatial and temporal variation of these data in the Lake.

2. METHOD

Sampling Area:

The Aswan High Dam was constructed in the 1960s creating a huge water body, Lake Nasser, which contains three regions: the riverine southern part; the lacustrine northern part; and a region in between that has riverine conditions during the flood season and lacustrine characteristics in the remainder of the year [6] (Figure 1).

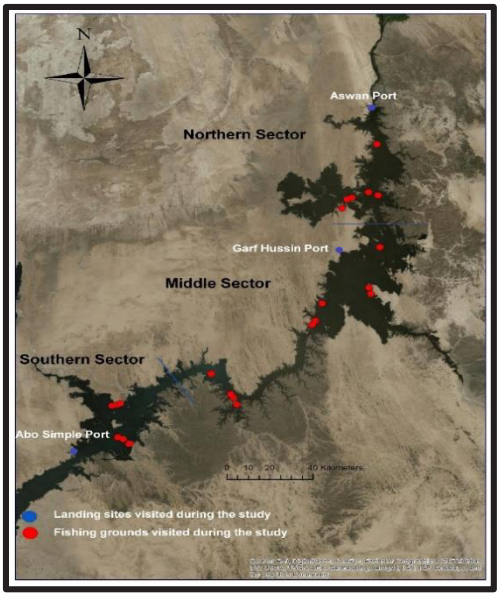

Fig. 1 Map of Lake Nasser showing sampling sites and different sectors of the lake.

Sampling of Fish:

Sampling was carried out during the period between October 2016 and September 2017. Monthly landing surveys of fishing ports (Aswan in the North, Garf Hussin in middle, and Abo Simbel in the South) have been conducted, in addition to bimonthly spatial surveys to cover the entire lake. A total of 13,091 fish belonging to six fish species (three families) were collected. Total length of each fish was taken to the nearest millimetre from the tip of the snout (mouth closed) to the extended tip of the caudal fin using a measuring board. Body weight was measured to the nearest 0.1 gram using a top loading balance.

Data Analysis:

Parameters of the length-weight relationship (LWR) of identified fish species were estimated using the equation:

$W = a L^b$ [7]; where, W = Weight of fish (g), L = Length of fish (cm), *a* = y-intercept or the initial growth coefficient, *b* = Slope or the growth coefficient.

The values of constants *a* and *b* were estimated after total weight (TWt) was plotted against total length (TL) and a power trend line (curve) of the form $y = a x^b$ fitted to the data using Microsoft Excel. Only extreme outliers attributed to data error were omitted from analyses. Condition factor (K) was calculated by the formula: $K = 100W/ L^3$ [8]. Variations in TL, TWt, LWR (represented by '*b*') and K of the individual fish living in the lake's three regions during different seasons were analysed with one-way analyses of variance (ANOVA) with subsequent Tukey's honestly significant difference (HSD) tests using Xlstat software. All the statistical analyses were considered at significance level of 5% ($p<0.05$). Due to statistical constraints, only those species represented by at least 20 individuals in each season and sector of the lake and with a relatively wide size range were considered for ANOVA and Tukey's (HSD) tests. Therefore, *Alestidae* species were excluded from these analyses.

3. RESULTS

The species, number of specimens, LWR parameters *a* and *b*, correlation coefficient (r^2), condition factor, mean length of fish species, mean weight of fish species and growth type (allometric or isometric) are presented in (Table 1).

The family with the highest number of species was *Cichlidae*, which had three species (*Oreochromis niloticus*, *Sarotherodon galilaeus* and *Tilapia zillii*) and two species were recorded for *Alestidae* (*Alestes baremoze* and *Hydrocynus vittatus*), while, the last family *Latidae* had one species *Lates niloticus*. The sample size for the fish species varied from 375 in *A. baremoze* to 4562 in *S. galilaeus* while the value of *b* ranged from 2.92 in *S. galilaeus* to 3.29 in *A. baremoze*. The lowest condition factor (K) (0.57) was recorded in *H. vittatus* while the highest value (2.06) was observed in *O. niloticus*. The values of correlation coefficient (r^2) varied from 0.9396 in *T. zillii* to 0.9885 in *O. niloticus*. All *Alestidae* species had positive allometric growth while all *Cichlidae* species had negative allometric growth except *O. niloticus*, which had isometric growth similar to *L. niloticus*. An ANOVA revealed significant differences ($P<0.0001$) in all tested biological parameters among various seasons and locations for the four investigated species except for *b*. As ANOVA has shown an overall statistically significant difference in seasons and locations TL, TWt and K means, Tukey's (HSD) test was done to confirm where the differences occurred by pairwise comparisons for seasons and locations. The results of both statistical analyses are shown in Table 2.

4. DISCUSSION

This study provides an updated information on LWR of six fish species in Lake Nasser, Egypt. Unfortunately, the available literature on LWR parameters in Lake Nasser is outdated and limited to Nile tilapia (*O. niloticus*) as it was the main commercial fish species, besides few studies on mango tilapia (*S. galilaeus*) [9-11]. Nevertheless, the values of *b* obtained in current study for these two species (3.04 and 2.92 respectively) are very close to the values recorded by those studies where it ranged between 2.6 and 3.02 for Nile tilapia and 2.5 and 3.12 for mango tilapia. It is likely that this slight inconsistency is due to seasonal variability of the environment, food availability [12], sampling size and

the length interval within different areas or habitat suitability [13].

K of the six fish species ranged between 0.57 and 2.06 which is generally lower than that reported by Adam, 2004 [14] for the years between 1984 and 2000. This suggests that the current condition of Lake Nasser, in comparison to its former status, may be becoming unfavourable to fishes. Therefore, there would be need for more studies on the physico-chemical properties and the condition factors of other fish species to be able to establish the sustainability of the lake for fish.

Table 1. Estimated parameters of the length-weight relationships (LWR), growth type, condition factors (K) and growth performance (total length & total weight) for six fish species in Lake Nasser.

Family	Species	N	Length (cm)			Weight (g)			K	Parameters of the LWR			Growth type
			Min	Max	Mean	Min	Max	Mean		a	b	r^2	
Alestidae	*Alestes baremoze*	375	21	47	29.3982	48.8	758.4	175.206	0.59255	0.0022	3.2915	0.9617	P
	Hydrocynus vittatus	606	21.4	78	37.7711	45.9	3042	362.89	0.56516	0.0021	3.2751	0.9788	P
Latidae	*Lates niloticus*	2278	13.5	160	30.2517	26.8	43000	458.421	1.15231	0.0116	2.9968	0.9763	I
Cichlidae	*Oreochromis niloticus*	2874	14	54.7	28.7166	54.8	3384.3	600.033	2.0594	0.0177	3.0447	0.9885	I
	Sarotherodon galilaeus	4562	10.6	38	21.6902	24.5	1011.3	225.045	2.05335	0.0257	2.9249	0.9562	N
	Tilapia zillii	2302	11.5	30.5	20.3957	39	632	181.779	2.0453	0.0244	2.9404	0.9396	N

N= number of samples, K= condition factor, a= intercept of regression line, b= slope of regression line, r^2 = regression coefficient, P= positive allometric , N= negative allometric ,I= isometric

Table 2. Results of ANOVA and Tukey's (HSD) tests of studied biological parameters among various seasons and locations in Lake Nasser.

	Oreochromis niloticus			*Sarotherodon galilaeus*			*Tilapia zillii*			*Lates niloticus*		
(ANOVA)												
	T.L.	T.Wt.	K	T.L.	T.Wt.	K	T.L.	T.Wt.	K	T.L.	T.Wt.	K
R^2	0.057	0.057	0.074	0.162	0.164	0.113	0.040	0.050	0.061	0.022	0.006	0.047
F	34.791	34.544	45.578	175.767	179.248	115.833	18.938	24.207	30.019	10.271	2.682	22.597
Pr > F	**< 0.0001**	**< 0.0001**	**< 0.0001**	**< 0.0001**	**< 0.0001**	**< 0.0001**	**< 0.0001**	**< 0.0001**	**< 0.0001**	**< 0.0001**	**0.020**	**< 0.0001**
Tukey's HSD (LS means) - Seasons and Sites												
Autum	28.957 a	599.413 b	2.061 b	22.117 b	235.046 b	2.027 b	20.751 a	189.682 ab	2.023 b	32.083 a	623.566 a	1.128 b
Winter	29.901 a	687.274 a	2.130 a	22.313 b	250.415 a	2.137 a	20.771 a	195.584 a	2.101 a	30.737 ab	525.006 ab	1.194 a
Spring	29.667 a	653.363 ab	2.010 c	22.690 a	256.143 a	2.035 b	20.198 b	182.886 b	2.076 a	29.102 c	359.691 b	1.179 a
Summer	27.372 b	522.441 c	2.014 c	19.939 c	168.336 c	2.016 b	19.920 b	162.460 c	1.992 c	29.725 bc	383.852 b	1.125 b
Pr > F	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**	**0.020**	**0.000**
North	27.858 b	530.394 b	2.061 a	20.537 c	182.487 b	2.002 c	20.460 b	180.906 b	2.026 b	29.718 b	443.114 a	1.137 b
Middle	31.278 a	758.423 a	2.033 b	22.576 a	253.408 a	2.038 b	20.825 a	195.369 a	2.047 b	29.698 b	439.360 a	1.154 b
South	27.787 b	558.052 b	2.067 a	22.181 b	246.558 a	2.122 a	19.946 c	171.684 c	2.071 a	31.820 a	536.611 a	1.178 a
Pr > F	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**	**0.020**	**0.000**

T.L.= total length, T.Wt.= total weight, K= condition factor

This study reveals, for the first time, the geographical and seasonal variations of the studied parameters in Lake Nasser. All investigated species showed different mean TL, mean TWt and mean K in different geographical areas of the lake and through different seasons. These differences could be related to spatially different environmental and biological conditions. This variation is related to many factors such as temperature, salinity, food (quantity, quality and size), habitat and gonad development, spawning period season, sex. Fishing time, fishing gear and area may be additional causes of such variation [3, 7].

5. CONCLUSION

The results obtained from this study are contributing to the knowledge of fish populations in Lake Nasser, as a large lake system, and highlighting the spatial and temporal variation of fisheries biological parameters in such large lake system. This variation should be considered by fisheries scientists and managers in informing future studies, and preparation of fisheries management plans. This is especially necessary for the heavily exploited populations, as well as those under stock recovery plans or other management and conservation programmes.

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O1-31

霞ケ浦のワカサギ資源変動要因の抽出及び早期資源評価モデルについて

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キーワード:ワカサギ, *Hypomesus nipponensis*, 水産・漁業, 生物利用

抄録

茨城県水産試験場では霞ケ浦のワカサギ(*Hypomesus nipponensis*)の資源を管理し, 持続的に利用できるよう, 本種の資源評価及び資源変動要因の解明に取り組んでいる。本種の資源変動に影響している要因を抽出するため, これまでに蓄積された資源評価結果や餌生物, 水質など 18 項目 212 種類のデータを用いて, 無相関検定に供した。その結果, 資源変動は「①親の資源水準」「②ふ化初期時点の餌料生物の発生量」「③気象要因」と比較的強い相関があることが判明し, 湖内環境や漁業の影響だけでなく, 気象要因も無視できないことが示唆された。これらの要因を説明変数にして GLM 解析を試み, 早期資源評価モデルを作成した。

1. はじめに

霞ケ浦(ここでは単体呼称を「西浦」及び「北浦」, 西浦と北浦を合わせた水域全体を「霞ケ浦」とする。)のワカサギ(*Hypomesus nipponensis*)は, 重要な水産資源であり, 全国屈指の漁獲量を誇る。漁業を安定的かつ持続的に営むためには, その資源量が再生産可能なレベルで安定させることが望ましいが, 霞ケ浦の本種資源量は増減を繰り返しており, 変動要因として, 漁法の変化や常陸川水門の閉鎖による淡水化や富栄養化など, 社会・物理・生物的要因が複合的に作用していると考えられる。一方, 当場のこれまでの知見から, 本種の資源量は, ふ化初期段階での生残, 特に餌生物の発生量と関係が深いことが分かっている[1]。変動する本種資源に対し, 漁業者は持続的利用を図るため, 操業調整やふ化増殖活動などに取り組んでおり, 特に若手漁業者を中心として積極的な増殖手法の改善が進められている。水産資源を管理し, 持続的に利用できるよう, 当場では本種の資源評価及び資源変動要因の解明を進めている。

本研究では, これまでに蓄積された資源評価結果や餌生物, 水質など, 霞ケ浦の各要因を取りまとめ, 本種資源変動の関係性解析, および早期資源評価に向けた指標作成(モデル化)を試みた。

2. 方法

(1) 資源評価モデルの作成及び応答変数

本研究では, 本種の早期資源評価を目的とし, 一般化線形モデル(GLM: Generalized Liner Model)解析によって資源評価モデルを作成した。本種資源量の指標として応答変数には, 資源水準値(PLI: Population Level Index)を用いた。PLI は当場が漁業協同組合とともにワカサギ漁開始直前の 6-7 月に実施している定点での曳き網調査の漁獲尾数を基に, 単位面積密度法を用いて求める値であり, ワカサギ漁開始直前の資源評価に利用している[2]。PLI は尾数を基礎としているため, 確率分布は Poisson 分布に従うと仮定した。link 関数は log を指定した。なお, PLI の西浦と北浦の母集団の差は Mann-Whittny の U 検定に供して判断した。

(2) 説明変数

本種資源変動には, 広く様々な要素が影響を与えていると見込まれる。そこで, 可能な限り網羅的に比較検討するため, 本研究では当場で調査・収集している水質などの物理的要素, 動物プランクトンや前年親魚資源水準などの生物的要素, 霞ケ浦周辺観測所で記録・公表している気象要素など, 説明変数候補(以下「要素」)は西浦, 北浦ともに Table1 に示す 18 項目 212 種類のデータを用いた。説明変数は全て数値型である。

霞ケ浦では 7 月 21 日にワカサギ漁が始まり, また応答変数とする PLI の値が 6, 7 月には定まるため, 7 月以降の要素と比較しても変動要因の探索には意味を成さない。そこで, 漁期中の 7-12 月の値については全て前年のものを用いた。また, 水産関係者の操業調整や経営判断材料として資源評価情報の提供を考えたとき, 実務上は漁開始の 2 カ月より前(5 月)に評価を示す必要がある。そこで本研究では, 4 月時点で確定値が得られない要素はモデル作成から除外した。なお, 本種の資源変動に対する遺伝的影響は, 事前に霞ケ浦各水域の本種ハプロタイプ分析を実施し無視できると示唆されたため本研究では考慮していない[3]。

説明変数の選択は, 応答変数と各要素を無相関検定に供して関係を判断した。欠測値は検定時に除外した。

要素が多量であり，変数全ての特性を把握することは難しいことから，相関係数は Spearman の順位相関係数を選択した。併せて，以下の条件を設定することで,多量のデータの中から簡便に説明変数を選択できるか試みた。

1）応答変数との相関係数が $\rho > |0.4|$である。

2）西浦と北浦共通で 1)を満たし，かつ符号が等しい。

3）2）を満たし，かつ検定結果が $p<0.01$ で有意である。

本研究では本種生息水域が比較的近く,また遺伝的にも同様の系群傾向であったことから，水域の違いはあるが西浦と北浦とも基本的には同じ要素に資源変動が左右されていると仮定し，2)の条件を含めた。 両湖の値を全てまとめて解析処理に供するかは，（1）の検定結果を踏まえて判断した。

Table1 Response variable and Candidate explanation variables

	Name	Period	n
PLI:	Population level index	2001-'17	17
PY.PLI:	Previous year PLI	2000-'16	17
SAL:	Spowning adult stock level	2000-'16	17
AEL:	Aboundance of Egg-laying level	2000-'16	17
IFL:	Initial feed level	Mar.1st.week until Apr.1st.week in 2001-'17	17
IFL-*Syn* .:	*Synchaeta* sp. in the IFL	Mar.1st.week until Apr.1st.week in 2001-'17	17
IFL-*Pol* .:	*Polyarthra* sp. in the IFL	Mar.1st.week until Apr.1st.week in 2001-'17	17
IFL-*Bra* .:	*Branchionus* sp. in the IFL	Mar.1st.week until Apr.1st.week in 2001-'17	17
IFL-*Ker* .:	*Keratella* sp. in the IFL	Mar.1st.week until Apr.1st.week in 2001-'17	17
ZLm*1:	Zooplankton level at the offing	Jan. until Jun. in 2001-'17	17
ZLmP:	Previous year ZL	Jul. until Dec. in 2000-'16	17
RLm:	Rotifer level in the ZL at the offing	Jan. until Jun. in 2001-'17	17
RLmP:	Previous year RL	Jul. until Dec. in 2000-'16	17
NLm:	Nauplius larva level in the ZL at the offing	Jan. until Jun. in 2001-'17	17
NLmP:	Previous year NL	Jul. until Dec. in 2000-'16	17
CLm:	Small crustacea level in the ZL at the offing	Jan. until Jun. in 2001-'17	17
CLmP:	Previous year CL	Jul. until Dec. in 2000-'16	17
CLLm	Chironomidae sp. larva level	Jan. until Jun. in 2001-'17	17
CLLmP	Previous year CLL	Jul. until Dec. in 2000-'16	17
OLm	Oligochaeta sp. level	Jan. until Jun. in 2001-'17	17
OLmP	Previous year OL	Jul. until Dec. in 2000-'16	17
WTSm:	Water temprature at the shore	Jan. until Jun. in 2001-'17	17
WTSmP:	Previous year WTS	Jul. until Dec. in 2000-'16	17
WTOm:	Water temprature at the offing	Jan. until Jun. in 2001-'17	17
WTOmP:	Previous year WTO	Jul. until Dec. in 2000-'16	17
TRm:	Trancparency at the offing	Jan. until Jun. in 2001-'17	17
TRmP:	Previous year TR	Jul. until Dec. in 2000-'16	17
SSm:	Suspended solid level at the offing	Jan. until Jun. in 2002-'17	16
SSmP:	Previous year SS	Jul. until Dec. in 2002-'16	15
VSSm:	Volatile suspended solid level in the SS at the offing	Jan. until Jun. in 2002-'17	16
VSSmP:	Previous year VSS	Jul. until Dec. in 2002-'16	15
FSSm:	Fixed suspended solid level in the SS at the offing	Jan. until Jun. in 2002-'17	16
FSSmP:	Previous year FSS	Jul. until Dec. in 2002-'16	15
Tm:	Monthly average temperature	Jan. until Jun. in 2001-'17	17
TmP:	Previous year T	Jul. until Dec. in 2000-'16	17
Dm:	Sunshine duration	Jan. until Jun. in 2001-'17	17
DmP:	Previous year D	Jul. until Dec. in 2000-'16	17
Wm:	Monthly average wind speed	Jan. until Jun. in 2001-'17	17
WmP:	Previous year W	Jul. until Dec. in 2000-'16	17
Rm:	Monthly average rainfall	Jan. until Jun. in 2001-'17	17
RmP:	Previous year R	Jul. until Dec. in 2000-'16	17
SRm:	Monthly sum rainfall	Jan. until Jun. in 2001-'17	17
SRmP:	Previous year SR	Jul. until Dec. in 2000-'16	17

*1 "m" is month. Ex. ZL1, ZL12P.
*2 T,D,W,R,SR data by the Tsuchiura（Nishiura） or Hokota(Kitaura) AMeDAS observatory

(3)統計解析

検定・解析など計算処理は，全て R Ver.3.4.3（ https://cran.r-project.org, R Development Core Team）を使用した。解析用データセット作成，表の整理やグラフ描写は MS-Excel（Microsoft Corporation）を用いた。

3. 結果

(1) 応答変数

西浦の PLI（NPLI: Nishiura PLI）と北浦の PLI（KPLI: Kitaura PLI）は，同じ母集団に属するとは認められなかったことから（$p<0.05$），西浦と北浦のデータはまとめず個別に解析を進めた。

(2)説明変数

西浦北浦共通でかつ有意な相関が認められる要素として，Table2 に示す 5 項目 14 種類を選択し，説明変数とした。ただし，4 月時点で得られない要素は除外するとともに，餌料要素の IFL-*Bra.* 及び IFL-*Ker.*は，IFL に内包されており，IFL と RL3 は，ともに 3 月時点のワムシ類発生量を示していることから，影響の重複を防ぐため，代表して IFL のみ説明変数とした。

Table2 Candidate explanation variables and Test for no correlation results

	Correlation ρ				
Factor	Nishiura		Kitaura		
PY.PLI	0.801	***	0.620	**	Previous Year PLI
IFL	0.831	***	0.784	***	Initial feed level
IFL-*Bra* .	0.868	***	0.853	***	*Branchionus* sp. in the IFL
IFL-*Ker* .	0.723	**	0.647	**	*Keratella* sp. in the IFL
ZL5	0.831	***	0.618	**	Zooplankton level at the offing in May
RL2	0.660	**	0.612	**	Rotifer level in the ZL at the offing in Feb.
RL3	0.636	**	0.721	**	RL in Mar.
RL5	0.635	**	0.632	**	RL in May
D5	0.738	**	0.672	**	Sunshine Duration in May
W2	0.695	**	0.646	**	Monthly average wind speed in Feb.
W3	0.736	**	0.608	**	W in Mar.
W4	0.711	**	0.685	**	W in Apr.
W9P	0.764	***	0.683	**	Previous Year W in Sept.
W10P	0.767	***	0.748	***	Previous Year W in Oct.

Signif. codes: '***' $p<0.001$, '**' $p<0.01$, '*' $p<0.05$

(3)資源評価モデル

選択された説明変数及び GLM 解析に供した結果は Table3 に示す。NPLI を応答変数とする西浦のモデルを「Nmodel」，KPLI を応答変数とする北浦のモデルを「Kmodel」とした。なお，モデル毎に分散拡大要因を，vif 関数を用いて確認をしたところ，多重共線性は疑われなかった（vif<10）。併せて Stepwise 関数を用いて変数選択（AIC 基準変数増加法）したところ，AIC の改善は全ての説明変数を選択して止まったため，Full モデルを採用した。モデルによる PLI 推定値（N，Kmodel）と PLI（N，KPLI）とをグラフにした結果は Fig.1 に示す。

4. 考察

本種資源変動に影響を与えている要因として，本研究から「①親の資源水準（PY.PLI）」，「②ふ化初期時点の餌料生物の発生量（IFL,RL2）」，「③気象要因

Table3 Explanation variables and GLM coefficients

Nishiura	Model name "Nmodel"			
Factor	Estimate	Std. Error	z value	Pr(>|z|)
Intercept	3.007000	0.016600	181.17	***
PY.PLI	-0.000003	0.000000	-69.61	***
IFL	0.001417	0.000007	214.96	***
RL2	-0.005336	0.000041	-130.05	***
W2	0.158500	0.015310	10.35	***
W3	1.065000	0.009869	107.92	***
W9P	1.958000	0.013700	142.99	***
W10P	0.269300	0.010900	24.70	***
Kitaura	Model name "Kmodel"			
Factor	Estimate	Std. Error	z value	Pr(>|z|)
Intercept	4.891000	0.058360	83.80	***
PY.PLI	0.000018	0.000001	13.18	***
IFL	0.000383	0.000006	64.79	***
RL2	-0.000271	0.000029	-9.39	***
W2	0.517500	0.028120	18.41	***
W3	0.167800	0.026280	6.39	***
W9P	1.426000	0.023220	61.43	***
W10P	-0.291900	0.035560	-8.21	***

Signif. codes: '***' p <0.001

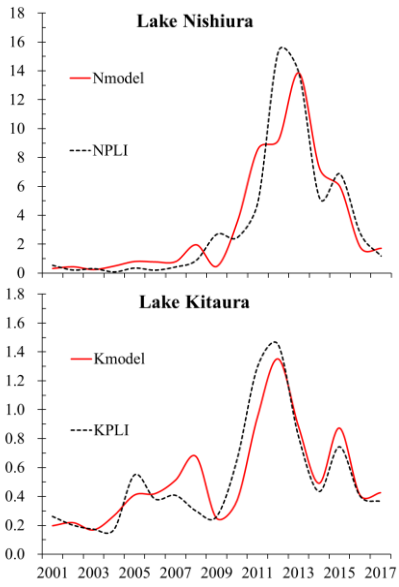

Fig.1 N,Kmodel (GLM estimate) and PLI (response variable)

(W2,3,9P,10P)」の 3 要因が示された。各要因を説明変数に用いた資源評価モデル(GLM)の結果も，応答変数とした PLI の変遷を十分描写できていると見込まれるものであった。4 月時点で確定値が得られるものから当モデルを作成したことで，実運用においては漁開始前に定量的な資源評価が可能となり，これまでの実漁獲に基づく 7 月時点の資源評価より早期に，操業調整や経営判断材料として活用できるものと期待できる。しかし，Nmodel と Kmodel とで係数符号が一致しない説明変数があること(PY.PLI，W10P)，RL2 の係数符号が負の値を示す理由などは，本稿執筆時点では検討課題となっている。また，当モデルの検証・精度向上は，実運用と併せて毎年継続していく必要がある。これらについては今後解決すべき課題として，引き続き取り組んでいく。

各要因についてみてみると，「①親の資源水準」は，親の多寡が仔の資源に影響を与えるのは，当然妥当なものと考えられた。「②ふ化初期時点の餌料生物の発生量」も，本種の初期生残に餌料条件が関係していることなどを示した過去の当場の研究結果と合致するものであり，妥当と考えられた。一方で，「③気象要因」が本種資源変動と高い相関を示したことは興味深い結果であった。これまで，本種の資源変動を考える際には，湖内環境や漁業の影響など，湖内要因についてのみ着目しており，気象要因を加味したものは無い。しかし，本研究の結果は，気象の影響も無視できないことを示唆するものであった。気象要因が直接的又は間接的に，本種資源変動にどのような影響を与えているかは，本研究のみでは解釈できないが，引き続き解析を進めることで，新たな視点からの本種資源特性が明らかになる可能性がある。

5. 結論

(1) 霞ケ浦のワカサギ資源の変動は「①親の資源水準」「②ふ化初期時点の餌料生物の発生量」「③気象要因」と比較的強い相関があることが示唆された。

(2) 本研究からワカサギ資源変動を考えるうえで，湖内環境や漁業の影響だけでなく，気象要因も無視できないことが示唆された。

(3) (1)の要因を説明変数としてGLM解析を試み，早期評価資源評価モデルを作成した。

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O1-32

Paper title：“Fish Conservation Areas as a tool to strengthen freshwater community fisheries: Project experience from the Tonle Sap”

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Keywords: fish conservation area, community fisheries, common-pool resource management, sustainable conservation and livelihood benefits

ABSTRACT

As one of the world’s most unique freshwater ecosystems, the Tonle Sap lake is a dynamic socio-natural system. It is also a system under threat by rapid environmental change and weak governance. Not only does this have implications for the wider Tonle Sap ecosystem, but for the livelihoods of millions of Cambodian citizens, who depend on the resources provided by this natural ecosystem. To address this, the EU-funded Non-State Actors project, implemented by the International Union for the Conservation of Nature (IUCN) and the Fisheries Action Coalition Team (FACT), sought to improve the livelihoods of fishing communities at three target sites in the Tonle Sap: Kampong Phluk, Boeung Chhmar, and Phlov Touk. In collaboration with the target communities and relevant authorities, each site implemented a fish conservation area (FCA) where fishing is prohibited year round to protect key fish refugia, benefitting both the aquatic ecosystems and productivity of community fisheries. The project applied an ecosystem-based management approach, combined with common pool resource management principles and a highly participatory approach to achieve sustainable conservation and livelihood benefits in these communities. This paper outlines key elements with the intention of providing flexible guidance for other projects working for sustainable and conservation based community fisheries management in the Tonle Sap and beyond.

1. INTRODUCTION

The freshwater fisheries of the Tonle Sap and Mekong River form the foundation of Cambodian livelihoods and the economy (Baran and Gallego 2015). The Tonle Sap lake is a critical component of fisheries productivity, both within the lake itself and throughout the Mekong, due to the dynamic flood-pulse system and the importance of spawning grounds within the lake. The biodiversity of this system is internationally recognised as a biodiversity hotpot, being designated as a UNESCO Biosphere reserve.

The ecosystems and social systems of the Tonle Sap are facing increasing and unprecedented challenges. These arise from population growth, climate change, land use change, over exploitation of resources and modifications to river flows and fish migration resulting from hydropower development on the Mekong and tributaries (Ratner et al. 2017). Fish yields and diversity within the lake and inundation zone are plateauing and declining, reducing both the biodiversity and socio-economic values of the systems (Chap, Touch, and Diepart 2016).

The EU-funded Non State Actors project, “*Community-based Small-scale Fish Conservation Area Management in the Tonle Sap lake, Cambodia*” strengthened and empowered established Community Fisheries Committees to manage and improve fish stocks through the implementation of fish conservation areas (FCAs).

2. METHOD

Please describe the method you have chosen for your research here [3]. Apply (1) left- and right-justification, (2) automatic hyphenation as well as (3) spell check to all the text you write.

The conceptual basis of the project was to empower communities to create a sustainable resource management

system supported and respected by external stakeholders. The concept of the project was developed based on three fundamental principles:

- use of an ecosystem-based approach to achieving livelihood benefits and conserving a critical natural resource through establishment and management of Fish Conservation Areas (FCAs)
- considering common pool resources as complex socio-ecological systems in determining an intervention strategy aimed at long-term change
- "*giving people voices"* through a participatory approach to project development, monitoring and implementation, ensuring a focus on post-project commitment by communities and other stakeholders.

Development of the intervention strategy was informed by both scientific and local knowledge of ecological systems and theories for sustainable management of natural resource management (Cox, Arnold, and Tomás 2010).

Three sites were selected: Kampong Phluk, Boeung Chhmar and Phlov Tuk. These sites were selected based on clear opportunities to have a positive social and environmental impact through the establishment of FCAs in critical dry season fish refugia; having dry season refugia that were small and close to communities to enable cost-effective management, and in order to build on existing relationships and initiatives by the project partners.

The following objectives were used as a framework for the development of intervention activities:

- Capacity of CFs to negotiate, demarcate, and manage FCAs is strengthened.
- Capacity of CFis to network with other CFis managing FCAs is enhanced.
- Value of FCAs demonstrated and management costs are included in CDFs.

Specific interventions included, but were not limited to, demarcation of the resource, establishing rules and regulations for the CFis, ensuring clear user rules, ensuring equity amongst community members and empowering communities to work with local authorities to enforce the user rule. All interventions were adapted at each site to be context specific based on an independent situation analysis and ongoing adaptive response to community input collected through the ongoing engagement.

The project adopted a multi-level engagement strategy, with local communities as a core, integrating strategic and planned engagement with local and national authorities. Communities and local authorities were regularly engaged during the course of monitoring, workshops, practical works, and site visits. Establishment of relationships between communities and authorities was key.

The monitoring process was highly participatory, comprising of quarterly focus group discussions, and monthly collection of fisheries data by communities. Information collated was used to directly inform project implementation. The monitoring process doubled as a recourse mechanism for conflict resolution.

3. RESULTS

Communities strongly supported the establishment of FCA's based on the traditional understanding of the need for 'mother-fish' to be protected during the dry season. The physical demarcation of the FCAs had a positive impact on local support and participation. With the demarcation established, CFi rules and regulations established and with an on-going knowledge campaign regarding the benefits of ecosystem-based conservation, the FCAs became operational. CFi rules around FCA use were policed by local community members and local authorities in 2015. Since then, communities have reported remarkable increases in the amount of fish that have spawned and harvested for subsistence and income.

Joint enforcement activities greatly improved relations between local authorities and the CFis; local authorities became increasingly involved in law enforcement in collaboration, rather than in conflict with, the communities. The CFi committees are now confident enough to seek external assistance.

Incorporation of management costs in commune

development funds as determined to be impractical on a large scale, and the need for a broader range of financing options was identified. The following major long-term financing opportunities were identified include: sourcing money from CFi membership fees, defining a buffer zone payment, receiving funding from ecotourism, and receiving funding from community savings group.

The project monitoring was an instrumental component in establishing effective and trusting relationships not only between project staff and communities, but within communities and between communities and local authorities; and also of developing the skills and confidence of local community members.

4. DISCUSSION

The use of small community managed Fish Conservation Areas to protect critical dry season fish refugia not only protected an important and highly threatened component of the lifecycle of fish species, but also generated a high value resource during the wet season, around which fisheries were substantially more productive. This motivated communities and local authorities to invest energy in the protection and management of these areas, independently of project support.

The high degree of involvement by the local community in influencing the design and ongoing implementation of the project, both through the initial consultation and the ongoing engagement, resulted in exceptional to the project by communities. This also facilitated development of relationships with authorities and with other communities. Linking scientific knowledge with traditional knowledge, enabled communities to have strong understanding of the project basis and to be highly committed.

The focus on creating conditions conducive to self-organisation of management of common pool resources ensured that the project took a long term approach to the problem, ensuring that interventions were targeted to creating the motivational, economic social and governance conditions required for ongoing management of the resource by communities following project conclusion.

5. CONCLUSION

Overall, this project has demonstrated that in the complex socio-ecological system of the Tonle Sap, ecosystem based intervention through the establishment of Fish Conservation Areas can result in the successful achievement of both ecosystem conservation objectives and livelihood development activities.

The short term project interventions can assist in the generation of the physical, economic, social and governance conditions which support local communities to effectively manage valuable natural resources to deliver both both conservation and livelihood benefits in the longer term. With proper co-management, conservation, securing sustainable financing, and due care of the ecosystem services, contested fisheries can be effectively managed by local communities resulting improvements in both fisheries and the underlying aquatic ecosystems.

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O1-33

Application of a model for carrying capacity for aquaculture to a big overexploited lake

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Keywords: cage aquaculture; trout re-stocking; assimilative capacity; water level; anthropogenic pressure.

ABSTRACT

Lake Sevan in Armenia is one of the most overexploited freshwater mountain ecosystem in the world. Over the long term, severe and diverse anthropogenic pressures have converted it from an oligotrophic ¨trout¨ lake into a mesotrophic ¨carp¨ reservoir. Water level lowering during decades, drying out of the spawning grounds of endemic trout, illegal fishing, insufficient control of organic and pollutant input from catchment, occasional introduction of alien species, current water level fluctuations has caused significant changes in the limnosystem. The current situation is characterized as a disturbed ecosystem stability as evidenced by species succession at all trophic levels, intensification of bioproduction in the lake, shift of production-destruction processes. A recent governmental program for the restoration of the endemic Sevan trout stock though a cage-based aquaculture in the lake could be an effective intervention to re-stock the lake with valuable trout species and improve its ecosystem services. However, it is needed to estimate the carrying capacity of the lake given its current vulnerability and instability. In this work, we estimated the capacity of the lake to assimilate organic input from aquaculture with the maximum precaution, taking into account its historical trends and the current state.

1. INTRODUCTION

Freshwater resources have been severely overexploited by humans and the decline in biodiversity in freshwater systems are greater than in the most affected terrestrial ecosystems (Dudgeon, 2005; Sala et al., 2000). However, freshwater provides water for human consumption and biodiversity losses may cause water quality degradation (Cardinale, 2011).

Lake Sevan, a big alpine lake situated in Armenia, is one of the examples of the most overexploited limnosystems in the world. Long term, severe and diverse anthropogenic pressures have converted the lake from an oligotrophic ¨trout¨ lake into a mesotrophic ¨carp¨ reservoir (Gabrielyan, 2010). Recently, a governmental program for the restoration of the Sevan trout stock (through a cage-based aquaculture in the lake) has been adopted. It can be an important step toward re-stocking of the lake with a valuable trout species taking into account the dramatic state of the fish community. However, given the current state of the ecosystem and diversity and intensity of anthropogenic pressures, the aquaculture and re-stocking operations should be carefully monitored by science-based methods. Aquaculture is known to release solid and dissolved phosphorus and nitrogen that change the balance of nutrients and alters their life cycle in the environment (Azevedo et al., 2011; Canadian Science Advisory Secretariat, 2015). In this work, we aimed to assess the volume of aquaculture that Lake Sevan can safely support by applying a model of carrying capacity for aquaculture.

2. METHOD

2.1 Study area

Lake Sevan consists of two morphologically different parts which differ by morphology, size and depth: deeper Small Sevan (SS) and shallower Big Sevan (BS) (Fig.1). Before the anthropogenic lowering of the water level Lake Sevan was oligotrophic, hosting three endemic fish species: polymorphic Sevan trout *Salmo ischchan* with 4 races differing in a number of biological and morphological traits, barbell *Barbus goktschaicus* and khramulia *Varicorhinus capoeta sevangi*.



Fig. 1 Lake Sevan (Armenia) and location of aquaculture facility.

In the 20s, two species of whitefish (*C. lavaretus ludoga* and *C. lavaretus maraenoides*) were being gradually acclimatized to fill the empty niche of pelagic consumer in the lake's food web. The main primary producers were macrophytes (7000 g/m^3), the share of phytoplankton was low (0.3 g/m^3) and the lake had high phosphorus

concentration and nitrogen limitation in all seasons (0.32 g/m^3 and 0.003 g/ m^3, correspondingly) (Ecology…, 2010).

Regular and increasing water extraction since the 30s have resulted in a reduction of the water level by around 18.5 m by 1980 (Fig. 2), surface area reduced by 12.2% and volume by about 42.2% (Gezalyan, 1983; Hovhanisyan, 1994). This caused the destruction of the macrophyte zone and of the spawning sites of two races of Sevan trout, barbell and khramulia. Fish catches significantly decreased by the 50s (Fig. 2).

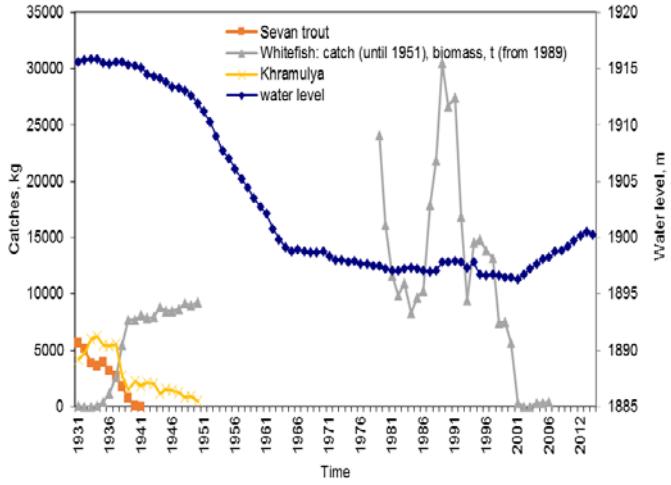

Fig. 2 Dynamics of water level drop, fish catches and whitefish biomass in Lake Sevan, Armenia.

In addition, nitrogen content has gradually increased due to the watershed development. As a result, phytoplankton has become the primary producer in the lake (Hovhanisyan, 1994). At the beginning of the 80s the status of the lake was estimated as euthropic with later shift towards mesotrophy (Ecology..., 2010). The whitefish stock reached ca. 30,000 t by the end of the 80s (Gabrielyan, 1998; Gabrielyan and Khosrovyan, 2006; Gerasimov et al., 2006). However, by 2001 it was overfished and depleted (Fig. 2). Currently, the ecosystem shows signs of instability such as unpredictable successions of phytoplankton species and main groups, shifts in production-destruction processes in the lake, changes in the composition and horizontal distribution of zooplankton, trends towards increasing phytobenthic forms (Ecology…, 2010; Lake Sevan…, 2016).

2.2 Aquaculture in the lake

In August 2016, a pilot aquaculture facility for breeding Sevan trout was installed in BS. According to December data (after 5 months) on feed distribution, around 50,013 kg of feed was applied and the biomass increment approached to 50 t. The emanation of nutrients from aquaculture during the 5 months is estimated by the company as 1.7 t of nitrogen and 0.25 t of phosphorus.

2.3 Model of the carrying capacity of a lake for aquaculture (Legovic et al., 2008)

The detailed description of the model can be found in (Legovic et al., 2008). Briefly, the model is based on the following equation:

$I_a = X_c - I_0$ (1),

where I_a - concentration of nutrients in water contributed by aquaculture, X_c - critical concentration of nutrients in phytoplankton (which leads to critical phytoplankton growth), I_0 – concentration of nutrients in water contributed by background sources (external to aquaculture). As fish cultures emanate nutrients and foster phytoplankton growth, it may reach such a growth that can effectively consume available oxygen in water, creating inappropriate conditions for oxygen-sensitive fish.

2.3 Maximum fish stock in aquaculture

The maximum fish stock in aquaculture can be estimated:

$S_{nut} = a * S_{max}$ (2),

where S_{nut} – nutrient mass emanated from aquaculture in a unit of time, a – nutrient mass from aquaculture by production of 1 t of fish, S_{max} – maximum standing stock of fish in aquaculture (t). The equivalent increase of nutrients in the lake from aquaculture can be expressed as:

$I_a = S_{nut} / (V * D)$ (3),

where V – lake's volume, D – flushing rate of the lake. For Lake Sevan, the flushing rate was estimated 0.04 /year (Hovnanisyan, 1994) and the volume 38.1 * 10^9 m^3 (Lake Sevan…, 2016).

2.4 Chlorophyll-a (Chl-a) – nutrient interrelationship

The components of the model are expressed in mass of nutrient per volume and we translated the mass of nutrient unit into phytoplankton-related Chl-a concentration to facilitate comparison with the critical Chl-a level in lake, suggested by Florida Lakewatch (2000) and Legovic et al. (2008) – 100 mkg Chl-a /l. For the Chl-a and total phosphorus (TP) relationship, the equation based on 19 Canadian lakes was used (Dillon and Rigler, 1974):

log10 (mkg Chl-a/l) = -1.134 + 1.5383 log10 (mkg TP/l) (4).

In these lakes, the ratio N:P ≥ 12, which is also characteristic for Lake Sevan. For estimation of critical Chl-a concentration in Lake Sevan, historical nutrient loads and the trends in the ecosystem state were taken into account (Hovhanisyan, A.S. Parparov, 1983; Nikoghosyan, 1979).

3. RESULTS AND DISCUSSION

The carrying capacity of Lake Sevan has been considered to be reached at 0.1 mg/l of TP and 88 mkg Chl-a /l. Using equation (4), nutrient loads were translated into Chl-a concentrations and these values were imposed into equation (1). Thus, the Chl-a concentration attributable to the additional input of nutrients from aquaculture was estimated:

88 mkg Chl-a/l. – 75 mkg Chl-a/l = 13 mkg Chl-a/l.

This level of Chl-a corresponds to TP = 0 .029 mg/l (the mass of nutrient per volume that can be contributed by aquaculture). From the data provided by the aquaculture company, the emanation of nutrients from growing 1 t of fish was estimated: 0.082 t/year of nitrogen and 0.012 t/year of phosphorus (a=0.012 t/year of phosphorus). By using equation (3) and imposing I_a (phosphorus contribution from aquaculture, mg/l), the mass of nutrient (phosphorus) emanated by the aquaculture in a unit of time (1/year) can be calculated as follows:

S_{nut} = 0.029 mkg/l * 0.04 /year * 38.1 * 10^9 m^3 = 44.196 t of phosphorus/year.

Lastly, from equation (2) the maximum fish stock in aquaculture (S_{max}) can be calculated:

$S_{max} = S_{nut} / a = 44.196 / 0.012 = 3683$ t.

Hence, at the present volume of water, flushing rate and the estimated level of organic input from external sources, Lake Sevan would support aquaculture with the maximum standing biomass of 3683 t without jeopardizing its water quality. This stock is considerably smaller than the wild stock existed in the past (e.g., ca. 30,000 t of whitefish at the end of the 80s) (Fig. 2). However, the present condition of the lake is different from the past, anthropogenic pressures are diversified and intensified, fish community is disturbed, water level fluctuates, the ecosystem shows signs of instability. Moreover, for the estimation of the carrying capacity of Lake Sevan, the Chl-a-TP equation for Canadian lakes was used. This is the first estimation of the carrying capacity of Lake Sevan and it can serve as a starting point for a scrutinized scientific monitoring of the effects of aquaculture activity on the health of the lake's ecosystem.

4. CONCLUSION

The acquisition of data for investigating the key impacts of fish farming is not easy and the use of proxies in the lack of appropriate data may be required. As aquaculture is an intensive pressure on the natural ecosystems, a cautious derivation of estimates of the carrying capacity is necessary. The estimates of phosphorus load from aquaculture and the maximum standing fish stock for Lake Sevan were derived taking into account historical characteristics and the current state of the limnosystem. However, proxies and alien equations were also used. Thus, the results obtained should be carefully verified by a constant monitoring program of the ecosystem health to ensure the protection of ecosystem services and provision of economic benefits.

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O1-34

Mass Balanced Model of Lake Volta Fisheries: The use of Ecopath Model

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Keywords: ecotrophic efficiency, functional groups, mass balanced model, trophic interaction

ABSTRACT

A mass-balanced model of trophic interactions among 10 key functional groups of Lake Volta was constructed using the Ecopath software to analyze the interactions and energy flows within Lake Volta. The study was based on secondary and primary data on fish catch, diet composition, phytoplankton and zooplankton biomasses, collected in 2015 and 2016. An additional information on growth parameters of major species required for balancing the Ecopath model were obtained from FishBase. The functional groups were detritus, phytoplankton, zooplankton, benthos, prey fish, *Tilapia*, *Bagrus*, *Chrysichthys*, *Alestes* and *Synodontis*. In this ecosystem, four trophic levels were identified and the energy flow mainly occurred within the first three levels. The calculated ecotrophic efficiency value of the primary producers (phytoplankton: 0.075; detritus: 0.090) showed that they were least exploited compared to the zooplankton (0.80) and benthos (0.50), the secondary producers. The main energy flows in the ecosystem were from detritus and phytoplankton at trophic level 1 with *Bagrus* species being the top predator at level of 3.30. The connectance index (0.44) and system omnivory index (0.06) indicated that the ecosystem was unstable, immature and still at a developing stage.

1. INTRODUCTION

Construction of dams for hydropower, water supply, flood control, aquaculture and agricultural irrigation is one of the major human disturbances in river ecosystems. Such constructions result in habitat changes from lotic to lentic conditions and the existing ecosystem exhibits multiple ecological stressors impacting the dynamics of fish stocks and community composition, leading to eutrophication, changes in zooplankton, aquatic vegetation, as well as invasion of species [1]. Such changes influences aquatic populations, trophic relationships and food web structures. Interaction between fish species has been a continued discussion with focus on best practice in managing fisheries resources, taking, where necessary, biological interaction into account [2]. The objective of the study was to construct a mass-balanced trophic model of Lake Volta using Ecopath model to reveal the trophic interactions and energy pathways in the food web and to analyze the ecosystem maturity using an ecosystem characterization index resulting from network analysis.

2. METHOD

The model area, Lake Volta, formed by damming River Volta for hydropower (Figure 1) has a surface area of 8,500 km^2 and a shoreline of 4,880 km with a maximum depth of 75 m and a mean depth of 14 m. The reservoir's fisheries, provide 90% of the national freshwater fish production [3]. The Ecopath software version 6.5 was used to construct the model. Parameters included for each group in order to develop a mass balanced model were biomass (*B*), production/biomass ratio (*P/B*), consumption/biomass (*Q/B*), diet composition and ecotrophic efficiency (*EE*). The model assumes an equilibrium condition such that the inputs to any functional group are equivalent to its outputs.

In the study, 10 functional groups were identified, these included 6 fish species (*Chrysichthys nigrodigitatus*, *Tilapia zillii, Bagrus bajad, Alestes baremoze, Syn-*

odontis ocellifer and prey fish). The fish species were selected based on catch landings in 2015 and 2016 and its economic value. In addition, the following food sources for fish were considered: zooplankton, phytoplankton, benthos and detritus groups which form the remaining 4 groups. A diet matrix was constructed based on the stomach content data of fish species sampled in the lake. Basic estimations were independently made for *EE* values of prey fish, zooplankton and benthos. Where three of the four basic input parameters (typically *B*, *P/B*, *Q/B*) of the model are provided for a group (from sampling and FishBase), Ecopath estimate the missing parameter (typically *EE*) for each group in the model.

After a preliminary run of the model, the ecosystem stability and degree of system maturity were analyzed by various system statistics and network flow indices in accordance with [4].

3. RESULTS

The output parameters (mass-balanced model) are summarized in Table 1. *Chrysichthys* and Tilapias had high biomasses of 3.94 and 3.75 t km^{-2} year^{-1}, respectively among fish groups. The *EE* values for the top predators (*Bagrus* and *Chrysichthys*) and primary producers (phytoplankton and detritus) were low as compared to the primary consumers (*Alestes*, Tilapia, Prey fish, zooplankton). Analysis of the trophic structure showed that the lake can be divided into 4 main trophic levels (Figure 2). Most of the functional groups were confined to trophic level II and III. The highest trophic level was 3.3 for *Bagrus* which is typical of top predators described as low-order secondary consumer. *Chrysichthys*, *Alestes*, *Synodontis*, and prey fish were between 2.5 and 3.0 belonging to high-order primary consumers. The low-order consumers with trophic levels 2 to 2.5 were tilapias, benthos and zooplankton whilst the main primary producers, phytoplankton and detritus in trophic level I.

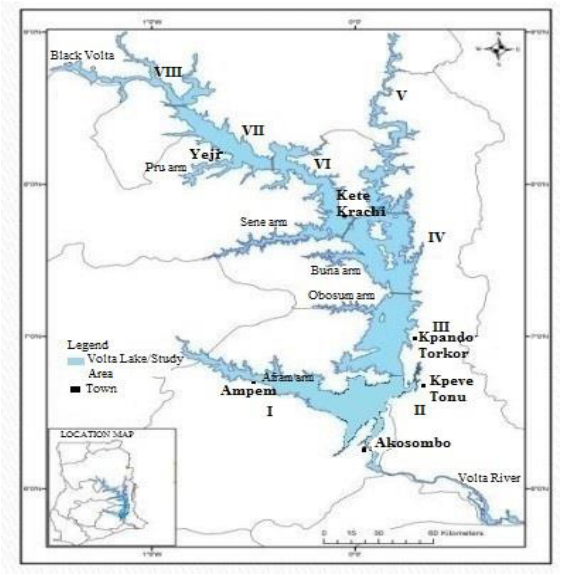

Figure 1: Map of the model area, Lake Volta.

Table 1: Basic estimated parameters generated after the mass-balance process in Lake Volta.

Group name	*TL*	*B* (t/km²)	*P/B* (/year)	*Q/B* (/year)	*EE*	*P/Q*
Bagrus	3.30	1.82	1.00	18.5	0.126	0.054
Chrysichthys	2.96	3.94	2.50	16.5	0.231	0.152
Alestes	2.80	1.18	2.60	17.4	0.786	0.144
Synodontis	2.59	0.87	1.50	20.9	0.463	0.072
Tilapias	2.03	3.75	2.00	113.0	0.762	0.018
Prey fish	2.50	5.76	4.00	20.00	0.900	0.200
Zooplankton	2.00	5.09	17.58	58.61	0.800	0.300
Benthos	2.00	17.40	10.00	33.33	0.500	0.300
Phytoplankton	1.00	41.90	200.00		0.075	
Detritus	1.00	10.00			0.090	

Note: TL = Trophic level; B = Biomass; P/B = Production biomass; Q/B = Consumption biomass; EE = Ecotrophic efficiency; P/Q = Production consumption

The system characteristics and degree of ecosystem maturity is shown in Table 2. A TPP/TR value of 8.98 was recorded indicating that the lake system is still in a developmental stage. CI and SOI values were 0.44 and 0.06 respectively which shows that the complexity of feeding activity of different trophic levels in the Lake are at a low level.

4. DISCUSSION

The *EE* values of detritus and phytoplankton suggest that their resource was not utilized adequately and their supply exceeded the demand of consumers in the food web.

This is an indication that the food availability in the lake is mainly primary producers based. The *EE* value

for the top predator, *Bagrus* indicating that they experienced low predation as most of the stocks have been exploited as shown by their reduced biomass level. Detritus and phytoplankton in the food web played an important role in the ecosystem and considered dominant components in the energy structure. This is consistent with the natural feature in aquatic environments as suggested by [2].

The four trophic levels identified in the lake is typical of other reservoir ecosystems in tropical lakes such as Lakes Awassa, Kariba, Victoria and Malawi [5] suggesting that species in these lakes exhibit similar feeding patterns. Fish groups were composed of three main feeding habits: carnivorous/piscivorous, omnivorous and herbivorous and fish species (e.g. *Bagrus*, *Chrysichthys*, *Synodontis, Alestes*) have the ability to switch to different feeding behaviour depending on food availability. The biomasses of functional groups at the base of the trophic level also conformed to the rules of the biomass distribution pyramid [1; 2] and this formed the basis of energy flow. The ecosystem statistics generated by the model indicated a total sum of production of 8690.12 t/km/yr. which is similar to most lake in Africa Lakes (Kariba, Awassa). This indicates a high productivity but not fully utilized by the fish species. The lake is considered in developmental stages as their TPP/TR ratios are above 1. Values of the SOI was low suggesting that the complexity of feeding activity of different trophic levels in the lakes are at a low level [2; 4].

5. CONCLUSION

The structure of the food web comprised four trophic levels with *Bagrus* species feeding at the highest trophic level. Network analysis showed that detritus and phytoplankton groups formed an important component of the food chain and are more susceptible to predation changes by fish functional groups at higher trophic levels. The lake is described as being at an immature stage.

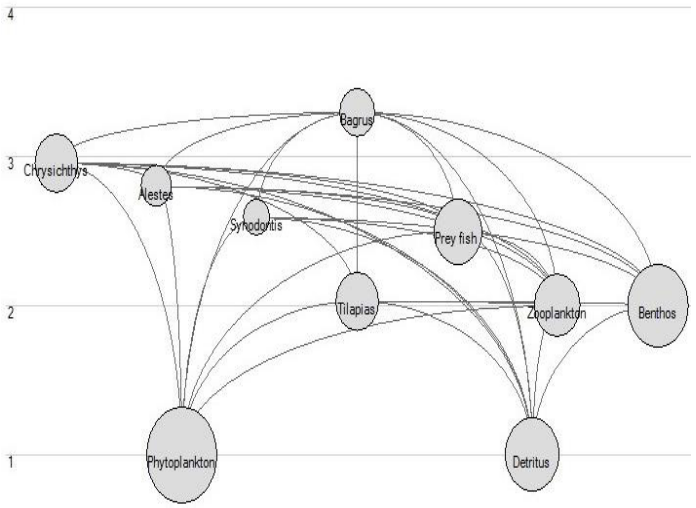

Figure 2: Flow diagram of the trophic structure and the functional groups in Lake Volta.

Table 2: System statistics estimated by the Ecopath model in Lake Volta.

Parameter	Value	Units
Sum of all consumption	1554.84	t/km²/yr.
Sum of all production	8690.12	t/km²/yr.
Mean trophic level of the catch	2.70	t/km²/yr.
Calculated total net primary production	8380.00	t/km²/yr.
Total primary production/total respiration (TPP/TRP)	8.98	
Connectance Index (CI)	0.44	
System Omnivory Index (SOI)	0.06	

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O1-35

The evaluation of the fulfilment of the obligations under the Convention on Biological Diversity in the South Caucasus

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Keywords: CBD, commitment to the Convention, freshwater biodiversity, protected area.

ABSTRACT

In the South Caucasus region, severe pressures were exerted on the water and biological resources of freshwaters that resulted in biodiversity decline or even extirpation of native populations. This work analyzed the state of the freshwater biodiversity in the selected countries of the region (Armenia, Azerbaijan, Georgia and southern Russia) before and after ratification of the Convention on Biological Diversity. A critical assessment of the level of the fulfilment of commitments to the Convention after ca. 20 years of ratification was conducted. Instruments or mechanisms that can improve the implementation of the provisions of the Convention were discussed.

1. INTRODUCTION

Biodiversity conservation and management is an important task for every nation as biodiversity resources provide means for country development, growth and self-reliance. However, about 60% of all surface waters have been lost in Asia and Europe, according to the Wetlands Extent Index. As 4/5 people live downstream of the freshwater or are served by renewable freshwater services (Millennium Ecosystem Assessment, 2005), freshwaters are threatened by pollution from watersheds and competitive water demands by urban, industrial and agricultural users. In the South Caucasus region, where biodiversity contained high endemism (Fig.1), severe pressures on freshwaters have resulted in biodiversity decline or even extirpation of native populations. Now, the region is part of Caucasian "biodiversity hotspot". Some of the countries of the region are part of WWF's "priority places" (Greater Black Sea Basin). The whole Caucasus is included in the list of Global 200 Ecoregions by WWF.

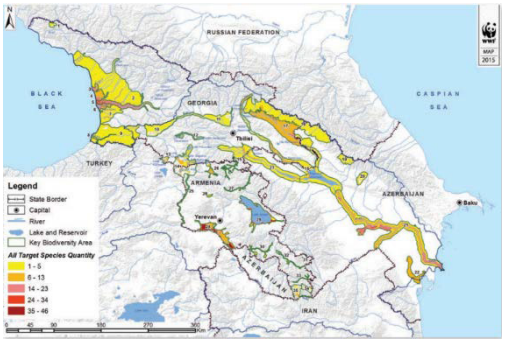

Fig. 1. Freshwater Key Biodiversity Areas with species richness in the South Caucasus (Freyhof et al., 2015).

This work aims to evaluate the level of the fulfillment of the commitments of the national governments to the provisions of the Convention on Biological Diversity (CBD) after ratification.

2. METHOD

For the assessment of the progress of the fulfillment of obligations under CBD the national reports of study countries (Armenia, Azerbaijan, Georgia and southern Russia), national strategies for biodiversity and actions plans and supplementary materials were analyzed and compared. A special focus was given to the biodiversity issues in inland freshwaters that include all permanent or temporal, deep or shallow water bodies within the territory of a country (e.g., lakes, rivers, reservoir/ponds, springs, floodplains, bogs, marshes, and swamps). A consolidated information such as the total area of protected sites or the number of animals in the Red Books was also used. The failures and successes of the national actions are compared and the causes of failures are discussed. The main threats to biodiversity addressed are: resource overuse, pollution, habitat destruction, species invasion, climate change. The assessment also covered the state of biodiversity in inland freshwaters of the South Caucasus region before and after ratification of the CBD. Often, the comparison of the national reports was complicated due to the differences in data presentation and the level of details provided. Commonly accepted taxonomy for describing the actions in a consistent way would allow a robust content management for reporting and would also facilitate learning from each other (UNDP, 2016).

3. RESULTS

Before ratification of the CBD agriculture, urban and industrial development and unsustainable natural resource management and low environmental awareness resulted in significant diverse pressures on inland freshwater ecosystems. For example, artificial lowering of the water level of Lake Sevan (Armenia) by about 20 m by 2003 has led to a disappearance or drastic decline of endemic species due to the degradation of spawning grounds (1st NRCBD Armenia, 1999). In Georgia, sturgeon numbers reduced several times by 2007 and numbers of trout declined by 30% from 1995-2005 (4th NRCBD Georgia, 2010). 29.2%

of land in the Caucasian Russia is completely transformed for cattle grazing and mineral resource extraction (1st NRCBD Russia, 1998). Construction and industrial development on Absheron Peninsula, where about 40% of population and 70% of the industrial potential of Azerbaijan is concentrated, resulted in a reduction of natural habitats, pollution of lakes by oil and domestic waste and biodiversity decline (1st NRCBD Azerbaijan, 2004). Currently, many of native fish species are red-listed: e.g., all endemic fish of Lake Sevan, river/lake trout and salmon entering rivers of Western Georgia from the Black Sea, all species of anadromous sturgeon in river waters of Georgia (4th NRCBD Georgia, 2010; 5th NRCBD Georgia, 2015).

There are 6 species occasionally introduced into formerly "trout" Lake Sevan. In 30 years the Crucian carp has become a common fish that negatively affects native fish population in Georgian inland waters (5th NRCBD Georgia, 2015). In Russia, 120/380 freshwater fish species are alien (3rd NRCBD Russia, 2007).

During 1993-2000 all the study countries ratified the CBD. Since then national biodiversity strategies and action plans were submitted to the CBD Secretariat. These documents allowed environmental issues including biodiversity conservation to receive importance at the level of political decisions. All the study countries are involved in the Emerald Network. Several RAMSAR sites were designated: 3 in Armenia, 2 in Azerbaijan and Georgia, and 35 in Russia (www.ramsar.org). Cooperation for transboundary ecosystem conservation or restoration within the South Caucasus has started. The establishment of the Caucasus Nature Fund in 2008 provided funding opportunities for effective regional cooperation for the protection of the Caucasus Ecoregion. As a result, biodiversity inventories have been implemented in key areas, protected areas have been defined and monitoring systems have been elaborated. By 2014, protected areas system covered 13% of total land of Armenia and 9 % of Georgia. In Azerbaijan, terrestrial protected areas covered 12% and marine 6% of the country's land by 2008 (5th NRCBD Armenia, 2014; 5th NRCBD Georgia, 2015; UNDP, 2011). In Russia, biodiversity and spatial conservation management operations were intensively decentralized, facilitating creation of new protected areas. There are 740 protected areas in Russia.

Substantial progress is made toward meeting Aichi targets by 2020. In particular, for Aichi target 5 (to half the rate of loss of habitats and reduce degradation and fragmentation) Armenia has implemented measures on the increasing of the water level of Lake Sevan. The benefits are already seen: improved water quality and living conditions of fish, benthic and planktonic communities. Bird fauna around the lake has also benefitted from newly formed shallow areas. Russia eliminated the number of species in the Red List due to improvement of their conservation status. However, the Georgian and Azerbaijan lists were expanded by the inclusion of endangered and critically endangered plant species. Pollution issues are also handled although from different aspects. For instance, Russia will achieve this by creation of economic motivation for a gradual diminution of emissions. Armenia has responded by the implementation of a regular chemical monitoring of key water bodies (39 risky rivers, 5 risky reservoirs and 2 lakes) and rehabilitation of sewage system. Georgia has developed actions for the mitigation of inland water pollution. Azerbaijan reported 25-50% progress in pollution reduction (from the 5th national reports).

4. DISCUSSION

The ratification of the CBD and integration of biodiversity vales into national programs were dictated by the obvious diminution of ecosystem services, globalization of economies and increased international cooperation. Nevertheless, despite this, insufficient and inefficient control over the use of bioresources is common. In Armenia, only 40% of waste water is treated and only mechanically (5th NRCBD Armenia, 2014). Adequate human resources and efficient mechanisms of control are not in place (5th NRCBD Russia, 2014). Although protected areas exist, they are not connected through ecological corridors regardless of the key importance of the areas (5th NRCBD Georgia, 2015). The lack of regular monitoring in Georgia and Azerbaijan prevents information update on the dynamics of populations or systematic reporting on the progress towards achieving the national targets (5th NRCBD Azerbaijan, 2014; 5th NRCBD Georgia, 2015).

Conservation status of the most fish species remains unclear. Fish surveys for assessing the health of ichthyofauna are not conducted since 1991, except for the Black Sea salmon and sturgeon. Many fish species are endemic species and have economic value, but data on their populations are missing and specific conservation needs are not identified. Inventory and ecological assessments of freshwater ecosystems have not been done and many are not protected. Meantime, unregulated anthropogenic activity modifying water levels or habitat integrity is carried out (4th NRCBD Georgia, 2010). Biodiversity conservation is implemented mainly in specially protected nature areas of Armenia (5th NRCBD Armenia, 2014).

Conservation success highly depends on anti-poaching. However, fishery bans and fish re-stocking activities in Armenia have been carried out for a long time but were inefficient. In Russia, strengthening of anti-poaching efforts and the expansion of state surveillance are needed (5th NRCBD Russia, 2014).

Still, the integration of biodiversity conservation into socio-economic development is not sufficient. The importance of biodiversity and ecosystem services is not adequately appreciated by decision makers and their value and benefits are not assessed (Protocol of the session of the Government of the Republic of Armenia, 2015). Ecosystem services concept is not integrated into conservation practice and research funding is not adequate to ensure comprehensive science-based evaluation of the impacts (5th NRCBD Russia, 2014).

Aichi targets are not adequately addressed. In Armenia with relevance to target 7 (sustainable management of areas under aquaculture) the use of natural resources is not managed. For example, aquaculture in Armenia is solely demand driven and resource-exhaustive (3 R STRATEGY, 2011). For target 8 (reduction of pollution and nutrients to non-detrimental level), measures are constrained to the monitoring of chemical parameters in Armenia. Municipal waste water remains the main source of pollution in Georgia. Also, 18 critical freshwater habitats only 25.81% are included in the protected category (5th NRCBD Georgia, 2015). The impacts of species invasion (target 9) are declared indirect in Armenia (5th NRCBD Armenia, 2014). In Russia, the establishment of a centralized system of monitoring of biotic invasions and control of aquatic organisms has failed. Azerbaijan fulfilled this target by 25-50%. Climate change impacts on the stability of ecosystems have not been sufficiently assessed. In response to Aichi target 15 (enhancing the contribution of biodiversity to carbon stocking thereby addressing climate change mitigation and adaptation) Armenia declared these impacts as indirect and not visible. Azerbaijan reported 50-75% progress. In Georgia, the main focus of climate change mitigation measures is put on the management of grasslands. Meanwhile, national goals for this target are not set in Russia (5th NRCBD Russia, 2014).

Transparency problems such as insufficient access to information, low public participation, problems in effective implementation of the State control are issues to be solved in the South Caucasus countries to satisfactory fulfill the commitments under the CBD.

5. CONCLUSION

Obvious improvements have been achieved in the biodiversity conservation and protection and conditions for the rehabilitation of disturbed populations in key freshwaters are being created. However, socio-economic situation in all the countries (poverty, poor political will, lack of sufficient control instruments) impede prioritization of biodiversity values in the national economic development programs. Participation in international treaties related to biodiversity evidently helps address national, regional and global environmental issues.

Nevertheless, executive agencies in each country should increase the efficiency and transparency of their work on biodiversity conservation and protection. Undoubtedly, the improvement of organizational and institutional capacities will require governance reforms to better regulate surveillance, monitoring, anti-poaching efforts to avoid further impoverishment or loss of biodiversity. Ecological state on inland waters is determined by the condition of their watersheds. Until the socio-economic improvement is achieved and adequate political decisions and human resources are available, realistic biodiversity conservation and protection cannot be achieved.

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O1-36

環境保全型農業がもたらす水田の生物多様性の保全効果の検証

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キーワード：生物多様性評価, 環境保全型農業

抄録

農地の拡大・集約化にともなう生物多様性の減少を食い止めるため、近年では世界中で環境保全型農業の生物多様性保全効果の検証が進められている。しかし水稲の主要生産地であるアジアでの検証例は未だに少なく、環境保全型農業の有効性を議論するための知見が不足している。そこで今回は、水田の有機栽培や特別栽培などの環境保全型農業が、日本の代表的な生物相（植物、節足動物、カエル、魚、鳥類など）にもたらす保全効果について、本研究所のこれまでの取り組みを中心に紹介する。特に、2013–2017 年度にかけて実施された農林水産省受託プロジェクトの研究成果など、最新の知見を紹介したい。またこれらの成果にもとづき、環境保全型農業の保全効果を今後より高めるために考えるべきことについても議論したい。

1. はじめに

農業の拡大・集約化は世界中で生物多様性における最大の脅威の一つとなっている。この減少を食い止めるため、欧州を中心に環境保全型農業が導入され、その効果が検証されてきた[1]。その一方、日本を含むアジアの主要作物である水稲については、環境保全型農業の導入および効果検証が遅れている。そこで本研究は、これまでの本研究所の取り組みを中心に、日本の環境保全型農業が水田の代表的な生物相（植物、節足動物、カエル、魚、鳥類など）にもたらす保全効果について議論する。

2. 農業に有用な生物多様性の指標及び評価手法の開発(2008-2011)

このプロジェクトは、水田の生物相を全国規模で調査した初めての取り組みといえるだろう。水田の有機・特別栽培の取り組みの効果を評価するうえで、クモ類、トンボ類、水生昆虫類およびカエル類が指標となりうることを明らかにした。さらに、これらの生物の簡便な調査法や、個体数にもとづく水田のスコア（点数）化によって、農業者への普及を促した[2]。これらの成果はマニュアルとして、無償で研究所HPからダウンロード可能である。また農業害虫の有用な天敵であるアシナガグモ属については、周囲の森林の豊かさや気候条件によって、減農薬の効果が左右されることも明らかになった（図 1）[3]。

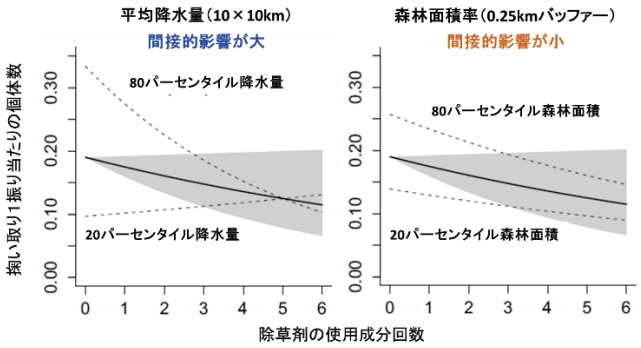

図 1 除草剤の使用成分回数がアシナガグモ属の個体数に与える影響は降水量・森林面積にともない変化する[4]。（左）降水量が多い地域ほど減農薬の効果が高い。（右）森林面積が多い地域ほど個体数が多い。

3. 生物多様性を活用した安定的農業生産技術の開発(2013-2017)

本プロジェクトは、先のプロジェクトよりもさらに数多くの生物群（植物、クモ類、トンボ類、水生コウチュウ類、カエル類、ドジョウ、鳥類）を対象とし、環境保全型農業（有機栽培・特別栽培）の取り組みの効果を全国規模で評価した。700 以上の圃場を調査し、一般化線形混合モデルで解析した。

その結果、特別栽培は植物種数およびアシナガグモ属・アカネ属の個体数を増やす効果があることがわかった。また有機栽培は、これらの種群に加えて、ダルマガエルおよびドジョウの数も増やしていた。また個々の農薬や畦管理など個々の農法の影響も調

べた結果、生物群によって異なる農法から影響を受けていることがわかった。具体的には、農薬（植物、アシナガグモ属、アカネ属）、畦管理（カエル類）、水管理（ドジョウ）といった差がみられた。これらの成果はマニュアルとして公開する予定であるとともに、現在学術論文としても投稿中である。

4. 結論

日本の水田においても、環境保全型農業、とりわけ有機栽培は様々な生物群の種数・個体数を増やす高いポテンシャルを持っていることが明らかになってきた。しかし、有機栽培は一般的に収量の低下を伴うことから、大規模に普及させることは現実的ではない。一方、特別栽培は収量の低下度合いも少なく、より広範囲に普及可能なオプションになるだろう。ただし、増加する生物群が有機栽培よりも限定されることは知っておくべきである。ただしこれも、実際にどういった農法を実施するのか、によって大きく効果は変わる。

もう一つの重要な知見として、生物の種数・個体数には農薬・畦・水管理などの圃場内の条件だけなく、森林・気候などの周囲の条件も重要であることが分かってきた。これは、同じ取り組みでも地域によって取り組みの効果が異なることを示唆する。今後、各地域で環境保全型農業の効果が高いと見込まれる生物群を事前に特定したがうえで、その種の保全に有効な農法を実施することで、最大の保全効果を発揮できるだろう。これにより、害虫抑制などの生態系サービスの最大化も期待される。

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O1-37

Restoration of a metapopulation of *Aster kantoensis* Kitamura, an endangered floodplain plant endemic to Japan

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Keywords: endangered species, nature restoration, gravel, extinction, collaboration

ABSTRACT

Aster kantoensis Kitamura is an endangered plant species, endemic to the gravelly floodplains of a few eastern central Japanese rivers, and a flagship species for gravelly floodplains. Reduction in habitat could accelerate the decline of *A. kantoensis* metapopulations. To avoid extinction, seven restoration programs were initiated along the Tama River in the 1990s and 2000s. However, only two programs, including our experiment, currently continue. We examined the effect of human-aided seed dispersal in 2002 on an artificial gravelly floodplain in the Nagata Area. After 15 years, the metapopulation was still thriving, as flooding created new safe sites for seed germination and seedling establishment. Furthermore, small populations of *A. kantoensis* were found to be thriving in the lower course of the Tama River. The institutional administration added 90 000 m^3 of gravel to the upper course of the Nagata Area. A large flood occurred in 2007 after which the population of *A. kantoensis* declined, before recovering in 2008. The dynamic aspects of this metapopulation may have recovered. Since maintenance of the first artificial floodplain was difficult, other plants have been growing densely in the area, which has reduced in 1/8 reduction in the original area. This experiment was conducted in collaboration with institutional administrators, citizens, and scientists. The restoration success of *A. kantoensis* in the artificial gravelly floodplain has led to similar restoration efforts near other rivers in Japan.

1. INTRODUCTION

Aster kantoensis Kitamura is an endangered plant in Japan. It has a narrow distribution range on the gravel floodplains of three rivers (Fig. 1), although its population was sometimes large before the 1990s. Following a rapid population decline, many citizen scientists tried to cultivate *A. kantoensis* to reintroduce it to the floodplains. While it was easy to cultivate the plant in a farm, it was difficult to reintroduce it to the floodplains. Professional scientists studied the ecology of *A. kantoensis*, including its distribution[2], demography[5], photosynthesis[4], seed dispersal[2], seed germination[6], and genetics[1,3]; *A. kantoensis* life history is easy to study. As the population of *A. kantoensis* declined, restoration studies were conducted[7, 8].



Fig. 1 The distribution of *A. kantoensis* populations

Reduction in habitat might accelerate the decline of this *A. kantoensis* metapopulation. To avoid extinction of this species from the Tama River, seven restoration programs were initiated in the 1990s and 2000s (Fig. 2). However,

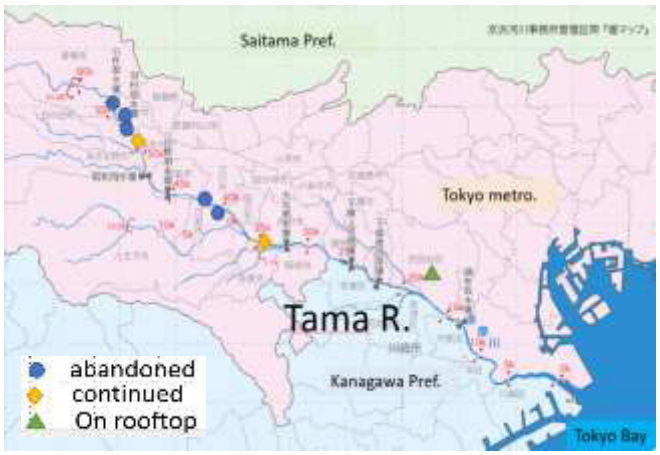

Fig. 2 Restoration activities for *A. kantoensis* in the Tama River

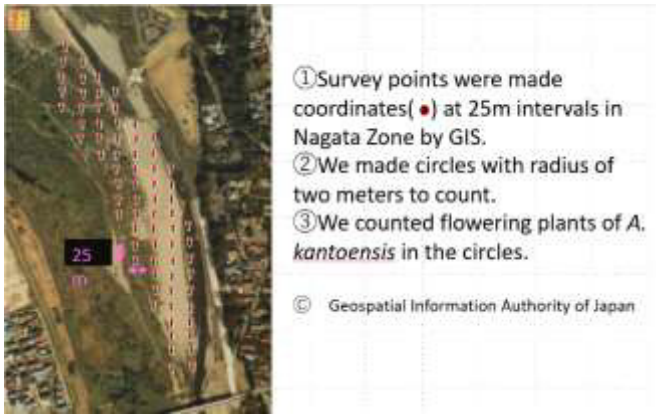

Fig. 3 Methods to count the number of *A. kantoensis* in the Nagata area.

only two programs, including the present experiment, have continued to date.

Our objective is to restore the local metapopulation dynamics of *A. kantoensis*.

2. METHODS

We surveyed the population and distribution of *A. kantoensis* on an artificial gravelly floodplain (Fig. 3) that was created in 2002 in the Nagata Area, Japan to conserve *A. kantoensis*, and assessed the ability of the floodplain to support a new metapopulation.

We examined the effects of human-aided seed dispersal.

3. RESULTS

Fifteen years after the creation of the artificial floodplain, the metapopulation of *A. kantoensis* was still thriving as flooding created new safe sites for seed germination and seedling establishment. However, maintenance of the artificial gravelly floodplain was difficult and other plants have been growing densely in the area, which has caused a one-eighth reduction in the management area.

The population of *A. kantoensis* had increased to 50,000 by 2010 but declined to 9,500 in 2017 (Fig. 4). A large flood occurred in 2007 and the population of *A. kantoensis* declined, followed by a recovery in numbers in 2008 (Fig. 5). Furthermore, small populations of *A. kantoensis* thrived in the lower reach of the Tama River (Fig. 6).

4. DISCUSSION

The dynamics of the metapopulation of *A. kantoensis* may

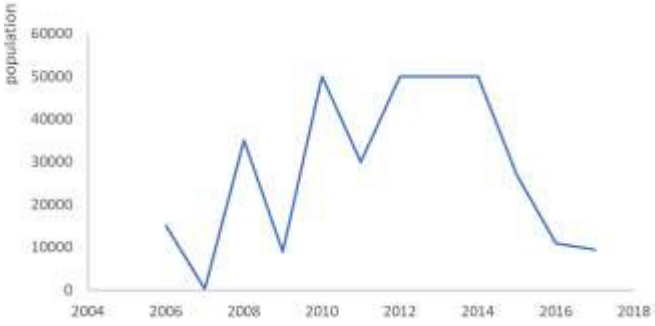

Fig. 4 The population of flowering plants of *A. kantoensis* in the Nagata area.

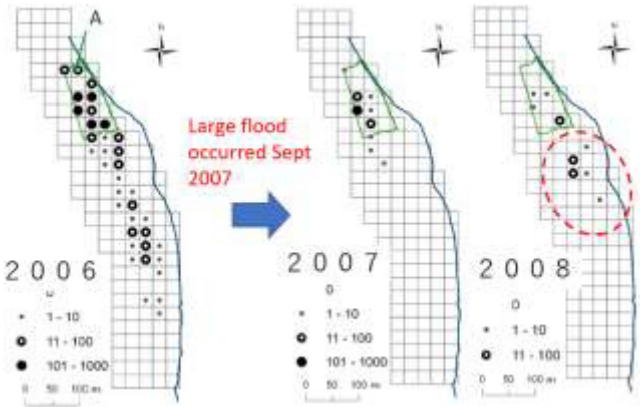

Fig. 5 Distribution and number of flowering plants of *A. kantoensis* in the Nagata Area 2006 to 2008.



Fig. 6 The distribution of flowering plants (●) of *A. kantoensis* below the Nagata Area.

have been restored. Maintenance of a gravelly floodplain is important for retaining the seed source of *A. kantoensis*. The Keihin River Office, one of the river authorities of the Ministry of Land, Infrastructure, Transport and Tourism added about 90 000 m^3 of gravel to the upper course of the Nagata Area, which created a new gravel floodplain in the Nagata Area. As many seeds were produced after 2010, small populations might thrive in the lower reach.

Our objective has been achieved to some extent. However, after 2013, large levee construction and levelling of the gravel floodplain destroyed small populations of *A. kantoensis* and restoration actions must be continued.

5. CONCLUSION

This experiment was conducted in collaboration with institutional administrators, citizens, and scientists. The coordinator of the collaboration is a scientist from Meiji University. The coordinator develops the plans and objectives for the year and maintains contact with the river manager and leader of the citizens. The collaboration and coordinated system have contributed to successful restoration efforts.

Successful restoration of the *A. kantoensis* population on an artificial gravelly floodplain has led to similar restoration efforts near other rivers in Japan. However, there are few floodplain endemic plants thriving in the restored flood plains. Therefore, inspection of all possible effects and identification of more efficient means of implementing the existing restoration methods is necessary.



Fig. 7 Collaboration in Aster Project (from the leaflet of Aster Project 2018)

Citizen is the citizen group involved in the conservation and restoration of *A. kantoensis* in the Tama River. The local government is Fussa City. The river manager is the Keihin River Office. Scientists were from Meiji University and the coordinator is a scientist from Meiji University.

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O1-38

A proposed application of tributaries for aquatic plant restoration on the lake basin scale

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Keywords: Aquatic plant, restoration, basin scale, tributaries into lake

ABSTRACT

In this study, we surveyed the potential of the tributaries of Lake Kasumigaura to serve as aquatic-vegetation-restoration areas. Our results show that although red-listed species of aquatic vegetation grow in these tributaries, and invasive species grow in some of these tributaries as well. Therefore, careful selection of tributaries will be important for planning the meta-population network.

1. INTRODUCTION

Lake Kasumigaura was dammed to serve as a water resource, and the water levels there have increased. The lake is used as both a daily human water resource and an industrial water resource and provides important ecosystem services. However, the increase in the water levels has influenced the growth conditions of the aquatic plants in the lake.

Submerged aquatic plants and floating leaf plants have been particularly influenced by the increase in the water level. The increase in the water level decreases the water light conditions, which influence the growth of submerged plants that depending on the water light conditions. In addition, the increase in the wave conditions directly influences the floating leaf plants and emergent plants via increased disturbances.

To study the response to these aquatic plants to the changes in their growth conditions and to restore the growth conditions of the aquatic plants, a trial restoration controlling the water level of Lake Kasumigaura has been successfully conducted. However, the yearling control is difficult due to water resource management.

To improve this difficult condition, we need to enlarge the field of view, to recognize the area not only inside the lake but also in the tributaries as restoration fields. For example, the tranquil areas spread around the river mouths of tributaries are areas preferred by aquatic plants. However, the trial study did not focus on the aquatic plant conditions in tributaries. With this background, this paper aims to report on the aquatic plant growth conditions and discuss the potential of tributaries as aquatic plant growth preference areas and the potential of the ecological network of Lake Kasumigaura.

2. MATERIALS AND METHODS

2.1 STUDY AREA

This study was conducted in Lake Kasumigaura. Lake Kasumigaura is the second largest lake in Japan. The area of Lake Kasumigaura is approximately 220 km2, and the average water depth is approximately 4 m. Lake Kasumigaura is comprised of Lake Nishiura, Lake Kitaura, and Lake Sotonasakaura. This study primarily focused on Lake Nishiura. A total of 22 tributaries flow into Lake Nishiura. Around the river mouths of these tributaries are agriculture fields such as paddy field areas that form stable water. The area is thought to be a preference area for aquatic vegetation. This study primarily investigated the growth conditions around the river mouth areas and the paddy fields.

2.2 FIELD SURVEY AND DATA ANALYSIS

Two field surveys were conducted in FY 2015 and FY 2016. The field surveys were conducted for 15 tributaries (Fig. 1).

From the river mouths along the tributaries to approximately 4 km upstream, the growth conditions of

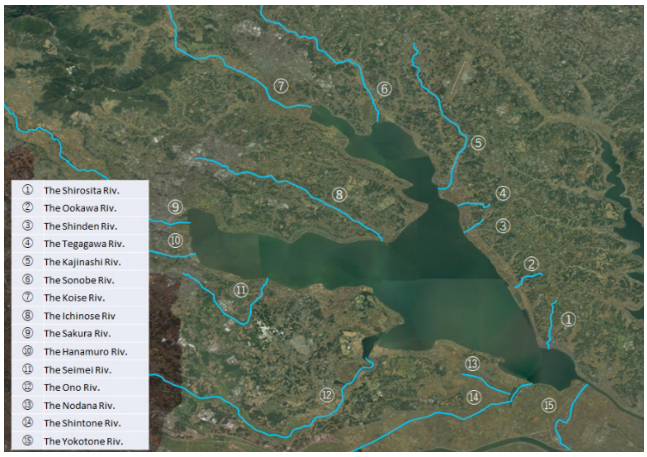

Fig. 1. Study area (Lake Nishiura and its tributaries).

the aquatic plants (emergent plants, floating leaf plants, submerged plants, and free-floating plants) were recorded and summarized into Geographic Information Systems.
The summarized data for the two FY were classified into three groups comprised of red-listed species, invasive species defined by the Ministry of the Environment, and "standard species" not belonging to either of the other two species groups.

3. RESULTS

Figure 2 indicates the total area of the red-listed species and invasive species for the two years. Even though most tributaries showed a coexistence of red-listed species and invasive species, the percentages differed between individual rivers. In the Shintone, Hanamuro, Koise, Tegagawa, and Okawa rivers, there were extremely small levels of invasive species growth.

Figure 3 indicates the correlation between the area of the standard species, the area of invasive species, and the area of the red-listed species. Corresponding to increasing areas of standard species, the area of red -listed species decreased, and the area of invasive species increased. At approximately 10,000 m^2, the curves of the areas of the red-list species and the invasive species crossed.

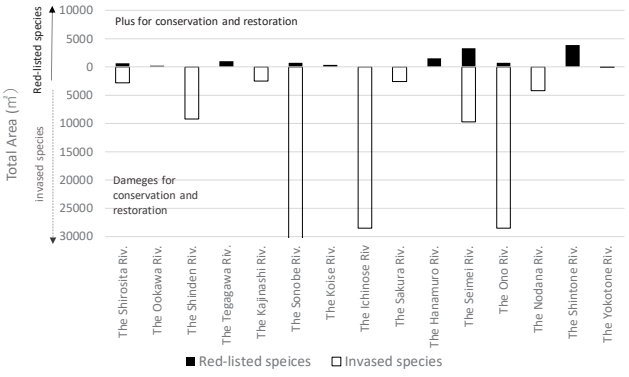

Fig. 2

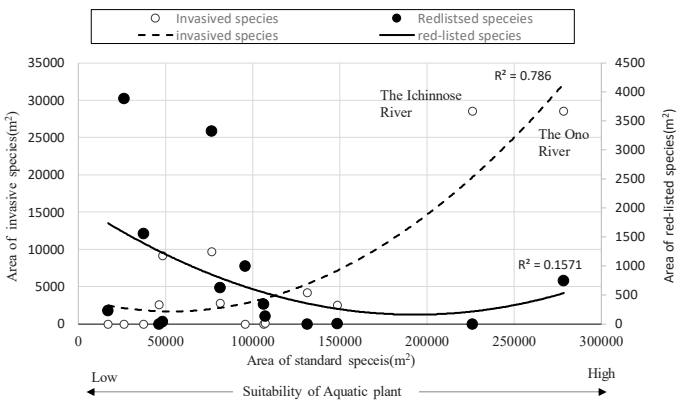

Fig. 3

4. DISCUSSION

Figs. 2 and 3 indicate the importance of tributaries for conservation and restoration of aquatic vegetation; in particular, Fig. 2 shows that many red-listed species grow there. Thus, it is important to incorporate these tributaries into conservation and restoration of red-listed species in terms of increasing metapopulations. In addition, the existing study indicates that channels foot of levees are important areas of aquatic-vegetation growth[1]. If we can form a metapopulation network between lakes, dike-foot water ways, and tributaries, it would create a vast network in basin scales.

However, we must carefully select tributaries in view of controlling invasive species (Fig. 2). We must prioritize tributaries where only standard and red-listed species grow. It is also important to consider the characteristics of basins wherein only red-listed species grow. Fig. 3 indicates interesting considerations for the conservation and restoration of aquatic plants. The results of Fig. 3 indicated that the exceeded suitable condition wherein standard species' growth or stable water areas are not good for the control of invasive species and restoration of red-listed species. Rivers in which standard species occupy an area of more than 200,000 m2 such as the Onogawa and Ichinose Rivers are very suitable for aquatic-vegetation growth in their mouth areas due to a very low riverbed slope. These stable conditions enhanced the growth of standard and red-listed species, on the other hand they permitted growth of invasive species. This hypothesis suggested important direction for the conservation and restoration plan of aquatic vegetation in the basin scale, though quantitative analysis will be needed in the future works.

5. CONCLUSIONS

This study revealed the potential of tributaries of Lake Kasumigaura to serve as aquatic-vegetation-restoration areas. Our main results were as follows: red-listed and invasive species of aquatic vegetation were both found to grow in tributaries. The tributaries highly suitable for standard species were also appropriate for red-listed species; however, invasive species also tended to inhabit there. Although tributaries have the potential to serve as effective conservation and restoration areas for aquatic vegetation, careful selection of tributaries will be important for the control of the metapopulation network.

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O1-39

Mainstreaming Biodiversity into Inland Fisheries and Aquaculture (with special focus on wetlands) – scopes and challenges

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Keywords : Biological resource use, Fisheries, Ecosystem services, Ecosystem management

ABSTRACT

Mainstreaming of biodiversity is basically the process of integrating biodiversity concerns into policies and practices that impact and work on biodiversity. The Convention of Biological Diversity (CBD) advocated for this in its Article 6(b), which has also been reflected in Biological Diversity Act, 2002 of India. India has developed 12 national biodiversity targets, as per the directives from CBD, which are to be met by 2020, in line with National Biodiversity Strategy and Action Plan. The targets (5, 6 & 8) related to inland fisheries emphasize to achieve sustainable fisheries, conservation of ecologically representative areas and to safeguard areas of ecosystem importance (*e. g*., inland water bodies, wetlands and aquatic fauna). India is endowed with vast inland resources which includes rivers, lakes, reservoirs, estuaries, wetlands lagoons, etc., that are providing habitats for some thousands of aquatic animal and plant biodiversity, along with various ecosystem services. These resources play a significant role in providing food, nutrition, and livelihood security of millions of people across the country, through different forms of inland fisheries and aquaculture. The present paper analyses the scopes and challenges for mainstreaming biodiversity concerns into inland fisheries and aquaculture (including wetlands) in Indian context and throws light on the present scenario and gives some recommendation in achieving this objective towards compliance to National Biodiversity Targets, Aichi Targets and Sustainable Development Goals.

INTRODUCTION

The inland fisheries and aquaculture plays a significant role in providing food, nutrition, and livelihood security for millions of people around the globe. Fish is a highly nutritious food item as it provides protein, essential micro nutrients, vitamins, minerals and polyunsaturated omega-3 fatty acids. The inland water resources (*viz.* lakes, rivers, canals, reservoirs, ponds, streams, groundwater, springs, cave waters, floodplains, estuaries, coastal lagoons, mangrove creeks, marshes, backwaters and swamps) provide habitat for fishes, amphibians, water birds, semi-aquatic animals, plants apart from supporting highly endemic and endangered taxa (CBD, 2017). These dynamic ecosystems provide an array of ecosystem services such as climate regulation, flood mitigation, nutrient recycling, water purification, waste treatment, etc.

INDIA'S INLAND WATER RESOURCES AND BIODIVERSITY

India's inland water bodies comprise of 29,000 km of rivers and canals, 0. 202 million hectare (ha) of floodplain wetlands, 0,3 million ha of estuaries, 40,000 ha of estuarine wetlands, 0.19 million ha of lagoons, 0.356 million ha of mangroves, 2.43 million ha of (potential) freshwater ponds, 1.14 million ha of (potential) brackish water ponds, 3.15 million ha of reservoirs (Draft NIFAP, 2017), 1.667 million ha of large and medium reservoirs and 1.485 million ha of small reservoirs (Ayyappan and Sugunan, 2009). India has a rich aquatic genetic resources, which includes 9.456 species representing approximately 9.7% of the total number of animal species (*i.e*.. 97,708 species). The Indian fish diversity comprises of 113 brackish water, 936 freshwater and 462 exotic finfishes.

Wetlands in India is bestowed with a rich diversity, ranging from high altitude lakes of the Himalayas, floodplains and marshes of the Gangetic - Brahmaputra alluvial plains, saline flats of Green Indian desert to extensive mangroves marshes bordering the country's East and West coastline. India has total of 7,57,060 wetlands covering a total area of 15.26 million ha, roughly equal to 4.6% of its land area. Of this, inland wetlands constitute 69.22% (10.56 m.ha) (SAC, 2011). Inland wetlands are also reservoirs of biodiversity, it supports unicellular algae, bryophytes, mosses and ferns to woody angiosperms. The wetland ecosystem is contributing widely for the societal development and well-being. Many cities (like New Delhi, Kolkata, Bhopal, etc.) depend on wetlands for their water

supplies. The wetland water is used for agriculture, horticulture, pisciculture and other livelihood activities of the local people. Dal Lake (Kashmir), Khajjar Lake (H.P), Nainital Lake (Uttarakhand) and Kodaikanal (Tamil Nadu) are important places for tourism. India's inland aquaculture production basically consists of freshwater and brackish water production along with small contribution from cold water.

CONCERNS

The fresh water habitats are under increasing threats and pressures due to the discharge of industrial wastes, sewage and agricultural runoff with chemical wastes and excessive nutrients. The other concerns includes: over exploitation, flow modification, degradation of habitat, eutrophication, siltation, macrophyte infestation, swampification, spread of, lack of river flows due to fragmentation of cascade by dams/ barrages and Invasive Alien Species. Many of the inland wetlands have been invaded by exotic species which have acquired nuisance proportions threatening the very existence of many of the habitats, and have considerably affect the native species. Some of the plant invasive recoded are water hyacinth, *Salvinia molesta*, *Ipomoea carnea spp* and *Alternanthera philoxeroides* (MoEFCC and GIZ, 2014). It was also reported that the Ornamental alien fish species hybridize with indigenous species in the wild and diluting the wild genetic stock leading to long term introgression of gene pools (Pimentel, D *et al*, 2001).

Majority of the estuarine ecosystems have become hyper-saline due to less ingress of freshwater from rivers, while few have lost their estuarine character due to excess ingress of freshwater. Estuaries are subjected to oil spill, which leads to the loss of economically important fish species such as hilsa, mullets, sea bass, pearl spot, prawns, etc. The mangrove vegetation spread over the estuarine areas are undergoing degradation and shrinkage due to increased biotic pressure and growing demand for timber, fuel wood and fodder. The degradation of reservoirs is increasing due to pollution from thermal power plants, siltation and poor environmental management of the varied catchment areas. The other biodiversity related concerns includes over-stocking, illegal introduction of exotic species, use of shore seines, use of small-sized mosquito nets, irrational lease policies, juveniles fishing and mining of ornamental fishes for export. Similarly, the wetland habitat is lost at an alarming rate due to changing land use pattern and reclamation for urban development. As per various estimates, nearly 30% of the natural inland wetlands in the country have been lost due to fragmentation of hydrological regimes, catchment degradation, pollution and spread alien species.

MAINSTREAMING BIODIVERSITY

Mainstreaming is an important policy tool which helps in strengthening the linkages between biodiversity and other sectors. The Convention on Biological Diversity has urged parties to develop national and regional biodiversity targets, using the Strategic plan and its global Aichi targets. Accordingly, India has developed 12 national biodiversity targets and these national targets need to be achieved by 2020. The targets (5, 6 & 8) related to inland fisheries emphasise achieving sustainable fisheries, conservation of ecologically representative areas and to safeguard areas of ecosystem importance (eg. Inland water bodies, wetlands and aquatic fauna). Some of the approaches suggested for mainstreaming biodiversity into inland fisheries includes: a) ecosystem approach; b) access & user rights; c) marketing incentive & export; d) policy & institutional strengthening.

INTERNATIONAL AND NATIONAL INITIATIVES

India is a signatory to several international conventions towards conserving biodiversity in the inland related biodiversity resources *viz* Convention on Biological Diversity (CBD)1992, the Convention on Conservation of Migratory Species (CMS), 1982, Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES), 1975 and Ramsar Convention on wetlands, 1982. At present there are 26 Ramsar sites have been identified in India. To implement the objectives of the convention, a regulatory mechanism was put in place through Wetlands (Conservation and Management) Rule, 2017. The rule stipulate prohibition and regulation of range of developmental activities within a wetland notified areas. The Ministry of Urban Development has issued an advisory on conservation and restoration of water bodies in urban areas. A river conservation programme was initiated with the launch of Ganga Action Plan (GAP) in 1985. The GAP was expanded to cover other rivers under National River Conservation Plan (NRCP) in the year 1995. The objective of NRCP is to improve the water quality of rivers, which are major water sources in the country through implementation of pollution abatement works in various towns along identified polluted stretches of rivers. The National Plan for Conservation of Aquatic Ecosystems (NPCA) is implemented for a holistic conservation and restoration of lakes and wetlands for achieving the desire water quality enhancement, beside improvement in biodiversity and ecosystem through an integrated and multidisciplinary approach and a common regulatory frame work. In 2001, National Lake Conservation Plan (NLCP) was introduced to address pollution issues in urban and semi-urban environment through interception, diversion and/or treatment of pollution load entering the lake. In 2013, the Ministry has since launched the National Programme on

Conservation of Aquatic Ecosystem (NPCAE) for conservation of both lakes and wetlands with a significant increase in allocation of resources (NR5, 2014).

CHALLENGES

It has been found that a number of Ministries and Departments at National and sub-national level are contributing directly or indirectly for biodiversity cause. All these departments are also making a considerable amount of expenditure every year to address different biodiversity related issues pertaining to their respective department. It is observed that there is a lack of cohesiveness among all these activities. The major reason for this is lack of a clear cut synergic roadmap. Every related government department should have a clear idea on their department specific responsibilities vis-a-vis deliverables towards biodiversity conservation, its sustainable utilisations aiming at livelihood promotion for the poor.

RECOMMENDATIONS

This study gives some policy recommendations along with implementation plan and clarifies the specific responsible national and sub-national level organisations for this. Such as, for Conservation and restoration of inland aquatic ecosystems – Water quality health card to be prepared for the river stretches and other inland water bodies by Ministry of Environment, Forest and Climate Change (MoEFCC), National Bureau of Fish Genetic Resources (NBFGR) and Central Inland Fisheries Research Institute (CIFRI), ii) Banning of riverbed and boulder mining by National River Conservation Directorate (NRCD), iii) Making environmental flows mandatory under the Environmental Impact Assessment (EIA) clearance by State/UT Governments, Ministry of Water Resources and NRCD, iv) Destructive fishing gears to be banned by State/UT Governments, v) Institutional and governance mechanisms for community-based management for the open water fisheries need to be strengthened by State/UT Governments, vi) Strategic Environmental Assessment (SEA) need to be carried for the developmental projects by MoEFCC. Likewise detailed policy recommendation along with responsible departments or institutions have been given for a) conservation of fish genetic resources, b) developing a database on fisheries biodiversity and their habitats, c) valuation and documentation of ecosystem services of fishery resources, d) developing regulatory mechanism to stop unsustainable practices, hatchery development, ornamental fish culture, d) diversifying the species mix, e) incentivising ecosystem based culture, f) managing Invasive Alien Species, g) promoting of green certification and eco-labelling of fish and fishery products, h) liking market for ecosystem based culture products, i) strengthening the implementation of the BD Act.

CONCLUSION

The current study reviews the existing policy, schemes, and programmes of the inland fisheries sector to know the scopes and challenges for mainstreaming biodiversity concerns into inland fisheries and aquaculture in Indian context, and brings out a set of recommendations to address the biodiversity concerns. The proposed policy interventions are expected to help in achieving the goal of enhancing fishery diversity as well as contributing to sustained biodiversity wealth of the country through complying National Biodiversity Targets, Aichi Targets and Sustainable Development Goals.

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O1-40

琵琶湖の湖辺域における二枚貝を評価指標とした水環境改善手法の検討について

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キーワード:生態系機能, 生態系管理, 自然再生

抄録

琵琶湖では、COD の高止まり、水草の過剰繁茂、在来魚介類の減少等の新たな課題が生じている。特に減少が著しいシジミ類等の二枚貝は、湖内では大きく移動せず、生息環境としての水質や底質、餌環境としての植物プランクトン群集等、湖辺環境を構成する多くの因子の影響を受ける。すなわち、二枚貝の生息状況は、水質や生態系の状態を総合的に評価する上で重要であり、地域住民にも分かりやすく、優れた指標として活用できる可能性がある。生き物がにぎわう湖辺域の浅い砂地の再生に向け、環境省と滋賀県では、2017 年度から、二枚貝等の底生生物の良好な生息環境を評価するための調査解析と、地域住民等との協働による現地での実証事業を実施している。また、有識者等による検討会を設置し、湖辺域の水環境改善に向けた手法の検討を進めている。本発表では、実施している調査解析や実証事業、手法検討の全体概要と途中経過を報告する。

1. はじめに

日本最大の湖、琵琶湖では、これまでの水質保全対策により流入負荷量は減少傾向にあるものの、環境基準 COD の高止まり、特に南部の浅い水域(南湖)における沈水植物(水草)の過剰繁茂、在来魚介類の減少等の新たな課題が生じている[1]。こうした中、2015 年に「琵琶湖の保全及び再生に関する法律」が公布・施行され、国民的資産である琵琶湖を、健全で恵み豊かな湖として保全・再生を図ることが求められている。

琵琶湖では、湖岸線総延長の 32%、南部の浅い水域である南湖では 72%が緩傾斜であった従前の地形から改変されている[2]。改変後の急傾斜断面は、湖辺の流れを停滞させやすく、湖底の低酸素化、泥質の堆積の原因となると考えられる[3]。中でも泥質の堆積は、二枚貝等の底生生物の生息環境悪化や、嫌気的な底質から発芽し餌となりにくい藍藻類の増加につながることが分かってきた(図 1)[4]。

底生生物は、湖内では大きく移動せず、生息環境として水質や底質、餌環境として植物プランクトン群集等、湖辺環境を構成する多くの因子の影響を受ける。中でも、比較的ライフサイクル(寿命)が長いシジミ類等の二枚貝の生息状況は、水質や生態系の状態を総合的に評価する上で重要であり、地域住民にも分かりやすく、優れた指標と考えられ[5]、地域の保全活動の目標として活用できる可能性がある。二枚貝等の底生生物の生息

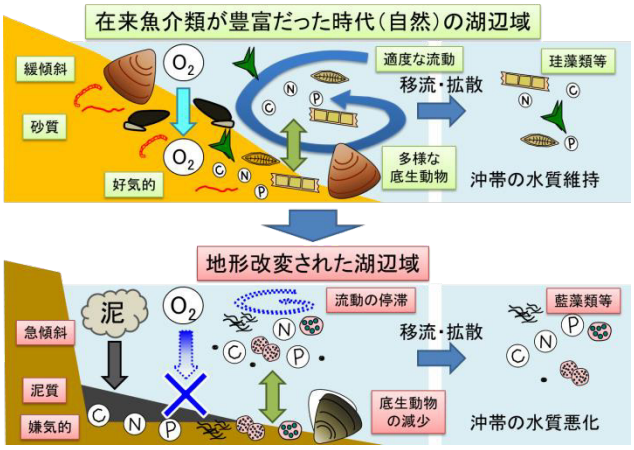

図 1 湖辺域における地形改変と水環境の変化(イメージ)

環境・餌環境の視点から、かつて在来魚介類が豊かであった時代の琵琶湖の水環境への回復に向けた改善策の検討が必要と考えている。

環境省と滋賀県は、生き物がにぎわう浅い砂地の再生に向け、琵琶湖の湖辺域において2017年度から、二枚貝等の良好な生息環境を評価するための現状把握調査、水環境を構成する要因間の影響評価とともに、地域住民等との協働による実証事業を実施している。また、行政担当者、研究者からなる検討会を設置し、湖辺域の水環境改善に向けた手法検討を進めている(図 2)。本発表では、これらの調査解析や実証事業、手法検討の全体概要と途中経過を報告する。

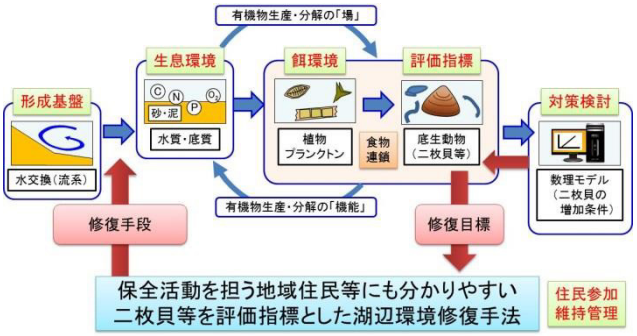

図 2 湖辺域の水環境改善に向けた手法検討に関する調査解析内容の構成

2. 水質・生態系に関する現状把握と影響要因の評価

湖辺域において望ましい水環境の状態を目指す上で、生物の生息環境・餌環境に着目する必要がある。このために、湖辺域での湖水の流れや波浪を考慮した湖底の地形、良好な底質（粒径等）の状態の知見を得る必要があることから、まず、水質や生態系を構成する複雑な要因間の関係把握を行うこととした。

検討にあたり、2017 年 12 月から 2018 年 1 月の間、琵琶湖湖辺域の 10 地点（北湖 6 地点、南湖 4 地点）において現状把握調査を実施した。

（調査項目）評価指標：二枚貝等の底生生物の生息状況、生息環境：水質と底質、餌環境：湖水中の植物プランクトンと底質中の藻類、生息環境や餌環境の形成基盤：水交換（流動、波浪）と湖底断面地形

底生生物の生息密度は、全地点の合計では水生貧毛類（ミミズ類）が 40.9%を占め最も高く、次いでユスリカ類（19.9%）、センチュウ類（19.3%）、シジミ類（10.6%）の順であった。生息環境との関係では、底質の粒径中央値が大きいほど、強熱減量が低いほど、ミミズ類とシジミ類の生息密度が高い傾向がみられた（図 3）。

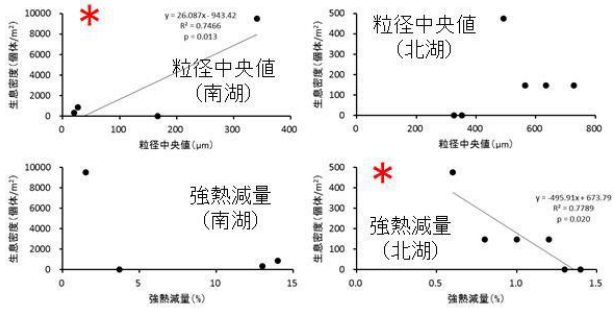

図 3 琵琶湖湖辺域における底質の粒径中央値・強熱減量とシジミ類生息密度の関係（＊$p < 0.05$）

餌環境では、湖水中の植物プランクトン、底質中の藻類量は、全体に北湖より南湖の地点で高く、シジミ類の肥満度も南湖の地点で高い傾向がみられた。また、脂肪酸をマーカーとした餌源分析により、シジミ類は餌として主に珪藻類、緑藻類、藍藻類を同化していたこと等が分かった。これらの現地調査は、地点・方法等を検討しつつ、季節変動も踏まえるため、2018 年夏季・秋季にも実施予定である。

また、特に南湖における近年の水草過剰繁茂は、湖底の低酸素化等を生じさせ、底生生物の生息環境悪化につながることが指摘されている[5]。南湖湖内の 9 定点において 2011 年から毎年夏季に実施している水草繁茂量と底生生物生息密度の調査結果では、2017 年夏季は、過去 7 年間で水草繁茂量が最も少なく、生息密度で優占するミミズ類の生息密度は 2 番目に高かった（図 4）。南湖の水草繁茂状況は年変動が大きく、湖辺域においても湖内の繁茂状況を反映すると考えられることから、今後もモニタリングを継続しつつ、水草が二枚貝等の底生生物の生息環境に及ぼす影響についても評価する必要がある。

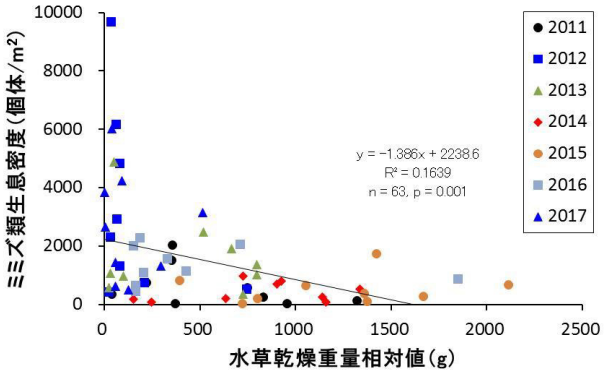

図 4 琵琶湖南湖湖内の 9 定点における水草繁茂量（相対値）とミミズ類生息密度の関係（2011 年～2017 年）

二枚貝等の生息に及ぼす影響要因の評価を行うため、シジミ類を対象とした調査結果等に基づく数理モデルの構成を検討した。作用機序を明示的に表現する物質収支モデルとして、大きくは個体成長モデルと個体群挙動モデルで構成するものとし、今後、調査結果や既存知見等に基づくモデルパラメータの調整とともに、理論式の構築を進める予定である。

3. 持続的・効果的な住民等との協働に向けた取組

地域住民や漁業者等との協働により湖辺域で行う実証事業として、琵琶湖南湖の湖辺域に設定した試験区（約 300 m²; 滋賀県大津市柳が崎）において、人力およ

び小型船舶による水草除去・湖底耕耘を実施している。この活動は、2017年7月から、夏季の水草伸長期となる7月～9月は毎月2回、その他の期間は毎月1回実施している。また、活動の効果を検証するため、2017年7月から3か月毎に1回、水草除去・湖底耕耘を実施した耕耘区および隣接する対照区において、住民等との協働による貝類調査と、研究者による底生生物調査を実施している。各回の活動および調査活動には、住民および住民団体、漁業者、滋賀県職員等の計20名程度が参加し、持続的な活動の目標として、目指すべき湖辺域の水環境のあり方を検討するため、作業後に参加者の意見交換の場を設けるとともに、意識評価のためのアンケート調査を実施している。

2017年7月から2018年3月までの計12回の活動では、計3,260 kgの水草を除去・回収した。貝類の生息状況については、耕耘区・対照区のいずれも、シジミ類の殻長中央値は2017年7月の5～6 mmから2018年1月の9～10 mmとなり、シジミ類稚貝の成長が確認された(図 5)。生息密度については、各回の調査において耕耘区と対照区の間に有意な差はみられなかったが、2018年1月時点では、殻長10 mm以上の個体は耕耘区の方が多い傾向がみられた。また、20 mm以上の個体がほとんど採集されなかったことから、現在生息している個体の生残と成長が、今後の重要な視点と考えられる。

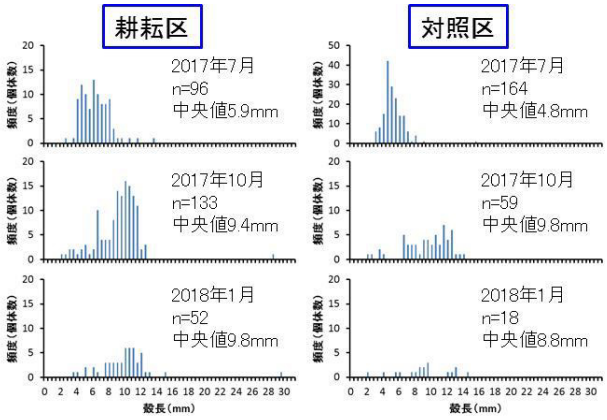

図 5 耕耘区・対照区におけるシジミ類の殻長分布

参加者の意識に関しては、活動の初期には水草の多さに驚いていたが、回数を重ねるにつれて作業中に二枚貝が発見されるようになったことから、活動の効果を実感してきていること等が分かった。

なお、湖辺域の底質環境保全の観点で重要と考えられている流入河川からの継続的な土砂供給機能の回復に向けた試みについても、2018年度から住民等の参加による取組を検討している。

4. 効果的な湖辺域の水環境改善手法等の検討

上記の調査解析、実証事業等の結果を踏まえて、湖辺域の水環境改善に向けた手法を検討していくため、学識経験者、自治体の環境行政担当者で構成する検討会を設置した。2018年3月に開催した第1回検討会において、住民等による持続的・効果的な湖辺の環境改善活動への活用を想定した手引き資料のとりまとめに向け、検討を開始した。また、二枚貝等の底生生物を指標に、場の特性に合わせた湖辺域の環境改善手法を検討することに対しては、①過去からの歴史的な経緯等を含めた状況や課題の整理、②現状把握、③改善目標の設定、④対策手法の選択、⑤モニタリング調査・維持管理活動の流れで取り組むこととし、現時点における課題・論点を整理した。引き続き調査解析、実証事業を行うとともに、検討会を継続していく予定である。

5. 結論

「琵琶湖の保全及び再生に関する法律」で目指す「健全で恵み豊かな湖」とは、水質と生態系が総体として良好に維持された状態と解釈できる。湖沼の水質・生態系の形成において重要な湖辺域[3]で、生息環境・餌環境の現状評価、因子間の関係評価を踏まえた「二枚貝の増加」という目標を設定し、湖沼生態系の機能を回復させ、良好な水質が保たれるよう、効果的な手法を確立したいと考えている。加えて、地域住民に分かりやすい二枚貝等の底生生物を指標とすることで、人と湖との関わりも回復させ、水質と生態系を総体として良好に維持することができるモデルを、全国の湖沼に先駆けて構築していく。その成果について、他の湖沼においても活用できる手引き資料としてとりまとめる。

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O1-41

Habitat restoration for Shijimi clam using local knowledge in the brackish lagoon Kugushi-ko

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Keywords: habitat loss, habitat restoration, nature restoration, Shijimi clam, local knowledge

ABSTRACT

Local knowledge (LK) is the knowledge that developed in a given region with histories of interaction with their natural environments, and had been historically used for resource use and conservation practices in estuaries and coastal habitats. However, it is overlooked recently in reliance on scientific knowledge and new technological ability. In this study, we identified local practices using LKs for conserving commercial bivalve Shijimi clam and verified whether the restoration practices resulted in the improved clam habitat in the brackish lagoon Kugushi-ko, in western Japan. It is demonstrated that elderly fishermen recognized that recent decrease in the clam harvest in the lagoon was mostly due to habitat loss, since the harvest declined after coastal revetment project in the late 1970s. On the assumption that the clam resource is under habitat limitation, they initiated habitat restoration practices recently using two different methods: modern method depending on engineering techniques using allochthonous sediments, and traditional method using LKs which depends on riverine sediment loads. The clam density was higher in the restored habitats than unrestored sites, and highest in the traditionally restored habitat using LKs, suggesting the effectiveness of the traditional restoration. These results suggest that approaches to nature restoration can be determined by using LKs even in less ecologically studied regions.

1. INTRODUCTION

Estuaries and coastal seas have been focal points of human settlement and marine resource use throughout history. In consequence, habitat loss is occurring rapidly in the ecosystems worldwide recently [1]. With recognition of their essential role for human and marine life, estuaries and coastal habitats have become the focus of efforts for conservation and restoration. To be successful, these approaches require historical references [2], including local knowledge.

Local knowledge (LK) refers to the understandings, skills and philosophies developed in a given region with long histories of interaction with their natural environments. LKs had been historically used for resource use and conservation practices in estuaries and coastal habitats [3], whereas it is overlooked recently in overreliance on scientific knowledge and new technological ability [4].

The aim of this study was to identify local practices using LKs for conserving commercial bivalve Shijimi clam (*Corbicula japonica* Prime, 1867) in the brackish lagoon Kugushi-ko, a part of the Mikata-goko (i.e., five lakes) (Fig. 1). In the lakes, Shijimi clam has been harvested from ~6,000 years ago [5], and recent (from ~350 years ago) major habitat of the clam has been in the Kugushi-ko lagoon. Recently, increased human activities resulted in local resource depletion, likely due to habitat loss. According to the Mikata-goko Nature Restoration Committee (since 2013), local efforts have been made to restore the clam's habitat using scientific knowledge [6], whereas the local practices using LKs have also been underway in recent decades. In this study, first, we conducted interviews with fishermen and residents in the region to identify local recognition on habitat status and practices for restoring the clam's habitat using LKs. Second, we verified whether the restoration practices resulted in the improved habitat using field census data.

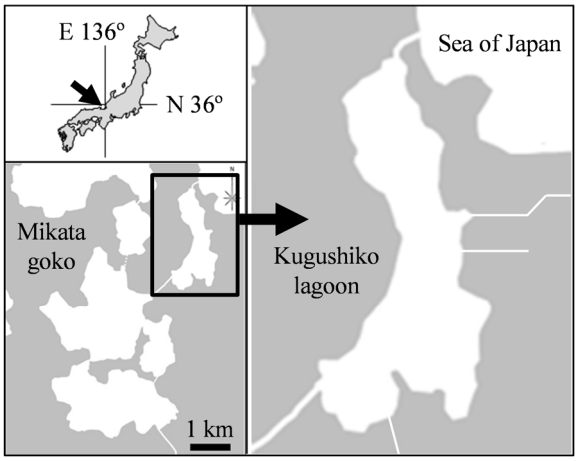

Fig. 1 Map of the present Kugushi-ko lagoon

2. METHOD

Shallow sandy coasts of the brackish lagoon Kugushi-ko

(Fig. 1) have been major harvested sites of Shijimi clam in the Mikata-goko, at least since the early 1600s [7]. In the late 1600s, developing new paddy fields projects decreased surface area of the lagoon by ~30% [8], resulting in a significant habitat loss of the clam [9]. Further, from 1976 to 1978, coastal revetments were installed along ~60% of coastline [10], linking further loss of the clam habitats.

In order to identify local recognition on habitat status and practices for restoring the clam's habitat using LKs, interviews were conducted with fishermen and residents in the region by showing past aerial photo images and landscape photos, and descriptions of ancient documents for the Kugushi-lagoon. In particular, we interviewed with people elder than 70 years old who possesses more LKs. To verify whether the restoration practices resulted in the improved clam habitat, we compared the clam density among restored and unrestored habitats using field census data conducted in 2017. Restored habitats were classified into two categories: using LKs or not.

3. RESULTS

Before the early 1970s when coastal revetments were not installed, Shijimi clams inhabited widely along west and southeast coasts of the Kugushi-ko lagoon (Fig. 2A). In the periods, the southeast coasts were still huge sandy shallows. However, after the 1980s, most of the clam's habitats were lost due to the coastal revetment project (Fig. 2B), and the amount of the clam harvest decreased.

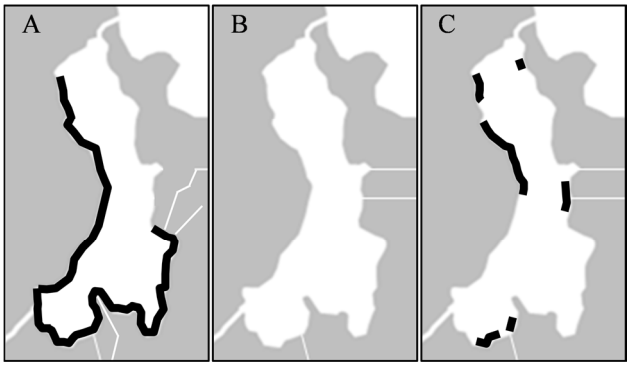

Fig. 2 Reconstructed clam habitats basing on interview results. A: ~1970s; B: 1980s-early 2000s; C: present.

Since the 2000s, habitat restoration (i.e., restoring sandy shallows) initiated by local fishermen (Fig. 2C). And in 2007, habitat restoration using LKs started at south coast; jetty was constructed at the small-river mouth aiming to enlarge sandy shallow along coastline of the lagoon (Fig. 3). After 10 years (2017), ~5,000m^2 of sandy shallows were successfully restored (Fig. 3). Shijimi clam density was higher in the restored habitats than unrestored sites, and the highest density was detected in the restored habitat using LKs (Table 1).



Fig. 3 Restored clam habitat using LKs. Jetty was build up at a river mouth in 2007.

4. DISCUSSION

Elderly fishermen recognized that recent decrease in the clam harvest in the Kugushi-ko lagoon was mostly due to habitat loss, since the harvest declined after coastal revetment project in the late 1970s. Huge sandy shallows at the southeast coast that used to be good clam-harvesting sites disappeared during the project. Considering the lagoon bottoms deeper than 1m depth were not preferable habitats for Shijimi clam in the past [11] and present, it seems plausible that habitat loss due to the artificial modification is a major factor for the decreased clam resources. Increase in the clam harvest after initiating habitat restoration practices since the 2000s further strengthened this fishermen's recognition.

To date, two different methods have been used in restoring the clam habitat practices. Modern method is a placement of sand covers on the coastal bottoms in a short time by engineering techniques, using allochthonous sands due to a scarcity of autochthonous materials. Traditional restoration, in contrast, depends on sand supply from rivers and on its dispersion by winter storm, thus taking a longer time. Traditional method is an application of ancient new-paddy development using river-supplied sediment, which has at least 300 years history in the region [12]. Interestingly, the clam density was higher in the traditionally-restored habitat than the

Table 1 Shijimi clam density in each habitat type in 2017. Errors are 95% confidence intervals.

Habitat type	N	Density (CPUE)
Restored (using LKs)	1	475.0
Restored (not using LKs)	7	169.7±39.7
Not restored	9	87.3±40.2

restored habitat using modern method, suggesting the effectiveness of the traditional restoration.

Habitat restoration using LKs has advantages and disadvantages. Lower cost is an economic advantage of the method; it costs only one-tenth of modern method to restore the same area of habitat. Furthermore, using autochthonous sediments supplied by river may be its ecological advantage, contributing inhibition of exotic benthic species invasion. The main disadvantage of traditional restoration is more consumption of time; it took 10 years to restore 5,000m^2 of habitat using traditional method (Fig. 3), whereas one year is sufficient to finish the same area of restoration using modern engineering method. Additionally, lesser feasible sites for restoration may be a disadvantage. Traditional restoration can be applied only near river mouth. However, considering that sandy shallows mostly forms near river mouth and the clam density was higher in traditionally restored habitat in such location (Table 1), the lesser feasible sites may not be a disadvantage if compared in terms of the productivity per restored area.

Unfortunately, the LKs for restoring Shijimi clam habitat have already been forgotten by many fishermen, whereas modern engineering method has been becoming popular in the region recently. However, in the 21st century, declining Japan's populations will result in reduced tax revenue, therefore, expensive public works projects such as modern engineering restoration of coastal habitat will likely be less feasible. On the other hand, frequency of heavy precipitation events which link to sediment supply into lagoons is increasing recently [13], suggesting that application of traditional habitat restoration depending on riverine sediment loads is becoming more feasible. These suggest that LKs concerning ecosystems would shed some light on future approaches to conservation and restoration practices.

5. CONCLUSION

We illustrated an example of coastal habitat restoration practice for Shijimi clam resources using LKs in the Kugushi-ko lagoon. The traditional restoration method is proven to have some advantages (e.g., low cost, low impact on ecosystem) and to be adaptive to recent economic and climatic changes. These suggest that approaches to nature restoration can be determined by using LKs even in less ecologically studied regions.

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O1-42

「里浜づくり」で泳げる霞ヶ浦を

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キーワード:自然再生, 生態系機能, 水辺空間, 生活, 地域づくり

抄録

(一社)霞ヶ浦市民協会は、1995(平成7)年開催の第6回世界湖沼会議にて採択された『霞ヶ浦宣言』の精神を理念に据え、1996(平成8)年に設立された。市民・行政・研究者・企業のパートナーシップのもと、霞ヶ浦という風土の中で培ってきた市民の英知を結集し、『泳げる霞ヶ浦』を目指して水質浄化の推進・啓発活動を続けている。『泳げる霞ヶ浦2020市民計画』は、2020年を目標に生活文化、水辺交流、環境保全、生態系保全、歴史文化、地域経済、啓発・環境学習など多岐にわたる分野での事業展開を示したもので、なかでも湖岸の整備、特に前浜再生に関わる「里浜づくり」事業を継続的に実践している。「里浜」とは、人の住む「里」と、自然の成す「浜」を合体させた造語だが、人と湖をつなぐ里浜(砂浜)をつくり維持管理しながら利活用することで、霞ヶ浦に対する人々の関心と、水質浄化への意識と行動を促すと考え、これを提案し事業として推進するものである。

1. 里浜の提案まで

1995(平成7)年に茨城県で開催された第6回世界湖沼会議は、学術会議にもかかわらず、多くの一般市民が参加したことでも記憶に残る。また、水環境保全を願う各国参加者の強い意志と決意の結晶である『霞ヶ浦宣言』がまとめられ、その宣言内容を設立理念とする社団法人(当時)霞ヶ浦市民協会が、1996(平成8)年に発足した。

2001(平成 13)年5月、当協会は 2020 年を目標に、『泳げる霞ヶ浦』の実現を目指すための『泳げる霞ヶ浦 2020 市民計画 基本構想』を、翌年には『同行動計画』を策定した。当時、20 年先の 2020 年は子どもたちが大人になり社会を担う時代であり、さらにその先へもつながる計画として、21世紀にふさわしい環境型循環社会の構築を背景にしたものである。これは、人と自然の共生を前提に、湖沼や河川の流域住民が、常に流域全体を視野に生活し、水系と関わっていることを自覚することで成り立つ、いわば『霞ヶ浦市民社会』とも言うべきネットワークの確立を目指したものでもある。

同計画の基本フレームは5つのプロジェクトから構成された。①暮らしのプロジェクト／新しい生活文化の創造…インフォメーションセンター「水の交流館」運営・夏休み教室・霞ヶ浦ジュニアレンジャー養成講座・自然観察会・環境学習・生活排水事業等 ②身近な川プロジェクト／生物多様性への模索…水質調査(地域・一斉)・新川クリーンアップ・どんぐり里子作戦・生物調査・河川清掃等 ③水辺交流プロジェクト／人と自然の回廊づくり…泳げる霞ヶ浦市民フェスティバル・水辺ふれあい事業・景観づくり等 ④地域経済プロジェクト／食に始まる霞ヶ浦ブランドづくり…土浦ビオパーク・新川浄化実験場・エコビジネス・地場産品の利活用 ⑤人とひとプロジェクト／プロジェクトの総括集結…シンポジウム・地域懇談会・世界湖沼会議・広報出版・交流会・研究など。これらの事業を市民、行政、研究者、企業、農林漁業者、学校、各種団体とともに協同・協働していく。

この5つのプロジェクトが相互に関連し合う、具体的な事業として辿り着いたのが、水辺の砂浜づくりである。昭和 40 年代初期までは霞ヶ浦沿岸に複数の遊泳場があり、人々は水に触れ、入り、泳いでいた。その泳げた時代をイメージしつつ掲げられた『泳げる霞ヶ浦』は、霞ヶ浦と流域住民の結びつきのもとで成立するものである。砂浜は、水辺の浄化機能を果たすのはもとより、親水空間としての利用価値がある。そこで、日常的に人々が集まり、水質浄化の意識行動のきっかけになる場としての砂浜を、人々の暮らす「里」と、霞ヶ浦の「浜」の結びつきを象徴する『里浜』という言葉で表した。しかし、同時

に維持管理が整わなければ砂浜は消失しかねない。

当協会は、多様な効用を持つ里浜の造成から維持のために、市民の立場で何をすべきか、何ができるかを考え、この里浜づくりを提案し、実践する。

2. 活動経過

『泳げる霞ヶ浦 2020 市民計画』策定後、里浜づくりに向けたシンポジウムやサマースクール等を開催、2006（平成 18）年3月には「第4回霞ヶ浦市民博覧会 2006」において、㈶土木研究センターなぎさ総合研究室長（当時）の宇多高明氏を講師に迎え、主に土浦市蓮河原・滝田地区の湖畔を対象に、現地視察と勉強会を行った。

宇多氏からは、養浜計画では、地形、地質、水深、汀線の角度、卓越風の方向、波の入射方向等の十分な事前調査が重要であることや、砂質、砂の安定のための方策、ヨシ浜との関係性が教示された。さらに、波のエネルギーを干さず、程よく浜に当てること、その地域にふさわしい姿にすることなどが浜づくりには重要であり、「相手は生きている湖」であることを忘れず、段階的な計画が必要であることを学んだ。

第6回世界湖沼会議後、旧建設省は、霞ヶ浦浄化の試みとして土浦市手野町石田地先に大量の砂を投入し、砂浜を造成していた。しばらくは前浜の形態を保ったものの、その後の管理が追いつかず、ヨシ等の植物繁茂、樹木の生長などで足を踏み入れる場もないほど荒れた。しかし、この湖岸は土浦の中心市街地からも近く、人々が利用する砂浜再生の場所としては適している。当協会では、この前浜をどうにか復活させ、里浜をつくろうということになった。



写真1　アシなどの草刈り

以降、年に数回、特に植物が繁茂する夏場には毎週のように、機械と人力による地道な草刈りと清掃作業を続け、各種イベントにも利用してきた。だが、整備エリアにもパワーにも限界は見えた。

2015年2月、事情を聞きつけた地元建設機械メーカーの全面協力のもと、約600㎡にわたる前浜部分のヨシを抜根した。根と砂を振るい分け、水辺近くでは浸出水に阻まれながらの大がかりな作業を終えると、地面に砂が見え始め、広々とした前浜が現れた。以降は人の手による継続的な整備作業が砂浜維持のための動力となっている。



写真2　前浜の草刈り作業

前浜の整備および利活用の一環としては、『水辺の楽校』と『砂浜の楽校』を年2回ずつ実施している。水辺の楽校は、主に子どもたちを対象に清掃活動と遊びを組み合わせたもので、自分たちできれいにした砂浜でペットボトル・ロケットを作り飛ばし、前浜にある流木でおこした焚き火で地元産サツマイモの焼き芋を作り食べるなど、水辺で遊び楽しんでもらう目的を持つ。



写真 3　砂浜でのペットボトル・ロケット飛ばし

砂浜の楽校は、建設会社関係者の協力による本格的な清掃作業で、不法投棄された大量のゴミや、漂流物、流木を除去する。景観の維持はもとより、霞ヶ浦の状況を目の当たりにすることで、浄化への意識啓発につなげることも目的のひとつとなる。こちらも作業後にはレンコンやサツマイモなど地元産の食材で作った総菜や菓子で一服する。

いずれにせよ、当協会会員のみならず、地域の団体・市民、企業等の協力を得ながら続けるこの活動に終止符はなく、人力による定期的な維持管理が常に欠かせない。



写真4　前浜の整備

3.　課題と展望

砂浜は造成しただけでは維持できない。ヨシなど植物が繁茂し、ゴミが溜まることで、人は訪れずに荒れていく。しかしながら、維持のためだけに活動を続けていくのにも限界がある。望ましいのは、日常生活の中で利活用しながら維持管理していくことであり、それが里浜の理念でもある。

かつて、人々は集落をつくり、霞ヶ浦沿岸には多くの漁村があり、遊泳場があった。霞ヶ浦と日常生活は同じ線上にあり、水辺は自ずと管理されていた。すなわち、そこにこそ里浜の原型があり、地域と住民の関わりが果たす役割の大きさに気づく。とはいえ、昔のように自立的持続的な水辺との関わりを求めても不可能に近い。現状を鑑みるならば、必要なのは、新たな循環型社会、持続的な水循環の構築ということになろう。

もともと砂浜には、有機物の分解やろ過などの水質浄化機能、そして消波作用や魚類の産卵場所などの機能がある。里浜は、こうした生物の営み、生態系保全の場でもなくてはならないが、地域住民の理解と協力があってこそ、これらの環境も維持される。さらに、その理解と協力を長期的に得るためには、人々にとっても何らかのメリットが必要だろう。人々の暮らしに役立ち、生物の営みにも役立つ場としての水辺空間たる里浜が求められる。

2003（平成 15）年施行の「自然再生推進法」に基づき、当地における「霞ヶ浦田村・沖宿・戸崎地区自然再生事業」には当協会ほか多数の団体・市民が参加し、『里と湖』の接点たる湖岸帯の保全・再生、生態系の維持に向けた活動を継続、年々成果を収めている。石田地区においても、子どもたちの環境学習、レクリエーションの場としての利活用が増えてきた。



写真5　子どもたちによる砂浜づくり

この前浜を砂浜として再生し維持していくことは生態系サービスの「調整」「文化的」観点にも貢献する。茨城県が「霞ヶ浦に係る湖沼水質保全計画」の長期ビジョンに掲げる『泳げる霞ヶ浦・遊べる河川』実現のためにも、この前浜の整備、砂浜化は有効と考える。

前出の宇多氏の弁を借りれば、里浜づくりは、かつて霞ヶ浦で泳いだ世代だけが満足するものではなく、多世代の共感を呼び、理念哲学を持つことが不可欠である。「人と生き物の共生を基本とし、暮らしの中で親しみながら守り育てる浜辺」としての里浜を、『泳げる霞ヶ浦』実現のための指標と位置づけている。

TS2-1

THE STATE OF THE GLOBAL WATER RESOURCES: HOW SUSTAINABLY DO WE USE THEM?

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ABSTRACT

The presentation will overview the current global perspective on freshwater with a view identify major likely future challenges along with an outline of potential opportunities for solutions. Given the projected demands for water, and the likely impact of climate variability and change, the present water uses, including those in/of rivers and lakes, are clearly not sustainable. Finally, the political recognition is born that freshwater is a major global issue. The presentation will attempt to identify the technical, social and ecological challenges that need to be addressed to establish sustainable river development and management practices for the future in the context of lake management. It will look into the catchment scale hydrological impacts of various global change drivers. All these changes imply strong non-stationarity. It will be argued that the design methodologies, such as the concept of design floods, developed under the hypothesis of stationary hydrological processes, need to be revisited and updated. Potential impacts of climate change will also be outlined along with the likely increase in the occurrence of extreme events such as floods and droughts. Mitigation and adaptation measures will shortly be outlined. Of the later structural and non-structural measures will be shortly examined. The presentation will argue that the re-examination of some of the structural measures, such as the need for more water storage, the need for more intensive hydropower development and the need to further develop inland navigation, respectively, is a timely task. These measures will pose new social and ecological challenges but also offer new opportunities. Various hypotheses will be entertained as to the relative importance of the various global drivers at catchment scale. The big question is: are we really dealing with the most important issues? What is indeed the major driver that will determine how rivers and lakes will be managed two generations from now? In case of transboundary water bodies, where nearly half of humanity leaves, who calls the shots? How effective international cooperation is? Why do we need that, to start with? Is sustainable water management an ethical and cultural issue or simple a matter of engineering by more structures? Isn't water just a matter of quick technical fixes by applying more technology? Is water a source of conflict or that of cooperation? Some of the potential responses to these questions will be outlined along with an assessment of emerging research needs.

TS2-2

日本における流域の水循環・水資源管理の展開と課題

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キーワード：流域水循環，水資源開発，水資源管理，リスク管理型

抄録

水資源の適切な開発管理は，流域における生活や生産の基本であり，そのためには流域の水循環の健全な保全管理が求められる。これは，流域における湖沼水資源の持続的利用はもちろんのこと，流域や関連するする地域や海域の環境保全の基本的な要件である。

日本では，流域における健全な水循環を維持・回復させ，経済社会や国民生活の一層の発展・安定を図るために，地下水を含む水循環に関する施策を総合的・一体的に推進する「水循環基本法」が 2014 年に施行された。また，主要水系においては，水資源の需給の逼迫度の低減，気候変動や災害対応の必要度の増大などを背景に，「リスク管理型」向けての水資源開発基本計画の改訂が 2017 年より順次進められている。

本報告では，日本におけるこれら水循環や水資源の開発管理に関わる基本的な考え方や法制度等の枠組みの近年の整備状況を整理し，湖沼を含む淡水資源の，今後の一層の持続的な利用に向けての課題を検討する。

1.　はじめに

流域の水資源の適切な開発・管理は，生活や生産の基本であり，そのためには流域の水循環の健全な保全と管理が求められる。これは，流域における湖沼水資源の持続的利用はもちろんのこと，流域や関連するする地域や海域の環境保全の基本的な要件である。日本では，洪水災害の防止や軽減とともに，安定した水供給のための制度が整えられ，さまざまな施設整備事業が進められてきた。また，水質や生態系を含め流域水環境の保全も取り組まれてきた。

近年，これらの整備の進展や水供給の安定化を踏まえ，また経済成長動向や人口動態の変化を背景に，新たに制度や仕組みの整備がなされ，その実施の具体化が進められている。本報告では，日本におけるこれら水循環や水資源の開発・管理の展開を整理し，水資源の今後の一層の持続的な利用に向けての課題を検討する。

2.　日本における治水と利水の展開の概要

日本はモンスーン地域に位置し，夏季の豪雨・洪水と干ばつ・渇水は，古来国土管理の中心的な課題であった。水資源の開発・管理に関しては，水田稲作のための用水確保が古代からの継続した課題で，近世に入っての進展と新田開発は，その後の人口増加と社会システムの基盤を形成した。近代に入っても，この基本は継続し，とくに第二次世界大戦以降は，土木技術の発展や経済成長に伴う都市用水の需要増大などを背景に，流域の水循環を管理し，水資源を開発する事業はより大規模に展開されてきた。

その結果として，洪水等の水害で死亡する人の数は大きく減少した。また，大規模な水資源開発によって，増大した需要にほぼ対応した用水供給が実現し，各地で頻発していた「水不足」も，限られた地域や期間に限られるようになったといえる。

一方で，高度経済成長や人口増加と集中に対応した水資源開発や管理は，一部で流域の水循環や水環境に影響を与え，その健全性の確保が課題として顕在化した。これに対しては様々な対応がなされてきているが，法制度としては，1997 年の河川法の改正がその象徴的なものであり，その目的に，河川環境の整備と保全が加えられた。これにより，具体的には，コンクリート主体の護岸工事の修正，河川生態系や植生の保護・育成などが進められることとなった。

3.　近年における流域の水循環・水資源の管理の展開

(1)健全な水循環系の構築

継続的に展開されてきた流域の水循環の改変や水資源の開発・管理に関わる様々な制度の整備や事業の展開を踏まえ，「健全な水循環」の構築が基本的な課題として認識されるようになり，1998 年に水に関係する6省庁は「健全な水循環系構築に関する関係省庁連絡会議」を設置し，1999 年にはその共通認識等を中間的にとりまとめている。その後の，これを目的とする基本法の策定必要性の議論を踏まえ，2014 年に「水循環基本法」が施行されることなった。

水循環基本法は,「水循環に関する施策を総合的かつ一体的に推進し、もって健全な水循環を維持し、又は回復させ、我が国の経済社会の健全な発展及び国民生活の安定向上に寄与すること」が目的とされている。この法律では,「水循環」は「水が、蒸発、降下、流下又は浸透により、海域等に至る過程で、地表水又は地下水として河川の流域を中心に循環すること」をいい,「健全な水循環」は「人の活動及び環境保全に果たす水の機能が適切に保たれた状態での水循環」をいう。

この法律は基本法であって,具体的な事業等は従来通り関連する個々の事業法等で対応することになるが,水循環を経済社会や国民生活との関係で明確に位置付け,「流域として総合的かつ一体的に管理されなければならない」ことを明確にしたことは重要な点である。政府は,施策の総合的かつ計画的な推進を図るために「水循環基本計画」を定め,水循環政策本部を設けて推進することとなった。今後,いくつかの流域で流域水循環協議会を立ち上げ,流域水循環計画を作成するなどの具体的な展開が進むことになっている。

(2)水資源開発基本計画のリスク管理型への転換

国土交通省は,2017 年,国土審議会からの「リスク管理型の水の安定供給に向けた水資源開発基本計画のあり方について」の答申[1]を受け,新たな水資源開発基本計画の策定を行うこととした。

「水資源開発基本計画(通称:フルプラン)」は,水資源開発促進法(1961 年)によって,指定された水資源開発水系において決定されるもので,1)水の用途別の需要の見通し及び供給の目標,2)供給の目標を達成するため必要な施設の建設に関する基本的な事項,3)その他水資源の総合的な開発及び利用の合理化に関する重要事項,を記載することになっている。これまで,指定された,利根川,荒川,豊川,木曽川,淀川,吉野川,筑後川の7つの水系について,総合的な水資源の開発と利用の合理化を図るために,水資源開発基本計画が定められてきた。

上記の答申では,新たな水資源開発基本計画の策定にあたって,需要主導型の水資源開発の促進を目指してきたこれまでの計画から,「リスク管理型」の水の安定供給を目指す計画への転換を図ることが提言されていて,現在これに沿った計画変更の検討が始まっている。これは,従来の需要の見通しとそれを賄う供給の目標,さらにそれに対応した施設建設という基本に対して,過去の需要の見通しと実績との乖離,用水需給逼迫の解消傾向,経済成長動向や人口動態による用水需要増加の抑制傾向,整備施設と老朽化の拡大,地震等への大規模災害への対応の必要性,気候変動に伴う用水需給量の変化とその見込みの不確定性など,様々な情況や要因の変化を鑑み,多様性や不確定性に対応した水資源開発に転換することを提唱したもので,それを「リスク管理型」という語で表現したと理解する。

その「リスク管理型」の計画のあり方は以下の4点にまとめられている。

1)水供給を巡るリスクへの対応:地震等の大規模災害,施設の老朽化に伴う大規模な事故,危機的な渇水等発生頻度は低いものの水供給に影響が大きいリスクにも対応。
2)水供給の安全度を総合的に確保:需要と供給の両面に存在する不確定要素を考慮して,水需給バランスを総合的に評価。地域の実情に即した取組を着実に推進。
3)既存施設の徹底活用:長寿命化対策を計画的に進め,大規模災害等の危機時も含めて水の安定供給を確保するため,既存施設を徹底活用。
4)ハード・ソフト施策の連携による全体システムの機能確保:様々なリスクや不確実性に対し,柔軟性をもって包括的に対応してシステム全体の機能を確保するため,ハード対策とソフト対策を一体的に推進。

4. 流域の水循環・水資源の管理の課題

最近の,日本における水循環管理と水資源の開発・管理に関わる制度等の整備の状況を概観した。そこでは,単に,法や制度の整備だけではなく,その背景となる実態や考え方の展開,そして具体的な計画や事業の実施を含めて今後の課題が,現れている。

水循環の管理については,既述した基本法と関係事業法との具体的実務的連携などの課題とは別に,これを契機に,改めて進展が求められる2つの課題を整理しておきたい[2]。まず一つは,法にもある「総合的かつ一体的」な施策の推進のためには,「水循環管理手法」(マネジメント・インストルメント)の整備が求められるという技術的課題である。総合的な管理には,法的枠組みだけでなく管理評価手法を用意することが必要であるが,その開発は案外進んでいない。水循環の健全性を評価し,改善の方策を提案できる具体的な指標や方法など,関係者が共有・活用できる情報を整える手立てが必要である。

もう一つは,理念に基づき関係者に求められる具体的な「協働」の仕立てである。健全な水循環の保全には,基盤となる基盤施設と規則制度だけでなく,それらの主体となるべき関係者の「共同」を仕立て直す必要があると考える。法にある「連携と協力」には,地域の住民や関係団体の協働に託す部分を計画的に配置すべきである。

水資源開発と管理については，指定水域を対象とする「水資源開発基本計画」の「リスク管理型」への展開を紹介した。この「リスク管理型」への転換の考え方は，指定水系に限らず，基本的には全国の水系にも展開すべきものであると考える。その内容は，これまでの計画の中心にあった，水資源利用における用水の需要と供給を，一定の条件において量的にバランスさせることを超えたものとなっていると理解できる。「水資源開発促進法」は，「水を必要とする地域に対する水の供給を確保するため」のものであり，目的にある「水源の保全かん養と相まって，河川の水系における水資源の総合的な開発及び利用の合理化の促進」を図るには，新たに策定された水循環基本法の理念とさらに整合性を高めた仕組みに転換させる議論が必要であろう。

なお、「水資源開発基本計画」を「リスク管理型」で策定する場合，様々な要因や対象に対する関係者や専門家の「主体的な判断」が求められる局面が多くなることが考えられる。計画の客観性やプロセスの透明性・公開性を向上させる視点から，ここでも，流域の水文現象や水利の状況を表現し，対応の選択肢の影響を客観的に表現する「水循環管理手法」（マネジメント・インストルメント）の整備が求められる。

5. おわりに

本報告では，日本における水循環管理と水資源の開発・管理の展開と課題を，近年の「水循環基本法」の制定と「水資源開発基本計画」の「リスク管理型」への展開を主な材料として検討した。これらは，広く統合的水資源管理の展開に向けてのプロセスとして位置付けることができるようになることが期待される。統合的水資源管理のための基本的な条件として，法的枠組み，協働と合意形成，管理手法の3つが一般に挙げられるが，日本においては，法的枠組みの整備が一定程度進んだとすれば，関係者の連携と合意形成のための枠組みの整備，そして具体的な管理ツールの開発・整備の展開が求められることになる。こうした日本の状況は，他の条件の異なる国や地域の流域における水資源管理の整備の視点からの検証も必要で，また，日本の経験が，他の国の流域における課題の解決につながるものとなることが望まれる。

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TS2-2

Recent Development and Challenges in the Management of Water Cycle and Water Resources of a Basin in Japan

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Keywords: basin water cycle, water resources development, water resources management, risk-management approach

ABSTRACT

Appropriate development and management of water resources is the basis of life and production in a basin, and for that purpose sound conservation and management of hydrological cycle is required. This is a fundamental requirement for environmental conservation in a basin and related areas and coasts as well as sustainable use of lake water resources in the basin.

In Japan, the "Basic Act on Water Cycle" was promulgated in 2014, which is a comprehensive and integrated promotion of measures concerning water circulation, including groundwater, in order to maintain and restore sound water circulation in the basin, further develop and stabilize economy and society and people's lives. In the main river systems, the "risk management type" basic plan for water resource development has been advanced from 2017, based on the reduction in tightness of demand and supply of water resources, and the increase in the necessity of measures against climate change and disaster, etc.

In this report, the basic thinking on water circulation and water resource development and management in Japan and the recent improvement situation of the framework of legal system are reviewed, and the further necessary challenges for further improvement of the sustainable use of freshwater resources including lakes.

1. INTRODUCTION

Appropriate development and management of water resources is the basis of life and production in a basin, and for that purpose sound conservation and management of hydrological cycle is required. This is a fundamental requirement for environmental conservation in a basin and related areas and coasts as well as sustainable use of lake water resources in the basin. In Japan, together with prevention and reduction of flood disasters, systems for stable water supply have been prepared, and various infrastructure development have been implemented. Conservation of basin water environment including water quality and ecosystems has also been tackled.

In recent years, based on the development of these improvements and the stabilization of water supply, and according to the economic growth trends and demographic dynamics, the establishment of new systems and mechanisms has been made and actual implementation of relevant projects are being advanced. In this report, the recent history on management of water cycle and water resources of Japan is summarized and the issues for further sustainable use of water resources are discussed.

2. OUTLINE OF THE DEVELOPMENT OF FLOOD AND DROUGHT MANAGEMENT IN JAPAN

Japan is located in the monsoon area, and floods with heavy rains and drought with dry spell during the summer season have been the central issue of land management from ancient times. Regarding the development and management of water resources, securing water supply for rice cultivation is a continuing task from the ancient, and its progress and further paddy field reclamation in the 16-17 C modern founded the base for the subsequent population increase and the social system. Even when entering the modern era, this basic principle continues, especially after the World War II, with the background of civil engineering development and demand for urban water accompanying economic growth, etc., the project to control water cycle and develop water resource of the basins has been advanced on a larger scale.

As a result, the number of people who die due to water related hazards including floods has decreased drastically. In addition, due to the development of large-scale water resources development, water supply has become almost corresponding to the increased demand, and "water shortage" which frequently occurred in various places was limited to some specific areas and periods.

Meanwhile, development and management of water resources in response to the higher economic growth and the population increase and concentration, in part, affected water cycle and environment in basins,

consequently ensuring “sound water cycle” became manifest as a subject. While various measures have been taken against this issue, as a legal system, the amendment of the River Law in 1997 is a symbolic one, with the objective of improving river environment and conservation. As a result, exact actions have been promoted, such as revision of concrete-based bank strengthening works, protection and improvement of river ecosystems and vegetation, etc.

3. RECENT DEVELOPMENT OF MANAGEMENT OF WATER CYCLE AND WATER RESOURCES IN BASINS OF JAPAN

(1) Construction of sound water cycle system

Based on the continuous modification of the water cycle and the improvement of various systems in the basins and implementation of relevant actual project related to the development and management of water resources, the establishment of "sound water cycle" was recognized as a fundamental issue. In 1998, the six ministries concerned with water established the "Liaison Committee on Relevant Ministries and Agencies concerning the Establishment of a Sound Water Cycle System", and in 1999 they drafted the common recognition on it. Based on the discussion of the necessity of formulating the basic law aiming at "sound water cycle", finally the "Basic Act on Water Cycle" was enforced in 2014.

The "Basic Act on Water Cycle" is "to promote comprehensive and integrated measures on water cycle, conserve or restore sound water cycle, and contribute to the sound development of the economy and society and stability improvement of the people's lives". In this Act, "water cycle" means "circulation of water around a river basin in the course to the sea area, as surface water or groundwater, by evaporation, falling, runoff or infiltration", and "sound water cycle" means "water cycle functioning appropriately to human activities and the environmental conservation".

While this law is a basic law and then the actual programs or projects are to be operated by the related business laws, it is importantly to be noted that water cycle is clearly recognized in relation to the socio-economy and people's lives there, and that it is prescribed as “must be managed in a comprehensive and integrated manner". According to the Act, the government should establish a "water cycle basic plan" to promote comprehensive and systematic measures, and to establish the headquarters for it. In the near future, concrete development such as to set up basin water cycle council in several basins and to prepare basin water cycle plan will be advanced.

(2) Conversion to the risk management-type basic plan for water resource development

In 2017, the Ministry of Land, Infrastructure and Transportation received a report from the Land Council [1] on "Basic Plan for Water Resources Development for Risk Management-type Stable Water Supply", and the Ministry decided to formulate the new approach to water resources development planning.

"Water Resource Development Basic Plan (so-called "Full Plan)" is draw up for the designated river systems according to the Water Resources Development Promotion Act (1961). In the Plan, the following items are to be described, including 1) water demand forecast for each water use sector and supply goals, 2) basic matters concerning the construction of necessary facilities to achieve supply goals, and 3) other important matters concerning comprehensive water resources development and rationalization of water use. So far, the basic plan has been established for the seven designated river systems, including the Tone, Arakawa, Toyo, Kiso, Yodo, Yoshino, and Chikugo Rivers.

In the above Council report, in planning a new water resource development basic plan, converting from the past style that has aimed to promote demand-driven water resource development, it is recommended to introduce "risk management type" for stable water supply, and the research of plan changes is now under way according to these recommendation and decision. This policy change is to be organized corresponding to actual changes in the various circumstances and factors, including the followings: the disparity between the forecast and actual performance of water demand, the tendency to eliminate the tightness in the balance of water supply and demand, the trend of suppression of increase in water demand due to actual economic growth and demographics, the increase of needs for maintenance and lifetime expansion of aged facilities, the need to respond to large-scale disasters such as earthquakes, and the uncertainty of changes in the water supply and demand due to the climate change. These approach is expressed as the term of "risk management type".

The core idea of the "risk management type" plan is summarized in the following four points.

1) Response to risks related to water supply: Responding to risks that have a large influence on water supply although their frequency of occurrence are low, such as large-scale disasters like earthquakes, big accident caused by aged facilities, and critical crisis of droughts.
2) Secure comprehensive safety of water supply: Assessing comprehensively the water demand-supply balance considering uncertain factors in both demand and supply.

Promoting steadily the initiatives consistent with local circumstances.

3) Full utilization of existing facilities: Planning progressively the countermeasures to prolong the lifetime of the existing facilities, and utilizing thoroughly them to ensure stable water supply including crises such as large-scale disasters.
4) Securing the function of the overall system through collaboration of hardware and software measures: Ensuring the function of the whole system, adapting to various risks and uncertainties flexibly and comprehensively, with combination of the hard-measures and soft-measures.

4. ISSUES ON MANAGEMENT OF WATER CYCLE AND RESOURCES IN A BASIN

Recent situation of the development of systems related to water cycle management and water resource development and in Japan was summarized. There, not only the re-tailoring of the laws and institutions, but also the actual situation and ideas that constitute the background, and the future issues including the implementation of actual plans and projects are addressed.

Regarding the management of water cycle, apart from issues such as practical cooperation between the basic law and related business laws as described above, two issues are to be discussed [2]. Firstly, in order to promote the "comprehensive and integrated" measures found in the law, as a technical issue, the development of exact "water cycle management method (management instrument)" is required. For the integrated water resources management, it is necessary to prepare not only a legal framework but also a method for evaluation of management performance, while its development has not progressed unexpectedly. It is necessary to establish a system for information that is to be shared and used by the all stakeholders, including quantitative indicators and methods for evaluation of the soundness of water cycle and for suggestion of improvement measures.

The other is a tailoring of concrete "collaboration" required by stakeholders. The conservation of the sound water cycle requires not only the basic infrastructures and institutions, but also "cooperation" of the stakeholders. To realize the real "collaboration and cooperation" described in the law, some parts or issues are to be entrusted to the local residents or their related organizations in the management plan in a systematic manner.

Regarding the water resources development and management, the idea of conversion to "risk management type" water is not limited to the designated river systems, basically it should also be developed in other river systems of the country. It can be understood that the contents are beyond quantitatively balancing the supply and demand of water for water resource utilization under a certain condition, which was the core of the plan to date. The "Water Resources Development Promotion Act" is for "to ensure the supply of water to the areas requiring water", and to realize its objective "to promote integrated water resources development and rationalization of water use in river system, with conservation and recharge of water resources", further discussion about the idea and process for establishing the advanced system in much deeper consistency with the newly formulated "Basic Act on Water Cycle Water".

When formulating the basic plan for water resource development with risk management type, many aspects might require "subjective judgment" by stakeholders and experts on various factors and subjects. From the viewpoint of improving the objectivity of the plan and the transparency and openness of the process, here also, "water cycle management method (management instrument)" is awaited, which can simulate the hydrological regime of the basin and the situation of water use and assess objectively the influence of the possible options.

5. CONCLUSION

In this report, the development and management of water cycle management and water resource development and management in Japan are discussed, reviewing the recent establishment of the "Basic Act on Water Cycle" and the introduction of the "Risk Management Type" of the "Water Resources Development Basic Plan". These are expected to be recognized in the future as a process for the integrated water resources management. While three basic conditions for integrated water resources management are the legal framework, collaboration and consensus formation, and management methods in general, and in Japan the legal framework has advanced a certain degree, it is to be required to develop a framework for collaboration and consensus building among stakeholders, and to develop an effective and serviceable management method or instrument. Such situations in Japan need to be reviewed from the viewpoint of water resource management in basins of other countries and regions with different conditions, and those Japan's experiences are desired to lead to the resolution of issues in basins in other countries and regions.

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O2-1

Water purification for portable water using Bio-fence around Nyanza Gulf of Lake Victoria

- Results in LAVICORD project -

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Keywords: Lake Victoria, water pollution, toxic cyanobacteria, microcystin

ABSTRACT

Kenya has been struggling with various water problems such as shortage of water, contamination of water sources and deterioration of water environment. Of course, although the problems have been addressed not only in Kenya but also in other countries so far, many problems remain yet. If a practical solution for such problem will be obtained, the solution can be spread to other countries in the world from Kenya. Hence, in LAVICORD (The Lake Victoria Comprehensive Research for Development) project, we focused on the development of several appropriate technologies for safe water. The studies were performed at Nyanza Gulf of Lake Victoria. At several beaches in Nyanza Gulf of Lake Victoria, we found cyanobacteria blooms. Therefore, first of all, we solved the cyanotoxin microcystin contamination problem, because we elucidated the remarkable microcystin contamination in drinking water collected from beach of Nyanza Gulf. Thus we installed Bio-fence system at Ogal beach, where highest contamination of microcystin was found, to produce safe portable water. The installed bio-fence using charcoal could effectively remove microcystin from lake water. However, it was significantly affected by the water level fluctuation of Lake Victoria. We should improve the system design of Bio-fence for practical use, because the strength of water level fluctuation recently became larger.

1. Introduction

Ogal Beach like many rural beaches along Lake Victoria is faced with the challenge of deteriorating water quality; evident in cyanobacterial blooms on and off-shore. The Inhabitants at shores of Nyanza Gulf face a risk of consuming cyanotoxin microcystin[1]. Many of them drink the lake water without adequate treatment to reduce cyanotoxin microcystin and boiling of water alone doesn't decompose microcystin. The lake water quality situation at the beach may not improve in the near future considering the introduction of cage fish culture in the area; hence, there is need to provide a practical and appropriate technology to improve the water quality for domestic use.

2. METHOD

The bio-fence is a simple mechanism of obtaining clean water by using crushed charcoal as a filtration medium as shown in Figure 1. The crashed charcoal forms a good habitat for predators of toxic cyanobacterial cells and degradation bacteria of microcystin. The frame of the structure was made of timbers s and a rubber sheet to seal the bottom. The both width and length of the bio-fence was 1m. Effective depth was changed by the lake water level. The minimum depth of the bio-fence was 30cm and the maximum depth was around 1m. The residence time of water flow thorough the bio-fence was around from 8 hr to 12 hr. Chl-a, TSS and microcystin were mainly measured as water quality parameters.

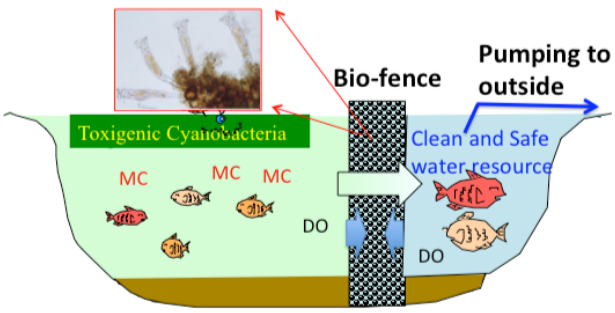

Fig. 1 Concept of Bio-fence



Fig. 2 Bio-fence Experiment at Ogal Beach

3. RESULTS

The typical results are shown in Figure 2. The transparent clean water in the water bottle was treated water from the cyanobacterial bloom water by the bio-fence. Water with green color showed the cyanobacterial contaminated water of Nyanza Gulf. The cyanobacterial bloom at Ogal Beach was mainly consisted with *Microcystis* sp.

Under optimal conditions, the biofence was effective in removing up to 94% of the harmful Microcysits from the lake water. It also removed 97% and 93% of Chlorophyll a and TSS respectively. The lowest values recorded for MC in the biofence treated water was 0.92 µg/l which is below the WHO guidelines [2] of 1 µg/l of MC in drinking water.

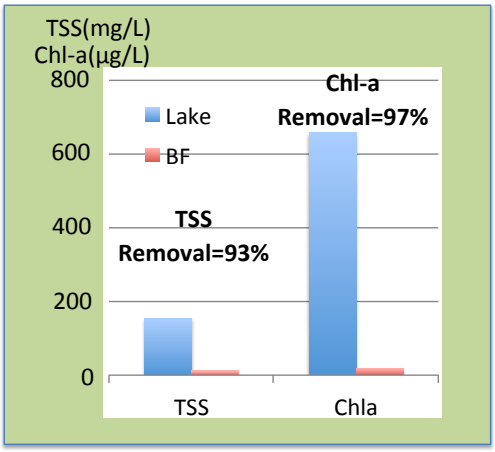

Fig. 3 TSS and Chl-a in Bio-fence treatment water and Lake water

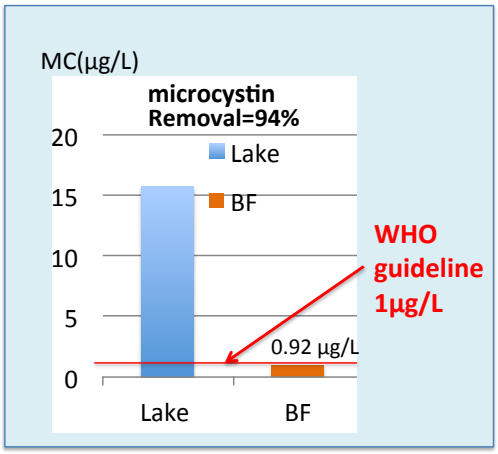

Fig. 4 Microcystin in Bio-fence treatment water and Lake water

These results showed that the water quality was drastically improved by the bio-fence system from the viewpoint of cyanotoxin contamination. However, after this good results, the water level of Ogal Beach was increased over the top surface of the bio-fence. The bio-fence couldn't purify the water. Then it didn't work well when water level was decreased until the depth of bio-fence of 30 cm.

4. DISCUSSION

The results showed the good treatment performance because it may be suitable media for the habitat of microbes which degrade cyanobacterial cells and cyanotoxin microcystin. In the previous study in Japan [3], we found the several metazoan whuch can degrade and remove toxic cyanobacterial cells in a bioreactor system for pond water treatment. Similar species could be acted on charcoal media effectively. However, the use of wood charcoal may affect the wood resource problem in Africa. Thus we will use maze charcoal (Bio-char) as media in future.

Then we have to improve the system regarding with the fluctuation of water level. A floating type bio-fence is one idea. It was succeeded in the experiment of a fishpond in Thailand. But it can be affected by the strong wave of Lake Victoria. Thus the other new idea have to be created.

5. CONCLUSION

This results showed that the biofence technology can be used a cost effective, efficient easy to operate technology for treatment of drinking water around Lake Victoria. However have to improve the bio-fence system for practical use in Lake Victoria, because we clarified several demerit of this system.

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O2-2

桜川及び千波湖における霞ヶ浦導水事業による水質改善

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キーワード:水質汚濁, アオコ, 水管理, 富栄養化, 水資源の利用・開発

抄録

水戸市を流れる桜川では、千波湖及び支川流域も含め、都市化の進展と共に生活排水の流入等による水質悪化が進み、夏季には千波湖や桜川下流においてアオコによる水面景観の悪化や悪臭が発生するなど水環境の悪化が著しく、様々な対策を講じている現状においても目標値を満足出来ない状況にあり、さらなる水質の改善が急務となっている。このような状況に対処するため、霞ヶ浦導水事業は第二期水環境改善緊急行動計画　桜川清流ルネッサンスⅡの施策の 1 つとして、桜川及び千波湖の水質浄化を図るものである。霞ヶ浦導水事業は、那珂川、霞ヶ浦及び利根川の 3 つの水域を地下トンネルで結び、それぞれの河川の水を相互に融通する流況調整河川として、霞ヶ浦及び桜川・千波湖の水質浄化、那珂川下流部及び利根川下流部の渇水時の既得用水の補給及び新たな都市用水の確保を図ることを目的とした事業であり、昭和 59 年度に工事に着手し、現在鋭意事業を進めている。

1.　はじめに

那珂川、霞ヶ浦及び利根川は、茨城県をはじめ周辺地域の水資源の安定的かつ広域的な供給等に重要な役割を果たし、流域の産業・経済の発展に寄与してきた。一方、流域の産業発展や都市化の進展によって、霞ヶ浦や水戸市を流れる桜川・千波湖では水質汚濁が進み、また那珂川・利根川では渇水時における取水制限など、様々な課題が発生するようになり、その対策として種々の取り組みがなされて、一定の効果は上げているものの、まだまだ課題解決には至っていない。

霞ヶ浦導水事業は、上流ダム群、中下流域の貯水池、湖沼開発、河口堰等とあわせ、限られた水資源を有効活用するため、流況調整河川として、流況の異なる那珂川・霞ヶ浦・利根川を地下水路で結び水のネットワークを形成するものであり、時期に応じて相互の導送水を行うことにより、河川及び湖沼の水質改善を図るとともに、それぞれの河川の流況を改善し、更に新規に都市用水を開発することを目的としている。



図 1　霞ヶ浦導水事業位置図

本報では、霞ヶ浦導水事業の目的の一つである「水質改善」について、水戸市を流れる桜川及び千波湖を対象として効果予測を報告するものである。

2.　水質汚濁の状況

桜川は、水戸市と笠間市の市境に位置する朝房山に源を発する那珂川の一次支川であり、水戸市・笠間市を流域に持つ、全長約 19km の一級河川である。上流部は笠間市の豊かな緑の中を流れ、中・下流は近年都市化の発展がめざましい水戸市の市街地を流れており、沿川には日本三名園の一つである偕楽園や千波湖などもあり、市民の貴重な憩いの場となっている。

しかし、一方で桜川は、流域の都市化の進展と共に生活排水の流入等による水質悪化が進み、夏には千波湖や桜川下流においてアオコによる水面景観の悪化や悪臭が発生するなど、親水性が損なわれており、流域住民から水環境の改善が強く望まれている。

桜川の水質は、環境基準点である駅南小橋地点では平成 10 年度から調査されており、BOD(75%値)が環境基準値の 5mg/L 前後で推移している。平成 26 年度のBOD(75%値)は 3.6mg/L であった。平成 10 年度以前から調査されている搦手橋地点のBOD(75%値)の変化をみると、下水道整備の進捗等により、平成 6 年度以降から水質が改善され、平成 26 年度のBOD(75%値)は 4.0mg/L であった。近年は環境基準値を満足する傾向にある。しかしながら、千波湖からアオコ混じりの水が桜川へ流出されることから、下流では夏季にアオコの発生が認められ、夏場における更なる水質改善

が望まれている。

千波湖の水質は、昭和 63 年に開始された渡里暫定導水によりCOD（平均値）が 28.5mg/L から 10mg/L 程度に改善された。平成 23 年度から 25 年度にかけては東日本大震災や渇水による千波湖導水量の減少によってCODがやや高くなっている。平成 26 年度のCOD（75%値）は 14.0mg/L であり、更なる水質改善が必要である。また、千波湖は、条件がそろえば、いつでもアオコが大量発生し、社会生活に影響を与える可能性がある。アオコの発生要因は滞留時間、栄養塩類、水温、日射の 4 条件であり、これらの条件が全て揃うとアオコが発生する。千波湖はアオコ発生に必要な条件が全て揃っており、夏場になれば、ほぼ毎日アオコが発生している状況にある。

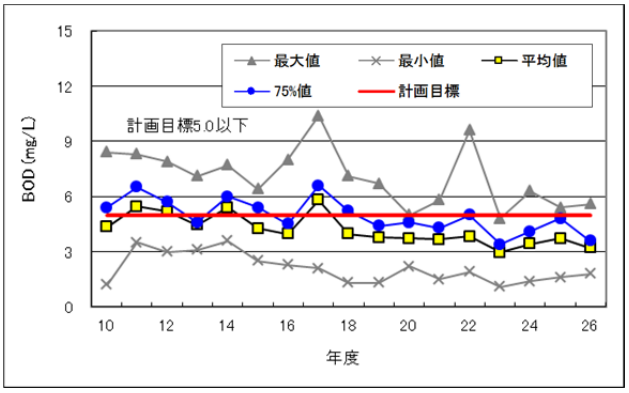

図 2　桜川（駅南小橋地点）水質経年変化

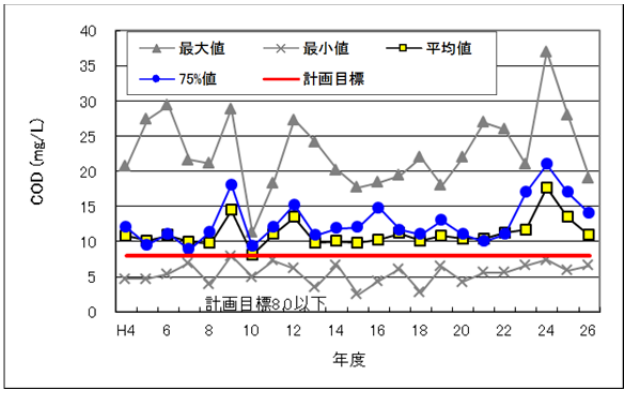

図 3　千波湖（千波湖中央地点）水質経年変化



図 4　千波湖アオコ発生状況（平成 24 年 8 月撮影）

こうした状況から、平成 19 年に策定（平成 28 年改定）した「第二期水環境改善緊急行動計画　桜川清流ルネッサンスⅡ」（以下「行動計画」という。）において、桜川・沢渡川・逆川の目標水質は、散策等の親水活動、環境基準（C類型）等を考慮して、BOD（75%値）5mg/L 以下とし、また、桜川下流については夏季のアオコ発生による水質悪化が顕著であるため、夏季においてもBOD 5mg/L 以下を目指すものとした。また、千波湖の水質目標は、アオコの発生の削減、親水活動や水戸市の水質保全計画等を考慮して、COD（75%値）8mg/L 以下とし、特に、夏季のアオコ発生による水質悪化が顕著であるため、夏季においてもCOD8mg/L 以下を目指すものとした。

3.　霞ヶ浦導水事業による水質改善

行動計画に基づく下水道の整備などの取り組みにより、桜川のBODが大きく改善するなどの水質改善の効果は現れてきているが、千波湖や桜川の下流部では依然として夏季にアオコが発生しており、さらなる水質改善が急務となっている。そこで、行動計画の水環境の改善に関する施策の 1 つとして位置付けられている霞ヶ浦導水事業の推進により、桜川及び千波湖の水質浄化を図るものである。霞ヶ浦導水路は、那珂川と霞ヶ浦とを結ぶ延長約 43km の第一導水路（那珂導水路）と霞ヶ浦と利根川とを結ぶ延長約 2.6km の第二導水路（利根導水路）から構成される総延長約 45.6km の地下トンネルである。このうち、第一導水路は水戸市渡里町地先（那珂川）から石岡市三村干拓地先（霞ヶ浦高浜沖）を経て土浦市湖北地先（霞ヶ浦土浦沖）に至り、導水管の他、那珂機場、桜機場、高浜機場及び放流口から構成され、桜川及び千波湖の水質浄化としては、那珂機場で取水した那珂川の水が導水路を流れ、桜機場から桜川へ最大毎秒 3 m³を注水するものである。



図 5　那珂川から桜川・千波湖への導水経路

4. 水質改善効果

霞ヶ浦導水事業を含む行動計画の実施による桜川及び千波湖における水質改善効果を予測するため数値シミュレーションにより予測を行った。予測方法は、河川については負荷量と河川流量を基に流達率・浄化残率を考慮した汚濁解析モデルを用い、千波湖については内部生産を考慮した富栄養化モデルを用いた。なお、水質予測モデルについては、近年の水質状況を踏まえて計算を行った。

平成 22～26 年度時点（実測値平均）において、桜川については、駅南小橋地点BOD（75%値）が 4.2mg/L、搦手橋地点BOD（75%値）が 4.1mg/L となっていることから、環境基準及び行動計画の目標値であるBOD（75%値）5mg/L 以下を満足する結果を得ているが、千波湖については、千波湖中央地点COD（75%値）が 16.0mg/L となっていることから、行動計画の目標値であるCOD（75%値）8mg/L 以下を満足できていない状況である。そのような状況に対し、行動計画を実施した場合の予測では、桜川については、駅南小橋地点BOD（75%値）で3.0mg/L、搦手橋BOD（75%値）で3.1mg/L、千波湖については、千波湖中央地点COD（75%値）で 6.7mg/L といずれも改善され、行動計画で示されている目標水質であるBOD（75%値）5mg/L 以下、また、桜川下流については夏季のアオコ発生による水質悪化が顕著であるため、夏季においてもBOD5mg/L 以下、千波湖の水質目標であるCOD8mg/L 以下、特に、夏季のアオコ発生による水質悪化が顕著であるため、夏季においてもCOD8mg/L 以下に改善という目標値を概ね達成することが出来る。[1]

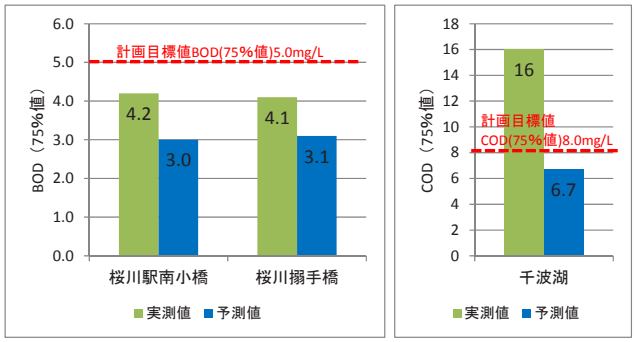

図 6 桜川・千波湖の水質予測値

さらに、アオコの発生原因の一つである滞留時間について、霞ヶ浦導水事業による那珂川から桜川への注水により、千波湖への流入量も増加し、湖水の 4～10 月上旬の平均滞留時間が約 8 日から約 4 日に短縮される。そのため、アオコに不規則な移動を強い、その微環境に変動が生じるため、アオコの増殖を抑制することが出来る。

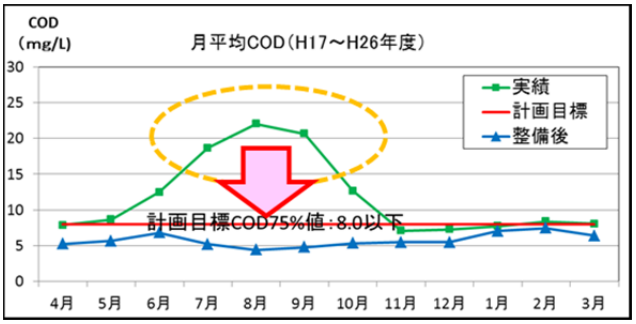

図 7 千波湖の水質予測値（月別）

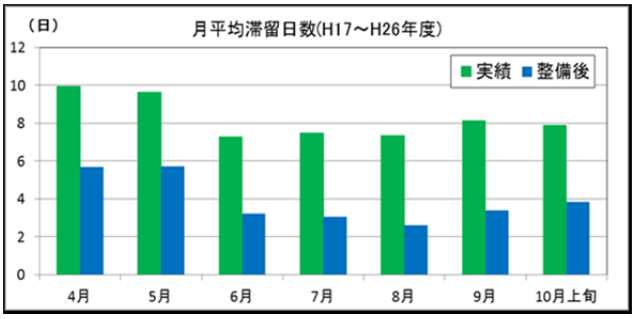

図 8 千波湖の滞留日数予測

5. おわりに

桜川及び千波湖では行動計画に掲げる水質目標値を満足するために、様々な対策を講じている現状においても未だ目標値を満足出来ない状況にある。

霞ヶ浦導水事業は、那珂川、霞ヶ浦及び利根川の 3 つの水域を地下トンネルで結び、それぞれの河川の水を相互に融通する流況調整河川として、霞ヶ浦及び桜川・千波湖の水質浄化、那珂川下流部及び利根川下流部の渇水時の既得用水の補給及び新たな都市用水の確保を図ることを目的とした事業であり、行動計画の施策の一つである。

霞ヶ浦導水事業を含む行動計画の実施により、桜川の水質目標値（環境基準値）であるBOD（75%値）5mg/L 以下を満足するとともに、桜川下流部の夏季におけるBOD5mg/L 以下も満足する。また、千波湖の水質目標値であるCOD（75%値）8mg/L 以下を満足するとともに、夏季においてもCOD8mg/L 以下に改善するという目標を概ね達成することから、多くの市民や観光客等の憩いの場である桜川・千波湖の景観維持や、アオコ悪臭問題の解決とともに、親水活動の促進に寄与するものである。

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O2-3

Assessing Threats to Transboundary Lakes and Reservoirs

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ABSTRACT

The International Lake Environment Committee (ILEC) conducted the transboundary lakes component of a global-scale assessment (TWAP) of five major transboundary water systems (lakes; rivers; groundwater; large marine ecosystems; open oceans), ranking them regarding the type and magnitude of the threats facing them. The study results highlighted that selecting different context for interpreting the significance of the threats changed the relative lake threat rankings. A sensitivity analysis changing the relative magnitude of the threats also produced differing threat rankings. The need to infuse Integrated Lake Basin Management (ILBM) within the context of the Water Resources Management (IWRM) framework also is discussed.

Keywords: basin governance; wise use and development of water resources; future scenarios of surface waters

1. INTRODUCTION

Lakes and reservoirs (terms used interchangeably herein) are fundamentally important for human health and socioeconomic development, and sustainable terrestrial and aquatic ecosystems. More than 90% of the liquid freshwater on our planet's surface exist in lakes and other lentic (pooled) water systems, collectively covering approximately 4.2 million km2 of land area (Downing et al. 2006).

Lakes possess unique characteristics making it difficult to assess their status, including a long water residence time (resulting in slow, incremental responses to environmental stresses), an integrating nature (ensuring in-lake problems cannot readily be separated) and a non-linear response to stresses (making lake behaviour unpredictable and uncontrollable).

2. METHODOLOGY

The transboundary lakes component of UNEP's Transboundary Waters Assessment Programme (TWAP) comprised 156 transboundary lakes in developing countries, plus 50 lakes in developed countries (for comparison), using GIS—based spatial analysis of NASA and other global-scale databases to identify the lakes and delineate their drainage basins (Figure 1; ILEC and UNEP 2016). Because of lack of uniform global-scale data for in-lake comparisons, their drainage basin characteristics were used to assess their potential threats, adapting the results of a global-scale study by Vörösmarty et al. (2010) on river basin human water security (HWS) and biodiversity (BD) threats.

After eliminating small lakes with sparse basin populations and/or lakes frozen for significant portions of the year, a Scenario Analysis Program (SAP) was used to calculate the relative HWS and BD threats. The SAP reduced the final study list to 53 transboundary lakes meriting most attention regarding potential management intervention needs (23 lakes in Africa; eight in Asia; nine in European region; six in South America; seven in North America; ILEC and UNEP 2016).

3. RESULTS

Based solely on one set of screening criteria (see ILEC and UNEP 2016), the top five lakes exhibiting the highest computed HWS and BD threat scores included two European (Cahul; Galilee) one North American (Falcon), and two Asian lakes (Mangla; Aras Su Qovsaginin Su Anban). The African lakes as a group generally ranked in the bottom half of the 53 study lakes.

Vörösmarty et al. (2010) also considered the ability of the

basin countries to make investments to address water threats (water supply stabilization, improved water services, etc.), producing a refined threat criterion (Adjusted Human Water Security, Adj-HWS). This refined criterion demonstrated that, even if initially exhibiting a high HWS threat rank, more economically developed countries exhibited lower Adj-HWS threats. In contrast, many developing countries lacking such resources exhibited higher Adj-HWS threats and, therefore, a greater need for management interventions. The relative threats to many African transboundary lakes increased substantially on this basis, while those of the European and North American countries decreased, with 11 of the 13 highest ranked transboundary lakes being located in Africa. The Asian Adj-HWS threat ranks also generally increased, although not the same magnitude as for Africa. Further details for interpreting the results regarding management intervention needs are provided by ILEC and UNEP (2016).

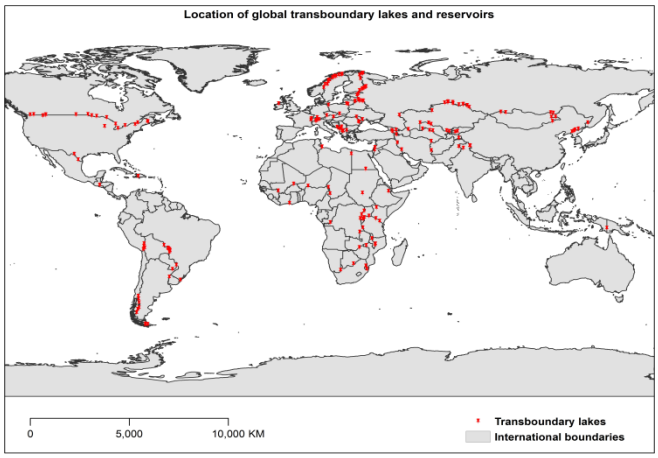

Figure 1. Global Distribution of Initial Group of Transboundary Lakes/Reservoirs in TWAP Study

Because the magnitude and significance of a lake threat(s) is a function of what a lake decisionmaker considers most important factor(s) regarding management interventions, it was also necessary to identify the appropriate context for interpreting the transboundary lake threats. Doing so involved supplemental activities, including Expert Group Meetings in Brazil, Ghana, India, Italy, Kenya, Malaysia, Mexico, Turkey and the Philippines, as well as a lake basin Questionnaire. A knowledge-based system with an extensive literature resource base, LAKES-III ("Learning Acceleration and Knowledge Enhancement System") also was developed to derive more accurate, meaningful conclusions regarding the status and potential for addressing lake threats. Used in conjunction with the SAP, it highlighted that calculated threat ranking scores can be very misleading for transboundary lake comparisons or lake management decisions unless the most important factor(s) for the user of the rankings was also considered (ILEC and UNEP 2016).

A parametric sensitivity analysis, which involved applying differing importance (weight) to the Adj-HWS and BD threats, as well using as the Human Development Index (HDI), also was undertaken, with the African transboundary study lakes continuing to exhibit the greatest threats, comprising 20 of the top 24 most threatened. The remaining four lakes comprised three South American and one Asian lake (ILEC and UNEP 2016).

The transboundary lakes analysis also provided guidance regarding the lakes most likely to benefit from Global Environment Facility (GEF)-facilitated management interventions, indicating some interventions should consider addressing multiple lake needs (e.g., Lakes Albert and Edward; Chilwa and Chiuta; Cohoha, Ihema and Rweru/Moero in Africa), while others required further evaluation of their scientific and/or political situation prior to considering interventions (e.g., Asian Lake Danbandikhan; South American Salto Grande). Still other lakes merited consideration of the larger river basins in which they were located (e.g., Cahora Bassa in African Zambezi River basin), while a large number also merited review of their current GEF status. Further details are provided in ILEC and UNEP (2016).

Integrated Lake Basin Management

Integrated Water Resources Management (IWRM) has become a widely used management approach for addressing freshwater resource issues (Global Water Partnership 2000). However, experiences within the lake scientific and management community have demonstrated 'operationalization' of IWRM principles to be difficult in many cases, including not being able to consider the unique characteristics of lakes, or their lentic (pooled)-lotic (flowing) linkages. To this end, ILEC developed an integrated management approach (Integrated Lake Basin Management, ILBM) to address the sustainable management of lakes through gradual, continuous and holistic improvement of basin governance

elements, comprising sustained efforts for integrating institutional responsibilities, policy directions, stakeholder participation, scientific and traditional knowledge, technical possibilities, and funding prospects and constraints (ILEC 2005). The conceptual ILBM framework was developed in the form of ILBM 'Platforms' for collective stakeholder actions to improve lake basin governance, thereby complementing the existing IWRM approach (Figure 2). Used in combination with the SAP and the LAKES-III knowledge-mining system, the ILBM Platform process represents a comprehensive, versatile assessment and management guidance tool for addressing transboundary water systems and related governance concerns (ILEC and UNEP 2016).

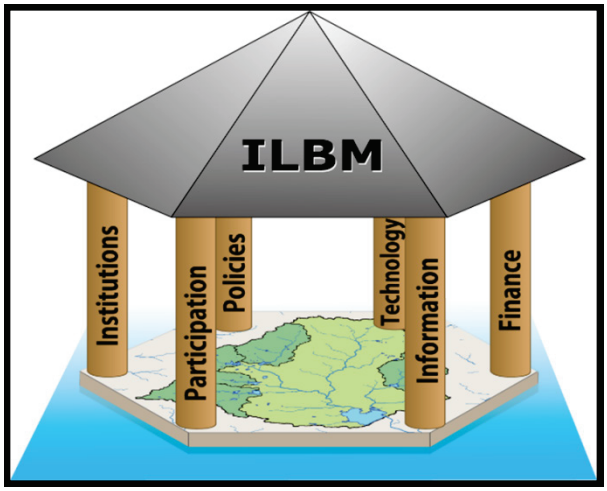

Figure 2. Overview of ILBM Governance Framework (Nakamura and Rast, 2014)

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O2-4

Sensitivity Analysis of Structure of the Stratification in Lake Biwa by Changing Meteorological Elements

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Keywords: Lake Biwa, hydrodynamic model, structure of stratification, and impacts of climate change

ABSTRACT

Climate change such as the change of air temperature and wind speed can affect the structure of the stratification in Lake Biwa. In general, the rise in air temperature and the decrease in wind speed weaken the vertical mixing, and strengthen the structure of the stratification, which interrupts the vertical transport of the substances. However, how much the change of each climate element can influence the structure of the stratification is not clarified. Therefore, it is important to distinguish the effects of each element on the stratification and evaluate them quantitatively. In the present study, we investigated the effect of the increase or decrease in air temperature and wind speed on the seasonal change of stratification in Lake Biwa by using a three-dimensional hydrodynamic model. Numerical simulations were carried out for a baseline case using realistic meteorological data from 2007 to 2011 and experimental cases using meteorological data with modified air temperature or wind speed for sensitivity analysis. The analysis showed that the increase and decrease in air temperature changed the vertical water temperature uniformly in almost all layers. The strength of the stratification hardly changed. The increase and decrease in wind speed, however, changed the structure of the stratification. The increase in wind speed made the water parcels of the surface layer well mixed, and the decrease in wind speed made the mixed layer and thermocline thinner.

1. INTRODUCTION

Some deep lakes face a lack of oxygen occurred in the deep layer during the stratified season because of the thermocline. In recent years, the dissolved oxygen has also decreased at the bottom of the northern part of Lake Biwa, the largest freshwater lake in Japan. The strength of stratification plays an important role in the change of concentration of the dissolved oxygen in the lake. The main cause of the change in stratification is weather and climate conditions such as air temperature, wind strength, and precipitation[1].

An increase in air temperature leads to the prolonged periods of stratification in lakes. In Lake Zurich, Switzerland, higher warming rates of water temperature near the lake surface (~ 0.024 K/year) and lower warming rates in the deep layer (~ 0.013 K/year) from the 1960s to the 1990s resulted in an increase of about 2-3 weeks in the duration of the summer stratification[2]. This directly affected the characteristics of the vertical mixing processes. As for the effect of wind, wind-driven currents in the surface layer provoke the movement of the lower layer, leading to the destratification. Moreover, wind also provokes the internal waves, and the breaking of the waves with large amplitudes induces vertical mixing. When severe winds associated with the passage of a typhoon blew in 1992, the depth of the thermocline rose gradually in Lake Biwa[3]. After the wind ceased, it declined suddenly more than 20 m. This movement generated waves that affected the deep layer.

In U.S. lakes and reservoirs, Butcher et al.[4] assessed the lake response to climate change by using one-dimensional model and reported that the increase in surface water temperature increases thermal resistance to vertical mixing and changes in wind could also have an important effect, with increased wind stress potentially counteracting the increase in thermal stratification.

Since the structure of the stratification changes seasonally with changes in water temperature, it is important to seasonally analyze the variation of the stratification in lakes. It is not clarified how the stratification changes due to meteorological changes throughout the entire waters in Lake Biwa.

In the present study, we investigated the effect of air temperature and wind speed on the seasonal change of stratification in Lake Biwa by using a three-dimensional hydrodynamic model. Numerical simulations were carried out for a baseline case using realistic meteorological data for validation and experimental cases using modified meteorological data for sensitivity analysis.

2. METHOD

This study utilized a three-dimensional hydrodynamic model described in detail by Koue et al.[5]. They reported that the model well simulated the vertical distribution of water temperature and the characteristics of flow field in Lake Biwa.

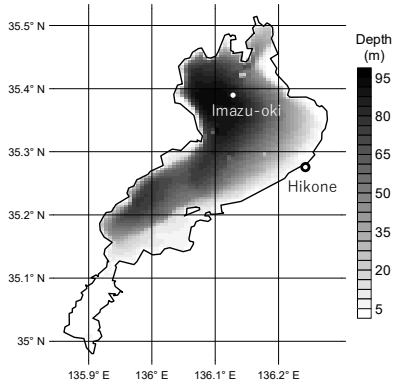


Fig. 1 Calculation domain with the topography of Lake Biwa

Fig. 1 shows the calculation domain and water depth in the hydrodynamic model of Lake Biwa. The horizontal domain is 36 km × 65.5 km with a horizontal resolution of 500 m. The vertical domain consists of 86 layers from the lake surface to the depth of 107.5 m. The vertical grid size is 0.5 m from the surface to the depth of 20 m and gradually increases up to 2.5 m.

For the initial conditions, the current velocity was set to be 0 m/s, and the water temperature was derived from linear interpolation of observed vertical profile data. The observations were conducted by the Lake Biwa Environmental Research Institute twice a month at the monitoring point in Imazu-oki (35°23'41" N, 136°07'57" E), the depth of which was 0.5 m, 5 m, 10 m, 15 m, 20 m, 30 m, 40 m, 60 m, 80 m, and approximately 90 m.

The baseline simulation (BASE) was conducted for a period from April 1st, 2006 to March 31st, 2012 including a spin-up period from April 1st, 2006 to March 31st, 2007 using meteorological data derived from Meso-Scale Model of Japan Meteorological Agency (GPV MSM). In addition, experimental simulations were conducted for the same period using meteorological data with modified air temperature and wind speed in order to investigate their effects on the stratification structure. For sensitivity analysis, the coefficient of variation (σ/μ) were obtained from the mean value (μ) and standard deviation (σ) of the annual mean air temperature and wind speed for 30 years from 1981 to 2010 at Hikone meteorological observatory (35°16'30" N., 136°14'36" E.). The coefficients $(\mu + \sigma) / \mu$, $(\mu - \sigma) / \mu$ were 1.0021, 0.9979 for air temperature and 1.04, 0.96 for wind speed. Each pseudo-weather data was created by multiplying $(\mu + \sigma) / \mu$, $(\mu - \sigma) / \mu$ by the air temperature and wind speed of GPV MSM data. The simulation cases named as AT+ (AT-) and WS+ (WS-) indicate the increase (decrease) in air temperature and wind speed, respectively.

3. RESULTS AND DISCUSSION

In this study, the mixed layer and thermocline were defined as the area that the change of water temperature was less than +0.1 K/m and the area that the one was more than +0.1 K/m, respectively. The depths of mixed layer and thermocline were calculated by averaging the values matching the middle point of observed data vertically and all horizontally. In each case, the periods from April to June, July to September, October to December, and January to March were defined as spring, summer, autumn, and winter respectively. Fig. 2 shows the mean depths of mixed layer and thermocline in the sensitivity analysis of air temperature and wind speed. Fig. 3 shows the vertical distributions of the difference of water temperature between BASE and the experimental cases.

In case of AT+, the structure of stratification changed little compared with the one in BASE. Water temperature in all layers increased almost equally (+0.2~+0.5 K), therefore, the stratification strengthened little (Fig.3 a).

In case of AT-, the 5-year mean depths of mixed layer and thermocline were shallower than those in BASE (Fig.2 a). Although the rate of decrease in water temperature in the surface layer was slightly higher than that in the bottom layer, water temperature in all layers decreased almost equally (-0.2~-0.5 K), thus, the stratification weakened just a little (Fig.3 a).

In case of WS+, the thickness of mixed layer became large in autumn (Fig.2 b). It is considered that the stratification easily collapsed so that the vertical mixing due to the wind occurred during the cooling period. The 5-year mean thicknesses of mixed layer in autumn was 1 m larger than that in BASE, and the depth of mixed layer and thermocline were also larger (Fig.2 b). The reason why the position of thermocline deepened was that due to the effect of the wind, the amplitude of internal wave was large and the effect of wind stress reached the lower layer. Furthermore, water temperature in the surface layer decreased more than that in BASE (-0.2~-0.1 K) from spring to autumn, the one near the thermocline increased (+0.4~+0.6 K) from summer to autumn, and the other one in the bottom layer increased approximately 0.1 K in all seasons (Fig.3 b). As the wind speed increased, the diffusivity increased. Thus, the vertical mixing was

promoted. In addition, the warm water parcels were transported to the lower layer. Then, the colder water parcels near the thermocline were transported to the upper layer, and the vertical mixing was promoted.

In case of WS-, the mixed layer and the thermocline became thinner than those in BASE in all seasons (Fig.2 b), and it shows that the vertical mixing due to the wind weakened. The 5-year mean thickness of mixed layer was approximately 1 m thinner, the one of thermocline was approximately 50 cm thinner and the depths of them were shallower than those in BASE. In addition, water temperature in the surface layer increased more than that in BASE (0.1 K) from spring to autumn, the one near the thermocline decreased (-0.5~-0.2 K) from summer to autumn, and the other one in the bottom layer decreased (-0.2 K) in all seasons (Fig.3 b). When the wind speed decreased, the water parcels between the surface layer and the thermocline became less mixed, and the stratification strengthened.

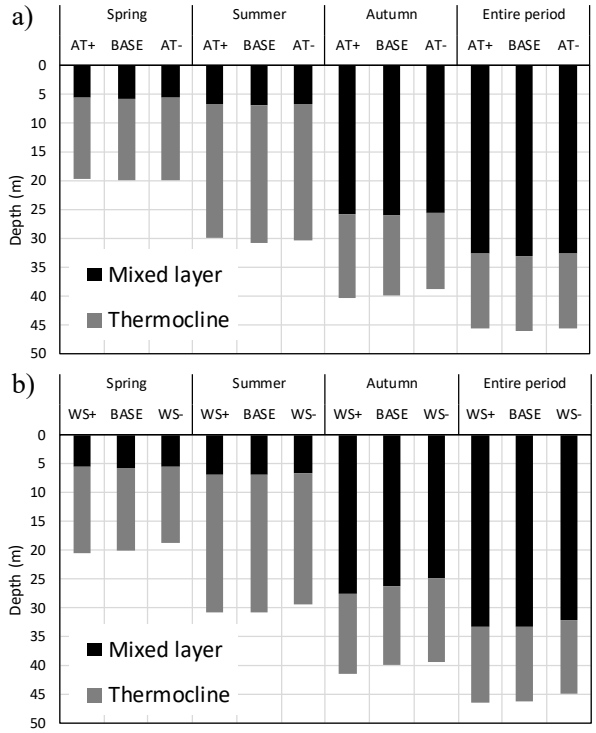
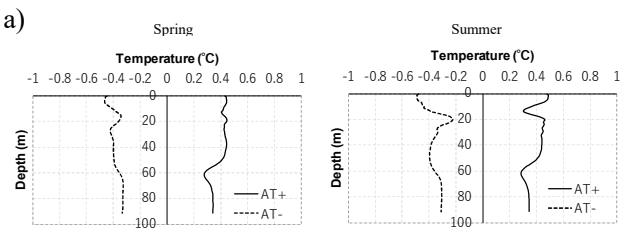


Fig.2 Average depths of mixed layer and thermocline in spring, summer, autumn, and entire simulation period for sensitivity analysis on (a) Air temperature and (b) Wind speed.



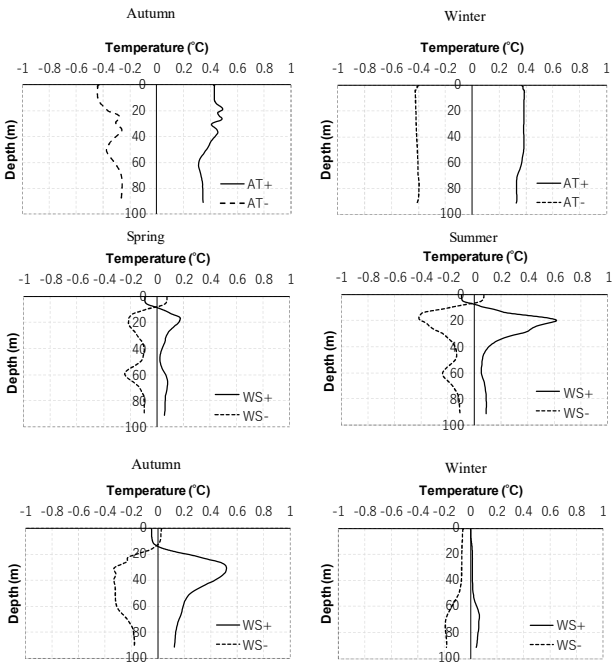


Fig. 3 Vertical distributions of difference of seasonal mean water temperature from the baseline case in a) AT+ and AT-, and b) WS+ and WS-.

4. CONCLUSION

When the air temperature increased or decreased, water temperature in all layers increased or decreased almost uniformly in all layers, therefore, the structure of stratification little changed. On the other hand, as the wind speed increased, the diffusivity increased. Thus, the vertical mixing was promoted. In addition, the warm water parcels were transported to the lower layer. Then, the colder water parcels near the thermocline were transported to the upper layer. When the wind speed decreased, the water parcels between the surface layer and the thermocline became less mixed, and the stratification strengthened. The effect of the change of wind plays an important role in the change of stratification.

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O2-5

Sustainability Challenges in Egypt under Limited and Threatened Water Resources

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Keywords: Water crises, Reuse, Water treatment

ABSTRACT

The water deficit that increases rapidly and the degradation of the irrigation network in Egypt resulted in serious irrigation problems and in higher dependence on the drainage water at tail end regions. During last decades and due to the degradation of the drainage water and the spread of the municipal water stations on the main canals, the strategy of the dependence on the drainage water has changed. The reuse has started in Egypt through mixing the drainage water with the fresh water in the main canals (official reuse). Currently, the trend changed to the direct dependence on the drainage water at the tail ends, where there is no municipal stations; either through lifting the drainage water to the tail ends of the branch canals (intermediate drainage reuse), or through direct use of the drainage water by the farmers (unofficial drainage reuse). With the operation of Grand Ethiopian Renaissance Dam, the Egyptian water resources will decrease, and this will have serious impact of the sustainability of agricultural sector. Currently, the per capita share of water is around 600 m^3/year. With the reduction of the irrigation water, the salinity of agricultural drainage water and the concentration of sewage and industrial wastes that are dumped in the drainage network will increase. In the same time, the dependence on the drainage water will increase. The situation might be critical during the coming years unless a new strategy is developed to enhance the quantitative and qualitative equity of water distribution and to ensure the sustainability.

1. INTRODUCTION

Egyptian agricultural is one of the oldest agricultural systems that remained sustainable for thousands of years. Such system is currently facing challenges with the increase of water demand in the other sectors and with the threatening of Egyptian water resources. The sustainability is also threatened due to the degradation of the irrigation network, which prevent water from reaching many tail end regions, and by the degradation of the quality of the drainage water with dumping of untreated sewage and industrial wastes in the drains. Big portion of dumped sewage and industrial wastes is untreated and the ability to treat them is limited due to the financial constraints. The attempts to improve irrigation efficiency, either through the implementation of Irrigation Improvement Projects (IIP) or through introducing new irrigation techniques had limited impact, and therefore the decrease in water resources is faced by depending on the reuse of drainage water, which contains different wastes from agricultural, sewage and industry. Some regions currently depend mainly on the drainage water to irrigate, and with the decrease of water resources, these areas will depend totally on these resources and in the same time, the quality of the drainage water will degrade significantly. Developing a strategy that could decrease the side effect of the reuse and distribute the burdens between head and tail farmers became essential. Such strategy depends on introducing simple and cheap water-treatment techniques that mitigate the pollution problem, return to the official reuse based on the quality of the drainage water, and define the suitable crops to be cultivated at different areas based on water quality.

2. Methodology

The study presented the current situation regarding the dependence on the reuse, anticipated the new situation with the reduction of water resources, and then it discussed the suggested steps to face the expected water crises. Regarding the current situation, the study presented the current deficit in water resources and the economic challenges for water treatment. Then, the study discussed the magnitude of the dependence on the drainage water, the quality of the drainage water, and the impact of using such

water on the productivity. For the anticipation of the new situation, the expectation about the reduction in the water resources will be used as the base for the discussion. The suggested strategy to face the irrigation deficit will be presented in its three steps.

3. Current situation

3.1 Limited water resources & increasing demand

Total Egyptian water resources is less than 60.0 BCM/year. River Nile is the main source (55.5 BCM/year). Other resources include the deep groundwater, the precipitation at the north shores, and tiny amount of desalination [1]. In the same time, there was a gradual increase in municipal and industrial water use. During 20 years (1990-2010), and while the population increased 50%, municipal water use increased from 3.1 BCM to 8.8 BCM (184%). Industrial water use increased during the 13 years (1997-2010), from 2.0 BCM to 4.4 BCM (120%). Based on the minister of Water Resources and Irrigation (MWRI) in Egypt, the current water deficit is around 20.0 BCM/year, and this is covered through intensive reuse. He added that our municipal requirements is increasing by 4.0 BCM each 10 years, which is a big challenge [2].

3.2 Water treatment and the economic challenge

The spread of municipal service was not associated with the sanitation service. While municipal service almost covered the whole country, the sanitation service covered only 56% of the country. Current capacity of municipal stations is 9.23 BCM/year, while the capacity of water treatment plants is 3.88 BCM/year. Considering that municipal consumption is ~20%, only 50% of the sewage is treated, and it is only primary treatment. During 2010, around 7.0 BCM of sewage returned to the system, 3.4 is primarily treated and the other are dumped without treatment [1]. The treatment of industrial wastes is limited as well. The budgeting for the agency of municipal and sanitation increased from 5.3 Billion L.E in 2015/16 to 8.3 Billion L.E in 2016/17, but this is still not enough to face the problem. The national plan for water resources until 2050 requires 900 Billion L.E, and a major part of it is water treatment [3]. Such big investments might not be available considering current economic situation in Egypt. Therefore, cheap and simple techniques should be introduced, in parallel with the current effort for water treatment.

3.3 Current dependence on the reuse

In 2010, and based on the strategic plan for 2017, total water reuse is around 14.0 BCM/year (more than 20% of irrigation water). Recently, and as stated before, the reuse is around 20.0 BCM/year. In some irrigation directorate at the tail end of the Egyptian irrigation network, the dependence on the drainage water constitutes around one third of the total water resources. In such areas, the drainage water is used directly without mixing with fresh water (intermediate drainage reuse & unofficial drainage reuse). Based on Molle et al., (2012), the intermediate drainage reuse exceeded 25% of water budget at some irrigation networks, besides big amount of unofficial drainage reuse [4]. Regarding the quality of the drainage water, and based on Satoh et al (2017), total coliforms exceeded 320 times the standard, and Ammonia exceeded 58 times the standard in some main drains [5]. The dependence on the drainage water has serious impact of the productivity, and based on different measurements, using the drainage water could reduce the productivity by 20-32% based on the crop and water quality.

4. Expected scenarios in the future

There is no confirmed number about the reduction in Egyptian water resources with the filling and the operation of the Ethiopian dam. However, many researchers / expertise expected that Egyptian water resources would be affected seriously. Based on Diab (2017), there will be a reduction of 7.5 BCM/year [6]. It is hard to split specific command area and stop cultivating it to reduce water consumption due to the spread of municipal stations along the Egyptian irrigation network until the tail end. The reduction will be partly at some branch canals or some tail end regions. These areas will try to use drainage water (or shallow groundwater), which will degrade with the reduction of water supply as explained before. If these areas can complete their requirements from drainage or shallow ground water, the consumption will be the same. Total drainage water that is dumped to the Mediterranean Sea and northern lakes will be reduced by the reduction in water resources (4.0~5.0 BCM/year). Most of the studies defined the minimum amount of the drainage water to maintain the salinity in the old land by 8.0 BCM/year, and therefore the salinity will be accumulated in the cultivated lands. If these areas could not complete their

requirements from unconventional water, there will be serious impact on productivity and salt accumulation as well. The sustainability is threaten at different scenarios, and new strategy should be developed to avoid such destination.

5. Facing the Challenge

Facing the new challenges required new strategy, which depends on three axes: introducing simple cheap techniques for water treatment, returning partially to official reuse, and introducing new cropping pattern strategy

5.1 Mitigating wastewater problem with low-cost treatment techniques and with the cooperation of civil societies

The objective of this component is to implement low cost wastewater treatment techniques with the cooperation of the non-governmental organizations. These techniques should achieve significant microbiological decontamination, offer very low O&M costs, and could mitigate the pollution in the drainage canals. Aeration and wetlands are among the suggested techniques. The role of non-governmental organizations is crucial. They should share in the construction, operation and maintenance of these techniques. The society should share in the cost through these organizations. Enhancing the capacities of these organizations and increasing the awareness about pollution problem are essential parts as well.

5.2 Partial return to official drainage reuse

With the degradation of the drainage water, many lifting stations on the main canals stopped. This cost the Egyptian water budget around 2.3 BCM/year. The main problem of the official reuse was the degradation of the drainage water with the spread of the municipal stations in the main canals. Mitigating the pollution in the drains through the previous step could give a chance for return, even partly to the official reuse. Good monitoring approach should be applied to define the amount of the lifted drainage water, based on its quality. Lifting the drainage water to the main canals decrease the burdens on tail end farmers, and enhance the chance of sustainability. Returning to official reuse might require changing the abstraction points of the municipal stations or using better technology in municipal stations for drinking water treatment.

5.3 Developing new cropping pattern strategy

The first two points decrease the burdens on tail end farmers. However, avoiding the direct dependence on the drainage water completely is very hard. The decrease of water supply will result in worse drainage water as explained before, and therefore the dependence on such drainage water should be associated with specific cautions. To avoid serious health risks, cultivating some crops should be prohibited in tail end regions. spreading of some crops, such as cotton crop, which was the famous Egyptian crop, and decreased significantly in last decades, became an important task.

6. Conclusion

Egyptian water resources is currently threatened. In the same time, water requirements will increase rapidly with the increase of the population. The gap between water supply and demand will be filled through higher dependence on unconventional water resources (drainage water and shallow groundwater) as improving water use efficiency faced different problems in Egypt. During last decades, the direct dependence on the drainage water increased with the decrease of the official drainage reuse, and the quality of the drainage water degraded with the increase of sewage and industrial wastes in it. Water treatment is the backbone of the sustainability. However, it is hard to improve water treatment rate to catch the expected reduction in water resources in coming years. Therefore, introducing cheap and quick treatment techniques, in parallel to the original water treatment, is essential. This should be associated with partial return to official drainage reuse and introducing new cropping pattern strategy to avoid any health risks.

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O2-6

Climate Action in lakes of *Haor* basin of Bangladesh

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Key words: Climate Action, Haor Basin, Adaptation, Institution, Policy

ABSTRACT

The Haor is a form of a back swamp, a bowl shaped shallow depression found in the north-east part of Bangladesh. Haor basin the second most climate change vulnerable ecosystem in Bangladesh. The people gain their livelihoods from wetland and floodplain resources. During monsoon, the whole area goes under water and there is no option in engaging earning activities except fishing. The rainfall pattern of the basin has changed and first flash flood is around two week ahead comparing with last decade. While flooding enhances floodplain fisheries, the early flashfloods, unique to this region, caused due to sudden onrush of rainwater from adjacent Indian Hills poses a high risk of damage to the standing crop just before harvesting. Data reveal that rainfalls in Meghalaya, India have increase in March and April that intensifies the severity of flashfloods. Submergible dykes to delay flashflood entry into crop fields is an action from the government. The community is diversifying the cropping. Building resilience into both human and ecological systems is the best possible way to deal with climate change risk. Climate response capacity and social acceptance build social and ecological resilience. The cross-sectoral multi-scale stakeholder engagement of the actors who influence or who are affected by the complex human-ecosystem interactions is the way towards building the social acceptance in an ecosystem. The current paper is based on observation of climate change impact and coping practices in the Haors of Moulvibazar and Sunamgang districts in the year 2017.

1. INTRODUCTION

Because of the local hazards, economy, local livelihood patters, impact of climate change and so on have made the Haor basin the second most vulnerable ecosystem after the coast. Haors, which are bowl-shaped depressions between the natural levees of a river subject to monsoon flooding every year, are mostly found in the eastern region of the country, known collectively as the Haor basin covering an area of approximately 24,500 km2. There are altogether 411 Haors comprising an area of about 8000 km2 dispersed in the districts of Sunamgonj, Sylhet, Moulvibazar, Hobigonj, Netrokona & Kishoreganj. The main hazard of Haor is flash flood. The major Constraints of Haor are; (1) Degradation of natural resources and biodiversity. (2) Natural disasters are the main reason of poverty, lack of availability of basic infrastructure and social amenities, inequity in resources acquisition and poor access to natural resources. (3) Crop damage by flash flood. (4) Declining productivity of crops. (5) Poor Market linkage and value addition.

The Haor is subject to deep monsoon flooding, supporting rich fisheries while the drier winter yields a bumper rice crop. While flooding enhances floodplain fisheries, the early flashfloods, unique to this region, caused due to sudden onrush of rainwater from adjacent Indian Hills poses a high risk of damage to the standing winter rice crop just 2/3 weeks before harvesting. Flashfloods remains the major climate risks to thousands of rice farmers in the region over years. Data reveal that rainfalls in Meghalaya, India have increase in March-April that intensifies the severity of flashfloods. Creating submergible dykes to delay or divert the entry of flashflood water into the crop fields is the only adaptation response from the government. However, there are incidents of failure of dykes almost every year and consequent losses of winter rice, the only crop in this vast basin covering 97% of the total cropped area. In 2003 over 80% of rice amounting to 0.6 million tons was completely damaged due to flashfloods [1].

2. METHOD

A number of tools were used in the study, including

1. Review of literature: Review of documents published by Government and NGO from 2010 to 2017
2. Community Consultation: 4 Consultations with fisher male and 2 with female fisher
3. Process documentation of the adaptation practice, and
4. Key Informant interview: 7 Key informants were interviewed

3. RESULTS

Climate Action on Haor:

(i) Community-Based Resource Management Project: project period was 2000-2010 and key roles were to improve participants' access to essential services and resources, to diversify their livelihood options, to empower women in a district that is remote, neglected and characterized by destructive flooding patterns, supports the transfer of water and land management rights, provides access to savings and credit services at

the village level, empowers women by addressing strategic gender needs.

(ii) Sustainable Environmental Management Programme (SEMP): prevent and reverse present trend of environmental degradation, promote sustainable development, reduce poverty, capacity strengthening at community, local and national levels.

(iii) Fourth Fisheries Project (FFP): project period was 200-2006 and major roles were to support sustainable growth in an equitable benefit distribution fashion, community based inland open-water fisheries management, development and management of coastal shrimp aquaculture, supply of equipment, transportation, and, studies for freshwater aquaculture extension and training; support to management, and assessment of ecosystems' sustainability, and, that of exotic species; institutional support, to include training, civil works, and/or equipment as needed.

(iv) Community Based Fisheries Management (CBFM)-I &II: project period was 2001-2007 and prime objectives were to ease the growing fishing pressure and stop fishing during the breeding season, usually for a three-month period – April to June each year, to establish fish sanctuaries where no fishing is allowed.

(v) Costal and Wetland Biodiversity Management Project (CWBMP): had been implanted since 2006 in the Ecological Critical Areas (ECAs), viz., Sonadia island, St. Martin's island and Teknaf peninsula and in Hakaluki haor, main objectives were to ensure the conservation and sustainable use of globally significant coastal biodiversity through management of ECAs,

(vi) Aquatic Ecosystem through Community Husbandry (MACH): project period was 1998-2008 and it included all floodplain resources (fish, plants, wildlife), support entire resource users (poorer fishers, farmers, landless labourers, women, local elites & govt. officials), two groups at each region of the sites, federation for Resource Users Groups and Resource Management Organization..

(vi) Integrated Floodplain Management (IFM): significant use of RNRSS and other natural resources research outputs for the benefit (direct/ in-direct) of poor men and women in diverse contexts, test, demonstrate and assess adaptive learning networks for co-production of knowledge, identify lessons and processes involving CBOs, generate comparisons between floodplain environments which are expected to improve understanding of generic lessons and issues of context specific organizational development and performance.

Sectoral Adaptations in Haor

Potential adaptation strategies exist for all sectors which can also be implemented as community based adaptation projects to address future risks:

Agriculture Sector

- Diversification of crop agriculture is a key approach in addressing climate change, but requires research on appropriate varieties for the new physical, social and climate conditions. Diversification should be coupled with the revitalization of local varieties that have a greater resilience to extreme climate events.
- Household and community assets can be reinforced through alternative livelihood options such as homestead gardening, horticulture, floating gardens and handicraft production. Increasing assets and diversifying livelihood options are key components in ensuring that communities are able to adapt to meet the challenges that climate change brings.
- Information on pest control and methods to protect winter Vegetables from extreme cold and fog needs to be disseminated
- Seeds banks can be established to ensure that varieties remain available following disaster periods.
- Awareness raising on strategies for building adaptive capacity and the implications of climate change amongst local level non-government organizations, agricultural extension officers, block supervisor of Department of Agricultural Extension (DAE), and farmers.

Housing and Settlement

- Flood risk can be alleviated through building raised house plinths for the homes of affected people.
- Homestead plantations can protect settlements from flood and erosion.
- Raising water pumps so that flood water does not contaminate drinking water.

Rivers

- Dredging of river beds combats increased sedimentation, thereby improving navigability.
- Increasing vegetative coverage along river banks protects against erosion resulting from increased flow and flooding.

Enabling Environment: Policy, Strategy Institutional Support

The success of any adaptation strategy will depend to a large extent on the proactive organizational environment as well as policy and institutional set-up.

- The services necessary to support capacity strengthening may be tailored according to the gaps and needs identified through 'knowledge management' and 'proper communication' activities in respective scope of work.
- Multi-stakeholder national coordination committees may be required, chaired by a 'national level authority' with sufficiently empowered to influence over macro policy formulation, planning

and implementation of risk reduction and adaptation initiatives within and among the Sectors.

- Basic framework should centre around existing government structures (institutions) through providing necessary technical assistance in order to build sufficient capacity through technology transfer to deal with Disaster Risk Reduction, and Climate Change and Adaptation matters, and to reflect the later in all development activities.
- Revisiting the roles and functions of existing institutions to have necessary adjustment/ revision towards response implementation' to disaster and Climate Change impacts should be the key strategy. This should be done in a harmonized way through the high powered multi-sect oral national level coordination mechanism.

4. Discussion

The Government of Bangladesh considers climate change as a development concern and is committed to take urgent and long term actions to reduce the vulnerability of its people and risks to national development. [2] Crop agriculture in Bangladesh is highly susceptible to variations in the climate system. It is anticipated that crop production would be extremely vulnerable under climate change scenarios, and as a result, food security of the country will be at risk. Despite being highly vulnerable, very little efforts have so far been made to understand potential of agricultural adaptation in Bangladesh [3]. Haor produces around 8% of the crops of the country. It is reported that the existing institutions had inherent inefficiencies, lack of foresight in planning for the future, poor coordination among relevant institutions, poor information assimilation capacity and lack of trained and motivated personnel [4]. As a result, those often proved to be ineffective. The central government could not successfully utilize the full potential of the local government and the latter could not assume the full responsibility of implementing local-level planning due to weaknesses in governance system. This made it difficult to implement development activities at the grassroots. All these are possible barriers to successful adaptation, which might have direct implications in agricultural sector.

The effort, experience and lessons in implementing and operationalizing the integration process need to be shared within organizations as well as between different organizations and agencies participating in the integration process. Development of Tools, Methods, Techniques, etc. may be required to facilitate awareness raising training and technical support change in operational practice, measuring progress and learning and experience sharing among the institutions and professionals involved throughout the processes.

5. Conclusion and Way forward

Adaptation to climate change at community level is considered as spontaneous or planned actions, modification, changes in behaviors, attitudes and practices in the way people struggle to maintain or improve their well-being and security owing to global warming and climate change, through formal and informal institutions. This includes a range of approaches currently practiced in the development and climate discourse, including community based adaptation, community led adaptation, community based disaster preparedness, disaster risk reduction, village and community development, sustainable livelihoods for communities/ households/ families, etc. It should be noted that each case where communities adapt successfully to address climatic risks provides useful lessons on how they engage and participate in assessing vulnerability, decide and plan to take actions, and implement those actions to reduce vulnerability and increase resilience. To make community based adaptation approach to be successful, a core pre-requisite is community participation. Another important pre-condition is that the adaptation required at the community level is considered as a part of on-going local development processes and actions, not as an isolated, ad-hoc or externally driven action. In Haor basin of Bangladesh as the water sources in upstream water governance and trans-boundary cooperation is also important.

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O2-7

The Lake Fund of Russian Federation, Spatial Heterogeneity and Established Trends

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Keywords: water resources, lake fund, lake water, federal districts

ABSTRACT

The results of estimation of the Russian Federation (RF) lake fund, carried out according to an original methodology involving modern satellite information, are presented. According to the assessment, ~3,900,000 water bodies of various origins are identified within the RF, the water resources of the water bodies of natural origin are estimated at ~25,910 km^3 of water, of which 91% is in Lake Baikal. In the artificial water bodies the reserves of waters are about 890 km^3. In spite of the huge lake water resources, their spatial distribution is extremely uneven and is weakly coordinated with the location of the population and industrial and agricultural production. The scarcity of water resources in the economically developed regions is usually overcome by the active construction of artificial reservoirs, which, as the analysis shows, is often accompanied by a decrease in the areas of natural water bodies. Quantitative changes in the lake fund are still localized. At the same time, the downward trend in natural water bodies fund in the most developed parts of the country is quite clear and can be intensified by climate change.

1. INTRODUCTION

The Russian Federation is one of the world's most well-endowed with water resources country. Along with the rapidly renewable water resources estimated at 4,322 km^3/year [1], the country has huge reserves of lake waters. At the same time, insufficient attention is paid to the assessment of lake waters, classified as static stocks. Due to their easy availability, lake waters are intensively exploited, which is affects both in their quality and volume. Changes in the lake fund occur due to anthropogenic factors and due to climate change. The work on the estimation of the Russian lake fund was carried out at the Institute of Limnology, Russian Academy of Sciences and includes calculation of the total number of water bodies, total water surface areas and total lake water volume [2]. Along with water resources, contained in natural water bodies, the resources of waters contained in artificial reservoirs were calculated.

2. METHOD

The assessment of the Russian Federation's lake fund was carried out on the basis of a specially developed methodology [3] based on a detailed accounting of the areas of water bodies, data on which were obtained from current satellite images, and on a subsequent calculation of the volumes of waters with due regard given to the mean depths of the water bodies. Mosaic of satellite images for various seasons and years (from 2003 to 2015) was used for determining the areas. This suggests that the obtained total areas of the water surface with respect to any significant territory can be taken for averaged value for the beginning of the 21st century.

During the work, a complete assessment of the water surface area of the lakes, the areas of which exceeded 1 km^2 (or 0.2 km^2 - with low lake coverage of a particular region), was made. This allowed to form an extensive base of modern morphometric characteristics of Russian lakes. For all water bodies, the values of water volumes were determined taking into account their mean depths, which for the morphometrically studied lakes are the measured characteristics whereas for morphometrically unexplored lakes the depths were determined on the basis of regional dependences [4], which characterize the relationship between different morphometric parameters of lake pans.

Morphometry of water bodies of a smaller area due to their huge quantity was estimated using the method of "sampling squares". Essentially, the method implies that the characteristics obtained in a detailed assessment of the water surface area in the “sampling squares” are used as representative analogues and are transferred to the remaining part of the explored area. The procedure assumed the hypothesis of a normal distribution of the characteristics of small water bodies throughout the territory. The number and size of the squares were determined depending on the area of a constituent entity; they were built in a staggered pattern and covered

about one-eighth of this area. As a result, the areas for all water bodies falling into squares which identified on space images from an observation altitude of ~2 km were digitized and calculated. In contrast to the first group of lakes for which volumetric characteristics were obtained for each particular entity, the total water surface and mean values averaged over the territory were used for small water bodies in the transition from area characteristics to water volumes. Homogeneity of the territory, its orographic features, the origin of the lakes and it`s belonging to one or another category of size was taken into account when carrying out averaging.

3. RESULTS & DISCUSSION

According to the assessment, ~3,800,000 water bodies of natural origins (including ~1,370,000 lakes with the area of >1 ha) and ~100,000 of artificial ones are identified within the RF. The total surface water area of the natural water bodies is ~335,000 km^2 (including lakes with saline water ~20,000 km^2) and of the artificial ones is ~65,000 km^2. These values were averaged using the images of the beginning of the 21st century, and they are characterized by intra-annual and long-term variations which are most significant in the zone of insufficient humidification as well as in the northern flat regions. The water resources of the water bodies of natural origins are estimated at ~ 25,910 km^3 (~55 km^3 are characterized by increased mineralization) and of artificial ones at 890 km^3.

The main quantity of lakes of the RF is located within the northern territories characterized by a low population, as well as Western Siberia, including its southern part, located in the zone of unstable and insufficient moistening. The Urals District has the largest number of lakes among the federal districts (FD) of the RF, this district accounts for slightly less than half of all water bodies that are decoded on satellite imagery, but their main part is characterized by small dimensions. The Far East, Northwest and Siberia FD are also characterized by significant number of lakes, with the share of medium and large lakes for each of them higher than for the Urals.

Since the main masses of water are concentrated in large and deep water bodies, the Siberian FD is characterized by the greatest resources of lake waters (24,636 km^3), even after deduction of the lake Baikal (234,615 km^3) more than 1020 km^3 of water is contained in Siberian lakes and reservoirs. Comparable stocks of lake water are observed only in the Northwest FD (see Table). In the lakes of the Far Eastern FD there are 276 km^3 of water, while in artificial reservoirs there are ~ 144 km^3. At the same time, despite the highest lakes numbers in the Ural FD, the total volume of its waters is only 118 km^3. The Central, Volga, South and North-Caucasus FD, within which more than half of the country's population live, and in which production of more than half of GNP falls on their joint share, are characterized by the least number of water bodies, even taking into account ponds and reservoirs. The lakes of these four districts contain only ~ 13.6 km^3 of water, including ~ 10 km^3 of fresh water.

Table. Distribution of lake water resources by federal districts of the Russian Federation

Federal district	Total volume of water (lakes and reservoirs), km^3	Mean lake percentage, %
Northwest	1 386	4.98
Central	39.7	1.42
Volga	130	1.86
South	57.4	2.65
North Caucasus	6.16	0.70
Ural	118	3.94
Siberia	24 636	2.07
Far East	420	1.53

Analysis of regional data indicates a weak coherence of the total number of water bodies in comparison with the total area of the water surface and water resources. That is, the high lake content of the territory is not yet an indicator of significant water resources. Within the Asian part of the RF, about 98% of the lake waters are concentrated in its mountainous part, at the same time, only 6% of the total number of water bodies are located here. The values of the total water surface (or mean lake percentage, as its specific index) calculated for different territorial formations along with the general water resources give a clear view of the distribution of the lake fund. Wherein mean lake percentage reflects the possibilities of the formation and continued existence of lakes in these physical and geographical conditions, but it may weakly reflect general water reserves, and the amount of water resources is primarily determined by the presence of large and deep lakes and is virtually independent of the total number of water bodies within the explored area. Despite the significant country's lake water resources, their spatial distribution is weakly coordinated with the centers of population distribution, industrial and agricultural production. The water reserves of many most in need regions is quite low.

Assessment of water resources of the lakes of Russia was accompanied by an analysis of quantitative changes in the lake fund during the 20th century. Changes occurred in two main directions: the number of creating artificial reservoirs increased, but at the same time a gradual reduction in the fund of natural water bodies took place, primarily in the most developed areas of the country.

Because of the construction of artificial reservoirs, the total reserve of water available for use has been increased in the country since the beginning of the 20th century by 890 km^3. Water reserves of the most demanding regions were significantly increased. In the early twentieth century 99% of the lake waters of the European part of Russia (EPR) were in the lakes of the North and North-West. To date, as a result of hydroconstruction the volume of fresh water in the central and southern parts of the EPR has increased 22 times (up to 220 km^3) and their total share has increased up to 15%.

At the same time, the analysis of modern lakes characteristics indicates significant changes that have occurred with the fund of natural water. Substantial area reduction of some lakes and its completely disappearance were revealed for the most economically developed regions of the country. It is most noticeable in the south and in central parts of the Russian Plain. For a number of river basins the disappearance of small water bodies is up to 20% and more. A significant reduction in the lake areas occurred in the lower reaches of the Volga, and the area of the western substeppe ilmens is most seriously affected, as the result of changes that occurred after the regulation of the Volga. During the period from the 1960s till the present the total water surface area of the water bodies exceeding 1 km^2 decreased in this region by more than 40%.

With the continuing pattern of land use and economic activity, the reduction in the lake fund can be up to ~ 10% in the central part of the ECHR and up to 20% in the southern part by the middle of the 21st century. At the same time, the state of the majority of lake ecosystems will remain ecologically extremely unfavorable in these regions.

Certain changes are also observed in a number of regions of Russian Asia. However, it is difficult to identify stable trends here based only on accumulated observational data. For areas of unsustainable and inadequate moistening, there are significant changes in the volume of lake water, both during the year and in the multi-year section. These changes are determined by the alternation of the watering phases caused by the intra-century fluctuations in climatic characteristics. Only in some cases it is possible to track a clear trend of changes in the area of lakes and associate it with anthropogenic activity. In comparison with the center and south of the EPR, the environmental situation in Russian Asia is generally more favorable, but it is significantly deteriorating in years of low water availability, when the majority of negative processes on lakes are sharply exacerbated. The climate change can significantly affect the deterioration of the current situation. Decrease the amount of precipitation will lead to a reduction in water flow from the catchment areas, which will lead to a general decrease in lake water supplies and aggravation of environmental problems. Along with the disturbances in the natural hydrological regime, climatic changes will also affect the hydrochemical regime of lakes, the water salinity will increase with a decrease in the inflow, and an increase in temperature will lead to activation of eutrophication processes.

4. CONCLUSION

The assessment of the RF lake fund has shown a significant spatial heterogeneity in the distribution of lake water resources across the country and their poor consistency with the distribution of the population and industrial production. A decrease of the lake fund in the regions of the main economic activity was revealed, moreover, further reductions can be expected in the coming decades.

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O2-8

Paper title : Integrated Management Approach of Selangor Dam and Ex-Mining Pond to Mitigate El-Nino Effect on Water Resources in Selangor, Malaysia

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Keywords: ex-mining ponds, Sungai Selangor Dam, water quality

ABSTRACT

Sungai Selangor Dam is among of seven dams in Selangor State together with ex-mining ponds located along Selangor River which are gazetted as Protected Zone under Section 48, Selangor Water Management Authority (SWMA) Enactment 1999. Management of the dam is inclusive of impounding water body and water catchment area to ensure the water resource security. Both dams and ex-mining ponds are functioning as water supply to the nearest Water Treatment Plant. Sungai Selangor Dam have been established in the basin to regulate the river flow and ensure sufficient amount of water is available to all even during dry seasons. LUAS monitor the water quality as well as water level and report regularly to the State of Selangor. Water resource from the ex-mining ponds are utilized by pumping from the ponds to the Selangor River. The total capacity that can be abstracted from the ponds is 1,000 million litres per day (MLD). The utilization of the ponds has been proven to reduce the dependency on the release of water from Selangor River Dam thus can increase the storage life of the dam. Weekly monitoring of the water quality from the ponds is also implemented to ensure that the raw water quality meets the Malaysian National Raw Water Quality Standard. Other initiative undertaken by the SWMA is the cloud seeding operation over the catchment areas of the 7 dams in the state of Selangor inclusive of Selangor River Dam. The cloud seeding operation is conducted daily depending on the meteorological conditions to increase the possibility and intensity of rainfall thus increasing the storage of the dams.

1. INTRODUCTION

SWMA is a one stop agency for water resource management in Selangor State of Malaysia. Selangor River Basin plays a very important role in water supply, accounting for about 60% of total water supply for Selangor, Wilayah Persekutuan Kuala Lumpur and Putrajaya.

2. SELANGOR RIVER AND WATERBODIES

Selangor State has seven water supply dams in total and more than 10 ex-mining ponds located along the Selangor River (Fig. 1). The Sungai Selangor Dam which is located at the most upstream of the rivers and all the ex-mining ponds have been gazetted as Protected Zone under Section 48, Selangor Water Management Authority (SWMA) Enactment 1999[1].

Management of the dam is inclusive of impounding water body and water catchment area to ensure the water resource security. Both dams and ex-mining ponds are currently functioning as water supply to the nearest Water Treatment Plant. Sungai Selangor Dam have been established in the basin to regulate the river flow and ensure sufficient amount of water is available to all even during dry seasons. El Nino phenomenon involving scorching heat conditions and long drought have been threatening the water resources throughout the country including Selangor. One such phenomenon was reported in 2014 in Malaysia of which dry conditions lasted from February to August and led to substantial drop in dam water level. To ensure management of the water, LUAS continuously monitor the water quality as well as water level and report regularly to the State of Selangor.

Water resource from the ex-mining ponds are utilized by pumping from the ponds to the Selangor River. The water abstraction is regulated and the total capacity that can be abstracted from the ponds is set at 1,000 million litres per day (MLD). The utilization of the ponds has been proven to reduce the dependency on the release of water from Selangor River Dam thus can increase the storage life of the dam. Weekly monitoring of the water quality from the

ponds is also implemented to ensure that the raw water quality meets the Malaysian National Raw Water Quality Standard.

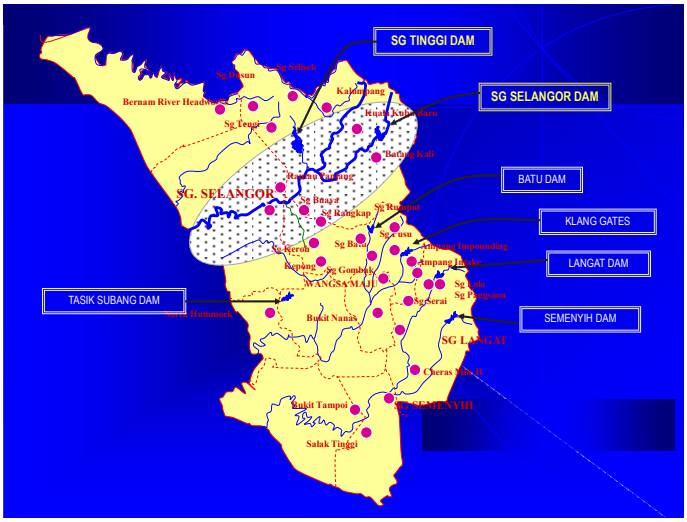

Fig. 1 Dams in Selangor

3. CLOUD SEEDING OPERATIONS

Another initiative that is undertaken by the Selangor Waters Management Authority (SWMA) during El Nino condition is the cloud seeding operation over the catchment areas of the seven dams in the state of Selangor inclusive of Selangor River Dam. The cloud seeding operation is conducted daily depending on the meteorological conditions to increase the possibility and intensity of rainfall thus increasing the storage of the dams.

4. CONCLUSION

Various initiatives that have being carried out is a commitment that sufficient water resources in the State of Selangor can be secured through efficient management of water resources.

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O2-9

Impact of LULC Change on Hydrological Response in Lake Maninjau Catchment Area

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Keywords: Land use change, Lake Maninjau, Hydrological Response, SWAT model

ABSTRACT

Lake Maninjau belongs to the type of volcanic lake in the form of caldera lake. Its eruption spouted 220-250 km^3 of volcanic herb spread over 75 km from the center of the eruption. This lake has a very small ratio of watershed and lake, where Maninjau watershed reaches 13,260 Ha and lake surface area 9,737.5 ha. Currently the water quality of the lake is decreasing due to the development of floating cage in the lake, but the change of land use in the catchment should also be considered, which can lead to changes in lake hydrological conditions. Based on classification on Landsat-8 Satellite image. Land use is dominated by agricultural area of 5,355.4 ha (37.8%); residential area of 216.9 ha (1.53%); forest area of 6,737 ha (47.4%); and the shrub and open area of 1,861 ha (13.1%). Land use changes may impact the hydrological characteristic such as water yield, surface runoff and base flow. The purpose of this study is to analyze the impact of land use changes on hydrological response in Lake Maninjau Catchment Area. SWAT hydrology model was used to assess the impact of land use changes from 1991 to 2018. The analysis of land change shows a reduction of forest area by 2.2%, 1.1% agriculture and 0.3% settlement increase. The SWAT model simulation results under land use conditions 1991 and 2018 showed the addition of surface runoff from 54 mm/year to 55 mm/year. While base flow is reduced from 406 mm/year to 334 mm/year.

1. INTRODUCTION

Lake Maninjau (0º 19' S, 100º 12' E) is volcano-tectonic lake situated in Agam District with altitude 461.50 m above sea level. The lake has an area of about 9.737,5 ha and catchment area 24.800 ha. The utilization of lake is for power plants that produce an average annual energy of 205 Giga watt hours (GWh), source of irrigation water, fish cultivation in floating cages, and as tourism destination. Based on rainfall data from 1984 to 2000 showed the monthly rainfall pattern that relatively uniform over the year, with average monthly rainfall of 299 mm and annual rainfall averaging 3.661 mm [1].

Currently, the water quality of the lake is decreased with the increasing number of floating cages in Lake Maninjau. This condition can lead to changes in lake hydrological conditions and reduce the ecological function of the lake. However, there is another factor to consider, which is a land use change. Land use change is very influential on the decline of water availability [2].

The existence of anthropogenic activity around the lake can contribute in lowering the environmental quality of Lake waters such as: disposal of domestic waste, hotels, restaurants, agriculture and fish feces produced from floating net cultivation. It is estimated that the total amount of organic waste entering the lake from residential area is around 209.93 kg /day or 75,574 kg/yr, while from KJA's fishing activities is 111,889.84 tons (from 2001-2013) [3].

Sensitivity and carrying capacity of the hydrological system as a result of land use change can be done in three stages: (i) the development of land use change scenarios; (ii) hydrology simulation; and (iii) evaluation of the impact of hydrological variations produced water resources system. These steps include aspects of the development and management as well as assess the performance of the system due to disasters such as floods and drought, the operation of reservoirs, channels, water quality, and environmental issues [2]. Analysis approach in the study of the hydrological system is a cornerstone of information theory to integrate the components of a watershed system into hydrological models [4].

The purpose of this study is to analyze the impact of land use changes on the hydrological response in Lake Maninjau Catchment Area.

2. METHOD

SWAT is a continuous model that simulated the hydrological cycle in two main parts, namely; land phase and routing phase. The land phase of the hydrologic cycle controls the amount of water, sediment, nutrients, and pesticides into the main channel. While the search phase

of the hydrologic cycle to simulate the movement of water, sediment, through a network of channels in the watershed to the outlet point. In the process of setting up and running the model input file with SWAT required a series of stages [5]. The first step is to delineate watersheds and sub-watersheds using the data DEM (Digital Elevation Model). After that, we define and enter the file of Hydrology Response Unit (HRU). Fig 1 shows a schematic framework SWAT models.

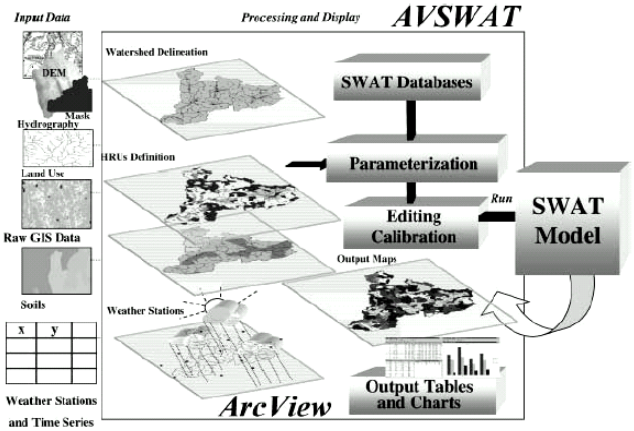

Fig 1. Schematic system of SWAT model

Analysis of the impact of land use change on the hydrological response is done by simulating the SWAT on different land use condition. Remote sensing method was used for satellite image classification. This study uses three series land use obtained from Landsat imagery, 1991 and 2018. Land use classes used in hydrologic modeling using eight categories SWAT model simulation results satellite image classification so that the natural adjustments HRU process definition, To compare the model output for each input map different land use needs to be done the same formation watershed characteristics through the process of Automatic Watershed Delineation.

3. RESULTS

Based on classification on the Landsat-8 Satellite image, Lake Maninjau Catchment area is a densely populated area with moderate land use changes. Land use is dominated by forest area of 6.375 ha (45%); Agriculture (including paddy field) of 2.322 ha (1.53%); and the settlement area of 283,5 (2%). Fig 2 shows the land use of Maninjau lake Catchment area.

The results of the analysis of land use changes over the 27-years (1991 to 2018) showed decreased of forest area (132 ha) and agricultural by 767 ha, while settlements over that time increased by 202 ha. Table 1 shows land use changes from 1991 to 2018 in detail.

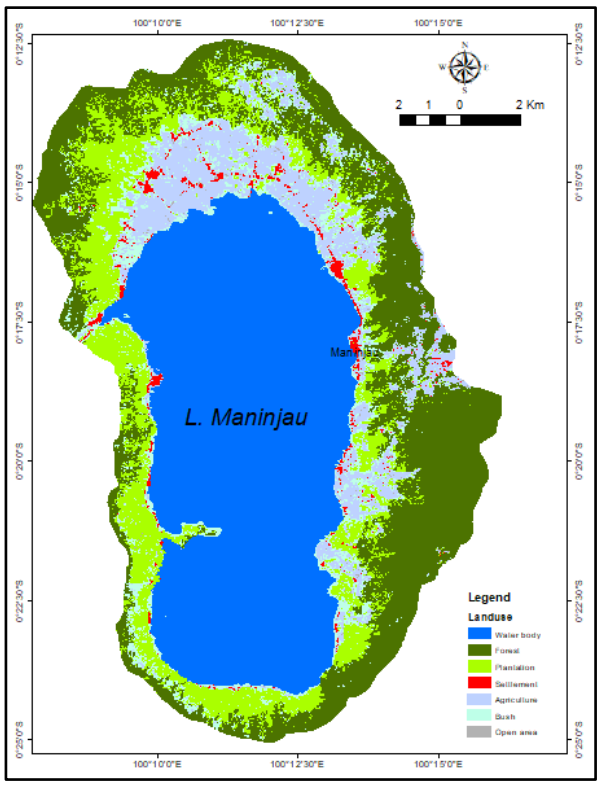

Fig 2.Landuse map of Maninjau Catchment Area (2018)

The results of the analysis of land use changes over the 27-years (1991 to 2018) showed decreased of forest area (132 ha) and agricultural by 767 ha, while settlements over that time increased by 202 ha. Table 1 shows land use changes from 1991 to 2018 in detail.

Table 1. Land use change in Lake Maninjau Catchment Area

Land use	1991		2018	
	Area (Ha)	%	Area (Ha)	%
Forest	6507.4	46.2	6375.0	45.3
Agriculture	3089.0	21.9	2322.0	16.1
Plantation	2821.1	20.0	3347.5	23.8
Settlement	81.5	0.6	283.5	2.0
Bush	1575.8	11.2	1679.2	11.9
Open area	2.1	0.0	50.7	0.4
Total	14,076.9	100.0	14,057.9	100.0

To get the impact of land use change on the hydrological response both land use conditions were simulated with the SWAT hydrology model, the simulation used the climate data measured in the weather station. The calibration and validation of the model are still in process so that the simulation results in two conditions compared to the magnitude of the parameters; surface flow, base flow and

water yield. The model simulation results are shown in Fig. 3 which is a river inlet flowing into Lake Maninjau. This result is still in the process of calibration and validation.

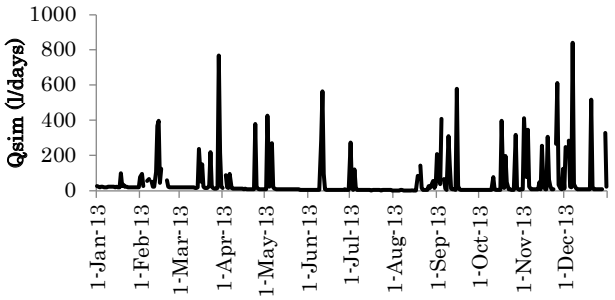

Fig 3. Discharge in river inlet

Simulation results show a 65% rise in surface flow, up from 247 mm/ year to 409 mm/year, while base flow drops by 17% from 406 mm/year to 334 mm/ year. As a result of changes in land use also resulted in a decrease in water yield of 51 mm/ year.

4. DISCUSSION

Maninjau Lake is a volcano-tectonic lake that has a wide ratio of the water body and catchment area. Therefore the water balance is essential in the processes that occur in the lake and is very sensitive to nutrient input due to the retention time of 25 years. Changes in land use will affect not only the water balance but also the nutrients flowed into the lake. Nutrients entering the lake will further trigger algal blooming events in Lake Maninjau. SWAT model can be used to calculate water balance and the loading of sediments and nutrients entering the lake, with this scenario as well as sediment loading and nutrient loading scenarios can be built.

5. CONCLUSION

For 27 years there has been a change of land use in the form of forest conversion, agriculture and the addition of large settlements in the catchment area. Consequently, there is a change in the water balance cycle such as runoff (65%), decreased base flow (15%) and water yield (51 mm /year).

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O2-10

Sustainable Development of Local community through Lake Economy

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Keywords: Economy, lake, Sustainability, Pollution

ABSTRACT

The Importance of Lakes. Healthy lakes and their shores not only provide us with a number of environmental benefits, but they influence our quality of life and they strengthen our economy. Lakes can also be used as a water supply for industry and an irrigation source for agriculture. We can consider Lake as fresh water resource. All great civilization in the human history flourished alongside lake or rivers. This was because of availability of fresh water easily for daily activities, and fertile land available for agriculture. India's huge water resources have helped in sustaining the agricultural output necessary to support a huge population.

1. INTRODUCTION

Lakes are one of the main drivers of tourism industry to strengthen local economy in all over the world. In India, river ganga is a huge source of religious tourism. In the mountain stretches, rivers serve as means for adventure sports. India has a large number of beautiful lakes and great rivers spread all over the country from Kashmir to Kerala and from Rajasthan to Assam. Lakes in India can be dividing as manmade as well as natural, further natural lake again divided as freshwater lake and brackish water lakes. Indira Sagar reservoir the big lake is the biggest reservoir in India and The Sambhar Salt Lake is India's largest inland Salt Lake. Most of the lakes in India are fresh water lakes, Dal Lake in Kashmir and Sasthamkotta Lake in Kerala are the example of freshwater lakes. These water bodies on the land surface are one of the most beautiful tourist attractions in India. Key word: Economy, Lake, Sustainability Pollution.

Economic sustainability of community through Lake Ecosystem development. Anyone who lives on, plays in, or otherwise appreciates lakes values them. But what are they worth? And should that worth only be determined for the lake's value to humans? In today's society, there is an undeniable "paradox of lake values."

We take lakes for granted in much the same way that Garret Hardin wrote in his famous 1968 essay, "The Tragedy of the Commons." Hardin referred to the village green of Colonial America on which folks grazed their horses and livestock when they came into town. Over time, the overuse of this shared limited resource resulted in its degradation, even though it was clearly in no one's interest for this to happen. Public lakes, as we now use and manage them, are a modern-day tragedy of the commons.

The economic importance of lakes is presumed to be high but is difficult to assess. What is the value of clean water? What would you be willing to pay to enjoy the peace and tranquillity of a quiet lakeshore or to take your child fishing? The "willingness to pay" has long been used to place economic importance in nature. But is this enough? If a polluter damages your lake, how much should the fine be? Courts follow the "law of economic waste" in which environmental damages are limited to the value of reduced property values. So what is the economic importance of a lake for sustainable development? Willingness to pay for lake water quality has not been observed across the Indian State.

A 2012 study conducted by SEERAM, in Maharashtra state India, reported that assessed residential property value was 60 to 65 percent higher than other part of the country with similar size and characteristics but without as many lakes. The study concluded that the increase in property values, and thus tax revenue, was due to the lakes.

Clearly, lakes have economical value and clear lakes have more value than turbid lakes. But these values are all based on Rupees and kind to humans. Are there not intrinsic values to lakes? A recent article (http://www.time.com/time/business/article/) quoted Pavan Sukhdev, a senior banker with Deutsche Bank and Special Advisor to the United Nations Environment Programmer's (UNEP) Green Economy Initiative as saying, "Biodiversity is the living capital of the planet." Currently, "the economic value attached to nature is zero. Our metrics are geared toward consumption and

production of man-made goods and services, and we tend to gloss over nature." This, he says, has led to "bad accounting," which, in turn, has contributed to rapid biodiversity loss.

What kind of value are we talking about? According to the UNEP study, an annual investment of $45 billion to biodiversity conservation worldwide could safeguard about $5 trillion in ecosystem services – a benefit to cost ratio of 100 to 1. Just how "ecosystem" nourish us?

Healthy Ecosystem of the Lakes can be the sure sustainable way to survive. Local population can obtain lots of benefit from ecosystems. These include provisioning such as food, water, timber, and fiber; regulating activities that affect climate, floods, disease, wastes, and water quality; cultural activities that provide recreational, aesthetic, and spiritual benefits; and supporting to soil formation, photosynthesis, and nutrient cycling. In eutrophic Lake, especially in the various parts of India is rapidly decreasing, the historic loss of ecosystem outcome (soil stability, nutrient sinks, sustainable shorelines, etc.) due to human development of the lake's watershed has been costly. Lake water quality has been degraded by a multitude of human activities influencing water and nutrient flows. Addressing the eutrophication of Lake could be realized by preserving and restoring environmental assets at the watershed scale. For example, if pre-settlement landscapes could be re-created, they would provide, on an annual basis, between $300 million and $2.1 billion of ecosystem outcome, and between $40 million and $1.1 billion worth of carbon offsets in the emissions market as per ecosystem financial expert. This is three times the current value of Lake Ecosystems economic.

Table No. 01:

Contextual Relevance	Ecosystem Service	Description – Function
Water Quantity and Quality - Lake Eutrophication	Water Regulation	Regulation of water flows, which entrains pollutants and purifies water – Regulating.
	Water Supply	Filtering, retention, and storage of fresh water – Provisioning.
	Erosion control	Maintains arable land and prevents water silting by lowering soil losses by wind and and sediment retention and runoff – Regulating.
	Waste Treatment	Removal, breakdown, or abatement of pollutants – Regulating.
Climate Change	Atmospheric Regulation	Regulation of atmospheric compositions by various processes such as carbon sequestration – Regulating.
	Climate Regulation	Influence of land covers on climate (temperature, precipitation, etc.) – Regulating.
Biodiversity	Biological Control	Control of populations, pests, and diseases through trophic-dynamic processes – Regulating.
	Habitat/Refugia	Suitable living space for species to evolve and breed – Supporting.
Material Benefits	Food Production	The conversion of solar energy into edible plants and animals suitable for human consumption – Provisioning.
	Raw Materials	Conversion of solar energy into materials suitable for construction – Provisioning.
	Genetic Resources	Genetic evolution in plants and animals – Provisioning.
Social Well-being	Disturbance Prevention	Dampening of environmental disturbances such as storm protection and flood prevention – Regulating.
	Recreation	Opportunities for recreation, relaxation, and refreshment – Cultural.
	Cultural	Spiritual, religious, historical, and symbolic values – Cultural.
Environmental Integrity	Soil Formation	Rock weathering and organic matter accumulation leading to the formation of productive soils – Supporting.
	Nutrient Cycling	Storage processing and acquisition of nutrients within the biosphere – Supporting.
	Pollination	Movement of plant genes for reproduction – Supporting.

Source: Voora and Venema (2008)

While some of these ecosystem services may seem esoteric.

3. CONCLUSION: As you can see, the value of our lakes can be measured by more than lakefront property values, tax bases, or fishing license revenue.

Lakes provide value for sustainable development to all community, whether that community lives on them or never even visit them. Quantifying and valuing ecosystem services losses or gains provides an economic rationale for the preservation and restoration of environmental assets.

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O2-11

Effect of soil type, slope and land use change on sediment yields in Tonle Sap Lake basins

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Keywords: sediment yield, soil type, slope, land use change, Tonle Sap Lake

ABSTRACT

Environmental factors such as soil type, slope and land use type are considered to have significant impact on sediment erosion and production in the river basin. Understanding their effects on sediment erosion and sedimentary process is crucially important in sediment erosion management and control. These effects of environmental factors have not been investigated in distributed and quantitative manner in river basins in Southeast Asia. Therefore, this study aims to assess the effect of shifting of environmental factors affecting sediment loads using a physical-based sediment model. A distributed hydrological model was coupled with a process-based distributed model describing soil erosion, sedimentary processes at hillslope units and channels. Model was then applied in two rivers, Chinit River and Sen River, that its tributaries of the Tonle Sap Lake basin located in central of Cambodia. The calibrated model was applied to assess the effect of soil type, slope (<0.2%, 0.2-2%, 2-5%, >5%), and land use change from 2000–2014 on the sediment load. River basins which have just only one soil type or lower slope (<0.2%, 0.2-2%) river basins tend to produce about 5 times higher sediment loads compared to some kinds of soil type or have a higher slope (2-5%, >5%). Changing in land use, specifically forest cover decreasing about 15%, resulted in increase of sediment load in all rivers (about 15%). The findings are useful for soil and land use management, agricultural practices and environmental management in the Tonle Sap Lake basin. The findings are also, in many cases, be likely extended to other river basins around the world which have similar environmental conditions or serve as useful cases for comparison with different environmental conditions.

1. INTRODUCTION

Erosion and sedimentation refer to the processes of erosion, transportation, and deposition which have been active throughout geological time and have shaped the present landscape of our world[1]. However, due to rapid increasing human activities, these processes are now progressing rapidly and leads to environmental damage through sedimentation, pollution and increased flooding [2][3]. Especially, soil erosion is serious environmental problem that human society is facing, as every year at global scale almost 10 ha of cropland are lost due to soil erosion[4]. Effective management of sediment in river is becoming increasingly important from an economic, social and environmental perspective[2]. One of the effective tools in the management of sediment is using sediment model to describe the sediment dynamics and to predict the changing in sediment loads due to Environmental factors and human activities. Environmental factors such as soil type, slope/elevation and land use type are considered to have significant impact on the sediment erosion and production in the river basin. Understanding their effects on the sediment erosion and sedimentary process is crucially important in sediment erosion management and control. In addition, in Tonle Sap Lake basins, sediment erosion is progressively increased and eventually leads to not only environmental damage through sedimentation, pollution and increased flooding but also to our human life due to environmental conditions of river basins (slope/elevation, soil type and land cover) and land use change by human activities (e.g. deforestation for agricultural land). These effects of environmental factors have not been investigated in distributed and quantitative manner in river basins in Southeast Asia. Therefore, this study aims to assess the effect of shifting of environmental factors affecting sediment loads using a physical-based sediment model.

2. METHOD

(2.1) Study area

The study area is Tonle Sap Lake (TSL) basin located in the central of Cambodia. The watershed extends over 43% ($85{,}786 km^2$) of the national land[5] and has 11 tributaries.

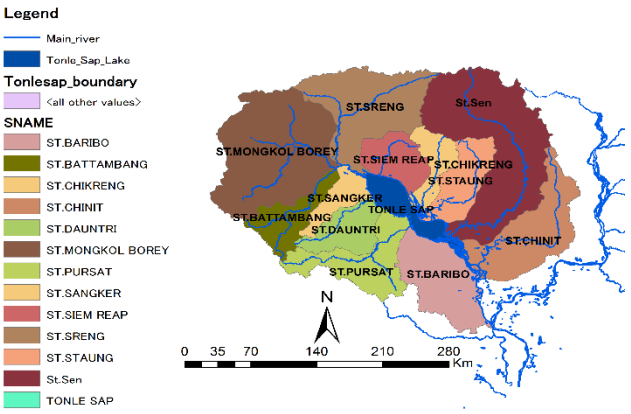

Fig. 1 Tonle Sap Lake basins

Tonle Sap area has a tropical monsoon climate and can form two distinct seasons, rainy and dry season. Rainy season from May to October, maximum and minimum mean daily temperatures in this season are 32.7ºC and 24.6ºC respectively. Mean total rainfall is 1222 mm in rainy season, which is around 75% of the whole annual rainfall. Dry season lasts from early November to March. Maximum and minimum mean daily temperatures are 32.40ºC and 23.1ºC respectively and the mean total rainfall is 411.3 mm is this season. In different seasons, relative humidity in TSL area changes from 65-70% in January to 85-90% in August. Annual evaporation is around 2,000 mm, monthly evaporation ranges from 240 mm in April to 150 mm in September [6].

(2.2) Geomorphology based hydrological model (GBHM)

We applied the distributed geomorphology based hydrological model (GBHM) that was developed by Yang et al. (2002). It solves the continuity, momentum, and energy equations using two modules: hillslope module and river routing module. Further details are described by YANG et al. (2002). GBHM was coupled with a process-based distributed sediment transport model describing soil erosion and sedimentary processes at hillslope units and channels and applied in 2 rivers of the Tonle Sap Lake basin. The input data for the model include weather data, topography data, soil properties and land cover. Shuttle Radar Topography Mission (SRTM) DEM of 90 m resolution was downloaded from http://gdex.cr.usgs.gov/gdex/ (Farr et al., 2007) was used to delineate the Tonle Sap Lake Basin. The land cover of year 2000 and soil type for the basin were obtained from Global Land Cover and the FAO soil map of the world (FAO, 2003), respectively. The elevation data was first converted to 900 m by 900 m resolution was used also to calculate the slope (in %). The Nash–Sutcliffe efficiency (NSE) was used to evaluate the agreement between the simulated and observed suspended sediment loads. The simulation showed a good agreement with the observed suspended sediment load in both rivers. NSE ranged 0.42–0.51 and 0.44–0.63 for calibration and validation, respectively[7].

(2.3) Effect of soil type, slope and land use change on sediment yields

Environmental factors such as soil type, slope and land use type are considered to have significant impact on the sediment erosion and production in the river basin. Their effects on the sediment load were calculated as:

$$Y_i = P_i \times SSL_j$$

where Y_i is the specific sediment yield of the i effects (e.g. soil type, slope) in ton/km^2, P_i is the proportion of the i effects in %, and SSL_j is the specific sediment load in the basin j calculated as the division of the annual sediment load by basin area (ton/km^2). In addition, the effect of land cover change (2000-2014) was analyzed by comparing the annual sediment load between the land use 2000 and 2014.

3. RESULTS

(3.1) Effect of soil type

Acrisol yielded the highest sediment load (18.07±13.5 ton/km^2) followed by Luvisol (14.88ton/km^2), Nitsol (12.16±14.08 ton/km^2), Gleysol (4.23±3.28 ton/km^2), Lithosols (1.3 ton/km^2), Vertisol (1.02 ton/km^2) and Fluvisol (0.39 ton/km^2) (Fig. 2).

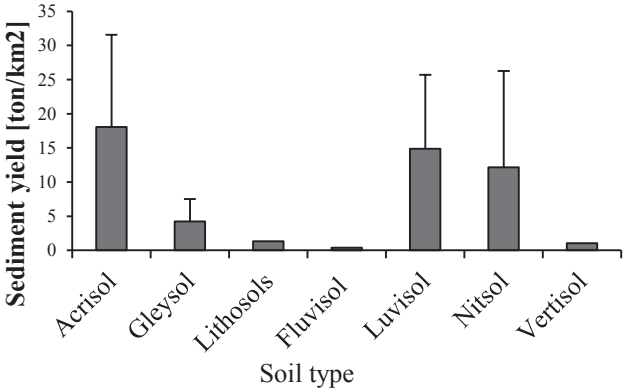

Fig. 2 The average sediment yield of each type of soil in the whole Tonle Sap Lake basin

(3.2) Effect of slope

The slope of less than 0.2% yielded the highest sediment load (13.17±10.63ton/km^2) followed by 0.2–2% (10.51± 7.14ton/km^2), 2–5% (2.83±3.75ton/km^2) and The slope of

greater than 5% (2.57±4 ton/km^2) (Fig. 3).

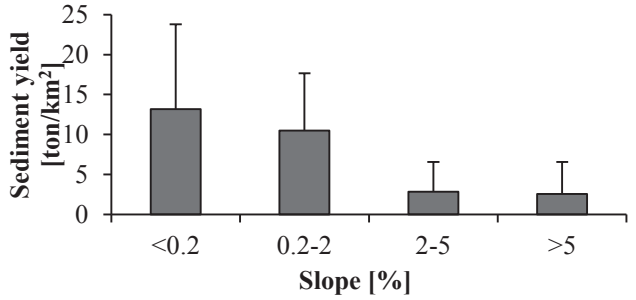

Fig. 3 The average sediment yield in different range of slope

(3.3) Effect of land use change

Due to the decreased of forest cover between the year of 2000 (26%) and 2014 (11%), the average sediment yield was 15.22 ±7.33 ton/km^2, and 18.26±9.38 ton/km^2 in 2000 and 2014, respectively, in the whole Tonle Sap Lake basin (Fig. 4).

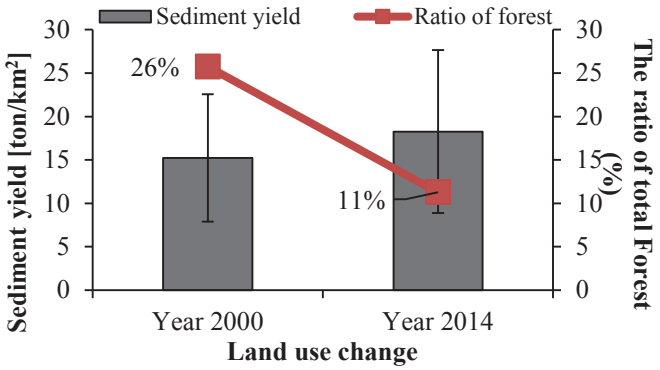

Fig. 4 The average sediment yield of each land use

4. DISCUSSION

Acrisol (67.9%), Luvisol (7.8%) and Nitsol (12.1%) soil showed the highest yield of sediment load compared to other soil type. These soil types are the important source of sediment erosion and sedimentation. Especially, Acrisol is high erosivity because of its low structural stability. Moreover, the topography in Tonle Sap Lake is relatively flat. Thus, the dominant slope ranged between 0–5%, in which the slope of less than 0.2% and 0.2–2% showed similar yield of sediment load while the slope greater than 2% showed significantly smaller. Furthermore, changing in land use, specifically forest cover, resulted in increase of sediment load in all rivers (about 15%) in the Tonle Sap Lake basin between 2000 and 2014. One of the reasons is because of the ratio of forest cover dropped from 26% to 11% resulting higher in sediment. Especially, the ratio of agriculture land is 42% in Siem Reap river catchment and 56% in south area of Cambodia including Dautri river and Pursat river catchment. From previous papers, the area dominated by Acrisol is easier to progress soil erosion but the erosivity has relationship with sediment size and shape in small catchments of central-south China and the Silesian Beskidy [7][8]. One of high erosivity area is Michigan in United States, and around this area human activities progress rapidly so land use change should be caused and the important factor of thinking about sediment dynamics[9].

5. CONCLUSION

The study assesed the effect of environmental factors affecting sediment loads using a physical-based sediment model. The environmental factors such as soil type, slope and land use change showed different effects respectively. Especially, the most important factor is land use change because the differences obviously were found. Soil type and slope doesn't change so much in short period, but at only 10 years sediment yield increases certainly. Human activities and recent development are the potential causes the increased in sediment yields in the basin.

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O2-12

The Effects of Climate Change to the Major Surface Water Resources and Treatment Facilities in the Western Part of Metropolitan Manila, Philippines

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Keywords: effects of climate change, water quality, effects of sediment, hypoxia, and eutrophication

ABSTRACT

From the recent years, the Philippines already experienced the effects of climate change such as facing numerous typhoons with record-breaking amounts of rainfall and severe drought in some areas. However, direct impacts of climate change to the major surface water resources, specifically in the country's capital city, are seldom being discussed. Hence, this proposal will talk about the current scenarios of Metro Manila's two major water sources, Angat Dam and Laguna Lake, and how climate change will affect the water quality as well as the current setups of water treatment facilities. Currently, Maynilad, the company tasked to deliver water in the western part of Metropolitan, Philippines, is investing an estimated amount of at least USD 135M to provide safe and potable water to over 9 million customers. Upgradation of plants requires both minor and major changes on its treatment processes. Some of the solutions are specific to the process train that would directly treat a certain parameter that was considered in the design but has to be updated due to the effects of climate change. These water quality parameters include turbidity, total suspended solids (TSS), manganese (Mn), taste-and-odor (T&O) and total dissolved solids (TDS), among others. Previous actions to lessen the effects of climate change were quite successful. But since climate change seemed to be "normal" globally, Maynilad opted to address the challenge through long-term solutions.

1. INTRODUCTION

For the past decades, the Philippines experienced the effects of climate change through El Nino and La Nina phenomenon. The Philippines ranked as one of the most affected countries by extreme weather events last 2013 and placed 5th for the countries affected most in the period 1994-2013[1]. The country also faced major drought years which were associated with El Nino events. According to the Philippine Atmospheric, Geophysical and Astronomical Services Administration (PAGASA) in the Philippines, El Nino could affect the normal rainfall pattern that generally leads to precipitation reduction. Aside from extreme heating and rainfall events, the country is also exposed to other risks brought by climate change such as sea level rise, disturbed water budget, and increasing ocean temperature [2].

Consequently, the risks mentioned by Department of Environment and Natural Resources (DENR) affect different sectors such as water resources, forestry, agriculture, coastal resources and health [3]. For the water resources, the effects of climate change are classified into four categories: increased precipitation intensity, decreased water flows, greater precipitation variability and sea level rise [4].

In the West Zone of Metropolitan Manila, there are two major surface water sources: (i) Angat Dam and (ii) Laguna Lake. For many years, the former has been the only water source for the majority of the customers. However, due to the increase in demand, Maynilad Water Services, Inc. (Maynilad) opted to use the lake as an additional raw water supply for the customers last 2009. Since then, the water treatment facilities of the company experienced different effects of climate change through variations on water quality parameters.

This paper aims to discuss how climate change affects surface water resources, the current setups of treatment plants and how these facilities will adapt on the inevitable impacts of climate change to provide an uninterruptible potable water supply to the customers.

2. METHOD

Sampling and analyses of physical and chemical parameters are done more frequently due to the unpredictability of raw water quality. Turbidity and total dissolved solids (TDS) are measured through the methods of turbidimetric and electrometric, respectively. Mn content was analyzed as described by the principal equipment manufacturers [5]. Procedures from the Standard Methods of Water and Wastewater are followed to analyze the threshold odor number (TON) and

biological counts of the samples [6]. TON analysis is completed thrice while biological analysis is accomplished once a day.

3. RESULTS AND DISCUSSION

Since 2010, the three water treatment facilities of Maynilad utilized raw water from Angat Dam and Laguna Lake. The La Mesa Treatment Plants 1 and 2 (LMTP1 and LMTP2) are using the former while Putatan Water Treatment Plant 1 (PWTP1) is extracting water from the latter. There were annual patterns observed for some water quality parameters that might be connected to climate change due to its occurrences and extreme values.

A. Turbidity and Total Suspended Solids

For Ipo Dam, the diversion dam after Angat, turbidity and suspended solids are expected to increase during southwest monsoon that usually occurs from April to October each year. While for Laguna Lake, turbidity is expected to increase during northeast monsoon which takes place from around September until April of next year. To treat turbidity and suspended solids, LMTP1 used sedimentation; LMTP2 is equipped with pulsation-clarification while PWTP1 has dissolved air flotation. It was observed that these three plants efficiently removed suspended solids whenever the raw values were within the design limits. But last August 2012, the average turbidity from Ipo Dam increased to almost 830 NTU with a maximum value of 1,836 NTU that retained for at least one hour. This maximum turbidity is almost 5 times higher than the design. Consequently, the volume produced by the treatment facilities at La Mesa was decreased to almost 25-35% of their capacity. Hence, the customers were also affected.

For Laguna Lake, the turbidity at the intake of the plant is starting to increase to a value higher than the design, lately. But due to the established operational procedures such as scheduled cleaning of dissolved air flotation (DAF) tanks and sludge extraction, the plant could still produce water, accordingly.

B. Manganese

Manganese is one of the most common metals in Earth's crust which is also occurring with iron [7]. It is also one of the concern parameters in other water treatment plants because it may discolor the product water once chlorinated.

For Maynilad's treatment facilities, high values of manganese can happen seasonally or on a daily basis. Due to high temperatures brought by El Nino, the Angat Dam might not be able to get enough to replenish the water consumed by the people. In addition, excessive temperature may also hasten evaporation rates in water resources. Hence, water with high levels of dissolved contaminants like manganese will be the remaining source for water treatment plants. As mentioned by (Van Benschoten et al. 1992), the soluble form of manganese is the most stable specie under reducing conditions like ground waters and the bottom parts of stratified lakes and reservoirs.

Maynilad experienced the first recorded high manganese at Angat Dam last 1998. This led to discoloration of product water after chlorination. Since then, it was observed that high dissolved manganese could occur whenever Angat level reaches below 180 m during El Nino.

On the other hand, manganese contents from the intake of PWTP1 might not be related to climate change only since these might also came from anthropogenic activities. Aside from domestic water supply, the lake is also being used for other purposes such as irrigation, aquaculture, power generation, and cooling water in surrounding industries, retention basin for flood control and a sink for treated and untreated waste [9].

C. Taste and Odor

Monitoring of taste-and-odor producing algae in PWTP1 Intake started last 2011 due to incidents and complaints related to water with objectionable odor. According to customers, the odor was musty and/ or grassy. However, there was no apparent trend on their appearances except during summer and/ or northeast monsoon seasons. Aside from these, there were also factors that could contribute to algal bloom that were seen such as long dry spell, low water level, high insolation and high contents of nutrients.

Based on 7-year monitoring data, the dominant algal species every T&O events were anacystis, anabaena and microcystis. Furthermore, it was also observed that at least 200 counts/mL of T&O algae could result to TON of 2.6. The event last June 2015 seemed to be different as the total count of algae analyzed was almost 4,000 counts/mL. Consequently, plant production was reduced to 70million liters per day (MLD).

D. Total Dissolved Solids

The problem on high TDS happened more often on Laguna Lake. This is because the lake is connected to Manila Bay through the 27 km Pasig River. Interaction between these two bodies of water took place when the lake level is lower than Manila Bay. It was observed previously that the TDS value can increase if the intake level of the plant is lower than 11m.

The highest TDS value occurred last 2014. As a result, the plant production was also reduced to 35% of its

designed capacity in order to produce water that was compliant to the drinking standards.

E. Current and Long-Term Solutions

At the moment, Maynilad already imposed solutions to solve these past episodes on water quality brought by unpredictable weather conditions. But please take note that most of the implemented solutions were not considered in the original designs of the treatment plants. To solve discoloration due to high dissolved manganese from Angat Dam, Maynilad opted to upgrade and construct potassium permanganate and sodium hydroxide dosing facilities for LMTP1 and LMTP2. The project was amounted to be almost USD 327,000. By having these facilities, LMTP1and LMTP2 were able to treat the raw water with high amounts of dissolved manganese every severe El Nino episodes. A quick reference guide was also established to optimize chemical consumption.

Previously, one of the strategies of LMTP1 and LMTP2 was to reduce plant production just to treat turbidity values greater than what were designed. But since high turbidity values seemed to occur more frequently these past five years and the facilities must still produce enough water during these spikes, the company decided to invest an estimated amount of USD 135M to improve the existing processes. These upgradation projects would include but not limited to improvement of clarifiers, modification of sedimentation tanks, replacement of existing equipment, upgrading of sludge extraction system, construction of new sludge treatment facility and replacement of filter media. But since this is an on-going capital expenditure (CAPEX) project, the realization of these improvements will be seen during the project process proving period. Some of the expected results that are process-related would be: (i) ensure compliance with Philippine standards and achieve 1,500MLD treated water production at 2,000 NTU, (ii) to effectively manage sludge and (iii) to reduce plant operational costs. In addition, existing laboratory procedures should also be updated based on these improvements, accordingly.

For the T&O challenge at PWTP1, Maynilad invested at least USD 77,000 during the 18-day incident last December 2016. The cost only includes the powdered activated carbon (PAC) applied in the raw water to reduce TON. The cost of temporary dosing facility was excluded to this amount since some of the equipment used already existed in the plant. Currently, the PAC dosing facility is temporary and as need basis of application. Exploration for the permanent strategy to solve T&O, such as ozonation, is currently ongoing.

Lastly, solving the problem connected to high TDS involved construction of additional 20MLD reverse osmosis (RO) system in PWTP1 which is amounting to at least USD 2.89M. Though there was an existing 30MLD RO system at PWTP1, recent events dictated that the current RO facility would not be able to produce enough water volume based on the raw water TDS level. Hence, the company decided to add 20MLD RO system to ensure more than 130MLD product water despite high TDS raw water values.

4. CONCLUSION

Effects of climate change in different sectors like the water industry seemed to be normal based on what is happening in the Philippines these past few years. Hence, private companies such as Maynilad opted to invest on high-costs projects. This is to continue their commitments to the public despite unpredictability of raw water sources in terms of water quality. This scenario should also be expected by other industries especially the ones that are dependent on natural resources.

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TS3-1

The interactions between eutrophication, damming and climate change on the role of inland aquatic systems in the global carbon cycle

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ABSTRACT

Lakes and rivers of the world are subjected to multiple and simultaneous environmental changes. How these changes have already affected the greenhouse gas footprint of lakes is largely unknown and even less can be predicted for the future. In this paper, we will use intermediate climate change scenarios from the IPCC as well as projected human population growth to assess their likely combined effects of GHG emissions. For the Asia-Oceania region, our simulations suggest that inland waters will respond to these environmental pressures with substantial increases in GHG emissions, in particular for methane (about 60%). The role of lakes on the global C cycle is therefore changing and constitute an additional source of GHG to the atmosphere.

1. Introduction

Lakes and rivers of the world emit naturally large amounts of greenhouse gases (CO_2 and CH_4) to the atmosphere with the latest current estimate exceeding 3.5 Pg C yr-1 (Drake et al. 2018). This figure is a significant component of the global carbon cycle and corresponds to about a third of annual anthropogenic emissions (fossil fuel and land use change, Le Quéré et al. 2016). As such the exact magnitude of the inland water emission is not critical as it is part of the natural cycling of organic carbon derived from terrestrial primary productivity. However, its magnitude is already known to be sufficiently large such that any changes to these emissions resulting from other anthropogenic perturbations could significantly enhance (or decrease) the role played by inland waters in the global carbon budget.

At the local scale, the main environmental factors known to affect lake GHG emissions are temperature (Rasilo et al 2014, Yvon-Durocher et al. 2014), trophic status (Delsontro et al. 2017, 2018) and DOC concentration (Lapierre et al. 2015), all of which are strongly modulated by lake size (Roehm et al. 2009, Rasilo et al. 2014) with small lakes having larger emission rates per unit area. Many of these factors are known to be changing globally as a result of other perturbations and the largest threats from a global carbon footprint perspective are eutrophication and climate change. For example, increase in population density and fertilizer use has led to greater nutrient loadings to lakes and eutrophication. Similarly, climate change has already increased surface water temperatures (O'Reilly et al. 2014) and is expected to continue albeit at different rates depending on the particular scenarios of anthropogenic GHG emissions. However, the possibility of interaction between these factors and their geographic distribution has not been to date clearly explored.

In addition to natural lakes, a large number of impoundments have been created (ICOLD, Lehner et al. 2011) totaling about 350,000 km^2 (Prairie et al., in prep) and a boom in the construction of dams is currently underway (Zarfl et al. 2014).

In this paper, I explore the likely combined consequences of eutrophication and climate change on the carbon footprint of both lakes and reservoirs in a spatially explicit analysis. Our results suggest that on a 2050 horizon, the GWP exerted by inland water emissions will have increased by about 30% relative to year 2000.

2. Effect of climate change on lake surface temperature

Lakes warm mostly by absorbing direct solar radiation but they lose heat through exchange with the atmosphere. Thus, the air temperature above lakes is a useful proxy of the minimum lake surface temperature and, over intermediate time scales, corresponds roughly to the average temperature (Tofollon et al. 2014). This is useful to estimate how climate change is likely to further enhance surface water temperature and, in turn, GHG emissions.

Using the global inland water distribution of Feng et al.

(2015) for waterbodies larger than 0.5 ha and the intermediate climate predictions of the IPCC (CCMS4, scenario 4.5), we derived the distribution the lake surfaces subjected to various degrees of warming. Focusing on the Asia-Oceania region, we can see that large parts of China and India are very rich in surface water (Fig.1).

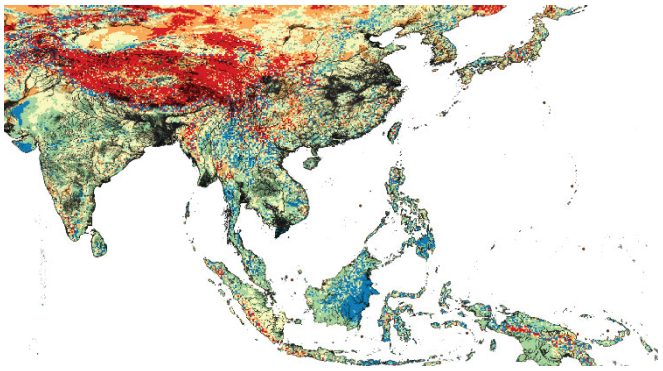

Figure 2 The distribution of waterbodies in the Asia region (black lines) overlaying a color-coded map of the expected change in temperature following the IPCC RCP4.5 scenario (warmer colors correspond to higher expected changes).

As a whole, this region comprises 2.6 million individual water bodies collectively covering a surface area of 522,000 km^2. Because climate is not expected to affect all regions equally, lakes will be impacted differently as well. Our analysis (Fig. 2) shows that, in this region, 50% of the lake surface will experience an average annual warming of 1.9 °C or more.

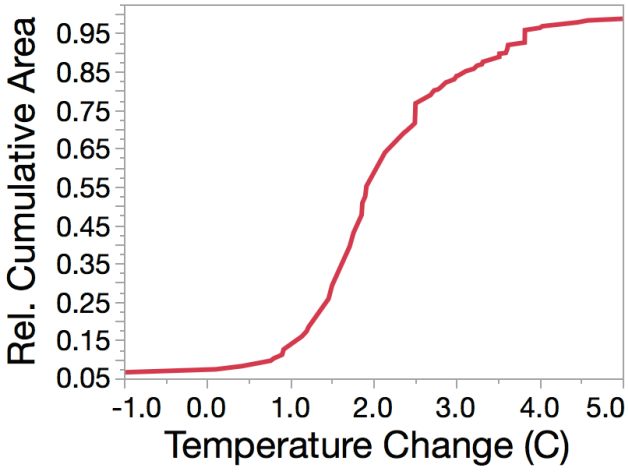

Figure 1. The fractional cumulative surface area of lakes with expected changes equal or greater than the Temperature Change axis. Analysis restricted to the Asia-Oceania region.

Furthermore, the top 25% of the lakes'total surface will warm by at least 2.5 C while only a few percent will experience average changes of more than 4 °C. This average increase on an annual scale is not uniformly distributed over the year and is usually greatest in the winter and spring. The next step in this analysis will be therefore to account for changes at a finer time scale. Nevertheless, the average annual increase can serve as an initial basis to predict the impact of this warming on GHG emission. Assuming that heterotrophic respiration has a temperature dependency (expressed as a Q10) averaging 2 (Berggren et al. 2012), we can estimate the expected increase in CO2 production for each individual water body as e^(0.069·ΔTemp) attributable to climate change by the year 2050 (relative to average 1970-2000 conditions). Similarly, we can assume for methane that the average Q10 is 4 (Yvon-Durocher et al. 2014), yielding an increase in methane emissions that can be estimated as e^(0.139·ΔTemp). This calculation does not consider the disproportional increase in bubbling emission (Delsontro et al. 2017) with temperature (Q_{10}>5) and is therefore conservative. Calculations based on these 2 assumptions yielded an area-weighted increase in CO_2 and CH_4 emissions of 16% and 36%, respectively, in response to the temperature increases alone.

As a comparison, the same exercise on the European continent (about 650,000 water bodies) suggest a similar pattern, with 50% of the lake surfaces experiencing an average warming of 1.9 °C or more. This would lead to an increase in CO_2 by 13% and that of CH_4 by 30% in this region.

3. Increase in CH_4 emission from eutrophication

The impact of eutrophication on the GHG footprint is more difficult to resolve spatially as we do not have eutrophication scenarios for each lake. Instead, we used the projected human population growth of each country as a proxy for the nutrient load that will ultimately reach surface waters of that particular country. In this contest, we simply assumed that eutrophication was proportional to nutrient enrichment. The country-specific population growth estimates that we used here represent the expected fractional increase in human population between 2000 and 2050 (World Bank statistics). Assuming further that that CH_4 emission rises as the 0.75 power of trophic status (as measured from chlorophyll or nutrients, see Delsontro et al. 2018), we calculate that eutrophication would cause an additional increase of 30% in CH_4 emissions. In this work, we did not calculate the effect of eutrophication of CO_2 flux as they differ systematically between large and small lakes (Delsontro et al. 2018) but would likely lead to a further increase in GHG footprint.

Our estimates are therefore conservative again.

Combining the effects of eutrophication and climate change therefore suggest that the methane output from lakes would increase by nearly 65% at the 2050 horizon. However, because of the relatively smaller contribution of CH_4 relative to CO_2 emissions (see Bastviken et al. 2011, Drake et al. 2018), the overall combined impact of these two perturbations would amount to an increase in GWP exerted by GHG emissions from inland waters of about 30%.

4. Implication for the global carbon cycle

Our preliminary analysis suggests that, in the first half of the 21st century, the carbon footprint of lakes will be significantly increased by both climate change and eutrophication in about equal proportion (at least in the Asia-Oceania region). Considering that the highest climate changes are expected to occur in northern latitudes precisely in lake-rich regions (Canada, Scandinavia, Russia), the effect is therefore probably even more pronounced at the global scale. Our analysis also ignored alterations that had occurred previously (during the 1900's) which certainly had already enhanced GHG emissions from inland waters. Reservoirs are new aquatic ecosystems and also constitute new sources of GHG to the atmosphere (Prairie et al. 2017) and the magnitude of the associated GHG emissions are likely to be further modulated by climate change and eutrophication as well. Because inland waters collectively constitute a sizeable share of the natural carbon cycle at the global scale (see Drake et al. 2018 for recent review), the higher emissions estimated as a result of the combined eutrophication and climate change effects constitute a new anthropogenic source of GHG to the atmosphere and will require accounting in future global assessments.

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TS3-2

A Unique Microbial Loop in the Hypolimnion of Lake Biwa with Special Reference to Long-term Changes in Water Quality

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Keywords: Eutrophication, Chemical Oxygen Demand, Dissolved Organic Matter, Phytoplankton, Bacteria, Decomposition, Microbial loop, Protists

ABSTRACT

We have clarified the presence of a unique microbial loop in the hypolimnion of Lake Biwa, the largest freshwater lake in Japan. In the epilimnion of the lake, phytoplankton biomass is produced through primary production, followed by sinking into the hypolimnion. In the hypolimnion, a part of the phytoplankton biomass is converted into and released as humic-like DOM through decomposition by planktonic bacteria. Fluorescence *in situ* hybridization (FISH) showed that bacterial clade, CL500-11 (phylum *Chloroflexi*), predominated in the hypolimnion. We made further analyses on prokaryotic community composition by high throughput 16S rRNA gene amplicon sequencing which showed the dominance by members of *Planctomycetes* exclusively occurred in the hypolimnion. In addition, FISH on eukaryotes showed that bacterivorous kinetoplastid flagellates are the dominant eukaryotes in the hypolimnion. So, the results suggest the presence of a unique microbial loop in the hypolimnion of Lake Biwa, where humic-like DOM is produced by the hypolimnion bacterial assemblages, and those bacteria are grazed by the dominant kinetoplastids and other hypolimnion dwelling bacterivorous protists. The water quality of Lake Biwa has been improved during the last 40 years. However, chemical oxygen demand (COD_{Mn}) in the lake has been gradually increasing every year. In the present talk, we will introduce the hypolimnion microbial loop, with special reference to long-term increase in COD_{Mn} of the lake.

1. INTRODUCTION

The planktonic food linkage from dissolved organic matter to bacteria to protists, microbial loop[1], has been intensively studied in marine and freshwater ecosystems. It was regarded that the herbivorous food chain where phytoplankton are preyed on zooplankton functions major matter cycling in pelagic ecosystems. On the other hand, microbial loop also functions as an important process for the matter cycling in pelagic food webs. Phytoplankton release dissolved organic matter (DOM) as intermediate products of photosynthesis and/or as autolytic products[2]. DOM thus released is used for growth of heterotrophic bacteria, followed by protistan grazing on bacteria. The roles of planktonic protists, such as heterotrophic nanoflagellates and ciliates, in microbial loop are to consume bacteria that are too small to serve directly as major prey items for most zooplankters, and to be themselves utilized by the zooplankton[1].

Lake Biwa is the largest and the most socially important lake in Japan. About 15 million people who live in Kinki Area use the water of the lake. Microbial loop in Lake Biwa has been intensively studied during the last three decades with special reference to DOM production through phytoplankton primary production[3], because matter cycling or DOM dynamics in a pelagic system is mainly driven by microbial loop.

2. HYPOLIMNION MICROBIAL LOOP IN LAKE BIWA

We have clarified the presence of unique microbial loop in the hypolimnion of Lake Biwa. In the lake's epilimnion, phytoplankton biomass usually dominated by diatoms and chlorophytes is produced through primary production, followed by sinking into the hypolimnion. In the hypolimnion, a part of the phytoplankton biomass is converted into and released as humic-like DOM through decomposition by planktonic bacteria[4] (in [4], "humic-like DOM" is expressed as "humic-like fluorescent dissolved organic matter, $FDOM_M$). Usually, humic substances including humic-like DOM are biologically refractory (not easily degradable) and/or semi-labile, and, due to this, bacterial decomposition of

the humic-like DOM is slow. The genus *Synechococcus,* which is the free-living cyanobacterial genus with small cell size (usually <2 μm), sinks so slowly (no faster than 0.01–0.02 μm s^{-1}) that the motion of the water is believed to keep them in suspension. Thus, it has been considered that they are too small to sink to the lake hypolimnion. However, recently, we have found that *Synechococcus* also sank to the hypolimnion of Lake Biwa, and that the contribution of *Synechococcus* chlorophyll *a* amount accounted for about 30% to total chlorophyll *a* concentration[5],[6]. So, it is likely that *Synechococcus* biomass is also converted into humic-like DOM.

In the hypolimnion of Lake Biwa, we have found that bacterial clade, CL500-11 (phylum *Chloroflexi*), predominates in the hypolimnion[7], using fluorescence *in situ* hybridization (FISH). Further analyses on prokaryotic community composition by high throughput 16S rRNA gene amplicon sequencing demonstrated that ubiquitous tribes in the epilimnion can also dominate in the hypolimnion (e.g. bacI-A1 & acI-B1), and that members of *Planctomycetes* (e.g. CL500-15, CL500-37 & CL500-3), together with CL500-11 exclusively occurred in the hypolimnion[8]. In addition, FISH on eukaryotes showed that bacterivorous kinetoplastid flagellates are the dominant eukaryotes in the hypolimnion[9]. Furthermore, high throughput 18S rRNA gene amplicon sequencing showed the presence of possibly novel hypolimnion dwelling bacterivorous flagellates (e.g. cercozoans, choanoflagellates and telonemids).

The seasonal changing pattern of vertical abundance of kinetoplastid flagellates was similar to that of CL500-11 bacterium, suggesting that similar environmental conditions may favor the growths of those two microorganisms in Lake Biwa. Large size and curved shape of CL500-11 bacteria might protect them from grazing and thus allow this group of bacteria to dominate in the hypolimnion of Lake Biwa. However, some flagellates, especially bodonids which belong to kinetoplastid flagellates, are capable of feeding on large bacteria. Therefore those kinetoplastids might have an advantage over other flagellates in the hypolimnion due to their ability to feed on large bacteria dominant in the deeper layers of Lake Biwa. Further research is needed to clarify whether CL500-11 bacteria would have high grazing pressure by protists such as kinetoplastids, or to identify major consumers on the bacteria.

3. LONG-TERM CHANGES IN WATER QUALITY IN LAKE BIWA

During 1960' and 1970's due to the large loading of phosphorus and nitrogen, eutrophication in Lake Biwa was serious, leading to phytoplankton blooms (since the late 1960's), freshwater red tides (since the late 1970's) and cyanobacterial blooms (since the early 1980's). In 1970's, Japanese Government and Shiga Prefectural Government had started some measures to reduce high phosphorus loading in Lake Biwa. Due to the efforts by multiple stakeholders, the water quality of the lake has been improved during the last 40 years.

Mysteriously, a portion of organic matter expressed by chemical oxygen demand (COD_{Mn}) in the lake has been gradually increasing every year[10]. COD_{Mn} is the indicator of organic matter loading, and a large portion of organic matter in Lake Biwa water is dominated by DOM. DOM in Lake Biwa is mainly derived from primary production by phytoplankton[11],[12], and some researchers have reported that the increase in COD_{Mn} might be due to the accumulation of refractory and/or semi-labile DOM[10]. As previously mentioned, we have clarified that humic-like DOM is probably intermediate products through bacterial decomposition. So, the reason for the increase in COD_{Mn} in Lake Biwa might be partly due to the accumulation of refractory and/or semi-labile DOM produced through and released after bacterial decomposition.

4. CONCLUSION

Our results indicate the presence of unique microbial loop in the hypolimnion of Lake Biwa, where humic-like DOM is produced and released by the hypolimnion bacterial assemblages, and those bacteria are grazed by the dominant kinetoplastids and other hypolimnion dwelling bacterivorous protists. Thus, the deep waters of Lake Biwa harbor active microbial loop consisting of novel hypolimnion-specific groups, which might play an important role in the production of refractory DOM. In addition, we have partly clarified the microbial processes with special reference to production and accumulation of humic-like DOM which may be the reason for the increase in COD_{Mn} in Lake Biwa.

5. ACKNOWLEDGEMENT

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O3-1

Application of non-powered water circulation system using wind and wind-driven current for shallow reservoirs

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Keywords: Water circulation, Eutrophication, Stratification, DO improvement, Water quality management of reservoirs

ABSTRACT

A large number of reservoirs in Korea have experienced severe deterioration of water quality due to eutrophication. The problems include (1) inflow of pollutants, (2) occurrence of algal blooms, (3) increased oxygen consumption and anaerobic condition near the bottom, and (4) elution of nutrients from the sediments. As more than 90% of reservoirs in Korea have average water depth less than 5 m, we need appropriate technologies coping with these situations. A non-powered water circulation system has been developed to improve water quality of reservoirs by inducing the descent flow of surface water using natural wind and wind-driven current. One of the functions of the system is to break thermal stratification and anaerobic condition near the bottom. Test-beds have been installed and operated at 2 reservoirs and monitored more than 1 year. The results have showed clearly that 1) continuous improvement of anoxic condition at deep layer (hypolimnion), 2) mitigation of DO supersaturation and 3) prevention of excessive increase of pH at surface layer (epilimnion).

1. INTRODUCTION

Many lakes and reservoirs in Korea have suffered from deteriorating water quality due to rapid eutrophication[1]. Stagnant areas such as lakes and reservoirs have problems including 1) eutrophication due to the inflow of pollutants, 2) occurrence of algal blooms due to decrease of flow rate, 3) anaerobic condition near the bottom, 4) massive death of fish due to lack of dissolved oxygen (DO), and 5) elution of nutrients (P, N, etc.) and metal ions from the sediment. In Korea, there are about 18,000 reservoirs, and more than 90% of them have average water depth less than 5 m[2]. Unfortunately, existing technologies have unsuitable characteristics such as 1) excessive energy needs, 2) maintenance difficulties, and 3) low efficiency of water circulation. This study has been conducted to overcome the limitations of existing technologies and to suggest an appropriate water circulation system for water quality management of shallow and small reservoirs.

2. METHOD

2-1. Principle of non-powered water circulation system

A water circulation system was developed to break thermal stratification and to mitigate anaerobic condition near the bottom by inducing the surface water's descent flow using wind and wind-driven current. The system was designed to use natural energy efficiently and to rotate by itself according to the direction of wind and wind-driven current continuously. Its typical image is shown in **fig. 1, (a)**.

The system, for the parts above water surface, is composed of (1) 'wind blade' to face with wind, (2) 'float' supporting the system by buoyancy. For the parts under water surface, it contains (3) 'guiding panel' inducing descent flow from the surface to the bottom, and (4) 'center shaft', located at the center of panel system, maintaining the rotation of total system around the axis of center shaft. Applying the Ekman spiral principle, the angle between wind blade and panel system is biased with 15°, and the direction of panel system and wind-driven current is always kept perpendicular to maximize the energy efficiency (**Fig. 1, (b)**).

2.2 Test-bed installation and monitoring

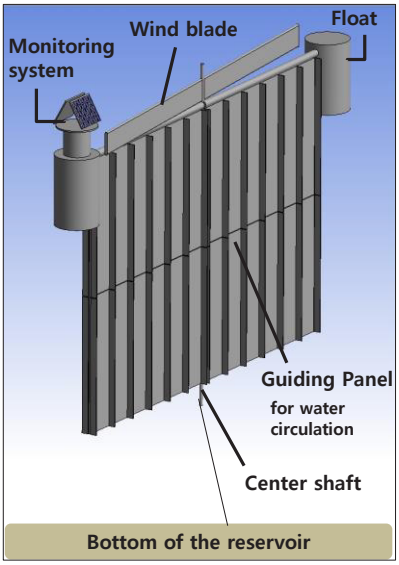
Test-beds have been operated to monitor the effects of water circulation system.

1) Gongneung reservoir (Paju-si, Gyeonggi province, Korea): This reservoir has a surface area of 0.4 km^2 and an average depth of 2.2 m. The upstream area of the reservoir is composed with mountains, golf courses, cultivated lands and residential areas. The scene of test-bed is **Fig 2, (a)**.

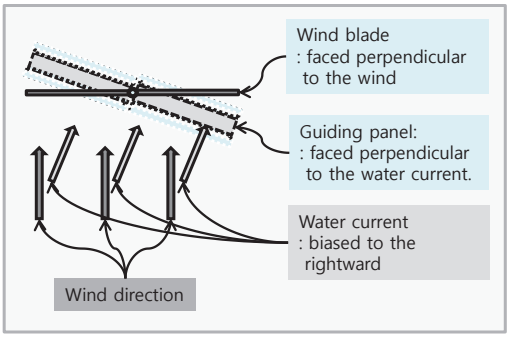
2) Giheung reservoir (Yongin-si, Gyeonggi province, Korea): The reservoir has an area of 2.6 km^2, an average

depth of 3.2 m. There are wastewater treatment facilities upstream of the reservoir (**Fig 2, (b)**).

A real-time monitoring system has been equipped at surface layer (within 30 cm from water surface) and at deep layer (0.5 ~ 1 m from the bottom) to observe the variation of each item including compass of the system, water temperature, pH, DO, DO saturation, and electric conductivity.



(a)



(b)

Fig. 1. (a) Feature of water circulation system, (b) Application of Ekman spiral principle



(a) (b)

Fig. 2. Test-beds of water circulation system: (a) Gongneung reservoir, (b) Giheung reservoir

3. RESULTS

Fig. 3 shows the results of (a) DO, (b) DO saturation, and (c) pH for the monitoring and control sites at Gongneung test-bed (period: 12th October ~ 23rd December, 2016, monitoring depth of 2.5 m). Several positive effects were observed through the operation of the system, which include that the system is able to (1) moderate the fluctuation of DO, (2) mitigate the supersaturation of DO, and (3) prevent the excessive increase of pH.

Fig. 4 illustrates DO variations of surface layer and deep layer (depth 2.5 m) at the monitoring site (period: 11th March ~ 20th May, 2017). The water quality of the reservoir had been deteriorated due to serious drought from April to June, and DO concentration of deep layer had been drastically reduced just after the stop of the system's normal rotation. During this period, anoxic states were observed at deep layer, that DO and DO saturation became closer to 0 mg/L and 0% respectively.

Fig. 5 represents the monitoring results at the second test-bed, Giheung reservoir. These graphs show that DO and water temperature of surface and deep layers at the monitoring site illustrate the system have mitigated the intensity of thermal stratification (**Fig 5, (a)**) and prevented anoxic states by prohibiting dropping of DO below 5.5 mg/L (**Fig 5, (b)**).

4. DISCUSSION

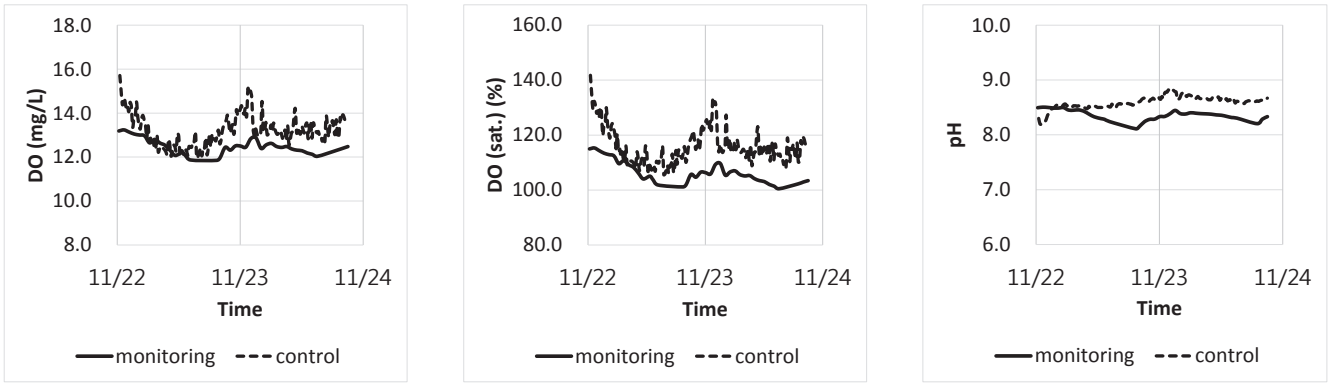
Based on the above results, the non-powered water circulation system is considered to be useful for Korean reservoirs experiencing periodic thermal stratification and turn-over events in spring and fall. In addition, this system is designed to be easy to apply to shallow and small reservoirs. Furthermore, it doesn't need any electric power supply, which is convenient to maintain and economically excellent.

5. CONCLUSION

A non-powered water circulation system has been developed to induce descent flow using wind and wind-driven current, and they have been installed and monitored intensively at 2 test-beds. The brief conclusions are as follows:

1) The water circulation system could maintain DO concentration upper certain level, 5 mg/L, and prevent anoxic states at near the bottom layer.

2) It could mitigate the excessive supersaturation of DO and increase of pH at surface layer by reducing the activity of algae.



(a) (b) (c)

Fig. 3.Water quality comparison between monitoring and control site: (a) DO, (b) DO saturation, and (c) pH

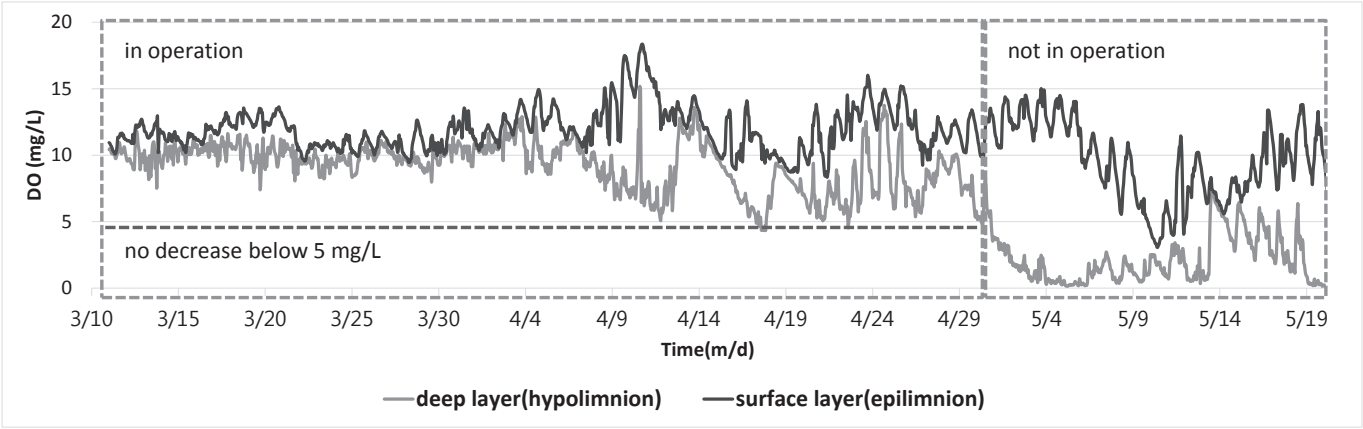
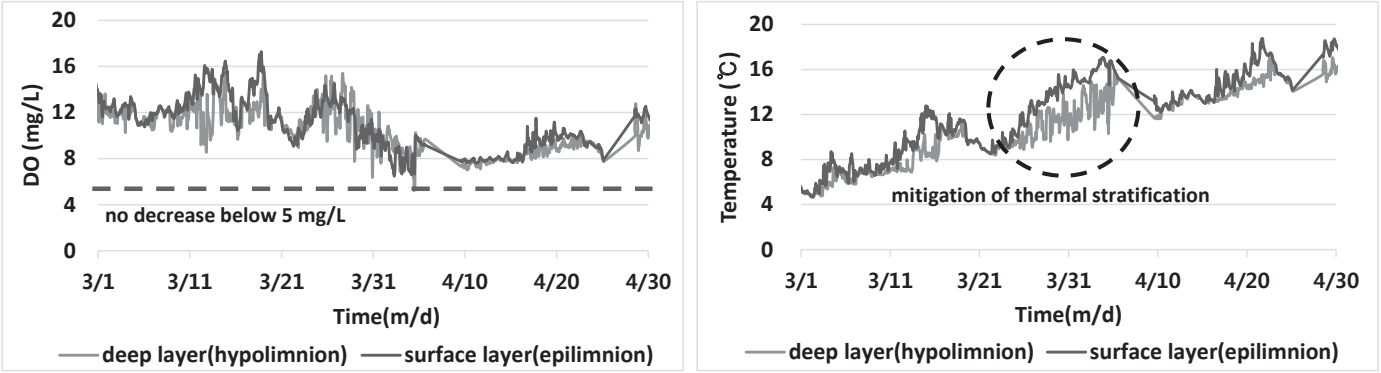


Fig. 4. Monitoring results of DO for deep and surface layer at Gongneung Reservoir



(a) (b)

Fig. 5. Monitoring results of DO and water temperature for deep and surface layer at Giheung Reservoir

ACKNOWLEDGMENTS

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O3-2

Oxygen nanobubble modified local soil (MLS) technology for sediment remediation and lake restoration

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Keywords: Eutrophication, Harmful algal blooms (HABs), anoxic sediment remediation, ecological restoration

ABSTRACT

Eutrophication, harmful algal blooms (HABs), and internal sediment release of nutrients represent increasing problems for public health, ecological restoration, and water quality worldwide. Modified Local Soil (MLS) materials are cost-effective in removing HABs at very large scale (Pan et al, Environ. Pollut. 2006, 141, 195; Environ. Pollut. 2006, 141, 201; Environ. Pollut. 2006, 141, 206; Environ. Sci. Technol. 2006, 40:1377; Environ. Sci. Technol. 2013, 47, 4555; Harmful Algae, 2011, 10, 381; J. Applied Phycology, 2016, 28, 357; Water Research, 2016, 97, 11; Water Research, 2016, 97, 19). MLS capping technology can reduce the release of nutrients or algae toxins from sediment and turn algal cells and the excessive nutrients in-situ into fertilizers for submerged machrophyte restoration in shallow water systems (Pan et al, Ecol. Eng. 2011, 37, 302; Environ. Sci. Technol. 2012, 46, 5077; Environ. Sci. Technol. 2015, 49, 426). MLS is also tested for manipulating nutrient limitation in natural water bodies (Pan et al., Water Research, 2016, 101, 25). Here, we report that surface oxygen nanobubbles can be loaded in MLS for effective and long-term remediation of sediment anoxia or hypoxia in deep water system (Pan et al, Sci Total Environ. 2018, in press). Combined with integrated management of external loads control, MLS technology can be used as environmentally friendly geo-engineering materials (Pan et al, Water Research, 2016, 97, 133; Environ. Sci. Technol. 2014, 48, 9977; J Environ. Sci. 2018, 65, 375) to achieve multiple functions for water quality improvement, sediment remediation, and ecological restoration.

1. INTRODUCTION

Eutrophication, harmful algal blooms (HABs), and internal sediment release of nutrients represent increasing problems for public health, ecological restoration, and water quality worldwide. The cause of these problems is complex, which can be partially due to the ever-increased nutrients run off from inland to natural waters because of agriculture, industrial, and other human activities. This nature determines that the mitigation of these problems are complicated and integrated management is often essential. External loads control and integrated basin management are important to prevent continuous input of nutrients from land to waters. When external loads are under control, the internal loads from polluted sediment often limits the improvement of water quality, and the latter is increasingly becoming compulsory in many countries within short period by local governance or environmental laws. Natural restoration of lake ecology or water quality often takes very long time, which is far beyond the above-mentioned requirement. With the help of geo-engineering materials, such as modified clays or soils, the improvement of water and sediment environment may be accelerated in an ecological friendly way[1] because particle-water interaction (suspended particles) represent an important natural process in scavenging pollutants from natural waters[2]. In return, the improved water and sediment environment is essential for ecological and biodiversity restoration.

Over the last decades, we have developed a series of modified local soil materials that use very small amount (usually less than 1% of soils) of natural products, such as natural polymers of chitosan[3-5], cationic starch[6], or oxygen [7], to modify clean local soil or commercially available clay/sand particles [8, 9], so that these modified soil particles can obtained multiple functions for algae flocculation, pollutants adsorption or decomposition (e.g. algae toxins [10]) in water or sediment environment. MLS can also be used for capping and locking the algae flocs or nutrients in the sediment so that the release of nutrients from sediment to the water column can be reduced [11]. MLS capping can also turn algal flocs and the excessive nutrients in-situ into fertilizers for the growth of submerged machrophyte in shallow water systems [12]. This will make it possible to put algae and excessive

nutrients into food chain by flocculating and removing them from water into the sediment and then to utilize and convert them by submerged vegetation. Recently, we developed a surface oxygen nanobubble technology [13, 14] which allow us to load large amount of oxygen into the microporous of clays. These clays can hold the nanobubbles stably within period of months so that once the oxygen are delivered by settling the clay particles onto the sediment, it can form an aerobic sediment-water capping layer, which can prevent the consumption of dissolved oxygen in water column by the anaerobic sediment hence provide a new principle for combating oxygen depletion or anoxia/hypoxia problems that are crucial for eutrophication [7].The objective of this paper is to present a series of pilot tests in the field to examine the short-term, middle-term, and long-term effects of MLS for future engineering and scalability optimization.

2. METHOD

2.1 Materials

The soil/clay used in the experiments was collected from the bank of local lakes. The soil was sieved through 180 mesh (74 μm), washed with distilled water, and dried for 10 h at 90 ℃ before use. Chitosan (solid) was obtained from Qingdao Haisheng Bioengineering Co., Ltd (deacetylation degree was 83.6%). Cationic Starch was prepared by reacting corn starch (Unilever Co. Ltd., China) with cationic monomer, 2,3-epoxypropyl trimethyl ammonium chloride (GTA), using the microwave-assisted method [6].

2.2 Preparation of Modified Local Soil

The soil suspension was prepared with the concentration of 100 mg/L in all the flocculation experiments. Deionized water was prepared using a Milli-Q filtration system (Millipore, Bedford, MA). For Chitosan MLS preparation, chitosan was dissolved by adding 100 mg of chitosan to 10 mL of 1% HCl and mixing until all chitosan was dissolved. This solution was diluted with deionized water to obtain a working solution of 1 mg/mL. Then, a certain volume of chitosan working solution was added to soil suspension [3-5]. The mixture was well stirred and then ready for use in the experiment. For Cationic Starch MLS preparation, certain amount of synthetics Cationic Starch was added to the soil suspension prior to the flocculation experiments [6]. The oxygen nanobubble MLS was prepared through the high pressure loading method into a pressure-resistant and airtight container [7]. Pure O2 (99.99%) was used to achieve supersaturation of O_2 in the particle micropores.

2.3 Experimental sites

The series experiments were conducted in two field experiment sites, 1) Meiliang Bay in Taihu Lake, Wuxi city, Jiangsu Province, China **(Fig. 1)**; and 2) Datong, Shanxi province, China **(Fig. 2)**. Taihu Lake has serious HAB problems every year due to the polluted external wastewater discharge and internal nutrients loading from the lake. Six enclosures with total area of 50,000 m^2 were constructed for the proposed research to removal HAB using MLS technology from 2004. From 2012, three groups of research facilities were constructed in Datong research site, which include 8 natural water ponds (100 m^2 per each with same height of 1.7 m), 12 large mesocosm systems (Ø 2.5 m per each with same height of 2.5 m), and an indoor lab facilities. All the facilities were used to simulate various environmental process at an ecologically meaningful scale for the study of MLS technology.



Fig. 1 Experiment site in Taihu Lake, Wuxi city, Jiangsu Province, China

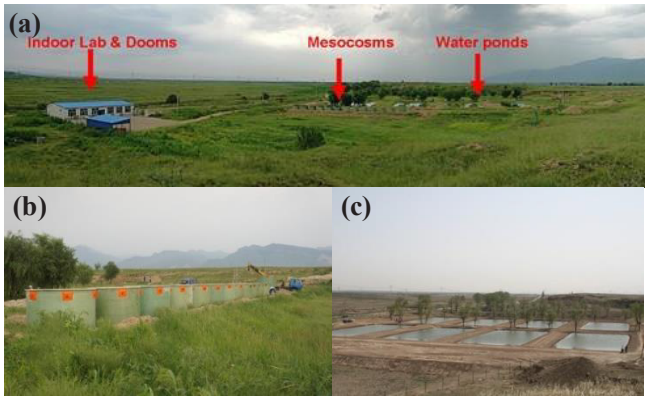

Fig. 2 Experiment site in Datong, Shanxi Province, China (a). (b) and (c) represent the mesocosms and water ponds experiment sites.

2.4 Sample analysis

For each experiment, the water samples were collected for turbidity and nutrient concentrations (TP, TN, NH_4^+-N, NO_3^--N, and NO_2^--N) analysis along the experiment. Turbidity was analyzed with portable turbidity meter (HANNA, HI98713). TP was determined using a potassium persulfate digestion-Mo-Sb-Vc colorimetric method, TN using an alkaline potassium persulphate

digestion–ultraviolet spectrometer, NH_4^+-N with Nessler's colorimetric, and NO_3^--N, and NO_2^--N with ultraviolet colorimetric method with and without cadmium column reduction, respectively (APHA, 1998). The DO was measured using a Yellow Springs Instruments (YSI, Proplus). Moreover, the algae cell concentration were calculated under the optical density of 0.100 at the wavelength of 680 nm (OD 680 nm). Concentration of chlorophyll-a, calibrated against direct microscope cell counts was used to monitor the concentration change of algae cells during the flocculation experiment.

3. RESULTS

1) Water quality improvement and algal bloom control

A pilot engineering was conducted under the witness of the Mayer and expert panel of Wuxi city to clean up heavy algal blooms in a designated enclosure in Taihu Lake in 2008 **(Fig. 3)** and 2009 **(Fig. 4)**. Chitosan MLS of 2000 Kg was sprayed using a ship over the entire enclosure within 30 min. After 1 day, the secchi depth increased from less than 5 cm to 60 cm. DO increased from 0.2 mg/L to 3 mg/L. TP and TN removal rate > 50%, NH3 removal > 85%.



Fig. 3 Pond pilot test in Meiliang Bai of Lake Tai in August 2008.



Fig. 4. Application of MLS at open water by WUXI city government at Lake Tai in 2009.

2) Sediment remediation

A one year monitoring experiment was conducted in an open water at Meiliang Bay of Lake Tai during the four seasons in 2010. Throughout the year **(Fig. 5)**, TP peak in treated area (1 m2) was largely removed in the summer compared to the untreated surrounding area. Lake Taihu in 2010 (surrounding water was not treated, only the sediment was capped with MLS).

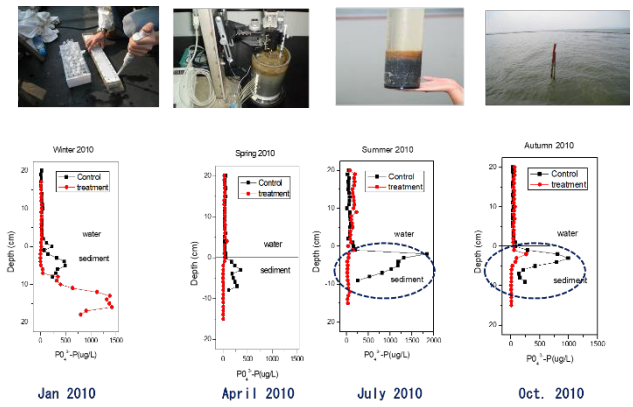

Fig. 5. MLS capping materials (about 1.5 cm) were placed (about 1 m2) in the open water in Meiliang Bay.

3) Ecological restoration.

Long term ecological effect of MLS treatment in replicated comparable whole water ponds were conducted in Cetian reservoir study site. The water quality in 140 days was presented in table 1. A 3 year's monitoring results were presented in **Fig. 6**.

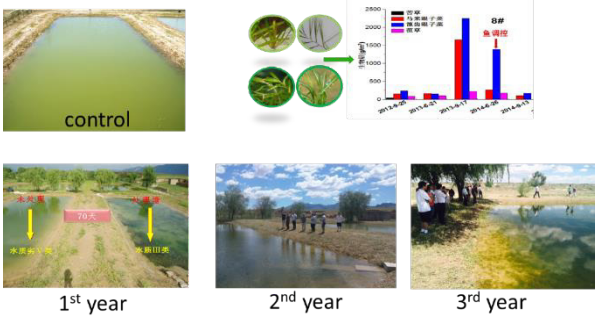

Fig. 6. A 3 year monitoring result after the application of MLS in replicated whole water response experiment.

4. DISCUSSION

The continued function and multiple principle of MLS are schematically summarized in **Fig. 7**. For practical lake restoration engineering, conditions are very complex and chanchable. There are many interfering factors in the field (such as wind and bio-disturbance) and there is a great need for more studies in order to make the principle studies into practice.

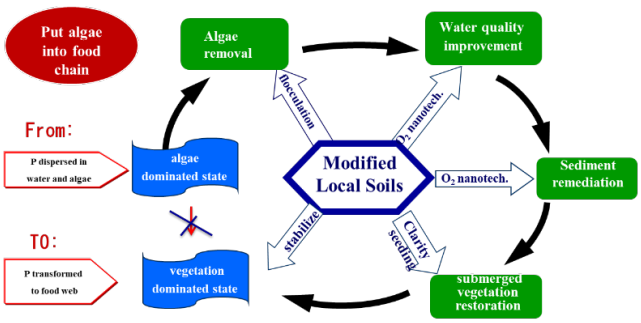

Fig.7. Multi-disciplinary principle of MLS technology

5. CONCLUSION

Combined with integrated management of external loads control, MLS technology can be used as environmentally friendly geo-engineering materials (Pan et al, Water Research, 2016, 97, 133; Environ. Sci. Technol. 2014, 48, 9977; J Environ. Sci. 2018, 65, 375) to achieve multiple functions for water quality improvement, sediment remediation, and ecological restoration.

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O3-3

水質浄化技術における実証試験場所の選定と評価手法

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キーワード:富栄養化, アオコ, 水質浄化技術, 水質改善, 評価手法

抄録

湖沼等の閉鎖性水域において富栄養化に伴う植物プランクトンの異常増殖による景観の劣化, 悪臭, アオコ等の水質問題が生じており, 効果的・経済的な水質改善対策が求められている。国内におけるこれらの問題について,ベンチャー企業等により水質汚濁等の環境問題を改善するのに効果的と思われる先進的環境技術が開発・実用化されているが,いまだ環境問題を抱える現場にあまり導入されていない。環境省の環境技術実証(ETV)事業は,先進的環境技術の普及促進を目的として,エンドユーザーが安心して使用できるように第三者機関である実証機関が先進的環境技術の環境保全効果等について客観的に実証する。筆者らは, 水質浄化技術における実証試験を合理的かつ適正に実施するために, 実証対象技術(水質浄化技術)に応じた試験場所の選定と評価手法を検討してきたので事例を踏まえて紹介する。

1. はじめに

国内の湖沼の環境基準達成率に関しては, 2015 年度では, COD(58.7%), 全窒素及び全りん(51.2%)と低い水準で推移し[1], 富栄養化に伴う植物プランクトンの異常増殖による景観の劣化, 悪臭, アオコ等の水質問題が生じており, 効果的・経済的な水質改善対策が求められている[2]。筆者らは, 湖沼等の閉鎖性水域の水質を良好な状態に改善し, 維持管理するための効果的かつ経済的な技術について数々の実証試験(技術性能の試験)を実施してきた。実証対象技術(水質浄化技術)に関しては, その原理, 機器の規模・設置条件等がそれぞれ異なる。実証対象技術が持つ性能を合理的かつ適正に実証するために, 試験場所の選定と評価手法について事例を踏まえて紹介する。

2. 方法

筆者らが平成 22 年度～平成 28 年度の期間に ETV 事業として実証試験を実施した実証対象技術を表 1 に示す[3]。浄化手法としては, 機器に原水を導入し, 処理水を放出する直接浄化が 4 技術と最も多く, 浮島, 浚渫及び撹拌がそれぞれ 1 技術であった。表 2 に各技術の浄化原理, 機器の規模及び試験場所を示す。筆者らは, 実証対象技術による水質改善の効果を評価するために, 技術を導入している「試験区」と, 導入していない「対照区」の水質等を比較する評価手法を基本としており, 公園池内に池底が解放系の隔離水界(10m×10m, 水深約 1m)を複数設置した試験場所を有している。技術Ⅰ, 技術Ⅱ, 技術Ⅳについては, 隔離水界を試験場所として選定したが, その他の技術については各技術の特長・条件等により他の試験場所を選定した。

表 1 実証対象技術(平成 22 年度～平成 28 年度)

手法	実証対象技術(水質浄化技術)
浮島	【技術Ⅰ】花卉等陸生植物を用いた観賞式「グリーン生物浮島」
浚渫	【技術Ⅱ】生態系保全型底泥資源化システム
撹拌	【技術Ⅲ】環境配慮型撹拌装置「エムレボ エムレボエア」
直接浄化	【技術Ⅳ】移動式高性能湖沼浄化システム 【技術Ⅴ】ダイワエース(精密ろ過・生物膜ろ過システム) 【技術Ⅵ】促進酸化水処理システム 【技術Ⅶ】超高速凝集沈殿処理アクティフロプロセス

表 2 技術の浄化原理, 規模, 試験場所

技術	浄化原理	規模*(縦×横×高さ)	試験場所
技術Ⅰ	浮島+活性化石炭	0.9 m(直径)×0.5 m【3 基設置】	公園池内隔離水界
技術Ⅱ	浚渫+汚泥分離	9.0 m×6.0 m×4.5 m	公園池内隔離水界
技術Ⅲ	曝気+撹拌	1.98 m×1.94 m×1.4 m	ゴルフ場内調整池
技術Ⅳ	浮上分離+凝集沈殿	4.0 m×2.0 m×2.0 m	公園池内隔離水界
技術Ⅴ	凝集ろ過	2.5 m×3.0 m×4.0 m【12 基設置】	皇居外苑濠
技術Ⅵ	砂ろ過+促進酸化	2.3 m×2.4 m×2.0 m	申請者敷地内(観賞池)
技術Ⅶ	凝集沈殿	7.9 m×3.3 m×3.8 m【2 基設置】	皇居外苑濠

＊ 実証対象機器 1 基あたりの規模

技術Ⅲは，撹拌・曝気による物理処理が特長であり，その性能を実証するために，鉛直方向で水温差を生じ，底層が貧酸素化している調整池を選定した。技術Ⅴは，開発されたろ材が対象技術であったため，その技術が導入されている既設の施設を選定した。技術Ⅵ及びⅦに関しては，それぞれの技術の特長を維持するために必要な定期的な保守管理や，自社試験の実績等を考慮し，対象技術が導入された既設の施設を選定することで試験の効率化を図った。

筆者らは，実証対象技術の特長及び設置状況等に応じた実証試験を実施するために，上述した試験区と対照区の水質比較の他に，実証対象機器に流入する原水と機器から放流される処理水のそれぞれの水質より求めた除去率等による処理性能の評価手法や，処理水が放流される水域の浄化前と浄化後のそれぞれの水質から求めた改善率等による改善効果の評価手法を検討してきた。また，浄化手法が撹拌である技術Ⅲでは，機器稼働時と停止時の水平・鉛直方向における水質変化をそれぞれ調査・比較することで改善効果を評価した。既設の浄化施設を試験場所として選定した技術Ⅴ及びⅦでは，除去率による性能評価の他に，既存データを活用することにより改善効果についても評価した。

3. 結果

技術Ⅲの機器稼働時・停止時における溶存酸素（DO）の水平・鉛直分布を図 1 に示す（縦軸は水深（m），横軸はDO（mg/L），各折れ線は機器からの水平方向への距離（1m～21m）を示す）。

図 2 に技術Ⅶの実証試験期間（平成 28 年 6 月～9 月）における流入水（原水）・処理水・各濠のクロロフィル-a と気象データの推移を示す。

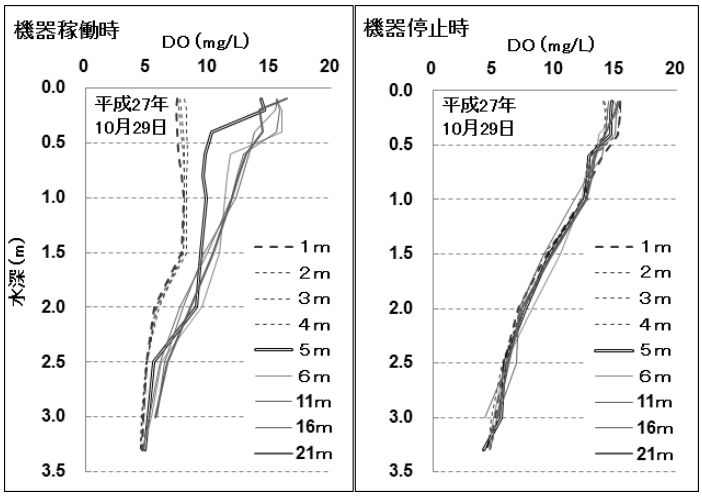
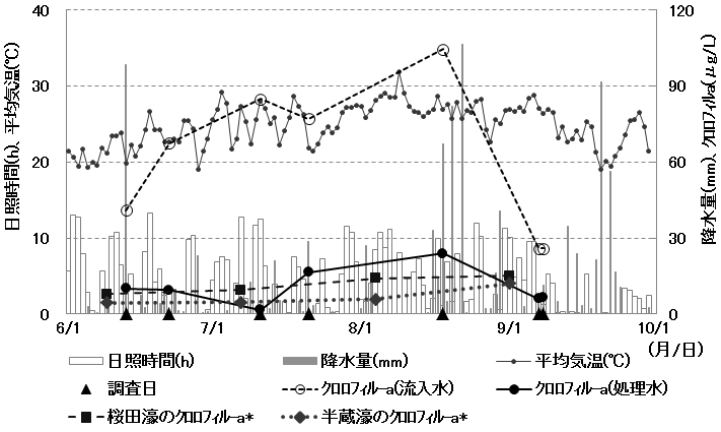


図 1 機器稼働時・停止時の DO の水平・鉛直分布



＊本データは平成 29 年 1 月現在速報値であり未確定のため参考値である。

図 2 クロロフィル-a と気象データの推移

（平成 28 年 6 月～9 月）

4. 考察

図1より，停止時（右図）は，DO の鉛直分布が水平方向（1m～21m）でほぼ同様の傾向を示したが，稼働時（左図）では，DO の鉛直分布が水平方向 5m を境に大きく異なり，機器による撹拌効果が水平方向 5m，鉛直方向 2m の範囲で示された。図 2 より，機器への流入水のクロロフィル-a は，植物プランクトンの増殖に伴い大きく変動（26～105μg/L）していたが，処理水は 1.7～24μg/L で推移し，除去率は 75.6～98.1%であった。また，放流先の各濠のクロロフィル-a（既存データ）に関しても処理水と同様なレベルで推移しており水質改善の効果がみられた。

5. 結論

筆者らは，実証対象技術に応じた試験場所の選定と評価手法を検討してきた。実証対象技術の特長及び設置状況等により，①試験区・対照区を用いた水質の比較・評価，②実証対象機器稼働前後の水質の比較・評価，③既存データによる水質改善効果の評価手法について検討し，実証試験を実施してきた。これらの方法を活用することで，気象条件等の影響を受ける野外での実証試験による水質浄化技術の性能評価が可能であり，より実態に近い状況での水質改善の効果を検証できることが示された。

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O3-4

A FUNDAMENTAL STUDY OF THE BLUE-GREEN ALGAE COUNTERMEASURES BY WASHOUT EFFECT IN LAKES

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Keywords: Blue-Green Algae, Specific Growth rate, Washout Effect

ABSTRACT

Algal bloom is a big problem that happens in lakes and reservoirs. Algal bloom is caused by blue-green algae and cyanobacteria increased and accumulated on the water surface. Blue-green algae thrive in warm, nutrient-rich water conditions in lakes, reservoirs with long retention times. The reason why blue-green algae become a problem is that: odors can be generated, and leads to landscape deterioration at the time of decomposition. In addition, it can be harmful to livestock and human health due to its liver poison. There is the drastic countermeasures in Japan, like water conduction which means using the river water and reclaimed wastewater to flush water bodies that suffered from algae bloom. The purpose of this study is to propose a method to simply define the safest required volume of water in order to prevent blue-green algae from growing by flushing out them. We know that we can tell whether the blue-green algae will die out or not by comparing the algae's growth rate and the rotation rate. In other words, it is better to conduct water more quickly than the growth rate of blue-green algae. Then, we evaluated applicability of this method by culture experiment about the blue-green algae.

1. INTRODUCTION

Algal bloom is one of the most common problems in lakes and reservoirs worldwide. Algal bloom is caused by blue-green algae and cyanobacteria increased and accumulated on the water surface. Blue-green algae thrive in nutrient-rich water conditions in lakes and reservoirs with long retention times. The reason why blue-green algae become a problem is that: odors such as 2-methylisoborneol and geosmin can be generated, and water body will turns into light blue and leads to landscape deterioration at the time of decomposition. In addition, it can be harmful to livestock and human health due to its liver poison. Fig.1 is Microcystis aeruginosa classified in Blue-green algae. Blue-green algae have high planktonic and adaptability compared to the other algae. Especially, they are resistant to high water temperature and high light intensity. And they're the optimum water temperature value are higher than other algae[1,2].In addition, It is feared that blue-green algae occur for water temperature rise due to global warming. There are mainly two types of countermeasures for improving blue-green algae problem, the first type is the temporary countermeasures, like constructed wetland, dredging, aeration, etc., the second type is the drastic countermeasures, like water conduction which means using the river water and reclaimed wastewater to flush water bodies that suffered from algae bloom. Generally, there is a method of decide the required volume of water in order to prevent blue-green algae using ecosystem and hydraulic model. Although ecosystem model can predict biomass in spatial and temporal detail, it is difficult to require a lot of variables and input parameters as the model structure becomes more complex. The purpose of this study is to propose a method to simply decide the required volume of water in order to prevent blue-green algae from growing by flushing out them. More specifically, considering the eutrophic environment, we propose the simple method to decide the safest required volume of water to flush out them by numerical analysis. In order to proof the applicability of the method, we made a culture experiment with blue-green algae using laboratory equipment.

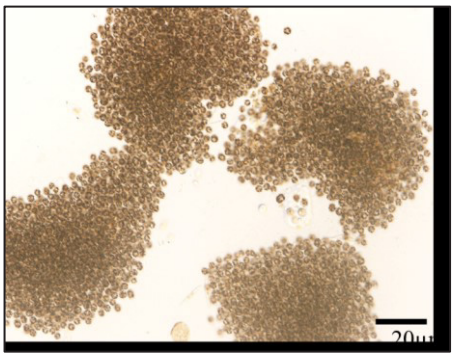

Fig. 1 Microcystis aeruginosa

2. THEORY AND METHODS

2.1 A METHOD OF DECIDE THE REQUIRED VOLUME OF WATER IN ECOSYSTEM MODEL.

Generally, Chlorophyll-a concentration which show the amount of phytoplankton in ecosystem model can be expressed by photosynthesis, extracellular secretion, respiration, feeding by zooplankton, mortality, sediment. Among them, the specific growth rate of algae by photosynthesis is expressed by the following formula.

$$r = r_{max} \cdot \left(\frac{N}{N+K_N}\frac{P}{P+K_P}\right) \cdot \frac{I}{I_{opt}} \exp\left(1-\frac{I}{I_{opt}}\right) \cdot \frac{T}{T_{opt}} \exp\left(1-\frac{T}{T_{opt}}\right) \quad (1)$$

r is the specific growth rate of algae (day^{-1}). r_{max} is the maximum specific growth rate of algae (day^{-1}). N is the Inorganic nitrogen (mg L^{-1}). K_N is the half saturation constant nitrogen (mg L^{-1}). P is the Inorganic phosphorus (mg L^{-1}). K_P is the half saturation constant phosphorus (mg L^{-1}). I is the Light intensity (MJ m^{-2}day^{-1}). *Iopt* is the most suitable Light intensity (MJ m^{-2}day^{-1}). T is the water temperature (°C). *Topt* is the most suitable water temperature (°C). The growth term by photosynthesis can be expressed by the specific growth rate multiplying Chlorophyll-a concentration. The specific growth rate is the incremental Chlorophyll-a concentration per unit time divided by Chlorophyll-a concentration. The specific growth rate can be expressed by the maximum specific growth rate, nutrients (inorganic nitrogen and phosphorous), the light intensity and the water temperature. The nutrients can be expressed by Monod type equations. The light intensity and water temperature can be expressed the growth of algae by the equations inhibition of high light intensity and water temperature considering environmental conditions[3,4,5]. In this study, we made a basic study using only the maximum specific growth rate removed the environmental conditions showing a value lower than 1 to propose the countermeasures toward the case of the worst water quality environment (eutrophication)($r = r_{max}$).

3. A METHOD TO SIMPLY DECIDE THE REQUIRED VOLUME OF WATER

Equation 1 is an exponential growth type (Malthus model) expressed by the maximum specific growth rate (r_{max}) multiplying the chlorophyll-a concentration when proposing countermeasures on the most safe side. However, it is necessary to consider the environmental capacity K that shows the maximum value can be grow because of algae is not able to grow exponentially forever. Equation 2 is an expressed that replaces the maximum specific growth rate with a function which decreases with the number of individuals. Generally that equation is called a logistic equation.

$$\frac{dC}{dt} = r_{max}\left(1-\frac{C}{K}\right)C \quad (2)$$

We added the washout effect to the logistic equation and found out that. The relation between the algae's maximum specific growth rate and rotation rate will decide the required volume of water in order to prevent blue-green algae. (Residence time is the water storage volume divided by the water conducting, rotation rate (day^{-1}) is its reciprocal number). In other words, blue-green algae cannot grow if the growth rate was lower than the rotation rate, that is, algae cannot grow if the washout effect is strong enough, and on the other hand it can grow as a solution asymptotically approaching the environmental capacity K if the rotation rate was higher than the growth rate. That is an important idea about the proposed equation in this study. Figure 1 shows the case of the number of algae when the maximum specific growth rate is faster than the rotation speed and lower than the rotation speed. As a previous study, about the relation between the algae's maximum specific growth rate and rotation rate, Amano(2008) evaluated the water conducting project of Lake Inbanuma by using the equation which added wash out effect proportional to algal to an exponential growth type[6] (Malthus model). However, detailed verification has not been done. Therefore, in order to prove this relation between the algae's maximum specific growth rate and rotation rate, we conducted a culture experiment.

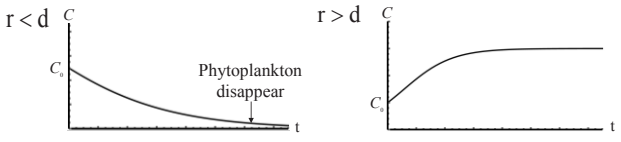

Fig.2 The relations of growth rate and rotation rate

4. PROVE BY CULTURE EXPERIMENT

We reanalyzed the data of continuous culture experiment using the retention time of dam and phytoplankton of algae growth by Kudo and Yamada (2004) from a point of view of specific growth rate and rotation rate of algae[7].

4.1 OVERVIEW OF THE CULTURE EXPERIMENT

In order to the culture condition be close to actual condition which increase of Blue-green algae in reservoir, we made a continuous chemostat culture. The condition of this culture experiment is water temperature is 20℃, light intensity is 2000 lux and complete mixing system. In addition, we used the phytoplankton at the experiment that is Phormidium which is a kind of the Blue-green algae and cause of the odors at reservoirs. The incubator is a mixed state using an air pump and air stone. Fig.3 shows the overview of the culture experiment. We made a culture experiment under phosphorous restriction and various retention time (0.7, 1, 1.2, 2, 3, 5, 7, 10, 20 day), and the specific growth rate r was calculated by the relationship between retention time and chlorophyll-a concentration (μg L^{-1}) in the exponential growth phase in the culture experiment.

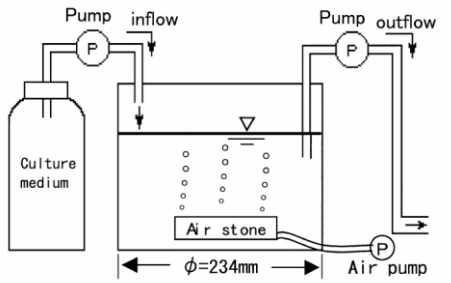

Fig.3 Overview of the culture experiment

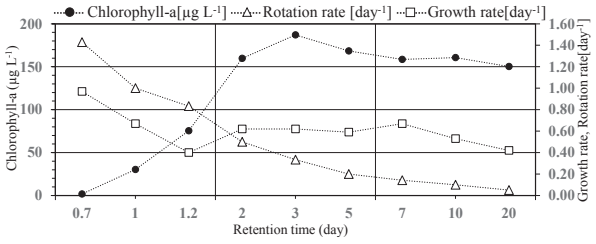

Fig.4 This figure is experiments results. Horizontal axis is retention time, vertical axis are chlorophyll-a (μg L^{-1}), rotation rate (day^{-1}) and growth rate (day^{-1}).

5. RESULT OF EXPERIMENT

Fig. 3 shows the results of the rotational rate, the specific growth rate and Chlorophyll-a concentration at each retention time obtained by the experiment. When the retention time is 0.7,1, and 1.2 days algae cannot grow because the rotation rate is higher than the growth rate (d>r). Whereas when retention time is 2,3,5,7,10,20 (days) algae can grow because the growth rate is higher than the rotation rate (d<r). Therefore, we found that the algae cannot grow as the retention time shorter because of algae flush out of the incubator faster than algae grow. Then, we evaluated applicability of this method by culture experiment about the blue-green algae.

6. CONCLUTION

The purpose of this study is to propose a method to simply define the safest required volume of water in order to prevent blue-green algae from growing by flushing out them. In order to prove this relation between the algae's maximum specific growth rate and rotation rate, we conducted a culture experiment.

We know that we can tell whether the blue-green algae will die out or not by comparing the algae's growth rate and the rotation rate. In other words, it is better to conduct water more quickly than the growth rate of blue-green algae. Then, we evaluated applicability of this method by culture experiment about the blue-green algae.

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O3-5

Flood Pulse in A Tropical Floodplain Lake and Its Implication on Aquatic Habitat Dynamics
Case study in the Sentarum Lakes Area, Kalimantan - Indonesia

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[1] Research Center for Limnology, Indonesian Institute of Sciences

Keywords: Floodplain lake, flood pulse, water level, water quality, fish diversity

ABSTRACT

The Lake Sentarum in West Kalimantan, Indonesia, refers to a complex of large and small floodplain lakes in the middle part of the Kapuas River system. Apart from its great ecological and economic importance, the Sentarum lakes complex and its catchment area are generally threatened by deforestation, fire, monoculture agroindustry, and pollution. The objective of this research is to establish the hydrological characteristics of the Sentarum lakes area and to reveal the dynamics of aquatic habitat resulted from changing water levels. The water level was measured using a pressure sensor, while rainfall data were obtained from the data portal of the Tropical Rainfall Measuring Mission. Inundation monitoring was carried out using a time-lapse camera. A hydrological model is used to simulate water levels beyond measurement period. Water quality and fish sampling were carried out representing the seasons. Vegetation observation was carried out by field observation as well as analysis using satellite images. Water level records show that the Sentarum floodplain lakes have two peaks of inundation period following the bimodal pattern of rainfall in the equatorial Kapuas catchment. This water level dynamics induced changes in water quality, nutrient availability, vegetation cover, and fish diversity found in the Sentarum lakes area. Despite its seasonal changes, water quality of Sentarum lakes is generally good and suitable for aquatic biota. Fish diversity of the Sentarum lakes is relatively higher during high water period.

1. INTRODUCTION

The Lake Sentarum in West Kalimantan, Indonesia, refers to a complex of large and small floodplain lakes in the middle part of the Kapuas River system. As wetland area characterized by seasonal inundation, the Sentarum floodplain lakes have flood pulse that is determined by hydrological factors in the area as well as the upstream part of the Kapuas catchment. In wetland with flood pulse, there is a strong correlation between hydrological variation and aquatic biodiversity with apparent spatial and temporal variability [1]. Therefore, a synthesis from hydrological and ecological studies will enhance understanding on how and why water chemistry properties and aquatic biodiversity are varied among different times and locations.

The Sentarum lakes area is a vast natural reservoir with a maximum area of 1000 km^2 (Fig. 1) that can store as much as 3 billion m^3 of water [2], and consists of peat swamp forest and freshwater swamp forest. During the long dry season, most of the lake is dry, while during the rainy season the swamp and peat forest of the Sentarum lakes area are inundated forming a large shallow lake as shown in the Landsat images (Fig 2).

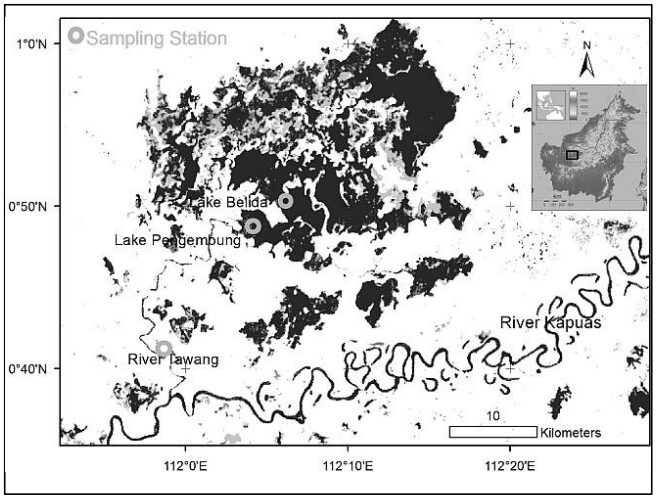

Fig. 1. Map of the Sentarum lakes area.

The Sentarum lakes area is an important source of livelihood of local people. The lake cluster produces about 18,000 ton of freshwater fish annually [3]. Apart from its great ecological and economic importance, the Sentarum lakes complex and its catchment area are generally threatened by deforestation, fire, monoculture agroindusty, and pollution.

The objective of this research is to establish the hydrological characteristics of the Sentarum lakes area and to reveal the dynamics of aquatic habitat resulted from changing water levels.

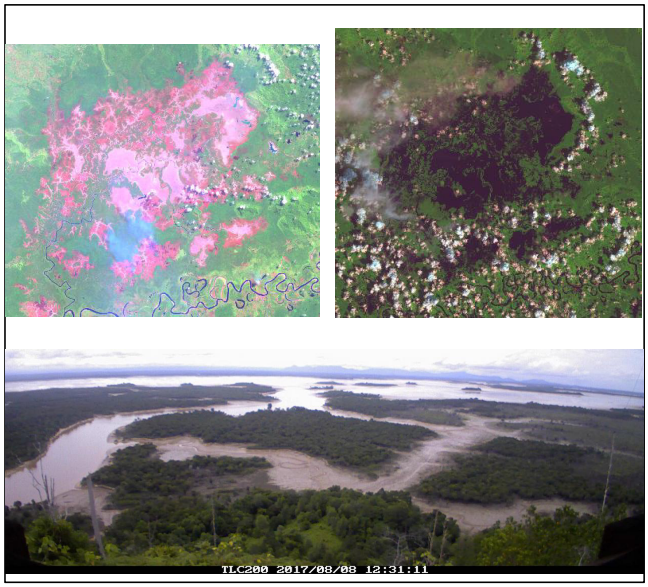

Fig. 2. Dry condition on 1 July 2004 (left), fully inundated on 1 October 2015 (right) of Lake Sentarum from Landsat images, and nearly dry condition on 8 August 2017 captured by time-lapse camera (bottom).

2. METHOD

Water level was measured using a pressure sensor, while rainfall data were obtained from the data portal of the Tropical Rainfall Measuring Mission. Inundation monitoring was carried out using a time-lapse camera. A hydrological model is used to simulate water levels beyond measurement period. Water quality and fish sampling were carried out representing the seasons. Vegetation observation was carried out by field observation as well as analysis using Landsat satellite images.

Water quality and vegetation sampling were carried out in 2013, 2016, dan 2017. Water samples were taken using Kemerrer Water Sampler at the lake surface and bottom analyzed for water quality Parameter including pH, DO, conductivity, nitrite, nitrate, ammonium, Total N, Total P, and organic matter (TOM). Vegetation sampling was carried out using the line transek method of 50 x 20 m with three replicates.

Fish samples were taken in March, June, October 2013, and March, June 2014. Fish sampling was carried out by experimental gill net with the total length of 350 m and height of 2 m. Different net mesh size was udes in every 50 meters distance: 12.70 mm, 19.05 mm, 25.40 mm, 38.10 mm, 50.80 mm, 76.20 mm, and 88.90 mm.

3. RESULTS AND DISCUSSION

Water level records show that the Sentarum floodplain lakes have two peaks of inundation period following the bimodal pattern of rainfall in the equatorial Kapuas catchment. Fig. 3 Shows measured water level of the Sentarum lakes.

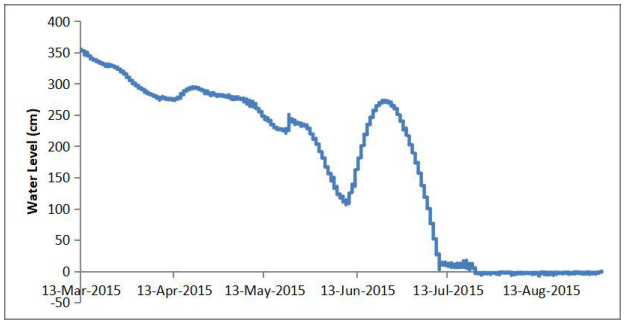

Fig. 3. Measured water level of Lake Sentarum.

Water quality observations show that aquatic environment of the Sentarum lakes area is relatively good for aquatic biota except that at the Seriang station Oxygen concentration of nearly zero was found at the lake bottom (Fig. 4). Fourteen riparian vegetation species were found in the lakes area, three of them are dominant species namely *Barringtonia acutangula* (Putat), *Ixora salicifolia* (Mentangis), dan *Maranthes corymbosa* (Melayak). The swamp forest provides feeding, refuge, spawning, and nursing grounds for fish [4].

Six orders, 15 families, and 39 species of fish were found in Tawang River, Lake Pengembung and Lake Belida in the Sentarum lakes area in the 2013 and 2014 fish sampling. The observed species diversity can be explained by the water level – hydrology – habitat – aquatic productivity – migration nexus as exemplified by the 'flood – pulse' concept [5]. Total number of species found in the dry season was less (20 species) than that in the rainy season (32 species). During low water level and low water depth, the highest number of species was found in River Tawang (16 species) compared to that of Lake Pengembung (5 species) and Lake Belida (3 species). Whereas during high water, the highest number of species

was found in Lake Belida (24 species) and the lowest species was in River Tawang (15 species).

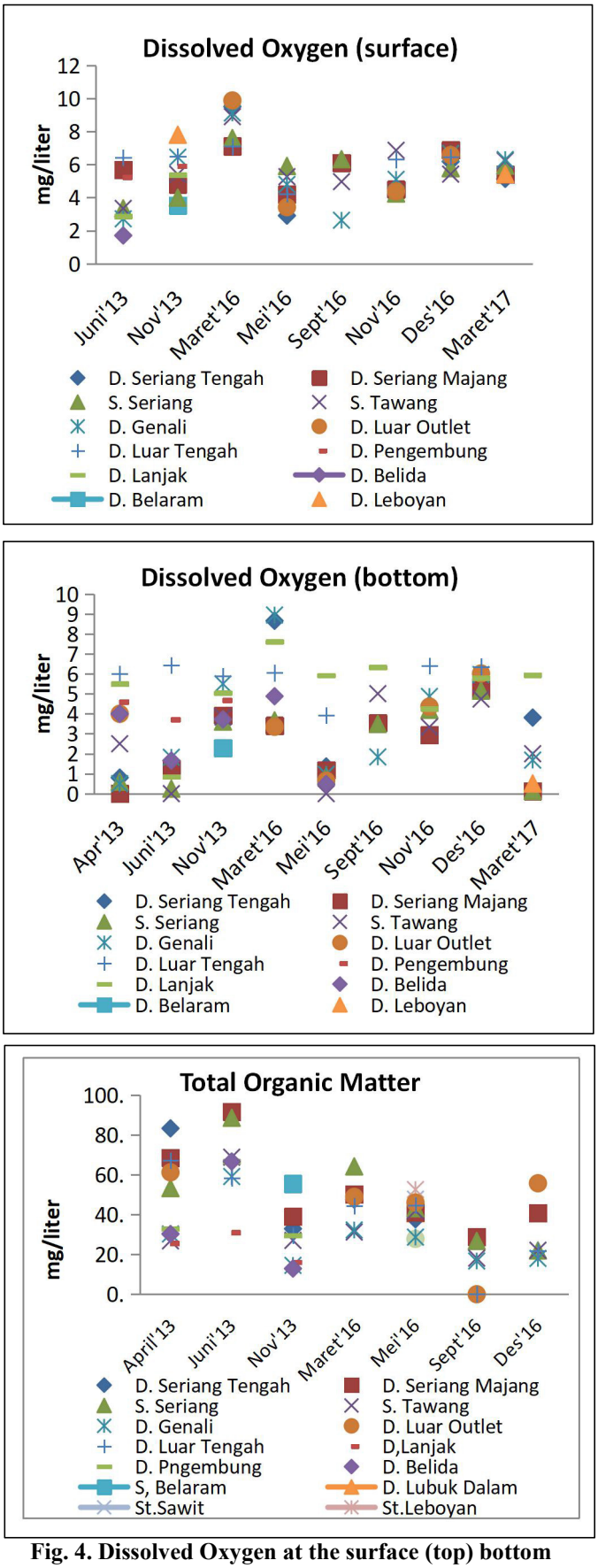

Fig. 4. Dissolved Oxygen at the surface (top) bottom (Middle) and Total Organic Matter during observation.

4. CONCLUSION

Hydrological characterization of the Sentarum Lakes area had been carried out considering the influence of water level changes to aquatic habitat dynamics. Water level dynamics induced changes in water quality, nutrient availability, vegetation cover, and fish diversity found in the Sentarum lakes area.

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O3-6

Dissolved oxygen profiles and its problems at Lake Maninjau, West Sumatera - Indonesia

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Keywords: water quality, dissolved oxygen, fish cage area and Lake Maninjau

ABSTRACT

In general, tropical lake in Indonesia is one of the unique ecosystems which are functioning in both ecological and economic services. The objective of this study is to analyze the dissolved oxygen profile of caldera tropical lake represented by Lake Maninjau at West Sumatera, Indonesia and its impact. Lake Maninjau, not only for fisheries culture, but also serves as important hydroelectricity power. Surveys at Lake Maninjau was conducted in August 2006, March 2014, September 2017 and April 2018. The results on the survey in Lake Maninjau showed that the average depth is 105 m. It covers 13,260 ha of area with a height of 461.5 m above sea level and maximum depth of 165 m. The lake water comes from rainfall, small rivers and the surrounding ground water and one outflow in Batang Antokan River. Based on the measurement results, it obtained that dissolved oxygen from the surface layer to a depth of 40 m (2006) has decreased to a depth of 12 m (2018), indicating the worse condition of water quality in 2018 compared with previous years. Currently, bad water quality and mass mortality fishes often occurred. Next, the percentage value of fish cages at Lake Maninjau in 2017 was 0.43%. Besides human activities, it suggested also that the potential impact from fish cages constributed pollutant concentration into this lakes. In order to maintain the sustainability of the lake, basic ecological information is necessary for the next study.

1. INTRODUCTION

Lake Maninjau is a large lake which including in the type of caldera lake. This lake is located in Agam District - West Sumatra and has an important role for daily life and the beauty of the lake (Fig.1). Further, it has become the pride of the surrounding community. Currently, Lake Maninjau has economic functions as a power plant that produces the annual rate of 205 GWH of energy, sources of irrigation water, fishing fish farming in floating cages and catching, and tourism destination [1 & 2]. In addition, from the view of ecological functions, Lake Maninjau could control the water balances of soil, microclimate and habitat for organisms.

Besides hydropower, utilization Maninjau also for fish farming activities in the floating net. Cultivation of fish in floating net began in 1990. Fish farming activities in floating net have increased the high economic growth for local communities. But since 1997, this activity began to decrease because of frequent death of fish caused the loss of business. Since when was there a public complaint that a decrease in water quality of the lake is causing economic loss to the community or local government from both fish farming activities in the cages and tourism. Besides for fish farming in floating cages, Lake Maninjau is also used for tourist activities, especially by foreign tourists [3]. The development of tourism activities also led to the growth of the hotel or inn and restaurant around the lake. But the water quality of the lake such as murky water and odor caused a decline in tourist numbers and the impact on the economy of the community and local government.

In early January 2009, more than 13 thousand tons of disaster death of fishes occurred at Lake Maninjau. From measuring the water quality of lake from observation by Limnology station - Research Centre for Limnology LIPI, on January 2009, reported a drop of dissolve oxygen (DO) 1.05 mg/l in water surface (normal conditions approximately 7 mg/l) with temperatures 28°C and pH 7.17. At three meters of water depth, dissolved oxygen (DO) content had reached 0.46 mg/l and temperature 27.2^{o}C. The water column is normally used for floating cage. The low oxygen content was causing mass death of fishes. This disaster is related to what is called by local people as "tubo sulfur." Generally sulfur turbo phenomenon has been frequently occurs at the beginning of the year. In addition, there is a possibility of circulation influence on the vertical profiles of dissolved oxygen in some of the lakes, where related to the seasonal

meteorological patterns [4].

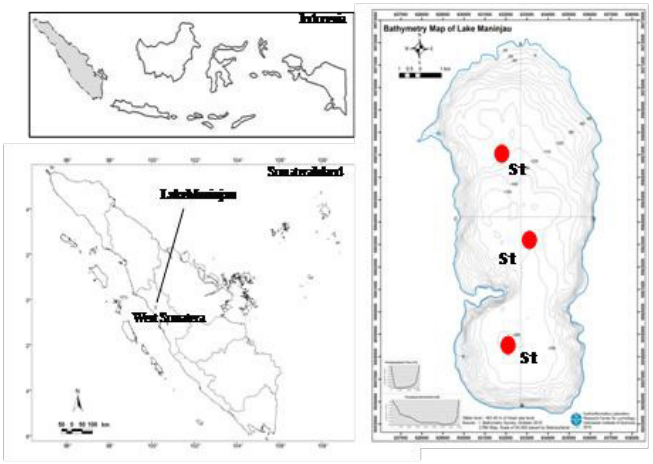

Fig. 1 Locations of study area

2. METHOD

Survey at Lake Maninjau was conducted in August 2006, March 2014, September 2017 and April 2018. Not only survey at field, but also to collect the secondary data for supporting the analyze.

We conducted dissolved oxygen (DO) profile measurememt in August 2006 by multi-probe sensor YSI 6600. Measurements were carried out until to the depth of 50 m with an interval of 0.4 m. Dissolved oxygen (DO) profiles was obtained with ranged 0 to 50 mg/L and resolution 0.01 mg/L. Meanwhile, DO profile measurement in March 2014, September 2017 and April 2018 were taken from three locations at Lake Maninjau by ringko profiler, supported by University of Tsukuba, Japan. The logger version CTD profiler with optical fast DO sensor RINKO-Profiler was used for survey. Depth (semiconductor pressure sensor with ranged 0 to 600 m and resolution 0.01m) and dissolved oxygen/DO (phosphorescence with ranged 0 to 20 mg/L and resolution 0.001mg/L) were obtained at each station. Measurements were carried out until to the depth of 160 m with an interval of 0.1 m.

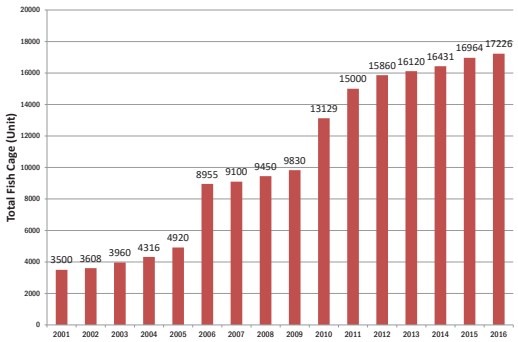

Fig. 2 The amount of fish cage at Lake Maninjau since 2001

Source : Agam Regency – West Sumatera (2016)[6]

Finally, fish aquaculture cages established at lake Maninjau was also observed and accounted (Fig. 2). At Lake Maninjau, there are approximately 16,000 unit fish culture cages in 2017, in general with sized 5 x 5 m [5].

Through campaigning "Save Maninjau" by local government [6], they succeed to hold the growth rate of fish cage and the total fish cage were 16,776 unit and 17,226 unit for 2017 and 2016, respectively.

3. RESULTS AND DISCUSSION

Lake Maninjau is located at an altitude of 461.5 m above sea level with a surface area of 9,737.5 ha and a maximum depth of 165 m. Lake Maninjau is a caldera lake formed by volcanic activity in 60,000 years ago [7]. The source of water comes from rain water lakes and streams as well as the surrounding ground water. This lake has a water line out called Batang Antokan flowing into the Indian Ocean, on the West coast of West Sumatra.

In Lake Maninjau, since 1983 is used for power generation that the average annual production of 205 GWH, by building a dam at the outlet (Antokan River, which is the basis of the river at an altitude of 462 m). The dam raised the water level of the lake from a height of 462 m from sea level to 464 m. In addition, outflow from the lake is used for power generation through the intake structure at a height of between 457.15 m to 453.75 m from sea level.

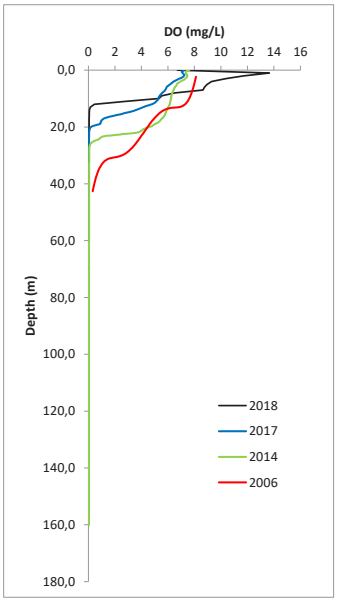

Fig. 3 DO profiles at Lake Maninjau (August 2006, March 2014, September 2017 and April 2018)

Based on Fig. 3, high dissolved oxygen content in the surface layer and the base of diminishing. Dissolved oxygen from the surface layer to a depth of 40 m (2006) has decreased to a depth of 12 m (2018), indicating the worse condition of water quality in 2018 compared with previous years.

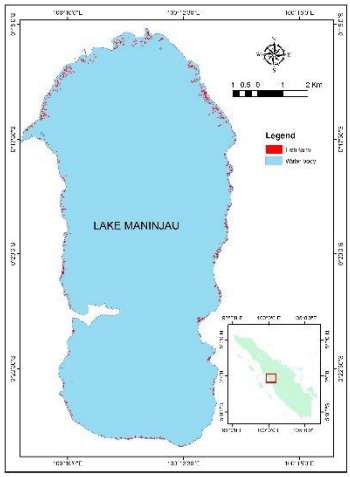

Fig. 4 Distribution of fish cage (red colour) in 2016

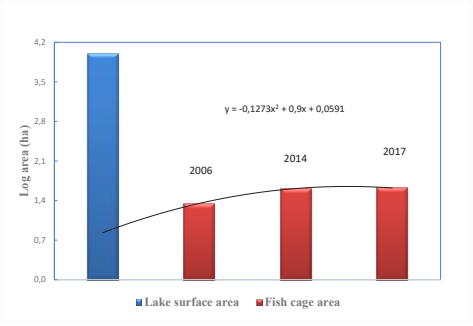

Fig. 5 Comparison between lake surface and fish cage areas for 2006, 2014 and 2017

Based on survey and secondary data, we obtained the distribution of fish cage (Fig 4). Next, in Fig. 5 showed comparison among fish cage areas (log area (ha)) in three years observed. The fish cage area were 22.4 ha, 41.1 ha and 41.9 ha for 2006, 2014 and 2017, respectively. It suggested the growth of fish cages as pollutant also influenced water quality at Lake Maninjau.

4. CONCLUSION

Lake Maninjau function in ecological and economic services as a caldera tropical lakes has faced in various problems. The decreasing of dissolved oxygen layer from the surface layer compared with previous years, indicating the larger impact from human activities constribute to the water quality on the lake.

It found the percentage value of fish cages at Lake Maninjau was higher in 2017 (0.43%) than that in 2006 (0.23%). Based on this ratio, the density of aquaculture which indicated the potential impact i.e. pollutants from fish cages at Lake Maninjau. Consequently, in order to maintain the sustainability of these lakes, basic ecological information is necessary for the next study.

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O3-7

霞ヶ浦外浪逆浦の浚渫窪地での水温成層形成とそれによる水質への影響

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キーワード:浚渫窪地, 水温成層, 水質変動

抄録

浚渫窪地は, 外部水域との水の交換が起こりにくいことから, 成層の形成で生じる貧酸素化を原因としたりんの溶出を生じる一因となっている。霞ヶ浦にもかつての土壌採取等による浚渫窪地が存在し, 特に南東部に位置する外浪逆浦に大規模な浚渫窪地があるが, これまで調査報告例はないため, 霞ヶ浦外浪逆浦の浚渫窪地を対象にして水温成層の形成状況及び水質の状況を調査した。窪地の内部では, 水温成層の形成と破壊が繰り返し生じ, 水温成層の破壊は主に気温の低下と強風により生じることが明らかになった。また, 水温成層の状況と水質との関係を検討したところ, 水温成層形成時には下層で DO 濃度が低下し, PO_4-P が高濃度となっていることが確認できた。

1. はじめに

海洋や湖沼の底には，局所的に深くなった窪地が存在しているところがある[1,2]。この窪地は東京湾・三河湾・大阪湾の三大湾，瀬戸内海及び九州沿岸に多く存在し，多くは砂利採取や海底掘削等により生じたものである。

窪地内部では，外界との水の交換が起きにくいため成層を形成して貧酸素水塊を生じるため青潮発生の原因や生物への悪影響になるとともに，底泥からのりんの溶出が生じて水質を悪化させる。例えば三河湾では，平成 13 年度及び平成 14 年度に窪地内部での貧酸素化により青潮が発生し，周囲のアサリ漁に壊滅的な打撃を与え，このことを受けて三河湾では平成 15 年度から窪地の埋め戻しが行われた[3]。この他にも東京湾，大阪湾，瀬戸内海でも窪地の埋め戻しが行われており，加えて平成 17 年 3 月の交通政策審議会答申及び平成 17 年 5 月の中央環境審議会答申において，窪地の積極的な埋め戻しが提案された[4,5]。これらのように窪地が水質や生物に与える悪影響が指摘され，埋め戻しの必要性が提唱されている。

茨城県南部に位置する霞ヶ浦においても，かつての砂利採取による窪地が存在し，特に外浪逆浦では，水深 20 m にもなる窪地が確認されている。この窪地が，りん等の溶出により水質に影響を及ぼす可能性が考えられるが，この窪地が水質に与える影響について評価した例はない。

そこで本研究では，外浪逆浦の北部に位置する水深約 11m の窪地を対象として，水質への影響を評価したので報告する。

2. 方法

2.1 調査地点諸元

外浪逆浦は，日本の茨城県南部に位置する霞ヶ浦の一水域で，湖面積 6.0 km^2 の淡水湖である。主要部の水深は 2～3 m であるが，図 1 に示すように一部にかつての土壌採取や砂利採取により水深 10 m 以上の窪地が生成されている。流入河川は，西浦と接続する北利根川と，北浦と接続する鰐川の 2 河川で，流出河川は常陸川の 1 河川のみであり，常陸川には海水の流入を防ぐための水門があり，その水門の開閉により外浪逆浦の湖流が変化することが報告されている[6]。

2.2 調査概要

調査対象は，外浪逆浦の北部に位置する，長辺 1 km，短辺 500 m，水深 11.5 m の窪地（周辺部は水深約 2 から 3 m）とした。

調査期間は，2016 年の 6 月 3 日から 8 月 31 日にかけて行った。

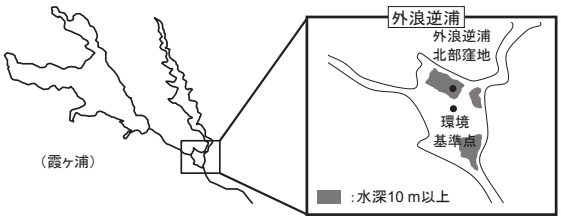

図 1　調査地点図

調査地点に水温ロガー（HOBO 製　Pro v2）を水面下 1 m から 10 m まで 1 m 間隔で設置し，1 時間ごとに連続測定を行った。また概ね 2 週間に 1 回程度の頻度で 0.5 m，2 m，4 m，6 m，8 m，10 m の深度で現地で DO の測定及び採水を行った。DO の測定には HACH 製　HQ 30d を用い，採水にはバンドーン採水器（離合社製，50260）を用いた。

2.3　分析方法

PO_4-P は，JIS K 0170-4 6.3.4 モリブデンブルーCFA 法で測定した。

2.4　気象等データ

気温及び降水量は，気象庁の鹿嶋の測定結果を用いた。風速は，国土交通省関東地方整備局霞ヶ浦河川事務所の潮来（調査地点より西北西に 4.7 km）の測定値を用いた。水門の開閉時間は，国土交通省霞ヶ浦河川事務所の測定値を用いた。

3. 結果

水温の連続測定結果を図 2 に，DO 及び PO_4-P の測定結果を図 3 及び図 4 に示す。また，DO 及び PO_4-P については，茨城県公共用水域及び地下水の水質測定結果及び霞ケ浦環境科学センター定期調査結果の中で，窪地水質調査日に最も近い測定結果を参考として示す。

図 2 は上層との水温差を示し，濃色部分が水温差が大きいところになる。水温の上下層差は，6 月から 8 月の間に断続的に変化し，調査期間中では計 7 回水温成層の破壊が生じた。

DO は，6 月 7 日，6 月 29 日は下層で顕著な貧酸素化が見られなかったが，7 月 14 日，8 月 10 日，8 月 26 日の調査時には下層で顕著に DO が低下していた。

PO_4-P は，6 月 7 日，6 月 29 日，及び 8 月 26 日は下層で PO_4-P の上昇は見られなかったが，7 月 14 日，8 月 10 日では下層で PO_4-P が上昇した

4. 考察

4.1　水温成層の破壊要因の検討

水温成層の形成状況及び破壊条件を把握することは，下層の DO 状況を推定する上で重要である。そこで，水温成層の破壊条件について検討することにした。なお，霞ヶ浦においては 1℃以下の水温差で湖水の上下流が抑制されるという報告があるため[7]，水温の上下層差が 1℃以上の時を，水温成層が形成されていると定義した。水温成層の破壊要因としては，主に気温の低下による表層水の冷却，強風による撹拌，降雨の影響，常陸川水門の開閉の 4 項目が主に考えられたため，これらの関係について検討を行った（図 2）。

初めに，水温成層と気温との関係を検討した。これを見ると，水温成層が破壊された時期には，8 月 17 日を除き直前に急激な気温の低下が見られた。このことから気温の低下は水温成層の破壊に寄与すると考えられたが，ほかの要因も寄与していると考えられた。

次に，水温成層と風速の関係を検討した。調査期間中では，日平均値で 5 m/s 以上の風が吹くと水温成層が破壊される傾向が見られた。気温との関係が見られなかった 8 月 17 日の水温成層破壊時にも 6.2 m/s の風が吹いていたことから，8 月 17 日の成層破壊は風の影響と考えられた。なお，8 月 8 日には 6.8 m/s の風が吹いていたが水温成層の破壊が見られなかった。前日の 8 月 7 日における水温差は，調査期間中最大の 4.4℃と大きく，水温成層の完全破壊までは至らなかったと考えられた。

次に，水温成層と降水量の関係を検討した。6 月 29 日，7 月 17 日，8 月 17 日の成層破壊時には直前に降雨があり，この期間については降雨との関計が考えられるが前述の気温低下も同時期に見られていることから，詳細な関係は不明である。

最後に，水温成層と水門の開閉について検討した。調査期間中における水温成層形成時の水門開閉は 8 月 6 日に 1 回行われたが，その時には成層破壊は見られなかったことから，水門の開閉は成層破壊に寄与しないと考えられた。

以上のように，外浪逆浦の窪地における水温成層の破壊要因としては，気温の低下，強風の影響が主に考えられた。なお，降雨の影響は不明なため，今後さらなる検討が必要である。

4.2　水温成層形成が水質へ及ぼす影響

水質調査を行った 5 日のうち，6 月 7 日，6 月 29 日には水温成層が形成されておらず，7 月 14

日，8 月 10 日，8 月 26 日には水温成層が形成されていた。これらの時の水温成層の状況と水質との関係の検討を行った。

まず水温成層と DO の関係の検討を行った。水温成層が形成されていなかった期間は下層での DO の顕著な低下が見られず，逆に水温成層が形成されていた期間は DO が顕著に低下していた。このことから，外浪逆浦においても他地域と同様に成層の形成による貧酸素水塊の形成が確認できた。

次に，水温成層と PO_4-P の関係を検討した。こちらも同様に，水温成層が形成されていなかった期間は下層の PO_4-P の上昇が見られなかった。また水温成層が形成されていた時期では，7 月 14 日と 8 月 10 日は下層で PO_4-P の上昇が見られた。一方で水温成層が形成されていた 8 月 26 日に PO_4-P の上昇が見られなかった原因については，8 月 26 日は水温成層が形成されてからの期間が短かったために，PO_4-P の溶出量がほとんどなかったことが原因と考えられた。

5. 結論

外浪逆浦にある，水深 11.5 m の窪地を対象にして，温度躍層の破壊条件及び水質への影響調査を行った。今回の結果からは，水温成層は主に気温の低下及び強風により破壊されると考えられた。また，成層形成時には DO の低下及び PO_4-P の溶出が確認できた。

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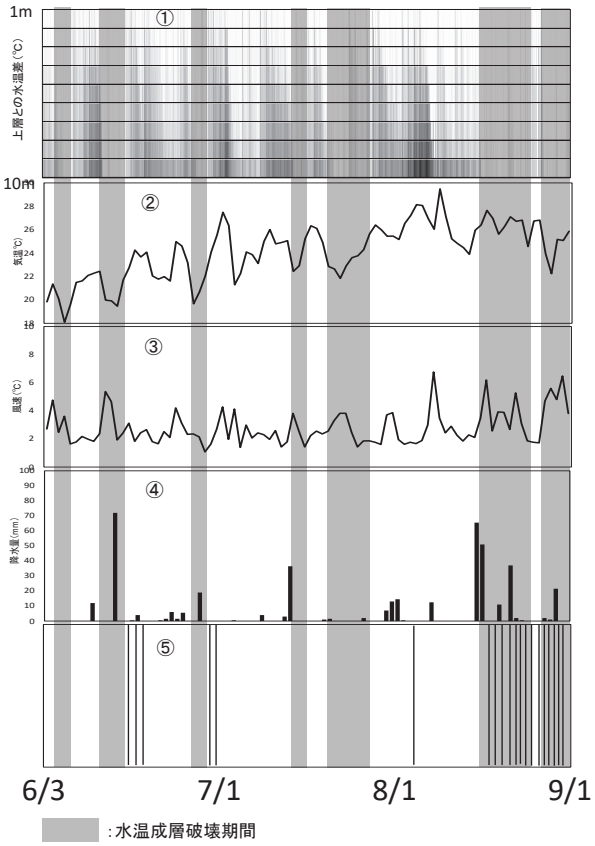

図 2　水温成層と各水質項目の関係
（①：水温成層，②：気温，③：風速
④：降水量，⑤：水門の開閉）

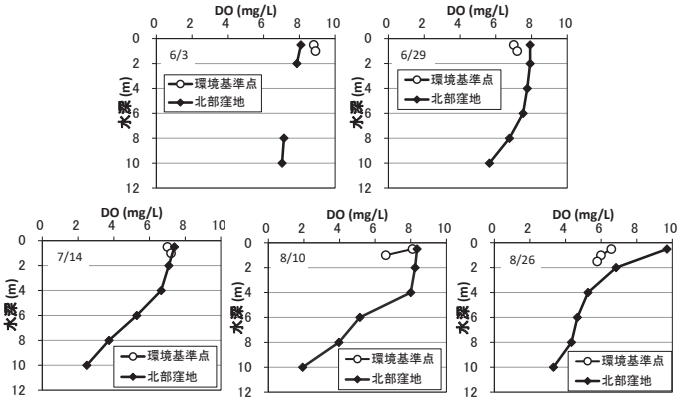

図 3　DO の測定結果

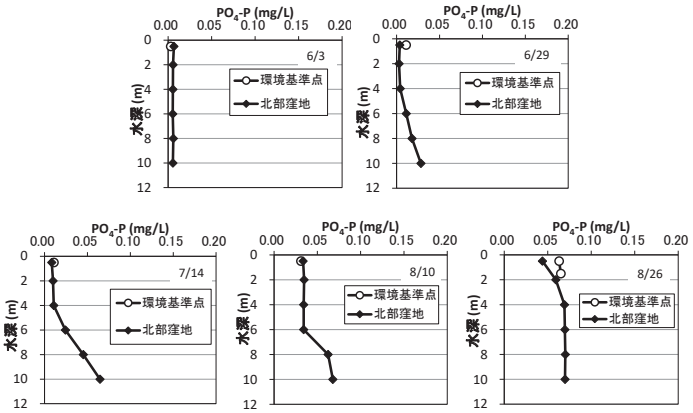

図 4　PO_4-P の測定結果

O3-8

Effects of Three Gorges Dam on spatiotemporal distribution of silicon in the tributary: evidence from the Xiangxi River

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Keywords: Silicon; Spatiotemporal distribution; tributary; Three Gorges Dam;

Abstract

In order to get insight into the impact of dam construction on silicon distribution pattern due to the altered hydraulic and environmental conditions, the Xiangxi River was chose as the delegate of the tributaries in the Three Gorges Reservoir to screen the effects of the Three Gorges Dam on silicon distribution. Dissolved silica (DSi), biogenic silica (BSi) and lithogenic silica (LSi) were investigated monthly from November 2015 to October 2016, the hydrodynamic conditions were addressed synchronously. DSi was significantly lower in the wet season than the dry season (P<0.05), BSi and LSi were significantly higher in the wet season than the dry season (P<0.05). DSi was dominant component in the total silicon (> 90%) and it has a relatively higher concentration in the upstream than the downstream in the main channel. BSi was higher in the upstream than the downstream. LSi was significantly higher in the upper tributaries than the main channel (P<0.05). Statistical analysis showed that DSi was linearly negatively correlated with water discharge（P<0.05）. BSi concentration showed a negative correlation with DSi (P<0.05). Water velocity and discharge exhibited a positive correlation with LSi concentration (P<0.05). DSi had a negative correlation with Chl *a* while BSi had a positive correlation with Chl *a* (P<0.05). The backwater area retained 2.59% bioavailable silicon (DSi+BSi). It was concluded spatio-temporal heterogeneity of silicon distribution related to hydrodynamics was determined by the regulation of dam, backwater area was the main deposition area for silicon.

1. Introduction

River is an important place for the silicon cycle because approximately 80% of silicon empties into the ocean through river, which pass from the lithosphere to the hydrosphere. Silicon in river is originally from rock weathering. At a global scale, tropical rivers have relatively higher dissolved concentrations than non-tropical rivers due to their high temperature and runoff, thus, high weathering rate, which influence the distribution of silicon. Dam construction will decrease DSi in a river. For instance, DSi concentration in the Nile River decreased by 200μg/L after the construction of the High Dam at Aswan. Similarly, DSi in the Black Sea showed a 60% decrease in wintertime after the construction of the Iron Gates dams. An obvious decline in DSi was observed when water passed through cascade reservoirs in Jiulong River.

In this study, we hypothesize that the silicon distribution and retention in the tributary were closely related to the hydraulic dynamics caused by dam operation in the Three Gorges Reservoir.

2. Materials and methods

2.2 Sampling and analytic methods

Twelve sample sites were set along the river (Figure1).

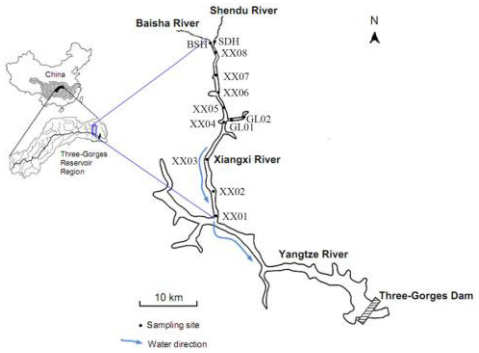

Figure 1 .Sketch map of sampling stations in the Xiangxi River

3. Results

3.1 Hydrodynamics

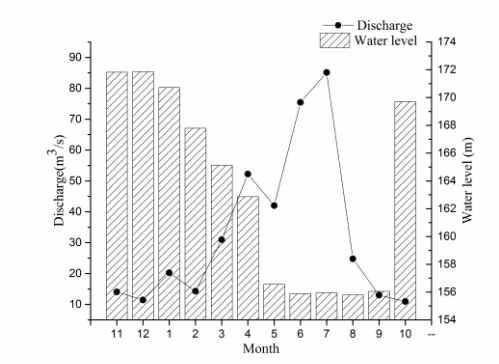

Figure 2. Variation of water level in the TGR and discharge in the Xiangxi River during the study period

3.2 Temporal distribution of silicon

Positive correlation was found between LSi concentration and discharge (Fig. 4)

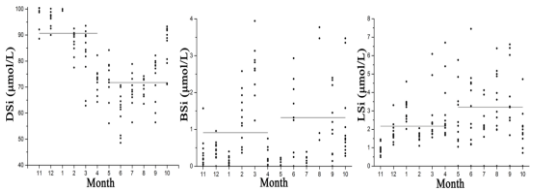

Figure 3. Variation of silicon monthly in the Xiangxi River, Spring is March ~ May, Summer is June ~ Augest, Autumn is September ~ November, Winter is December ~ next February.

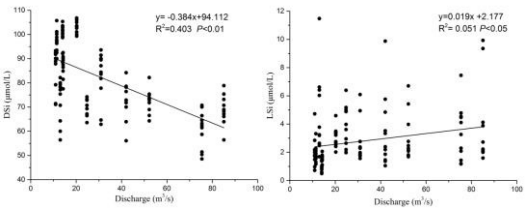

Figure 4. Relationship between water discharge and concentrations of DSi and LSi in the Xiangxi River

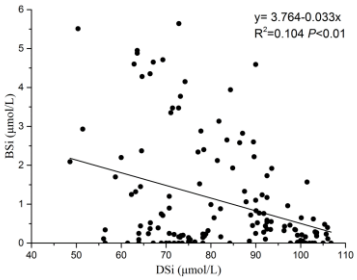

Figure 5. Relationship between DSi and BSi in the Xiangxi River

3.3 Spatial distribution of silicon

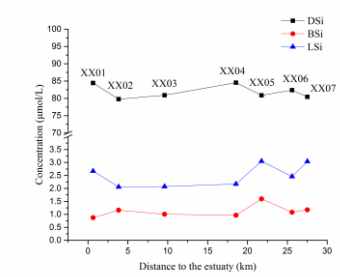

Figure 6. Longitudinal distribution of silicon in the main channel of the Xiangxi River

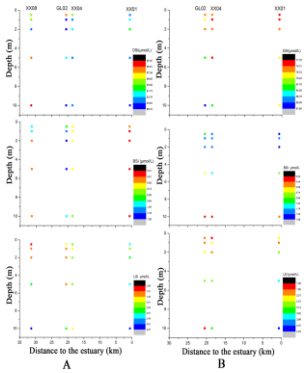

Figure 7. Vertical distribution of silicon at three sites in the dry season(A) and wet season(B)

3.4 Silicon retention in the backwater area

2.59% of the inflow total bioavailable silica (DSi+BSi) was retained. 3.67% of the TSi inflow was removed through the backwater area.

4. Discussion

4.1 Silicon fluxes in the Xiangxi River

Approximately 3.14% of DSi and 0.04% of BSi retained in the TGR were captured in the Xiangxi River. Silica retention efficiency in the reservoir was affected by the trophic state and reservoir age.

4.2 Silica dynamics and its influencing factors

DSi flux is controlled by the runoff and concentration of DSi. It is indicated that the BSi is primarily controlled by phytoplankton.

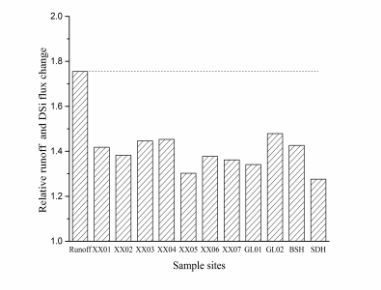

Figure 8. The relative changes of runoff and DSi at each site. The relative change were calculated by dividing the annual runoff and DSi fluxes in the wet season by those in the dry season. The upper broken line represents the runoff change. DSi fluxes that changed to the same degree as the runoff are controlled by runoff, and the one that differ from the runoff change are influenced by the DSi concentration.

4.3 Impacts of dam on the distribution of silicon

Dam will push Yangtze River water back to the tributary, which can also influence the distribution of silicon. The water intrusion process in the Xiangxi River has been investigated in detail .Silicon species structure changed under the intrusion process. The present study exhibited an increase DSi proportion in the downstream (XX01~XX04) but a decline of LSi proportion. Meanwhile, an obvious higher DSi and LSi at XX01 than other sites was observed (Fig 6).

5. Conclusion

Dam construction affects silica variation mainly through altering hydraulic conditions. It was concluded that silicon flux was determined by discharge, backwater area was the main retention area for silicon, and spatio-temporal heterogeneity of silicon distribution determined by regulation of dam was related to hydrodynamics.

O3-9

秋田県八郎湖における魚類による藍藻の餌利用状況

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キーワード:アオコ, 富栄養化, 食物連鎖

抄録

アオコを形成する藍藻類は、フロックの形成や毒素生産などの特徴から水生動物から摂食されにくいと考えられてきたが、実際の湖沼生態系で藍藻が水生動物によって餌として利用されているか調べた事例は少ない。本研究では魚類による藍藻の餌利用の状況を調べるために、秋田県八郎湖において、2016 年 6 月から 11 月にかけて月 1 回の建網調査を行った。そして、採集した魚類筋肉中の脂肪酸組成を調べることで、魚類が藍藻を餌として同化しているか検討した。7 月には藍藻が優占し始め、8 月から 10 月にかけてアオコ状に藍藻が発生している様子が確認された。本調査で採集された各魚類体内における藍藻に由来する脂肪酸(18:2ω6 および 18:3ω3)の含有率は 8 月までほぼ一定で推移したが、9 月に急激に上昇した。アオコ発生の初期においては魚類による藍藻の餌利用は認められなかったが、アオコ発生が継続すると、魚類が藍藻を餌として利用し始めると考えられた。

1. はじめに

富栄養化が進行した湖沼においてしばしばアオコが発生する。アオコとは異常増殖した藍藻類が水面を緑色に染める現象のことを指す。アオコを形成する藍藻類は、フロックの形成や毒素を生産することで、動物プランクトンによる摂食から逃れやすい。そのため、湖沼生態系において藍藻は餌として利用されにくく、アオコが発生すると生食連鎖が断ち切られると考えらえてきた。しかし、実際の湖沼生態系において、藍藻がどの程度餌として利用され、藍藻に由来する有機物が高次の動物に餌利用されているか検証した事例は少ない。

藍藻を餌利用しているか検証する方法として脂肪酸分析が挙げられる。藍藻にはリノール酸(18:2ω6)やリノレン酸(18:3ω3)といった脂肪酸が含まれており、これらの脂肪酸は動物からは合成されない。そのため、動物体内からこれらの脂肪酸が検出されれば、藍藻に由来する有機物を同化していると推定することができる。

そこで本研究では、魚類による藍藻の餌利用の状況を明らかにすることを目的として、毎年夏季にアオコが発生する秋田県八郎湖を対象に、魚類の脂肪酸組成の経月変化を調べることで、魚類が藍藻を餌として利用しているか検証した。

2. 方法

2.1 調査地概要

八郎湖は秋田県男鹿半島の付け根に位置する淡水湖である。富栄養化が進行し、夏季にアナベナ属やミクロキスティス属によるアオコの発生が報告されており[1]、平成 19 年度には湖沼水質保全特別措置法に基づく指定湖沼となっている。八郎湖は農業用水として利用されているほか、漁業も営まれている。ワカサギが八郎湖総漁獲量の 90%以上を占めており[2]、ワカサギが優占種となっている状況が伺える。

2.2 調査内容

2016 年 6 月から 11 月にかけて月に 1 回、八郎湖の湖心付近に一晩建網を設置し、魚類を採取した。また、表層水をポリ瓶で採水した。採取した魚類はクーラーボックスに入れて実験室に持ち帰り、尻ビレ付近の筋肉を切り出し、脂肪酸分析まで冷凍保存した。水試料はガラスフィルター(GF/F)でろ過し、ろ紙上にトラップされた粒子を懸濁物質サンプルとして脂肪酸分析に供試した。

脂肪酸分析は凍結乾燥した、魚類の筋肉、ガラスフィルターを対象として、One-step method [3]を用いて、脂質の抽出および誘導体化を行った。抽出・誘導体化した脂肪酸メチルエステルはキャピラリーカラム(アジレント社、Select FAME)を装填したガスクロマトグラク(サーモフィッシャーサイエンティフィック社、Trace1310)で定性・定量を行った。

3. 結果

目視および顕微鏡観察によって、8 月、9 月、10 月にアオコの発生が確認された。懸濁物質中の藍藻由来脂肪酸含有量は 9 月まで増加し続けた(図 1)。調査期間を通して、コイ、ギンブナ、ジュズカケハゼ、ヌマチチブ、

ワカサギが採取された。ワカサギは体長から当歳魚（≤50 mm）と1歳魚（≥80 mm）に分けて解析した。各魚類ともアオコが発生前の6月時点では藍藻由来の脂肪酸含有率が1～4%程度と低く、アオコの発生が認められた8月まで、低含有率のまま推移した（図2）。しかし、9月にワカサギ 1 才を除くすべての魚種において、藍藻由来脂肪酸含有率の増加が認められた（図2）。

4. 考察

これまで藍藻は湖沼生態系において食物連鎖に組み込まれにくいと考えられてきた。本研究においても、藍藻が優占し始めた 7 月およびアオコの発生が確認された 8 月時点では、魚類体内の藍藻由来脂肪酸含有率は増加せず、魚類が藍藻に由来する有機物を餌として同化していないことが示された。藍藻は最大数 mm のフロックを形成することで動物プランクトンからの摂食を逃れることができるが、本調査で採取した魚の口のサイズは数 mm よりも大きく、藍藻によるフロックの形成は摂食の妨げにならないと考えられる。それでも、8 月まで魚類による藍藻の餌利用は認められなかった。藍藻はエイコサペンタエン酸やステロールなど動物に不可欠な脂質栄養素を含んでいないことから、餌として低価値であるとことが指摘されており、魚類が藍藻の摂食を避けていた可能性が考えられる。しかし、9 月には魚類体内の藍藻由来脂肪酸の含有率が急上昇し、魚類が藍藻を餌として同化していることが明らかとなった。アオコが継続して発生し、藍藻優占の状況が続くと、魚類も藍藻を餌として利用し始めるのかもしれない。ただし、脂肪酸含有率の結果からは魚類が藍藻を直接摂食・同化しているのか、動物プランクトンなど他の動物を介して藍藻由来の脂肪酸を獲得しているかは判断することが出来ない。もし、後者であれば、藍藻の優占化に伴って、藍藻を餌利用できない動物プランクトン種から、藍藻を餌として利用できる動物プランクトン種に変遷していくまでの期間が、9 月以降に魚類から藍藻由来脂肪酸の増加を検出するというタイムラグを生じさせた要因である可能性がある。なお、本研究ではワカサギ 1 才からは藍藻由来脂肪酸の急激な増加は見られなかったが、ワカサギは動物プランクトン食者であることから、ワカサギ 1 才が摂食・同化していた動物プランクトンが藍藻を食べていなかった可能性が高い。今後、藍藻優占に伴う動物プランクトンの種構成の変遷や、各動物プランクトン種の藍藻摂食・同化能力を解明し、魚類の脂肪酸組成の変化と合わせて解析することで、アオコの発生する富栄養湖沼の食物網の理解が深まると期待される。

5. 結論と今後の展望

脂肪酸組成を指標として、魚類による藍藻の餌利用の状況を解析した結果、これまで食物連鎖に組み込まれにくいと考えられてきた藍藻が、魚類によって餌利用されていることが明らかとなった。今後は、魚類が直接藍藻を摂食・同化しているのか、動物プランクトンなど他の動物を介して藍藻由来の脂肪酸を獲得しているのか検討していく予定である。

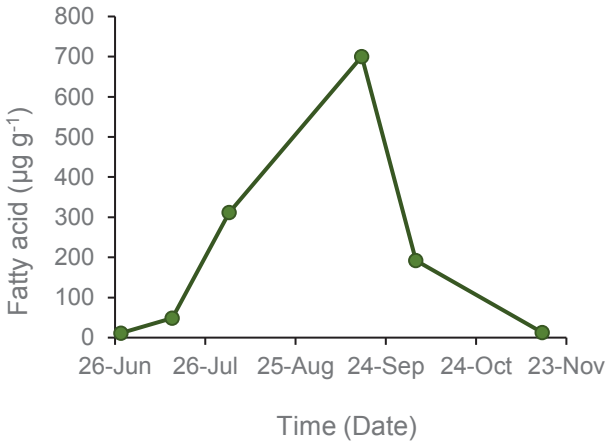

図 1 懸濁物質中に含まれる藍藻由来脂肪酸（18:2ω6 + 18:3ω3）含有量の経月変化

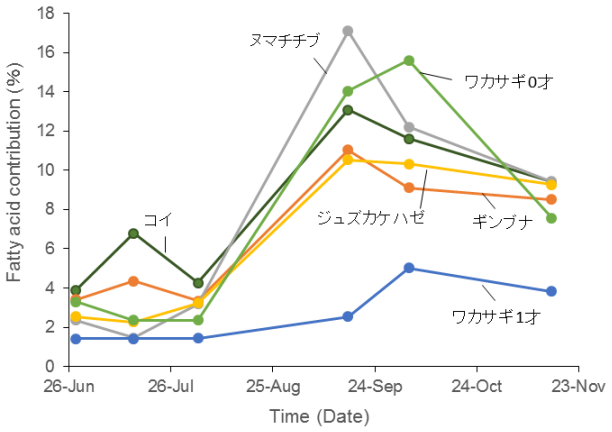

図 2 魚類筋肉に含まれる藍藻由来脂肪酸（18:2ω6 + 18:3ω3）含有量の経月変化

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O3-10

Cyanobacterial carbon transfer to higher trophic level in eutrophic lake Taihu

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Keywords: Cyanobacteria, algal blooms, carbon transfer, eutrophic lakes, fatty acid biomarker, stable carbon isotope

ABSTRACT

Cyanobacteria have been considered an inadequate food source due to a lack of vital nutrients, toxin production, and floc formation. This may interrupt carbon transfer to higher trophic level animals, including fishes. In this study, to elucidate the contribution of cyanobacteria for benthic animals in Taihu, we examined cyanobacterial carbon transfer in a eutrophic lake by using a fatty acid biomarker, stable carbon isotope ratios of fatty acid, and stable isotope ratios of bulk nitrogen. Terrestrial plant and animals (benthic animals, primary consumer) were collected via in July, from Lake Taihu, China. Combined dual stable isotopes ($\delta^{13}C$ and $\delta^{15}N$) and fatty acid biomarkers, the results revealed that there were only subtle differences in the diets of benthic and pelagic animals and cyanobacteria were their main food source. Concomitantly, results of $\delta^{13}C$ of bacteria-specific fatty acids demonstrated that bacteria equally and profoundly affected organics accumulation or preservation in the sediments, because they preferentially utilized labile cyanobacteria as their carbon source instead of terrestrial plants (>95% within these two sources). Consequently, these novel findings clarify that not only in deep lakes, but also shallow eutrophic ones, the extensive losses of autochthonous organic matter can be expected during sedimentation coupling with the dramatical modifications of biogeochemical processes.

1. INTRODUCTION

1. Introduction

Organic matter in lakes generally derives from autochthonous sources produced by phytoplankton and terrestrial (allochthonous) subsidies delivered by river discharge and runoff[1]. Therein, a critical portion provides carbon and energy sources for consumers and forms the base of the diverse food web, the residuals sink through the water column and are ultimately preserved in sediments[2]. The verti cal migration of organic matter drives the development of benthic communities; however, continuously increasing of sinking fluxes probably results in hypoxic or anoxic conditions coupling with the release of nutrients and deteriorates of the benthic habitats[3]. Therefore, a profound knowledge of organic matter dynamics including the fate of organic matter in water column, alternatively, the origin of organic matter in the sediments is crucial for understanding material flow and cycling in lake ecosystems and for decision-making in lake management.

The migration process of organic matter from the water column to the sediments is known to be affected by various biotic and abiotic factors. In deep lakes, vertical mixing above the thermocline induced by winds and waves or thermo convection prolongs the exposures of organic matter to oxidation. As a result, nearly 85% of the organic carbon losses before leaving the epilimnion (Eadie et al., 1984). Aquatic animal utilization by zooplankton or filter-feeder fishes and microbial degradation by heterotrophic organisms within the water column play a substantial role in decreasing the sinking flux of organic particles[1]. On the other hand, the sinking flux may significantly increase through light-mediated as well as microbially-induced flocculation of dissolved organic matter in the water column. These observations imply that organic particles sinking from surface water with long residence time in deep lakes are not necessarily proportional to the organic matter contents of underlying sediments. In contrast to the deep lake ecosystems, the information from shallow lakes especially eutrophic lakes is scarcely known. For tracking organics behaviors in shallow andeutrophic lakes, the suspended particulate organic matter (SPOM) in the water column and sedimentary organic matter (SOM) were systematically investigated in Lake Taihu, China. The sources and composition of SPOM and SOM were analyzed, and their relationships were compared with fatty acid biomarkers. Aquatic animals and benthic bacteria

were also performed for the interpretationof their roles in alternation of organics dynamics in the lake. In shallow eutrophic lakes, organic matter would have shorter sinking time and consequently shorter exposures to oxidation in the water column. Especially for photosynthetic organisms, export onto the sediments (as live or dead cells) is probably their fates with intensively and high-frequency sedimentation. Hence, we hypothesized that in large shallow and eutrophic lakes, organics in surface water are proportional to the contents of the sediments with faint influence of animal consumption and microbial utilization.

2. RESULTS

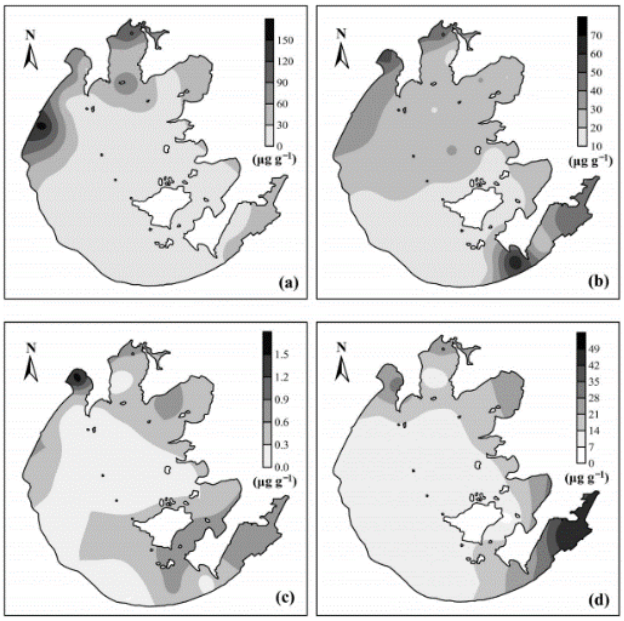

Fig.1 Spatial concentration variations in (a) cyanobacteria in suspended particles (μg/g), (b) terrestrial plants in suspended particles (μg/g), (c) cyanobacteria in sediments μg/g), (d) terrestrial plants in sediments (μg/g) from Lake Taihu, China.

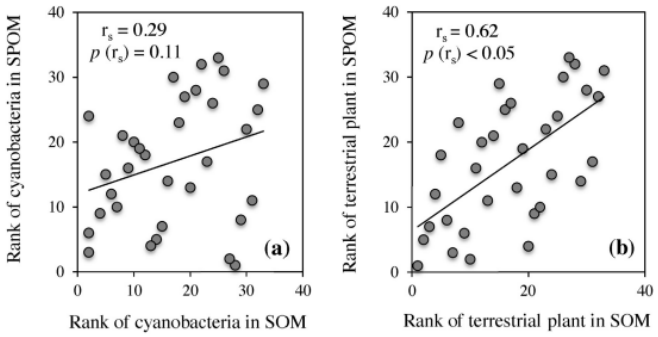

Fig. 2. Spearman's rank correlations between (a) cyanobacteria in SPOM and SOM, (b) terrestrial plants in SPOM and SOM from Lake Taihu. SPOM: suspended particulate organic matter, SOM: sedimentary organic matter.

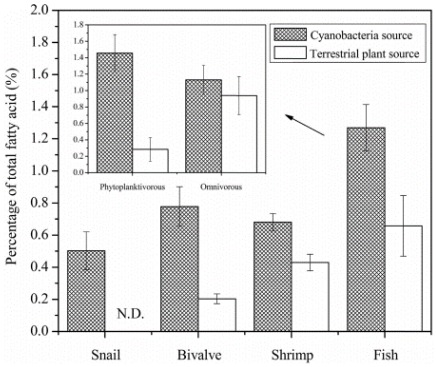

Fig. 3. Contributing percentage of cyanobacteria and terrestrial plants as food sources for aquatic animals including snails (n = 8), bivalves (n = 8), shrimps (n = 3), fishes (n = 7; therein, phytoplanktivorous (n = 3) and omnivorous (n = 4)) from Lake Taihu. ND: not detected

3. DISCUSSION

Asymmetry between SPOM and SOM indicated by fatty acids. As a prerequisite to the simultaneous comparison of multiple organics under the same condition, fatty acid biomarkers related the benthic organics to pelagic sources in Lake Taihu. Interestingly, against the aforementioned hypothesis, results exhibited the asymmetric phenomena between SPOM and SOM for cyanobacteriaand terrestrial plants, which were proposed as the major organics due to the faint contributions of other sources such as diatoms and dinoflagellates to both surface water and sediments. In surface water, not surprisingly, cyanobacteria showed a considerably higher prevalence. Their spatial pattern coincided with those studies of Lake Taihu, which were indicated by Chl-a concentrations. Compared with cyanobacteria, terrestrial plants displayed a relatively lower concentration level, although they spatially fluctuated within the range of other eutrophic lakes. In the sediments, the relatively low level of cyanobacteria was found to be spatiotemporally consistent together with the previous findings. Generally, there is a loss for organics during sinking, as it is easily subjected the strong influence by aquatic animal consumption and microbial degradation. However, if assumed that terrestrial plants did not vary and used the maximum concentration of organics to represent the entire lake, the loss of cyanobacteria would roughly decrease by 60 times during sinking (larger than 2 times in SPOM and smaller than 1/30 in SOM, Fig. 2). These observations suggested that the asymmetric phenomenon in essence was a more considerable loss of cyanobacteria compared with terrestrial plants during the migration process from surface water to sediments. Concomitantly, the asymmetric phenomenon also occurred for the spatial pattern of cyanobacteria abundance, which were not site-to-site symmetrical between surface water and sediments (Fig. 2). It is probably related to the spatial heterogeneity of biological abundance and community structure. For

instance, the maximum concentration of cyanobacteria lakewide shifted from the western freshwater entrance tothe Zhushan Bay during sinking (Fig. 1(a) and (c)). The extensive losses of cyanobacteria in the western freshwater entrance may be consumed by the higher abundance and biomass of macroinvertebrates compared with the Zhushan Bay, due to the influence of trophic status, wind-induced disturbance and habitat complexity. However, further investigation is necessary to analyze their correlations. Compared with cyanobacteria, the benthic terrestrial plants probably undergo slight or escape modifications by these biogeochemical processes and proportionate to the surface water, owing to their indigestible or refractory nature. Therefore, although shallow eutrophic lakes are characterized by the more highly productive and shorter residence time than deep ones, a disproportionate loss of autochthonous organics can be expected during sinking, caused by the modifications of biogeochemical processes with different degree.

Influence of animal consumption on organics dynamics

Based on fatty acid and stable isotope results, it appeared that terrestrial plants and cyanobacteria contribute, to different degrees, to the diets of pelagic and benthic consumers, and indicated that the food web in hypereutrophic Lake Taihu depends on both allochthonous and autochthonous organics. These, in turn, influence the quantity and quality of suspended and sedimentary organic matter. Interestingly, although the contributions of terrestrial plants and cyanobacteria as a direct food source were not as high as expected (<2% of the total fatty acids, Fig. 3), it clearly supported cyanobacteria served as a better food source than terrestrial plants to their consumers. Further evidence of this phenomenon is the $\delta^{13}C$ and $\delta^{15}N$ signatures exhibited a closer relationship between cyanobacteria and all kinds of consumers, rather than terrestrial plants. These results are congruent with previous studies that the relative importance of allochthonous and autochthonous resources for consumers shifts to the latter in nutrient-rich lakes. The benthic consumers utilize carbon from settled cyanobacteria detritus, while their pathways for deriving energy may differ from those of shrimps and fishes that directly filter cyanobacteria in the water column. Considerable studies have clarified that phytoplankton especially cyanobacteria were used as a food source by shrimps and fishes. However, cyanobacteria and terrestrial plants seemed to be equally important for shrimps and omnivorous fishes in the examined lake according to the results of fatty acids (Fig. 3). These observations are not surprising as a great variety of shrimps and omnivorous fishes showed a wide range of organic carbon sources including vascular plants, and particularly, some species of them may have the ability of selective predation among food types. Furthermore, the fatty acid results of omnivorous fishes appeared to be appalling with their $\delta^{13}C$ and $\delta^{15}N$ signatures, which were far away from the other consumers. It suggested that omnivorous fishes positioned at a higher trophic level of the local food web, because a general enrichment in $\delta^{13}C$ and $\delta^{15}N$ signatures, known as trophic fractionation, occurred from assimilated food sources to consumers with varying values of 0–1‰ and 2.5–3.4‰, respectively. Together with other consumers, they significantly correlated to cyanobacteria, which may not fully describe the whole food web in Lake Taihu as further studies on the separate benthic and pelagic food chains may need to be conducted, however, at least, describing a pathway for carbon flow based on cyanobacteria in Lake Taihu. Generally, compared with allochthonous organic matter, endogenous production such as various types of algae are higher in diet quality and more important for consumer production as they contain essential fatty acids such as eicosapentaenoic acids and docosahexaenoic acids or their precursors. These fatty acids are structurally important in cell membranes and play an important role in animal physiology such as growth and reproduction. In contrast, terrestrial vascular plants are little consumed by animals that graze directly on them, because they have a relatively high content of indigestible fiber and a low content of nitrogen. Therefore, consumers may preferentially utilize cyanobacteria rather than terrestrial plant in freshwater lakes, which is one of the crucial reasons that cyanobacteria do not appear to contribute significantly to the sedimentary organic carbon pool.

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O3-11

猪苗代湖の中性化が一次生産を担う生物の分布に及ぼす影響

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キーワード:水質汚濁, 一次生産, 富栄養化

抄録

猪苗代湖は pH の上昇が進み, それとともに湖内の一次生産の増加を示唆する水質の悪化が報告されている。一次生産に関する既往の報告では, 北岸部の水生植物調査, 北岸部の植物プランクトンの年変化の解析, 及び南岸部における植物プランクトンの調査と一部地域を対象とした研究が中心であった。そこで本研究では, 湖内で一次生産を担う生物(植物プランクトンと水生植物)について猪苗代湖全体を俯瞰して, pH 上昇による影響を調査, 考察した。湖水の pH は猪苗代湖全域で中性化していたが, リンの濃度は北岸部と南岸部で上昇傾向にあった。これらの環境因子は植物プランクトン数と種組成に猪苗代湖全域で影響を及ぼしていた。一方で水生植物の生息域は他の制限要因に強く影響されることが示唆された。

1. はじめに

猪苗代湖に流入する最大の河川は長瀬川であり, 全流入水量の約 50%以上を占める[1]。この長瀬川は上流河川の影響を受けて酸性を示す(pH 5.2, 2015 年 9 月)[2]。その結果, 猪苗代湖の pH は 1995 年頃までは 5.0 程度を示していた[3]。それと共に酸性の長瀬川から供給される凝集塊の効果によるリンの沈殿が起こり[4], 湖内における一次生産が抑制されてきた。その結果プランクトンは種類数と存在量ともに少ないとされていた[1]。しかしながら, その後湖内の pH は急激に上昇して中性化が進み, 2015 年には 6.8 を示した[2]。この pH の上昇は流入河川から猪苗代湖へ供給される硫酸イオン濃度の減少が大きな原因であると考えられている[5]。

このような水環境の変化は湖内における植物プランクトンや水生植物による一次生産に大きな影響を及ぼすと考えられる。Sutani et al. (2014) [6]は福島県の水質年報を 1984 年から 2011 年に渡って解析し、猪苗代湖湖心と北岸部の植物プランクトン相が pH の上昇に影響されて大きく変化したと報告している。また 1998 年から 2008 年に猪苗代湖の湖心と南岸部で菊池＆佐藤(2010) [5]によって行われた調査によると, pH の上昇に伴って植物プランクトンの種類と量が増加していることが明らかとなった。一方で, 黒沢ら(2011) [7]は猪苗代湖北岸部の水生植物相の変化を調査した。その結果, エゾノヒルムシロやコウホネ群落の消滅, マコモやヒメガマの減少, セキショウモの増加などの変化を報告している。

猪苗代湖は pH の上昇が進み, それとともに湖内の一次生産の増加を示唆する水質の悪化が報告されている。しかしながら今までは, 多数の群落が形成されている北岸部の水生植物調査[7], 湖心と比較した北岸部の植物プランクトンの年変化の解析[6], 及び南岸部における植物プランクトンの調査[5]と, 一部地域を対象とした研究が中心であった。そこで本研究では湖内で一次生産を担う生物(植物プランクトンと水生植物)の分布について猪苗代湖全体を俯瞰して, pH 上昇による影響を調査, 考察した。

2. 調査方法

調査対象湖沼

本研究で対象とした猪苗代湖は福島県の奥羽山脈の西側に位置し(湖心, 37°28′N 及び 140°06′E), 湖面標高 514 m, 面積 104.8 km^2, 最大深度 94.6 m である[1]。日本の湖沼の中で, 琵琶湖, 霞ヶ浦, サロマ湖に次ぐ面積を持つ大型湖沼である。

植物プランクトン数及び理化学性

猪苗代湖の 8 地点(高橋川河口付近, 天神浜, 安積疎水取水口, 浜路浜, 舟津港, 青松浜, 小石ヶ浜水門, 及び湖心)の植物プランクトン数及び理化学性(pH, T-N 及び T-P)のデータを水質年報[2, 3]から収集し、解析に用いた。データ収集期間は 1988～1992 年と 2011～2015 年とした。図 1 に対象とした調査地点を示す。

水生植物の分布調査

2015 年 9 月に水生植物の分布状況を調査した。猪苗代湖の湖岸から湖心に向け観測線を 1000 m 間隔で設定した。船で測線上をゆっくりとした速度で走り, 目視及び魚群探知機により, 水生植物の種相と分布状況を把

握した。測線の湖心側の終点は水深3 mの地点とした。

猪苗代湖北岸では水生植物の分布が密であったため，観測線を 100 m 間隔で設定し，より詳細な調査を行った。



図 1　水質年報における植物プランクトン数及び理化学性の調査対象地点（地理院地図を加工して作成した[8]）

3.　結果及び考察

湖水の T-N 濃度は0.24～0.28 (1988～1992 年)と0.20～0.26 (2011～2015 年)であり，ほとんど変化がなかった。一方で，pH は 1988～1992 年に全地点で 5.5 以下と酸性を呈していたが，2011～2015 年には 6.8～7.2 と中性となった。また T-P 濃度は湖心，小石ヶ浜水門及び安積疏水取水口では変化が見られなかった（≤0.005，1988～1992 年；≤0.004，2011～2015 年）一方で，北岸部（≤0.008，1988～1992 年；≤0.014，2011～2015 年）と南岸部（≤0.005，1988～1992 年；≤0.013，2011～2015 年）では約 2 倍の年平均値を示す調査対象地点が存在した。

図 2 に 1988～1992 年と2011～2015 年の植物プランクトン数の平均値を示す。全ての調査地点で細胞数は増加した。負荷量が非常に大きい高橋川と小黒川の影響を受ける北岸部（高橋川河口付近と天神浜）は他地点よりも極めて多い植物プランクトン数を示し，増加は1000 倍以上と高かった。注目すべきは湖心とともに，比較的負荷量の影響が低いと考えられる南岸部（浜路浜，舟津港及び青松浜）において 1000 倍以上の植物プランクトン数の増加が明らかとなったことである。植物プランクトンの生長を制限するリンの濃度は北岸部とともに南岸部で増加していた。一方で光合成に関わる鉄等の金属の湖水への供給は減少していると報告されている[5]。以上の結果より，pH の上昇による炭酸制限の解除が猪苗代湖全域における植物プランクトン数へ影響を及ぼし，一次生産の増加が進んでいることが示された。

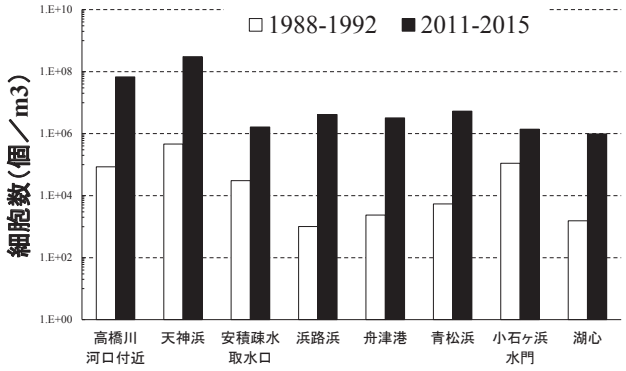

図 2　植物プランクトン数の変化（5 年間の平均値）

図 3 と 4 にそれぞれ 1988～1992 年と 2011～2015 年の植物プランクトンの分類群の構成割合を示す。1988～1992 年では湖心や南岸部を含めた多くの地域で珪藻類が優占していた。一方で 2011～2015 年には北岸部と南岸部で大きな違いが見られた。すなわち北岸部では珪藻類の割合が上昇したが，南岸部では鞭毛類と緑藻類の割合が大きく増加した。今後の研究で、湖水のケイ素濃度分布などを測定することが植物プランクトンの構成割合が変化した原因の解明につながるかもしれない。

2015 年の植生調査により，猪苗代湖の北岸部（高橋川河口・天神浜の周囲）では広く水草が生息していることが確認された。浮遊，沈水，浮葉，抽水，及び湿生植物に属する 24 種が確認されたが，特にオニビシ・ヒシ・アサザ（浮葉植物）及びクロモ（沈水植物）が優占していた。一方で北岸部以外では南岸の鬼沼と東岸の志田浜北側のみで水生植物の生息が確認された。鬼沼ではコウホネ，ヒシ，アサザ，コカナダモ，クロモ，セキショウモ，ヒルムシロ，及びヒメホタルイの計 8 種が確認された。志田浜北側ではコウホネ，ヒシ及びコウキクサの 3 種が確認された。猪苗代湖の北岸部では黒沢ら(2011) [7] の報告と同様に，多様な水生植物が広範囲に渡って生息していた一方で，その他の地域では貧弱な植生であ

ることが明らかとなった。pH の中性化は猪苗代湖全域で進んでいるが，水生植物の生息分布は広範囲に及んでおらず，底泥の堆積量などの他の制限要因に生長が強く影響されることが示唆された。

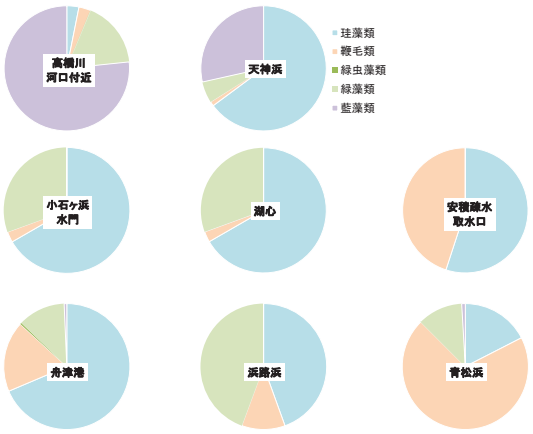

図 3　植物プランクトン分類群の構成割合（1988～1992）

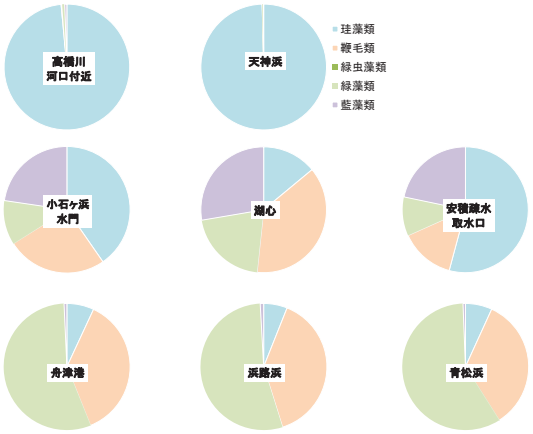

図 4　植物プランクトン分類群の構成割合（2011～2015）

4.　結論

猪苗代湖における pH の上昇が湖内の一次生産を担う生物の分布にどのような影響を与えているのかを調べるために，植物プランクトンと水生植物に着目して調査，考察した。

1）湖水の pH は猪苗代湖全域で中性化していたが，リンの濃度は北岸部と南岸部でのみ上昇傾向にあった。

2）植物プランクトン数は猪苗代湖全域で増加し，一次生産の増加が顕在化していることが示された。北岸部では珪藻類の割合が上昇したが，南岸部では鞭毛類と緑藻類の割合が大きく増加した。

3）水生植物の生息は北岸部に偏っており，pH よりも他の制限要因に強く影響されることが示唆された。

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O3-12

霞ヶ浦土浦入を対象に構築したアオコ予測システムの紹介

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キーワード:アオコ, 回帰, 生態系モデル, 深層学習, 行政利用

抄録

霞ヶ浦土浦入におけるアオコ発生の問題に対し, 迅速な対策のためにアオコ発生の予測が求められている。そこで本研究では, アオコ予測のため, アオコのシードとなる湖底泥中の *Microcystis* に着目し, その存在量を明らかにした。また生態系モデルを用いて, アオコ発生メカニズムを検証した。その結果, 底泥中には *Microcystis* が存在し, 湖水中に回帰している可能性が示された。一方で生態系モデルによる検証からは, 底泥中からの回帰だけでなく, 風による輸送の影響も大きいことが示され, 底泥中の存在量のみでは予測が難しいことが示された。これらの結果を受け, 生態系モデルに深層学習モデルを組み合わせたハイブリットモデルを構築したところ, 過去のアオコ発生状況を再現でき, アオコ予測システムが構築できた。

1. はじめに

霞ヶ浦では, 夏季に *Microcystis* を主とするアオコが発生することがある。なかでも土浦港をはじめとする土浦入湾奥部(図1)は JR 土浦駅に近く周辺人口が多いため, 景観の悪化や腐敗臭などの面からアオコの発生が社会問題化しやすい。茨城県ではアオコフェンスの設置や, アオコ回収, 土浦港浄化施設の設置などの対策を講じているが, 効果的な運用のためにアオコの発生場所や量の予測が必要とされている。これに対し, 茨城県霞ケ浦環境科学センターでは, 水質調査結果をまとめた「アオコ情報」を発信している。そのなかでは, 湖水質と気象予報から翌週のアオコの発生しやすさを A~C で評価しているが, もっと早いタイミングでの予報や, 面的な分布の情報が必要とされている。

アオコが発生する水域では藍藻類のコロニーや休眠細胞が底泥中に高密度で存在していることが多く, これらが水中へ回帰することで, アオコの発生を促進させていると考えられている[1]が, 霞ヶ浦全域において, 底泥に堆積した *Microcystis* 細胞濃度を測定した例はなく, 回帰量も不明である。

また, アオコの発生予測は需要があるものの極めて難しく, 運用事例・研究事例は少ない[2]。北澤ら[2]は, 湖水流動と水質変動のシミュレーションモデルを構築し, アオコの発生を説明できるモデルが構築できたとしているが, 実運用については言及がない。芹沢ら[3]は神奈川県の相模湖と津久井湖を対象に2変数数理モデルを作成して検討した結果, アオコの発生量, 発生パターンの変動には生態学的, 生理学的要因とともに偶発的要因も深く関与していると考察している。

これらのことから, 本研究では①底泥中の *Microcystis* 量を把握し, 回帰量を検討した[4]。次に, ②土浦入におけるアオコ発生メカニズムを検討した[5]。そしてこれらの知見をもとに③アオコ予測システムを構築し, その応用可能性について検討した[6]。

2. 方法

2. 1　底泥中の *Microcystis* 量の把握[4]

2015 年に, 新川河口, 土浦港, 土浦沖, 掛馬沖, 湖心(図 1)で底泥を採取した。なお, 新川河口の調査地点は, 図1に示すよりも河道内に寄っている。改良した湖沼型コアサンプラー(離合社)を用いて 0~1cm 深さの底泥を採取し, rDNA 用チューブにいれ-80℃で保存した。その後, Extrap Soil DNA Kit Plus ver.2 (J-BIO)を用いて rDNA を抽出・精製し, リアルタイム PCR(7500

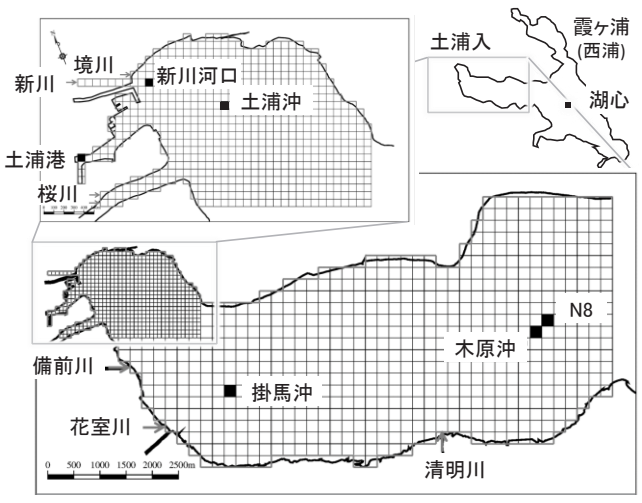

図 1 対象水域と地点図[5]

Real-Time PCR System, Applied Biosystems)を用いて遺伝子量を測定した。その際，既知細胞濃度培養液からのrDNA抽出液を段階希釈したものを標準列として用いて，細胞濃度が未知であるサンプルのCt値から細胞濃度へと換算した。

2.2 アオコ発生メカニズムの検討[5]

Microcystis の底泥からの回帰，鉛直移動，風による輸送に着目し，アオコ発生を説明する生態系シミュレーションモデル（以下，生態系モデル）を構築した。生態系モデルは，流体力学の基礎方程式を直交座標系において差分化して解く流動サブモデルと，物質循環を考慮した水質サブモデルから構成した。計算範囲・格子サイズは図1のとおり，層分割は0.5mである。植物プランクトンは*Microcystis*とその他の植物プランクトンを想定し，水温と栄養塩に対する応答を変化させて表現した。また，底泥からの*Microcystis*の回帰フラックスは，底泥中の存在量と湖底に到達した光量で説明されると仮定した。鉛直移動は，沈降速度を時間別に与えることで表現した。風による輸送は，水柱第1層上部にアオコ用の仮想層(第 0 層)を設定することで表現した。アオコ発生メカニズムの検討は，構築した生態系モデルを用い，表 1 に従ってそれぞれの因子の寄与を変化させ，計算結果と実測値を比較することで行った。

2.3 アオコ予測システムの構築[6]

アオコの予測可能性を，二つのモデルを用いて評価した。一つは方法2. 2で構築した生態系モデル，もう一つは生態系モデルに統計モデルを組み合わせたモデル（以下，ハイブリッドモデル）である。統計モデルは，畳み込みニューラルネットワーク（Convolutional Neural Network: 以下，CNN）と変分オートエンコーダ（Variational Autoencoder: 以下，VAE)を組み合わせた。統計モデルのための学習用データは湖心（36º 02' 17" N, 140º 24' 15" E）表層20または50 cmにおけるフィコシアニン濃度とし，既存モデルを用いて算出した計算値を日平均値に圧縮したものと，実測値を基に補間した日平均値のデータセットを用いた。期間は2007年から2016年とし，*Microcystis* が増殖する6月から9月を対象とした。実測値は，2012年から2017年は，およそ週に1度の頻度で当センターによって配信された「アオコ情報」におけるフィコシアニン濃度を用いた。 2012年以前は，国立環境研究所の霞ヶ浦データベース[7]の*Microcystis* 細胞体積を用いて補間した。*Microcystis* 細胞濃度からフィコシアニン濃度への換算は，2013-2015年の *Microcystis* 細胞濃度とフィコシアニン濃度の関係から求めた係数7.3×10^6を掛けて行った。

また，生態系モデルは気象条件によって計算結果が変化するため，将来予測のためには気象予測が必要であった。そこで，気象庁の暖候期予報と三カ月予報を利用した。2007年から2016年までの気温と降水量から，平年より高い（多い）年と平年より低い（少ない）年を割り出し，暖候期予報と三カ月予報の結果に従って適当な年度を選び，その年の気象を予測値として与えた。

3. 結果と考察

3.1 底泥中の *Microcystis* 量[4]

土浦入の底泥表層には*Microcystis* 細胞が存在し，6月初旬に減少し8月にかけて増加する傾向がみられた（図2）。底泥表層中の*Microcystis* 細胞数の減少要因として，底泥からの回帰のほかに，降雨に伴う流出と，底泥中での分解が考えられたが，降水量と濁度には特徴的な上昇が見られなかったため，湖水中への回帰に伴うものであると示唆された。そこで，この期間における 5 地点の平均減少濃度を日数で割り，土浦入の底泥における *Microcystis* 細胞のみかけの回帰速度を算出したところ，5.6×10^2cells/g-wet sediment/dayと示された。

3.2 アオコ発生メカニズム[5]

流動サブモデルを用いた物理場の再現状況は良好であった。アオコ発生機構検討のための比較結果を図3に示す。Case 1とCase 2を比較すると，風による拡散の影響が加わったことで2013年や2014年の再現性が向上したと考えられた。また，底泥からの回帰量は現存量の増加を促進したが，実測ベースの底泥中現存量を用いる必要が示唆された。また，実測値で見られるような，局所的かつ一時的な集積を表現するためには，風による輸送の影響を加えることが有効であることが示された。

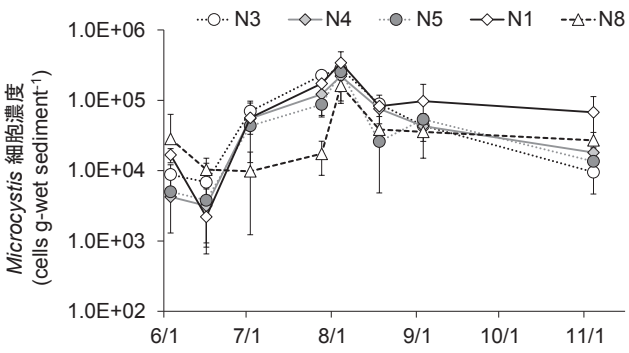

図 2 霞ヶ浦土浦入における各地点の底泥表層中の *Microcystis* 細胞濃度。なお，N3は湖心，N4は掛馬沖，N5は土浦沖，N1は土浦港，N8は新川河口を示す。[4]

3.3 アオコ予測システムの検討[6]

生態系モデルで計算されたフィコシアニン濃度と過去の実測値を比較した結果，相関性は高くなかった。一方で，2007 年から 2016 年までの湖心フィコシアニン濃度と実測値のデータセットを用いて学習させたところ，深層学習モデルは生態系モデルと実測値の差異をうまく学習した。湖心における，2007 年から 2016 年までの実測値と (a) 生態系モデルの計算値，(b) 生態系モデルに深層学習モデルを組み合わせたモデル（以下，ハイブリッドモデル）の計算値を比較した（図 4）。その結果，ハイブリッドモデルにおいてのみ実測値と有意な正の相関が示された(n=97, (a): r =-0.08, n.s., (b): r=0.75, p<0.05)。また，掛馬沖，土浦沖，土浦港でも同様の検討をした結果，同様にハイブリッドモデルのほうが高い相関性を示すことが分かった。

4. 結論

霞ヶ浦土浦入におけるアオコの発生予測のために底泥中の *Microcystis* 量を把握し，生態系モデルを用いて発生メカニズムを検討した。その結果，底泥中には *Microcystis* が存在し，湖水中への回帰が示唆された[4]が，発生メカニズムの検討からは，風による輸送の影響が大きいことが示唆された[5]. これらの研究結果をもとにアオコ予測モデルを構築した結果，深層学習モデルの組み込みは，過去の再現精度を向上させた[6]。過去 9 年の再現性について，どの地点でも向上が見られたことから，霞ヶ浦におけるアオコ予測に対し，今までの生態学モデルを中心としたものよりも，高い精度で予測できることが期待される。今後は，今回の学習に用いていないデータセットや気象データを用いてテスト運用を行い，将来予測の可能性について検証していく。

謝辞

底泥中の *Microcystis* rDNA の測定に関しては国立環境研究所の冨岡典子先生にご尽力いただき，重要なご助言を数多く頂いた。本研究で使用した *Microcystis* の細胞体積データは，国立環境研究所の霞ヶ浦長期モニタリング事業によって提供された。ここに記して感謝を記す。

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表 1 計算ケース一覧とその条件[5]

	輸送	(第0層)	回帰	(vmax)	鉛直移動	(Setvel)
Case 1	-	無	-	0	-	0
Case 2	+	有	-	0	-	0
Case 3	+	有	+	1	-	0
Case 4	+	有	+	1	+	0.24, -4.0
Case 5	-	無	-	0	+	0.24, -4.0

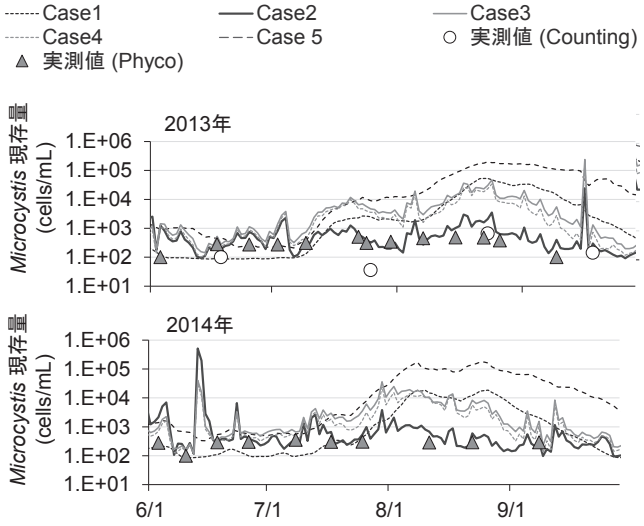

図 3 土浦沖表層における *Microcystis* の現存量の経時変化の実測値と一時間毎の計算値．実測値(Counting)は検鏡値，実測値(Phyco)はフィコシアニンからの換算値[5]（一部改）

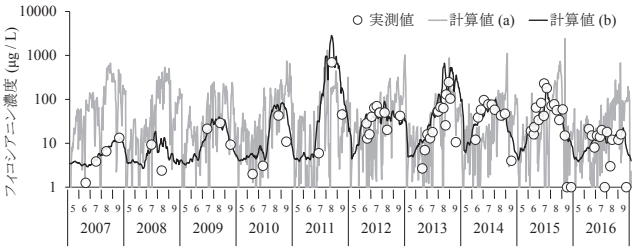

図 4 土浦沖におけるアオコ予測モデル計算値と補間された実測値の比較[6]

O3-13

Warming and eutrophication effects on phytoplankton community of two tropical systems with different trophic states – an experimental approach

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Key words: global warming; eutrophication; cyanobacterial blooms; trophic state

Abstract

Global warming and eutrophication are predicted to promote cyanobacterial blooms but how tropical phytoplankton from different trophic state systems respond to temperature is less known. To explore the effect of temperature changes and nutrient addition on phytoplankton and to verify possible resistance to these effects, we conducted an experiment with phytoplankton from two aquatic ecosystems differing in trophic state. Water samples from eutrophic and oligo-mesotrophic systems were collected and incubated in 25 and 30ºC. Treatments that received a surplus of N and P were included as eutrophication treatments. Temperature variation itself did not promote cyanobacteria growth in either water from the oligo-mesotrophic or the eutrophic system. However, nutrient enrichment of water from the eutrophic system significantly boosted cyanobacteria, and biomass increased 10 times in both 25ºC and 30ºC treatments. In contrast, eutrophication of water from the oligo-mesotrophic system did not change the relative contribution of phytoplankton groups and response ratios were much lower than those from eutrophic water. Although using a simple experimental design, the results suggest that in eutrophic systems cyanobacteria dominance can be favored by further addition of nutrients, independently of a direct temperature effect and that more pristine environments possess some resistance against eutrophication. Since global warming is assumed to intensify eutrophication indirectly, our study underscores the importance of nutrient control.

1. Introduction

Human activities are causing severe alterations in ecosystems worldwide and freshwater ecosystems are being transformed rapidly (Carpenter et al., 1992). These systems have experienced altered precipitation patterns, more intense and longer periods of thermal stratification, modified hydrology, elevated carbon dioxide concentration, increased nutrient loading and elevated temperatures as a consequence of global change (Carey et al., 2012; Paerl and Huisman, 2008). These changes will probably be intensified in the next decades following the expected increase in global temperatures and inputs of anthropogenic nutrients (O'Neil et al., 2012). Phytoplankton, as primary producers of aquatic ecosystems, can be considered a target to experience these environmental changes since nutrient availability and temperature are among the main conditions that drive competitive advantage and regulate phytoplankton species distribution. Some studies indicate that increasing nutrients and temperature may exert a synergistic effect on cyanobacteria dominance (Jöhnk et al., 2008; Paerl and Paul, 2012). In this context, the objective of this study was to examine the effect of temperature alone and in combination with high nutrient addition on phytoplankton communities from tropical ecosystems of two different trophic states. We tested hypotheses that 1) temperature variation favours cyanobacteria growth more than eukaryote competitors, 2) temperature variation will have a
stronger effect on cyanobacteria dominance in tropical eutrophic water than in oligo-mesotrophic water and 3) nutrient addiction will promote a stronger effect on cyanobacteria favoring in oligo-mesotrophic water than eutrophic water.

2. Methods

To evaluate the effect of temperature variation and nutrients addiction on phytoplankton from tropical ecosystems of different trophic states, water samples from an eutrophic system (Jacarepaguá lagoon, RJ) and from an oligo-mesotrophic system (Samuel reservoir, RO) were collected and incubated at 25 and 30°C, with and without addition of nutrients. The lowest temperature (25°C) tested was chosen based on the annual average temperature in the water body from southeast of Brazil, and the highest temperature (30°C) considered an increase of 5°C to the annual mean (predicted by IPCC 2013 as result of global warming).

Eutrophication was simulated by the addition of 7.0 mg N. L^{-1} as $NaNO_3$ and 0.8 mg P. L^{-1} as K_2HPO_4, to N+P treatment. Flasks were incubated under 60µmol photons m^{-2} s^{-1}, photoperiod of 12 h and shaken manually twice every day. Total-cyanobacteria and eukaryote chlorophyll-*a* concentrations were measured using a PHYTO-PAM phytoplankton analyzer, during 7 days.

The response ratio of cyanobacteria (RR_{cyano}) and eukaryote algae (RR_{algae}) was calculated as a ratio between the growth rate of each treatment *T* (30ºC, 25ºC+N+P and 30ºC+N+P) and the growth rate in the sole 25ºC incubations (used as control, *C*) following $RR_x = \ln(T/C)$ (Elser et al., 2007), for eutrophic water system. However, for oligo-mesotrophic system, we used the growth rate in the sole 30ºC incubations as control (*C*), since 30ºC was closest the annual average water temperature of that system. A two-way ANOVA was performed to test whether temperature and nutrients addition affect the response ratio of cyanobacteria and eukaryotic algae. All the statistical analysis was performed using tool-pack SigmaPlot, Version 12 (Systat Software, Inc).

3. Results

The 5ºC temperature variation was not an important factor to change the phytoplankton composition, in both experimental conditions (Fig. 1a,c and 2a,c). At start of the experiment, the phytoplankton community from the eutrophic system was dominated by cyanobacteria (88%) with an average biomass of 127µg chl-*a*. L^{-1}. At the end of the experiment, cyanobacteria (70%) remained dominant over eukaryote algae (30%) in both treatments, 25ºC and 30ºC (Fig 1a,1c). When nutrients were added cyanobacteria remained dominant (97.3%). However, nutrient additions boosted cyanobacteria biomass that increased from about 125µg L^{-1} to about 1330µg L^{-1} in 25ºC N+P and 30ºC N+P treatments (Fig. 1b, 1d).

In oligo-mesotrophic system at start of the experiment, eukaryote algae were more abundant (66.4%) than cyanobacteria (33.6%) (Fig. 2a, 2c). The temperature variation, from 30ºC to 25ºC, did not change the contribution of phytoplankton groups and total biomass without nutrient additions remained < 20 µg chl-*a* L^{-1} (Fig. 2a, 2c). Addition of nutrients caused a slight increase to about 30 µg L^{-1} in the 30ºC N+P treatments (Fig. 2d) and a stronger increase from 11 to 60 µg L^{-1} in the 25ºC N+P treatments (Fig. 2b).

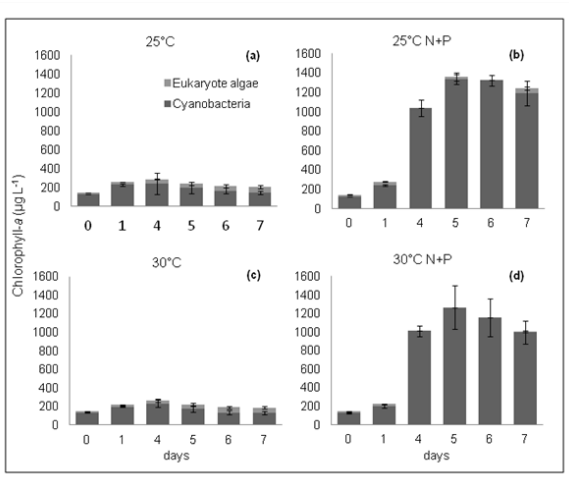

Figure 1: Eukaryote algae and Cyanobacteria biomass in the experiments with Eutrophic system phytoplankton community. Error bars indicate plus or minus one standard error.

Warming in itself led to negative response ratios for both cyanobacteria (RR_{cyano}) and eukaryote algae (RR_{algae}) in eutrophic system, reflecting a decrease in biomass compared to the sole 25ºC incubations. The temperature decrease from 30ºC to 25ºC, in oligo-mesotrophic system, promoted the positive response ratios for both cyanobacteria (RR_{cyano}) and eukaryote algae (RR_{algae}), indicating the biomass increase with decrease of 5 ºC. In water from the eutrophic system, nutrient addition caused a strong positive response ratio of cyanobacteria, while eukaryote algae remained a negative response ratio. The elevated temperature and nutrient addition (30ºC N+P) intensified the negative response ratio of eukaryote algae. In contrast, RR_{algae} in water from the oligo-mesotrophic system were positive in both in nutrient enriched treatments, but significantly higher than RR_{cyano} only in 25ºC N+P treatment ($p<0.001$).

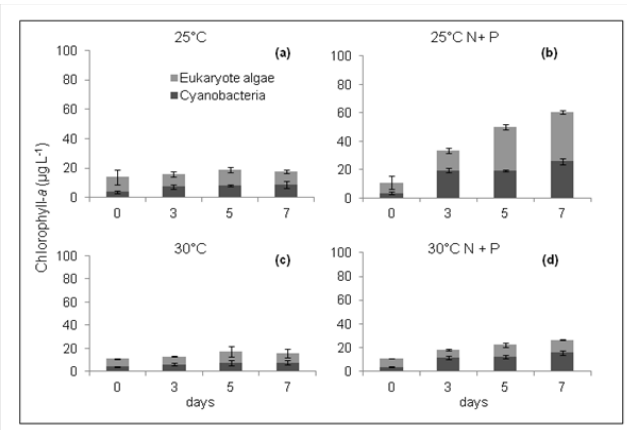

Figure 2: Eukaryote algae and Cyanobacteria biomass in the experiments with Oligo-mesotrophic system phytoplankton community. Error bars indicate plus or minus one standard error.

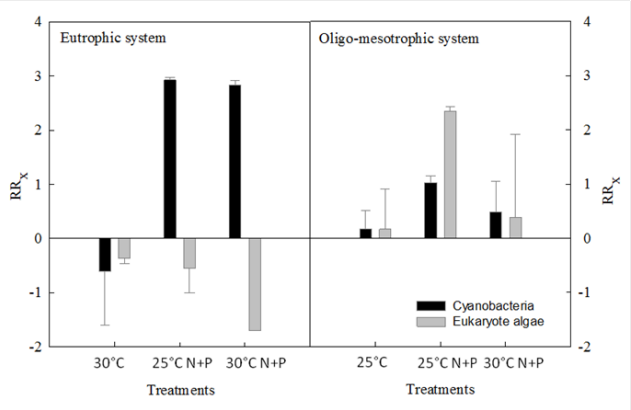

Figure 3: Response ratio of cyanobacteria and eukaryotic algae growth rate to each treatment (25ºC, 30ºC, 25ºC N+P and 30ºC N+P) in Eutrophic system and Oligo-mesotrophic system experiments. Error bars indicate plus or minus one standard error.

4. Discussion

Our results clearly showed that temperature in itself did not lead to higher cyanobacteria biomass in water from an oligo-mesotrophic and a eutrophic system. In fact, response ratios even were negative meaning phytoplankton biomass declined in eutrophic system. Hence, the importance of a direct warming effect on freshwater phytoplankton - and particularly on stimulation of cyanobacteria - may be questioned. It seems more likely that indirect effects of warming such as increased thermal stratification and water column stability will promote cyanobacteria (with buoyancy control) over non-flagellate eukaryote algae (Carey et al., 2012). However, by far the most important driver of cyanobacteria blooms is increased nutrient concentrations (Brookes and Carey, 2011). The nutrient addition response was much stronger in water from the eutrophic system in which cyanobacteria biomass was boosted to higher level. However, there was no synergism between nutrient addition and temperature in the cyanobacteria development, as was suggested by Rigosi et al. (2014).

The difference in response to nutrient addition between water from the oligo-mesotrophic and the eutrophic system underpins that lowering the nutrient status of lakes will render them less vulnerable to predicted effects of global changes (Brookes and Carey, 2011). These are likely the indirect effects that favor cyanobacteria biomass accumulation either at the water surface as a consequence of water column stability, or when populations are fueled from enhanced internal nutrient release and pulsed nutrient additions following precipitation. The lower biomass observed in oligo-mesotrophic systems seems to enhance resistance against nutrient pulses as is evident from the lower RR_{cyano} found in this study.

Some studies have addressed that indirect effects of climate change through nutrient loading may be more important than direct effects of temperature increase (Carey et al., 2012; De Senerpont Domis et al., 2013), which points to eutrophication.

5. Conclusion

It is widely believed within the scientific community that global warming and the corresponding increases in water temperatures will promote cyanobacteria blooms. Our results shows that an increase of temperature itself is not necessarily the main case because warming alone does not significantly change the phytoplankton community but rather the process of eutrophication contributes more to such changes than warming.

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O3-14

Evaluation of the Degradation Function of Microcystin-LR on Sediment Collected from Isahaya New Pond and Isahaya Bay

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Keywords: Eutrophication, Water blooms, Microcystin-LR in sediment, Isahaya new pond and Isahaya bay

ABSTRACT

Microcystin species (MCs) produced by toxic cyanobacteria has become a serious problem in the world. Up until the present, it has been focused on MCs degradation in freshwater bodies only, although all lakes and ponds connect to the sea. Therefore, the aim of this study was to estimate the behavior of MCs discharged from freshwater bodies to sea such as the degradation, through the degradation of MC-LR in surface-water combined with sediment collected from the Isahaya new pond and the Isahaya bay as a model for effluent source and discharged estuary. The result showed that no MCs have accumulated long-term in surface water and sediment of the Isahaya new pond as an effluent source to the Isahaya bay. Moreover, these both areas have a potential of a degradation of MC-LR lower than 0.01 μg・l^{-1} for 17 days at 30℃ and 21 days at 20℃. Interestingly, a sea water component had no effect. As a result of bacterial isolation, the decrease of concentration was probably caused by the degradation bacteria. These results supports that no MCs accumulate in the Isahaya new pond and the Isahaya bay, and thus it was strongly suggested no MCs was concentrated biologically into the aquatic organism via benthos. These results will contribute to the estimation of MCs behavior in sediment of the lake and estuary such as Lake Kasumigaura.

1. INTRODUCTION

Recently, the eutrophication and water blooms have become a serious problem world-wide in closed water bodies such as lake and pond. Water blooms are a massive growth of cyanobacteria, which is mainly *Microcystis* sp. This species can produce a hepatotoxin, Microcystin species (MCs), thus many researchers have studied this topic and reported some useful results, including the degradation bacteria of MCs collected from lakes and ponds. On the other hand, it is also important whether these degradation bacteria have the activity in sea water or not, because all lakes and ponds connect to the sea via a river and MCs can contaminate sea and accumulate in the sediment. Therefore, the aim of this study was to determine the MCs degradation activity in raw sediment collected from sea. In this study, we choose the Isahaya bay, Japan, as a model. Isahaya bay was divided by the dike since 1997. Fresh water from rivers has remained inside of the dike, thus the artificial freshwater pond has been made, which is called the Isahaya new pond. Because of the elevation of water surface level, sometimes water is discharged from the Isahaya new pond to the Isahaya bay. Recent years, toxic cyanobacteria, *Microcystis* sp., and produced MCs have been observed in the Isahaya new pond. Therefore, Isahaya bay is proper to the experimental model area.

2. METHOD

Measurement of MCs concentration in Isahaya new pond

To estimate the MCs loading to the Isahaya bay, MCs concentration has been measured in surface water and sediment collected from the Isahaya new pond since 2009. Sampling points are B1, B2 and the bridge of the north drainage gate (BNDG) where is the monitoring points of MAFF (Fig. 1)[1]. Collected surface water was combined with acetic acid, and sediment was freeze-dried and combined with 50 % methanol and 50 % phosphate buffer (pH 3.0). Then, each sample was shaken, centrifuged and filtrated. Supernatants were stored in -20℃ until MCs extraction and HPLC analysis.

MC-LR degradation activity in raw samples

MC-LR was used in this study because the toxicity is higher than other MCs. MC-LR was extracted from *Microcystis aeruginosa* NIES-298 strain (National Institute for Environmental Studies, Japan). Sediment samples were collected from S21, S24, S25 point in the Isahaya new pond and B3, S1, S4, S6 point in the Isahaya bay (Fig. 1). 100 g-wet weight (W.W.) of each sediment was charged into Erlenmeyer flask and combined with 250 ml of surface water collected from same collecting point with MC-LR (100 μg・l^{-1}). Flasks were cultivated at 20 and 30℃ without shaking, and 1 ml of surface water

was collected weekly. Then, collected surface water was filtrated and MC-LR was extracted. After a month later, sediments in each flask were collected and MC-LR was extracted with same method as above section.

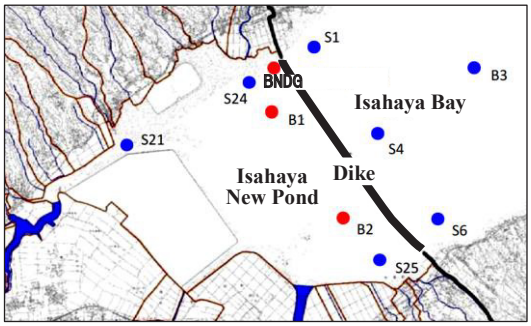

Fig. 1. Sample collecting points

MCs Extraction and HPLC analysis

MCs were extracted and pre-purified from samples by the solid phase extraction method using C18 (ODS) and silica column (Wako Chem.). Finally, MCs are analyzed by HPLC (Shimadzu Co., Ltd.).

Isolation of MC-LR degradation bacteria

To determine the presence of MC-LR degradation bacteria in sediment, isolated bacteria group was cultivated in M-11 media with 100 μg・l^{-1} of MC-LR under 30℃. Carbon source in this media is only MC-LR, thus grown bacteria would likely be able to use MC-LR.

3. RESULTS

MCs concentration in the Isahaya new pond

Long-term observation revealed that MCs in surface water had been detected and maximum concentration was 13 μg・l^{-1} until 2014 (Fig. 2). Meanwhile, almost surface water samples collected after 2015 had no MCs and detected concentration was lower than 1 μg・l^{-1}, which is the guideline value for the drinking-water on source water proposed by WHO[2]. Results in sediment also showed almost samples accumulated no MC-LR and sometimes detected concentration was much lower.

Characteristics of MC-LR concentration decreasing

In this study, samples collected from B3, S1, S4 and S6 are seawater, and samples from S21, S24 and S25 are fresh water. 0.11 and 0.16 μg・l^{-1} of MC-YR were detected from surface water at S6 and S24, respectively. However, no MCs were observed from sediments in B3, S1, S4 and S6. This indicates that no MCs accumulate in the sediment of the Isahaya bay.

Fig. 3 shows MC-LR concentration in surface water of flask depending on cultivation time. About a week later, 3.20-6.04 μg・l^{-1} of MC-LR was detected at 20℃

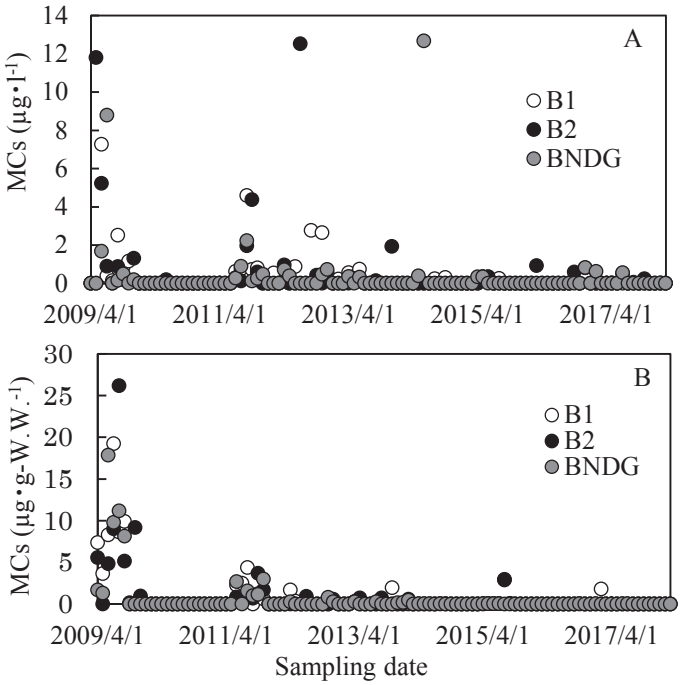

Fig. 2. Change of MCs concentration in the Isahaya new pond (A: Surface water, B:Sediment)

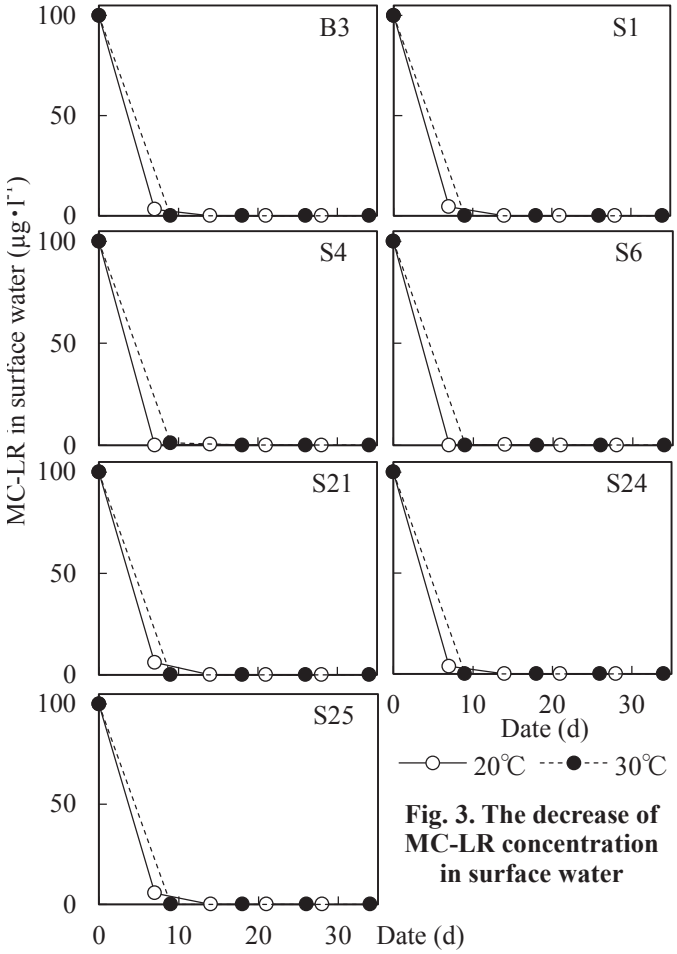

Fig. 3. The decrease of MC-LR concentration in surface water

excluding S4 and S6, and 1.11 μg・l^{-1} in S4 at 30℃. No MC-LR was observed in S4 and S6 at 20℃, and flask under 30℃ cultivation excluding S4. No MC-LR was observed after 21 day at 20℃ cultivation and 16-17 day in S4 at 30℃. Therefore, the degradation speed of MC-LR increased with the increase of temperature.

Furthermore, MC-LR in surface water was decreased, whether seawater or fresh water condition. After the experiment, each sediment in flask was analyzed and MC-LR concentration of all cultivation condition was lower than 0.01μg･g-wet weight (W. W.)$^{-1}$.

Isolated MC-LR degradation bacteria from sediment in the Isahaya new pond and the Isahaya bay

As a result of bacteria cultivation using M-11 media combined with MC-LR, many colonies were grown on agar plates not only at fresh water samples but also from seawater. These bacteria were classified into 4 general groups based on morphological characteristics of colony.

4. DISCUSSION

This study revealed a trend of MCs concentration in the Isahaya bay in Nagasaki prefecture, Japan. Although over 10 μg･l^{-1} of concentration had been detected in the past, MCs are not accumulated in surface and sediment in the long-term. Recent observed MCs concentration is lower than the proposed concentration by WHO[2)], thus MCs concentration is much lower in the Isahaya new pond. These results suggest that MCs is degraded by the bacteria. At the same time, a microscopic observation indicates that dominant cyanobacteria have been changed from *Microcystis* sp. to *Arthrospira* sp. in recent years (Fig. 4). Mussagy et al.[3] reported no cyanotoxin was produced by *Arthrospira* sp., thus above succession also might cause the decrease of MCs concentration in the Isahaya new pond.

The degradation study of MC-LR with the sediment was to determine the behavior of MCs surrounding sediment in the Isahaya new pond and the Isahaya bay. The result revealed that MC-LR concentration was decreased lower than 0.01 μg･l^{-1} by 21 days at a realistic water temperature between 20 to 30℃ when water blooms has been observed, in the presence or absence of the component of seawater. HRT in the Isahaya new pond is approximately a month, thus MCs produced in this pond will be removed from freshwater bodies, and it will be also degraded in the Isahaya bay if MCs are discharged from the Isahaya new pond. Especially, MC-LR concentration in surface is lower than the guideline value for the recreational water quality proposed by Health Canada (20 μg･l^{-1}) [4] during about a week, and the guideline value by WHO[2] until 17 days. This decrease of MC-LR was probably caused by the bacteria because the decrease of concentration was enhanced by the increase of temperature and MC-LR amount in sediment was lower than 0.01 μg･g-W. W.$^{-1}$ after the experiment. In addition, bacterial degradation was also supported by HPLC chromatogram which has some peak like a degradation product of MC-LR in some experimental series. Especially given that isolated bacteria from all sediment samples have a possibility of MC-LR degradation, the result strongly suggests that isolated bacteria play a prominent role in the degradation of MCs in these areas. Moreover, it was suggested that no accumulation of MCs into sediment and biological concentration to aquatic organisms via benthos.

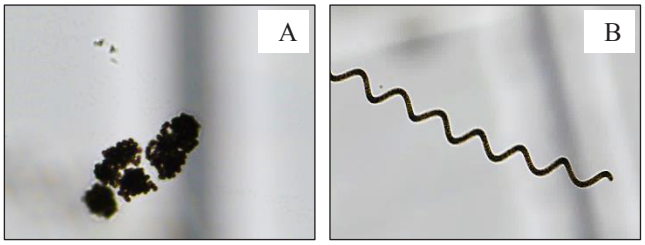

Fig. 4. Main cyanobacteria observed in water bloom of Isahaya new pond (A: *Microcystis* sp., B: *Arthrospira* sp.)

5. CONCLUSION

1) No MCs have accumulated long-term in the surface water and the sediment of the Isahaya new pond up until the present. 2) Whether the presence of the component of sea water or absence, there is a potential of the degradation of MC-LR in the Isahaya new pond and the Isahaya bay. 3) The degradation time is 17 days at 30℃ and 21 days at 20℃. 4) Isolated bacteria probably have an ability of MC-LR degradation in the Isahaya new pond and the Isahaya bay. 5) The result from this study suggested no MCs accumulate in sediment, and thus it was suggested no MCs accumulate into the aquatic organism as the biological concentration. Furthermore, through the relationship with the physicochemical characteristics of sediment, applying the result in this study will contribute to the advancement of environmental countermeasure of MCs in other lake such as Lake Kasumigaura.

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O3-15

Influence of environmental factors on cyanobacterial biomass and microcystins concentration in the Dau Tieng Reservoir, a tropical eutrophic water body in Vietnam

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Keywords: cyanotoxins; harmful algae blooms; total phosphorus; Dau Tieng reservoir

ABSTRACT

Cyanobacterial blooms can be harmful to environmental and human health due to the production of toxic secondary metabolites, known as cyanotoxins. In the present study, we examined the effects of environmental parameters on cyanobacterial community structure and MCs concentrations in the Dau Tieng reservoir (DTR), a tropical, eutrophic water body in Southern Vietnam. Cyanobacterial biomass and MCs contents were monitored monthly from March 2012 to February 2013, when MCs were present in the DTR. The highest concentrations of intracellular MCs were found in September and February when cyanobacteria biomass reached maximum values, with 2.50 and 2.13 μg/L, respectively. Multivariate analysis showed that MCs concentration was positively correlated with the biomass of the cyanobacterial order Chroococcales, whereas total phosphorus (TP) was the primary abiotic factor influencing cyanobacterial biomass and MCs concentrations in the DTR.

1. INTRODUCTION

The frequent occurrence of toxin-producing from harmful cyanobacterial blooms (HCBs) poses a serious threat to environmental and human health because of their ability to produce a wide variety of toxic secondary metabolites including hepatotoxins, neurotoxins, and dermatotoxic compounds throughout the world [1].

Numerous studies have shown that an increase in the biomass of MCs producing species is typically associated with elevated total MCs concentrations in the water column. In tropical regions, nutrient levels may be play the most important factors influencing cyanobacterial blooms [2]. The objective of this study was to investigate environmental variables influencing on MCs concentrations and cyanobacterial biomass in the Dau Tieng reservoir.

2. METHOD

Cyanobacteria and environmental parameters were collected monthly on the same day for each sampling event at five different sites (DT1–DT5) in the Dau Tieng Reservoir (DTR), Vietnam.

Chemical parameters were analyzed colorimetrically in triplicate with a spectrophotometer using the APHA (2005) [3] methods. Living and Lugol-fixed cyanobacterial species were morphologically identified and counted under a light microscope. Biovolume was calculated based on geometrical cell- or colony volumes [4,5].

Intracellular MCs (MC-LR, MC-RR, and MC-YR) were extracted with 100% methanol (MeOH) and analysed by using a HPLC system.

Principle component analysis (PCA) was used to investigate the association of MCs concentrations and cyanobacterial biomass according to the method of Leps and Smilauer (2003) [6] .

3. RESULTS

Physical and nutrient characteristics

The concentration ranges and averages of water quality variables between March 2012 and February 2013 are shown in Table 1. the TN and TP concentrations (0.28 to 16.4 mg/L and from 0.03 to 0.36 mg/L, respectively) are characteristic of eutrophic conditions according to Reynolds (2006) and were no limiting factors for cyanobacterial development at any time during the sampling period.

Cyanobacterial species composition

During one year of monitoring, a total of 3 orders, 16 genera and 42 cyanobacterial species were recorded in the DTR.

Table 1. Environmental variables in the DTR

	Mean	Min	Median	Max	C.V.
Tem (°C)	31.0	27.5	31.2	34.0	0.04
pH	7.04	6.30	6.90	8.70	0.06
Trans (cm)	115.5	40	115.0	210	0.34
TIN (mg.L^{-1})	0.24	0.06	0.105	1.55	1.49
TN (mg.L–1)	3.22	0.28	1.78	16.4	1.1
TP (mg.L^{-1})	0.06	0.03	0.06	0.36	0.67
TN:TP ratio	55.7	6.0	33.0	274.	1.05
Chro (mg.L^{-}	0.35	0.0	0.08	7.54	2.87
Nost (mg.L^{-1})	4.71	0.01	1.00	192.	5.25
Oscil (mg.L^{-}	0.03	0.0	0.01	0.60	2.47
TCB (mg.L^{-}	5.09	0.02	1.20	200.	5.04
MCs (µg.L^{-1})	0.47	0	0.23	2.50	2.46

Trans: Transparency; TIN: Total inorganic nitrogen; TN: Total nitrogen; TP: Total phosphorus; Chro: Chroococcales; Nost: Nostocales; Oscil: Oscillatoriales; TCB: Total cyanobacterial biomass.

Cyanobacterial biomass

The cyanobacterial biomass of Chroococcales, Oscillatoriales and Nostocales were shown in table 1 and Fig. 1. Total biomass ranged between 0.55 and 41.72 mg fresh weight (FW)/L and was especially high in

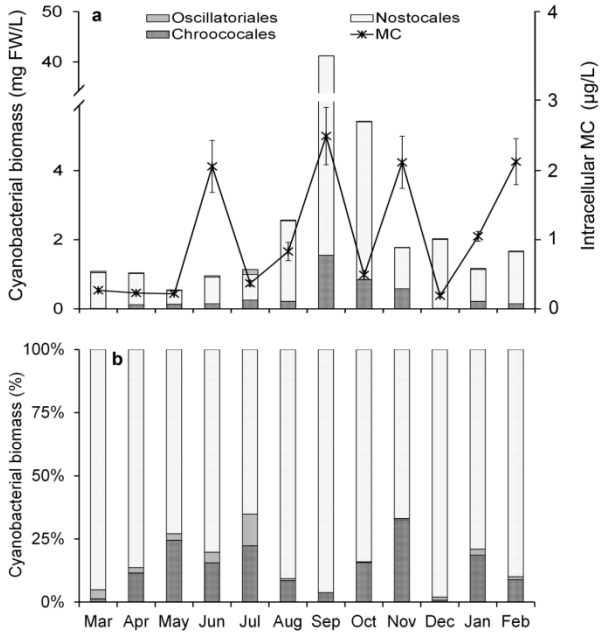

Fig. 1. Variations of (a) cyanobacterial biomass and intracellular MC

September 2012 due to a bloom of *Dolichospermum flos-aquae*. The biomass of Nostocales was the dominant component of the cyanobacteria, contributing 65.2 to 98.5% of the total biovolume (ranging from 0.40 to 40.16 mg FW/L). Biomass of Chroococcales ranged from 0.013–1.55 mg FW/L with peak in September 2012. Oscillatoriales accounted for a small proportion of total cyanobacterial biomass in many sampling events (ranging from 0.006 to 0.14 mg FW/L) (Fig. 1a).

Intracellular MC concentration

The HPLC results revealed that intracellular MCs were detected in all samples except 2 samples (DT2 and DT3) in December 2012. The concentrations of intracellular MCs (only the three most dominant MC variants MC-RR, -LR and -YR were measured) ranged from 0.19 to 2.50 µg/L. The maximum concentration was measured in September 2012 (2.50 µg/L at station DT3) Variant dominance followed the order MC-RR>MC-LR>MC-YR across all sites and time (Fig. 1b).

Relation between abiotic and biotic variables

Using a PCA correlation biplot revealed the first axis (PC1) represented by the biomass of Chroococcales, Nostocales and MCs concentrations and explained 55.7% of total variation, whereas the second axis (PC2) was mainly related to biomass of Oscillatoriales and explained 25.5% of total variation. Measured MC concentrations were closest related to the biomass of their producing group Chroococcales (Fig. 2).

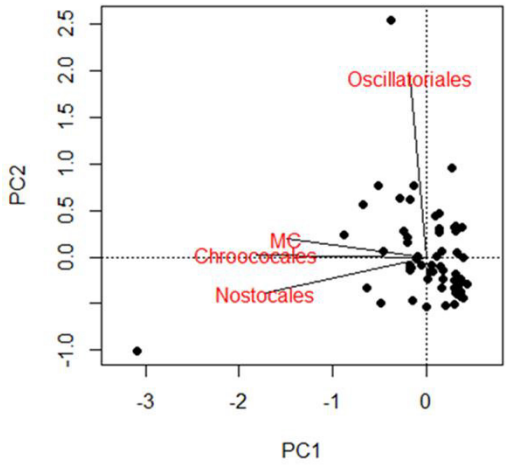

Fig. 2. Variations of cyanobacterial biomass and intracellular MC

4. DISCUSSION

The DTR is a large tropical water body; hence the temperature did not vary much over the seasons and was favorable for cyanobacterial growth [7,8]. The pH values ranged from slightly acidic to slightly alkaline and were within a similar range observed in the Nui Coc and Tri An Reservoirs in Vietnam [7,9]. Although transparency in the reservoir revealed a low trophic state, the TN and TP concentrations (0.28 to 16.4 mg/L and from 0.03 to 0.36 mg/L, respectively) are characteristic of eutrophic conditions according to Reynolds (2006) [10].

Our results showed that light, temperature and nutrient

availability support both *Microcystis* and *Dolichospermum* growth. Therefore, other factors may govern the bloom of *Dolichospermum,* e.g. high light intensity, iron or other micronutrient limitation, water column mixing and extracellular allelochemicals [11]. The exact environmental factors, which favour *Dolichospermum* blooms at certain times, need further investigation.

Our results indicated that the cyanobacterial proliferation and measured MCs concentration in the DTR were positively correlated with phosphorus and nitrogen, with the strongest correlation found for TP. Our observations were consistent with Lee et al. (2015) [12] who found that TP was the main environmental variable influencing the abundance of *Dolichospermum*, total cyanobacteria abundance, and intracellular MCs concentration from *Microcystis* sp. in the temperate Vancouver Lake.

In the present study, intracellular MCs concentrations were strongly associated with the abundance of Chroococcales, and to a lesser extent with the biomass of Nostocales. Since no MCs production was detected from a culture of *D. flos-aquae* isolated from the the DTR (unpublished results), we concluded that the detected MCs could be attributed to the toxic *Microcystis* species, as proven in a previous investigation by Pham et al. (2015) [13].

Microcystins concentration in raw water from the DTR was sometimes higher than the WHO guideline value of 1 µg/L. Hence, during periods of high MCs concentrations in the reservoir, local residents may be prone to suffer from hepatotoxic effects via their daily consumption of MC-contaminated drinking water or contaminated field products from spray irrigation.

5. CONCLUSION

Our findings reveal that the biomass of Chroococcales could be used as indicator for increased phosphorus levels and measured MCs concentrations in the reservoir, whereas Nostocales could be used in more productive waters. We propose that phosphorus supports the growth of the potentially toxic cyanobacteria, *Microcystis* spp., and may be the limiting factor in measured MCs production during the growing season.

6. ACKNOWLEDGMENTS

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O3-16

Limnological characteristics, eutrophication and cyanobacterial dominance in three Ugandan national park shallow lakes

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Keywords: lake ecosystem functions; water quality; nutrient dynamics; eutrophication and harmful algal bloom

ABSTRACT

Limnological studies that started in Uganda in the second half of the twentieth century, illustrates that water quality remains a major driver in lake ecosystem functions in the tropics. As it advances, interrelation and combination of physical, chemical and biological parameters in East Africa lakes started. The works centred on Lake Albert then Victoria shared between Kenya, Tanzania and Uganda. Uganda astride the equator is 18% covered by other lakes, rivers and wetlands besides Albert and Victoria. Three of these major lakes are Edward, George and Kyoga plus many crater lakes, small lakes and rivers. Among the five major lakes, Lake George was intensively studied in 1970 unlike lakes Edward and Mburo despite their equal water resources socio-economic development and value in supporting wildlife and conservation. We assessed the status of Lakes George; Mburo and Edward describing their physico-chemical, biological and environmental variables using standard methods from May 2007 to April 2008. In conclusion, the factors that have driven changes in the other lakes: high nutrient concentration; high phytoplankton biomass dominated by harmful algal bloom are discussed. Four decades later Lake George limnological conditions remained stable providing an insight of alternative states of tropical shallow lakes.

1. INTRODUCTION

Unlike in the temperate, most limnological studies in the tropics were made in the second half of twentieth century. In Uganda, early studies were in the 1920 (1). Work before 1925 as summarise by (2) were short-term expeditions with mainly taxonomic, faunistic and floristic approach. The expeditions that followed forty-five years later included two prolonged and more quantitative studies (3). Later, studies in East Africa by, (4) opened the interrelation of physical, chemical and biological parameters, and paved way to the quantitative studies on phytoplankton (5).

These early studies gave valuable insight used later to show the impact of human development as the major cause of nutrient loading in Lake Victoria. Apart from Victoria, Uganda have nearly 18% of its total area covered by other lakes, rivers and wetlands (6). Four of these major lakes are Edward, George, Albert and Kyoga plus many small lakes and rivers. Much as the three lakes do not make a significant contribution to the global surface area, their aesthetic value supports wildlife that attracts tourist. They are also important to the local communities as source of water supply for domestic use and livestock. Wetlands surrounding these lakes are all gazetted as Ramsar sites because of the high biodiversity they support, therefore high conservation status.

Previous studies of 1967 to 1968 in L. George describe it as a lake that experiences constant climate with incidence radiation although irregularly intercepted by cloud, varies within only ±13% of the mean. The potential effect of the two usual dry seasons (June to July and December to February) towards controlling changes in nutrient loading is offset by mountains in the catchment whose high runoff allows a continuous flow to the lake. By that time, a dense permanent phytoplankton population measured up to a concentration of 250 µg chlorophyll-a L^{-1} with the major component of mainly three blue-green algae comprising of *Anabaenopsis* species, *Aphanocapsa* species and *Microcystis* species (7).

It is since then known that Lake George is not a recently polluted lake, but has had a naturally large crop of blue-green algae presumably for a long-time (8). This would add more valuable insight if the current condition is documented to compare with the development over the past years. A number of the cyanobacterial species recorded earlier has been shown to produce toxic substances now. The genus *Microcystis* species is well described to produce the hepatotoxic microcystins and local microcystin concentrations determined previously (9). However, species occurring in Lake George might also include additional cyanotoxin producers such as *Cylindrospermopsis raciborskii*. Thus a more detailed analysis of phytoplankton composition is required to monitor potential harmful effects of these cyanobacteria to the aquatic, human and wild lives. Since the lakes have enabled potential rural development as stated above, we aimed to re-assess the current status of Lake George (Kahendero) for service to the community. In parallel we also sampled Edward (Katwe) and Mburo for physico-chemical and phytoplankton community composition during one year from May 2007 to April 2008.

2. METHOD

Three inshore sites were chosen one for each lake. Kahendero (0°03.004'N, 30°03.439'E) with a mean depth of 1.8 m. Katwe (0°09.198'S, 29°53.056'E) with mean depth of 3.2 m. Lake Mburo (0°38.513'S, 30°56.869'E) with a mean depth of 2.8 m.

Physical and chemical characteristics

In-situ parameters (pH, dissolved oxygen, temperature, and conductivity) were measured using a Hach Lange HQ 40d multiprobe monthly from May 2007 to April 2008.

Dissolved nutrients: soluble reactive phosphorus (SRP), soluble reactive silica (SRSi), nitrate (NO_3-N), nitrite (NO_2-N) and ammonia (NH_4-N) using (10). Total phosphorus (TP) was determined as SRP after persulphate digestion of unfiltered sample. Total nitrogen (TN) analysis from the unfiltered sample was as described in (10).

Phytoplankton abundance and community distribution

Algae were counted by the inverted microscope from samples fixed with Lugol solution as described in (11) and identified with the help of standard literature (12 and 13).

3. RESULTS

In-situ measurement

Monthly measurement taken from May 2007 to April 2008 with n = 12 showed the following temperature in Lake George 24.3 - 29.3ºC; Lake Edward had 25.4 - 29.0ºC and a colder Lake Mburo ranging from 22.4 - 26.2ºC. pH were all above 7.0 ranging from 9.8 - 11.0 in George, 9.7 - 10.2 in Edward and 7.5 - 9.5 in Lake Mburo. Compared with the available data of 1967-1968 only from Lake George and Lake Edward, the 2007 to 2008 measurements encompass the historical data. The two lakes (Edward and George) were more alkaline.

Nutrient measurement

The nutrient measurements were all high (Fig. 1) but within the same range forty years ago. No significance difference between wet and dry season in almost all measurement. Even with SRSi that showed a slight variation within some few months in Kahendero the difference was not statistically significant (P = 0.163, Kruskal Wallis One-way ANOVA). TP and SRSi used as the main features in defining the phytoplankton community and abundance in the lakes showed no statistical significance difference either (P = 0.689 and P = 0.076 respectively, Kruskal Wallis One-Way ANOVA on Ranks) among the three lakes.

Phytoplankton community and abundance

Chlorophyll a was high in the ranges of 30-177 µg L^{-1} and Kahendero showed a six fold increase from the dry month (June 2007) to the wet month (August 2008). Katwe and L. Mburo had intermediate concentration with less variation within months.

Four classes of phytoplankton were constantly present and identified as Bacillarophyceae, Chlorophyceae, Cryptophyceae and Cyanoprokaryota.

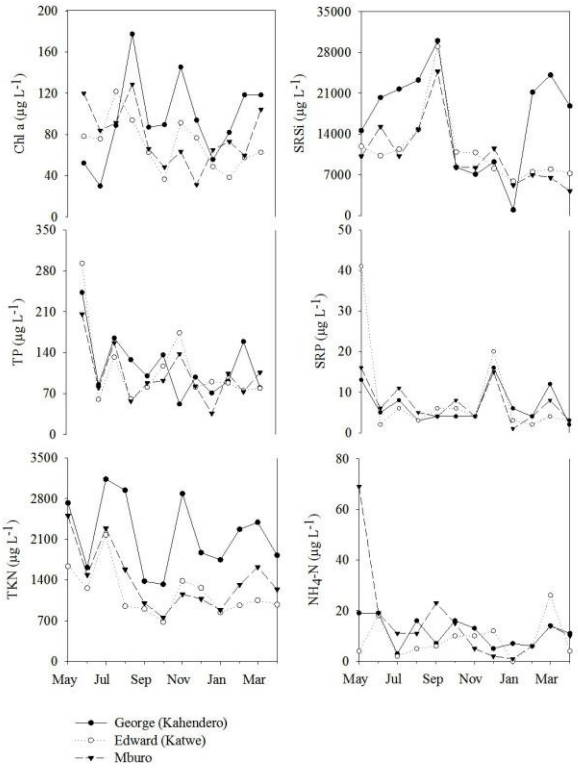

Fig. 1 Physical, chemical and biological conditions of Lakes Edward, George and Mburo May 2007 to April 2008. Vertical axes are different for each particular parameter

Biovolume was higher in Kahendero (93-432 mm^3 L^{-1}) followed by Katwe (35-228 mm^3 L^{-1}) and least in L. Mburo (40-83 mm^3 L^{-1}). Kahendero had a twofold increase from the dry month (June 2007) to the wet month (August 2008). Biovolume dropped further in January 2008, the driest month during the sampling period. Katwe and L. Mburo had stable intermittent biovolume with Katwe showing slight decrease in January 2008. There was a statistical significance differences (P = <0.001, Kruskal Wallis One-Way ANOVA on Ranks) among the sites with Kahendero ranking first.

4. DISCUSSION

In-situ measurements in Lakes: Edward, George and Mburo showed lowlight transparency because of the shallow lakes condition therefore ease of mixing as one condition that was report in (14). Apart from wind mixing, the animals that come to drink, bath and those like the hippopotami that partially leave in stirs the bottom and suspend the sediment therefore lowering the light penetration. Low transparency was also because of the high standing biomass of the phytoplankton. All these were the major internal factor with less influence from the human activities around the area. Because of the high standing crops of phytoplankton in Lake George and Edward, high algal production within led to the higher pH values in some months reaching over 10. These values were occasionally above the 1967 to 1968 measurements (7).

TP and TN concentrations throughout the study period

within the three sites did not change much. The climatic condition depicted in the temperature variation of 24.3-29.3ºC in Lake George did not correlate with the change in the nutrient concentration. A similar observation was made by (15) in that, the lake has a fairly constant environmental conditions. Forty years ago Lake George TP concentration was equally higher at 250 μgL^{-1} (7) falling at the far right-hand side of the alternative states in shallow lakes. Lake George in 2008 mean concentration of 117±15.2 μgL^{-1}, n = 12 although slightly lower than the 1968 measurement, is at the same region of alternative state preserving its original natural pristine condition. This system agrees with the finding that they do conserve nutrients and store organic matters while others that have been disturbed by humans for agricultural purposes, industries, domestic sewage lacks conservation mechanisms leaking nutrient into the streams and other water bodies (15). Lake Edward with TP concentration of 111.0±65.9 μgL^{-1}, n = 12 and Lake Mburo with TP concentration of 102.0±13.3 μgL^{-1}, n = 12 are also documented. The variations were also insignificant despite the marked seasonal temperature and rainfall variation. This however could not be compared with earlier published data as they were lacking. The study fills in the gap for future references and increasing knowledge of shallow lakes in Uganda to the wider scientific community.

Coupled with the TP, the TN concentration and other nutrients (SRSi, SRP, NH_4-N, NO_2-N and NO_3-N) were documented (Fig. 1). It was noted; that flow of water to the lake increased when it rain however the relative proportions of the solutes and their total concentrations in the lake did not change much throughout the year. It is in a mark contrast to the equivalent productive temperate lakes (14). The explanation why Lake George environment remained in equilibrium forty years goes back to the earlier finding. The enormous amount of organic material present in the mud and the high flow rates during the rainy season supplies the lake constantly with high nutrient contents therefore upholding it's productive.

Phytoplankton community and abundance

The historic work of 1967-1968 in Lake George documented a permanent phytoplankton population density of 250 μgL^{-1} chlorophyll-a described as pea-green "soup" (7). (2) portrayed the same algal community as remarkably stable and uniform through the years, 1967-1968 and 1969-1970. Forty years later, chlorophyll-a remained high ranging from 30-177 μgL^{-1} with slight annual variation. Lake Edward and Mburo probably studied earlier but not documented showed intermittent chlorophyll-a concentration. The biovolume was contributed majorly by Cyanobacteria. Lake Edward inflow is beginning influenced by the community around Katwe settlement and Mweya Lodge while Mburo receives greater inflow from the Rinzi River with degraded catchment area of Mbarara Town.

5. CONCLUSION

The factors that have driven changes in other lakes: high nutrient concentration and phytoplankton biomass were recorded in Lakes Edward and Mburo describing them as hyper eutrophic. Lake George had its peculiar high nutrient that is hyper eutrophic also with high biomass of blue green algae but remained stable for the last four decades providing an insight of alternative states of tropical shallow lakes that can be applied in ecosystem management. This information provides valuable inputs into compilation of historical physical and chemical trends in three shallow lakes for the water managers, conservationist and policymaker.

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O3-17

Properties of cyanobactericidal bacteria and growth inhibiting bacteria associated with waterweeds against *Dolichospermum crassum* (Cyanophyceae) causing musty odour problem in drinking water

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Keywords: Musty odor, Cyanobactericidal bacteria, *Dolichospermum crassum*, Waterweed, *Potamogeton malayanus*

ABSTRACT

The population dynamics of effective bacteria (cyanobactericidal bacteria and growth inhibiting bacteria) against the nuisance cyanobacterium *Dolichospermum crassum* were investigated at two habitats, the surface water of a reservoir and the waterweed zone (containing *Potamogeton malayanus* Miq.) of Lake Biwa. The number of effective bacteria associated with *P. malayanus* in the lake water in the waterweed zone greatly exceeded the number in the reservoir where algal blooms frequently occur. Trichomes of *D. crassum* were rapidly destroyed by effective bacteria when they were co-incubated with a biofilm from *P. malayanus* or water from the waterweed zone of Lake Biwa. The effects of other predators and chemicals were negligible, and it is concluded that waterweed beds play a significant role in preventing *D. crassum* blooms as providers of effective bacteria. Possible control of *D. crassum* blooms was discussed in relation to effective bacteria as feasible prevention strategies for the nuisance cyanobacterial blooms in water environments.

1. INTRODUCTION

Musty odor in drinking water supplies is a worldwide problem. In Japan, the odor compounds geosmin and 2-methylisoborneol are included in the quality standards for drinking water (less than 10 ng/L), and water suppliers struggle to provide good-tasting drinking water. The Cyanophyceae species *Dolichospermum crassum* (Lemmermann) Wacklin, Hoffmann et Komárek (syn.: *Anabaena crassa* [Lemmermann] Komárková-Legnová et Cronberg) is the major producer of geosmin in eutrophic lakes in temperate areas of the world. Kobe City, Japan, has been suffering from musty odor in water caused by geosmin, which is mainly produced by *D. crassum* since the mid-1990s. Chemicals such as copper sulfide have been widely used to terminate these algal blooms. However, this is not a fundamental solution strategy.

Several types of bacteria have been reported to show algicidal activity against harmful plankton in marine coastal systems (Imai et al. 1993, Harvey et al. 2016), and eutrophic lakes and ponds (Li et al. 2015). These bacteria are found at high density in biofilms on seaweeds (Imai et al. 2006) and seagrasses (Imai and Yamaguchi, 2012). Therefore, seaweeds and seagrasses are attracting attention as important players not only in environmental remediation, but also as sources of effective bacteria in water environments. However, there are no reports on the ecology of bacteria with cyanobactericidal activity against *D. crassum* in fresh water. We previously reported the isolation and characteristics of bacteria possessing cyanobactericidal activity against *D. crassum* from the Karasuhara Reservoir (Shimizu et al. 2017). Here, we monitored the seasonal dynamics of effective bacteria in the reservoir. Then, we compared cyanobactericidal populations in this reservoir and in the waterweed zone of a lake. We verified the effectiveness of these bacteria inhabiting on the waterweed for controlling the growth of *D. crassum*.

2. METHOD

Surface water samples were taken from the Karasuhara Reservoir, which is a water source for Kobe City, every month from May 2013 to October 2014. The seasonal dynamics in the populations of effective bacteria against *D. crassum* were monitored with algicidal assays in which isolated heterotrophic bacteria were co-incubated with an axenic culture of *D. crassum*. Then, the densities of effective bacteria in the waterweed zone (containing *Potamogeton malayanus* Miq.) at Yanagasaki of Lake Biwa were counted for comparison.

A small piece of *P. malayanus* or lake water in the waterweed zone was inoculated into a culture of *D. crassum,* and the change in the *D. crassum* populations

were monitored during incubation.

3. RESULTS

In the Karasuhara Reservoir, cyanobacteria dominated most of the year, and algal blooms occurred during summer. *D. crassum* increased up to 1.5×10^3 cells mL^{-1} in 2013, and 1.1×10^3 cells mL^{-1} in 2014. The number of effective bacteria increased in summer and autumn; however, their numbers were relatively low (7.0×10^0 cfu mL^{-1}–3.4×10^2 cfu mL^{-1}) throughout the experimental period (**Fig.1**). In contrast, the number of effective bacteria in the waterweed zone of Lake Biwa was much higher (3.1×10^3 cfu mL^{-1}) than that in the Karasuhara Reservoir, and they accounted for 54% of the total heterotrophic bacteria. In the *P. malayanus* biofilm, the number of effective bacteria was 6.4×10^6 cfu g^{-1} -wet weight. Trichomes of *D. crassum* were rapidly destroyed by attached bacteria when inoculated with a piece of *P. malayanus* or lake water from the waterweed zone. The effects of viruses or chemicals were negligible.

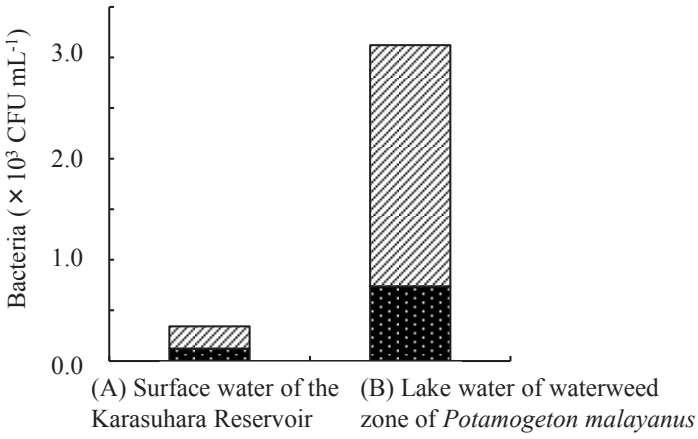

Fig.1 Comparison for densities of the effective bacteria (sum of cyanobactericidal bacteria and growth inhibiting bacteria) in surface water of the Karasuhara Reservoir and waterweed zone of *Potamogeton malayanus* in Lake Biwa.

A, Maximum density of effective bacteria in the surface water of the Karasuhara Reservoir during the monitoring from May 2013 to October 2014. The water sample was collected on 3 September 2013.

B, Density of effective bacteria in lake water collected from waterweed zone of *P. malayanus* at Yanagasaki in Lake Biwa on 3 August 2017.

■ Cyanobactericidal bacteria ▨ Growth inhibiting bacteria

4. DISCUSSION

There was no waterweed in the Karasuhara Reservoir, and densities of cyanobactericidal bacteria and growth inhibiting bacteria were very low. Therefore, the absence of water plants probably enhanced the growth of algae such as *D. crassum*. On the other hand, waterweed beds served as sources for effective bacteria. Suspended biofilm released from *P. malayanus* were abundant in waterweed zone, and it means effective bacteria from waterweeds prevent occurrences of cyanobacterial blooms in freshwater environments. Similar results were reported on toxic *Microcystis aeruginosa* with the water plant *Trapa japonica* (Miyashita et al. 2018). The musty odor remains a serious problem for drinking water suppliers in the world. Effective bacteria associated with waterweeds will be the clue for solving this problem.

5. CONCLUSION

Densities of cyanobactericidal bacteria and growth inhibiting bacteria associated with *P. malayanus* in the lake water in the waterweed zone of Lake Biwa were significantly higher than the densities in the Karasuhara Reservoir where cyanobacterial blooms frequently occur. It is hence concluded that waterweed beds are the key providers of cyanobactericidal bacteria and growth inhibiting bacteria for preventing occurrences of nuisance cyanobacterial blooms in fresh water environments.

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O3-18

"Ecosystem health assessment of Powai Lake, Mumbai, India"

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Keyword: Powai lake, Water Quality, Eutrophication processes, Conservation

ABSTRACT

Powai lake is an important ecological landmark on the map of megacity with more than 2 billion population of Mumbai that provides the citizens an opportunity for some recreation and natural ambience. The lake has an unique location with reasonably well protected catchment having Indian Institute of Technology and Sanjay Gandhi National Park. In the past two decades, the lake has suffered significant environmental injury in terms of siltation, weed growth, blue green algal blooms and deteriorated water quality. The concomitant urban activities at the bank are increasing rapidly with more potential for environmental impact.

Powai Lake is one of the best studied freshwater ecosystems in this region and a good record of its water quality over a period of time is available. Relatively higher values of dissolved solids, nitrates and phosphates as well as COD and BOD and primary productivity along with significant decrease in transparency in Powai lake indicates hyper eutrophic conditions. This is further corroborated with symptoms such as foul odors, prolific growth of water hyacinth (*Eichornia crassipus*) and blooms of blue green algae (*Microcystis sp.*) with recurrence of mass mortality of fish species.If appropriate measures are taken, the lake can be revived for future sustenance of the lake itself, supporting ecosystem and for the benefit of the lake dependent community as a whole.

1. INTRODUCTION

Urban lakes are very often man-made ecosystems and in several cases they result from excavation activities to provide building material for residential development, road system and walkways. In some cases they come from the enlargement of smaller water bodies to provide recreational activities (angling, swimming, and boating). The small and shallow aquatic ecosystems are more sensitive to water pollution and eutrophication processes. The high population density around urban lakes makes them vulnerable to release of sewage, solid waste dumping, reclamation and various other anthropogenic activities including improper beautification. Due to these, the lakes are getting polluted and are losing their utility. It has become very much essential to come together, discuss different issues about the urban lakes, exchange ideas so that we can effectively plan for rejuvenation and restoration of the urban lakes.

The water quality and conservation aspects of five water bodies in and around Hyderabad, Andhra Pradesh are discussed by Kodarkar, M.S. (1995). In the last two decades it has become a recurrent phenomenon in water bodies particularly in urban areas and linked to environmental degradation due to unprecedented urbanization and industrialization. (Kodarkar, 1995). Extensive limnological work of Powai Lake was carried out by a number of workers (Thakhare, 1969; Bhagat, 1977; Singh Kohili M.P., 1991).

Powai Lake is situated in metropolitan city of Mumbai, the financial capital of India, and has total water spread area of 210 hectors. It is a man-made impoundment built in 1891. Powai lake (19°07,862'N and 72°53,153'E) situated 55 meters above the mean sea level (msl) is known as 'Anglers Paradise'. The lake has an unique location with reasonably well protected catchment having Indian Institute of Technology and Sanjay Gandhi National Park. In the past two decades, the lake has suffered significant environmental injury in terms of siltation, weed growth, blue green algal blooms and deteriorated water quality. The concomitant urban activities at the bank are increasing rapidly with more potential for environmental impact.

Nauashad Ali Sarovar Samvardhini (NASS) is a body constituted for the conservation of urban lakes in Mumbai base on the Sarovar Samvardhini concept. NASS initiated its field activities at Powai Lake since February 2008. A field station dedicated to the fond memory of Late DR M.S. Kodarkar, an International Expert on Lake Management and former Secretary, Indian Association of Aquatic Biologist (IAAB) was established on 8th September, 2012. Dr M.S. Kodarkar Field Station provides facilities for field work to the students, researchers, NGO and citizens interested in the environmental issues of Powai lake apart from sharing

literature on environmental aspects of lakes and their conservation. Museum on flora and fauna of Powai lake is proposed to be established in future.

Table 1 Profile of the lake (physical):

Particular	Powai lake
Location	North-eastern suburb of Mumbai
Year of Impoundment	1891
Purpose	Drinking water
Constructed by	Mumbai Municipal Corporation
Lakes Types	Fresh water reservoir
Geographical features	19°07,862'N 72°53,153'E
Water spread area (Wet season)	2.1 sq.km
Maximum depth	6.1 meter
Source of water	Rain Water
Main use of water	Recreation and fishing

2. COLLECTION AND ANALYSIS OF SAMPLES

Sampling was carried out on a monthly from 03 stations of each lake, usually between 09.00 and 10.00 hr. Sub-surface (0.3 m) water and plankton samples were collected from May, 2016 to December, 2017. Surface water sampling was done using 05 liter polythene cans. The can was washed in ambient water before sampling. Care was taken to preventing entry of air bubbles. Standard methodology as per APHA (1981) has been used for sample collection, physicochemical and biological analysis of lake water.

Table 2. Average values of Water quality of Powai lake

Sr. No.	Parameters	Unit	Average value
1	Transparency	cm	27.6 ± 0.98
2	Dissolved Solids	mg/l	257.0 ± 116.2
3	pH	…	7.4 ± 0.86
4	Total Hardness	mg/l	128.0 ± 18.4
5	Total Chlorides	mg/l	42.8 ± 8.4
6	Dissolved Oxygen	mg/l	5.1 ± 0.46
7	Total Alkalinity	mg/l	146.8 ± 48
8	Phosphate	mg/l	0.28 ± 0.24
9	Calcium	mg/l	34.8 ± 6.14
10	Magnesium	mg/l	19.36 ± 4.60
11	Sulphate	mg/l	11.46 ± 18.84
12	Nitrates Nitrogen	mg/l	1.34 ± 0.56
13	BOD (5-days at 20°C)	mg/l	17.8 ± 2.56
14	COD	mg/l	113 ± 4.16

3. FINDINGS AND ARGUMENT

Powai Lake is one of the best studied freshwater ecosystems in this area and a good record of its water quality over a period of time is available. Water quality assessment of the lake water from five different locations revealed that the Chemical Oxygen Demand (COD), Biochemical Oxygen Demand (BOD) as well as Dissolved Solids were highest in the northern part followed by Ganapati Immersion Point of the lake. A relatively higher value of dissolved solids, nitrates and phosphates as well as COD and BOD and primary productivity along with significant decrease in transparency in Powai lake indicates hyper eutrophic conditions. This is further corroborated with symptoms such as foul odors, prolific growth of water hyacinth (*Eichornia crassipus*) and blooms of blue green algae (*Microcystis sp.)*.The sewage entering the lake is rich in pollutants like nitrates and phosphates that lead to algal bloom thus depleting the oxygen levels of the water causing mass death of fishes.

4. AWARENESS

Sarovar Samvardhini has invited people by organizing educational or recreational events. Sarovar Samvardhini has connected local environmental NGOs, local governments and residents efficiently and its staff members work hard to keep their momentum in activities.

There is no more effective, longer-term and preventative approach towards protecting the lakes than teaching children to value the very resources that they will need in the future. Children, who are inspired at an early age, will take small, but continual actions that will make the world a better place for the environment and the people. The children's enthusiasm in doing their voluntary work can even sometimes put an adult's lethargy and apathy to shame.

5. WAY AHEAD

1. Fountains and aeration systems: Introduction of fountains and aeration systems in the lake can have beneficial effects on the lake water quality.
2. Traditional use: The lake is also being used as immersion site for Ganesh idol and other rituals and suitable measures will have to be adapted to accommodate these demands.

3. Powai lake conservation and management society (Sarovar Samvardhini): Powai lake Sarovar Samvardhini will be platform for all the stake holders

including neighborhood communities for discussing the issue of sustainable management of Powai lake ecosystem.

4. Annual lake festival: To raise lake environmental awareness Powai lake festival should be arranged annually.

5. Educating and creating awareness about limited nature of fresh water and need for protection of lakes among the common man goes a long way in protection of lakes.

6. Educating children about water-related issues is a beneficial long-term measure for achieving sustainable lake use. It is necessary to educate use of free P detergents and also pre treatment of domestic wastes before releasing then in water bodies.

7. Propagation of World Lake Vision (WLV) through training programmes and other activities can be a very effective measure to implement Integrated Lake Basin Management (ILBM).

6. CONCLUSION

Powai Lake is polluted mainly by sewage disposal, growth, death and decay of aquatic weeds, and blooms in the lake. Regular cleaning of the macrophytes, enhancing public awareness, scavenging of polluted sediments, proper regulatory measures for anthropogenic waste disposal and strict measures to prevent further encroachment to the catchment area are needed for the restoration of Powai Lake. To generate public interest and involvement in the lake's conservation, there is a need of bringing together diverse groups of stake holders including NGOs, Civic body, Fishermen, Angler's Association and other organized sections of the society.

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O3-19

The influence of eutrophication on methane production and its potential as a carbon source for zooplankton

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Keywords: methane flux; methane oxidizing bacteria; carbon isotopes; zooplankton grazing; food web

ABSTRACT

Methane constitutes a minor part in entire greenhouses emission, nevertheless its global warming potential is 20-30 times higher than carbon dioxide. Moreover, methane production and emission increases with eutrophication, and it has been demonstrated to serve as a carbon source for pelagic food webs. The methane oxidising bacteria (MOB) are the only group, which is able to utilize methane, as their sole source of carbon and energy and make a link between methane producers and higher food chain levels. However, the environmental controls of this alternative carbon source for plankton community in lakes with different trophic statuses are still poorly understood. Here we evaluated differences in fluxes of CH_4 and its potential as a carbon source for zooplankton in relation to the trophy state of two lakes. For this purpose two morphologically similar lakes with different trophy levels were investigated to determine methane efflux as well as zooplankton community structure and carbon stable isotope ratios in order to determine sources ($^{13}C/^{12}C$). The results revealed that C-CH_4 is incorporated into zooplankton through MOB community. Based on literature C-CH_4 has lower share of total carbon built into zooplankton in environments with higher trophy. However, our result showed that this process is more sophisticated and depends on food selectivity and vertical distribution of zooplankton members.

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1. INTRODUCTION

In lakes large quantities of organic matter are degraded under anaerobic conditions through methanogenesis, what contributes 30-80% of the anaerobic carbon mineralisation[1]. The produced methane volume strictly depends on the trophic state of the lake and increases in higher trophy[2]. A large proportion of the methane diffusing from the deep water layers can be utilized by methane-oxidizing bacteria (MOB)[3]. This is small but important group of bacteria that use CH_4 as their sole source of carbon and electrons. However, MOB need also oxygen as coreactant in the oxygenase reaction and as electron acceptor. Thus, their highest abundance occurres at the interface between anaerobic and oxygen zone. This bacterial biomass is available to zooplankton and protozoans. Although, MOB constitute ca. 3% of total bacteria, recent studies demonstrated that they may be an important component of zooplankton diet. Their significance increases with a limited amount of phytoplankton[4]. Further, the ability of zooplankton to exploit bacterial resources is not limited to the euphotic zones of lakes. Due to the vertical migration, seeking food in deeper water layers may be advantageous especially when zooplankton is forced to seek refuge from fish predation in deeper and dark water layers. However, the significance of methane-derived carbon to potential consumers under these conditions is largely unknown. Moreover, interactions in the food web, which influence on methane-carbon transfer are also little recognized. Thus, the aim of the study was to test hypothesis that C-CH_4 may consist a significant part in zooplankton food resources, and this is more depend on food selectivity and vertical distribution than on lake trophy.

2. METHOD

The study was carried out in two lakes with similar morphology, yet different trophy: Lagowskie Lake and Lodzko-Dymaczewskie Lake, located in Western Poland. Sampling and field measurements were conducted every month in the deepest place. Total phosphorus concentration was made according to standard methods[5]. Chlorophyll a concentration was determined by extraction

with boiled ethanol, with a correction on pheophytin a. Aqueous concentrations of CO_2 and CH_4 were collected by headspace method and analyzed by gas chromatography. Water samples to MOB quantity analysis were taken from surface layer, aerobic-anaerobic interface and above bottom sediments. The MOB quantity was analyzed by real-time qPCR method. Zooplankton samples were collected from the same depth as MOB. 20 liters of water was filtered through 30µ, 100µ and 250µm mesh to separate the different size fractions. Then, individuals were selected and grouped under dissecting microscope. Values of isotopic carbon composition are expressed as conventional δ13C‰ notation (relative to international standard Pee-Dee Belemnite). The trophic conditions were estimated using the trophic state index (TSI) described by Carlson[6]. The classes of trophy were established as mean value of all TSI indexes (total phosphorus - TSI_{TP}, chlorophyll a concentration - TSI_{Chla}, Secchi disk visibility - TSI_{SD}).

3. RESULTS

The average TSI index value in Lodzko-Dymaczewskie Lake was 64, which confirmed the lake's strong eutrophy (Fig. 1). The $TSI_{TP} < TSI_{Chla} = TSI_{SD}$ relationship means that TP was limiting factor for algae development. However, chlorophyll a concentration at 55 µg dm^{-3} indicated strong phytoplankton bloom. TSI in Lagowskie lake (Fig. 2) indicate mesotrophy level (average TSI = 49). The opposite relation to Lodzko-Dymaczewskie Lake $TSI_{TP} > TSI_{Chla} = TSI_{SD}$ signalized that limiting factor for phytoplankton is other than TP, e.g. zooplankton pressure. At the same time chlorophyll concentration in lake was low (3 µg dm^{-3}).

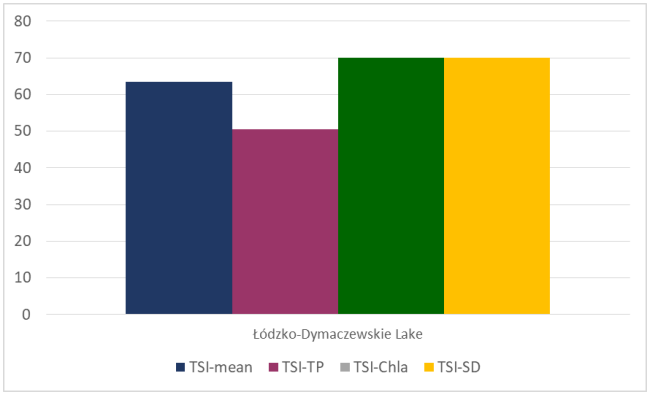

Fig. 1. Trophic state of Lodzko-Dymaczewskie Lake based on particular indexes

The ^{13}C signature of zooplankton was assessed throughout the summers 2016 and 2017 and the mean values for the crustacean community are given on Fig. 3.

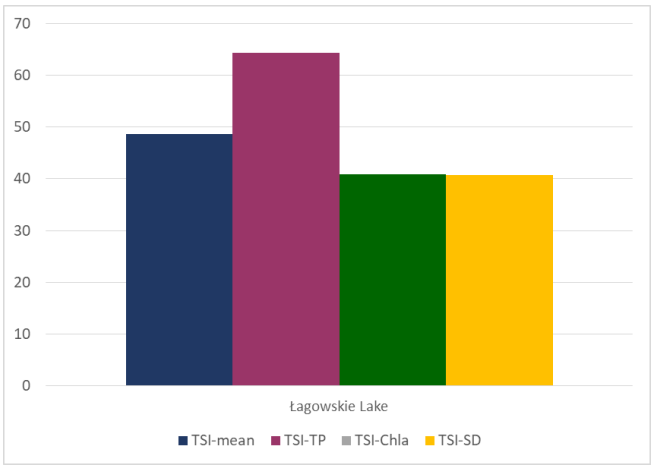

Fig. 2. Trophic state of Lagowske Lake based on particular indexes

The $\delta^{13}C$‰ were much lower in Lodzko-Dymaczewskie lake in comparison to lake Lagowskie. However there was a clear tendency towards lower values at deeper water layers. This pattern is correlated to the vertical methane concentrations (Fig. 4) which reaches highest values in hypolimnion of Lagowskie Lake and meta and hypolimnion of Lodzko-Dymaczewskie Lake.

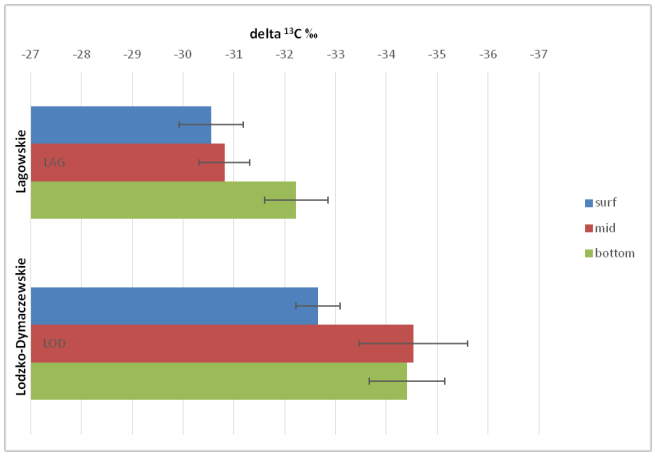

Fig. 3. The $\delta^{13}C$‰ signature of zooplankton on different level in Lagowskie and Lodzko-Dymaczewskie lakes

4. DISCUSSION

Transfer of carbon from CH_4 to higher trophic levels is mediated by methane oxidizing bacteria that are abundant at the water-sediments interface as well as in the suboxic hypolimnetic waters. The importance of this carbon source may depend on the prevailing biogenic gas production and emission pathway (diffusion or ebullition), on the activity and abundance of MOB, on the vertical distribution and grazing rates of zooplankton as well as their ability to exploit bacteria[7].

The importance of CH_4 for carbon budget in aquatic food chain strongly depended on the MOB abundance in the

lake. The abundance and activity of MOB is regulated by the availability and concentrations of CH_4 and O_2 at the sediments interface and in the water column[8]. In consequence, the highest MOB concentrations were found in the middle level with oxycline and in the deepest water level.

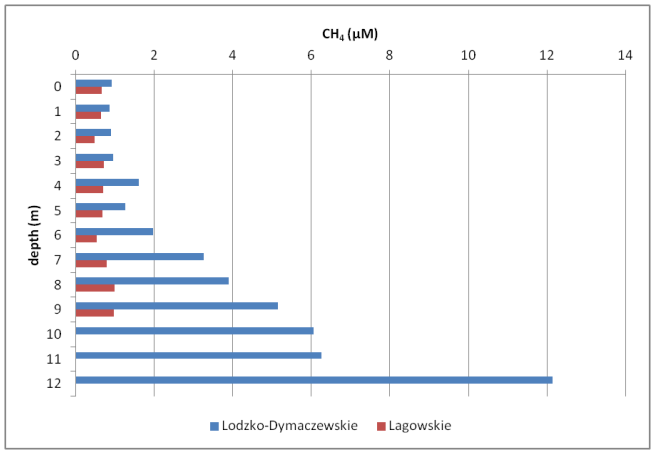

Fig. 4. Vertical profile of methane concentrations in the studied lakes

Methane oxidizing bacteria vary in size from 0.5 to 1.5 µm thus the importance of MOB food (and C-CH_4) for pelagic grazers may depend on their ability to efficiently exploit small sized particles. It was shown before that *Daphnia* sp. can efficiently graze on MOB community[9]. Therefore, larger zooplankton species, seeking refuge from predation in the dark hypolimnetic waters may gain additional energy feeding on more abundant MOB food.

5. CONCLUSION

The results revealed that C-CH_4 is incorporated into zooplankton body as result MOB consuming. However, the proportion of MOB in the zooplankton diet, expressed as lower values of $\delta^{13}C‰$, is not always negatively correlated with the water trophy. These values are more related to vertical distribution of zooplankton. Deeper water layers in eutrophic lakes are characterized by a higher concentration of MOB, and simultaneously they play role as a shelter for zooplankton. Thus, zooplankton members staying at this layer may consume more MOB due to poor phytoplankton food base.

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O3-20

Long-term variation of CO_2 flux and the controlling factors in Asia's largest brackish water system, Chilika Lake

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Keywords: greenhouse gas, climate change, carbon dynamics, trophic status, source and sink of CO_2

ABSTRACT

Carbon dioxide (CO_2) is one of the greenhouse gas known to be the main driving factor of global warming; however, the role of the coastal ecosystem on global CO_2 fluxes remains unclear due to lack of adequate data. With an objective to bridge this knowledge gap, an estimation of CO_2 flux was made analyzing the 19 years data (1999-2018) from 30 sampling locations covering entire Chilika Lake, India. ANOVA test revealed a significant variation of CO_2 flux with respect to regions as well as seasons. The overall positive value of CO_2 flux indicates Chilika Lake acts as a source of CO_2 to the atmosphere. The northern region (NR) recorded highest release of CO_2, followed by the inlet (IR), central (CR) and southern region (SR). A significant relationship between apparent oxygen utilization (AOU) and excess DIC (dissolved inorganic carbon) in the NR indicates biological respiration is the major factor for rapid ventilation of CO_2 to the atmosphere. The sink of CO_2 and minimal C source in the SR could be attributed to the presence of seagrass bed and dominate primary productivity. The C estimation from this long-term data set ($8.27x10^{-6}$ PgC Y^{-1}) indicates, Chilika contributes ~ 0.0019%C to global C emission to the atmosphere. The trend obtained through 19 years of monthly data indicated a significant annual increase of pCO_2 (µatm) and CO_2 flux (mmol $m^{-2}d^{-1}$) which are 1.57 & 0.048 respectively. At the same time, a significant decrease in pH @ 0.0006/year was observed which supports the phenomena.

1. INTRODUCTION

Nowadays global warming is a major concern. The increasing level of greenhouse gases such as CO_2, CH4, N2O, etc. are mostly responsible for the same. CO_2, being a major greenhouse gas and its impact on the biogeochemistry of coastal ecosystems, has drawn attention all over the world [1,2]. Lakes cover less than 2 % of the continent's surface but play a significant role in the global carbon cycle contributing significantly to C burial and emissions to the atmosphere. The lakes transform, store and exchange carbon with the atmosphere and considered frequently to be net heterotrophic as it promotes the emission of CO_2 to the atmosphere. Many studies have found that nearly 90% of the lakes are supersaturated with CO_2 with a net diffusion of CO_2 from surface waters[3]. Many pieces of evidence suggest that CO_2 supersaturation in lakes as the result of biological and abiotic in-lake processing of allochthonous organic matter.

Despite the importance of the above global issue, there is lack of studies on carbon biogeochemistry in Indian ecosystems except few (Hoogly estuary[4]; Godavari estuary[5]). Asia's largest brackish water lake and the first Ramsar site of India, Chilika Lake has been studied in this aspects only twice [2,6]. However, to have a better understanding of the ecosystem functioning of the lake, long-term time series data would be helpful. Hence in order to reveal the carbon dynamics, analysis of long-term time series data from (1999 to 2018) by Chilika Development Authority, Odisha, India was carried out. This study focused on following objectives: i) Estimation of CO_2 flux during last 19 years with respect to global C flux, ii) Understanding the controlling factors of CO_2 dynamics in Chilika Lake

2. METHOD

30 stations spread over the entire lake and the inlet channel were sampled on monthly basis during March 1999 to March 2018 (Fig.1). Sub-surface water samples were collected and *in situ* measurements were done for basic water quality parameters such as water temperature, pH, salinity, wind flow, depth and transparency. Dissolved oxygen (DO) measured following the modified Winkler's method. Total alkalinity (TA) measured using titration method. The pCO_2 was computed using measured salinity, temperature, nutrients (phosphate, silicate), pH and alkalinity using dissociation constants derived by Cai and Wang (1998) with a precision of 9-13 µatm[7]. Since Chilika maintains salinity range of 0 to 36 and the water temperature in the range of 20-35°C during the study period, Cai and Wang[7] was preferred over Millero[8] while computing pCO_2 using CO_2 SYS.XLS (version 14). CO_2 was calculated as a difference of pCO_2 of water and air [6]. The data for atmospheric pCO_2 for dry air for the period

of 1999 to 2012 obtained from WDCGG (World data centre for greenhouse gases) and the data of 2013 to 2018 from ESRL (GMD). The average was corrected for water vapour using the algorithms [6]. For seasonal comparison, all the 30 stations data from May, September and December (during 1999 to 2018) were considered as summer, monsoon and winter. In order to compare the data with respect to regions SR, CR, NR and IR, stations 8,17, 2 and 28 were considered.

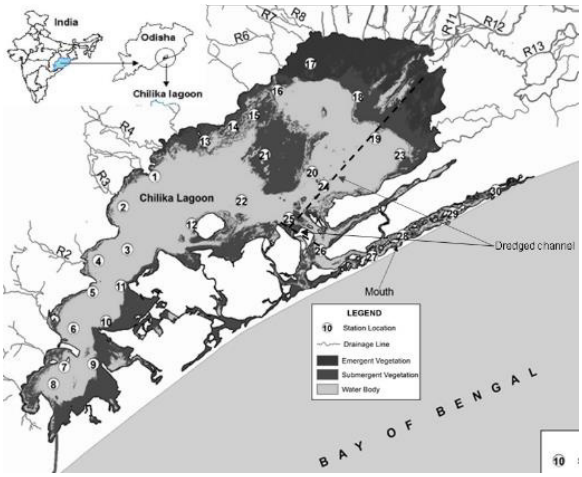

Fig. 1 Sampling map of Chilika Lake

3. RESULTS

The Chilika Lake recorded depth between 0.27 to 7.48 m with an average of 1.78 ± 0.93m didn't vary significantly throughout the study period. Higher depth mostly recorded in the IR followed by SR, CR and NR. The salinity ranged between 0 and 36 with an avg. 11.17 ± 9.20. Like other tropical coastal ecosystems, the salinity recorded minimum during monsoon due to the mixing of fresh water through riverine discharge and the level goes highest during peak summer when mixing of seawater through the Bay of Bengal becomes dominant. IR records the maximum salinity followed by SR (connected to the bay of Bengal through Rusikulya estuary), CR and NR (dominated with fresh water discharge from Mahanadi tributaries). There is no significant variation of salinity since last 19 years in the Chilika Lake.

The DO ranged between 0.3 and 14.69 with an avg.7.23 ± 1.67 mg lit^{-1}. Very low DO <4 only recorded at st-17 which could be due to decomposition of freshwater macrophytes. The average alkalinity of 113.98±34.37 mg lit^{-1} indicates the Lake maintains alkaline nature, however; it varies between 20.4 to 304 mg lit^{-1} according to the season and regions. The pH during the study period was ranged between 6 and 10.4 with an avg. of 8.2±0.53. The results of the pCO_2 and FCO_2 with respect to stations and seasons with a standard error bar has been shown in the Fig.2.

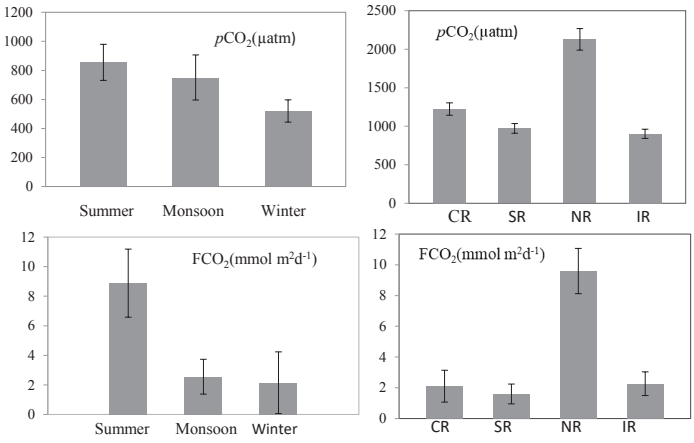

Fig. 2 Spatio-temporal variability of pCO_2 and FCO_2

4. DISCUSSION

The pCO_2 showed a pronounced gradient between the seasons. pCO_2 during summer was as high as 855.63 µatm, followed by monsoon (751.17 µatm) and winter (520.24 µatm). ANOVA test showed a very significant variation with respect to the season (n=1578, p=0.002). The observed values were quite lower than that observed in other Indian ecosystems such as in Mandovi–Zuari estuarine systems (monsoon: 2,250 µatm, non-monsoon: 2,600 µatm[9] but are near to the range as observed in the mangrove creeks of Godavari estuary (500– 6,500 µatm)[5]. The Chilika Lake also experienced significant variation in pCO_2 with respect to different regions (n=1578, p=0.002). The NR recorded the highest followed by CR, SR and IR.

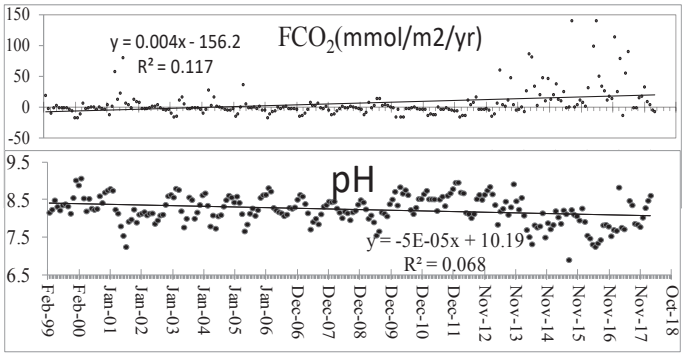

Fig. 3 Monthly variation of pH and FCO_2 in Chilika

The signature of summer, monsoon and winter are mostly found in May, September and December. Hence pulling together all the data of these months during the last 19 years, it was found that during summer and monsoon ~55% and in winter there was 71% occurrence of '–'ve CO_2 flux. This evidence that there are more chances of a sink of CO_2 during winter but rest of the seasons there is almost equal chances of source and sink of CO_2. Similarly, region wise data showed that the NR mostly results in the source of CO_2 (<40% '-'ve CO_2) and rest of the regions dominates sink of CO_2 (69%, 66% and 65% for CR, SR

and IR respectively).

Out of 6870 values of calculated CO_2 flux (monthly data of 19 years from 30stations), 65% values were the negative indicating majority of the time the Chilika Lake behaves as a sink of CO_2. Rest 35% of data were positive indicates the source of CO_2 to the atmosphere. The mean of all the negative and positive values of CO_2 flux is -6.8 and 32.3 mmol m^{-2} day^{-1}. Although the occurrence of the sink was higher than that of the source, the quantity of CO_2 sink was relatively less than the CO_2 source. Hence, overall the Chilika behaves as a source of CO_2 to the atmosphere contributing to the global warming.

Station averaged (30 sampling stations) monthly data of last 19 years data showed a gradual significant increasing trend of pCO_2 and CO_2 flux with respect to time @0.1311 μ atm/month and 0.004/month respectively (Fig.3). pH showed an opposite trend (decreasing) @$5x10^{-5}$/month. This phenomenon could be the indication of acidification (though very minimal) and the impact of climate change (increasing C flux to the atmosphere) (Fig.3).

In order to compare with global carbon source and sink, the conversion of mmol $m^{-2}d^{-1}$ to $PgCyr^{-1}$ done considering the average surface area of 1000km^2 (summer: 850 km^2 to monsoon:1150 km^2[2]). As per Richey et al. (2002)[10], the global C emission is 0.9 $PgCyr^{-1}$ and as per Borges (2005)[1], the carbon emission from global estuaries are 0.43 $PgCyr^{-1}$. The mean CO_2 flux from Chilika Lake during last 19years calculated as $8.27x10^{-6}$ $PgCyr^{-1}$ (1.888 mmol C $m^{-2}d^{-1}$) which is 0.0009% of the global carbon emission and 0.0019% of the emission from global estuaries (Chilika acts as an estuarine ecosystem as it is connected to the sea through a narrow mouth as well as a riverine system).

The net CO_2 efflux, in the NR (39.311 $x10^{-3}$ GgC d-1) was higher by 4 times than that observed in other regions (9.999 $x10^{-3}$ GgC d-1) of the Chilika Lake (Fig.2). A significant relationship between AOU and excess DIC in the NR indicates the biological respiration is the major factor for rapid ventilation of CO_2 to the atmosphere. The lowest flux in the SR could be attributed to lower bacterial respiration and higher primary production which utilizes the CO_2 [6]. Apart from this, most of the seagrasses in the Chilika Lake also covered in the SR and CR which could have also resulted in a significant sink of CO_2. Abnormally high pCO_2 (<10,000atm) and CO_2 flux recorded in the NR could be due to very low pH (<7) recorded in the NR due mixing of fresh water of low pH.

Excess DIC did not show any significant correlation with salinity indicates release of CO_2 not only confined to the freshwater region but throughout the salinity gradient recorded in Chilika Lake. Multi dimensional scale (MDS) showed two groups of the sampling stations. The first group includes the stations in the SR (most of the seagrass bed) and IR whereas, the rest of the stations from CR & NR (usually dominated with submerged macrophytes) formed the other group. This indicates the impact of submerged vegetation (macrophytes and seagrass) on the CO_2 flux in Chilika Lake.

5. CONCLUSION

The long-term monitoring of water quality is vital for understanding the ecosystem functioning. 19 years of monthly data revealed a significant rate of decrease of pH (0.0006/year) and an increase of CO_2 flux in the Chilika Lake which could be due to the impact of climate change on the ecosystem. The C estimation from this long-term data set indicates, in global perspective, the Chilika Lake contribute ~ 0.0019% C to global estuarine C emission to the atmosphere. Mineralisation of organic carbon, primary productivity and submerged vegetation are the controlling factors CO_2 flux in Chilika Lake. However, for accurate budget estimation, further study needs be focused on estimation of C flux with respect to seagrass bed, submerged, emerged and floating vegetation in Chilika Lake.

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O3-21

レジームシフト解析による霞ヶ浦での水質生態系変動要因の分析

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キーワード:時系列変動解析, レジームシフト解析, 気象パラメータ, 湖内水質パラメータ

抄録

環境分野で時系列変動解析は環境変動要因を分析する上で重要である。レジームシフト解析もその一つだが、水質や生物群集を対象としたレジームシフト解析により「水質・生態系がある安定な状態から他の安定な状態へ、安定状態の持続時間よりはるかに短い時間で遷移すること」の有無と遷移したタイミングとその内容を比較検討することができる。レジームシフトの起きるタイミングが各パラメータ間で同期していれば因果関係が強いと考える根拠となる。気象、河川水質、湖内水質に関する 1970 年代から 2010 年代までの連続環境パラメータの年平均値を用いてレジームシフト解析を行った。その結果、西浦では透明度が大きく低下した時期のはじまりと終わりに同調するように湖内の化学、生物、物理パラメータでもレジームシフトが生じていた。一方、北浦では、湖内水質パラメータで 4 回のレジームシフトが見られ、うち 2 回のシフトタイミングは流入河川の水質パラメータのそれとおおよそ一致していた。

1. はじめに

近年、時系列変動解析に用いられる統計手法は深化し、多様になってきている[1], [2]。古くからある方法としてはフーリエ解析や移動平均を用いて、時系列変動を短期から長期までの個々の時間周期をもった時間変動成分の足しあわされたものとみなし、各時間変動成分を分離・抽出し、環境要因との関係性を議論されてきた[3]。また、一見して単調増加や単調減少している時系列データの場合でも、変動成分に分離せず、時間軸に対して単に線形回帰等を行い、増加、減少傾向を議論することは統計学的には支持されないことが明らかとなっている[4]。その理由としては、データ値が増加方向にも減少方向にもランダムに変動する場合でも、過去の値の変動を蓄積する時系列データでは、多くの場合、増加傾向か減少傾向のいずれかを示すことになるからである。このように、直感的に時系列変動を議論することのリスクを認識し、時系列変動解析にかけることで、統計学的根拠を担保しつつ変動要因の解析を進めることが本分野のグランドトゥルースになりつつある。

時系列変動解析は株価の変動に代表されるような経済指標の予測や環境分野では大気や海洋といった気候変動予測の分野で注目され、その解析手法も多岐にわたっている[1]。状態関数を用いて、観測誤差や観測時の異常性の影響を排除することで真の変動傾向を解析する方法や、ウェーブレットや STARS 等によるレジームシフト解析もその一つである[5]。レジームシフト解析はその名のとおりレジームがシフトしているか否かとその発生タイミングを検出する解析手法である。水質におけるレジームシフトを解析する場合、

「水質がある安定な状態から他の安定な状態へ、それぞれの安定状態の持続時間よりはるかに短い時間で遷移すること」

の有無と遷移したタイミングを解析することになる[6]。すべての水質でどの場所においてもレジームシフトが生じている保証はないことから、レジームシフト解析が、すべての水質変動機構の解明に資するか否かは現時点では不明である。しかしながら、長期間の時系列データであればあるほど、レジームシフトの起きている可能性は高く、そのタイミングが各パラメータ間で同期していれば因果関係が強いと考える根拠となる[5]。

湖沼環境の分野でレジームシフトの研究が脚光を浴びるきっかけとなったのは Scheffer et al. (2001)による研究成果である[6]。この研究では、湖沼への栄養塩負荷に対する水草と植物プランクトンの現存量の変化をもとに、富栄養化すると突然植物プランクトンの優占する湖に変化すること、逆に水草の優占する湖沼に戻るには、植物プランクトンの優占するようなった栄養塩レベルよりも低い負荷量が必要であることを示した。この現象以外

にも、湖沼環境ではレジームシフトは下記の系で見られることをScheffer and van Nes (2004)は報告している[7]。1）貧酸素化による底泥からのリン回帰、2）浮葉植物の優占、3）湖底堆積物の安定性、4）ラン藻の優占。

石川ら(2006)は琵琶湖南湖で2000年以降急速に水草の優占するようになった点や港湾部でのハスやホテイアオイの群落の急激な消長はレジームシフトと考えられるとした[8]。霞ヶ浦においても、植物プランクトンの季節変化のパターンが 1993 年以前は夏季のラン藻と冬季の珪藻と緑藻の繰り返しパターンであったのに対し、1994年から2000年までは年間を通してラン藻が優占するようになり、2001 年以降は年間を通して珪藻がみられるパターンへと変化しており、レジームシフト様の変化を示している[9], [10]。

こうした事実から、日本の湖沼の生物・水質環境の変化の有無とその変動要因を解析する上で、レジームシフト解析は有効な分析手法の一つと考えられ、今回霞ヶ浦の長期モニタリングデータを対象に解析を行った。

2. 方法

レジームシフト解析に用いるデータソースは、以下の６つのカテゴリーにごとに分けて解析した。1）気象パラメータ群（気象庁および気象研究所の公開データ）、2）河川水質パラメータ群（国土交通省の公共用水域データ）、3）湖内物理パラメータ群（国土交通省の公共用水域データ）、4）湖内化学パラメータ群（国立環境研究所の霞ヶ浦モニタリングデータと国土交通省の公共用水域データ）、5）湖内生物パラメータ群（国立環境研究所の霞ヶ浦モニタリングデータ）、6）底質パラメータ群（国土交通省霞ヶ浦河川事務所のデータ）。

レジームシフトの同期性を議論する際に、より上位の環境因子で起こったレジームシフトが下位の環境因子に影響を及ぼす際の影響の強さによって、レジームシフトの発生の有無やそのタイミングが異なってくる可能性のあることも考慮した。湖沼の環境パラメータを物理と化学と生物の３種類のパラメータ群に分けた場合、水温や水深といった物理パラメータは化学パラメータや生物パラメータに大きな影響を与えるが、その逆は稀である。その意味で、湖内の物理パラメータ群は湖内の生物や化学パラメータより上位にくると言える（図１）。同様に、気象パラメータや流入河川の水質パラメータは湖内パラメータ群に大きな影響を与える一方、その逆は小さいことから、湖沼パラメータ群の上位に気象や流入河川水質のパラメータを配置した（図１）。

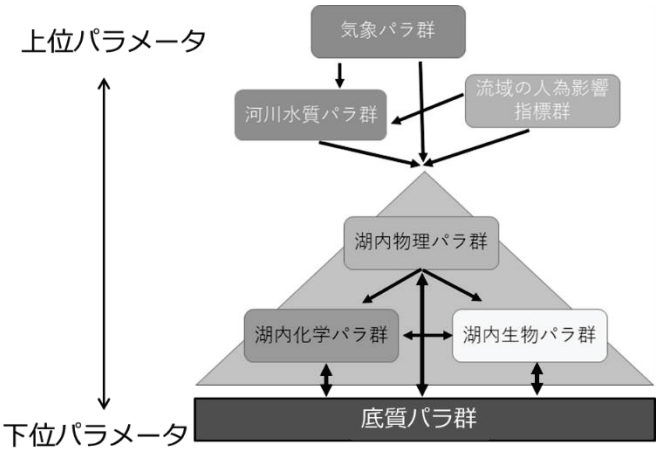

図 1 解析したパラメータ群の階層構造

レジームシフト解析はRによるパラメータ群ごとに主成分分析を行い、各主成分スコアの時系列データを用いて、Excel のマクロ機能（STARS）によりレジームシフトの有無とそのタイミングを決定した。５％の有意確率で、Cut-off Length は 10 年とし、Red noise estimation は IP4 を選択した。詳細は Möllmann and Diekmann (2011)に従った[2]。

もう一つのレジームシフト解析として、R ソフトウェア上で Chronological Clustering を読み出し、Vegan と rioja という R パッケージを読み込ませ、時系列クラスタリング解析を行った。本手法は DNA 解析等でも多用されている通常のクラスタリング解析（似た配列を近い枝になるように配置する樹形図として出力される）の一種であるが、水質が似通った 2 つの年がある場合でも、それらの年が離れている場合には、樹形図で近い枝として配置されない等の工夫がなされている。

上記 2 種類のレジームシフトの解析結果を、霞ヶ浦の西浦と北浦別々に、水質に関連する上位パラメータ群から湖内パラメータ群まで、同一の時間軸上に整理しなおし、最長で過去 44 年間におけるレジームシフトの有無とその発生タイミングとその大きさ、内容に関する結果を比較検討した。

3. 結果

霞ヶ浦の西浦での上位パラメータ群から湖内パラメータ群までのレジームシフト解析結果を図2に示す。西浦と北浦でのレジームシフト解析により明らかとなった点は

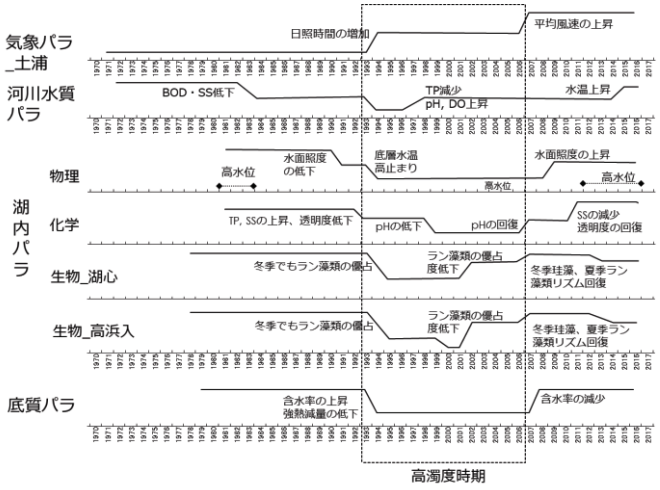

図 2 西浦での各種パラメータ群におけるレジームシフト発生状況の概略図

以下の4点である。

1）1993～1994 年を境に日照時間が増加した気象変化は、浚渫等による無機質な濁質成分の増加の時期と重なっていたが、ほぼ同時期に水質パラメータ群や生物パラメータ群においても大きなレジームシフトが起きていた（図2）。

2）西浦の湖内水質・底質と植物プランクトン相では高濁度時期（先述した無機質な濁質成分の増加時期）の開始時期、最盛期、終了時期とほぼ一致する 3 つのレジームシフトが検出された（図2）。

3）2010～2011 年を境に西浦では SS 濃度の減少や透明度の回復が見られており、夏季のアオコの発生や冬季の珪藻優占状態が観察されるようになった。

4）北浦では、1980 年代前半に流入河川水質の TP が低下した。湖内水質では 2003～2004 年を境に pH と底層 DO の上昇がみられ、2010～2011 年を境に透明度の回復が見られた。

4. 考察

得られたレジームシフトの結果をまとめた図2からも分かる通り、多くのレジームシフトは重大な環境要因の変化がその直前にある事が多く、またそうでないときには、どうしてシフトのタイミングが同期しなかったの原因を考えることができ、新たな発見や要因を見つけるきっかけにもなった。本レジームシフト解析結果で明らかとなった点は以下の3点である。

1）1993～1994 年を境に日照時間が増加した気象変化は、植物プランクトンの生産量や易分解性有機物濃度の増加を引き起こし、北浦では pH や DO の上昇につながった可能性が考えられた。一方、西浦では同時期に浚渫等による無機質な濁質成分の増加の影響が強く現れ、気象変化の影響を抽出することは難しかった。

2）西浦の高濁度時期は湖内水質・底質と植物プランクトン相に大きな影響を与えたと考えられ、その変化内容も濁質成分の増減で整合的に説明できるものであった。

3）日照時間が高止まりした 2000 年代後半には高濁度時期も脱し、西浦では SS 濃度の減少や透明度の回復が見られており、西浦では、アオコの発生をはじめ、新しい安定状態へとシフトしたと考えられた。

5. 結論

今回の霞ヶ浦のレジームシフト解析結果から、日本の湖沼の生物・水質環境の変化の有無とその変動要因を解析する上で、レジームシフト解析は有効であることが分かった。今後、気象変動影響や流域改変の影響評価をする上で有効な解析手法となりうる。しかしながら、ほぼ同時期に複数の外的要因に大きな変化が複数生じた際には、どの要因がより強く影響したかについて要因分離をおこなうことが困難な場合もあることが分かった。

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O3-22

池田湖の水質変動及び全層循環の発生要件について

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キーワード:全層循環, 水質管理, 気候変動

抄録

2018 年 2 月, 6 年ぶりに池田湖の全層循環が確認された。そこで池田湖における水質変動について, DO 及び水温の調査結果を用いて解析を行った。DO の結果から, 底層(200m)の調査が開始された 1983 年度以降, 全層循環が確認されたのは, 1984 年, 1986 年, 2011 年, 2012 年及び 2018 年の 5 回であった。全層循環が確認されたとき, 表層と底層の水温差は 0.2℃以下であり, また, 全層循環の要件として, 1 月及び 2 月の平均気温が関係し, より 1 月の平均気温の影響が大きいと考えられた。

1. はじめに

図1に示す池田湖は, 鹿児島県薩摩半島の南端に位置する湖面積 10.95km^2, 最大水深 233m の九州最大の自然湖沼であり, 約 6400 年前の火山活動に伴い形成されたカルデラ湖である。年間を通じて表層の水温が 4℃以上であることから, 熱帯湖に分類される[1]。

池田湖の水質は, 1955 年頃から周辺地域における社会活動の活発化に伴い, 淡水赤潮が発生するなど水質悪化が顕在化した。このため, 鹿児島県は, 1983 年 3 月, 池田湖の水質環境を保全することを目的に,「池田湖水質環境管理計画[2]」を策定し, 総合的な水質保全対策を推進している。

その結果, 表層における池田湖の水質は概ね良好な状態を維持し, OECD の栄養レベルに基づく調和型湖沼の分類では, 中栄養から貧栄養に分類されるようになった。



図1 池田湖位置

一方, 池田湖においては, 循環が湖底まで到達しない状態が 1987 年から 2011 年までの 25 年間, 継続したことに伴い, 無酸素状態の継続や底泥からの窒素, りんの溶出など, 底層部における水質悪化が顕在化していた[2]。

このような中, 2011 年に全層循環が確認され, その後, 2012 年, 2018 年と従来よりも短いスパンで全層循環が確認されたことから, 本研究では, 池田湖の水質変動及び全層循環の発生要件について, DO, 水温及び気象データを用いて解析を行ったので報告する。

2. 方法

調査は, 最大水深地点に設定されている基準点 2 において, 年 6 回(偶数月)実施した。

調査期間は, 底層(200m 層)の調査が開始された 1983 年 4 月から 2018 年 2 月までとした。

調査項目は, DO 及び水温を設定した。

DO は, バンドーン採水器で採水し, 試験室にて JIS K 0102 により分析を行った。

水温は, メモリー水深水温計(アレック電子株式会社(現:JFE アドバンテック株式会社)製 ABT-1)を用い, 表層から底層までの水温を現地で記録した。

気象データについては, 鹿児島県指宿の気象観測所のデータ[3]を使用した。

3. 結果

3.1 DO

図 2 に表層(0.5m層)及び底層における DO の経年変化を示す。底層の DO が表層と概ね一致したときを全層循環とした場合, 1983 年以降において全層循環が確認されたのは, 1984 年, 1986 年, 2011 年, 2012 年及び 2018 年の 5 回であった。

層別では, 表層の DO は, 概ね, 春季から夏季にか

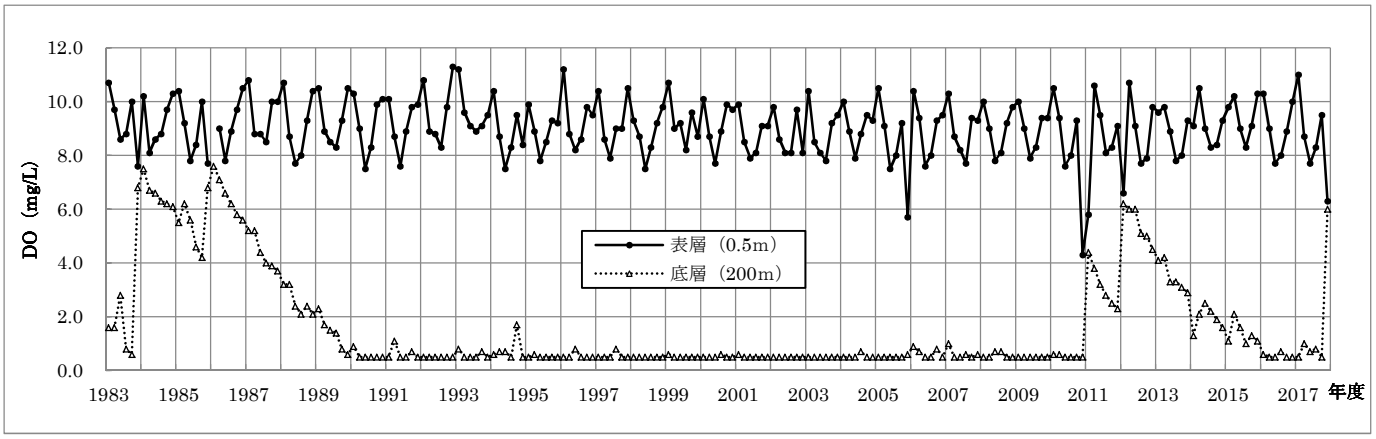

図 2 表層及び底層の DO の経年変化

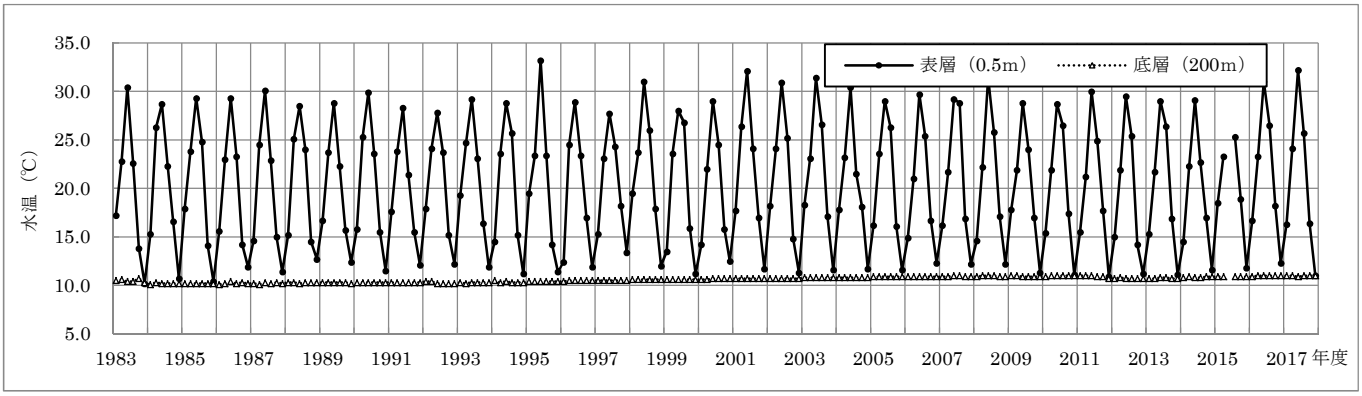

図 3 表層及び底層の水温の経年変化

けて減少し，秋季から冬季にかけて増加するといった季節変動が確認された。しかしながら，全層循環が確認された年においては，底層との混合による影響と考えられ表層 DO の低下が冬季に確認された。底層は全層循環発生時に DO が上昇し，その後低下するといった明瞭な変動が確認された。なお，1986 年及び 2012 年の全層循環をみると，全層循環後に新たな全層循環が発生しない場合，概ね 4 年程度でほぼ無酸素状態となっていた。

3.2 水温

図 3 に 2 月の表層及び底層の水温の経年変化を示す。表層の水温は，春季から夏季にかけて上昇し，秋季から冬季にかけて低下するといった季節変動を繰り返していた。

一方，底層の水温については，1984 年 4 月が 10.1℃と最も低く，その後上昇傾向を示し，2018 年 2 月は 11.0 と最も高く，その上昇率は約 0.027℃/年であった。これは，鹿児島における 1931～2016 年の気温変化率[4]（2.8℃/100 年＝0.028℃/年）と概ね一致していた。

2 月における表層及び底層の水温について図 4 に示す。全層循環が確認された年は，表層と底層の水温差が 0.2℃以下のときであった。

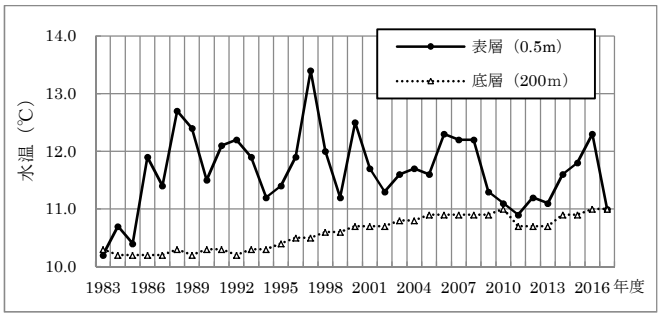

図 4 2 月における表層及び底層の水温の経年変化

4. 考察

全層循環の発生には，主に次の 2 つの物理過程が考えられる[5]。

(1) 気温の低下と冷たい季節風の吹き出しによって冷却された湖面水が，強制対流によって下方にもぐりこむ。重くなった表面の水が徐々に沈み，下方の水と混合しながら下降する。

(2) 湖岸の水が冷やされて，密度流となって湖底に流れ込む。

池田湖においては，流入河川は延長 2km 未満の小規模な河川のみであることから，河川からの冷たい水により湖岸の水が冷却されることは考えにくい。

したがって，池田湖における全層循環は，前述(1)のとおり，気温と風速が関係していると考えられる。

ここでは，気温の気象データを使用し，池田湖における全層循環の発生要件について，検討を行った。

指宿観測所における 12 月から 2 月までの気温の推移を図 5 に示す。1 月の平均気温が 7℃を下回る場合，又は 1 月の平均気温が 8℃以下でかつ 2 月の平均気温が 9.5℃を下回る場合のいずれかの要件で，全層循環が確認された。

よって，池田湖における全層循環の要件として，1 月及び 2 月の平均気温が関係しており，より 1 月の平均気温の影響が大きいと考えられた。

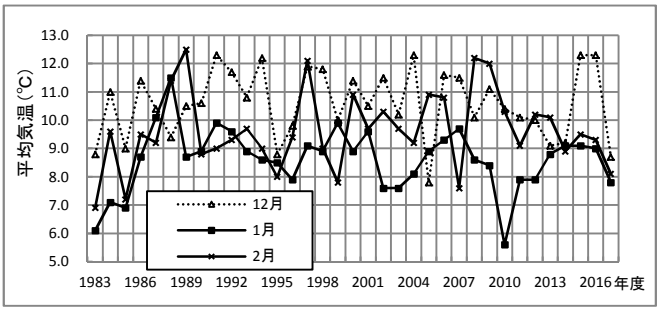

図 5 指宿観測所における平均気温の推移

5. 結論

全層循環前後における池田湖の水質変動に及び全層循環の発生要件について，DO，気温，水温の結果を用いて解析を行ったところ，以下のことが明らかになった。

(1) 1983 年以降において全層循環が確認されたのは，1984 年，1986 年，2011 年，2012 年，2018 年の 5 回であった。

(2) 底層の水温は上昇傾向を示し，上昇率は約 0.027℃/年であった。これは，鹿児島における 1931～2016 年の気温変化率(2.8℃/100 年＝0.028℃/年)と概ね一致していた。

(3) 2 月の調査結果から，表層と底層の水温差が 0.2℃以下のときに全層循環が確認された。

(4) 池田湖における全層循環の要件として，1 月及び 2 月の平均気温が関係しており，より1月の平均気温の影響が大きいと考えられた。

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O3-23

Study on similarity of COD fluctuation in Lake Kasumigaura and Lake Teganuma

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Keywords: Water pollution, Water quality management, Moving average, COD

ABSTRACT

Lake Kasumigaura, Teganuma and Inbanuma are lakes located in an area with the same meteorological conditions,total catchment areas are with a radius about 30 km^2. Lake Kasumigaura is a symbol of Tsuchiura City, the second largest lake in Japan. On the other hand, Lake Teganuma and Inbanuma are located in Chiba Prefecture and are used as a place for people's relaxation. Moreover, it is used as drinking water in Lake Inbanuma and important water resource for people. Although they are independent lakes, and external factors are influenced to fluctuations COD, but the annual values of COD are similar to over the years. Therefore, in this study, we analyzed COD fluctuation for Lake Kasumigaura and Teganuma that have 1 hour COD data. As a result, clear variations in COD fluctuations are found, indicating that the COD is fluctuating due to external factors. It is necessary to consider the fluctuation of COD value due to external factors in analyzing the water quality influenced by dredging and purification water guidance conducted in the lake.

1. INTRODUCTION

After the war , wastewater from factories and households were discharging into public water in Japan. As a result, the water quality of public water were dirty and caused people's health problem. In 1986, when a water quality standard were enacted as a water pollution prevention law, 11 lakes in Japan are chosen as water quality natural lakes. Field observation, and numerical analysis, investigation and research have been conducted for many years in order to find out comprehensive and systematic water quality conservation measures in these lakes. However, environmental standard such as the Chemical Oxygen Demand(COD) and Biochemical Oxygen Demand(BOD) of river used as an organic pollution indicator in public water are lower than that of sea and river[1]. **Figure 1** shows the location map of Lake Teganuma , Kasumigaura and Inbanuma (hereinafter referred to as 3 lakes) which are the objects of this study. The catchment area of 3 lakes is within a radius of 30 km and is located in an area with similar weather condition. **Table 1** shows parameters of 3 lakes. The average depth of Lake Kasumigaura is 4.0 m deep and about 4 times deeper than Teganuma, the catchment area is about 17 times larger than the Teganuma and Inbanuma. 3 lakes pollution has become a problem since the late 1900s, and we have been working on water quality improvement for many years. In Lake Teganuma, the COD value was high during 27 consecutive years from 1974 to 2001 and it was the worst in Japan. By the operation of the Kita-Chiba headrace tunnel, the water quality were improved about half of the 1990's. However, it still showed high COD value compared with others. **Figure 2** shows the change over the years of COD in 3 lakes. The figure is important at the beginning of this research. The change over the years of COD are similar for 20 years until the operation of Kita-Chiba headrace tunnel is started in April 2000. In general, COD fluctuation factors can be divided

Table 1 Parameters of Teganuma･Kasumigaura･Inbanuma

	Area [km^2]	Lake volume [km^3]	Average depth (Max depth) [m]	Basin area [km^2]	Basin population [people]
Kasumigaura	172.0	850 million	4.0(7.0)	2156.7	970,000
Teganuma	6.5	190 million	0.8(3.8)	143.9	510,000
Inbanuma	11.5	50 million	1.7(2.5)	493.9	780,000



Figure 1 The location map of Lake Teganuma･Kasumigaura ･Inbanuma

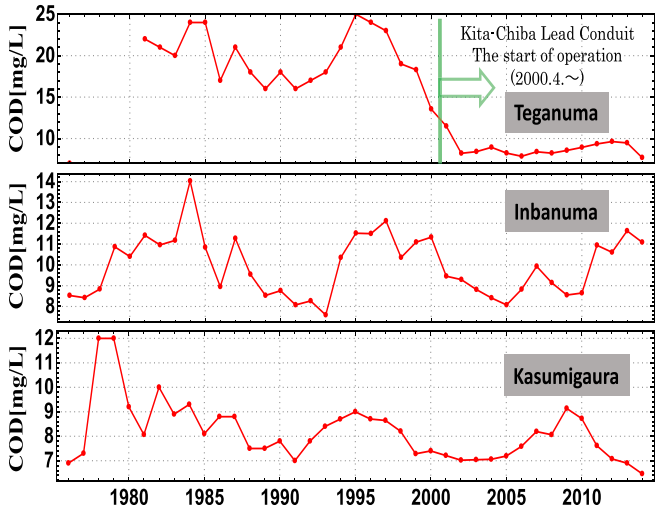

Figure 2 The change over the years of COD in 3 Lakes(Inbanuma:Jyousuidousyusuigutisita , Teganuma:Teganumachuo, Kasumigaura:mean of Kosin · Asouoki · Kakeumaoki · Tamatukurioki)

into internal factors that organic matter is generated by plankton in the lakes and external factors due to pollutant loads discharged from outside the lakes. From the above, 3 lakes are an independent lake, it is considered that external factors have influenced the COD fluctuation. So far, many studies aimed at elucidating water quality variation characteristics for each lake have been done, but in order to grasp water quality variation due to external factors for multiple lakes have not yet. In this study, we will concentrate on external factors such as weather, focusing on the relationship between rainfall and water quality variation.

2. RESULTS

2.1 COD fluctuation after rain

The water quality date of Lake Kasumigaura and Teganuma (hereinafter referred to as 2 lakes) was observed at a water quality automatic observation station (Teganuma:Teganumachuo, Kasumigaura:Kosin) managed by the Ministry of Land infrastructure and Transport. And, the rainfall of 2 lakes were observed at ground rain gauge (Teganuma:Abiko, Kasumigaura:mean of Tutiura · Tukuba · Simotuma · Kakioka · Minori) managed by the Japan Meteorological Agency. 2 lakes COD fluctuation were observed within 3 days after observing rainfall intensity 10 mm/h. At this study is defined that increase or decrease of COD is increased or decreased by 3 mg/L or more from monthly average COD value in each year. The reason for choosing 3 mg/L or more is that the daily variation of COD in the two lakes is mostly distributed from 1 mg/L to 3 mg/L. The reason for setting it to 10 mm/h or more was set with reference to the value of 10 mm/h to 20 mm/h, which is defined as a slightly strong rain in the Japan Meteorological Agency. As a result, there were 77 cases of rain events that recorded rainfall intensity of 10 mm/h or more during 1997 to 2011 in Lake Kasumigaura, 15 cases which the COD increased after rainfall, and 1 case was decreased. The other hand, in Lake Teganuma, there were 88 cases of rain events that recorded rainfall intensity of 10 mm/h or more during 2002 to 2014, 17 cases in which the COD increased after rainfall, and 5 cases was decreased.

2.2 The similarity of daily average COD

Changing of average COD value is illustrated for the purpose of checking the trend of COD fluctuation. **Figure 3** shows 15 day moving average (7 days before and after) of daily average COD in 2 Lakes. In this study moving average of 7, 15, 60, 180, 360 days is showed. In this paper, we describe the 15-day moving average that is the shortest number of days even though similarities are found in the fluctuation of moving average in 2 Lakes. The similarities of COD fluctuations in 2 Lakes are seen from 2004 to 2009 and, The peak of COD value

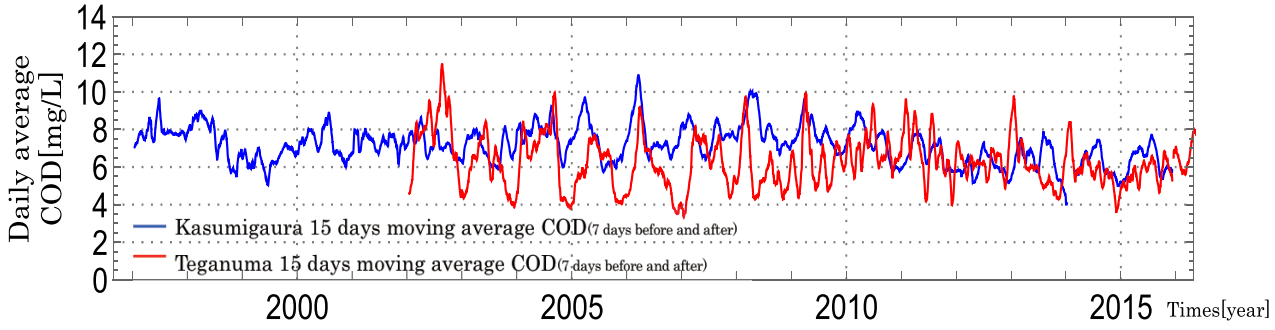

Figure 3 15 day moving average of daily average COD (7 days before and after)

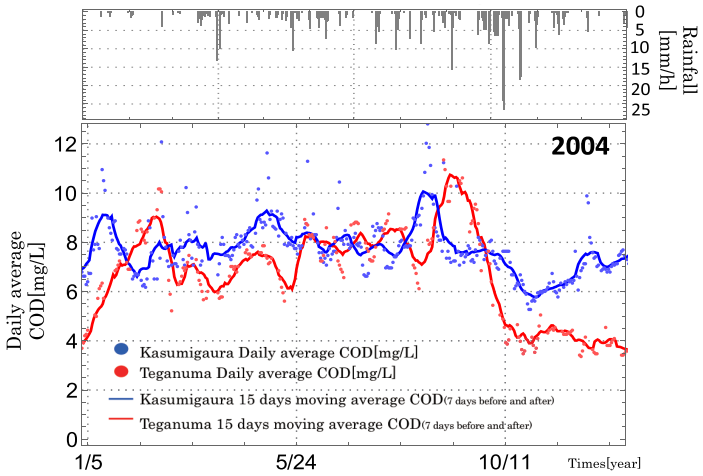

Figure 4 15 day moving average (7 days before and after) of daily average COD in 2 Lakes and rainfall (Lake Kasumigaura: Tutiura)

in Kasumigaura can be seen at an earlier time in Teganuma. **Figure 4** shows the 15 day moving average of daily average COD value when the similarity of the COD fluctuation was most characteristically observed in 2 Lakes and rainfall at Lake Kasumigaura. The peak of COD value in Teganuma can be seen about 1 month after the peak of daily average COD in Lake Kasumigaura.

3. Consideration

3.1 Regarding COD increase/decrease after rain

There are two reasons why COD increases after rain with rainfall intensity of 10 mm/h or more. The first is that the COD increases as COD of outside water is higher than the COD of inside the lake flows the lake. The second is that plankton, which is an internal factor of COD increase, increases COD by ingesting and propagating substances flowing from the outside of the lake. On the other hand, there are two possible reasons why COD decreases after rain. The first is that the COD decreases as the lake water is diluted. Secondly, the COD is reduced by the influent from the outside of the lake extruding the water staying inside the lake to the downstream. About 20 % of all cases in 2 Lakes COD increases after rain with rainfall intensity of 10 mm/h or more. On the other hand, the decreases in COD are less than 10 % of all cases. In contrast to showing that COD increases after rain with a rainfall intensity of 10 mm/h or more, as a reason for not showing a decrease in COD, the amount of water diluted or spilled out to the lake was shortage.

3.2 The similarity of COD fluctuations

The fact that the peak of the moving average of daily average COD value in 2 Lakes was observed at almost the same time can be thought to be an increase in COD due to external factors. From this it can be said that it is necessary to consider the COD fluctuation due to external factors caused by climate change in improving water quality such as dredging and vegetation purification in the lake.

4. Conclusion

(1)The COD increased by 3 mg/L or more within 3 days after rain with rainfall intensity of 10 mm/h or more in the 2 Lakes. On the other hand, it was shown that COD does not decrease more than 3 mg/L within 3 days after rainfall.

(2)The peak of the 15 day moving average of the daily average COD in 2 Lakes is seen almost at the same time and the peak of Lake Teganuma can be seen about 1month after the peak of Lake Kasumigaura.

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O3-24

琵琶湖における有機物指標の検討

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キーワード:水質保全, 有機物管理, COD_{Mn}, TOC

抄録

環境基準としての COD は, 水質汚濁の程度を示す指標とされ, 汚濁防止に一定の役割を果たしてきたが, 現代では COD の指標を見直すべきである。本研究では, 琵琶湖における定期調査より COD と TOC のデータの比較を行った。その結果, 琵琶湖水の COD 値は有機物の汚濁レベルを見る上では差し支えないが, 有機物の絶対量を量る指標としては問題があった。水質汚濁対策が進み, 流域からの有機汚濁負荷が削減された結果, 湖内の内部生産が有機物の主体となっている。これからの対策には, 外来魚の増加, 水草の大量繁茂, 在来魚類や二枚貝等の著しい減少等, 生態系の脆弱化の問題と合わせ, 上記問題の解明には生態系の物質収支の把握を進める必要がある。

1. はじめに

日本国の水質汚濁防止の枠組みは, 公共用水域の水質汚濁にかかる環境基準を設け, 行政目標として基準を満たすよう事業所等からの排水規制や下水処理等の対策が講じられてきた。環境基準としての BOD, COD は, 利水条件により階級化されており, 水質汚濁の程度を示す指標として, 汚濁防止に一定の役割を果たしてきた。BOD, COD は微生物学的視点や測定の簡便さなどの利点があり有効な指標であるが, 一方で有機物の絶対量を把握できないことや, 河川は BOD, 湖沼や海域は COD とする基準の不統一について昔から議論があった。近年は, 水域の汚濁削減対策が進み, 著しい水質汚濁が減少してきたにもかかわらず, 全国の多くの湖沼では COD 環境基準値を達成できていないことから, COD の指標を見直す動きがある。また, 公共用水域の水利用の変遷や多様化によって, 水環境の保全には水質汚濁を防止するだけでなく, 豊かな水辺や快適な生活空間の創造等まで期待されるようになった。そのため, 水の濁りや着色の程度を予測するために水中の有機物量を把握するだけでなく, 湖沼生態系の状態を示す新たな指標が期待されている。

我々のこれまでの研究では, 琵琶湖の COD の大部分が溶存有機物であり, COD の 6 割が難分解性有機物であること, 収支の推定から湖内由来の有機物が湖内全有機物の半分以上を占めることがわかってきた[1] [2]。これらの結果は, 湖水中の COD が流域からの直接の有機汚濁を反映しないだけでなく, 水中の酸素消費をしないものを測定していたことが明らかとなり, ますます COD の意味合いがあいまいとなっている。それゆえ, COD に代わる指標として,有機物の絶対量を把握できる全有機炭素(TOC)が提案されている[3]。

新たな有機物指標の是非を議論するには, COD のモニタリングデータの継続性も考慮して, COD と TOC の特性の違いを知っておく必要がある。COD_{Mn} は酸化力が不十分なことが知られているが, TOC に比較しての特性は定かとなっていない。そこで本研究では, COD が示す有機物の質を検討することを目的として, 琵琶湖およびその流域の河川や排水を用いて, COD と TOC との比較を行い, COD の検出特性を検討した。

2. 方法

滋賀県では, 1998 年から琵琶湖水質調査において, COD のモニタリングに加え, TOC の測定を開始した。加えて, 試水をガラス繊維ろ紙 Whatman GF/B(孔径 1 μm)でろ過して, 粒子態と溶存態に分画して P-COD, POC, D-COD, DOC 測定も開始している。そこで, 2014 年までの滋賀県が定点観測を行っている地点での湖水のモニタリングデータ[4]を用いて解析を行った。時系列解析は, 統計解析ソフト SPSS Trend によった。

TOC の測定は, ろ液を TOC 計にて, ろ紙で捕捉した POC を元素分析計により計測し, その和を TOC としている。COD, D-COD(ろ液の COD)は公定法にて測定し, P-COD は COD から D-COD を引いた差分である。

また，2007～2010 年度にかけて，琵琶湖，琵琶湖流域の主要な8つの河川水，流域内に存在する事業所排水，下水処理施設，水田および畑，宅地道路，山林他の面源等から各種排水より採取し，有機物の検討を行った[1] [2]。

3. 結果と考察

滋賀県定期調査での，湖水中の COD と TOC の時系列変動解析の結果を示した（図 1）。COD と TOC のトレンドや季節変動は類似していた。しかし，湖水中の粒子態と溶存態別に TOC と COD の関係をみると，湖水の粒子態では TOC に対する COD の回帰直線の傾きが溶存態のそれより低かった（図 2）。粒子の酸化が不十分なため，P-COD の酸化率が低下することが考えられる。北湖，南湖の定点の平均値の COD/TOC は，湖水中の POC/TOC の比と相関があり，COD 値の分布には粒子態の有機物が影響している。

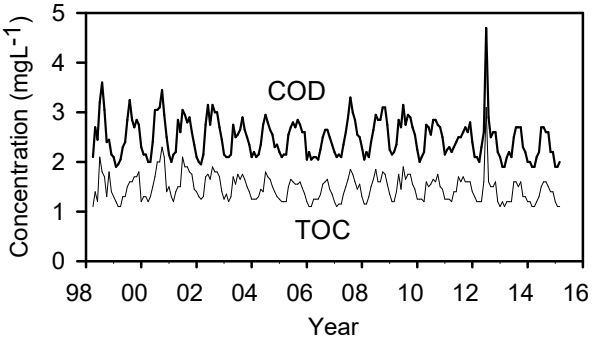

図 1 琵琶湖北湖17B点における COD, TOC の定期調査結果

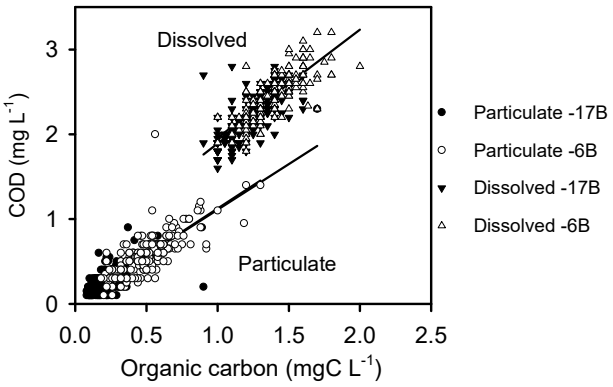

図 2 琵琶湖北湖(17B)，南湖(6B)における粒子態と溶存態別の TOC と COD の関係

また，河川や排水など様々な水環境調査の結果からも，COD/TOC の違いが確認された。河川水，特に渓流水で比が高くなる傾向がみられた。渓流水は比較的 COD で検出されやすい有機物を多く含むと考えられ，この特性は流域からの有機物負荷の算定に影響を及ぼす。滋賀県の第 5 期の湖沼計画での COD 負荷量推定から，本研究の COD/TOC を用いて TOC 負荷量を算出すると，流域からの有機物総負荷量に対する山林からの負荷量の割合が TOC で計算した場合に比べて 11%高い結果が得られた。したがって，COD で推定された有機物の負荷量計算は，実際の（TOC の）有機物負荷量より山林からの負荷を過大評価している。

COD/TOC が試料により違いが表れる原因には，粒子の他にも，有機物が低濃度での COD 測定時の過分解が考えられる。図2のグラフの DOC と D-COD の一次回帰式は D-COD = 1.36 DOC + 0.54 となり，X軸に切片がある。琵琶湖水中のアンモニア濃度は極めて低く，この切片を満たすほどの還元性物質は水中に存在しない。この切片は，低い有機物濃度では相対的に酸化剤の量比が増えてしまうため，過剰に酸分解が起こるCOD 値の過大評価であると考えられた。市販の試薬（糖，アミノ酸）の COD 測定をすると，2 mgL^{-1} 以下では，理論的な酸化率が上昇する傾向が見られる（図3）。

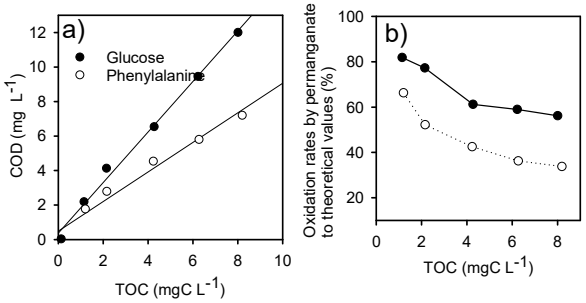

図 3 低濃度における COD の過剰酸化の影響

以上により，琵琶湖流域では，湖水や河川水の COD は有機物全体の半分程度を検出して，有機物濃度の分布を捉えているものの，1）有機物の性状や種類による検出感度の変化，2）低濃度での過大評価などの問題がある。それゆえ，琵琶湖水の COD 値は，有機物の汚濁レベルを見る上では差支えのない指標であるが，有機物の絶対量を推し量る指標としては問題がある。

4. 新たな有機物管理指標について

琵琶湖では，水質汚濁対策が進み，流域からの有機汚濁負荷は削減されてきた（図4）が，湖水中の有機物量には減少が見られない（図1）。湖内の内部生産によ

って有機物量が維持されているものと考えられる。

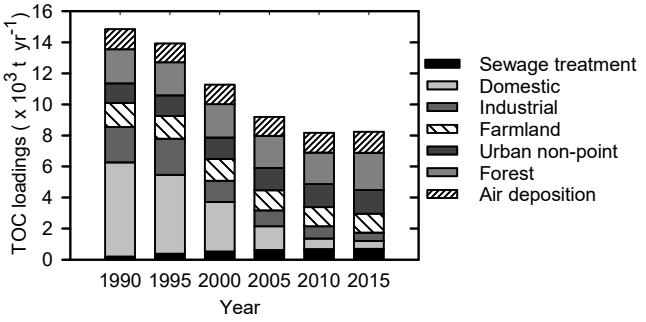

図 4 流域からの TOC 発生負荷量推定[5]

また，水質改善にもかかわらず，異臭味の発生による利水障害，外来魚の増加，水草の大量繁茂，在来魚類や二枚貝等の著しい減少等の問題が起きている。

このような生態系構造の不安定化に対して，生物の生息環境や産卵環境の保全はもとより，生態系を構成している生物群集相互やそれをとりまく環境との間での相互作用の円滑化が求められる。これらの相互作用を把握する鍵は生態系の物質収支の把握であり，生態系を構成している生物群集組成とその生産力の評価のための TOC 指標の導入による生態系の包括的な保全には欠かせない。

さらに水質監視では，河川は BOD，湖沼は COD と水域に応じた評価がなされているが，河川から湖沼までの生態系とそのつながりを含めた水環境を保全するためには，水域によらず統一的な指標で精度よく有機物動態を測る必要がある。それには TOC 指標による生産性の評価と合わせた有機炭素量のストックとフローの評価がふさわしいといえる。

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O3-25

伊豆沼沿岸部における底質有機物堆積機構の解析

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キーワード:底質有機汚濁, 流速, 連続観測, 浅い湖沼

抄録

湖沼の水質は, 河川や海域と比較して低い水準にある. この要因の一つには, 底質に蓄積した有機物などの汚濁物質による内部負荷が挙げられる. そこで本研究では, 湖沼における底質汚濁のメカニズムを踏まえた合理的な底質改善技術を提案するために, 底質の有機汚濁化に着目し, 底質有機物の堆積機構を明らかにすることを目的とした. 加えて, 流動が沈降や再懸濁と行った減少を通じて底質における有機物量を支配しているとの仮定のもとで, 底質有機物量変動のシミュレーションモデルを構築し, 流動制御が底質改善に寄与する可能性を検討した. その結果, 底質有機物量は流動によって支配されており, 底質からの再懸濁量が沈降量を上回ることで底質有機物量が減少することが示された. また, シミュレーションによって, 実際の底質有機物量の変動を再現でき, 底質有機汚濁が進んだ底質において流動を強化することによって, 底質改善の効果が見込めることが示された.

1. はじめに

湖沼の水質改善を推進するためには, 流域から河川を通じて流入してくる外部負荷対策と併せて, 湖内での内部生産や底泥に蓄積した汚濁物質による内部負荷対策を行うことが重要である. 一般的な内部負荷(底泥)対策としては, 浚渫や覆砂が挙げられるが, こうした対策はその後の汚濁物質の再堆積・再溶出によって持続的な効果を得ることはできず, 底質環境に対する根本的な改善策にはならない. また, シードバンクの喪失等が懸念され, 底生生態系への配慮に欠けることから, 新たな底質改善技術が求められている. しかし, 新たな底質改善技術の確立にあたっては, 湖沼における底質汚濁のメカニズムを踏まえた合理的な方法を考案することが緊要である. そこで本研究では, 内部負荷の大きな要因となっている底質の有機汚濁化に着目し, 底質有機物の堆積機構を明らかにすることを目的とした. さらに, 流動の強さと底質有機物量には負の相関があり, 底質に蓄積している有機物は高等植物由来の難分解性有機物であるという既往の知見[1]から, 流動が沈降・再懸濁といった現象を通じて底質における有機物量を支配しているという研究仮説のもと, 流動制御が底質改善に寄与する可能性について検討した.

2. 研究手法

2.1 現地観測

流動と底質有機物に関するデータを現地観測により収集・解析することで, 底質有機物堆積機構を明らかにすることを目指した. 水環境の改善が進んでいない浅い湖沼として, 宮城県北部に位置する伊豆沼を観測対象とした. 伊豆沼は面積 3.69 km^2, 最大水深 1.6 m, 平均水深 0.76 m の浅い湖沼である. **図 1** に示す沿岸部の 4 地点で観測を行い, 各地点で底質有機物量の指標として有機炭素(OC)含有率の測定, セディメントトラップによる沈降物質の捕集, 流速や濁度等の連続観測(10 分毎に 1 秒間隔で 30 秒)を 2016 年 12 月から約 1 年間実施した.

2.2 底質有機物堆積機構の解析

下記の解析手法で流動が沈降・再懸濁を通じて底質における有機物量を支配するという研究仮説の検証を行った.

2.2.1 沈降・再懸濁と流動の関係

浅い湖沼においては, 鉛直方向の SS 濃度は均一であると想定できるため, 水中の SS 濃度の時間変化量は, 式(1)で表せる[2].

$$h\frac{dC}{dt} = E - S \qquad (1)$$

ここに, h:水深(m), C:SS 濃度(g/m^3), t:時間(10 分間), E:再懸濁フラックス(g/m^2/t), S:沈降フラックス(g/m^2/t)である. SS 濃度に関しては, 観測した濁度から検量線を作成して換算した.

式(1)において, 左辺が正のときは再懸濁量が沈降量より大きいことを意味し, 左辺が負のときは沈降量が再懸濁量より



図1 伊豆沼の全体図と観測地点

も大きいことを意味している. ここで, 再懸濁量が沈降量を有意に上回る際の流速を明らかにするため, 流速とSS濃度の相関が強かった期間に関して以下の解析を行った.

① 10 分毎の SS 濃度の平均値から, dC/dt を算出
② 10 分毎に 1 秒間隔で 30 秒間連続観測された流速データのうち最大のものを瞬間最大流速 u_{max} として抽出
③ 1 cm/s 毎に流速の閾値 u_c を設定
④ $u_{max} > u_c$ となる時の dC/dt について一群の t 検定
⑤ 95%信頼区間の下限値が正となる最小の u_c を算出
この時の u_c を, 再懸濁量 > 沈降量となる流速とした.

2.2.2 底質有機物量と流動の関係

底質有機物量と流動の関係を解析するため, 本研究では既往の研究[1]と同様に, 流動の指標として流速超過確率を用いた.

$$\mathrm{F}(V \geq V_c) = \frac{V_c\text{を超える流速の発生頻度}}{\text{流速データ数}} \quad (2)$$

ここに, F : 流速超過確率, V_c : 閾値とする任意の流速(cm/s)である. なお, 流速データは流速超過確率を算出する期間中に, 10 分間隔で 30 秒間連続観測した全てのデータ(1 個/s)を用いた.

2.3 底質有機物量変動のシミュレーション

底質有機物堆積機構のシミュレーションモデルを構築し, 実際の湖沼における底質有機物含有率の変動を底質における物質収支で表現することを試みた. なお, 本モデルは底質を有機物と無機物に分けて行い, 簡易的に底質有機物含有率と底質 OC 含有率は等しいものとした.

2.3.1 底質有機物含有率

底質厚 0.1 m における有機物, 無機物量の経時変化を求めるため, SS 濃度および流速の観測間隔である 10 分間隔で, 以下の計算を行った.

$$Sed(O)_n = Sed(O)_{n-1} + S_O - \hat{E}_O \quad (3)$$

$$Sed(I)_n = Sed(I)_{n-1} + S_I - \hat{E}_I \quad (4)$$

ここに, $Sed(O)_0$: 底質有機物量(g/m^2), $Sed(I)_0$: 底質無機物量(g/m^2), $S_O(S_I)$: 有機物(無機物)沈降フラックス(g/m^2/t), $\hat{E}_O$ ($\hat{E}_I$) : 有機物(無機物)再懸濁フラックス(g/m^2/t)である. なお, n : 10 分間隔の計算ステップ(n=1,2,3...)である. 求めた底質有機物, 無機物量から底質有機物含有率を算出した.

2.3.2 沈降フラックス

式(3)および式(4)における沈降フラックスの算出方法は以下のとおりである.

$$S_O = w_O(C_O - C_{O(min)}) \quad (5)$$

$$S_I = w_I(C_I - C_{I(min)}) \quad (6)$$

ここに, $w_O(w_I)$: 有機物(無機物)沈降速度(m/s), $C_O(C_I)$: 有機(無機)懸濁物質量(g/m^3), $C_{O(min)}(C_{I(min)})$: 計算期間中の有機(無機)懸濁物質量の最小値(g/m^3)である. また, 沈降速度の算出方法は以下のとおりである.

$$w_O = \frac{q_O}{C'_{O(ave)}} \quad (7)$$

$$w_I = \frac{q_I}{C'_{I(ave)}} \quad (8)$$

ここに, $q_O(q_I)$: セディメントトラップで捕集した有機物(無機物)沈降量の平均値(g/m^2/t), $C'_{O(ave)}(C'_{I(ave)})$: セディメントトラップ設置期間中の有機(無機)懸濁物質量の平均値(g/m^3)である. なお, $C_O(C'_O)$は SS 濃度に懸濁物の OC 含有率を乗じて求めた. $C_I(C'_I)$については, SS 濃度と $C_O(C'_O)$との差から求めた.

2.3.3 再懸濁フラックス

式(3)および式(4)における再懸濁フラックスの算出方法については, 以下の式を用いて, 水中懸濁物質の物質収支から再懸濁フラックスを算出した.

$$E_O = S_O + h\frac{dC_O}{dt} \quad (9)$$

$$E_I = S_I + h\frac{dC_I}{dt} \quad (10)$$

次に, 再懸濁フラックスを流速の関数として表現するため, $E_O(E_I)$と流速について回帰分析を行った.

$$\hat{E}_O = \alpha_O v \quad (11)$$

$$\hat{E}_I = \alpha_I v \quad (12)$$

ここに, $\alpha_O(\alpha_I)$: 各地点における再懸濁係数, v : 瞬間最大流速(cm/s)である.

3. 結果

3.1 現地観測

平均底質 OC 含有率は, Stn.A : 7.0 %, Stn.B : 2.5 %, Stn.C : 0.5 %, Stn.D : 3.3 %であった. また, 年間の推移については観測期間全体を通じて目立った季節的な傾向は見られなかった. **図 2** に代表的な地点における底質, 沈降物質, 水中懸濁物質の OC 含有率の時系列データを示す. 各地点ともに水中懸濁物質 > 沈降物質 > 底質の順に有機物量が多かった.

3.2 底質有機物と流動の関係解析

図 3 に各地点の流速超過確率と底質 OC 含有率の関係を示す. 任意の閾値を 1 cm/s 刻みで 1〜10 cm/s まで変化

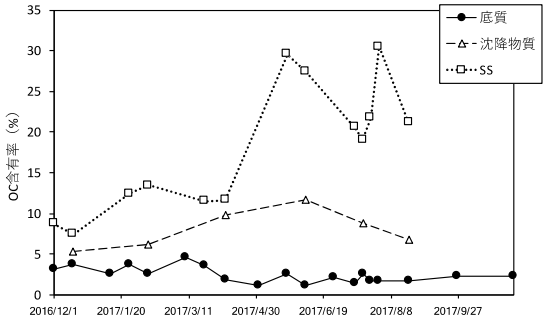

図2 Stn.Bにおける底質, 沈降物質, SSのOC含有率

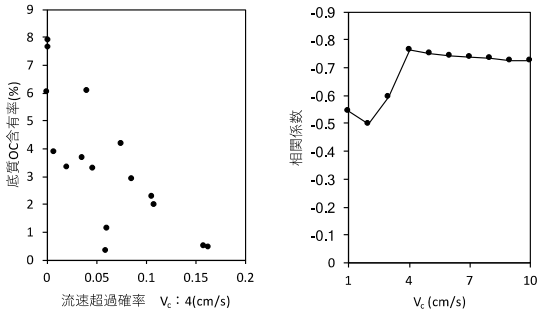

図3　底質OC含有率と流速超過確率の関係

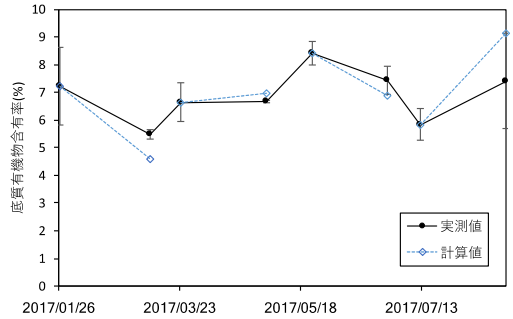

図4　Stn.Aにおける実測値と計算値の比較

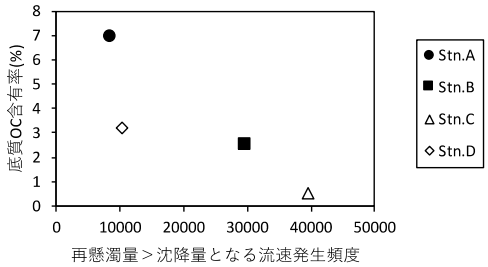

図5　再懸濁量＞沈降量となる頻度と底質OC含有率の関係

させたところ，4 cm/s 以上の流速発生頻度と底質 OC 含有率の間に最も強い負の相関を得た($r=-0.76$, $p<0.01$)．また，各地点で底質の再懸濁量が底質への懸濁物質の沈降量を上回る流速の条件を解析した結果，4～6 cm/s を超える流速が観測された時，有意に再懸濁量が沈降量を上回っていることがわかった($p<0.05$)．

3.3 底質有機物量のシミュレーション

図 4 に Stn.A における底質有機物含有率の計算結果と実測値の比較を示す．再懸濁量を流動に比例する関数として与えることで，底質有機物含有率の増減を再現することができた．

4. 考察

沈降・再懸濁と流動の関係を解析した結果，各地点で，4～6 cm/s 以上の流速が発生した際に再懸濁量が沈降量を上回っており，4 cm/s を超える流速発生頻度が多くなれば底質有機物量が減少することが分かった．さらに，底質 OC 含有率と流速超過確率の間で，負の相関のピークが現れた閾値が 4 cm/s であり，それ以上の閾値においても同程度に強い負の相関を得たことから，再懸濁量が沈降量を上回るとき，底質の有機物量が減少すると考えられる．したがって，研究仮説のように流動が沈降・再懸濁を通じて底質における有機物量を支配していることが示唆された．

再懸濁が卓越するときに底質有機物量が減少する理由は，SS，沈降物質，底質の OC 含有率の大小関係(**図 2**)から説明できる．セディメントトラップで捕集した沈降物質は，主に底質が巻き上がり，再沈降したものであると考えられる．その理由として，セディメントトラップの開口部は 20 mm であり，それより大きな物体は捕集されないこと，伊豆沼の水深は浅いため，沈降の過程で植物の枯死体等が細かくなる可能性は低いこと等が挙げられる．これを踏まえた上で SS，沈降物質，底質の OC 含有率の大小関係を比較すると，概ね SS ＞ 沈降物質 ＞ 底質という関係にあったことより，底質の再懸濁時には有機物が選択的に再懸濁していると考えられ，その一部は再懸濁したまま水中に残存すると予想される．したがって，再懸濁量が沈降量を上回る頻度が低い地点(Stn.A)では，底質有機物含有率が，湖内で生産された高等植物の枯死体等の有機物含有率に近づき，再懸濁量が沈降量を上回る頻度が高い地点(Stn.C)では，底質からの有機物の選択的な離脱が起こるために，有機物含有率が低くなるものと考えられる．**図 5** に，各地点における再懸濁量＞沈降量となる流速の発生頻度と平均底質 OC 含有率を示す．

底質有機物量のシミュレーションでは，Stn.A で底質における有機物・無機物の収支を計算することで有機物含有率の変動を再現することができた．また，再懸濁フラックスは流動に比例する関数として与えることで良好な再現性を得ており，再懸濁の卓越が底質有機物量を低下させることから，Stn.A のような底質有機物含有率の高い場では，流動の強化によって底質改善の効果が見込めることが示された．

5. まとめ

浅い湖沼においては，流動が沈降，再懸濁を通じて底質における有機物量を支配していることが示唆された．底質の再懸濁時に，有機物は底質から選択的に離脱するため，再懸濁量が沈降量を上回る頻度が高まるほど底質有機物量は少なくなる．また，底質有機物量の変動は底質における有機物，無機物の物質収支を計算することで再現できた．再懸濁量を流速に比例する関数として与え，良好な再現性を得たことから，流動の強化が底質有機汚濁の改善に有効であることが示された．

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O3-26

Nutrients and molar C:N:P ratios in surface sediments of the Songkhla Lagoon system in southern Thailand

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Key words: sediment nutrients, coastal lagoon, Songkhla Lagoon system, Thale Sap, Songkhla Lake

ABSTRACT

Information pertaining to temporal and spatial variations in nutrients concentrations in the surface sediments of the Songkhla Lagoon system is limited. Therefore this study aimed to examine the proportion of silt and clay and total carbon, nitrogen and phosphorous concentrations in the surface sediments from the windward and leeward sites of Thale Sap and Thale Sap Songkhla in the Songkhla Lagoon system between August 2017 and March 2018. Samples taken from leeward shores exhibited significantly higher proportion of silt and clay. The sediments of Thale Sap were characterized by higher concentrations of carbon and nitrogen, owing to the colonization of aquatic macrophytes within this lake. The phosphorous concentrations were relatively high in the sediments of Thale Sap Songkhla, owing to the proximity of this lake to discharge sources such as urbanization, industries, and human settlements. The sediments of Thale Sap had a relatively higher molar C:N:P ratios (437:43:1) than that of the sediments of Thale Sap Songkhla (233:23:1).

1. INTRODUCTION

Coastal Lagoons are transitional zones located between fresh- and salt-water nvironments and, have high ecological and socio-economic values. The Songkhla Lagoon system in southern Thailand is a shallow and well-oxidized tropical coastal lagoon that supports fisheries for shrimp, crab, and various fish species, including intensive aquaculture of barramundi (*Lates calcarifer*)[(1)]. As other coastal lagoons, the Songkhla Lagoon system is also subject to strong anthropogenic pressure associated with urbanization, industrialization, artisanal fishing, and recreation[(2)]. In 2005, a study reported evidence of eutrophication in the Thale Luang and Thale Sap lakes of the lagoon system[(3)]; however, this study was limited to estimating chlorophyll *a* concentrations, with no information regarding excess nutrient concentrations.

Due to the shallowness of the Songkhla Lagoon, wind direction and velocity can force the sediments to be resuspended, redistributed, and redeposited within the system. During these processes, the coupling nutrients in the overlying waters along with microbial-mediated nutrients, the associated pore water, organic detritus, and inorganic particles associated with geochemical processes are also released within the system[(2)]. Studies investigating nutrient concentrations within the lagoon system are critical to discerning changes in the biological behavior of the lagoon; however, such information concerning the distribution and retention of sediment nutrients in the Songkhla Lagoon is currently lacking.

The objectives of this study are to 1) characterize the temporal and spatial patterns in the nutrient (C, N, and P) concentration and 2) analyze the relationships among C, N, and P concentrations in the surface sediments of the Songkhla Lagoon system. To my knowledge, this study is the first to report the temporal and spatial patterns in the nutrient concentration in the sediments of the Songkhla Lagoon system. The results of this study will aid in the broader understanding of the fate of nutrients within this lagoon system.

2. MATERIALS AND METHODS

Study sites

The Songkhla Lagoon system, also known as Lake Songkhla (ASI-02)[(1)], is a large shallow water body located on the east coast of Thai's Peninsula in southern Thailand situated between 7° 08′N and 7° 48′N and between 100° 07′E and 100° 35′E. The lagoon system covers approximately 1,082 km^2, comprises four distinct parts: Thale Noi, Thale Luang, Thale Sap, and Thale Sap Songkhla, and exhibits three water regimes: fresh, brackish, and salt water arranged from north to south, respectively, with the southern end connected to the Gulf of Thailand. Within the lagoon system, salinity ranges from 0 to 34 psu in Thale Sap Songkhla to almost zero in Thale Noi. The shores of the Songkhla Lagoon system comprise a mixture of urban areas, fishing villages, shrimp ponds, seasonally flooded forests, paddy fields, and mangrove forests. The submerged vegetation in Thale Sap is dominated by *Najas marina*, *Najas minor*, *Hydrilla verticellata*, and *Potamogeton malayanus*. Conversely, the growth of submerged macrophytes is limited. In both Thale Sap and Thale Sap Songkhla, the substratum is primarily mud.

Sampling methods

Bed sediments were collected at monthly intervals between August 2017 and March 2018 from eight stations located along the shores of the lakes Thale Sap and Thale Sap Songkhla. In each part of the lake, there were two stations classified as windward and the others were leeward with two replicates at each site. Bed sediments representing recent deposits were collected using a plastic spade by scooping from the upper 5 ± 5 cm of the surface sediments at a water depth of approximately 50–150 cm. The sediments were then packed and sealed in plastic containers and transferred to the laboratory of Faculty of Science, Prince of Songkla University, where they were air-dried in an oven at 60°C.

Data collection

Sediment samples were passed through a 0.0625-mm standard mesh sieve to separate the silt and clay fractions from the sand fractions. The total carbon (Tot-C) and total nitrogen (Tot-N) concentrations in the sediment samples from each replication were determined by combustion of the dried and processed surface sediments in a CHN analyzer. The total phosphorus (Tot-P) concentration was determined using ICP-AES.

Data analysis

Nutrient concentrations in the sediment samples were compared using a three-way analysis of variance. The sampling month, lake, and shore were considered as independent variables and the proportion of silt and clay and the concentrations of C, N, and P as dependent variables.

3. RESULTS

The sediments from both Thale Sap and Thale Sap Songkhla are dominated by silt and clay. The sediment samples from both lakes predominantly comprised grains <63 μ (51.77 %–91.87% by weight). There was no significant difference in the proportion of silt and clay within the sediments in both lakes. At closer distribution patterns, there was a significant difference in the proportion of silt and clay among sampling months and between both shores (Table 1). The proportion of silt and clay was higher in sediment samples from leeward shores than in those from windward shores (Fig. 1A). The sediment samples from Thale Sap and Thale Sap Songkhla had significantly different carbon (Tot-C) and nitrogen (Tot-N) concentrations (Table 1). The concentrations of C and N in the sediments of Thale Sap were significantly higher than that in the sediments of Thale Sap Songkhla (Figs. 1B and 1C). Similar patterns were noted across sampling months, where Tot-N concentrations were consistently higher in the sediments of Thale Sap than in the sediments of Thale Sap Songkhla (Fig. 1D). During the rainy season (September–January), the sediments of Thale Sap Songkhla had significantly higher phosphorous concentrations than that in the sediments of Thale Sap, while no different for the rest (Table 1 and Fig. 1E). The highest molar C:N:P, C:P, and N:P ratios were found in the sediments of Thale Sap (Table 1). However, there were no significant differences in the C:N:P and C:N ratios between the two lakes.

4. DISCUSSION

A high proportion of silt and clay measured in sediments from the leeward shores of both Thale Sap and Thale Sap Songkhla suggests that the wind-driven waves that dominate the windward shore keep the silt and clay resuspended, rendering the water turbid during periods of high wind [2,4]. These alterations in the present study were governed by the seasonal northeast monsoon wind, a primary force that influences several coastal lagoons. Particle size of the sediments may therefore particularly small on the leeward and increase toward the windward shore.

The relatively high nutrient concentrations, particularly those of carbon and nitrogen, measured in the sediments of Thale Sap suggest that the aquatic macrophytes that inhabit Thale Sap strongly contribute to the nutrient enrichment of the lake sediment. In general, macrophyte detritus alters sediment stoichiometry by accumulating more C relative to N and P, making the sediments of Thale Sap more suitable for decomposers when compared with the sediments of Thale Sap Songkhla. The importance of macrophytes is not restricted to the sediment. They also influence the composition of suspended POM and thus, represent an important coupling between benthic and pelagic habitats within this lagoon. High C:P ratios measured in the sediments of Thale Sap and some stations within Thale Sap Songkhla may also reflect the influence of the macrophytes that are abundantly present in this region. It is interesting to note that there were relatively low nutrient concentrations measured in the sediments of Thale Sap Songkhla, however, the annual catches for penaeid prawns were obviously high suggest that nutrients that originate from autochthonous in Thale Sap may then be transferred to Thale Sap Songkhla. The relatively high phosphorus concentration in the sediments of Thale Sap Songkhla may be associated with urbanization, industrial activities, and the high population densities of the Songkhla and Hat Yai cities.

Table 1 Percentage of Silt & Clay, Nutrient concentrations (Mean ± SE) Total Carbon, Total Nitrogen and Total Phosphorus (μmol g^{-1}), molar C:N:P, C:N, C:P and N:P ratios for sediment nutrients in Thale Sap(TS) and Thale Sap Songkhla (TSS) of the Songkhla Lagoon system

Locality	Silt&Clay Fraction	Total Carbon (μmol g^{-1})	Total Nitrogen (μmol g^{-1})	TotalPhosphorus (μmol g^{-1})	C:N:P	C:N	C:P	N:P
TS	68.12±1.16	1599.1±100.31	157.12±17.48	3.66±0.56	437:43: 1	10	437	42.9
st 1	67.70±2.61	1191.4±51.82	131.73±6.23	1.23±0.75	967:107:1	9	967	107.1
st 2	68.89±2.58	1369.6±114.67	141.52±8.55	2.99±0.82	458:47:1	10	458	47.3
st 3	64.12±1.56	1795.4±295.35	136.46±10.22	4.08±1.05	440:33:1	13	440	33.4
st 4	72.32±1.88	2039.9±180.18	148.87±10.65	6.18±1.36	330:24:1	14	330	24
TSS	70.11±1.14	1112.1±58.02	105.46±4.54	4.77±0.76	233:22:1	11	233	22.1
st 1	76.50±1.94	1449.0±122.69	104.64±4.35	2.50±0.70	580:42:1	14	580	41.9
st 2	69.43±1.23	797.0±61.68	93.77±7.08	6.30±1.56	126:15:1	8	126	14.9
st 3	61.32±1.13	1403.6±69.70	138.76±9.52	7.01±2.07	200:20:1	10	200	19.8
st 4	73.14±1.39	776.4±27.34	83.83±7.29	3.39±1.20	229:25:1	9	229	24.7

5. CONCLUSION

In this study, sediment nutrient concentrations (Tot-C and Tot-N) were higher in Thale Sap than in Thale Sap Songkhla. Thus, within the Songkhla Lagoon system, Thale Sap is an important organic source and sink, contributing to the nutrient concentration of Thale Sap Songkhla. It is interesting to note that the C and N concentrations measured in the present study in surface sediments of both Thale Sap and Thale Sap Songkhla are higher than the concentrations reported from the Songkhla Lagoon system's terrestrial catchments[5]. This suggests that the excess nutrients driving eutrophication in the Songkhla Lagoon system are generated by sediment resuspension processes coupled with the biological activities of microorganisms and hydro-biogeochemical features within the system.

Further studies

1) Investigation of the role of dominant aquatic macrophytes as a source of organic matter to nutrient cycles in the Songkhla Lagoon system.
2) Examination of bacterial metabolism and growth efficiency associated with nutrient availability in the lagoon system.
3) Assessment of nutrient concentrations, biomass, and detritus from aquatic macrophytes within the lagoon system in relation to salinity and rainfall.

Acknowledgment

The present study is a part of a research on Distribution patterns and variability in abundance of postlarvae and juveniles of *Metapenaeus* spp. for fishery status and management guidelines in Thale Sap Songkhla, southern Thailand, supported by a grant SCI600364S from Prince of Songkla University.

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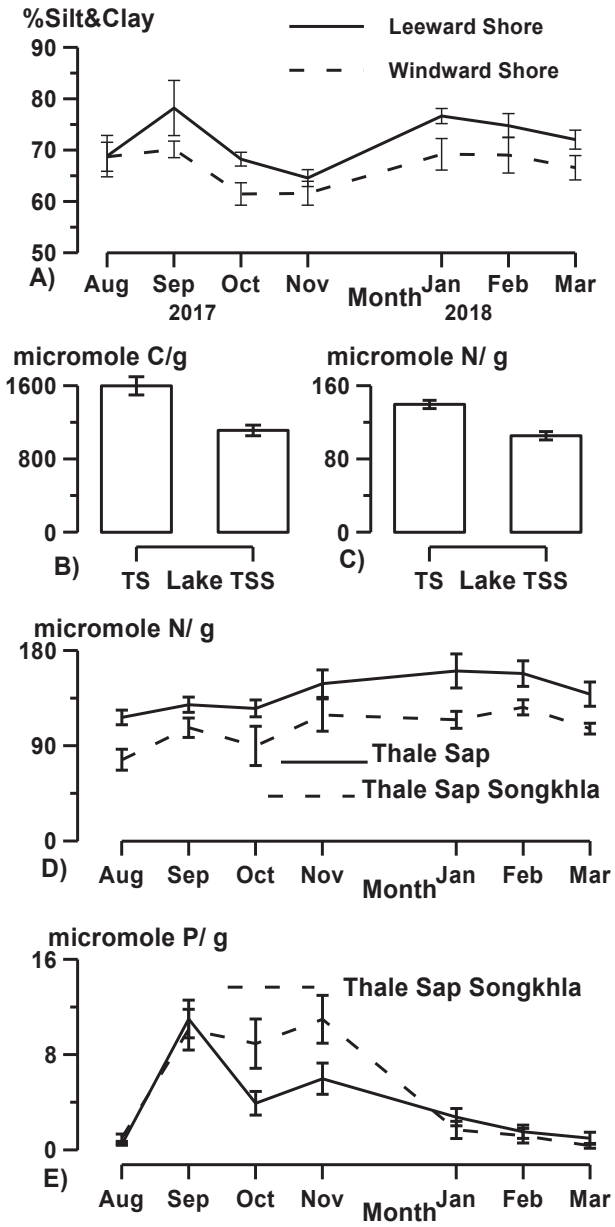

Figure 1. Temporal and spatial variations in nutrient sediments of Songkhla Lagoon system, southern Thailand.

- **A) Proportion of silt and clay between windward and leeward shores, between Aug 2017 and Mar 2018**
- **B) Tot-C Concentration in nutrient sediments between Thale Sap(TS) and Thale Sap Songkhla(TSS)**
- **C) Tot-N Concentration in nutrient sediments between Thale Sap(TS) and Thale Sap Songkhla(TSS)**
- **D) Tot-N Concentration in nutrient sediments from Thale Sap(TS) and Thale Sap Songkhla(TSS) between Aug 2017 and Mar 2018**
- **E) Tot-P Concentration in nutrient sediments from Thale Sap(TS) and Thale Sap Songkhla(TSS) between Aug 2017 and Mar 2018**

O3-27

Phytoplankton Communities and Water Quality Characteristics in Lake Paldang, South Korea

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Keywords: Lake Paldang, phytoplankton, environmental index, trophic state, principal component analysis

ABSTRACT

The present study carried out the temporal characteristics and variation of phytoplankton diversity, composition and their abundance with water quality using statistical techniques in Lake Paldang, South Korea. A total of 91 species of phytoplankton were identified from the Lake Paldang in 2016, belonging to 6 functional groups i.e., Chlorophyta(35 species), Bacillariophyta(34), Cyanophyta(11), Ochrophyta(5), Cryptophyta(4), and Miozoa(2). Throughout the study period, the occurrence of most dominant species was observed from Bacillariophyta(*Stephanodiscus hantzschii* and *Cyclotella atomus*). The performed statistical analysis on phytoplankton species, the evenness and Shannon-wiener diversity index were found to be higher in winter than those of spring. PCA applied to compare the compositional patterns among the analyzed water samples, identified and four factors accounting for almost 84.4% of the total variation representing water compound concentration are mainly related to point and non-point source as well as natural process. We therefore suggest wise management of anthropogenic activities in the catchment of Lake Paldang and their tributaries.

1. INTRODUCTION

The lakes and rivers represent the major source of water used for human consumption culture irrigation, industrial purposes and drinking water. Water resources require information about water quality and its variability. Phytoplankton is the primary source of a food chain, which contributes to the major fishery resource around the world. They are responsible for the formulation of a biological community and regulate the food web[1,2].

Phytoplankton community structure, composition and species diversity in aquatic ecosystem are determined by several physic-chemical parameters[3]. Temporal variations in phytoplankton distribution are widely affected by the hydrochemical and physical factors such as temperature, pH, TSS and nutrients. Phytoplankton reacts rapidly to environmental changes and are regarded proper indicators of water quality and trophic conditions owing to their short generation time and fast population renewal[4]. Freshwater communities are very sensitive to environmental variables. Local processes interact to produce phytoplankton patterns of species abundance and diversity in a freshwater ecosystem[5].

Recently, the multivariate statistical approach is popular form a better understanding of water quality and aquatic status, in view of their ability to treat large volume of spatial and temporal data from a variety of monitoring sites. In the scientific published papers, principal component analysis(PCA) was used for this sort of studies in that they are capable to assess temporal variations in water quality and to identify potential sources of water pollution[6,7].

The present study aims to show characteristics and variation of phytoplankton diversity, composition and their abundance in Lake Paldang, South Korea. Temporal variations in different physic-chemical factors and environmental indices affect the phytoplankton growth have been discussed.

2. METHODS & MATERIALS

Study location

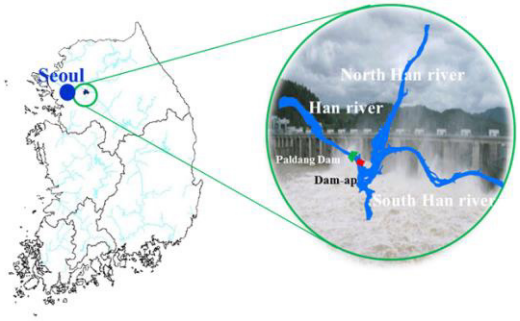

Fig. 1. Location of Lake Paldang with sampling site

Lake Paldang is constructed in 1973 for the purpose of hydroelectric power generation and creating a drinking water source an artificial dam reservoir (Fig.1).

The location is in the central part of the Korean Peninsula(37°29′ N, 127°26′ E), serving as a major source of drinking water for more than 25 million people in the Seoul, South Korea. The catchment area of the lake is as much as 23,800 km^2, which corresponds to a quarter of the total area of South Korea(100,032 km^2).

Sampling and water quality analysis

For qualitative and quantitative studies of phytoplankton, 2 liters of water sample was taken from near surface and fixed with few drops of acid Lugol's iodine solution(1 ~ 2%). After the settling and siphoning procedure, 1 ml of aliquot of the sample was taken in a Sedgewick-Rafter counting cell in duplicate under the inverted microscope(Eclipse Ni-E, Tokyo, Japan) for identifying and counting phytoplankton cells.

Water temperature, dissolved oxygen(DO), pH, conductivity(EC), were measured in situ with a portable multi-prove(YSI EXO, Yellow Springs, OH, USA). 2 L water samples were also collected from mixture of subsurface(0.5 m) and middle(10 m) and bottom(17 m) level for analysis at site, including the following parameters; total phosphorus(TP), total nitrogen(TN), nitrate nitrogen(NO_3-N), ammonia nitrogen(NH_3-N), five-day biochemical oxygen demand(BOD_5), chemical oxygen demand(COD_{MN}), chlorophyll-*a*(Chl-*a*), total suspended solid(TSS). All samples were analyzed according to Korean Standard Method for Examination of Water Quality[8].

Environmental index and statistical analysis

Diversity index(H`), evenness(J`) and richness index(S) were used to calculate community metrics of phytoplankton[9]. The trophic state index(TSI) is obtained by incorporating data for these three parameters into the corresponding Carlson(1977) equation[10]. In order to facilitate consistent evaluation of the dataset of these multiple variables monitored during various periods, multivariate analyses of the water quality dataset were performed through principal component analysis(PCA). Statistical computations in this study were made using IBM SPSS20.

3. RESULTS & DISCUSSION

Species composition and diversity of phytoplankton

A total of 91 phytoplankton species belonging to 6 phyla were recorded in 2016, including Bacillariphyta, Cyanophyta, Chlorophyta, Cryptophyta, Ochrophyta and Miozoa. In terms of species number, 35 species was group of Chlorophyta, followed by Bacillariphyta with 34 species, Cyanophyta with 11 species and other algal groups were total 11 species. Among them, 57 species in 6 phyla were collected in summer while 28 species from 5 phyla were observed in winter. Although the highest number of species was Chlorophyta the Bacillariphyta was the most dominant group with the high abundance(141 × 10^3 cells L^{-1}) in all seasons, except of August(Cyanophyta) and December(Cryptophyta). The variation of cell number and relative abundance of each phytoplankton group were illustrated in Fig. 2.

The species richness(S), and Shannon-Wiener diversity(H`) were generally low in the Lake Paldang, which ranged from the highest 57 species in summer to the lowest 28 species in winter, and diversity varied between 0.40 and 2.70. Seasonally, species diversity and evenness were much higher in winter(average H = 2.08; J` = 0.79) than those of spring(average H = 1.73; J` = 0.58). The richness(S) were much higher in spring(average S = 2.13) than that of autumn(average S = 1.54). The low evenness in spring indicated that the phytoplankton community was dominated by a few species, coinciding with the observation of the blooms of *Stephanodiscus hantzschii* and *Cyclotella atomus* in the study area during spring sampling.

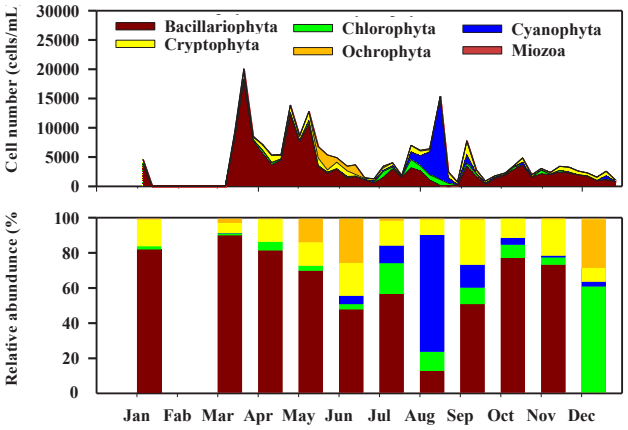

Fig. 2. The variation of cell number and relative abundance of each phytoplankton group

Source identification of monitored variables and TSI

The PCA based on the correlation matrix was performed to understand the underlying relationships between the water quality variables of Lake Paldang and to identify their characteristics. The Kaiser's criterion was used to determine the number of PCs to retain[11]. The scree plot(Fig. 3) showed the sorted eigenvalues from large to small as a function of the PC number. Loadings of four retained PCs are expressed in Table 1.

The first factor(PC1), according 40.82% of the total

variance, showed high positive loadings of NO_3-N, DO, T and NH_3-N, and high negative loading of TEMP. The second factor(PC2) explained 19.31% of the total variance. It had strong positive loading on COD, pH, BOD and Chl-*a*. The third factor(PC3), explained 15.30% of the total variance, contains a large positive loading on TP and SS. The fourth factor(PC4) accounting for the lowest total variance(9.01%), has a strong positive loading on EC. This contamination is due to a mixed source including natural processes and anthropogenic activities. The average values of TSI(SD), TSI(TP) and TSI(Chl-*a*) are 51.59, 48.66 and 54.10 respectively, showing in the category of mesotrophic/eutrophic.

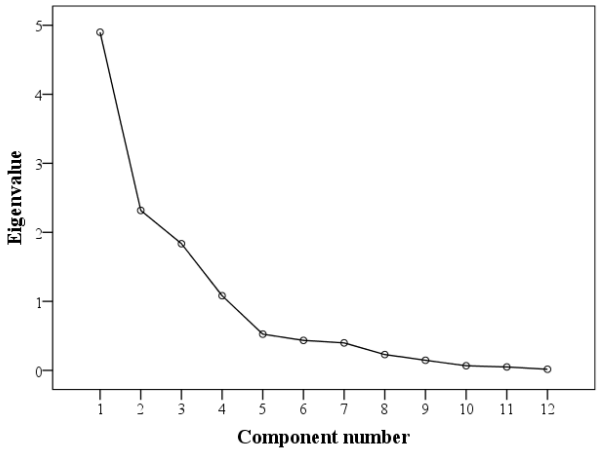

Fig. 3. Scree plot of the eigenvalues.

Table 1. Loading of experimental variables on principle components for the whole datasets

	PC1	PC2	PC3	PC4
Temp	**-0.933**	0.113	0.038	0.108
NO_3-N	**0.824**	0.313	0.267	0.187
DO	**0.821**	0.402	-0.223	-0.078
TN	**0.801**	0.320	0.323	0.300
NH_3-N	**0.607**	-0.289	0.143	0.521
COD	-0.164	**0.820**	0.347	0.127
pH	0.152	**0.789**	-0.335	0.283
BOD	0.384	**0.756**	0.222	-0.025
Chl-*a*	0.294	**0.557**	0.450	-0.141
TP	-0.092	0.039	**0.951**	-0.099
SS	0.243	0.178	**0.917**	0.017
EC	0.091	0.234	0.007	**0.893**
Eigenvalues	4.899	2.317	1.836	1.082
% of variance	40.822	19.312	15.297	9.014

4. CONCLUSIONS

This paper summarized the weekly variations of physic-chemical parameters and their influences on phytoplankton community of Lake Paldang with environmental indices and statistical data output in 2016. The phytoplankton community was found to belong to 6 groups, with Bacillariophyta dominating except of August and December. The indices of phytoplankton species diversity(H`) and evenness(J`) in winter(av. H = 2.08; J` = 0.79) were higher than spring(av. H = 1.73; J` = 0.58). Several trophic state indices and water quality parameters have been applied an overall analysis pointed out mesotrophic/eutrophic characteristics. As a result of PCA, water pollutants are mainly in associated with both natural processes and anthropogenic activities.

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O3-29

ヨシ根圏におけるビスフェノール類の分解に関する検討

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キーワード:ビスフェノール類, ヨシ, 根圏微生物, 分解

抄録

ビスフェノール A (BPA) やビスフェノール F (BPF) 等のビスフェノール類 (BPs) は工業的に重要な化学物質であるが, 内分泌攪乱性を有しており, 水域への排出に伴う生態系への悪影響が懸念されている。他方, 世界各地の湖沼などの水域や湿原に生息するヨシは, 水質浄化機能や生物多様性の保全機能等を有することが知られている。そこで本研究では, ヨシと根圏微生物の存在下における BPA 及び BPF の挙動について検討した。その結果, 特に BPA においては, ヨシが存在しない場合と比べて, ヨシと根圏微生物の存在下で分解が促進されることが確認された。また, 微生物群集解析の結果, 分解の進行とともに BPs 分解微生物と考えられる特定の微生物の集積が観察され, さらに, ヨシ植栽により微生物群集の多様性が高まることも確認された。これらの結果から, ヨシの植生は水域における BPs の分解, 及び微生物生態系の多様性維持にとって重要な意義を有するものと示唆された。

1. はじめに

ビスフェノール A (BPA, 図 1(a)) はポリカーボネート樹脂やエポキシ樹脂などの原料として工業的に幅広く使用されている重要な化学物質であるが, 内分泌攪乱化学物質であることが知られている。近年では, 様々な水環境中において検出されており, 水域生態系への悪影響が懸念されている。そこで, BPA の代替物質としてビスフェノール F (BPF, 図 1(b)) 等のビスフェノール類 (BPs) の使用が進められているが, それらの中にも内分泌攪乱性を有するものが存在しており, BPA と同様に水環境汚染に伴う生態系への悪影響が懸念されている[1]。このため, 水環境中における BPs の消長について詳細に理解することが必要である。他方, ヨシ (*Phragmites australis*) は世界各地の水域や湿原に生息しており, その群落には水質浄化機能や生物多様性の保全機能等が期待されている。既往研究では, ヨシの根圏に BPs を含む芳香族化合物の分解微生物が選択的に集積することも明らかにされている[2,3]。そこで本研究では, ヨシと根圏微生物の存在が BPs の挙動に及ぼす影響について検討した。

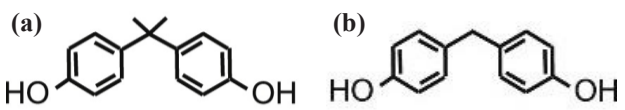

図 1 BPA (a) と BPF (b) の構造式

2. 方法

2.1 実験に使用したヨシ及び微生物群集

ヨシは, 種子をエタノール, 次亜塩素酸ナトリウム, 滅菌脱イオン水で洗浄した後, 滅菌改変 Arnon & Hoagland (A&H 培地) で 8〜12 週間栽培したものを使用した。また, 大阪大学内にある犬飼池より採取した池水を孔径 10 μm のフィルターでろ過して夾雑物質を除去した後, 遠心分離 (10,000×*g*, 4℃, 10 分) によって水中の微生物群を回収し, A&H 培地で 2 回洗浄し, A&H 培地に再懸濁させたものを微生物懸濁液として実験に使用した。

2.2 BPs 除去実験

BPA または BPF を 20 mg/L となるように添加した A&H 培地 100 mL を植物培養瓶に分注して実験系を作成し, 人工気象器内 (28℃, 16 h-light/8 h-dark) に静置して実験を行った。実験系は, ヨシと微生物懸濁液の両者とも植栽／植種しない系 (A), 微生物懸濁液のみを植種した系 (B) , ヨシを 2 株植栽した系 (C) , (B) にヨシを 2 株植栽した系 (D) の 4 種類を作成した (各々1 連)。

2.3 分析方法

実験期間中は, 適宜, 各実験系から 1 mL の試料を採取し, 2N HCl を 10 μL 滴下して生物反応を停止させた後, 孔径 0.45 μm のフィルターでろ過し, HPLC を使用して BPs 濃度を測定した。ただし, 実験期間中の水の蒸発による実験結果への影響を避けるため, 試料採取時には事前に滅菌超純水を用いて蒸発した水量を補完した。また, 実験系 B および D については, 実験開始時, 実

験中，終了時の試料から微生物 DNA を抽出し，16S rRNA 遺伝子を標的とした Terminal Restriction Fragment Length Polymorphism (T-RFLP) 法を用いて微生物群集構造を解析した。

3. 実験結果および考察方法

3.1 BPsの分解挙動

各実験系における BPA，BPF の濃度変化を図 2 に示す。BPA は，ヨシと微生物群集の両方を含む実験系 D，及びヨシのみを含む実験系 C において減少し，分解の進行が確認された (図 2(a))。実験系 B，C，D における結果から，BPA は環境中の微生物のみでは分解されにくく，ヨシと微生物の共生により分解が促進されることが示唆された。また，実験系 D で明確な分解が確認されたことから，BPA を添加した微生物懸濁液で 2 週間栽培したヨシを植え継ぎ，さらに 2 週間栽培したヨシを 2 株植栽した系を実験系 E として作成し，同様の実験を行った。その結果，実験系 E では実験系 D よりも BPA の減少速度が向上したことから (図 3)，実験系 E では事前の培養によってヨシ根圏に BPA 分解菌が集積されたことにより，分解が促進されたものと考えられた。また，BPA の分解に伴う代謝物の生成についても検討を行ったところ，Spivack ら[4]が BPA の生分解代謝物として報告している 4-ヒドロキシ安息香酸 (HBA)と 4-ヒドロキシベンズアルデヒド(HBAL) または 4-ヒドロキシアセトフェノン (HAP) の生成が確認され，本研究の実験系においても，BPA が既知の微生物分解経路によって分解されたものと示唆された。

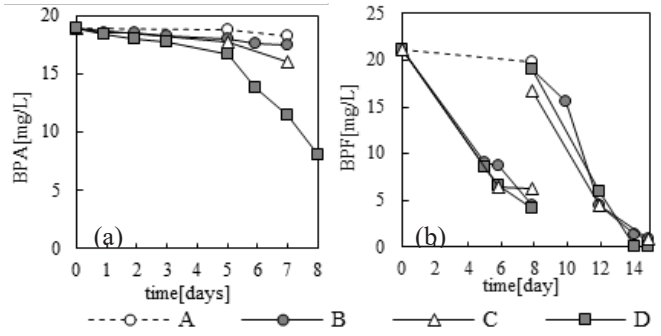

図 2 各実験系における BPA (a)，BPF (b) の濃度変化

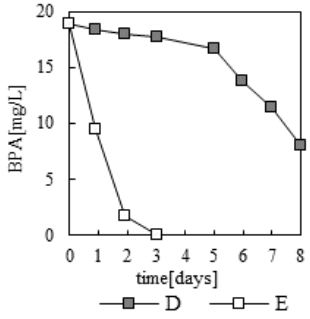

図 3 BPA 除去実験の実験系 D，E における濃度

他方，BPF は，微生物群のみを含む実験系 B，ヨシのみを含む実験系 C，ヨシと微生物群を含む実験系 D において類似の減少傾向を示した (図 1(b))。しかし，実験系ごとに生成する中間代謝物は異なった。

3.2 微生物群集構造の遷移

BPA 除去実験の実験系 D における T-RFLP 解析の結果を図 4 に示す。実験系 D では 6 日目から 8 日目にかけて 560 bp 付近のピークの優占度が顕著に高まることが観察され，このピークを示す微生物種が BPA 分解に関与した可能性が示唆された。他方，BPF 除去実験の実験系 B，D では 203 bp のピークの優占度が高まったことから，このピークを示す微生物種が BPF 分解に関与した可能性が考えられた。また，BPA，BPF 除去実験ともに，ヨシを植栽した実験系 D では植栽していない実験系 B に比べて微生物群集の多様性が高いことが観察され，ヨシの存在が微生物群集に影響を及ぼすことが示された。さらに，BPs の除去の進行によっても多様性が高まる傾向が観察され，中間代謝物を資化できる微生物種の増加により微生物多様性が高まった可能性が考えられた。

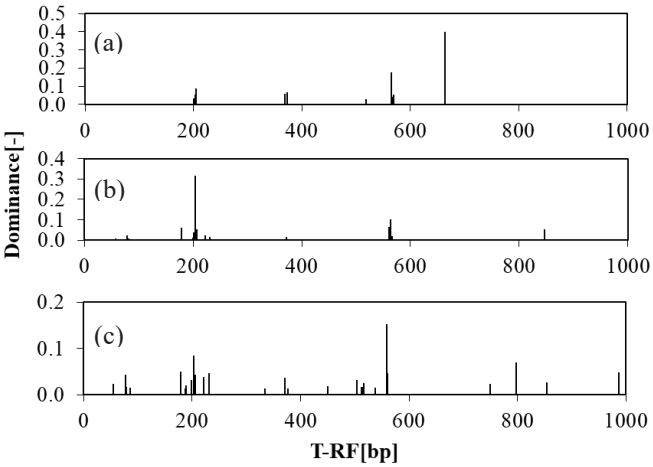

図 4 BPA 除去実験の実験系 D における微生物群集構造の変化 (0 日目(a)，6 日目(b)，8 日目(c))

4. 結論

本研究の結果から，BPF ではヨシ植栽による分解促進効果は見られなかったが，BPA では，ヨシと根圏微生物の存在下において，ヨシが存在しない場合と比べて明確な分解促進が確認され，ヨシの植生が水域における BPA の除去に寄与し得ることが示唆された。また，いずれの BPs の除去実験においても，ヨシが存在する場合に微生物群集の多様性が高まることが確認されたことから，ヨシの植生は汚染物質存在下における微生物生態系の多様性維持という面でも重要な意義を有することが示唆された。

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O3-30

Determination of Chelators in Lake Water using Ultra-Performance Liquid Chromatography/Quadrupole Time-of-Flight Mass Spectrometry

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Keywords: chelating agents or chelators, HILIC amide column, UPLC-Q-TOF-MS, water quality, freshwater

ABSTRACT

The determination of chelators in environmental samples is an analytical challenge due to their structural similarities and presence of low concentrations. We report a rapid and sensitive method for the determination of both the non-biodegradable (ethylenediaminetetraacetic acid, EDTA; N-(2-hydroxyethyl)ethylenediamine-*N*,*N*',*N*'-triaceticacid, EDTA-OH) and biodegradable (ethylenediamine-*N*,*N*'-disuccinic acid, EDDS) chelators as their corresponding Cu^{II}-complexes in the aqueous matrices. An ultra-performance liquid chromatography/quadrupole time-of-flight mass spectrometry was used. Chromatographic separation was performed using a UPLC HILIC amide column. Sample preparation is easy without pre-treatment steps. Limit of detection was 0.004 $\mu molL^{-1}$ (EDTA), 0.007 $\mu molL^{-1}$ (EDTAOH) and 0.008 $\mu molL^{-1}$ (EDDS). The coefficient of determination (R^2) was 0.999 for the chelators with repeatability of ≤3%. The developed method was successfully applied to the measurement of chelator concentration in lake water samples.

1. INTRODUCTION

Synthetic aminopolycarboxylate chelators are emerging environmental contaminants and extensively used for industrial and domestic purposes worldwide [1]. Chelators are produced in massive quantities every year because of their broad application range. In 2015, global chelators market size was 1026 kilotons. However, continuous exposure of non-biodegradable chelators such as EDTA and its homologs have hazardous environmental effects. Chelators form stable water-soluble complexes with metal ions, which increase metal solubility causing risk to enter the food chain. Although WHO set a tolerable limit of EDTA is 600 μgL^{-1} in drinking water and European Aminopolycarboxylate Committee established no-effect limit of 2.2 mgL^{-1} in an aqueous environment, there were reports of up to 12 mgL^{-1} EDTA in European water bodies [2].

Therefore, sensitive determination technique is essential to check the content of chelators in the open-water bodies. Some methods have been established to determine the chelator and their metal complexes in environmental matrices. However, the detection of metal-chelator complexes is still a challenge due to their structural similarities and presence of low concentrations in environmental samples [3].

The objective of the present study is to develop a rapid, sensitive and precise method for the determination of both non-biodegradable and biodegradable chelators in natural samples using an ultra-performance liquid chromatography quadrupole/time-of-flight mass spectrometry (UPLC-Q-TOF-MS).

2. METHOD

EDTA, EDTA-OH, and EDDS was used in the present study (Fig. 1). The metal-chelator complex solution contained 10^{-2} $molL^{-1}$ Cu^{II} standard, 10^{-3} $molL^{-1}$ chelator standard, 10 $mmolL^{-1}(NH_4)_2CO_3$, and acetonitrile / H_2O (70%/30%) as the sample diluents. Real samples from five different lakes, as collected during July to September was used (Fig. 2). Samples were filtered with 0.45 μm filters (Millipore, HA), and stored in polyethylene bottle at 5°C.

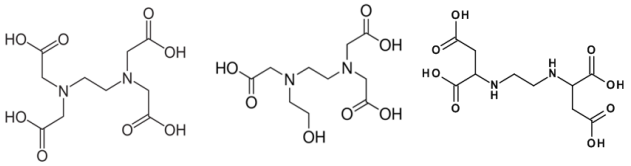

Fig. 1 Structure of chelating agents used in the study

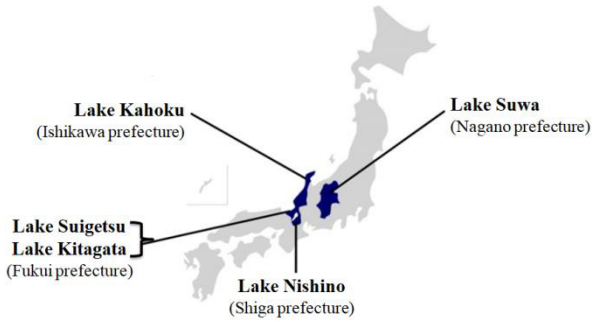

Fig.2 Sampling sites

A UPLC-Q-TOF-MS system (Xevo G2-S QTOF MS, Waters, Milford, USA) was used for the determination of the metal-chelator complexes. Chromatographic separation was achieved using an ACQUITY UPLC BEH amide column (particle size 1.7 µm, 2.1× 150 mm, Waters). A mobile phase consisting of 10 mM $(NH_4)_2CO_3$, and acetonitrile with 0.1 M $(NH_4)_2CO_3$ was used. The gradient condition was as follows: initial, 3% A/97% B; initial -11 min, 3% A/ 97% B to 50% A/ 50%B; 11–13 min, 50%A/ 50% B; 13–13.1 min, 50% A/ 50% B to 3%A/ 97% B. The flow rate of the mobile phase was 0.3 mL min^{-1}, and the injection volume was 10 µL. Acquisition mode was set as negative polarity in resolution analyzer mode. The LC-Q-TOF-MS system was controlled using the MassLynx 4.1 (Waters) software program. The data were generated based on peak intensities, and m/z values were used to identify individual peaks. Peak areas and the signal-to-noise (S/N) ratios were generated using the TargetLynx software as part of MassLynx 4.1.

3. RESULTS

Chelators were determined as their corresponding Cu^{II}-chelator complex. Cu-EDTA, Cu-EDTAOH, and Cu-EDDS samples were analyzed both in positive and negative polarity in electrospray ionization (ESI) mode. Mobile phase composition, pH of the mobile phase, sample diluents, capillary voltage (kV), desolvation gas flow (Lh^{-1}) were optimized. Cu-EDTA (m/z, 352.1), Cu-EDTA-OH (m/z, 338.1) and Cu-EDDS (m/z, 352.1) were detected individually at optimized operating conditions (Fig. 3). Limit of detection (LOD) was calculated based on signal-to-noise ratio of 3. LOD was 0.004, 0.007 and 0.008 µmolL^{-1} for EDTA, EDTA-OH, and EDDS, respectively. The linearity of the calibration curve was verified by plotting the peak area of the signal versus the amount of chelator added. The coefficient of determination as R^2 was 0.999.

Repeatability of the method was ≤3% as calculated from ten consecutive measurements for a given concentration value. The method validity was checked using five different lake water samples by standard additions (recovery 91.8 to 97.3%). The method was further applied to detect 0.068 µmolL^{-1} EDTA in lake Nishino located at Shiga prefecture.

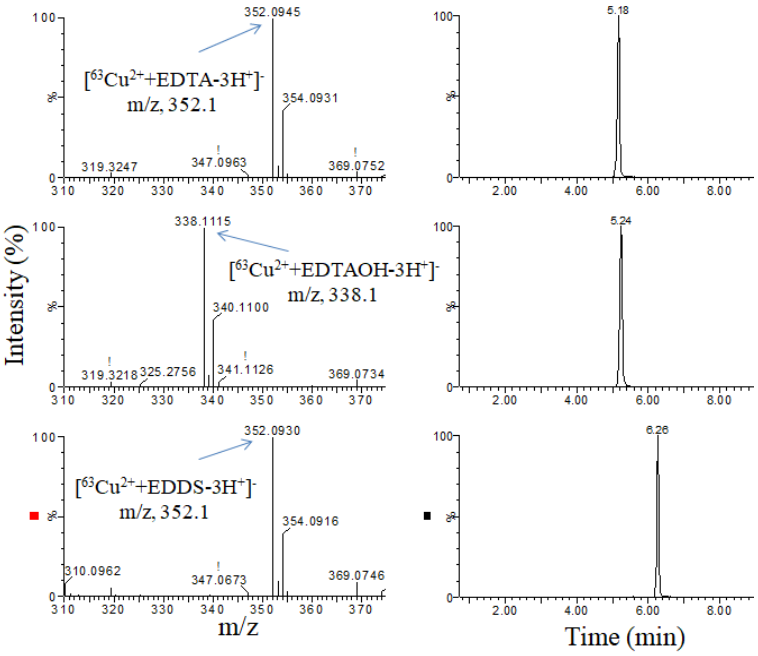

Fig. 3 Mass spectrum and mass chromatogram extracted at optimized operating condition, final concentration of chelator was 2 µmolL^{-1} in the sample

4. DISCUSSION

The chelators were analyzed in positive and negative polarity in electrospray ionization (ESI) mode by UPLC-Q-TOF-MS. The target peak was detected in both positive and negative mode. However, the signal per noise ratio (S/N ratio) was higher in the negative mode (Fig. 4). The carboxylic group of chelators may facilitate the detection of the anion with high sensitivity. The effect of mobile phase composition and the pH of the mobile phase solution was evaluated for the better sensitivity and satisfactory retention of the analytes. The sensitivities (as S/N ratio) of three Cu-chelator complexes were improved at higher pH (pH 9.0) (Fig. 5). Three mobile phase compositions were selected based on the compatibility with mass spectrometry such as (a) 10mM $(NH_4)_2CO_3$/ acetonitrile + 0.1 M $(NH_4)_2CO_3$ (b) 10 mM CH_3COONH_4/ acetonitrile + 0.1 M CH_3COONH_4 and (c) 10 mM NH_4COOH/ acetonitrile + 0.1 M NH_4COOH. The improved sensitivity of the analytes was achieved when using the composition (a) (Fig. 6). The satisfactory retention was also observed using this mobile phase composition. The desolvation gas flow (Lh^{-1}) and the

capillary voltage (kV) were optimized during the measurement by UPLC-Q-TOF-MS.

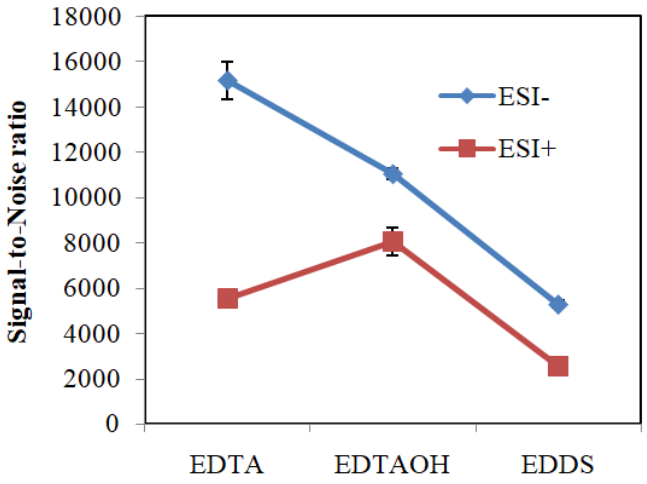

Fig. 4 Selection of polarity (positive/negative) in ESI mode for the determination of Cu-chelator complexes, final concentration of chelator was 10 µmolL^{-1}

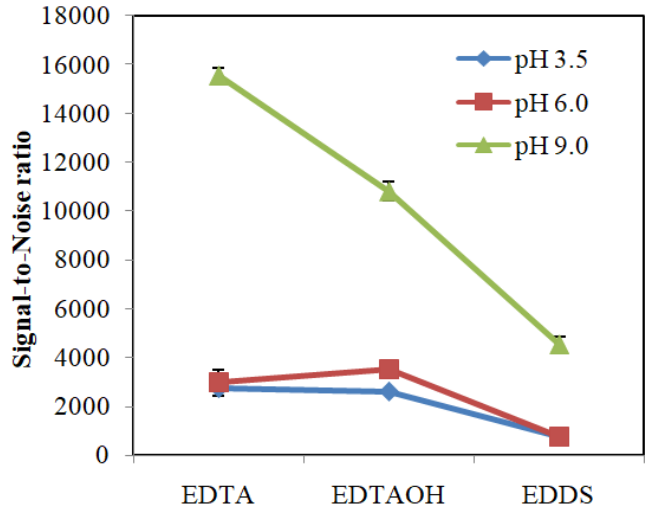

Fig. 5 Effects of mobile phase pH on sensitivity of Cu-chelator complexes, final concentration of chelator was 10 µmolL^{-1}

Five lake water (Fig. 2) samples were analyzed among which Lake Nishino of Shiga prefecture has shown the detection of 0.068±0.08 µmol L^{-1} EDTA content, whereas other found below the detectable limit. It would better be noted that EDTA might hamper the biological process at >1 mgL^{-1} concentrations [4]. The proposed technique was fast, sensitive and useful for the determination of chelating agents from natural samples.

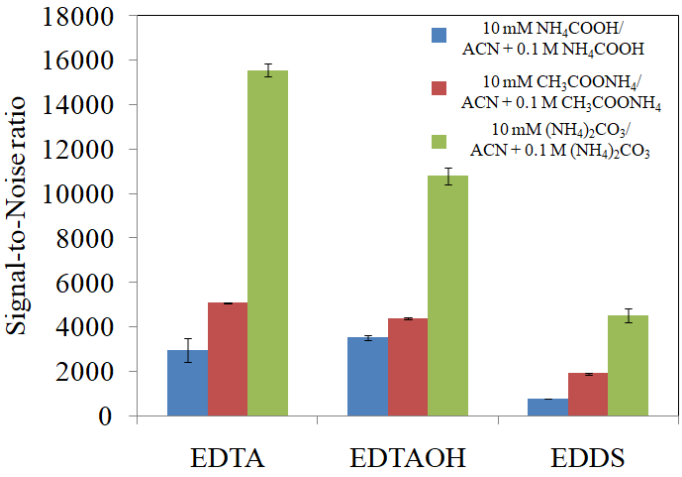

Fig. 6 Effects of mobile phase composition on the sensitivity of Cu-chelator complex, final concentration of chelator was 10 µmolL^{-1}, ACN indicates acetonitrile

5. CONCLUSION

The strengths of the proposed method include rapid determination, fast separation, and high sensitivity and resolution, and no pretreatment step to enrich the target species.The method was also successfully applied to the determination of Cu-EDTA complexes inlake water samples.

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O3-31

Characteristics of phosphorus sorption-desorption behaviour and effects of salinity, pH and temperature on phosphorus sorption in sediments of a largest brackish water lagoon, Chilika, South Asia – A case study

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Abstract

The lagoon, Chilika positioned as one of the largest brackish water ecosystems and designed as a Ramsar site in South Asian continent. Phosphorus sorption and desorption process can able to predict the status of phosphorus as the source or sink for coastal lagoon ecosystems. A very few studies on this aspect has been standardized for coastal lagoon in the south Asian continent. The sorption-desorption processes standardize in the laboratory maintaining the same environmental condition of the lagoon, Chilika. The effects of major water quality parameters like salinity, pH and temperature on phosphorus sorption on sediments were studied for the outer channel (OC), northern sector (NS) and southern sector (SS) in the lagoon, Chilika. The lagoon sediment for phosphorus sorption could be better assigned by the modified Langmuir model than by the modified Freundlich model. Effect of salinity, pH, and temperature on phosphorus sorption could be better understood by a binomial equation. The rate of phosphorus sorption increases with increasing salinity, pH, and temperature at low ranges. Whereas it decreases in excess of threshold values. The maximum phosphorus sorption capacity (Q_{max}) was more for NS sediments (258 mg/kg) compared with OC (219 mg/kg) and SS sediments (237 mg/kg) ($p < 0.05$). The percentage of phosphorus desorption (P_{des}) in the NS sediments (8.5-64.5%) was much lower than those in OC (29.7-126.9%) and SS sediments (21-109.5%). This study can able to help wetland manager to control eutrophication status of the lagoon by immediate effect of increasing P sorption through freshwater restoration.

Key words: Phosphorus; sorption; desorption; isotherm models; brackish water lagoon

O3-32

Characteristic of the photochemical release of phosphate from resuspended sediments under solar irradiation

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Keywords: sediment, resuspension, phosphorus, photochemical, vertical distribution

ABSTRACT

In previous studies, resuspended sediments that were exposed to simulated solar irradiation could release dissolved phosphate (PO_4^{3-}). However, the mechanisms of phosphate release remain unclear. In this research, a battery of experiments was performed to reveal the mechanisms of the photochemical release of phosphate from resuspended sediments of a shallow eutrophic lake under solar irradiation. The results show that the PO_4^{3-} released in resuspended sediments was significantly higher than that in the dark control or in water alone after treatment with solar irradiation for 6 h. The results of sequential chemical extractions showed that the concentrations of labile organic, moderately labile organic and residual organic phosphorus decreased in the resuspended sediment after 6 h of solar irradiation; of these, moderately labile organic phosphorus was the greatest contributor to the release of dissolved phosphate in resuspended sediment. Orthophosphate, phosphate monoesters, phosphate diesters and pyrophosphate were detected with ^{31}P-NMR. It is worth mentioning that the diester- P and pyro-P species disappeared after 6 h of irradiation. All of these results suggest that photochemical processes may lead to PO_4^{3-} release from sediment in aquatic environments. Moreover, the content of photochemical release of PO_4^{3-} increased with the increasing of suspension concentration within a certain concentration range and the photochemical release of PO_4^{3-} has significant spectral sensitivity.

1. INTRODUCTION

A recent study demonstrated that dissolved nutrients could be released when resuspended marine and estuarine sediments were irradiated by sunlight [1,2,7]. In a suspension constituted with autoclaved sediment (< 30 μm) and filtered seawater, more dissolved PO_4^{3-} was released under solar irradiation than in dark conditions. Because biological effects had been eliminated, the increase in PO_4^{3-} in the suspension was attributed to the photochemical decomposition of organic phosphorus from sediments [8]. These findings suggested that photo catalysis had a significant impact on organic phosphorus production into the surface waters, leading to the increase of the concentration of available phosphorus [9]. These earlier studies have found that photochemical processes play an important role in nutrient recycling in aquatic environments, but there is scant research of environmental controls and mechanisms of the phosphate released from resuspended sediments under solar irradiation.

Here, we undertook a detailed study of PO_4^{3-} release from resuspended sediments of a shallow eutrophic lake, under simulated solar irradiation. Sequential chemical extractions and ^{31}P-NMR were used to investigate variations in the phosphorus speciation during sediment resuspension under solar irradiation. Environmental parameters, such as the initial concentration of the resuspended sediment and the radiation spectrum were considered. The results will be useful to understanding the phosphorus cycle in aquatic environment.

2. METHOD

The water and sediment used in the experiment were collected from Lake Nan in Wuhan, China. Sediment samples were mixed,and autoclaved at 115–120 °C for 30 min. The mixed lake water was stored at 4 °C after being filtered with a 0.2 μm polysulfone filter (Supor-200, PALL) to remove microbes and suspended particulate. The fractionate and speciation change in organic phosphorus before and after solar irradiation was determined by sequential extraction procedure and ^{31}P-NMR [3]. Overall, the concentration of dissolved phosphate was determined using the molybdenum blue method.

3. RESULT

3.1. Release of PO_4^{3-} during sediment resuspension

As shown in Fig. 1a and b, the initial concentration of PO_4^{3-} in the filtered water and filtered autoclaved sediment resuspension was 0.18 and 0.30 mg/L, respectively. After solar irradiation for 6 h, there was no significant difference in the PO_4^{3-} concentration in the filtered water. However, the PO_4^{3-} concentration increased from 0.30 to 0.32 mg/L in the filtered autoclaved sediment resuspension after 6 h of solar irradiation. Most notably, the concentration of PO_4^{3-} increased from 0.31 to 0.41 mg/L in the suspension after solar irradiation for 6 h (Fig. 1c), which suggested that the resuspended sediments that were exposed to simulated solar irradiation could quickly release PO_4^{3-}.

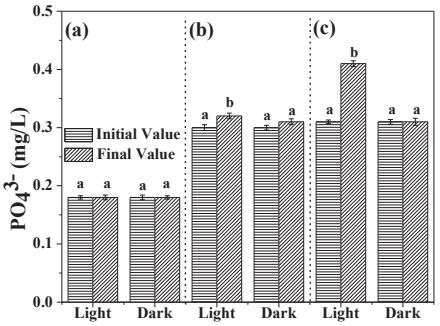

Fig. 1 The release of PO_4^{3-} in (a) filtered water, (b) filtered autoclaved sediment resuspension and (c) autoclaved sediment resuspension under solar irradiation.

3.2. Fractionation of phosphorus during sediment resuspension under solar irradiation

In this work, the organic phosphorus in the autoclaved resuspended sediments were divided into the labile organic (LOP), moderately labile organic (MLOP) and non-labile organic phosphorus (NLOP) groups, as in Lü's report [5, 6]. As shown in Table 1, the concentration of the different components of organic phosphorus was significantly lower after solar irradiation, comparedwith before the solar irradiation. The mean concentrations of LOP, MLOP and NLOP decreased from29.29 ± 2.93, 185.66± 3.38 and 42.02 ± 4.22mg/kg to 12.79± 2.53, 105.71 ± 4.24 and 23.47±2.21mg/kg, respectively. The results from ^{31}P-NMR indicated that the resuspended sediments were composed predominantly orthophosphate (ortho-P), phosphate monoesters (mono-P), phosphate diesters (diester-P) and pyrophosphate (pyro-P) (Fig.2). In the process of solar irradiation, the peaks of the diester-P and pyro-P disappeared .Meanwhile, the peak formono-P also changed after solar irradiation, indicating that the constituents of the mono-P changed.

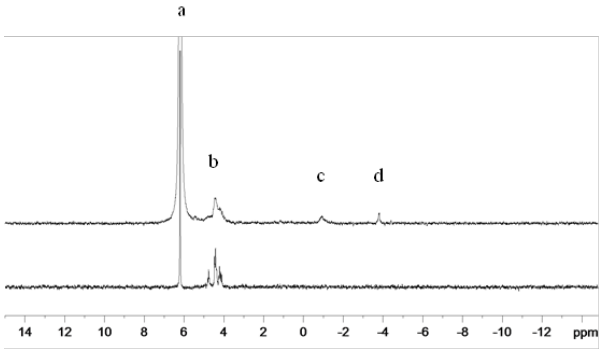

Fig. 2 ^{31}P-NMR spectra of NaOH–EDTA extracts of the resuspended sediments before and after solar irradiation for 6 h: (a) Ortho-P; (b) Monoester-P; (c) Diesters-P; (d) Pyro-P.

Table1 Different organic phosphorus concentrations in resuspension sediments

Classification of OP	Value (mg/kg)		Transformation rate (%)
	Before irradiation	After irradiation	
LOP	29.29 ± 2.93	12.79 ± 2.53	56.33 ± 1.12
MLOP	185.66 ±3.38	105.71± 4.24	43.06 ± 1.12
LOP	42.02 ± 4.22	23.47 ± 2.21	44.15 ± 1.12

3.3. Effects of environmental parameters on the photorelease of PO_4^{3-} during sediment resuspension

The environmental parameters are important factors that influence the photochemical release of PO_4^{3-} during sediment resuspension. As shown in Fig.3a, the initial concentrations of the resuspended sediment in the resuspension prepared by adding 1, 2 and 3 g of autoclaved sediment was 33, 73 and 101 mg/L, respectively. And the initial concentration of PO_4^{3-} in the suspensions was 0.28, 0.31 and 0.32 mg/L, respectively. The initial concentration of PO_4^{3-} increased with increasing amounts of resuspended sediment. After 6 h of solar irradiation, the concentration of PO_4^{3-} increased to 0.34, 0.41 and 0.43 mg/L, and the release of PO_4^{3-} increased by 0.06, 0.10 and 0.11 mg/L in the samples with the resuspended sediment concentrations of 33, 73 and 101 mg/L, respectively.

PO_4^{3-} released from resuspended sediment under solar and visible light irradiation, and a 420 nm filter was used to remove the light that has wavelengths shorter than 420 nm. As shown in Fig. 2b, the concentration of PO_4^{3-} in the experiments with solar and visible light irradiation increased to 0.44 and 0.33 mg/L, respectively.

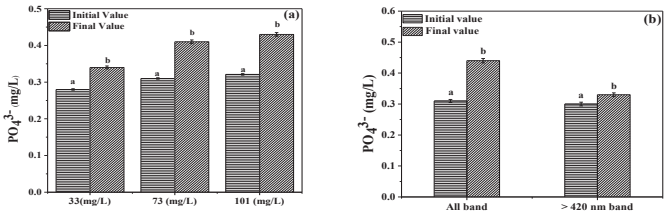

Fig. 3 Effect of environmental parameters on the PO_4^{3-} photo-released from resuspended sediment under solar irradiation: (a) initial concentration of resuspended sediment and (b) irradiation spectrum

4. DISCUSSION

Dark control was set up in this experiment, as shown in Fig.1. Because the biological effects were removed,the increase in dissolved PO_4^{3-} concentration should be attributed to the photodegradation of organic phosphorus. Compared to the amount of PO_4^{3-} that resulted from the dissolved organic phosphorus, the photodegradation of particulate organic phosphorus to PO_4^{3-} played an important role in phosphorus release.

The concentration of resuspended sediment could influence the initial concentration of phosphate and organic phosphorus in the water environment. In addition, as reported by Mayer, high concentrations of resuspended sediment could block the transmission of light in the water [8]. However, as shown in Fig.3a, when the resuspended sediment concentration increased to 101 mg/L, the amount of PO_4^{3-} that was released decreased. This result is mainly because the distribution of dense particles blocked the transmission of light in the suspension with a high sediment concentration, inhibiting the photolytic degradation of organic phosphorus during the sediment resuspension.

The radiation spectrum significantly affects the number of free radicals that are generated, which will further influence the photodegradation of organic matter in the natural aquatic environment [4]. The Fe^{3+} ion has also been shown to be a photoreactive species, in terms of •OH generation irradiation with visible light [10,11]. In this experiment, The amount of PO_4^{3-} released from resuspended sediment under solar irradiation was higher than that of visible light treatment, which suggested that PO_4^{3-} released from organic phosphorus photodegradation

during sediment resuspension was highly spectrum-sensitive.

5. CONCLUSION

This study revealed the mechanism of PO_4^{3-} release from resuspended sediments under solar irradiation. The amount of PO_4^{3-} that was released dramatically increased when the sediment resuspension occurred under solar irradiation, and the initial concentration of the resuspended sediment and radiation spectrum affected this process significantly. ^{31}P- NMR and the sequential extraction of organic phosphorus clearly demonstrated that the organic phosphorus component changed when the resuspended sedimentswere exposed solar irradiation. Together, these results benefit our understanding of the phosphorus cycle in the process of shallow lake eutrophication. Continued investigation is necessary to understand the transformation process of particulate phosphorus to phosphate under solar irradiation and to fully understand the fate and transport of sediment phosphorus

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O3-33

Spatio-Temporal Variability of Water Quality in a Large Shallow lake In Southeast Asia: Tonle Sap Lake, Cambodia

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Keywords: Tonle Sap Lake, water quality, spatio-temporal variability

ABSTRACT

Tonle Sap Lake (TSL) in lower Mekong River Basin and also is the largest freshwater lake in Southeast Asia at the end of the wet season. The water quality and decline in biological resources have been raised regarding the degradation of water quality in Tonle Sap Lake. The study aimed to study variability in water quality in the large shallow lake scale at temporal and spatial scale; and to better understand the state of water quality in this largest Southeast Asia shallow lake. The presented study was based on surface water quality collected from cross-section of Tonle Sap Lake covering a maximum of 37 sampling stations during December 2016 and June 2017 corresponding to receding and rising stage of lake volume, respectively. Variation of water depth was high between December and June (on average 2.7 m in June and 4.7 m in December) and caused high variability for TSS (170 mg/l in June and 7 mg/l in December). However, low variability of rising and receding stage had been detected for DO. Based on information obtained from this study, it provided the information regarding to the spatio-temporal water quality in various layers to understand the state of water quality in TSL. Additionally, the integration of process-based information with interpolation maps could support the further study of prior sampling points or monitoring program.

1. INTRODUCTION

The Tonle Sap Lake (TSL) and its floodplains contain the largest continuous areas of natural wetlands habitats remaining in the Mekong system while being the largest permanent freshwater body in Southeast Asia. During the dry season, November to April, the lake size is about 120 km long and 35 km wide, with an area of about 2500 km^2 and flow to Mekong River from the northwest part. In the wet season, from May to October, flooding and the associated water level increase in the Mekong River causes the Tonle Sap River to change flow direction and flow towards the northwest (upstream) into Tonle Sap Lake [1]. During the flood phases, the lake receives a large amount of water volume from Mekong River through reversal flow and enlarges to about 250 km long and 100 km wide, with an area of about 17,500 km^2 [2]. Some concerns have been raised regarding the degradation of water quality in Tonle Sap Lake due to multiple pressures ranging from human activities in floating houses in the lake to agricultural activities in watershed [3]. Investigations into the variations in water quality should be based on monitoring over a sufficient spatial extent to the whole lake. However, due to the variation of the size during dry and wet season of the Tonle Sap Lake, spatial and temporal variations studies in the water quality of Tonle Sap Lake remain limited.

The presented study was based on surface water quality collected in December 2016 and June 2017 in Tonle Sap Lake corresponding to receding and rising stage of lake volume, respectively. The study aimed to study the variability in water quality in the large shallow lake scale at temporal and spatial scale.

2. METHOD

The data collection comprised of 37 sampling stations and two sampling campaigns in December 2016 and June 2017 corresponding the beginning of the receding stage and beginning of the rising stage of the lake volume. The exact sampling locations were fixed by using Global Positioning System (GPS). All the sampling locations (Fig. 1) have been projected on cross-section lines (CS) passing through the entire lake. Surface water layer and bottom water layer (0.5 m above the bed) were collected for this study from the lake, as the depth of water is less 3m and 7m in the dry and wet season, respectively. Temporal variations of different parameters had been assessed using descriptive statistic. The ordinary kriging (OK) had been performed to map selected water quality since it could provide outperforms than other spatial interpolation methods in Tonle Sap Lake for both layers [4]. Targeted parameters are total depth, Electrical conductivity, water temperature, oxidation-reduction potential, pH, dissolved oxygen, Turbidity, Total suspended solid. All water quality parameters (except TSS) were conducted in-situ measurement using YSI EXO Water Quality Sondes. The

sensors had been calibrated regularly (before conducting the field survey) to ensure accuracy and response times. TSS had been conducted analysis in laboratory adapted from American Public Health Association (APHA).

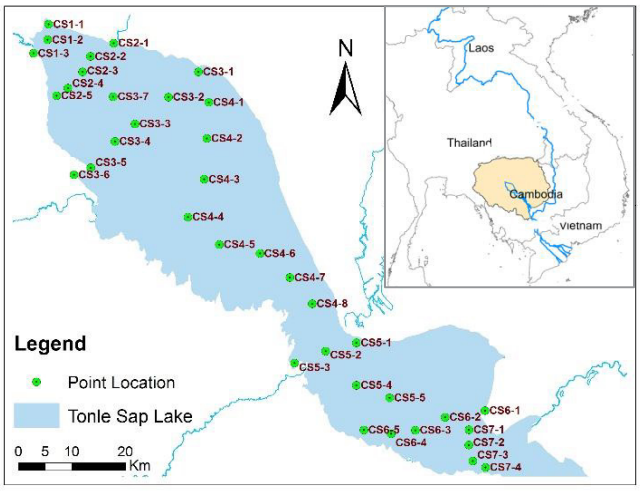

Figure 1: Sampling locations in Tonle Sap Lake

3. RESULTS AND DISCUSSION

Temporal water quality

The descriptive statistic was applied to the dataset and showed in Table 1. The result enabled us to compare water quality parameters between two separated stages.

Table 1: Descriptive statistic of the selected water quality parameters during December, 2016 and June, 2017 in-situ measurement campaigns

		Surface Layer							Bottom layer						
	Parameters	Min	Max	Average	S.D	C.V	Skewness	Kurtosis	Min	Max	Average	S.D	C.V	Skewness	Kurtosis
Jun-17	Total Depth (m)	1.60	5.53	2.78	0.64	0.23	1.98	9.02	1.60	5.53	2.78	0.64	0.23	1.98	9.02
	Temp (°C)	29.30	35.70	31.98	1.36	0.04	0.56	0.28	28.90	32.30	30.09	0.67	0.02	0.88	1.81
	EC (µS/cm)	51.40	248.0	154.75	37.00	0.24	-0.49	1.68	40.40	211.00	142.28	31.83	0.22	-1.02	2.29
	pH	6.66	8.94	7.84	0.64	0.08	0.17	-0.97	6.66	8.55	7.63	0.46	0.06	-0.29	-0.59
	ORP (mV)	138.0	250.0	186.6	29.6	0.16	0.18	-0.75	19.0	240.0	188.8	42.0	0.22	-2.94	10.12
	DO (mg/L)	4.11	10.93	7.08	1.57	0.22	0.11	0.03	3.38	7.67	6.28	0.94	0.15	-1.66	2.93
	TSS (m/l)	4.50	405.0	169.50	103.22	0.61	0.42	-0.23	10.00	716.0	160.6	208.9	1.30	1.68	1.76
		Surface Layer							Bottom layer						
Dec-16	Total Depth (m)	3.55	8.78	4.75	0.86	0.18	2.93	13.37	3.55	8.78	4.75	0.86	0.18	2.93	13.37
	Temp (°C)	25.70	29.40	27.15	0.87	0.03	0.52	0.13	25.60	28.70	26.81	0.90	0.03	0.68	-0.37
	EC (µS/cm)	47.90	140.70	101.73	24.16	0.24	-0.70	-0.27	25.80	143.70	100.60	27.43	0.27	-1.06	0.79
	pH	6.82	8.34	7.55	0.40	0.05	-0.17	-0.96	6.51	8.10	7.45	0.43	0.06	-0.45	-0.88
	ORP (mV)	137.0	472.0	238.7	108.7	0.46	1.27	0.01	19.2	462.0	228.4	112.1	0.49	1.01	-0.04
	DO (mg/L)	1.53	8.70	6.58	2.03	0.31	-1.39	0.87	2.47	8.27	6.62	1.56	0.24	-1.12	0.46
	Turb (NTU)	2.60	36.00	14.67	8.27	0.56	0.61	-0.14	3.25	53.40	17.52	10.15	0.58	1.28	2.97
	TSS (m/l)	3.31	11.50	7.91	2.04	0.26	-0.03	-0.42	4.50	24.0	9.65	3.66	0.38	1.63	5.26

Note: Min: minimum, Max: maximum, S.D: standard deviation, C.V: coefficient variation

The table showed the high variation of water depth in December and June. At the beginning of the receding stage, water depth ranged from 3.5 to 8.7 meters in the lake and result the lake surface was larger than June (water depth ranged from 1.6 meters to 5.5 meters). In general, the concentrations of most water quality parameters shall differ between seasons or lake volume. In June, beginning of rainy season, water levels were low which resulted in an accumulation of TSS in the lake and reached a high level. These were confirmed by both water layers, the surface layer (4-450 mg/l, on average 170 mg/l) and the bottom layer (10-710 mg/l, on average 160 mg/l). The TSS concentration is diluted by monsoonal rainfall events after the beginning of rainy season, inflow from the Mekong River and high lake volume.

After the peak water depth in between October and November, water in Tonle Sap Lake starts to fall and December is the beginning of the receding stage. However, the water level was still in the high level during the study period. Water depths ranged between 3.5 meters to 8.7 meters and on average was 4.7 meters. The turbidity and TSS concentration in this stage were diluted by lake volume; Turbidity was in between 2.6 to 36 NTU (average 14 NTU) for the surface layer and in between 3.2 to 53 NTU (average 17 NTU) for the bottom layer. TSS concentration also showed the decrease trend during these periods as on average was 7.9 mg/l for surface layer and 9.6 mg/l for the bottom layer. Turbidity and TSS established a good agreement that this shallow lake clarification follows the variability of the lake size and volume.

Regarding DO, the low variability of this rising and receding stage has been detected. In June 2017, the average DO was 7 mg/l and 6.2 mg/l for surface and bottom layer. In December 2016, DO was 6.5 mg/l and 6.6 mg/l for surface and bottom layer. Between DO and pH in both observed months showed good positive correlation and could indicate the production of dissolved oxygen by photosynthetic activity.

Spatial Variability of Water Quality

TSS, DO and EC was selected for spatial variability study based on high variability among the sampling stations and importance of each parameter. A coefficient variation (CV) was used to compare variability between different sampling stations. TSS is one of the indicators for lake clarification, DO is an essential factor for aquatic life,

while EC of lake water is an estimator of the amount of total dissolved salts. The distribution maps of selected water quality parameters had been constructed to visualize the spatial variability in both water surface layer and bottom layer during rising and receding stage of the lake volume. The ordinary kriging (OK) had been performed to map selected water quality in Tonle Sap Lake for observed months and both layers [4] (Figure 2).

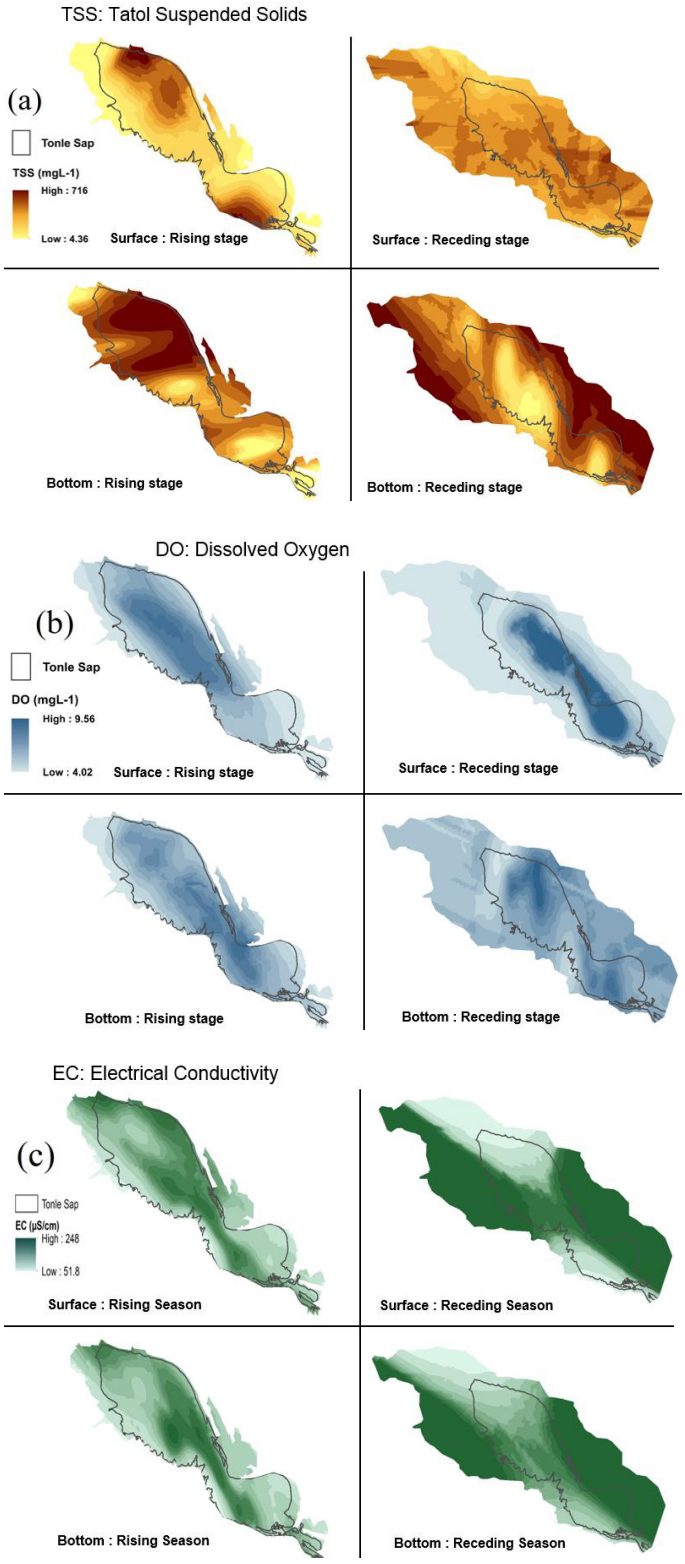

Figure 2: Distribution maps of selected water quality in Tonle Sap Lake and its floodplain, (a) TSS, (b) DO and (c) EC. Top left: surface layer in rising stage, Bottom left: bottom layer in rising stage, Top right: surface layer in receding stage, Bottom right: bottom layer in receding stage.

In June, TSS concentration was high in upper part of the lake in both surface and the bottom layer (160-400 mg/l). Another concentrated area of TSS was in lower part (180-450 mg/l) for the surface layer. However, bottom layer concentrations of TSS were lower in this area (15-65 mg/l). In receding stage, TSS concentration was low, in particular, in the middle of the lake (5-25 mg/l). The contrast of TSS, DO was good in the middle of the lake in these months and bother layer (5-9 mg/l) because of dilution from the lake volume. While near the lake boundary, DO was lower (4-6 mg/l) due to agricultural activities around the lake and floating villages in that area. EC provided different spatial variability in June and December, but good agreement in surface and bottom layer. In June, high EC (150-200 µS/cm) occurred in the middle of the lake but in December, the middle of the lake, EC was lower (20-150 µS/cm).

4. CONCLUSION

In this study, descriptive statistic and geospatial interpolation method had been used for spatio-temporal study of water quality collected in December 2016 (receding stage) and June 2017 (rising stage) in Tonle Sap Lake. Based on results obtained from this study, it could provide information regarding the spatio-temporal water quality in various layers to understand the state of water quality. Additionally, the integration of process-based information with interpolation maps could support the further study of prior sampling points or monitoring program. The targeted parameters can be used in the future study to establish correlations among parameters.

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O3-34

Status of biological water quality of main rivers connected to Tonle Sap lake, Cambodia

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Keywords: Biological water quality, lake, river, wastewater, environmental water

ABSTRACT

Water sources in the Cambodia are being contaminated by the untreated wastewater discharge from the city; however, the biological water quality data is scarce in the region. We investigate the presence of *Escherichia coli* (*E. coli*), coliform and its gene (*uidA*) in Mekong river, Tonle Sap river and Tonle Sap lake since this environmental water was affected by domestic wastewater. Concentration of *E. coli* and coliform in Tonle Sap river were higher than those in Tonle Sap lake and Mekong river. *E. coli* concentration in Tonle Sap river is about 10 times higher than in Tonle Sap lake and about 100 times higher than in Mekong river. The *uidA* gene was identified in Tonle Sap river almost every month from March to December 2017 while *uidA* was identified in Mekong river only from March to May 2017. The results from this study demonstrated that the main water sources in the country such as Tonle Sap lake, Tonle Sap river and Mekong river are under the pressure of fecal contaminated source. The untreated wastewater from the city, which may contain high concentration of virulent microorganisms, was discharged into the water body in daily basis. The construction of wastewater treatment plant in the country is necessary for removal of unwanted substances or microbes for improving the water source quality and for sustainable development.

1. INTRODUCTION

Cambodia economy gradually rose year by year with the average of 7.6% growth rate from 1994 to 2015 (http://www.worldbank.org/en/country/cambodia/overview). The infrastructure in the country is much improving recently, particularly in Phnom Penh capital city. Cambodia economy largely depends on the natural resources such as agriculture and fisheries production.

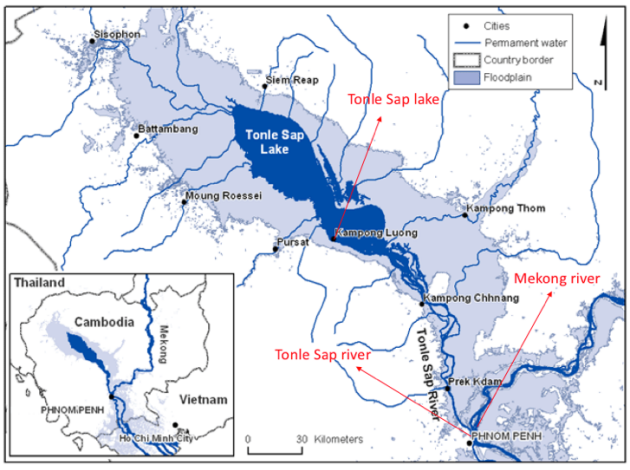

Fig.1 Sampling point of Mekong river and Tonle Sap river and Tonle Sap lake.

Tonle Sap lake, the largest fresh water body in Southeast Asia, offer uncountable benefit for Cambodia and play an important role in flood regulation in the region[1,2]. The water cycle in this lake is exceptionally unique. The water usually flows from Mekong river into the lake in rainy season (from December to April) and flow from the lake to Mekong river via Tonle Sap river in dry season (from May to October). The lake and rivers offer a ton of fish, snake, shrimp, and other aqua products for supporting the food demand[3,4].

The connection between Mekong river and Tonle Sap river is located at the capital city of Phnom Penh, Cambodia. Since, there is no wastewater treatment plant in Phnom Penh, the untreated wastewater was discharge into water source such as Tonle Sap river, Mekong river, Bassac river and wetland[5]. Even though those water sources provide uncountable advantages for human, they were reported under threat due to the inflow of not only the domestic wastewater but also industrial, agricultural, and floating villages waste. As an estimation, more than 234 tons of feces was discharged into water source and among of those waste, 77 tons was discharge into the lake body in daily basis. There is a plenty of water in the country, but 66% of people could not access safe water and 65% of water pollution derived from domestic wastewater[6,7]. Those wastewaters may highly have contributed to lake and river water quality and driven the negative impact on the human; especially floating villager, since they use the lake water for their daily life activities[2,7,8]. As a reported

consequence, the numbers and the species of diversity in water source such as fish, snake, as well as wildlife, were declined gradually[1,9,10]. Hundred cases of typhoid and pediatric bloodstream infections caused by pathogenic bacteria were determined in the hospital[4,11]. The mortality rate of children under five years in Cambodia is high in Southeast Asia. Cambodia has loss US$448 million per year for health cost due to poor sanitation[6,12].

Even though many cases of waterborne diseases were reported, the biological water quality data in the country is very scarce in the region and people are still exposed to health risk. Understanding the status of biological water quality of water source in the country in necessary. Our study's aim is to determine the presence and concentration of *Escherichia coli* (*E. coli*), coliforms and *uidA* gene in Tonle Sap river, Mekong river and Tonle Sap lake as affected by anthropogenic pollutants.

2. METHOD

2.1 Water sample

Water sample was taken from a Kampong Loung floating village, Tonle Sap lake (12.57383, 104.2082) in March 2017 and samples were taken from Tonle Sap river (11.586765, 104.920232) and Mekong river (11.590092, 104.938058) from March to December 2017 for the analysis (Fig. 1). A part of samples was used for plating and other water samples were filtrated through 0.45 µm mixed cellulose ester membrane (A045A025A, ADVANTEC). The samples were store in 70% ethanol for the analysis.

2.2 Culture based method

To count the number of *E. coli* and coliforms in water samples, Chromocult® Coliform Agar (Merck KGaA, Germany) was used. *E. coli* produces a purple colony, coliform produces pink colony and other bacteria produce white colony on the Chromocult plate.

2.3 Gene based method

The membrane after sample filtration in 70% ethanol was transferred into glass bead (ø 0.1 mm and ø 0.5 mm) tube. The suspension in ethanol phase was centrifuge at 8,000 g for 10 min and the pellet was resuspended with 200 µL pure water. The resuspension was transferred to the glass bead tube contained the membrane. The further DNA extraction process was described in the literature[13]. DNA template was precipitated in isopropanol containing 1 µL of glycogen at - 20ºC for 30 min. After centrifugation at 15,000 g for 15 min, the pellet was washed with 70% ethanol. After drying, the DNA templates were finally dissolved with 30 µL TE buffer and measured their concentration and purity by spectrophotometer (NanoDrop 2000, Thermo Fisher Scientific). The DNA templates were store at - 20ºC for further analysis. The oligonucleotides primer (*uidA* gene, 162 bp) was constructed following the reported paper[14]. To identify uidA gene presented in *E. coli*, the DNA templates were subjected for PCR amplification as follows: 95°C for 53 min of initial denaturation step, 35 amplification cycles (95°C for 30 s of denaturation, 58°C for 30 s of annealing, and 72°C for 60 s of elongation), and 72ºC for 10 min of final extension step. The PCR products were loaded in gel electrophorese and the band of target gene were confirmed under UV light.

3. RESULTS

E. coli and coliforms bacteria have been used as indicators of water quality and fecal contamination in environmental water. Our analysis in Fig. 2 showed that the concentration of *E. coli* and coliforms were found the highest in Tonle Sap river while the lowest were found in Mekong river. Coliform concentration is above 10 times higher than *E. coli* concentration in Tonle Sap lake and Tonle Sap river. However, coliform concentration is about 100 times higher than *E. coli* in Mekong river.

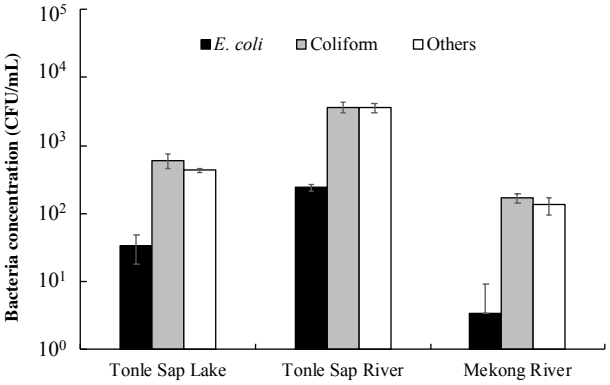

Fig.2 Concentration of *E. coli* and coliforms in Tonle Sap lake, Tonle Sap river and Mekong river.

By using one of the specific gene (*uidA*) in *E. coli*, we determined its existence in Tonle Sap river and Mekong river from March to December 2017 (Fig. 3). We detected *uidA* gene almost in all samples that were taken from different month in dry season of Tonle Sap river, except rainy season from October to November 2017. However, *uidA* gene was detected in some of Mekong river samples in March, April and May 2017. In the samples from following month in rainy season, *uidA* gene was not detected.

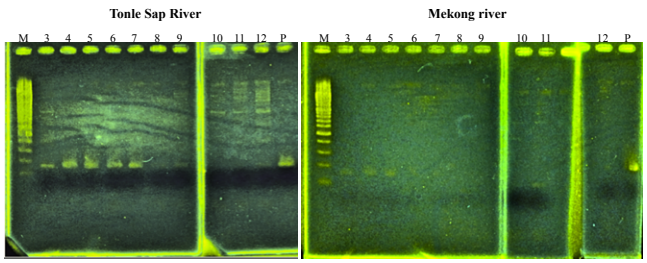

Fig. 3 Detection of *uidA* gene in Tonle Sap river and Mekong river from March to December 2017. Number represented the sampling for each month from March to December, 2017. M: marker, 1: January, 2: February, 3: March, 4: April, 5-May, 6-June, 7-July, 8-August, 9-September, 10-October, 11: November, 12: December, P is positive control.

4. DISCUSSION

Balancing between country development and environmental status is necessary for sustainable development. For understanding the basic biological water quality, detection of indicator of pathogenic bacteria concentration such as *E. coli*, coliforms and its gene in environmental water is important. The presence and the consistence of *E. coli*, coliforms and *uidA* gene in Tonle Sap lake, Tonle Sap river and Mekong river illustrated that the water source was recently or simultaneously polluted from the fecal wastewater source derived from humans. However, *E. coli* and coliforms concentration was lower in Mekong river than Tonle Sap river and Tonle Sap lake. It's reasonable since the water volume of Mekong river is larger than Tonle Sap river and less contaminated from capital city. The polluted water may be threatening the diversity in water source and human health, especially the floating villagers since they used the lake water for their daily life activities.

The results investigated in this study was clearly showed that the river water in Phnom Penh city and also Tonle Sap lake was continuously contaminated from human waste. High concentration of *E. coli* and coliform found in those water sources may reflect the health and environmental vulnerability in a developing country such as Cambodia. Wastewater treatment plant is needed for a speedy developing city such as Phnom Penh and the development of an appropriate septic tank is also necessary for floating villagers.

5. CONCLUSION

High concentration of *E. coli* and coliform were found in Tonle Sap river and Tonle Sap lake while their abundance was low in Mekong river. The *uidA* gene was also detected in Tonle Sap river and Mekong river especially in dry season.

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O3-35

Survival of *Escherichia coli* K12 and Detection of Antibiotic-resistant Bacteria in Tonle Sap, Mekong and Basac Rivers

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Keywords: Tonle Sap River, Mekong River, Basac River, *E. coli* K12 and antibiotic-resistant bacteria

ABSTRACT

The freshwater ecosystem has been depleted gradually by human activities along the rivers including the waste disposal, which will contaminate water ecosystem, and uncontrolled widely antibiotic use in aquacultural purpose. Fecal contamination and the presence of antibiotic-resistant bacteria can cause serious problems to people living along the lake and rivers. Therefore, this study aims to investigate the survival of *Escherichia coli* K12 using dialysis membrane and to detect the antibiotic-resistant bacteria (ABR) in Tonle Sap River (TSR), Mekong River (MR) and Basac River (BR). The physiochemical and microbiological characteristics of waters in these 3 sites were analyzed. Moreover, control (*E. coli* K12/PBS) and sample (*E. coli* K12/River water) conditions were placed on the surface of TSR, MR and BR and the survival of *E. coli* K12 was observed for 12 days. In addition, six antibiotics including ampicillin, meropenem, ciprofloxacin, vancomycin, kanamycin and tetracycline were used to detect the antibiotic-resistant bacteria in these 3 sites. As the result, physiochemical characteristics slightly affect the survival of *E. coli* K12 as the turbidity was higher which could block sunlight to get through the waters. Moreover, it was found that *E. coli* K12 could survive only 8 days in TSR and they continued to survive until day 10 and died out in day 12 in MR and BR. The detection of ARB showed that high numbers of bacteria ranging from 3×10^2 to 2.31×10^4 CFU/mL were resistant to all antibiotics used. Among these 3 sites, ARB were detected in high amount in TSR.

1. INTRODUCTION

Despite the fact that Tonle Sap Lake has enormous significant for Cambodia in term of hydrological system, diverse aquatic system, aquatic food source to human, and also the place where fishes can breed, its water quality is reported to be declined because of the discharge of agricultural wastes, urban area wastes and human activities[1,2]. For instance, floating villages on Tonle Sap Lake (TSL) is reported to be a major fecal contamination to the lake and also to rivers because of poor household sanitation system.

Escherichia coli is known as fecal indicator organism and some strains of this specie are pathogenic bacteria causing serious public health concern. However, the fate of *E. coli* in natural environment has not been well explained when they are released to the water environment which can lead to the public health problems[3]. And *E. coli* K12 is well known as model organism that is extensively studied to understand particular biological phenomena.

The spread of antibiotic-resistant bacteria in the environment may compromise the ability to treat microbial infections and has become an increasing challenge to public health[4]. In order to complete microbial risk assessments and develop policies to protect public health, understanding the fate of fecal indicator in the lake and river waters, and antibiotic- resistant bacteria (ARB) are needed.

The objective of this study was therefore to investigate the survival of *E. coli* K12 and to detect the antibiotic-resistant bacteria in Tonle Sap, Mekong and Basac rivers in Cambodia.

2. METHOD

2.1. Physicochemical and microbiological analysis

The physicochemical and microbiological characteristics of waters in 3 sites (**Fig. 1**) were first analyzed during

rainy season in July 2017. For microbiological analysis, *E. coli*, coliforms and other Gram-negative bacteria were investigated using Chromocult® coliform agar.

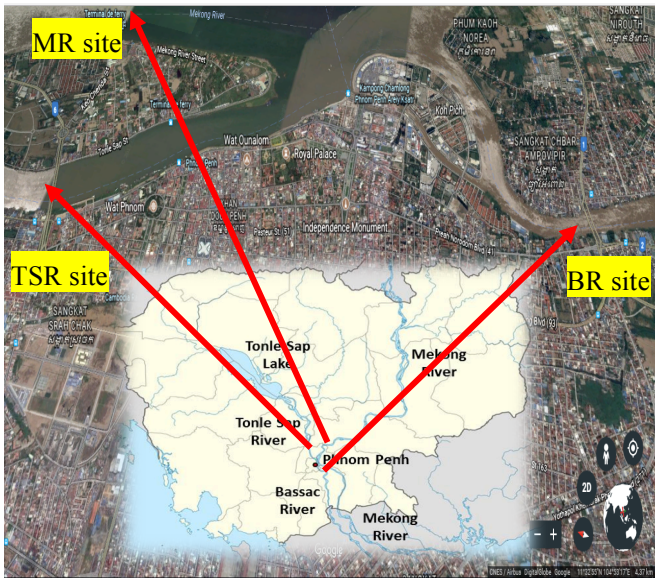

Fig. 1 Study sites

2.2. Experiments on survival of *E. coli* K12

Float-A-Lyzer® G2 was used as a dialysis membrane with molecular weight cut off (MWCO) from 0.1-1,000 kilo Dalton. The overnight culture of *E. coli* K12 strain W3110 was centrifuged at 4000 rpm for 15 minutes and washed twice with Phosphate Buffer Saline (PBS). Then the final cells were diluted 10 times with PBS in order to start field experiment with 10^8 or 10^7 CFU/mL There were 6 experimental conditions as shown in **Table 1**. The control was done by adding 1 mL of bacterial suspension inside the dialysis membrane with 9 mL of PBS while the outside of membrane, 9 mL of river water was added with 1mL of bacterial suspension. The dialysis membranes were placed on the surface of waters for 12 days and 1 ml samples were collected on day 0, 1, 2, 4, 6, 8, 10 and 12 for microbial counts by spread plate technique and incubated at 37°C for 48h. The numbers of colonies with salmon to red (coliforms), blue to violet (*E. coli*) and white colonies (other Gram-negative bacteria) were counted and calculated as CFU/mL.

Table 1 Experimental conditions of *E. coli* K12

Condition	Bacteria	Inside	Outside	Site
1	*E. coli* K12	PBS	RW	TSR
2	*E. coli* K12	RW		
3	*E. coli* K12	PBS	RW	MR
4	*E. coli* K12	RW		
5	*E. coli* K12	PBS	RW	BR
6	*E. coli* K12	RW		

2.3. Detection of antibiotic-resistant bacteria

River water samples were also collected from the 3 sites above. The colonies that could grow on R2A agar plates containing ampicillin (50 µg/mL), meropenem (5 µg/mL), kanamycin (50 µg/mL), ciprofloxacin (5 µg/mL), vancomycin (30 µg/mL) and tetracycline (50 µg/mL) were ARB. And cycloheximide was added to these plates in order to inhibit the growth of yeasts and molds.

3. RESULTS

3.1. Physicochemical and biological characteristics of river waters

The physicochemical and microbiological characteristics of TSR, MR and BR are shown in **Table 2**. The turbidity of these rivers was a bit different between them. In addition, *E. coli* were present highest in TSR, 1.27×10^3 CFU/mL, followed by BR, 7.67×10^2 CFU/mL, and MR, 6×10^1 CFU/mL, was the lowest.

Table 2 Physiochemical and biological characteristics of waters in TSR, MR and BR

Parameter	TSR	MR	BR
pH	5.70 ± 0.02	5.87 ± 0.02	5.90 ± 0.01
EC (mS/m)	10.26 ± 0.01	10.52 ± 0.04	10.58 ± 0.02
Turbidity (NTU)	186.60 ± 1.25	250.00 ± 1.63	267.33 ± 1.25
TDS (ppm)	67.33 ± 0.47	69.33 ± 0.47	70.67 ± 0.47
TP (mg/L)	0.47 ± 0.00	0.43 ± 0.00	0.54 ± 0.01
TN (mg/L)	2.50 ± 0.01	2.40 ± 0.01	2.65 ± 0.00
E. coli (CFU/mL)	$1.27\times10^3 \pm 3.09$	$6\times10^1 \pm 2.45$	$7.67\times10^2 \pm 4.62$
Coliforms (CFU/mL)	$2.8\times10^3 \pm 8.83$	$1.60\times10^2 \pm 9.81$	$2.47\times10^3 \pm 1.70$
Other bacteria (CFU/mL)	$2.6\times10^3 \pm 11.43$	$3.07\times10^2 \pm 3.09$	$1.27\times10^3 \pm 3.09$

3.2. Comparison of the survival of *E. coli* K12 in TSR, MR and BR

The survival of *E. coli* K12 in 3 different sites with two different conditions (control and sample) is shown in **Fig. 2**. In day 1 of control condition, the concentration of *E. coli* K12 in TSR was higher than that in MR and BR, while *E. coli* K12 in BR were the lowest (**Fig. 2a**). However, the number of *E. coli* K12 in TSR became the lowest while those in MR were the highest in day 2. In contrast, their numbers were lowest in MR and highest in TSR in day 4. Moreover, there were similar concentrations of bacteria in these 3 sites in days 6 and 8. On the other hand, *E. coli* K12 in TSR site were not detected in day 10. In **Fig. 2b**, the numbers of *E. coli* K12 in day 0 were not different between these 3 sites. It was noticed that *E. coli* K12 in MR were highest in day 1 and

they were highest in BR in day 2. In day 6, their numbers were similar among these 3 sites. Despite of this, their number was high in MR while they were similar in TSR and BR in day 8. Finally, only there was no *E. coli* K12 detected in TSR but they still be detected in MR and BR in day 10. And their number was high in MR than in BR.

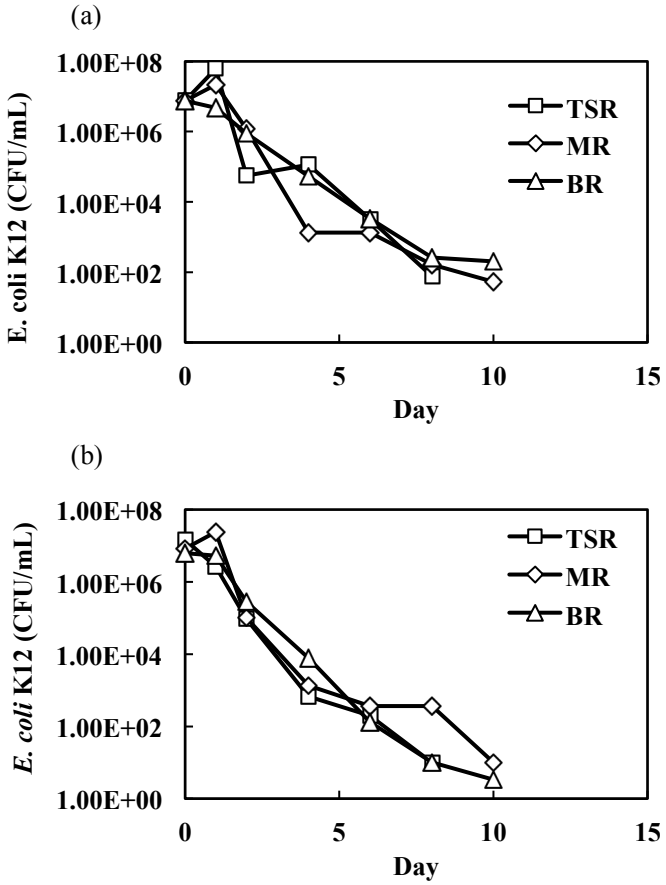

Fig. 2 Survival of *E. coli* K12 in TSR, MR and BR: (a) control and (b) sample

3.3. Comparison of antibiotic-resistant bacteria TSR, MR and BR

The numbers of bacteria resistant to all antibiotics were found to be high ranging from 3×10^2 to 2.31×10^4 CFU/mL. Among these 3 sites, the bacteria resistant to ampicillin, meropenem and tetracycline were reported to be the highest in TSR and lowest in MR. Moreover, the bacteria resistant to ciprofloxacin, kanamycin and vancomycin were found to be highest in TSR and lowest in BR. For the controls which contained only cycloheximide, the numbers of bacteria were 2.55×10^5 CFU/mL, 6.59×10^3 CFU/mL and 9×10^3 CFU/ml in TSR, MR and BR, respectively.

4. DISCUSSION

Comparing to drinking water quality standard by Institute of Standard of Cambodia (2004), which allowed only other bacteria to be present in the range of 100 CFU/mL while Coliforms and *E. coli* are not allowed to be present, 0 CFU/mL. It could be interpreted that it would affect to people who consumed these waters directly without boiling or any treatment, especially referred to those people who are living along the rivers.

In our previous study, the survival experiments were conducted only 6 days. The result showed that *E. coli* K12 in TSL lost their presence on day 6 while on that day, they were still detected for all conditions conducted in TSR. Therefore, TSR provided better conditions for the survival of *E. coli* than TSL. In this recent study, it also showed that *E. coli* K12 in TSR could survive until day 8 and *E. coli* K12 in MR and BR could survive until day 10. It is suggested that MR and BR provide better conditions than TSR and TSL. Therefore, the survival of *E. coli* K12 is not short and their presence can be harmful to people who use these waters without treatment before drinking.

Among the 3 sites, the bacteria in TSR were resistant to all antibiotics with the highest concentration. This result may be because of the multiple usages of antibiotics along the Tonle Sap River and Tonle Sap Great Lake for aquacultural purpose or left over after human consumption to treat diseases.

5. CONCLUSION

The physicochemical characteristics of waters did not affect the survival of *E. coli* K12 in these 3 sites even though the turbidity was reported to be highest in BR that could block the sunlight into the water. In TSR, *E. coli* K12 could survive for 8 days only but they continued to survive until day 10 in both MR and BR. In addition, the bacteria present in these 3 waters were resistant to all antibiotics used in this study with high concentrations from 3×10^2 to 2.31×10^4 CFU/mL. And the highest concentration of all antibiotic-resistant bacteria was found in TSR.

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O3-36

Temporal Dynamics of Water Quality in Tonle Sap Lake in Kampong Loung, Cambodia, Based on Historical Data

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Keywords: temporal variation, Spearman, Mann-Kandall, Sen's slope, cluster analysis.

ABSTRACT

Assessment of seasonal changes in surface water quality is an important aspect for evaluating temporal variations of river pollution due to natural or resulting from inputs of point and non-point sources. In this study, the total of 16 surface water quality parameters was collected from 1995 to 2010 at the Kampong Loung, the Southern part of the largest freshwater source in South East Asia, Tonle Sap Lake by MoWRAM. Hierarchical agglomerative clustering technic was applied to assess classification of the data. The trend analysis was done using the Mann-Kandall and Sen's slop estimator based on cluster and monthly average from 1995 to 2010. The analysis reveals 3 classes were found with the level of (Dlink/Dmax) x100 < 25%. The significant trend was detected significance for most parameters except CODMN for the monthly average trend analysis. The positive trend was determined in the first cluster. The test found temperature has significantly increased which lead to increasing concentration Ca, K, and TOTP. The reason of increase TSS due to the movement of floating village and busy boat navigation. The study is crucial for understanding for future sampling as well as supporting a decision on lake management.

1. INTRODUCTION

Surface water quality is the vulnerable to pollution from runoff which contributed by nature or human activities [1]. The water quality of water resource is an unending issue. Conducting the water quality assessment for long-term water quality is the main challenging problem to research around the globe. In the last decade, water quality inspection has rapidly increased to raise awareness for a better understanding of its temporal corresponding the future study and evaluation of water quality characteristic. However, the result has to be interpreted or simplified be useful to the public [2]. The multivariate statistical method is widely used to better understanding of water quality characteristic and its source. The methods are known as parametric and non-parametric. The parametric method is more powerful than non-parametric but its required normal distributed time series data and independent. The method is used to determine the linearity of the regression using a t-test to compute the significance level of slope. The Mann-Kendall's test is the most common method applied in non-parametric parameters. The increasing and decreasing can be computed by the test [2-3].

The presente study aimed to classify the sampling frequency for the future monitoring program in the Kampong Loung using hierarchical agglomerative cluster analysis and to assess trend of water quality by monthly average and trend of water quality in each cluster using Mann-Kendall Sen's slop test.

2. METHOD

Study Site: The Tonle Sap Lake is located in central part of Cambodia in **Fig 1**. It is an integral part of the Mekong River system. It is the largest permanent freshwater body in Southeast Asia and an important natural reservoir for the Mekong River. This phenomenon occurs annually in May–June. In September–October, when the water level in the Mekong starts to recede, this stored water starts to drain back into the lower Mekong and Bassac Rivers Fig.1.

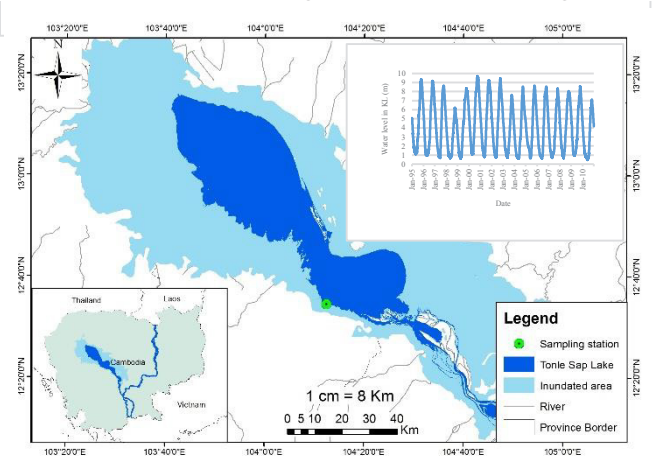

Fig. 1 Location of Kampong Luong station and its fluctuation of water level during 1995-2010

Hierarchical Agglomerative Cluster Analysis was used to group sampling frequency. The monthly average of water quality parameters from 1995 to 2010 were used.

In order to detect a trend, Mann-Kendall Seasonal Test was

applied on 16 water quality parameters from 1995 to 2010. The level of the positive or negative trend was found by means of Sen's slope. The targeted parameters were: water temperature (TEMP), pH, Total suspended solids (TSS), conductivity (COND), calcium (Ca+2), magnesium (Mg+2), sodium, (Na+), potassium (K+), Alkalinity (ALK), chloride (Cl), sulfate (SO4-2), Nitrates (NO3-2), Ammoniacal-nitrogen (NH4-N), total phosphates (TOTP), dissolved oxygen (DO), chemical oxygen demand of permanganate (CODMn).

3. RESULT AND DISCUSSION

Temporal Cluster Analysis: In cluster 1, the clustering showing the convenient time by combining the 5 months together starting from February to June which corresponding to the lowest season (dry season). Cluster 2 (September to November) and cluster 3 (December, January, July and August) **Fig. 2**. With consistent to the peak and receding period (water in the lake start to rise to peak in September to November and start to recede in December, January, July and August). This suggest that for water quality assessment, only one time in each the cluster is adequate enough to represent water quality data in the study area (i.e. sampling frequencies can be done 3 times a year in Kampong Loung). Among all clusters, most water quality parameters in cluster 1 found consist of positive trend while cluster 2 has no trend and a negative trend found in cluster 3.

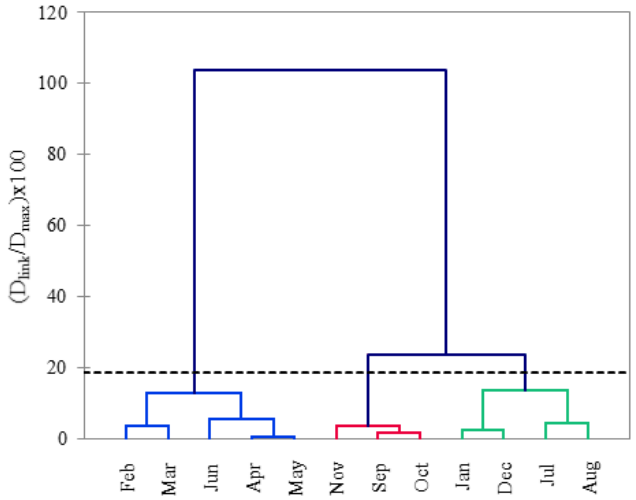

Fig. 2 Dendrogram showing cluster analysis of sampling frequency

Temporal variability of monthly water quality: To understand the temporal variability of monthly water quality, result from analysis was used to group the monthly water quality. The average monthly water quality was shown in **Table 1**. The average monthly water quality supported the clustering results by showing the similar of monthly average value of each parameters. From February to June (cluster group 1, water lever was from 1-2.4 meters. Sept to November (cluster group 2). The rising and falling months (cluster group 3: December, January, July and August), water level were 3.5 to 5.7 meters. Temporal variation of water level resulted in the temporal variation of water quality variables in this area as shown in **Table 1**.

Table 1 Monthly water quality in Kampong Luong by cluster analysis.

Parameters	Cluster 1					Cluster 2			Cluster 3				
Month	Feb	Mar	Apr	May	Jun	Sep	Oct	Nov	Dec	Jan	Jul	Aug
WL_m	2.43	1.55	1.02	1.02	1.57	8.07	8.43	7.49	5.64	4.05	3.59	5.77
TEMP_C	29.5	30.6	31.7	31.3	31.1	29.9	30.6	29.6	28.0	28.4	30.7	29.7
pH	7.30	6.96	6.89	6.99	6.97	6.91	6.98	6.86	6.83	6.91	7.10	7.09
TSS_mgL	37.1	100.9	249.0	247.7	173.5	21.6	7.3	6.1	15.9	27.4	24.8	39.6
COND_mSm	8.12	9.03	8.48	8.71	10.97	9.60	8.56	7.44	7.77	8.69	11.16	10.50
Ca_meqL	0.38	0.33	0.27	0.30	0.44	0.53	0.44	0.37	0.34	0.39	0.53	0.57
Mg_meqL	0.17	0.20	0.19	0.16	0.24	0.25	0.22	0.20	0.22	0.23	0.25	0.25
Na_meqL	0.24	0.26	0.35	0.35	0.34	0.17	0.17	0.16	0.19	0.24	0.26	0.23
K_meqL	0.05	0.05	0.06	0.07	0.05	0.03	0.04	0.03	0.04	0.04	0.04	0.04
ALK_meqL	0.61	0.56	0.50	0.46	0.63	0.80	0.68	0.57	0.58	0.66	0.73	0.84
Cl_meqL	0.09	0.10	0.12	0.16	0.14	0.06	0.06	0.05	0.08	0.09	0.10	0.08
SO4_meqL	0.11	0.12	0.17	0.22	0.27	0.11	0.12	0.11	0.13	0.10	0.21	0.14
NO3_mgL	0.06	0.39	0.60	0.55	0.26	0.08	0.05	0.07	0.07	0.15	0.18	0.16
NH4-N_mgL	0.08	0.14	0.11	0.05	0.06	0.09	0.07	0.06	0.08	0.08	0.10	0.09
TOTP_mgL	0.05	0.11	0.17	0.26	0.15	0.03	0.04	0.03	0.09	0.09	0.06	0.08
DO_mgL	6.70	6.95	5.29	5.96	5.63	5.73	5.70	6.59	5.98	6.27	6.19	5.30
CODMn_mgL	5.65	5.69	5.83	5.06	4.23	3.17	3.09	3.59	4.37	4.78	3.57	2.59

Trend analysis: The test was applied on non-parametric parameters to study the significance of trend at on each month. The result shows the trend detections on monthly average **Table 2** and by the cluster.

The study reveals that positive trend was detected significance for COND, K, SO_4 with the mean value of Sen's slope shown in **Table 2**. Among 16 parameters, SO4 has the most frequent significance trend compare to the other variable (clearly detected as 66% over the year) and COND has significance trend 58% over the year. The increasing of SO4 mainly contributed by SO4 base fertilizer of agricultural land nearby the station (i.e. agricultural land increases its area and consumes more fertilizer). The negative trend was found significance with the average of Sen's slope -0.006 and -0.015 for May and

July respectively for NH4-N. The trend also spotted with CODMN (41% over the year). There is no trend detected for Temp and TOTP. For the rest of parameters such as pH, TSS, Ca, Mg, Na, K, Alk, Cl, NO3, and DO, the trend was detected in less than 25% over the year.

The trend of total suspended solid shows the significance at all level (0.01, 0.05 and 0.11) in February, September and August. TSS has a strong correlation with turbidity.

Therefore, the increase of concentration can be clearly identified. This might cause by the floating village which moved to the concerned area during the lowest season (February) lead to high turbidity. Among all clusters, most water quality parameters in cluster 1 found consist of the positive trend while cluster 2 has no trend and a negative trend of CODMn found in cluster 3. The output of trend study by cluster can be found in **Table 1**. In cluster 1, the temperature was detected increase which leads to significantly increase in Ca, K and TOTP concentration in the lake. Because of lower water level in February, March, April, May and June, the turbidity has significantly increased.

4. CONCLUSION

This study present temporal analyzing of 16 water quality variables from 1995 to 2010 in Kampong Loung, Southern part of Tonle Sap Great Lake. The result from cluster shows the sampling period can be classified into 3 clusters corresponding to three sampling frequency. Water quality sampling can be done in one of the following month, February, March, June, April, or May for cluster 1. In cluster 2, the sampling frequency is done either November, September or October. The third cluster was found and can be grouped January, December, July and August together. The Mann-Kendall and Sen's Slope estimator test reveal both the negative and positive trend. In monthly average, SO4 was found positively increase 66% over the year which contributed by the fertilizer consumed in the paddy field. Moreover, TSS also found a significant increase in February due to the movement of floating house and busier boat traffic. The test shows most water quality variables in cluster 1 such as Temp, TSS, Na, P, Cl, and TP has a significant positive trend. The concentration of the parameters is increase due to the increase in water temperature. The study provides better and understanding of future sampling. Moreover, it has a positive impact to support a decision on lake management.

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Table 2 Trend direction and magnitude of monthly water quality in Kampong Luong from 1995-2010

Month	Temp	pH	TSS	COND	Ca	Mg	Na	K	ALK	Cl	SO4	NO3	NH4-N	TOTP	DO	CODMN
Jan	n.t.	n.t.	n.t.	0.235	n.t.	n.t.	n.t.	n.t.	n.t.	n.t.	0.006	n.t.	n.t.	n.t.	n.t.	n.t.
Feb	n.t.	n.t.	2.36	0.190	n.t.	n.t.	n.t.	n.t.	n.t.	0.005	n.t.	n.t.	n.t.	n.t.	n.t.	n.t.
Mar	n.t.	n.t.	n.t.	n.t.	n.t.	n.t.	n.t.	n.t.	n.t.	n.t.	0.013	n.t.	n.t.	n.t.	n.t.	-0.258
Apr	n.t.	n.t.	n.t.	0.3377	0.012	0.008	n.t.	n.t.	0.012	0.011	0.014	n.t.	n.t.	n.t.	-0.197	n.t.
May	n.t.	n.t.	n.t.	0.431	0.028	n.t.	n.t.	n.t.	n.t.	n.t.	n.t.	n.t.	-0.006	n.t.	n.t.	-0.224
Jun	n.t.	n.t.	n.t.		n.t.	n.t.	n.t.	n.t.	n.t.	n.t.	n.t.	n.t.	n.t.	n.t.	n.t.	n.t.
Jul	n.t.	n.t.	n.t.	0.219	0.020	n.t.	0.009	n.t.	0.022	n.t.	n.t.	n.t.	-0.015	n.t.	n.t.	-0.309
Aug	n.t.	n.t.	3.874	n.t.	n.t.	n.t.	n.t.	n.t.	n.t.	n.t.	0.007	n.t.	n.t.	n.t.	n.t.	n.t.
Sep	n.t.	-0.043	2.507	n.t.	n.t.	n.t.	n.t.	n.t.	-0.008	n.t.	0.007	n.t.	n.t.	n.t.	n.t.	n.t.
Oct	n.t.	n.t.	n.t.	n.t.	n.t.	n.t.	n.t.	n.t.	n.t.	n.t.	0.01	-0.003	n.t.	n.t.	n.t.	-0.125
Nov	n.t.	n.t.	n.t.	0.129	n.t.	n.t.	n.t.	n.t.	n.t.	n.t.	0.007	n.t.	n.t.	n.t.	n.t.	-0.170
Dec	n.t.	n.t.	n.t.	0.181	n.t.	n.t.	0.004	0.0010	n.t.	0.003	0.009	n.t.	n.t.	n.t.	n.t.	n.t.

+	significance at alpha=0.1
*	significance at alpha=0.05
**	significance at alpha=0.01
n.t.	no trend

O3-37

猪苗代湖における湖水水質の長期変動

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キーワード:水質汚濁, 栄養塩動態, 一次生産

抄録

猪苗代湖では, 1990年代中頃から始まった湖水の急激なpH中性化とともに, CODや大腸菌群数の上昇に代表される水質の悪化が顕在化している。本研究では, この原因を調べるために, 福島県が保有している水質データを集計して湖水水質の長期変動傾向を解析した。その結果, 猪苗代湖湖水におけるCODおよび大腸菌群数の上昇は, 中性化後に湖内の生物生産量が飛躍的に増大したことに起因する可能性が高いことがわかった。また, この生物生産量の増大から, 猪苗代湖における栄養塩類動態が pH 上昇とともに変化した可能性が考えられた。今後の猪苗代湖の水質改善策を検討するにあたって, 湖水水質および流入河川水質の長期モニタリングの継続に加えて, 猪苗代湖内の有機物および栄養塩類動態, 流入河川から汚濁負荷実態に関する詳細な調査・研究の実施が必須であると考えられた。

1. はじめに

猪苗代湖は, 酸栄養湖に分類されており, 1995 年頃までは, 湖水の pH が 5 前後の弱酸性を示していた。しかし, 2010 年には 6.8 まで上昇し, 以降は pH がほぼ中性を維持し続けている。また, このpH上昇に伴い, 猪苗代湖では 2002 年頃から COD が上昇し, さらに, 2006 年以降は, 表層水の大腸菌群数が環境基準である(1000MPN 100mL^{-1})を超過し続けるなど, 水質の悪化が顕在化している。

大腸菌群数の上昇は, 猪苗代湖湖水内において, 従属栄養細菌類が中性化に伴って増加していること示唆している。同時に, その増加を支えるだけの炭素基質が湖水内に存在することも示唆している。したがって, その原因を明らかにするためには, 有機物生産に関わる水質項目の長期変動を調べる必要がある。

福島県では, 1970 年代後半から猪苗代湖およびその流入河川において水質データを取得し, 福島県水質年報や福島県環境センター年報という形で公表してきた。しかし, これらのデータを使用して水質の長期変動傾向を解析した例は, 流入河川からの酸性物質負荷量についての報告例[1]が 1 件存在するのみであり, 湖水中の有機物生産の面から長期変動を解析して水質悪化の原因について考察した例については今のところ見当たらない。

そこで本研究では, 福島県がこれまでに蓄積してきた猪苗代湖湖水および流入河川水の水質データについてとりまとめをおこない, 猪苗代湖湖水のCODおよび大腸菌群数上昇の原因について考察した。

2. 方法

2.1. 猪苗代湖の概要

猪苗代湖は, 福島県のほぼ中央に位置する, 集水域面積 820.2 km^2, 湖面積 103.3 km^2 (日本第 4 位), 最大深度 94.6 m, 平均深度 51.5 m の湖である。おもな流入河川は, 北岸へ流入する酸性河川の長瀬川であり, 河川からの総流入量の 50%以上を占めている。猪苗代湖への河川からの流入水量は約 31.7 m^3 s^{-1}, 平均滞留時間は 5.4 年である[2]。

長瀬川河川水が酸性を示す原因は, 長瀬川の支流である酸川の上流部に硫黄川が存在するためである。硫黄川は, 安達太良山の沼ノ平火口が起点であり, 流下に伴い酸性の温泉水(硫黄泉)や旧硫黄鉱山の坑道からの流出水が合流しており, 河川水の pH が 2 前後の強酸性を示すのが特徴である。

2.2. 調査地点

本研究では, 猪苗代湖湖水水質の長期変動を解析するための調査地点として, 環境基準点である猪苗代湖湖心の水質データを使用した。調査地点の位置は, 図 1 に示した。

2.3. 調査期間

前節に記述した調査地点の水質データを福島県水質年報(1974～2014)[3]および福島県環境センター年報(2002～2016)[4]から抜粋して集計した。

3. 結果

3.1. 湖心表層水における pH, アルカリ度およびイオンバランスの長期変動

猪苗代湖湖心における表層水の pH は，1995 年頃から急激な上昇が始まっている。しかし，1974 年から 1995 年の間にも緩やかな上昇が見られた（図 2 (a)）。

表層水のアルカリ度は，pH が急激に上昇している 2002～2016 年の 14 年間の間に，約 3 倍（1.4 mg L^{-1} から 5 mg L^{-1}）の増加が見られた（図 2 (b)）。

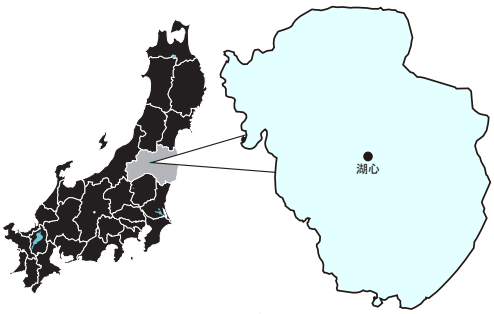

図 1 調査地点位置図

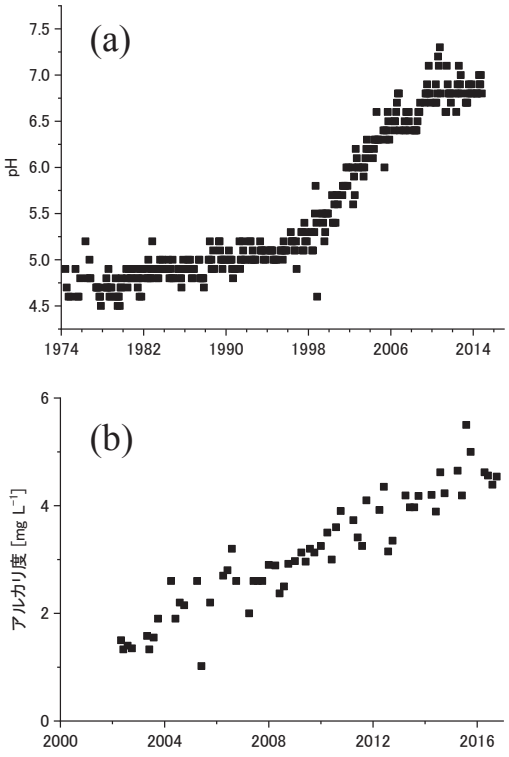

図 2 湖心表層水における(a) pH および(b) アルカリ度の時系列変化

3.2. 動植物プランクトンの細胞密度の長期変動

湖水 pH の中性化以前と以後の動植物プランクトンの細胞密度には大幅な増加が見られた（図 3）。植物プランクトンの細胞密度は，湖水 pH が 5 以下だった 1980～1985 年頃には 10^3 cells m^{-3} 以下だったのに対し，pH が 6.8 になった 2010 年には 10^6～10^8 cells m^{-3} まで増加していた。動物プランクトンの細胞密度も植物プランクトンと同様に 10^2 cells m^{-3} から 10^4 cells m^{-3} に増加していた。

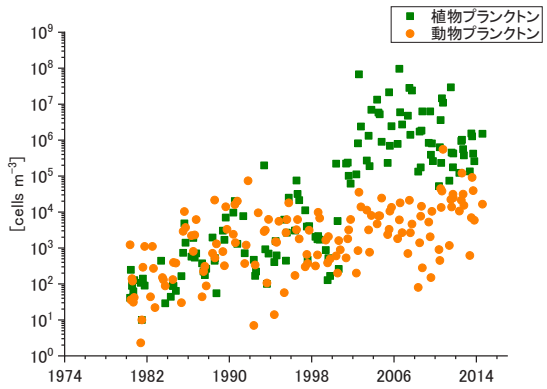

図 3 湖心表層水における動植物プランクトンの時系列変化

3.3. 全窒素濃度の長期変動

猪苗代湖湖水の全窒素濃度は，1982～2014 年の間では 0.17～0.5 mg L^{-1} の範囲で推移していた（図 4）。

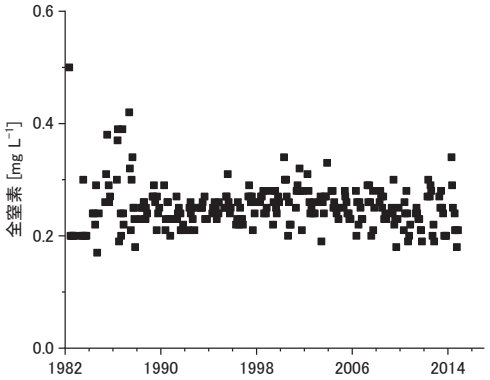

図 4 湖心表層水における全窒素濃度の時系列変化

4. 考察

猪苗代湖の表層水において，動植物プランクトンの細胞密度が湖水 pH の中性化以後に大幅に上昇した。これは，湖水における一次生産量が中性化以後に急激に増加したことを示しており，これが河川からの流入負荷に上乗せされる形になり，COD が上昇したと考えられた。さらに，植物プランクトンの細胞や分泌物には多量の糖質が含まれること[5,6]や細菌類によって優先的に分解されること[5,6]が明らかになっている。猪苗代湖湖水には，これらを炭素基質としている従属栄養細菌類が中性化以後に増加している可能性が考えられた。大腸菌群数の上昇は，従属栄養細菌類のバイオマスの増加を

示唆するものと推察された。

表層水において，湖水 pH の中性化以後に植物プランクトンが急激に増殖した原因は，湖水の pH 上昇によって生体毒性が低下したことに加えて，光合成の炭素基質である重炭酸イオンの増加にもあると考えられた。また，猪苗代湖では，全窒素に関して環境基準の類型指定はされていないが，仮に全リンと同じ類型をあてはめた場合，環境基準値の 0.2 mg L^{-1} を達成できておらず，高濃度の状態が継続している。これは，猪苗代湖への栄養塩類の負荷が大きい可能性を示唆するものと考えられる。猪苗代湖では，酸性の河川から供給される鉄やアルミニウム水酸化物を主成分とするフロックによってリンが吸着されることなどによって湖水中のリン濃度が極端に低い状態にあり，それが生物生産を抑制してきたと考えられている[7]。しかし，湖水の pH が弱酸性から中性に変化する過程において，大きな時間差がなく細胞密度が増加したことから，湖水 pH の上昇とともに湖水中の栄養塩類動態が大きく変化した可能性が考えられた。

5. 結論

長期モニタリング結果の解析から，猪苗代湖湖水における COD および大腸菌群数の上昇は，湖水 pH が弱酸性だった時代には生物生産が著しく抑制された状態にあったものが，中性化後に湖内の生物生産量が飛躍的に増大したことに起因する可能性が高いことがわかった。また，この生物生産量の増大から，湖水中での栄養塩類動態が pH 上昇とともに変化した可能性が考えられた。今後の猪苗代湖の水質改善策を検討するにあたって，湖水水質および流入河川水質の長期モニタリングの継続に加えて，猪苗代湖内の有機物および栄養塩類動態，流入河川からの汚濁負荷実態に関する詳細な調査・研究の実施が必要と考えられた。

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O3-38

Water Quality of Five Selected Lakes in Southern Luzon, Philippines

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Keywords: Physical Parameters, Chemical Parameters, Water Quality, Lakes

ABSTRACT

The study focuses on important lakes in the Philippines such as Bunot Lake, Taal Lake, Tikub Lake, Bato Lake and Buhi Lake. This paper aimed to describe the physical and chemical parameter analyses of five selected lakes in Southern Luzon, Philippines. Three replicates of water samples were collected (phosphate and TSS); and others were measured on sites from five lakes (January to March 2017). The physical parameter included water temperature, pH and turbidity, whereas the chemical parameters included conductivity, dissolved oxygen (DO), phosphate, ammonia, and total suspended solids (TSS). These five selected lakes revealed that conductivity, turbidity, TSS, phosphate and ammonia content exceeds the DENR Administrative Order (DAO 2016-08) range. The results are significantly different between 0.22±0.00 to 1779.42±59.41 mg/L for conductivity; 8.42±1.00 to 50.23±23.02 NTU for turbidity; 1±0.00 to 96±76.68 mg/L for TSS; 0.07±0.01 to 1.22±0.03 mg/L for phosphate; and lastly, 0.27±0.04 to 1.47±0.35 mg/L for ammonia. Taal Lake has the largest variation of conductivity, phosphate and ammonia. Bato Lake has the largest variation of turbidity and TSS. Bunot Lake has the largest variation of phosphate and ammonia because of anthropogenic activities. The extremely high content of TSS and turbidity has caused poor and stressful conditions for the aquatic life of lakes. Proper management, planning and monitoring is required to prevent further damage of the lake ecosystem from different anthropogenic activities.

1. INTRODUCTION

In the Philippines, where there is an increasing number of polluted aquatic ecosystems [1]. Researchers and studies directed to restoring, rehabilitating and managing deteriorating water bodies are gradually getting priority.

Lakes are very valuable resources that provide people with prime opportunities for recreation, tourism, and residential living. Lakes are also home for a huge diversity of flora and fauna in the Philippines.

Through the years, DENR-EMB has proposed water quality parameters – Dissolved Oxygen (DO), pH, Total Suspended Solids (TSS), turbidity, conductivity, water temperature, phosphate and ammonia which are suitable for temperate regions [2]. Water quality parameters are based on DAO 2016-08.

The findings of this research illustrate the potential significance of the lakes in Bicol Region since the production of this fishes known as *Mistichthys luzonensis* or also known as "sinarapan", the world's smallest fish that can be only seen in the Philippines particularly in Lake Bato and Lake Buhi. In Taal Lake which is situated in Talisay, Batangas – this is known for the home of the lowest active volcano and the only freshwater sardinella (*Sardinella tawilis*) in the world. In Tikub Lake which is located in Tiaong, Quezon, it is still unexplored and it has the potential to be one of the tourist destinations in the Philippines. Lastly, the Bunot Lake in San Pablo, Laguna this lake is known for its cultured tilapia and fish pens for *Nilotica* fingerlings.

Therefore, nowadays the solution of water quality and recovery of the multiple functions of water system have become the key issues for environmental biologists. This study aimed to describe the physical and chemical parameter analyses of five selected lakes in Southern Luzon, Philippines.

2. METHOD

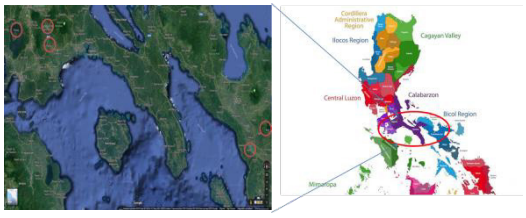

Fig 1. Location of the sampling sites in Southern Luzon, Philippines.
Source: Google map (2018)

Location and Description of the Study Area

Luzon is the largest and most populous island in the Philippines. It is also ranked 15th largest in the world in terms of land area. The study was conducted in two regions of Southern Luzon. First is in Region 4A (CALABARZON: Cavite, *Laguna*, *Batangas*, Rizal and *Quezon*), and second is in Region 5 (Bicol Region: Albay, Camarines Norte, *Camarines Sur*, Catanduanes, Masbate and Sorsogon). Every sampling site is divided into four quadrants.

Sampling Methods

Twelve sampling sites (4 quadrants), 1km from each other were selected in each sampling location. Water temperature, DO, conductivity, turbidity, pH, turbidity and ammonia were measured onsite using a pre-calibrated Horiba (model: U-10) water quality checker. The probes were immersed in water and the parameter readings were noted after measurement stabilization.

Water samples were also collected for each sampling sites for the parameters that were not measured onsite. Sterile bottles were used to contain water samples for the TSS and Phosphate. These two are brought to Department of Environment and Natural Resources – Environmental Management Bureau (DENR-EMB) Region 4-A Laboratory for the analyses test. Method of analysis for Phosphate (as Ortho) is Ascorbic Acid Method and for TSS is Gravimetric Method [3]

3. RESULTS

Table 1. Mean value±SD for the Physical and Chemical Parameters of the Five Selected Lakes along the Southern Luzon, Philippines.

Parameters	Units	Lakes				
		Bunot (Laguna)	Taal (Batangas)	Tikub (Quezon)	Bato (Camsur)	Buhi (Camsur)
Temperature	°C	25.7±0.13	26.8±0.39	27.2±0.14	28.65±0.59	26.25±0.33
Turbidity	NTU	8.42±1.00	14.65±0.92	9.50±0.52	50.23±23.02*	16.26±17.59
pH	-	7.65±0.24	8.41±0.86	7.60±0.10	8.16±0.18	8.45±0.15
Conductivity	µS/cm	0.22±0.00	1779.42±59.41*	0.24±0.00	340.25±65.83	236.83±101.87
TSS	mg/L	7±2.75	1±0.00	1±0.29	96±76.68*	3±0.72
Phosphate	mg/L	1.22±0.03*	0.77±0.01*	0.07±0.01	0.24±0.13	0.11±0.30
DO	mg/L	7.43±0.26	6.78±0.46	5.48±0.52	7.51±0.64	7.97±0.21
Ammonia	mg/L	1.47±0.35*	1.03±0.39*	0.45±0.21	0.66±0.16*	0.27±0.04

Notes: * indicates that the lake's values are significantly different from those of every other lake ($\alpha<0.05$)

Table 1 summarizes the mean±SD of the physical and chemical parameters from the five lakes along Southern Luzon, Philippines. The water temperature of the five lakes ranged from 25.7±0.13°C to 28.65±0.59°C. All the data of water temperature are within the standard limit of DENR. The turbidity is become high also in Bato Lake (50.23±23.02 NTU) because of the dipersion of suspended particles. It is caused by fine sediment and organic particles. The turbidity values of the five lakes varied from 8.42±1.00 NTU to50.23±23.02 NTU, which exceeds the maximum standard of Minnesota Pollution Control Agency (25 NTU) [4]. A significant difference was found between the Bunot Lake (8.42±1.00 NTU) and Bato Lake (50.23±23.02 NTU). pH levels of this study is within the standard limit of DAO 2016-08.

The water conductivity of the surface water varied from 0.22±0.00 µS/cm to 1779.42±59.41 µS/cm. The only lake which exceeds the maximum limit of US EPA in conductivity was Taal Lake which has the value of 1779.42 µS/cm. The TSS included silts and clays, which cause the brownish color of the lake. The lakes in Southern Luzon ranged from 1±0.00 mg/L to 96±76.68 mg/L, which exceeds the DAO 2016-08 limit for Class C. The smallest value of TSS at Taal Lake (1±0.00 mg/L) and the greatest value at Bato Lake (96±76.68 mg/L). The TSS for the Southern Luzon was significantly different between Taal and Bato Lake.

Phosphate values range from 0.11±0.30 mg/L to 0.77±0.01 mg/L, which is alarming that exceeds in the DAO 2016-08 limit for Class B and C for Taal and Bunot Lake. The DO levels of the lakes varied from 5.48±0.52 mg/L to 7.97±0.21 mg/L which is within the DAO 2016-08 limit. The maximum value of DO was detected at Buhi Lake (7.97±0.21 mg/L) and the lowest DO value was detected at Tikub Lake (5.48±0.52 mg/L). The results for ammonia, exceeds for both Class B and C limit: for Bunot Lake (1.47±0.35 mg/L), Taal Lake (1.03±0.39 mg/L), and Bato Lake (0.66±0.16 mg/L) but according to BFAR (Bureau of Fisheries and Aquatic Resources) the values are still safe for fishes.

4. DISCUSSION

These five lakes were classified into polluted and non-polluted lakes according to their classification, but after the results it turned out that rapid changes happened in these lakes. Before Taal Lake was classified at Class B, but due to certain results that above the maximum levels of parameters this lake fall into Class C.While Bunot and Bato Lake exceeds in the results for Class C. Tikub Lake maintains its Class, one of the non-polluted lake in the Philippines that has a huge potential of tourist destination.

The water temperature is the most important ecological

factor because it controls the physiological behavior and distribution of organisms [5]. The highest turbidity value was observed in Bato Lake (50.23±23.02 NTU) and the lowest turbidity value was observed in Bunot Lake (8.42±1.00 NTU). High tubidity can significantly reduce the good quality of lakes and can harm aquatic organisms by reducing food supplies, affecting gill functions and degrading spawning beds, it has been found out that the lake are turbid this means that there are a lot of suspended solid particles in the lake (soil from erosion, particulate matter, unconsumed fish feeds, and some plankton or microorganisms). The pH is one of the most important factors and serves as index for pollution. pH range between 6.5 to 9.0, where the fish grows well and fast in freshwater ecosystem [6].

The values water conductivity for the lakes is the following: low conductivity has 0 to 200 µS/cm; it means an indicator of pristine or background conditions. Mid-range conductivity is about 200 to 1000 µS/cm which is normal background for most freshwater. Conductivity outside this range could indicate that the water is not suitable for certain species of fish. High conductivity around 1000 to 10,000 µS/cm is an indicator of saline conditions [7]. TSS content between 1 and 96 mg/L on the mean values previously indicated the poor condition of aquatic ecosystems [8]. The high value of TSS during the season occurred because of the floating fine silt and detritus that was carried by the rainwater from the catchment [9]. Rapid changes and extremely high TSS values are stressful to fish and other aquatic organisms.

The low DO value may be because of high organic matter content. High organic matter limits primary production, and the senescence of phytoplankton increases microbial respiration that leads to the depletion of DO [8,9,10]. Meanwhile, ammonia (NH_3) is the major end product of protein catabolism excreted by fish and this is due to decomposed organic matters like unconsumed feeds and fertilizers, industrial and domestic wastes and decomposition of phytoplankton.

5. CONCLUSION

Physical and chemical analysis of the lakes in the study area demonstrated that the lakes was clean, with the exception that certain physicochemical parameters (such as TSS, turbidity, phosphate, ammonia and conductivity) had increased to extremely high levels that exceed the standards of DAO 2016-08, US EPA (conductivity) and Minnesota Pollution Control Agency (turbidity). As a result of Bunot Lake has the greatest variation in terms of Phosphate and Ammonia; Taal Lake has the greatest variation of Conductivity, Phosphate and Ammonia; and lastly, Bato Lake which has the highest value of Turbidity and TSS, and also exceeds in Ammonia.

Therefore, the researchers conclude that Taal Lake doesn't meet the criteria for Class B in terms of the parameters of Phosphate, Ammonia and Conductivity. Bato Lake is considered polluted for having high results of Turbidity and TSS of the water lake and ammonia results also is above the maximum value. Taal Lake and Bato Lake are both major lakes of the Philippines and also classified as big lakes, these two played an important role in the community, proper management and planning is required to prevent further damages of the lakes. It is noted that the recovery of the lakes from effects may take several years depending on the people's efforts and concerns as well as earth dynamics.

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O3-39

Genomic analysis of two odoriferous *Streptomyces* sp. isolated from tropical freshwater of Southeast Asia provide an insight into the identification of potential temperature sensor

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Keywords: Streptomyces, Temperature Sensor, Genome Sequence, Biosynthesis, Musty Odor

ABSTRACT

Musty odor compounds released have mostly been studied during the warmer season and well documented. Previous study successfully isolated two odoriferous *Streptomyces* sp. (S1 and S5) from tropical freshwater of Southeast Asia. Both isolates showed distinct characteristics against temperature difference (20°C and 30°C). S1 showed clear induction of geosmin at 30°C and none at 20°C contradict with S5 which produced higher amount of geosmin at 20°C compared to 30°C. In case of temperate isolate, they have thermosensing device to adapt temperature changes. However, S5 does not work to sense the temperature as it shows less sensitivity than S1 which lead to our hypothesis that S5 does not have the sensor for temperature stress. These isolate were then sequenced using Illumina HiSeq4000 and draft genome sequence yielded 7.79 Mb and 7.20 Mb genome size of S1 and S5, respectively. Since the genome size of S5 is smaller compared to S1, there might be some regulatory proteins which not available in the genome of S5 is/are available in S1 may be the possible temperature sensor. Here, we provide draft genome sequence analysis of both isolates which is very important for discovery more about this temperature sensor and to understand how the mechanisms involve in these isolate.

(204 words)

1. INTRODUCTION

Streptomyces is one of the most promising producer of secondary metabolites including antibiotics, immunosuppressant, extracellular enzymes and terpenoid metabolites [2, 4]. Geosmin, a terpenoid compound is widely known for its responsibility towards musty odor issue in freshwater systems worldwide. This odor issue is mostly prominent during cyanobacterial blooms in a warmer month in temperate regions. However, geosmin production by *Streptomyces* in tropical Asia has not yet been elucidated in details. Since tropical Asia is warm and stable throughout the year, the odor events can be expected to occur at any time of the year.

Our previous study investigated the effect of temperature on musty odor production by *Streptomyces* sp.[1]. Two isolates (S1 and S5) showed unique features to sense temperature stress. S1 shows high geosmin production at 30°C but no detection at 20°C which indicate that it has a good sense of temperature. But S5 does not work to sense the temperature as it produced higher amount of geosmin at 20°C compared to 30°C. S5 may possess some unique traits that allows it to produce large amount of geosmin at low temperature which contradicts with previous research of larger production at high temperature or in warmer seasons. We postulated that S5 did not contain the temperature sensor. Since S5 showed less sensitivity to temperature compared with S1, maybe some of the genes related to temperature sensor in S5 is missing. We need to see the difference between these two isolate and find which genes or proteins are available only in S1 and S5. If we find several genes in S1 but absent in S5, that genes supposed to be the temperature sensor. Therefore, draft genome analysis of these isolates were done in order to identify the missing or adding genomic content for temperature stress responded protein.

2. METHOD

General procedures.

Isolation of bacterial strains, temperature condition experiment and molecular experimental were discussed in details in our previous study [1].

DNA extraction, library preparation, sequencing, data preprocessing and assembly.

Bacterial DNA samples were extracted by using EZ-10 Spin Column Bacterial Genomic DNA Miniprep Kit according to the manufacturer's protocol. All the standard bioinformatics data analyses were provided by sequencing company (Genome Solution Sdn Bhd). Genome sequencing was performed using high-throughput Illumina

HiSeq4000 with a 150bp Paired End (PE) strategy. Sequencing reads were preprocessed, in order to use for de novo genome assembly and scaffolding. To predict putative genes in assembled genomes, an automated web-based tool RAST was used.

Bioinformatics analysis.

Ten homologous genes related to known germacradienol/geosmin synthase were obtained from GenBank (Q9X839, ABY50951, WP_003971162, WP_012382258, WP_014158016, WP_010983603, WP_018956438, WP_018515109, WP_014143690, and WP_012999852). BLAST algorithm was used for searching the homologous genes. Amino acid sequences alignment by MAFFT was done for searching the geosmin synthase conserved motifs in the isolates. To find unique protein sequences only in S1 (possible temperature sensor), USEARCH [3] analysis was used. S1 was used as query sequence and S5 was used as database. Then the sequences were analyzed using Pfam database to categorize the protein into several transcriptional regulators.

3. RESULTS

Genome properties

The draft genome of S1 contains 7.79 Mb with GC content of 72.33%, which containing 5792 protein-coding genes. As for S5, 7.20 Mb genomic size with 71.96% GC content and total of 6860 protein-coding genes. The summary of assembly statistics are shown in Table 1.

Table 1 Summary of the RAST-predicted genes and RNAs in the assembled genomes of S1 and S5

	S1	S5
Genome size (bp)	7,791,937	7,203,872
Number of Protein-coding Genes	5,792	6,860
Number of RNAs	72	70
GC content (%)	72.33	71.96
N50	33506	8483
Contig number	515	1463

Homology-based search

S1 and S5 shows high sequence similarity to the known germacradienol/geosmin synthase database with more than 60% similarity (data not shown). Bacterial terpene synthase typically displays two highly conserved Mg^{2+} binding motif: aspartate rich motif (**DD**XXX) and **NSE** triad. From the alignment results by MAFFT, N- and C-terminal of S1 and S5 (only S1 result was shown) shows significant sequence similarity to germacradienol/geosmin synthase to the homologous genes with the repetition of NSE motif **N**DLLT**S**RLHQF**E** at the N-terminal (Figure 1).

Predicted temperature sensor

Here, we want to identify which amino acid sequences is available only in S1 but absent in S5 which can be a candidate for the temperature sensor. From the USEARCH analysis, we found 5 query sequences that matched and 5787 sequences that not matched with the database (data not shown). From these 5787 unique protein sequences, we categorized each sequence into their possible transcriptional regulators (TRs) and separated it into two groups based on their regulated functions (Table 2). Group 1 comprised of TRs needed for the basic of cell functions and Group 2 TRs involved in either organism's metal homeostasis or in response to stressful situations [5].

Table 2 Transcriptional regulators (TRs) found in the unique sequences

Group 1	AraC, AsnC, DeoR, GntR, IclR, LacI, LuxR, ROK
Group 2	ArsR, MarR, MerR, TetR, LysR, PadR

4. DISCUSSION

Amino acid alignment shows that germacradienol/geosmin synthase has four Mg^{2+} binding motif, **DD**HFL and **N**DLF**S**YQR**E** in N-terminal and **DD**YYP and **N**DLF**S**YQK**E** in C-terminal which is essential for catalysis of geosmin [6]. Based on the amino acid alignment and conserved domains, we propound that S1 and S5 can serve as a germacradienol/geosmin synthase similar to already characterized *S. coelicolor* A3(2) SCO6073 and *S. avermitilis* SAV2163.

Comparison of the draft genome results between both isolates shows that S5 have smaller genome size compared to S1. Therefore, lead to our hypothesis that S5 does not have a good sensor for temperature. We therefore were intrigued that there might be some genes that supposed to be involved are absent in S5. USEARCH analysis with the 'search_exact' command have been performed on the amino acid sequences of S1 against of amino acid sequences of S5. Based on USEARCH results, 5787 amino acid sequences that have no matched within S5 database are defined as unique proteins. We managed to get these temperature sensor candidates. This result is very important for the screening of temperature sensor before proceed with the molecular experimental works. Bacteria that exposed to environmental stress need to adapt and response in order to survive by modifying their gene expression. One of the major players in this mechanism is a protein called transcription factors (TFs) which responsible for induction and repression of certain genes.

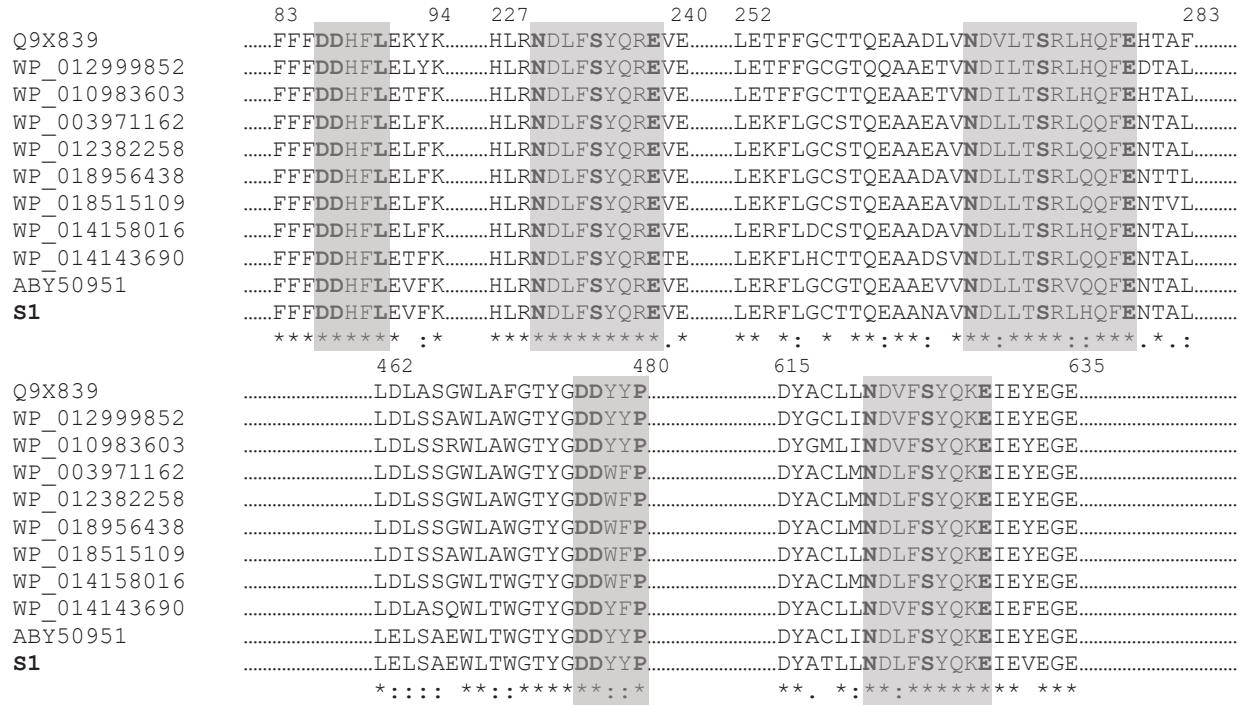

Fig.1 Amino acid sequence alignment of S1 with its homologs. Shadow boxes indicate Mg^{2+} binding motif of germacradienol/geosmin synthase, "*" indicates exact match, ":" indicates moderate match and "." indicate low match

So far, there is no evidence on regulatory protein that can sense the temperature stress which act as a switch in any *Streptomyces*. To gain better understanding, we characterized the unique sequences into several transcriptional regulatory families. Since this is just a preliminary result, we believe that our progress will uncover a novel temperature sensing mechanism. However, this presumption needs further investigation.

On the other side, we also interested in looking at the differences between temperate and tropical *Streptomyces*. There is no clear proof evidence between the tropical and temperate bacterial genome so far. In temperate zone, the weather range from warm or hot in summer and cold in winter in which bacteria may need extra genes to keep them to adapt with the cold temperature. But different from the tropical zone where the weather is warm year round, they do not need to keep this gene. Since it is unnecessary for keeping of the gene, their size is expected to be small. They supposed to remove all unnecessary functions as keeping or duplication of the genes, they need to use lots of energy. Basically, what we are trying to propose is that the element of sensing temperature is not necessary to be carrying in the genus of *Streptomyces* in tropical country.

5. CONCLUSION

Overall, results presented here are still in the preliminary stage. Genomic analysis and transcriptional regulators characterization provide better understanding on what is happening inside. We are now continuously working deeper into the regulatory mechanism underlying temperature response which may lead to the discovery of the new enzyme or pathway for secondary metabolite production from tropical isolates.

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O3-40

Eutrophication Mapping of Lowland Lakes in Nepal

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Keywords: water quality, Chl-a, eutrophication

ABSTRACT

Eutrophication is a major water quality problem in the lakes of lowland of Nepal, causing turbid water with high algal biomass and offering poor condition loadings of limiting nutrients, such as nitrogen and phosphorus (i.e., cultural eutrophication), to the aquatic ecosystem with dramatic consequences for drinking water sources, fisheries and recreational water bodies. To mitigate these problem this study was conducted to assess the status of eutrophication of Betana Lakes, Rajarani Lakes and Tal Taliya Lakes of Eastern Nepal through remote sensing techniques and comparing the eutrophication indices derived from field data with remote sensed data. For each lake, two sites were sampled and two samples were collected for the measurement of Chlorophyll-a (Chl-a), Phaeophytin, Nitrate, Phosphate, and Ammonia. Chl-a concentration was found to be in the range of 9.6 -38.7 in Betana Lakes, 1.5-38.28 in Raja Rani and 8.9-39.0 in Tal Taliya of lowland Nepal. The remote sensing based Chl-a prediction model was applied where the Landsat visible bands ranging from blue (OLI 2) to green (OLI 4) and near-infrared band (NIR) (OLI 5) were used and applied to obtain the relationship between the sub-surface reflectance and the bio-physical parameters. Highest correlation (R2= 0.9176) was found between in-situ Chl-a concentration and band ratio of the reflectance of Landsat 8 OLI band (B5/B4). Therefore, this band ratio (B5/B4) was considered as the best predictor of Chl-a concentration and further used for developing the prediction model for the eutrophication mapping of the lakes.

1. INTRODUCTION

Inland waters are important natural resources around the world; yet they are threatened by eutrophication due to climate and anthropogenic changes. Eutrophication is a major water quality problem worldwide, causing turbid water with high algal biomass and offering poor condition to the aquatic ecosystem(Portielje and Van der Molen, 1999). Eutrophication occurs naturally over centuries as lakes age and are filled in with sediments(Odermatt et al., 2012).

Chlorophyll-a (chl-a) is a photosynthetic pigment that is found in all green floral components including algae(Wetzel, 2001). However, excessive concentration of Chlorophyll is undesirable as it inculcates eutrophic condition of the lake(Hallegraeff, 2003) and results in increment of phytoplankton standing crop(Boyd and Tucker, 1998). So, Chlorophyll estimation is regarded as an indicator of nutrient status of aquatic body and helpful for monitoring and managing the eutrophic lakes (Carlson, 1977).

Satellite remote sensing is fast and relatively low operational cost process and can be used as a tool to derive spatio-temporal variability in lake water quality (Zilioli and Brivio, 1997).

Landsat imagery has proven to be useful in understanding global trends in landuse change over different timescales. Recently, satellite-derived data are being used to monitor water quality among other things. The 15 m and 30 m resolution of the Landsat 8 Operational Land Imager (OLI) combined with high global data availability, present a unique platform to provide the first and most up-to-date global inventory of the world's lakes and water quality information retrieval at high spatial resolution and positional accuracy using recent Landsat algorithms (Li and Sheng, 2012; Sheng and Li, 2011; Smith, 2005). This study is the first time that a remote sensing technique is being utilized for the measurement of eutrophication and lake management in Nepal.

Objectives

The main objective of this study is to assess the status of eutrophication of various lakes using remote sensing techniques and compare the eutrophication indices derived from field data with remote sensed data. The specific objectives are:

- To determine the effectiveness of spectral

reflectance values from the Landsat-8 OLI in respect to measurement of Chl-a and Trophic State Index (TSI) in the Betana Lake of Morang district, Tal Talaiya of Sunsari district and Rajarani Lake of Dhankuta District.

- Compare in-situ Eutrophication index with Remote Sensed Eutrophication index and validate result.
- To analyze the seasonality of the eutrophication at the study sites.

2. METHOD

The Betana Lake in Morang District, TalTalaiya Lake in SunsariDistrict, and Rajarani Lake in Dhankuta District, the lowland lakes of Nepal were selected as the study area to assess the applicability and pilot the application of remote sensing to measure eutrophication levels in Nepal.

Water sampling procedure for in-situ measurement

The in-situ sampling was performed on the prefixed date when Landsat satellite overpasses the Study area. For each lake, two sites were sampled and considered as study points in this study. From each of the sampling sites two samples were collected for the measurement of Chlorophyll-a (Chl-a) as per APHA using the formula;

$$Chl\text{-}a = 11.85(OD664) - 1.54(OD647) - 0.08(OD630)$$

Remote sensing with Google Earth Engine

The Google Earth Engine (GEE), an online environmental data monitoring platform in 30 m spatial and 15 m multispectral resolution incorporates was used for studying inland water bodies of the study areas.

Retrieval of Eutrophication Indices from LANDSAT data

Correlation between OLI brightness values and the water quality parameter by linear regression analysis was used in the study.

3. RESULTS

Table 1 Pearson correlation coefficients (R) between Chlorophyll-a (Chl-a)concentrationand various Landsat OLI bands and band ratios of the study points

Band Combinations	*R*	*Band Combinations*	*R*
B2	0.41	(B3+B5)/2	0.32
B3	0.16	(B2+B5)/2	0.45
B4	0.3	(B4+B3)/2	0.23
B5	0.49	(B4+B2)/2	0.37
B5/B2	-0.54	(B3+B2)/2	0.3
B5/B3	0.009	(B2+B3+B4)/3	0.3
B5/B4	**0.9176**	(B2+B3+B5)/3	0.36
B4/B3	-0.26	(B3+B4+B5)/3	0.31
B4/B2	-0.64	(B2+B4+B5)/3	0.31
B3/B2	-0.71	(B2+B3+B4+B5)/4	0.35
(B4+B5)/2	0.4	**The bold indicates highest correlation**	

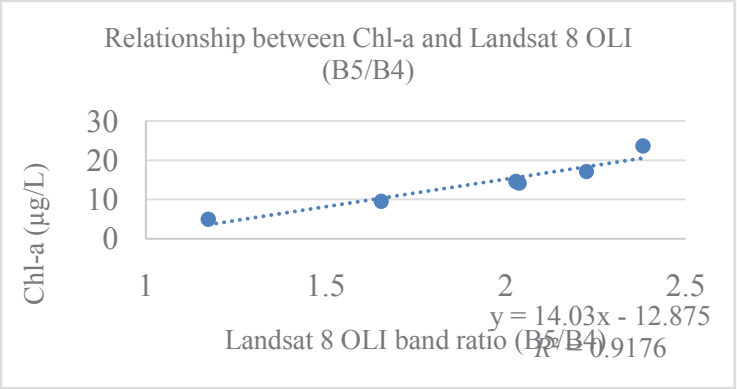

Fig1 Relationship between Chl-a and Landsat 8 OLI band ratio (B5/B4)

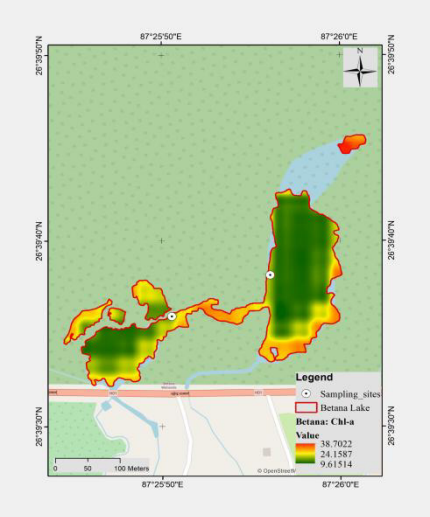

Fig 2 Eutrophication map of Betana Lake

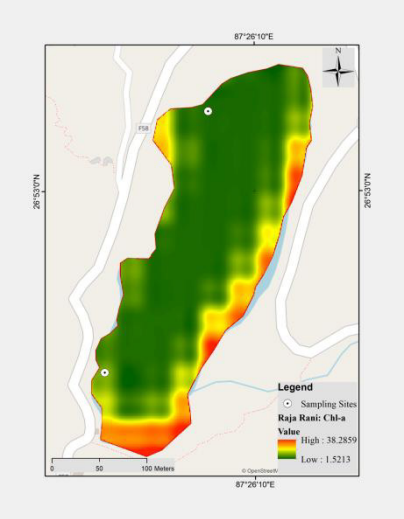

Fig 3Eutrophication map of RajaRani Lake

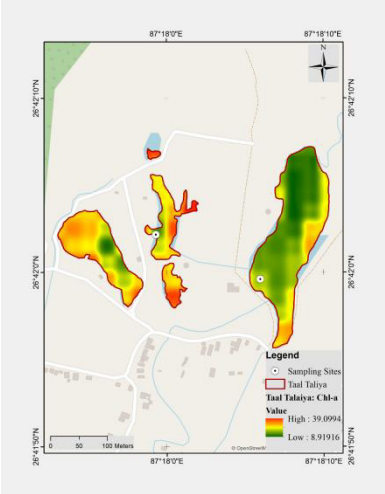

Fig 4 Eutrophication map of TaalTalaiya Lake

4. DISCUSSION

The eutrophication levels at the three lakes studied show that larger water bodies have higher eutrophication levels along the shore line while smaller water bodies from the lake clusters in Betana and TaalTalaiya have larger levels of eutrophication throughout.

5. CONCLUSION

This study was a pilot study to use a remote sensing and GIS techniques in the estimation of eutrophication levels at various lakes in the Eastern Nepal. The results of the prediction model suggest that a similar model is highly suitable (R2= 0.9176) for applications otherwise requiring large inputs of resources and time for the mapping. The surface flow is believed to lead to a higher eutrophication level as it would bring runoff of chemical fertilizers used in the agricultural fields as well as accumulated organic matter in the watershed.

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O3-41

Lakes of the Chernobyl exclusion zone: the effects of long-term radiation exposure on aquatic biota

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Keywords: Chernobyl exclusion zone, lake ecosystems, radioactive contamination, higher aquatic plants, mollusks, fish

ABSTRACT

The effects of chronic irradiation of aquatic biota in lake ecosystems within the Chernobyl exclusion zone during 1998-2017 were studied. It is determined that the rate of chromosomal aberrations in the root meristem tissues of aquatic plants in the most radioactive contaminated lakes on average in 2-3 times, and in cells of the pond snail embryos in 4-6 times exceeding the spontaneous mutagenesis level, inherent to aquatic organisms. Analysis of leukograms of fish peripheral blood showed the decrease of lymphocyte cells, as well as the increase in the number of granulocytic cells (neutrophils and pseudoeosinophils) with increase of radiation dose rate. Along with changes in leukograms an increased level of morphological damages of erythrocytes (structural and proliferation abnormalities) was determined, which is generally for pray fish in 4-12 times and for predatory fish in 7-15 times higher than in fish from reference lakes. Some morphological changes in gills and axial skeleton of fish were determined as well. Analysis of the viability of the seed progeny of the common reed from contaminated lakes at germination in the laboratory showed a reduction in technical germination, germination energy and seed viability with increase of radiation dose rate. At the same time significantly increased the number of abnormalities of seed seedlings in view of necrosis of roots, disturbance of gravitropism, damages of organogenesis and disorder of chlorophyll synthesis were discovered.

1. INTRODUCTION

The Chernobyl NPP (CNPP) accident is a most scale catastrophe in history of nuclear energy both for the amounts of the radioactive matters thrown out in the environment and on the area of contaminated territories. Currently the radioecological situation in the Chernobyl exclusion zone (CEZ) is determined primarily by long-lived radionuclides ^{90}Sr, ^{137}Cs, ^{238}Pu, ^{239}Pu, ^{240}Pu and ^{241}Am. Along with natural decontamination processes in aquatic ecosystems such as physical decay of radionuclides and their hydrological transport outside the CEZ, there is a change of physical and chemical forms of radioactive substances in soils of catchment areas, their transformation and transition in the mobile and bioavailable state, and accumulation by hydrobionts. This is essentially deteriorates the radiation situation in lake ecosystems, which are some kind of "storage system" of radioactive substances in the CEZ, and results in increase of radiation dose to aquatic species that exhibits in a variety of radiation effects at different levels of biological systems.

Thus the main tasks of our researches within the CEZ were: radiation dose rate estimation due to external and internal sources of irradiation for different groups and species of hydrobionts; evaluation of dose-dependent cytogenetic, haematologic, morphometric, productional and parasitological effects due to long-term radiation exposure on aquatic species.

2. METHODS

Our studies were carried out during 1998-2017. The water bodies of research were the flood plain lakes of the Pripyat River within 10-km area around the destroyed unit of the CNPP - Azbuchin Lake, Yanovsky Backwater, Dalyokoye Lake, Glubokoye Lake as well as cooling pond of the CNPP. The results of radiobiological analyses compared to the data received for hydrobionts from the reference lakes with background levels of radioactive contamination.

The concentration of the main dose-forming radionuclides was measured by α-, γ-spectrometry and radiochemical methods. The results were measured in Bq/kg at natural humidity and the mistake of estimated radionuclide concentration fell within 15-25%. The

estimation of the radiation dose rate for aquatic species, due to external and internal sources of irradiation was carried with use of ERICA Assessment Tool 1.2.1 [1]. All dose rate calculations performed on the basis of our own data.

The chromosomal aberration rate was measured in embryo cells of the gastropod pond snails by the standard anaphase method [2] and in the apical root meristems of the eight species of higher aquatic plants - by the modified method [3].

Haematological studies of molluscs were carried out in mantle liquid of the pond snails by the analysis of dead cells, young amoebocytes and phagocytic cells quantity [4, 5]. The leukograms and rate of abnormal red cells in peripheral blood of fish were identified by [6, 7].

3. RESULTS

The highest rate of chromosomal aberration in embryo tissue of gastropod snail (*Limnaea stagnalis*) in lakes within the CEZ was found in snails from Glubokoye Lake (up to 27%), located within the dammed territory on the left-bank flood lands of the Pripyat River and characterized with highest density of radioactive contamination (Fig. 1). The rate of chromosomal aberration for snails from the reference lakes was about 1.1-2.0%.

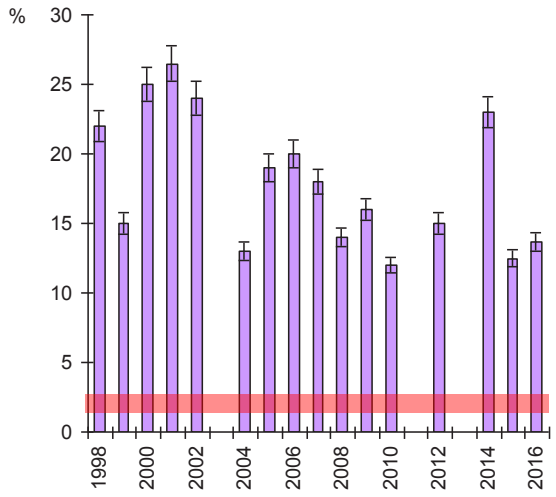

Fig. 1 Dynamics of chromosomal aberration rate in the pond snail (*Lymnaea stagnalis*) embryos in Glubokoye Lake during 1998-2016 (red line – spontaneous level 2.0-2.5%)

The rate of chromosomal aberration in the root meristem tissue of higher aquatic plants from lakes within the left-bank flood plain of the Pripyat River was in 2-3 times higher than spontaneous mutagenesis level.

Analysis of leukograms in peripheral blood of fish showed the decrease of lymphocyte cells, responsible for the implementation of immunological reactions, as well as the increase in the number of granulocytic cells (neutrophils and pseudoeosinophils), responsible for phagocytic function and involved in allergic and autoimmune reactions.

Drawing attention the high rate of red cells aberrations and abnormalities in peripheral blood of fish from the stagnant water bodies within the CEZ, where the absorbed dose rate on the fish organisms due to internal and external sources of irradiation have reached 70-100 μGy h^{-1} that is more on three orders higher in comparison with water bodies with background level of radioactive contamination (Fig. 2).

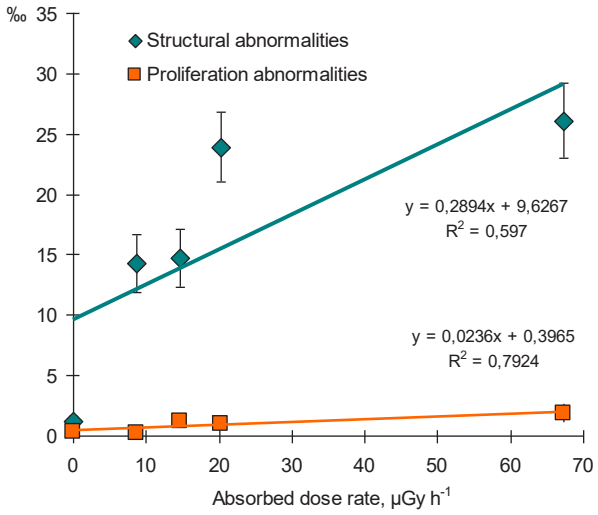

Fig. 2 Dose-dependent rate of red cells abnormalities in the peripheral blood of the common roach (*Rutilus rutilus*) from the CEZ

Our studies in peripheral blood of fish from lakes within the CEZ have shown an increased level of abovementioned morphological damages of erythrocytes, which is generally for pray fish in 4-12 times and for predatory fish in 7-15 times was higher in comparison with individuals from the reference water bodies with background levels of radioactive contamination. The rate of micronuclei in red cells was very low and did not exceed 0.3-0.6‰. For the fish from reference water bodies this type of abnormality are not discovered.

The comparative analysis of morphometric parameters of erythrocytes in peripheral blood of the common rudd showed that corpuscular volume of fish from the reference lake characterised by the homogeneous structure – a high quantity of cells has a similar volume. As to water bodies with medium (CNPP cooling pond) and high levels of radioactive contamination (Glubokoye

Lake), we can observe here an increased tendency of heterogeneity of studied parameters with formation of so-called "double-humped" curve, which is the most expressed for fish from Glubokoye Lake and can testify to the anaemic processes in blood of fish.

During the period of studies we analyzed morphological parameters and the presence of anomalies of egg capsules and egg mass of the pond snails: despiralization or weak spiralization strand with egg capsules; multilane organize of egg capsules in egg mass; location loose of egg capsules; twin egg capsules; polyzygosity of egg capsules; egg capsules without zygotes; zygote outside the egg mass; egg capsules larger or smaller sizes, as well as irregular shape.

Analysis of the viability of the seed progeny of the common reed (*Phragmites australis*) at germination in the laboratory showed that in gradient of absorbed dose rate for parental plants in lakes, there is a reduction in technical germination from 93 to 60%, germination energy - from 91 to 30% and seed viability - from 54 to 38%. At the same time significantly increased the number of abnormalities of seed seedlings: necrosis of roots - from 1.3 to 14.7%; disturbance of gravitropism - from 2.6 to 17.0%; damages of organogenesis - from 4 to 24% and disturbance of chlorophyll synthesis - from 0 to 2%.

4. DISCUSSION

During 1998-2017 a tendency to decrease of chromosomal aberration level in molluscs from all lakes of the exclusion zone was registered. The probabilistic prediction of the chromosomal aberration rate for gastropod snails in lakes of the CEZ have shown that spontaneous mutagenesis level (2.0-2.5 %) can be reach in Azbuchin Lake and Yanovsky Backwater in 2020-s - 2030-s and in lakes Daloykoye and Glubokoye - in 2060-s - 2070-s.

High amount of erythrocytes with structural and proliferation abnormalities in the peripheral blood of fish from lakes with high levels of radioactive contamination allows us to assume that the qualitative indexes of red cells in blood of fish are more sensitive to chronic radiation influence in comparison with the elements of white blood.

A variety of forms of pathological changes in the structure of blood cells, mainly erythrocytes, may indicate low resistance of cytogenetic apparatus of fish in the face of considerable mutagenicity and genotoxicity of environment. In this situation the ionizing radiation causes damage to the lipid structures of biological membranes (e. g. lysosomes) and violation of their barrier functions that ensure compartmentalization in the cell. This leads to disruption of spatial isolation of enzymes to their substrates and release enzymes to further destruction of macromolecules and intracellular structures. As a result, there are changes not only in the cytoskeleton, but also in functioning of all the organelles in the cell.

5. CONCLUSION

Self-purification of closed water bodies within the CEZ is an extremely slow process. Therefore, ecosystems of the majority of lakes, dead channels and backwaters possess high levels of radionuclide contamination of all components.

The established dose-related effects in hydrobionts of lakes within the CEZ indicates a damage of biological systems at subcellular, cellular, tissue, organ, organism and population levels as a result of chronic exposure to low doses of ionizing radiation.

Cumulative radiobiological processes can last for many generations of aquatic biota allowing currently assume the possibility of incomplete realization of the long-term effects of irradiation.

The rate of chromosomal aberrations in cells of aquatic species in many times exceeds the level of spontaneous mutagenesis level to aquatic biota. Increased levels of chromosome damages may be a manifestation of radiation-induced genetic instability, which is one of the main mechanisms for the protection of living organisms from exposure to stressors with subsequent implementation at higher levels of organization of biological systems.

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O3-42

Abundance of Ciliated Protozoans in a Tropical Lake: The Case of Lake Lanao, Philippines

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Keywords: Lake Lanao, tropical lake, trophic status, ciliated protozoans, abundance

ABSTRACT

Lake Lanao in the Southern Philippines is the second largest lake in the country and considered to be one of the ancient lakes of the world. It is best known for its endemic cyprinid fishes but there is a scarce information regarding its trophic status with the use of biological indicators particularly ciliated protozoans. This study was conducted to determine the abundance of ciliates in Lake Lanao across the littoral and pelagic zones of Ditsaan-Ramain, Marawi City, Binidayan, Balindong and Taraka and to evaluate the usefulness of ciliates as indicators of trophic status. Water samples were collected in three replicates using plankton net. The total mean abundance of ciliates in Lake Lanao was 1,071.70 and 1,686.21 (indiv/m^3) for the littoral and pelagic zones respectively; however, the difference was not statistically significantly significant. Both the ciliate mean abundance and the Trophic State Index based on Secchi disk transparency supported an oligotrophic classification of Lake Lanao. Among the measured physico-chemical parameters, only temperature was positively correlated to the mean abundance of ciliates whilst conductivity, pH and dissolved oxygen were negatively correlated.

1. INTRODUCTION

Lake Lanao is the source of power supply in the Mindanao regions but little is known regarding its trophic status with the use of ciliated protozoans as biological indicators. Their abundance increases as the trophic state of freshwater changes from oligotrophic to mesotrophic or to eutrophic condition [1]. Moreover, their grazing activity increases the rate of decomposition and thus their presence and abundance are good indicators of organic pollution [2]. Like other indicator organisms in aquatic environment such as phytoplankton and zooplankton, their diversity becomes low as pollution increases[3]. Ciliated protozoans usually inhabit environments which are low in oxygen concentration. Because of their size that ranges from 20µm to 2mm, their community structure can be studied easily [4]. Lewis (1985) [5] was the first to describe ciliates as part of the protozoan composition of Lake Lanao. However, to our knowledge, there is neither published study on the abundance nor the composition and of ciliated protozoans in Lake Lanao.

This study was conducted to evaluate the abundance of planktonic ciliated protozoans both in the littoral and pelagic zones that can be used as bioindicators of the trophic status of Lake Lanao. Hence, this study provided baseline information on ciliates in the study areas that can be very important in studying the ecological dynamics in freshwater tropical lakes and in giving some insights on the possible Lake Lanao monitoring campaign to maintain a good trophic status and conservation of biological resources.

2. METHOD

Location of the study

This study was conducted in selected areas of Lake Lanao, along the municipalities of Ditsaan-Ramain, Binidayan, Balindong and Taraka, and Marawi City, Lanao del Sur (Fig.1). Ditsaan-Ramain and Marawi City are situated in the Northern and shallower portion of the lake; Ditsaan-Ramain site is near the Ramain River, a lake tributary, while Marawi City is near the lake outlet, the Agus River. Binidayan is the deepest site situated in the southern part while Balindong is in the western part with domestic activities. Taraka is an eastern site locally known as the "basak-area" due to with agricultural activities and near to Taraka River, another main tributary of the lake.

Sampling strategy Abundance and trophic state index

Collection of water samples were done with the use of conical plankton net with mesh size of 53 µm and mouth diameter of 0.48895 m. For the littoral zones, the plankton net was towed obliquely to get an integrated water sample representing the surface and middle parts of the water column. For the pelagic zones, the plankton net was towed vertically at a distance of five meters in each specific sampling site. Only the planktonic ciliates were considered in this study. The actual volume of the water that was sampled was 0.9388 m^3. For every concentrated 10mL of water sample, 1mL of 5% formalin and a drop of acidified Lugol's solution were added after transferring the water samples into the plastic sampling bottles.



Fig. 1 Location of Lake Lanao and sampling sites [27].

Ciliates were counted manually per observation of water samples for fixed samples using the right-hand rule method for microscopy. Abundance (indiv/m^3) of the ciliated protozoans was calculated according to Harris *et al.*, (2000) [6]. Trophic state index (TSI) based on Secchi disk transparency was calculated according to Carlson (1977) [7].

Physico-chemical parameters & statistical analysis

Two physical factors, temperature and Secchi depth and three chemical factors namely pH, dissolved oxygen (DO) and water conductivity were also measured during the sampling using portable devices. All statistical tests utilized Statistical Package for Social Sciences (SPSS), Version 22 namely Shapiro-Wilk test test for normal distribution of the ciliates' mean abundance; Levene's test for equality of variances; t-test for comparing mean abundances; and Pearson test for correlation between ciliates' mean abundances and measured physical and chemical parameters.

3. RESULTS AND DISCUSSION

Abundance of ciliated protozoans

A total of 30 ciliated protozoans observed in this study with a total mean abundance of 2,728.10 (indiv/m^3) (Fig. 2). *Vorticella* sp.3 obtained the highest abundance (567.11 indiv/m^3) while *Spirostumum* sp. obtained the lowest count (0.10 indiv/m^3). As can be seen in Fig. 3, the mean abundance of cilaites in the littoral and pelagic zones vary. Combining all the data of the five sampling sites, the littoral zone has a total mean abundance of 1,071.70 (indiv./m^3) ciliated protozoans while pelagic zone was higher with the value of 1,686.21 (indiv./m^3) but these values are not significantly different using Mann-Whitney Test (Asymp. Sig.: 0.507, $\alpha = 0.05$). Surprisingly, the abundance of ciliates in pelagic zone of Taraka was significantly higher than its littoral zone. A similar trend

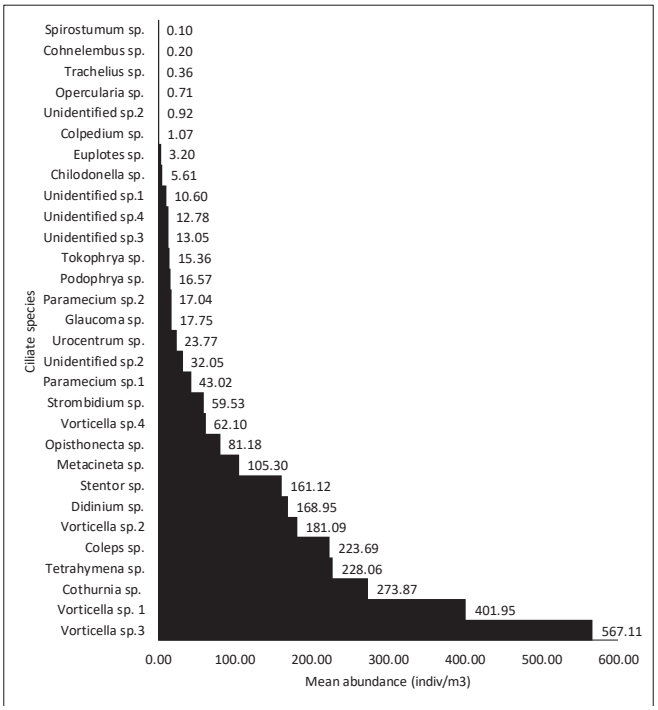

Fig. 2 Total mean abundance of ciliated protozoans

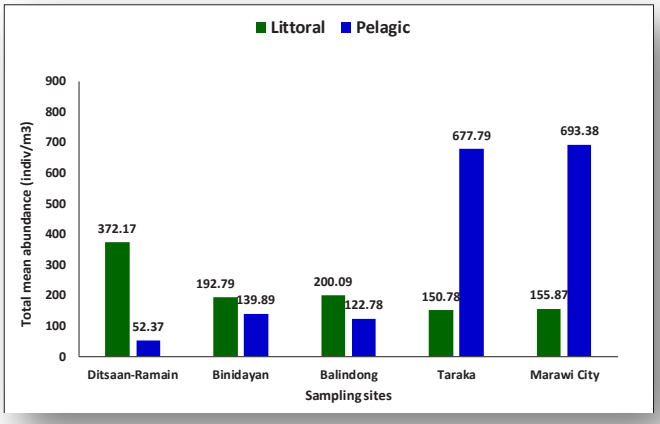

Fig. 3 Mean abundance of ciliated protozoans in the

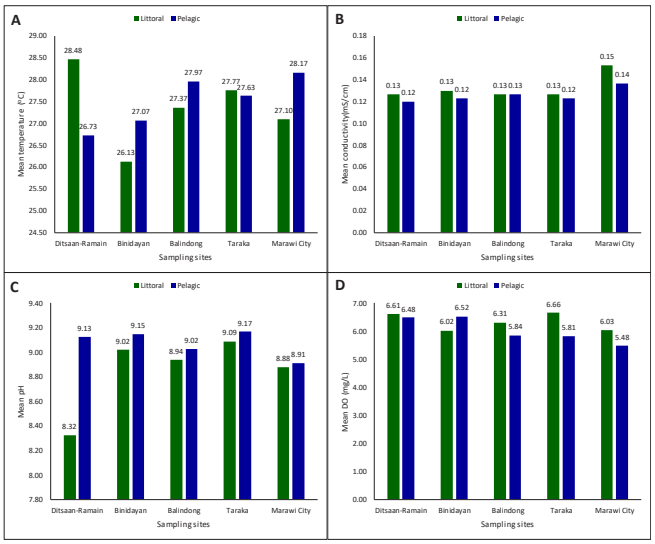

Fig. 4 Measured physico-chemical parameters. A. Mean temperature; B. Mean conductivity; C. Mean pH; D. Mean dissolved oxygen (DO)

was also observed in the Marawi sampling site. Based on ocular observation, the Taraka site has relatively turbid water both in the littoral and pelagic zones as compared to other sites. Since the mouth of Taraka river is close to the sampling site, this might account for the turbidity reaching the pelagic zone of which ciliated protozoans might be carried by the water current along with some debris and organic matters. In the case of Marawi, this could be attributed to the domestic activities such as bathing and washing of the inhabitants near the sampling site. In fact during sampling, direct discharge of soaps and detergents in the sampling area was observed.

Physico-chemical parameters

The physico-characteristics of the sampling sites are shown in Fig 4. The temperature of the five sites ranged from 26.13°C to 28.48°C (Fig 4A) and showed a positive correlation of 0.244 with ciliate abundance by Pearson test. This is expected though since temperature increases as the rate of metabolic reaction increases [7]. For the conductivity, the different sampling locations have relatively uniform values of 0.12 – 0.13 mS/cm (Fig. 4B) having negative correlation (-0.044) with abundance by Pearson's. This result is in contrast to the study of Yasindi

& Taylor (2006), in which conductivity and trophic status were the most important environmental variables influencing the distribution of ciliate species in East African lakes [8]. For pH, the values ranged from 8.32 to 9.17 (Fig. 4C) having a -0.175 Pearson correlation with ciliate abundance. Lake Lanao is expected to have high pH based on the study by Beaver and Chrisman (1989) [9] on subtropical lakes in which abundance and biomass of total ciliates generally decreased with increased acidity.

For DO, the highest value recorded was 6.6g mg/L in the littoral zone of Taraka while the lowest was the pelagic zone of the same site with the value of 5.81 (Fig.4-D). The Pearson correlation analysis on DO and ciliate abundance revealed a negative (-0.241) value in which the sampling sites with high abundance had low levels of DO. Across all sites, the pelagic zone of Taraka marked the lowest record of DO but it also hit the highest record of ciliate abundance. This result was consistent with the study of Dias *et al.*, (2008) [10] in the urban stream of southeast Brazil in which low DO were recorded in sampling sites with high ciliates abundance and these sites were receiving high sewage loads indicative of organic pollution. Taraka also had a lower DO and it was corroborated by high ciliate abundance. This was probably due to the agricultural activity near the site and its nearness to the lake tributary Taraka River, which was evidenced by the turbid run-off waters.

Moreover, *Vorticella* spp. were accountable for the alarmingly high abundance of ciliates in the pelagic zone of Taraka. This result is not surprising since *Vorticella* ciliates are strongly related to organic pollution. As early as 1952 *Vorticella* spp. were already listed as typical indicators of organic pollution from moderate to heavily polluted condition. Higher counts of the same genus were also observed at littoral zone of Binidayan. Though this sampling site was deepest part of the Lake but it was surrounded with households. In addition, in the littoral zone of Ditsaan-Ramain, high abundance of *Vorticella* sp. was also accounted. Ditsaan-Ramain site was shallower and received waters from one of the main tributaries of Lake Lanao – the Ramain River. The site was exploited for fishing and domestic uses. Probably during sampling, these sites mentioned most likely received higher loads of domestic waste as indicated by higher abundance of *Vorticella* spp.

Trophic State Index (TSI) and Ciliate Abundance

Trophic status of the lake can be indicated in two ways, namely TSI based on Secchi depths following the work of Carlson (1977) [7] and the standards set by Beaver and Crisman (1989) [9] based on ciliate abundance. Littoral zones of Ditsaan-Ramain and Balindong had no Secchi depth values because the water levels were shallow and clear enough to see the Secchi disk at the bottom. The sampling sites of the pelagic zone had Secchi depth values of 4.33m – 5.85m (data not shown). Calculating these values to TSI yielded a range from 34.51 to 47.83 which are interpreted as oligotrophic category [12]. This is also confirmed by comparing the abundance of ciliated protozoans in this study against the standards set by Beaver and Crisman (1989) [9], in which Lake Lanao is considered as ultraoligotrophic, i.e. lake water in the sampling sites is still pristine.

5. CONCLUSION

Based on the total mean abundance of ciliates and Secchi depths, Lake Lanao is classified as oligotrophic lake. Ciliated protozoans in the lake did not significantly vary in the littoral and pelagic zones during the time of sampling. Furthermore, for the physico-chemical parameters, only temperature was positively correlated to the mean abundance of ciliates whilst conductivity, pH and dissolved oxygen were negatively correlated. Thus, it is highly recommended to obtain comprehensive data on ciliated protozoans and other biological indicators to generate an overall picture of the dynamics of the biological community in Lake Lanao ecosystem. Public policy and ordinance on bio-monitoring and assessment of Lake Lanao by the concern local government units is also needed. This is to preserve the Lake Lanao and prevent any further degradation that is influenced by anthropogenic activities.

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TS4-1

北海道テッシ-オ-ペッはカヌーの聖地

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キーワード:水辺空間の利用・文化・観光・地域づくり

抄録

北海道遺産「天塩川」(全長 256 ㎞)は、一級河川の中では珍しく、北に向かって流れる大河で、人工構造物がなく、カヌーで河口までロングツーリングできる区間は、日本最長の 157 ㎞(約 100 マイル)を誇る。

天塩川には、かつて鮭や鱒を獲って生活するアイヌの人たちの暮らしがあった。今年、生誕200 年を迎えた北海道の名付け親で、幕末から明治維新に活躍した探検家・松浦武四郎(1818～1888)は、丸木舟で天塩川を遡り、流域を踏査した。その後、開拓者は未開の地に豊かな資源を求め、天塩川から開拓地に分け入ることで始まり、村や町が生まれた。そんな未開の地を開拓していくような冒険感覚をカヌーでの川下りイベントを通じて、天塩川の魅力を全国に発信し続けている組織の活動について紹介する。

北海道命名 150 年を迎えた 2018 年、27 回大会を初の国際大会として開催。上流から下流へと自治体間を漕ぎ下ることにより、流域連携が深まり、現在、北海道最大級のカヌーツーリング大会として定着。これまでに延べ5千人以上が参加し、地域活性化に大きく寄与している。

1. はじめに

天塩川は、石狩川に次ぐ北海道第 2 の大河であり、本流の長さ全国第4位、流域面積は全国第10位の規模を誇る日本有数の大河でもある(図表 1)。



図表 1 天塩川とその流域

北海道士別市と滝上町にまたがる天塩岳に源流を発し、1級河川としては珍しく日本で唯一真北に流れながら日本海へと注いでいる。名寄川や剣淵川など大小160もの支流を持ち、周辺の 13 の市町村(流域市町村は 11 市町村)に大きな恵みを与えている。

天塩川の名前の由来は、アイヌ語の「テッシ-オ-ペッ(tesh-o-pet)」で「梁(魚を取る仕掛け)-多い-川」が語源である。

1857 年、幕末から明治維新に活躍した探検家で北海道の名を命名した松浦武四郎は、5 回目の蝦夷地調査で、丸木舟を使って天塩川に入り、河口から現在の名寄の地、さらには源流である天塩岳まで 24 日間をかけて踏査し、その記録は『天塩日誌』として残された。

その天塩川で、1992 年から開催されているのが、「ダウン・ザ・テッシ-オ-ペッ」である。天塩川の大自然と触れ合い、河川景観や流域市町村に賦存する素晴らしい魅力を再発見し、環境保全等に対する関心を高める機会を提供するとともに、参加者やスタッフ、地域住民との交流を通じヒト、モノ、情報の提供や交換の場を創出し、天塩川流域圏の地域振興を図ることを目的に北海道カナディアンカヌークラブが中心となり「ダウン・ザ・テッシ実行委員会」を 1992 年に発足し、現在まで 27 回の大会を開催している。

本論文では、今年、北海道命名 150 年を迎え、第 27 回大会を初の国際大会として開催した「ダウン・ザ・テッシ-オ-ペッ」のこれまでの活動を報告し、上流から下流へと自治体間を漕ぎ下ることにより、流域連携が深まり、現在、北海道最大級のカヌーツーリング大会としてきた歴史を分析する。

2. 現在の「ダウン・ザ・テッシ-オ-ペッ」

この組織は、長年にわたり、道内外に生涯を通した親水スポーツの普及 PR を図るとともに、カヌーツーリングの醍醐味と魅力、感動を伝える活動を展開してきた経験と実績をもつ。これまでに「ダウン・ザ・テッシ-オ-ペッ」への参加者数は延べ 5,000 人を超える。今後、天塩川を活かした魅力ある地域づくりを一層推し進めるためには、社会的信用度や行政との契約など任意団体での限界を感じ、さらなる事業の拡大を図るために、2017 年から準備を進め、2018 年「特定非営利活動法人ダウン・ザ・テッシ」を設立した。

奇しくも 2018 年は北海道を命名した探検家松浦武四郎生誕 200 年、北海道命名 150 年の記念の年であることから、第 27 回の大会を、「天塩川 100 マイル国際カヌーツーリン

グ大会　ダウン・ザ・テッシ-オ-ペッスペシャル 2018」として開催した。

名寄市の名寄大橋から天塩町の天塩川河川公園までの151km を 3 泊 4 日の日程で漕ぎ下る大会で、悪天候で一部の区間は中止になったものの、世界 5 か国から 115 チーム 201 人が参加した。

3. 現在に至るまでに

この大会のスタート地点は 1988 年までさかのぼる。まだまだ天塩川でカヌーが一般的でなかった頃、カヌー選手としては「はまなす国体」（1989 年開催）出場を目指していた酒向勤氏が、手づくり木製カヌーの普及によるカヌーの振興を図ろうと「北海道カナディアンカヌークラブ（以下、HCCC）」を 1988 年に結成したことに始まる[2]。

おりからの、自然志向やアウトドアブーム、また地域のおまつり会場で手作りカナディアンカヌーの製作実演や展示などを行った結果、次々と流域市町村にカヌークラブが結成されていった。

和寒町にて酒向氏が結成した HCCC が、活動を通じて流域市町村民への手作り木製カヌーの製作普及などを行った結果、流域のカヌークラブのリーダーたちが HCCC に参加していった。

1992 年、まちおこしのきっかけを開拓の出発点となった天塩川に求め「開拓の歴史は川から始まり、原始林に覆われていた一帯の交通手段は丸木舟によるもの。手作りカヌーで川を下ることが原点」との思いで始められたのが、「ダウン・ザ・テッシ-オ-ペッ」である。

実行委員会では、より多くの人々がふるさとを見直し、自然を見直していくことにつながることを願うとともに、継続開催により、カヌーの普及と流域市町村の地域活性化への起爆剤となることを目指した。

大会当初は、名寄市から天塩町までの 100 マイル（約160km）を 4 つのステージに分け、4 年をかけてすべてを下ることを目指していた。開催 2 年目には参加者数が 200 人を超えていき、1998 年にはそれまでの継続開催が認められ、日本カヌー連盟公認・主催の「全日本カヌーツーリング大会」が開催され 402 人の参加者があった。

また、2002 年には日本最長 100 マイルを一気に下るスペシャル大会を 4 日間の日程で開催しました。土曜日から始まる 4 日間で開催された大会は、スタッフ以外は、参加者はそれほどいないのではないかと考えると思うが、ふたを開けてみると 234 チーム 404 人の参加があった。このスペシャル大会も 2018 年には 4 回目を数えている。

これまで 27 回もの大会を継続できたのは、大会スタッフともなる流域市町村単位のカヌークラブが、「常に自分たちが参加したい大会を目指し」、実行委員会を構成し大会を開催しているからであろう。

また、大会を継続していくためには安全が第一である。危険ポイントにはスタッフを配置し、万が一、沈（転覆）しても、素早いレスキュー体制が整っている。このことも、継続開催を通して多くの仲間が増え、経験を積み、スタッフ体制が充実していった。

回	開催年	区　間	距離	参加者
1	1992	名寄～美深	45km	79 チーム 151 人
2	1993	美深～中川	41km	114 チーム 232 人
3	1994	中川～幌延	36km	137 チーム 275 人
4	1995	幌延～天塩	31km	133 チーム 260 人
5	1996	士別～美深	43km	90 チーム 220 人
6	1997	美深～音威子府	16km	113 チーム 201 人
7	1998	天塩岳～士別	8km	20 チーム 35 人
全日本	1998	名寄～音威子府	42km	215 チーム 402 人
8	1999	音威子府～中川	25km	124 チーム 217 人
9	2000	中川～幌延	21km	125 チーム 220 人
10	2001	幌延～北上幌延	24km	85 チーム 145 人
11	2002	風連～天塩	157km	234 チーム 404 人
11	2002	サロベツ川～天塩	18km	43 チーム 74 人
中止	2003	風連～音威子府	65km	台風中止
12	2003	美深～音威子府	25km	81 チーム 146 人
13	2004	風連～美深	40km	69 チーム 120 人
14	2005	音威子府～幌延	46km	102 チーム 193 人
15	2006	風連～天塩	157km	93 チーム 162 人
16	2007	士別～名寄	25km	48 チーム 90 人
17	2008	名寄～美深	34km	52 チーム 102 人
18	2009	美深～音威子府	25km	61 チーム 107 人
19	2010	音威子府～中川	25km	56 チーム 102 人
20	2011	名寄～天塩	151km	94 チーム 158 人
21	2012	名寄～音威子府	59km	78 チーム 144 人
22	2013	美深～中川	50km	95 チーム 171 人
23	2014	音威子府～幌延	46km	90 チーム 160 人
24	2015	中川～天塩	60km	90 チーム 160 人
25	2016	名寄～音威子府	59kn	93 チーム 172 人
26	2017	美深～中川	50km	82 チーム 148 人
27	2018	名寄～天塩	151km	115 チーム 201 人

図表 2 ダウン・ザ・テッシ-オ-ペッ開催経過 ＊風連は現名寄市風連



図表 3 自分たちが参加したい大会を目指す

4. 「ダウン・ザ・テッシ-オ-ペッ」を支える人

「ダウン・ザ・テッシ-オ-ペッ」は、行政主導のイベントでもなければ、どこか大きな組織によって運営されるものでもない。HCCC をはじめ、流域市町村にある各カヌークラブが自分たちの流域に来たカヌー愛好家たちを出迎えるといった体制で開催されてきた。そこには何の強制性もなく、しなければいけない大会でもない。それでも 27 回を迎えられたこの組織には独自の特徴がある。

若月はその特徴をリーダーシップになるのではないかと研究した。行政主体と民間主体のスポーツイベントを比較しながら、民間主体のイベントの場合、専制的なリーダーシップより、民主的なリーダーシップが組織の凝集性を高めると指摘した[3]。

そのような凝集性の高い組織を作り上げているのが HCCC 代表、北海道カヌー協会理事長、NPO 法人ダウン・ザ・テッシ理事長であり、和寒町議会議員としても活動している酒向氏である。

また、流域市町村にあるカヌークラブの代表者が HCCC に参画し、1 つの組織として動ける体制になっている他、地域に戻ってもそれぞれのクラブで情報共有できている。その中にはそれぞれの地域の中でオピニオンリーダーとして活躍しているものも多く含まれ、天塩川やカヌーのことだけでなく、様々な地域の問題が共有できることになっている。

5. 「ダウン・ザ・テッシ-オ-ペッ」の今後

ダウン・ザ・テッシでは、天塩國パスポートの発給や、100 マイル全てを下った参加者を対象に「テッシ-オ-ペッ・マスター」の認定を行っている。天塩川の悠久の歴史に触れ、自分の手だけで完漕したことの証である。この活動を通じて、天塩川の情報発信、また天塩川への愛着を持ってもらうことができ、リピータに繋がる。そして、継続開催の大会に必要なスタッフの養成にもつながっている（図表 4）。

また、天塩川下りという地域振興イベントは行政にも認められ、自然景観に配慮した親水護岸（カヌーポート）の整備、



図表 4 テッシ-オ-ペッ・マスター認定証

カヌー工房の設置など、行政による条件整備支援もなされ、官民一体になった流域振興策に繋がっている（図表 5）。また、カヌーポートに温泉やキャンプ場が隣接されているところも多く、カヌーによるロングツーリングには最適な条件になっている（図表 6）。

多くの地域でイベントが行われているが、行政主導により予算上継続ができなくなったり、民間主導でも、スタッフの高齢化や、やる気の喪失など様々な理由で継続できないイベントが多くある。

その要因は、組織のリーダーシップであったり、自分たちの行ってきたことが正しく評価されなかったり、様々なことが考えられる。

27 年間、最北の大河で行われているこの大会運営母体は、新たに NPO 法人格を取得し、さらに大きなものに挑戦していく。それは単に大会の拡大だけではない。天塩川流域に生まれたから、天塩川の歴史を知っているから、天塩川から多くのことを学んだから、そこにある文化を引き継ぎ、活かし価値を高めていくのは、流域住民の役割であり責任であると考えている。



図表 5 親水護岸、カヌーポートの有効利用

美深町	びふかアイランドカヌーポート、びふかアイランド、びふか温泉
音威子府村	川の駅「天塩川温泉」、「中の島」、天塩川リバーサイドキャンプ場、天塩川温泉
中川町	ナポートポート、ナポートパーク、ポンピラアクアリズイング
天塩町	天塩川河川公園、鏡沼海浜公園、てしお温泉「夕映」

図表 6 流域町村のカヌーポート周辺

6. 引用文献

[1] ダウン・ザ・テッシ-オ-ペッ実行委員会、「北海道遺産天塩川カヌーツーリング大会ダウン・ザ・テッシ-オ-ペッ」資料

[2] 前田和司、「天塩川流域におけるカヌークラブの実践」、『北海道教育大学大雪山自然教育研究施設研究報告』、第 30 号、pp. 13-18、1995.

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持続可能な湖沼地域と観光の関係について

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抄録

本研究は、湖沼地域社会の持続可能性を実現する観光まちづくりの可能性について議論する。従来、湖沼を対象とする観光によって様々な負の影響が生じたため、多くの場合、湖沼地域の観光開発は批判を浴びた。ところが、1990 年代に実践され始めた持続可能な観光は、ヨハネスブルグサミット（2002 年）において持続可能な開発の唯一の成功事例として評価された。そして、持続可能な観光が地域振興に活用された事例として、日本では「観光まちづくり」が、1990 年代後半に広く注目を集めた。観光まちづくりとは、観光によって地域の文化を継承・創造したり、自然環境を保護したりしながら、コミュニティを活性化する、住民主体の地域振興である。こうした観光まちづくりを湖沼地域に適用するさいの課題が、琵琶湖沿岸地域の事例を手がかりとして検討される。結論として、湖沼地域の観光まちづくりには、水環境にかかわる伝統文化と教育観光が重要な要素となることが浮かびあがる。

1. はじめに

本研究は， 湖沼地域と観光を結びつけ、湖沼地域社会の持続可能な地域の振興を実現できるか、という問いを議論する。観光による持続可能な地域振興は、日本において、すでに「観光まちづくり」という地域振興の形態によって実践されている。そこで、本研究は、湖沼地域において観光まちづくりがいかに実践されるか、を問う。

この問いについて、本研究は、次の 3 つの課題を順に検討しながら、解答を見つけだしたい。第一に、観光が観光地に持続不可能な現実をもたらした経緯を概観する。第二に、持続可能な観光が、いかに観光地の自然環境を保護し、文化を継承・創造したか、を解明する。そして、第三に、「観光まちづくり」がいかに持続可能なコミュニティを形成するか、を考察する。

最後に、以上の課題についての議論を受けて、「観光まちづくり」が湖沼地域の持続可能性をいかに実現できるか、を議論したい。日本の代表的な湖である琵琶湖の周辺地域を事例として、観光まちづくりによる持続可能な湖沼地域コミュニティ形成の可能性を検討する。

2. 観光がもたらす持続不可能な現実

多くの湖沼地域は、世界中で古くから有数の観光地となってきた。観光対象としての湖沼地域の主な魅力は、豊かな水を湛える景観であり、その景観を水環境とともに生みだした、地域に固有の伝統文化や自然環境である。日本においても、湖沼地域は多くの観光客を集める観光地となっている。

しかし、観光がそうした湖沼地域の景観や水資源を破壊した事例は、少なくない。もとより観光は、湖沼地域にとどまらず、あらゆる観光地に多くの様々な負の影響をもたらしてきた。たとえば、ゴミ、混雑、騒音、犯罪などは、観光による典型的な負の影響であり、これらはしばしば観光公害と総称される。

さらに観光は、観光地の環境破壊や文化変容を惹き起こした[1]。観光地の自然や文化は、観光客を誘引する魅力である。ところが、自然や文化が、それらの魅力を必要不可欠とする当の観光によって破壊されると、観光地に観光客が訪れなくなり、観光地の地域社会全体が衰退してしまう。つまり、観光が、地域社会に持続不可能性をもたらす。

このように観光地が崩壊する根本的な原因は、社会現象としての「大衆観光」にあった。大衆観光は、1960 年代に、未曾有の経済的豊かさを獲得した先進国に出現した。先進国に経済的豊かさが社会全体に浸透すると、人口の大多数を占める大衆が、史上で初めて観光を享受できるようになった。観光客の急増は、1960 年代から現在に至るまで続いている。1980 年代後半には、経済成長を達成した中進国でも、多くの観光客が国内に溢れだし、やがて海外の観光名所に殺到した。大衆観光は、ひとつに「大量の観光客」によって特徴づけら

れる。

「大量の観光客」を受け入れた観光地で、自然環境の破壊や文化の変容が生じた。自然環境の破壊は、主に、観光客入込数が、観光地の社会的収容限度を遙かに超えた結果として発生した。たとえば、経済効果を見込んだ観光地が、大勢の観光客を受け入れるために自然環境を損ねる観光開発をしたり、大挙して観光地を訪れた観光客が、自然・生態系を踏み荒らしたりした。

また、地域文化の変容は、主に「観光デモンストレーション効果」や観光による「文化の商品化」を通して起きた。たとえば、観光地住民が、観光客の行動や生活スタイルを模倣する傾向によって、地域固有の伝統文化を放棄したり、観光地で文化の表象や物品が、商品として興行、展示、販売され、それによって文化が「低俗化」したりするような事態が生じた。

こうして、大衆観光は、1970 年代に世界全体で厳しく批判された。そのために、大衆観光は、「悪い観光」という、もうひとつの意味をもつようになった。

しかし、UNWTO（国連世界観光機関）等の国際機関が 1980 年代初めから主導して、大衆観光に代わる新しい観光形態が国際的に模索された。そうして提案されたのが、「持続可能な観光」の形態であった。

3. 持続可能な観光への転回

新しい観光形態は、1980 年代後半から UNWTO が主導して、エコツーリズム等の形態で実践された。新しい観光形態とは、大衆観光が経済効果だけを追求して、無秩序・無管理に観光開発を推進したのに対して、観光地住民が自身の地域の文化や自然環境の社会的機能と重要性を認識し、観光の開発や運営に主体的に関与する、計画的かつ管理された観光である[1]。

このような新しい観光の形態は、2002 年のヨハネスブルグ地球サミットにおいて、「持続可能な開発」の唯一の成功事例だと評価された。持続可能な開発は、開発政策の実践目標として、1992 年のリオ地球サミットで国際的公約となった。しかし、それから 10 年間、あらゆる領域で持続可能な開発の実践が頓挫したなかで、観光だけがそれを実践できた。かくして、観光の新しい形態は、「持続可能な観光」と呼ばれるようになった。

4. 観光まちづくりと持続可能なコミュニティ

持続可能な観光は、UNWTO が各国政府を先導するトップーダウン型の指揮系統で、1980 年代初めから実践されていたが、他方で同時期に、持続可能な観光と実質的にみなされる観光形態を、住民主体で活用した、ボトムーアップ型の地域振興が、主に先進国の周辺地域で実践され始めていた。

そうした地域振興には、たとえば、欧米のトランジションタウンやエコヴィレッジ等がみられる。それと同様な地域振興が日本各地にもみられ、それは「観光まちづくり」とよばれた[2]。

観光まちづくりは、1980 年代初め頃に日本各地で着手され、バブル景気が崩壊した直後の 1990 年代初め頃から次第に話題となりはじめた。バブル景気の崩壊から深刻な不況が実感された 1990 年代後半には、観光まちづくりで活気に溢れる地域振興の様子が、評判となった。

観光まちづくりの成功事例はどれも、住民が主体となり、外部に頼らず「内発的」に取り組まれた。住民はコミュニティの自然環境や固有の地域文化を重視して保全し、それらの魅力を観光対象としてまちづくりに活用する。観光まちづくりの最終的な目標は、経済効果を追求する観光地開発ではなく、住民の「生活満足度が高い持続可能なコミュニティ」の構築であるとみなされる。

観光まちづくりが実現する持続可能なコミュニティとは、社会を構成する「経済」「社会関係」「文化」そして「人間生態系」という、相互に連関する 4 つの制度的要因が、動的均衡を保つ状況と理論的に想定される（図 1）[3]。

それら要因は、それぞれ次のように特徴づけられる。第一に、「経済」では、地産地消や食住衣の基礎欲求を充足できる地域自足型と、循環型とを実現することが理想的となる。第二の「社会関係」は、ネットワーク型の社会関係資本が強固な状況によって特徴づけられる。第三に、「文化」は、地域の自然環

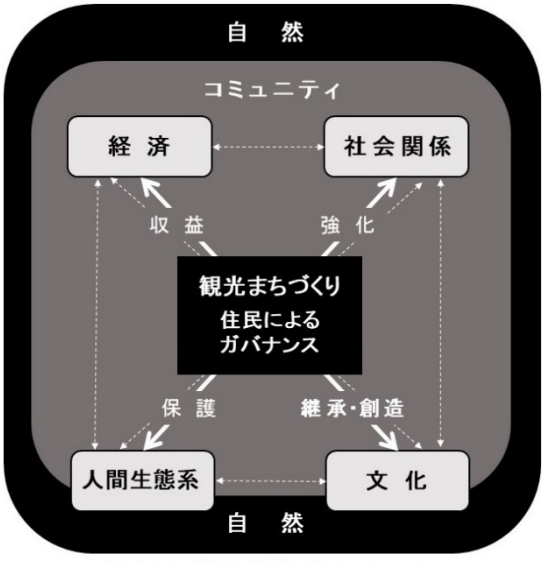

図 観光まちづくりと持続可能なコミュニティ

境と社会関係から伝統的に生みだされた価値体系とその表象実体であり、その伝統的な価値体系の上に新たな文化が創造される状況が理想的とみなされる。そして第四に、人間生態系は、地域の自然と人間が共生して構成される、たとえば里山のような自然・生態系の存在である。

観光まちづくりの過程において、それらの要因には、持続可能な観光の力学が次のように作用する（図 1）。第一に、観光が地域に「経済」的収益をもたらす。第二に、観光まちづくりという目標達成に向けて住民が主体的に協働するので、コミュニティの「社会関係資本」が強化される。第三に、地域の伝統文化が、観光対象として継承され、創造される。そして、第四に、地域の人間生態系もまた、観光対象として保全される。こうした観光まちづくりの力学は、住民によるガバナンスで統制される

観光まちづくりの上述の過程によって、コミュニティにおける 4 つの制度的構成要因に均衡が保たれ、結果的に持続可能なコミュニティが形成されると考えられる。

5. 湖沼地域で観光まちづくりを実践する可能性 ——琵琶湖周辺地域を事例として

琵琶湖は、滋賀県に位置する、日本最大の面積と貯水量を有する湖であり、世界中でも希少な古代湖である。このような琵琶湖周辺地域には、森—川—里—湖がつながる固有の自然・生態系と伝統文化が歴史的に形成されてきた。

しかし、1960 年代の高度経済成長期から琵琶湖の水環境が急速に悪化し、同時に周辺地域の景観も変化した。大阪や京都といった大都市に隣接する、特に琵琶湖南部の地域において工業化や宅地化が進展したため、琵琶湖には、工場排水や生活排水などによる水質の汚染や富栄養化などが発生した。そして、琵琶湖流域の文化や自然・生態系が絡みあって形成されたその景観も破壊された。

こうした琵琶湖の水環境や景観の問題の改善は、1980 年代になると、多くの関係者によって本格的に着手された。まず国や自治体がその問題に取り組みはじめ、そこに琵琶湖周辺地域の多くの住民が参加した。また、住民が主体的に琵琶湖の水環境や景観の保全に取り組む事例も多い。観光まちづくりは、その一例である。

滋賀県には全体に官民一体となった活動が盛んであり、琵琶湖周辺地域の住民活動の特徴として、大学や研究機関による琵琶湖の水質環境や景観保全などに「住民参加型調査」が多くみられる。そして実際に、その調査に多くの住民が参加して、その調査の組織やネットワークが観光まちづくりと結びついている。

かくして、琵琶湖周辺地域の観光まちづくりでは、住民参加型調査の研究成果に基づいた、湖や周辺の自然・生態系や伝統文化を観光対象とする事例が多くみられる。たとえば、1）長浜市菅浦の湖岸集落、2）高島市針江の生水の郷、3）近江八幡市の湖上の孤島沖島などがその事例である。

それらの 3 つの事例における観光の魅力は、琵琶湖の自然・生態系と伝統文化が融合し継承された、生活形態と景観である。それらのどのコミュニティにおいても、住民が市民参加型調査の研究成果を踏まえた知識を有していて、観光振興において地域と訪問者の「インタープリター」としての役割を果たす。すなわち、地域住民は、琵琶湖周辺地域における自身のコミュニティの成り立ちを、学術的知見から訪問者に語ることのできるインタープリターとなっている。このように実践される観光形態は、「教育観光」と類型化される。

このように、菅浦、針江、沖島という 3 つのコミュニティは、前述の観光まちづくりの過程において、それぞれに古い歴史をもつ住民自治に支えられた、持続可能なコミュニティを形成している。それぞれの住民は、観光を通して、自らのコミュニティの成り立ちを理解し、コミュニティの自然・生態系を保護し、伝統文化を継承して、自身の生活形態を創造する。こうして、それぞれのコミュニティは、経済、社会関係、文化、人間生態系のバランスが取れた持続可能なコミュニティとなる。

6. おわりに

本研究の事例で呈示された菅浦、針江、沖島において、全てのコミュニティは、持続可能な観光を通して、湖沼地域に特有の伝統文化を継承し、水環境と景観を保全して、生活満足度の高い持続可能なコミュニティを形成した。このような、湖沼地域の持続可能な観光を特徴づけるのは、湖沼地域に形成された「伝統文化」と、住民がインタープリターとなる「教育観光」である。

事例となったコミュニティは限界集落化しているため、それらに持続可能なコミュニティを想定しにくい。それにしても、それらのコミュニティの実践は、観光による新たなコミュニティ像の構築に多くの示唆をもたらす。

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TS4-2

The Sustainability of Relationships between the Lake Regions and Tourism

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Keywords: lake regions, tourism-based community development, sustainability

ABSTRACT

This study discusses the possibility of "tourism-based community development" (TBCD) in materializing the sustainability of the lake regions and the inland waters around them. Tourism in many of the lake regions has been criticized until now because of various negative influences caused by its development and management. However, sustainable tourism (ST) initiated since the 1990s such as ecotourism and cultural tourism was evaluated as the only successful case of sustainable development by the World Summit on Sustainable Development (Johannesburg Summit) in 2002. Such ST can be found in the TBCD of Japan. Successful cases of TBCD have acquired a good overall reputation in Japan since the late 1990s. TBCD is characterized as the regional promotion of sustainable community by community residents. A community is constructed through ST on the basis of a dynamic balance among the four component factors of its social structure, namely 1) the economy, 2) social capital, 3) culture, and 4) the human ecosystem. ST functions in the process of TBCD as follows: 1) ST development yields "economic profits," 2) strengthens "social capital" as residents collaborate with each other in the process, 3) protects the indigenous "culture" as a tourist attraction, and 4) conserves "nature" and the "human ecosystem" in the community. Issues in introducing TBCD into lake regions are examined based on cases of TBCD around Lake Biwa, Shiga. Consequently, this study concludes that the two factors of traditional culture and educational tourism related to the water environment have critical importance in the TBCD of the lake regions.

1. INTRODUCTION

This study discusses how tourism can foster the sustainability of the lake regions and the inland waters around them. The formation of a sustainable community in several regions has already been practiced successfully through the tourism-based community development (TBCD). afterwards, this study examines how the lake regions can practice the TBCD successfully.

For this examination, this study investigates the following three themes. Firstly, the process through which tourism has brought tourist destinations unsustainable realities is surveyed. Secondly, the mechanisms of how sustainable tourism (ST) can protect the local natural environment and preserve traditional cultures in each region are elucidated. Thirdly, the structure through which the TBCD can form a sustainable community is considered.

Based on the investigations concerning the three above mentioned themes, this study further discusses the possibility of TBCD in fostering the sustainability of the lake and its regions. This discussion covers accomplished case studies on three communities around Lake Biwa, Shiga Prefecture in Japan.

2. THE UNSUSTAINABLILITY CAUSED BY TOURISM

Many lake regions have been eminent destinations from the ancient days all over the world. The main tourist attraction of the lake region is scenery of rich water in one pace, and the combination of culture and nature producing the scenery in the other. Many lake regions in Japan also attract tourists.

However, there are several cases claiming that tourism has destroyed scenery of lake regions and has polluted their water environment. After all, negative impacts by tourism are experienced not only in lake regions but in every destination. The typical negative impacts are garbage, congestion, noise, and crimes among others. Such impacts are often generally referred to as tourism pollution.

Tourism, furthermore, has often caused environmental destruction and acculturation in tourist destinations [1]. When culture and nature as tourist attractions in a destination are deteriorated or destroyed by tourism, tourist visit rapidly decreases. As a result, the region of the affected tourist destination almost deteriorates. Thus, tourism brings about unsustainability in regional societies of tourist destinations.

The basic cause of deterioration of tourist destinations has been mass tourism (MT) as a social phenomenon. MT appeared in the then developed countries in the 1960s. When the overall affluence infiltrated the society of the then developed country, the masses came to enjoy tourism for the first time in history. The rapid increase of tourists has continued all over the world to date from the 1960s. After the late 1980s, the semi-developed countries also have generated a number of tourists, and then, before

long, the tourists have rushed in overseas destinations. Thus, MT is characterized by a large number of tourists

In destinations receiving a large number of tourists, environmental destruction and acculturation crop up. The destruction of natural environments occurs mainly because the number of the tourists is far beyond the social carrying capacity of the tourist destination. For example, this phenomenon unfold as follows. An area in pursuit of economic gain destroys the environment through large-scale tourism development meant to accommodate a large number of tourists. Similarly, a large number of tourists visiting a particular tourist destination devastate its nature and ecosystem.

Acculturation in tourist destinations occurs mainly due to the demonstration effect and cultural commodification in tourism. The following is an example of the unfolding of this phenomenon. Hosts in tourist destinations abandon their culture and model after tourists' mode of conduct and lifestyles. Similarly, representation and materials of culture in tourist destinations are staged, exhibited, and sold as tourist attractions, and consequently culture tends to trinketize.

Thus, MT was strictly criticized around the world in the 1970s. Since then, MT has been characterized by the property of bad tourism.

World Tourism Organization (existing UNWTO) has been in search of alternative tourism (AT) to MT since the early 1980s. A form of sustainable tourism (ST) was later proposed and practiced.

3. THE SWITCH TO SUSTAINABLE TOURISM

Some of the concrete AT types that have been initiated and implemented are ecotourism and cultural tourism by the UNWTO. AT is characterized by planned, controlled, environment friendly and cultural-oriented tourism development through the residents' initiative, whereas MT is characterized by unplanned, uncontrolled, and economic-oriented tourism management by tourism–related companies and administrations [1].

AT was evaluated as the only successful practice of sustainable development (SD) at the Johannesburg Summit in 2002. SD was internationally ratified as a practical pledge of the development policy at the Rio Earth Summit of 1992. Ten years later, the practice of SD was delayed in every field of development policy as the only exception in tourism. Thus, AT has been referred to as ST since the early 21st century.

4. TBCD AND THE SUSTAINABLE REGION

While ST has been practiced through the top-down approach that UNWTO suggested for every country since the 1980s, for the same period, the bottom-up type of community development utilizing ST has been practiced in periphery areas of developed countries.

Such types of community development are called, for example, transition town movement and ecovillage among others in Western countries. Similarly, the same type of community development named TBCD evident in various regions of Japan [2].

TBCD has been initiated in various regions of Japan since the early 1980s, and has attracted attention from all over Japan since the early 1990s when the Bubble Economy collapsed. In those days when serious recession was feared because of the collapse of the Bubble Economy, communities that had been overflowing with vigor due to the success of TBCD gained great popularity throughout Japan.

TBCD is characterized as endogenous regional promotion by residents' initiative. The residents consider the environment in their region and their own culture as tourist attractions, and therefore they protect their environment and culture. The goal of TBCD is not the pursuit of economic gain but the construction of a sustainable community with high life satisfaction.

The sustainable community that TBCD realizes can be theoretically considered a social system with four interrelated component factors, namely 1) the economy, 2) social capital, 3) culture, and 4) the human ecosystem, mean to maintain dynamic balance (Fig.) [3].

These four factors are characterized respectively as follows. First, ideal economy realizes regional self-sufficiency satisfying basic needs such as food, shelter, and clothing, and is recycling oriented. Secondly, a goal of social capital is to construct network-shaped, strong, and social cohesiveness." Thirdly, culture is

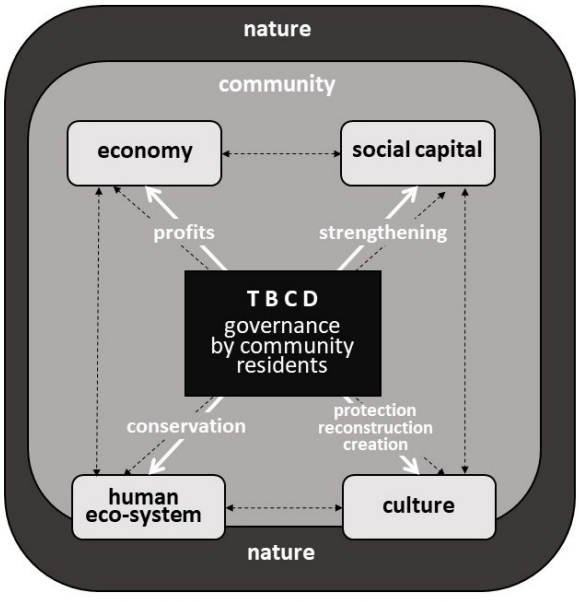

Fig. TBCD and Sustainable Community

defined here as a value system and its representation is formed through interaction between the environment and social relations. An ideal of culture would be to create new culture on the basis of traditional culture. Fourthly, the human ecosystem is generated by symbiosis of persons and nature.

The dynamics of ST in the TBCD process affect these four factors as follows (Fig.). First, ST yields economic profits within the community. Secondly, ST strengthens social capital as residents collaborate with each other in the TBCD process. Thirdly, ST protects indigenous culture as a tourist attraction. Fourthly, ST conserves nature and human ecosystem as tourist attractions in the community. Such dynamics of ST and TBCD are controlled by resident self-governance.

The TBCD process mentioned above can maintain the stability of the four component factors in social system. Consequently, the sustainable community can be formed in the TBCD process.

5. THE POSSIBILITY OF PRACTICING TBCD IN THE LAKE REIONSs: Lessons from the Cases of Lake Biwa

Lake Biwa located in Shiga Prefecture, Japan is a rare ancient lake with the largest area and impoundment in Japan. In Lake Biwa and the regions around it, indigenous natural landscapes and traditional cultures formed have linked between woods, rivers, villages, and the lake.

Since the high economic growth period of the 1960s, the water environment of Lake Biwa has degraded, and at the same time, the landscape of the regions around Lake Biwa has changed. In the southern area of Lake Biwa in particular, water pollution and the eutrophication of the lake occurred due to factory effluent, and drainage. The landscape around Lake Biwa has deteriorated.

The improvement of such problems in Lake Biwa has been undertaken on a large scale by many people and organizations since the early 1980s. At first the central and local governments worked on the problem, and then several residents participated in these actions. There were several community activities aimed at maintaining the environment and landscape in the regions around Lake Biwa. One such activity is the TBCD.

In the whole of Shiga Prefecture, public-private united activities are vigorous, and as a characteristic of the resident activity of the regions around Lake Biwa, residents' participatory research is frequently conducted with universities and research organizations in regard to the maintenance of the environment and landscape of Lake Biwa. In each region around Lake Biwa, the organizations and human networks related to such residents' participatory research are closely linked to the TBCD.

Thus, in the regions around Lake Biwa, there are many cases of the TBCD that provide their own ecosystems and traditional cultures as tourist attractions by referring to the results of each residents' participatory research. For typical cases of the TBCD, this study presents three communities: 1) Sugaura, the lakeshore village, 2) Harie, the village of *Shouzu* (spring water), and 3) Oki-shima, the isolated island on the lake.

The tourist attractions in these three cases each have their own life style that have been integrated into the landscape, natural environment, and traditional culture of Lake Biwa. In each of the three communities, many residents have rich scientific knowledge about nature and the culture of their own community and they play the role of the 'interpreter' between their community and tourists. This type of tourism is called 'educational' tourism.

As mentioned above, the TBCD of Sugaura, Harie, Oki-shima has been managed by traditional resident self-governance. Consequently, all three communities have formed a sustainable community. Through the ST in the TBCD process, each of the residents objectively understands the structure of their own community, protect its nature and ecosystem, preserve their traditional culture, and create their life styles. Thus, the TBCD of all three communities has generated a sustainable community by maintaining balance among the economy, social relations, culture, and human ecosystem.

6. CONCLUSION

ST in the TBCD process examined through the three cases of Sugaura, Harie, and Oki-shima has generated a sustainable community characterized by traditional cultures of the regions around Lake Biwa. The characteristics of ST in the Lake Biwa regions are the 'traditional cultures' formed in the lake regions and 'educational tourism' with interpreters from the community residents there.

However, it might be difficult to regard the three cases that this study adopts as sustainable communities, because the population is aging in all three cases. Yet ST and TBCD that the three communities have practiced can suggest a new image of the sustainable community of lake regions.

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O4-1

湖沼を活用したサイクルツーリズムの推進

＝滋賀県における「ビワイチ」の取組と「霞ヶ浦、浜名湖、琵琶湖　3湖連携」について＝

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キーワード：水辺空間の活用，観光,自転車活用推進

抄録

滋賀県では、自転車による琵琶湖 1 周「ビワイチ」（琵琶湖一周の略といわれる）がサイクリング愛好家の間で注目され、体験者数は年々増加している。このような中、滋賀県では「ビワイチ」を県全体の地域振興のほか、環境保全意識の醸成、県民の健康増進等にも活かすため、ビワイチ推進総合ビジョンを策定し、県庁内はもとより、市町や民間事業者、関係団体とともに取組を進めている。

また、同様に湖沼の魅力を中心としたサイクルツーリズムに取り組んでいる霞ヶ浦（茨城県）、浜名湖（浜松市、静岡県）とも連携し、更なる盛り上げを目指している。

1. はじめに

わが国では近年スポーツサイクルを中心に自転車で周遊するサイクルツーリズムが広がっている。その先駆者ともいえる「しまなみ海道」（広島県、愛媛県）では、サイクリングでの来訪者が 2012 年約 17 万から 2017 年には約 33 万人へと大きく増加し（いずれも今治市による推計）、世界的にもサイクリングコースとして注目されるようになっている。

一方、滋賀県では琵琶湖一周を意味する「ビワイチ」という言葉が自然発生的に生まれ、琵琶湖を中心に広がる水辺景観を自転車で楽しむ『ビワイチ』サイクリングがじわじわと広がってきた。琵琶湖周辺の道路は比較的平坦で走りやすいうえ、水辺の風景は変化に富み、走るエリアによって琵琶湖は違う表情をみせる。また、一周が約 200kmあり、全てを走破した達成感はなんともいえないものであるとも評価されている。このような魅力がサイクリング愛好家の間で広まるとともに、民間事業者や団体による「ビワイチ」サイクリングを推進する取組や、県・市町等行政による取組等の広がりも相まって、大きな盛り上がりを見せている。

2. 「ビワイチ」の取組

もともと琵琶湖を中心とした自然環境保全に取り組んできた滋賀県では、二酸化炭素を排出しない環境にやさしい交通手段である自転車の活用促進にむけ先駆的に取り組んできた。その始まりと思われるのは、1973 年に旧八日市市（現東近江市）で、全国に先駆けて、自転車を活かしたエコロジーな街づくりにむけた「自転車都市宣言」がなされたことである。その後、県全体でもエコロジーと自転車（バイク）を掛け合わせた「バイコロジー」という造語のもと、継続的に自転車利用を推進してきたところである。

2012 年 8 月には、自転車の「日常利用」と「観光利用」を2つの軸として、車から自転車への転換を促すまちづくりにむけた連携・情報共有のプラットホームとして、「滋賀プラス・サイクル推進協議会」が、行政、民間事業者、関係団体参画のもと設立された。

一方、「しまなみ海道」はじめ、近年各地で地域の魅力を活かしたサイクルツーリズムの取組が進められ、大きな盛り上がりをみせている。サイクリング関係のイベントには多数の来訪者が集まり、海外からのサイクリングツアーも増加するなか、滋賀県においても「ビワイチ」サイクルツーリズムの取組が進められている。

そもそも「ビワイチ」については、発祥の時期は定かではないが、その始まりとなったのは、1972 年から 25 年かけて、琵琶湖の環境保全・治水・利水にかかる総合開発事業により、琵琶湖沿いの「湖周道路」が完成したことがある。これを受けて、県では 2001 年、琵琶湖沿いをサイクリングする 193kmのコース「ぐるっとびわ湖サイクルライン」を沿線市町、関係機関と調整し、サイクリングマップを作成するとともに、案内看板や距離標等を整備するなど、環境整備を行ったことがきっかけで「ビワイチ」が広がったものと推測されている。インターネット上で一

番古い「ビワイチ」の表記がみられたのは、2001 年といわれており、この頃から「ビワイチ」という言葉が、サイクリングファンの間で静かに広がり始め、全国的なサイクリングの盛り上がりの中で、大きく注目を浴びるようになったものである。

この盛り上がりを確固たるものとし、地域振興に活かしていくため、各主体がそれぞれの取組を進めてきた。

まず、滋賀県では、「ビワイチ」による消費支出拡大のほか、生活文化や歴史遺産など奥深い魅力にふれていただくきっかけづくり、水辺空間とのふれあいを通じた環境保全意識の醸成や、有酸素運動を通じての健康増進等を期待して取組を進めている。まず、サイクリングマップをサイクリスト視点で刷新し、きめ細かい注意箇所情報、沿線の立ち寄りスポット情報のほか、「ビワイチ」体験に必要な準備、ルールやマナーまで様々な情報をひと通り網羅したものとした。また、海外からの来訪に対応するため、多言語版（英語・中国語（繁体字））も作成した。

また、琵琶湖岸だけでなく内陸部を周遊する「ビワイチ・プラス」コースを設定し、県内の街道や歴史遺産、紅葉などの絶景、サイクルトレインなど、琵琶湖岸だけでなく県内全域でサイクリングを楽しんで頂けるよう、テーマで巡る自転車での楽しみ方も提案している。

また、「ビワイチ」を安全に楽しんでいただけるよう、まずは道路の段差解消、矢羽根による路面表示・案内整備など条例に基づく安全対策や分かりやすいコース案内の整備を進めるとともに路肩拡幅による自転車の走行空間の整備もあわせて行っている。また「ビワイチ」ルートでもある湖周道路の除草回数を従来より増やすなど維持管理の強化にも進めている。

これらの取組は部局の枠を超えて連携して推進することが必要であることから、2018 年には「ビワイチ」専門の部局である「ビワイチ推進室」を知事部局内に設置するとともに、理想となる「ビワイチ」を物語形式で示し、関係者が一丸となって取り組む道標とする「ビワイチ推進総合ビジョン」を策定したところである。

先に述べた「滋賀プラス・サイクル推進協議会」では、行政・民間の横断的な取組がすすめられ、受入体制整備として、サイクリストにトイレや自転車用工具類等の貸し出しを行い、「ビワイチ」体験をサポートする「サイクルサポートステーション」の設置や、サイクルツアーガイド講座の実施、歴史・文化・豊かな自然など、滋賀の多彩な魅力を体感・体験するサイクルツーリズムを推進していくための旗印として、「ビワイチ」サイクルツーリズムのロゴを定め、「ビワイチ」体験者向けグッズやサービスの開発促進などの活動を行っている。

サイクルサポートステーションについては、2016 年に募集を開始し、200 ヶ所を目標としていたところ、現在までに 283 ヶ所となっているほか、ロゴマークを活用した「ビワイチグッズ」も 12 商品が開発され、それぞれ好調な売れ行きを示し、地域経済活性化に寄与している。

県の観光推進団体である「びわこビジターズビューロー」においては、「ビワイチ」の魅力を多くの人に知ってもらうため、サイクリングイベントへの出展や自転車情報雑誌への掲載など広報活動を行っている。

県内市町では、守山市では「ビワイチ」の発着点としての PR を進められると共に、市民による協議会を設置されるなど、自転車文化の普及にも努めている。また米原市では米原駅へのレンタサイクル拠点の設置や地域ルートの設定・PR を地域と共に進められている。さらに大津市、草津市、彦根市、長浜市、高島市、日野町、愛荘町等の県内市町では、自転車イベントやサイクリングガイドツアーの実施、サイクリングマップの作成、レンタサイクルの推進が進められるなど、県内各地でそれぞれの特色を活かした取組が進められている。

また、琵琶湖一周サイクリングが注目を集めるに伴い、「ビワイチ」の盛り上がりを地域振興に活かそうとする取組も広がり、湖上交通・サイクルトレインの活用、インバウンドを含むツアー造成推進も行われるようになった。

このような取組を通じて「ビワイチ」体験者は大きな伸びをみせ、推計値を算出し始めた2016年以降、右肩上がりとなっている。

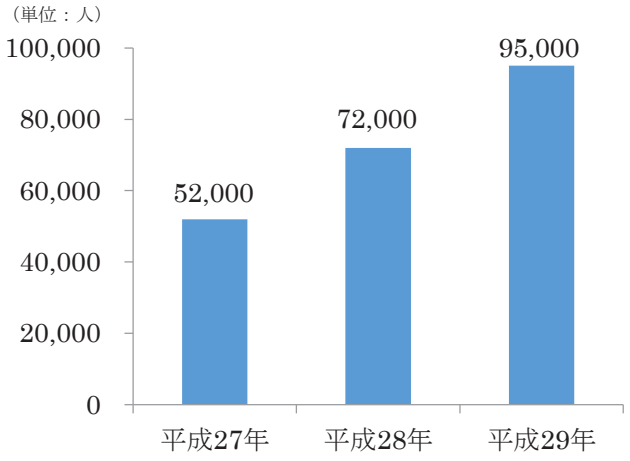

図 1「ビワイチ」体験者数推計値
（滋賀プラス・サイクル推進協議会）

今後も引き続き、県だけではなく、市町、民間事業者、地域住民など様々な主体と連携し、琵琶湖の恵みを活

かした「ビワイチ」で県全体が活性化するよう取組を進めていきたい。



図2「ビワイチ」サイクリング

3. 環境保全意識の醸成へ

自転車は二酸化炭素を排出せず、環境にやさしい乗り物であり、その推進による環境保全を軸に、バイコロジーやプラス・サイクル推進協議会の活動は行われてきたが、「ビワイチ」においては、環境にやさしいから自転車利用するというのではなく、あくまで「楽しみ」として行われている。県では、都市計画公園内に水辺と触れ合う空間を創設し、ただ走るのではなくじっくりと琵琶湖の風景を楽しむサイクリングを提唱し、「ビワイチ」の盛り上がりが環境保全意識醸成につながるよう取組を進めている。このなかで、少しずつではあるが、市民レベルでの自主的な取組も生まれつつあり、例えば、夏休みを利用して親子連れをメインターゲットとして実施される「ビワイチ」体験イベントでは「湖岸でのごみ拾い」が組み込まれたり、また別のサイクリストグループは、「ビワイチ」という楽しみを提供してくれる琵琶湖に感謝するという意味を込めて、サイクリングシーズンの幕開けとなる春に、「ビワイチ感謝の日」と題して、自主的な清掃活動を展開している。

これらは、行政が仕掛けることなく、市民レベルで自然発生的に生まれたものであり、今後、更なる発展や広がりを期待したいと考えている。

4. 結論（3湖連携へ）

湖を周遊するサイクルツーリズムは琵琶湖に限ったものではない。海外でもドイツのボーデン湖やイタリアのガルダ湖、台湾の日月潭が大変有名であるし、国内でも各地で行われている。なかでも、湖周囲の総延長距離がトップ3である、霞ヶ浦（総延長約 252km）、浜名湖（同約 128km）、琵琶湖（同約 235km）、は、違った魅力を有するサイクリングコースを持ち、それぞれサイクリング推進に向けて官民一体で取組が進められている。

比較的平坦で走りやすく、首都圏から日帰りサイクリングも可能な霞ヶ浦、海に近く、また湖面のすぐそばを走行でき、明るく開放的な雰囲気が味わえる浜名湖、生活文化、歴史遺産など豊富な立ち寄り先のある琵琶湖。それぞれの地域で、湖が持つ魅力を活かし、受入環境整備、サイクリング走行環境整備など、それぞれがサイクルツーリズム推進の取組を進めてきたところである。

観光誘客の世界では一般的に、遠隔地にある観光地同士は「競争関係」となり、限られた観光客を奪い合うのが基本的関係といえるが、サイクルツーリズムにおいては、サイクリング愛好家そのものの拡大を期待できるほか、異なる魅力を持つ地域であることから、順次回遊する動きも期待できる。

今回連携する3地域は、これまでにそれぞれ特徴を活かしたサイクルツーリズムを推進し、一定レベルの環境整備が進んでいる。このような中、湖沿いに広がる水辺空間の魅力を共同でプロモーションすることを通じて、それぞれが単独で行っている以上の集客効果が期待できるものと考えている。

2017 年 2 月に基本的な方向性を確認し、まず皮切りとして各地域で開催されるイベント等で共同発信を始めたところであるが、滋賀県においては地元新聞の 1 面を飾るなど、すでに大きな反響を呼んでいる。

今後、それぞれの魅力を活かし、「湖を巡るサイクリング」の魅力を発信し、誘客を推進するほか、その体験者が湖の魅力を肌で感じ、湖を中心に広がる水辺空間を大切にしたいという想いが広く醸成することにつながればと期待しているところである。



図3 3湖担当者による共同プロモーション
（2018 年 3 月「びわ湖一周ロングライド」彦根市）

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O4-2

ベトナム中部タムジャンラグーンでのラムサール条約登録を目指した取り組み

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キーワード:ラムサール条約，自然保護区，資源管理，エコツーリズム，ワイズユース

抄録

ベトナムの中部海岸地帯には，面積 10 ㎢以上の 5 つのラグーンを含む多くの湖沼が分布し，国際的に重要な渡り鳥の越冬地になっている。その中で Tam Giang ラグーンは，1990 年代から国内でも重要な湿地の一つとして認識され，ラムサール条約登録の有力な候補地となっている。そこで本報告では，Tam Giang ラグーンにおける条約登録を目指したこれまでの取り組みを整理し，現在および今後の課題について検討した。その結果，まず生物多様性や生態系保全の核となる自然保護区の設定が急務である。その際，現在計画されているコアゾーン内の中州でのヨシ原の再生だけでなく，水域の汽水環境の復元も重要である。ただし自然保護区の設定や汽水環境の復元は，住民の生業を制限することにもなるため，その保障や代替となる新たな雇用機会の創出が必要である。その手がかりとして，豊かで多様な生態系を目指すエコツーリズムの開発や，条約登録を活かす地域ブランドの育成が挙げられる。

1.　はじめに

ラムサール条約は，その正式名称にあるように，元々は水鳥の生息地として国際的な湿地の保全に関する条約であったが，近年は湿地（水深 6m を超えない水域も含む）における生態系を含む自然資源の保全とワイズユースを目指すものと位置づけられている。これは，今回の世界湖沼会議のテーマ「人と湖沼の共生−持続可能な生態系サービスを目指して−」と大きく重なる。

日本を含むアジア各国では，最近 10 年ほどの間，ラムサール条約への登録数が増加している。1986 年のドイモイ政策後，急速に湿地の開発が進んだベトナムでも，2005 年以降徐々に条約への登録数が増加し，現在東南アジアではタイに次ぐ 8 カ所となっている。国土の北部に 2 カ所と南部に 6 カ所で，そのうち 4 カ所が内陸の淡水湿地，2 カ所が海岸のマングローブ林・干潟，あと北部山岳地帯にある淡水湖とメコンデルタ沖合の群島である。中部海岸地帯には，1989 年に IUCN の報告書で「ベトナムの重要湿地 33 カ所」の中に取り上げられた面積 10 ㎢以上の 5 つのラグーンを含む多くの湖沼が分布し，国際的に重要な渡り鳥の越冬地にもなっている（図 1）。しかし，湖岸周辺での稲作や養殖が盛んで，住民や行政による自然資源の管理や保護が十分なされていないため，いずれも未だ条約に登録されていない。

ただし，これらの湖沼の中で国内最大の Tam Giang ラグーン（面積約 250 ㎢，霞ヶ浦の約 1.5 倍）については，1990 年代から国内でも重要な湿地の一つとして認識され，条約登録の有力な候補地とされている。そこで本報告では，Tam Giang ラグーンにおけるラムサール条約登録を目指したこれまでの取り組みを整理し，現在および今後の課題について検討した。

なお現在日本では，50 カ所がラムサール条約に登録され，そのうち湖沼が 21 カ所と最も多い。その中には中海，宍道湖，涸沼など 8 つのラグーン（汽水湖）が含まれており，ベトナムでも中部海岸地帯のラグーンがラムサール条約に登録される可能性と期待は大きい。

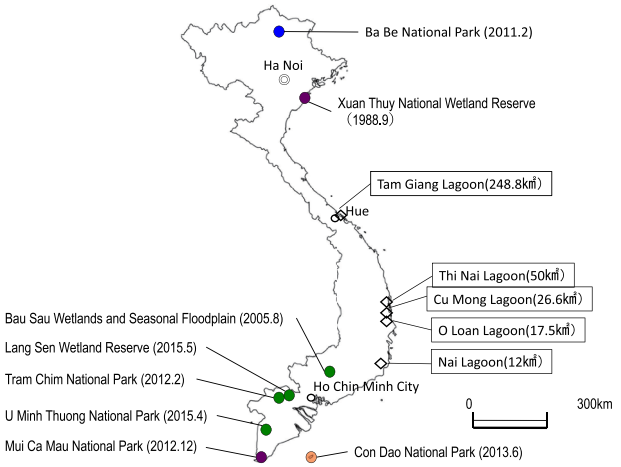

図 1　ベトナムのラムサール条約湿地とラグーンの分布

（●ラムサール湿地，◇面積 10 ㎢以上のラグーン）

2. 方法

まず Tam Giang ラグーンに関する基礎的文献，資料，地形図(1968 年米国陸軍地図局発行および 1994 年ベトナム土地管理総局発行の 1/5 万地形図，2002 年の同局発行の 1/2.5 万地形図)を収集・分析した。また 2002 年以降に撮影された Google Earth 画像を利用し，対象地域の土地利用および水域利用について解析を行った。

ついで，Tam Giang ラグーンおよびその周辺地域における生態系の保全とワイズユースに関する近年の具体

的な取り組みについて，トゥアティエン・フエ省（以後フエ省と略する）環境保全局，および同省文化・スポーツ・観光局ツーリズム計画・推進部を訪問し，関連資料の閲覧・提供を受け，聞き取りを行った。また，2016 年 3 月には現地調査を実施し，Quang Thai 村および Dien Hoa 村で，それぞれの村の現状について聞き取りを行った。

2. 結果

ベトナムは，1989 年に北部紅河デルタの河口干潟およびマングローブ林をラムサール条約に登録し，現在までに国内 8 カ所が条約登録湿地となっている。これらはすべて，国の自然保護区また国立公園に指定されており，そのうち 3 カ所はユネスコの生物圏保護区にもなっている。自然保護区は，科学的な重要性を有し立ち入りが制限される小面積区域で，一方国立公園は全国で 30 カ所あり，一般的に面積数万 ha で，自然環境の保全に配慮したエコツーリズムや文化的な必要性から，保護地区にも立ち入りが許されている。現在のところ Tam Giang ラグーンは，上記のいずれにも指定されていない。

フエ省では 1997～98 年に，渡り鳥とくにカモやシギ・チドリ類の主要な越冬地であり，生物の多様性が高い Tam Giang ラグーン北西端の O Lau 川河口域を，湿地保護区とする可能性調査を実施した。しかし報告書では，過剰な漁業や養殖池の造成等によるラグーンでの海草・海藻や湿地の減少，水質汚染の加速などが指摘され，これらに対し自然保護のための計画やゾーニング，管理組織の設立，保護区のための規制や制度の創設，コミュニティ教育の必要性などが提言された[1]。以下，Tam Giang ラグーンのとくに O Lau 川河口域を対象とした，生態系の保全とワイズユースに関わる近年の取り組みについて，以下にまとめた。

1) IMOLA プロジェクトの実施

2005～11 年には，イタリアおよび FAO の事業として IMOLA(ラグーンでの諸活動の総合的管理)プロジェクトが実施された[2]。この事業は Tam Giang ラグーンでの自然資源の健全かつ持続的な管理および利用を通し，地域の漁民の生業を増進することを目的とした。詳しい実態調査にもとづいた規制や新しい資源管理のあり方が提言され，漁民自らが資源管理に取り組むよう，ラグーン沿いの 42 村でそれぞれ複数の漁業協同組合が設立された。O Lau 川河口域を占める Quang Thai 村でも 2 つの漁協が組織されている。

2) 自然保護区の設置

2006～10 年に，O Lau 川河口域に自然保護区を設定し，自然環境の保護と生態系の再生，地域の持続的発展とワイズユースを目指すことが計画された。O Lau 川のタムジャンラグーンへの流入地点に築かれた河口堰の上流および下流側，それぞれ 200ha を自然保護区のコアゾーンとし，上流側では生業活動は一切禁止，下流側では漁業・養殖業のみ可と言うものである（図 2）。

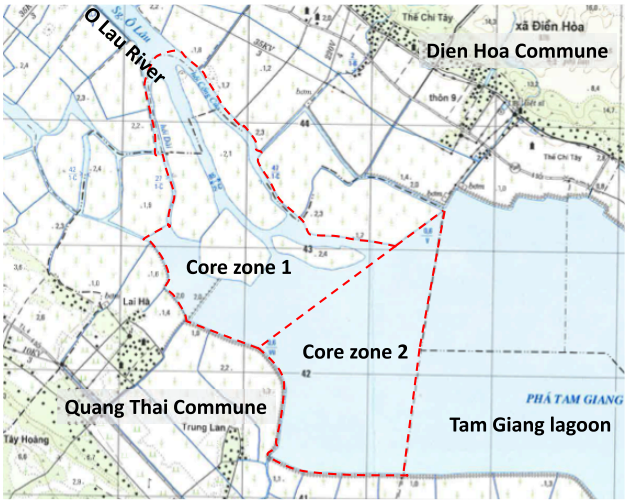

図 2. O Lau 川河口域での自然保護区の設定案
(2002 年発行の 1/2.5 万地形図，グリッドは 1 ㎞間隔)

2002 年発行の 1/2.5 万の 1 地形図および複数時期の Google Earth 画像（2010.6.19～2017.8.7 撮影）を比較すると，河口堰上流側のコアーゾーン 1 内では，中央の中州で湿地の自然再生が進み，水域に多数あった養殖用のケージが堰の下流側に移動しているのが確認できる。しかし計画では，4 つの中州すべてで稲作禁止であるが，最新の画像でも中州に水田の畦が写っており，計画はまだ完全には実施されていない。



図 3. O Lau 川河口域の Google earth 画像
（2017.8.17 撮影，図 2 と同じ範囲）

3) 禁漁区の設定

フエ省では，新たに 2015～18 年の事業として，Tam Giang ラグーン内に，23 カ所，面積合計 700ha の禁漁区

を設定し，ラグーンにおける適正な資源管理を計画した。各禁漁区の面積は 10〜30ha であるが，O Lau 川河口域では最大の 70ha となっている。この計画に対し，2016 年 3 月に当該の Quang Thai 村を訪れたところ，村ではこの計画を 2 週間前に知ったばかりで，当惑気味であった。当村は，農地が約 500ha（うち水田が 350ha，そのほか 150ha），水面が約 500ha（うち養殖水域が 8ha）の半農半漁村で，河口域での漁業が制限されると，住民への影響は大きい。

なお，Quang Thai 村の対岸に当たる O Lau 川河口左岸の Dien Hoa 村では，海岸砂丘上にエビ養殖池を造成して集約的な養殖が行われている。ここでは現在 10ha の養殖池を，今後 64ha まで拡大する予定とのことであったが，海に面していない Quang Thai 村ではそのような戦略は不可能である。

4) フエ省による観光開発事業

フエ省では，2016 年〜20 年の事業として，4 つの民間の旅行会社とともに，ラグーンでの新しいエコツーリズムの推進に乗り出した。まずラグーン内の 7 カ所に舟着場を整備し，5〜7 人乗りのツアーボートを就航させる計画である。すでにラグーンをめぐるエコツアーは，複数の事業者によって実施されている。ツアーはいずれも半日程度で，ラグーン湖岸の村を訪ね，農漁村の生活を見たり，実際にボートに乗たり，また地元産の果物，野菜，水産物を食し，野鳥や植物，朝日または夕焼けを撮影するなどの楽しみが紹介されている[3]。Quang Thai 村の東隣のよりフエ市街地に近い Quang Loi 村 Ngu My Thanh 集落は，そのようなエコツアーの拠点の一つになっている。

O Lau 川河口の Quang Thai 村では，まだそのようなツアーは導入されていないが，副村長はもしそうなれば積極的に対応したいとのことであった。

3. 考察

Tam Giang ラグーン，とくにその北西端の O Lau 川河口域でのラムサール条約登録を目指した取り組みについて，現在および今後の課題について考察した。

1) 自然保護区の設定と住民との関係

ラムサール条約への要件の一つとして，生物多様性や生態系保全の核となる自然保護区の設定は急務である。その際，現在計画されているコアゾーン 1 内の中州での，かつてのヨシ原の再生だけでなく，水域の水質の保全も重要である。現在コアゾーン 1 の水域は，3 月〜7 月の乾季に塩水遡上防止のために，河口堰の水門が締め切られ，生き物の移動ができない。さらに本来ここは，生物の多様性や生産性が高い汽水環境であったと考えられる。したがって，人為的に設けられた河口堰を撤去するのは不可能としても，生物にとっての本来の生息環境を復元するために，堰の上流側への移設や堰に魚道を設置するなどの配慮が必要であろう。

ただし，自然保護区の設定や汽水環境の維持は，住民の稲作や漁業・養殖業を制限することにもなる。その保障やその代替となる新たな生業の創出が必要である。その手がかりの一つとして，次に述べるエコツーリズムの開発・導入が考えられる。

2) ワイズユースとしてのエコツーリズム

O Lau 川河口域に自然保護区を設定し，それを核とした地域がラムサール条約に登録できれば，この地域のツーリズムサイトとしての価値，とくに野鳥をはじめとする多様な生物に焦点を当てたツアーの魅力が上昇するであろう。そしてある程度のツーリストが訪れれば，ツアーボートの船頭や専門的なガイドを地元住民が務めたり，また村で食事や農業・漁業体験などを提供することで，地域住民の就労や所得と結びつくことが期待される。

一方，O Lau 川を河口から約 20km 遡った国道一号線と交わる地点にある Phuoc Tich 村では，ベトナムの伝統的集落景観の復元と新しいルーラルツーリズムの開発で年間 500〜600 人が宿泊し，同約 6，000 人が訪れている。この村までの川沿いにも特色ある集落が点在することから，これらを結ぶボートツアーなども考案できよう。

その他，将来この地域がラムサール登録地になることで，それを活かした地域ブランドの育成，すなわち地域資源を活かした食料品や工芸品など付加価値を高めた商品の開発なども考えられる。いずれの場合も，行政の政策に頼らず，地域住民も参加する自立的な取り組みが求められる。

4. 結論

Tam Giang ラグーンでは，1990 年代以降ラムサール条約への登録を目指して，様々な取り組みがなされてきた。まずは，生物多様性や生態系保全の核となる自然保護区の設定が急務であるが，これは住民の生業を制限することにもなるため，エコツーリズムの開発や条約登録を活かす地域ブランドの育成等によって，地域住民の生業の保障も考慮する必要がある。その際，国，省，村の連携，またそれら行政と研究者，NGO，住民の協働が重要である。

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O4-3

縄文時代における霞ヶ浦の環境変遷と人間活動

亀井　翼[1]

[1] 上高津貝塚ふるさと歴史の広場・筑波山地域ジオパーク推進協議会

キーワード：縄文時代，海進，貝塚，文化，ジオパーク

抄録

霞ヶ浦は，誕生から現在までのほとんどの時間を海として存在してきた。縄文時代早期，縄文海進によって霞ヶ浦が内湾として誕生すると，新たに形成された泥底干潟に対応してハイガイやカキを主体とする貝塚が形成された。その後，砂泥底干潟の環境が安定すると，ハマグリを主体とする貝塚が残されるようになる。海進最盛期である前期前葉以降は，海水準は徐々に低下し，桜川流域などでは海岸線が後退する。海進最盛期に形成された溺れ谷は海退に伴って湿地化するが，そこはドングリやトチのアク抜きや木工，漆工などの作業場として利用された。一方で，貝塚出土の貝からは，霞ヶ浦は縄文時代を通じて海域であり続けたことがわかる。後晩期に開始される土器製塩は，海退期であっても十分な鹹度があった証左である。海であった霞ヶ浦と人間との関係を象徴する縄文貝塚遺跡は，霞ヶ浦の歴史と文化を考える上で極めて重要であり，今後も保全と活用が必要である。

1. はじめに

海跡湖である霞ヶ浦は，誕生から低鹹汽水化するまでの約 1 万年間，古鬼怒湾という内湾であり続けた[1]。このことから，霞ヶ浦沿岸における人間活動の歴史も，その大部分は内湾としての霞ヶ浦と人間との関係史であったといえる。そこで本稿では，霞ヶ浦が誕生した縄文時代に注目し，霞ヶ浦の環境変遷と人間活動について議論する。

2. 霞ヶ浦の環境変遷

霞ヶ浦の器となる谷地形は，最終氷期に古鬼怒川の下刻によって形成された[2]。縄文海進によって海が侵入することで内湾が形成され，霞ヶ浦が誕生した[2]。印旛沼周辺における研究成果によれば，8,500 年前に約-10m であった海面は 7,800 年前にかけて急上昇し，6,500～6,400 年前に最高水準に達したという[3]。最高水準の時期は，縄文時代前期前葉（関山式～黒浜式）ごろに相当する[4]。貝塚の形成時期と分布からは，古鬼怒湾最奥部（小貝川流域）における縄文海進最盛期は関山式期であると想定されており[5]，無矛盾である。

海進最盛期の海水準は，利根川下流域のボーリング調査に基づく海水準変動曲線によれば+2～3m であったようである[6]。陸平貝塚周辺の谷底平野で行われたボーリング調査の結果，海成層の上限高度は標高 4m であった[7]。先述の印旛沼周辺の研究において，縄文時代の平均潮位と満潮時の潮位差は 1.7m であったことから[3]，海成層上限高度を満潮時の潮位と仮定すれば，海水準は 2.3m であると考えられる。上高津貝塚周辺の桜川低地において実施したボーリング調査でも，標高 1.5～2m で海成層が検出されている[8]。これらのことから，霞ヶ浦における縄文海進期の最高水準は 2～3m 程度と考えられる。

海進最盛期の海域は，小貝川流域では貝塚の分布から現在の常総市旧石下町付近まで到達していたと考えられている[5]。桜川沿いでは，現在の常磐道よりも西側，土浦市飯田のあたりまで海域となっていたことが，ボーリング調査による海成層の分布から示されている[9] [10]。桜川両岸の関山式期の貝塚分布からも，やはり海域は飯田のあたりまで到達していたとみられ，地質学の成果と調和的である[11]。

印旛沼周辺では，＋2～3m に達した海水準は徐々に低下し，2,600 年前ごろまでには-2.5m まで低下したという[3]。貝塚の分布からは，前期中葉の諸磯式期から海退の兆候が伺える[5]。桜川流域では，前期前葉には赤弥堂遺跡においてマガキ，ハイガイ，サルボウ主体の貝塚がみられるが[12]，後期中葉以降には上境旭台貝塚や上高津貝塚においてヤマトシジミが主体となり，海域から汽水域への変化が想起される。とはいえ，後述するように霞ヶ浦全域でみれば後晩期までハマグリ主体の貝塚が継続して形成されることから，縄文時代を通じて霞ヶ浦は海域であった。また，8 世紀に編纂された『常陸国風土記』では，霞ヶ浦は「流海」と記述され，浮島では塩づ

くりを行っていたことが記されている。霞ヶ浦が低鹹汽水化した時期は，湖底堆積物のテフラの年代から 15〜17 世紀が想定されるという[1]。霞ヶ浦が完全な淡水湖となるのは，常陸川水門が完成した 1963 年以降である。

3. 霞ヶ浦における貝塚形成と生業

貝塚とは，昔の人々が捨てた貝殻などが堆積した遺跡である。一般に，日本列島の土壌は弱酸性を示し，そのままでは骨が分解されてしまう。しかし，貝塚では多量の貝殻が土中の酸性を中和することから，骨がよく保存されている。当時の人々が食べた貝殻，魚骨，獣骨が保存されている貝塚は，当時の生業活動を考えるうえで重要な遺跡である。なお，縄文時代の貝塚からは，一般的に土器や石器など日常生活に必要な道具が発見されることから，一時的なゴミ捨て場や貝の加工工場ではなく，長期間居住した集落であったと考えられている。そして，霞ヶ浦は日本列島の中でも，東京湾沿岸と並び，縄文時代の貝塚が最も多く分布する地域のひとつである。

古鬼怒湾における貝塚形成は，千葉県西ノ城貝塚[13]や鴇崎貝塚[14]，茨城県利根町花輪台貝塚[15]において早期前葉（11,500〜10,690年前）に始まる。これらの貝層はヤマトシジミが主体となっており，海進が始まり汽水域が形成されたことが伺える。一方，霞ヶ浦沿岸では，より海面が上昇した早期後葉（8,500〜7,000 年前）から，狭間貝塚[16]，地蔵久保貝塚[17]，陸平貝塚[18]などで貝塚形成が始まる。内湾泥質干潟に生息するマガキやハイガイが目立ち，海進に伴って溺れ谷と泥質干潟が形成されたことが分かる[19]。 これ以降，湾奥部を除いて前期から後晩期にいたるまで，貝塚出土貝類の主体は内湾砂泥底に生息するハマグリとなり，砂泥質干潟が安定して存在したことが伺える。これらの貝塚から出土する貝は，これまで見てきたように汽水域ではヤマトシジミ，内湾ではマガキやハマグリといった，いまでもよく食べられている貝が主体となっている。

貝塚出土の魚骨から漁労対象を概観すると，ニシン科（マイワシなど），スズキ属，クロダイ属，ウナギ属，ハゼ科など内湾から汽水，淡水域に生息する多様な魚が，縄文時代を通じて利用されている[19]。湾口部の一部の貝塚ではマダイなど外洋性の魚も見られるものの，内湾の小型魚の漁が中心である。出土遺物からその手法を考えると，土器片錘やヤス状刺突具の存在から，浅い水域での投網漁や見突漁であったと想像される。狩猟はシカ，イノシシが主な対象で，中期ごろまで低調であるが，後晩期に活発化する[19]。

4. 溺れ谷の陸地化と低湿地遺跡の形成

縄文海進によって形成された溺れ谷は，海退ともに陸地化していった。陸平貝塚周辺の谷底低地においては，海進により溺れ谷が形成されていたが，後期前葉〜中葉ごろ（約 4,000〜3,800 年前）には湿地化したことがわかっている[7]。縄文時代後晩期には，台地上の貝塚や集落に伴って，こうした谷底低地の利用痕跡が増加する。先述した陸平貝塚周辺低地では，海成堆積物の直上に，後期前葉から後葉にかけて，多量の土器が集中的に廃棄された「土器集積址」が検出されている[20]。また，近年発掘調査が実施された上境旭台貝塚の低地部では，木道の可能性がある木材の集積や，鉢，飾り弓，把手坏鉢など様々な木胎漆器が発見された[21]。こうした低湿地遺跡は一般に，ドングリやトチのアク抜き，木工のための貯木場など，水を多量に使う作業場であると考えられている。海退に伴って出現した新たな土地を，縄文人が積極的に利用していたことが伺える。

5. 土器製塩の開始

縄文時代後晩期には，霞ヶ浦沿岸で土器製塩が開始される。無文で薄手粗製の塩づくり専用の土器を用いて，海水を煮詰め，塩を得ていた痕跡が広畑貝塚[22]や法堂遺跡[23]で見つかっている。こうした塩づくりの痕跡からも，霞ヶ浦が縄文時代を通じて海だったことがわかる。近年では，縄文時代の土器製塩に海草を焼いた灰が利用されていたことが分かっている[24]。時代はずっと下るが，万葉集などに見られる「藻塩焼く」という記述を彷彿とさせる。

6. まとめ

霞ヶ浦は縄文時代早期，縄文海進によって誕生して以降，縄文時代を通じて海域であった。霞ヶ浦沿岸には縄文時代の貝塚が多数残されている。こうした遺跡は縄文人が霞ヶ浦の環境変遷に適応して生活していた証拠であり，極めて貴重である。遺跡は地中にあるという性質上，現在の経済活動に伴う工事や建設によって容易に破壊されてしまう。そこで，文化財保護法ではこうした遺跡を埋蔵文化財として位置づけ，保護するともに，保護が難しい場合には発掘調査を実施することを義務付けている。なかでも貴重な遺跡は県や国の指定史跡として保護が図られており，霞ヶ浦沿岸の貝塚では，上高津貝塚，広畑貝塚，陸平貝塚が国の史跡に指定されている。

保存とともに，活用も重要である。上高津貝塚と陸平貝塚は史跡整備が実施され，遺跡を安全に見学することができ，隣接するガイダンス施設では出土資料が展示されている。また，2016 年 9 月，霞ヶ浦から筑波山までの 6 市域が，筑波山地域ジオパークとして日本ジオパークに認定された。上高津貝塚ふるさと歴史の広場は，貝塚を通して海だったころの霞ヶ浦を学習できる，ジオパークの拠点施設としても位置付けられている。霞ヶ浦沿岸の歴史，文化だけでなく，過去の環境変遷を考えるうえでも，縄文時代の貝塚遺跡は重要であり，今後も保全と活用が必要である。

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O4-4

霞ヶ浦が育む常世国と人類と自然の共生関係

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キーワード：豊かな自然の恵み，自然への畏怖と感謝，人類と自然との共生関係の歴史

抄録

霞ヶ浦地域は、文化人類学者である佐々木高明氏が提唱するナラ林文化と照葉樹林文化の接点と捉えることが可能な地域である。この自然環境は、豊かな恵みをもたらすことになり、霞ヶ浦地域の人々は自然の恩恵にあずかる生活をしてきた。奈良時代に編纂された『常陸国風土記』では、当地方が「常世国」とされ、人類が生活する所としては理想的と記されている。その後も豊かな自然環境と人類との共生が図られ、いつの時代も霞ヶ浦地域は繁栄した文化が形成されていったのである。歴史に見る人類と自然との共生は、自然への畏怖と感謝の気持ちを持ち続けることにより成り立っていた。このような自然と接する姿勢が、破壊することなく、負荷を与えることなく、より良い距離感をもった共生関係となっていたのである。小論では、自然への意識が低くなりつつある現代に、この日本人のすばらしき精神文化を引き継ぐ大切さを紹介した。

1. はじめに

地方では、少子高齢化が進み、加えて都市部への人口流出に歯止めがかからない現在に、日本社会は縮小の一途をたどっている。こうした状況の中に地方の疲弊と共に訪れているのが、自然環境への意識の軽薄化である。そこには、水質汚濁や森林破壊が極めて進行する状況が見て取れ、一部の人を除いて、先人が保ち続けてきた人間と自然とのより良き共生関係への配慮は、もはや存在しないように思われる。その配慮を少しでも取り戻すためには、多くの人に如何にして状況打開を図るかを共に考えていただく機会を設けていかねばならない。重要な視点は、人間と自然との共生関係が保ち続けられていた、人類発生から昭和時代の高度経済成長期までの総論的な日本人の歴史と各論的な地方の歴史を伝えていくことが肝要と考える。歴史には、人間の自然への畏怖と感謝があり、この行為があってこそより良い共生関係が生まれてきた。小論では、霞ヶ浦地域に生きた人間が豊かな自然環境に対して畏怖や感謝を重ねてきた歴史を紹介し、このような関係が今後のあらゆる地域において共生関係を構築するにあたり重要な視点であることを示してみたいと思う。

2. 霞ヶ浦地域の自然環境と基層文化

北東から南西部に長い、弓なりの形をした日本の森林帯は、大きく見て北東部の落葉広葉樹林と南西部の常緑広葉樹林に属しており、ここに文化人類学者である佐々木高明氏はナラ林文化と照葉樹林文化と呼ばれる文化圏を設定している。この文化圏は、南北に分かれる形で、東アジアの広範囲に存在しているようである。

茨城県は、落葉広葉樹林と常緑広葉樹林が混在する森林帯がみられる。垂直分布では、筑波山系の山並みの海抜６００㍍付近までにシイ、タブノキ、アカガシといった常緑広葉樹林がみられ、海抜８００㍍を過ぎる所からブナ、ミズナラなどの落葉広葉樹林がみられる。一方の水平分布では、茨城県南から県北に向かうほど常緑広葉樹林から落葉広葉樹林へ変化する様相がみられている。佐々木氏が提唱する文化圏の東アジアの東端に位置するのが茨城県域といえるのである。

一方で、水辺に目を向けると、茨城県の沖合は、暖流である黒潮と寒流である親潮がぶつかり合う環境と成り、豊富な魚介類が棲息する地域である。この海域に湾口をもつ霞ヶ浦は、自ずと影響を受ける内海となっていった。黒潮と親潮は、やはり展開するそれぞれの文化があり、文化圏を構成している。

以上のような森林帯と海流に南と北の様相がみられ、南と北の文化が混在し、多様な文化を持ち得る茨城県地域であるが、加えて、平地が広がり水資源を確保し易いところが、人間が生活する理想的な環

境となるであろう。その代表的な地域こそが霞ヶ浦地域なのである。

3. 霞ヶ浦地域の人類の豊かな暮らしと繁栄

霞ヶ浦地域は、自然環境や地理的環境により人間が生活を営むには、非常に恵まれた地域といえる。当地域には、これらの環境を理解し、活かしてきた歴史が刻まれてきた。それでは、霞ヶ浦の繁栄の歴史を古代・中世・近世の３時期にわたる特徴的な事象を紹介し、改めて霞ヶ浦地域のすばらしさを検証してみる。

まず、古代であるが、いち早く霞ヶ浦地域の豊かさを捉えたのが縄文人であった。霞ヶ浦に生きた縄文人は、当地域に日本有数の貝塚文化を展開させ、様々な文化の基盤を形成していった。貝塚文化を代表する要素は、漁業、舟運、塩作りなどである。縄文海進によって霞ヶ浦各地に形成されたラグーンに拠点を設けた縄文人は、海の幸を捕獲するための道具や技術、水辺の交通と操船技術、副産物といえる調味料、保存食品に欠かせない塩づくりなど、この地域ならではの文化を創り上げていった。この縄文人によって形成された文化をさらに発展させていったのが、古墳時代である。当地域の安定した気候や農耕に適した地形・地質、粘土や砂鉄、石材に恵まれた環境は多くの産業を生み出すことになり、霞ヶ浦地域を拠点とした豪族は、ヤマト政権との奉仕と連携の関係を強めながら、これらの産業を発展させるための情報や新技術を移入させていった。さらに、これらの産業の中で、農耕祭祀から展開した民俗文化は、当地域に人々を集わせるものとなっていった。それが嬥歌という行事である。風光明媚な土地に男女が集い、歌を掛け合う春と秋の行事で、これは縄文時代から引き継がれる自然神への畏怖と感謝を示すものであった。

中世は、霞ヶ浦の漁業や水上交通を熟知した「海夫」が活躍した時期である。海夫は、専門的職業として漁業、物資輸送や旅客などを乗せた舟運に携わった人々である。潮来市の臨済宗長勝寺の国指定重要文化財の梵鐘にあるように、中国の蘇州になぞれた板来津の繁栄の様子、神栖市の嶋崎山宝蔵院にある碇石が物語る唐船が入港していた可能性、そして行方市の鳥名木文書にみられる商船を狙う海賊の様子など我が国を代表する繁栄した水辺が、中世の霞ヶ浦地域に展開したが、これらは海夫の活躍によるものであった。さらに、中世の時期には、多くの著名な宗教者が霞ヶ浦沿岸で布教活動を展開していた。西大寺流真言律宗の僧である忍性、浄土真宗の開祖である親鸞などはその代表的存在である。これら宗教者の布教活動は、多くの人々が集住する地域のおいて可能なことから、海夫による各種商品が集積され、物資流通や商品経済によって繁栄を極める霞ヶ浦沿岸の港町は格好の布教の場となっていたのである。しかし、繁栄は永遠とは言えないため、繁栄を維持するために海夫たちは自らの行為を制限あるいは律するための行動をとっていた。それは、霞ヶ浦地域を見守る鹿島・香取の神への畏怖と感謝であった。霞ヶ浦沿岸地域の人々の鹿島・香取の神への信仰は、古墳時代には形成されていたが、職業民となった海夫が神のご加護への祈りと感謝をすることで舟運の安全や漁業の豊漁の保障を受けるという関係を育ませていったのである。

近世は、霞ヶ浦地域が最も繁栄した時期といえる。１００万人都市とも言われる江戸の食料や物資の流通を霞ヶ浦の水運が担ったからである。中世の時期に海夫が創り上げた舟運文化が、江戸への廻米や物資輸送のために無くてはならない存在となり、それに伴って同時に木造船に関わる木挽き、船大工などの職人、物資流通に関わる河岸問屋、操船に携わる船頭や水主など水辺の職業が確立していったのである。港には、霞ヶ浦周辺の物資のみならず内陸部から霞ヶ浦に流入する河川を利用し運び込まれ物資や東北諸藩の廻米など遠方の物資も霞ヶ浦水運を扱うようになり、中世の時期以上の人々が霞ヶ浦を往来するようになっていった。そして、一方で、近世の霞ヶ浦沿岸の特徴的な産業として発展したのが醸造業である。醸造業は、霞ヶ浦地域を繁栄と共に有名にするものとなり、東の灘といわれた府中（石岡市）の酒、そして土浦の醤油は代表的なものである。物資の流通と経済の発展により、霞ヶ浦地域に更なる繁栄がもたらされたのであった。これらに携わる人々は、水神講という信仰組織をつくっていった。

近世はこの水神講により畏怖と感謝を示していたのである。

このように、霞ヶ浦沿岸の地域史を紐解くと、古代から近世に至るまで、常世国ならではの様々な繁栄の歴史を刻んできたことが分かる。霞ヶ浦に住み、或いは利用する人々は、繁栄を維持するための畏怖と感謝に代表される自然環境への配慮を忘れてはいなかったのである。つまり、より良い共生関係を保持していたことで、繁栄がもたらされたのであった。

4. 歴史にみる繁栄の背景にある人間の精神

人間が生きるには、どうしても様々な負荷を自然に与えることとなる。特に生業や産業を展開するには直接的な負荷が多大に生じる。

霞ヶ浦の水辺の主たる産業である漁業は、漁獲量を求めすぎると生態系の種の保全が図れず、湖岸の植生などの維持管理をしていかねば産卵場所の確保もままならない状況に陥る。魚への直接的な配慮と魚が育つ環境への配慮が必要となる。

一方で霞ヶ浦地域の陸地の産業の一つに稲作がある。稲作には、耕地を広げるための干拓などの土地改変、潅漑を設けるための環境整備などは水の流れを変化させることとなり、収穫量を上げるため、病害虫から守るためといえども農薬散布は環境汚染となり、人間の営みは、自然へ負荷を与えているのである。

『常陸国風土記』の行方郡の条には、谷津を水田とするために開発したり、湧水を利用して溜池を構築したりする人物の話が登場する。その際に、自然から人工へ改変される土地状況を阻む神が現れるが、開発者は自然界への畏怖心による祈りと自然界がもたらす恵みへの感謝を表わすことで、地域開発の許しを得ていた。また、中世の時期に霞ヶ浦の漁業や水運に携わる海夫が、先述したように鹿島や香取の神へ供祭料を奉納し、それらに対するご加護が得られると信じたことや近世に始まる水神という水辺の神へ、水辺を利用する者達が集団で祈る行事の水神講などは、霞ヶ浦地域の歴史に一貫して存在した自然界への畏怖と感謝を引き継ぐ精神であった。その後も霞ヶ浦地域の自然に対する人間の精神文化は、伝統的に行われていったのである。

このような行為は、人間が自然を利用することへの配慮から生じるもので、自ずと自然とのより良い共生関係を築くものとなっていたのである。自然神に八百万の神を信じ、自然神への祭祀を行う日本人の精神文化が、自然界に生きる人類を安定した共生関係へ導いていたのである。

5. 霞ヶ浦地域の歴史に学ぶ自然との共生関係

人工的なものがあふれる現代社会に埋没すると、人間が自然や生態系の中に生きていることを忘れてしまいがちになる。自然と人間との共生には、日常的な関わりが重要であるが、関わりがある程度に定期的にあることでも効果は期待できる。筆者は、人間の営みの歴史という人文科学的な面から、より良い自然とのつきあい方を探り、定期的に多くの人に紹介する機会を勤務する博物館で実施している。特に今回紹介したような地域の精神史からの視点は、全国各地においても、より良い自然との共生関係を考える上で重要と考えている。その地域においてどのような人間の行為が負荷となるかを考え、地域に生きる人間が自然に対して如何なる接し方をしてきたか、それらを知ることで今後の有効な共生関係を考えることができるのである。筆者は、これからも歴史に見る人間と自然との共生のあり方を見いだし、多くの人に紹介し続けていきたいと思う。

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O4-5

水辺の交流「泳げる霞ヶ浦市民フェスティバル」

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キーワード：水辺空間, レクリエーション, 地域づくり, 協働, 市民参加

抄録

1995（平成7）年 10 月に第6回世界湖沼会議が開催されるのに向け、1993（平成5）年9月、『人・まちが動き 水が動く』をスローガンに、4者パートナーシップ（市民・行政・産業界・研究者）のもと、「世界湖沼会議市民の会」が発足した。この時に開催した2回の「霞ヶ浦市民の夕べ」が、現在の「泳げる霞ヶ浦市民フェスティバル」の前身である。当フェスティバルは、ランドエリアとウォーターエリアに分かれ、毎年 6,000 人を超える来場者で賑わいを見せている。多くの地域住民、産業界、行政関係者等に、霞ヶ浦に来て触れてもらい、今日の現状と水質浄化の取り組みについて理解を深め、自然（霞ヶ浦）に関心をもってもらう。そして、地域の宝であり、私たちの大切な水資源である霞ヶ浦に、より一層の親しみを感じてもらい、地域（霞ヶ浦）のために自ら行動を起こせる人づくりを目的とする。『泳げる霞ヶ浦』の実現を目指し、人々の憩いの場としてのまちづくり（地域づくり）を進めている。

1. フェスティバルの精神

1995（平成7）年開催の第6回世界湖沼会議を2年後に控えた 1993（平成5）年9月、学術会議にも市民が参加することで霞ヶ浦浄化の気運を高めようと、「世界湖沼会議市民の会」が結成された。会には個人はもとより、各種団体、行政、企業、研究者等が趣意に賛同し結集している。これは、かつてない新しい市民団体の形であった。会の結成に奔走し、会長を務めた堀越昭氏は、「市民活動に、行政対立型、行政共存型、行政指導型の3つがあるならば、この会は行政共存型として出発したい。市民と行政には『緊張感ある協調関係』が望ましく、皆が同じテーブルに着き、討論し、出た結論には皆で協力する」と述べた。これはのちに第6回会議で採択された霞ヶ浦宣言の『市民・行政・産業界・研究者のパートナーシップ』の文言にも結びつくもので、会の方針、ひいてはその後に設立する「霞ヶ浦市民協会」の理念の土台にもなる表明だった。

各種団体の集まりである当会会員は 1,000 名を超え、人材はもとより、それぞれに培ってきた経験や技術の宝庫でもある。主義主張も常に同じ方向を向くとは限らない。必要なのは、互いを尊重しつつ、常に聞く耳を持ち、意見を交わし、交流しながら同じ目的に進むことである。こうした道程を経て、満場一致で得たスローガンが『泳げる霞ヶ浦』である。1973（昭和 48）年のアオコ大発生など、当時の霞ヶ浦は水質が悪化し、以降の社会問題にも発展していた。このままでは、霞ヶ浦は永遠に負のイメージから抜け出せない。では、その意識から変えよう、霞ヶ浦への夢や提案を市民の手で集めよう、と会の事業体制を方向づけた。霞ヶ浦流域に住む市民に向けては、「私たち市民の使った水は、必ず湖に還る」という水循環の原則と現実を訴えつづけた。まずは流域市民が霞ヶ浦への関心と浄化の意識を持ち、家庭からの排水に責任を持つことから始める。個人の意識や行動が町内に広がり、やがて地域・自治体を巻き込みながら政策にも反映され、浄化につながる。その構図を表した『人・まちが動き 水が動く』を『泳げる霞ヶ浦』へ向けてのメインテーマに据えた。

人々や地域の交流の場を提供しながら、世界湖沼会議に向けての勉強会やレクリエーション、啓発事業が行われた。親子学習会、料理会、アシ工芸講習会、英会話教室、湖沼セミナー、指定湖沼フォーラム、琵琶湖ツアー、土浦ビオパーク、浜辺づくり、船上観察会、わくわく市、霞ヶ浦清掃大作戦、かすみがうら親子たんてい団、ILEC 交流会、アメリカ五大湖ツアー、世界湖沼セミナー、など多種多様である。また、加古隆ピアノコンサート、映画「米」上映会、3,000 人大合唱という大規模なイベントも主催した。なかでも、水辺の交流として盛大に開催されたのが、1994（平成6）年8月の「霞ヶ浦市民の夕べ」と、第6回会議直前の 1995（平成7）年8月の「霞ヶ浦の夕べ Part 2」だ。思い思いの仮装をして霞ヶ浦に飛び

込むターザンジャンプ、ビオパーク試食会・音楽祭、わくわく市、ヨット試乗など、地域の文化や産物をベースに楽しめるイベントとして大いに盛り上がった。

これこそが水辺の交流であり、1996（平成8）年3月に同会が解散したあと、同7月に設立した霞ヶ浦市民協会の『泳げる霞ヶ浦市民フェスティバル』に引き継がれていくことになる。



写真 1 フェスティバル会場風景

2. 活動経過

第1回泳げる霞ヶ浦市民フェスティバルは、1996（平成8）年9月1日、社団法人霞ヶ浦市民協会の設立記念式典とともに、土浦ビオパーク隣りの湖畔で開催された。各種団体を共催に、国や県、流域市町村や広域団体の後援を得ての、まさに前述の4者パートナーシップで支える水辺の交流イベントである。人気のターザンジャンプほか、水上でのフラッグバトル、ヨットやカヌー試乗、投網体験、魚獲りなどのウォーターエリアのほか、音楽、ダンス、遊び、環境学習などラウンドエリアのメニューも盛り沢山。子どもも大人も楽しめる企画で満載となる。



写真 2 霞ヶ浦でＥボート体験

また、国交省の同時企画「霞ヶ浦夏休み教室」の運営も行い、のちに「霞ヶ浦インフォメーションセンター・水の交流館」が開館すると「夏の霞ヶ浦何でも相談室」も開催、人気を博した。

2001（平成 13）年5月、当協会は 2020 年を目標に、『泳げる霞ヶ浦』の実現を目指すための『泳げる霞ヶ浦 2020 市民計画 基本構想』を、翌年には『同行動計画』を策定した。当時、20 年先の 2020 年は子どもたちが大人になり社会を担う時代であり、さらにその先へもつながる計画として、21世紀にふさわしい環境型循環社会の構築を背景にしたものである。これは、人と自然の共生を前提に、湖沼や河川の流域住民が、常に流域全体を視野に生活し、水系と関わっていることを自覚することで成り立つ、いわば『霞ヶ浦市民社会』とも言うべきネットワークの確立を目指したものでもある。

同計画の基本フレームは5つのプロジェクトから構成されている。①暮らしのプロジェクト／新しい生活文化の創造…インフォメーションセンター「水の交流館」運営・夏休み教室・霞ヶ浦ジュニアレンジャー養成講座・自然観察会・環境学習・生活排水事業等 ②身近な川プロジェクト／生物多様性への模索…水質調査（地域・一斉）・新川クリーンアップ・どんぐり里子作戦・生物調査・河川清掃等 ③水辺交流プロジェクト／人と自然の回廊づくり…泳げる霞ヶ浦市民フェスティバル・水辺ふれあい事業・景観づくり等 ④地域経済プロジェクト／食に始まる霞ヶ浦ブランドづくり…土浦ビオパーク・新川浄化実験場・エコビジネス・地場産品の利活用 ⑤人とひとプロジェクト／プロジェクトの総括集結…シンポジウム・地域懇談会・世界湖沼会議・広報出版・交流会・研究など。これらの事業を市民、行政、研究者、企業、農林漁業者、学校、各種団体とともに協同・協働していく。

水辺交流プロジェクトの事業となる泳げる霞ヶ浦市民フェスティバルは、流域各種団体の連携のもとで『泳げる霞ヶ浦』の実現を目指す、市民交流の場として位置づけられる「お祭り」である。生活文化や信仰に端を発する日本の祭事は、地域の人々が協力し支え合いながら生きていく相互認識の確認の場であり、最大の交流の場でもある。『泳げる霞ヶ浦』という共通の目標を、祭りのベ

ースにある神事・信仰という不動の原動力とするならば、このフェスティバルはまさに地域交流の「祭り」である。毎年の海の日に 6,000～8,000 人の来場者を呼び、23 回目の今年は、本会議のサテライト事業である『ハイスクール会議』も開催した。

3. 課題と展望

23 回の開催を支えてきたのは、人々の精神的、物理的な支援とマンパワーにほかならないが、不可欠なのは活動資金である。現在は、地域の商店、企業、団体等の協賛金のほか、当協会からの予算を計上しながら運営している。フェスティバル自体は、土浦・つくば・牛久・石岡の各青年会議所メンバーが交代で実行委員長に、参加各団体が実行委員として全体の企画から運営までを引き受ける。皆、自分の仕事と並行して動いている以上、フェスティバルの規模が大きくなればなるほど時間も費やされ、しかも手弁当では、時に大きな負担を抱え、支障も出るのが当たり前だろう。重要な課題のひとつである。

地域での活動には、住民の理解と協力が必要であり、それを得るためには、住民にとっての何らかのメリットがなければならない。その簡単そうで難しいことを、我々は今までの協会事業で会得してきた。このフェスティバルが「祭り」の機能を果たしながら、地域交流の場としての役割を果たせるかどうか。『泳げる霞ヶ浦』を掲げても、足元から崩れては元も子もない。フェスティバルは、ともに『泳げる霞ヶ浦』の実現を目指し、自主的に霞ヶ浦と関わり合おうとする人を育てる場であり、自分たちのまちや地域をつくりあげていく交流の場である。

『泳げる霞ヶ浦 2020 市民計画』の目標地点である 2020 年を目前にした今、水辺のお祭りであるフェスティバルを、尚一層、人々の交流と憩いの場として全世代に提供していくことが、協会の大きな課題であり、展望でもある。



写真 3 伝統芸能・亀城太鼓の演奏



写真 4『泳げる霞ヶ浦』で子どもたちが遊ぶ



写真 5 子どもに大人気のアクア・ボール

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O4-6

サイクリング天国いばらきを走ろう！
ー「つくば霞ヶ浦りんりんロード」サイクリングイベント実践報告ー

HMBアウトドアクラブ　霞ヶ浦サイクリングチーム　会長　張替　幸一、副会長　古川　ゆかり

キーワード：霞ヶ浦の特性とサイクリングへの活用

抄録

私たちHMBアウトドアクラブは、「サイクリング天国いばらきを走ろう！」をテーマに 2004 年から、霞ヶ浦の特性を生かしたサイクリングイベントを提供し実践していくことで、茨城県内にとどまらず関東・東北一円から延べ 1400 人に上る参加者を呼び込んで来た。これは、その発想から実践に至った経緯と今後の目標についての記録である。

1. はじめに

“人はなぜ回りたがるのか”サイクリングを趣味とする人々の共通点として、何かの回りを回ってみたいという発想がある。これは、道を知らなくとも回れるということだけでなく、同じルートを通らずに、より長い距離を走りたいという気持ちや、往復ルートと違って走り出した途端ゴールまでの道のりが縮んでいくという利点、そしてスタート地点が見えゴールした時のこの上ない達成感など様々な動機づけがあるからである。

特に母なる湖ともいえる霞ヶ浦は、スーパーフラットな湖岸道路とは対照的に一歩内陸に入ると、まぶしいほどの緑で覆われた森や畑、台地が広がる。

私どもHMBアウトドアクラブは、2004 年日本初の船を使ったファミリーサイクリング「霞ヶ浦サイクル＆クルーズ」を実施した。その後、この霞ヶ浦の特性を生かした多種多様なサイクリングイベントを計画、実行し、茨城県内だけでなく関東、東北一円から述べ 1400 名に上る参加者を呼び込んできた。この湖沼会議の開催を機に、その方法や実施記録をまとめ、今後の事業継続や継承の一助とし、霞ヶ浦や茨城県の魅力度アップに貢献したいと考える。

2. 方法

① ＜霞ヶ浦サイクル＆クルーズ＞

土浦港から発着する遊覧船「ホワイトアイリス号」を特別にチャーターし潮来まで自転車といっしょにクルーズ後、潮来から土浦までの約 50km をサイクリング。サポートカーで並走し、途中で、地元の食材を使ったおやつや、特色のある弁当などを提供した。ファミリーの中でも走れる大人には、内陸の小高い丘の上の公園へのヒルクライムや、起伏のある里山をめぐるアトラクションを用意し、湖岸を走る子どもや女性に後方から追いつき合流するという工夫をした。

② ＜くるっと霞ヶ浦　高浜入り湖岸道路 40km＞

行方市玉造にある霞ヶ浦ふれあいランド発着で、高浜入りの湖岸道路約 40kmを一周するというファミリーサイクリングである。サイクル＆クルーズに比べて乗船料がかからないため、参加費を 1000 円～1500 円という安い料金に設定した。こちらも、走れる大人のために湖岸の古墳や里山をめぐるアップダウンを楽しめるアトラクションを用意し子どもらとのバランスに配慮した。

③ ＜スーパーチャレンジ霞ヶ浦　西浦 130km＞

サイクリングビギナーにとって、100km走破というのはロングライドの最初の目標となる距離である。霞ヶ浦 1 周というと 90kmと考えられているが、霞ヶ浦大橋以北の高浜入りを加えることで 130kmという距離となる。そこで過去にファミリーサイクリングに参加した家族からより長い距離に挑戦したい成人のビギナーを募り実施した。ビギナーにとっての挑戦という意味でスーパーチャレンジという名称をつけたものである。

④ ＜霞ヶ浦 1 周フィットネスサイクリング 90km＞

霞ヶ浦を 1 周するサイクリングは以前から行われていたが、ビギナーに特化したものではなかった。そこでサポートカーで並走し地元の名物をおやつや昼食として提供したり、スタッフが乗り方や走り方をアドバイスしたり、時には湖岸をはなれてアップダウンを走るアトラクションを楽しんだりなど、ビギナーがより楽しめる工夫を随所に盛り込むことで差別化を図った。

3. 結果

① ＜霞ヶ浦サイクル＆クルーズ＞

写真 1



第 1 回は広報に大変苦労した。りんりんロードでビラ配りをしたり、掲載無料の情報誌に掲載していただくなどして何とか集まったのは 60 名。約 10 名のサポートスタッフで運営した。しかし 60 名分の自転車を船に積み込むことはできず、やむなく自転車はトラックで潮来まで運ぶこととなった（写真 1）。船の中では東大の助教をしているスタッフが霞ヶ浦の環境などについての話をするなどしながらクルーズを楽しんだ。

特に初回は、全国初の船を使ったファミリーサイクリングということでNHKの取材スタッフが同行し（写真 2）、潮来に下船した際には潮来市役所の有志の方が横断幕を掲げて出迎えてくださるなどした。

写真 2



写真 3



また「潮来ふるさと館」ではトイレ休憩だけでなくザリガニ釣りをしたり（写真 3）、天王崎公園では牛乳普及協会から協賛を受けた牛乳と地元の店のケーキをおやつとして提供したりした。全員が完走し霞ヶ浦総合公園にゴール。完走証とともに、JA土浦から協賛を受けたレンコンをお土産として配り終了した。翌年の第 2 回からは、特に広報はしなかったが前回の参加者と、そのクチコミを聞いた参加者ですぐに満員御礼となった（写真 4）。計 4 回の参加者の合計は約 330 名に上った。

写真 4



② ＜くるっと霞ヶ浦　高浜入り湖岸道路 40km＞

船のイベントとはちがって参加費も安く人数制限もないことから、広く参加者を募り計 4 回実施した。

写真 5



高浜入りの湖岸を走るコースは、特に筑波山をコースの延長に臨むことのできるすばらしい景観が特長で、晴れた日のサイクリングには非常に適した環境である（写真 5）。合計参加者は約 150 名であった。

③ ＜スーパーチャレンジ霞ヶ浦　西浦 130km＞

初回は 6 月でありながら 8 月並みの気温となり、ビギナーにとっては予想以上に過酷なサイクリング環境となった（写真 6）。しかし 100 ㎞地点では全員で達成感をかみしめ最後は感動のゴールとなった。その後、ロングライドの魅力に目覚めたビギナーが繰り返し参加するなどしたことから、2 回目以降は、湖岸道路から離れて起伏にとんだ丘陵や心地よいアップダウンのある里山を走るなど毎回違った趣向を取り入れ人気企画となった。

写真 6



④ ＜霞ヶ浦 1 周フィットネスサイクリング 90km＞

1 人で霞ヶ浦を 1 周する自信のないビギナーと、いっしょに楽しく走りたいサイクリストを対象に募集したところ、意外にも後者の方が多く集まった。そのため、ただ湖岸を走るだけでなく、毎回違った趣向を凝らし人気企画となり計 13 回実施した。

しかし、回を重ねるうちに、パンクを起こして全員が足止めされたり、集団のスピードに付いて行けずに皆を待たせたりするケースも見受けられるようになった。ふつうの集団走行であれば、他の参加者に迷惑をかけたと気おくれしたり、次の参加を見合わせたりする人もいるだろう。しかし、私どもHMBアウトドアクラブでは、「サイクリングはあくまでも遊びであり今日は休日なのだ」という精神を表す“It’s a holiday!”を合言葉に、ハプニングもすべて含めて休日の遊びのすばらしい思い出とする精神で、参加者が決して罪悪感を持たずに何度でも参加できるような雰囲気づくりをしてきた。その甲斐あって、誰かがパンクするたびに全員がその参加者を囲んで記念撮影をするなど、考えられない光景が見られるようになった。中でも一番全員が盛り

上がったのは、会長自身がパンクを起こした回である（写真 7）。

写真 7



また、このような会長のフレンドリーな性格も手伝って、回を重ねるごとにコース沿いで出合う人々と徐々に顔見知りとなり、そのうち自ら協力してくれる方も現れるようになった。特に、農家の方が自宅に招き入れ甘酒やバナナを振る舞ってくださったり、収穫体験をさせてくださったり（写真 8）、忘れられない回となることもしばしばであった。

写真 8



4. 考察

約 1400 名もの参加者を呼び込むことができたのは霞ヶ浦とその周辺地域の自然環境が無限の可能性を秘めているからに他ならないであろう。一方、ビギナーが個人でサイクリングしようとしても、トイレが少なく、パンクなどの急なハプニングや突然の悪天候などに対応できる施設やサービスがなく、また、補給食を購入できる店も限られていることから、非常に困ったという話をよく聞く。さらに、回遊性を持たせるための船やバスについても宣伝不足のためかあまり認知されておらず、利用者が少ないという皮肉な結果が生じている。

したがって、たとえば霞ヶ浦の湖岸 10～20kmおきにトイレと、現在地や救急時の連絡先、最寄りの交通機関などを記したインフォメーションボードを立てるなどが急務となるであろう。トイレを造ることが難しければ、近隣の店に協力を仰ぎ、トイレを貸してもらえる店として経路や距離をボードに記載することもできるであろう。

次に今後のサイクリングイベントの展望について、まず＜サイクル＆クルーズ＞については、個人による継続的な実施は難しいと考えている。前述のとおり、チャーター代 10 万円を賄うには 100 名近い参加者がいて初めて 1 人あたり 1000 円ほどの負担で済むわけであるが、参加者が 100 名集まっても、実際に船に自転車を持ち込んで乗れるのは 40 名程度が限界である。そこで私たちは走れる参加者には船に乗らず自走で潮来まで走ってもらい、その問題を何とか解決してきた。ここ数年茨城県や土浦市の社会実証実験でサイクルーズの運航が始まったが、これも予算が下りなくなれば終了してしまうであろう。週末には自転車を載せられる小型のサイクルバスが常に霞ヶ浦を時計回りに周回するなど、画期的な対策が望まれるのではないか。

＜くるっと霞ヶ浦＞について、このイベントは今後もっとも発展していく可能性を持つイベントだと考えている。現在は個人のできる範囲で行っているが、福島の「檜原湖 1 周ファミリーサイクリング」のように地元の商工会や婦人会を巻き込んで 10kmおきにおやつや飲み物を提供するエイドステーションを作り、「あと半分だよ。がんばってね！」などの一言がもらえるだけでも、参加者にとって忘れられない体験となるはずである。特にファミリーで参加することによって、子どもたちが次に親となり、自分が味わった感動を子どもに味わわせたいと願うことで、継続可能なイベントとなっていく。プロやタレントを呼んでサイクリング振興を図るよりはるかに地域の観光にも寄与する継続可能で持続性の高い振興策となるのではなかろうか。

成人ビギナー対象のイベント＜霞ヶ浦 1 周フィットネスサイクリング 90 ㎞＞や＜スーパーチャレンジ霞ヶ浦 130 ㎞＞は、今後も人気イベントとして年間を通してできるだけ開催し、需要に応えたいと考えている。ただ、個人では広報に限界があるため、サイクリングや霞ヶ浦に関する情報を一括して探すことのできるサイトなどの設営が望まれる。また、スピードが増せば増すほど、ちょっとした路面の傷が命取りになる。未舗装区間の完成とともに、劣化した個所の修理が急務であると考える。

5. 結論

サイクリングにとって母なる湖、霞ヶ浦の可能性は無限である。しかし、それを生かすのも殺すのもマンパワーに他ならない。私どものような個人や協会でサイクリングイベントを実践している集団を取りまとめ、ネット媒体だけでなく紙媒体、テレビ、ラジオなど様々な媒体を使って広報していくことで、必要な情報が必要な人に届き、霞ヶ浦や茨城県がますます「サイクリング天国」として認知され、魅力度が高まるのではないだろうか。今後の茨城県の施策にさらに注目するとともに、微力ながら、私どもにできることを可能な限り実践し、霞ヶ浦や茨城県の魅力度アップに貢献していくことができればうれしい。

O4-7

内水面利用の多様化と利用調整問題：四国吉野川上流域を事例に

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キーワード：内水面, 漁業, レジャー, 利用調整ルール

抄録

本研究では、内水面の多面的利用に伴うステークホルダー間の利用調整問題に焦点を当て、日本で最もラフティングが盛んな徳島県の吉野川上流域を事例として取り上げ、そこにおいて展開されるレジャーによる水面利用とその利用調整ルールの特質および意義、課題を明らかにし、望ましい水面利用のあり方について考察した。当該地域では、ラフティング業者と地元漁協の間で協定が結ばれ、多様な利用主体が存在するなかにあっても円滑な河川の利用を目指す努力がなされている。内水面の利用調整問題に関しては、これまで主に「漁業対レジャー」という構図で研究されてきたが、本事例では「レジャー（遊漁）対レジャー（ラフティング）」という構図においてルールの構築が果たされており、河川の多様な利用を整序するうえで評価できる。しかしながら、ルールの内容については安全性、さらに公平性といった観点から課題も残されていることがわかった。

1. はじめに

1980 年代以降、日本では経済の成熟化に伴い、国民の余暇に対するニーズが高まり多様化してきた。内水面においても、湖水浴をはじめとして、釣り、クルージング、ジェットスキー、カヌーなどの多様なレジャーが楽しまれるようになり、本研究で取り上げる小型ボートを使って急流を下るラフティングも典型的なレジャーの一つである。ところが、こうした水面利用の多様化につれ、利用主体間でさまざまなコンフリクトが発生するようになり、特に内水面の先発的利用者である漁業者および遊漁者と新参レジャー側との対立が問題化するようになった。

内水面における漁業は漁業権に基づき、シジミやサケ・マス類、コイ・フナ類、アユなどの魚種を対象として営まれてきたが、水産動植物の生息環境の悪化が進行したことで、漁業生産量は 1970 年代後半をピークに減少の一途をたどっている。一方、内水面漁業の管理を担う漁協は、1950 年代から始まった河川の開発事業に伴う漁業補償への対応調整[1]のほか、水産動植物の増殖を図るという義務が課せられており、漁協は釣り人の遊漁料や組合員から納付される漁業権行使料を用いて、漁業権対象魚種の種苗放流や漁場の管理等を行い、水産資源の維持増大と遊漁を含めた利用の両立を図るという利用調整の役割も担ってきた[2]。

内水面の遊漁的利用は、都道府県知事の認可を受けた遊漁規則で整序されており、遊漁者は通常は漁協が発行する遊漁券を購入するか、賦課金・出資金を払って漁協の組合員となって遊漁を行うことになる。地域によっては、組合員のほとんどが遊漁者に占められる漁協も珍しくない。ところが、近年遊漁人口、特に装備が高額なアユ釣りの人口が大幅に減少し、内水面漁協の組合員数も減少傾向で推移している。また、漁協には水産動植物の増殖が義務付けられる一方で、水産動植物の生息環境の整備は義務付けられておらず、漁場環境・資源状況の悪化という深刻な問題を抱えている。

レジャーと漁業の水面利用を巡る研究は、海面においては徐々に進んできているが、内水面を対象としたものはきわめて少ない。すなわち、内水面という地域資源を多様な利用主体が持続的に利用していくためには、どのような利用調整ルールが必要なのかといった議論は十分に進んではおらず、そのあるべき姿の確立が大きな課題となっている。

そこで本研究では、日本で最もラフティングが盛んな徳島県の吉野川上流域を対象事例として取り上げ、そこにおいて展開されるレジャーの水面利用とその利用調整ルールの特質および意義、課題を明らかにし、望ましい水面利用のあり方について考察する。

2. 方法

2-1. 対象地域

吉野川は高知県吾川郡いの町の瓶ケ森を源流とし、幹川流路延長 194km、流域面積 3,750km^2 で、四国全体の約 20%にあたる広さを占める四国第一の河川である。ラフティングが盛んな吉野川上流の大歩危・小歩危（おおぼけ・こぼけ）一帯は、日本一の激流とも言われ、年間を通じて水量が安定していることから、全国からラフティングやカヌーの愛好家が訪れる地域である。

2-2. 調査の概要

本研究では、内水面とレジャーの利用調整に関する既存文献を整理するとともに、対象地域のレジャー関係者および行政関係者に対して、聞き取り調査を行った。

3. 結果

3-1. 吉野川上流域の水面利用

現在、吉野川上流域の主な水面利用形態はラフティングと遊漁である。吉野川上流域には、20 数社のラフティング業者が点在し、2017 年 10 月には国内で初めてラフティング世界選手権が開催されるなど、日本で最もラフティングが盛んな地域である。ラフティングが行われているエリアは高知県大豊町および徳島県三好市にまたがり、近年は両市ともラフティングの振興に力を入れている。ラフティング客は、年間約 4 万人が訪れており、地域の宿泊施設や農泊、飲食店の利用、あるいは雇用などが促進されて、地域経済にも少なからずプラスの効果をもたらしている。

遊漁の利用は盛んだが、全国的な傾向と同じく減少傾向で推移している。遊漁者は遊漁券を購入あるいは地元漁協の組合員になって釣りを楽しんでいる。

そのほかの当該地域の水面利用としては遊覧船やカヌー、スタンドアップリバーサーフィンなどのレジャー的利用もあるがラフティングと比べると規模は小さい。

3-2. 水面利用調整のルール

吉野川上流の水面利用にあたっては、ラフティング利用が始まった当初、遊漁とのトラブルが頻発していた。釣りのラインがラフティングのボートに引っかかったり、狙いたいポイントをボートが通過したり、仕掛けていた漁具が破損されたりする。また、吉野川上流は激流であることから事故も多く、流木等の情報共有も必要なため、ラフティング業者側は協会を組織し（すべての業者が参加しているわけではない）、業者同士でネットワークを構築するとともに、漁業者側との調整を進めていった。

その結果、ラフティング協会と地元漁協は、三好市を介して協定を結び、ラフティングの通過時間が定められた。通過時間は、アユが集中して生息している瀬を中心に組まれており、協会に所属するラフティング業者は船に番号が振られ、このルールを守る義務が課せられた。そのほかにも、遊漁者の近くを通過する際には笛を吹くことなどが定められている。この協定は、約 20 年前に初めて交わされ、毎年更新されることとなっているものの、必ずしも毎年締結手続きが行われているわけではないようである。しかし、ラフティング業者側は協定の通過時間にのっとったツアーのスケジュールを常に立てることとしており、無用なトラブルを避けて、地域との共存共栄を図っていくという意識が強く、フォーマル、インフォーマルにかかわらずルールの遵守が図られている。

また、協定には含まれてはいないが、パドルで水面をたたないこと、遊漁者から 30m 以内では遊泳しないことなどの漁協から申し入れのあった事項についても協会内で徹底周知しており、トラブルの防止に努めている。

さらに、ラフティング業者側は、毎年資金を拠出してアユの稚魚を購入し、漁協の種苗放流にも協力している。

4. 考察

内水面の利用をめぐっては、遊漁規則で定められた遊漁券を購入し、遊漁を行う権利を得た遊漁者と、公共物である河川の自由使用の原則にのっとって利用するレジャーを如何にして調整するかという問題が顕在化してきているなかで、その解決に際して「協定」という明文化されたインフォーマルなルールが形成された例は少ない。その意味で、吉野川上流域で構築されたラフティングと遊漁をめぐる当該事例の利用調整ルールは、多様な利用主体が円滑な河川の利用を果たす上できわめて有意義であり、評価できる。

ただし、通過時間のルールは、時間を守らなければならないという意識が時として安全運航を阻害することにもなりかねないという懸念の声も聞かれ、現在のルールが最適なのかどうかといったルールの内容に関する検討の余地はまだ多く残されている。また、ラフティング協会には関係業者全員が参加しているわけではなく、協定の効力を削ぐ恐れも懸念される。

5. 結論

当該地域では、ラフティング業者と地元漁協の間で協定が結ばれ、多様な利用主体が存在するなかにあっても円滑な河川の利用を果たす努力がなされている。水面の利用においては、これまで「漁業対レジャー」という構図において多くの問題が指摘されてきたが、本事例では「レジャー（遊漁）対レジャー（ラフティング）」という構図において利用調整ルールが構築されており、河川の多様な利用を図るうえで評価できる取組である。しかしながら、ルールの内容については安全性、さらに公平性といった観点から課題が残る。

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O4-8

玉川上水に関する現地調査及び通水能力の水理学的検討

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抄録

2020年にオリンピックが開催される日本の首都東京では, 水辺空間の不足や閉鎖性水域の水質悪化が近年問題となっている. その問題の解決策の一つとして, 江戸時代において江戸の経済や工業, 農業, 交通などを支えた人工水路である「玉川上水」を復活させることが提案されている. そのため本論文では, 現在の玉川上水本川及び分水の流況把握を目的とした現地調査と, その結果に基づいて数値計算を行い, 玉川上水の通水能力について検討した. その結果, 以下の3点がわかった. ①現地調査より, 上流約12kmから23km間の玉川上水本川の減少流量は, 分水に流入する総流量の約5倍であることがわかった. その原因として, 観測誤差や水の地下への浸透・他水路への流入等が考えられる. ②上流から30 $m^3 \cdot s^{-1}$の水を流すと, 下流の流路幅が狭くなっている箇所で越水が起こる. ③閉鎖性水域の水質浄化には, 上流端で1.3 $m^3 \cdot s^{-1}$の河川水を確保する必要がある.

1. はじめに

今から約400年前, 徳川家康によって江戸に幕府が開かれ, 急激に人口が増加し, 経済が発展した. それを支えていた一つに, 人工水路の「玉川上水」がある. 玉川上水は, 武蔵野台地を西から東に向かって約43 kmの距離を, 約100mの標高差で水が流れるように設計して作られた. このことから, 玉川上水建設当時の測量の正確さが読み取れる. そして, 玉川上水の利用最盛期には, 分水路が33本引かれ, 現在の東京都だけでなく埼玉県にまで導水が行われていた. さらに, 玉川上水の水は, 江戸の経済や工業, 農業, 交通の面で多岐に亘って江戸を支え, 江戸市を人口100万人の世界最大規模の都市に発展させたと言われている. それに加え, 桜の名所でもある玉川上水は, 江戸市民の憩いの場として利用されていた. そして現在, 玉川上水付近には, 合計44の文化財が登録されている. 玉川上水及び分水, 周辺の河川を図1に示す.

しかし, 江戸時代を支えた玉川上水は, 1886年のコレラの流行を受け, 東京の近代水道計画が進んだことによって, 現在では上流の約12km区間のみ通水が行われ, それ以降には河川水は流されていない. さらに, 33本あった分水は, 現在8本となっている.

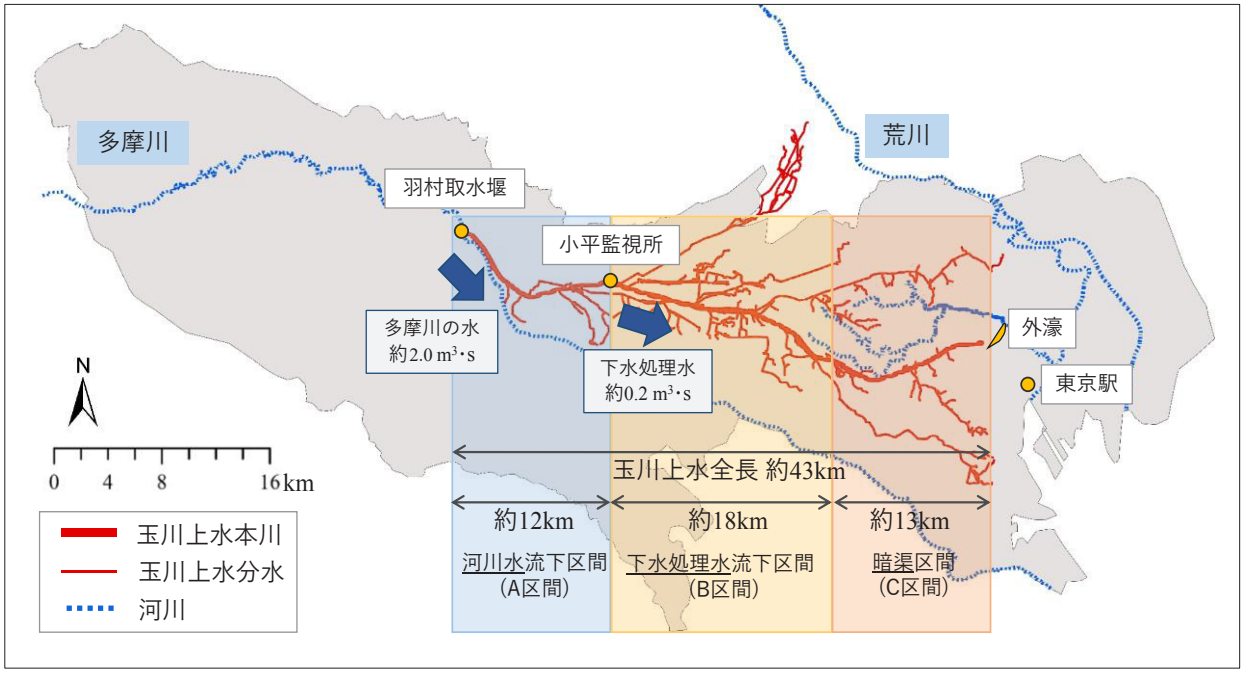

図1 玉川上水及び分水, 周辺の河川

一方で，2014年に水循環基本法が施行され，適切な水辺空間，水循環の再構築が問われている状況を受け，産・官・学・民で玉川上水に河川水を通水することに向けた活動が行われている[1]．玉川上水が復活することにより，東京都の水辺環境が改善されるだけでなく，災害時の緊急水循環システムの構築や周辺河川の水源，分水に通水することによるせせらぎの復活などの効果が見込まれる．かつてのように河川水を流すように願う声もある中，著者が知る限り玉川上水に関する水理学的アプローチの研究は存在しない．そこで本研究では，現在の玉川上水本川及び分水の流況把握を目的とした現地調査とそれに基づく数値計算を行った．

2. 玉川上水及び周辺水域の現況

現在の玉川上水を本川の状況によって大きく3つに分けたものを図1に示す．羽村取水堰から流入した河川水は，羽村取水堰から約12 km下流に存在する小平監視所まで(A区間)を約2.0 $m^3 \cdot s^{-1}$以上流れている．その水は，小平監視所から浄水場に送られるため，小平監視所より下流に河川水は流れていない．A区間の玉川上水の流況を写真1に示す．玉川上水上流は，護岸が整備され，河川に沿うように桜並木が続いており，市民の憩いの場となっている．小平監視所から約18km下流に存在する四谷大木戸まで(B区間)には，約0.2 $m^3 \cdot s^{-1}$ (このうち，分水に流入する流量は0.19 $m^3 \cdot s^{-1}$)の下水処理水が流下している[2]．B区間の玉川上水の流況を写真2に示す．玉川上水中流は，上流とは流況が異なり，河道整備があまり行われていないため，草木が無造作に生えている．四谷大木戸から下流まで(C区間)は，暗渠になっているため，水が流れているのか確認ができない．

玉川上水の周辺には，多摩川や神田川，江戸城外濠等の水域が複数存在する．その中でも，玉川上水の最下流に位置する江戸城外濠(以下，外濠)は，かつて玉川上水の余水吐として利用されていたが，現在は閉鎖性水域となっている．そのため，外濠では夏季に発生するアオコによる景観の悪化や悪臭が問題となっている．

3. 玉川上水分水の現地調査について

玉川上水分水の現地調査結果は，過去には渡部一二[3]によって公表されている．しかし，この調査は1978年から行われたため，約40年前の調査結果が含まれている．そのため，著者は現在の玉川上水本川及び分水の川幅や水位，流速を測量し，その地点での流量やマニングの粗度係数算出を目的として，現地調査を行った．本調査は，2017年5月4日に実施した．調査地点は，現在も利用されている8分水の分水口である．その結果を図2に示す．なお，図2中の①及び②は，分水口が2つあることを表している．

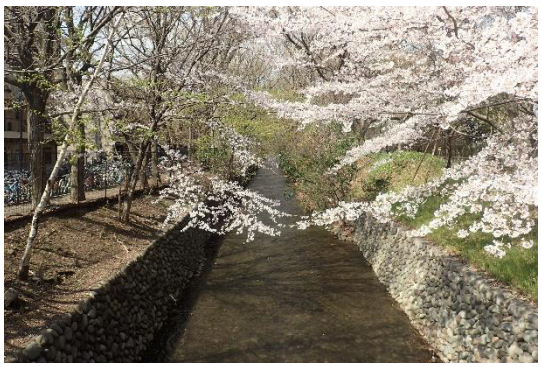

写真1 玉川上水上流の流況(2017年4月 著者撮影)



写真2 玉川上水中流の流況(2017年4月 著者撮影)

	分水口の羽村取水堰からの距離[km]	1.9	3.1	5.3	7.9 ①	7.9 ②	12.0 ①	12.0 ②	22.7
本川	流速[$m \cdot s^{-1}$]	0.40	0.56	0.41	0.98	0.98	0.55	0.52	0.20
	川中央の水深[m]	0.47	0.40	0.52	0.44	0.44	0.22	0.17	0.25
	川幅[m]	11.0	9.0	8.9	6.9	6.9	6.9	3.5	5.8
	粗度係数	0.006	0.028	0.045	0.051	0.051	0.014	0.008	0.072
	流量[$m^3 \cdot s^{-1}$]	1.98	1.95	1.74	0.98	0.98	0.90	0.31	0.29
分水	流速[$m \cdot s^{-1}$]	0.25	0.22	0.11	0.42	0.78	0.11	0.19	0.20
	川中央の水深[m]	0.12	0.20	0.27	0.11	0.35	0.15	0.37	0.28
	川幅[m]	1.30	0.35	0.90	1.80	1.00	1.90	2.14	1.30
	粗度係数	0.005	0.000	0.001	0.001	0.022	0.000	0.080	0.096
	流量[$m^3 \cdot s^{-1}$]	0.04	0.02	0.03	0.08	0.09	0.03	0.13	0.07

図2 玉川上水分水の現地調査結果

現地調査の結果，上流約12kmから23km間の玉川上水本川の減少流量は，分水に流入する流量の約5倍であることがわかった．その原因として，水の地下への浸透や観測誤差，別の流路の存在などが考えられる．

調査により，上流約12kmから23km間の玉川上水本川の減少流量及び分水に流入する総流量は，それぞれ約1.6 $m^3 \cdot s^{-1}$及び0.3 $m^3 \cdot s^{-1}$であることがわかった．つまり，玉川上水本川の減少流量は，分水に流入する総流量の約5倍である．その原因として，水の地下への浸透や観測誤差，著者が把握していない分水口や取水口の存在等が考えられる．

4. 玉川上水及び分水の流量算出計算

(1) 計算条件

本研究では，流量の計算を3パターン行った．1つ目は，羽村取水堰から四谷大木戸まで河川水を流した場

合の計算(計算1). なお, 計算1では, 羽村取水堰から玉川上水に現在流している流量を本川の流量とする. 2つ目は, 玉川上水に治水機能を持たせることを想定して堤防から越水が起こる場合の流量を求める計算(計算2). 3つ目は, 外濠の水質浄化に必要な流量0.5 $m^3 \cdot s^{-1}$を, 玉川上水の水で補うとした場合に必要な羽村取水堰からの取水流量を求めるための計算(計算3)である. 夏場に悪臭を放つアオコの除去のためには, 0.5 $m^3 \cdot s^{-1}$の水を流すことで解消されること[4]が著者らの研究によって明らかになっている. 計算方法として, 玉川上水本川及び分水の河道断面及び堤防高, 河床高は, それぞれ著者が現地に赴き測定した値及び渡辺一二による文献[3], 国土数値情報から得られた標高データを使用し, MIKE 11を用いて1次元不定流の基礎式で計算を行う.

(2) 計算結果

計算1の場合, 下流端に約1.0 $m^3 \cdot s^{-1}$の水が流れることがわかった. 計算2の場合, 上流端に30 $m^3 \cdot s^{-1}$流したところ, 上流5.2 km 地点で堤防を20 cm 越水することが計算により明らかとなった. この地点は川幅が狭くなる地点である. 最後に計算3の場合, 下流端に0.5 $m^3 \cdot s^{-1}$の水が行き届くためには, 1.3 $m^3 \cdot s^{-1}$の水を堰で取水する必要があることがわかった.

計算により明らかとなった上流に与える流量と下流端に届く流量の関係を図 3 に示す. 計算より, 上流で流す流量に比べ下流に届く流量が少ないことがわかった. それは, 上流で流している流量に対して分水に流れる量が多いため, 下流の流量が確保できないことが考えられる. つまり, 取水する流量に対して最適な分水口の高さを与え, 分派率を考慮した計算を行う必要がある.

5. 考察

玉川上水分水口及び分水口周辺の本川において, 河道断面及び水位, 流速を測定し, それに基づき流量及びマニングの粗度係数を算出した. その結果, 玉川上水本川の流量は, 分水だけでなく, その他の要因によって減少していることがわかった. その要因として, 観測誤差及び水の地下への浸透・他水路への流入等が考えられる. 地下水については, 実際に玉川上水開削時に, 玉川上水上流部で水が残らず地中に吸い込まれたという話が残っている[5]. つまり, 玉川上水通水に向けて, 玉川上水本川に存在する分水口・取水口の位置を再度調査するだけでなく, 玉川上水周辺の地下水位及び湧水量への影響を計算することが必要である.

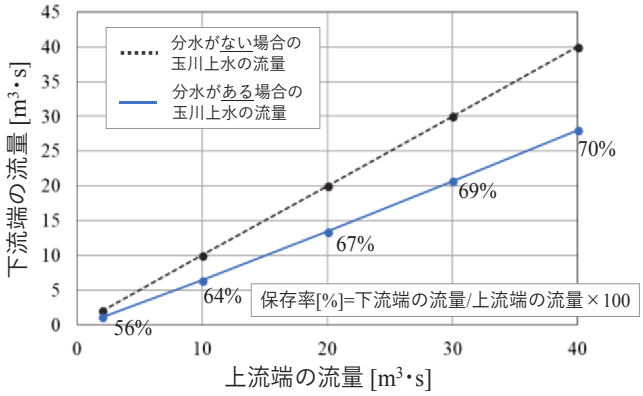

図 3 上流に与える流量と下流端に届く流量の関係

下流に届く流量は, 上流に与える流量に対して, 約60%から70%の流量になることがわかった. さらに計算より, 上流に与える流量が多いほど, 下流に行き届く流量が多くなることがわかった.

6. まとめ

本研究では, 玉川上水本川及び分水において流路幅や流速, 水位を調査し, 流量及びマニングの粗度係数を算出した. さらに, その結果を用いて, 玉川上水に通水を行った際の流量を求めるために数値計算行った. 本研究で得られた知見を以下に示す.

1. 上流約 12km から 23km 間の玉川上水本川の流量の減少量は, 分水に流入する総流量の約 5 倍であることから, 水の地下への浸透や観測誤差, 分水以外に違う河川に流れていること等が考えられる.
2. 羽村取水堰から約 2.0 $m^3 \cdot s^{-1}$ の水を取水しているとし四谷大木戸まで流す計算を行った結果, 下流端に約 1.0 $m^3 \cdot s^{-1}$ 行き届くことがわかった.
3. 外濠浄化のためには上流から 1.3 $m^3 \cdot s^{-1}$ 以上の水を流す必要があることが分かった.
4. 堤防から越水し始める上流の流量は 30 $m^3 \cdot s^{-1}$ で, その地点は上流から 12 km 下流の地点あった.

謝辞

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O4-9

Dhanmondi Lake: A Cultural Assimilation of The City Dwellers

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Keywords: Dhanmondi, Dhaka, Baishakh, Rabindra-Sarobar, Cultural hub

ABSTRACT

Dhaka, the capital of Bangladesh was known by its heritage, culture, canals & lakes which were connected to the three main rivers that encircled it. In the frenzy of urbanization, Dhaka has seen a drastic reduction of its lakes and canals resulting in the brutal transformation of urban tissue. Dwindling water bodies has an adverse impact on the urban environment of Dhaka but this lakes and canals have also cultural values to the city dwellers. Dhanmondi lake is located in the center of the city (23°43'N and 90°26'E). It is 3 km in length, 35-100m in width, with a maximum depth of 4.77m and the total area of the water body is 37.37 ha. There is one box culvert to pass the heavy rainfall. The lake is under the management of several authorities looking after its various aspects: City Corporation, Fisheries and Environment Department etc. The Lake has now become a popular tourist attraction, with cultural hubs, lush green vegetation, islands, lakeside walkway and benches for visitors to sit and relax on. The open-air amphitheater, Rabindra-Sarobar, is also located on its banks, mostly recognized venue for concerts, dramas, theater performances and a variety of cultural programs, festivals and holiday celebrations. During festivals such as Independence Day, Eid and Pohela Baishakh (Bengali New Year) it becomes a harbor of joys and color. The founding father of Bangladesh, Bangabandhu Sheikh Mujibur Rahman had chosen his residence at the bank of this lake. The lake is the lifeline to citizen of the capital.

1. INTRODUCTION

Most of the lakes of Dhaka city are now more or less occupied due to encroachment; the lakes are still an integral part of the ecosystem. A lake is a terrain feature, a body of liquid on the surface of the world that is localized to the bottom of basin and moves slowly if it moves at all. They act as water retention basins during the Monsoon; and besides being the sources of biodiversity of the area, they are an important part of the scenic beauty. Dhanmondi lake is the part of long demand of the urban dwellers for their physical as well as mental nourishment. The park beside the lake has also vision to restore the environmental quality enhancement of public facilities. Thousands of people of different ages visit the lake every day. Among them some take exercise in groups or individually, but most of them walk along the walkways around the lake breathing fresh air. Dhanmondi lake is situated in the middle of Dhaka City (23°43'N latitude and 90°26'E longitude). Beginning from Jigatola-Road-2 the lake extends up to Road-27 (new 16A), and bounded by the Mohammadpur-Lalmatia area in the north, Satmasjid Road in the west, Border Guard Bangladesh gate-Road-2 in the south and in the east by Kalabagan residential area. It is 3 km in length, width varies from 35 m to 100 m with a maximum depth of 4.77 m and the total area of the water body is approximately 37.37 ha. There is one box culvert in the lake near Sukrabad area, which is the only outlet of the lake. The lake is under the management of several authorities looking after its various aspects. The Ministry of Works has its ownership; the Fisheries Department looks after fishery development; the Dhaka City Corporation, being the principal civic body, exercises some responsibility in its improvement. The Department of Environment looks after the aspects of proper

environment and protection of aquatic resources of the lake.

2. METHOD

Two methods were applied to get information based on research objective on May-July 2017. A questionnaire was developed initially and applied for pilot basis. After few piloting of the questionnaire, all necessary questions/queries were incorporated in the questionnaire and finally required data was collected by the final version. Formal interviews had been conducted with different categories of people including management authorities. Survey was mainly focused on areas such as cultural values of the area to the city dwellers, present condition of the lake and the reason of its deterioration, refreshment facilities, and public awareness about the lake. The initiative taken by the concern department for proper maintenance of the lake was also considered. To get the mass information 05 most popular and crowded hotspots of the lakeside park areas (Zigatola, Medinova area, Robindro Shorobor, Kalabagan, Dhanmondi 32) were surveyed.

Literature review had been made to study the lake area. The required data and information have been collected from different sources like Dhaka South City Corporation (DSCC) and Public Works Department (PWD), Department of Environment (DoE), Department of Forest, Print & Electronic Medias and conservation NGOs related to environmental issues.

3. RESULTS

73% people often go to Rabindra-Sarobar for various purposes for instance, gossiping with friends, occasional day outing with family, to enjoy concerts and dramas, and also a variety of cultural programs, festivals and holiday celebrations. Among the five hotspots Rabinda-Sarobar is the most favorite destination with 57% followed by Dhanmondi-32 with 35%. During festivals such as Independence Day, Eid and Pohela Baishakh (Bengali New Year) it becomes a harbor of joys and color.

Regarding the present condition of lake it was noted that 67% people mentioned about the lack of awareness where as 41% people told about inadequate maintenance by the management authorities. In terms of environmental and structural development of the lake, 35% think about improvement of security is needed whereas 29% feels the improvement of refreshment facilities is needed, 49% people think that environment of the lake should be improved.

4. DISCUSSION

Dhanmondi lake is precious asset of Dhaka city with unique regional characteristics. Apart from its scenic beauty, it has great economical and environmental value which has also been reflected in the survey result. Majority visitors love to visit the Robindro Shorobor, which is really a cultural hub for the city dwellers for any occasions either it is national, religion based or personal. Around fifty percent visitor loves to spent time in Dhanmonti-32 area which also simultaneously has value to them for architectural showpieces, island of the lake and foods, house of the Father of the Nation Bangabandhu Sheikh Mujibur Rahman etc. The lake sides are also tourist hubs for celebration time for instance, Independence Day, Eid and Pohela Baishakh (Bengali New Year) etc.

According to two-third interviewed people, the lake environment and infrastructure is now vulnerable only because of no awareness. But the lake has enormous social, economical and ecological values. During extremely dry seasons, the lake retain considerable amount of water. These water bodies account for fisheries and provide a habitat for a wide variety of aquatic vegetation and birds.

The survey results also demonstrated the opinion of the visitors on different ratios but they incur about the necessity of proper and regular maintenance of the lake itself, refreshment facilities, and security.

5. CONCLUSION

Saving the lake from the pollution should be a priority concerns for the sake of environment. Awareness program is necessary to stop unauthorized activities that seriously lead to pollution of the lake and surrounding environment. For sustainable culture and the heritage of the lake in future good environmental condition and refreshment facilities has to be ensured. A coordinated plan for Dhanmondi lake should be taken as considering the ecology of the lake.

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O4-10

Impact of Climate change on the folk culture of Haor Basin in Bangladesh

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Keywords: Lake, Folk Culture, Climate Change, Documentation, Traditional Knowledge

ABSTRACT

Bangladesh is a land of wetlands. The folk culture of the country is mostly associated with the wetlands. Haor basin is a special type of back swamp with many lakes found in northeastern part of Bangladesh and adjacent India. Haor is the second most vulnerable ecosystem in Bangladesh. There is a significant change in the season due to climate change in that lake areas. The changes in the seasons has interfered the folk festivals as those events are following the calendar dates. Many lake festivals are under risk of extinction. There is huge deviation on the local sayings which was the major part of the culture. Traditional knowledge is found not in function due to erratic rainfall and unpredictable weather. According to the community documentation and support to practice can help the community protect and conserve the cultural values. Community based planning and community lead implementation have the capacity of incorporating cultural values in development action. The initiative to support the conserve the cultural heritages can be care as climate action. The study has been conducted in the Medir Haor, a lake in the Haor basin of Bangladesh. Following the participatory research tools the study was conducted in January and February 2018.

1. INTRODUCTION

Bangladesh is a country of wetlands, around 60% of the country is wetland. Haor, baor and beel are the major types of natural lake in the country. The northeast and the mid-west parts of the country are rich with lakes. The life and the livelihood of the country is mostly wetland dependent and in lake rich areas there is distinct lake based and driven culture. Bangladesh is an agrarian country but the lake basin also has fisheries as major occupation. Because of the geographic location, the country is one of the most vulnerable to climate change. The country is situated at the interface of two different environments, with the Bay of Bengal to the south and the Himalayas to the north, and the delta of the mighty Gangage and the Brahmaputra. Climate change resulting number of challenges. According to the community the character of the seasons has been changed. There are scientific evidences that the rainfall pattern in Bangladesh changed. To cope with the changes community is being practicing different adaptation option and changes in livelihoods are reported significant. The present research aims to know if the impact of climate change interfering the cultural of the lake dependent community. The livelihood in Bangladesh is mostly dependent on natural resources, so the cultures are too. The study was conducted on the Medir Haor, one of the small haor of the haor basin. Haor is a form of a back swamp, a bowl shaped shallow depression found in the north-east part of Bangladesh. Medir haor is local in Nasirnagar Sub-district under Brahmanbaria district. The field research was conducted in January to March 2018.

2. METHOD

With the research question “if climate change impact has been interfering the local culture?” the study had investigated (1) Changes in season character, as the folk festivals are based on calendar days for hundreds of years, and (2) Changes in the practices of folk festivals. The study was conducted with the fisher communities who are mostly Hindu by religion. To identify the changes in the character of the season 2 group discussions were conducted at the village of Nasirnagar. Total 26 elderly individuals attended the discussion. The discussion was attended by both man and women and all of them were farmer but 6 males also engaged in seasonal fishing in a wetland. The main discussion points were the variance that community feel in the variables like temperature, water availability in lakes and rivers, rainfall, flowering in the major fruit plants and growth of wild plans in backyard comparing the year 1987, when the sub-district system started in Nasirnagar. To double check the identification from the consultation a Baromashi Gan, means ‘song of twelve months’, which is a form of folk song was used as reference document. The name of that song is Dukhinir Baromaisya, where a woman of Haor basin is describing the life around the year.

The folk culture was identified in consultation with 2 families of the village. This was a mapping of festivals celebrated by Hindu community of the wetland basin. Hindus are minority with 35% of the population of the areas. The main occupation of the majority of the Hindus in Madir Haor area is fishing in the Haor, but in the lean season they are also framing. The festival calendar was consulted with 5 religious leaders to know if there was any deviation in current practice and whether the changes in the character of the seasons has any interference on it.

3. RESULTUS

MAJOR CHANGES IN THE MONTH

If was found that the character of the seasons in the Haor basin has been changed significantly. It was not like that

is a shifting of month. Though the months of first quarter in the native calendar behaving like the immediate earlier mouth but in other quarters they are not following any common form change.

Table 1: Changes in months

Month in Bangla Calendar	Major changes comparing with 30 years earlier	Behaving like	In Gregorian Calendar
Baishakh	No moon flooding, earlier navigable water was in canals. Mangoes are green and no small cat fishes in lake	Chitra	14 April-mid May
Jestya	Water is just raising in lakes	Bishak	Mid May-Mid June
Ashar	Now heavy shower in a very short time	Jestya	Mid June-Mid July
Shrabon		Sharbon	Mid July-Mid Aug
Vadro	Bright sunlight, less hit	Ashar-Shrabon	Mid Aug-Mid Sept
Arshin	Now very less fog	Shrabon	Mid Sept-Mid Oct
Kartic	No water in lakes and wetland	Arshin	Mid Oct-Mid Nov
Agrahon	Now no fog	Arshin	Mid Nov-Mid Dec
Poush	Very few cold days		Mid Dec-Mid Jan
Magh	No fog, too less cold, no flowering in mango	Poush	Mid Jan-Mid Feb
Falgun	No cold too hot, flowering in mango	Chaitra	Mid Feb-Mid Mar
Chaitra	Very less warm days, cold during night, too few northwester, too late hot weather	Falgun	Mid Mar-Mid April

CHANGES IN THE FOLK FESTIVALS

It was found that there is huge deviation in practice of the folk festivals. Though there is a rapid raising of religious practices globally but the folk festivals are gradually getting less importance. Climate is one of the major factor of creating such a change.

Table 2: Climate impact on folk festivals

Festival	Climate Challenges
Lengri broto (in Baishakh) Related too new rice and the warship is by rice cake	To cope with climate change community cultivating new varieties of rice, which are early. The festivity is no more with just harvested rice
Sasti (in Jestya) Mango and jackfruit leaves are essential	
Hatty broto/ Friendship day (in Jestya) Cornflower of difference cereals	Late monsoon derived many cereals not cultivated; As adaptation there is increasing monoculture of paddy
Halbangha (in Ashar) No digging/ plough for from 7th to 10th Ashar	Rain fall erratic now. In a rain feed farming it is not possible to follow
Sidhyswari broto (in Vadro) 7 type cakes required	Frequent flooding is not favorable to cultivate different types of crops
Konkai broto (last day of vadro)	
Garoi (Last Day Arshin) 8 vegetables cooked	Prolong flooding has reduced the growth of wild vegetables
Akash Prodwip (in Kartic)	
Bhulapura (last day of kartic) No more mosquitoes in rest of year	No more geographical or time barrier for insect pest due to global warming
Jorajori broto (in Poush)	
Beraghor (in Poush Parban) Temporary hut made of straw to fire	To cope with flash flood community is cultivating short duration early variety of rice that have small straw
Bagher broto/ Tiger warship (in Magh)	No cold days, so no festivity
Maghbur/ Bath in early cold winter (in Magh)	A few winter days, no festivity
Kunai broto Indian jujube branch with fruits and cakes must for worship	Jujube flowering early
Garur pitha Decorate the cattle	
Ghataband (in Falgun) Boarding the periphery of house with white wild flower	Flower is late
Harbisu (Last day of Chaitra) Eat sour testy vegetable, many dishes of vegetable cooked	Less growth of wild leafy vegetable as the month is dry

LOCAL FAIR

It was found that traditional and community fairs are not being observed in festive mood as it was earlier. Urbanization and developed road communication are also causes. Climate change consequences also have

good impact on it. According to the community the fair on 'bathing in hole water' is nearly meaning less as due to dry March no rainfall in upstream, earlier it was bathing in new clean water. Community in the Medir Haor is observing the following fairs, 5 were interfered by climate change; 2 were benefited due and 3 losers. The state of the fairs due to the climate change is as follows:

1. *Sidyaswari*: Associated with Goddess Kali. No climate change concern noted.
2. *Rothmela*: There was a believe that on that day there will rainfall, but for the last few years it was heavy shower and the yard came muddy.
3. *Swaner banni*: Under risk of extinction. Late normal monsoon resulted it not popular any more.
4. *Sutkhi banni*: This is on the New Year Day. Was very popular for the dry fishes. But due to erratic rainfall the quality of open sun dried fishes depurated.
5. *Kather banni* (rash Purnima): It was too famous for the wooden furniture. Less fog has benefited the environment
6. *Charak mela*: Not interfered
7. *Chaidhya madal*: Less fog and no cold are helpful for people to come.

QUOTE BY KHONA

Quote by Khona is popular proverbs. It is being widely used by the community since long years. Many framers and fishers are following those quotes to plan faring action. Community also cite the quotes in different discussion and dialogue. It was found that some quotes are not resulting as those were earlier. This is because of the erratic rainfall only.

Ame dhan tatule ban, means 'if mango production is high in a year there will good production of rice, but if it is tamarind there will flooding'. Now it was frequent disasters made the proverb not accurate. The community is too confused that many of them has forgotten the right form of this quote. Some makes the words rice and tamarind shifted.

Chaitre khor khor boishakhe jhor pathor, 'if it is dry Chaitra then it will hailstorm in Baishakh'. Hailstorm is increased now as days but Chaitra is no more a hot month.

COMMUNITY PERSPECTIVES

According to the community the frequency of Hazars are increasing and prediction from their indigenous knowledge are some time cannt make a good guess. The lakes and the culture of lake people is dependent on the water mostly. The most victim natural resources due to climate change is the water. To survive and cope with the culture community is practicing adaptation. But many adaptation tools and techniques are totally new to the community. There is risks of shifting the main occupation.

Climate change is interfering the local folk cultural; the adaptation options that community are practicing may also create a new form of knowledge and new tradition.

Practicing folk culture brings people of different race, religion, economy, etc. together. Loss of cultural practices make opportunity of mass gathering and cooperation among different people fewer.

4. DICUSSION

Dekota (2013) has identified that climate change has interfered the culture of the Himalayan people, the social-economic states including livelihoods and food being changing [1], the glacial melting are the main cause here for the change. Erratic rain fall and resulted floods were found as the main cause will the community of Haor basin. Although local knowledge and practices can be effective for progressively adapting to climate change, they may have limited utility when cultures are confronted with rapid or nonlinear changes [2]. In case of the Haor the changes are rapid, the potential of traditional knowledges and customs towards adaptation needs to be analyzed. The disruption of the cultural and religious calendar is the evidence of severe imbalance in India [3]. Indian culture and faith traditions have very strong connections to weather patterns embodied in language, stories and festivals. One of the key ways by which people notice and measure the shift in climate is in relation to these cultural benchmarks, and the dates of festivals. These are also a key way to initiate and maintain a public conversation: for example, when there is no wind for a kite festival, the harvest is too early for a harvest festival, or a fruit, vegetable, flower or bird associated with a particular event is not available.

5. CONCLUSION

Climate change interferes the culture and tradition of a lake. There are other environmental and development concerns that also amplifying the threats. Value addition in climate adaptation plan and climate action from the scope of cultural values needs to be well documented. Community based planning and community lead implementation have the capacity of incorporating cultural values in development action.

A scholarly analysis of those scope is an urgent otherwise the culture from the lake will be lost. Deviation from own culture and practice is a conservation threat also. Haor lake are a very different form of lake and also found in a limited area of Bangladesh and India. A join, comprehensive and wider attempt to have compile the knowledge heritage of the basin can draw attention of the stakeholders in wetland, climate change and development to act for Haor lake culture.

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O4-11

Management of Mangrove fringed Koggala lagoon for Sustainable Livelihood Development - Case study in Sri Lanka

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Keywords: Biodiversity, Fishing, Koggala lagoon, Livelihood, Tourism

ABSTRACT

The livelihood framework identifies five core capitals which sometimes are called livelihood building blocks. These are natural, social, human, physical and financial capital. On the other hand, rapid deforestation and biodiversity losses are depriving people of valuable mangrove based water resources, such as fuel wood, fish, shrimp, food, medicine, and ecosystem based services such as bird watching, boat riding. Koggala lagoon is located on the southern coast of Sri Lanka. It consist 14 islets with forest, mangroves and terrestrial shrubs. Livelihood around the lagoon mainly depended on tourism and fisheries.

Fishing mostly depends on brackish waters due to sea water intrusion into the lagoon. Respondents mentioned there are number of societies, local government involve managing tourist industry as well as environment. They have been restricted harvesting of mangrove for timber and fuel wood. The landing of sea planes in the lagoon is known to affect the bird populations, and cause erosion of the lagoon banks due to the large waves created during landings. Respondents claims that decreasing of biodiversity in lagoon directly affected on their livelihood due to large scale clearing of mangroves for construction purposes. It was identified operate boats by unskilled people without using safety jackets. Government involvement is necessary to prepare policies to regulate tourist industry and improve infrastructure facilities. Regulate unauthorized construction beside the lagoon and control discharge effluent from nearby free trade zone to improve lagoon biodiversity.

1. INTRODUCTION

Koggala lagoon is located between 5º 59' - 6º 02' N and 80º 18' - 80º 21' E on the southern coast of Sri Lanka with total water spread area of 7.27 km2. Water depth of lagoon ranges from 1.0 to 3.7 m (CEA, 1995). The lagoon mainly identify as a rain fed coastal lake with catchment area of 60 km2 (G.P.Amarasekara et al., 2012). There are number of streams are connected to the lagoon, the main fresh water supplier is “koggala oya” (Warabokka-ela stream). Other than “Koggala oya” Heen-ela stream contributes a minor to the freshwater inflow. A narrow 300 m long canal named as “Pol-oya” canal is the only sea outlet of lagoon, located at the southeast corner (Fig. 1). (Gunaratne et al., 2010). At the lagoon mouth, there was a naturally built sand bar perpendicular to the lagoon mouth which controlled the seawater intrusion into the lagoon. With the opening of the lagoon mouth during the rainy season, rapid outflow of water begins. However, the flow of seawater into the lagoon during the monsoon and high tides ceases the formation of sand bar again in the dry season. In early 1990’s it has been followed by unplanned removal of sand barrier near the lagoon mouth for some development activity, a groyne system was built to minimize coastal erosion. However, since then mouth of lagoon has been kept open throughout the year. Therefore Strong sea water influence seem to have felt by the lagoon as far as about 2 km from the lagoon outlet (G.P.Amarasekara et al., 2012, Gunaratne et al., 2010, Silva et al., 2013)

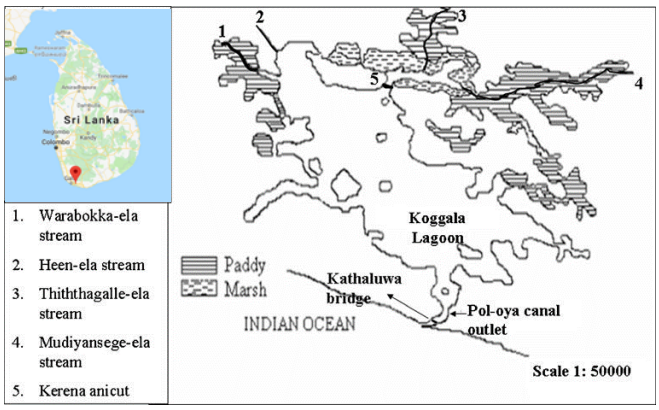

Fig. 1 Map of Koggala lagoon with the locations of outlet and major freshwater inflows (Source: Gunaratne et al., 2010)

This study was conducted to identify the socio-economic situation of community around the Koggala Lake; to identity environmental aspects and issues; to identify the issues related to livelihood and to make appropriate suggestions to overcome the recognized issues

2. METHOD

The study was conducted in Koggala lagoon in Galle district in the Southern province Sri Lanka (Fig 1). Peoples who live around Koggala lagoon were interviewed to collect primary data. Additional information was collected through systematic field observation. In addition, past research articles were used to obtain secondary information.

Demographic information on age, education, family size, income, nature of the occupation, experience, major cost components for the occupation, importance of lagoon for livelihood, government and social legislation were collected using pre-tested structured questionnaire.

3. RESULTS

Livelihood around the lake mainly depended on the agriculture, tourism and fisheries. After removal of natural sand barrier salinization of paddy fields shifted livelihood towards tourism and fisheries. Male peoples, age ranging from 20 to 45 years mainly engage with boat riding and fishing. 33% from them are boat owners and more than 30 boats are work for lagoon tours. There average family size determined to be 4 (range 3 - 5). The experience of boat riding people varied from 5-30 years. All boat riders and fishing community indicated that their whole family engaged in similar occupation. 75% respondents claimed that over fishing, over tourism, illegal fishing and deforestation is low under society based regulation.

4. DISCUSSION

The Lake consist 14 islets of varying sizes with forest, mangroves and terrestrial shrubs. The largest islet is located in the southeast corner of the lagoon near Gurukande Temple. There are a number of sites/islets of historical and cultural value in the area including Madol Duwa, Thalathuduwa aranya senasanaya. Other than above sites there are many sites have been developed for tourism like Fish therapy, cinnamon pealing center, bird watching and tours. There are numerous direct and indirect benefits possess from the lake including fuel wood, medicinal plants etc.

Tourists both local and foreign varies with time, approximately 50-200 local tourists visit per day (mostly on the weekends) and 50-100 foreign tourists per day (From December to April) (IUCN Sri Lanka and The CEA, 2006). Therefore income is fluctuating according to the number of tourist average yearly income claims as 200,000.00 LKR.

Fishermen involved in Koggala Lagoon claim that present fishing industry mostly depend on brackish waters due to seawater intrusion into the lagoon. Important species for fisheries identified as prawn (Metapenaeus dobsoni, Penaeus indicus and Macrobrachium rosenbergii) (IUCN Sri Lanka and The CEA, 2006), brackish water fish species (Parati, Godaya), fresh water fish species (Malkoraly, Thilapia, Lula). (Kithsiri.M.K.U., 2009) and Crabs (water/ mud crabs).

Respondents mentioned that, there are number of societies, local government involve to manage tourist industry as well as environment. They have been restricted harvesting of mangrove for timber and fuel wood as well as deforestation by their societies.

Disturbances and threats

Removal of the natural sand barrier decreasing of the fish production. The landing of seaplanes in the lagoon is known to affect the bird populations, and cause erosion of the lagoon banks due to the large waves created during landings. Respondents claims that decreasing of biodiversity in lagoon directly affected on their livelihood. Large scale clearing of mangroves for construction purposes. IUCN Sri Lanka and The CEA (2006) showed that growth of invasive plant species within the lagoon (i.e. *Salvinia molesta*) has led to a decrease in other species naturally found in the area. It was identified operate boats by unskilled person with less safety (i.e. without safety jackets) will be badly to the tourism industry.

Future prospect to develop livelihood of the society around the Koggala Lake

It will be need urgent government involvement to prepare policies to regulate tourist industry. Improve infrastructure facilities like toilets, vehicle parks. Regulate unauthorized construction beside the lagoon and discharge of effluent from free trade zone koggala. Sandika and Hirimuthugoda (2012) Identified major cost items of fishing industry as boats, nets, hand nets, snare, floaters and baits.

5. CONCLUSION

Koggala lagoon play an important role in livelihood development of community in koggala area. Brackish water fishing is main income source followed by tourism industry. It is important in government involvement to make policy for develop eco-tourism industry. Rules and

regulations should be prepare to regulate unauthorized construction of the lagoon boundary and despotic discharge of effluent from koggala industrial zone and domestic waste to the lagoon. Need urgent actions to overcome erosion of the lagoon banks and to increase mangrove population and biodiversity in lagoon area.

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O4-12

The Sustainable approach to conserve the religious water bodies in Western part of India

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Keywords: Bramagiri, Godavari, Devote, Nasik, Tirth

ABSTRACT

India having ancient history of Buddhism and Hinduism was a harbor of numerous water bodies in the premises of temples and religious places where water use to be treated as holy and was protected by visiting themselves only. In history, it was a classic example of water conservation through public participation. Today's scenario is tragic one. These religious places are flourishing but water bodies in their premises are depleting. In many places these are completely dry up. The pressure on ground water, cutting of large age old trees adjacent to water bodies and increasing load of devotees can be the possible causal factor. These water bodies are the true aquifers which were charged from ground water.

The author conducted the survey of 92 such aquifers located in the premises of Bramhagiri mountain located 28 KM from the mega industrial city Nasik in Western part of India. This mountain is also an origin of holy River Godavari which is one of the longest in South India hence called South Ganges. Our survey shows that majority of these shallow aquifers though completely dry but still holds religious status where thousands of devotee annually visit them for water worship. Our in depth analysis of each aquifer indicate that these can be revived back to their original fresh water form. If revijuvinied and conserved back then river Godavari can get best strength of water from her origin itself. If water bodies are saved, river can also be saved is a positive message from this lake conservation episode. This research paper highlight the efforts taken by two NGO's working in water sector using public participation as a weapon for sustainable approach to save the water bodies

1. INTRODUCTION

In Indian scenario, water bodies are classified in to six types as urban, rural, saline, estuarine, farm ponds and religious one. Compare to rest, the religious water bodies are totally neglected in India (Kodarkar, M.S., 2009). These water bodies are small one and confined in the premises of religious places where devotetreat them as holy one. Because of increase in the visiting population of pilgrims, load of urbanization and siltation, cutting of age old trees around the water body and excessive pressure on ground water, the majorities of religious water bodies are slowly disappearing keeping their dry place intact as it is. Each religious water body was built by great ruler in the history and should be preserved as heritage. Majorities of them has mythological/legendary references hence known as Tirth/kund and each has its own architectural design with historical addedvalue.

The objective of this work was to make the in depth survey of these water bodies, find out their present status, their underground link to river flow and prepare a plan to rejuvenises them scientifically by using public participation as asuccess tool.

2. METHODS

For the survey of existing religious water bodies, we selected Bramhagiri Mountain located 28 KM from mega industrial city Nasik. The river Godavari originate from the top of this mountain, get continuous water supply from these scattered water bodies on her downwards flow ,disappear in basalt rock and reappear again at ground level in another religious water body mythologically named as Kushwrat.This holy mountain receive heavy rainfall but sadly water get washed out because of totallybarren soil. Entire water goes waste .The list of 92 water bodies was prepared with the help of local people and pilgrims from which 45 are located on the hill top of Bramagiri and around holy circle in the periphery of river Godavari. In our in depth survey, we noticed that river flow from mountain is depleting becauseof detoriating status of much neglected water bodies surrounding to her. This finding also support to the objective to revive the river with continuous flow of fresh water. We studied physical status of each water body including the area covered, presence of water, surroundingtrees, visit of pilgrims, architectural status, Mythological significance, pollution if any, Ground water charge, cleanliness and local participation in

protection. In survey we also studied a large water body which is located on the top of mountain.

3. RESULTS

After analyzing the physical status of each water body, we observed that though mountain receives heavy rainfall in monsoon, just because of loss of vegetation, there is huge amount of siltation from top towards the downward side filling all the water bodied on the way.All these religiouswater bodies are full of silt because of which their natural water source is almost stopped resulting in to their new identification as shallow aquifers. The pilgrims are visiting them for worship of water. The majority of age old trees around these water bodies are missing.

4. DISCUSSION

We had meeting with local stake holders which were ready to adopt one water body each provided it is rejuvenated with charge of ground water. We discussed with 100 schools in surrounding 30 Km area to promote the tree plantation drive on mountain and around each water body to check the soil erosion and siltation. The schools assured us to give a batch of 50 student each for tree plantation. This Work will be initiated in this monsoon under tri party agreement between Government, Corporate and NGO to aceive the goal by June 2021

5. CONCLUSION

It is decided to initiate the rejuvenation of 45 religious water bodies confine in the mountain areas from this June,2018 by taking the help of local people, supporting NGO's, school and college Students, waterexpertise, Govt and forest official, archeology department and financerepresentatives for providing the funding. Treeplantation along with the grass cover work on mountain slops will be completed immediately with the help of students by adopting themas two schools: one water body. Desiltation of each water body will be initiated after the plantation of vegetation. We expect Godavari river to be recharged in the process.

Thissustainable work needs minimum three years. We need this success story for the replication in other places where thousands of water bodies waiting for their rejuvenation at an earliest.

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TS5-1

Tracing nutrient sources contributing to harmful algal blooms and other ecological problems in aquatic systems using a multi-isotope approach

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Keywords: nutrients, isotopes, harmful algal blooms, water pollution, ecosystem health

ABSTRACT

Excess nutrients from anthropogenic sources to lakes and other water bodies can cause significant problems for ecosystem health and for the usefulness of the water body for drinking water, recreation, and other purposes. Solutions for these environmental problems are difficult to determine because there are usually many different land-uses that contribute nutrients and organic matter to the ecosystem. In recent years, numerous studies have shown that stable isotopic techniques – particularly multi-isotope approaches piggybacked onto routine monitoring programs -- are a powerful tool for determining sources of nutrients contributing to ecological problems because different kinds of nutrients and kinds of dissolved and particulate organic matter derived from different sources and land uses often have distinctively different isotopic compositions.

The basis for using isotopes to determine the sources of nutrients and other solutes to algae and bacteria is that autotrophic organisms preferentially assimilate the lower-mass isotopes of dissolved solutes. Hence, a comparison of the isotopic compositions of the organisms and the solutes from different sources allows estimation of the relative contributions of different specific nutrient and solute sources to the organisms. And since different nutrient and other solute sources frequently have distinctive compositions, the relative contributions from these different sources can often be reliably determined. This presentation will present an overview of the "state of the science" regarding the ability of isotopes to distinguish point and non-point anthropogenic impacts at various spatial scales, provide suggestions for successful pilot studies, and outline guidelines for future monitoring programs in biologically active and human-impacted systems.

TS5-2

From leaves to lakes: Revealing the nitrogen dynamics in catchment ecosystems using stable isotope techniques

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Keywords: NO3- isotopes, microbial denitrifier method, terrestrial ecosystem, microbial ecology

ABSTRACT

The measurement of nitrogen (N) and oxygen (O) isotope values of dissolved nitrate (NO_3^-) has been used for water quality surveys since 1980s. Isotope information of various origins of NO_3^- has been compiled for many different ecosystems. In the beginning of 2000s, the development of the microbial denitrifier method for this measurement has made its throughput higher dramatically. As this method requires a tiny amount of sample volume, it allows us to execute spatiotemporally high resolution and simultaneous measurements of N and O isotopes of NO_3^-. Using this technique, we have been able to reveal the details of transformation and movement of NO_3^- and related N compounds in various ecosystems. We have applied this method to describe the transformation of N in the surface of plants, litter layers, soils and groundwater zones, and used for identifying the origins of NO_3^- in river catchment. Here, we described how we have approached to the N dynamics in various scales of ecosystems using this isotope technique and discussed the future directions of this study area and associate methodologies applicable to reveal the new insights of N dynamics in terrestrial ecosystems. Combined approach with microbial ecological investigations may provide synergetic effects for mechanistic understandings of N dynamics of terrestrial ecosystems.

1. INTRODUCTION

The measurement of nitrogen (N) and oxygen (O) isotope values of dissolved nitrate (NO_3^-) has been used for water quality surveys since 1980s. Isotope information of various origins of NO_3^- has been compiled systematically for many different ecosystems by Kendall [1]. The typical ranges of $\delta^{15}N$ and $\delta^{18}O$ of NO_3^- from various sources was illustrated in her review chapter. This $\delta^{15}N$- $\delta^{18}O$ plot, the so-called "Kendall Plot", has been referred for identifying origins of NO_3^- and for detecting the effect of denitrification in various case studies in past two decades.

In the beginning of 2000s, the microbial denitrifier method was proposed for this measurement (Sigman et al. [2]; Casciotti et al. [3]). This method has made its throughput higher dramatically. As this method requires a tiny amount of sample volume, it allows us to execute spatiotemporally high resolution and simultaneous measurements of N and O isotopes of NO_3^-. Using this technique, we have been able to reveal the details of transformation and movement of NO_3^- and related N compounds in various ecosystems. The new method has been applied to understand the microbial and physical mechanisms behind the spatiotemporal changes of NO_3^- abundance in various ecosystems including rivers (e.g. Ohte et al.[4]; Johannsen et al.[5]), lakes (e.g. Finlay et al.[6]) and oceans (e.g. Wankel et al.[7]). The Kendall plot was updated by adding the NO_3^- data for atmospheric depositions using the microbial denitrifier method[8].

The advantages of this method requiring a small amount of sample are not only to allow us to increase the spatiotemporal resolution, but also to allow us to apply this method to small-scale phenomena in terrestrial ecosystems. For example, we can measure the $\delta^{15}N$ and $\delta^{18}O$ of NO_3^- in throughfall, stem flow and soil waters, which has usually been difficult to collect sufficient sample volume for the previous method, such as the silver nitrate method. Consequently, more detailed understandings on N dynamics along the elemental hydrological processes has become possible (e.g. Osaka et al.[9]; Shi et al.[10],[11]).

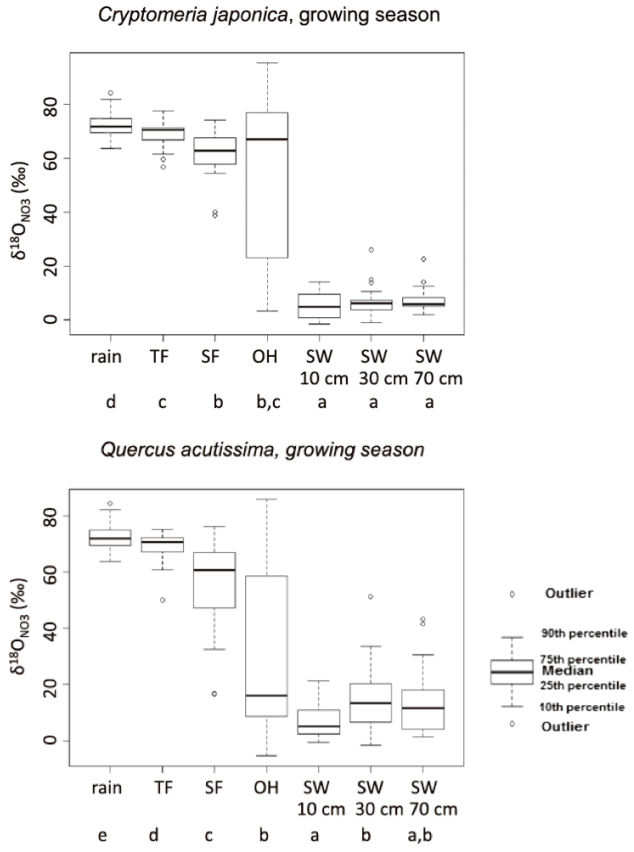
This paper is aiming to describe usefulness of and applicability to wide range of scales of N dynamics in terrestrial ecosystems; from a small-scale plot in a forested ecosystem to river, lake and catchment ecosystems. From a leaf surface to a lake, various N transformations and related biogeochemical phenomena occur in a catchment ecosystem which consists of multiple ecosystems such as forests agricultural fields and streams, and NO_3^- is one of the most important N compounds for evaluating the nutrient status and linkages

of ecosystems. Additionally, we tried to propose new approaches associated with isotope measurements of NO_3^- to elucidate more insights of N dynamics in terrestrial ecosystems.

2. IN THE FORESTED ECOSYSTEMS

NO_3^- is one of the most important bioavailable nutrients in the temperate forest ecosystem. Its major sources are atmospheric deposition and microbial production. As there is significant difference of the $\delta^{18}O$ value between atmospheric and microbially produced NO_3^-, a $\delta^{18}O$ value can be used for evaluating the relative contribution of those two sources.

Shi et al.[10] have monitored NO_3^- isotope changes during the processes that rain touches and passes thorough a canopy, or flows on the surface of tree body, and then infiltrates into soil profile (Fig. 1). The $\delta^{18}O$ values of rain, throughfall (TF), stem flow (SF) waters were significantly higher than those of soil waters even at shallowest part. In the organic soil layer (OH), the $\delta^{18}O$ was occasionally close to that of atmospheric deposition and close to that of soil waters. These suggest that the NO_3^- derived by the atmospheric deposition was quickly replaced by the one produced by microbial activities



especially in the organic soil layer. In the same forest ecosystem, The N transformations (mineralization, nitrification and immobilization) were significantly more active in the OH layer than the mineral soils underneath the OH layer (Shi et al.[11]). These implied that the NO_3^- replacement was made by co-occurrence of the immobilization of the atmospheric NO_3^- and the active nitrification in same layer.

Fig. 1 The $\delta^{18}O$ values of NO_3^- in rainfall (rain), throughfall (TF), stem flow (SF), the organic horizon (OH), and soil water (SW; 10, 30, and 70 cm depths) during the growing at the *Cryptomeria japonica and Quercus acutissima* stands. Box plots with different lowercase letters indicate significant differences among sample types. (Shi et al.[10]).

In addition to above, it is worthy to note that the $\delta^{18}O$ of NO_3^- in stem flow waters was lower than those of rain and throughfall waters especially in the *Q. acutissima* stand. Considering that the stem flow water contacts with leaves and bark surface, the replace or addition of NO_3^- by the microbial activities occurred on the tree surfaces.

In the groundwater body, denitrification may affect the isotope values of NO_3^-. Osaka et al.[9] demonstrated for a small headwater catchment in central Japan that the $\delta^{15}N$ of NO_3^- in the subsurface groundwater increased during flowing from the slope side to the stream riparian zone, while the $\delta^{18}O$ of NO_3^- did not change significantly. The increase of $\delta^{15}N$ was explained by an isotope enrichment with the denitrification in the water-saturated soil layers. On the not significant increase in the $\delta^{18}O$, Osaka et al.[9] hypothesized the co-occurrence of nitrification and denitrification within a similar hydrological zone in the relatively shallow part of the groundwater body.

3. IN THE RIVER CATCHMENTS

For the streams in headwater catchments, the major NO_3^- sources are basically soil layers and groundwater aquifers. Generally, the population density increases toward the downstream regions in a lager river catchment. Agricultural fields and industrial areas may also increase from the mid-stream regions. This social situation supplies multiple anthropogenic sources of NO_3^- load into rivers.

The riverine changes of the $\delta^{15}N$ and $\delta^{18}O$ of NO_3^- and NO_3^- concentration of two similar scale rivers (catchment area: 300-400 km^2) in the central Japan demonstrated that the isotope values of NO_3^- indicated the geographical points where the anthropogenic NO_3^- input occurred and increased (Fig. 2). In the case of the Yasu river in Fig. 2, the parallel increase of $\delta^{15}N$ and NO_3^- concentration begging from the midstream part indicated the NO_3^-

originated from the septic wastewater was discharge from the residential areas of the midstream part of the catchment, while $\delta^{15}N$ and NO_3^- concentration did not increase with river flow through the midstream part of the Ado river having no intensive residential areas (Ohte et al.[12]).

4. TOWARDS NEW STRATEGIES

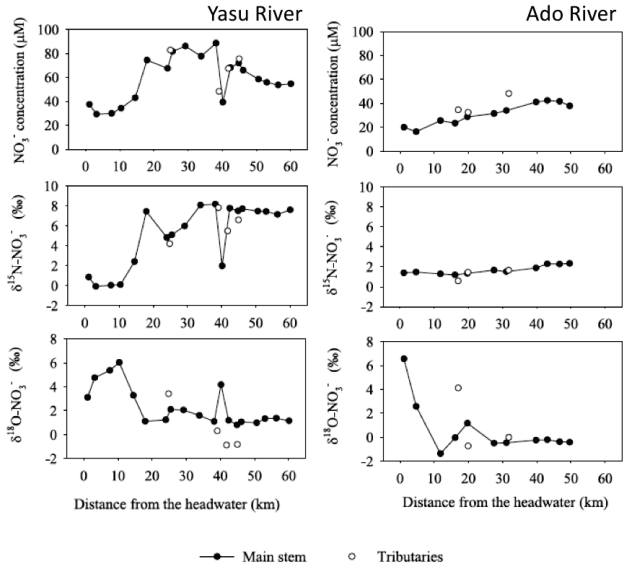


Fig. 2 Riverine distributions of $\delta^{15}N$, $\delta^{18}O$ of NO_3^- and NO_3^- concentration in two rivers in central Japan (Ohte et al.[12]).

The isotopic measurements of NO_3^- as a method to know the origins of N for the river and lake ecosystems have already well developed for a broad usage in research and operational works. The applications for those needs will continue in the field of environmental sciences.

On the other hand, it will be possible that new targets will be created in the field of the N dynamics in spatially small-scale ecosystems using isotope techniques. This is because the denitrifier method can be applied to a small volume samples as we mentioned in the introductory section. For the spatially specific processes in the forested ecosystems as introduced in the chapter 2, both qualitative and quantitative information on microbial activities is highly useful for interpretation of the changes in $\delta^{15}N$ and $\delta^{18}O$ of NO_3^- and NO_3^- abundance.

The attempts to link microbiological community dynamics with N biogeochemistry have performed in the several case studies in forest ecosystems (Isobe and Ohte[13]). But, more detailed information on related microbiological community dynamics are still needed from the in-situ condition. Not only the DNA presence, but also the information from RNA- or protein-based analysis for the field samples can be provide more mechanistic understanding of N dynamics. These efforts combined with N isotopic measurements should also contribute to more realistic model predictions of the N cycle.

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O5-1

Identification of Nitrate Sources in Groundwaters of Silang-Sta. Rosa Subwatershed: Towards the Watershed Governance

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Keywords: groundwater, nitrogen pollution, nitrate stable isotopes, denitrifier method, Silang-Sta. Rosa subwatershed

ABSTRACT

Water quality degradation caused by contamination of nitrate from various sources has become a worldwide environmental problem. Stable isotopes of nitrate-nitrogen ($\delta^{15}N$) and oxygen ($\delta^{18}O$) have been used to trace nitrate sources in the hydrosphere. In Silang-Sta. Rosa subwatershed of Laguna de Bay, the Philippines, in which sewage systems have not yet developed well, groundwater nitrate pollution is a matter of great concern to the society. Here, we conducted nitrate $\delta^{15}N$-$\delta^{18}O$ stable isotope analysis with a denitrifier method to identify the source of nitrate pollution in the groundwaters during the dry and wet seasons. Biplots of the nitrate $\delta^{15}N$-$\delta^{18}O$ values suggest that the groundwater nitrate isotope signatures in a hot spot of nitrate pollution are imprinted by those of fertilizers as well as manure/septic wastes. Principal component analysis for groundwater trace element also reveals that groundwaters in the polluted area are derived from the upstream cropland. These results suggest that chemical fertilizers can be one of the major sources of groundwater nitrate pollution in this watershed. The use of this isotope technique aids for the practice of watershed governance, in which variety of stakeholders are involved in mitigation of the nitrate pollution through the integration of local and scientific knowledge.

1. INTRODUCTION

The water quality of groundwater, as one of the sources for drinking water, is threatened by nitrate (NO_3^-) contamination. Nitrate in groundwater comes from several sources such as agricultural activities and atmospheric deposition. These NO_3^- sources have distinct stable isotope signatures ($\delta^{15}N$-NO_3^- and $\delta^{18}O$-NO_3^-)[1]. Identifying the sources of NO_3^- in groundwater is an initial step in the development of management practices to guarantee long-term protection. This will prevent further deterioration of the quality of groundwater.

The ground waters in Silang-Sta. Rosa subwatershed of Laguna de Bay watershed were studied. Silang-Sta. Rosa subwatershed (*see* Figure 1) is an urban ecosystem with different land use types such as residential, commercial, and industrial. This subwatershed is located at the western portion of the lake basin. The increasing demand for land use change to attain economic development in the subwatershed is due to its close proximity to Metro Manila and the abundance of quality groundwater in the area. In Sta. Rosa City, higher economic returns are achieved by conversion of farmland to non-agricultural uses. This negatively affects agricultural production. The headwaters of the subwatershed located in Silang, Cavite with its sloping nature are threatened because of the on-going urban sprawl in the uplands. This results in the occurrence of frequent soil erosion and surface run-off[2].

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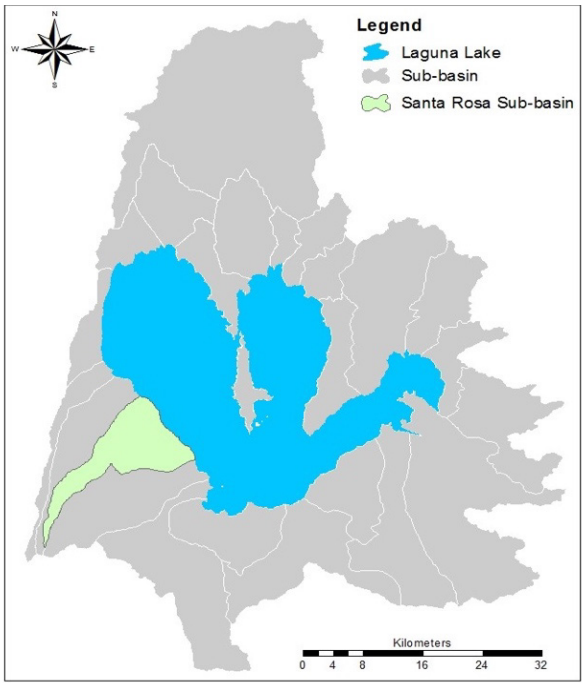

Figure 1. Map of Silang-Sta. Rosa subwatershed

2. METHOD

Ground water samples in the Silang-Sta. Rosa subwatershed were collected from determined sites in September 2016 (wet season) and in March 2018 (dry season). *In-situ* parameters such as pH, temperature, and electrical conductivity were measured using portable sensors. Samples were filtered using 0.22 µm cellulose-acetate filter papers, stored in pre-washed 100-mL polyethylene bottles, and kept in the refrigerator at 4°C to minimize microbial activity. These were brought to RIHN in Kyoto, Japan and kept frozen.

The identification of nitrate stable isotopes ($\delta^{15}N$-NO_3^- and $\delta^{18}O$-NO_3^-) was conducted using the denitrifier method that utilizes an aerobic bacterium with a denitrifying strain called *Pseudomonas chlororaphis* subsp. *Aureofaciens* ATCC 13985.[3,4] The nitrous oxide (N_2O) gas produced was simultaneously measured for the ($\delta^{15}N$-NO_3^- and $\delta^{18}O$-NO_3^- values using PAL-Precon-Gas Bench-Delta Plus^{XP} isotope ratio mass spectrometer at RIHN. The concentrations of the major ions and metals in the groundwater samples were analyzed in RIHN using an ion chromatograph (ThermoFisher Scientific Dionex ICS-3000) and an inductively coupled plasma – mass spectrometer (Agilent Technologies 7500 Series), respectively.

3. RESULTS

Figure 2 shows the map of decreasing NO_3^- concentrations from upstream to downstream in the groundwaters of Silang-Sta. Rosa subwatershed.

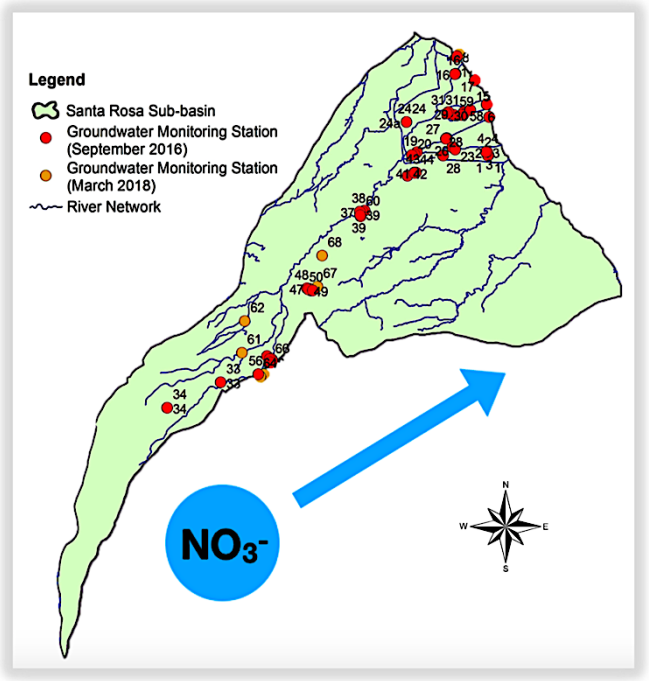

Figure 2. Map of decreasing nitrate concentrations for the groundwaters of Silang-Sta. Rosa subwatershed

4. DISCUSSION

The groundwaters in Silang-Sta. Rosa subwatershed have NO_3^- that originates from fertilizers and manure/septic wastes from the upstream/midstream and midstream/downstream, respectively. This comes from the fertilizers used in agriculture in the upstream area and in some downstream parts of the study site. The increasing land use changes in the downstream from farmland to commercial and industrial activities affects the natural cycling of nitrogen. The chemical contamination alters the biogeochemical processes from upstream to downstream.

The nitrate concentrations in the ground water samples conformed to the Philippine National Standards for Drinking Water of 50 mg/L except for the sample collected in Barangay Sto. Domingo during the wet season sampling. Barangay Sto. Domingo is considered to be a hotspot be-

cause of the high NO_3^- concentrations relative to the surrounding area.

5. CONCLUSION

The ground waters in Silang-Sta. Rosa subwatershed were assessed to identify the NO_3^- sources using the denitrifier method for the wet and dry seasons. The NO_3^- sources for the study site are fertilizers and manure/septic wastes.

This initial assessment of the groundwater for the identification of NO_3^- sources in Silang-Sta. Rosa subwatershed using stable isotope analysis is important in understanding of the impacts of NO_3^- contamination and in the development of watershed governance to control NO_3^- pollution.

Understanding the sources and biogeochemical cycling of nitrate in the groundwater can throw light on proper eutrophication control measures. With this study, it provides a scientific data that could help in developing policies in the implementation and pollution strategies to promote a more sustainable watershed management in Laguna de Bay.

Ions contamination specifically the nitrate cannot be categorically defined due to the limited data. But by employing a new technique called stable isotope analysis that requires less frequency of sampling, provides an avenue for the regulatory agencies such as LLDA to have a better understanding of the sources of nitrate.

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O5-2

硝酸イオンの窒素及び酸素安定同位体比を用いた茨城県鉾田川流域地下水の窒素負荷源の推定

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キーワード:霞ヶ浦に係る水質保全計画(第7期), 施設園芸, 水田, 堆肥, 脱窒, 養豚

抄録

霞ヶ浦北浦に流入する茨城県鉾田川流域(53 km^2)は、畜産及び施設園芸が盛んで窒素負荷量が大きい。鉾田川流域内の井戸(n = 60)を対象に硝酸イオン(NO_3^-)濃度を測定したところ、平均値±標準偏差は 9.4±4.2 mg N L^{-1}であった(NO_3^-等水質環境基準:10 mg N L^{-1})。地下水中 NO_3^-の窒素($\delta^{15}N_{NO3}$)及び酸素($\delta^{18}O_{NO3}$)安定同位体比(7.9±1.9‰及び 1.2±1.2‰)から、主な N 負荷源は化学肥料及び家畜排泄物の混合物と推定された。三区分したサブ流域毎の $\delta^{15}N_{NO3}$–$\delta^{18}O_{NO3}$ プロットの分布範囲は概ね一致し、流域全体で化学肥料と家畜排泄物が併用されている可能性が示唆された。全データの $\delta^{15}N_{NO3}$–$\delta^{18}O_{NO3}$ プロットの一次回帰直線の傾きは 0.42 であり、一部の NO_3^-は脱窒の影響を受けたものであることが示された。以上より、NO_3^-による地下水汚染を防止する上で、化学肥料と家畜排泄物の両方の削減の必要性が示された。

1. はじめに

「泳げる霞ヶ浦・遊べる河川」の実現に向け、霞ヶ浦に係る水質保全計画(第 7 期)の水質保全目標値(COD:7.8 mg L^{-1}、全窒素:1.1 mg N L^{-1}、全りん:0.090 mg P L^{-1})が策定された[1]。霞ヶ浦(220 km^2)の主要流入河川のうち、茨城県鉾田川は硝酸イオン(NO_3^-)等の窒素(N)濃度が最も高く、この 10 年間で水質環境基準(10 mg N L^{-1})の超過がみられるようになった[2]。

この理由として、近年、鉾田川流域では畜産及び施設園芸の集約化が進み、流域内における 1 日あたり N 負荷量は畜産が 262 kg、畑地が 87.5 kg、生活排水が 87.6 kg あり(平成 17 年)、とくに畜産排泄物の適正な管理と利用が推進されてきた[3]ことが挙げられる。これに関連し、鉾田川河川水中の N に着目した研究が多くある一方で、鉾田市の調査(平成 28 年)で NO_3^-等による地下水汚染例が報告されている[4]にもかかわらず、地下水についての知見が乏しい。鉾田川流域では、水田や施設畑の灌漑に主に地下水が使用されていることから、安定的な農業生産の為には地下水中 N の実態把握と汚染対策は重要である。

地下水への NO_3^-汚染を論じる際には、科学的な根拠に基づく汚染源の特定が必要である。一般的に、N の起源や脱窒・混合の度合いによって NO_3^-の酸素と N の安定同位体比($\delta^{15}N_{NO3}$ と $\delta^{18}O_{NO3}$)の値が異なることが知られており[5]、試験管から地球規模での N 動態評価に用いられている。霞ヶ浦流域では、筑波山麓水田集水域での N 動態評価に河川水中の $\delta^{15}N_{NO3}$ と $\delta^{18}O_{NO3}$ 値が用いられた[6]。本研究は、鉾田川流域の地下水中 $\delta^{15}N_{NO3}$ と $\delta^{18}O_{NO3}$ 値に基づき、家畜排泄物や化学肥料等の地下水への N 負荷源、ならびに硝化や脱窒等の N 動態が当流域内の NO_3^-による地下水汚染に与える影響を評価することを目的とした。



図 1; 採水地点

2. 方法

茨城県鉾田川流域（53 km^2）を 3 つのサブ流域（上流 1、上流 2、下流）に区分し、計 60 箇所の井戸で地下水を採取した（2014～2016 年）（図 1）。河川水は、2014 年に鉾田川本流（下流部の飯名橋近傍）で採取した。水試料中の NO_3^-濃度はイオンクロマトグラフ法で測定し、$\delta^{15}N_{NO3}$ と $\delta^{18}O_{NO3}$ 値は脱窒菌法[5]により求めた。

3. 結果

全地下水（n = 60）の NO_3^-濃度は 9.4±4.2 mg N L^{-1}、$\delta^{15}N_{NO3}$ は 7.9±1.9‰、$\delta^{18}O_{NO3}$ は 1.2±1.2‰で、河川水（n = 1）は 6.5 mg N L^{-1}、3.4‰、4.4‰だった（図 2）。

各サブ流域の地下水の NO_3^-濃度は、上流 1 が 9.8±5.2（n = 41）、上流 2 が 8.8±7.6（n = 8）、下流が 8.5±5.1 mg N L^{-1}（n = 11）で、水質環境基準超過率はそれぞれ 46%、25%、42%だった。$\delta^{15}N_{NO3}$ は、上流 1 が 8.3±2.3‰、上流 2 が 7.2±1.9‰、下流が 6.9±4.0‰で、$\delta^{18}O_{NO3}$ はそれぞれ 1.4±1.4‰、0.5±1.4‰、1.2±3.0‰であり、いずれも有意差は認められなかった。

4. 考察

4.1 鉾田川流域における N 負荷源

地下水への N 負荷源には大気降下物、化学肥料、畜産排泄物や生活排水等があり、鉾田川流域では人間活動の影響が明らかである。人為的な N 負荷源の $\delta^{15}N_{NO3}$ 値は、化学肥料が−4～+4‰、畜産排泄物が+10～+20‰、生活排水が+8～+15‰とされる[7] [8]。鉾田川流域の全地下水のうち、$\delta^{15}N_{NO3}$ 値 4‰以下の値は 3 地点（NO_3^-濃度：0.1～9.6 mg N L^{-1}）のみで検出され（図 2）、NO_3^-の起源が化学肥料 N のみに由来するとは考えにくい。さらに、計 47 地点の地下水が、化学肥料 N と有機物（家畜排泄物と生活排水）N の間の範囲（$\delta^{15}N_{NO3}$：4～10‰）に分布した。また、前述のように、畜産由来 N 負荷量は生活排水 N の約 3 倍あり、生活排水が汚水処理施設に集められて浄化されるのに対し、家畜排泄物は堆肥化されて農地等に面的に散布される。したがって、これらを考え併せると、化学肥料 N と畜産排泄物 N の混合物に由来する N が鉾田川流域の地下水における主な N 負荷源と考えられる。また上流 1、上流 2 及び下流の $\delta^{15}N_{NO3}$–$\delta^{18}O_{NO3}$ プロット分布範囲は概ね一致し、全流域の地下水中 NO_3^-の起源は類似と考えられた。

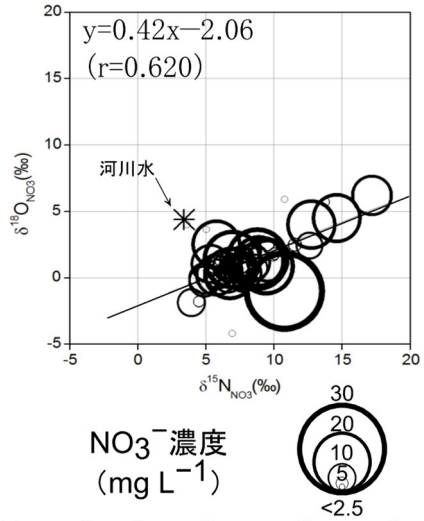

図 2；地下水の $\delta^{15}N_{NO3}$–$\delta^{18}O_{NO3}$ プロット

全地下水の $\delta^{15}N_{NO3}$ 値のヒストグラムは、5.00±0.73‰（n＝14、Group1）、7.14±0.57‰（n＝26、Group 2）、10.7±2.40‰（n＝20、Group 3）に三分した（図 3）。Group 2（$\delta^{15}N_{NO3}$ 値 6～8‰）の度数が突出し、かつ $\delta^{18}O_{NO3}$ 値がほぼ同じ（0.61±1.07‰）だったことから、鉾田川流域全体で同様の肥培管理（化学肥料と家畜排泄物の併用率）が実施されていると推察された。グループ別の $\delta^{15}N_{NO3}$–$\delta^{18}O_{NO3}$ プロットをみると、Group 3 では傾き 0.59 の直線が得られ、脱窒に伴う同位体分別（$\delta^{15}N_{NO3}$ と $\delta^{18}O_{NO3}$ 同位体比増加）の影響が示された（図 3(c)）。しかし、NO_3^-濃度（10.6±7.2 mg N L^{-1}）は有意差は無いものの他より高く、脱窒による地下水中 NO_3^-の浄化傾向は認められなかった。

4.2 鉾田川流域における N 循環

全地下水の $\delta^{15}N_{NO3}$–$\delta^{18}O_{NO3}$ プロットを一次回帰した結果、傾き 0.42 の直線が得られ、流域内における脱窒の傾向が示された（図 2）。サブ流域別にみると、上流 2 と

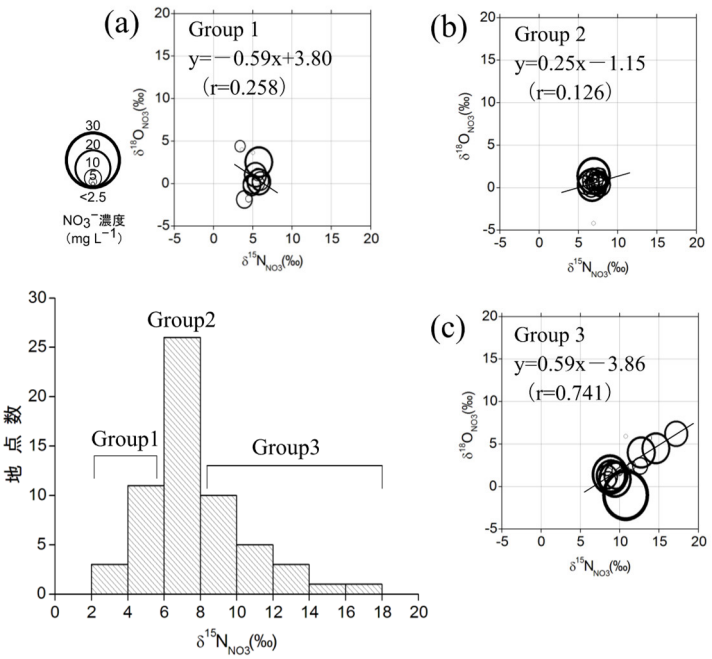

図 3；地下水の $\delta^{15}N_{NO3}$ 値のヒストグラム、及びグループ別の $\delta^{15}N_{NO3}$–$\delta^{18}O_{NO3}$ プロット(a) Group1、(b) Group2 及び(c) Group3

比較し上流 1 及び下流でより脱窒傾向が示され、各サブ流域の土地利用に占める水田面積率（上流 1：9.7%、上流 2：7.4%、下流：11.3%）と合致した。地下水を採水した井戸の深さが判っているもの（n=19）について、深さを海抜標高に換算すると−26m～+42m であり、−21～+22m の広範囲に水環境基準値を超過する地下水が分布した（図 4）。井戸の深さと NO_3^- 濃度、ならびに $\delta^{15}N_{NO3}$ と $\delta^{18}O_{NO3}$ 値との間には統計的に有意な相関関係は認められなかった。鉾田川流域は、砂層と粘土層で形成される鹿島台地と関東ローム層からなり透水性が高い[9]。このため、土壌に負荷された N のうち、作物が吸収しきれなかった余剰の N が、地層内で顕著な脱窒を受けること無く地下水面に到達する場合が多くあると考えられた。また、霞ヶ浦（北浦）の周辺地域は地下 70m 深さで霞ヶ浦基底面の沖積層と連続しており[9]、鉾田川流域の地下流動系に到達した N は、霞ヶ浦湖盆の水頭圧を受けて地下水帯に滞留する傾向があると考えられた。

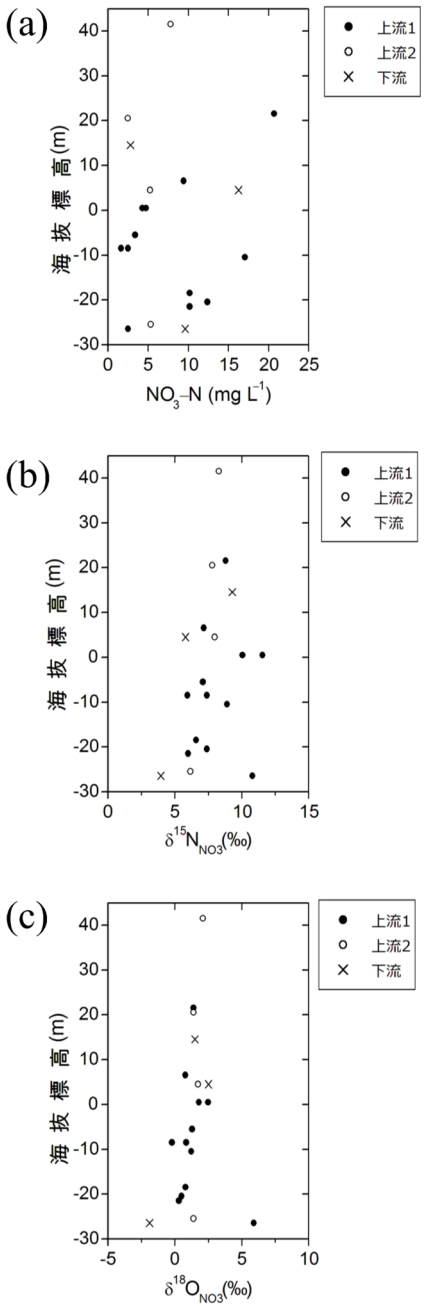

図4；井戸の水面標高別の地下水の(a) NO_3^- 濃度、(b) $\delta^{15}N_{NO3}$ 及び(c) $\delta^{18}O_{NO3}$

5. 結論

鉾田川流域の地下水の $\delta^{15}N_{NO3}$ と $\delta^{18}O_{NO3}$ 値から、N 負荷源は主に化学肥料と家畜排泄物の混合物であると考えられた。水田等への地下水灌漑による N 浄化（脱窒）の可能性も示唆されたが、顕著な NO_3^- 濃度低下は認められなかった。鉾田川流域における適切な肥培管理の重要性は従来から指摘されてきたが、本研究により、化学肥料と家畜排泄物の両方の削減が必要であることが安定同位体分析結果に基づき初めて明示された。

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O5-3

茨城県霞ケ浦流域における大気アンモニア濃度の広域観測

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キーワード:広域的大気環境の影響, 窒素・りん循環, 点源及び面源汚染

抄録

農業・畜産系から放出された大気アンモニア(NH_3)の沈着は, 放出源の周辺に窒素負荷をもたらすが, その負荷量を決める NH_3 濃度の観測データは国内では限定的であり, 流域への窒素の負荷量を推計する上で不確実な要因となっている。このことを背景に, 2017 年 6 月から茨城県霞ケ浦流域に分布する 13 地点を対象に, 拡散型パッシブサンプラーとイオンクロマトグラフィーを用いた NH_3 濃度の観測網の整備を進めている。観測された月平均 NH_3 濃度の大きさや変動傾向は地点ごとに異なり, 特に, 観測地点の近傍に畜舎などの放出源が想定される場所では, 濃度の変動幅が大きいことが示された。今後, 本研究の広域観測を継続することによって, NH_3 の沈着がもたらす霞ケ浦流域や窒素飽和が起こっている筑波山の森林への窒素負荷量の推計を目指す。

1. はじめに

農業活動に伴う施肥や家畜ふん尿などから発生する大気アンモニアガス(NH_3)は, 降雨に取り込まれて落下する湿性沈着や大気乱流により下方へ輸送され樹木の葉などへと直接吸着する乾性沈着を通じて, 特に放出源の近傍に大量の窒素を負荷する[1]。乾性沈着量の推計には NH_3 濃度のデータが必要であるが, 大気汚染物質ではない NH_3 には環境基準や監視体制が存在せず, データは限定的である。また, NH_3 の発生源は局所的かつ広く分布しているため, その大気中の挙動を把握するためには流域への負荷を意識した広域的な NH_3 濃度の観測網が必要である。

本研究では, 農業・畜産系発生源が広く分布する茨城県霞ケ浦流域を対象に, NH_3 濃度の多地点観測を実施する。得られた結果を公表されている NH_3 の排出インベントリデータと比較し, 濃度変動の要因を解析する。

2. 方法

Figure 1 は, 本研究で実施する対象地域を示す。観測地点は, 次の 13 地点である:Ami(茨城大学阿見キャンパス), Ushiku(牛久自然観察の森), Kakioka(石岡市柿岡), Itako(茨城大学広域水圏環境科学教育研究センター), IKESC(茨城県霞ケ浦環境科学センター), Tsuchiura(土浦保健所), Nishiura(西浦湖心), Inashiki(稲敷合同庁舎), Hokota(鉾田合同庁舎), Tokusyuku(鉾田市徳宿), Mt. Tsukuba(国立環境研究所筑波山森林試験地), Chiyoda(森林総合研究所千代田試験地), Omitama(小美玉市倉数)。観測地点を選定する上では, 同図に示した大気汚染物質の総合排出インベントリー EAGrid2000-Japan[2]による 1 km 解像度の NH_3 の年間排出量分布を参考にした。EAGrid2000-Japan では, 国内で最大規模の排出源は農業・畜産系由来であると推計されている。

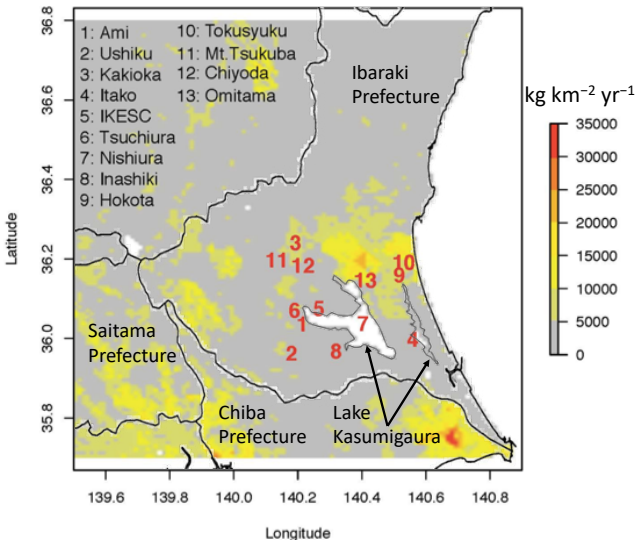

Fig. 1 Sampling locations of NH_3 concentration in Kasumigaura basin in Ibaraki Prefecture, Japan. Shaded areas show the 1-km resolution emission inventory of NH_3 from revised EAGrid2000-Japan[2].

NH_3 濃度の観測には，大気汚染物質の観測に広く利用されている拡散型パッシブサンプラー（小川商会製）を用いた。このサンプラーを 4 週間おきに回収した後，ろ紙に吸着したアンモニウム（NH_4^+）成分をイオンクロマトグラフィー（ThermoFisher Scientific 製 Integrion, CS16）で分析し，暴露時間とその期間の平均気温を用いて NH_3 濃度に換算した。暴露時間中の平均気温は，観測点に近い気象庁アメダス（つくば館野，土浦，鉾田，鹿島）の 1 時間値を用いて計算した。

本稿では，Fig. 1 の Nos. 1–4 にそれぞれ位置する Ami（2017 年 6 月以降），Ushiku（2017 年 7 月以降），Kakioka（2017 年 8 月以降）および Itako（2018 年 1 月以降）の観測結果を解析した。その他の地点（Nos. 5–13, Fig.1）には，2018 年 4 月から 5 月にかけて順次サンプラーの設置作業を行い，観測を進めている。

3. 結果と考察

Figure 2 は，Ami, Ushiku, Kakioka および Itako の 4 地点で観測した NH_3 濃度の経時変化である。すべての地点でデータが利用可能な 2018 年 1 月における濃度の大小関係は，下記のようであった：Ushiku（12 ppb）＞Kakioka＝Ami（3 ppb）＞Itako（2 ppb）。

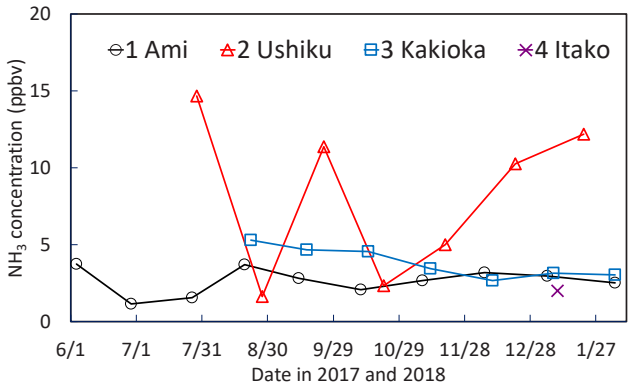

Fig. 2 Temporal changes in measured monthly NH_3 concentration at Nos. 1–4 in Fig. 1 from 1 June 2017 to 4 February 2018.

Itako を除く上記 3 地点のうち，Ushiku では，月ごとの NH_3 濃度が他の地点より広い範囲（1–15 ppb）で変化していた。その原因として，Ushiku の観測地点から南東方向 130 m 離れた場所にある養豚・堆肥製造工場を発生源とした NH_3 の風下方向への揮散が考えられる。実際に，土浦アメダスの風向データから観測地点が工場の風下になった割合を計算すると，風下割合と濃度との間には弱い正の相関がみられた（図略）。また Ushiku の近傍では比較的大きい年間 NH_3 排出量（5000–10000 kg km^{-2}）も推計されており（No. 2, Fig. 1），観測地点を含む 130 m 範囲での NH_3 の大気拡散過程が濃度の経時変動を決めていた可能性がある。

2017 年 8 月から 10 月の夏から秋にかけて，Kakioka の NH_3 濃度は Ami に比べて常に高い値を示した。Kakioka では，この周辺に分布する NH_3 の排出源（No. 3, Fig. 1）から揮散した NH_3 の影響により濃度が増加した可能性がある。Kakioka の近くには，2018 年 4 月から観測を開始した Mt. Tsukuba（No. 11）があり，この森林では高い窒素負荷により河川水の硝酸イオンが増加した状態が続く「窒素飽和現象」が古くから観測されている[3]。今後，霞ケ浦流域や Mt. Tsukuba での NH_3 濃度の観測とその結果に基づく乾性沈着量の推計を進める必要がある。

謝辞

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O5-4

牛舎周辺のアンモニア濃度と負荷量の局所空間分布に関する調査

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キーワード:大気アンモニア, アンモニア濃度, 牛舎, 揮散, パッシブ法, 乾性沈着

抄録

大気中のアンモニアガス(NH_3)は, 大気乱流により下方へ輸送され樹木の葉などに直接吸着する乾性沈着によって流域へ窒素を負荷する。この量を推計することは, 農業・畜産系の NH_3 発生源が広く分布する茨城県霞ヶ浦流域への窒素負荷量を把握する上で重要である。本研究では, 畜産由来の NH_3 濃度と乾性沈着量の空間分布の傾向を調べるために, 茨城大学が所有する牛舎内およびその周辺でパッシブ法を用いた NH_3 濃度の多点観測と降水採取によるアンモニウム(NH_4^+)の湿性沈着量の観測を行った。乾性沈着量は, 気象データを用いた抵抗モデルにより計算した沈着速度と NH_3 濃度との積によって推計した。風向と NH_3 濃度の観測値の関係を解析した結果, 観測地点が牛舎の風下になった割合に比例して NH_3 濃度が増加することがわかった。また, NH_3 の乾性沈着量は, 降水に含まれる NH_4^+の湿性沈着量の 31%に達することが明らかとなった。

1. はじめに

人間活動に伴い生成するアンモニウムイオン(NH_4^+)や硝酸イオン(NO_3^-)などの反応性の高い窒素(反応性窒素)は, 河川を通じて湖沼へ流入し, 世界各地で環境悪化を引き起こしている[1]。特に, 反応性窒素が流域を通して湖沼や海に流入し, アオコや赤潮(大量の植物プランクトン)を発生させる富栄養化が問題となっている[2]。茨城県では, 霞ヶ浦(特に, 北浦)で夏季を中心にアオコの発生が観測されており, 周辺地域の良好な環境や水質への悪影響が懸念されている[3]。

反応性窒素の一つである大気アンモニアガス(NH_3)は, 家畜やその排泄物などの発生源から大気へと放出(揮散)する。そして, 雨や雪に取り込まれて地表へ落下する湿性沈着と大気乱流により下方へ輸送され樹木の葉などに直接吸着する乾性沈着を通じて流域に窒素を負荷する。特に, NH_3 は発生源の近傍(およそ 1 km 範囲)で高濃度となり, 乾性沈着によって大量の窒素を負荷することが報告されているが[4][5], NH_3 濃度の観測例は限られており, 濃度の空間分布を決定づける気象要因も明らかにされていない。また, NH_3 の乾性沈着量を推計することは, その発生源となる農業・畜産関係の施設が広く分布している霞ヶ浦流域への窒素負荷量を正確に把握する上でも重要である。

本研究では, 茨城大学農学部附属国際フィールド農学センター(IFC)の牛舎周辺で NH_3 濃度の多点観測を実施し, その空間分布を定める要因を明らかにする。さらに, その結果に基づいて牛舎近傍の NH_3 の乾性沈着量を推計し, 降水採取により観測した NH_4^+湿性沈着量と比較する。

2. 方法

Fig.1 に, IFC での NH_3 濃度と湿性沈着の観測地点を示す。牛舎内外の NH_3 濃度の観測には, 大気汚染物質の観測に広く用いられている拡散型パッシブサンプラー(小川商会製)を用いた。また, 湿性沈着量の観測には, ポリエチレン製ボトルと漏斗を組み合わせて自作したバルクサンプラーを用いた。パッシブサンプラーとバルクサンプラーを用いた観測期間は, それぞれ 2017 年 5 月から 2018 年 2 月および 2017 年 8 月から 2018 年 2 月であった。回収した大気および降水試料中の NH_4^+を, イオンクロマトグラフィー(ThermoFisher Scientific 製 Integrion, CS16)で分析した。

NH_3 濃度と風向の関係を調べるため, IFC で常時観測されている 16 方位の風向の1時間値を用いて, 観測期間内に発生源の風下に観測地点が含まれる割合を風下割合(percentage of leeward)と定義した。発生源である牛舎の形状が複雑であるため, **Fig.2** に示すように, 発生源の大きさを直径 70 m(牛舎の南北方向 90 m, 東

西方向 50 m の平均値）の円とみなし，風下方向の 2 本の接線からそれぞれ 22.5°（16 方位の方位間隔）の範囲に観測点が含まれる場合を風下に位置するとした。

乾性沈着量は，パッシブサンプラーによる NH_3 濃度の観測値と，乾性沈着の速度を空気力学的抵抗，準層流抵抗，表面抵抗の合成抵抗としてみなした抵抗モデル[6]による NH_3 の沈着速度との積で沈着量を計算する推計法（インファレンシャル法）から求めた。地表面状態を表すパラメータには，典型的な農地の値を用いた。観測期間中の乾性沈着量は，観測した NH_3 濃度と気象データ，抵抗モデルにより 1 時間ごとの沈着量を積算して求めた。抵抗モデルの入力データには，日射量と気温・気圧・風向および風速は，それぞれアメダス（つくば）と IFC で観測された 1 時間値を用いた。

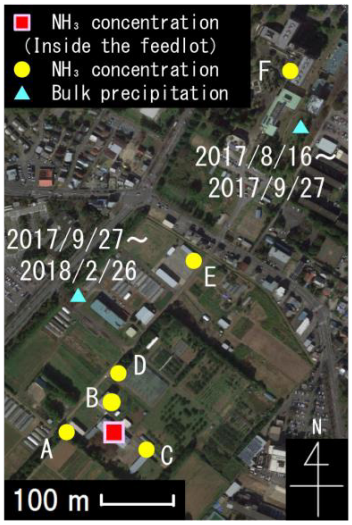

Fig. 1　Sampling locations of NH_3 concentration and bulk precipitation in IFC. The latter was measured at two locations before and after 27 September 2017. Background was obtained from © 2018 Google Map.

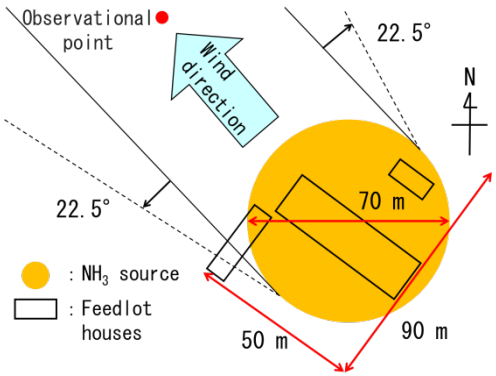

Fig.2　An example when the observational point is located downwind from the NH_3 source, and squares are feedlot houses in IFC.

3.　結果と考察

観測期間中の全地点の NH_3 濃度の時系列変化を **Fig.3** に示す。牛舎内の NH_3 濃度は 200–400 ppbv，その他の地点では 2–10 ppbv で変動していた。牛舎内の NH_3 濃度は，2017 年 10 月から 11 月に高かった。一方，D, E および F 地点の濃度は 1–5 ppbv であった。A 地点では 2017 年 8 月から 11 月頃，B および C 地点では 2018 年 1 月から 2 月に 5–10 ppbv まで増加し，D, E および F 地点より高い時期があった。牛舎内の NH_3 濃度は，牛舎外の NH_3 濃度の 60–120 倍であった。

パッシブ法を用いた野外における NH_3 濃度の過去の観測では，都市部で 1.0–1.5 ppbv [7][8][9]，山間地で 0.2–1.0 ppbv [7][8][9]，畜産地域で 1.5–5.5 ppbv [9]が報告されている。本研究で観測された全期間全地点の NH_3 濃度の変動範囲と平均値は 1–10 および 3.7 ppbv であり，上述した畜産地域の観測結果に近かった。また，牛舎から 50 m 風下の A 地点の NH_3 濃度は，牛舎を除くその他の地点よりも常に高く，牛舎から揮散した NH_3 の影響を受けやすかったと考えられる。また，その影響は 50 m 以上離れると低下し，NH_3 が高濃度になる範囲は限定的であることがわかった。

Fig.4 に，牛舎から 580m 範囲の 6 地点で観測された NH_3 濃度とそれらが牛舎の風下になった割合（風下割合）の関係を示す。その結果，上述した範囲では，風下割合に比例して NH_3 濃度が有意に増加する関係がみられた（$n=34$, $R^2=0.621$, $p<0.001$）。牛舎から最も離れた F 地点では，直線関係を下回る値が 2 点観測された（**Fig.4**）。この原因としては，牛舎から風下方向に流れる NH_3 ガスの軌道が，建物の影響などにより F 地点に到達する手前で反れた可能性が考えられる。また，NH_3 濃度に影響を及ぼす可能性のある他の気象要素（風速，気温，降雨期間）についても調べたが，相関は見られなかった（図略）。このことから，牛舎近傍の月平均の NH_3 濃度の局所的な空間分布は，風向によってほぼ説明できると考えられる。

NH_3 濃度の観測値を用いて，牛舎の風下 50 m 地点の NH_3 の乾性沈着量をインファレンシャル法で推計したところ，2017 年 8 月から 2018 年 2 月の NH_3 の積算値は 0.64 kgN ha^{-1} であった。一方，同期間の NH_4^+ の湿性沈着量は 2.06 kgN ha^{-1} であり，乾性沈着による NH_3 負荷

量が湿性沈着量の 31%に達することが明らかになった。この結果は，流域への窒素負荷量を推計するうえで NH_3 の乾性沈着量は無視できないことを意味しており，継続的な観測によって年間の乾性沈着量を推計する必要がある。

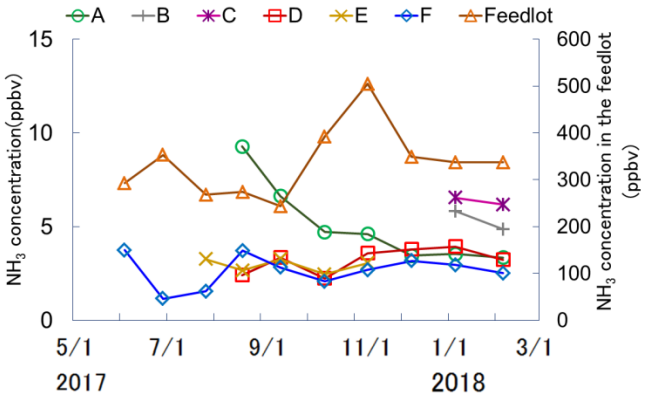

Fig. 3 Time series in measured monthly NH_3 concentration in IFC from 23 May on 2017 to 21 February 2018. Alphabets in the legend show the sampling locations illustrated in Fig. 1.

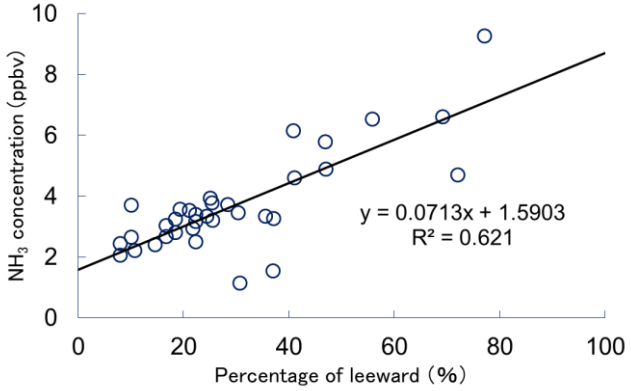

Fig. 4 Relationship between the percentage of leeward and monthly NH_3 concentration measured at all sampling locations in IFC.

4. 結論

拡散型パッシブサンプラーを用いて，茨城大学の保有する牛舎内外で月平均の NH_3 濃度の多地点観測を行い，その局所的な空間分布を調べた。その結果，観測期間中の牛舎の風下になった割合によって，発生源から 580 m 範囲の NH_3 濃度の空間分布を説明できることがわかった。また，牛舎の 50 m 風下での NH_3 の乾性沈着量の推計値は，NH_4^+の湿性沈着量の 31%になることが明らかとなった。

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O5-5

巴川・鉾田川流域における地下水の硝酸態窒素による汚染状況及びその要因

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キーワード:窒素・りん循環, 点源及び面源汚染, 土地利用管理

抄録

畑地での野菜類の栽培並びに畜産が広く行われている巴川・鉾田川流域（茨城県）では，地下水の硝酸態窒素（NO_3-N）及び亜硝酸態窒素（NO_2-N）濃度が環境基準値（10 mg/L）を超える井戸の存在が 1998 年以降続けて認められている。本研究では，2016 年 11 月に同流域内にある 8 地点の井戸で地下水水質調査を実施し，NO_3-N による汚染状況及び要因について検討した。5 地点で NO_3-N 及び NO_2-N 濃度が環境基準値を上回り，特に巴川上流域の 2 地点では 20 mg/L 以上の高い値を示した。また，4 地点では 2009 年以降環境基準値を継続して超過しており，最近 2 年間ではほぼ横ばいあるいは上昇傾向で推移している。地下水の水質組成並びに硝酸イオンの窒素安定同位体比の分析結果から，10 mg/L 以上の NO_3-N が検出された地点では，いずれも畑地に施用された硫酸塩化成肥料や家畜排せつ物が NO_3-N の主な汚染要因となっていると推定された。

1. はじめに

北浦（茨城県）の主要流入河川である巴川及び鉾田川の流域では，畑地での野菜類の栽培並びに畜産が広く行われている。一方，畑地に施用された化成肥料や土壌に還元された家畜排せつ物（堆肥を含む）等に由来する硝酸態窒素（NO_3-N）が溶脱し，地下水を汚染する問題が各地で顕在化している。[1] 巴川・鉾田川流域でも，NO_3-N 及び亜硝酸態窒素（NO_2-N）濃度が環境基準値（10 mg/L）を超える井戸の存在が 1998 年以降続けて認められている。[2]

本研究では，巴川・鉾田川流域内にある 8 地点の井戸を対象に地下水水質調査を実施し，その結果を元に NO_3-N による汚染状況及び要因について検討した。

2. 方法

2.1. 採水

調査井戸の位置を図 1 に，井戸のタイプ及び深さを表 1 にそれぞれ示す。W1 ~ W4 及び W7 では，NO_3-N 及び NO_2-N 濃度が環境基準値を 2008 年以降継続して超過している。また，W5 及び W6 は W4 の半径約 300 m 以内に位置している。調査は 2016 年 11 月に実施した。採水した試料は実験室に持ち帰り，孔径 0.45 μm のメンブランフィルターでろ過した後，次に示す水質分析に供した。

2.2. 水質分析

NO_3-N，NO_2-N 及びアンモニア態窒素（NH_4-N）の各濃度を，オートアナライザー（ビーエルテック，QuAAtro）を用いて定量した。また，主要陽イオン（ナトリウム(Na^+)，カリウム(K^+)，カルシウム(Ca^{2+})，マグネシウム(Mg^{2+})）及び陰イオン（塩化物(Cl^-)，硫酸(SO_4^{2-})）の各濃度を，イオンクロマトグラフィー（Dionex，ICS-2000）を用いて定量した。

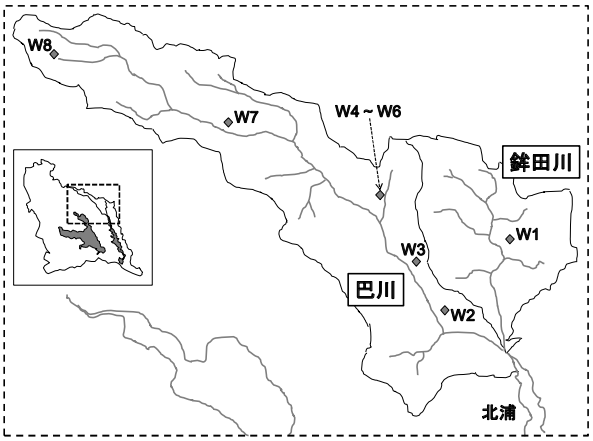


図 1. 調査井戸

上記のろ液を孔径 0.22 μm のシリンジフィルターでさらにろ過した試料について，硝酸イオン（NO_3^-）の窒素安定同位体比（δ^{15}N-NO_3^-）を脱窒菌法[3-5]により測定した。測定には，自動前処理ライン[6]を連結させた同位体比質量分析計（Thermo Finnigan，Delta plus Advantage）を用いた。

表 1. 調査井戸のタイプ, 深さ及び硝酸態窒素 (NO_3-N) 濃度

井戸番号	タイプ	深さ (m)	NO_3-N (mg/L)
W1	打込	(不明)	15.44
W2	打込	(不明)	13.60
W3	打込	60	17.05
W4	掘抜	26	8.61
W5	打込	(不明)	8.80
W6	打込	(不明)	3.05
W7	打込	(不明)	22.30
W8	掘抜	20	20.41

＊井戸のタイプ及び深さは, 茨城県環境対策課からの提供情報。

3. 結果及び考察

3.1. NO_3-N 濃度の空間分布及び経年変化

各井戸における地下水中 NO_3-N 濃度を, 表 1 に示す。W1 ~ W3, W7 及び W8 で 10 mg/L を超過し, 最高濃度は 22 mg/L (W7) であった。一方, W4 とそれに隣接する 2 つの井戸 (W5, W6) においては, W4 と W5 で NO_3-N 濃度がほぼ同じであったのに対し, W6 ではその半分以下 (3.0 mg/L) であった。なお, いずれの井戸においても, NO_2-N 濃度は NO_3-N 濃度の 0.07%以下と低かった。

W1 ~ W4 及び W7 における 2008 年以降の NO_3-N 及び NO_2-N 濃度の経年変化を, 図 2 に示す。鉾田川流域内の W1 並びに巴川中~下流域の左岸側に位置する W2 ~ W4 では, 2011 ~ 2014 年にかけて濃度が低下したが, それ以降はほぼ横ばいまたは上昇傾向で推移している。一方, 巴川上流域に位置する W7 では, 2010 ~ 2011 年にかけて大きく上昇し, それ以降はほぼ横ばいで推移している。

3.2. ヘキサダイアグラムによる汚染要因の推定

各井戸における地下水のヘキサダイアグラムを, 図 3 に示す。

NO_3-N 濃度が最も低かった W6 はきれいな菱形に近い Ca-HCO_3 型の水質組成を示し, 土壌・岩石由来のイオン成分が基本となっていると考えられる。[1] 一方, W6 に隣接する W4 及び W5 では Na^+が他のイオン成分と比べて濃度が高く, Na-Cl 型と見なせることから, 生活系 (浄化槽) 排水の影響が示唆される。[1]

NO_3-N 濃度が 10 mg/L を超えた W1 ~ W3 及び W7 ではいずれも Ca-(SO_4 + NO_3)型の水質組成を示した。一般に, 畑地に硫酸アンモニウム (硫安) 等の硫酸

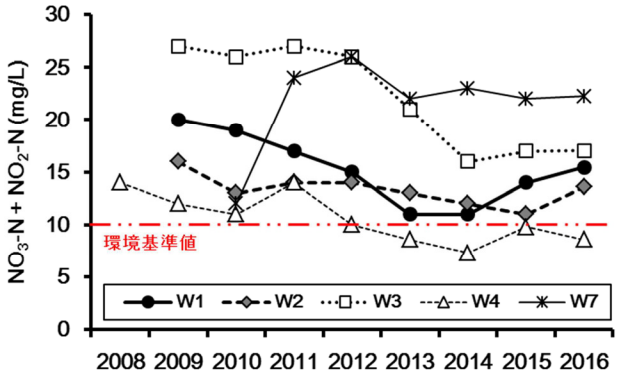
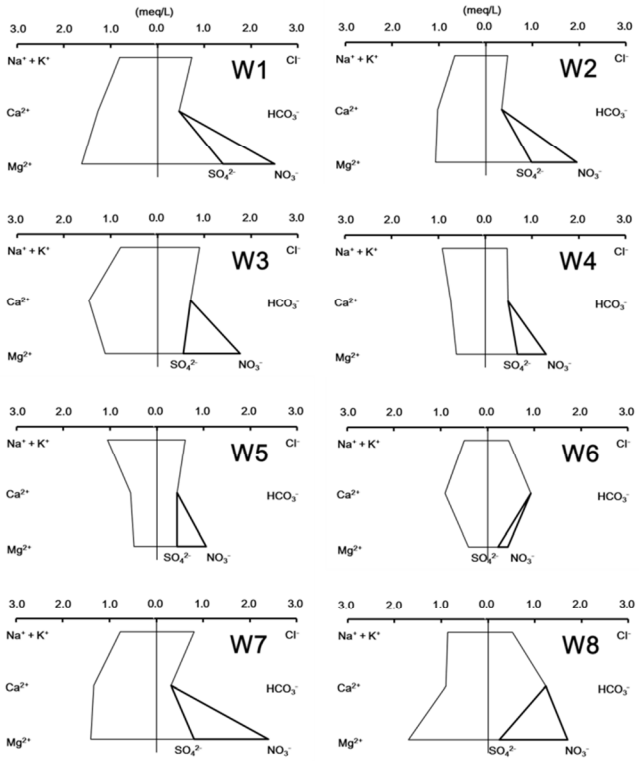


図 2. W1 ~ W4 及び W7 における硝酸態窒素及び亜硝酸態窒素 (NO_3-N + NO_2-N) 濃度の経年変化



＊炭酸水素イオン (HCO_3^-) の等量濃度は, 主要陽イオン (Na^+, K^+, Ca^{2+}, Mg^{2+}, アンモニウム(NH_4^+)) の等量濃度の和から主要陰イオン (Cl^-, SO_4^{2-}, NO_3^-) の等量濃度の和を差し引いた値に等しいと仮定して算出した。

図 3. 各調査井戸における地下水のヘキサダイアグラム

塩化成肥料や苦土石灰 (土壌改良材) が施用された場合, その影響を受ける地下水は自然状態のものと比べて NO_3^-, SO_4^{2-}, Ca^{2+}及び Mg^{2+}が増加すると考えられること[1, 7]から, これらの井戸における NO_3-N 汚染の要因の一つとして, 畑地に施用された硫酸塩化学肥料が考えられる。また, これらの井戸では HCO_3^-濃度も低いが, これは畑地に大量に施用された化成肥料や家畜排せつ物由来の NH_4^+の硝化によ

り消費されたためと考えられる[1]。これに対し，同じく NO_3-N 濃度が 10 mg/L を超えた W8 では，NO_3^- 濃度に対して SO_4^{2-}濃度が低く，Ca-NO_3 型となっていた。家畜排せつ物による汚染の場合，NO_3-N 濃度の上昇に対して SO_4^{2-}濃度の変化が小さいことが報告されていること[8]から，同地点における NO_3-N の汚染要因として家畜排せつ物の寄与が大きいと推察される。

3.3. δ^{15}N-NO_3^-に基づく NO_3-N の起源の推定

各井戸における地下水の δ^{15}N-NO_3^-を，NO_3-N の起源となる化成肥料，土壌，家畜排せつ物並びにし尿・下水に含まれる窒素の安定同位体比（δ^{15}N）の文献値[9, 10, 他]と併せて図 4 に示す。W1 及び W2 の δ^{15}N-NO_3^-は 3.3 ~ 3.8‰と低く，化成肥料（-6.1 ~ 3.6‰）起源の寄与が大きいと考えられた。これに対し，W3，W7 及び W8 では 7.7 ~ 15.5‰と高い値を示し，ヘキサダイアグラムからの知見を併せると，家畜排せつ物（3.1 ~ 23.2‰）起源の寄与が大きいと推定された。

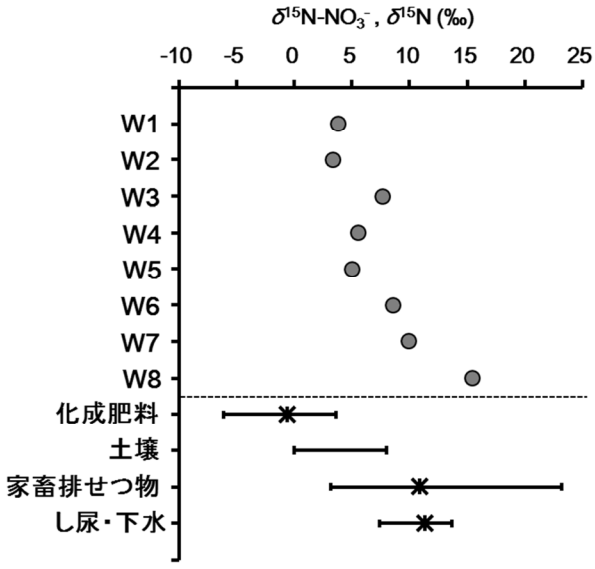
一方，W4 及び W5 の δ^{15}N-NO_3^-は 5.0 ~ 5.6‰と比較的低く，ヘキサダイアグラムから示唆された生活系排水（し尿・下水 : 7.4 ~ 13.7‰）よりも低かった。これらの井戸は畑地と住宅地とが混在する地域に位置することから，NO_3-N の起源としては畑地に施用された化成肥料の寄与がより大きいものと推察される。

4. 結論

畑作並びに畜産が盛んに行われている巴川・鉾田川流域における地下水の NO_3-N 汚染の状況及び要因について把握することを目的に，同流域内の 8 地点の井戸で地下水水質調査を行い，以下の結果を得た。

- 5 地点で NO_3-N 及び NO_2-N 濃度が環境基準値を上回り，特に巴川上流域の 2 地点では 20 mg/L 以上の高い値を示した。
- 地下水の水質組成及び δ^{15}N-NO_3^-の分析結果から，10 mg/L 以上の NO_3-N が検出された地点では，いずれも畑地に施用された硫酸塩化成肥料や家畜排せつ物が NO_3-N の主な汚染要因となっていると推定された。

流域内の広い範囲で環境基準値を超える濃度の NO_3-N 及び NO_2-N が検出されたことから，今後より多くの地点で地下水を採取し，同様の水質分析を行うことにより，地下水における NO_3-N の濃度分布を詳細に把握するとともに，その汚染要因について検討する必要がある。



＊各起源のエラーバーは δ^{15}N の文献値[9, 10, 他]のとり得る範囲を，＊は中央値をそれぞれ表す。

図 4. 各調査井戸における硝酸イオンの窒素安定同位体比（δ^{15}N-NO_3^-），並びに各起源の窒素安定同位体比

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O5-6

園芸品目における改善施肥技術適用時の窒素フットプリントの仮想窒素係数とその硝酸態窒素溶脱指標としての有効性

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キーワード：窒素フットプリント, 窒素溶脱, 仮想窒素係数

抄録

作物栽培において窒素は必須多量元素である一方で、多投入は環境負荷の原因となり得る。これまで茨城県では生産コスト削減と環境負荷低減の面から改善施肥技術を開発してきた。本研究では茨城県の園芸品目における施肥改善技術ごとのデータベース化と、窒素フットプリント内の重要な指標値である仮想窒素係数（VNF）の計算を行った。また、VNF が地下水への窒素負荷指標として有効かどうか検討するため、VNF と硝酸態窒素溶脱量との関係について検討した。その結果、葉菜類においては改善施肥により VNF と硝酸態窒素溶脱量が低下する傾向があり、両者には比例関係が認められた。一方、根菜類では改善施肥適用時にも硝酸態窒素溶脱量が低下しない事例も認められ、VNF との関係は判然としなかった。以上のように VNF を地下水への負荷指標として用いる際には品目ごとの特徴を把握することが重要と思われた。

1. はじめに

作物栽培において窒素は最も重要な必須多量元素である一方で、多投入は環境負荷の原因となり得る。肥料として投入される窒素はいわゆる反応性窒素（Nr：N_2 を除く窒素化合物すべて）であり、大気圏内の窒素循環の中において形態を変化させながら存在している[1]。施肥窒素のうち作物に利用されなかった余剰窒素は、水圏に対しては硝酸態窒素（NO_3^--N）、大気圏に対しては温室効果ガスである一酸化二窒素（N_2O）等の形態で環境に負荷を与える。

過去の農業研究において、施肥技術開発等により環境負荷を低減する試みが多く行われてきたが、多くの場合これらの取組みは特定の形態の Nr を対象として研究されており、事例を並列に検討することが困難であった。窒素負荷がもたらす環境影響を評価する新たな指標として、窒素フットプリントがある。窒素フットプリントの定義は、「個人（または組織、国など）の資源消費の結果として環境中に排出される反応性窒素の総量」である[2]。作物生産の窒素フットプリント（N-Calculator 法）は、食糧消費窒素あたりの環境中への Nr ロス量を示す仮想窒素係数（VNF: Virtual Nitrogen Factor）に基づき算出される[2]。VNF は当該作物の生産から消費までのプロセスにおいて環境中に放出される Nr 量を、消費 Nr 量で除した値であり[3]、各国への適用が進んでいる

そこで本研究では、茨城県の園芸品目における窒素フットプリント計算の適用性を評価するため、過去の窒素動態に関する調査結果のデータベース化と VNF 等の算出を行った。また、窒素フットプリント計算で使用される VNF が地下水への窒素負荷指標として有効であるか検討するために、VNF と硝酸態窒素溶脱量との関係について検討した。

2. 方法

（1）窒素動態に関する既往の調査データの収集、データベース化

VNF 算出等の窒素負荷指標の検討に資するため、茨城県の園芸品目における過去の窒素動態に関する調査事例のデータベース化を行った。データベースの対象文献は、日本土壌肥料学雑誌、茨城県園芸研究所研究報告、茨城県園芸研究所試験成績書である。データベースの内容は文献情報、負荷量情報、調査情報、営農情報、各指標とし、各事例の VNF 計算シートに個票として添付するとともに、総合した整理票を作成した（表1）。

（2）既往の調査データに対する窒素負荷指標の適用

収集した窒素動態に関するデータベースを基に、慣行および改善施肥を行った場合の VNF 等の各指標と硝酸態窒素溶脱量の変化について評価した。評価の対象となる調査データは、施肥量および収穫物の窒素含量等の VNF 算出に必要な項目と、硝酸態窒素溶脱量の両方が含まれる事例とした。慣行施肥と改善施肥法実施時の VNF および硝酸態窒素溶脱量の違いについては、データを葉菜類、根菜類、果樹類に区分して

表1　データベースの内容

文献情報	論文タイトル・資料名
	公表年
	著者名
	収録雑誌名
	巻号
	ページ
負荷量情報	測定期間
	硝酸態窒素溶脱量(kgN/期間)
	一酸化二窒素排出量(kgN/期間)
	その他
調査情報	調査場所
	調査年・期間
	調査頻度
	灌漑水調査
	降水調査
	浸透水調査
営農情報	作物
	慣行農法・改善農法の別
	改善農法の種類
	施肥量(化学肥料kgN/10a)
	施肥量(堆肥kgN/10a)
	施肥量(計kgN/10a)
	有機物の種類
	収量(kg/10a)
	窒素吸収量(kgN/10a)
	調製物窒素含量(kgN/10a)
	その他窒素情報
	土壌の種類
指標	NUE1[1)](施肥→吸収)
	NUE2(吸収→収穫物)
	NUE3(収穫物→流通)
	NUE4(流通→摂食)
	VNF[2)]

1)NUE(Nitrogen Use Efficiency):窒素利用効率
2)VNF(Virtual Nitrogen Factor):仮想窒素係数

評価した。また、VNF と硝酸態窒素溶脱量との関係の評価は品目ごとに行った。

3. 結果

(1)窒素動態に関する既往の調査データの収集、データベース化

現在までのところ、15 文献、83 事例を整備しており、引き続きデータベース作成を行っている。調査データと既存の標準データ(日本食品標準成分表(文部科学省)、バイオマス成分データベース(農研機構))を用いることで、窒素利用効率(NUE:吸収・利用窒素量／窒素供給量)および VNF が算出可能な事例はそれぞれ 71 事例、73 事例と、収集事例の多くを占めた。VNF の算出にあたって、減肥や有機物の連用事例において投入窒素よりも作物吸収窒素が大きいことにより負値となる場合が 13 事例でみられた。

(2)既往の調査データに対する窒素負荷指標の適用

収集した窒素動態に関するデータベースを基に、慣行および改善施肥を行った場合の VNF と硝酸態窒素

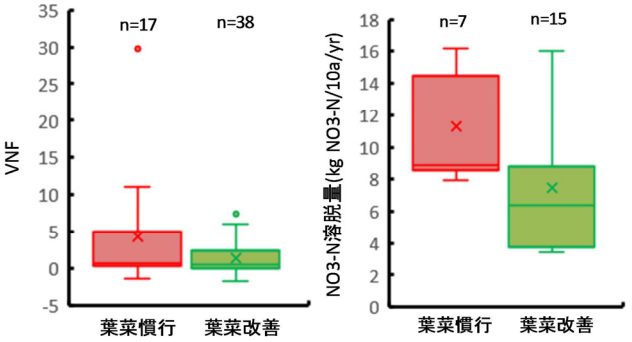

図1　葉菜類における慣行および改善施肥法実施時の VNF と硝酸態窒素溶脱量の違い

垂線は上端が第三四分位数＋1.5×四分位範囲の最大値、下端が第一四分位数－1.5×四分位範囲の最小値を示す。×は平均値、○は外れ値を示す。

溶脱量の変化について評価した(図1)。葉菜類の例では、各種改善施肥を実施すると VNF および硝酸態窒

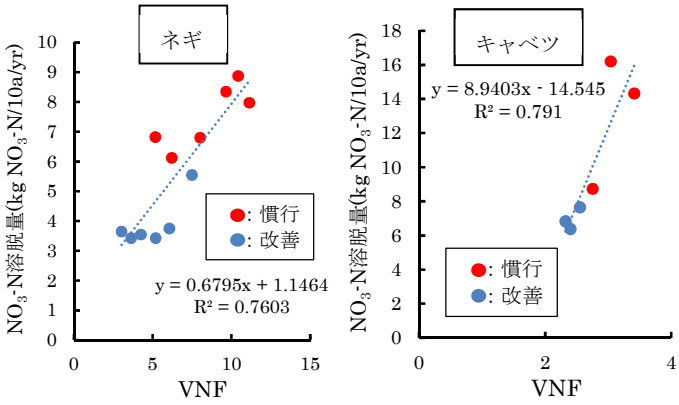

図2　ネギおよびキャベツにおける VNF と硝酸態窒素溶脱量の関係

素溶脱量が小さくなる傾向がみられた。また、キャベツとネギの場合、VNF と硝酸態窒素溶脱量の関係は比例する傾向がみられ、これらの品目においては VNF が地下水に対する影響指標として利用できる可能性が示唆された(図2)。ただし、この比例関係は同一試験条件(圃場、有機物の種類、施肥資材等)で成り立つため、異なる品目および試験条件での利用にあたっては注意する必要がある。

一方、根菜類においては、改善施肥により投入窒素量が減少するため VNF が低下するが、硝酸態窒素溶脱量が低下する事例は少なかった(データ省略)。ナガイモの事例では VNF と硝酸態窒素溶脱量との間に有意な相関関係は認められず、地下水への窒素負荷指標として利用できないと考えられる。

果樹類で VNF が算出可能な事例はニホンナシのみであった。ニホンナシの調査データは施肥、窒素吸収量、硝酸態窒素溶脱、一酸化二窒素排出、土壌炭素含量など非常に詳細であり、VNF と硝酸態窒素溶脱量との間には高い相関関係が認められた(データ省略)。

4. 考察

本研究では、これまで個別の研究で評価されてきた窒素動態に関するデータを、VNF のような指標を用いて並列に評価するためのデータベース作成を行っている。収集した各事例は調査項目も様々であり、NUE および VNF をこのデータのみで算出することは困難なケースが多い。これらについては既存の標準データを活用して、指標の算出を行った。例えば、食品の廃棄率は日本食品標準成分表（文部科学省）、植物体の窒素含量はバイオマス成分データベース（農研機構）から引用した。このように既存のデータを用いることで指標の算出が可能となる事例が多くあり、推定手法として有効と思われた。

VNF の算出にあたって負値となる事例がみられ、これらの多くが減肥や有機物連用により投入窒素を削減する事例であった。現在用いている計算方法は土壌由来窒素の変化を考慮しておらず、作物栽培におけるいわゆる肥料成分の持越しが反映されないスキームとなっている。堆肥の連用により施肥窒素の削減が可能な事例は多くあり[4,5,6]、連作に対応した VNF の計算方法が必要である。食糧消費窒素に対する土壌蓄積窒素の寄与を評価する手法として Soil Mining Factor がある[7]。Soil Mining Factor は作物の窒素吸収量のうち土壌由来分（＝無窒素区における窒素吸収量）を食糧消費窒素量で除した値である。VNF と合わせて Soil Mining Factor のような指標を用いることで、土壌蓄積窒素の影響を表現できる可能性がある。

今回収集した各事例は必ずしも環境負荷に関する調査データ（硝酸態窒素溶脱等）があるわけではなく、そのような場合において VNF 等の指標が負荷の指標として有効であるかどうかを検討した。収集データの範囲においては、葉菜類は VNF が硝酸態窒素溶脱量をよく反映しており、指標として有効であった。しかし、根菜類においては有意な相関は見られなかった。これは、硝酸態窒素溶脱量が環境中への放出窒素に占める割合が異なることによるものと思われる。葉菜類は全体的に多肥傾向になりがちで改善施肥技術の効果が高いことが要因の一つと考えられる。一方根菜類は慣行施肥量が比較的少なく、改善施肥による窒素削減効果が小さいケースが多い。このように品目ごとの特徴を把握することで指標をより有効に活用できるものと思われた。

他の硝酸態窒素溶脱量の推定法として、数値モデル（例えば、LEACHM モデル）の利用が挙げられる。LEACHM モデルは土壌中の水や窒素の動態を長期予測するモデルで、国内土壌への適用を目的に改良が進められている[8,9]。現在のところ VNF 等の指標がカバーできない土壌窒素蓄積の動態などがモデルにより推定できれば、その結果を窒素フットプリントや VNF の計算にフィードバックすることで実態に近い窒素負荷指標を得ることができるものと思われる。

5. 結論

茨城県における窒素動態に関する調査研究成果についてデータベース化を実施し、VNF 等の窒素負荷指標の算出を行った。このデータベースに基づき、窒素負荷指標と地下水への硝酸態窒素溶脱量との関係について検討した結果、葉菜類においては改善施肥により VNF と硝酸態窒素溶脱量が共に低下する傾向が認められ、両者には比例関係が認められた。一方、根菜類では改善施肥適用時にも硝酸態窒素溶脱量が低下しない事例も認められ、両者の関係は判然としなかった。

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O5-7

Utilization of cover crops for soil and water conservation

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Keywords: cover crop, carbon, Nitrogen, soil and water conservation

ABSTRACT

Residual fertilizer nitrogen (N) in soil represents a potential environmental contaminant because of the risk of nitrogen leaching into ground water. Winter cover crops can conserve residual soil N. Soil organic carbon (SOC) has various roles in producing crops and improving their environment. Cover crop is a potential method for conserving or increasing SOC. However, the effectiveness of utilization of cover crops for soil and water conservation has not been clear yet. This study compared dry matter (DM), N content, N accumulation, soil organic C and N in different soil layers (0-2.5, 2.5-7.5, 7.5-15 and 15-30 cm) among different cover crops, including fallow (native weeds), hairy vetch (legume cover crop) and rye (grass cover crop) in soybean production to investigate the effect of cover crops on C and N dynamics in agroecosystem. The results showed that rye had significantly higher dry matter than fallow and hairy vetch, and it also had the highest N accumulation. However N content in rye was significantly lowest, there was no significant difference between fallow and hairy vetch. Soil organic C and N content were higher in rye and hairy vetch compared to fallow in each depth. Soil organic C and N content were significantly higher in 0-2.5 and 2.5-7.5 in relative to 7.5-15 and 15-30 cm layers. These results indicated that cover crops can improve N accumulation and increase soil organic C and N content, it should help inorganic fertilizer of farm.

1. INTRODUCTION

Lake Kasumigaura is a eutrophic lake in Japan. Because it is important to reduce the N load from diffuse nonpoint sources to improve water quality, the local government encourages farmers in the Lake Kasumigaura basin to reduce their use of inorganic fertilizers through a soil nutrient management program called the "eco-friendly farming system." Cover crop is one of the management method. Cover crops can reduce nonpoint source pollution caused by nutrients and agricultural chemicals. In particular, non-leguminous cover crops have been shown to prevent leaching of nitrogen into groundwater by accumulating excess soil N in upland dry fields. Non-leguminous cover crops grown in winter are an effective tool for managing inorganic N in these soils in the spring because these winter cover crops retain residual soil N remaining after the summer crop harvest [1]. Legume cover crops fix both C and N in plant by increasing biomass production. SOC can be increased by elevating biomass production, practicing crop rotation including cover crops. The objectives of this study were to (1) determine the difference of soil organic C and N between with and without cover crop, (2) investigate the effect of cover crops on N accumulation.

2. METHOD

The experiment was conducted at the Center for International Field Agriculture Research and Education, Ibaraki University, Japan. This site was established in 2002 for research on tillage and cover crop systems. It was a split plot design with 4 replication, consisting of two tillage methods, three cover crops (fallow, hairy vetch and rye) and two potassium fertilizer input levels. In this report, only one of the factors-cover crop was discussed for carbon and nitrogen problems. Cover crops in 2016 were harvested on 27th may, 2017 by using 0.25 m^2 quadrat sampling, 2017. Oven-dried weight were measured as biomass. Carbon and nitrogen content of cover crops were measured by C/N corder (Samika chemical analysis service, Ltd.NC 900). Soil samples were took in October 2016 by hand with a steel cylinder. The samples were divided into 4 layers (0-2.5, 2.5-7.5, 7.5-15 and 15-30 cm) for the measurement of soil organic carbon and nitrogen by C/N coder. Data were statistically by ANOVA (StateView, SAS Institute).

3. RESULTS

Dry matters were significantly different among three cover crops. Rye had the highest value, which was 5.8 times and 3.3 times higher than fallow and hairy vetch, respectively (Fig.1). Fig.2 showed fallow and hairy vetch had higher N content, which were significantly higher than rye treatment. As for N accumulation, rye and hairy vetch were superior

to fallow treatment. They were 72.38% and 55.34% higher than fallow (Fig.3). Soil organic C and N content gradually decreased with the depths. Soil surface (0-2.5cm) had the highest soil organic C and N content. Significant differences were observed in 0-2.5 and

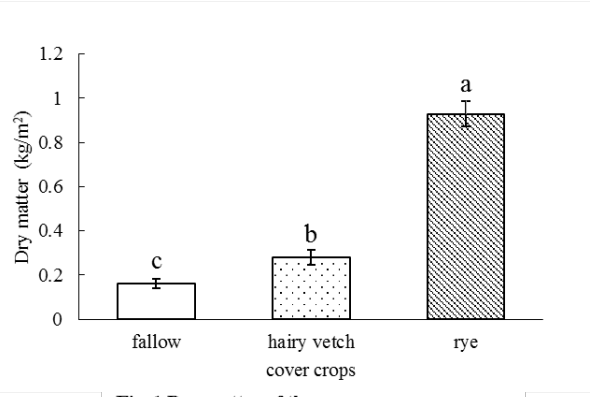

Fig. 1 Dry matter of three cover crops

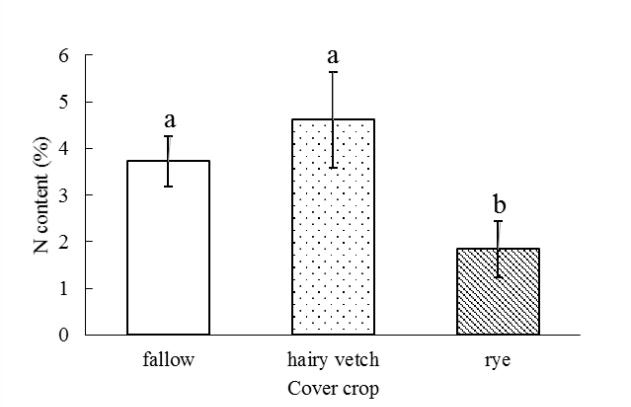

Fig. 2 N content of three cover crops

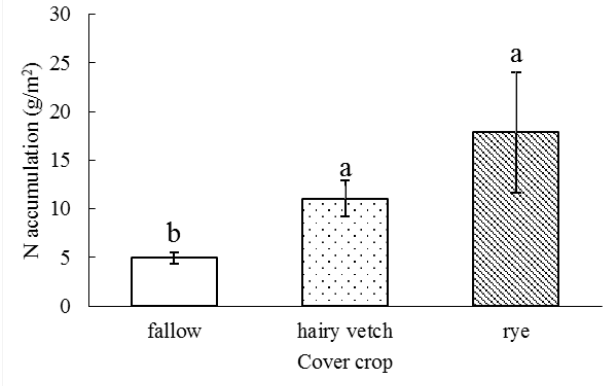

Fig. 3 N accumulation of three cover crops

2.5-7.5 cm depth in relative to the other depths. Cover crops treatments showed higher soil organic C and N than fallow in each depth. But no significant difference was found between rye and hairy vetch (Fig.4 and Fig.5).

4. DISCUSSION

Rye had the highest biomass, the lowest N content, and the

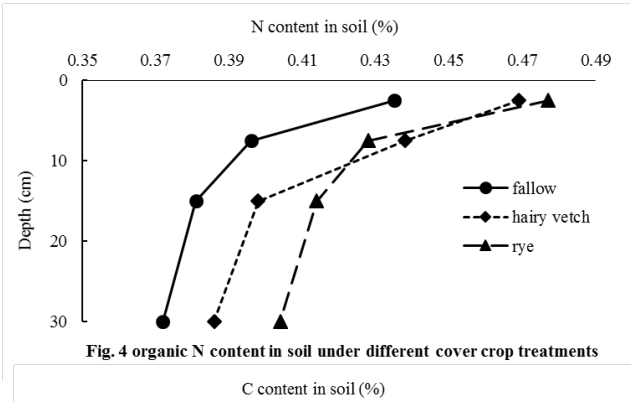

Fig. 4 organic N content in soil under different cover crop treatments

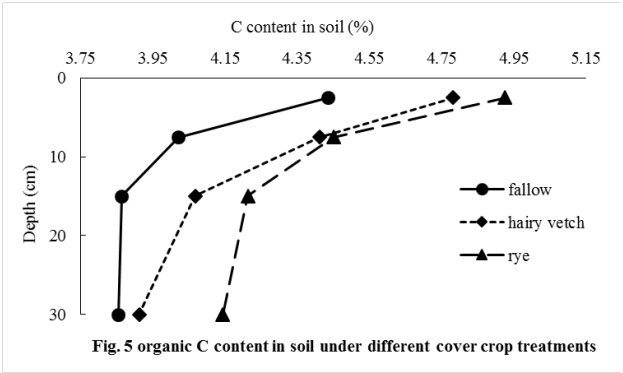

Fig. 5 organic C content in soil under different cover crop treatments

highest N accumulation. Even though fallow and hairy vetch had significant higher N content than rye, actually, the difference between biomass plays a more important role in N accumulation. Dry matter and N content of plant should be took into consideration at the same time when thinking about conserving residual soil N. Biomass retention results in higher organic C and N content in surface soil (0-7.5cm). Rye and hairy vetch had no significant difference in N accumulation and soil C, N content of each depth. N accumulation amount may closely connect to the effect of cover crops on soil C and N enhancement. Soil C and N content were higher at each depth in cover crop treatments compared to fallow (native weeds).

5. CONCLUSION

Rye and hairy vetch had higher amount of N accumulation than fallow. Moreover, soil organic C and N content were higher at rye treatment and hairy vetch in each depth from 0-30 cm than fallow. Cover crops showed excellent ability to scavenge soil nitrogen and improve soil nutrient to reduce the addition of fertilizer input.

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O5-8

Improvement of nitrogen removal rate estimation method for wetlands focused on temperature factors

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Keywords: wetland, nitrogen removal rate, temperature factor

ABSTRACT

The nitrogen removal equation for paddy fields is that R = a*C. Where is the nitrogen removal rate(R), nitrate nitrogen concentration(C) and nitrogen removal coefficient (a). "a" is a = 0.00002*Temperature(T)^2 + 0.005 under light condition. This equation is an empirical formula obtained under constant temperature test. We investigated the temperature of nitrogen removal coefficient for practical applications. The investigation was carried out almost every week from January 2015 to December 2016. Investigated items are flow rates (inlet / outlet), T-N concentrations and water temperatures (inlet, center, outlet), and soil temperatures (at central part, 1 cm interval in the depth direction to 10 cm). We also used AMeDAS (Automated Meteorological Data Acquisition System) temperature data about 10 km away from the site. The results of the investigation showed that nitrogen removal rate was more related to soil temperature of 10 cm depth or the average integrated time temperature from AMeDAS temperature data than the water temperature at the time of investigation. Calculating the nitrogen removal rate at this temperature will reduce the error. Therefore, it was calculated by multiplying the average integrated time temperature of the nitrogen removal equation by the temperature factor. As a result, the best result was obtained when the average integrated time temperature (light condition) and the temperature factor 1.3 are used.

1. INTRODUCTION

In Lake Kasumigaura basin, research on nitrogen load calculation in paddy fields/wetlands has been carried out for many years. Because paddy fields/wetlands have nitrogen removal capability, so examining the parameters of nitrogen removal function of paddy fields/wetlands soils is indispensable for calculating environmental impacts. Tabuchi (1993, 2005) and Hirano (2007) proposed calculation equations for nitrogen removal rate of paddy soils as follows.

$$R = F \cdot P \cdot a \cdot X \quad \cdots(1)$$

Where is, R is nitrogen removal rate (g m^{-2} d^{-1}), F is vegetation factor (range: 1~4), P is water flow factor (range: 0~1), a is nitrogen removal coefficient, X is nitrogen concentration.

In addition, "a" is a function of temperature(T) as follow.

Dark condition : $a = 0.000011 \cdot T^2 + 0.005$ $\cdots(2)$

Light condition: $a = 0.00002 \cdot T^2 + 0.005$ $\cdots(3)$

Tabuchi carried out experiments under two light conditions in a temperature-controlled chamber. The nitrogen removal equation shows that the nitrogen removal rate has temperature and concentration dependence. When we use this equation so far, we have substituted the water temperature at the survey time into T. However, it was not a temperature considering the daily temperature change in the field.

Therefore, the purpose of this study is to show the adapted temperature when using the nitrogen removal equation in fields. We examined appropriate temperature to use for the above equations and made the equation more generic.

2. METHOD

2.1 Test plot description

This research was under taken at the O area in Ami town, Ibaraki prefecture in Japan. In this study area, there are upland fields and forests on the plateaus, and the lowlands are paddy fields.

This study area has been maintained as an experimental paddy field for studies of the nitrogen removal for more than 20 years. The test plot is a non-vegetation plot under flooded in all year. The test plot size is 25 m * 1.4 m. Depth

of flooding is 5~ 6 cm. There is no subsurface infiltration in this area.

2.2 Measurement item

The investigation was carried out almost every week from January 2015 to December 2016. Investigated items are flow rate (inlet / outlet), T-N (total nitrogen concentration) and water temperatures (inlet, center, outlet), and soil temperatures (at central part, 1 cm interval in the depth direction to 10 cm). We measured water temperatures and soil temperature by the Sanitary Thermo TP-100MR waterproof handy thermometer. We used a measuring cylinder to measure the water amount. The inflow water amount was the water amount per second.

We also used AMeDAS (Automated Meteorological Data Acquisition System) temperature data about 10 km away from this site. We calculated the average integrated time temperature from the temperature data of AMeDAS.

Using these results, the nitrogen removal rate estimation by the nitrogen removal equation was analyzed. The nitrogen removal rate was calculated by substituting the outlet water temperature, the central water temperature, and the soil temperature every from 1 to 10 cm into the temperature term in the nitrogen removal coefficient.

Inflow load, outflow load and nitrogen removal rate were calculated by following equations.

$$L_{IN} = A_{IN} \cdot C_{IN} \quad \cdots(4)$$

$$L_{OUT} = A_{OUT} \cdot C_{OUT} \quad \cdots(5)$$

$$R = (L_{IN} + L_R - L_{OUT}) / 35 / 1000 \quad \cdots(6)$$

Where is, L_{IN} is Inflow load (mg d^{-1}), A_{IN} is inflow amount (L d^{-1}), C_{IN} is inflow T-N concentration (mg L^{-1}), L_{OUT} is Outflow load (mg d^{-1}), A_{OUT} is outflow amount (L d^{-1}), C_{OUT} is outflow T-N concentration (mg L^{-1}), L_R is rainfall load (mg d^{-1}), and the study site area was 35 m^2.

We calculated evapotranspiration by Penman-Monteith equation (Miura et al., 1993). We selected dates of day-average temperatures (℃), the highest and lowest temperatures (℃), sunlight hours (h), wind speeds (m s^{-1}) from AMeDAS Tsuchiura. And we selected relative humidity dates (%) from aero logical observatory.

Tabuchi suggested the temperature range of nitrogen removal formal was from 10℃ to 40℃. Considering practicality in field, we also used other temperatures for analysis.

3. RESULTS

3.1 Field survey

We collected 82 samples during two years. The average of the inflow nitrogen concentration in the test plot was 5.4 (± 1.5) mg L^{-1} (**Fig. 1**), and the average of the nitrogen removal rate was 0.095 (± 0.130) g m^{-2} d^{-1}. The average of water temperature in the test plot was 21.2 (± 19.0) ℃ (**Fig. 2**). Also, the fluctuations in temperature and nitrogen removal rate were similar.

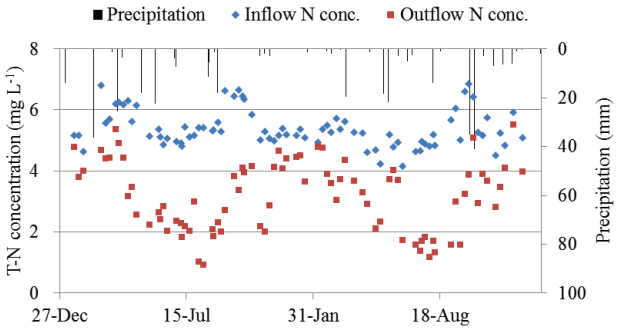


Fig. 1 Total nitrogen concentration of inflow and outflow.

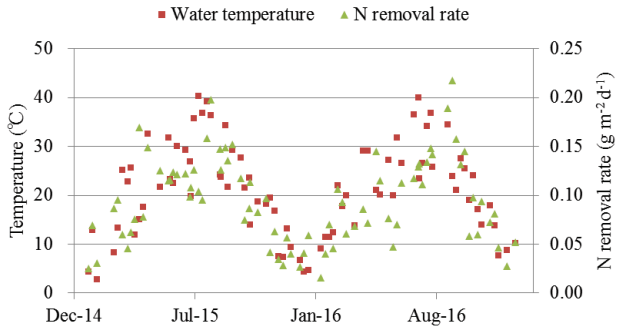


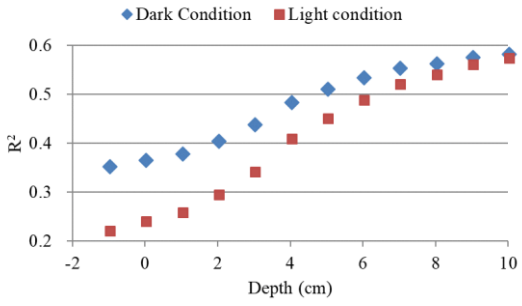
Fig. 2 Changes in water temperature and nitrogen removal rate.

3.2 Analysis

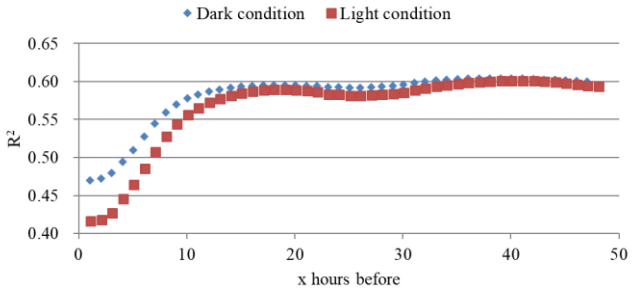
3.2.1 The R^2 value

Water temperatures (center), soil temperatures and the average integrated time temperatures were substituted into Equation (2) and Equation (3). The correlation (R^2 value) between the calculated value of the nitrogen removal rate and the observed value was compared at each temperature.

When we used soil temperatures in both equations, it was almost the same R^2 value at underground 10 cm. In addition, when we used the average integrated time temperatures, it was almost the same R^2 value from 14 hours ago. The correlation was the highest when using 10 cm depth soil temperature or the average integrated time temperature from 40 hours ago (**Fig. 3**).



(a)



(b)

Fig. 3 (a) The R^2 value between calculated values and observed values of nitrogen removal rate when using 0 ~ 10 cm depth soil temperature. -1 cm was the water temperature. (b) The R^2 value between calculated values and observed values when using average integrated time temperatures.

4. DISCUSSION

4.1 Applicable temperature

From the results, we considered the soil temperature and the average integrated time temperature was more accurately for the nitrogen removal equation than water temperature. Because the nitrogen removal equation was obtained by a temperature-controlled experiment, it was desirable to use a temperature with less fluctuation. The value of soil temperatures (median: 18.6℃, maximum: 29.4℃) or the average integrated time temperatures (40 hours ago, median: 17.5℃, maximum: 29.2℃) was less scatter than Water temperatures (median: 21.7℃, maximum: 40.2℃).

4.1 Temperature factor

The nitrogen removal equation was an expression made on the premise of substituting the temperature at the time of survey. The average integrated time temperature or the soil temperature is lower than the water temperature at survey time. Calculating the nitrogen removal rate at this temperature will reduce the result. Therefore, it was calculated by multiplying the average integrated time temperature of the nitrogen removal equation by the temperature factor "D" (equations 7 and 8). As a result, the best result was obtained when the temperature factor was 1.3.

$$R = (0.000011 \cdot (D \cdot T)^2 + 0.005) \cdot X \quad \cdots(7)$$

$$R = (0.00002 \cdot (D \cdot T)^2 + 0.005) \cdot X \quad \cdots(8)$$

5. CONCLUSION

From this study, we found the following.

1) The observed nitrogen removal rate was more related to the soil temperature at 10 cm depth or the AMeDAS average integrated time temperatures than the water temperature at the time of survey. From this result, it was found that there is a possibility that estimation of nitrogen removal rate can be well estimated using meteorological observation data even if there is no measured value.
2) It is better to use the nitrogen removal coefficient in the light condition.
3) When calculating the nitrogen removal rate using weather observation data, a temperature factor is required. This value was in the range of about 1.2 to 1.3 from this result.

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O5-9

Verification of a Simple Watershed Land-use model to estimate the Net Nutrient Loads from Non-point Sources to Rivers

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Keywords: land-use model, specific load factor, non-point source, nitrogen, phosphorus

ABSTRACT

The aim of this study was to evaluate the impact of land-use on total-nitrogen and total-phosphorus concentrations in river water (R-N and R-P). The study area consisted of 13 watersheds covering about half of Hokkaido, and 12 watersheds covering about half of Tohoku and those 12 sub basins in Japan. We estimated N and P specific load factors, which showed the magnitude of the upland fields, paddy fields, forests and urban land-use contributions to R-N and R-P. The N and P specific load factors were gained as partial regression coefficients using a multiple regression analysis of the R-N and R-P concentrations and the land-use ratios in each of the watersheds. The results showed that The N specific load factor was -2.4, 2.4, 0.1, and 39.8 for the watersheds in Hokkaido, 2.9, 9.8**, 0.49, and -6.8 for the watersheds in Tohoku, and 1.2, 6.7, 0.4, 4.3 for the sub watersheds in Tohoku for paddy, upland, forest, building site, respectively. The P specific load factors were 0.08, 0.07, 0.02, and 1.4 for the Hokkaido watersheds, 0.20**, 0.23**, 0.00, and 0.01 for the Tohoku watersheds, and 0.15, 0.10, 0.00,and 0.80* for the Tohoku sub watersheds for paddy, upland, forest, building site, respectively (* 5% **, 1% significance). The surplus-N (nitrogen applied to cropland via fertilizer without being absorbed by crops) was found to be gently correlated to R-N by a non-linear curve with a contribution rate R^2 of 0.43 in spite of a simple calculation.

1. INTRODUCTION

Increased nitrate levels in drinking water, eutrophication of closed water bodies, and algal blooms are all major environmental issues in the world[1][4]. It is therefore important to quantify nutrient loads from both non-point sources and point sources. The increasing proportion of cropland area in drainage basins has been found to be strongly correlated with the nitrogen concentration of river water[3]. Woli *et al.*[7] employed regression slope, or the increase in NO_3-N concentration in river water (mg L^{-1}) vs. the increase in the proportion of upland in the drainage watersheds (%), as “the impact factor” to assess stream water quality. They also found a correlation between impact factor and watershed-mean surplus-N (N applied by fertilizer without absorbed by crops), except in watersheds with large point sources of nitrogen. This impact factor can be employed as an index of the land-use characteristics of a watershed. Jordan *et al.*[2] and Vitousek *et al.*[4].found a significant correlation between surplus-N and N concentration in river water. Here, we applied a simple watershed land-use model to quantify the net nutrient loads from non-point sources to rivers. Furthermore, we investigated the relationships between the surplus-N and river-nitrogen (R-N) concentration, and between the surplus-P (P applied by fertilizer without absorbed by crops) and river-phosphorus (R-P) concentrations.

2. METHODS

The study area was 37 watersheds in Northeastern Japan. It was consisted of 13 watersheds (37,966 km^2, 45.5%) in Hokkaido Island, and major 12 watersheds (34,047 km^2, 50.9%) with 12 sub watersheds (3,777 km^2, 5.6%) as the tributaries in the major watersheds in Tohoku district (Fig. 1). We estimated R-N and R-P specific load factors in four land-use types (upland fields, paddy fields, forests and urban), which represents the magnitude of contribution to R-N and R-P concentrations. The watersheds were delineated based on the datasets of a 50 m digital elevation data (Geospatial Information Authority of Japan, 2001), and watershed/coastal area boundary data (National Land Numerical Information, National Land Agency, 1977) using a Geographic Information System (GIS) (Arc GIS, ESRI Ltd.) (Fig.1). Land-use ratio in each watershed was calculated using land-use subdivision mesh data (National Land Numerical Information, National Land Agency 1997) and boundaries of the delineated watersheds. Land-use was classified into the four categories. R-N and R-P concentrations were obtained from a database of the Measurement Results of Water Quality in Public Waters from FY 2000 to 2009 (Ministry of the Environment, 2000-2009). R-N and R-P concentrations were simply averaged as yearly mean concentrations since the measurements were conducted once a month at each river mouth.

We employed the model of Mochizuki *et al.* [3] to estimate R-N and R-P specific load factors for each land use type using the following equation (1).

$$C=\sum_{i=1}^{4} a_i x_i \quad (1)$$

where C is the watershed-mean R-N or R-P, a_i is the R-N or R-P specific concentration for land-use type i, and x_i is the land-use ratio for the land-use type i. The a_i was estimated as partial regression coefficients for the multiple regression analysis of the 13 or 12 R-N or R-P concentrations and the land-use ratios of the watersheds. Watershed-mean Surplus-N was estimated based on a statistical table of cropping area that had been prepared for each Prefecture for 72 main crops (MAFF Japanese food information, 2005), application guidelines of fertilizer and manure for main crops and data about nitrogen uptake by crops[5] for 12 watersheds in Tohoku district. The R-N and R-P concentrations were analyzed in relation to the watershed-mean surplus-N and surplus-P by single regression analysis.

3. RESULTS

The R-N specific load factors were -2.4, 2.4, 0.1, and 39.8 for the watersheds in Hokkaido island (n=13), 2.9, 9.8, 0.49, and -6.8 for the major watersheds in Tohoku district (n=12), and 1.2, 6.7, 0.4, 4.3 for the sub watersheds in Tohoku district (n=12) for paddy field, upland field, forest, and urban, respectively (Table 1). The R-P specific load factors were 0.08, 0.07, 0.02, and 1.4 for the watersheds in Hokkaido island, 0.20, 0.23, 0.00, and 0.01 for the major watersheds in Tohoku district, and 0.15, 0.10, 0.00, and 0.80 for the sub watersheds in Tohoku district for paddy field, upland field, forest, and urban, respectively. The R-N and R-P load factors were highest for urban in Hokkaido island. The highest factor was found in upland field in Tohoku district. The dependencies of the R-N and R-P load factors to size of the watershed were not significant. The estimated concentrations coincided relatively well with the measured ones(Fig.2). The estimated breakdown of the applied N and P as fertilizers for each crop are shown in Fig. 3. Almost half or less amount of applied N, and only small part of applied P were found to be absorbed by crops. The surplus-N was gently correlated to the R-N concentration with a contribution rate R^2=0.43 (Fig.4). This result suggests that the N applied artificially in fertilizer to croplands without being absorbed by crops themselves could be an important contributor to the N pollution in river water. However, poor relationship was found between the surplus-P and R-P.

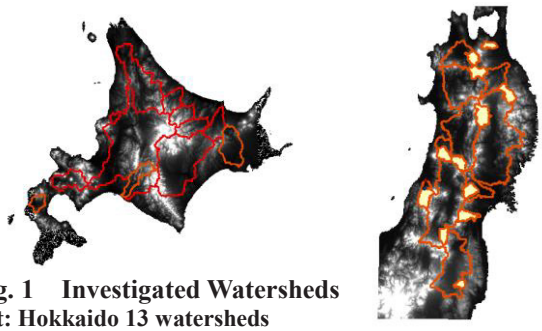

Fig. 1 Investigated Watersheds
left: Hokkaido 13 watersheds
right: Tohoku 12 watersheds and 12 sub watersheds

Table 1 Land-Use Specific Load Factors

Nitrogen	Hokkaido 13 watersheds	Tohoku 12 watersheds	Tohoku 12 sub watersheds
Paddy	−2.38	2.91	1.24
Upland	2.39	9.79 **	6.71
Forest	0.12	0.49	0.42
Urban(Building)	39.8	−6.76	4.29
determination coeff., significance(P value)	0.88 P<0.01	0.90 P<0.01	0.73 P<0.01

Phosphorus	Hokkaido 13 watersheds	Tohoku 12 watersheds	Tohoku 12 sub watersheds
Paddy	0.084	0.203 **	0.157
Upland	0.073	0.232 **	0.104
Forest	0.015	0.003	0.001
Urban(Building)	1.37	−0.013	0.798 *
determination coeff., significance(P value)	0.91 P<0.01	0.98 P<0.01	0.89 P<0.01

*5%significance **1%significance

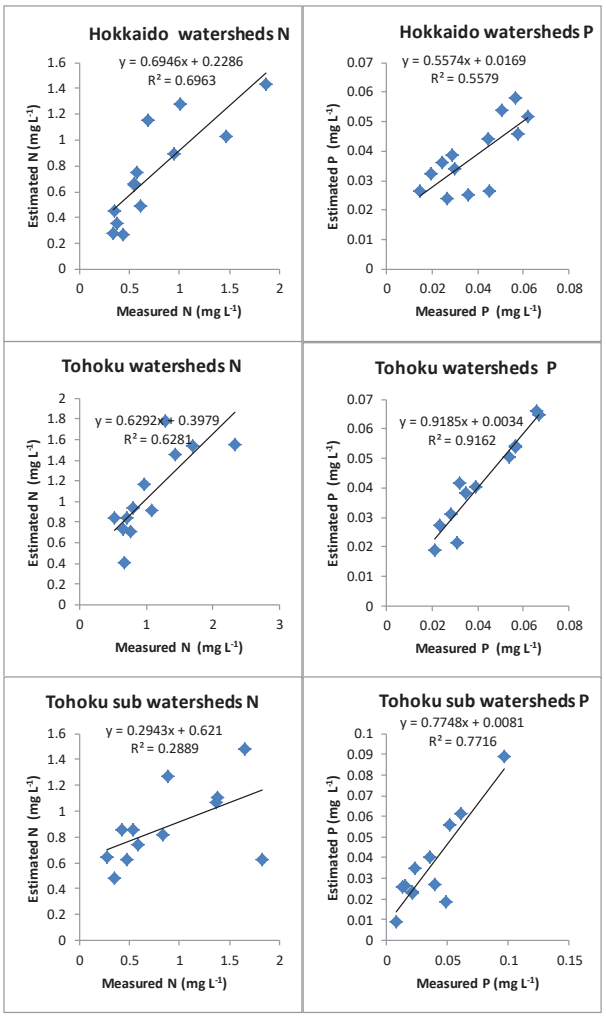

Fig. 2 Measured and Estimated N and P Concentrations

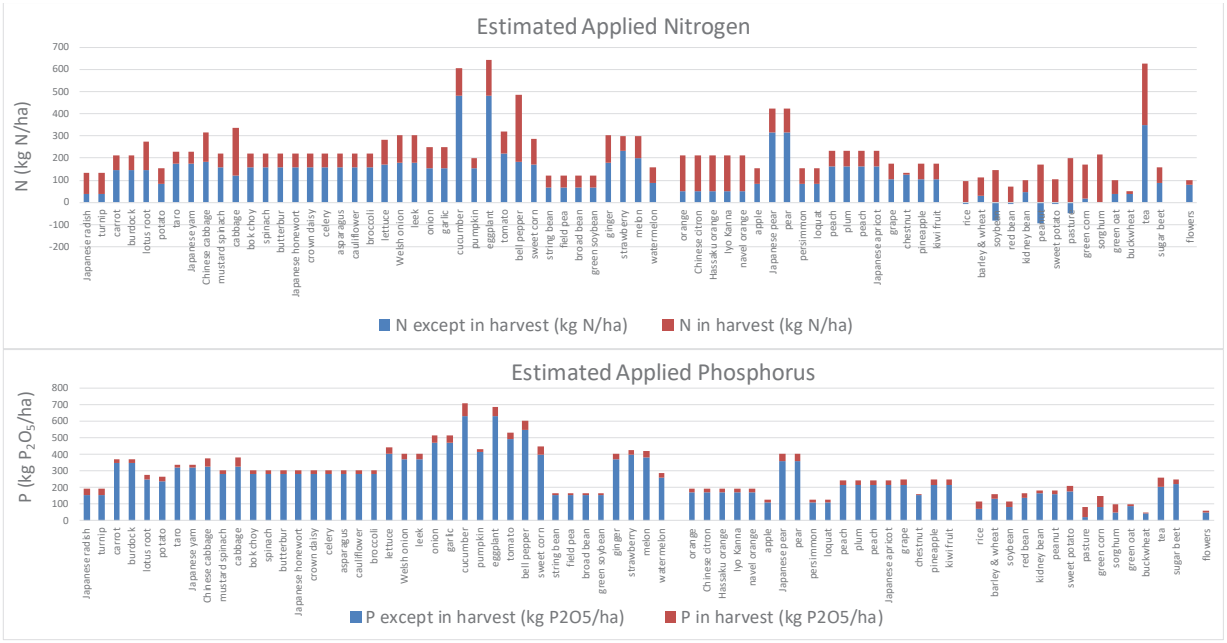

Fig. 3 Estimated Applied N and P as fertilizers for each crop (based on [5])

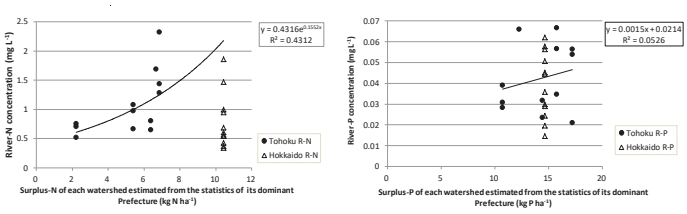

Fig. 4 Relationship between Surplus-N, P and River-N, P

4. DISCUSSION

The minus values of the land-use specific load factor mean "purification" type. The values without asterisk include uncertainty. However, roughly speaking, N specific load factors for urban and upland were larger than those for paddy and forest, and P specific load factors for urban were larger than paddy and upland, and much larger than forest. The N and P specific load factors for paddy and upland were larger in Tohoku district than in Hokkaido district. The reason that the surplus-P was not correlated to R-P was supposed to be reduced from the large phosphorus adsorption ability of Andosols which spread widely in Tohoku district. In this and the previous paper[3][8], we propose a simple method to determine the specific load factors for different land-use types. The model has a simple framework and does not need special data. The model proposed here needs at least the same number of watersheds as the number of land-use types, and its applicability could be improved in cases where the loads from point sources are not large.

5. CONCLUSION

We propose a simple method to determine the specific load factors for different land-use types. We applied the method to evaluate the impact of land-use on total-nitrogen and total-phosphorus concentrations in river water in Hokkaido and Tohoku districts. The model was thought to be useful to estimate the change in N and P concentrations in river water resulted from land-use change.

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O5-10

Evaluation of Nutrient Load Reduction by Precision Water Management from Paddy Field in Lake Inbanuma Watershed

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Keywords: water environmental conservation, nitrogen runoff, phosphorus runoff, automatic irrigation

ABSTRACT

In this study, the impact of nutrient load reduction by precision water management was evaluated to improve the water environment of Lake Inbanuma. Kashima district, which was managed by Inbanuma land improvement district, was selected for the test site. Water, nitrogen and phosphorus concentration was monitored at Iino pumping station and paddy drainage. From the monitoring data, water balance and nutrients balance were estimated. As a result, precision water management by automatic irrigator can reduce 65% of irrigation water, 58% of nitrogen load and 43% of phosphorus load.

1. INTRODUCTION

Irrigation water is essential for food production especially in paddy rice, and much water was withdrawn from water sources compare to other water use sector [1]. In Japan, water delivery system for agriculture was highly-developed and managed by land improvement district [2]. The 1st priority of irrigation is water supply to avoid the water stress, however, saving a labor input for agricultural land management such as weed control also the important factor. Therefore, farmers want to input much water for their paddy to save a labor cost [3]. However, much irrigation water leads much energy consumption for pumping, as a result, water fee also increases. In addition, increase of drainage water cause a much nutrient effluent to downstream water environment[4][5]. Historically, water delivery system in paddy agriculture has been supply-oriented system. However recent innovation of field monitoring or automatic regulation system will change it to demand-oriented system. In this study, the impact of precision water management by auto irrigator was evaluated to improve the water management system in paddy without the additional labor input.

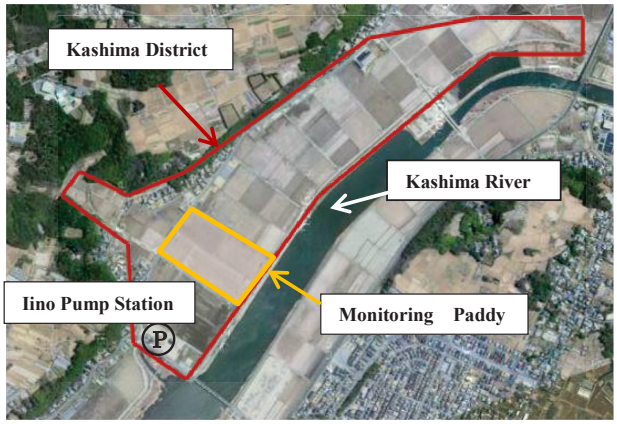

Fig.1 Outline of study area

2. STUDY AREA

For the test site, Kashima district was selected which was managed by Inbanuma land improvement district and having 46.1 ha benefit area (Fig.1). Fig.2 shows the monitoring paddy fields having 6.48 ha. All of these paddy fields were cultivated by same farmer group. Irrigation water was pumped up from Inbanuma lake, and water from paddy was drained to Inbanuma again flowing through Kashima river. In this paddy fields, open type drainage canal was not existed, and subsurface drainage system was installed in all paddies so that all drained water, which was percolated through paddy soil layer and overflowed from paddy outlet, gathers to drain pipe. Inbanuma lake is closed water area and eutrophic lake [6][7]. Therefore, drainage water from paddy fields was one of the pollution sources. Although drainage water from paddy have relatively low nutrient concentration compare to that from upland, drainage water amount is larger. Therefore, nutrient load from paddy fields could not be negligible for the conservation of lake water environment.

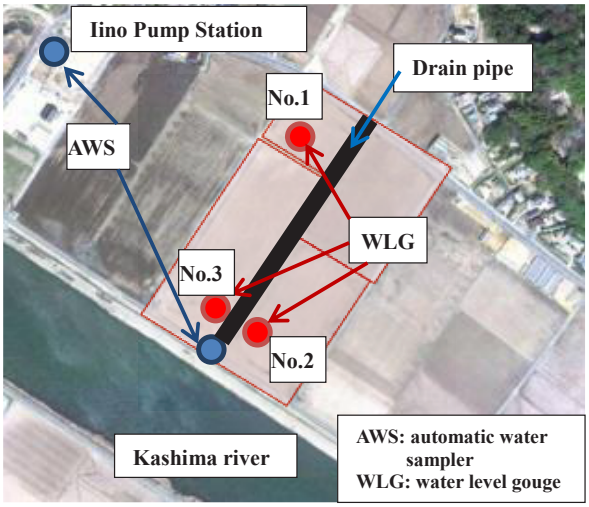

Fig.2 Monitoring paddy fields

3. FIELD MEASUREMENT

To evaluate the water balance such as how much water was irrigated, evaporated and drained, paddy water level was monitored in hourly basis at 3 paddies by using HOBO U20 water level loggers (Onset Co. Ltd.). Water quality at Iino pumping station and paddy drainage pipe was measured in daily basis (at noon) such as soil sediment (SS), total nitrogen (TN), nitrate nitrogen (NO_3-N), ammonium nitrogen(NH_4-N), chemical oxygen demand (COD) and total phosphorous (TP). Meteorological data also measured at Iino pumping station for calculating evapotranspiration. Measured items were rainfall, solar radiation, wind speed, air temperature, relative humidity and atmospheric pressure. Rice variety was *Momiroman* which was not for human food but for livestock feeding. Observation period was from 4 /Jun/2012 to 22/Sep/2014 for 3 years, but only irrigation periods. A questionnaire to the farmer also conducted to grasp the fertilizer input or land management practices.

Fig.3 shows the variation of rainfall, paddy water depth, TN and TP concentration of in and outflow at paddy field during observation period. In 2012, paddy water depth was controlled relatively deep, so the amount of drained water also became larger than 2013-2014. Much drained water leads much TN and TP concentration in 2012.

4. RESULT AND DISCUSSION

The pollution load through surface runoff can be reduced by controlling the surface drainage water volume [8][9]. Such water management leads water and irrigation cost saving, and pollution load to downstream water environment also can be reduced. For saving water and farmer's labor input, automatic irrigation system was developed and introduced in some irrigation district. Fig. 4 shows schematized description of float auto irrigator. Farmers just set the target water level and auto irrigator supply water until float level increase at target depth. In this study, the effect of this auto irrigation system on water saving and nutrient load reduction was estimated and compared with conventional water management case.

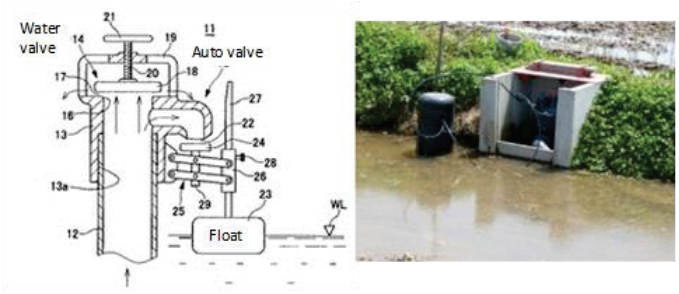

Fig.4 schematized description of float auto irrigator

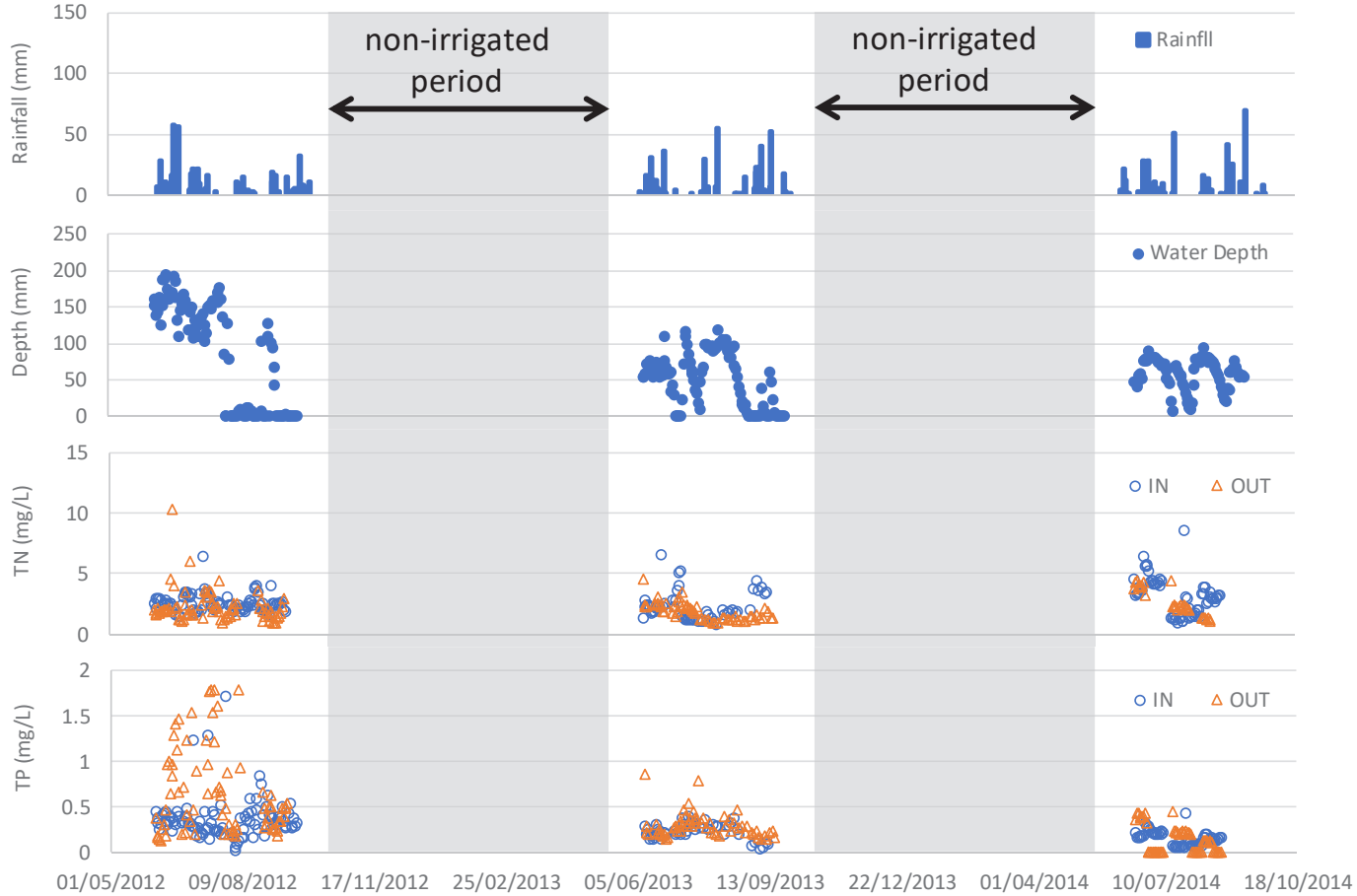

Fig.3 Variation of rainfall, water depth, TN and TP concentration of observed paddy during irrigated period (2012-2014)

Table1 Annual averaged nitrogen and phosphorus balance in irrigation period during 2012-2014

		Nitrogen				Phosphorus			
		Conventional		with Auto Irrigator		Conventional		with Auto Irrigator	
		(kg/ha)	(%)	(kg/ha)	(%)	(kg/ha)	(%)	(kg/ha)	(%)
INPUT	rainfall	7	4	7	4	0	0	0	0
	irrigation	39	20	15	9	8	12	3	5
	fertilizer	154	77	154	88	58	88	58	95
	Total	200	100	176	100	66	100	61	100
OUTPUT	surface runoff	26	13	0	0	4	6	0	0
	percolation	10	5	12	7	3	5	3	5
	harvest	101	51	101	57	19	29	19	31
	removal, absorbed	63	32	63	36	40	61	39	64
	Total	200	100	176	100	66	100	61	100

From observed data, water balance was estimated during 2012-2014. At the monitoring paddy fields, 2045mm/year water was pumped up for irrigation and 53% of supplied water was released by surface drainage from paddy outlet in current situation. Therefore, there was still large possibility to save water by introducing elaborated water management system to reduce surface drainage water [8]. With installing auto irrigator case, the water saving effect was about 1335mm (65%) and energy consumption for pumping also can be saved. As a result, farmer can save water fee which farmer pay to land improvement district for the maintenance and operation of water delivery facilities.

Table1 shows annual averaged nitrogen and phosphorus balance in irrigation period during 2012-2014. Generally, in the conventional paddy field, 90-120 kg/ha nitrogen was recommended in food rice cultivation. However, much nitrogen was fertilized in this monitoring paddy compared with conventional one. Because, in feed rice cultivation, farmers do not need to pay attention to a taste of rice, therefore much amount of fertilizer was input to increase the rice biomass. In addition, farmer can get manure in free from livestock sector by exchanging the rice straw. Estimated nitrogen and phosphorus loads from paddy were 36 kgN/ha and 7 kgP/ha. In Inbanuma watershed, there are 7,370 ha paddy field so that about 265 ton nitrogen and 52 ton phosphorus were flow into the Inbanuma lake from all paddy fields. With auto irrigator case, nitrogen and phosphorus load reduction were expected as 21 kgN/ha(58%) and 3 kgP/ha(43%).

5. CONCLUSION

In this study, field monitoring was conducted to grasp the current condition of water and nutrients balance in the paddy field. Large amount of irrigation water and nutrient fertilizer were inputted in monitoring paddy of Kashima district, because feed rice was cultivated in this paddy. And high input of water and nutrients leads much effluent load to downstream water environment. Recently, feed rice paddy area is increasing under the governmental regulation policy. Therefore, water pollution in closed type lake may become worse if feed rice paddy spread widely. Auto irrigation system is effective to save irrigation water input and pumping energy consumption and to conserve the water environment without more farmer's labor input for water management.

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O5-11

Analysis of Water and Nutrient Movement in a Cyclic Irrigation System to Paddy Fields

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Keywords: cyclic irrigation, paddy field, nutrient load, lake environment, drainage canal

ABSTRACT

Imbanuma at Chiba Prefecture has had a serious problem of water quality deterioration in recent years. In order to improve the circumstances, cyclic irrigation is proposed to be one of feasible measures. In a cyclic irrigation system, drainage water discharged from paddy fields is pumped and reused as irrigation water. Cyclic irrigation is expected to decrease the nutrient load because it decreases the amount of water flowing into the downstream lake, and because some of the nutrient in drainage water would be returned to the paddy field. The purpose of this study is to evaluate quantitatively the effect of the cyclic irrigation system on the nutrient load for Imbanuma. Three research approaches were conducted in this study. First, the record of the main pump and the map of the drainage canal network were analyzed. It was revealed that fifty-one percent of the total irrigation water was reused and that fifty-seven percent of paddy fields returned to the main pump. Second, a water movement model was developed which consists of tank models representing the paddy fields and the background catchment and a drainage canal model. This model roughly reproduced the observed water level in the downstream drainage canal, but further improvement seemed necessary. Third, the relations between water quality and precipitation of farming activities were analyzed using water quality data observed monthly. It was suggested that more frequent observation is necessary to clarify the water and nutrient movement in the system.

1. INTRODUCTION

Imbanuma is located about 50 km east of the center of Tokyo. The total water surface is about 9.43 km2. The area of Imbanuma basin is about 487 km2, most of which had been covered by forest and agricultural land but is rapidly urbanized recently to have population more than 780 thousand within the basin. The lake is well known by its deterioration of water quality in recent years. As one of the options to improve the lake environment, cyclic irrigation was adopted for irrigation to paddy fields surrounding the lake and started in 2015. In the cyclic irrigation system, drainage water from paddy fields is pumped from the downstream drainage canal and reused as irrigation water. Cyclic irrigation is expected to decrease the nutrient load to the lake because it decrease the amount of drainage water to the lake, and because some of the nutrient load may be consumed at paddy fields.

The purpose of this study is evaluation of the effect of the cyclic irrigation to paddy fields on variation in the discharge and the nutrient load to the downstream drainage canal

2. MATERIALS AND METHOD

2.1 Research field

To construct the new cyclic irrigation system, many old pump stations are consolidated into new six pump stations. Two of the pump stations have been already in operation, and the others are under or before construction. The area whose irrigation water is supplied by one of the two pump stations in operation was selected as the study area.

2.2 Analysis of irrigation water

The operation records of the main pump for the cyclic irrigation was analyzed, referring to the irrigation pipe network to each paddy field plot.

2.3 Making hydrological model

A model which represents the water movement in the basin during the cyclic irrigation was proposed. With pump operation data and meteorological data as input to the model, the variation of the observed water level at the downstream drainage canal was acceptably reproduced by the model output.

2.4 Analysis of water quality

The relation between nutrient concentration variation in the drainage canal and the occurrence of precipitation and fertilization was analyzed.

3. RESULTS and DISCUSSION

3.1 Analysis of irrigation water

It was found that the drainage water from 57 percent of the paddy field area receiving the irrigation water from the pump returned to the pump again and that 51 percent of the total irrigation water returned to the pump to be reused as irrigation water again. To compare with former study of cyclic irrigation in Japan [1] [2], this ratio is higher in such irrigation system which is adopted for environmental improvement.

3.2 Making hydrological model

The 2 layered tank models for paddy fields and for background basins and the model of the downstream drainage canal was adopted in the model.Figure1 shows schematic diagram of this model and parameter values. This model has two features. One is that height of hall of paddy-field-surface-tank is available according to farmer's water management. The other is that drainage canal is connected with ground water tanks of both paddy field and background. It interpret that water in drainage canal and groundwater has relationship, if water level in canal come down water will flow from under-ground by water level difference between canal and under-ground.

It is admitted, however, that there is still some room for improvement in the model structure as well as the model parameter values.

3.3 Relation between T-N concentration of discharged water in drainage canal and rainfall

N day cumulative precipitation is cumulative height of rainfall from sampling day to N day before sampling day. For example from following sample in Table1, each cumulative precipitation is displayed like Table2.

Table1, example data

Date	Rainfall(mm)
2017/5/4	0
2017/5/5	5.3
2017/5/6	11.5
2017/5/7	0
2017/5/8	4
2017/5/9	0
2017/5/10(Sampling Day)	0

Table2, Each day cumulative precipitation of example data

N day	Cumulative precipitation (mm)
Three	4
Five	15.5
Seven	20.8

Figure2 shows that relationship between three, five and seven day cumulative precipitation and T-N concentration of the samples. One sample data is stacked with as day is increased. From this figure, we know that there is no point plotted at where both of T-N concentration and N day cumulative precipitation are high. And point are gathered in where value of T-N concentration is nearly 1.5mg/L. So we discussed T-N concentration is attenuated by rainfall.

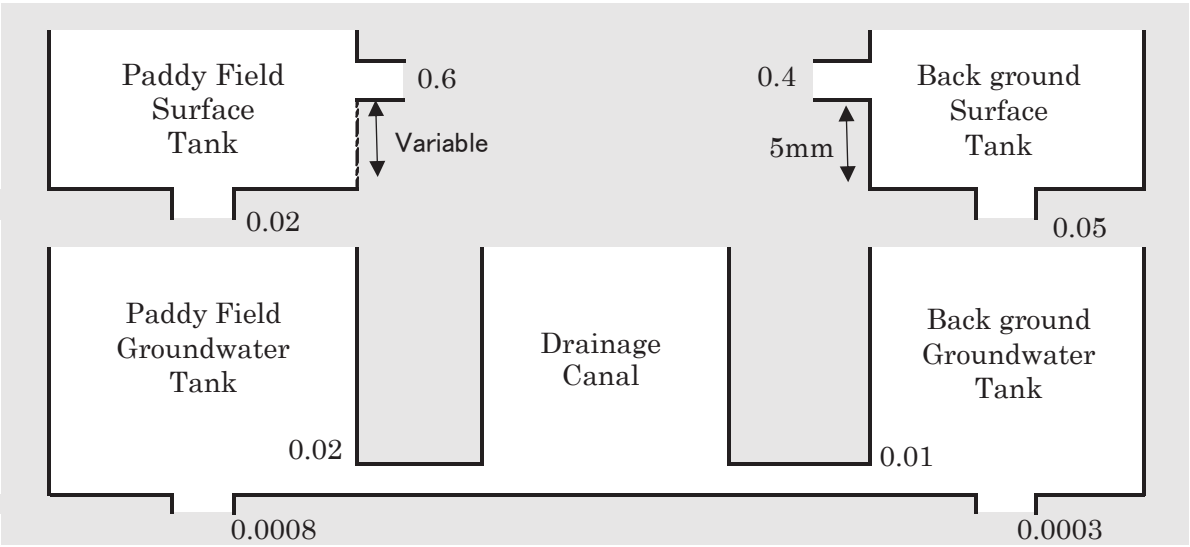

Fig1.Schematic diagram of the proposed model

3.4 A comparison between irrigation water and discharged water about T-N concentration

To compare between irrigation water and discharged water, T-N concentration of discharged water is lower than one of irrigation water at most data.(Figure3) So it can be said that paddy field in this area can reduce the T-N concentration of water. But at this analysis it is not considered that there is time lag between flowing into paddy field and draining off from paddy field.

4. CONCLUSION

This research's conclusive purpose is to reveal movement of water and to reveal movement of water quality.

But sampling in this research was done three times in a month at most. For this purpose sampling should be done more frequently.

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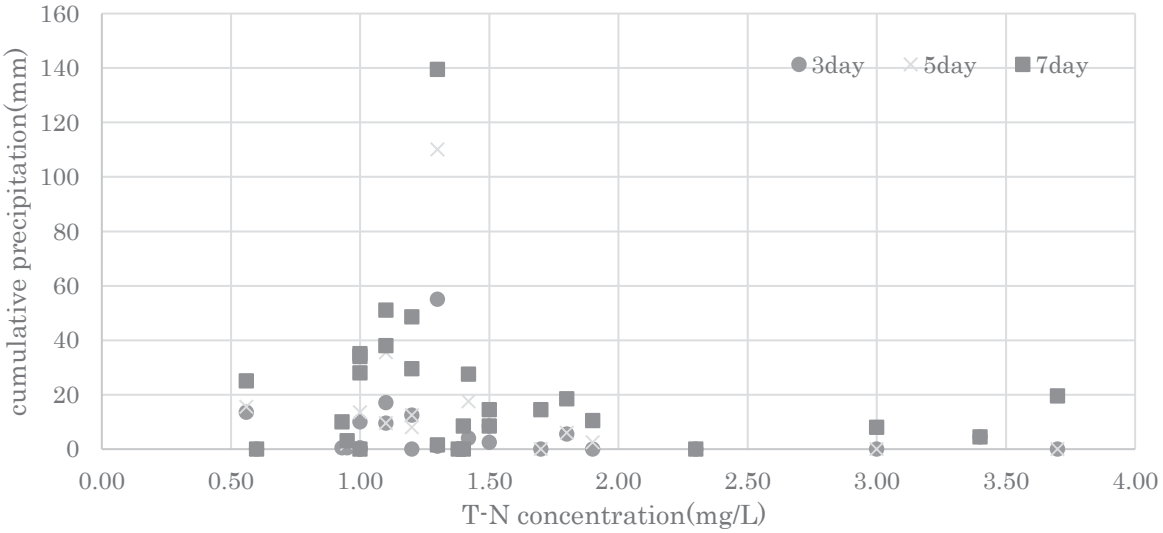

Fig2, Relation between T-N concentration and N day cumulative precipitation

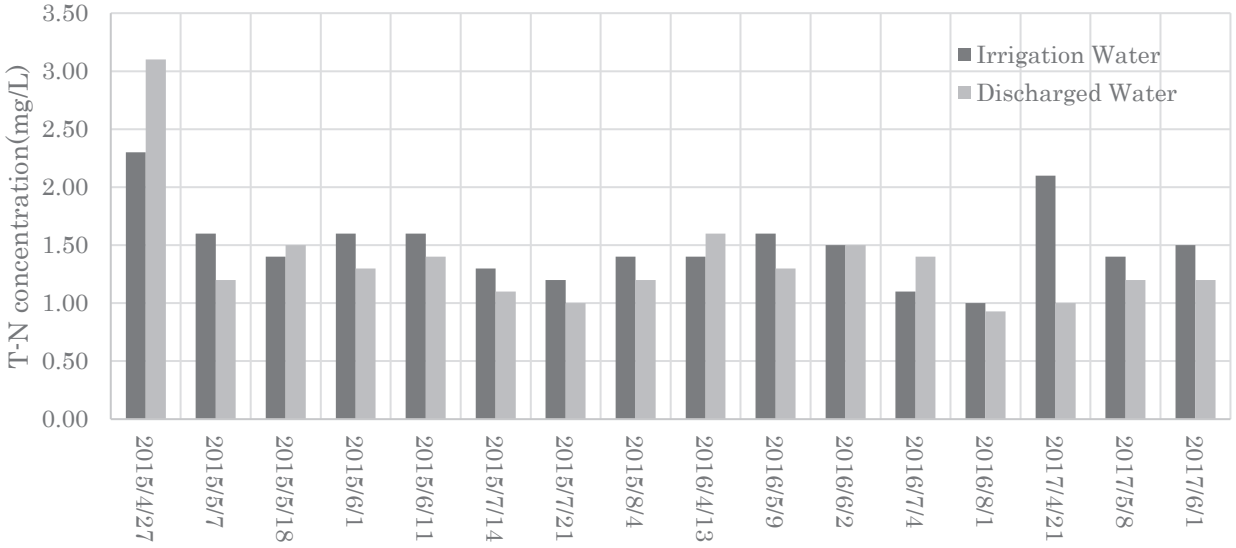

Fig3, Comparison between irrigation water and discharged water

O5-12

霞ヶ浦新利根川流域における湖沼と水田地帯の水環境保全に向けた循環灌漑の適用可能性

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キーワード:水田, 循環灌漑, 水質浄化, シナリオ分析

抄録

霞ヶ浦に代表されるように, 宅地と農業地域を流域内に持つ湖沼の水環境は, 生活排水の対策が進んだことにより一時期改善が見られたが, その後, 横ばい傾向を示している。これは, 農地に施用された余剰肥料等の影響や, 土壌に蓄積した窒素やリンなどの汚濁負荷の影響が長期に渡り継続しているためではないかと考えられている。したがって, 湖沼のさらなる水環境の改善のためには, 農業排水の対策が期待されており, 水田地帯における循環灌漑は, その対策の一つと考えられている。そこで, 霞ヶ浦流域内の新利根川土地改良区を対象に, 循環灌漑を導入した場合の, 水質浄化効果と, ブロック内の負荷の蓄積がどの程度になるかを検討するため, 1時間単位で水位と EC を測定し, それに基づき水収支と物質収支を明らかにし, 循環灌漑を導入する場合のシナリオ分析を実施した。測定期間は 2017 年 1 月～12 月である。

1. はじめに

新利根川沿岸地区は, 霞ヶ浦流域南部, 利根川左岸に位置する低平地水田を中心とした灌漑地区である。灌漑用水, 排水とも揚水機場を必要とする。また, 排水においては, 地区の常時排水機能も担っており, 灌漑期, 非灌漑期を問わず洪水対策としての排水管理を用水管理と併せて土地改良区が実施しているのが特徴である。

特に, 本地区は霞ヶ浦流域内に立地していることから, 水質保全(窒素, リン, 有機物)が重要視されている。さらには、経年変化等による施設の老朽化が進んでおり, 用排水機場等の施設の更新が待たれている状況であるが, 施設の更新時には, 農村周辺の環境保全や洪水対策といった公益性をより考慮し, 持続的な農村社会システムに寄与することが望まれている。

一般に水質保全や, 農業からの汚濁負荷を軽減する手法として, 農業用水の観点からは循環灌漑が提案されている[1]。すなわち, 水田排水を灌漑用水として再利用し, 水質保全や節水型の水利用となる循環灌漑システムである[2][3]。ただし, 水田排水が, 灌漑用水として適当であるかどうか, 水量はどの程度確保できるか, どの程度の浄化効果を期待することができるか等の検討が必要である。

以上から, 本調査は, まずは水田灌漑における主排水路の水質を調査対象とし, 水収支, 物質収支を明らかにすることを目的とする。この知見に基づき, 本地区と霞ヶ浦流域への物質循環の適正化に資する, 循環灌漑の水管理の効果について検討する。

2. 方法

新利根川沿岸地区は茨城県の南部に位置し, 新利根川沿岸に展開する農業地域であり, 関係市町村は稲敷市(旧新利根村、旧東村、旧江戸崎町、旧桜川村)及び河内町からなる。受益面積は用水、排水改良を合わせて 7,030ha (水田 6,770ha、畑 260ha) である。

今回調査対象とした金江津地区(Fig.1)は, 用水源および排水先とも新利根川である。用水機場を通じて, パイプラインで水田圃場へ直接水が配分され, 新利根川と



Fig.1 新利根川沿岸地区および測定地点

利根川との間に位置する中央排水路(Fig.2)に水が集まり，排水機場(Fig.3)によって，新利根川に排水される。低平地の干拓地であることから，排水機場は周辺の洪水排水のため，設定水位を超えると稼動することとなる。

太田金江津用水機場は，揚水後，一度太田配水槽に貯水され，その後重力で各水田圃場に配分していく。用水はパイプライン化されており，揚水から配水の段階での排水の混入はほぼ無い状態であり，新利根川の比較的良好な水質が灌漑に利用可能である。また，土地改良区内の土地利用はほぼ水田であり，一部，ハス田等が散在する。管内では，農家の住宅もあり，合併浄化槽または，集落排水，流域下水道が混在する。

図中の太田金江津用水機場，十平用水機場，金江津排水機場にて，水位と EC の連続モニタリング装置を設置した。水位計（Onset 社，Hobo U20L 04），EC 計（Onset 社，Hobo U24-001）を太田金江津用水機場と金江津排水機場に，十平機場にはEC計のみを設置した。補正用の大気圧計は，金江津排水機場に設置した。また，ポンプ稼働量については，各機場の管理月報からまとめた。

金江津排水機場の排水面積全体は水田面積で1,670ha，流域としてみると 2,020ha を持っているが，太田用水機場から金江津排水機場までのブロックは，そのうちの 930ha である。流域としては Google Earth を用いて面積を測定したところ，980ha であった。

気象データは，降雨量については気象庁の「江戸崎」観測所，蒸発散量の推定のための項目については「筑波（館野）」のデータを利用した。

他の水質項目については，窒素，リンについても 2 ヶ月に一回の頻度で測定した。どちらも各機場において，マニュアルで採水し，本学の実験機器にて分析を行った。窒素については，全窒素，全リンについては JISK102 に準拠した方法にて分光光度計（UVmini1240, Shimadzu 社）で測定した。硝酸態窒素，リン酸態リンはイオンクロマトグラフ（HIC-SP, ShimPack A3, Shimadzu 社）を用いて測定した。

金江津排水機場から太田用水機場までのブロックを一つの境界とし，水収支，物質収支を求める。灌漑期においては，降雨量，灌漑用水量を流入とし，蒸発散量，排水揚水量を流出して求める。流入と流出の差は差分となり，ブロック内での貯留もしくは系外損失（地下浸透または横浸透）として扱う。物質収支は，各流入，流出項目に水質項目を乗じて求める。本報告では，EC に着目して EC 負荷量（フラックス）の収支を求める。

$$\Delta S = R + \sum In - ET - Out \qquad (1)$$

ここで，ΔS は流域貯留の変動量，R は降雨量，In は太田用水機場，十平用水機場の流入量（m3/d），ET は蒸発散量，Out は金江津排水機場量（m3/d）となる。降雨量，蒸発散量は（mm）であるがブロック面積 980ha を乗じて，流量に換算した。

上式の結果を用いて，EC 負荷（フラックス）の収支を求めた。

$$\Delta ECL = ECLin - ECLout \qquad (2)$$

$$ECLin = R \cdot ECrain + \sum In \cdot ECin + \Delta S \cdot ECavr \qquad (3)$$

$$ECLout = Out \cdot ECout \qquad (4)$$

ここで，ΔECL はブロック内の貯留量変化を，*ECLin*, *ECLout* は流入負荷，流出負荷の合計である。*ECrain* は降雨の EC，*ECin* は各機場の測定された EC，*ECavr* は本来は上流ブロックからの流入 EC を表すが，測定機器の設置の制限上，今回は金江津の EC の期別平均値を用いる。

3. 結果

金江津排水機場の水位とＥＣの変動結果を示す。金江津排水機場は，洪水対策のため常時排水が行われており，水位設定でポンプの on/off 制御が行われている。そのため，頻繁にポンプが揚水を繰り返すため，水位変動は常に上下を繰り返している状態である。なお，金江津排水機場における，EC の変動は，灌漑期に減少し，非灌漑期に増大する傾向があった。特に，1 月期に EC が高い数値を示しているが，これは，降雨が少ないため流域から流出する EC 値を希釈することができなかったためと考えられる。2016 年 12 月から 2017 年 1 月にかけての EC の変動と降雨量の関係を見ると，降雨により希釈されている現象が見受けられる（Fig.2）。

対象ブロックに対して，水収支式を適用した。入力には，2017 年の日降雨量，日蒸発散量（ペンマンモンティ

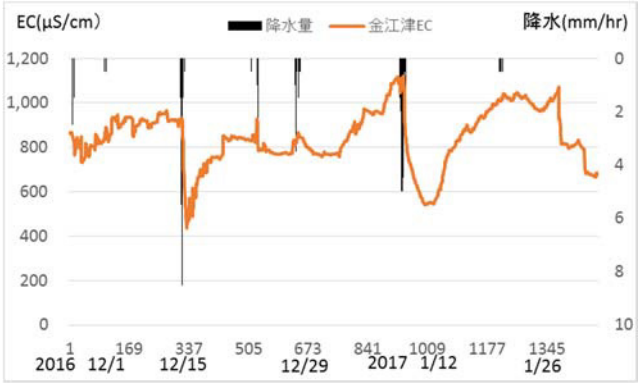

Fig.2 金江津機場の EC 変動と降雨
（2016 年 12 月～2017 年 1 月）



Fig.3 排水ブロックにおける年間水収支

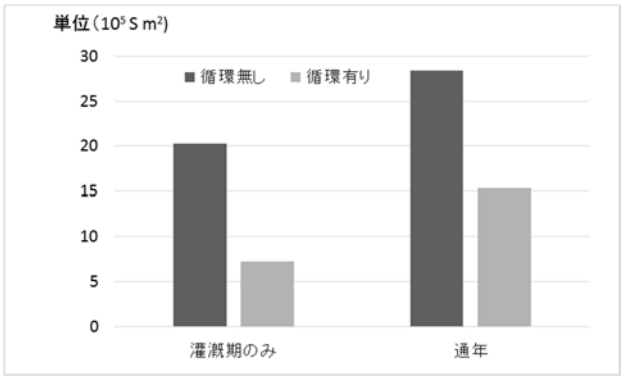

Fig.4 循環灌漑による EC 負荷削減量

ス式)，太田，十平，金江津の揚水量をそれぞれ求めた。式の差分から，残渣項が残るが，低平地であり地下浸透としての損失は無視できると考え，上流からの流入量として考え，Fig.3 に示す結果が得られた。また，物質収支としては Table2 の結果が得られた。

このことが示すのは，EC は，水中における溶存態イオンの含有量を概ね表す指標である。灌漑期に EC の排出フラックスが減少したのは，水田の灌漑排水を通じて，イオンの総量が土壌に吸着し，また植生による吸収がすすんだためと考えられる。いわゆる，水田の浄化機能が発揮されたためと考えられる。

Table 2 EC 負荷収支の概要

単位　(10^2 S m^2)

	流入(*ECL in*)			流出(*ECL out*)	残差(*ΔECL*)
	降雨負荷	用水負荷	上流からの流入負荷	金江津負荷	ブロック内貯留変化
通年	357	5,659	9,989	18,815	−2776
	平均EC 30				−7.61(日当たり)
灌漑期 (4月1日~9月15日)	122	5,643	4,230	11,090	−1059
	平均EC 30		平均EC 529		−6.92(日当たり)
非灌漑期 (1月1日~3月30日) (9月16日~12月31日)	235	15	5,758	7,725	−1715
	平均EC 30		平均EC 661		−8.09(日当たり)

4. シナリオ分析

物質収支解析を元に，循環強度を 100%と仮定し，循環灌漑を実施した際の削減負荷量と排水水質の汚濁上昇率を算定した。つまり，用水機場からの供給量を，排水機場から分水することで全てまかなうとした。流域内の EC の流出状況が循環灌漑の適用前と同じであると仮定し，エクセルのソルバーを用いて排水の EC を求めた。削減できる EC 負荷量は，灌漑期には，循環灌漑が無い場合に新利根川に流出する負荷量の約 64％（$20.3 \times 10^5 (Sm^2) \rightarrow 7.3 \times 10^5 (Sm^2)$）であった。通年で計算しても約 45%の効果が得られることが示された。一方，灌漑ブロックに負荷が還元されるため EC の上昇は，平均で 1.8 倍（灌漑期 EC, 528（μS/cm）→971（μS/cm））となることが示された。

5. 結論

以上から，循環灌漑による霞ヶ浦への EC の負荷削減量を示し，同時に，灌漑ブロック内でどの程度 EC が増加するかについて示すことができた。実際の農家は，EC が高い場合，塩分濃度の上昇を懸念し，収量や品質低下につながると考えることから，EC が極端に上昇するような循環灌漑の運用は，難しいと考える。循環強度を下げることにより，霞ヶ浦に対する浄化効果は小さくなるものの，水田の用水基準として受け入れられる EC 値で，循環灌漑を運用することは，実現可能である。

今後の課題として，循環強度と EC との間でのトレードオフ関係を明示しながら，循環強度を提言することを考えたい。また，EC に含まれるカチオンを特定し，塩害を引き起こすレベルにあるかどうかを測定する必要がある。EC は連続モニタリングが可能であるので，そのようなカチオンの挙動と EC の変動との間に関連性を特定すれば，リアルタイムの制御にもつながることが期待できる。

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O5-13

大潟村におけるGNSS直進アシスト田植機を活用した水稲無落水移植による八郎湖の環境改善 ①GNSS直進アシスト田植機の無落水移植試験

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キーワード:GNSS, 自動操舵, 水稲, 田植機, 無落水

抄録

秋田県大潟村の八郎潟干拓地残存湖である八郎湖では八郎潟中央干拓地の営農などにより富栄養化が進み、環境負荷の軽減が課題となっている。代かき後の濁水を水田から排出しなければ環境負荷の低減が図られると考えられるため、大潟村にRTKGNSSの基準局を設置し、GNSS直進アシスト田植機によりマーカーなしで、無落水で田植え作業を行った。条件のよいところでは直進精度±5cmを達成でき、熟練オペレータの作業精度に遜色のない結果を得られた、植付けの精度についても、代かき水30、43mmを落水しない条件で欠株率、植付け深は慣行の落水移植と同等であった。また、慣行と比べて水稲生育に差はなく、収量や玄米品質の低下もなかった。

1. はじめに

54年前に我が国第2の湖沼面積を持った八郎潟を干拓して大潟村が誕生し、昭和48年から農地利用が始まった。八郎潟の残存湖である八郎湖は、面積がもとの1/5になり長年の干拓地の営農による肥料成分等の流入により富栄養化が進み、アオコの大量発生などの問題を引き起こしている。

田植え前の代かき作業は、耕起後の水田で土塊を攪拌し、土塊を細かくして地下浸透を防いで水をためやすい状態にし、田植えに最適な土壌条件を実現するために実施する。代かき後の水田の上層の水(代かき水)には肥料成分等が含まれているが、これまでの田植え作業では次の作業行程の目印とするマーカー跡を田面につける必要があり、作業前に代かき水を排出(落水)してマーカー跡をつけやすくしている。この代かき水が八郎湖へ流入することが富栄養化の原因の一つであると考えられており、代かき後に落水しなければ流入する肥料成分を抑制することができる。しかし、落水しないとマーカー跡をつけることはできないため、これまで落水しないで移植作業を行うことは想定されていなかった。

近年になって測位衛星を利用して高精度に位置情報を得ることができるRTKGNSSを利用した自動操舵装置がわが国でも北海道を中心に普及しており、都府県の水田地帯でも一部導入されつつある。報告者らは、このGNSS自動操舵装置を田植機に装着することで高精度に直進走行できることから、マーカー不要で落水することなく移植作業を可能とする技術開発を進めてきた[1]。

本研究では、GNSS自動操舵装置を装着した田植機(GNSS直進アシスト田植機)の無落水移植での作業性能を検討し、直進性、移植精度等を調査したので報告する。

2. 方法

RTKGNSSの基準局を、秋田県大潟村にある秋田県立大学大潟キャンパス清新寮屋上(地上約30m)に設置し、基準局からの補正信号を5W出力のデジタル簡易無線装置で電波を送信した(図1)。GNSS直進アシスト田植機の移植作業については、基準局から直線距離で2km程度離れたほ場A、5km程度離れたほ場B、3km程度離れたほ場Cで(図2)、合計約17haの実証試験を行った。

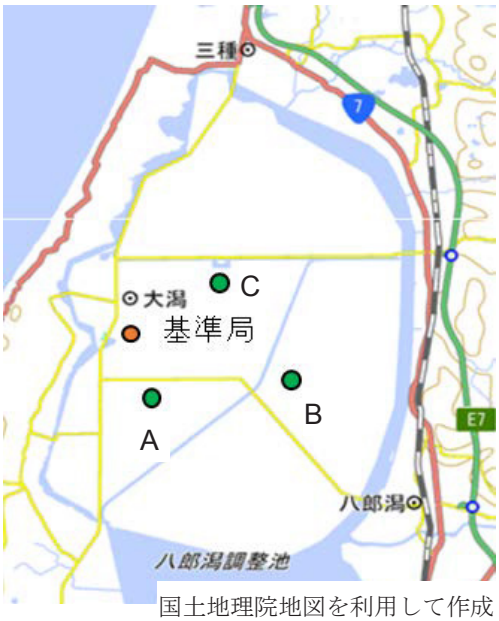
GNSS直進アシスト田植機(図3)は、K社製8条植田植機にT社製自動操舵装置を装着しており、基準局からの補正信号を受信して±2cmの精度で測位することができ、位置情報のほか進行方位や傾斜も同時に計測し、操舵ステアリング内蔵のモーターを駆動して自動操舵を行った。各ほ場毎に操舵のための各種パラメータを調整し、農家の運転で作業を行った。作業の直進部分は自動で、旋回および外周の枕地部分は手動で作業を行った。GNSS受信機から出力される位置情報をロガーに記録し、作業後にデータ処理をして作業軌跡の精度を評価した。

移植精度および水稲生育への影響は、大潟村現地のA、Bほ場で調査した。さらに、収穫後に収量、玄米品質などを解析した。供試水田は、いずれも重粘土(強グ

ライ土）であり、区画は A ほ場が 1.2ha、B ほ場が 2.5ha の水田であった。



図 1　RTKGNSS の基準局（清新寮屋上）



国土地理院地図を利用して作成

図 2　試験ほ場の配置

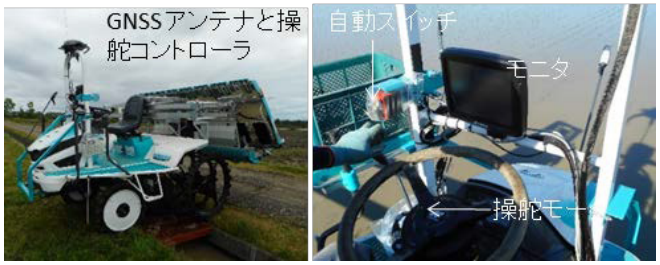


図 3　GNSS 直進アシスト田植機

3.　結果及び考察

GNSS 直進アシスト田植機を利用した移植作業作業の、ほ場 B での往復作業の軌跡を図 4 に作業の状況を図 5 に示す。行程ごとの作業精度を検証したところ、旋回後の作業開始直後 10m を除くと、直進作業精度は±5cm、目標経路からの偏差は二乗平均平方根（RMS）で 2cm であった。条件が悪いところでは±8cm 程度、RMS で 4cm であり、マーカーが見えない状況でも十分な精度が得られた[2]（表 1）。

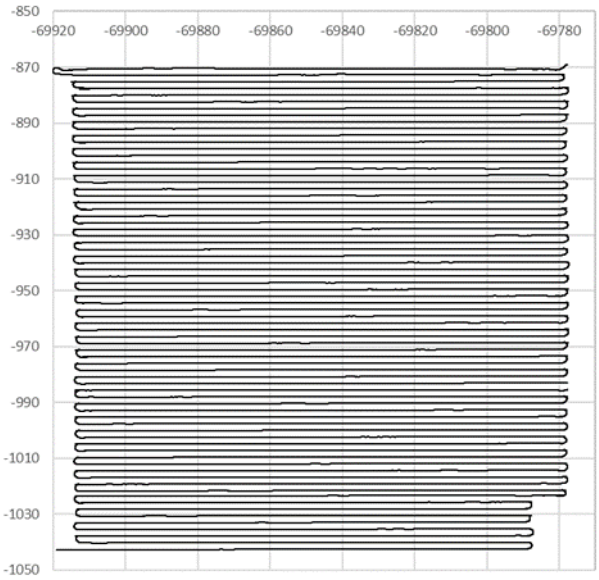


図 4　GNSS 直進アシスト田植機の作業軌跡



図 5　B ほ場の直進性が高い無落水移植作業

しかし、耕盤の凹凸や明渠跡など土の状態が均一でないと蛇行することもあり、高精度作業のためには均一なほ場の準備が必要であると考えられた。また、B ほ場では基準局からの無線信号が途切れて測位精度が低下することがあり、田植機の補正信号受信アンテナの高さを約 1m 上昇させると、その後の作業において信号の遮断はなくなった。

GNSS 自動操舵を利用したほ場 A およびほ場 B における無落水移植の移植精度は、それぞれ落水しない水深 43mm、30mm の条件で、欠株率 0.7%、0.3%、植え付け深 33mm、38mm であった[3]。無落水移植は落水移植と同等の精度で移植作業が可能であった[3]（表 2、3）。

表１　B ほ場における直進アシスト田植機の直進精度評価（m）[2]

行程数	3	4	5	6	7	8	9	10	11	12	13
最大値	0.04	0.05	0.03	0.03	0.03	0.04	0.02	0.06	0.03	0.04	0.02
最小値	-0.05	-0.03	-0.03	-0.03	-0.03	-0.03	-0.03	-0.04	-0.02	-0.03	-0.03
平均	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
RMS	0.02	0.02	0.01	0.01	0.01	0.02	0.01	0.02	0.01	0.01	0.01
5cm 以内の割合	99%	100%	100%	100%	100%	100%	100%	97%	100%	100%	100%

表２　A ほ場における移植時の苗と植え付け精度[3]

	移植時の苗			移植時水深		植込本数		植え付け深		欠株率	
	苗丈 (cm)	葉齢 (葉)	充実度 (mg/cm)	cm	SD	本/株	SD	cm	SD	%	SD
無落水	11.2	3.8	1.55	4.3	(0.76)	5.4	(0.84)	3.3	(0.34)	0.7	(0.21)
落水(慣行)				–	–	4.7	(0.55)	2.9	(0.55)	0.6	(0.28)

1)移植時の植込本数・植え付け深、移植時水深は6地点の平均値。欠株率は1000株×6地点の平均値。

表３　B ほ場における移植時の苗と植え付け精度[3]

	移植時の苗			移植時水深		植込本数		植え付け深		欠株率	
	苗丈 (cm)	葉齢 (葉)	充実度 (mg/cm)	cm	SD	本/株	SD	cm	SD	%	SD
無落水	10.4	3.6	2.33	3.0	(1.14)	8.8	(1.01)	3.8	(0.64)	0.3	(0.26)
落水(慣行)				–	–	8.0	(0.38)	3.7	(0.25)	0.2	(0.21)

1)移植時の植込本数・植え付け深、移植時水深は6地点の平均値。欠株率は1000株×6地点の平均値。

その後の無落水移植の生育は、落水移植と大きな差はなかった。また、無落水移植による坪刈収量は、A ほ場 63.3kg/a（あきたこまち）、B ほ場 64.5kg/a（トキメキモチ）と慣行の落水移植に対する低下はなく、玄米品質も慣行と同等であった[3]。

４．結論

大潟村内に RTKGNSS の基準局を設置し、基準局から 2~5km 離れた水田において農家の運転で GNSS 直進アシスト田植機による田植え作業を落水することなく行った。条件のよい場所では作業精度±5cm 以内で作業できた。耕盤の状態によっては作業精度が低下することがあった。基準局から離れた水田では、補正信号を受信するアンテナ位置を高くすることで安定して補正信号を受信することができた。

無落水移植作業の作業精度は、水深 30、43mm では欠株率はそれぞれ 0.3%、0.7%でと慣行の落水移植と同等であった。移植後の水稲生育は、慣行と比べ差はなく収量や玄米品質の低下はみられず、良好な結果を得た。代かき水を落水しない移植作業の環境負荷軽減効果は次報に示す。

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O5-14

大潟村におけるGNSS直進アシスト田植機を活用した水稲無落水移植による八郎湖の環境改善 ②無落水移植による水田排出負荷削減効果

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キーワード:水田、負荷削減, GNSS, 田植機, 無落水

抄録

八郎潟干拓地残存湖(八郎湖)は、主に農地負荷の影響で富栄養化が進行し毎年アオコが発生する水質汚濁問題が慢性化している。湖へ排出される負荷は 5 月に大きく、主要因は田植え直前の強制落水による代かき濁水の流出で、有効な対策が求められてきた。本報では、田植機にGNSSによる直進アシスト機能を装着することで可能となる無落水移植で濁水負荷を軽減できることを報告する。GNSS 直進アシスト機能によりマーカーが不要となり、代かき濁水を田植前に落水せず湛水状態で移植でき、水田排出負荷の抑制になる。流出水対策地区に指定されている八郎潟中央干拓地の水田で、GNSS 直進アシスト田植機を用い無落水移植を行い、水田排出負荷の抑制効果を高精度に測定した。試験年の移植時の排出抑制水深は25mm程であったが、比負荷での比較から5月の干拓地差引排出負荷量の窒素約22%、リン約19%、SS約18%の排出削減になると評価された。

1. はじめに

八郎潟干拓地残存湖(八郎湖)は農地排水負荷の影響などにより富栄養化が急速に進行し毎年アオコが発生する水 質汚濁問題が慢性化し指定湖沼に指定されている。流出水対策地区に指定されている八郎潟中央干拓地(大潟村)の差引排出負荷量が測定され、1.0×10^2km^{2}の水田含む面積 1.564×10^2km^{2}の干拓地から、窒素(N)は約 3×10^5kg/y、リン(P)は約 6×10^4kg/y、懸濁物質(SS)2×10^7kg/yの排出があることが判明した[1]。

特に5月の代かきから田植時に集中した排出があり、7月、8月のアオコの発生に大きく影響していることが懸念されている。除草剤散布や土粒子の沈降、乾燥硬化防止を目的に、代かき後に約 10cm の湛水状態で維持され、7〜10日後の田植え前日に強制的に落水される。強制落水の目的は移植時に次の走行線をマーカーにより泥面に記しづけ田植機による移植を等間隔かつ直線的に行うことで移植密度を均一にして収量を安定化することにある。この落水が大きな負荷発生要因となっていた(**図 1**)。

GNSS 直進アシスト[2] 田植機により、移植精度、作業性や収量の確保・向上が確認された[3]が、加えてマーカー不要で代かき濁水を田植前に落水せず湛水状態で移植ができることから、水田排出負荷の抑制が期待できる。そこで八郎潟中央干拓地の水田ほ場で、実際にGNSS直進アシスト田植機を用い無落水移植を行い、水田排出負荷量の抑制効果を高精度に測定した。



図 1 中央干拓地から八郎湖への濁水の流出

(2004年5月 秋田県八郎湖環境対策室撮影)

2. 方法

試験区として、2区(4ほ場)、1.25ha区2ほ場(Aほ場落水区(慣行区)、無落水区)、2.5ha 区 2 ほ場(Bほ場落水区(慣行区)、無落水区)を設定した。各ほ場に水位計、流量計、減水位計、データロガー、オートサンプラーを用い、水田取水および地表排水、田面水位変化等の水収支、および、流入・流出水に含まれる栄養塩(窒素:T-N、リン:T-P)と懸濁物質(SS)の濃度を測定し、負荷量の出入りを求めた。負荷発生要因となる田植え前の強制落水は、オートサンプラーを用いて 10 秒〜30分間隔で流量の変化に合わせて地表排水を採水し、T-N、T-P、SS 濃度を JIS K0102 工業排水試験法により測定し、流量との積から高精度に負荷量を求めた。

八郎潟中央干拓地からの負荷量を、用水取水地点と排水地点で実測し、干拓地の差引排出負荷量(排出負荷から農業用水などによる流入負荷を差引いた正味の

排出量)を求めることで、水田の負荷抑制量の削減効果について定量的に評価した。

3. 結果

田植え直前の無落水管理により約 25mm(250m^3/ha)の取水量と排水量の節水となった(**図 2,3**)。これに伴い N 0.9～2.0(平均 1.6)kg/ha、P 0.13～0.37 (平均 0.30) kg/ha、SS 45～233(平均 147)kg/ha の汚濁負荷の排出が抑制されたと評価できる。 八郎潟中央干拓地から八郎湖に排出される負荷量を、毎日の排水量と濃度測定値(**図 9**)との積から日毎に差引排出負荷量として求めた(**図 11**)ところ 2017 年間における中央干拓地(1.564×10^{2}km^2)からの差引排出負荷量は、N:3.54×10^{5}kg/y、P:6.06×10^{4}kg/y、SS:2.44×10^{7}kg/y となった。このうち 5 月が最も大きく、N:0.744×10^{5}kg/y (21.0%)、P:1.62×10^{4}kg/y(26.7%)、SS:0.810×10^{7}kg/y (33.2%)であった。

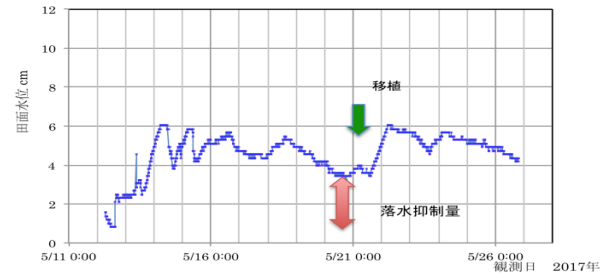

図 2 無落水区の田面水位観測結果

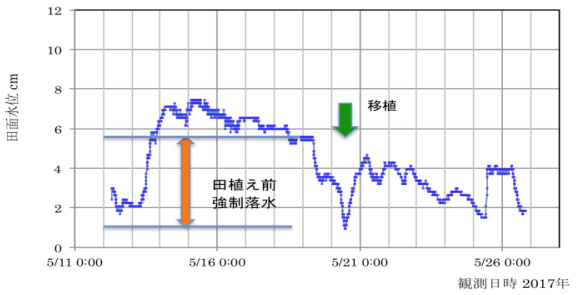

図 3 落水区(慣行区)の田面水位観測結果

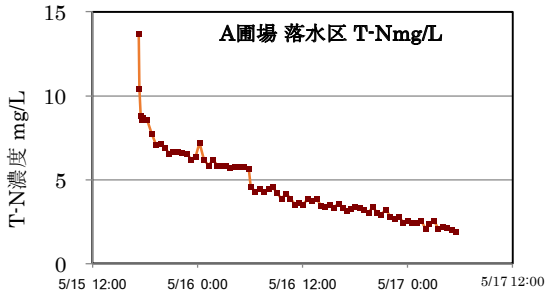

図4 田植え前の落水時の地表排水中の T-N 濃度

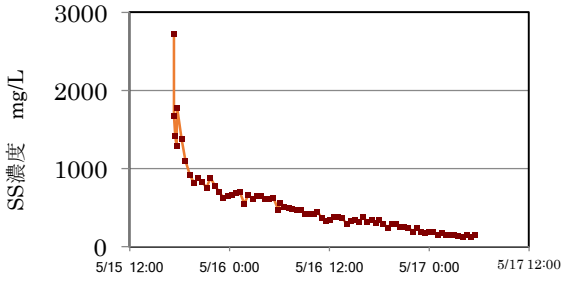

図 5 田植え前の落水時の地表排水中の SS 濃度





図 6 試験ほ場の流量測定　図 7 水田落水の採水



図 8 八郎潟中央干拓地の負荷量観測点

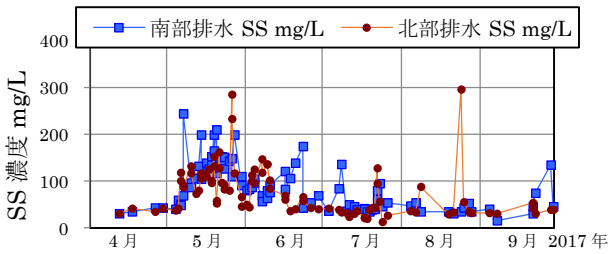

図 9 干拓地排水中の SS 濃度測定結果

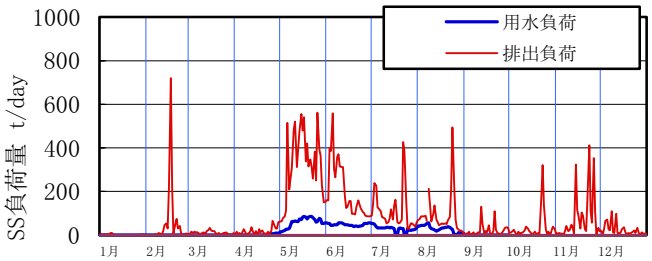

図 10 SS 日流入負荷と干拓地日排水負荷:2017 年

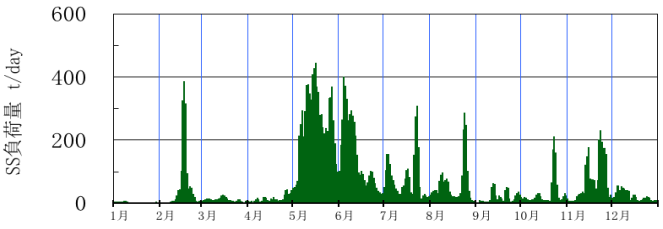

図 11 八郎潟中央干拓地からの SS 差引排出負荷量

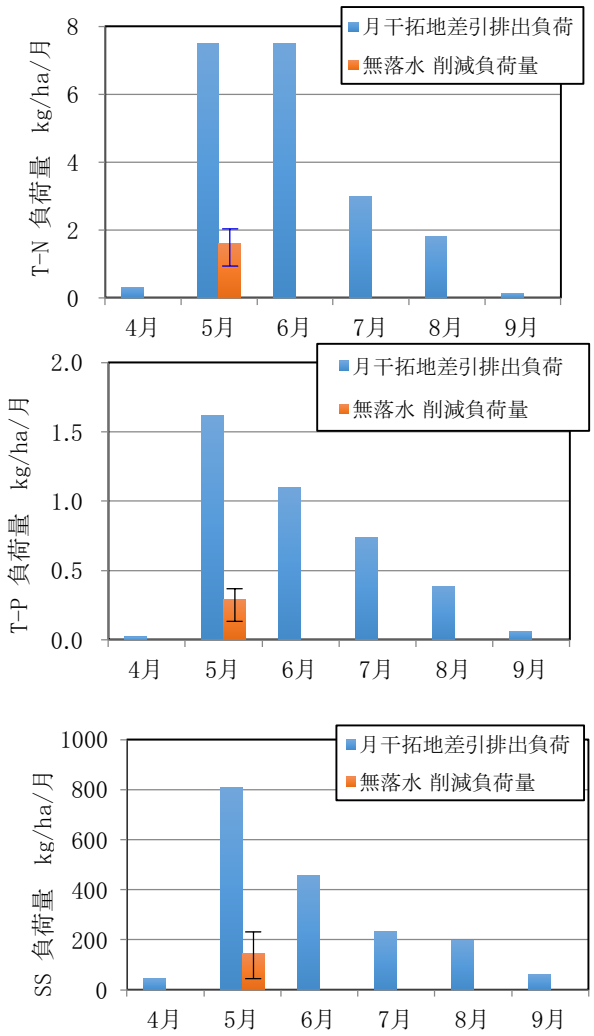

図 12　中央干拓地月別差引排出負荷量とほ場実測汚濁負荷削減量の比較（上:N ,中:P,　下:SS, 2017 年）

4.　考察

慣行水田における水管理では、代かき後の湛水深が 60～100mm に維持され、7 日目に落水し、翌日田植え時 5～10mm 程度の地表水を残して移植が行われた。これに対し、無落水区では代かき後 6 日目以降は給水せず田面水の蒸発と浸透による減少後、40mm 程度の田面水深を残して移植された。両調査区の差から少なく 25mm の強制落水の抑制となったことになる。

田植え前の田面水の強制落水では、水尻部の落水枡への流れが表土を巻き上げで掃流し、高濃度の懸濁物質を伴って排出され、その濃度は水深の低下とともに減少する傾向を示した。流出過程での濃度の推移は N:14～2mg/L、 P:3～0.5mg/L、SS:2700～170mg/L と同時期の八郎湖水に比較し大幅に高濃度であった[4]。落水区ＡおよびＢの田植え直前の強制落水による負荷量は、N:2kg/ha、P:0.34kg/ha、SS:115～194 kg/ha の

表 1　田植え前の落水量、負荷量測定結果(2017 年)

		水量 mm	全窒素 kg/ha	全リン kg/ha	SS kg/ha
A 無落水区	推定削減量	25.0	1.7	0.37	233
B 無落水区	推定削減量	25.0	0.9	0.13	45
A 落水区	田植前集中落水	47.1	1.9	0.34	194
B 落水区	田植前集中落水	29.2	2.0	0.35	115
	平均	31.6	1.6	0.30	147
	最大	47.1	2.0	0.37	233
	最小	25.0	0.9	0.13	45

排出となった。無落水区の落水抑制量を 25mm とした場合にも、相応の抑制量と推定された**(表1)**。

単位ほ場の田植え前の強制落水による実測平均値を無落水による削減量として、八郎潟中央干拓地の負荷量測定結果から求めた水田 1ha あたりの比流出負荷量（単位面積当たりの流出負荷量）とで比較すると、削減効果は 5 月期の差引排出負荷の N:22%、P:19%、SS:18%に相当した**(図 12)**。本技術の普及により大きな負荷削減効果が期待できる。

5.　結論

浄化対策の指定湖沼、八郎湖の流出水対策地区における排水と流入水の詳細な負荷量測定を行い、差引排出負荷量を年間で求めるとともに、中央干拓地の水田で、実際に GNSS 直進アシスト田植機を用い無落水移植を行い、水田排出負荷の抑制効果を定量的に評価した。試験年の移植時の排出抑制水深は 25mm 程であったが、比負荷による比較から干拓地の 5 月の差引排出負荷量の窒素（N）約 22%、リン（P）約 19%、懸濁物質（SS）約 18%の排出削減になると推定された。本技術の普及により大きな負荷削減効果が期待できるものと結論づけられた。

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O5-15

琵琶湖の保全・再生の視点に立った森林整備指針の策定について

田中　理[1]

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キーワード：水資源の保全，森林保全

抄録

滋賀県の森林は県土の約半分を占め、琵琶湖の水源林として大きな役割を果たしている。この森林では近年、シカの食害等による林床植生の消失やそれに伴う土壌流出、また、局地的な集中豪雨による山腹崩壊や流木・流出土砂の発生、といった新たな問題が発生しており、閉鎖性水域である琵琶湖の環境に影響を及ぼしている。一方で、人工林は利用期を迎え森林資源として充実しつつある。この森林資源を適切に活用し、同時に新たな課題に対応した森林整備を行っていくため、これまでより一層、琵琶湖の環境に配慮する必要に迫られている。そこで今回、琵琶湖の保全・再生の視点に立ち、適切に林業生産活動を実施していくため、3つの視点（持続的な資源利用の視点、流木・流出土砂対策の視点、水源かん養機能維持の視点）に基づく、森林整備の指針を示すこととした。指針では、琵琶湖の水源林の立地条件等を整理し、森林整備の基本的な考え方を示すとともに、これを実践していくため重視すべきことを記載した。

1.　はじめに

滋賀県は中央に位置する琵琶湖とそれを取り囲む山々から形成されており、降水はほぼすべて琵琶湖に注ぎ込む地勢となっているため、森林が、琵琶湖の環境維持に大きな役割を果たしている。

かつては里山林周辺の住民等により活用され管理されることにより、水源としての機能を発揮してきたが、林業生産活動の低迷等により、適切に管理されずに放置され、荒廃した森林がみられるようになってきた。

滋賀県では平成16年3月に琵琶湖森林づくり条例を制定し、また、平成18年3月には県独自課税である琵琶湖森林づくり県民税による事業を開始し、森林の持つ多面的機能が持続的に発揮できるよう、手入れの進まない人工林の間伐など、総合的な施策を行ってきたところである。

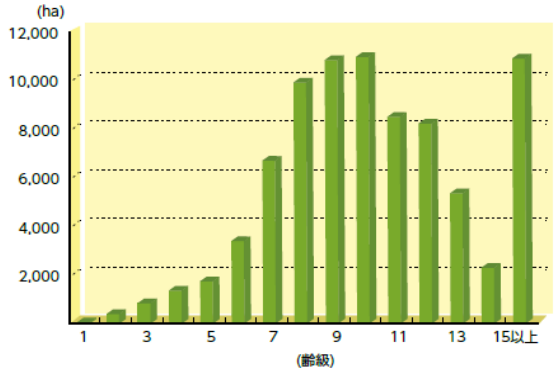

図 1　滋賀県の人工林齢級別面積配置

一方で、戦後植栽された人工林は、利用期を迎え充実しつつある。しかしその資源は十分に活用されず、森林の高齢化が進行しているため（図 1）、持続的な資源利用や森林吸収源対策のための適切な更新が課題となっている。

さらに近年、森林では、ニホンジカの食害等による林床植生の消失やそれに伴う土壌流出、生態系の破壊や、局地的な集中豪雨による山腹崩壊や流木・流出土砂の発生といった災害リスクの上昇など、新たな問題が顕在化しつつある。琵琶湖は閉鎖性水域であり、流木や流出土砂は、漁場環境の悪化など深刻な影響を及ぼす可能性がある（図 2）。



図 2　琵琶湖に流出した流木

近年の課題に対応し、森林資源を適切に利用していくためには、行政だけでなく、森林面積の約 9 割を占める民有林の所有者や、林業技術者など林業に関わる主体が、今後の森林づくりの手法について、理解し共有

する必要がある。

今回、有識者の助言を受け、琵琶湖の保全・再生の視点に立ち、3つの視点（持続的な資源利用の視点、流木・流出土砂対策の視点、水源かん養機能維持の視点）に基づく森林づくりの指針を示すこととした。

2. 策定の方法

前述のように、多くの森林が民有林である滋賀県では、森林所有者の理解が不可欠あり、指針の基本的な考え方について、わかりやすく表現する必要がある。

そこで、滋賀県の置かれた自然環境や森林立地、災害の履歴などの現状や課題を整理し、今後、林業生産活動を行う上での基本的な考え方について検討した。

次に、基本的な考え方を実務に適用するために、必要な情報の入手、評価方法、また、評価の区分毎に、森林整備において重視すべきことについて検討した。

3. 結果と考察

滋賀県の自然環境等の現状や課題について、次のとおり整理した。

- 琵琶湖を中心として外側を分水嶺が取り囲む同心円状の地勢で、河川は延長が短く急勾配、出水しやすく渇水にも見舞われやすい。山に囲まれた地形条件などから局地的な集中豪雨が発生しやすい。
- 急峻な地形や花崗岩等の風化しやすい地質条件が相まって、多くの天井川を形成
- 地震発生と密接な関わりをもつ活断層の分布密度が高い。
- 土砂災害や水害などが発生しやすいだけでなく、閉鎖性水域である琵琶湖の生態系や水質に影響しやすい土地条件を備える。
- 林業生産活動が低迷する中、森林資源の蓄積量は増加しており、資源を循環利用（「植える→育てる→使う→植える」サイクルのこと）し、持続的な森林整備を行っていく必要がある。

このような滋賀県の独特な地形や近年の豪雨など災害リスクの上昇を踏まえ、特に保安林のような伐採や開発の制限の少ない普通林において、“減災”の思想を取り入れることとし、「適地適業」を、森林整備の基本的な考え方とした。

「適地適業」は林業と県土保全とを両立する林地利用を指し、森林資源の循環利用する中で、災害リスクを踏まえて伐採方法を選択する「適地適伐」と、その土地の土壌や水分、地形などの条件にあった樹種や植栽方法を選択する「適地適木」から成る。

また、適地適業を実践していくための判断基準として、斜面単位で森林の状況を把握し、収益性と災害リスクの評価結果の組み合わせごとに、4つの象限に整理した（図 2）。

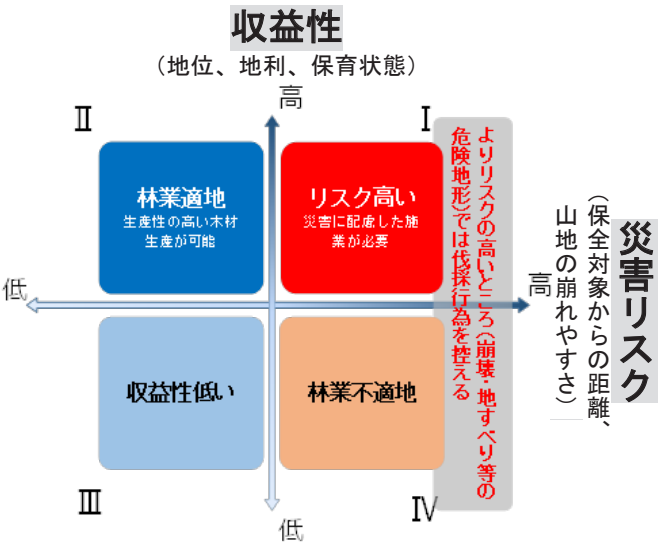

図 3 収益性と災害リスクを評価した四象限図

収益性や災害リスクの判断には複雑な要素があり、この四象限図を実務に適用するためには、それぞれの軸についてわかりやすい評価方法が必要となる。

収益性については、立木の生育条件として「地位」、作業効率として「地利」、保育状況として相対幹距比や形状比などを指標に用いた。

災害リスクについては、人命への直接の影響として「保全対象からの距離」と、斜面の傾斜、地形や地質等から判断される「山地の崩れやすさ」を組み合わせて評価することとした。この際、インターネットから入手可能な地形図、地質図や CS 立体図（長野県林業総合センターが開発した立体判読図、G 空間センターよりダウンロード）、防災情報（ハザードマップ）、滋賀県で作成している水源涵養機能評価マップ[1] などを参考にすることとした。

また、各象限において、重視するべき施業方法の例について整理した（表1）。

次に、森林整備を実践するためのポイントを、3つの森林づくりの視点ごとに、既存文献を元にまとめた。また、各視点における森林づくりの実践に向け、現地調査による知見を反映することとした。

森林整備を実践するための調査として、持続的な資源利用の視点において、再造林の低コスト化を目指した調査、水源かん養機能維持の視点では、森林植生衰

退度調査（SDR 法）[2]を実施した。

表 1 各象限における施業方法の例

象限	施業方法例
Ⅰ	皆伐を避ける。生長の良い木を残し、土壌緊縛力の維持を図る。植栽により確実に更新を行う。
Ⅱ	森林資源の循環利用を推進する。皆伐を行う際には伐採箇所の分散に配慮する。
Ⅲ	路網整備等により収益性改善を図ることが可能。
Ⅳ	適正な密度管理や林相転換により公益的機能を維持する。

再造林の低コスト化を目指した調査では、県内で 1 箇所モデル地区を設定し、県産コンテナ苗を用い、伐採と造林の一貫作業システムの工程調査を実施した。この調査では、伐採に用いた架線で資材運搬や地拵えを行うなど、工程の短縮等に向けた実証を行った。今後、様々な条件での知見を集積し、より滋賀県の実情に則した、森林の更新の手法を検討する必要がある。

また、森林植生衰退度調査では、5 年前と同地点 180 箇所で調査を行い、ニホンジカによる植生被害や回復状況を検証した（図 4）。地域により重点的な被害対策や捕獲の推進に生かしていくこととしている。

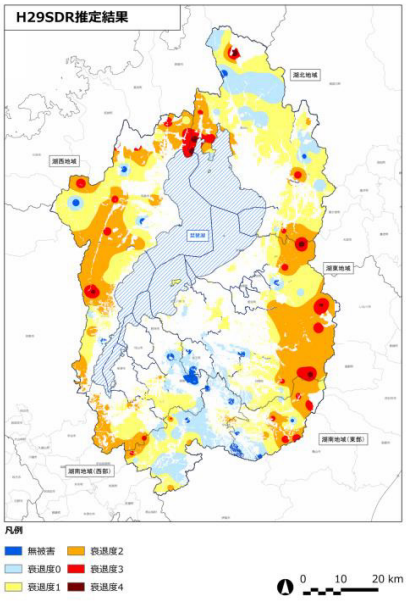

図 4 平成 29 年度植生衰退度調査結果

4. おわりに

今回の指針は、今後、市町村森林整備計画におけるゾーニング等に反映し、森林整備に生かされていくことを想定している。このためには、GIS を活用して、既存の情報を効率よく、正確に得ること、また現地で得られる情報を見る目が必要となる。考え方の普及啓発や林業技術者の人材育成を重視するべきと考える。

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O5-16

Soil Environmental Condition and Vegetation Recovery of the Abandoned Cropland around Komado-Shitsugen Moor, Fukushima Prefecture

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Keywords: abandoned cropland, beech forest, Komado-Shitsugen moor, soil genesis, vegetation management

ABSTRACT

In the area around Komado-Shitsugen moor, beech forest was reclaimed to be the agricultural fields to increasing the vegetable productivity in 1950s and abandoned until 2000. Reforestation activities started from 2000, however, in some area, planted beech trees shows poor growth, and the area is still covered by Japanese pampas grass. In this study, we surveyed soil environmental condition in beech forest area, abandoned cropland area and transit area to reveal the factors inhibit the growth of beech trees. Topographical measurement, vegetation survey and soil sampling were carried out at 10×30 meter quadrat containing forest area, transit area and grassland area. From the edge of forest to the edge of grassland, soil profiles survey was examined in every 10m. At the profile 3, which might be affected by field grading, the top soil under bamboo grass showed relatively brownish color and moderate carbon content. On the contrary, at the profile 4 under the grassland, organic A horizon was not detected and the top soil showed brown color and low carbon content which resembles to the subsurface soil of beech forest. From these results, bamboo grass in transit area was possibility related to the formation of surface A horizon, and naked subsurface soil under the grassland supposedly inhibit the growth of planted young beech trees.

1. INTRODUCTION

In the area around Komado-Shitsugen moor, Fukushima prefecture, Japan, beech forest was reclaimed to be the agricultural fields to increasing the vegetable productivity in 1950s[1]. Deforestation continued until 1976, and surface soil layer was lost by logging and field grading. Komado-Shitsugen moor was designated as a national natural treasure in 1970, and agricultural activities around the moor was gradually decreased. The catchment area was additionally designated as a national natural treasure by 2000, and the reclaimed cropland was eventually abandoned. Then reforestation activities started in abandoned field. However, in some area, planted beech trees shows poor growth, and the area is still covered by Japanese pampas grass. In this study, we surveyed soil environmental condition in beech forest area, abandoned cropland (grassland) area and transit area (covered by bamboo grass) to reveal the factors inhibit the growth of beech trees.

2. METHOD

Topographical measurement, vegetation survey and soil sampling were carried out at 10×30 meter quadrat containing forest area, transit area and grassland area (Fig. 1). Fig. 2 shows the micro-topography of the quadrat measured. From the edge of forest to the edge of grassland, soil profiles survey was examined in every 10m (totally 4 profiles).

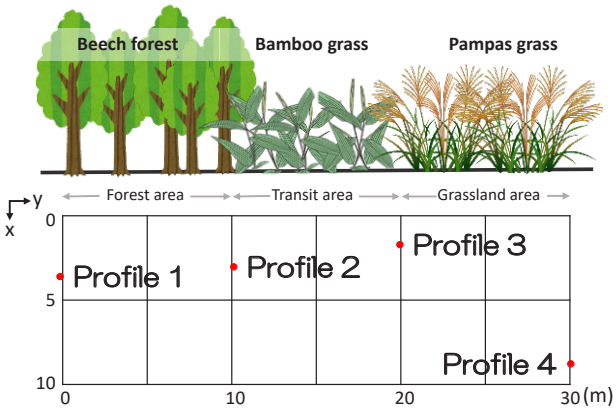


Fig. 1 Figure to describe a graph

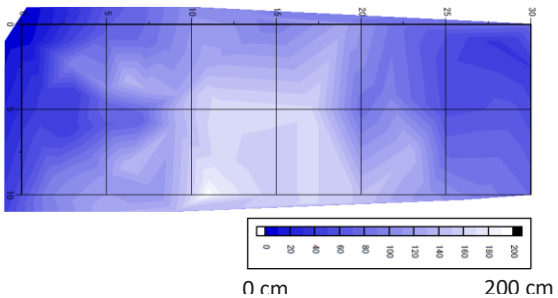
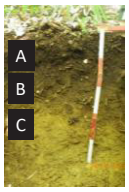


Fig. 2 Micro-topography of the quadrat

Soil samples were collected from each soil horizons, and then air-dried and sieved under a 2 mm sieve for the soil analyses. Furthermore, the quadrat was subdivided to the sub-quadrat (5×5 m), and the distribution of soil hardness and carbon content at each depth (10cm, 20cm, 30cm) at each nodes.

3. RESULTS and DISCUSSION

Fig. 3-6 shows the soil profiles at the beech forest, transit areas under bamboo grass (one near forest, and one near grassland), and grassland. Organic A horizon (>10cm) was detected at the profile 1 under the forest which was not affected by reclamation. It showed typical forest soil with low pH and high content of total carbon and nitrogen. At the profile 2, surface A horizon was also detected but higher pH comparing to profile 1 was possibly affected by deforestation and vegetation change. At the profile 3, which might be affected by field grading, the top soil under bamboo grass showed relatively brownish color and moderate carbon content. On the contrary, at the profile 4 under the grassland, organic A horizon was not detected and the top soil (BA horizon) showed brown color and low carbon content (<5%) which resembles to the subsurface soil of beech forest. From these results, bamboo grass in transit area was possibility related to the formation of surface A horizon, and naked subsurface soil under the grassland supposedly inhibit the growth of planted young beech trees. We will obtain further information on forest and grassland ecosystem and biogeochemical process of soil formation and vegetation recovery.



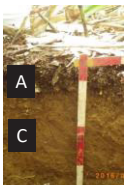
	Deprh cm	Soil Color	pH (H_2O)	T-C %
A	0-11	10YR2/3	3.9	24
B	11-19	10YR3/3	4.6	13
C	19-50+	10YR4/6	4.7	1.5

Fig. 3 Soil profile under beech forest



	Deprh cm	Soil Color	pH (H_2O)	T-C %
A	0-12	10YR2/2	4.3	21
B	12-21	10YR3/3	4.8	8.5
C	21-50+	10YR4/6	4.8	3.4

Fig. 4 Soil profile in transit area (near forest)



	Deprh cm	Soil Color	pH (H_2O)	T-C %
A	0-4	10YR2/3	5.0	15
C	4-30+	10YR4/6	5.5	4.0

Fig. 5 Soil profile in transit area (near grassland)



	Deprh cm	Soil Color	pH (H_2O)	T-C %
BA	0-11	10YR4/3	5.2	4.6
B	11-30	10YR4/6	5.4	3.8
C	30-50+	10YR4/6	5.5	1.8

Fig. 6 Soil profile under grassland

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O5-17

Phosphorus Runoff Loads from Paddy Fields and Forested Watersheds in Sengari Reservoir Basin

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Keywords: phosphorus, paddy, forest, and Sengari reservoir

ABSTRACT

In Sengari Reservoir supplying domestic water to Kobe City, Japan, total phosphorus (TP) concentration remains higher than a prescribed environmental standard value. Field survey was conducted to estimate TP loads emitted from a paddy field and from a forested watershed in the reservoir basin, measuring TP concentration and discharge in an agricultural drainage canal as well as in a mountain stream. The two measurement points were located 6.2 km apart in different sub-catchment basins of the reservoir. Water samples were collected once a week during the irrigation season (from May to mid-September) and also occasionally in rainy days during the non-irrigation season. Data loggers were operated to record water depths with an interval of 10 minutes, to determine the discharges with relevant hydraulic methods. The total TP loads from the paddy field were estimated at 6.0 kg/ha and at 6.2 kg/ha during the irrigation and the non-irrigation seasons, respectively, while that from the forested watershed was estimated at 0.49 kg/ha. As a result of hydrological analysis, it is concluded that less frequent heavy rainfall events cause significant intensification of TP loads both from the paddy field and from the forested watershed.

1. INTRODUCTION

Sengari Reservoir, whose storage volume is 11.6 millions m^3, was constructed for supplying domestic water to Kobe City in 1919. The amount of water supplied from the reservoir is 0.119 millions m^3 a day. Hatsuka River and Hazu River, whose lengths are 26 km and 9 km, respectively, are major rivers flowing into the reservoir. Catchment area of the reservoir is 94.5 km^2, extending to 4 cities (Kobe, Sanda, Sasayama, and Takarazuka) and 2 towns (Inagawa and Nose). Around 86% and 10% of the catchment area are forest and paddy fields, respectively.

Total Phosphorus (TP) concentration in the reservoir has been over an environmental standard figure (= 0.01 mg/L) assigned to the reservoir in 2002. Phosphorus is the limiting nutrient in the reservoir. As a first step to set up a countermeasure against water quality degradation in the reservoir, TP runoff loads from a paddy field and a forested watershed have been investigated for several years. This paper presents temporal change of water discharge and phosphorus concentration, on the basis of the results in 2017.

2. STUDY AREA AND METHOD

2.1 Paddy Field

Study field composed of 5 plots for paddy is located along Hazu River and agricultural water is pumped up from the river. Total area of the paddy field is 1.6 ha and it drains water into a drainage channel. A flow gauging weir was set at the end of the drainage channel. Overflow depth at the weir was measured every 10 minutes using a pressure gauge and then the discharge was calculated from an H-Q curve of the weir. Water in the channel and in the river was sampled around 1 week interval during irrigation season, which is from May to mid-September. In non-irrigation season, drainage water was sampled in four rainfall events, since water in the channel flows only when it rains.

2.2 Forested Watershed

Study field for forested watershed is set in a part of Sueyoshi River basin, which is a tributary of Hatsuka River. The area is 111 ha. A pressure gauge was installed at a ground sill in the river and water depth was measured every 10 minutes by the gauge. Water was collected 25 times from May to December and 15 discharge measurements were conducted to make an H-Q curve.

3. RESULTS

3.1 Paddy Field in irrigation season

Figure 1 shows daily discharge, TP, particulate phosphorus (Particulate-P) and dissolved phosphorus (Dissolved-P) concentrations in the drainage channel and TP in the river during irrigation season in 2017. As for the phosphorus concentration, **Figure 1** illustrates that most

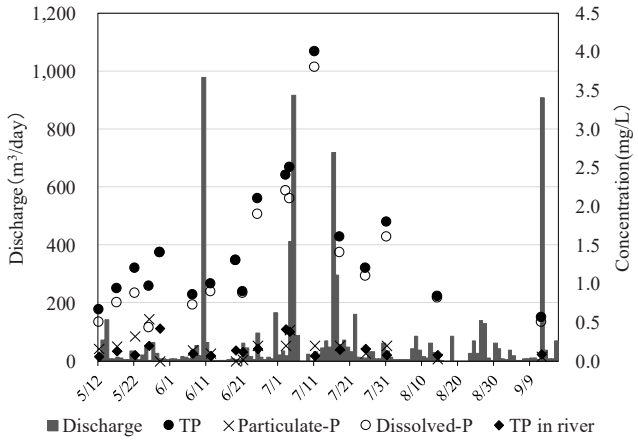

Fig.1 Discharge and phosphorus concentration during irrigation season

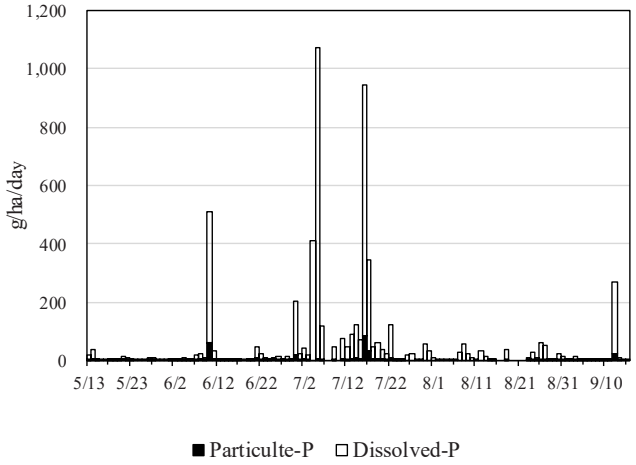

Fig.2 Phosphorus runoff load during irrigation season

part of TP consists of Dissolved-P. **Figure 1** also shows the concentration of TP seems gradually increasing from the beginning of irrigation season to mid-July and then rapidly decreasing toward the end of irrigation season. Average concentration of TP in July is over 2 mg/L and it is reduced to 0.5 mg/L at the end of irrigation season. Since the concentration of TP in the river remains low, it is clear that TP concentration increases during water flows through paddy fields. Maximum discharge was observed on June 10, it seemed to be caused by draining water for preparing rice transplanting. Large discharges observed on July 4 - 5, and September 12 were due to rainfall event. Another large discharge observed on July 16 was caused by large amount of water pumped up from the river, since a pump worked continuously for 8 hours. Total discharge of 5 days above mentioned accounts for half of the total discharge in irrigation season.

Daily phosphorus runoff load calculated from discharge and interpolated phosphorus concentration between consecutive data is illustrated in **Fig.2**. Sum of the loads on June 10, July 4, 5 and July 16, 17, which are the top 5

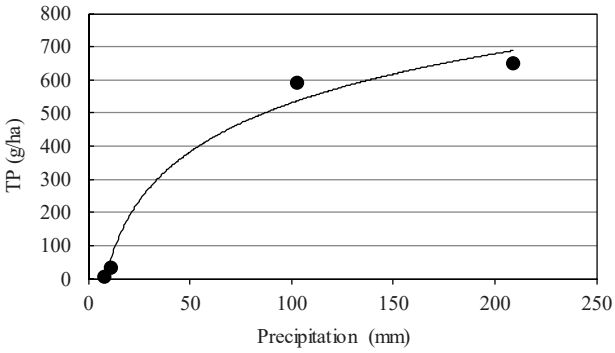

Fig.3 Relation between TP and precipitation

daily loads, accounts for half of total loads in irrigation season. Total TP load was 6.0 kg/ha, 91% of which was Dissolved-P.

3.2 Paddy Field in non-irrigation season

In non-irrigation season, water and TP runoff from the paddy field occur only when it rains. Thus, we conducted intensive sampling of water during 4 rainfall events and then proposed a relation between precipitation and TP load for the paddy field, as shown in **Fig.3**. The regression curve in **Fig.3** is expressed as

$$TPL = 214\ln(r) - 454 \qquad (r \geq 8.4) \qquad (1)$$

where TPL is TP load (g/ha) and r is total precipitation (mm) in a rainfall event.

Using Eq.(1), we calculated TP load in every rainfall event as shown in **Table 1** and estimated total TP load is 6.2 kg/ha, half of which was discharged in 6 rainy days.

3.3 Forested watershed

Figure 4 shows a relation between river discharge and TP concentration, obtained from 24 observations. A linear regression gives the relation expressed below,

$$TP = 0.0316Q + 0.0071 \qquad (2)$$

where TP is TP concentration (mg/L) and Q is river discharge (m^3/s).

Using Eq. (2), we calculated TP runoff loads from May 8 to December 31, 2017 and illustrate daily TP load with river discharge in **Fig.5**. Maximum river discharge and maximum TP load were observed on October 21-22, when the 21st typhoon hit Sengari Reservoir basin. Half of total TP load, which was 40 kg for about 8 months, was discharged during the flood caused by the typhoon, though 15% of total river discharge was observed at that time. Total load of Particulate-P was about 85% of total TP load, though most of the TP consists of Dissolved-P at a normal flow rate. In addition to that, we estimated one third of the TP runoff load originated from TP in rain, whose concentration was about 0.008mg/L[1]. With additional observations, we estimated yearly TP load from the

Table 1 Precipitation and TP load in non-irrigation season of 2017

Date in 2017	Rain (mm)	TP(g)	Date in 2017	Rain (mm)	TP(g)
Jan. 8	9.5	27.8	Sep. 17	103	590
Jan. 14-16	43	350	Sep. 28	15.5	133
Jan. 29	11.5	68.7	Oct. 2	70	455
Feb. 5	11.5	68.7	Oct. 6	31	280
Feb. 20	10	38.8	Oct. 15-16	27.5	255
March 15	18	166	Oct. 17	15.5	133
March 21	33	296	Oct. 19	25	235
April 7	15	126	Oct. 21-23	243	722
April 11	13	94.9	Oct. 24-25	11.5	68.7
April 17	94	518	Oct. 28	14.5	118
April 26	41.5	343	Oct. 29	63.5	434
			Nov. 14	15	126
			Nov. 22-23	12	77.8
			Dec. 8-9	18	165
			Dec. 24	33.5	297

forested watershed at 0.49 kg/ha.

4. DISCUSSION

TP runoff load from the paddy field in irrigation season (134 days) is almost the same as that in non-irrigation season (222 days). This indicates we have to pay attention to reduce the runoff load from paddy field not only during irrigation season, but also during non-irrigation season. Around half of total TP load was discharged in 10 days. This can be said TP load is negligible most of the year. From **Fig.2**, relatively large runoff load was caused by poor water management on June 10 and July 16, then conducting proper water management could reduce the load in irrigation season. For non-irrigation season, installing a low-height plate for controlling drainage at the outlet of each plot could be a measure to reduce the runoff load, which also lead to flood mitigation by paddy field ponding.

As for TP runoff load from the forested watershed, it is difficult to take an effective measure, since half of the load was occurred during flood caused a typhoon. From **Fig.4**, we could make the gradient of the regression line milder by proper forest management to prevent from slope erosion in heavy rain, then it would lead to reduction of TP runoff load.

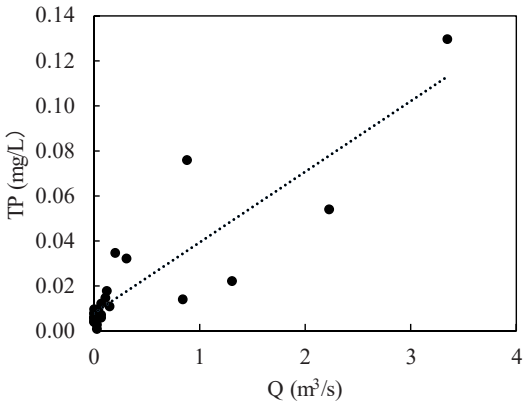

Fig.4 Relation between river discharge (Q) and TP

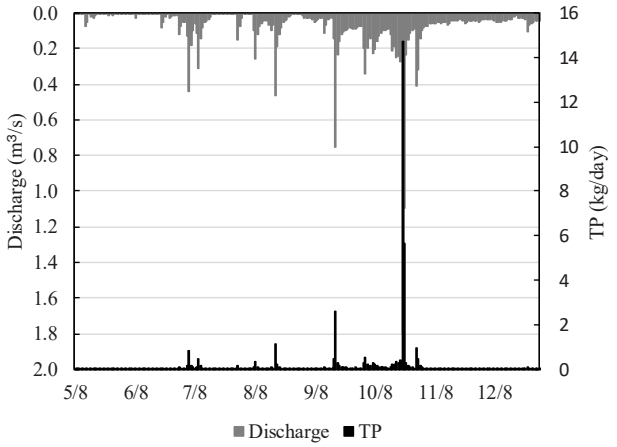

Fig.5 TP load and river discharge

5. CONCLUSION

To investigate water and TP runoff loads in the catchment of Sengari Reservoir, where water quality does not satisfy the environmental standard, we conducted field observation in the paddy field and in the forested watershed. Results from the observation revealed that high TP runoff loads both from paddy and forest did not frequently occur but did only in several days a year when it rained heavily. This indicates sum of TP load in several days accounts for major part of the total load.

6. ACKNOWLEDGEMENT

This study was supported by JSPS KAKENHI Grant Number 16K15007.

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O5-18

Observation and Modeling of Phosphorus Runoff Loads from Sengari Reservoir Basin

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Keywords: phosphorus runoff, landuse, linear multiple regression analysis

ABSTRACT

Sengari Reservoir basin, Hyogo Prefecture, Japan, is an agricultural watershed dominated by a mountainous area, and has a problem of water quality, especially of phosphorus, in Sengari Reservoir. In the basin, temporal and spatial distribution of phosphate-phosphorus (PO_4-P) concentration along the rivers flowing into the reservoir was investigated regularly. From the measured results, it was found that PO_4-P is high during the irrigation period specifically in sub-basins where domestic waste water is treated by septic tanks, although PO_4-P is low throughout the year in sub-basins where domestic waste water is treated in rural sewages. With the measured data and GIS data of landuse and altitude, linear multiple regression models whose explanatory variables are the area ratio of landuse type to the catchment area of a sampling point, the area ratio of the catchment area of the sampling point to the whole area of the sub-basin, and a dummy variable that distinguishes between rural sewage and septic tank sub-basins were formulated. The estimated PO_4-P distribution along rivers shows good agreement with the measured one except for some outliers, and the obtained coefficients imply that Paddy Field and Residential Area are major source of PO_4-P.

1. INTRODUCTION

Excessive nutrients inflow into closed water areas causes water quality degradation and eutrophication, and those cause environmental problems such as water-bloom and red tide. Especially in a case of reservoirs for domestic water, the problem becomes serious because much cost is required to treat water contaminated by cyanobacterium. Sengari Reservoir, which is one for drinking water and is classified into Category II in the environmental standard for lakes, is one of reservoirs having a eutrophic problem. According to Fujiwara (2014)[1], phosphorus is the limiting factor for reproduction of algae, and more than 90% of TP flowing into the reservoir is in a form of phosphate-phosphorus (PO_4-P). Various countermeasures such as underwater aeration and purification by vegetation has been conducted to reduce phosphorus in the reservoir. However, regardless of the long-term countermeasures, total phosphorus (TP) does not satisfy the standard value 0.01 mg/L.

In the Sengari Reservoir basin, there is no major industrial load source, and most part of environmental load comes from non-point sources such as agricultural fields and forests. Hence, it is difficult to grasp actual condition of the load in the basin. In this study, a regular water quality measurement along rivers flowing into the reservoir was conducted to ascertain the temporal and spatial distribution of PO_4-P, and linear multiple regression models were made to estimate phosphorus load from different items of landuse.

2. METHOD

2.1 Study area

Sengari Reservoir is located in the north of Kobe City, Japan. It has 11.6 millions m^3 water storage and supplies 0.119 millions m^3 domestic water a day to Kobe City. Two major rivers, Hatsuka River and Hazu River, flow into the reservoir, and total catchment area of the reservoir is 94.5 m^2. In the present study, the basin is divided into seven

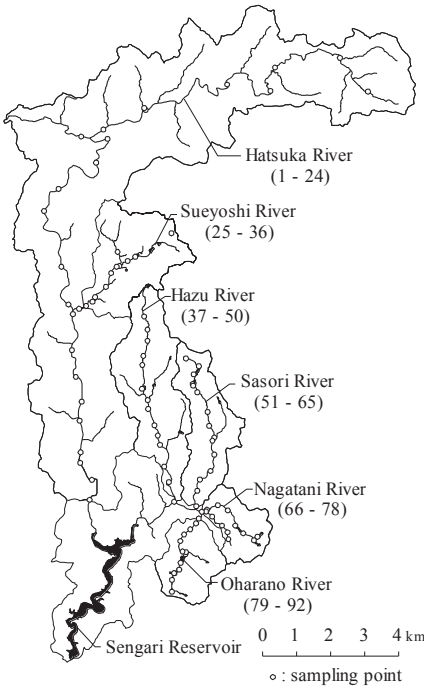

Fig. 1 Sengari Reservoir basin

Table 1 Landuse ratio of Sengari Reservoir basin (%)

Sub-basin	Area (km^2)	Forest	Paddy Field	Residential Area	Golf Course	Upland Field	Waste Land	Lake Pond	Others
Hatsuka	60.67	87.52	9.30	1.51	0.77	0.14	0.38	0.14	0.22
Sueyoshi	6.74	86.46	8.76	0.41	4.24	0.00	0.00	0.14	0.00
Hazu	8.41	91.66	8.23	0.11	0.00	0.00	0.00	0.00	0.00
Sasori	5.26	83.93	13.71	1.52	0.51	0.17	0.00	0.00	0.17
Nagatani	3.13	74.77	13.23	2.15	9.85	0.00	0.00	0.00	0.00
Oharano	3.60	70.03	21.16	7.05	0.00	1.26	0.00	0.00	0.50

sub-basins as shown in **Fig. 1**, and water samples were collected in six sub-basins. The six sub-basins are referred to as Hatsuka, Sueyoshi, Hazu, Sasori, Nagatani, and Oharano sub-basins after the rivers passing through each sub-basin. The ratio of the areas occupied by different types of landuse to the whole area of each sub-basin is shown in **Table 1**. Forest is the dominant landuse, and paddy field follows it. The six sub-basins are divided into two groups in regards to domestic waste water treatment. One is the treatment by rural sewages, and the other is one by septic tanks. Hatsuka, Sueyoshi, and Hazu sub-basins belong to a rural sewage group, and Sasori, Nagatani, and Oharano sub-basins to a septic tank group.

2.2 Field Observation

Water samples were collected along the rivers in the six sub-basins regularly, i.e., once a month in the irrigation period and once in two months in the non-irrigation period. Rainy days and days just after rainfall are avoided to obtain data in an ordinary water level. The location of sampling points is shown in **Fig. 1**, and the index for sampling points is given from upstream to downstream in each sub-basin. The concentration of PO_4-P of the collected water samples were measured with Digital Pack Test (DPM-PO4-PD, Kyoritsu Chemical-Check Lab., Corp.) or Photometer (YSI 9500, xylem), and the measuring ranges are 0.03 – 1.00 mg/L and 0.00 – 1.30 mg/L, respectively, with 0.01 mg/L resolution.

2.3 Linear Multiple Regression Model

At first, the following steady model that estimates the PO_4-P concentration at a sampling point is assumed, based on the unit value method.

$$cQ = R\sum_i \alpha_i c_i A_i \qquad (1)$$

where c is the concentration of PO_4-P in the river water at a sampling point, $Q\,(=\alpha RA)$ is the discharge, R is the amount of rainfall, α is the runoff ratio to the rainfall, A is the catchment area of the sampling point, and the subscript $i\,(\in\{\text{forest, paddy field,}\ldots\})$ means a member of the landuse set. The variables without a subscript i is the one of the whole catchment area. Being divided by Q and an error term u is added, this model could be regarded as a linear multiple regression model.

$$c = \sum_i \beta_i X_i + u \qquad (2)$$

where $\beta_i\,(=\alpha_i c_i/\alpha)$ are the regression coefficients, and $X_i\,(=A_i/A)$ are the explanatory variables.

In addition, other explanatory variables could be considered in the model. Here, the area ratio to the whole sub-basin[2] and the dummy variable that represents type of waste water treatment are considered.

$$X_{\text{arearatio}} = A/A_{\text{sub-basin}} \quad \text{and} \quad X_{\text{dummy}} = \begin{cases} 0 & \text{rural sewage} \\ 1 & \text{septic tank} \end{cases} \qquad (3)$$

where $A_{\text{sub-basin}}$ is the area of the whole sub-basin to which the objective sampling point belongs. In this study, eight models listed in **Table 2** are tried. In Model 1 and 2 groups, three and four major landuse types are used as the explanatory variables, respectively. The performance of the models is evaluated by AIC (Akaike Information Criteria).

3. RESULTS AND DISCUSSION

3.1 Field Observation

Figure 2 shows the measured PO_4-P concentration. It shows that the concentration is high during the irrigation period (from May to August) especially in the septic tank sub-basins, and that the concentration and the variance in the rural sewage sub-basins are low.

Table 2 Multiple regression models

Model	Explanatory variables
1-1	Forest, Paddy Field, Residential Area
1-2	Model 1-1 + area ratio
1-3	Model 1-1 + dummy variable
1-4	Model 1-1 + area ratio, dummy variable
2-1	Forest, Paddy Field, Residential Area, Golf Course
2-2	Model 2-1 + area ratio
2-3	Model 2-1 + dummy variable
2-4	Model 2-1 + area ratio, dummy variable

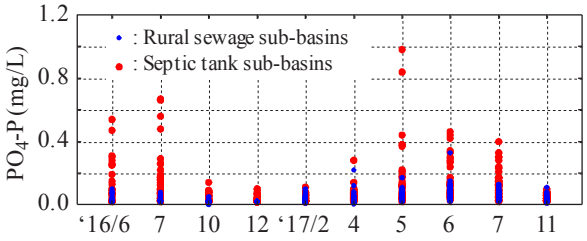

Fig.2 PO_4-P concentration in Sengari Reservoir basin

3.2 Linear Multiple Regression Model

The obtained model performances (AIC) and coefficients of the multiple regression model are shown in **Table 3**, and generally the model performance becomes good as the number of the explanatory variables increases. But in Model 2 the coefficient for Golf Course is negative, which is an unrealistic result. The obtained coefficients imply that Paddy Field and Residential Area are major sources of PO_4-P. The measured and estimated PO_4-P concentrations along the rivers are shown in **Fig. 3**. These figures show relatively good estimation in the rural sewage sub-basins (from 1 to 50) compared with that in the septic tank sub-basins (from 51 to 92). Especially, there are large deviations around 58 and 78. Actually, there is a livestock waste treatment site and there was a cowshed near 58 and 78, respectively.

4. CONCLUSION

In this study, the temporal and spatial distribution of PO_4-P concentration was investigated in the Sengari Reservoir basin, and linear multiple regression models based on the unit value method were formulated. The estimated PO_4-P distribution shows good agreement with the measured one except for some outliers derived from livestock waste.

5. ACKNOWLEDGEMENT

The authors express their sincere gratitude to Water Quality Examination Laboratory, Kobe City Water Works Bureau for provision of data. This study was supported by JSPS KAKENHI Grant Number 16K15007.

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Table 3 Model performance and coefficients

Model	AIC	Forest	Paddy Field	Residential Area	Golf Course	Area Ratio	Dummy Variable
1-1	-298.2	0.034	0.373	0.414	-	-	-
1-2	-306.9	0.051	0.485	0.384	-	-0.048	-
1-3	-312.0	0.027	0.251	0.185	-	-	0.043
1-4	-313.8	0.039	0.345	0.215	-	-0.029	0.034
2-1	-296.5	0.036	0.364	0.412	-0.005	-	-
2-2	-305.4	0.053	0.475	0.382	0.002	-0.049	-
2-3	-318.6	0.036	0.160	0.093	-0.178	-	0.059
3-4	-318.9	0.044	0.239	0.124	-0.151	-0.022	0.050

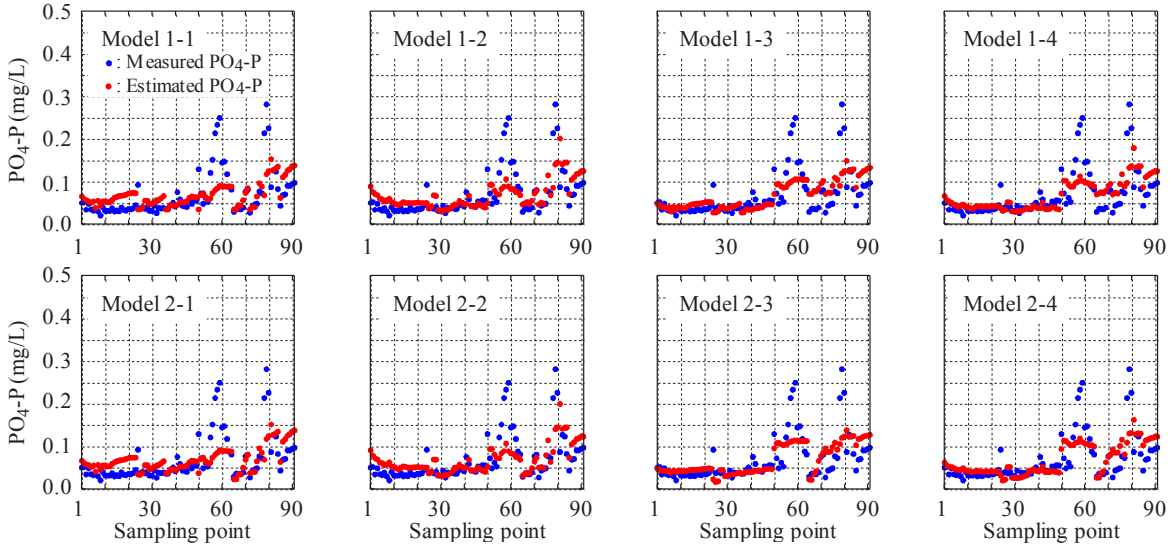

Fig.3 Measured and estimated PO_4-P concentration

O5-19

諏訪湖における底質中リン濃度の経年変化

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キーワード：窒素・りん循環，諏訪湖，下水道，底質

抄録

水質浄化過程にある諏訪湖において，底質中リンの経年変化および湖内でのリンの動態を明らかにすることを目的として，湖内 22 地点において底質中のリンを形態別に定量した。1970 年代後半の調査結果と比較すると，近年の底質中リン濃度は約 4 割減少していることが確認された。これは流域での下水道の普及が進み，諏訪湖へのリン負荷量が減少したためと考えられた。この間に大きく減少したリンは主に非アパタイトリンであった。非アパタイトリンは地点間での濃度差が大きかった。非アパタイトリンは平均粒径と負の強い相関が認められ，湖内では細かな粒子と共に挙動していると推察された。

1. はじめに

水中のリンと窒素は富栄養化に関わる主要な栄養塩であり，水質浄化のためには，水中のリンおよび窒素濃度の低減が不可欠である。諏訪湖は長野県中央部に位置する富栄養湖である。諏訪湖では集水域に下水道が整備されたことで，湖水中のリン濃度は 2000 年ごろまでは大きく減少し，それ以降は環境基準値(50μg-P/L)と同程度で推移している（図1）[1]。

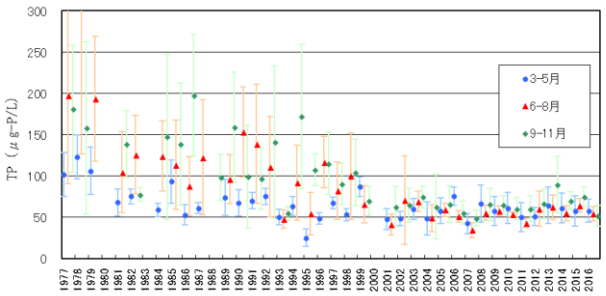

図 1. 諏訪湖における季節別の湖水中全リン濃度の経年変化（宮原，2018）

底質に含まれる成分の変化は水質よりも遅いが，湖内でのリンの循環と密接な関係にある。先行研究（宮原ら，2016）より，湖心の底質中リン濃度が過去と比べ減少していることが報告されている[2]。しかし，諏訪湖では湖全域における底質中リン濃度の変化は明らかになっていない。

本研究では水質浄化過程にある諏訪湖において，湖全域での底質中リンの分布と経年変化及びリンの湖内での動態を明らかにすることを目的とし，湖内底質中のリンを形態別に定量した。

2. 方法

2016 年 9~10 月と 2017 年 5~6 月に湖内 22 地点でエクマンバージ採泥器を使用し，底質を採取した（図 2）。これら 22 地点は，1978~1979 年に長野県によって調査された場所である（長野県衛生公害研究所，1982）[3]。

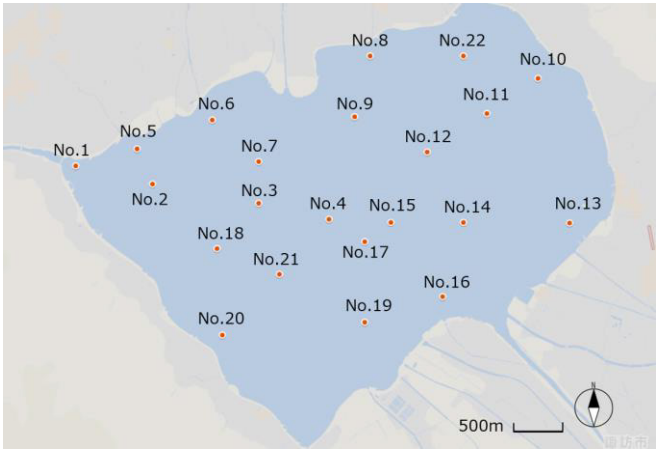

図 2. 底質の採取地点

採取した底質は静置後，上澄みを取り除き，75℃で乾燥させた。乾燥試料は小松ら（2009）のリン抽出法に準じ， CDB (citrate-dithionite-bicarbonate), NaOH, HCl 溶液を用いてリンの抽出を行い，画分ごとにリン定量を行った[4]。ここで，CDB 抽出無機態リン(鉄結合リン：Fe-P)及び NaOH 抽出無機態リン(アルミニウム結合リン：Al-P)は非アパタイトリン，HCl 抽出無機態リン(カルシウム結合リン：Ca-P)はアパタイトリンとした。

また，福原らが 1977 年に湖心でコア採取した底質（コア長 11cm）についても同様に形態別リンの定量を行った。

3. 結果

諏訪湖全域における底質中の全リン濃度の経年変化をみるために本研究結果を過去の研究結果と比較した[3]。図 3 に 1978, 1979, 2016, 2017 年の全リン濃度を示した。それぞれの全リン濃度(平均±標準偏

差)は, 2902±637, 3178±1024, 1789±360, 1751±422 µg-P/g-dry であった。また, 図 4 には 1977 年, 2016 年秋, 2017 年春に湖心で採取した試料の形態別リン濃度に示した。なお, 図 3 において 1978, 1979 年と, 本研究では測定方法が異なるが, 図 4 で示した本研究の結果と矛盾しない。これらより, 近年では 1970 年代後半と比べ, 表層底質中の全リン濃度がおよそ 4 割減少していると言える。また, 近年では 1970 年代後半よりも地点間での全リン濃度のばらつきが小さくなっていた(図 3)。

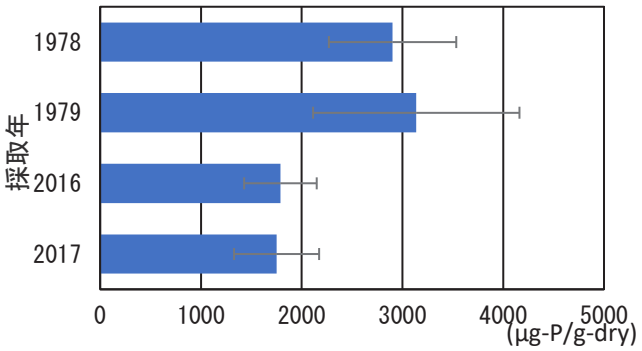

図 3. 諏訪湖底質中における全リン濃度
(1978, 1979 年は長野県衛生公害研究所, 1982)

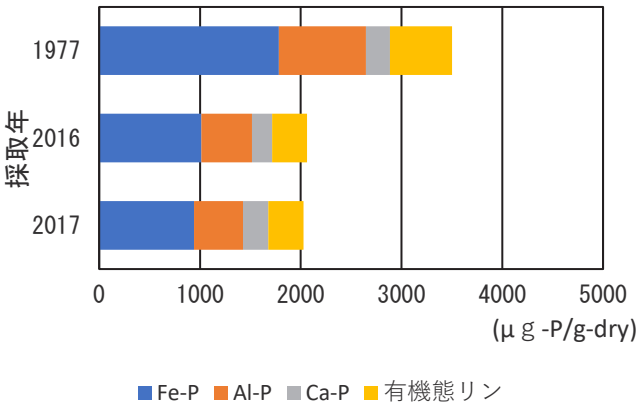

図 4. 諏訪湖底質中の形態別リン濃度(湖心)

4. 考察

諏訪湖底質中の全リン濃度は 1970 年後半と比べると大きく減少していた。諏訪地域における水洗化率の経年変化を図 5 に, 諏訪湖の全リンの発生負荷量を図 6 に示した[5][6]。諏訪湖へのリン発生負荷量は下水道が諏訪地域に広く普及し始めた 1986 年から 2011 年にかけて 247kg/day から 56kg/day に減少している。また図 1 に示したように 2000 年以降は湖水中の全リン濃度が低く維持されていることから, 諏訪湖では湖水と底質間でのリンの循環量が減少していると考えられた。

1977 年と比べ近年では非アパタイトリン濃度が大幅に減少していたことから(図 4), 諏訪湖全域での全リン濃度の減少には非アパタイトリンの寄与が大きいと考えられた。また, 非アパタイトリンは平均粒径と負の相関が見られたことから, 底質内で細かい粒子として挙動していると考えられた。

下水道が普及したことによりそれまで主なリン供給源の一つであった生活雑排水が直接諏訪湖へ流入する事がなくなり, 諏訪湖へのリンの負荷量, そして湖水中の全リン濃度が減少した。このことにより, 湖水と底質との間でのリン循環に関わるアパタイトリンの量が減少したのではないかと考えられた。

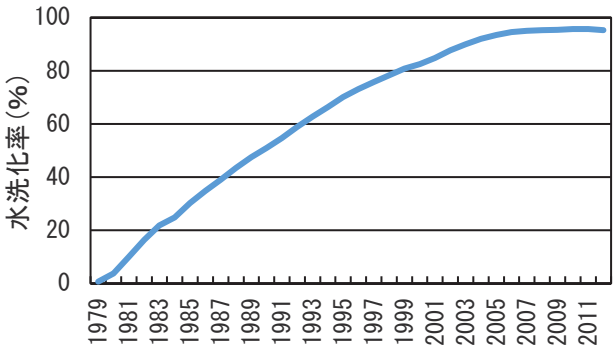

図 5. 諏訪地域の水洗化率
(諏訪湖流域下水道事務所 HP)

$$\text{水洗化率(\%)} = \frac{\text{接続人口}}{\text{行政区域内人口}} \times 100$$

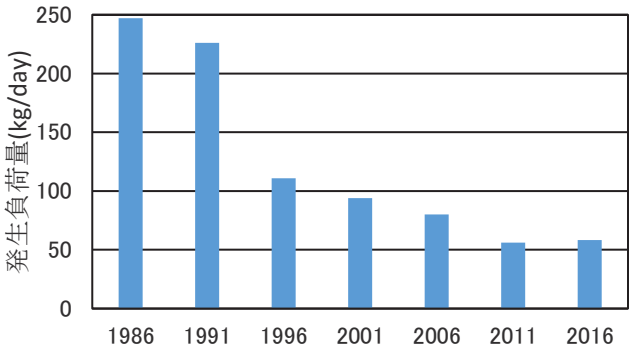

図 6. 諏訪湖の全リンの発生負荷量
(諏訪湖に係る湖沼水質保全計画 平成 29～33 年度(第 7 期)より)

5. 結論

諏訪湖の底質中のリンは 1970 年代後半と比較すると大きく減少していた。それには諏訪地域におけ

る下水道の普及により，諏訪湖へのリン負荷量，湖水中のリン濃度が低下したと考えられる。また，湖水と底質でのリンの循環に関わる非アパタイトリンの減少も認められた。

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O5-20

土壌の粒子状リンの化学形態および藍藻による利用

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キーワード:リン循環, 富栄養化, 面源負荷, 生物利用性

抄録

湖沼や海域へのリン・窒素の過剰な流入に伴う富栄養化現象は, 藍藻の大量増殖を誘発し問題となっている. 効果的な富栄養化対策を実施するためには, リンの排出源の特定が容易である点源負荷だけでなく, 面源負荷に分類される農地由来のリンにも着目する必要がある. 農地由来のリンは土壌物質に吸着していると考えられるが, 溶存態のリンとは藍藻による利用性が異なる. 本研究では, 土壌由来のリンの存在形態を調べ, 藍藻による利用性を解明することを目的とした. 土壌の粒径 20~1000 nm の微粒子に存在するリン(粒子状リン)は, 鉄やアルミニウムの鉱物に吸着して存在することが X 線吸収微細構造法によって明らかになった. また, *Synechococcus* sp.の培養試験によって, 鉄の酸化物に吸着したリンは, 短期的に藍藻の生育を抑制する可能性が示唆された. したがって, 農地由来のリンの一部は, 酸化鉄鉱物に吸着した形態で湖沼等へ輸送されて, 藍藻の生育に影響を及ぼすと考えられる.

1. はじめに

近年, 湖沼や海域へのリン(P)や窒素の過剰な流入による富栄養化現象は, 藍藻の大量増殖を誘発し, 水質悪化などの環境問題を引き起こしている. 日本では, 湖沼の富栄養化問題の解決を目的として法律が制定され, 排出源が特定できる点源負荷を対策の中心に据えてきた. しかし, P 濃度の環境基準の達成率は, 50%と依然低い. その要因として, 排出源の特定が難しい面源負荷への対策が不足していることがあげられる. 面源負荷には農地や山地などが分類される. 多くの農地には施肥により, 高濃度の P が蓄積している. 先行研究では, 山地など他の面源と比較して, 施肥が盛んに行われる農地に単位土壌当たりの水抽出態 P が多く含まれるという報告がある[1]. したがって, 単位面積当たりで考えた場合, 農地の土壌を介した人為的な P の供給による水域への負荷は, 他の面源負荷よりも大きいと考えられる.

土壌から水域への P の流出には, 土壌の粘土鉱物などの微粒子に吸着したPが重要になる[2]. 土壌に存在する粒子の中でも, 粒径が 1~1000 nm 程度の微粒子は, 土壌から水域へ元素を輸送する担体となることが知られている. したがって, 粒径 1~1000 nm 程度の微粒子に存在する P(粒子状 P)の生物利用性に着目することで農地由来の P の負荷を予測できる. しかし, 粒子状 P の生物利用性に関する既往の研究においては, 土壌由来の複雑な成分から成る粒子状 P を分画した試料を用いて生物利用性を評価するものが多く[3], 粒子状 P を構成する土壌成分とその成分それぞれの生物利用性については, ほとんど明らかにされていない. 本研究では, 農地土壌から流出する粒子状 P の存在形態を詳細に分析し, その代表的な存在形態における生物利用性を明らかにすることで, 土壌由来の P が流域の環境へ及ぼす影響を評価することを目的とした. 土壌に普遍的に存在する代表的な酸化鉄鉱物に P を吸着させた試料を調整し, 藍藻の生育に及ぼす P の利用性を検討した.

2. 方法

2.1. 農地土壌由来の粒子状 P の化学形態

農地土壌として水田の土壌を用いた. 灰色低地土および褐色低地土に分類される 6 つの水田土壌から, 粒径 20~1000 nm 程度の微粒子を分画した. 風乾した土壌にイオン交換水を添加・振とうして懸濁液とし, 1 μm 孔径のメンブレンフィルターでろ過して, 粒径 1 μm 以下の粒子を含むろ液(水抽出画分)を得た. 得られたろ液から超遠心分離機を用いて, 粒径 20~1000 nm の微粒子を分離し(粒子状 P), 上澄み液(< 20 nm)を溶存態画分とした.

ろ液(< 1000 nm)と上澄み液(< 20 nm)の各種元素濃度を測定し，その濃度差から粒子状 P 画分(20~1000 nm)の元素濃度を算出した．分離した微粒子を凍結乾燥して，X 線吸収微細構造(XAFS)分光法に供試し，粒子状 P および鉄の化学形態をバルク土壌とともに特定した．

2.2. 酸化鉄に吸着した P を用いた藍藻培養試験

実験に用いた藍藻は，独立行政法人国立環境研究所微生物系統保存施設より購入した無菌培養株 *Synechococcus* sp.の NIES-945 を使用した．培養方法については，同施設の HP 内の記載を参考にした[4]．また無菌にすべき操作は，バイオクリーンベンチおよびオートクレーブを用いて行った．本研究中の全ての培養は，器内温度を 15ºC に調整したインキュベーター内で，照度 1500 lux，明暗周期が 10 時間対 14 時間の光条件下で行った．

P 飢餓状態で培養後の藍藻 *Synechococcus* sp.を用い,Cornell and Schwertmann (2000)の方法で合成した酸化鉄鉱物（ferrihydrite）に P を吸着した微粒子を P の供給源とし，この添加量を変えた実験処理を設定した(+FhP 区, +1/2FhP 区)．これ以外には，溶存態 P のみ添加した区(+P 区)および P 無添加区の合計 4 処理区を設定した．培養開始後，定期的に培養液を採取し，藍藻の増殖量評価のためにクロロフィル a 濃度を測定した．クロロフィル a に関しては，培養液を 0.45 µm ガラス繊維フィルターでろ過後，エタノール抽出液を蛍光分析にて求めた．溶液中の溶存態 P および Fe 濃度，pH および Eh を測定した．

3. 結果

3.1. 農地土壌由来の粒子状 P の濃度

供試土壌の全 P 濃度および粒子状 P 濃度を表 1 に示した．

表 1. 土壌の全 P 濃度および粒子状 P 濃度

	土壌種類	土性	全リン濃度	粒子状リン濃度
			g kg^{-1} soil	g kg^{-1} colloid
土壌 C	灰色低地土	軽埴土	1.22	1.40
土壌 F	灰色低地土	軽埴土	2.77	0.00
土壌 G	褐色低地土	埴壌土	1.83	2.20
土壌 O	灰色低地土	埴壌土	1.61	2.30
土壌 T	灰色低地土	砂質壌土	2.04	0.70
土壌 V	灰色低地土	砂質壌土	0.49	0.50

土壌の微粒子中の P 濃度は，それぞれ，土壌 C(1.4 g kg^{-1} colloids，以下単位同)，土壌 F(0.00)，土壌 G(2.20)，土壌 O(2.30)，土壌 T(0.70)，土壌 V(0.50)であった．土壌 F および土壌 T を除き，粒子状 P は，土壌の全 P 濃度より 1～1.4 倍程度高い値を示した．

3.2. 農地土壌由来の粒子状 P の化学形態

粒子状 P の化学形態に関して，X 線吸収微細構造(XAFS)分光法を用いて詳細な分析を行った．代表として土壌 O の結果について示し（図 1），土壌 G および O の結果について述べる．この方法では，標準試料（鉄(Fe)，アルミニウム(Al)，カルシウム(Ca)鉱物への吸着態）との比較により，微粒子に含まれる P の化学形態を同定することができる． なお，鉄鉱物に吸着した P を総称して Fe-P，同様にアルミニウム鉱物については Al-P，カルシウム鉱物については Ca-P と表記した．

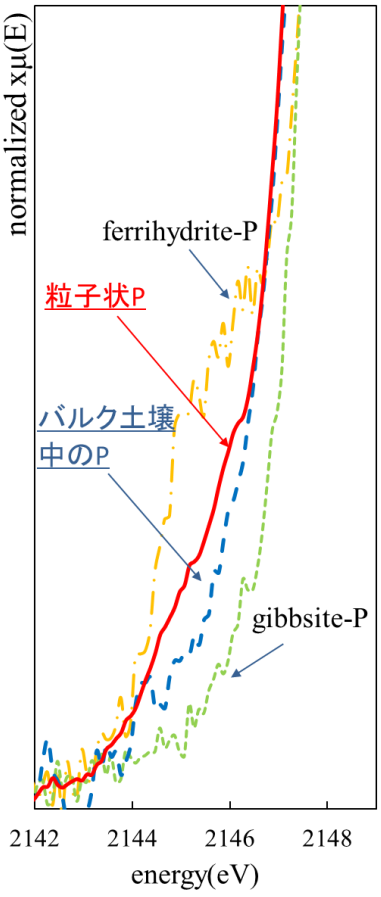

図 1. 土壌 O の微粒子に含まれる P の XAFS スペクトル

土壌 G および土壌 O の粒子状 P は，Fe や Al 鉱物に吸着して存在していることが示唆された．土壌 O に関しては，微粒子と土壌全体(バルク土壌)で，P の形態に違いがみられた(図 1)．図 1 において，実線で示した粒子

状 P のスペクトルの形状は，2144~2146 eV 付近でバルク土壌の形状と異なり，Fe-P の形状に近づく傾向がみられた．このことは，土壌 O の粒子状 P はバルク土壌中の P と形態が異なること，鉄鉱物への吸着態の存在割合が大きいことを示している．

3.3. 酸化鉄に吸着した P を用いた藍藻培養試験

藍藻の培養試験の結果を図 2 に示した．培養期間中の最大増殖量(クロロフィル a 濃度)は，+P 区(868 μg L^{-1}) > +1/2 FhP 区(368 μg L^{-1}) > -P 区(351 μg L^{-1}) > +FhP 区(190 μg L^{-1})の順に高値を示した．この結果は，酸化鉄に吸着した P が存在することによって，藍藻の増殖量が低下することを示している．溶液中の pH は各処理区による違いが確認された．培養開始時の pH はそれぞれ，-P 区(pH 8.1)，+P 区(pH 7.6)，+1/2FhP 区(pH 7.6)，+FhP 区(pH 6.7)であった．

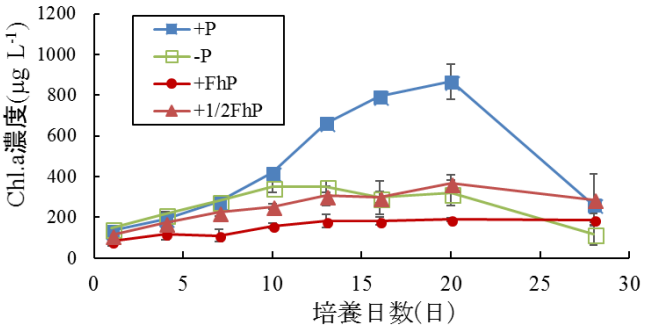

図 2. 培養期間中の各処理区における クロロフィル a(Chl.a)濃度

4. 考察

土壌由来の粒子状 P は，Fe や Al 鉱物に吸着した状態で存在することが分かった(図 1)．土壌 O に関しては，土壌全体の P と粒子状 P で形態に違いがみられた．この結果は，土壌の P は，土壌全体を対象とした場合と微粒子では異なる化学形態で存在することを意味しており，特に鉄鉱物に吸着した P が水域での移動において重要であることが示唆された．

藍藻の培養前半において，培養液中のクロロフィル a 濃度は，時間の経過とともに+P 区で明らかに増加する傾向が見られた(図 2)．それ以外の処理区(-P 区，+FhP 区，+1/2FhP 区)においてもクロロフィル a 濃度が増加する傾向は確認されたが，+P 区以外の処理区における培養期間中の藍藻の最大増殖量は，+P 区の半分以下の値であった．特に，酸化鉄鉱物に吸着した P を添加した FhP 区のクロロフィル a 濃度に関しては，実験期間を通じて最も低く推移し，その最大増殖量は，+P 区の 1/4 以下の値を示した．この結果は，ferrihydrite 吸着態 P の生物利用性の低さを表しており，既報と一致する結果となった[5]．

5. 結論

農地土壌由来の粒子状 P の多くは，鉄やアルミニウム鉱物に吸着した形態で存在した．また，鉄の酸化物に吸着した P の藍藻による短期利用性は，溶存態 P と比較して低かった．本研究により，水田土壌から河川への微粒子の流出に伴い，P が鉄やアルミニウムの鉱物に吸着した形で流域へ流出することが示唆された．その中でも，代表的な粒子状 P の形態として考えられる酸化鉄鉱物に吸着した P は，過剰に存在することによって藍藻の生育を抑制することが示された．ただし，本研究の結果は 30 日程度の短期間で得られたものであり，長期的にはこの P が溶出することも考えられるため，検証が必要である．

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O5-21

Formulation of Multiple 'Resources-from-Biowaste System' Models based on Subcritical Water Reactor

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Keywords: resources-from-biowaste, subcritical water reactor, clean cycle. mitigating of eutrophication,

ABSTRACT

Massive biowaste generation causes serious environmental degradation due to low-cost landfill system for its disposal commonly applied in most Asian countries. We assume that an appropriate solution would be formulation of multiple 'resources-from-biowaste system' as an appropriate alternative measures through the accelerated thermal hydrolysis processing based on a subcritical water reactor. Whereas, a wide range of socio-economic benefits could be expected in our society, if well-linked with value-added organic farming, as follows: (1) production of functional compost and recovery of ever-depleted phosphorus resources, (2) heightening of resource efficiency in malfunctioned biowaste management and (3) contribution to mitigating eutrophication in the public waters and so forth. Hereupon, we firstly analyzed functions of the subcritical water reactor, and secondly conducted actual project-based feasibility study on the leading system models formulated by the subcritical water reactor.

INTRODUCTION

As economy grows rapidly in Asia, generation of biowaste increases in every sector, agriculture, industrial and municipal, either. Total amount of the them is estimated as much as 2.6 billion tons a year in 2012, of which Japan accounts for approximately 10% [1].

Whereas, the conventional sink for biomass waste disposal relies majorly on low-cost landfill and partly on high-cost incineration technology coupled with no proper clean cycle neither.

In this study, we assume that this core reactor should contribute reduction of pollutant discharge into the public waters due to the current malfunctioned waste management through formulation of multiple 'resources-from-biowaste system' as shown in **Fig**,1, namely (1) high-quality-cattle-feed-from-wood-residues, (2) probiotic/ functional organic-fertilizer-from-cattle-excreta, (3) increased-biogas-production-from-sewage-sludge and so forth.

Hereupon, our previous study verified that the accelerated thermal hydrolysis processing by using a subcritical water reactor was quite workable in producing of functional organic fertilizer with affordable cost to formulate value-added probiotic agro-production model well in Taiwan and China [2].

Hereupon, we conducted additional project-based study to verify the wide-ranged assumption mentioned-above.

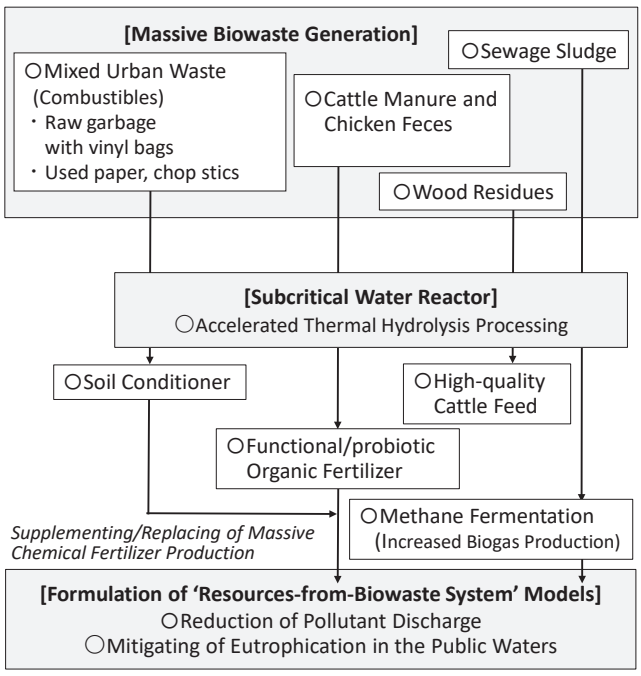

Fig.1 Multiple 'Resources-from-Biowaste System' based on Subcritical Water Reactor

MATERIALS AND METHODS

The method of this study is not laboratory-based, but actual project-based and/or real machine based-experiment.

Firstly, an analysis was conducted on the functions of the subcritical water reactor of batch type to enable accelerated thermal hydrolysis processing, successfully utilized so far to formulate leading 'resources-from-biowaste system' models in several Asian countries. Secondly, verification was made, from technical and socio-economic views, on the feasibility of those system models formulation. And lastly, discussion followed on the appropriate way to promote those multiple systems in the region, where biowaste recycling measures are required toward bettered lake environment conservation.

RESULTS

(1) Analysis on Functions of Subcritical Water Reactor

The subcritical water reactor is practically operated under the subcritical water condition with temperature of 100-200℃ and pressure of 1-2 MPa in the pressure vessel. Iron product of ion becomes increased by as high as 30 times to accelerate thermal hydrolysis processing[3], and to demonstrate useful effects in dissolving polymer structure of biowaste into low molecule materials for the wide range of biowaste within much shorter processing time of 10-60 min.

The types of reactors for such thermal hydrolysis processing are classified into batch type and continuous type, both already commercialized in Japan and spreading to Asia [4]. Whereas, the batch type is judged to be much superior in its flexible applicability to varied biowaste properties including urban mixed waste against the continuous one, which is applicable only to liquid biowaste such as raw sewage sludge.

(2) Feasibility of 'Resources-from-Biowaste System' Model Formulation

Hereupon, our study focused on workability of the subcritical water reactor of batch type, hereinafter simply called SCW rector, to formulate the following three types of system models. The technical features of the said reactor are summarized in **Fig. 2**.

High-quality-cattle-feed-from–wood-residues

A model plant has been operated since 2016 with a 2-m3 reactor installation in Hokkaido Province, Japan.

From technical views, wood-based coarse cattle feed was

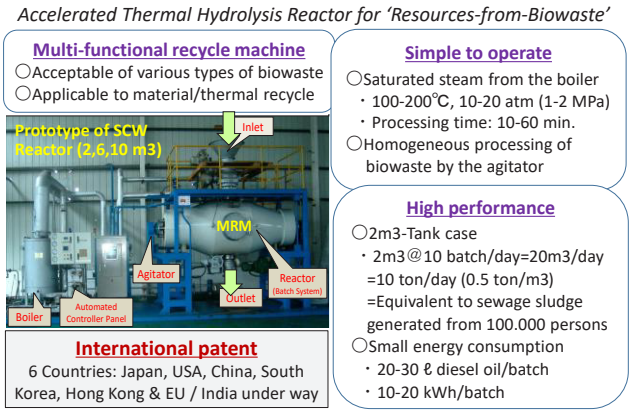

Fig. 2 Technical Features of Subcritical Water Reactor (Batch Type)

verified to be produced every 15-20min. operation of the SCW rector per a batch. The product was quite functional enough in stimulating the appetite of tested cattle greatly and strengthening their digestibility as well, and therefore helpful in promoting of high-quality Japanese Wagyu beef production[5].

From socio-economic views, the product cost including the purchase cost of wood residues was approximately 20-30% cheaper, if compared to international market price of cattle feeds. Therefore, it was clarified that this business model contributed highly to bettered management of the local breeding industry and logging industry as well. In the wake, it was improving the low feed self-sufficiency in the province, which had been highly dependent on imported feeds so far.

Probiotic/functional-organic-fertilizer-from-chicken-feces

A model plant has been operated since 2009 with two 2-m3 reactor installation in Yilan Province, Taiwan.

From technical views, raw material was proved to be converted speedily into low-molecular organic particulates within 20 min. operation of the SCW reactor per a batch. Then, it was observed that quick composting progressed within 2 weeks. Our bacteria flora analysis using a next generation sequencer revealed that dominant bacterial grope in the end product were almost crop-friendly good micro-organism, such as Actinobacteria[2].

From socio-economic views, the operation company has obtained the official certificate on its end product as qualified organic fertilizer by the governmental institution. In addition, our hearing survey to local famers clarified that the end product worked successfully, with good micro-organism effect combined, to suppress crop impediments due to repeated cultivation in their farmlands, thus making

itself more value-added and marketable with price as high as US$200/ton to well meet the operation cost.

Herewith, similar operation has been commenced since 2014 for pig manure recycling in Jiansue Province, China.

Enhanced-Biogas-Production-from-Sewage Sludge

In order to push thermal recycling rate for sewage sludge up more, streamlining of methane fermentation processing becomes the new target in Japan[6]. On this context, we conducted a comparative test to analyse the biogas generation capability from sewage sludge with/without the accelerated hydrolysis processing by the SCW reactor prior to the methane fermentation.

From technical views, it was revealed that initial acidification phase became quite shortened from around 7 days to only one hour with the accelerated hydrolysis processing. And such effect contributed to shortening of total methane fermentation time of 30-60 days by around 20-30%. In addition, biogas production was increased by 50% or more with the said processing[7].

From socio-economic views, it was implicated that installation cost of the SCW reactor could be payable enough, since double merits were to be expected, namely construction cost reduction for sludge digestion tank due to the shortened acidification phase and income surplus from the increased biogas production.

DISCUSSION AND CONCLUSION

In accordance with our actual project-based study, it was verified that the SCW reactor was workable enough as the core technology to firmly drive formulation of 3 types of multiple 'resources-from-biowaste system' models forth coupled with technical and/or socio-economic merits. If integrated well, those system models could lead to totalization of food loops and reduction of pollutant discharge as well to mitigate eutrophication in the public waters as shown in **Fig. 3**.

Further scrutinizing of this verification result mentioned-above should be desired on an actual project-basis in lake basins in Asia and other regions in the world.

As a result, it was concluded as follows:

(1) The SCW reactor was proved to be capable enough as a core technology to drive those biowaste recycle system models forth, either material recycling of wood residues and chicken feces or thermal recycling of sewage sludge.

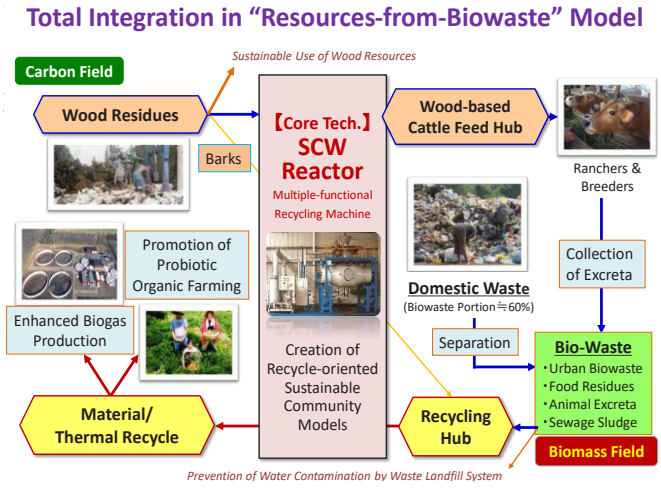

Fig. 3 Totalized 'Resources-from-Biowaste System' based on Subcritical Water Reactor

(2) From technical views. the said reactor could accelerate hydrolysis processing effectively to dissolve biowaste into low molecule particulates which were suitable for either material recycle or thermal recycle.

(3) From socio-economic views, the said reactor could promote formulation of multiple 'resources-from-biowaste system' models with smaller operation cost and higher economic benefits.

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O5-22

Water Quality Conservation by Circulative Use of Biomass

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Keywords: biomass, nitrogen and phosphorus cycle, food production

ABSTRACT

Some rural areas have problems of water pollution in lake, pond, river and canal no good for human life, irrigation and ecosystem. Most reasons come from insufficient recycle of nitrogen and phosphorus contained in various biomass and water as well as fertilizing design. Authors have developed diagnosis tool for regional biomass use that show present and planned material balance. Objective feedstock biomass is such as livestock wastes, residues of food and sludge. This study dealt with methane fermentation technology. Katori city of Japan and Thai My village of Vietnam were chosen as case study area and the effect by plan with some scenarios were quantified. The results indicated how the use of chemical fertilizer, disposal and influent load to water bodies decreased by circulative use of biomass. Appropriately designed and managed biomass use system can contribute to water quality conservation, sound material cycle, creation of value-added food production and vitalization of regional economy throughout local production for local consumption.

1. INTRODUCTION

Some rural areas have problems of water pollution in lake, pond, river and canal no good for human life, irrigation and ecosystem. Most reasons come from insufficient recycle of nitrogen and phosphorus contained in various biomass and water as well as fertilizing design. Biomass use has great potential for prevention of global warming, creation of a recycling-oriented society, fostering of sound soil and food production, vitalization of agriculture and rural communities. This paper clarifies effect of biomass use focusing decrease of influent load to water bodies.

2. METHOD

Authors have developed diagnosis tool for regional biomass use [1] that show present and planned condition of material balance as shown in Fig.1. Main parameters are raw weight, nitrogen, phosphorus and carbon. Dynamics in farmland is analyzed based previous studies and statistics as shown in Fig.2. Objective feedstock biomass is such as

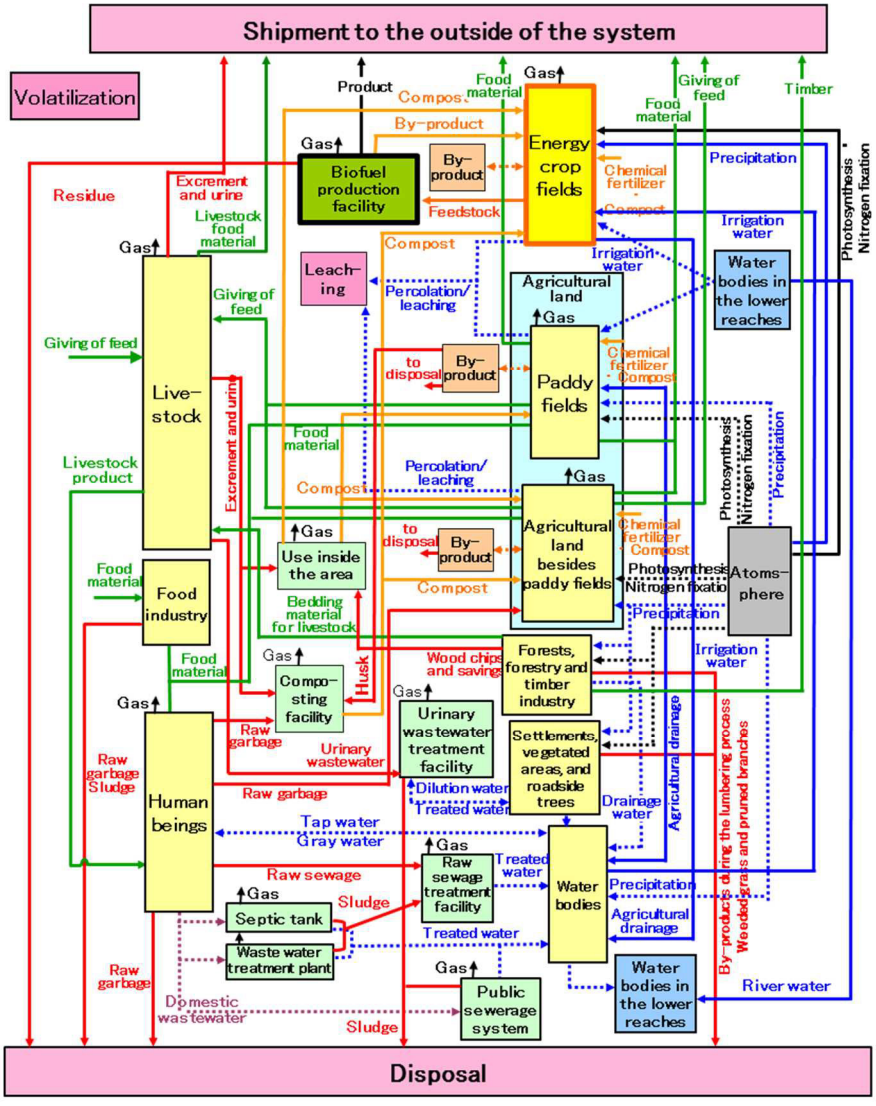

Fig. 1 Basic diagnosis model of regional biomass use

livestock wastes, residues of food and sludge. They are often converted by composting or methane fermentation technology. This study deals with the latter because it can produce energy and information of methane fermented digested slurry use is not so many. Nakamura et al. compared nitrogen balance for two years by lysimeter test between ammonium sulfate and digested slurry application and showed that the leaching ratios were almost same [2].

Two case study areas in Japan and Vietnam are chosen and the effect by plan with some scenarios are quantified.

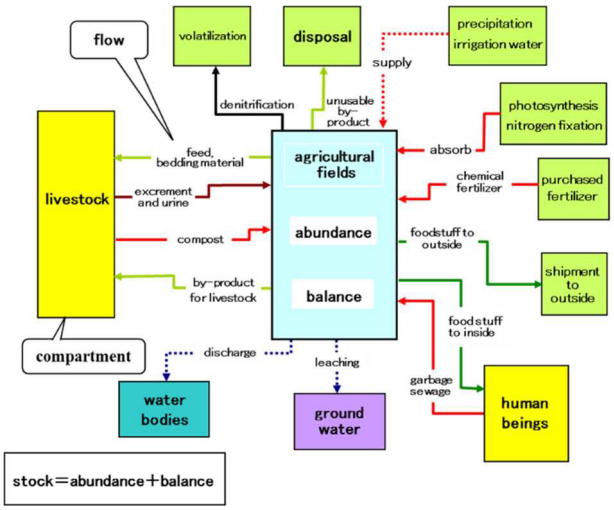

Fig. 2 Material balance in farmland

Table 1 Nitrogen balance by application of fertilizer (%)

	uptake by plant	leaching	N_2O volatilization	accumulation to soil, ammonia volatilization etc.
ammonium sulfate	32	46	0.11	22
digested slurry	27	44	0.41	29

3. RESULTS

Katori city, Japan was chosen as case study area where agriculture and livestock industry is prosperous. Scenario for promotion of methane fermentation system was designed as follows:

1) 30% of milk cow waste is provided for methane fermentation (presently, composting)
2) 24% of pig waste is provided for methane fermentation (presently, wastewater treatment and composting)
3) 3,650t/y of domestic sewage sludge is provided for methane fermentation (presently, disposal)
4) 1,825t/y of food industry garbage is provided for methane fermentation (presently, disposal)
5) 3,650t/y of household garbage is provided for methane fermentation (presently, disposal)
6) Produced digested slurry is used at farmland

Using feedstock biomass shown in Table 2, 2,828 thousand Nm^3/y of biogas, 1,018 MWh/y of surplus power, 5,882 GJ/y of surplus heat and 71,462 t/y of digested slurry were estimated to produce. Table 3 indicated how use of chemical fertilizer, disposal and influent load to water bodies decreased [3].

Table 2 Feedstock biomass used for methane fermentation in Katori city

feedstock biomass	raw weight(wet-t/y)	water content(%)
waste of milk cow	11,623	90
waste of pig	58,654	90
domestic sewage sludge	3,650	98
food industry garbage	1,825	80
household garbage	3,650	80
sum	79,402	-

Table 3 Effect of promotion of biomass use in Katori city

item		unit	present	senario
area		ha	26,231	
agricultural field	paddy	ha	7,130	
	non-paddy	ha	3,625	
population		people	87,837	
paddy	self-use compost	tN/y	150	116
	digested slurry and compost produced at biomass plant	tN/y	-	185
	chemical fertilizer	tN/y	454	316
non-paddy	self-use compost	tN/y	404	314
	digested slurry and compost produced at biomass plant	tN/y	-	370
	chemical fertilizer	tN/y	194	-
disposal		tN/y	290	219
influent load to water bodies		tN/y	1,120	989
volatilization		tN/y	1,310	1,140

Thai My village located in Ho Chi Minh city, Vietnam was also chosen as case study area [4]. Livestock and rice farming is popular there. 111 households have biogas

digesters with capacities of 7.8±1.2 m^3 of fermentation tank volume. The main feedstock is pig and milk cow feces and urine mixed with the washing water of livestock farming shed. Biogas is mainly used for cooking in the homes. Most of the digested slurry is discharged to the infiltration pits, river or canal although a little of them is used as fertilizer for plants in yards or non-paddy fields.

To overcome water pollution and realize desirable biomass use, the plan was designed as follows:

1) All unused livestock excreta are considered feedstock for biogas digester. By increasing the number of biogas digesters, excreta from 10,000 heads of pigs and 60 heads of milk cows becomes the target.
2) Digested slurry produced at the digesters is applied to paddy fields as liquid fertilizer.
3) Half of the nitrogen contained in the slurry is considered effective for a crop uptake, because the ratio of ammonia nitrogen to total nitrogen is approximately 50%. This portion is assumed to replace the chemical nitrogen fertilizer in paddy fields.

Results were summarized in Tables 4. Influent nitrogen load to water bodies decreased from 122 to 70 t/y. Application rate of nitrogen fertilizer decreased from 250 to 130 kg·ha^{-1}·y^{-1} owing to application of digested slurry. Biogas generation rate increased to 330,000 Nm^3/y, 8 times larger than the present condition.

Table 4 Effect of promotion of biomass use in Thai My village

(a) Change of nitrogen load to the lower water bodies (t/y)

source	present	plan
manure of livestock	59.1	12.9
digested slurry	5.8	0.0
others	57.4	57.4

(b) Chemical fertilizer use rate at paddy fields (t·ha^{-1}·y^{-1})

present		plan	
raw weight	nitrogen content	raw weight	nitrogen content
2.1	0.25	1.09	0.13

(c) Change of biogas generation from biogas digester (Nm^3/y)

source	present	plan
pig manure	39,340	320,452
milk cow manure	731	6,370

4. CONCLUSION

The results of analysis in two study areas indicated how the use of chemical fertilizer, disposal and influent load to water bodies decreased by circulative use of biomass. Methane fermented digested slurry was useful as liquid fertilizer. Diagnosis of soil and fertilizer design are key component. Its effect might come to conservation of ecosystem, because the circulative use of biomass leads environmentally friendly agriculture. Moreover, it would lead mitigation of global warming. In conclusion, it can be said that appropriately designed and managed biomass use system contribute to water quality conservation, sound material cycle, creation of value-added food production and vitalization of regional economy throughout local production for local consumption. This kind of efforts in watershed of a lake should be focused and promoted more strongly. In a region level, systemization of organization, technology, institution, fund and information are essential. Judgement of promotion of the plan should be considered from lifecycle profitability among organizations concerned and sustainability of land use.

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O5-23

水草バイオマスを汚泥脱水助剤として活用するための基礎的研究

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キーワード:水草,下水汚泥, 脱水助剤, バイオマス

抄録

河川、湖沼等の公共用水域において異常発生している、水草バイオマスの有効利用方法として、下水汚泥の脱水助剤としての活用に着目した。そこで本研究では、スズメノヒエおよびオニビシを下水汚泥と混合させた、実験室レベルの脱水試験を行った。その結果、スズメノヒエは、汚泥の含水率低減に寄与しないが、脱水汚泥量をほぼ増加させずに、水草と汚泥を同時に処分できる可能性を示した。オニビシは、脱水助剤として汚泥の含水率低減に寄与し、脱水汚泥量を約 80%程度に削減できる可能性を示した。また、琵琶湖南湖で下水道部局により刈取られた水草を下水処理場で脱水助剤として受け入れた場合、数日以内に処分できる試算結果となった。湖沼等で発生する水草バイオマスを下水処理場で受け入れ、下水汚泥の脱水助剤として活用する技術は、水草バイオマスの有効利用、下水道事業における未利用バイオマスの有効活用に資するものであり、かつ経済性で有用な技術である可能性が示唆された。

1. はじめに

近年、河川、湖沼等の公共用水域において、富栄養化などの原因により水草が異常発生しており[1]、水域の水質悪化、悪臭の発生、景観悪化、生物多様性の減少などに繋がるため、全国的に問題となっている。特に琵琶湖南湖では、水草(沈水植物)が大量繁茂しており、船の横行障害など、様々な悪影響をもたらしている[1]。琵琶湖で刈取られた水草は、一部堆肥化され、地域住民に無料配布されている[2]が、それ以外は焼却処分されているのが現状である。水草バイオマスの活用の研究は、堆肥化、バイオエタノール化、メタン発酵によるエネルギー化などがあり、特にメタン発酵は含水率が高い水草バイオマスを、低エネルギーで、エネルギー回収できるため、有用な方法と考えられている[3][4]が、実用には至っていない。

本研究では、水草バイオバスの活用方法として、下水汚泥の脱水時の脱水助剤としての利用に着目した。本研究室では、河川等で発生するイネ科の刈草を、下水汚泥の脱水助剤として有効利用する方法について検証しており[5]、汚泥に刈草を混合することにより、脱水後の汚泥の含水率の低下や、凝集剤添加量の削減の可能性を見出している。また、河川事業における刈草処分費や、下水道事業における脱水汚泥の処分費においても、削減可能な混合条件があることを試算により示している。脱水性向上の原理は、汚泥に固形物を投入することで、固形物が汚泥中の空隙を確保することで、汚泥中に水分の通り道ができ、水分が抜けやすくなる[6]ためだと考えられる。同様の原理で、繊維質や木質チップなどの地域バイオマスを下水汚泥の脱水助剤として利用する研究[6][7]も行なわれており、刈草と同じ植物系バイオマスである水草においても、同様の効果があるのではないかと考え、実験室レベルでの検証を行った。

2. 方法

脱水試験は、下水汚泥、凝集剤、および水草を混合し、遠心分離機による脱水を行い、脱水後の固形物の含水率を測定する方法で行った。下水汚泥は、A 処理場の最初沈殿池の重力濃縮汚泥と、余剰汚泥の機械濃縮汚泥を1対1で混合したものを用いた。実験に用いた濃縮汚泥の TS(全固形物量)は 2.3% であった。凝集剤は、カチオン系高分子を用いた。水草は、琵琶湖南湖において、B 処理場を管理する下水道部局によって、敷地の管理の一環として、敷地周縁部において表層刈取りにより回収されたものを用いた。2016 年 12 月に、主にスズメノヒエ、2017年7月に、主にオニビシを採取した。下水道部局で刈取られた水草は、下水処理場内で1カ月程度天日干しされたのち、一般廃棄物として処分されている。実験には、1 カ月程度天日干しされた水草を用いた。スズメノヒエは、ハサミで 10 ㎜程度に裁断し、オニビシは、家庭用の小枝粉砕機(MGS-1510Si, ミナト)により、3～5 ㎝程度に裁断し(図-1)た。実験に用いた水草の TS は、スズメノヒエが 92%、オニビシが 49% 程度であった。脱水試験に供した凝集剤の添加率は、汚泥 TS に対して、0%、0.5%、1.5%とし、水草 TS の混合率は汚泥 TSに対して、0%、10%、30%とした。遠心分離機の回転速度や運転時間等の脱水試験条件は、刈草の脱水試験と同様とした[5]。汚泥よりもTSが高い水草



スズメノヒエ　　オニビシ
(10 ㎜裁断) (粉砕機による粉砕)
図-1　脱水試験に用いた水草

の混合により、含水率は物理的に減少するため、水草のTS、水分量を差し引くことで、汚泥のみの含水率を試算した。また、脱水汚泥量は、凝集剤添加率 1.5%、水草混合率0%での脱水汚泥量を1としたときの各混合条件での脱水汚泥量を試算し、相対値として示した。

3. 結果

図-2 左図に脱水後の水草混合脱水汚泥の含水率の結果、図-2 右図に刈草量を差し引いて試算した汚泥中の含水率の結果を示す。図-2 左図より、TS が高い水草を下水汚泥に混合することによって、水草混合脱水汚泥の含水率が減少することが確認できた。図-2 右図より、凝集剤添加率 0%のとき、水草混合により、含水率が減少する傾向がみられ、水草混合割合が 30%までは、水草を増加させるほど、含水率の低減効果がみられることが示された。水草混合割合0%と比較して、30%では、スズメノヒエでは3.4%、オニビシでは4.5%、脱水汚泥のみの含水率が減少する試算結果であった。凝集剤を添加した場合、スズメノヒエでは脱水汚泥のみの含水率の低減化は、ほぼ見られなかった。これは、凝集剤による含水率の低減効果が大きいためである。オニビシでは、凝集剤を添加した場合、混合割合を増やすほど含水率が低下する結果となった。凝集剤 0.5%の時、水草 0%と比較して、30%で含水率 4.9%の低減、凝集剤 1.5%の時は、含水率 6.7%の低減がみられると試算され、水草混合割合 30%までは、水草混合割合が高いほど、低減効果も高くなる可能性が示唆された。例えば、凝集剤を0.5%に削減し、オニビシを 10%混合させることで、脱水汚泥の含水率を変えずに、凝集剤費の削減および、水草と汚泥の両方を処分できる可能があることがわかる。

図-3 に、凝集剤 1.5%、水草混合 0%時の脱水汚泥量を 1 としたときの、各混合条件における脱水汚泥量の相対値を示した。これは、凝集剤 1.5%、水草混合 0%時の脱水汚泥量を、下水処理場での現状の脱水汚泥量と仮定して、水草を混合した場合の脱水汚泥量と比較することを目的としている。図-2 より凝集剤添加率 0%の時は1.5%の時と比較して含水率が 10%以上高いため、脱水汚泥量も2倍程度多いが、図-3より、凝集剤0%でも、水草を30%混合すれば、スズメノヒエでは1.8倍、オニビシでは 1.3 倍まで脱水汚泥量を減少させることができることがわかる。凝集剤添加率 1.5%では、スズメノヒエを30%混合した場合、脱水汚泥の汚泥量は、1.1 倍程度の増加であった。図-2 より、水草混合脱水汚泥の含水率の低減効果が約 4%あるため、脱水汚泥量をそれほど増やさず、スズメノヒエと汚泥を一緒に処分できる可能性が示された。オニビシを 30%混合した場合、凝集剤添加率 0.5%の時、汚泥量を 96%、凝集剤 1.5%の時、汚泥量を 84%に削減できる可能性を示した。汚泥とオニビシを同時に処分でき、かつ汚泥量も減少可能となり、処分費の削減効果も期待できることが示された。

上記の結果より、水草の種類や混合条件によっては、水草を汚泥と混合して脱水することで、凝集剤費の削減や、脱水汚泥量の低減化が見込まれる可能性が示された。琵琶湖で刈取った水草を脱水助剤として利用する処理場として、琵琶湖南湖の湖周辺に立地する、B（b 市）、C、D（c 市）、3 か所の下水処理場を想定し、刈取った水草量に対して、処分に掛

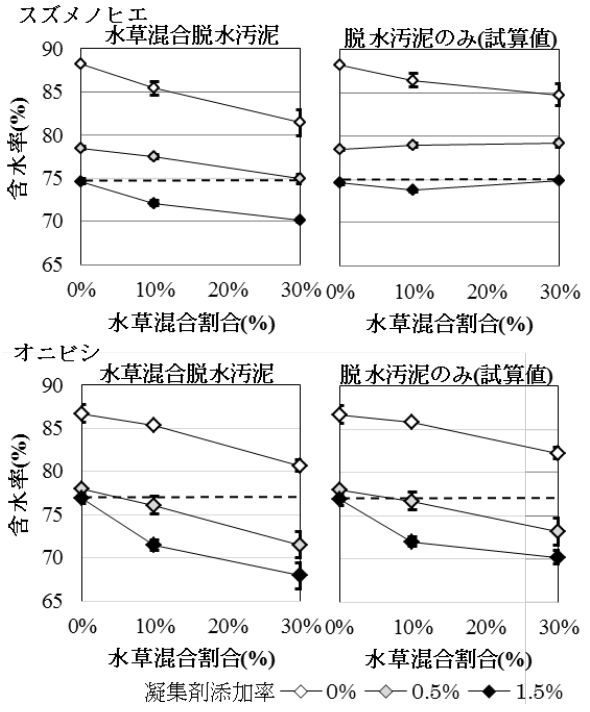

図-2 水草混合脱水汚泥と脱水汚泥のみ(試算値)の含水率

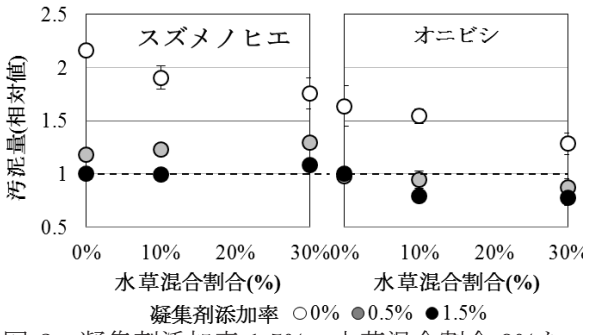

図-3　凝集剤添加率 1.5%、水草混合割合 0%を1とした時の脱水汚泥量の相対値

かる日数を試算した。水草刈取り量は、下水道部局による刈取り分とし、湖の管理者によって実施される刈取り分の 100 分の 1 と仮定した。B 処理場で受け入れ可能な水草量は、B 処理場が立地する自治体 b 市での下水道部局分とし、H29 年度の表層刈取り量の実績[8]より、約 3.5 t とした。C、D 処理場が立地する自治体 c 市においても同様の考えにより試算し、約 13.2 t とした。脱水機への投入汚泥量は、平成 27 年度実績より、B 処理場は 1,752 m^3/日（TS: 2.8%）、C 処理場は、172.1 m^3/日（TS:4%）、D 処理場は、208.8m^3/日（TS:3.1%）とした[9]。これらに対し、水草を 10%混合すると仮定し、1 日に必要な水草量を試算した。その結果、B 処理場では、水草がすべてスズメノヒエの場合、5.3 t－湿重量/日となり、2/3 日で処分できると試算された。一方、水草がすべてオニビシの場合、10.0 t－湿重量/日となり、約 1/3 日で処分できると試算された。C、D 処理場においては、スズメノヒエの場合、それぞれの処理場で 0.70 t－湿重量/日、0.75 t－湿重量/日必要となり、約 9 日で処分でき、オニビシの場合、1.3 t－湿重量、1.4 t－湿重量/日必要となり、約 5 日で処分できる試算結果であった。以上より、下水道部局による水草刈取り量は、脱水助剤として活用することで、短期間で処分ができる可能性が示された。仮に、湖管理者による水草刈取り量を下水道部局で受け入れた場合、受け入れる水草量が約 100 倍となるため、B 処理場では約 1~2 カ月で処分できる試算であった。一方、C、D 処理場では、1 年半～2 年半かかると試算され、水草混合割合を 30%に増やした場合、半年～9 カ月程度で処分可能である試算となった。

脱水汚泥の処分方法として、下水処理場内において、焼却炉や炭化炉で処分する場合、焼却灰や燃料化物は、水草の投入により増加する。水草を 600℃の恒温炉で 1 時間加熱した時の灰分の割合は、スズメノヒエが 5.3%、オニビシが 29%であった。オニビシの灰分割合が高いのは、水草に土壌が付着していたためだと考えられる。汚泥の TS に対して水草を 10%混合した場合、灰分は 1.1%程度、30%混合した場合は、1.2~1.4%程度増加する試算となった。燃料化の場合は、生成物を売却するため、収入量が増加する可能性がある。焼却灰を処分する場合は、処分費が増加する可能性があるが、水草により低位発熱量が上昇するため、補助燃料量の削減が見込まれる可能性がある[5]。これらについては詳細に試算し、検証する必要がある。

4. 結論

本研究では、バイオマスとしての活用が求められている水草に着目し、スズメノヒエ、オニビシの汚泥の脱水助剤としての有用性を実験室レベルで検証した。その結果、スズメノヒエは脱水助剤として、汚泥の含水率低減にほぼ寄与しないが、脱水汚泥量を増やさずに、水草と汚泥の処分が可能である可能性を示した。オニビシは、脱水助剤として汚泥の含水率低減に寄与し、汚泥量も約 80%程度に削減できる可能性が示された。

また、琵琶湖南湖で刈取った水草量に対し、下水処理場において、どの程度の期間で処分可能か試算した。琵琶湖南湖で刈取られた水草のうち、下水道部局による刈取り分を脱水助剤（汚泥 TS に対して水草 TS10%混合）として活用する場合、10 日程度あるいはそれ以下で処分可能であり、湖管理者による刈取り分も受け入れる場合は、水草30%混合により1年以内に処分できる試算結果となった。

湖沼等で発生する水草を下水処理場で受け入れ、下水汚泥の脱水助剤として活用する技術は、水草バイオマスの有効利用のみならず、下水道事業においても、未利用バイオマスの有効活用および経済性の両面で、有用な技術である可能性が示唆された。

水草バイオマスを有効利用するための課題は、水草と土壌やゴミとの分別、水草の破砕、運搬、また水草刈取り量や水草の種類の変動など、いまだ多くあり、今後は、これらも含めた活用検討が必要である。

謝辞：A 処理場には汚泥の採取、B 処理場には水草の採取において、多大なるご協力を賜りました。ここに記して謝意を示します。

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O5-24

水田に施用した低温メタン発酵消化液の窒素無機化特性

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キーワード:メタン発酵, 消化液, 液肥利用, 施肥設計, 窒素負荷

抄録

生活排水処理施設から排出される汚泥はメタン発酵の原料としての利用が期待されており, 大規模下水処理場では利用されているが, 小規模施設ではエネルギー効率が低いため利用が限定的である。発酵温度が通常(35℃)より低い低温メタン発酵と消化液の液肥利用は, エネルギー効率を改善できる有望な技術であるが, 低温条件が消化液の肥料特性に及ぼす影響は未解明である。そこで本研究では, 室内培養試験により, 脱水汚泥を原料とする低温メタン発酵消化液(15, 25, 30℃)の水田施用後の窒素無機化特性を調査した。その結果, 消化液中の有機態窒素の無機化に伴うアンモニア態窒素の増加割合は発酵温度に関わらず小さかった(3～13%)ことから, 消化液のアンモニア態窒素分を考慮して施肥設計すればよく, そうすることで河川や湖沼への窒素負荷が増加する懸念が小さいことが示された。

1. はじめに

メタン発酵は家畜排せつ物, 汚泥, 食品廃棄物等を嫌気条件で処理し, メタン濃度約 60%のガスを取り出す技術である。生活排水処理施設から排出される汚泥は, メタン発酵の原料としての利用が期待されており, 大規模下水処理施設では利用されているが, 小規模施設では, エネルギー効率が低いことや経済性の問題により, 利用が限定的な状況である。その対策として, 発酵温度が通常(35℃)より低い低温メタン発酵と発酵残渣の消化液の液肥利用は, エネルギー効率や経済性を改善できる有望な技術である。

しかしながら, 低温条件が消化液の肥料特性に及ぼす影響は未解明である。また, 農地に肥料として施用される窒素のうち, 作物に利用されないものの一部は水域への負荷となる。そのため, 作物要求量に合わせて適正量を施肥し, 極力, 作物の窒素利用率を高める対応が基本となる。消化汚泥等の有機性資材の場合には, 含まれる有機態窒素が農地施用後にどの程度無機化し, 作物が利用できる形態の窒素(水田の場合はアンモニア態窒素)がどの程度供給されるのか, を把握することが施肥設計のために不可欠である。

そこで本研究では, 室内培養試験により, 脱水汚泥を原料とする低温メタン発酵消化液(15, 25, 30℃)の水田土壌施用後の窒素無機化特性を調査した。

2. 方法

培養試験は, 南雲ら[1]を参考にした, 中村ら[2]により行った。試験区として, 発酵温度の異なる 3 種の消化液, 脱水汚泥をそれぞれ施用する試験区(消化液(15℃)区, 消化液(25℃)区, 消化液(30℃)区, 脱水汚泥区)と資材を施用しない無施用区を設定した。各資材の成分を表1に示す。

約 60 mL のバイアル瓶に, 風乾後 2 mm のふるいを通過させた, 農村工学研究部門内の重粘土水田土壌(土性, 全炭素, 全窒素, CEC, 遊離酸化鉄含量は, それぞれ HC, 17 g/kg, 1.2 g/kg, 15.4 $cmol_c$/kg および 13.6 g Fe/kg)を乾土あたり 5 g, 各試験区に資材(脱水汚泥, 消化液)をVS 施用量が 0.2g となる量を施用し, 脱気した脱イオン水を総量で 10mL になるように加えた後, ブチルゴ

表１　各資材の成分

	TS (%)	VS (%)	VS/TS -	TC (%)	TN (%)	NH_4-N (mg/L)	pH -
脱水汚泥	18	15	0.82	39.0	7.2	1700	-
消化液 (15℃)	5.1	3.7	0.73	-	-	1100	7.3
消化液 (25℃)	5.5	4.0	0.72	-	-	1100	7.4
消化液 (30℃)	5.3	3.7	0.71	-	-	1300	7.4

ム製の栓で密栓した。その後，気相部分を高純度窒素（純度 99.9995 %以上）で置換して試験管ミキサーで攪拌する操作を3回繰り返し，その操作の終了を培養開始とした。培養期間中，バイアル瓶は，30 ℃に設定した恒温庫に静置した。培養開始前（バイアル瓶に土壌，脱イオン水，資材を入れた直後），および開始後 14，70 日後については，各資材から無機化した窒素量を把握するため，土壌中のアンモニア態窒素量を測定した。所定の培養期間経過後の各試験区の土壌に 10%塩化カリウム溶液 50mL を加え，100rpm で 30 分間振とうした後，ろ過した。その後，ろ液のアンモニア態窒素濃度を吸光光度法[3]で分析して，土壌中のアンモニア態窒素量を求め，式(1)を用いて培養 70 日間における各資材由来のアンモニア態窒素の増加率を算定した。この増加率は，70 日間における各資材に含まれる有機態窒素の無機化に伴うアンモニア態窒素の増加割合を示し，消化液を用いた作物栽培における施肥設計のための参考情報となる

各資材由来のアンモニア態窒素の増加率(%)

=((各試験区の NH_4-N 量（70 日後）－無施用区の NH_4-N 量（70 日後））/((各試験区の NH_4-N 量（培養前）－無施用区の NH_4-N 量（培養前））×100 (1)

3. 結果および考察

培養期間中の各試験区の土壌中のアンモニア態窒素量の推移を図1に示す。培養開始後 2 週間までの土壌中のアンモニア態窒素の増加に着目すると，消化液を施用した試験区に比べて脱水汚泥区ではアンモニア態窒素量が急激に増加しており，脱水汚泥に含まれる易分解性有機物が施用直後に分解し，それに伴い有機態窒素の無機化が生じたと考えられる。このことは，メタン発酵過程で分解が進み，原料の脱水汚泥に比べて消化液中の有機物は安定しているためであると考えられる。したがって，消化液を施用した場合には，たとえ 15℃程度の低温条件の消化液であっても，新鮮有機物の施用に伴う土壌微生物による作物への害作用（作物の窒素飢餓，微生物による作物生育阻害物質の生成等）[4]を起こす懸念が小さいことが示唆された。

培養 70 日後の各試験区におけるアンモニア態窒素の増加率は，脱水汚泥区，消化液（15℃）区，消化液（25℃）区，消化液（30℃）区でそれぞれ，85，13，5.4，3.0%であった。発酵温度による違いに着目すると，アンモニア態窒素の増加率は，15℃の条件でやや高い傾向があるものの，脱水汚泥区の 85%に比べて小さかった。つまり，発酵温度条件によらず，メタン発酵過程で脱水

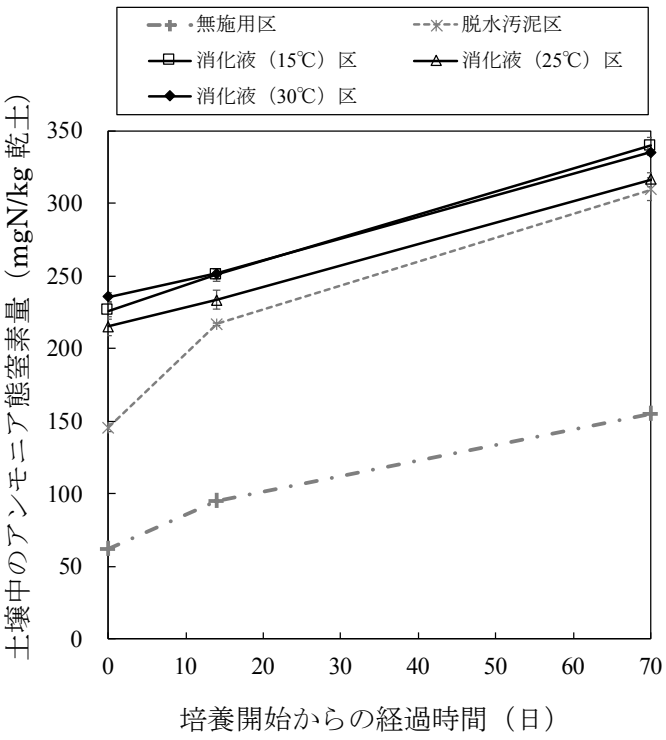

図１　培養期間中の各試験区の土壌中のアンモニア態窒素の推移

汚泥中の有機態窒素の大部分が無機化し，水田土壌施用後の無機化量が少ないことが示された。このことは，メタン発酵温度に関わらず，消化液には土壌施用後に遅れて効いてくる窒素（遅効性窒素）は少ないこと，土壌施用後に無機化し供給されるアンモニア態窒素量が気温等の気象条件により変動することがなく，施肥設計通りの肥効を見込めることを意味する。

4. 結論

消化液中の有機態窒素の無機化に伴うアンモニア態窒素の増加割合は，発酵温度に関わらず少なかった（3~13%）ことから，消化液のアンモニア態窒素分を考慮して施肥設計すればよいことが示された。つまり，本研究の結果をもとに，適正な施肥設計を行うことにより，低温メタン発酵消化液を化学肥料の代わりに使用しても，河川や湖沼への窒素負荷が増加する懸念が小さいことが示された。

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O5-25

Risk Assessment of Persistent Organic Pollutants in a Small Catchment

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Keywords: sediment, persistent organic pollutants, risk assessment and catchment

ABSTRACT

To evaluate the relative ecological risk of harmful pollutants in the sediments of a small catchment, the concentrations of persistent organic pollutants (POPs) in the sediments were measured. Results show concentrations of polycyclic aromatic hydrocarbons (PAHs), polychlorinated biphenyls (PCBs) and organochlorine pesticides (OCPs) were in the range of 2.7~82.2 μg·kg^{-1}, 0.11 ~ 0.59 μg·kg^{-1} and 1.12 ~ 2.83 μg ·kg^{-1}, respectively. A potential negative impact on the ecological environment in the region was found.

1. INTRODUCTION

POPs is a natural or synthetic organic pollutant which is not quickly degraded in the environment. Once enter into the background, the POPs can stay in environmental media (Water, air, soil, sediment and so on) for years or even decades or longer. They can be transported through the atmosphere and water for a long distance to affect the global environment. The sediment is one of their essential fate.

2. METHOD

The sampling site is a closed lake bay and is the only port in the northwest corner of Taihu, with an area of 58 km^2. Sediment samples were taken with conventional gravity coring equipment (diameter 6 cm). The samples were dried naturally, then remove the animal and plant debris and stones. All natural-dried samples were ground, passed through the 100 mesh sieve. The identification and quantification of PAHs, PCBs and OCPs (DDTs, HCHs) were performed through the gas chromatograph-mass spectrometer manufactured by Shimadzu Corporation of Japan (QP2010 ultra, Japan). The ecological risk of PAHs, PCBs and OCPs was evaluated by environmental quality standards of POPs in the sediments [1]. The USEPA has now defined this rule as the national standard.

3. RESULTS

Results show concentrations of polycyclic aromatic hydrocarbons (PAHs), polychlorinated biphenyls (PCBs) and organochlorine pesticides (OCPs) were in the range of 2.7~82.2 μg·kg^{-1}, 0.11 ~ 0.59 μg·kg^{-1} and 1.12 ~ 2.83 μg ·kg^{-1}, respectively. The total PAHs and PCBs at all sites are below the ERL. The highest concentration of DDTs in the sediments of each sampling sites is close to the ERL value. These findings indicate that no samples contained POPs whose concentration exceed ERM. Therefore, the ecological risk of POPs in the sediments of the small catchment was relatively low.

4. DISCUSSION

Because of the regional industrial development, emissions of large amounts of untreated industrial wastewater, the Taihu watershed has become the one of the most serious polluted area. The enterprises in this region should accelerate the transformation of economic development mode, optimize the financial structure, and develop low energy consumption, small pollution industries, vigorously. In addition, companies should improve the sewage treatment facilities.

5. CONCLUSION

1) The origins of PAHs were mostly wood and coal combustion.
2) PCBs mainly come from industrial production.
3) OCPs mainly came from the excessive use of pesticides and fertilizers.
4) The ecological risk of POPs in the sediments was relatively low.

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O5-26

Long term monitoring of radiocesium in soybean field, Lake Kasumigaura basin

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Keywords: radiocesium, soybean, tillage, cover crop

ABSTRACT

The nuclear accident at Fukushima Dai-ichi Nuclear Power Plant (FDNPP) occurred as a consequence of the massive earthquake and associated tsunami on March 11, 2011, which was the first nuclear power plant accident in Asia [1]. A long term monitoring of radiocesium content in soybean and cover crops was conducted from 2011 to 2017 in soybean field (~170 km from FDNPP), Lake Kasumigaura basin, to clarify the changes of radiocesium in soybean and cover crops. From 2011 to 2017, soybean was cultivated from July to October and cover crops (fallow weeds, FA; rye, RY; and hairy vetch, HV) was cultivated from October to June with three tillage systems (moldboard plow, MP; rotary cultivation, RC; and no tillage, NT). Radiocesium content declined steadily in soybean grain from 2011 to 2014, however, this reduction slowed down from 2014 to 2017. Comparing with in MP and RC, radiocesium content in soybean grain under NT system was consistently higher in every year. Radiocesium content in three kind of cover crops also decreased sharply from 2011 to 2014 and became stable since 2015. Radiocesium content in rye was consistently lower than hairy vetch and fallow weeds. This research revealed that tillage can continuously reduce the radiocesium content in soybean grain for a long term, although in NT system still showed higher radiocesium content in soybean grain in Lake Kasumigaura basin.

1. INTRODUCTION

A large amount of nuclear material was leaked and scattered throughout Japan, at Fukushima Dai-ichi Nuclear Power Plant accident on March 11, 2011. The farm land in Lake Kasumigaura basin, Ibaraki prefecture was also be polluted seriously [1].

Radiocesium (Cs) is a radioactive isotope of cesium, the half-life of ^{137}Cs and ^{134}Cs were 30.17y and 2.062y, respectively. It is difficult to remove cesium from the soil due to the tight chelation of clay in soil and cesium [2]. So though more than 7 years passed after Fukushima Dai-ichi Nuclear Power Plant accident, the radiocesium content is still high in farmland. This nuclear accident has different radionuclide movement in agroecosystem compare with Chernobyl Accident in 1986. We focuses the long term radiocesium movement in agroecosystem in Japan especially the relationship between tillage inversion and radiocesium contamination. This information will be important to many country and area where the nuclear power plants are located. Therefore, in this study, we monitored the radiocesium contamination in soybean and cover crops under different agriculture managements from 2011 to 2017. The objectives of this study were to clarify the change of radiocesium content in soybean and cover crops under different tillage systems.

2. METHOD

A 7-years field experiment was conducted from 2011 to 2017 at Center for International Field Agriculture Research and Education (36° 1′ 57.7″ N, 140° 12′ 43.6″ E) in Ibaraki University, this site located 170km from FDNPP in the Kanto region of Japan. Split plot experimental design with 4 replications was used in this study. Tillage systems (Moldboard Plow: MP, Rotary Cultivation: RC, No Tillage: NT) were the main factors and cover crop species (rye: RY, hairy vetch: HV, fallow: FA) were side factors. Soybean was cultivated from July to October and cover crops was cultivated from October to June from 2011 to 2017. Soybean and cover crop samples were collected by a 0.25 quadrate. Cover crop biomass and soybean yields were calculated. The concentration of ^{134}Cs and ^{137}Cs in soybean grain and cover crops were determined by Ge-semiconductor detector. Transfer factors (TF) relating soil concentrations to plant concentrations of contaminants were calculated as follows:

$$TF = \frac{(^{134,137}\mathrm{Cs(Bq\ kg^{-1}\ dry\ weight)})_{plant}}{(^{134,137}\mathrm{Cs(Bq\ kg^{-1}\ dry\ weight)})_{soil}}$$

3. RESULTS

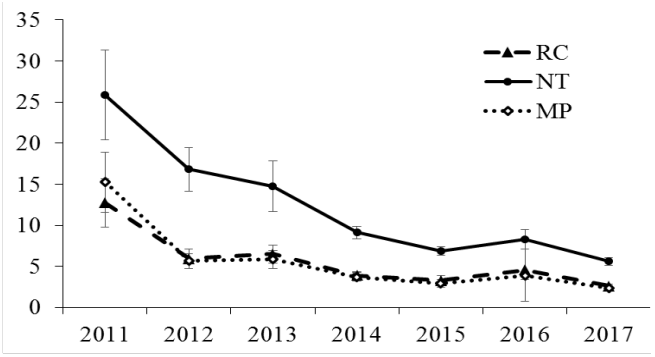

Figure.1 radiocesium content in soybean grain under different tillage systems was measured from 2011 to 2017. Error bars correspond to standard error.

Radiocesium content continuously decreased in soybean grain from 2011 to 2014(Figure.1). In NT, radiocesium content decreased from 25.86 to 9.10 Bq/kg; in MP, it even decreased by 4.13 times from 2011 to 2014. However, this tendency slowed down from 2014 to 2017. Radiocesium content only decreased from 6.9 to 5.6 Bq/kg in NT, and no significant difference was observed from 2014 to 2017 in MP. Rradiocesium content in soybean grain had no significantly difference between in MP and RC, while in NT system was consistently about 2 fold higher than those in MP and RC in every single year.

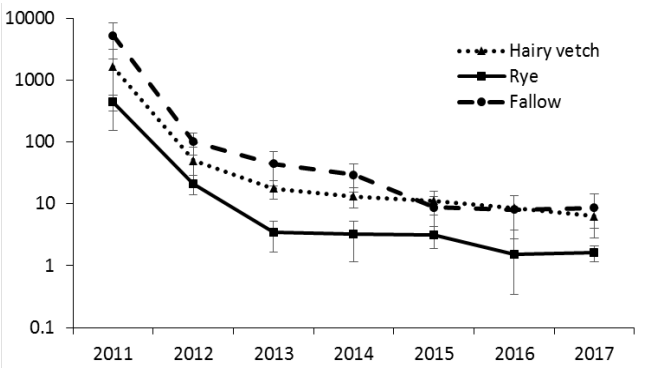

Figure.2 radiocesium content in different cover crop species was measured from 2011 to 2017. Error bars correspond to standard error.

In 2011, radiocesiun content in three kind of cover crops peaked at 428.9 to 5268.2 Bq/kg, which was significantly higher than those in other year (Figure.2). And radiocesium content fell sharply from 2011 to 2014, in fallow weeds, it decreased from 5268.2 to 29.5Bq/kg. Then it became more stable since 2015, no significant difference was observed in fallow weeds since 2015 to 2017. Radiocesium content in different cover crop species was also different, comparing with those in hairy vetch and fallow weeds, radiocesium content in rye was consistently lower from 2011 to 2017. However, the gap between radiocesium content in rye and those in hairy vetch and fallow weeds narrowed considerably over the 7-years period.

4. DISCUSSION

Radiocesium content decreased in soil with each passing year after FDNPP accident, due to the natural decay and migration [3], therefor the radiocesium in soybean also decreased generally. However, the content of ^{134}Cs decreased sharply after several years because of natural decay, and the natural decay of ^{137}Cs was slow, so the radiocesium content in soybean become stable from 2014. Comparing with in MP and RC, radiocesium content in soybean grain under NT system was consistently higher in every single year. Because tillage can displace the high contaminated soil into deeper layers, and it can also enhance the formation of Cs-specific edge sites with clay minerals for chelation [3]. In 2011, the nuclear materials was contacted with cover crop directly from atmosphere, so the radiocesium content in cover crop in 2011 was significantly higher than other years. Frissel et al.(2002) legume crop had higher radiocesium accumulation ability than other grass crop [4], the similar phenomenon was also found in this research.

5. CONCLUSION

After the FDNPP accident, the radiocesium contamination in soybean and cover crops continuously decreased from 2011 to 2014, but this trend gradually slowed down from 2014 to 2017. Legume cover crop had higher radiocesium accumulation ability than grass crop. Tillage can reduce the radiocesium contamination in soybean grain from 2011 to 2017.

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O5-27

霞ヶ浦周辺環境における薬剤耐性菌の分布

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キーワード: 土地利用管理、食糧生産、薬剤耐性菌、テトラサイクリン、有機質資材

抄録

近年、薬剤耐性菌の自然環境中への流出が問題視されてきている。当研究グループでは霞ヶ浦水域とその周辺農耕地における薬剤耐性細菌の分布や動態を明らかにすることを目的として、特に安価で感染症に効果があり、畜産業の現場で飼料添加物として広く利用されているテトラサイクリン（TC）を標的抗生物質として調査を行った。霞ヶ浦周辺では環境中に一般的であり、優占していると考えられる細菌である *Gammaproteobacteria* 綱細菌、*Betaproteobacteria* 綱細菌や *Alphaproteobacteria* 綱細菌で TC に耐性を示す細菌が多く分離され、さらにそれらが環境中に広く分布していることが明らかとなった。霞ヶ浦周辺の水域・土壌圏生態系に TC 耐性細菌が拡散していることが顕在化され、それら TC 耐性細菌が定着していることが示唆された。

1. はじめに

霞ヶ浦は茨城県南東部にあり、日本第 2 位の湖面積（220 km^2）をもつ淡水湖である。霞ヶ浦が位置する茨城県南東部は養豚業が盛んな地域であり、豚への飼料添加物として抗生物質が使用されている。昨今、飼料添加物の薬剤や家畜体内で増殖した薬剤耐性菌が糞尿を介して環境中に拡散し、薬剤耐性菌による環境汚染が懸念されている。中でもテトラサイクリン（TC）は安価で一般的な抗生物質として使用量が多く、医療現場に限らず自然環境中でも耐性菌が多く報告されている。家畜糞尿中に含まれる薬剤や薬剤耐性菌が、農耕地への糞尿の資材としての施用や地下水脈を通して霞ヶ浦流域に拡散している事が考えられる。

細菌に薬剤耐性能を付与する遺伝子は、トランスポゾンやプラスミドなどの可動性遺伝因子、また細菌の接合伝達によって、種の異なる細菌間で拡散すると報告された[1]。リボソーム保護タンパク質をコードする遺伝子（*tetW*、*tetM*、*tetO*、*tetQ*）によって耐性能を付与することが知られている。特にトランスポゾンに挟まれた *tetW* は、異種の細菌間で伝播することが報告された[2]。本研究では、霞ヶ浦水域とその周辺の農耕地における薬剤耐性細菌の分布と動態を明らかにすることを目的として、霞ヶ浦流域に生息する抗生物質耐性菌を分離し、その耐性遺伝子の分子生態学的解析を行った。

2. 方法

2-1. サンプル採取

水試料は茨城県北浦とその上流域の 4 地点（図 1）で 2010 年 4 月から 2011 年 2 月にかけて 1 ヶ月に 1 回の間隔で柄杓を用いて採取を行い、また 2013 年 5 月にも同地点で同様に採取した。土壌試料は 2013 年 12 月に茨城県南東部の堆肥施用履歴のない畑（休耕地）、2014 年 3 月に畑地、また 2014 年 9 月には畑地（施設栽培）で表層から 10mの土壌層位をボーリング採取した。さらに 2017 年 6 月、7 月、9 月に茨城大学農学部附属フィールドサイエンス教育研究センター（FSC）の田畑圃場で、有機質資材（牛糞堆肥）が施用された施肥区と無施肥区の表層 0-10cm から土壌を採取した。



図 1. 霞ヶ浦およびサンプル採取地点
LK，水試料採取地点（北浦）；CP1-4，水試料採取地点（北浦上流域）；FA，ボーリング採取地点（畑地）；FO，ボーリング採取地点（林地）；RF，土壌採取地点（施肥区）；RN，土壌採取地点（無施肥区）

2-2. 細菌数測定とその分離および系統解析

水試料の生菌数測定には、R2A 培地[3]と NB 培地を用い、土壌試料には PTYG 培地[4]を用いて行った。

TC 耐性菌数の測定および分離には、2010-2011 年採取の水試料については終濃度 0, 30, 60, 90, 120 μg/mL のテトラサイクリン塩酸塩を添加した培地を用い、それ以外の試料全ては終濃度 0, 20 μg/mL のテトラサイクリン塩酸塩を添加した培地を用いて行った。分離された TC 耐性菌から DNA を抽出し[5]、16S rRNA 遺伝子を標的としたシークエンス解析によって系統解析を行い[5]、MEGA7 を用いて系統樹を作成した[6]。

2-3. TC 耐性遺伝子の PCR 増幅

土壌中の TC 耐性遺伝子の検出を目的としてリボソーム保護タンパク質をコードする TC 耐性遺伝子である、*tetW*、*tetM*、*tetO*、*tetQ* を標的にしたプライマー[7]を利用し、土壌から抽出した DNA を用いて TC 耐性遺伝子の PCR 増幅を行った。

3. 結果

3-1. TC 耐性細菌の出現率

2010－2011 年の 2 年間の調査では、霞ヶ浦の水域における TC 耐性細菌の計数および分離の結果、TC 耐性菌数は 1.9×10^3 ~ 2.9×10^6 CFU/mL であり、生菌数に占める TC 耐性菌の割合は検出限界以下から 5.78%の間で変動した。7 月から 9 月の夏期において生菌数に占める TC 耐性菌の割合（出現率）は最大で約 6%であり、他の月では約 1%前後であった（図２）。また、2013 年 5 月の調査では TC 耐性菌の出現率はどの地点においても 1%以下であった。

3-2. 水域圏から分離された TC 耐性細菌

霞ヶ浦水域における調査で分離された TC 耐性菌全 110 株の 16S rRNA 遺伝子解析の結果、105 株がグラム陰性菌であり、グラム陽性菌は 5 株のみであった。分離されたグラム陰性 TC 耐性菌は *Serratia* 属、*Chryseobacterium* 属、*Burkholderia* 属など様々な種類に属していた。そのうち半数以上が Proteobacteria 門 *Gammaproteobacteria* 綱に属する *Serratia marcescens* に近縁であった。さらに、Bacteroidetes 門に属する *Chryseobacterium* 属、*Elizabethkingia* 属など以前まで *Flavobacterium* 属に含まれていた魚類の病原菌が多くを占めることが示された[8]。

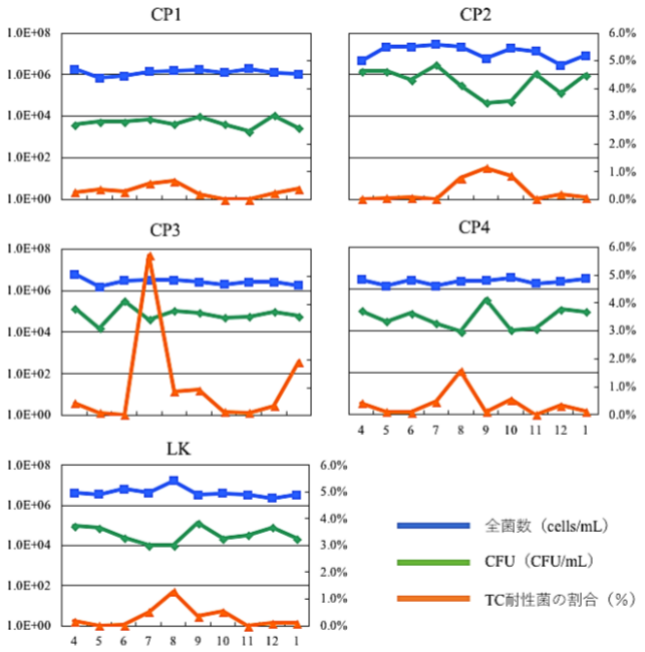

図 2. 霞ヶ浦流域 5 地点の水試料の全菌数，生菌数，TC 耐性菌の割合の季節変動

3-3. 農耕地土壌から分離した TC 耐性細菌

土壌圏では全 72 分離菌株について水域と比較して同じ Proteobacteria 門でも、土壌に広く分布するとされる *Betaproteobacteria* 綱や *Alphaproteobacteria* 綱に属する *Bradyrhizobium* 属や *Burkholderia* 属、*Xanthomonadaceae* 属の細菌などが 87.5%を占めていることが示された（表 1）。さらに 2015 年の調査では、霞ヶ浦流域の土壌中から最大で約 2%の TC 耐性細菌が検出された。

3-4. TC 耐性遺伝の PCR 増幅

2017 年の農耕地における調査では、有機質資材を施用している場合と不施用の場合では、施用地で TC 耐性菌の CFU は有意に高い値を示した。さらに、TC 耐性遺伝子領域を標的とした PCR 増幅の結果、有機質資材には TC 耐性遺伝子の存在が示された。

4. 考察

霞ヶ浦流域では環境水と土壌に TC 耐性菌が広く分布していることが示唆され、生息する TC 耐性細菌群集に違いがあることが示された。環境水では *Gammaproteobacteria* 綱の中でも腸内細菌であり、医療の現場では日和見感染菌として知られる細菌が多く分離された[9]。一方、土壌からは特に *Betaproteobacteria* 綱や *Alphaproteobacteria* 綱の土壌で頻繁に検出される細菌が多く分離された[10]。いずれのサンプルにおいても検出された細菌は環境中か

表 1. 水域および土壌から分離されたテトラサイクリン耐性細菌

Class and Order	Genus	Sites		Total number
		Soil	Water	
Alphaproteobacteria				
Rhizobiales	*Bradyrhizobium*	22	2	24
	Phyllobacterium		1	1
Rhodospirillales	*Skermanella*	1		1
Caulobacterales	*Caulobacter*		4	4
Betaproteobacteria				
Burkholderiales	*Burkholderia*	34	3	37
	Polaromonas	1		1
	Variovorax	5		5
	Burkholderiales bacterium		3	3
Gammaproteobacteria				
Enterobacteriales	*Serratia*		57	57
	Providencia		3	3
	Enterobacteriales bacterium		5	5
Xanthomonadales	*Lysobacter*	4		4
	Xanthomonadales bacterium	1	3	4
Pseudomonadales	*Pseudomonas*		1	1
Bacilli				
Bacillaceae	*Bacillus*		3	3
	Paenibacillus	2		2
	Bacillaceae bacterium	1	1	2
Flavobacteriales	*Chryseobacterium*		16	16
	Elizabethkingia		3	3
Actinobacteria				
Actinomycetales	*Brevibacterium*		1	1
Streptomycetales	*Streptomyces*	1		1
Sphingobacteria				
Sphingobacteriales	*Sphingobacterium*		4	4
Total number		72	110	182

ら高い頻度で分離される。それらの細菌は TC 耐性能を保持することが明らかとなった。

薬剤耐性遺伝子は比較的他の細菌に伝播しやすく、TC 耐性遺伝子でもその伝播は確認されている[2]。環境中で優占していると考えられる細菌が薬剤耐性遺伝子をもつことは、未分解の TC 残渣が混入した圃場で TC 耐性細菌の急激な増殖・拡散の可能性が高まる[11]。また、農耕地において施用される有機質資材に TC 耐性遺伝子が確認されたことから、資材を農耕地に施用することで土着の TC 耐性能をもたない細菌でも TC 耐性能を獲得する可能性がある。さらに、環境中の細菌に留まらず、人間や動物の腸内細菌や病原菌に TC 耐性遺伝子が伝播することで、医学的な面でも深刻な問題を引き起こすと懸念される。

5. 結論

本研究から霞ヶ浦のような淡水や霞ヶ浦周辺の農耕地土壌に生息する TC 耐性細菌の分布および TC 耐性遺伝子の種類について新たな知見が得られた。今後、自然環境中における TC 耐性細菌群集の動態や遺伝子伝播機構に関する研究の継続が必要である。

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TS6-1

摩周湖 － 鋭敏でありかつ安定である湖における環境記録の読み取り

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キーワード:摩周湖, 透明度, 長期変動, 微量分析, 安定同位体

抄録

摩周湖は北海道東部にある複循環を示すカルデラ湖で, 流出入河川のない閉塞湖である。1931 年に 41.6m の透明度を記録し, 長く陸水における世界最大の透明度を示していた, 集水域内には農業を含む一切の人為汚染源はない。例えば, 湖水中の有害元素等の濃度は極めて低く, モニタリング対象としてチャレンジングであるとともに, 世界的にも希有な観測フィールドと言える。そのため, 摩周湖は国連環境計画 GEMS/Water において, 国内唯一のベースラインモニタリングステーションに登録されている。国立環境研究所を主体とする観測が, 唯一の科学的モニタリングである。

ここでは, 3 つの研究結果について発表する。1)厳しい自然環境における連続データの採取による高い透明度の生成機構と透明度の年間変動の推定について。2)水収支や湖水の成分の高精度・高感度測定を通じた長期的変動の検出について。3)鉛同位体の精密測定によるさらに長期の環境変動の解析について。

1. はじめに

摩周湖は北海道の東部(北緯 43 度, 東経 144 度), 阿寒摩周国立公園内に位置し, 湖面を含む集水域全域が国立公園特別保護地区に指定されている。最大水深は 212 m で, カルデラ湖の特徴として湖底面は比較的平坦である。湖面は比高 100 mを超える切り立った崖で覆われており, 流出入河川のない閉塞湖である。

観光客は展望台から湖面を望むだけで, 湖面への立入は自粛されている。加えて, 集水域内での農業・林業を含む一切の人為的活動はなく, 流入による人為汚染源は極めて乏しい。春秋の 2 回, ほぼ全層混合をする複循環で, 厳冬期には結氷することも多い。

高安・近藤は1931年に41.6 mの透明度を記録した[1]。これは, 長く陸水における世界最大の透明度であった。一方, 長期にわたる透明度の低下傾向があり, 地元自治体や観光業にとっての懸念事項となっている。

湖水中の栄養塩, 水銀などの有害元素や残留有機物質等の濃度は極めて低い。このことから, 摩周湖は国連環境計画が進める陸水監視プログラム(GEMS/Water)において, 国内唯一のベースラインモニタリングステーションに登録されている。国立環境研究所を主体とする機関が, 過去 30 年以上, 物理的, 化学的, 生物的観測を行ってきた。これは摩周湖における唯一の水質モニタリングデータと言える。観測結果は, GEMS/Water のデータベース(GEMStat)に登録するとともに, 国立環境研究所のホームページにおいてデータ公開している[2]。

2. 方法

摩周湖での水質調査の地点等の概要を図 1 に示した。中央火口丘であるカムイシュ島により, 南北 2 つの湖盆に分かれている。我々の調査は主として北側湖盆に位置する最深部で行っている。小規模調査では, 南側湖盆や, 比較的岸に近い地点を調査地点とした。

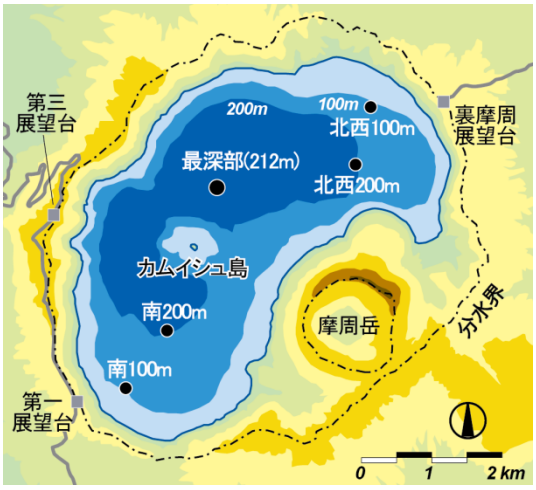

図 1 摩周湖の概観と主な調査地点

湖水中の成分分析法は, ICP 発光分光法(AES), ICP 質量分析法(MS), 吸光光度法, イオンクロマトグラフィ(IC), GC/MS をはじめ, 多岐にわたる。光学観測は, 輝度・照度・スカラー照度(TriOS 社), プロファイリング及び係留による観測は, クロロフィル・濁度・水中光量子・水温計(JFE アドバンテック)によった。水深 20 m と 40 m に測器群を配置し, ブイを含め全体を水中に沈めた。別途, Onset 社等の水温ロガーを複数台係留している。

特記すべき方法は，以下のとおりである。微量ニッケルは溶媒抽出後，同位体希釈 MIP-MS，鉛同位体比は精製後，多重検出器型(MC)ICP-MS によった。湖水のほかにも，湖底堆積物や湖沼周辺の湧水・河川についても採取，観測を行っている。

3. 結果・考察

図 2 に摩周湖に特徴的な項目の鉛直分布を示した。硝酸態窒素は貧栄養であることを端的に示す。0.04 mg/kg 程度の濃度であり，吸光光度法では検出困難なレベルであった。夏季には生物に利用され大きく減少する。溶存酸素飽和度は，底層直上まで 80%以上を示し，底質からの栄養塩の溶出も少ないと推定される。

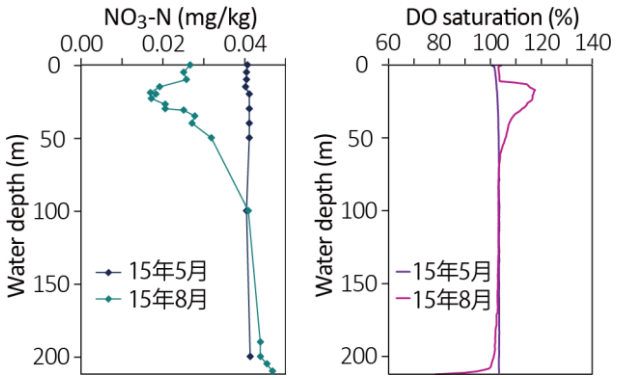

図 2 硝酸塩と溶存酸素飽和度の鉛直分布（2015 年）

1）係留観測による透明度の年間変動の推定と高い透明度の形成機構

湖面に出ることが難しい厳冬期を含む通年観測には，データロガーを用いた連続観測が必須となる。図 3 に，2015 年の 1 年間の水温の変動を示した。この年は，5 月及び 12 月末にほぼ全層循環していることがわかる。

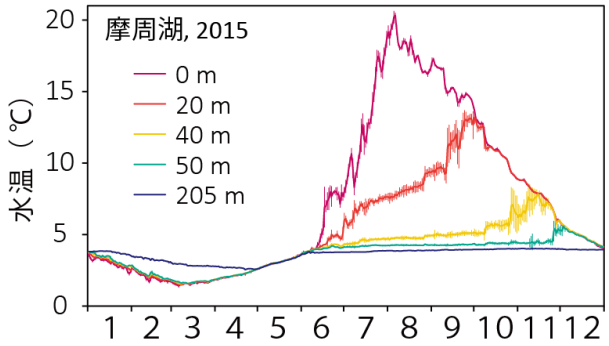

図 3 摩周湖水温の年間変動（2015 年）

また，2015 年 8 月の吸収係数の二次元分布を図 4 に示した。この時の透明度は 17.2 m であり，波長 400 nm 近傍に代表されるクロロフィルによる吸収が顕著であり，透明度はこのような植物プランクトンの極大層に大きく影響されることが示されている。図 3 と同期間の推定透明度を図 5 に掲げた。透明度は，異なる深度に係留した光量子ロガーの指示値から求められた下向き減衰係数を利用して推定した。夏季の植物プランクトンの増殖とともに，クロロフィル濃度が極大を示し，循環期に極小となる。栄養塩濃度が低く，生物粒子量の少ない底層水の湧昇によって，光透過性が上がり，透明度が上昇する。図に〇で示した実測透明度との一致が高いことも確認できる。

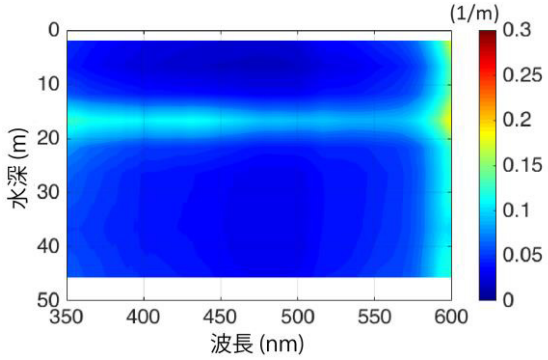

図 4 摩周湖水の吸収係数（2015 年 8 月）

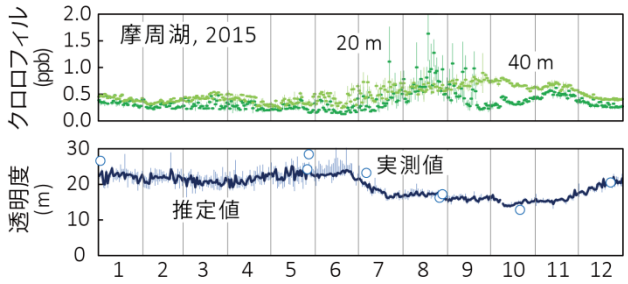

図 5 クロロフィルと透明度推測値の年間変動

（2015 年。○は実測値）

2）湖水成分の高精度・高感度測定と長期的変動

図 6 に成層期（2017 年 9 月）のマグネシウムの鉛直分布を示す。この鉛直プロファイルには 3 つの特徴がある。表層部の低濃度は，雨水による希釈効果を示す。粒子化による除去や生物による同化が起きにくいマグネシウムは，中層部では完全に一定の濃度となる。底層部の高濃度は，溶存成分に富んだ湖底湧水からの負荷を示す。

このことは，イオン成分に限らず，微量汚染成分等にもあてはまる。循環期と成層期との鉛直プロファイルの変化から，当該期間内の湖面への物質流入の有無や単位時間あたりの負荷量に関する情報を与える。

一方，図 7 に示したニッケルの鉛直分布の場合，通常の ICP-MS では検出が困難な濃度レベルであり，濃縮操作を必要とした。有機溶媒を直接導入する同位体希釈 MIP-MS 法を適用することで，高精度かつ高感度な観測が可能となった[3]。これによると，燃焼起源の指標元素であるニッケルは，水温躍層上部に濃集することが多く，大気経由の負荷物が蓄積，除去されるプロセス

を示していると考えた。

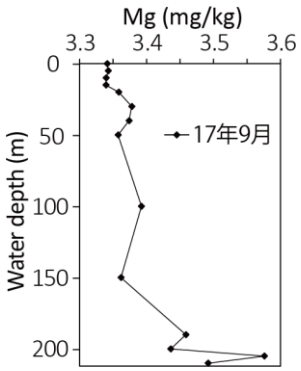

図 6 マグネシウムの鉛直分布（2017 年 9 月）

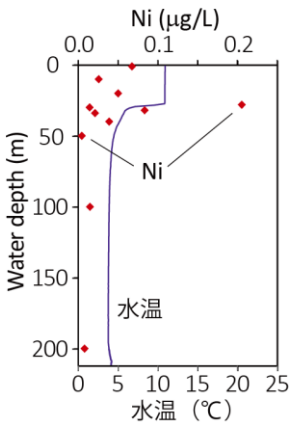

図 7 ニッケルの鉛直分布（2007 年 10 月）

摩周湖水は外輪山外の周辺湧水へ流出しており，同位体混合モデルや水収支から 120 年程度の長い滞留時間を持つと推定されている。また，SF_6 等のガス成分の輸送モデルからも数十年かけて流出することが推測されつつある[4]。

鉛直プロファイルで例示したように，摩周湖は大陸間の長距離輸送などについて，年々の負荷情報に鋭敏に応答する特性を持っている。このためには，変化を検出する相対的な高精度分析，あるいは微量成分を定量する高感度分析法を必要とする。一方，長い滞留時間を有することは，平均濃度（観測では，中層部の濃度）の年変化は 0.1%を大きく下回ることになる。この点で，摩周湖は非常に安定な湖と言うことができる。

摩周湖においては，30 年以上にわたって観測を続けており，分析者，分析手法ともに変化している。表 1 にマグネシウム濃度の分析例を示した。相対精度（再現性）にくらべて，正確性を伴う絶対精度を確保することは難しい。自然の濃度変化を検出するには，それを上回る正確な分析技術を維持することが求められる。分析者や手法，標準物質の供給体制などの問題から，これを実現することは極めて困難な課題である。濃度比を用いた解析は，1 つの有効な対策であろう。

表 1 摩周湖水中のマグネシウム濃度の長期観測値

観測年	中層平均濃度 (mg/kg)	n	方 法
1931[1]	3.92	3	滴定法
1983	3.55	7	原子吸光法
1992	3.20	10	ICP-AES
2017	3.38	7	IC

3）鉛同位体比の精密測定による長期間の環境解析

さらに過去にさかのぼった環境解析には，湖底堆積物を利用することが一般的であろう。流入河川のない摩周湖の場合，年間 10 mg/cm^2 程度の遅い堆積速度となる。柱状堆積物試料を用いることで，過去数百年までの情報が得られた。

代表的な汚染物質である鉛は，起源によって同位体比が比較的大きく変動することが知られている。図 8 に 2006 年に採取したの堆積物表層，中層，深層と底質標準物質（文献値[5]と実測値）の鉛同位体比を示した。

過去 30 年で，ICP-MS は飛躍的な進歩と普及をとげた。しかしながら，四重極型 ICP-MS による同位体測定精度では，底質の深さごとの同位体変動を正確に描けなかった。MC-ICP-MS による測定結果では，深層部は日本固有の鉛同位体比，表層部は海外由来の鉛の影響を受けて 1%程度異なる値，中層部では両者の中間的値が得られ，両成分の混合比が計算できる。

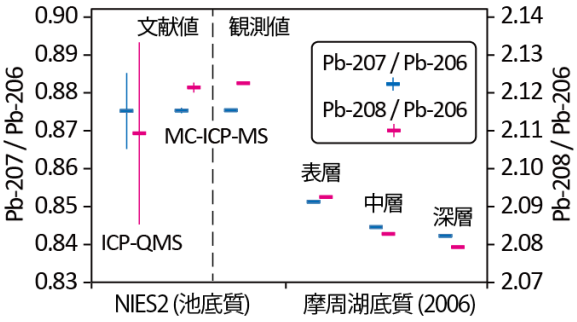

図 8 摩周湖底質と底質標準物質(NIES2)の鉛同位体比

4. 結論

世界的にも珍しい観測フィールドである摩周湖において，30 年間のモニタリング結果を概観した。

透明度については湖水循環と生物量が重要なキーとなっていた。物質負荷については，循環期と成層期との鉛直分布の差から評価できた。一方，滞留時間の長い摩周湖では，自然の微小変化を下回る正確性を持つ観測体制が必要となる。MC-ICP-MS のような高精度測定を行うことで，長期的な環境変動を底質から読み取ることも可能であった。

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TS6-1

Lake Mashu – How we revealed environmental records from a sensitive and stable lake

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Keywords: Lake Mashu, Secchi disk transparency, environmental changes, trace analysis, stable isotopes

ABSTRACT

Lake Mashu is a dimictic caldera lake located in the eastern part of Hokkaido, Japan. It is a typical closed lake with no inflowing nor outflowing rivers. In 1931, Lake Mashu recorded 41.6 m of Secchi disk transparency, which has been the largest transparency record exceeding that of Lake Baikal. There is no anthropogenic pollution sources including agricultural nor forestry activities inside the watershed. For example, concentrations of heavy metals and persistent organic substances in lake water are extremely low. Therefore the detection of trace components itself was a challenging monitoring objective and it can be said that Lake Mashu is a unique field for the environmental scientists. Lake Mashu is the sole lake registered as a baseline monitoring station in Japan at the UNEP GEMS/Water programme. Physical, chemical and biological observation by the National Institute for Environmental Studies and collaborating institutions is the only scientific monitoring of water qualities for the last three decades.

Three findings about the lake monitoring will be provided. 1) A mechanism of formation of large transparency, and reproduction of seasonal variation of transparency by planktonic evidences and continuous logging data in the severe environmental conditions. 2) An estimation of long term variation of lake water constituents through the isotopic and gaseous analysis of water balance and accurate and/or sensitive analytical methods for elements. 3) Examination of longer term environmental changes by a precise measurement of lead isotope ratios.

1. INTRODUCTION

Lake Mashu, located in the east part of Hokkaido (N43, E144), is a closed oligotrophic lake. It is dimictic and occasionally ice-covered in winter. The maximum depth is 212 m. The lake surface is surrounded by steep caldera walls exceeding 100 m in height.

The world largest Secchi disk transparency of 41.6 m was recorded in 1931[1]. The transparency decreased gradually. It is a concern for local governments and tourism.

There is no human activity such as agriculture and forestry in the catchment area, and anthropogenic pollution load is extremely small. Concentrations of nutrients, heavy metals, POPs in lake water are quite low. Therefore Lake Mashu has been registered as the only baseline monitoring station lake in Japan in the UNEP GEMS/Water programme. National Institute for Environmental Studies and collaborative institutions have conducted physical, chemical and biological observations for over 30 years. The monitoring data are registered to GEMStat database, and also available on the web[2].

2. METHOD

An overview of Lake Mashu is shown in Fig.1. A central volcanic cone, Kamuishu Is., divides lake bottom into two basins. Our survey is conducted mainly at the deepest part located in the northern basin. In the small scale observation, the survey site was chosen from the southern basin or the points close to the shore.

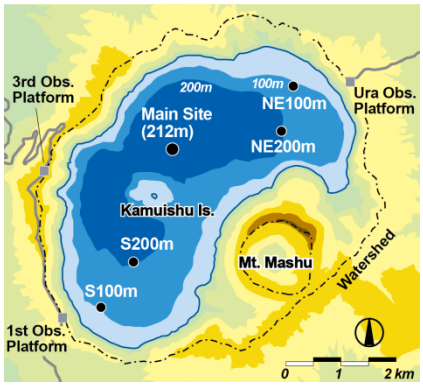

Fig. 1 Overview of Lake Mashu

Constituents were analyzed mainly by ICP-AES, ICP-MS, spectrophotometry, ion chromatography (IC), GC/MS. Optical data were recorded on TriOS instruments. Data loggers for chlorophyll, turbidity, photon flux and water temperature (JFE Advantech) were used for profiling and mooring. Instruments were moored at water depths of 20 m and 40 m, and the whole system including buoys was submerged in water. Several water temperature loggers

(Onset and JFE Advantech) were also moored.

Notable methods are as follows. Trace Ni was solvent extracted and determined by isotope dilution MIP-MS, Pb isotope ratios were analyzed by multiple collector (MC) ICP-MS. Spring and river waters around the lake, and lake sediment samples were also analyzed.

3. RESULTS AND DISCUSSION

Two vertical profiles characteristic to the oligotrophic state were depicted in Fig.2. The concentration of NO_3-N was as low as 0.04 mg/kg, which was difficult to detect by spectrophotometry. It seems to be deficient around 20 m where photosynthesis activity is dominant in summer. Dissolved oxygen was abundant down to the bottom and elution of nutrients from the sediment was limited.

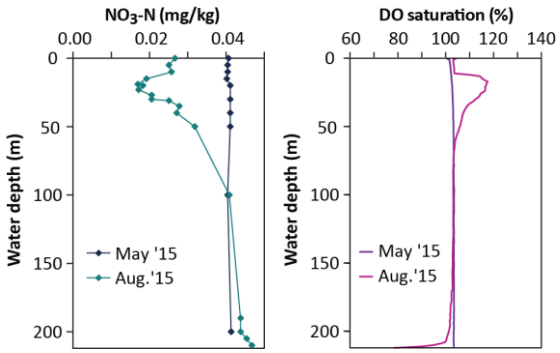

Fig. 2 Profiles of nitrate and DO saturation (2015)

1) Mechanism of formation of high transparency

Continuous data using data loggers are essential for full year observation including severe winter season when it is difficult to reach to the lake surface. Figure 3 shows a seasonal variation of water temperature in 2015. Perfect mixing occurred twice a year in May and the end of December.

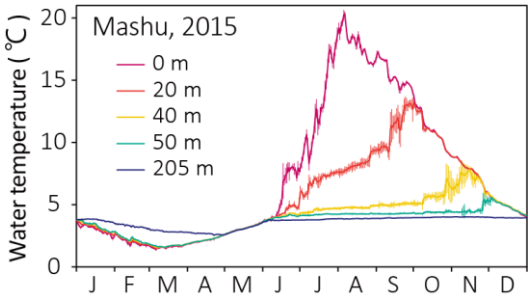

Fig. 3 Time variation of water temperature (2015)

A two-dimensional distribution of the absorption coefficient in August 2015 is shown in Fig.4. Relatively high absorption band was found near the transparency depth of 17.2 m and it corresponded to the chlorophyll maximum. Prominent absorption around 400 nm also corresponded to the absorption band for chlorophylls. Temporal variations of chlorophyll and transparency in 2015 are shown in Fig.5. Transparency was estimated using the downward attenuation coefficient obtained from the readings of two photon flux loggers moored at different depths. The estimated transparency agreed well with the observed transparency indicated by ○ in the figure. From July to September, concentration of chlorophyll, indicating phytoplankton biomass, was maximized at the shallower depth and it becomes minima in the circulation periods. Concentrations of nutrients and biological particles are low in the bottom layer water. When it upwells, the light permeability and transparency increase.

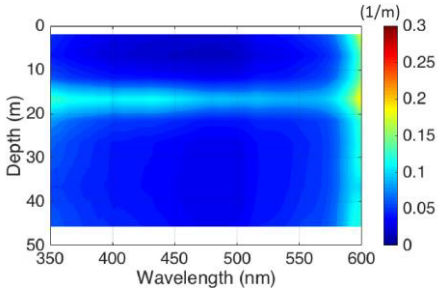

Fig. 4 Distribution of absorption coefficient (Aug. 2015)

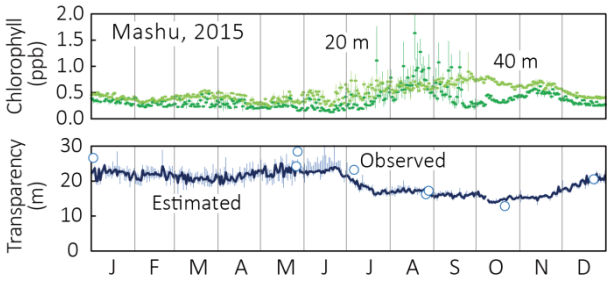

Fig. 5 Time variation of chlorophyll and estimated transparency (2015)

2) Need for accurate and/or sensitive measurement

Figure 6 shows a vertical profile of dissolved Mg in the stratification period (Sep. 2017). This vertical profile has three features. The low concentration in the surface layer is attributed to the dilution effect by rainwater less abundant than lake water. Magnesium is one of conservative elements and assimilation by organisms is low. Constant distribution in the middle layer was found. The high concentration near the bottom is attributed to the load from the bottom spring affected by volcanic activities.

This applies not only to ionic components but also to trace contaminants. From the change of vertical profiles between the circulation period and the stratification period, we can detect the event such as addition, decomposition or removal of material fallen onto the lake surface after the last circulation, and the flux can be calculated.

On the other hand, concentration of Ni is too low for conventional ICP-QMS equipping Ni interface due to an interference of molecular ion. By a combination of solvent extraction of Ni chelate and isotope dilution for the preconcentration, organic phase can be directly introduced to nitrogen plasma MIP-MS equipping Pt cone. By developing this method, precise and sensitive determina-

tion became possible[3]. Nickel, which is an indicator of combustion, often concentrated in the upper part of thermocline (Fig.7), indicating the process of atmospheric load and accumulation in the water column.

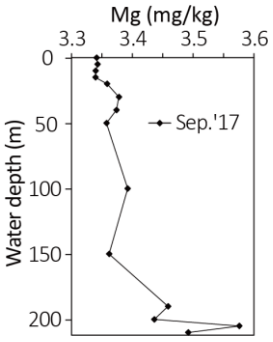

Fig. 6 Profile of Mg (Sep. 2017)

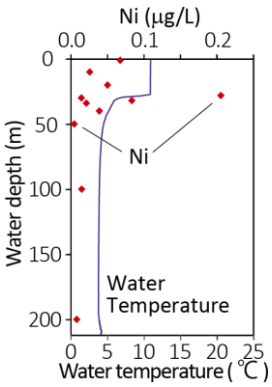

Fig. 7 Profile of Ni (Oct. 2007)

Lake water flows through the outer rim of crater and flows out as surrounding springs. A long residence time of about 120 years was obtained from the water balance and isotope mixing model. It is estimated that the age of spring water is over several decades from the transportation model of gaseous components such as SF_6 [4].

As exemplified in the vertical profile of Mg, Lake Mashu has characteristics that respond sensitively to a load of long-range transported material or supply from the bottom. To fulfil this purpose, a precise analytical method to detect the change or a highly sensitive technique to determine ultratrace components is required. On the other hand, having a long residence time implies that the annual change of the average concentration (appearing in the middle layer in the observation) is far less than 0.1%. In this respect, Lake Mashu can be said a very stable lake.

During the monitoring of Lake Mashu over 30 years, both analysts and analytical methods varied. An example of Mg results is shown in Table 1. It is difficult to ensure absolute accuracy, as compared to relative precision (repeatability). To detect natural minute changes, it is required to maintain accurate and precise analytical techniques over the years. It is an extremely difficult task to realize this because the analytical conditions (analysts, methods and even standard substances) change. Analysis using concentration ratios normalized with one component would be an effective measure to detect natural changes.

Table 1 Analytical values for Mg for a long period

Year	Mean concentration of middle layer (mg/kg)	n	Analytical method
1931[1]	3.92	3	titration
1983	3.55	7	AAS
1992	3.20	10	ICP−AES
2017	3.38	7	IC

3) Sedimentary records of lead isotopes

Sediment it often utilized for a retrospective analysis. However, because of the lack in inflowing rivers and narrow catchment area, the sedimentation rate is as low as 10 mg/cm^2/y. By using sediment core samples, information up to the past hundreds of years was obtained.

Lead, a typical pollutant, shows relatively large isotopic deviation depending on its origin. Figure 8 shows the lead isotope ratios of sediment in the surface, middle and deep layers collected in 2006, and of a sediment reference material (literature[5] and observed value).

In the past 30 years, ICP-MS has made a striking progress and become popular. However, it was almost impossible to distinguish isotopic variation precisely each other by ICP-QMS. According to the measurement by MC-ICP-MS, the deep layer has a Pb isotopic ratio inherent to Japan, the surface layer has a value different by about 1% affected by Pb overseas, and intermediate values were obtained in the middle layer. A mixing ratio of both components can be calculated.

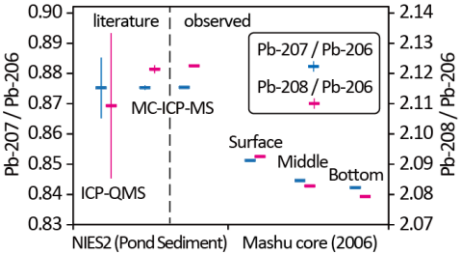

Fig. 8 Pb isotope ratios of Mashu sediment and CRM

4. CONCLUSION

Water circulation and biomass are important key factors which control transparency. It was possible to evaluate material flux from the difference in vertical distributions between the circulation and stratification periods. Due to the long residence time, it is required to maintain an accurate observation system lower than natural minute change. By conducting precise measurements by MC-ICP-MS, long-term environmental changes can be revealed from the sediment core.

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TS6-2

Integrated data, models and networks provide opportunities to advance lake science and predictions

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Keywords: GLEON, networks, high frequency data, databases, professional societies

ABSTRACT

The challenge to manage lakes under global change trajectories of increasing diffuse nutrient pollution, climate change and invasive species is intensifying. Network-based science will have an increasingly important role in addressing these threats to the sustainability and service provisions of lakes. Network science can increase the number and breadth of case studies, provide greater interdisciplinary coverage, and advance the uptake of novel technologies like high-frequency sensor monitoring. The Global Lake Ecological Observatory Network (GLEON) uses network-based science to seek to understand and interpret high-frequency sensor data from lakes across the world. Complimenting networks are databases like LAGOS-NE and Takiwa, which provide geospatially and temporally resolved databases for lakes at national scale (USA and New Zealand, respectively). New sensing technologies and practices, as well as greater accessibility of this information, are leading to dissemination of best practice approaches and implementation of systems to avoid 'reinventing the wheel' in terms of data acquisition and modelling tools. Global networks of researchers are well positioned to address the challenges of increasing availability of high frequency data but the synthesis studies that are enabled by these networks need to be directed towards improved process representations as well as statistical generalizations. Moreover, societies will continue to play an important role as persistent organizations to promote the profession, provide regular meetings and maintain the standards of disciplinary journals.

1. INTRODUCTION

Affiliations of water managers, scientists and engineers to international professional societies can have important career implications and provide opportunities to engage in dialogue about research agendas and sustainable water management practices. Nowadays, with global issues of water scarcity, floods, diffuse pollution and water quality impairment, there is a wide variety of networks and societies to support exchange of research ideas and develop management plans to deal with these issues. The objective of this study is to analyze a lake research network in the context of the evolving nature of professional scientific societies and research agendas, and to consider some of the advantages and disadvantages of trends towards more network-based science.

2. RESULTS AND DISCUSSION

Figure 1 outlines some of the scientific affiliations available to water science researchers and professionals. Four main affiliation categories have been identified:

(1) limnology-related networks,
(2) research coordination networks,
(3) international societies, and
(4) groups whose objective is mostly to organize international disciplinary meetings.

The foundation of international professional engagement is international societies like the International Lake Environment Committee Foundation (ILEC; http://www.ilec.or.jp/en/) and the Association for the Sciences of Limnology and Oceanography (ASLO; https://aslo.org/), but many societies have not maintained high rates of growth that occurred in the 1960s-80s and some appear to have reached ceiling numbers of members, or may even be declining[1]. The reasons for the existence of these societies are as important today as ever; to develop collegial networks, exchange knowledge, support early career scientists, and raise issues that are important for human society (e.g., to develop sustainable management of the world's lakes and reservoirs – ILEC).

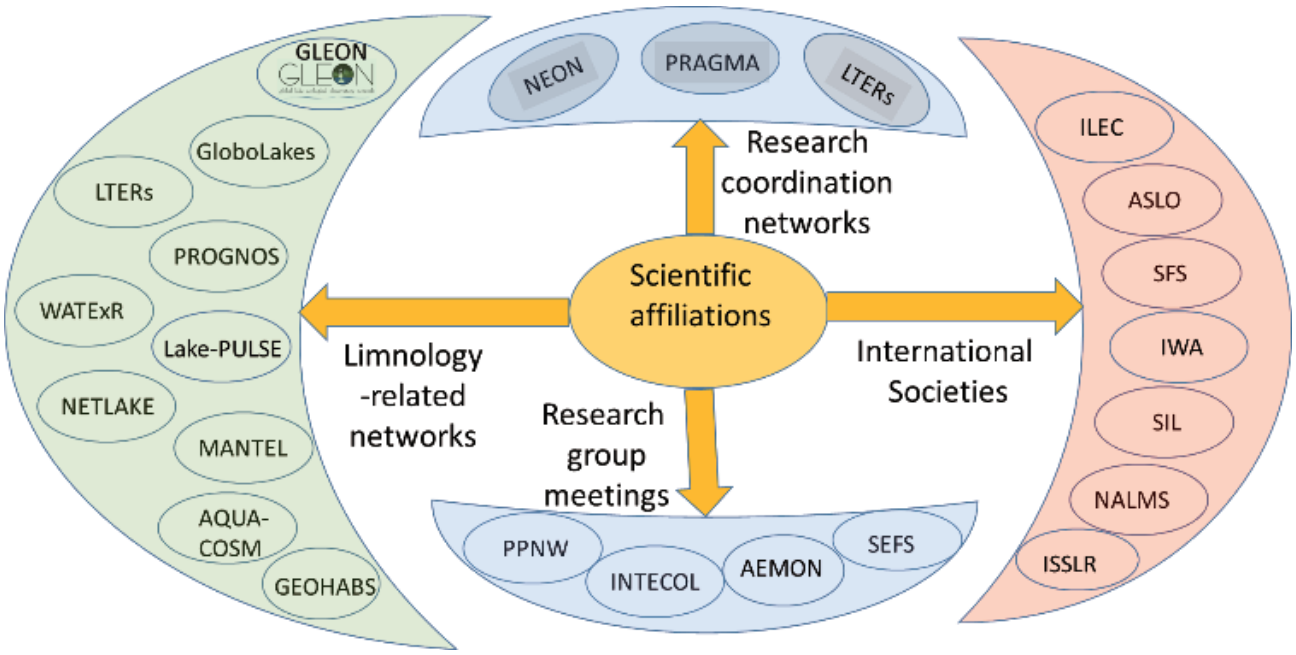

Fig. 1 Scientific affiliations that support researchers and water professionals, grouped by four categories

One of the reasons for the static nature of many societies is the advent of research networks, which are generally either dedicated to specific areas of research or to coordinating a body of research[2]. These networks have often been able to provide funding to support travel and meetings on a regular (e.g., biannual, annual) basis, and members do not generally pay a subscription – a basic tenet for membership of a society. The networks have been a means of focusing research on topical areas and bringing teams and diversity to research and management challenges. These aspects of team science, diversity and topical research issues are attractive to funding agencies[2]. However, networks tend to be temporary, often lasting the duration of a funding cycle, and for this reason they do not necessarily provide persistence and stability that are required to support careers in research and industry. For example, many international societies support scientific journal publications which are not the domain of networks. Even in this area, however, international societies have increased competition from independent publishers whose motivation is primarily profit-driven and who may be more responsive to the changing modes of publication (e.g., Open Access publication)[3].

The Global Lake Ecological Observatory Network (GLEON; www.gleon.org) is an example of a network that has been stable and persistent since its inception in 2005. It has grown to have over 800 members across the globe and it has well developed operating principles and procedures. GLEON is a grassroots organization that relies on locally supported high-frequency monitoring platforms in lakes and provides a coordinating network to synthesize and analyze the data arising from these platforms[4]. Some features of GLEON have been its ability to develop software to assist with analysis and interpretation of high-frequency lake data, and new insights into lake processes generated from the high-frequency data across a diversity of latitudinal, size and trophic state gradients.

Tools to analyze high-frequency lake data have evolved quickly in the GLEON environment. They include:

- VEGA, a program that allows storage of time series in an environment where lake sensor deployments and configurations may need to be highly flexible, and its component software VADER (VegA Data EditoR) – see www.gleon.org;
- B3 (Buoys 3) and dbBadger, software to carry out quality analysis/quality assurance of data – see www.gleon.org;
- A collaboration of GLEON with the Data Observation Network for Earth (DataONE – https://www.dataone.org/) to provide a data repository and archiving system;
- Analytical tools to examine specific lake processes using high frequency data, including rLakeAnalyzer[5] to quantitatively evaluate lake mixing zones and stratification; LakeMetabolizer[6] to carry out lake metabolism calculations (see www.gleon.org); and Lake Heat Flux Analyzer[7] to evaluate the constituents of lake heat fluxes with user flexibility in the equations that are used to parameterize the heat flux.

- Numerical modelling tools that are being used to simulate lake hydrodynamics and water quality, including the General Lake Model (GLM; www.gleon.org) and can link to other model developments like the Framework for Aquatic Biogeochemical Models (FABM)[8] to link ecological models to a number of different hydrodynamic models including GLM.

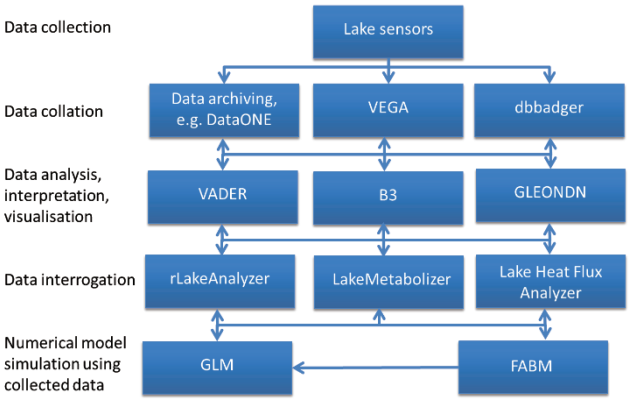

Fig. 2 Software tools developed and utilized in GLEON (Global Lake Ecological Observatory Network) to facilitate understanding of lake processes from lake sensor data. See text for descriptions of the tools and acronyms.

Increasingly, geospatial platforms are being associated with sensor and other lake data, as well as model outputs, to visualize data. Examples of these platforms include LAGOS-NE[9] and Takiwa (lakes.takiwa.co), which provide multi-scale geospatial and temporal resolution for lakes across the United States and New Zealand, respectively.

3. CONCLUSION

GLEON is an example of a lake research network that has been successful in terms of its longevity, engagement of early career scientists, and contributions to new understanding of lake processes using high frequency sensor data. It is more 'organic' in form than a professional society, which primarily promotes scholarly publications and disciplinary meetings. Through GLEON, many software tools have been developed to assist with processing, archiving, visualizing and modelling data. Efficiency gains have been made and cross-continental-scale studies have become possible through the network. At the same time, however, there is a need to encourage process-based understanding of lake systems and not solely statistical inference derived from the growing volume of lake data. A wider dialogue is required about how the acquired information can be used to contribute to some of the goals of ILEC based on promoting integrated lake basin management and contributing to some of the Sustainable Development Goals.

ACKNOWLEDGMENTS

This work benefited from participation in or use of the Global Lake Ecological Observatory Network (GLEON). I am grateful to colleagues in GLEON and the International Society of Limnology (SIL) with whom I have engaged in discussions about the role of societies and networks in promoting lake science.

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O6-1

Web Application for Examining Hydroclimate Information of Global Lake Basins: CGLB Using a latest world lake database

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Keywords: lake database, climate variabilities and disaster preventions and reductions, modeling, ILBM

ABSTRACT

More than 1 million of lakes are listed in the upgraded version of Web application, Climates of Global Lake Basins (CGLB). CGLB combines existing datasets and interactively displays geographical, hydrological, and climatological information for hundreds of lakes around the world. CGLB also provides landscape photographs provided by Global Confluence Project as well as quasi-real time monitoring of lake water levels using satellite altimetry provided by U.S. Department of Agriculture. CGLB can interactively create and animate time series of climatological data in a one-dimensional or two-dimensional (geographical) form. The listed lakes in the new version is based on the HydroLAKES provided. Other new features of the CGLB are: interactive drawing lake shapes, topography, land cover type, lake surface temperature, submonthly climatology in ClimatView developed by Japan Meteorological Agency. SQLite is embedded into the end program, allowing more than 1 million entry and search by key word. These functions are useful for education, expedition planning, and scientific research.

1. INTRODUCTION

Lakes has roughly 0.5% of the global land area[1] and hold more than 90% of the world's liquid freshwater in readily accessible bodies. Lakes are also one of the important components of hydrological cycles and at the same time have biogeochemical and ecological processes. In a changing climate under greenhouse gas emissions, these aspects will be affected by the global warming and will impact on human societies as well as on readily accessible water bodies.

Future projections of climates require the biogeochemical and ecological processes in lakes since they are embedded in the Earth system and interact with each other. Future projections of lakes require the lake information about their hydrological properties of distribution, volume and residence time. Therefore, global lake databases have been developed. Such databases are usually based on only the lake information because of their objectives. Public may want to know a climate in a target lake.

Then, we developed web application, Climates of Global Lake Basins (CGLB; http://hydro.iis.u-tokyo.ac.jp/CGLB/), combines existing datasets and interactively displays geographical, hydrological, and climatological information for hundreds of lakes around the world in 2015[2]. The lake information in CGLB is based on the World Lake database (WLDB) [3]. Unique features of WLDB is comprehensive information about lakes from geographical information to biogeochemical one but lists only about 650 lakes. The number of the lakes in WLDB for each country is distinctly biased since they are selected as important order for people.

Recently, a new lake database, HydroLAKES has been developed with more than 1 million entry[4]. We upgraded CGLB based on HydroLAKES.

2. WEB APPLICATION

We designed CGLB as provision of climatological information for a target lake basin so that one who want to look into the lake basin can obtain the information interactively for each own purpose.

SQLite is employed to deal with more than 1 million entry. SQLite is a relational database management system and often embedded into the end program but not client-server database engine.

New features of the CGLB are summarized below:

- replace of base lake geo-spatial information: HydroLAKES; more than 1 million lakes are listed in CGLB and other components such pouring points are newly included in CGLB,
- figures of lake shapes with either elevation or land cover type can be drawn interactively,
- Lake surface temperature can be drawn in one- or two-dimensional time series,

- link to submonthly climatology in ClimatView developed by Japan Meteorological Agency: daily data can be seen but the number of the stations are small, and
- SQLite is embedded into the end program, allowing more than 1 million entry and search by keywords.

3. CASE STUDY

We demonstrate what CGLB can provide the data for the Caspian Lake as a target. Fig. 1 shows a screenshot of CGLB for the Caspian Lake. Geographical area of the Caspian Lake are shown on the Google Maps on the left-hand side and lake information based on WLDB and HydroLAKES are displayed on the right-hand side. Left-bottom below the Google Maps provides interactive draw of figures: 1-dimensional time series and 2-dimensional geographical distribution of land surface meteorological variables.

Observation stations operated by National Meteorological and Hydrological Services appear on this Google Map by one click and climatological monthly mean surface air temperature and precipitation can be seen on ClimatView developed by Japan Meteorological Agency (Fig. 2). These data are called as CLMAT and provided through World Meteorological Organization (WMO)[5]. CLIMAT is the names of the codes for reporting monthly values of meteorological parameters from weather stations and for reporting monthly aerological means from weather stations.

4. DISCUSSION AND CONCLUSION

We upgraded a web application of CGLB by introducing a new lake database, HydroLAKES with more than 1 million entry of lakes by combining existing datasets and interactively displays geographical, hydrological, and climatological information around the world. These functions are useful for education, expedition planning, and scientific research.

Global Framework for Climate Service (GFCS) led by WMO is a global partnership of governments and organizations that produce and use climate information and services. It seeks to enable researchers and the producers and users of information to join forces to improve the quality and quantity of climate services worldwide, particularly in developing countries. CGLB may contribute to GFCS by bridging dialogues between lake-relevant communities and climate ones. Since CGLB is developed by climatologists and/or producers, more ideas by limnologists and/or lake-relevant users must be

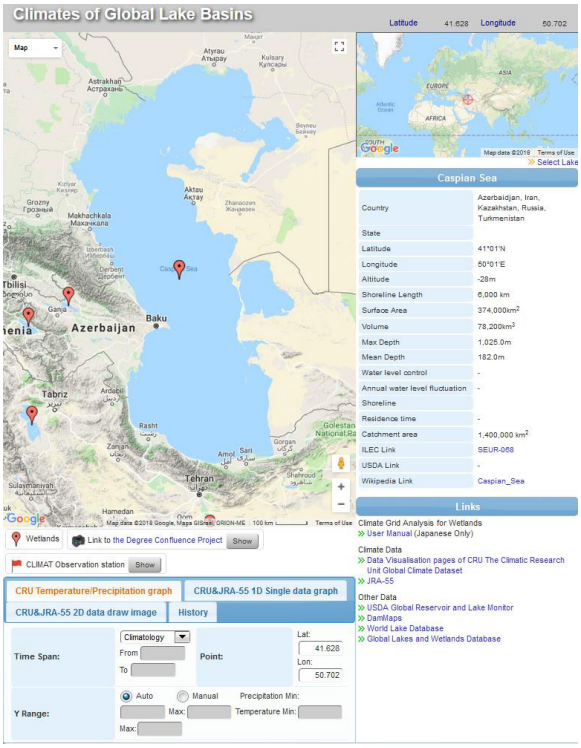
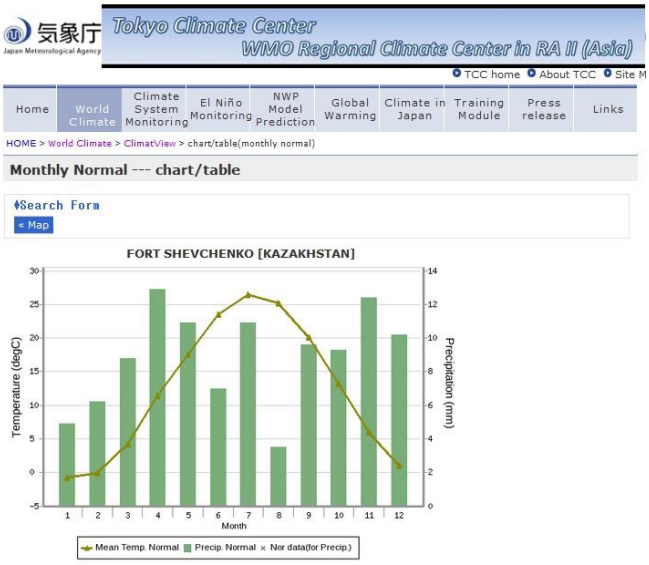


Fig. 1 Screenshot of CGLB for the Caspian Lake.



Month	Normal	
	Mean Temp. degC	Precip. mm
01	-0.8	4.9
02	-0.1	6.2
03	4.2	8.8
04	11.4	12.9
05	17.5	10.9
06	23.5	7.0
07	26.5	10.9
08	25.2	3.5
09	20.1	9.6
10	13.2	9.3
11	6.0	12.4

Fig. 2 Screenshot of climatological monthly mean surface air temperature and precipitation at Fort Shevchenko on the shore of the Caspian Lake for the Caspian Lake. http://ds.data.jma.go.jp/gmd/tcc/tcc/products/climate/climatview/

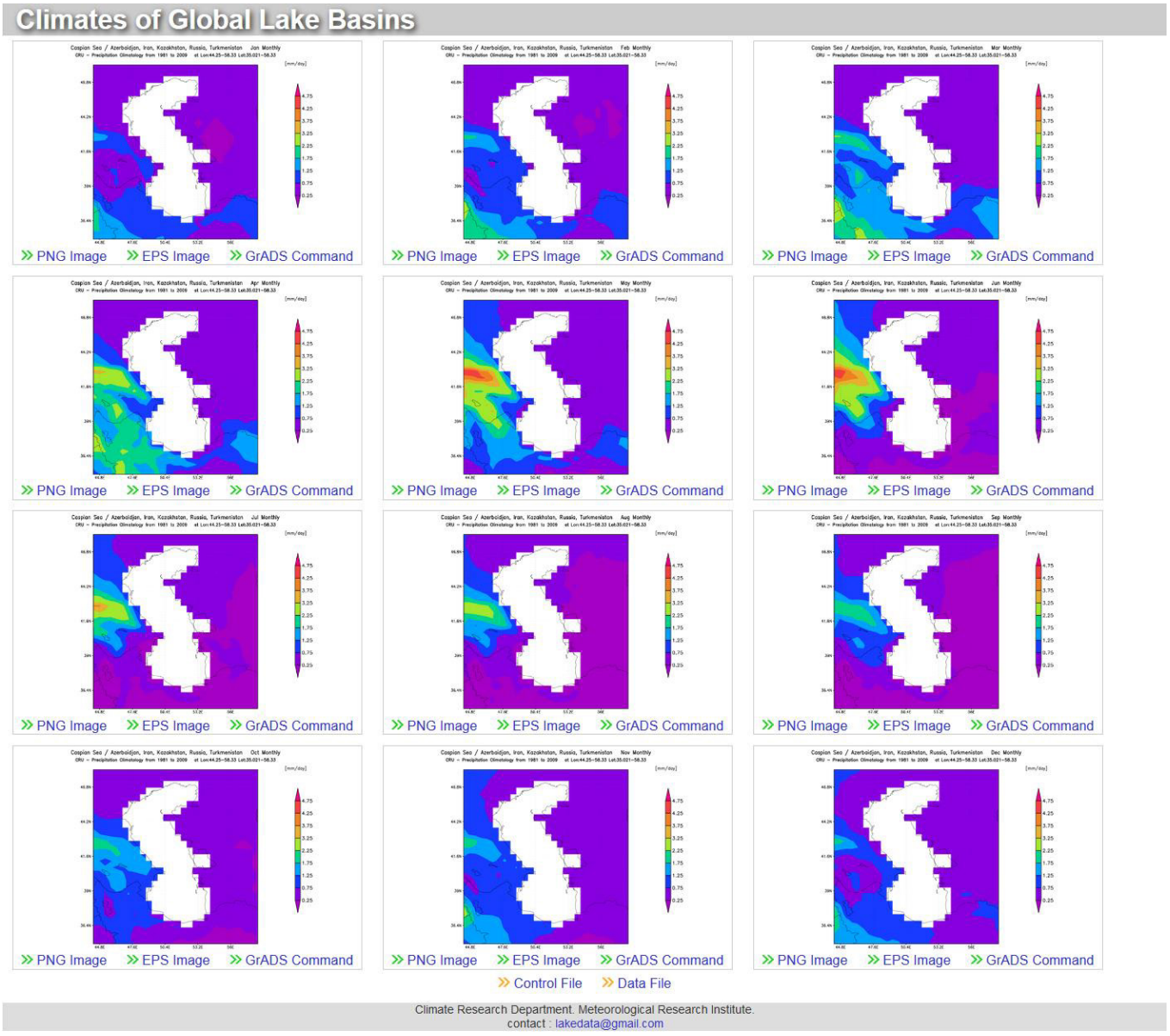


Fig.3 Climatological mean monthly precipitation around the Caspian Lake for each month in two-dimensional form or geographical one. The area drawn in each panel is completely same area as in Fig.1. This figure is drawn interactively on CGLB.

required for further developments.

Although CGLB provides figures on demand, but not even simple analysis. This implementation may depend on users' request. CGLB contains comprehensive information, and therefore would provide an opportunities in a variety of unique research on global lakes.

AKNOWLEDGEMENTS

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O6-2

Environmetric techniques for spatiotemporal hydrochemical characterization and Pollution source identification of the Dal lake, Kashmir Himalaya, India

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Keywords: Environmetric, Water Quality Index, GIS, Aquatic Vegetation, Himalaya

ABSTRACT

The paper explains the background processes responsible for the spatial distribution of hydrochemistry of the picturesque Himalayan Lake, Dal, in Kashmir, India. Statistical analyses were used to understand the spatiotemporal variability of 18 hydrochemical parameters collected from 30 sampling sites well distributed within the lake (grid spacing of 1 km^2) from Mar 2014-Feb 2016. Hierarchical Cluster Analysis (HCA) grouped all the data into 3 clusters based on the hydrochemical similarities, Discriminant analysis (DA) also revealed the same clusters and patterns, validating the results of HCA. Wilk's λ distribution revealed the contribution of ions, nutrients, secchi disk transparency, dissolved oxygen and pH in the formation of clusters in the lake. The results are in consonance the Principal Component Analysis (PCA) of the whole lake data and individual clusters, which showed that the variance is maximally explained by the ions (46.82%), DO and pH (9.36%), nitrates and phosphates (7.33%) and SDH (5.98%). Overall, the WQ of the lake is unfit for drinking due to the presence of coliform bacteria.

1. INTRODUCTION

Anthropogenic and natural causes contribute towards the deterioration of surface water quality of a lake and seriously impair its use for drinking, recreation, aquatic life, agricultural and industrial purposes [1]. Understanding the lake processes and functions to deduce its ecological significance is dependent on our ability to determine the patterns of variation in physical, chemical and biological characteristics at relevant ecological spatiotemporal scales. Dal lake, spread over an area of about 24 km^2 with a catchment of 337 km^2 and average water depth of 2.32 m, is known for its scenic, environmental, cultural and socio-economic importance in Kashmir valley, India (Fig. 1). However, due to the rapid unplanned urbanization, land use/land cover changes in the catchment, and inflow of nutrients, the lake WQ has severely degraded over time [2]. Since a large population in the region is dependent on the lake for varied services and products, the lake degradation besides hindering sustainable development of the lake, exposes the human and aquatic life within and in the vicinity of the lake to various risks. Regular monitoring of lake WQ on scientific basis is a challenging task and requires human resources and equipment to sustain the program. The present research, to the best of our knowledge, is first of its kind in terms of the scientifically adequate time series of WQ data well represented in time and space for understanding the spatial variability of hydrochemical characterization of the Dal waters using rigorous statistical methods in GIS environment. The main objectives of this work are to; a) assess the overall Dal lake hydrochemistry; b) evaluate the spatial variability and distribution pattern of WQ parameters and; c) to identify the underlying ecological processes that cause this pattern.

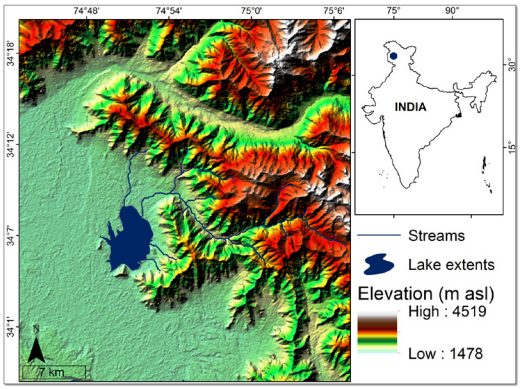

Figure1: The Dal lake, Kashmir Himalaya

2. METHODS

18 WQ parameters, analysed as per the standard methods[3] for 2 years at 30 locations of 1 km^2 grid each (12960 observations) are; Temperature, SDT, pH, EC, DO, TA, TH, Ca^{+2}, Mg^{+2}, Na^{+}, K^{+}, Cl^{-}, SO_4^{2-}, NH_3-N, NO_2-N, NO_3-N, PO_4^{2-}-P and TP. Environmetric analysis of the WQ data was conducted using HCA, DA and PCA. Suitability of the data for PCA was determined using Kaiser-Meyer-Olkin (KMO) and Bartlett's Sphericity test (BST). DA was applied on the original data, whereas HCA and PCA were used on the standardized data by z-scale transformation to avoid any errors due to the differences in data dimensions. HCA was done using Ward's method and squared Euclidean distance. DA was used to verify the accuracy of clusters delineated by HCA using the equation (1).

$$f(G_i) = k_i + \sum_{j=1}^{n} w_{ij} p_{ij} \quad \ldots\ldots (1)$$

where i is the number of groups (G), k_i is the constant inherent to each group, n is the number of parameters used to classify a set of data in a given group, w_j is the weight coefficient assigned by DA to a given parameter (p_j). After

the verification of the clusters, the influence of every WQ parameter in the formation of a cluster was determined using Wilk's λ distribution given below.

$$\lambda = \frac{\sum_i \sum_j (x_{ij} - \bar{x}_i)^2}{\sum_i \sum_j (x_{ij} - \bar{x})^2} \qquad (2)$$

where x_{ij} is the jth element of the ith cluster, $\bar{x}i$ the ith cluster's mean and $\bar{x}$ the total mean.

PCA works with a correlation matrix and thus reflects the stochastic interdependencies. The correlation coefficients obtained between the original parameters and PCs are the factor loadings which describes the weights of the PCs in the original variables. The PC is expressed as:

$$z_{ij} = a_{i1}x_{1j} + a_{i2}x_{2j} + \cdots + a_{im}x_{mj} \qquad (3)$$

where z is the component score, a the component loading, x the measured value of parameter, i the component number, j the sample number and m the total parameters.

The WQ maps were prepared in GIS using natural neighbour (NN) interpolation method. To determine the value of an attribute at location x, values of the points which are the natural neighbours of x and their relative weights are used. If we assume that each data point in a set has a scalar attribute *ai*, then the NN is represented by:

$$f(x) = \sum_{i=1}^{n} w_i(x) a_i \qquad (4)$$

where f (x) is the interpolated function value at location x.

WQI is a very useful method for assessing water quality. Each of the lake WQ parameter was assigned different weights ranging from 1 to 5 based on critical health effects. WQI is computed using the following equations:

$$Rw_i = \frac{w_i}{\sum_{i=1}^{n} w_i} \qquad (5)$$

where Rwi is the relative weight, wi is weight of each WQ parameter and n is the number of WQ parameters.

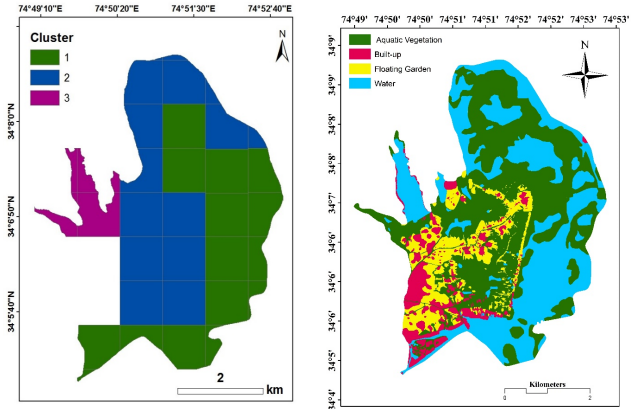

Figure2: Showing the 3 cluster(a) and land use and land cover

3. RESULTS

The analysis of the WQ shows that water temperature varied from 2.5 °-30.3° C. SDT, that represents not only the inorganic suspended solids but also the phyto-planktons, showed a mean value of 1.31m. The average values for pH and EC of all the sites were in the range of 7-10 and 110-680 µS/cm respectively. DO varied greatly from 0.8 to 14 mg/l with a mean value of 7.17. The Dal waters are well buffered and hard with an average value of 101.8mg/l and 112.8mg/l for TA and TH respectively. Among the ions, $Ca^{+2}$was found to be the dominant ion with an average value of 31.7(mg/l), followed by Cl^-, calcium chloride (10.3), Mg^{+2}(8.1), SO_4^{2}(7.1), Na^+(4.6) and K^+(1.7). NO_3-N among other forms showed dominance with the value ranging from 0.01 to 2.03 mg/l. Similarly, presence of TP varied between 0.02 to 1.21 mg/l.

Spatiotemporal variability of the WQ of Dal lake is aptly represented by the cluster analysis which identified 3 distinctive and homogenous clusters (Fig. 2a**).** DA showed that the original clusters were correctly recognized in 78.3% of the cases. Wilk's λ quotient was determined for all the WQ parameters at each point to assess the influence of each parameter on the cluster pattern. The lower values are depicted by Cl^-(0.570), Na^+(0.599), K^+(0.621), SDT(0.641), NO_3-N(0.753) and EC(0.781). It is clear from the Wilk's λ distribution that there is a mixed role of most of the parameters; both nutrients and ions in the cluster formation. This is due to the fact that the Dal, besides being hard and well buffered has a significant anthropogenic influence and allochthonous organic matter, mostly in the form of sewage and aquatic vegetation respectively.

A similar kind of pattern and behavior is exhibited by ions, total alkalinity, total hardness and conductivity. Therefore, to keep the discussion succinct and avoid the repetition, we chose chloride as the representative WQ parameter for discussion here, as it scores highest value in discrimination of clusters. In Cluster 3, the chloride shows the higher median value and the lowest value of the parameter is observed towards eastern (crescent shaped) part of the lake (Cluster1). The 3 clusters cover variable number of sites based on the WQ of the Dal lake. The eastern crescent shaped basin (Cluster 1) of the lake comprises of the maximum number of sites (14). The cluster encompasses the lake area from the northern side stretching through the eastern shore and ends up at the southern tail of the lake, which is also its outlet. The cluster is having higher values of pH, DO and SDT compared to other clusters. Aquatic vegetation is also significant in this cluster as can be seen in the land use land cover map of the lake (Fig. 2b). Cluster 2 mostly comprises of lake areas located towards the inner portion of the lake and is spread over 12 grid samples. The Cluster 2 is complex in terms of the heterogeneity of LULC (Fig. 2b) comprising of built-up (permanent structures), floating gardens and aquatic vegetation.

To understand underlying ecological and hydrochemical processes responsible for the observed distribution and clusters of WQ patterns, PCA was performed on the entire WQ dataset and on the clusters as well. PCA yielded four Principal Components (PCs) accounting for 69.5% of the data variance. Isoline maps of PCs were generated in GIS describing spatial changes of the component scores for each sampling site. Since cluster analysis showed that there are three distinguishable areas in the lake, hence, PCA was applied on the WQ data cluster-wise. The 1st PC of the clusters explains 51-55% of the cumulative variance of the data, 2nd PC of the cluster data accounts 10-14% and 3rd PC accounts only 9-10% of the variance.

The WQI was computed cluster-wise which were identified using HCA and DA analysis, and have distinct WQ characteristics. The data pertaining to coliform bacterial count was taken from the published and unpublished work. The seasonal WQI values of the 3 clusters indicated that the highest WQI values are observed in summers and the lowest in winters in all the 3 clusters. Moreover, the seasonal WQI values were registered higher in cluster 3 (~2011) followed by cluster 2 (~1977) and then cluster 1 (~710), which further substantiates the fact that the most polluted part of the lake lies within the cluster 3.

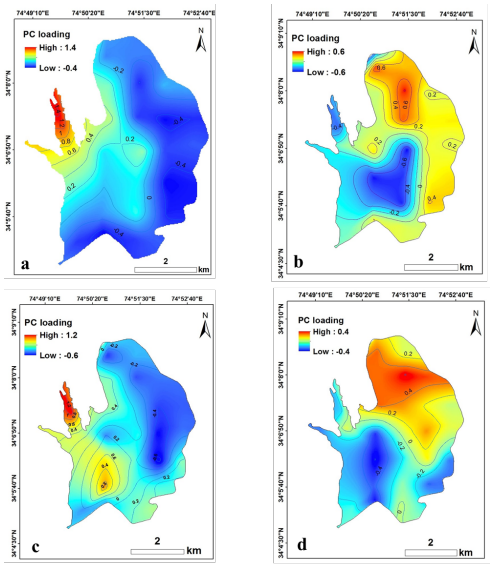

Figure 3: Spatial distribution of PC loading scores (a-d) 1st-4th PC

4. DISCUSSION

The environmetric analysis indicates the dominant role of inorganic variables, which could be attributed to the weathering, dissolution and erosion of the geological formations in the catchment. The high concentration of WQ parameters during winter is due to the low vegetation metabolism; as a result of which the decomposed organic matter remains unutilized. The determining character of pH and DO is due to the presence of luxuriant aquatic vegetation which during the photosynthetic process releases oxygen and utilizes dissolved Co2 and its associated hydrogen ions. The higher score of pH and DO are observed in the eastern part of the lake as compared to the central and western parts, which have less macrophytes. The sources of nitrate and phosphate nutrients are domestic sewage from the settlements in the vicinity, agricultural run-off, stream effluents, fertilizers and manures used in croplands in the catchment. The high PC scores are observed in Nigeen and central portion of the lake due to the high anthropogenic pressures. A positive loading of moderate nature was exhibited by SDT due to the presence of macrophytes which provides a refuge to zooplanktons, thus effectively checking the population of phytoplankton, leading to the less turbidity. Also, the presence of the aquatic plant slows down the flow of the lake waters, resulting in a decrease in the concentration of suspended sediments in the water. The PC scores (Fig. 3d) are in conformity with this reasoning as high scores are found in the eastern basin compared to the central and western basins having less vegetation. The striking observation of this assessment is that the highest effective weights are contributed by the coliform bacteria in all the 3 clusters and ranged from 95.874% to 99.497%. This clearly indicates that the coliform bacterial count is the primary parameter responsible for making the waters of the lake unfit for drinking.

5. CONCLUSION

The environmetric and GIS techniques are appropriate for inferring the intricate spatiotemporal variability of water quality and pollution sources in the lake. These methods recognize the lake spatial heterogeneity in terms of the water quality with much robustness and would therefore help planning any future spatial sampling strategy in an optimal manner by reducing time and costs. Moreover, the approach is helpful in understanding the consequence of lake water interventions and the underlying processes in both space and time. Therefore, the environmetric techniques, used in this study for assessing the spatiotemporal variability and pattern recognition of the lake water quality, should act as a pre-requisite for lake managers across the globe to effectively initiate and implement any lake conservation and restoration strategies.

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O6-3

Using Multimetric Benthic Macroinvertebrate Index for the Assessment of River Health in Thailand

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Keywords: bioassessment, biotic index, multimetric index, Loei river, water quality

ABSTRACT

Today, the health of streams and rivers has been dramatically changed by anthropogenic disturbances. The Loei River in Loei province, Thailand is one of the Mekong River tributary which affected by many anthropogenic disturbances such as agricultural activities, urbanization and industry. In Thailand, standard water quality is based on chemical measurements, which are not reflect cumulative stressors. Use of multimetric benthic macroinvertebrate index can reflect overall streams and rivers ecological. The aim of this research is to evaluate rivers health by using multimetric benthic macroinvertebrate index. Ten sampling sites were selected to evaluate rivers health. The result showed that Loei river has been threating by many anthropogenic activity. Thus, river and land use management are urgent need in this catchment.

1. INTRODUCTION

Today, rapid population growth, industrialization and urbanization are the main threats to river basins especially developing countries. Many bioassessment approaches are used for evaluating the conditions of streams and rivers. Use of macroinvertebrate species as indicator are one of aquatic bioassessment approaches in the United States, Europe, Australia, Thailand and other countries [1-3]. However, the indicator species concept is an insufficient to measure of overall streams and rivers ecological [4-5]. Thus, other bioassessment approaches, such as multimetric indices, have been developed to reflect overall streams and rivers ecological. The first multimetric method which was developed for use with fish communities [6]. Now various types of multimetric indices have been subsequently proposed in other aquatic habitats and benthic macroinvertebrates [7,8,9].

The Loei River in Loei province, Thailand is one of the Mekong River tributary which affected by many anthropogenic disturbances such as agricultural activities, urbanization and industry. In Thailand, the national standard assessment of water quality is based on chemical measurements [10], which are not reflect cumulative stressors. However, the official national standard method on using macroinvertebrates as key biological indicators has not been established. The multimetric benthic macroinvertebrate index for the assessment of The Loei River was developed by Boonsoong et. al. in 2009 [11].

The aim of this research is to evaluate rivers health by using multimetric benthic macroinvertebrate index.

2. METHOD

Study area and site selection

The study area was in The Loei River catchments, Loei province, Northeastern Thailand. The study area was at latitude 16°58′–17°52′ N, longitude 101°28′–101°47′ E. Sampling periods were chosen to follow seasonal patterns in Thailand (hot, wet, and cold seasons).

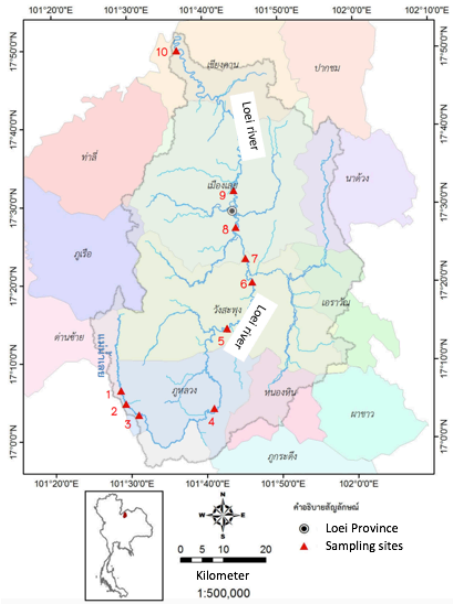

Fig.1 Map of Loei river catchment and sampling sites

Water quality and macroinvertebrate samples were collected seasonally for a period of 2 years, which included cold season (January 2016 and late of February 2017) and hot season (March 2016 and May 2017). No samples were collected in wet season because flooding and other seasonal disturbance. Sampling sites were divided in 3

groups, upstream (site 1-3), midstream (site 4-7) and downstream (site 8-10) (fig.1).

Field and laboratory methods

Ten water quality parameters (table 1) were measured along with the collection of macroinvertebrate at each of the sampling sites.

Table 1 Mean ± SD of physico-chemical parameters of The Loei river

Parameters	Cold 2016	Cold 2017	Hot 2016	Hot 2017
Temperature (◦C)	25.5 ±1.5	28.5 ±1.5	28.7 ±2.0	26.0 ±1.7
pH	7.25 ±0.31	8.18 ±0.29	7.42 ±0.43	6.38 ±0.29
conductivity ($\mu S\ cm^{-1}$)	247.6 ±110.4	314.2 ±155.2	357.2 ±178.9	97.2 ±44.3
TDS ($mg\ l^{-1}$)	124.2 ±54.7	167.2 ±81.2	178.5 ±90.3	49.8 ±22.9
Turbidity (NTU)	11.5 ±8.3	25.1 ±57.7	6.9 ±4.0	281.4 ±290.8
Dissolved Oxygen($mg\ l^{-1}$)	7.1 ±1.1	7.5 ±0.7	7.4 ±2.4	5.9 ±1.4
BOD ($mg\ l^{-1}$)	2.2 ±2.7	2.8 ±2.1	2.8 ±0.9	1.9 ±1.4
NH^{4+} ($mg\ l^{-1}$)	0.07 ±0.08	0.49 ±0.21	0.22 ±0.15	0.43 ±0.23
NO^{3-} ($mg\ l^{-1}$)	1.2 ±0.7	1.5 ±0.7	1.3 ±0.6	3.9 ±1.9
PO_4^{3-} ($mg\ l^{-1}$)	0.22 ±0.15	0.41 ±0.46	0.48 ±0.37	0.14 ±0.12

At each site, both river banks were divided into 3 transects (total 6 transects for each site). Macroinvertebrates were collected using a D-frame (0.3 m. wide, 500 µm. mesh) 5 sweeps for each transects. All samples were preserved in the field with 80% ethanol. In the laboratory, specimens were rinsed in 500 µm. mesh sieves and large organic materials were removed. All organisms from the sorted sample were identified to the lowest possible taxonomic.

Data analysis

Benthic macroinvertebrate assemblage data were analyzed for 9 metrics follow Boonsoong et. al [11] and categorized into 3 scoring range (table 2). The multimetric index was calculated by aggregating the scores of each of the 9 metrics. The possible index values ranged from 9 to 43; this was derived by summing the minimum and maximum scores for each metric. The range of the multimetric index was divided define five classes of biological integrity, excellent condition (scores of 37-43) equivalent good (30-36), fair (23–29), poor (16–22) and very poor (9–15).

3. RESULTS AND DISCUSSION

Mean of 10 water quality parameters were showed in table 1. The macroinvertebrates multimetric index of ten sites were showed in table 3. The index showed good-fair water quality for upstream site (1-3) of cold 2017 and hot 2016. The upstream of Loei river was disturbed by some agricultural activities such as farming. Agricultural activities can be a non-point source pollution that polluted the river by runoff water [12]. Most sampling site of the midstream and downstream of Loei river were categorized into fair and poor water quality because most of the area are urban area, industrial and mining.

4. CONCLUSION

The multimetric benthic macroinvertebrate index can be used to evaluate rivers health. From the results, the Loei river was treated by many human activities. Thus, river and land use management are urgent need in this catchment.

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Table 2 Score for the core metrics for the cold season and hot season.

Metric	Categorical scoring range for cold season			Categorical scoring range for hot season		
	5	**3**	**1**	**5**	**3**	**1**
No. of total taxa	≥ 32	31-16	< 16	≥ 35	34-18	< 18
No. of Diptera taxa	≥ 5	4-3	< 3	≥ 5	4-3	< 3
No. of EPTC taxa	≥ 19	18-10	< 10	≥ 21	20-11	< 11
(%) Plecoptera	≥ 3.0	2.9-1.5	< 1.5	≥ 3.1	3.0-1.5	< 1.5
(%) Tolerant organisms	≤ 22.4	22.3-33.6	> 33.6	≤ 33.7	33.8-50.6	> 50.6
Beck's Biotic Index	≥ 14	13-7	< 7	≥ 13	12-7	< 7
(%) Intolerant organisms	≥ 9.9	9.8-5.0	< 5.0	≥ 16.8	16.7-8.4	< 58.4
No. of shredders taxa	–a	≥ 3	< 3	–a	≥ 2	< 2
No. of clingers taxa	≥ 16	15-8	< 8	≥ 15	14-8	< 8

a Considered a weak metric for discrimination and given only two scoring criteria

Table 3 Class of water quality of 10 sampling sites and index score.

Site	Multimetric			
	Cold 2016	**Cold 2017**	**Hot 2016**	**Hot 2017**
1	fair 29	good 33	good 31	fair 27
2	v-poor 11	good 35	good 31	fair 25
3	fair 25	fair 29	good 27	poor 15
4	fair 25	fair 27	poor 17	poor 19
5	fair 25	fair 25	fair 29	fair 23
6	poor 17	good 31	poor 21	poor 17
7	fair 25	fair 25	poor 21	v-poor 15
8	poor 21	fair 23	poor 19	poor 17
9	fair 25	good 33	poor 21	poor 17
10	poor 21	fair 29	fair 27	poor 15

O6-4

Environmental monitoring and Ecotoxicology for Tropical Environment: Standard and Application in Mekong River Countries

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Keywords: water quality guideline, Environmental Risk Assessment, water pollution, sustainable development

ABSTRACT

The aquatic resources of the Mekong River are importance to supporting the livelihoods of a large percentage of 60 million who live along the Lower Mekong Basin. The protection of aquatic habitat from damage and understanding of both sensitivity of aquatic organisms to contaminant and ecological effects are needed. Mekong River quality criteria of aquatic life for metals are largely driven by the extremely sensitive small organism's toxicity which should be the Mekong native species. Environmental monitoring and Ecotoxicology of heavy metal (copper) on several tropical freshwater biota was studied using field-collected water from local sites along Lower Mekong Basin in Thailand, Laos and Cambodia, which had different water quality parameters under tropical environment in the range of total hardness, alkalinity, pH and dissolved organic carbon. The result showed the mortality rate of organisms increased with increasing of copper concentrations and exposure time. The results found that copper toxicity of fish, invertebrates and other aquatic organisms are influenced by water quality parameters such as hardness, alkalinity, pH and DOC. Copper (Cu) is a big concern for environment, human and aquatic organisms because it can accumulate in to plant and animals via food web. The outcoming of this series of laboratory experiment will provides a worst-case scenario and useful for determine the risk assessment of copper on local freshwater organisms in Mekong River Basin in order to help and protect the Mekong River in the future and to set a water quality standard for heavy metal in the Mekong River Basin countries.

1. INTRODUCTION

The Mekong River is one of the world's greatest river systems and sustains human life and ecosystems. The livelihoods of 60 million people who live along the Lower Mekong Basin (LMB) rely on both the economic resource and the ecological health of the river [1]. However, the development activities during the past decade and up to now, including mining, industries, agriculture, deforestation, and household wastes have caused of extensive soil erosion and contributed increasingly to environmental levels of heavy metals especially copper (Cu) into water body [2]. Although the water quality of the Mekong River is considered to be remarkably good, some areas of the Mekong Delta, which are adversely inflicted by high population density, irregular mining activities, and increasing agricultural activities, have experienced worsening water quality [1].

Copper is known as the important that all living organisms require its small amounts (5-20 µg/g) to survive. However, too much copper concentration more than (20µg/g) become toxic [3]. Copper has been documented as one of the most toxic metals to aquatic organism and ecosystem [4].

Impacts of copper on an aquatic atmosphere are complex and depend on the physicochemical characteristics of water [5]. Copper toxicity of fish, invertebrates and other aquatic organisms are influenced by water quality parameters such as hardness, alkalinity, pH and DOC (dissolved organic carbon) [6].

The United States Environmental Protection Agency (US.EPA) has issued a guideline for conducting

early-life-stage toxicity test suitable for acute and chronic toxicity tests used for measuring the aggregate toxic chemicals in an effluent or receiving water to freshwater and marine organisms [4]. Moreover, many research papers were designed and conducted on ecotoxicology of copper worldwide, but most of them focused on temperature aquatic species. In Mekong River Basin Countries, the information on the impact of toxicity effects of soluble

copper on the tropical aquatic biota is limited. Therefore, the ecotoxicology of copper on local species with Mekong River will be a good representative for tropical aquatic

species. In the present study, the ecotoxicology of copper on several local aquatic biota under different water parameters were investigated in order to help and protect the Mekong River in the future and to set a water quality standard for heavy metal in the Mekong River in the Mekong River Basin.

2. METHOD

Water sampling

Water samples were collected from several sites along the Mekong River in Thailand, Laos and Cambodia during wet and dry season in Year 2016 which focused on different water quality parameters.

Surface water for physical-chemical analysis and toxicity tests was sample at the middle of the River. All water samples were transferred back to the Ecotoxicology laboratory in Khon Kaen University.

Water quality Analysis

Water quality parameters including heavy metal, pesticide and nutrient concentrations were measured using standard techniques [8]. Concentrations of metals were estimated by the analysis by inductively-coupled plasma mass spectrometry (ICPMS). Measurements were made of pH, electrical conductivity (EC), temperature, dissolved oxygen (DO) concentration in river water using field equipment. Active sampling was employed to collect water samples (1L) for total dissolved solids (TDS), total

alkalinity (mg/L $CaCO_3$), hardness (mg/L $CaCO_3$), nutrients (total N and P, nitrate (NO_3^-) and ortho-phosphorus [P]) and dissolved organic carbon (DOC). All measurements on the active water samples were undertaken in the field or at the Division of Land Resources and Environment, Department of Plant Sciences and Agricultural Resources, Faculty of Agriculture Khon Kaen University.

Ecotoxicology Test

In this study, US EPA method (2002) was used for the acute toxicity with different water quality parameter on tropical aquatic biota.

RESULTS

The result of chemical characteristics and water quality parameters of field-collected samples are given in Table 1 and Table 2. In general, the waters are considered as not being contaminated. In table was shown concentration of toxic metal (e.g., Cu, Cr, Pb, Ca, As, Fe, Zn and Mn) were below detection limit or less than the maximum acceptable limited for aquatic life in Thailand. And also, pesticides (Organochlorine group, Organophosphate group, Chlrorinated Baenzenes, Chloronitirile Pesticides, Cholordane-related Compounds and Cholorinated Herbicides) were not detected in the collected water were shown in (Table 3)

Table 1. water quality parameters of Mekong River in Thailand, Laos and Cambodia

Parameters	Results		
	Thailand	Laos	Cambodia
pH	6.39	6.67	7.2
EC (µS/cm)	86	94	84
Total alkalinity (mg/Las$CaCO_3$)	81	94	83
Total hardness (mg/Las$CaCO_3$)	95	120	92
TDS (mg/L)	93	96	91
Total N (mg/L)	10	23	10
NO_3^- (mg/L)	1.0	1.8	1.2
Ortho-P /Total P (mg/L)	0.002/ 0.26	0.05/0.36	0.04/0.34
BOD (mg/L)	3.7	18.1	9.3
DOC (mg/L)	1.9	6.83	2.3
Calcium (mg/L)	30	41	33
Magnesium (mg/L)	3.91	8.34	3.93
Mn (µg/L)	1.19	9.17	2.08
Zn (µg/L)	2.98	3.86	2.75
Fe (µg/L)	0.68	4.80	2.43
Arsenic (µg/L)	0.028	0.053	0.022
Cadmium (µg/L)	0.01	0.021	0.00
Lead (µg/L)	0.042	0.081	0.047
Cr (µg/L)	0.048	0.059	0.050
Copper (µg/L)	0.35	0.39	0.32

Table 2. LC_{50} with 95 percent confidence interval of formalin on chironomus javanus *(C. javanus)* and fish Nile tilapia (*Oreochromis niloticus)* of two different DOC of Mekong River

Species	DOC (mg/L)	LC_{50} with 95% Cl (µg/L)			
		24h	48h	72h	96h
Nile tilapia	5.74	1228 (1138-1340)	1052 (890-1296)	939 (771-1185)	742 (562-981)
	1.12	1236 (1128-1371)	806 (494-1334)	561 (129-1177)	397 (123-761)
C. javanus	5.74	8237 (5471-32105)	5033 (3035-88359)	2206 (-)	853 (-)
	1.12	2864 (-)	2443 (-)	983 (-)	707 (-)

CL= Confidence limit, LC_{50}= Median lethal concentrations, (-) = 95% Confidence limit (lower-upper value) exposure at 96 hours

Table 3. Pesticide in Mekong River in Thailand, Laos and Cambodia

Parameters	Results		
	Thailand	Laos	Cambodia
Organochlorine Group			
Alpha HCH	nd	nd	nd
Gamma HCH	nd	nd	nd
Delta HCH	nd	nd	nd
Beta HCH	nd	nd	nd
Mirex	nd	nd	nd
Aldrin	nd	nd	nd
Dieldrin	nd	nd	nd
Endrin	nd	nd	nd
Heptachlor Epoxide/OCS	nd	nd	nd
Gamma Chlordane	nd	nd	nd
Alpha Chlordane	nd	nd	nd
2,4' DDE/ENDOSULFAN I	nd	nd	nd
4,4' DDD	nd	nd	nd
4,4' DDT	nd	nd	nd
2,4' DDT	nd	nd	nd
2,4' DDD	nd	nd	nd
Endosulfan sulfate	nd	nd	nd
Endosulfan II	nd	nd	nd
Organophosphate Group			
Chlorpyrifos	nd	nd	nd
Chlrorinated Benzenes			
Tetrachlorobenzene 1,2,4,5	nd	nd	nd
Tetrachlorobenzene 1,2,3,4	nd	nd	nd
Pentachlorobenzene	nd	nd	nd
Hexachlorobenzene	nd	nd	nd
Chloronitrile Pesticides			
Chlorthalonil	nd	nd	nd
Chlordane-related Compounds			
Heptachlor	nd	nd	nd
cis-Nonachlor	nd	nd	nd
trans-Nonachlor	nd	nd	nd
Methoxychlor	nd	nd	nd
Oxychlordane	nd	nd	nd
Chlorinated Herbicides			
Pentachloroanisole	nd	nd	nd

Note: Organochlorine Group: LOD=0.001 mg/L, LOQ=0.01 mg/L
Organophosphate Group: LOD=0.001 mg/L, LOQ=0.01 mg/L
Pyrethroid Group: LOD=0.001 mg/L, LOQ=0.01 mg/L
Cabamate Group: LOD=0.01 mg/L, LOQ=0.01 mg/L

3. DISCUSSION

Generally, water quality of Mekong River in Thailand is good, but some areas of the Mekong Delta, which are harmfully inflicted by high population density, irregular mining activities, and increasing agricultural activities, have experienced worsening water quality. Present study indicated that water chemistry parameters can influence on copper toxicity to tropical freshwaters biota. Increasing hardness ions, and DOC all resulted in some reduction of copper neurotoxicity to individual sensory neurons in Moina (*Moinama crocopa*), Chironomidae (*Chironomus javanus*), Grass Carp (*Ctenopharyn godon* Idella) Nile tilapia (*Oreochromis niloticus*) and Greater bony-lipped barb (*Osteochilus melanopleurus)*

4. CONCLUSION

Present study indicated that water chemistry parameters can influence on copper toxicity to tropical freshwaters biota. DOC, pH and hardness might provide protection against Cu toxicity in the freshwater. This series of laboratory experiment provide a worst-case scenario and useful for determine the risk assessment of copper on Mekong tropical freshwater animals. Other acute toxicity studies of copper under the different water quality parameters with more tropical organism's species should be encouraged and help and protect the Mekong River in the future and to set a water quality standard for heavy metal in the Mekong River Basin countries.

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O6-5

汽水湖涸沼における水質の周期変動について

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キーワード:データ解析とモニタリング, ウェーブレット解析, 周期変動, 汽水湖

抄録

茨城県中央部に位置する涸沼は, 那珂川を介して太平洋に接続する汽水湖である。茨城県では 1970 年代から湖内3地点で毎月1回の定期観測を継続してきた。水質の代表的な指標である化学的酸素要求量(COD)は, 湖内において長期的には横ばいに推移し, 基本的には1年周期で変動しているが, 他に数年周期の変動も見られるなど複雑な水質変動が認められる。そこで湖内並びに流入河川, 流出河川の水質変動についてウェーブレット解析を行い, その変動周期と各種水質項目の関係を検討した。その結果, COD は全期間中で, 1 年周期のピークが確認され, 1年周期のピークは 7～8 年の期間で途切れ, その期間中の季節変化が小さくなること, 3 年周期が検出される期間は COD が増加することが分かった。また, 湖内 COD の1年周期の出現パターンは上流側河川のそれに似ており, 湖内変動は上流側からの影響をより強く受けることが示唆された。

1. はじめに

茨城県中央部に位置する涸沼は, 湖面積 9.35km^2, 平均水深 2.1m, 那珂川を介して太平洋に接続する汽水湖である(図1)。そのため, 上流河川のみならず, 那珂川の影響を受けた海水が湖内に遡上流入し, それぞれが相互に作用するという複雑な水域であり, 湖内水質の変動について未解明な部分がある。これまでは汽水湖であることから潮汐の影響を把握する調査研究を行われ, 湖内の塩分成層の状況やそれに伴う貧酸素水塊発生状況, そして湖内の流況など短期間の水理的考察[1]が行われてきた。

一方, 長期的な水質変動については, 茨城県が 1970 年代から涸沼湖内及びその流域において定期観測を継続しており 40 年以上に観測データが蓄積されているが十分な解析は行われておらず, 長期的観点からの水質の変動要因が明らかにされていない。涸沼湖心(宮前)の湖内水質(COD)は, 図 2 の上段で示すように長期的には低下傾向にあるが, 現在においても 6mg/L 程度と環境基準(湖沼 B 類型)を達成できない状況にある[2]。水質は, 基本的には年周期で変動しているが, 他に数年周期のうねりも見られ, また, 近年は年間の最大値と最小値の差が, 小さくなる傾向にあるなど複雑な水質変動が認められる。

水質は, 様々な要因が重なり合い一つの値を形作っているものであることから, 成分に分け解析することは要因を明らかにするため重要である。汽水域である本水域は周期性の強い潮汐の影響を受ける特徴があり, その他の様々要因の変動周期により水質が変動している。そのため, 本研究では水質変動の周期性に着目し, ウェーブレット解析により周期解析を行った。

周期解析には代表的なものとしてフーリエ変換があるが, これは継続する波動の周期を分離するものであり, 含まれる波動の周期を示すのみである。一方, ウェーブレット解析は波動周期だけでなく, 分離した波動の存在期間を示すことが可能であることから[3], 変動要因が時期により異なり周期の存在が不均一な湖水などの解析により効果的である。[4]

ウェーブレット解析により長期間の湖内水質の周期解析を行い, 地点間や項目間の比較などから, 長期的な視点から湖内水質の変動要因について検討を行った。

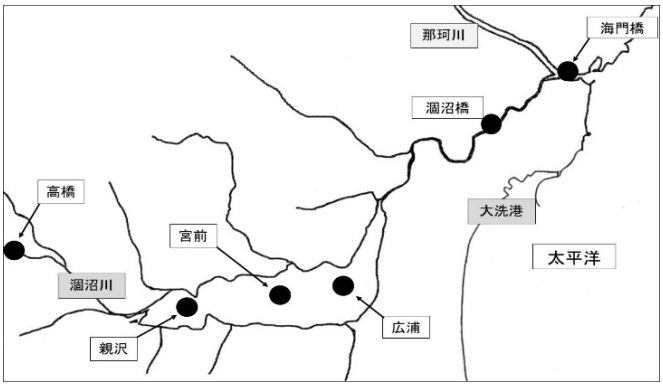

図 1　涸沼流域図

2. 方法

解析対象には，茨城県が公表している公共用水域の水質測定結果（1974 年度～2016 年度）の測定データを用い，そのうち当初から測定を継続している水温，pH，DO，COD，BOD 及び SS についてウェーブレット解析（R 言語　morlet関数を使用）による周期解析を実施した。

なお，周期解析により，「主要周期とその出現傾向」，「地点毎の周期傾向から上下流域からの寄与」及び「水質項目の周期傾向から項目間の関係」を検討した。

3. 結果及び考察

3.1 主要周期とその出現傾向

涸沼湖心（宮前）の COD ウェーブを対象としたウェーブレット解析の結果を図 2 の下段に示す。周期分布上方の網掛部分は棄却域であり，有意水準は1％とした。

ウェーブレット解析の結果は，縦軸は周期としての月数，横軸を測定年とするコンター図として表現され，時間ごとの周期(周波数)をピークとして示し，そのピークが継続する場合は帯として表現される。ピークの強度は灰色の明るさよって示され，明るい灰色が最も強度が強い。

湖内 COD のウェーブレット解析の結果は全期間中で 1 年（12 ヶ月）周期のピークが認められ，1 年周期のピークが 7～8 年の間隔で途切れる。期間中のピークの途切れは，1983 年，1994 年，2007 年及び 2014 年の 4 か所で確認されるが，それに対応する年では COD の季節変化も著しく小さくなる。また，1 年周期の以外にも3年（36 ヶ月）周期と 7 年（84 ヶ月）周期もあり，3 年周期は，1978 年と 1998 年の2度出現し，4 年ほど継続し，その時期は COD が上昇していた。

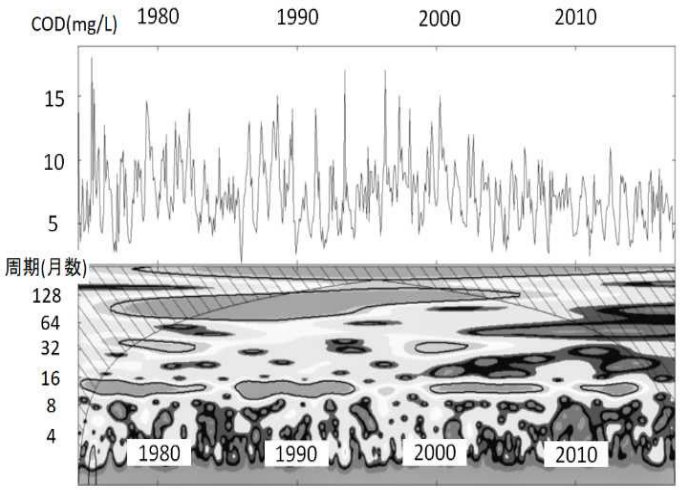

図2 COD 経年図(上段)　周期分布図(下段)

3.2 地点毎の周期傾向と上下流域からの寄与

次に涸沼湖内の水質に対する上・下流域の影響を検討するため，涸沼川の流下方向 6 地点の COD についてウェーブレット解析を行い，1 年周期のみを切り出し，その出現パターンを比較した。ピークは明灰色の帯状として示される（図 3）。なお，1 年周期を選択した理由は，最も強いピークであること，対象期間全域でピークが出現することから，周期の比較がしやすいためである。

湖内 3 地点（親沢，宮前，広浦）とその上流に位置する高橋は 1 年周期の出現パターンが似ており，涸沼の下流域に位置する涸沼橋，海門橋でも 1 年周期は出現するが，湖内より断続することが多く，より下流に位置する海門橋のほうがその傾向が強い。下流域の涸沼橋，海門橋は出現パターンが異なる。下流域での出現位置は，湖内で隙間が生じる箇所に見られる。このことから遡上水が湖内に影響を及ぼし，1年周期を断絶させている可能性が示唆される。一方，海水が及ばない上流側（高橋）においても湖内同様の1年周期のパターンが見られることから，湖内変動は上流側からの影響をより強く受けることが示唆された。

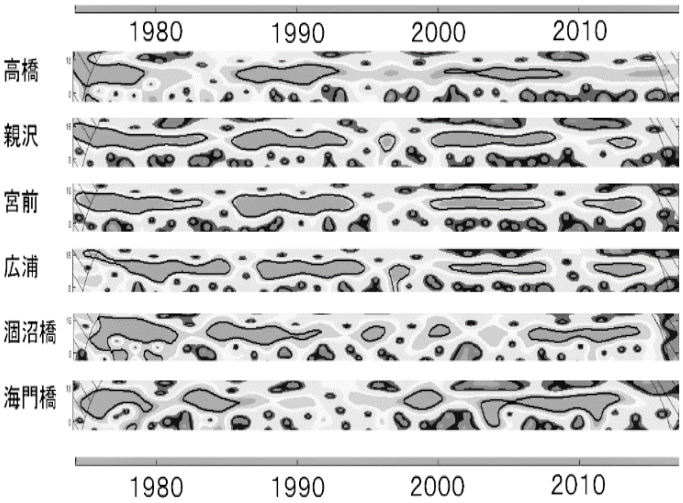

図3　地点別 COD の1年周期分布図

なお，湖内 3 地点の 1 年周期の出現パターンおいて，下流側の地点ほど出現と消滅の時期に遅れが生じているが，出現パターンは 3 地点とも同じような継続時間，消失時間を有していることから似ていると判断した。下流側ほどずれが大きいのは海の影響と考えられる。

また，公共用水域の観測は表層のみのため河川の影響が強く出すぎている可能性ある。しかし，塩分が底層で高い場合は，表層でもその影響を受け塩分は多少上昇することから，底層と表層の塩分は連動する。さらに遡上水に関する周期は数日単位と月単位比べ短いことか

ら，長期間の変動を見ているかぎり，短期的な塩分躍層など影響は相殺され周期解析への影響は少ないと思慮される。

3.3 水質項目の周期傾向と項目間の関係

涸沼湖心（宮前）において水温，pH，DO，COD，BOD 及び SS についてウェーブレット解析を行いにより1年周期のみを切り出しの出現パターンを比較した。1年周期のピークは濃灰色で示される（図4）。水温は全期間中で 1 年周期が途絶えることなく出現し，安定した周期性が認められる。その他項目については，1980 年代半ばまでは同じような周期パターンであったが，その後は，SS は断続的に短期間のピークが出現しており，pH，DO，COD は比較的出現パターンが似ていた。BOD は COD と 1990 年代まで同パターンであったが，2000 年以降ほとんど出現されなくなっている。

これらのことから，1年周期の出現パターンが似ており，湖内の COD，pH，DO に関連があることが示唆された。これらの項目は，一次生産に関わる項目であるが，湖内の栄養源は河川を通じて流入してくることから，湖内での一次生産の増減は河川の挙動が影響する。そのため，湖内でのこれらの項目の挙動は，上流域からの影響を反映したものであり，3.3 で示したように上流側からの影響をより強く受けることと合致する。

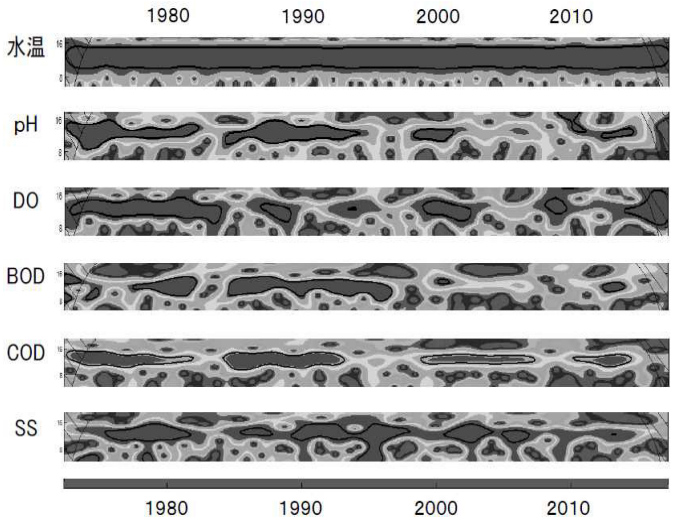

図4 項目別の1年周期分布図（宮前）

4. 結論

ウェーブレット解析の結果，涸沼湖内 COD 変動の主要周期は1年であり，その他に3年及び7年周期が確認された。1年周期は7～8年間継続し，断絶した区間は COD の年間変動が小さかった。また，3年周期が出現した時期は COD が上昇していた。

涸沼湖内 COD の1年周期の出現パターンは上流側のそれに似ており，湖内変動は上流側からの影響をより強く受けることが示唆された。また，湖内では pH，DO，COD の一年周期の出現パターンから，COD と pH，DO との密接な関係が示唆された。

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O6-6

Mixing processes associated with hypoxia in Lake Kasumigaura

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Keywords: Hypoxia, Shallow lake, Vertical mixing, Stratification, Heat flux.

ABSTRACT

This study reports hypoxia events associated with suppressed vertical mixing during the summer season, Kitaura, Lake Kasumigaura, Japan. Mooring data obtained at the Kamaya monitoring station were used to investigate physical processes causing hypoxia events. Hypoxia appears under conditions of strong stratification due to strong incoming heat flux into the lake. The square of buoyancy frequency (indicator of the stratification strength), N^2, reaches 2.4×10^{-3} in July, 2016. On the other hand, hypoxia water disappears under weak stratified or mixing conditions when moderate winds (~ 5 m s^{-1}) and weak incoming heat flux. The bottom oxygen concentration is highly related with the buoyancy frequency, thus, the bottom oxygen concentration can be explained by the vertical physical mixing processes. In order to evaluate forcing conditions controlling mixing processes in the lake, we propose a non-dimensional number, the ratio of two forcing into the lake, (1) time-integrated incoming heat flux and (2) horizontally-integrated surface wind stress. The non-dimensional number is in a good correlation with the buoyancy frequency. This study found that suppressed vertical mixing causing hypoxia can be simply explained by the balance of the two surface forcings (heat flux and wind stress). In addition, the heat budget analysis shows a contribution of the sediment hear flux to mixing processes in the lake.

1. INTRODUCTION

Mixing processes are essential to understand oceanic and lake's physical processes and ecosystems [1, 2]. It is well known that vertical heat and mass transports are suppressed by vertical stratifications. In stratified oceans and lakes, vertical transports are dominated by diffusive processes by mixing, rather than advections due to currents. Mixing mechanisms have to be revealed to understand and maintain lake environments [2].

Hypoxia is one of crucial problems that have to be solved for worldwide lakes [3]. Oxygen supplies into water is mainly from surface gas exchanges and photosynthesis by phytoplanktons. In bottom boundary layers with limited solar radiation, oxygen supplies are only from upper layers through vertical mixing. This study investigates mixing processes associated with hypoxia in Lake Kasumigaura (Kitaura) located in the middle of Japan main land (Fig. 1). The depth of the lake is quite shallow with a maxumium depth of approximately 6 m, however, the solar radiation is limited in the bottom boundary layer due to highly concentrated turbidity. This condition leads to serious hypoxia issues in the lake.

2. METHOD

Observed data from the Kamaya monitoring station

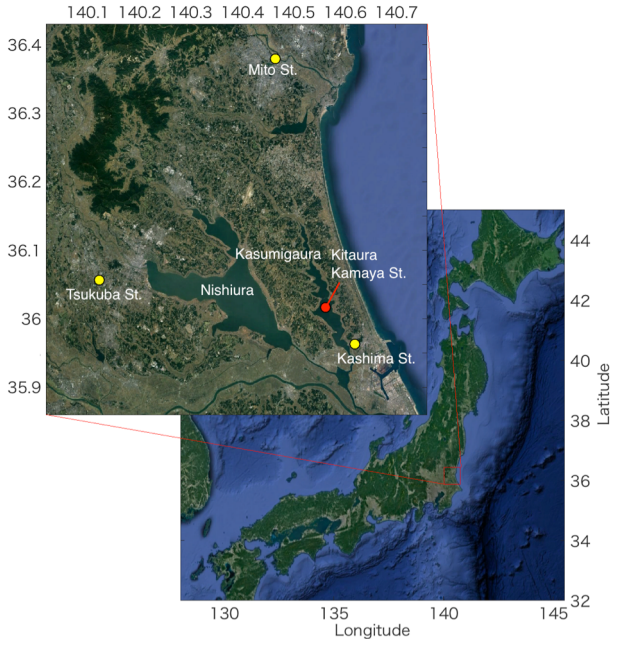

Fig. 1 Map of the study site. Red circle and yellow circle show locations of the Kamaya monitoring station and JMA weather stations.

(Japan Water Agency) in Kitaura Lake and weather stations (Japan Meteorological Agency, JMA) nearby the study site were sued to investigate physical processes associate with mixing processes and hypoxia. The Kamaya monitoring station is located at the middle of the Lake Kitaura (Fig. 1) and obtains data of water temperature, pH, chlorophyll *a* concentration, dissolved oxygen (DO) concentration, turbidity, conductivity every one hour with

a vertical interval of roughly 1 m. This study used temperature and oxygen concentration data from the Kamaya mooring station. Three JMA weather stations (Kashima, Tsukuba, Mito stations, Figure1) were selected to obtain data used for the heat flux analysis: Air temperature, wind data are from the Kashima station; Relative humidity (RH), pressure and shortwave radiation data are from the Tsukuba station; Data of the cloud cover ratio are from Mito station. The incoming heat flux into the lake was computed by using data from the mooring station and weather stations. The total heat flux is assumed as the sum of the long wave radiation (L_w), shortwave radiation (S_w), sensible heat flux (H_s) and latent heat flux (H_l), and these flux are estimated by conventional methods. We analyzed six years data set from 2011 to 2016, results from 2016 are shown in this paper.

3. RESULTS

Data from Kamaya monitoring station show that hypoxia water intermittently appears on the bottom during the summer season in every year (2011–2016). An example of temperature and DO in July, 2016 are plotted in Fig1. ab. Low oxygen concentration waters appear two periods July 10–15 and 17–23. In these two periods, the surface DO is approximately 10 mg L^{-1} (close to saturation) and the vertical temperature gradient is high, reaching 2.5 ^{o}C between the surface and bottom. Meanwhile, hypoxia waters disappear coinciding with vertical mixing after the hypoxia events (July, 16 and 23). According to long term mooring data, the time scale of hypoxia events is roughly one day–several days.

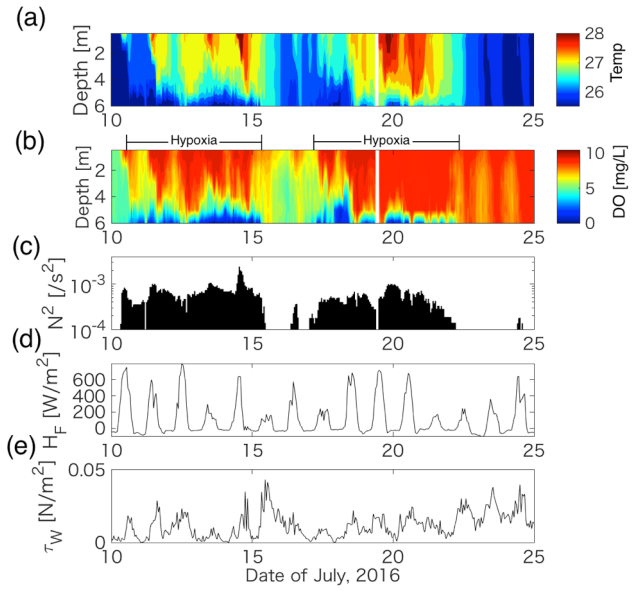

Fig. 2 Time series data of temperature, DO, buoyancy frequency (N^2), surface heat flux in the lake, surface wind stress in July 10–25, 2016.

To evaluate the strength of the stratification, the buoyancy (Brunt-Väisälä) frequency, N, is computed, which is given by

$$N^2 = -\frac{g}{\rho_0}\frac{\partial \rho}{\partial z} \quad (1)$$

where g is the gravitational acceleration, ρ is the density and ρ_0 is the reference density (1000 kg m^{-3}). Fig. 2bc clearly shows that hypoxia events coincide with strong stratifications events (N^2 ~ 10^{-4} – 10^{-3} s^{-2}). The stratification decreases on July, 16 and 23 with a high wind stress and weak incoming heat flux event. The 48 hourly time averaged N^2 in 2016 is plotted as a function of the 48 hourly averaged bottom DO in Fig 3a. The bottom DO concentration is clearly related with N^2 and hypoxia events (DO < 3 mg L^{-1}) only appear N^2 higher than 3.1×10^{-4} s^{-2}.

4. DISCUSSION

4.1 Physical forcing controlling mixing

According to results described above, hypoxia events in Lake Kitaura are highly related with the strength of the stratification, and the vertical mixing (stratification) is supposed to be controlled by two surface physical forcings: (1) surface heat flux and (2) surface wind stress. In global scale fluid dynamics (in large lakes and oceans), the earth's rotation and tides need to be considered [4, 5]. However, the scale of our study filed is much smaller than the global scale, thus we don't have to pay attention to the earth's rotation, tides. In order to explain vertical mixing

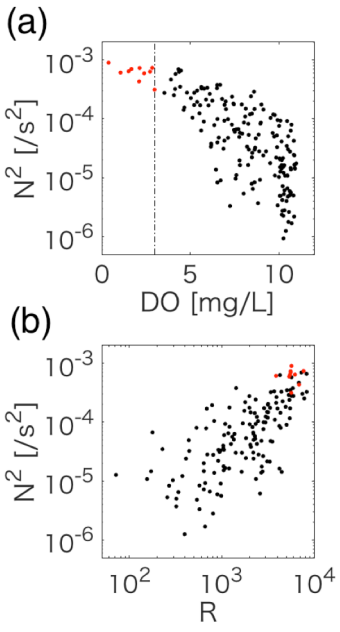

Fig. 3 Scatter plots of (a) the time-averaged bottom DO against N^2 and (b) the surface flux mixing number, R, against N^2. Red dots indicate DO less than 3 mg L^{-1}.

in the lake, we developed a non-dimensional number, the ratio of the time-integrated surface heat flux and horizontally-integrated wind stress, given by

$$R = \frac{\tau_w L}{H_F T}$$

where τ_w is the surface wind stress, L is the fetch length of the wind over the lake (10 km), H_F is the incoming heat flux into the lake, T is the scale for the heat flux integration (3600 s). Fig.3b shows the time-averaged R and time-averaged N^2 with an averaging scale of two days, which indicates a clear relationship between the ratio of the two forcings and stratification (correlation coefficient = 0.73). Therefore, mixing/stratification can be explained by the surface heat flux and surface wind stress for Lake Kitaura. This paper only presents results for 2016, but data from other years (2011–2015) also show similar results to that of 2016.

4.2 Contribution of the sediment heat flux

Annual averaged short wave radiation (S_w), long wave radiation(L_w), sensible heat flux (H_s) and latent heat flux (H_l) in 2016 are listed in Table1. Excepting the short wave radiation, L_w, H_s and H_l are negative values, namely heat transports toward the atmosphere. If the annual heat budget is only controlled by the surface heat flux, the sum of these four averaged heat fluxes has to be close to zero. However, our heat budget analysis show that the sum of the heat fluxes is 61 W m^{-2}, far from zero, which implies that only the surface heat flux cannot explain the total heat budget in Lake Kitaura.

In addition to the surface heat flux, the bottom heat flux into bottom sediments play a significant role in heat budgets in shallow lakes [6]. Although the monitoring station did not observe the bottom sediment heat flux, we hypothesized that the sediment heat flux largely contributes to the lake heat budget. Assuming the sediment heat flux is 61 W m^{-2}, 42% of the incoming short wave heat flux radiates into the bottom of the lake. Although we don't have enough observed results to prove the sediment heat processes, the sediment heat radiation might enhance the stratification leading to hypoxia in the bottom boundary layer.

Table1. The annual averaged surface heat flux into the lake in 2016 with a unit of W m^{-2}.

	S_w	L_w	H_S	H_l
Heat flux	145	-54	-6	-24

5. CONCLUSION

This study investigated hypoxia events in the bottom boundary layer in Lake Kasumigaura (Kitaura) with long term observed data and found following mixing mechanisms associate with hypoxia:

(1) The strong stratification condition ($N^2 > 3.1 \times 10^{-4}$ s^{-2}) leads to hypoxia (DO < 3 mg L^{-1}).

(2) The stratification is controlled by two forcings, the surface heat flux and surface wind stress. The ratio of these two forcings can explain the stratification is the lake.

(3) The heat flux from the lake water toward the sediment might lead to decreasing in the bottom temperature resulting in increasing in the stratification. The sediment heat flux is desire to understand heat budget in the lake.

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O6-7

無試薬光反応を利用した水質分析法のメンテナンス低減化・高感度化

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キーワード：水質、分析、モニタリング、全有機炭素、重金属

抄録

溶存有機炭素および有機態ヒ素を分解試薬を使用せず、1 分以内に迅速に無機化できる Lamp-pass-through (LPT) 光反応器を開発した。LPT 光反応器は水銀ランプに反応管を貫通させることにより、ランプから発する真空紫外光の反応管内の試料水への照射効率を高めることで、試料水に含まれる水分子からの OH ラジカル発生および溶存有機物の分解を高効率化した。この無試薬無機化法と非分散赤外分光法を組み合わせた溶存有機物(DOM)の分解試薬フリー・オンライン全有機炭素(TOC)分析法を開発した。本法は酸化剤や触媒など分解試薬を使わずに河川水中溶存有機物のオンライン TOC 分析を実現した。また、この無試薬無機化法はヒ素化学形態分析法の高感度化にも有用であった。液体クロマトグラフにより分離したヒ素化合物を無試薬無機化することで、全てのヒ素化合物を水素化物発生法により還元気化し、誘導結合プラズマ質量分析(ICP-MS)装置に大量導入することで、ヒ素化学形態分析の高感度化を実現した。

1. はじめに

水中の溶存有機物(Dissolved Organic matter。以下 DOM と略称)は水環境の炭素循環の鍵物質の1つであり、また、水質管理において、過剰量の DOM は水質汚染の主要因の一つである。このような水環境の炭素循環の解明や適切な水質管理や処理を行うためには DOM の全有機炭素(TOC)量を安価、簡便、迅速、そしてメンテナンス負担が少なく測定できる手法が必要とされている。

水中の全有機炭素量を測定するためには、試料水中の有機炭素を分解して二酸化炭素などの無機炭素に変換して非分散赤外分光分析法などで検出する。この有機炭素の無機化については、従来法は試薬を用いて行うものがほとんどであり、例えば、高温燃焼酸化(High Temperature Combustion Oxidation。HTCO と略称)による分解は、600 度を超える高温条件下で白金触媒を用いて酸化分解を行う。また、紫外光照射条件下でペルオキソ二硫酸塩を用いた酸化分解法もある。いずれの方法も有害・高価な試薬を要し、加えて、水現場での TOC 監視を想定した場合、試薬の交換、補充、廃水管理といった保守の負担が大きいと考える。

本研究では、水銀ランプから発する真空紫外光を試料水に高効率に照射できる Lamp-pass-through(LPT)光反応器を開発した。この光反応器を利用して、酸化剤や触媒などの分解試薬を必要としないオンライン TOC 分析法を確立した。また、この方法の実用性を明らかにするため、河川水および水道水試料中 DOM に適用できるかを検証した。

また、この LPT 光反応器は無試薬光反応による高効率な有機物分解が可能であることから、別の元素分析への応用も検討した。具体的には、ヒ素の化学形態分析法の高感度化である。ヒ素の高感度化学形態分析法の代表的分析法としては液体クロマトグラフー誘導結合プラズマ質量分析法(LC-ICP-MS)がある。例えば、イオン排除クロマトグラフを分離部とした LC-ICP-MS は、人尿中の陽・陰イオン・中性化合物といった広範囲のヒ素化合物を対象とした化学形態分析が可能であるが[1]、検出したヒ素化合物濃度の総和は、人尿中のヒ素総濃度よりも低値となった[2]。このことは、LC-ICP-MS であっても、一部のヒ素化合物が LC による分離や ICP-MS の感度が十分でないためと考えられる。

本研究では後者の ICP-MS の感度を改善するため、LPT 光反応器を用いて LC 分離後のヒ素化合物を無試薬条件下で迅速に無機化してひ酸に変換し、水素化物発生法によってアルシンに気化することで ICP-MS 装置への大量導入を可能とすることで高感度化した。また、この方法の実用性を検証するため、人尿試料への適用性を検証した。

2. 方法

有機炭素化合物、河川水試料中 DOM、ヒ素化合物の無試薬光反応処理は、LPT 光反応器を用いた。LPT

光反応器は水銀ランプに反応管を貫通させる構造とした[2]。LPT 光反応器の概略図を図 1 に示す。有機炭素および有機態ひ素の無機化率は、光反応後の残留有機炭素濃度を HTCO 式 TOC 計および LC-ICP-MS により定量することで決定した。

LPT 光反応器を用いた TOC 測定装置の概略図を図 1 に示す。TOC 測定装置[3]は、総炭素(Total carbon。以下、TC)測定と無機炭素(Inorganic carbon。以下、IC)測定との差分である TC-IC 測定モード、および不揮発性有機炭素 (Non-purgeable organic carbon。以下、NPOC)測定モードに対応可能である。本報告では TC-IC 測定モードについて述べる。TC 測定は、試料水にリン酸緩衝液をオンラインで添加して pH2 に調整した後に、LPT 光反応器に送液し、有機炭素を無機化した。得られた無機炭素は二酸化炭素として気液分離器で分離後、高純度空気をキャリアガスとして用いて非分散赤外分光計に導入し検出した。IC 測定は、試料水を酸性化後、上記の LPT 光反応器を通過させずに測定した。

LPT 光反応器を用いたヒ素の化学形態分析装置の概略図を図 2 に示す。試料水中のヒ素化合物は東ソー社の分離カラム TSKgel OApak-A および硫酸塩酸性溶液を溶離液として用いたイオン排除クロマトグラフィーにより分離し、その溶離液を LPT 光反応器に通液し、ヒ素化合物をヒ酸に変換した。この処理液に硝酸を添加して酸性化した後に、水素化ホウ素ナトリウム水溶液と混合することでアルシンを発生させ、これを気液分離器で分離して、アルゴンガスをキャリアガスとして ICP-MS 装置(Agilent 社 7500cx)に導入しひ素を m/z75 で検出した。

TOC 測定で使用した河川水、および湖水試料は涸沼川および霞ケ浦(共に茨城県)で採取し、0.45 μm のフィルターでろ過し、測定まで 4℃で保存した。人尿試料は採取後直ちに 0.45 μm のフィルターでろ過し分析に供した。

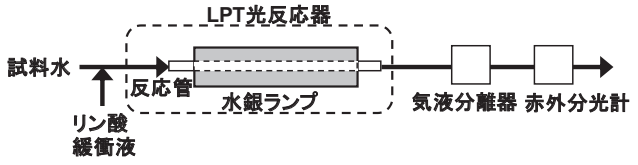

図 1　LPT 光反応器および分解試薬フリーTOC 測定装置の概略図

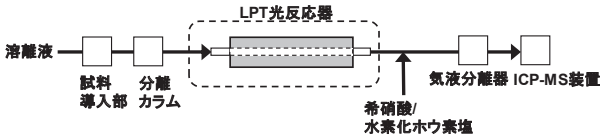

図 2　ヒ素の高感度化学形態分析装置の概略図

3. 結果と考察

LPT 光反応器は水銀ランプに反応管を貫通させることにより、ランプから発する真空紫外光の反応管内の試料水への照射効率を高めることが可能となり、試料水に含まれる水分子からの OH ラジカル発生と、そのラジカルによる溶存有機物質の分解を高効率化させることが可能となった。例えば、自然水由来の有機炭素物質の中で難分解性物質として知られる腐植物質の無機化については、International Humic Substances Society の標準物質であるフルボ酸(Nordic Aquatic Fulvic Acid, 1R105F) およびフミン酸(Nordic Aquatic Humic Acid, 1R105H)、各々2 ppm(mg of Carbon/L)を 6W 出力の水銀ランプを用いた LPT 光反応器を用いて分解したところ、わずか 1 分で各々90%以上の無機化率を示した[2]。この無機化性能を検証するため、従来のバッチ式光反応器法として、試料溶液が入った試験管に同出力の 6W ペン型水銀ランプを挿入し無試薬分解を行う方法と比較した。比較のため反応時間を短くして 15 秒としたときの 2ppm のフミン酸標準物質の無機化率を表 1 に示す。

表 1 フミン酸標準物質の無機化

(フミン酸炭素濃度、2ppm; 水銀ランプ 6W)

	無機化率
LPT 光反応器	62%
バッチ式光反応器 (ペン型ランプ+試験管容器)	～0%

LPT 光反応器は約 62%の高い無機化率が得られたのに対して、バッチ式光反応器は無機化が観測されなかった(無機化率～0%)。他の低分子有機酸、アルコール、糖類についても同様に LPT 光反応器の方が無機化率は高かった。これは、LPT 光反応器の構造によって差が生じると考えている。水銀ランプの真空紫外光(185nm)は試料水中の水による光吸収による減衰が極めて大きいため、内径がミリメートルレベルの狭い反応管を有し、全方向から光照射が行われる LPT 光反応器は、高い光照射率および無機化率が得られると考えられる。次に、この LPT 光反応器の実用性について検証した。多種の無機物質が含まれる実際の河川水および湖水(涸沼川よおび霞ケ浦)中 DOM も、1 分以内で 90%以上の迅速な無機化が得られた。さらにこの LPT 光反

応器を組み込んだ図 1 に示す分解試薬を使わないTOC 測定装置を開発した。分析性能を従来の金属触媒を用いるHTCO 式TOC 分析法と比較すると、検出下限は1/8 倍程度の6ppb である一方、分析時間はTC-IC 測定モードで 10 分とほぼ変わらなった[2]。また、実際の河川水試料(涸沼川)中のDOM のTOC 測定では、本法の分析値はHTCO 法の98±5%と測定誤差内で一致した。

LC-ICP-MS によるヒ素の化学形態分析法の高感度化については、水素化物発生法(HG)によりヒ素化合物を気化して ICP-MS 装置に大量導入して高感度化を図る LC-HG-ICP-MS は、有機態ヒ素はメチルヒ素など一部の化合物しか気化せず高感度化範囲は限定的であった。そこで110W 出力のランプを用いたLPT 光反応器を用いることで、HG 法で気化しないアルセノベタインやテトラメチルヒ素など含む全てのヒ素化合物をわずか約3.5 秒で気化可能なヒ酸に変換することが可能となった[1]。この機構を取り入れた図 2 の装置によりひ素の化学形態分析法の高感度化が行われ、アルセノベタインの検出下限は、LC-ICP-MS の約 1/10 倍の 3ppt (ng of As /L)に低減された。この高感度化は、LPT 光反応器による迅速な無試薬無機化が要因と考えている。一方、酸化剤など試薬を用いる無機化処理は酸化剤溶液の添加による希釈および後段の水素化還元反応への残留酸化剤による高感度化への抑制効果が生じない点にあると考える。また、本研究法は人尿試料や食事由来のヒ素の有害性評価を行うための食事試料の模擬胃液抽出液(塩酸、ヘパリン混合液)のヒ素の高感度化学形態別分析に適用可能であった[1][4]。例えば、人尿試料の分析では、LC-ICP-MS では 7 種類のヒ素化学種を検出したのに対して、本分析法は 20 種類のヒ素化合物を検出することができた。

4. 結論

溶存有機炭素および有機態ヒ素を分解試薬を使用せず、1 分以内に迅速に無機化できる LPT 光反応器を開発した。この光反応器を用いることで、分解試薬由来のコストやメンテナンスを低減しつつ、河川水に適用できる TOC オンライン測定法を確立した。また、この光反応器による無試薬無機化法と、LC-ICP-MS および水素化物発生法を組み合わせることで、ヒ素の化学形態分析を高感度化した。この LPT 光反応器を用いた無機化処理はこの他にもセレンの還元気化原子吸光分析の高感度化にも有用であった[5]。このように試薬を使用しないため広範囲の元素分析への適用が期待される。

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O6-8

Graphene-based electrochemical sensor as a microcystin-LR detection tool in water

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Keywords: Graphene film, MC-LR, biosensor, electrochemical detection, nanomaterials

ABSTRACT

In this work, we showcased a novel graphene film composite biosensor for microcystin-LR detection as an alternative to time-consuming, expensive, non-portable and often skills-demanding conventional methods of analysis involved in water quality monitoring and assessment. Excellent linear correlation (R^2=0.99) of the electron-transfer resistance was achieved over a wide range of MC-LR concentration, i.e. 0.05-100 μg/L. As-prepared graphene film composite biosensors can specifically detect MC-LR with remarkable sensitivity and detection limit much lower than the World Health Organization (WHO) provisional guideline limit of microcystin-LR concentration (i.e. 1 μg/L) in different water sources. Their great potential can be attributed to large active surface area of graphene film and efficient charge transfer process enabled by their high conductivity. Developed graphene film composite biosensors were also successfully applied to determination of MC-LR in several environmental water samples with high detection recovery. The developed technique offers a promising solution to quick in-situ detection of MC-LR in the contamination point of water source.

1. INTRODUCTION

Access to safe drinking water is of paramount importance to people's health and quality of life in any community around the world. Ever increasing episodes of harmful algal blooms (HAB) resulted from intensified anthropogenic activities such as agricultural run-off, urban waste discharge, and manufacturing of detergents has exerted a significant strain in drinking water access worldwide, especially where drinking water treatment plants receive from surface water sources. Since they contain harmful cyanobacteria, which are also known as blue-green algae and can produce and release highly potent cyanotoxins to the surrounding environment, their occurrence has become serious hazards to local public health. For example, residents in the city of Toledo, USA could not use and drink tap water in the summers of 2013 and 2014 due to the presence of cyanotoxins in drinking water supplies. Estimated 50 to 70% of intracellular metabolite released during a cyanobacterial HAB are harmful toxins (i.e. cyanotoxins) [1]. Microcystins is one of most frequently detected cyanotoxin throughout the world and some variants of MCs have been claimed to be bioaccumulative through the biological chain. To date, 80 variants of MCs have been isolated and identified from freshwater cyanobacteria genera, among which microcystin-LR (MC-LR) is the most toxic variant. Due to its severe toxicity, the provisional guideline concentration limit of 1 μg/L MC-LR in drinking water was assigned by the World Health Organization (WHO) in 1998 [2]. Following a significant HAB event, there is an urgent need to establish when a water source is safe to use or to evaluate the level of treatment required to make a source safe using a cost-effective generic analysis platform. These platforms should be easily tailored to provide early warnings of contamination episodes and allow reliable screening in water quality from catchment to consumer. Well-established methods to detect MC-LR in water include high-performance liquid chromatography/mass spectrometry (LC/MS), bioassays, biochemical assays, and immunoassays, which often require long processing times, sophisticated instruments, complex procedures, or high processing cost and are in general used in the laboratory, not in situ.

Recent advances in graphene synthesis and understanding of properties have led to enormous applications in a variety of areas. Graphene and its unique electrical properties can favour electrochemical biosensor applications for aqueous toxin monitoring. Graphene-based biosensors can be used as an alternative to time-consuming, expensive and non-portable conventional methods of analysis involved in water quality monitoring and assessment. In this work, we showcased a novel graphene-based biosensor for microcystin-LR (MC-LR) detection and quantification.

We report the efficient functionalization and immobilization of microcystin-LR and its antibodies on the facile synthesized CVD graphene/PET composite electrode.

2. METHOD

Cu foils (25 μm thick, 99.8%, Alfa) as graphene growth substrate was cut into pieces of 10×10 mm^2 and cleaned by acetone, methanol, and deionized water. During CVD process, Cu foils were first heated up to 950 °C in a horizontal quartz tube furnace under Ar (100 s.c.c.m.) and H_2 (200 s.c.c.m.) and annealed for 15 min to clean their surfaces and increase the Cu grain size. Graphene growth was then carried out at 1050 °C by introducing CH_4 of different concentrations balanced in Ar and H_2 with a total flow rate of 1500 sccm (1.3% H_2) for growth time between 5 and 60 min. After growth, samples were rapidly cooled to room temperature at a rate of ~100 °C/min in the protection of Ar (500 s.c.c.m) and H_2 (200 s.c.c.m.). In next step, GF grown on the Cu foil was attached to a thermal release tape (Nitto Denko Co.) by applying soft pressure (~0.2 MPa) between two rollers. After etching the Cu foil in a plastic bath filled with etching solution of iron nitrate (0.05 g/mL) for around 12 h, the transferred GF on the tape was rinsed with deionized water to remove residual etchant. Subsequently, the GF on the thermal release tape was inserted to the rolls together with 130 μm thick polyethylene terephthalate (PET) substrates and exposed to mild heat of 90~120°C for 3~5 min, resulting in the transfer of GF from the tape to the target substrate.

To fabricate the GF biosensor, a pre-cut GF sheet was attached to a copper wire tip using conductive silver epoxy (M. G. Chemicals, Ontario, Canada) and dried for 24 h at room temperature. This was followed by electrochemical functionalization, where a potential of 1.2 V vs. Ag/AgCl was applied to of GF biosensor tips for 1 min, in 1.0 M NaOH/0.5 M NaCl aqueous solutions. The functionalization potential (i.e. 1.2 V) was determined by choosing highest generated current on the surface of GF biosensor in linear sweep voltammetry without observations of water hydrolysis.

Specifically in this work, the GF biosensors were first incubated in a solution of 5 mM sulfo-NHS and 2 mM EDC in 0.1 M MES buffer, which was followed by 4 h incubation in 500 μg/L MC-LR solution (5 mL) made with PBS buffer. 1% (v/v) ethanol amine was used to washed them thoroughly after. As a result, amine group of MC-LR was conjugated to the oxygen containing functional groups (i.e. carboxyl group) on the surface of the electrochemically functionalized GF electrode through a stable covalent link. Next, MC-LR solutions of a range of concentrations from 0.05 to 100 μg/L were added into a fixed concentration of antibodies (i.e. 2.2 μg/mL) and incubated for 30 min to prepare a series of incubation standard solutions (i.e. 0.05, 0.5, 5, 20 and 100μg/L) using PBS buffer. The GF biosensors saturated with 500 μg/L MC-LR solution in the previous step were then dipped into these incubation standard solutions, where remaining free antibodies in the solutions would bind to the MC-LR on the GF biosensors.

The electrochemical properties of the GF electrodes were first evaluated using cyclic voltammetry (CV) in a typical three-electrode cell (i.e. a working, an auxiliary and a reference electrodes) at ambient temperature on a potentiostat analyzer (Autolab PGSTAT128N plus an FRA32M module). The GF electrodes was characterized by CV in 2 mM potassium ferricyanide ($K_3[Fe(CN)_6]$) solution using 0.5 M KNO_3 as the supporting electrolyte, with a Pt wire (1mm diameter, 99.95%) as auxiliary electrode and a saturated Ag/AgCl electrode as the reference. Faradaic electrochemical impedance spectroscopy (EIS) analysis was carried out with an open-circuit potential from 0.1 to 1×10^4 Hz with the amplitude of 0.01 V in the same three-electrode cell configuration but in a solution of 5.0 mM potassium ferricyanide ($K_3[Fe(CN)_6]$)/potassium ferrocyanide ($K_4[Fe(CN)_6]$) solution using 0.5 M KNO_3 as the supporting electrolyte (see Figure 1).

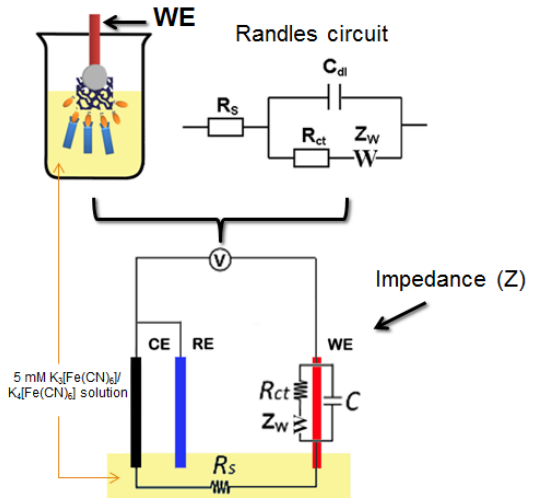

Figure 1 A illustration of Randles circuit and EIS experimental set-up

3. RESULTS AND DISCUSSION

Quantitation calibration curve of the GF biosensor response (i.e. the electron-transfer resistance) for different concentrations of MC-LR detection in the incubation solutions was shown in Figure 2. A Randles model equivalent circuit were used during the EIS measurements to interpret the behaviour of the GF biosensors, which consisted the solution resistance (R_s) in series with a parallel arrangement of the double layer capacitance (C_{dl})

and the electron-transfer resistance (R_{ct}) in series with Warbur impedance (Z_w). The determined values of the R_{ct} were then plotted as a function of the MC-LR concentration using a logarithmic scale. A great linear sensing response (R^2=0.99) of the electron-transfer resistance (R_{ct}) over a wide MC-LR concentration (C_{MC-LR}) range between 0.05 and 100 µg/L was thus achieved, which allowed the toxin detection well below the WHO provisional guideline limit of 1 µg/L for MC-LR in drinking water.

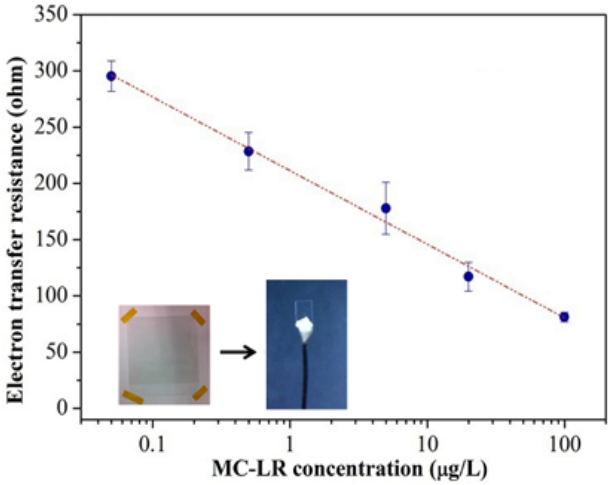

Figure 2 Linear response of MC-LR concentration to electron transfer resistance, where the inset is graphene-PET biosensor fabrication.

Table 1 Validation results of MC-LR detection using GF electrochemical biosensor

	GF biosensor value (µg /L)	**Recovery (%)**
Tokyo tap water	0.965±0.031	96.5
Inba lake water	0.958±0.029	95.8
Sanshiro pond water	0.949±0.037	94.9
Shinobazu pond water	0.961±0.026	96.1

GF biosensor detection results of MC-LR in four different environmental water samples are listed in Table 1, where it can be seen that potential interference (i.e. metal ions and dissolved organic compounds) has insignificant effects on the detection results. Obtained high MC-LR detection recovery (> 90 %) were also very comparable to most of recent literature studies using nanomaterial biosensor based on different electrochemical detection principle [3,4.5].

4. CONCLUSION

A fit-for-purpose biosensor for MC-LR detection as alternatives to the time-consuming, expensive, non-portable and often skills-demanding conventional methods of analysis involved in water quality assessment has been developed using GF/PET composite grown by a modified CVD method. A two-step linking procedure that enabled the immobilization of MC-LR onto the GF electrodes and conjugation of monoclonal antibodies specific to MC-LR in the incubation solutions has been employed to provide the required specificity for detecting MC-LR toxin. CV analysis revealed well-defined redox peaks in the presence of redox species, which can indicate efficient interface charge-transfer. After conjugation of MC-LR and antibodies to graphene, the increase of EIS measurements was used to detect the change of MC-LR concentration. A great linear sensing response (R^2=0.99) of EIS change was established over a wide MC-LR concentration range of 0.05 to 100 µg/L with good repeatability. Environmental water samples from different local sources, i.e. Tokyo metropolitan tap, Sanshiro pond (Tokyo, Japan), Shinobazu pond (Tokyo, Japan) and Inba lake water (Chiba prefecture, Japan), has been used to validate the sensing results of developed GF biosensors and investigate potential interfering effects of factors, such as metal ions and dissolved organic compounds. With insignificant interference effects on the detection results and high MC-LR detection recovery, developed GF biosensor technique in this work offers a promising solution to quick in-situ detection of MC-LR in the contamination point of water source with very low detection limits.

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O6-9

題名:危機管理型水位計による河川水位モニタリング技術

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キーワード:危機管理型水位計, 河川, 水位計測, 洪水, クラウド

抄録

日本全国には河川が約 20,000 ある。この大多数を占める中小河川において、水位計が未設置の個所が数多く存在し、洪水時の河川水位の把握が困難な状況にある。従来型の水位計は、河川管理を主体とするため、初期投資が大きく、普及を拡大するには制約がある。このため、国土交通省では従来の技術的枠組みにとらわれない新しい河川管理を目指した「革新的河川管理プロジェクト」を立ち上げ、2017 年度に実証試験を実施した。本発表では、このプロジェクトに参画し開発した危機管理型水位計の仕様概要、計測データの処理、メンテナンスフリーの対応、実証試験結果の評価について述べる。出水期の 5 回計測した洪水時観測結果は洪水波形特性を再現した安定した計測ができた。その中で 8 月 19 日は 2 時間で約 1,000 発の落雷があったにもかかわらず、データ欠測のない安定した計測が確認できた。また、水位計測データの利活用はどのようにすべきかについて、いくつかの提言をする。

1. はじめに

平成 27 年関東・東北豪雨災害[1]、平成 28 年北海道・東北豪雨災害、平成 29 年九州北部豪雨災害等[2]、水害の頻発化・激甚化が顕著である。日本全国の河川約 20,000 の多くは中小河川である。中小河川における水害が多発しており、洪水時に河川水位の情報をもとに的確に避難の判断をすることが要求されている。このため、水害危険性の周知方法の一つとして危機管理型水位計の設置が検討[3]され、低コストの水位計を実用化し、普及を促進することとなった。

2. 革新的河川管理プロジェクトにおける実証試験

2.1 革新的河川管理プロジェクト

「革新的河川管理プロジェクト」[4]は、国土交通省が最新の技術・ノウハウを持ち寄りスピーディーに実装化を図る技術開発の取り組みの一環として、オープンイノベーションを採用し、従来の技術的枠組みにとらわれない新しい河川管理を目指したものである。12 チーム 21 者がクラウド型メンテナンスフリー水位計として危機管理型水位計を開発し、平成 29 年夏より鶴見川水系の鳥山川に据え付け、水位観測を実施した。

2.2 危機管理型水位計の仕様概要

従来の初期投資、維持管理コストがかかるといった課題を解決するため、国土交通省から提示された要求仕様は下記である。目標は IoT 技術を応用し、短期間で実装化し、普及することである。

(1)メンテナンスフリー

(2)省スペース

(3)通信コストの縮減

(4)クラウド化でシステム経費の縮減

(5)低コスト(1 台 100 万円以下を目標)

要求仕様に対して開発した水位計仕様は、表 1 の通りである。要求仕様ごとに水位計の設置環境を考慮して、仕様を決定した。

表 1 危機管理型水位計の仕様

No	仕様項目	仕 様
1	共通部 温度・湿度条件	-20℃～55℃
	耐用年数	5 年間
2	水位計測部 計測方法	水圧式,超音波式
	計測範囲	0～10m
	最小読取範囲	1cm
	観測精度	±0.1%以内
3	計測制御部 データロガー機能	測定時刻,水位,電池電圧,温度をメモリ記録し、クラウド伝送
	時刻補正機能	基地局からの電波による時刻補正
4	電源部 バッテリー仕様	12V24Ah
	太陽光パネル容量	30W
	無日照保証日数	9 日間
5	観測周期(自動切替)平常	10 分
	設定水位変動以上	1～5 分の可変

2.3 計測データの処理

図 1 に示すように危機管理型水位計は、水位観測データと水位計環境情報を閉域無線回線経由でクラウドに伝送する。クラウドでは観測データを時系列にデータベース化すると共に水位計環境情報を記録する。水位情報は、インターネットによりスマートフォンで水位計の位置、河川断面表示と重畳した水位グラフ、過去時系列等の検索閲覧ができる。また、基準設定以上に水位が超過した場合は警報が鳴る。水位観測周期は、水位の上昇速度が設定値を超過すると自動的に平常時 10 分周期から 5 分周期に早まる。これは中小河川の水位上昇速度が速いため、観測周期を可変とし、かつ機器の電池消耗を最小限とするための方法である。



図 1　水位計測とクラウド構成

2.4 メンテナンスフリーの対応

水位計は従来、1 回/年の定期点検等維持管理コストがかかっている。危機管理型水位計は、5 年間のメンテナンスフリーを要求されており、水位計環境情報を同時に収集し、遠隔診断処理により早期の異常検知をし、予防保全につなげる。環境情報は、センサ・通信機電源電圧、電波状態、温度等であり、通信安定性、電源状態、機器環境を判断する。

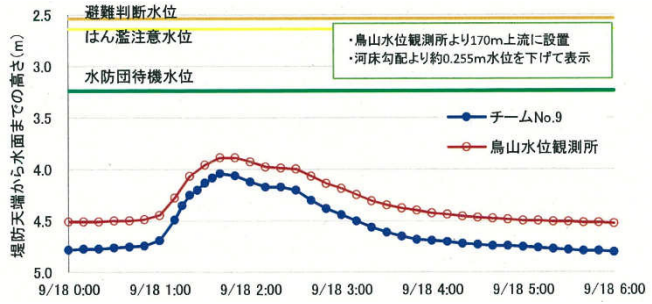
3. 実証試験結果

3.1 洪水時試験計測結果

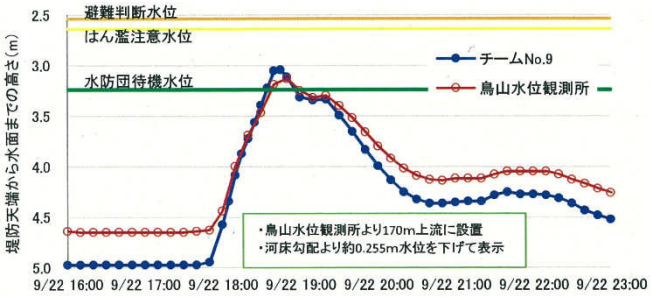
図 2 は 9 月～10 月の洪水時の試験計測結果である。グラフは既設の鳥山水位観測所の計測データと本チーム(チーム No.9)の計測データを比較している。河床勾配より約 0.255m 水位を低く表示しているため、全体に低く表示されている。計測結果は公表[5]され、本チームを含めた 6 チームが「洪水波形特性を再現しており、良好な結果」と評価された。観測周期は、水位が急上昇したときの平常時 10 分から 5 分に自動切替されている。これにより、水位計測は急峻な水位変化に追従できた。特に 9 月 22 日の水位ピーク値は 5 分周期の場合、的確に捉えている。

図 3 は、本チームが先行して 8 月に設置したことにより計測できた試験結果である。8 月 19 日は、水位計設置場所近傍で 2 時間に約 1,000 発の落雷があり[6]、豪雨となった。その結果、最大水位は堤防天端から 2.41m に達し、最大水位上昇速度は 0.86m／5 分と急激であった。このような厳しい環境下でも水位計とクラウド間のデータ欠測処理機能によりデータ欠測は全くなく、安定して観測できた。

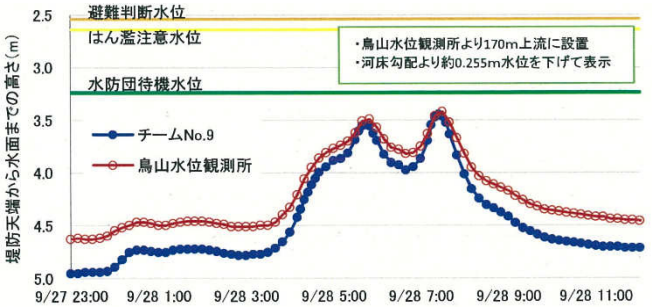
(1)平成 29 年 9 月 18 日



(2)平成 29 年 9 月 22 日



(3)平成 29 年 9 月 28 日



(4)平成 29 年 10 月 29 日(台風 21 号)

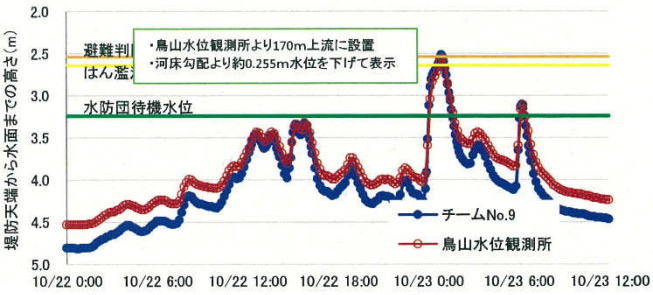


図 2 洪水時試験計測結果

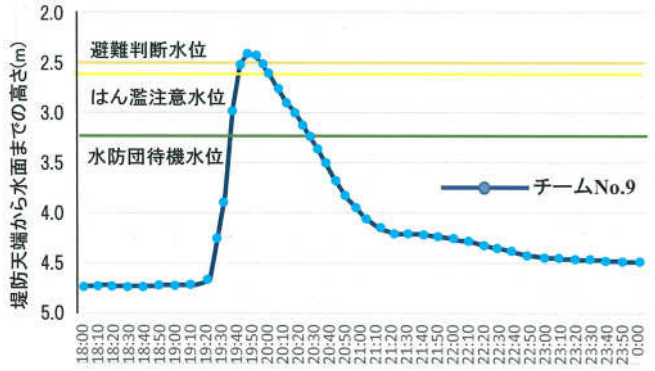


図 3 雷雨時の洪水試験計測結果(8 月 19 日)

3.2 水位計の電源電圧監視結果

図 4 は、通信機電源電圧の気象条件による変動を示したものである。1 ヶ月間に 10 数日の降雨日があったが、天候悪化の影響を受けず基準電圧 12V の安定した電源供給を実現している。通信機電源電圧の日間変動は太陽光パネルからの充電の変化による。

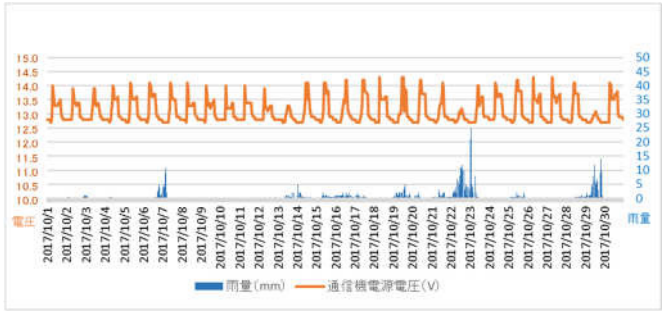


図 4 電源電圧変化と気象状況(観測地点雨量)

4. 考察

4.1 メンテナンスフリー

5 年間無給電で運用ができるように、バッテリーと太陽光パネルを組み合せた。電源容量は 9 日間の無日照を保証する。水位計の稼働状況がリアルタイムで監視できるように電源状況、通信状況、装置環境情報を水位情報と同時にクラウドへ伝送・解析することにより、遠隔で機器の予防保全ができる環境とした。

4.2 省スペース

水位計装置は、計測部、計測制御部、通信部、電源部を組み合せて 1 本のポールに設置できるようにコンパクト化した。

4.3 通信コストの低減

通信は携帯無線回線を利用する。伝送項目は最適化して伝送量を極力減らし、平常時と降雨時を合わせた通信コストを低減した。また伝送時間の短縮により、災害時の通信輻輳時にも安定した通信が確保できるように配慮した。

4.4 クラウド化でシステム経費の縮減

水位データはクラウドで処理することにより、ハードウェアの初期投資の低減、ソフトウェア開発の共有化等により重複開発を縮減した。また、実証試験の実績を生かして、早期のシステム立ち上げを可能とした。

4.5 低コスト

水位計装置は、装置のコンパクト化、汎用部品の採用等により目標コストを実現した。通信は伝送時以外を休止モードとして低消費電力化を図り、電源部容量の小型化により、コストを低減できた。

4.6 今後の展開

河川水位の情報は、的確な避難の判断に重要な情報である。中小河川への設置が今年度から実施され、水位計のデータはクラウドに集中して収集される[7]。これらの水位情報はオープンデータとして公開される予定であり、その利活用が今後本格化する。管理者、住民に対してわかり易く情報提供することが重要である。応用例として、避難に有用な避難所情報の提供、スマートフォンの GPS 機能を活用した位置表示、過去のアーカイブ情報との比較、地理情報との連携などが挙げられる。

5. 結論

中小河川への設置が実現できる危機管理型水位計を開発し、実証試験により洪水時の安定した計測ができることを実証できた。危機管理型水位計はこれから本格的な設置が進められる。水害危険性の周知方法として、河川水位のモニタリングが的確な避難の判断情報として活用されるように、安定した情報提供ができる環境づくりに寄与したい。

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O6-10

Estimation of Secchi Disk Depth in Lake Kasumigaura from MERIS

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Keywords: Secchi disk depth, remote sensing, Lake Kasumigaura

ABSTRACT

Secchi Disk Depth (Z_{SD}), also called transparency, is an important indicator of water quality. The manual and point-based measurement of Z_{SD} has a long history with more than 200 years. With the development of remote sensing, satellite image can provide the potential for large spatial and long time-series monitoring of Z_{SD}, which is also developing to an important way for lake environment management. In this study, MERIS images from 2003 to 2012 were employed to retrieve Z_{SD} in the Japanese turbid Lake Kasumigaura. The absorption and backscattering coefficients were firstly retrieved using two versions of quasi-analytical algorithm: QAA_V6 and QAA_turbid, and then Z_{SD} were estimated based on the new method proposed by Lee in 2015. Results were validated using in-situ Z_{SD}, the RMSE and MAPE of Z_{SD} estimated using QAA_turbid were 0.10m and 14.96% respectively, the estimated Z_{SD} using QAA_V6 showed overestimation with RMSE and MAPE of 0.65m and 97.83%. This indicated that Z_{SD} estimation using absorption and backscattering coefficients from QAA_turbid was more accurate than that from QAA_V6. Long time-series results of Z_{SD} estimated from MERIS using QAA_turbid matched the in-situ Z_{SD} well, all of them showed an increase trend from 2003 to 2012 in Lake Kasumigaura. Results in this study implied that estimation of Z_{SD} from MERIS images is a potential way for long time-series Z_{SD} monitoring in lakes.

1. INTRODUCTION

Secchi Disk Depth (Z_{SD}), also termed transparency, has been recorded for more than 200 years in natural waters. Measuring Z_{SD} is a direct and efficient way for water condition evaluation[1][2]. The general way to measure Z_{SD} is by lowering down a 25 or 30 cm white disk or white-and-black disk into the water, and Z_{SD} is recorded as the depth when the disk can no longer be seen[1][3]. Lee et al.[3] developed a mechanistic model to estimate Z_{SD} in different types of waters from remote sensing, which can be applied to satellite images to produce large coverage and high frequency Z_{SD} observations. In this method, absorption and backscattering coefficients are key parameters for Z_{SD} estimation, which is a big challenge for turbid waters. At present, quasi-analytical algorithm is a solution for absorption and backscattering coefficients retrieval, QAA_V6[4] and QAA_turbid[5] are two typical algorithms which can be used for absorption and backscattering coefficients retrieval in turbid waters. But the performance of those two algorithms still need more tests in turbid inland lakes, because usually the inland turbid waters are more complicated than ocean waters. Knowing the importance and challenges of Z_{SD} retrieval in inland turbid waters, the objectives of this study were to: (1) evaluate the performance of Lee's Z_{SD} model combined with two quasi-analytical algorithms, QAA_V6 and QAA_turbid, in the turbid Lake Kasumigaura, and (2) produce the long time series of Z_{SD} from MERIS satellite image in Lake Kasumigaura.

2. METHOD

In this study, totally 507 MERIS images covering Lake Kasumigaura were downloaded from ESA, those images were further pre-processed in BEAM software following the steps as: research area subset, radiometric correction, case-2 atmospheric correction. Absorption and backscattering coefficients were then estimated from the pre-processed images using QAA_V6 and QAA_turbid respectively, and then the diffuse attenuation coefficients were estimated[6], at last, Z_{SD} were estimated using Lee's Z_{SD} model[3]. The in-situ Z_{SD} data covering 2003-2012 from the National Institute for Environmental Studies (NIES) were used for result validation, it is noted that the

in-situ data were collected every month in 10 monitoring sites in Lake Kasumigaura.

3. RESULTS

By searching the in-situ database, 19 matched in-situ Z_{SD} were found, Fig.1 shows the results of validation using in-situ Z_{SD} data which collected on the same day with satellite image. It is clear that Z_{SD} estimated using QAA_V6 shows overestimation, with RMSE and MAPE of 0.65 m and 97.83% respectively. Z_{SD} estimated using QAA_turbid shows good correlation with in-situ data, the RMSE and MAPE are 0.10 m and 14.96%, which are significant better than the results using QAA_V6.

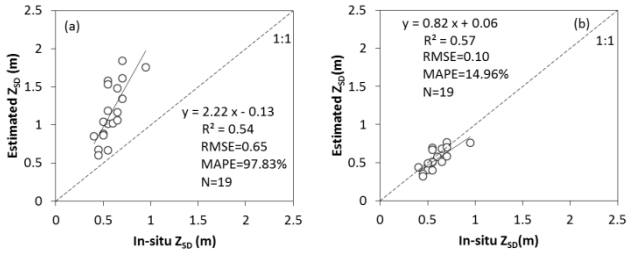

Fig1. Validation results of retrieved Z_{SD}. (a) Z_{SD} retrieved using QAA_V6, (b) Z_{SD} retrieved using QAA_turbid.

All estimated Z_{SD} were averaged to monthly mean Z_{SD} to compare with in-situ data, Fig2. shows the results of monthly mean Z_{SD} changes from 2003 to 2012 in the center of the lake. We can see that the retrieved Z_{SD} using QAA_V6 is apparently higher than the in-situ Z_{SD}, while QAA_turbid matches well with the in-situ data. Furthermore, both of the retrieved Z_{SD} and in-situ Z_{SD} show an increase trend during the 10 years.

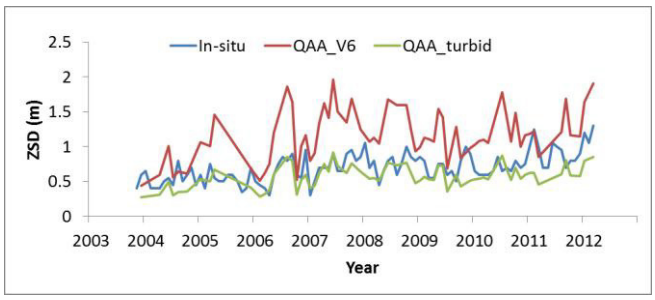

Fig.2 Z_{SD} changes in the center of Lake Kasumigaura from 2003 to 2012

4. DISCUSSION

Absorption and backscattering coefficients describe the inherent optical properties of the water, they are key parameters in Z_{SD} retrieval when using Lee's Z_{SD} model. The QAA_V6 from IOCCG can be generally used for both turbid and clear waters according to previous studies, but for extreme turbid inland waters, such as Lake Kasumigaura in this study, QAA_V6 gave an overestimation of Z_{SD}, the potential reason is that QAA_V6 is mainly used for ocean waters, therefore the retrieved absorption and backscattering coefficients are lower than the true values when using it for turbid inland waters, this leads to the overestimation of Z_{SD}. QAA_turbid was developed for turbid waters, it gives the accurate absorption and backscattering coefficients, so the estimated Z_{SD} is reasonable. Moreover, the estimated long time series Z_{SD} using QAA_turbid in this study showed the same change trend with in-situ data, that means combining Lee's Z_{SD} model with QAA_turbid can be used for Z_{SD} monitoring from satellite images in turbid inland lakes.

5. CONCLUSION

This study used MERIS images to evaluate Lee's Z_{SD} model combined with QAA_V6 and QAA_turbid in the turbid Lake Kasumigaura, results revealed that Lee's Z_{SD} model with QAA_V6 lead to overestimation of Z_{SD} in extreme turbid waters, but QAA_turbid performed well. Results in this study also indicated that long time Z_{SD} monitoring using Lee's Z_{SD} model based on QAA_turbid is reasonable in Lake Kasumigaura, retrieved results agreed with in-situ data and showed increase Z_{SD} from 2003 to 2012.

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O6-11

気候変動観測衛星「しきさい」による湖沼観測

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キーワード：気候変動観測衛星，GCOM-C，多波長光学放射計，SGLI，リモートセンシング，水色，水温

抄録

2017年12月に打ち上げられた気候変動観測衛星「しきさい」には，250m空間解像度，1150～1400 km観測幅で近紫外～熱赤外波長を19チャンネルで観測する多波長光学放射計（SGLI）が搭載されている。2018年12月から一般配布の開始が計画されているクロロフィル a 濃度や海面水温等のプロダクトは外洋や沿岸域を想定したものではあるが，導出原理としては湖沼でも導出が可能であると考えられる。衛星打ち上げ後実際に取得されている観測画像からは，霞ヶ浦のような大規模な湖だけでなく，数 $10km^2$ スケールの湖沼でも水色や水温推定値の空間パターンが識別できている。湖沼の水中特性の現場観測研究との連携を通じ，「しきさい」の250m解像度と広い観測幅による高頻度観測を生かした湖沼の環境変動監視への貢献が期待できる。

1. はじめに

気候変動観測衛星「しきさい」は2017年12月23日に種子島から打ち上げられ，2018年4月から定常運用を開始している。「しきさい」には，250m 空間解像度・1150 km～1400 km 観測幅で近紫外～熱赤外波長の19 チャンネル（表1）で観測する多波長光学放射計（SGLI）を搭載している。

表 1　多波長光学放射計（SGLI）チャンネル[1]

CH	λ	$\Delta\lambda$	L_{std}	L_{max}	SNR	IFOV
	nm		$W/m^2/sr/\mu m$ TI: Kelvin		TI: NEΔT	m
VN01	380	11	60	210	675	**250**/1000
VN02	412	10	75	250	800	**250**/1000
VN03	443	10	64	400	517	**250**/1000
VN04	490	10	53	120	865	**250**/1000
VN05	530	20	41	350	482	**250**/1000
VN06	566	20	33	90	1040	**250**/1000
VN07	672	22	23	62	1002	**250**/1000
VN08	672	22	25	210	549	**250**/1000
VN09	763	11	40	350	1646	250/**1000**
VN10	867	21	8	30	491	**250**/1000
VN11	867	21	30	300	498	**250**/1000
PL01	672	21	25	250	655	**1000**
PL02	866	20	30	300	723	**1000**
SW01	1050	21	57	248	951	**1000**
SW02	1390	20	8	103	346	**1000**
SW03	1630	196	3	50	100	**250**/1000
SW04	2210	51	1.9	20	379	**1000**
TI01	10800	760	300K	340K	0.039K	250/**500**/1000
TI02	12000	780	300K	340K	0.069K	250/**500**/1000

SNR is defined at L_{std} and IFOV shown by bold characters

この観測データから250m解像度の海色や海面水温プロダクトを作成・配布予定である（表 2）。これらのデータや推定手法は湖沼への応用が可能であるため，250m 解像度が生かせる比較的大きな湖沼については、2日に1度（曇天でなければ）の高頻度観測データの取得が期待できる。

表 2　GCOM-C 海洋分野プロダクト

カテゴリ		プロダクト名
海色	標準プロダクト	正規化海水射出放射輝度
		大気補正パラメータ
		光合成有効放射
		クロロフィル a 濃度
		懸濁物質濃度
		有色溶存有機物吸光係数
	研究プロダクト	海水固有の光学特性
		有光層深度
		植物プランクトン機能別分類
		赤潮
		海洋純基礎生産力
		多センサ複合海色
温度	標準プロダクト	海面水温
	研究プロダクト	多センサ複合海面水温

2. 方法

衛星光学観測値から海色（水色）を導出するためには、大気の散乱や吸収を補正する必要がある。波長毎の衛星観測光を水平面に入射する太陽入射光で割った大気上端反射率ρ_tは以下のように近似できる。

$$\rho_t / t_g = \rho_r + \rho_a + t_d \rho_w / (1 - s_a \rho_w) + t_b \rho_g \qquad (1)$$

ここで、t_g 大気分子の吸収，ρ_r 大気分子の散乱，ρ_a エアロゾルの散乱，t_d 大気の直達+散乱透過率，t_b 直達透過率，s_a 球面アルベード，ρ_w サングリント反射率，ρ_w 水面反射率である。実際の計算では，大気放射伝達コード（例えばPstar-4[2]）を用い、観測量であるρ_tとρ_w以外の変数について，様々な観測幾何条件やエアロゾル等の条件における各波長の値を計算したルックアップテーブル LUT を作っておく（水面での反射光成分をρ_r に含めて計算し、ρ_wを水中からの射出光成分だけにすることが多い）。この LUT と複数の波長で観測したρ_t が整合するような(1)式中の変数を探すことにより，ρ_w（水色）を推定する[3]。

クロロフィル a 濃度（Chl-*a*）等の水中の物質量については，衛星で観測された複数の波長におけるρ_w から，現場観測等による物質量と光学特性（吸収や散乱特性）の関係の知見（回帰式[4]や水中光学モデル[5]）を用いて推定する。

海面（水面）温度については、熱赤外波長の複数のチャンネル（しきさいでは 10.8μm と 12μm）での観測値から大気の放射・吸収を分離し，水面からの熱放射を抽出することによって推定する[6]。

3. 結果

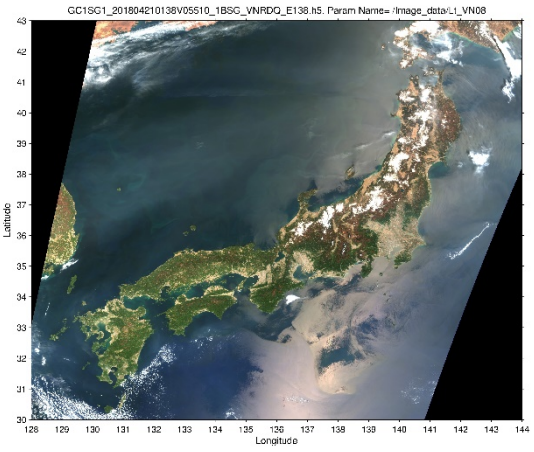

図 1「しきさい」の観測例（RGB 合成画像 2018/04/21）

図 1 の左上と右下の黒い部分を除いた範囲が SGLI 可視波長チャンネルの観測幅（約 1150km）である。「しきさい」は日本列島を一度に観測できるこの広い観測幅で地球を 1 日に約 14 周回（485 周/34 日）することにより，中緯度帯では 2 日に 1 度程度観測することができる（晴天の場合）。

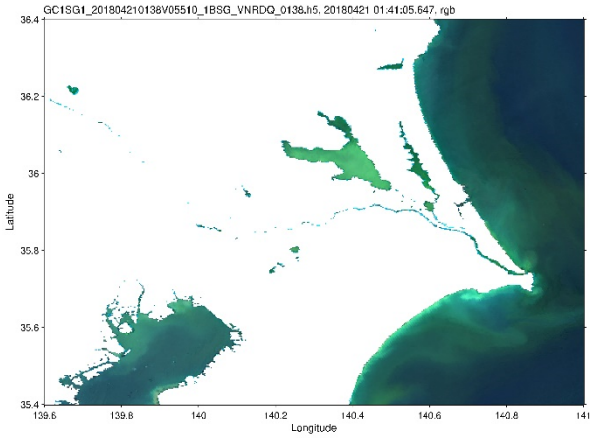

図 2 ρ_w の RGB 画像の関東東部拡大図（2018/04/21）

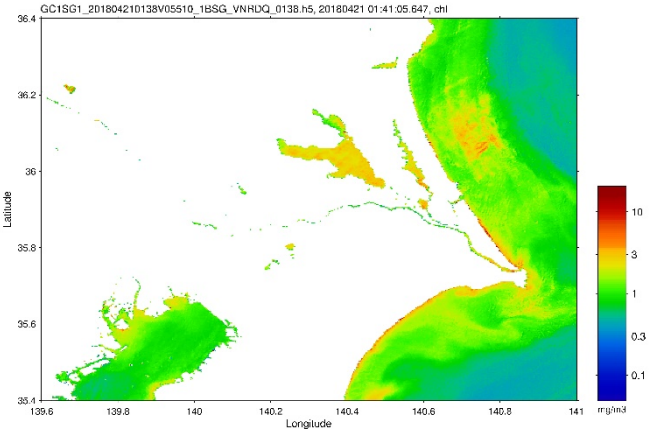

図 3 Chl-*a* の関東東部拡大図（2018/04/21）

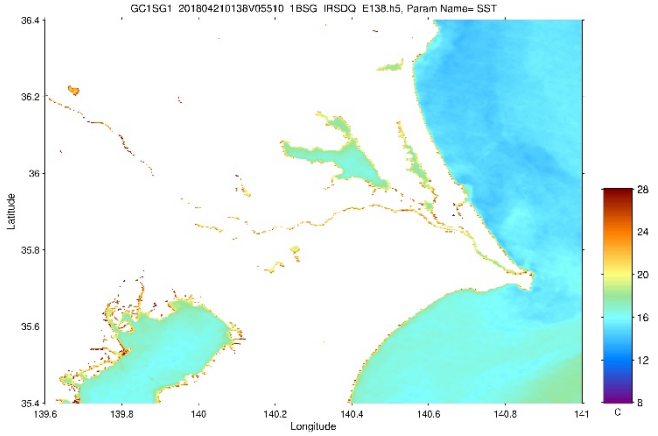

図 4 水面温度の関東東部拡大図（2018/04/21）

図 2, 3, 4 は，大気補正後の水中射出反射率，Chl-*a*，水面温度プロダクトを試作したものである。霞ヶ浦のような大きな湖沼だけでなく，印旛沼や谷中湖，涸沼などのサイズの湖沼（～数 10km^2）についてもその中の空間パターンをある程度識別できている。

4. 結論

「しきさい」の海洋分野の標準プロダクトとして Chl-*a* や水温等のプロダクトの作成が計画されており，2018 年

12 月から一般提供を開始する計画である。元々は外洋や沿岸域を想定したプロダクトであるが，実際に取得されている観測画像からは，霞ヶ浦のような大規模な湖だけでなく，数 10km^2 スケールの湖沼でも水色や水温推定値の空間パターンが識別できており，ある程度のサイズ以上の湖沼であれば水色や表面水温等の推定が可能であると思われる。

もちろん，Chl-*a* 等の水中の物質量の推定に必要な水中光学特性は，湖沼では地域性が大きいと考えられるため、個々の湖沼における現場観測等による水中光学特性の知見の蓄積が重要である。今後この知見の蓄積が進めば，より定量的な物理量推定が可能となり，「しきさい」の広い観測幅による高頻度観測を生かした湖沼の環境変動監視への貢献が期待できる。

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O6-12

In-Situ Hyperspectral Remote Sensing as An Aid in Wetlands Condition Assessment – A Case Study of Indian Man-Made Wetland

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Keywords: Wetland, hyperspectral, remote sensing, spectroradiometer, data analysis technologies and modeling.

ABSTRACT

Worldwide, wetland ecosystems are facing natural and anthropogenic pressures resulting in deterioration of their health and resilience. Conventional methods commonly use point physico-chemical measurements to characterize and monitor the health of lakes and aquatic ecosystems. Moreover, such methods fail to provide information in spatial domain. Hyperspectral remote sensing is fast emerging as a potential standalone tool for assessment of health of aquatic ecosystems. In the present study, *in-situ* hyperspectral remote sensing was employed to test its potential for condition assessment of Bhindawas lake, largest man-made wetland in the state of Haryana, India. Spectral reflectance data for wetland water column and representative macrophyte species was collected at different sampling sites within the wetland using a SVC GER Spectroradiometer (350-1050 nm) during the year 2014 and 2015. Water samples were collected for the analysis of bio-optical water quality parameters (Chl-a, TSS and Turbidity). Various spectroscopic methods (smoothing and derivative analysis) and linear regression were used to analyze the spectral data. Results have revealed that spectral reflectance data allows identification of various macrophyte species. Linear regression models were developed for estimation of bio-optical parameters in the wetland water column that can successfully replace the conventional field-based methods for wetland condition assessment.

1. INTRODUCTION

Globally, conservation and management of wetlands has become a cause of concern for researchers, conservation agencies and people. Multispectral Remote Sensing has been used to assess and monitor wetland condition for several decades. Inspite of its wide use, it is associated with inherent limitations associated with sensor technology, measurement methods and resolutions. According to Ustin et al., (2004) [1] imaging spectroscopy or hyperspectral remote sensing provides a prospect to overcome the shortcomings of multispectral satellite data for wetland related studies. Data dimensionality of hyperspectral sensors allows detailed analysis of ecosystem properties and processes surpassing other remote sensing modalities.

In the context of wetland science, hyperspectral data has been used to achieve a variety of objectives including delineation of wetlands and characterization of hydrophytes [2]. Monitoring of water quality conditions and parameters of freshwater ecosystems is one of the major advantages of hyperspectral data. It has been used for classifying trophic levels of lakes [3] and estuaries [4], characterizing algal bloom [5] and assessment of ammonia dynamics for wetland treatments [6]. In-situ spectroradiometer data has proved useful in estimating total suspended matter, chlorophyll content and total phosphorus [7]. With respect to wetland vegetation, hyperspectral data has been successfully used for spectral discrimination of wetland species in comparison to the general classification achieved using multispectral data [8]. In spite of the increase in application of hyperspectral remote sensing for wetland studies there exists a paucity in its application for assessment of inland wetlands of India.

The main aim of the study is (i) to develop models for estimation of bio-optical parameters which effect wetland condition functioning using *in-situ* hyperspectral data and (ii) to test the potential of *in-situ* hyperspectral data for identification of macrophyte species.

2. METHOD

Study area

Bhindawas Bird Sanctuary, a man-made wetland designated as a protected area in the year 1986, is the largest wetland in the state of Haryana (412 ha) with a periphery of 12 km (28°28′00″ to 28°36′00″ N; 76°28′00″ to 76°38′00″ E).

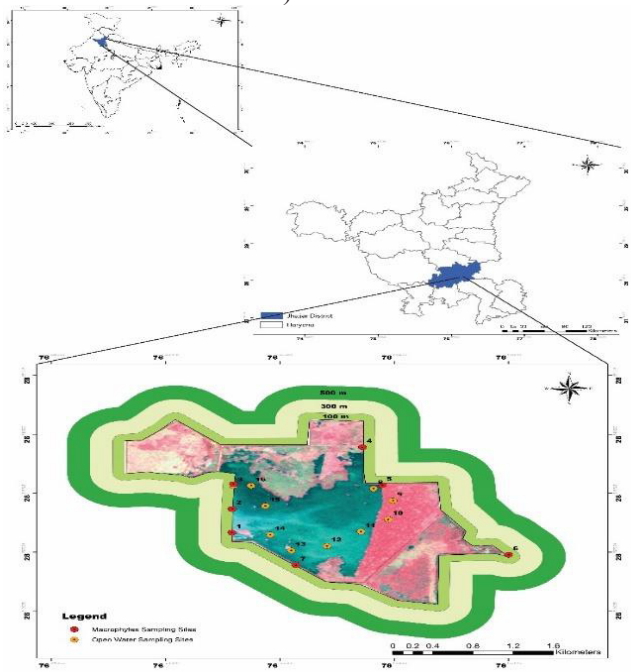

Fig 1. Study area maps showing Bhindawas wetland and sampling sites

Data Collection

Sampling was conducted during May, September and December for 2014 and 2015. *In-situ* spectral measurements were collected on a survey boat within solar noon (i.e. 1000 to 1400 hours) during each survey. Hyperspectral (approximately 512 bands with sampling interval of ~0.3 nm and spectral resolution of ~1.4 nm) water irradiance was measured with a SVC GER1500 spectroradiometer having a range of 350 to 1050 nm.

Sample points (shown in fig 1) within the seven transects perpendicular to the shore covering dominant macrophyte

species were identified for homogeneous patches of macrophyte vegetation (emergent, submerged and floating species). Eight macrophyte species *Ageratum conyzoides, Phragmites karka, Cyperus alopecuroides, Typha sp., Anisomeles indica, Paspalum paspaloides, Achyranthus aspera, Alternanthera sessilis and Cynodon dactylon.* Reflectance R(λ) was calibrated by measuring the upwelling radiance of a white Spectralon© panel and a custom software package "GER 1500 PC Data Acquisition Software" compared the signals from the two and generated a normalized percent reflectance.

Sample analysis

At each sampling station, the following water quality parameters were measured: conductivity (Cond.), temperature, pH, secchi depth (SD), turbidity, chlorophyll-a (Chl-a) and total suspended solids (TSS) using laboratory procedures in consistent with Standard Methods for Examination of Water and Wastewater [9].

Spectral analysis

After pre-processing, spectral data were smoothed using Savitzky-Golay (SG) filter. In this study, following Tsai and Philpot (2002) [10], first derivative was estimated by dividing the difference between successive spectral values by the wavelength interval using the following equation:

$$\frac{dr}{d\lambda} = \frac{r(\lambda_i) - r(\lambda j)}{\Delta\lambda} \quad \text{(i)}$$

Statistical analysis

For statistical analysis, reflectance values between 400-800 nm wavelength range were included. The dataset was normalized by subtracting the spectrum mean from each spectrum. The principal components extracted using PCA were then correlated to the concurrently measured optically active components. Correlation analysis was also applied to the measurements of optically active water parameters. Furthermore, to explore the relationships between the spectral reflectance and optical parameters Canonical Correspondence Analysis (CCA) was applied. Bio-optical models were developed using stepwise linear regression.

3. RESULTS AND DISCUSSION

Wetland water quality

Table 1 Descriptive statistics of bio-optical parameters

Parameters	SI Unit	Min	Max	Mean	SD
Temp	℃	13	34.6	26.76	8.14
SD	m	0.24	1.35	0.59	0.26
Cond.	µS/cm	208	357	246.9	40.6
Chl-a	µg/l	1.14	107.5	22.76	19.75
TSS	mg/l	17.8	415.8	173.91	135.9
Turbidity	NTU	0.81	35.15	6.06	6.65
TOC	mg/l	0	13	2.59	3.7

Despite the variability observed in water column reflectance, a constant spectral pattern is observed typical of Case II waters (Fig. 2). Spectra characteristically show a peak reflectance around 570 nm, caused by minimal absorbance by phytoplankton pigments and backscattering by suspended matter [11]. A second reflectance peak near 700 nm results from phycocyanin absorption at around 675 nm and strong water absorption at longer wavelengths (λ > 700 nm). As compared to other spectral regions, the R(λ) in the blue region (400-500 nm) was lower and exhibited small variation as compared to the green, red and infrared (NIR) regions suggesting strong absorption by organic matter as well as phytoplankton's in this region.

Principal component analysis of the reflectance dataset resulted in three dominant principal components first component accounts for 84% of the total variance, while the second and third components account for 10.7% and 4% respectively. The interpretation of the components is amalgamated with a correlation analysis performed between the water quality parameters characterizing the wetland water and the amplitude of the components.

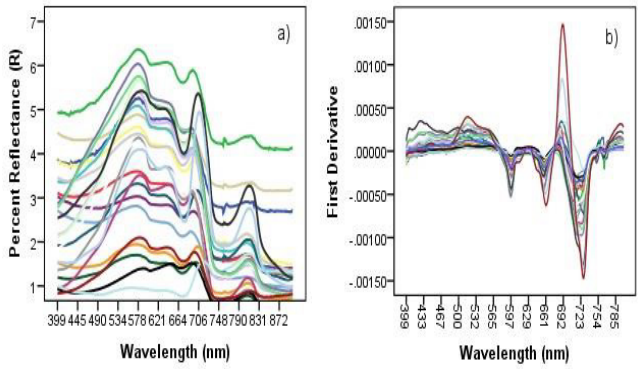

Fig 2 Reflectance Spectra of Bhindawas wetland-a) percentage reflectance b) first derivative spectra.

The regression models developed using step-wise linear regression for bio-optical parameters including Chlorophyll-a, TSS and turbidity were examined and evaluated based on the coefficient of determination (R^2), root mean square error (RMSE) and mean square error (MSE). The log-transformed data were used in this study for the development of models for Chl-a. In this study, the most suitable model for TSS is derived using combination of R_{755} and R_{758} explaining the highest variation in TSS concentration (R^2 = 0.83, RMSE = 62.63 mg/l). The best fitting model identified for Chl-a is derived using R'_{675} and R'_{743} with value of R^2 = 0.80 and RMSE = 0.12. The most suitable model for retrieval of turbidity in this research is derived using a combination of R_{596}, R_{599} and R_{615} with a R^2 = 0.55 and RMSE = 5.34 NTU.

Reflectance spectra of Macrophytes

Analysis of reflectance spectra indicates that macrophyte species exhibit typical vegetation spectra with distinct red and near infra-red boundary. The variation observed in the reflectance spectra of different macrophytes can be attributed to species-specific factors such as canopy structure, water content, chlorophyll concentration, plant vigor and leaf orientation (Pu. 2008)[12]. In addition to these factors, Artigas (2003)[13] suggested that the spectral response of macrophyte species is a function of the phenological stage, season and light conditions categorized as environmental factors.

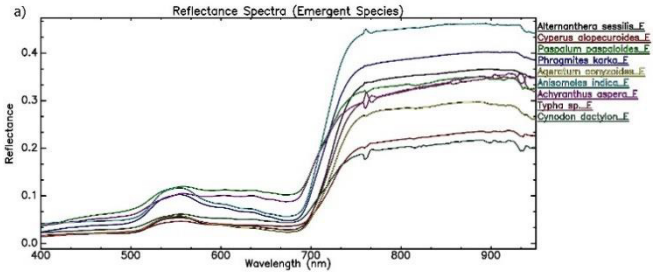

Fig 3 Reflectance spectra of wetland macrophytes.

The first derivative spectra of different macrophytic were found to have similar features with maxima and minima occurring at almost similar wavelengths with variable magnitude. First derivative spectrum is characterized by two prominent peaks indicating an increase in spectral values at 520 and 700 nm. The peak at 520 nm indicates chlorophyll reflectance whereas the peak at 720 nm designates the red-edge phenomenon.

The magnitude and position of the red-edge peak was derived for each of the macrophyte species. *Ageratum conyzoides* had the highest red-edge maximum at 722.32 nm with a value of 0.00879 while *Cynodon dactylon* was lowest (0.00274) at 698.84 nm. Second derivative spectra show a pronounced absorption feature in the red region (685-695 nm wavebands) whereas the NIR region has a distinct reflectance feature in the 720-740 nm region for different macrophytes.

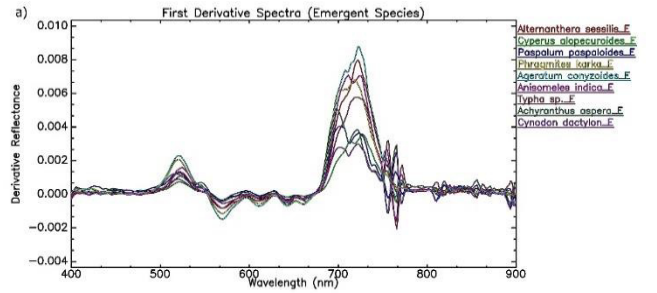

Fig 4 First derivative spectra of wetland macrophytes.

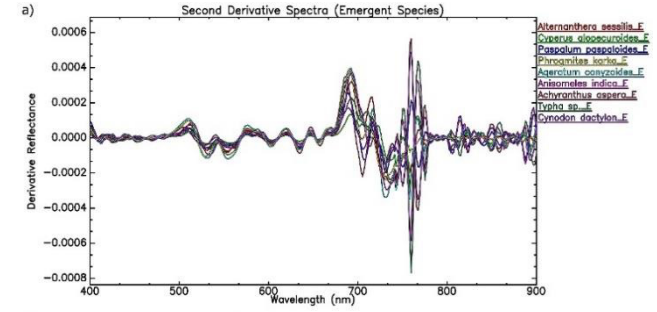

Fig 5 Second derivative spectra of wetland macrophytes

The maximum absorption and reflectance features have values within a narrow range i.e. +0.0006 to -0.0008. The steepest slope was observed for *Ageratum conyzoides* whereas lowest values were seen for *Cyperus alopecuroides*. Despite the similarity, differences can be observed in terms of absorption depth and absolute reflectance. Spectral characteristics of each of the species vary according to their phenological stages [13].

4. CONCLUSIONS

The availability of retrieval algorithms for water constituents based on spectral signatures measured by satellite sensors and aerial platforms is the essence for remote sensing of water quality over large spatial areas. Several retrieval algorithms have been identified in the study to retrieve the concentrations of bio-optical properties in the wetland water. This clearly indicates that hyperspectral sensor can be a reliable tool for monitoring water quality in terms of its bio-optical properties. Present study has brought out vividly the utility of in-situ hyperspectral data in wetland condition assessment. Further research is required to be carried out using orbital hyperspectral data for wetland health and integrity assessment.

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O6-13

湖沼データの整備，提供及び活用

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キーワード：湖沼データ，数値データ，湖沼画像データ

抄録

国土交通省国土地理院では，平成 29 年（2017 年）3 月 1 日に国土地理院ウェブサイトから湖沼データの無償ダウンロード提供を開始しました．湖沼データは湖底地形，底質，水生植物の分布などに関する数値データ及び数値データを元に作成した地図形式の湖沼画像データから構成されています．湖沼データを活用することにより，湖沼を詳細で定量的，視覚的あるいは立体的に把握でき，湖沼に対する各種取り組みに対して有用に活用できるものと期待できます．

1. はじめに

国土交通省国土地理院は，湖沼の利用，開発，保全の各種計画の策定等，様々な業務の基礎資料として活用されることを目的に，昭和 30 年（1955 年）から湖沼調査を実施し，その成果は紙地図の「湖沼図」として取り纏めてきました．現在，湖沼図に代わる数値データとして湖沼データの整備・提供を進めています．数値データ化することで多様な表現が可能となり，湖沼を詳細かつ定量的，視覚的または立体的に監視，把握，解析できるようになりました．

2. 方法

全国の概ね 1km^2 以上の 79 湖沼を対象に，以下の湖沼調査を実施してきました．（図1及び表1）

①湖底地形調査：測量船に搭載した音響測深機で水深を測定します．船の位置情報は GNSS 衛星により求められます．この際，水中音速度計測や水位観測の結果を使って水深データを補正します．

②底質調査：湖底の表層物質を採取して粒度分析により分類し，底質の分布を調査します．

③水生植物調査：空中写真判読や現地調査により，水生植物の分布状況を調査します．

これらの調査結果を以下の各データ形式で取りまとめたものが湖沼データです．①～④は「数値データ」，⑤の「湖沼画像データ」と区分しています．

①GML 形式：湖底地形（水深点，等深線，水深グリッド，湖岸線），底質，水生植物等の各データを地理情報標準（JPGIS2014）準拠で作成しています．

②シェープファイル形式：GML 形式のものをシェープファイル化したものです．

③TIFF 形式：水深グリッドを TIFF 形式にしたもので，厳密には位置情報を持った GeoTIFF 形式です．

④CSV 形式：水深グリッドを X，Y，Z 形式かつ CSV 形式にしたデータで，グリッド間隔は 10m です．

⑤PDF：地図形式の画像データで PDF 形式です．湖沼部を段彩表示するとともに，湖沼周辺部は最新の電子地形図（タイル）を使用しています．多色表示かつ縮尺 1 万分 1 です．また，1 枚の用紙で湖沼全域を表示したより小縮尺のものも作成しています．

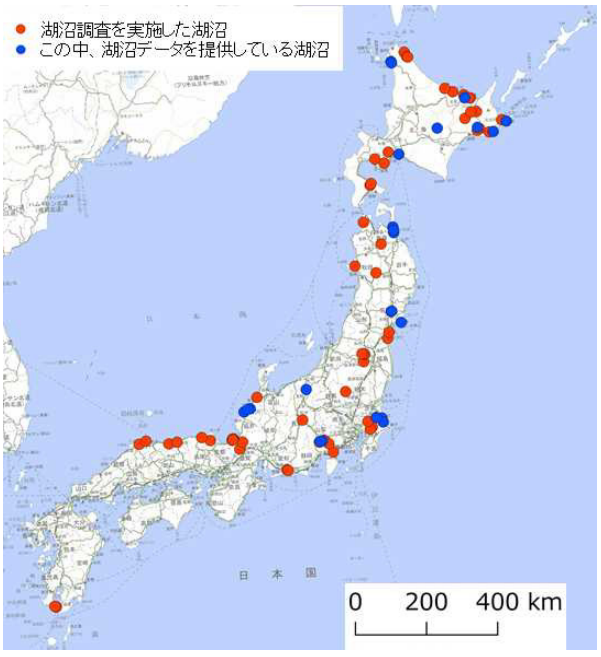


図 1　湖沼調査を実施した湖沼

表１　湖沼データの提供開始日等（平成 30 年 4 月現在）

	湖沼の名称	都道府県	面積(km2)	提供開始日
1	クッチャロ湖(大沼)	北海道	13.40	(未提供)
2	クッチャロ湖(小沼)	北海道	0.00	(未提供)
3	ポロ沼	北海道	1.97	(未提供)
4	ペンケ沼	北海道	1.27	平成29年9月1日
5	パンケ沼	北海道	3.55	平成29年9月1日
6	サロマ湖	北海道	151.59	(未提供)
7	能取湖	北海道	58.20	(未提供)
8	網走湖	北海道	32.28	平成29年3月1日
9	コムケ湖	北海道	4.84	(未提供)
10	涛沸湖	北海道	8.19	(未提供)
11	藻琴湖	北海道	0.98	(未提供)
12	風蓮湖	北海道	59.01	(未提供)
13	温根沼	北海道	5.72	平成29年9月1日
14	屈斜路湖	北海道	79.54	(未提供)
15	厚岸湖	北海道	32.31	(未提供)
16	摩周湖	北海道	19.22	(未提供)
17	阿寒湖	北海道	13.25	(未提供)
18	塘路湖	北海道	6.27	(未提供)
19	達古武湖	北海道	1.31	(未提供)
20	シラルトロ沼	北海道	1.72	平成29年9月1日
21	火散布沼	北海道	3.76	平成29年9月1日
22	然別湖	北海道	3.59	平成29年9月1日
23	支笏湖	北海道	78.48	(未提供)
24	洞爺湖	北海道	70.72	(未提供)
25	倶多楽湖	北海道	4.70	(未提供)
26	ウトナイ湖	北海道	2.10	平成29年9月1日
27	大沼	北海道	5.31	(未提供)
28	小沼	北海道	3.80	(未提供)
29	内沼	青森	62.12	平成30年2月28日
30	小川原湖	青森		平成30年2月28日
31	姉沼	青森	1.57	平成30年2月28日
32	十和田湖	青森・秋田	61.11	(未提供)
33	十三湖	青森	17.82	(未提供)
34	万石浦	宮城	7.30	平成30年2月28日
35	伊豆沼	宮城	3.31	平成29年9月1日
36	内沼	宮城	1.05	平成29年9月1日
37	井土浦	宮城	0.40	(未提供)
38	鳥の海	宮城	1.35	(未提供)
39	八郎潟調整池	秋田	27.75	(未提供)
40	田沢湖	秋田	25.75	(未提供)
41	猪苗代湖	福島	103.24	(未提供)

	湖沼の名称	都道府県	面積(km2)	提供開始日
42	桧原湖	福島	10.70	(未提供)
43	小野川湖	福島	1.72	(未提供)
44	秋元湖	福島	3.62	(未提供)
45	北浦	茨城	35.04	平成30年3月30日
46	外浪逆浦	茨城・千葉	5.93	平成30年3月30日
47	霞ヶ浦	茨城	168.22	平成30年3月30日
48	牛久沼	茨城	3.55	(未提供)
49	中禅寺湖	栃木	11.90	(未提供)
50	西印旛沼	千葉	9.43	(未提供)
51	北印旛沼			(未提供)
52	芦ノ湖	神奈川	7.03	(未提供)
53	河北潟	石川	4.20	(未提供)
54	柴山潟	石川	1.92	平成29年9月1日
55	木場潟	石川	1.13	平成29年9月1日
56	北潟湖	石川・福井	2.16	平成29年9月1日
57	水月湖	福井	4.18	(未提供)
58	三方湖	福井	3.58	(未提供)
59	久々子湖	福井	1.40	(未提供)
60	日向湖	福井	0.93	(未提供)
61	菅湖	福井	0.91	(未提供)
62	山中湖	山梨	6.57	(未提供)
63	河口湖	山梨	5.48	(未提供)
64	本栖湖	山梨	4.70	(未提供)
65	西湖	山梨	2.10	平成29年3月1日
66	精進湖	山梨	0.51	平成29年3月1日
67	諏訪湖	長野	12.81	(未提供)
68	野尻湖	長野	4.45	平成29年9月1日
69	浜名湖	静岡	64.91	(未提供)
70	猪鼻湖	静岡	5.36	(未提供)
71	琵琶湖	滋賀	669.23	(未提供)
72	余呉湖	滋賀	1.75	(未提供)
73	久美浜湾	京都	7.18	(未提供)
74	阿蘇海	京都	4.80	(未提供)
75	湖山池	鳥取	6.99	(未提供)
76	東郷池	鳥取	4.05	(未提供)
77	中海	鳥取・島根	85.68	(未提供)
78	宍道湖	島根	79.25	(未提供)
79	池田湖	鹿児島	10.91	(未提供)
80	鰻池	鹿児島	1.20	(未提供)
	計		2,235.33	

3.　結果

平成29年(2017)年3月1日から，以下に示す国土地理院のウェブサイトで湖沼データの無償ダウンロード提供を行っています．(図2，図3及び図5)

http://www.gsi.go.jp/kankyochiri/lakedata.html



図２　湖沼データのダウンロードサイト

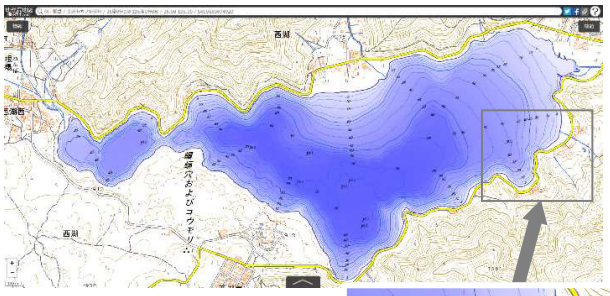
平成 30 年(2018 年)4 月現在，湖沼調査を実施した全国の 80 湖沼中，22 湖沼の湖沼データの提供を開始しました．霞ヶ浦は，北浦及び外浪逆浦とともに平成 30 年(2018 年)3 月 30 日に提供を開始しました．(図5)

ウェブ地図の「地理院地図」でも，「地理院タイル(湖沼データ)」として湖沼データを閲覧できます．(図4)

地理院地図は，各種地理情報を階層的に表示できる上，3D 表示も可能です．ただし， 地理院地図自身では湖沼データの3D表示が現在できないため，他のGISソフトウェアが必要です．



図３
数値データ
「小川原湖」



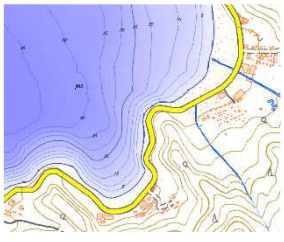


図４
地理院タイル
(湖沼データ)
「西湖」

4. 考察

霞ヶ浦の湖沼データを使って地形的性質を見たところ，局所的に何カ所かの窪みが存在しますが，水深は概ね10m以下で全体的に浅く，最深部は11.5mでした．また，ヒストグラムで見ると，水深 4m～6m の範囲が全体の55%を占めることが分かりました．（図5及び図6）

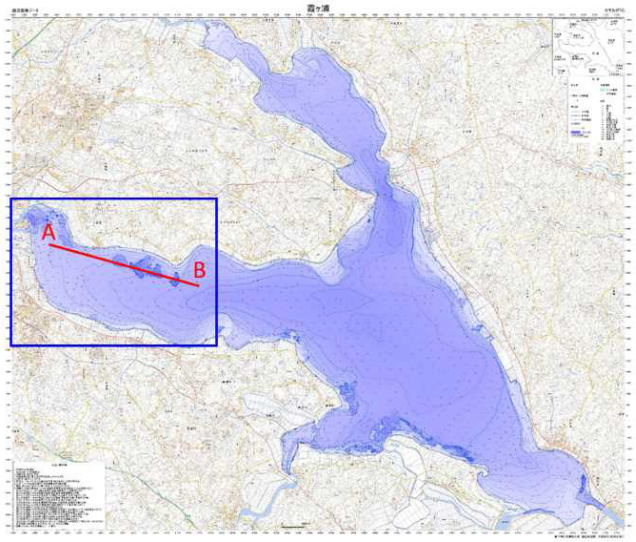


図５　湖沼画像データ「霞ヶ浦」

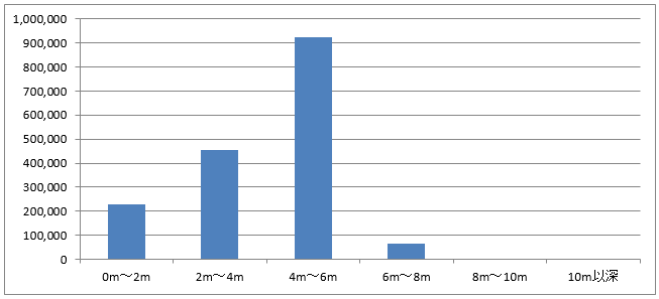


図６　霞ヶ浦の水深ヒストグラム

湖沼データを使って湖底地形の断面図を作成することもできます．断面図は湖底の地形的特徴を詳細に把握するのに効果的な資料になります．（図7）

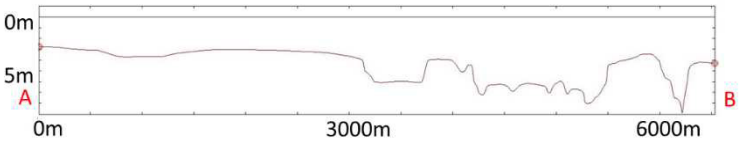


図７　図４の赤線位置の断面図
（縦方向と横方向の縮尺は異なる）

湖沼の面積や湖岸線は容易に把握できますが，湖底地形の詳細な形状や深度分布の定量的把握は容易ではなく，湖沼データが有用であることが分かりました．

等深線の GML や CSV のデータを使えば，湖底地形の傾斜分布，方位分布，谷線などの二次加工した地理情報も作成でき，流入土砂の流送や堆積などの各種シミュレーションに役立つと考えています．土浦市付近の霞ヶ浦の傾斜を見ると大部分が平坦ですが，凹地部分では最大 15°程度の傾斜がありました．（図8）



図８　図４の青線範囲の傾斜分布図

更に，湖底地形データに別に整備された各種データを組み合わせれば水深との相関情報を得ることもでき，湖沼環境対策などで効果的であると考えられます．

陸域の航空機や人工衛星から撮影した画像の 3D 表示には高い視覚性がありますが，湖沼データを活用すれば湖沼部の 3D 表示も可能になり，視覚的・立体的な把握に効果的であることが分かりました．なお，特殊なメガネをかけて見ると立体的に見られる地図による手法もあります．（図9）

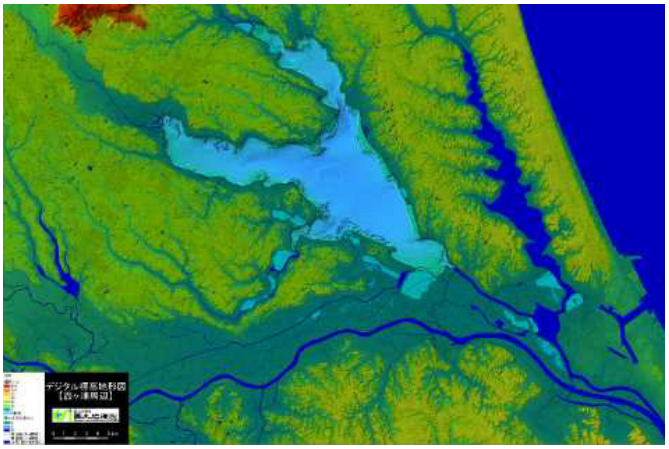


図９　霞ヶ浦周辺のデジタル標高地形図
（ChromaDepth3D メガネで立体的に見える）

5. 結論

湖沼データを活用して湖沼の詳細かつ定量的，視覚的，立体的な把握が可能になりました．霞ヶ浦を初めとする全国の湖沼での各種取り組みに対し，湖沼データは有意義に貢献できるものです．関係機関における湖沼データの活用をよろしくお願いします．

O6-14

Long-Term Monitoring of Lake Surface Area Change in Indonesia from Global Surface Water Data

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Keywords: Lake monitoring, Surface Area changes, Landsat, Google Earth Engine

ABSTRACT

Currently, the conditions of lakes in Indonesia have changed in terms of water surface area, especially for the main lake (larger than 10 km^2). A manual method to extract the water surface area for long-term monitoring requires time, is costly and requires a lot of resources. Nowadays, with the development of digital image processing, the manual method is no longer effective and efficient. In this study, Global Surface Water provided by Google Earth Engine combined with simple polygon masking was used to identify lakes larger than 10 km^2. Results from this study show that total water surface area has increased for inland water body in Indonesia from the year 1988 until 2015. Some because of new water body formed from the former mine sites. In the other hand, some lakes decreased their water surface area. Lake Limboto, in the north side of Sulawesi Island, decreased by 12.8 km^2 from 2001 until 2014. The objectives of this study are to obtain long-term monitoring water surface area for all main lakes so that it can be used to update lake information in Indonesia.

1. INTRODUCTION

Indonesia consists of 17,504 islands with 1,905 million km² land area. With this separated land and a wide area, effective and efficient ways to monitor all resources are needed. Accurate maps of surface water are essential for many environmental applications, such as lakes monitoring. The assessment of the role of lakes requires good estimates of the areal extent and shape of water bodies. Upscaling to large regions, except in limited areas where precise maps are available, so far depends on statistical estimates of the number and size of lakes [1].

Precise estimation of surface water using satellite imagery remains a challenging task due to the sensor limitations, complex land cover, topography, and atmospheric conditions [2]. There are many lakes in Indonesia, some are facing drought, water loss, and decreasing water surface area.

Calculation and monitoring temporal change for all lakes in Indonesia is very expensive if done manually. In the other hand, using remote sensing satellite data is time-consuming to identify the main lakes by manual digitation. Especially for a large number of lakes and small size water surface area. Join Research Center of European Commission already provide Global Water Surface [3] through Google Earth Engine data catalog. The problem is that the water body information is mixed for all types such as lake, reservoir, river and coastal object. Therefore the objectives of this study are: separation of all waterbody types (lake, reservoir, river and coastal object) from Global Surface Water data, calculate water surface area and count the number of all lakes larger than 10 km^2. In addition monitoring spatial and temporal change for all lakes in Indonesia.

2. METHOD

The research area of this study is Indonesia inland water surface. Global Water Surface was used as the main input to identify main lakes in Indonesia. This data was extracted and processed using Landsat TM, ETM and OLI from 1982 until 2015. There is much information provided by Global Water Surface, yearly water history which consists of permanent water and seasonal water.

High-resolution satellite data from Google Maps and Google Earth were used for validation of all the lakes identified. River and coastal object masking were built to separate from other water bodies. All processing was done by Python arcpy.

3. RESULTS

The permanent water surface was used as main data input in the processing to identify all lakes larger than 10 km^2. Years 1984 – 1987, 1992 - 1993 and1998 were not included in the processing because the water surface did not cover all inland Indonesia area. River and coastal object were separated from permanent water to reduce the waterbody types. Some river in Kalimantan island and Irian Jaya island have big water surface area. Many pond

and paddy fields are spread along north coast Java island.

Figure 1 shows processing results from water surface area after separating into waterbody types. Water surface with seasonal data is very dynamic, and in this data, it is also included seasonal water body for all types. If we see the differences with permanent water, the pattern is not so different. The differences occur very prominently after the separation of the river and coastal water bodies. Although small, the water surface area seems to increase significantly from 1988 until 2015.

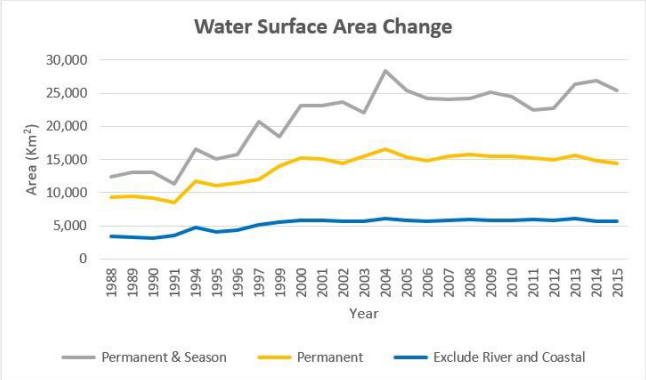

Fig. 1 Total water surface area change over years

48 lakes were found with an area larger than 10 km^2 (Table 1). Most of the lakes are on the Irian Jaya island. Compared to the number of lakes from [4] in [5], there is a difference in the number of lakes on the Sumatera, Kalimantan, Nusa Tenggara, and Mollucas Islands.

Table 1 Number of main lakes

Location/Island	Lake >10 km^2
Sumatera	9
Java and Bali	1
Kalimantan	8
Sulawesi	9
Nusa Tenggara (West and East)	2
Irian Jaya	16
Mollucas	3
Total	48

4. DISCUSSION

Even though the total water surface area is increasing, some lakes are decreasing their water surface area. One of the cases is happening in Lake Limboto, reduce by 12.8 km^2 from 2001 to 2014 (Table 2). This value was calculated from permanent water only. As shown in figure 2, seasonal water surface area changes dynamically, but still in the range between 20 – 45 km^2. Water surface area of Lake Limboto changes every two to four years decreasing and increasing. But with a small area, significantly reduce for each year. With this temporal change of surface area, we can monitor all changes happening for all main lake in Indonesia.

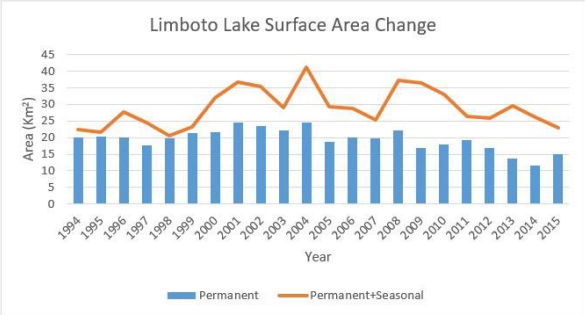

Fig. 2 Water surface area change of Limboto Lake

Table 2 Limboto Lake water surface area decrease

Year	Area (km^2)	Change (km^2)
2001	24.44	-2.25
2003	22.19	-2.12
2006	20.07	-0.15
2007	19.92	-1.9
2010	18.02	-1.12
2012	16.9	-3.31
2013	13.59	-1.94
2014	11.65	-12.8

5. CONCLUSION

Over the year 1988 until 2015, permanent water increased significantly even though in a small value. In the last year of this study, 2015, it was found 48 main lakes spread over Indonesian Islands. In the opposite side, some lakes face water loss and decreasing water surface area (e.g: Lake Limboto). Lake Limboto from 2001 until 2014 already lost 12.8 km^2 of its water surface area. New water surface formed from the former mine sites. These results are expected to be additional information to save all lakes decreasing its water surface area in Indonesia.

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O6-15

帰還困難区域に生息する渓流魚の放射性セシウムのモニタリングと標識放流実験による渓流魚の ^{137}Cs 蓄積速度の推定

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キーワード:ヤマメ, イワナ, 森林小河川, ^{137}Cs のモニタリング, 標識放流実験

抄録

帰還困難区域の空間線量率の異なる 4 地点の森林河川で, 渓流魚のヤマメとイワナの ^{137}Cs 濃度をモニタリングした。また, ヤマメとイワナの標識放流実験により, 2 魚種の ^{137}Cs 蓄積速度を調べた。その結果, ヤマメとイワナに含まれる ^{137}Cs 濃度は, 2 魚種ともに環境中の放射能強度が高い地点ほど有意に高かった。空間線量率の最も高い地点 D で採捕した 2 魚種の ^{137}Cs 濃度は, 2016 年～2017 年度の 2 年間で, ヤマメとイワナでそれぞれ 855–27,738 Bq/kg と 651–18,865 Bq/kg の範囲にあった。いずれの地点・魚種ともに ^{137}Cs 濃度の明瞭な減少傾向は認められず, 福島第一原発事故から約 7 年が経過した現在では 2 魚種の ^{137}Cs 濃度は平衡状態に達していると推測された。

2016 年に実施した標識放流実験の結果, ヤマメの ^{137}Cs 蓄積速度は, 線量の最も低い地点 A と最も高い地点 D でそれぞれ 2.5 Bq/kg/day と 24.9 Bk/kg/day であり(実験期間 150 日), 空間線量率の高い地点 D において有意に速かった。またイワナの蓄積速度はヤマメよりも有意に遅かった。

1. はじめに

2011 年 3 月の東京電力福島第一原子力発電所事故により, 環境中へ多量の放射性物質が放出された。事故から約 7 年が経過した現在でも, 避難指示区域内およびその近傍の河川に生息するほぼすべての内水面魚種について採捕・出荷の制限・自粛がなされている。避難指示解除後の地域の再活性化と内水面漁業の復興のカギの一つとして, ヤマメやイワナに代表される森林小河川での渓流釣りや, より下流側でのアユ釣りなどのいわゆる遊漁活動の復活があげられており, 地元の漁業組合関係者, 地域行政関係者や住民の方々も強く熱望している。しかしながら, 避難指示地域において遊漁対象となる魚類については, 生息地環境を含めたそれらの放射性セシウム濃度の現状が十分調べられておらず, 異なる空間線量環境下における魚への放射性セシウム蓄積速度の差異やそれをもたらす理由などが未解明である。さらに, 今後の放射性セシウムの推移や収束時期の予測等など多くの課題についても手つかずのままである。被災地での遊漁活動を復興・復活させるためには上記のことを十分に理解・把握しながら, 適切な方策を立案することが重要と思われる。

そこで私ども茨城大学広域水圏センターの陸水生物研究グループでは, 地元の漁業組合と共同で 2015 年 3 月から 2018 年の現在まで, 福島県の避難指示区域内 (帰還困難区域) にある空間線量率の異なる複数の森林河川を研究フィールドとして以下に述べる 2 つの研究を実施している。

①魚を含めた生物群集と生息環境中の放射性セシウム濃度の現状を把握することを目的とした, 遊漁対象魚種のヤマメとイワナ, 大型無脊椎動物および河川環境試料の放射性セシウム濃度のモニタリング。また渓流魚の主要な餌資源を明らかにするための, 捕獲した魚類の胃内容物分析。

②異なる空間線量環境下における魚への放射性セシウム蓄積速度の差異の有無を明らかにするための「標識放流実験」。この実験は放射性セシウムを含まない養殖イワナ・ヤマメを異なる空間線量をもつ河川に放流し, 定期的に再捕獲することで放射性セシ

ウムの蓄積速度(見かけの増加量)を評価するものである。

今回の発表では，2015 年から現在まで実施している帰還困難区域の森林河川に生息する代表的な渓流魚であるヤマメとイワナの ^{137}Cs 濃度のモニタリング結果を報告し，さらに異なる空間線量環境下での当該魚種への ^{137}Cs の蓄積速度を評価するための標識放流実験を実施した結果について報告する。

2. 方法

渓流魚および河川環境試料の放射性セシウム濃度のモニタリング

避難指示区域内にある山地渓流の 4 地点（地点 A,B,C,D）において定期的に空間線量率の測定と試料採取を行った。河川環境試料として河川近傍の山土（表層約 50 ㎜），河床堆積物（川砂），水底落葉および河川水を採取した。渓流魚のヤマメとイワナはミミズやブドウ虫を餌とした釣りによって採捕し，冷蔵して研究室に持ち帰った。測定の前処理として，魚類試料についてはホールボディーの放射性セシウム分析後に可食部のみをU8 容器に充填した。河川水は，カートリッジ型フィルタ装置 [1],[2],[3]によってろ過・濃縮を行った。処理後の河川環境試料および魚類は，Ge 半導体検出器（CANBERRA 社製）を用いて放射性セシウム濃度を測定した。これらの調査は地点 A，B，C では 2015 年 3～5 月から，地点 D では 2016 年 3 月から実施した。

渓流魚の標識放流実験

標識放流実験は，4 定点の中では空間線量率の最も低い地点 A と最も高い地点 D の 2 か所を実験フィールドとして，2016 年 5 月と 2017 年 5 月に実施した。また晩秋から厳冬期にかけての水温の低い時期における ^{137}Cs の蓄積速度を調べるために，2017 年 10 月に地点 D でのみ放流実験をした。各実験ともに魚類・甲殻類用麻酔剤 FA100 で麻酔後にイラストマー蛍光タグ（NMT 社製）で標識した養殖イワナとヤマメを各地点に 100～200 尾程度放流した。ちなみに，これらの養殖魚には ^{137}Cs がほとんど含まれていない（5 Bq/kg 以下）。これらの魚は釣りによって定期的に再捕獲した。採捕した魚は速やかに冷蔵保温して実験室に持ち帰り，Ge 半導体検出器による放射性セシウム分析を行うまで冷凍保存した。

また 2018 年 5 月中旬には地点 D において個体識別が可能な VI タグ（NMT 社製）を用いた放流実験を実施する予定であり，これにより個体ごとの ^{137}Cs 蓄積速度や成長速度のモニタリングが可能となる。

3. 結果と考察

避難指示区域内の森林河川に生息する渓流魚の ^{137}Cs 濃度の推移

2017 年 3 月～12 月の各地点の空間線量率の平均値は地点 A，B，C，D でそれぞれ約 0.4，1.2，2.4，3.1 μSv/h であり，空間線量率の強度は地点 D＞地点 C＞地点 B＞地点 A の順に高かった。各種環境試料も同様の傾向であり，地点間での環境試料の放射性セシウム濃度の強度の違いが各地点での空間線量率の差に影響しているものと考えられた。2015 年～2017 年度までの山土，水底落葉，川砂，河川水中の溶存 ^{137}Cs 濃度の推移をみると明瞭な減少は見られなかった。

ヤマメとイワナに含まれる ^{137}Cs 濃度は，2 魚種ともに環境中の放射能強度が高い河川ほど有意に高かった（K-W test，$p<0.01$；地点 D＞地点 C＞地点 B＞地点 A，Steel-Dwass，$p<0.01$）。空間線量率のもっとも低い地点 A で採捕した 2 魚種の ^{137}Cs 濃度は 2015 年～2017 年度までの 3 年間でヤマメおよびイワナでそれぞれ 102-3,829 Bq/kg と 73-2,260 Bq/kg の範囲にあった。また 3 年間に採捕されたヤマメ・イワナの平均値はそれぞれ 581 Bq/kg と 485 Bq/kg であり，魚種による ^{137}Cs 濃度の統計的な有意差はなかった。

空間線量率の最も高い地点 D で採捕した 2 魚種の ^{137}Cs 濃度はヤマメとイワナで 855-27,738 Bq/kg と 651-18,865 Bq/kg の範囲にあり，2016 年～2017 年度までの 2 年間に採捕された各魚種の平均値はそれぞれ 5,137Bq/kg と 4,083 Bq/kg であった。魚種による ^{137}Cs 濃度の平均値に統計的な有意差は見られなかった。本研究での調査期間内で，いずれの地点・魚種ともに ^{137}Cs 濃度の明瞭な減少傾向は認められず，福島第一原発事故から約 7 年が経過した現在では 2 魚種の Cs 濃度はほぼ平衡状態に達しているものと推測された。

標識放流実験によるヤマメとイワナの 137Cs 蓄積速度

の推定

2016 年 5 月の放流実験の結果を図 1 と図 2 に示した。いずれの魚種とも放流後の経過日数が多い個体ほど ^{137}Cs 濃度が高かった。個体によってその濃度には差異が見られたものの，放流後から 150 日まではほぼ直線的に濃度が増加した。その直線の傾きから計算した一日当たりの見かけ上のヤマメの ^{137}Cs 蓄積速度は，地点 A と地点 D でそれぞれ 2.5 Bq/kg/day と 24.9 Bk/kg/day であり，空間線量率の高い地点 D において有意に速かった。

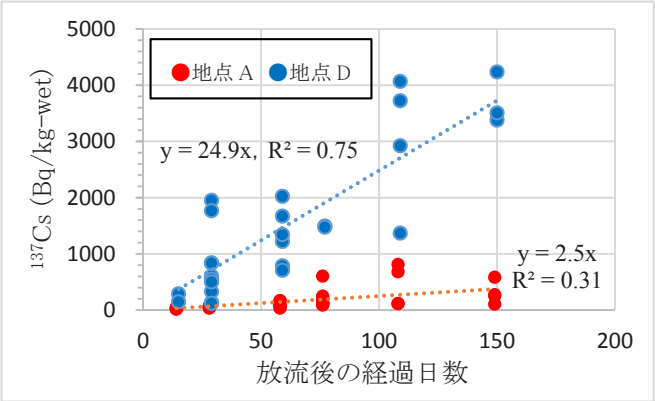

図1　2016 年 5 月に地点 A と D に放流した“ヤマメ”の ^{137}Cs濃度の推移.

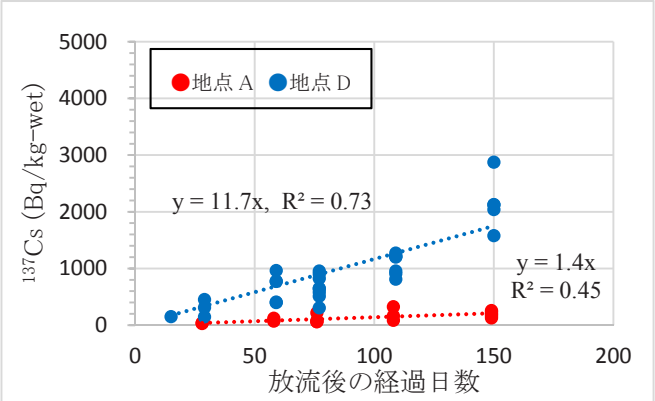

図2　2016 年 5 月に地点 A と D に放流した“イワナ”の ^{137}Cs濃度の推移.

一方，イワナの場合は，ヤマメと同様に空間線量率の高い地点 D においてその蓄積速度は速かったが，見かけ上の蓄積速度はヤマメと比較して有意に低く，地点 A と地点 D でそれぞれ 1.4 Bq/kg/day と 11.7 Bq/kg/day であった。このように ^{137}Cs 蓄積速度が魚種間で異なったことは非常に興味深いが，現在のところ，この理由については不明であり，今後の検討課題としたい。

2017 年 5 月の放流実験も 2016 年とほぼ同様の結果となった。また 2017 年 10 月に地点 D で実施した放流実験での 1 日あたりの ^{137}Cs 蓄積速度は，5 月の値とは大きく異なり，ヤマメ・イワナともに約 2.8 Bq/kg/day と極めて低かった（表１）。この理由は実験の期間である 2017 年 10 月末から翌年 3 月までの低い水温（0.5～11.5℃）により魚の活性が低下したため，利用可能な餌資源や水経由での 137Cs の取り込み量が低下したためと推測された。ちなみに地点 D における 2017 年 5 月下旬～10 月上旬までの 133 日間における水温は 12.3～17.6℃の範囲であった。

表1　地点 D における 1 日あたりの ^{137}Cs 蓄積速度(Bq/kg/day)

放流した時期	放流期間	ヤマメ	イワナ
2016 年 5 月中旬	150 日	24.9	11.7
2017 年 5 月下旬	133 日	26.0	17.8
2017 年 10 月下旬	147 日	2.9	2.8

4.　結論

2015 年から 3 年にわたる帰還困難区域でのモニタリング結果から，震災後 7 年が経過した現在でも渓流魚に含まれる ^{137}Cs 濃度は収束することはなく，高いレベルで平衡状態に達していると考えられた。また放流実験から空間線量の高低や魚種による ^{137}Cs の蓄積速度にも差があることが明らかとなり，これらの成果が遊漁活動の再開方法を模索する上での何らかのヒントになるかもしれない。

本発表では，VI タグでの個体識別をした放流実験の結果についても合わせて報告する予定である。

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O6-16

Evaluation of anthropogenic impacts on reservoir water quality: A case study in a reservoir catchment in southern Taiwan

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Keywords: reservoir catchment, human activity, BPA, pesticide, OTC, water quality

ABSTRACT

Recently, the need for high quality finished water has brought the land-use management around reservoir catchment area to the public attention. Human activities would damage the source water quality by different levels based on the types of activities. The objective of this study is to evaluate the impacts of anthropogenic sources on water quality around the reservoir catchment area by monitoring the occurrence of selected contaminants, including four pesticides (glyphosate, glufosinate, fenthion and thiophanate-methyl), one antibiotics (oxytetracycline) and one endocrine disrupting substance (bisphenol A) to reflect the pollution from agricultural run-off, aquaculture wastes and domestic sewage, respectively. Basic water quality parameters were also acquired to examine the relation between water qualities and the occurrence of trace organic pollutants. Samples were collected every month from March to July in 2017 near a reservoir located in southern Taiwan. Results showed bisphenol A exists ubiquitously and glyphosate concentration varies along with farmer's behavior. Glyphosate concentration was positively correlated to ammonia nitrogen and total phosphorus and inversely correlated to dissolved oxygen. As for oxytetracycline, its polluted area was not as wide as bisphenol A and glyphosate, indicating the aquaculture activities was limited in the area. Overall, this study revealed that the occurrence of selected contaminants can be surrogates to indicate human pollution. This approach can be applied to other reservoir. The results from this study can provide the government better land use managements in catchment area.

1. INTRODUCTION

In recent years, considerable attention of land-use management around reservoir catchment areas have been raised because of the need of high quality finished water. If no restriction is enforced around the reservoir catchment areas, pollution derived from anthropogenic activities may lead to drinking water source contamination.

This research aims to evaluate the anthropogenic impacts on a reservoir catchment by monitoring the occurrence of selected trace organic compounds including four pesticides, one antibiotics and one endocrine disrupting substance which serve as surrogates to reflect the pollution from agricultural run-off, aquaculture wastes and domestic sewage, respectively. Four pesticides include glyphosate, glufosinate, fenthion and thiophanate-methyl which are applied popularly in the field for decades due to their short half-life in the environment (Table 1). The selected endocrine disrupting substance is bisphenol A (BPA) which commonly exists in plastic products. The selected antibiotics is oxytetracycline (OTC) which is widely applied in animal feeds to control bacterial infection. Water quality including pH, dissolved oxygen (DO), ammonia-nitrogen (NH_3-N) and total phosphorus (TP) was monitored to examine any relation between water quality and the trace organic pollutants. Study area is located at Yanchao District, Kaohsiung in southern Taiwan (Fig. 1), which is Agongdian reservoir serving water for about 127,000 population. The results from this study can be provided for the government to develop proper policies to regulate the land use of water source protection area.

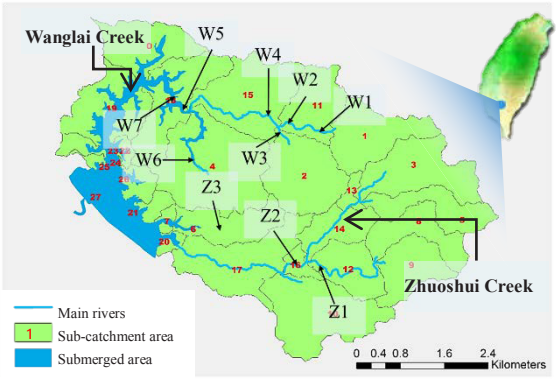

Fig. 1 Study area and sampling sites

2. METHOD

Liquid chromatography equipped with a C18 (Acclaim 120 series, 3μm, 4.6×150 mm) was used to carry out the separation. Fluorescence detector was used to quantify BPA and triple quadrupole tandem mass spectrometry was for pesticides and OTC.

32% of Agongdian reservoir catchment area is orchards and minor area is used for aquaculture. Only 10% is occupied by household. There are 10 sampling sites, 7 sites along Wanglai Creek and 3 sites along Zhuoshui Creek. Samples were taken once a month, from March to July in 2017, four times in total, and 40 samples in total.

3. RESULTS AND DISCUSSIONS

Occurrence of pesticides

Glyphosate has been widely used as non-selective herbicides since 1970s, so it has been frequently detected in 50% of the surface water samples [4-5]. Similar occurrence ratio (50%) was acquired in this study (Table 1). It was also found that the occurrence of glyphosate was higher in summer season (May and July) with detection frequency up to 80% and lower in March (16.7%) and April (25%). As for glufosinate and thiophanate-methyl, they were detected from April to July, with increasing concentration when the weather became warmer. The above correlation could be attributed to chemical weed and pest control strategy in summer, so the occurrence of agrochemicals in surface water is strong correlated to farmer behavior. W6 located at the intensive agricultural area where glyphosate concentration was positively correlated to NH_3-N and TP and adversely correlated to DO (Fig. 2). W3, W4, W5 and Z3 also showed similar correlation inferring that agriculture activities resulted in the residue of pesticides and bad water quality.

Occurrence of OTC

The detection frequency of OTC was 22.5% with maximum concentration 1.9 μg/L (Table 1). Only four sampling sites (W1, W3, W5 and W6) were found with OTC. It was previously reported OTC appeared in rivers with high nitrogen and phosphorus when aquacultural land use predominated [7]. However, the correlation was not observed in this study due to insignificant aquaculture activity in Agongdian reservoir catchment area.

Occurrence of BPA

BPA was detected in 55% of 40 samples with maximal concentration 0.41 μg/L (Table 1). Sub-ppb level of BPA was found nearly in all sampling sites. Lee et al. (2013) indicated that BPA had negative correlation between DO and pH, but had positive correlation with NH_3-N in rivers [8]. However, those relations were not observed because of less industrial pollution and population in the studied area.

Table 1 Half life and monitoring results (Unit: μg/L)

Compound	*Half-life (day)*	*Conc. range*	*Detection* [a]	*MDL* [b]
Glyphosate	>35 [1]	ND[c]-4.53	20/40	0.12
Glufosinate	-	ND-1.23	11/40	0.12
Fenthion	4.6 [2]	ND	0/40	16.62
Thiophanate-methyl	-	ND-0.12	5/40	0.01
OTC	2.7-6.5 [3]	ND-1.90	9/40	0.25
BPA	2.5-4 [6]	ND-0.41	22/40	0.01

[a]: Detected samples/all samples. [b]: Method detection limit. [c]: Lower than MDL marked as ND. -: not available.

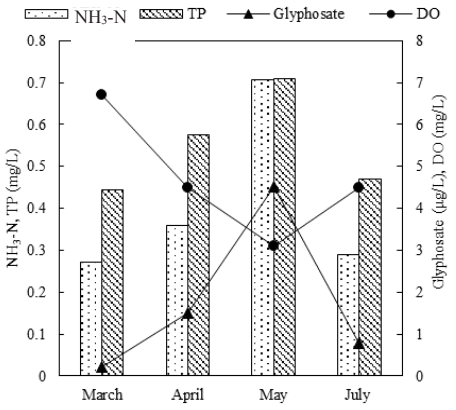

Fig. 2 The relations between water quality and glyphosate (W6 sampling site)

4. CONCLUSION

Results showed BPA existed everywhere and glyphosate concentration varied along with farmer's behavior. The relation between water quality and glyphosate might result from the domination of agriculture activities. As for OTC, its polluted area was not as wide as BPA and glyphosate, indicating the aquaculture activities was limited in the study area. Overall, this study revealed the occurrence of selected contaminants can be used as surrogates to reflect human pollution. This approach can be applied to other reservoir catchments. The results from this study can be provided to the government for better land use managements in the catchment area.

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O6-17

琵琶湖南湖で検出される大腸菌の起源推定

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キーワード:琵琶湖, 大腸菌, 全ゲノム解析、起源推定

抄録

現在、日本では衛生学的水質基準として大腸菌群から大腸菌への変更が検討されている。しかし、水環境から検出される大腸菌のうちどれくらいがヒト糞便由来であるのか、よくわかっていない。本研究は、琵琶湖南湖および下水処理場由来の大腸菌の全ゲノム塩基配列を解読して比較することで、琵琶湖南湖の大腸菌のどれくらいがヒト糞便由来なのか、ヒト以外の動物由来の大腸菌はどれくらいいるのか推測した。その結果、琵琶湖から検出される大腸菌の由来は下水が主ではなく家畜や水鳥の寄与が高いと示唆された。

1. はじめに

日本では、水環境における衛生学的水質基準として大腸菌群が長らく用いられてきた。しかしながら、土壌由来の大腸菌群も検出してしまうため、正確に糞便汚染を示しているとは言えない。そのため、現在、大腸菌群から大腸菌への環境基準の変更の検討が進んでいる。変更が検討されている大腸菌についても、ヒト以外の様々な温血動物の腸管から排出されたり、環境中での増殖の可能性が指摘されており、糞便汚染指標としてどこまで有効か、さらなる検証が必要である。そのためには、環境水から検出される大腸菌が果たして下水由来の大腸菌と同じ系統なのか否かの検証が必要である。一口に大腸菌と言っても、遺伝子の種類や塩基配列の変異のパターンによって多くの系統に分類される[1), 2)]。

疫学の分野ではゲノム塩基配列に基づいて大腸菌の分類を行う方法の一つに Multi Locus Sequence Type (MLST)がある。MLST では特定の遺伝子群の型(allele)の違いに基づいて大腸菌が sequence type (ST)として分類できる。もともとは特定の複数の遺伝子の配列を個別の PCR とサンガーシーケンス法によって解読して ST を決定していたが、近年は次世代シーケンサーの低コスト化によって、大腸菌の全ゲノムを解読してしまい(whole genome sequencing: WGS)、その塩基配列情報から MLST を実施することも現実的となった。また、WGS で得られる全ゲノムの塩基配列から系統樹を作成し、細菌の株がどれくらい近縁であるのかを推定することも可能となってきている[3)]。疫学だけでなく環境分野の研究においても、河川水から単離された病原性大腸菌の遺伝子的特徴の詳細な解析にこれらの方法が利用され始めている[4)]。

本研究は、琵琶湖南湖および周辺下水処理場から単離される大腸菌がどれくらい類似しているのか調べることを目的とした。そのために、大腸菌の全ゲノム塩基配列を次世代シーケンサーを用いて解読し、MLST 解析および k-mer 系統樹、single nucleotide polymorphisms (SNPs)系統樹の作成を行った。

2. 方法

2.1 採水、大腸菌の培養

琵琶湖南湖および周辺下水処理場で採水を行った。琵琶湖南湖では、2017 年 3 月に 11 地点で採水を行い、XM-G 寒天培地によって大腸菌を単離した。また、琵琶湖南湖周辺に位置する 3 か所の下水処理場で 2016 年 12 月および 2017 年 3 月に放流水を採水し、同じく XM-G 寒天培地によって大腸菌を単離した。形成された青色コロニーはシングルコロニーを選択して爪楊枝でピックアップし、新しい XM-G 寒天培地でさらに培養した。コロニーの密度が高くてシングルコロニーが得られない場合には、PBS によって希釈し XM-G 寒天培地で培養することでシングルのコロニー(株)を得た。

2.2 大腸菌からのゲノム DNA 抽出

大腸菌のゲノム DNA は DNeasy Blood & Tissue Kit (Qiagen)を用いて抽出した。琵琶湖南湖水由来の株 14 個、下水処理場流入水および放流水由来の株をそれぞれ 9 個および 15 個から DNA を抽出した。抽出した DNA の濃度は Qubit 2.0 Fluorometer (Invitrogen)を用いて測定し、ライブラリーの調整に供した。

2.3 ライブラリーの調整

五味らの報告[4)]に従い、イルミナの Nextera XT DNA library prep kit を用いてライブラリーを作成した。ライブラリーの品質の確認および定量は Agilent2100 バイオアナライザ(Agilent)を用いた。

2.4 次世代シーケンサー、データ解析

イルミナ社製の次世代シーケンサーMiSeq を用いて大腸菌全ゲノムの塩基配列を解読した(paired-end read, 600 cycle)。得られたリードから市販の解析ソフト CLC Genomics Workbench (CLC bio) を用いて de-novo assembly により contig を作成し、各株毎に全 contig のトータルの長さを確認した。大腸菌のゲノムサイズ(約 500 万塩基)に該当する株の数は琵琶湖南湖水由来は 15 株下水処理場流入水は 9 株、放流水は 15 株であった。これらの株について、市販の解析ソフト Microbial Genomics Module (CLC bio) を用いて、MLST 解析、k-mer 系統樹、および SNP 系統樹の作成を行った。Microbial Genomics Module は Warwick Medical School (Coventry, UK)から提供されている大腸菌の MLST scheme に基づいて MLST 解析を実施してくれる(7 つの遺伝子の allele の組み合わせから ST 番号を決定)。また、K-mer 系統樹の作成では、各大腸菌株の contig から k-mer (長さ k 塩基)の断片配列のセットを作成し、そのセットが大腸菌株の間でそのくらい類似しているかを数値化して系統樹を作成する。配列が似通った株ほど同じ配列の k-mer を共有していることに基づく系統樹作成方法である。以上の解析から、琵琶湖南湖水から単離した大腸菌と下水処理場放流水から単離した大腸菌の ST の比較および、ゲノム配列がどれくらい似ているのか考察を行った。

3. 結果

琵琶湖水、放流水、糞便株由来の大腸菌(黒字、実線表記)と従来から系統分類の代表として用いられている大腸菌 reference 株(灰色字、点線)の全ゲノム情報を合わせて k-mer 系統樹を作成した(図 1)。琵琶湖水、放流水由来の大腸菌の株名は採水時期と水試料、株番号で表示(例:2017July_Biwa3)。株毎に宿主特異的マーカー遺伝子の保有状況、系統分類(A, B1, B2, C, D, E, F) 2)を表記。どの Phylogroup に属するかは Clermont et al.(2015)[1]および Kaas et al (2012)[2]に従った。糞便株(DRR で始まる株名)の宿主、およびは宿主特異的なマーカー遺伝子の保有状況は五味らの報告に基づいて記載[4]。

放流水由来の大腸菌は系統Aが最も多く 12 株中 5 株(42%)だった。これに対して琵琶湖水由来の大腸菌は系統 A はゼロで、系統 B1 が最多で 12 株中 7 株(58%)だった。ヒト糞便由来の株は 9 株中 4 株(44%)が系統 A に分類されている。放流水由来と類似した系統である。トリ糞便由来の株は 5 株中 4 株(80%)が B1 に分類された。琵琶湖水と類似した系統である。

放流水由来の大腸菌はヒトマーカーを保有している株が最も多く 4 株、ついで 3 株がトリマーカーを保有していた。これに対して琵琶湖水由来の大腸菌はヒトマーカーを保有する株はゼロで、トリマーカーを保有する株が 5 株であった。ウシマーカーを保有する大腸菌が 1 株見られた。他の採水月でもおおむね同様の結果が得られた。

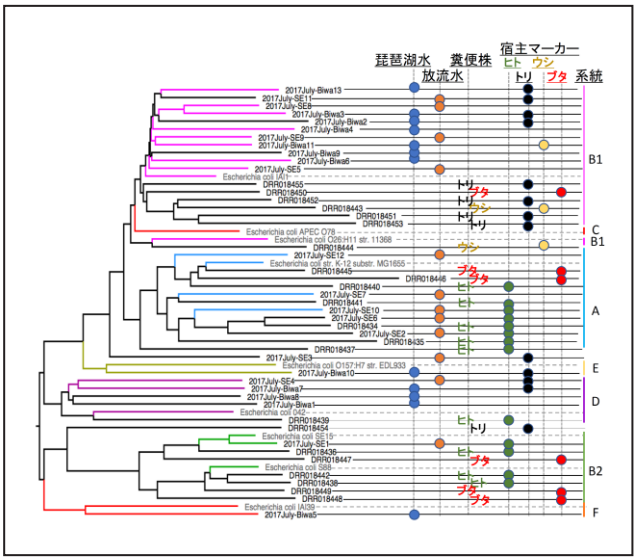

図 1 琵琶湖水、下水処理場放流水、および糞便株由来の大腸菌の k-mer 系統樹(2017 年 7 月採水の例)

4. 考察

生活排水を含む放流水由来の大腸菌が、系統樹上の位置関係でも系統の分類でも宿主マーカー遺伝子の保有状況でもヒト糞便由来の大腸菌に最も類似している結果は理解しやすい。これに対して、琵琶湖水由来の大腸菌はトリ糞便由来の大腸菌と最も類似しており、その由来は下水と異なる可能性(家禽、水鳥等)が示唆された。

5. 結論

琵琶湖から検出される大腸菌の由来は下水が主ではなく家畜や水鳥の寄与が高いと示唆された。

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O6-18

Estimation of Dissolved Oxygen Deficiency in Aquatic Environments with Time Spread Based on Dissolved Methane and Nitrous Oxide Measurements

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Keywords: dissolved oxygen (DO), dissolved nitrous oxide (DN_2O), dissolved methane (DCH_4), hypoxia/anoxia, aquatic environment monitoring

ABSTRACT

We constructed and proposed a method to estimate the dissolved oxygen (DO) deficiency in aquatic environments with time spread ranging from hours to an entire day, with measurement of dissolved methane (DCH_4) and nitrous oxide (DN_2O). Based on the results of the water purification experiment, the determination threshold of the DO deficiency in this method was set to 0.025 mgC/L and 0.003 mgN/L for DCH_4 and DN_2O, respectively. Next, the threshold value was verified from continuous monitoring in actual ponds and data of past literature. As a result, although it may be necessary to set a value for each field, since at least detection of DCH_4 reflects the occurrence of an anaerobic environment, the method can be used for screening of a detailed investigation site related to DO depletion. In this way, the most important merit of our method is that it can be used to estimate previous DO levels especially, without the need for continuous DO monitoring. In addition, as sampling of dissolved gases by the headspace method is simple, a large number of gas samples can be collected efficiently by field survey and analyzed collectively by laboratory etc. It can be analyzed with GC-FID for CH_4 and GC-ECD for N_2O: both analytical instruments are relatively inexpensive and easy to introduce. Applying this method to similar lakes can be expected if knowledge about thresholds is accumulated and diversified in various regions, climate, lake size (breadth and depth), eutrophication level, etc.

1. INTRODUCTION

Lack of DO, roughly below 2 mg/L, has severe impacts on aquatic organisms, especially benthic organisms. However, when the hypoxia/anoxia occurrence is relatively short, or DO frequently change, the current DO value does not indicate whether there was a period of hypoxia/anoxia in the past, or if it will occur in the near future.

In this study, we constructed and examined a method to estimate DO conditions in aquatic environments with time spread ranging from a few hours to an entire day, based on current values of dissolved gases, including CH_4 and N_2O[1]. This method was evaluated based on previous knowledge concerning the behavior of DO, DCH_4, DN_2O, and water quality, especially of nitrogen compounds in a wastewater treatment process, in which DO concentrations, ranging from oxic to anoxic/anaerobic levels, were artificially controlled. Based on an in situ wastewater treatment experiment, we set the threshold in order to determine that the previous DO condition for DCH_4 and DN_2O. We then verified the method and each threshold based on an investigation in small ponds as well as on previous studies. Finally, we propose to investigate whether the method can be put to practical use or to accumulate and organize surveys and knowledge in various lakes.

2. MATERIALS AND METHOD

Microbial metabolic reactions in aquatic environments ranging from oxic to anaerobic

Metabolic reactions in aquatic microorganisms vary according to the environment, which ranges from oxic to anoxic (anaerobic). Dynamics of carbon and nitrogen by microbial metabolism in a lake is shown in Fig. 1.

Theoretical behavior of DCH_4 and DN_2O, which reflect DO deplete conditions

N_2O is produced under both decreased and increased levels

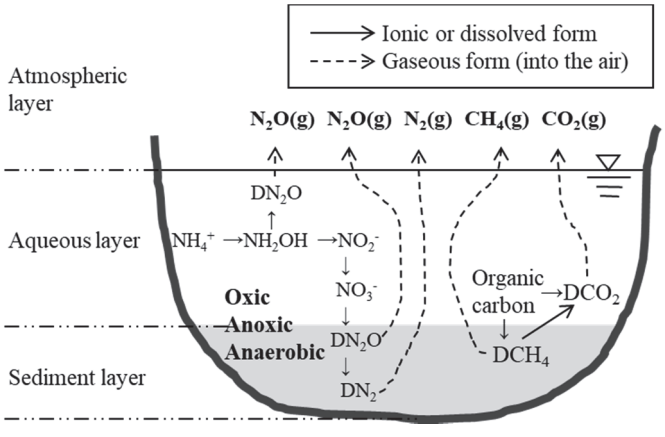

Fig. 1 Dynamics of carbon and nitrogen by microbial metabolism in a lake

of DO: DN_2O can be positioned as a factor determining micro-oxic and anoxic conditions. CH_4 is produced only under anaerobic conditions, and is easily depleted with an increase in the DO concentration. Since the solubility of CH_4 in water is very low, which indicated that it is highly volatile, it is difficult to detect DCH_4 in aquatic environments. In other words, CH_4 detection in aquatic environment means serious DO lacking due to anaerobic conditions. Model behavior of both substances according to DO decrease and increase is assumed in Fig. 2.

Development of a method to estimate previous DO levels in aquatic environments by measuring current DCH_4 and DN_2O values

Here, we propose a new method to estimate of previous DO levels in aquatic environments using DCH_4 and DN_2O (Table 1). The assumed cases are as follows.

Case 1: Detection of neither DCH_4 nor DN_2O

The condition might not have been due to the lack of DO, we labeled it as "negative", indicating that there was no risk of occurrence of anoxic conditions.

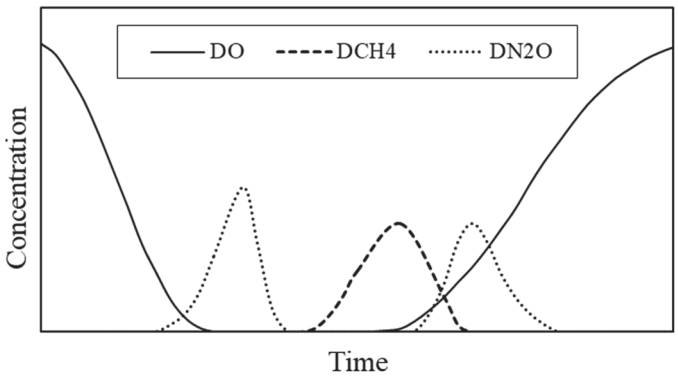

Fig. 2 Model behavior of DCH_4 and DN_2O according to changes in DO levels.

Case 2: Detection of DN_2O and non-detection of DCH_4

Presence of DN_2O indicates low DO concentrations; we labeled it as "false-positive", indicating that the area was likely hypoxic in the past. Such regions would require continuous monitoring of DO.

Case 3: Detection of DCH_4

Presence of DCH_4 indicates that the area was previously anaerobic, thus, we labeled this region as "positive". Such areas require improvement in DO levels.

Assumption of the threshold of DCH_4 and DN_2O based on the wastewater treatment experiment

In wastewater treatment process, decrease and increase in DO levels in the treatment tank can be regarded as similar to its behavior in aquatic environments. In setting the threshold of DCH_4 and DN_2O, we used the data of the domestic wastewater treatment experiment[2].

Verification of the threshold of DCH_4 and DN_2O by continuous monitoring in actual ponds

We verified the threshold of DCH_4 and DN_2O by minute monitoring of DO, DCH_4, DN_2O as well as the water quality in small ponds. There are two ponds: the pond A (rectangle shape, 1mW x 7mL x 1mD) and the pond C (oval shape, 18mW x 42mL x 1.2mD). As sediment accumulated on the bottom of every pond, actual water depth of the ponds A and C was 0.6m and 0.8m, approximately. Monitoring was made at the bottom layer, almost 5cm above the surface of the sediment in the pond A (St. 1) and the pond C (St. 2). General water quality of the ponds was about 10mg/L of DOC and 0.5mg/L of T-N, with almost no difference by the sampling station.

Test decision of lake environment on the data in previous researches by the new estimation method

Test decision of lake environment in some countries was made on the data in previous reports based on the threshold of DCH_4 and DN_2O, set on the wastewater experiment.

Table 1 Estimation of previous DO concentrations in aquatic environments by measuring DN_2O and DCH_4

DCH_4, DN_2O	Decision	Remarks
All non-detection	Negative (No risk)	Oxic condition including past few hours
Detection of DN_2O and non-detection of DCH_4	False-positive (Need for DO continuous monitoring)	Suspicion of hypoxic/anoxic/anaerobic condition (Even if present DO is sufficient, it might have decreased to nearly zero in the past)
Detection of DCH_4	Positive (Need for improvement of DO condition)	Occurrence of anaerobic condition for several hours in the past (Detection of CH_4 means existence of a few hours of 0mg/L DO in the past)

3. RESULTS AND DISCUSSION

Verification of theoretical behaviors of each substance and consideration of the new estimation method through a wastewater treatment experiment

Based on the results obtained from experiments on water treatment of anoxic/oxic process, threshold values for judging the state of oxygen deficiency were temporarily set. The behavior of each gas in the reaction tank was similar to that shown in Fig. 2. The threshold to estimate previous deplete DO conditions would be 0.003 mg N/L (100 nmol/L) for DN_2O, and 0.025 mg C/L (2,000 nmol/L) for DCH_4. In particular, DCH_4 detection at this level would indicate previous continuous conditions of DO at 0 mg/L.

Verification of the threshold of DCH_4 and DN_2O by continuous monitoring in actual ponds

In terms of DO, it decreased during the night, and increased in the daytime up to 14mg/L at St. 1. On the other hand, there was almost no DO at St. 2. As for DCH_4, we couldn't necessarily observe the phenomenon that DCH_4 increase with DO decrease or DCH_4 decrease with DO increase, at St. 1. However, it could be said with certainty that DCH_4 was always greater than the threshold of 0.025mgC/L, regardless of the DO value. Similarly, DCH_4 was always extremely high at St. 2. As for DN_2O, it was always less than the threshold of 0.003mgN/L at both of St. 1 and St. 2. From these results, at least the DCH_4 value would be useful tool in order to determine and screen the required minute investigation site.

Test decision of lake environment on the data in previous researches by the new estimation method

Results of test decision on the environment of several pond and lakes in previous studies are summarized in Table 2. It can be considered that we could almost determine the lake environment in the literature using this method based on provisionally set threshold. Though the threshold value itself needs further study, the usefulness of this method in determining the lake environment was suggested.

4. CONCLUSION

A method to estimate DO deficiency in aquatic environments with time spread with measurement of DCH_4 and DN_2O proposed,. Applying this method to similar lakes can be expected if knowledge about thresholds is accumulated and diversified in various regions, climate, lake size, eutrophication level, etc. We hope that many researchers will examine this new method in various fields, and that it will contribute to the conservation and improvement of aquatic environments globally.

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Table 2 Test decision of water environment on the data obtained by previous studies

Field	Condition	DO (mg/L)	DCH_4 (mgC/L) (nM)		DN_2O (mgN/L) (nM)		Decision	References
Lake Kasumigaura	Eutrophic	Oxic			Max. 0.0006 (22)	Min. 0.0003 (10)	Negative	Hashimoto et. al. 1993 [3]
			Max. 0.012 (1,000)	Min. 0.0006 (50)				Nojiri et. al. 1995 [4]
Lake Tahihu	Eutrophic	Oxic	Max. 0.0010 (83)	Min. 0.0001 (10)	Max. 0.0031 (110)	Min. 0.0013 (47)	False-positive	Wang et. al. 2010 [5]
			0.0005 (38)	0.0002 (15)	0.0013 (46)	0.0010 (35)		
Lake Kuivajärvi	Mesotrophic	0	Min. 0.08 (6,000)		Min. 0.006 (200)		Positive	Miettinen et. al. 2015 [6]

O6-19

Source estimation of veterinary drugs in Yodo River watershed, Japan

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Keywords: veterinary drugs, source estimation, field study, livestock population, human population

ABSTRACT

Twelve veterinary drugs were monitored at four rivers in Yodo River watershed, Japan over 17 sampling events. Among the five frequently detected veterinary drugs, mass flux in the river was significantly correlated with human population in the catchment for three veterinary drugs substantially used by humans, sulfamethoxazole, trimethoprim, and sulfadimethoxine. Sources of the three would be sewage treatment plants and household septic tanks. On the other hand, mass fluxes of the remaining two, sulfamonomethoxine and lincomycin, in the rivers showed positive correlation with swine population in the catchment, although sulfamonomethoxine is equally used in both cattle and swine farming. This was attributable to application of cattle excrement as manure, and lability of sulfamonomethoxine during composting processes. The major source of the two would be on-site treatment facilities of swine urine.

1. INTRODUCTION

Veterinary drugs are one of the most noticeable emerging contaminants due to their potential risks to aquatic organisms, and they have been widely detected in surface waters[1]. Therefore, source identification and mass loading prediction should be conducted to develop reduction strategies of the veterinary drugs. However, most studies only reported qualitative outcomes for their sources.

We therefore conducted this study to provide quantitative source characterization of veterinary drugs in the Yodo River watershed, Japan. We monitored 12 veterinary drugs at four rivers in the watershed over five months. The sources of veterinary drugs were evaluated by linking their mass fluxes in rivers with human or livestock populations in catchment areas and flow rate patterns.

2. METHOD

Yodo River watershed (8,240 km^2) comprises residential area (21%), agricultural land (25%), forest (47%), and others (7%). The population is approximately 12,000,000, of which approximately 95% use the sewer system in the watershed. Human and livestock populations in catchment areas of sampling sites are summarized in Table 1. Human and livestock population were obtained from Ministry of the Environment[2] and Ministry of Agriculture, Forestry and Fisheries[3], respectively.

Field surveys were conducted in the middle basin of the watershed. Surface water samples were collected from the Katsura River (Miyamae Bridge), the Uji River (Ujigokou Bridge), the Kizu river (Kizugokou Bridge), and the Yodo River (Hirakata Bridge) approximately weekly between October 2009 and February 2010, yielding a total of 17 sampling events. Samples were collected using a grab in a stainless steel bucket. The samples were stored in amber glass bottles with 1.0 g/L ascorbic acid in darkness and taken to the laboratory. The 12 selected veterinary drugs in the dissolved phase were concentrated by solid-phase extraction, measured by UPLC-MS/MS, and quantified by the absolute calibration method[4]. Signal to noise ratios (S/N) of 3 were used as the detection limit. The flow rates at sampling sites were obtained from the Ministry of Land, Infrastructure and Transport[5].

Table 1 Human and livestock populations in catchment areas of sampling sites.

	Human	Cattle	Swine
Katsura River	125,285	3,675	4,895
Uji River	1,758,892	18,952	7,704
Kizu River	390,907	7,810	26,600
Yodo River	4,088,883	33,040	40,055

3. RESULTS

Among the 12 selected veterinary drugs, sulfamethoxazole, sulfadimethoxine, trimethoprim, sulfamonomethoxine and lincomycin were frequently detected (> 50%) in more than one river. Concentrations of the former three drugs were in the same order of magnitude among rivers, while those of the Kizu River were much higher than the other rivers for the latter two drugs and thiamphenicol (Figure 1).

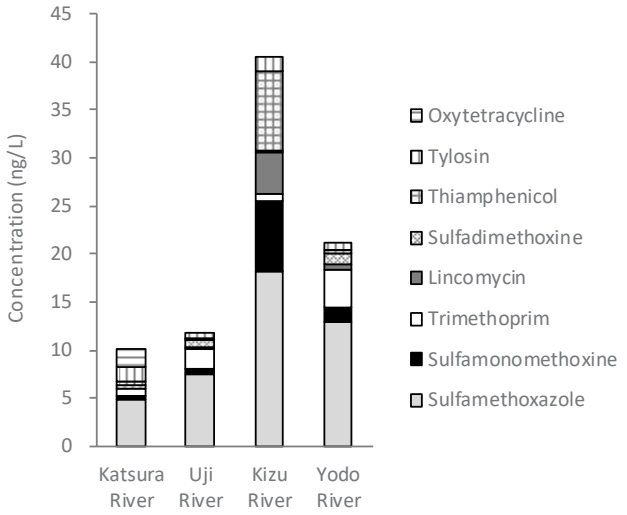

Fig. 1 Concentrations of veterinary drugs in study area. Vertical bars denote means of 17 samplings. Tiamulin, sulfadimidine, sulfamerazine, and ceftiofur were not shown due to their low concentrations (<1 ng/L).

Since the five frequently detected veterinary drugs are relatively conservative during river transport in this watershed[6], their mass fluxes in a river indicate total mass loadings at sources located in the catchment area. Among the five drugs, the mass fluxes in rivers were significantly correlated with human population in the catchment area for sulfamethoxazole, trimethoprim, and sulfadimethoxine (Table 2 and Figure 2A). This is attributable to their substantial usage by humans[7]. Therefore, sources of the three drugs would be sewage treatment plants (STPs) and household septic tanks.

On the other hand, mass fluxes of sulfamonomethoxine and lincomycin in rivers showed positive correlation with swine population in the catchment (Table 2 and Figure 2B). As lincomycin is mostly used for swine farming[8], the correlation reflects its usage. However, sulfamonomethoxine is equally used for both cattle and swine, indicating existence of influential factors determining the sources other than usage. Though both feces and urine of cattle are mostly applied to agricultural land as manure after composting or storage, approximately 60% of swine urine is discharged to the aquatic environment via on-site treatment facilities[9]. Therefore, given the correlation with swine population, runoff of land-applied manure does not have appreciable impact for sulfamonomethoxine, compared with discharge from on-site treatment facilities of swine urine. This would be mostly attributed to lability of sulfamonomethoxine during composting process (removal >98%, measured at several cattle farms in Japan by the Research Institute for Animal Science in Biochemistry and Toxicology[10]). Low contribution of the runoff is complemented by the lack of correlation between mass flux in a river and its flow rate ($p > 0.05$ for four studied rivers, for both sulfamonomethoxine and lincomycin, data not shown). Therefore, on-site treatment facilities of swine urine are influential sources for these drugs. Thus, not only use application but also livestock waste management significantly affect the sources of veterinary drugs.

Table 2 Correlation coefficients (R^2) between mass fluxes in rivers and human or livestock population in the catchment areas for five frequently detected veterinary drugs [a].

	Human	Cattle	Swine
Sulfamethoxazole	0.983	0.431	0.010
Trimethoprim	0.953	0.554	0.000
Sulfadimethoxine	0.964	0.534	0.001
Sulfamonomethoxine	0.006	0.525	0.982
Lincomycin	0.151	0.151	0.843

[a] Correlation includes four rivers in this study for lincomycin, while observations in the Hirose River reported from Nakada et al. [11] were additionally included for the other drugs.

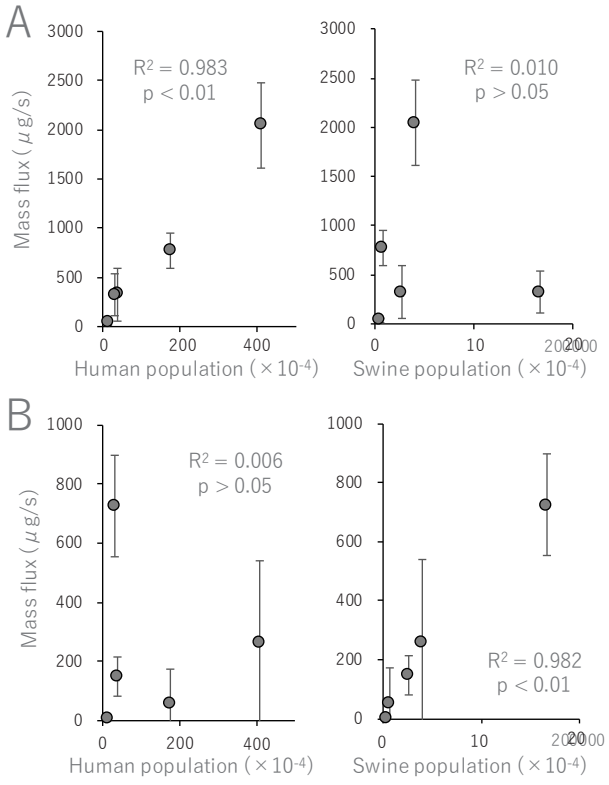

Fig. 2 Relationships between mass fluxes in rivers and human or swine population in the catchment areas for (A)

sulfamethoxazole and (B) sulfamonomethoxine. Relationships include four rivers in this study and the Hirose River observed by Nakada et al.[11]. For the mass flux, symbols denote means and error bars denote standard deviations (n = 3 for the Hirose River, and n = 17 for the other rivers).

Since human waste is treated in STPs or household septic tanks in most countries, they would be generally the major sources of drugs mostly used by humans. However, management systems of livestock waste vary among countries, resulting in different sources of veterinary drugs between countries. In the USA, most livestock waste is applied to agricultural fields as manure after storage and not directly discharged to the aquatic environment[12], also generally applicable to European countries[13]. Therefore, the major source of veterinary drugs in these regions is likely manure applied to agricultural land. On the other hand, a substantial portion of livestock waste directly enters the aquatic environment with or without treatment in Asian countries[14][15]. Although field measurements were extensively conducted there, the relationship between the spatial distribution of veterinary drugs and livestock populations in the catchment areas has not been quantified. Therefore, our findings of their correlations would provide more reliable source identification of veterinary drugs and advance our understanding on their mass loading prediction in Asian countries.

4. CONCLUSION

Mass fluxes of sulfamethoxazole, trimethoprim, and sulfadimethoxine, veterinary drugs substantially used by humans, in rivers showed a positive correlation with human population in the catchment. Their major source was considered to be STPs and household septic tanks in this area. On the other hand, mass fluxes of sulfamonomethoxine and lincomycin in rivers showed a positive correlation with swine population in the catchment area. A comprehensive analysis including their usage, livestock excrement management, and reported stability in composting process indicated that their major source is on-site treatment facilities of swine urine. To our knowledge, this is the first study linking the spatial distribution of pharmaceuticals with livestock population in the catchment.

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O6-20

Impacts of Sediment Supply from a Dam Reservoir on Heavy Metals Concentrations in Downstream River Water

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Keywords: Water quality, Chemical substances, Sediment supply, Heavy metals, *Oryzias latipes*

ABSTRACT

Sedimentation in a dam reservoir is one of the important issues to overcome for utilizing the reservoir over a long term. In order to solve this, in Japan, sediment supply from reservoirs to their downstream rivers has been attempted. However, there is limited knowledge on the impacts on the water quality just after the sediment supply. In this study, leaching tests of heavy metals from reservoir sediments were conducted to evaluate the occurrences of heavy metals at the downstream after sediment supply. As a result, manganese (Mn) was considered as the dominant and concerned heavy metal in the assumed case. In addition, short-term toxicity test was conducted to determine the toxicity of Mn to Japanese medaka (*Oryzias latipes*) and the No Observed Effect Concentration (NOEC) was derived as 5 mg-Mn/L. The Predicted Environmental Concentration (PEC) / the Predicted No Effect Concentration (PNEC) ratio regarding to Mn was obtained from the result of leaching tests as 0.015 which was much lower than the value (4.67) obtained from the data of Mn contents in the sediment. It was indicated that leaching from sediment is an important factor to evaluate the environmental risk of Mn to fishes just after an event of sediment supply.

1. INTRODUCTION

Sedimentation in a dam reservoir is one of the important issues to overcome for utilizing the reservoir over a long term[1]. In addition, interrupting continuity of sediment transport by dams may cause downstream river flows to be sediment-starved (so-called hungry water), resulting in incision of river channels and/or coarsening of the bed materials[2]. In order to solve these situations, in Japan, sediment supply from reservoirs to their downstream rivers has been attempted using approaches such as sediment augmentation, sediment flushing and sediment bypass. However, there is limited knowledge on the impacts on the water quality just after the sediment supply operation despite the assumption that chemicals such as heavy metals are accumulated on the deposited sediment at the bottom of dam reservoirs.

In this study, leaching tests of heavy metals from dam reservoir sediments were conducted to evaluate the occurrences of heavy metals in river water just after sediment supply. In addition, a short-term toxicity test was conducted to determine the toxicity of manganese (Mn) to Japanese medaka (*Oryzias latipes*).

2. METHOD

(1) Leaching test of dam reservoir sediment

On November, 2016, sediment and water samples were collected from Yahagi Dam reservoir and they were used to evaluate leaching of heavy metals from reservoir sediments. Leaching test was conducted by following the standard leaching test method defined in Notification No.46 of the Environment Agency (JLT 46), Japan. Sediment was passed through 2 mm mesh sieve before tests. In addition to the condition defined in JLT 46, different liquid to solid ratios (L/S (%): 3, 5, 10, 20, 25) were examined to evaluate the relationship between leached concentration and L/S. For leaching solvents, ultrapure water (*Milli-Q*) and reservoir water were used. Test was operated by horizontal shaking for 6 hours.

The collected reservoir sediment, reservoir water and supernatants from leaching tests (filter by 0.45 μm membrane filter) were subjected to heavy metals analysis. Water samples were treated by nitric acid digestion and sediment samples were treated by microwave-assisted digestion. Pre-treated samples were analyzed by ICP-MS (X7CCT, Thermo Fisher Scientific). Target elements were Lead (Pb), Arsenic (As), Copper (Cu), Zinc (Zn) and Mn. Water content of sediment sample was also analyzed.

(2) Short-term toxicity test of Mn to *Oryzias latipes*

Oryzias latipes (*O. latipes*) was obtained from the National Institute for Environmental Studies in Japan (NIES). Mn was targeted based on the result from (1). Manganese chloride was used to prepare five different Mn solutions (Control, 0.5, 5.0, 50, 500 mg-Mn/L) and they were used for batch tests with eggs of *O. latipes*. In each beaker, 10 eggs and 50 ml test solution were added, and incubated at 24 ± 1 °C for 14 days. (Until 5 days after

hatching). Solution was replaced every other day. Four replicates were performed for each solution. Hatch of eggs and viability rate of larval fish were documented every day. Statistical analysis was performed using the statistical package R. The homoscedasticity of viability and hatching rate was examined by Bartlett test (p<0.05). Statistical significances were evaluated using Dunnett test (p<0.05), in the case that homoscedasticity was rejected in all the tests. The highest concentration with no differences among all treatment including control was determined as the No Observed Effect Concentration (NOEC).

RESULTS & DISCUSSION

(1) Leaching test

Results of leaching test were shown in **Figure 1**. In case of the test with *Milli-Q*, heavy metals were leached at the range of 0.02 to 0.04 μg/g-dry for Pb, 0.02 to 0.05 μg/g-dry for As, 0.02 to 0.05 μg/g-dry for Cu, 0.02 to 0.11 μg/g-dry for Zn and 1.8 to 2.2 μg/g-dry for Mn. Leached amounts tended to be more at lower L/S (For example, As was leached at 0.05 μg/L at 3%, 0.04 μg/L at 5%, 0.02 μg/L at 10-25%). In case of the test with dam reservoir water, heavy metals were leached at the range of 0.01 to 0.02 μg/g-dry for Pb, 0.01 to 0.0 2 μg/g-dry for As and Cu, 0.03 to 0.05 μg/g-dry for Zn and 0.06 to 1.27 μg/g-dry for Mn. For Pb, As, Cu and Zn, there were no significant differences among leached amounts under different L/S. In contrasts, Mn was more leached at the lower L/S (1.3 μg/g-dry at 3%, 1.1 μg/g-dry at 5%, 0.88 μg/g-dry at 10%, 0.24 μg/g-dry at 20%, 0.06 μg/g-dry at 25%).

In *Milli-Q* itself, Pb, Cu, Zn and Mn were found at 0.03, 0.18, 3.4, 0.07 μg/L, respectively. As was not detected. In contrast, in dam reservoir water itself, Pb, As, Cu, Zn and Mn were found at 0.06, 0.25, 0.45, 3.2, 0.30 μg/L, respectively. It was indicated that not only heavy metals but also other water qualities in reservoir water affected the leaching behavior of the reservoir sediment. The relationship between leaching solvent and leached amount of heavy metals were plotted as shown in **Figure 2**. Heavy metals were tended to be more leached in *Milli-Q* than reservoir water. In consideration of the both tests with *Milli-Q* and reservoir water, Mn was significantly more leached, especially at the lower L/S, among all the targeted heavy metals. **Table 1** describes the parameters of the tested reservoir sediment. The tested sediment contained Mn at 659 μg/g-dry which was the highest among all targeted heavy metals. Thus, Mn was considered as the most concerned heavy metal in this study.

Mn concentration at the downstream river water during an event of sediment supply from the upstream reservoir

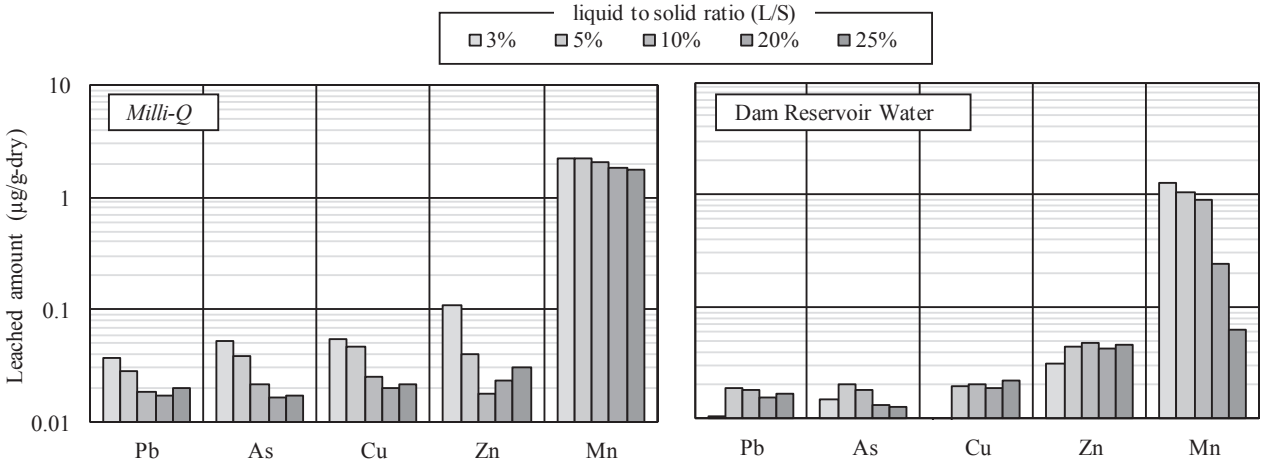

Fig. 1 Leached amounts of Pb, As, Cu, Zn, Mn after leaching tests of the reservoir sediment (Left: dissolution solvent was *Milli-Q*, Right: dissolution solvent was dam reservoir water)

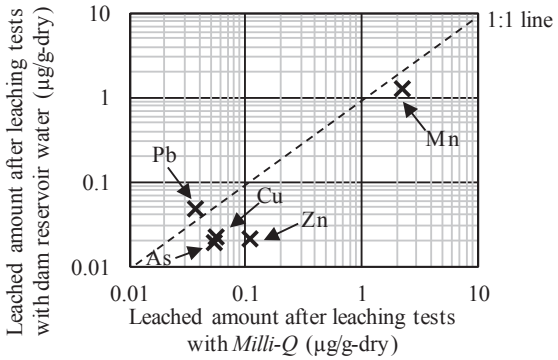

Fig. 2 Relationship between leaching solvent and leached amount of heavy metals

Table. 1 Parameters of the tested dam reservoir sediment

Particle size distribution	(%)
Sand (0.075 - 2 mm)	14.6
Silt (0.005 - 0.075 mm)	56.9
Clay (< 0.005 mm)	28.5

Heavy metals contents	(μg/g-dry)
Pb	17
As	10
Cu	20
Zn	115
Mn	659

was calculated using the information obtained from previous report[4]. Firstly, sediment concentration was calculated as 1.259 g/L (which was significantly lower than the L/S tested above) by the equation below.

Sediment concentration (g/L)
= Flux of input sediment (m^3/s)・Unit weight (t/m^3)・10^6 / River water flow (m^3/s)・10^3 **Equation 1**

where flux of input sediment was provided as 0.14 m^3/s (from the data gained in a sediment supply experiment [4]). Unit weight was set as 1.6 t/m^3 assuming that the sediment contained pore water to the extent of a general sediment. River water flow was provided as 177.9 m^3/s.

Secondly, dry sediment concentration (g-dry/L) was calculated by using the water content of the reservoir sediment (71.9%), resulted in 0.354 g-dry/L. This value and the result obtained from the leaching test with the reservoir water (In this case, maximum leached amount (1.27 μg/g-dry) was used) were used for calculating dissolved Mn concentration at the downstream as 0.30+ 0.45 = 0.75 μg/L (Defined as Predicted Environmental Concentration (PEC)1). When all the Mn contained in reservoir sediment was assumed to be suspended in the river water, total Mn concentration was calculated as 0.30+233.37 = 233.7 μg/L (Defined as PEC2).

(2) Short-term toxicity test of Mn to *Oryzias latipes*

Japanese medaka (*O. latipes*) is one of the species recommended by OECD test guideline to evaluate the quality of river water where the temperature is relative warm. This condition is also found at the Yahagi River located at the downstream of Yahagi Dam reservoir, which was focused in this study. The result of short-term toxicity test of Mn to *O. latipes* was shown in **Figure 3**. There were no significant differences in hatching rate among all treatments. In contrasts, survival rate was significantly lower at the treatment with 50 and 500 mg-Mn/L. Thus, the NOEC of Mn to *O. latipes* (survival rate) was calculated as 5 mg-Mn/L in this study. Interestingly, *O. latipes* was more vulnerable to Mn at the stage of larval fish after hatching than the stage of embryo protected by egg. This result was similar to a previous study in which NOEC was calculated as 2.84 mg-Mn/L using eggs of brown trout (*Salmo trutta*) exposed to manganese chloride under an early-life-stage test condition for 62 days[5].

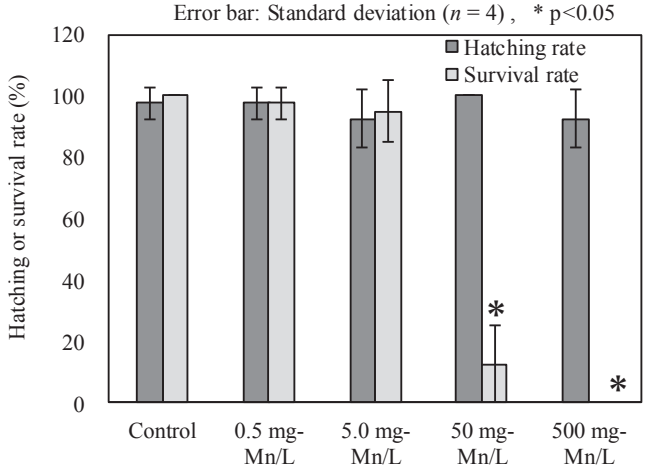

Fig. 3 Evaluation of solutions at different Mn concentration using *O. latipes* (Short-term toxicity test)

Environmental risk of Mn to fishes in a downstream river of a dam reservoir just after an event of sediment supply was evaluated using the test results. The Predicted No Effect Concentration (PNEC) of Mn was calculated as follows. The value of NOEC (5mg-Mn/L) was divided by the acute-chronic ratio of 10 because the obtained NOEC was considered as a subchronic toxicity index while the situation needed to be evaluated just after sediment supply seemed to be acute. In addition, another assessment factor of 10 was applied to consider the differences in sensitivities between *O. latipes* and other species. Therefore, PNEC in this study was derived as 50 μg-Mn/L. From the result of (1), PEC1/PNEC ratio was calculated as 0.015 while PEC2/PNEC ratio was calculated as 4.67.

3. CONCLUSION

In this study, leaching tests of heavy metals were conducted using dam reservoir sediments. As a result, Mn was considered as the dominant and concerned heavy metal in the downstream river water just after sediment supply. In addition, a short-term toxicity test was conducted to determine the toxicity of manganese (Mn) to Japanese medaka (*Oryzias latipes*). NOEC was derived as 5 mg-Mn/L. Consequently, PEC/PNEC ratio regarding to Mn was obtained from the result of leaching tests as 0.015 which was much lower than the value (4.67) obtained from the data of Mn contents in the sediment. It was indicated that leaching from sediment is an important factor to evaluate the environmental risk of Mn to fishes just after an event of sediment supply.

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O6-21

Recent Progress of an Advanced Eco-Hydrologic and Biogeochemical Coupling Model in Terrestrial-Aquatic Continuum

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Keywords: modeling, eco-hydrology, biogeochemical cycle, coupling model, inland water

ABSTRACT

The author has developed process-based National Integrated Catchment-based Eco-hydrology (NICE) model to integrate coupled human and natural systems and to assess impact of water degradation on ecosystem change. Here, the author further developed an advanced model coupling eco-hydrology and biogeochemical cycle (NICE-BGC), which incorporates the whole process of carbon cycling including surface runoff, groundwater, weathering, CO_2 evasion and sediment storage in water, and outflow to the ocean. Because the new model included CO_2 evasion and lateral carbon transport explicitly, the result suggests most previous researches have generally overestimated the accumulation of terrestrial carbon and underestimated the potential for lateral transport. The model result also showed that there is a great variability of DOC, POC, and DIC transport to the ocean reflecting biologic and hydrologic processes, and CO_2 degassing affected by both terrestrially derived CO_2 and CO_2 production through aquatic metabolism.

1. INTRODUCTION

Recently, some studies have pointed out that inland waters including rivers, lakes, and groundwater may act as a significant transport pathway for both water and dissolved substances[2,4]. However, their contribution to continental-scale carbon cycling has remained uncertain because they are generally more difficult to measure and the available data for global aquatic ecosystems are fewer and more heterogeneous than those for terrestrial ecosystems[1,4]. In this paper, the author showed the recent progress in eco-hydrology and biogeochemical cycle model in terrestrial-aquatic continuum[26]. Because these mechanisms are closely interconnected with each other[30] and sometimes the carbon cycle may be triggered or greatly altered by extreme events[31], the coupling simulation will play a role in the integration of greenhouse gas budget of the biosphere, quantification of hot spots along a terrestrial-aquatic continuum, and bridging the gap between bottom-up and top-down approaches.

2. MODEL DEVELOPMENT

2.1. National Integrated Catchment-based Eco-hydrology (NICE) model

The author and his colleagues have developed the National Integrated Catchment-based Eco-hydrology (NICE) model (Fig. 1)[5-25]. NICE takes into account complex interactions between the forest canopy, surface water, the unsaturated zone, aquifers, lakes, and rivers. This model also simulates iteratively nonlinear interactions between hydrologic, geomorphic, and ecological processes. Using NICE, the author has previously attempted to extract the impacts of discharge and groundwater-level change, sediment deposition, and nutrient availability on the complex pattern of vegetation succession in Kushiro Wetland[5,8,9,12,19,21,24]. The model was also applied to Lake Kasumigaura[10], Tokyo Metropolitan Area[7,13,17,18,20], Changjiang and Yellow Rivers[6,11,14-16,22,23,25], West Siberia[29], and Mekong River[26], etc.

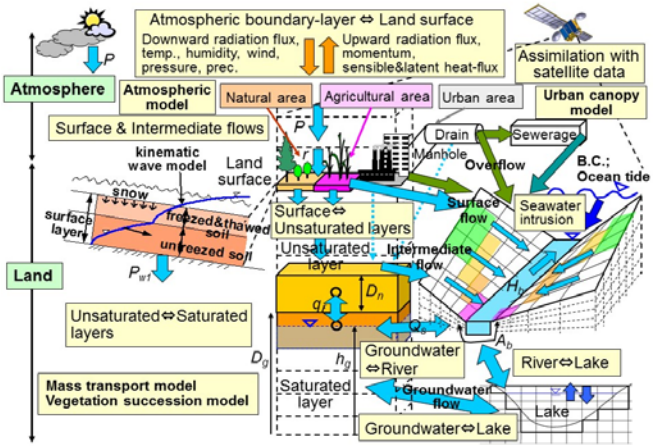

Fig. 1 NICE model

2.2. Coupling NICE with Biogeochemical Cycle Models (NICE-BGC)

In order to fill the gap in the current eco-hydrology models, the author has recently coupled the original NICE with various biogeochemical cycle models, including terrestrial ecosystems, water quality in aquatic ecosystems, and carbon weathering (Fig. 2)[26,27]. In this modified NICE

(NICE-BGC), all submodels were coupled together with the original NICE to conserve the carbon budget. Each submodel offers iterative simulation in the most efficient way by combining on-line and off-line modes. The newly coupled model incorporates the connectivity of the biogeochemical cycle and the hydrologic cycle for surface water and groundwater, hillslopes and river networks, and other intermediate regions.

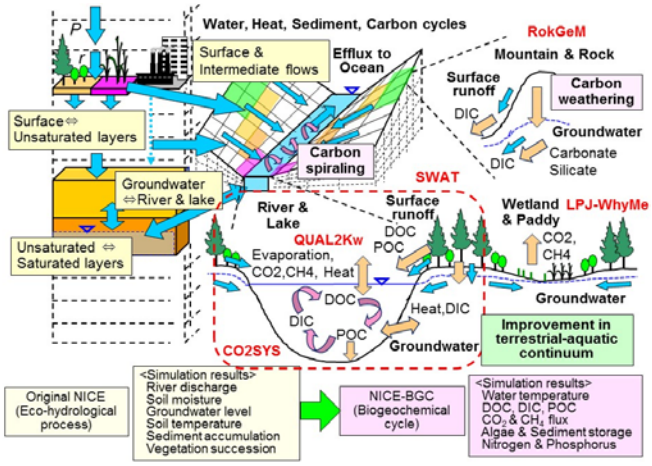

Fig. 2 New development of NICE-BGC

3. RESULTS

The author has compiled as many data as possible and calculated averaged values of CO_2 evasion to the atmosphere, and discharge, TOC, DOC, POC, DIC-flux to the ocean at global major basins. The author also showed that annual-averaged values obtained by NICE-BGC were generally in the ranges of previous studies; carbon export from land to inland water was about 2.01±1.98 PgC/yr, degassing above the water about 0.79±0.38 PgC/yr, sediment storage about 0.20±0.09 PgC/yr, and the rest transported to the ocean about 1.13±0.50 PgC/yr[27]. Fig. 3 shows the simulated seasonal variations of global carbon flux from terrestrial into aquatic ecosystems and in inland water[28]. As for terrestrial carbon flux, more DOC and POC are exported (about 458.38±474.41 TgC/season and 239.25±289.90 TgC/season) during Jan. - Mar., dominantly affected by the transport in rivers of South America and secondly by the spring snowmelt in northern boreal and subarctic peatlands[29]. In contrast, DIC flux is smallest (about 45.22±50.31 TgC/season) during Jan. - Mar. The seasonal variation of inland carbon flux is more complicated by terrestrially derived carbon inflow and carbon production through aquatic metabolism. While DOC and DIC flux are similar trend as in the terrestrial carbon flux, CO_2 degassing is higher (about 294.66±93.80 TgC/season) during Apr. - Jun. remarkable in South America, Africa, and Asia[3]. Sediment storage is larger (about 76.80±13.19 TgC/season) during Jul. - Sept. greatly affected by the higher flow in Asia and North America.

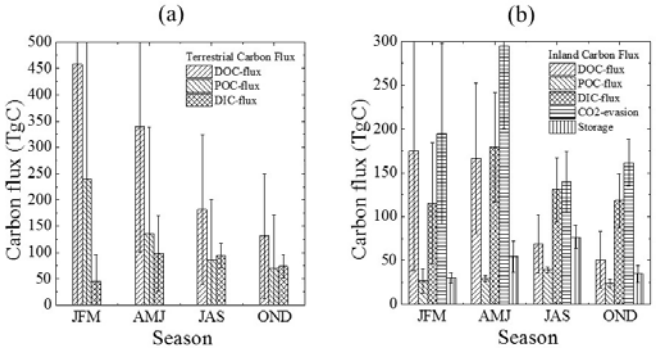

Fig. 3 Seasonal variations of global carbon flux; (a) from terrestrial and (b) in inland water.

4. DISCUSSION

NICE-BGC calculates the whole process of carbon cycling including surface runoff, groundwater, weathering, CO_2 evasion and sediment storage, and outflow to the ocean. Yet it is necessary to improve the accuracy of the simulations; carbon assimilated by plants and water availability, weathering process, and the carbon cycle in the estuary, etc. In order to separate more clearly the carbon source in inland waters from the terrestrial carbon sink, it is necessary to couple this process-oriented model with scaling up site-level observations of aquatic ecosystems, and to improve a spatial resolution of atmospheric inverse model assimilated with the bias-corrected satellite data. If this component proves to be important, it is likely that the terrestrial CO_2 sink will prove to have a smaller contribution to the global carbon cycle than considered so far.

5. CONCLUSION

The new process-based model NICE-BGC incorporates the whole process of carbon cycling in terrestrial-aquatic continuum. The model result showed that there is a great variability of DOC, POC, and DIC transport to the ocean reflecting biologic and hydrologic processes, and CO_2 degassing affected by both terrestrially derived CO_2 and CO_2 production through aquatic metabolism. Because these were usually evaluated separately in the previous researches, there is a great improvement from them.

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O6-22

Impact of climate change on changes in river water temperature simulated with SIPHER model in Takasaki River basin, Chiba, Japan

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Keywords: land use, meteorological, SIPHER model, Takasaki basin, long term monitoring

ABSTRACT

In this research, uncertainty of the future climate change was investigated by continuous long term monitoring and validation of the simulated temperature obtained with SIPHER^{TM} model. Model was calibrated and validated for 2012 – 2016 from water temperature collected across 8 stations in Takasaki river, Chiba, Japan. Water quality parameters namely, water temperature, water depth, and electrical conductivity were measured at every 10 minute interval with sensors. Monthly average of the observed and simulated water temperature for stations with higher pervious areas was found to be close to each other ($R^2 > 0.90$). In general, it was observed that the simulated temperature obtained with SIPHER model was less reproducible for small basin ($R^2 < 0.90$). Future metrological parameters were predicted with CNRM-CM5 general circulation model. Impact of climate change in river water was then done for the present (2000 – 2010) and future (2060 – 2070) decade. Monthly average future temperature decreased by at least - 0.2 ^{O}C in Dec-Jan-Feb-Mar, and increased by 1.2 ^{O}C in October, and at least 0.2 ^{O}C in Apr-May-Jun-July-Aug-Sep. It is confirmed that due to climate change, temperature in winter decreases whereas it increases in summer.

1. INTRODUCTION

In order to understand long term effect of the climate change, it is necessary to do continuous long term monitoring of the river water temperatures. The temperatures simulated with various models needs to be validated with the observed water temperature. Uncertainty of the future climate change must be investigated with the available data, which can be done by continuous long term monitoring and validation of the monitored data with the simulated data.

Most of the model for the simulation of water temperature is based on the net heat balance across water bodies. The heat load comes from shortwave and long wave radiation, latent and sensible heat, wastewater and groundwater. The radiations are in-turn dependent on metrological condition, mainly the air temperature absorbance or reflectance of the water bodies and upper basin area. Depending on the nature of the basin area, it might be pervious or impervious. In pervious area, the heat from radiation is absorbed and transmitted into the ground surface, whereas in impervious area, mainly consisting of concrete drainage channel, roads, and buildings, surface runoff increases and higher will be reflectance of the longwave radiation, and higher will be the absorbed heat from the shortwave solar

radiation (insolation). With urbanization, population growth, the pervious area decreases and at the same time increase in industrial activity leads to increase in wastewater discharge, which might also act as a source of heat to the receiving water bodies.

The temperature across the Takasaki basin is simulated with deterministic model employing the physics of heat exchange between the river and the surrounding environment. Model calibration and validation was carried out using water temperature data collected at several monitoring sites during 2012 - 2016. The data are composed of the monitoring of the temperature in 8 stations across Takasaki river basin, and 1 each in Taguri and Kashima river.

The main objective of this paper is to analyze an impact of climate change in variation of present (2000 – 2010) and future (2060 – 2070) decade river water temperature in Takasaki River, Chiba, Japan simulated with SIPHER™ model across wide range of catchments.

2. METHOD

The study is Takasaki river Basin in Chiba prefecture, Japan. This Taksaski river is one of the major tributary river flowing into the lake Inba-Numa. Map of observation site and landuse pattern is shown in **Fig. 1**.

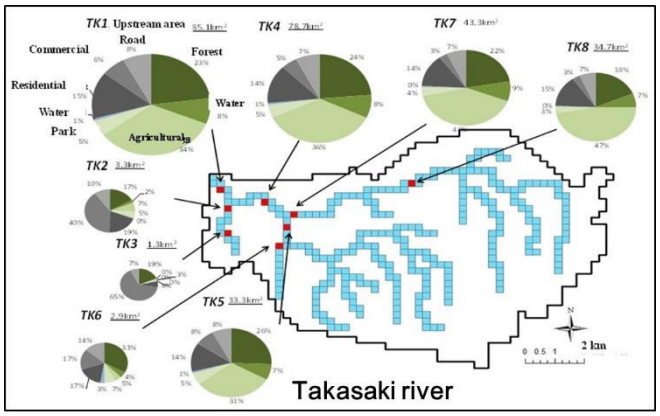

Fig. 1. Map of the sampling point in Takasaki river

The routine water quality parameters, water temperature, water depth, electrical conductivity were measured at every 10 minute interval with sensors TidbiT v2 Temp Logger, water depth HOBO Water Level Loggers respectively from April 2012 to Dec 2016.

River water temperature was simulated with the SIPHER™ model (Pacific Consultants, Tokyo, Japan), which is a GIS based hydrologic model consisting of six submodels of evapotranspiration, ground water flow, surface water flow, channel routing, point and non-point source pollutants loading (Uehara et al., 2008). Future metrological parameters were predicted with CNRM-CM5 general circulation model.

3. RESULTS

Time series variation of observed and simulated temperature along with the precipitation and simulated flow rate for 2012-2016 for stations TK1 is given in **Fig. 2.** St. TK1 is characterized by greater pervious area (71%) and higher upper river basin area (85.1 km^2), whereas St. TK2 has lesser pervious area (30%) and lower upper river basin area (3.3 km^2) (**Table 1**). The weighted pervious area in St TK1 and TK2 is 60.4 and 1.0 km^2 respectively.

For St. TK1 with higher weighted pervious area, the simulated and observed temperature were close to each other (R^2=0.9525), and that for St. TK2 with lower weighted pervious area, the simulated and observed temperature (R^2=0.9010) varied a lot. It was found as the weighted pervious area decreased, the coefficient of determination decreased (**Table 1**). The exact reason for the higher simulated water temperature in lesser pervious area is not clear, however it might be due to overestimation of heat load from the shortwave and longwave radiation. In an area with lesser pervious area, or to say with higher impervious areas, the presence of concrete like materials, as evident by concrete water tunnel in St, TK2, the incoming shortwave radiation is overestimated than the outgoing longwave radiation and net heat load from latent and sensible heat.

Table 1. Regression coefficient for observed and simulated temperature

Weighted pervious area, km^2	Regression equation	R^2	St. code	Pervious %	Upper river basin area, km^2
60.4	y = 0.8383x + 2.934	0.9525	TK1	71	85.1
57.5	y = 0.7903x + 3.710	0.9462	TK4	73	78.7
32.9	y = 0.7652x + 4.324	0.9516	TK7	76	43.3
26.4	y = 0.6697x + 5.620	0.9163	TK8	76	34.7
23.6	y = 0.7457x + 3.981	0.9335	TK5	71	33.3
1.5	y = 0.7123x + 5.379	0.9037	TK6	53	2.9
1.0	y = 0.7214x + 0.638	0.9010	TK2	30	3.3
0.3	y = 0.5409x - 0.486	0.8123	TK3	22	1.3

Variation in present and future decade water temperature for St. TK1 varied with a minimum of -0.3 ^{O}C in February and maximum of 1.2 ^{O}C in October. In general, future water temperature during winter (Dec-Jan-Feb-Mar) decreased and in summer (Apr-May-June-Jul-Aug-Sep-Oct-Nov) increased than the present decade temperature (**Fig. 3**).

4. DISCUSSIONS

The net heat balance across water bodies is the sum of incoming shortwave radiation, outgoing longwave radiation, latent of vaporization (or condensation) and sensible heat. If heat received by water bodies is taken as positive, then shortwave is positive, longwave is negative, latent heat of vaporization is positive (or condensation is negative), and sensible heat positive or negative depending on the temperature change of water. In SIPHER^{TM} it might be that the shortwave radiation is overestimated and longwave radiation is underestimated due to higher impervious nature of the surface. In addition, heat load from groundwater is also not considered in SIPHER which makes it difficult to calibrate for the smaller basin. The upper basin land use pattern also has an influence on heat load received from surface runoff and wastewater inflow, which needs to be further streamlined to validate heat load in the smaller basin

5. CONCLUSION

- SIPHER model can accurately simulate the river water temperature in an areas with highly pervious area (> 70%), and higher upper basin area (> 30 km^2), than that in the lower pervious area (< 50%) and lower upper basin area (< 3 km^2).
- Due to climate change monthly average temperature in winter and summer will be lower and higher than the current temperature.

6. Acknowledgement

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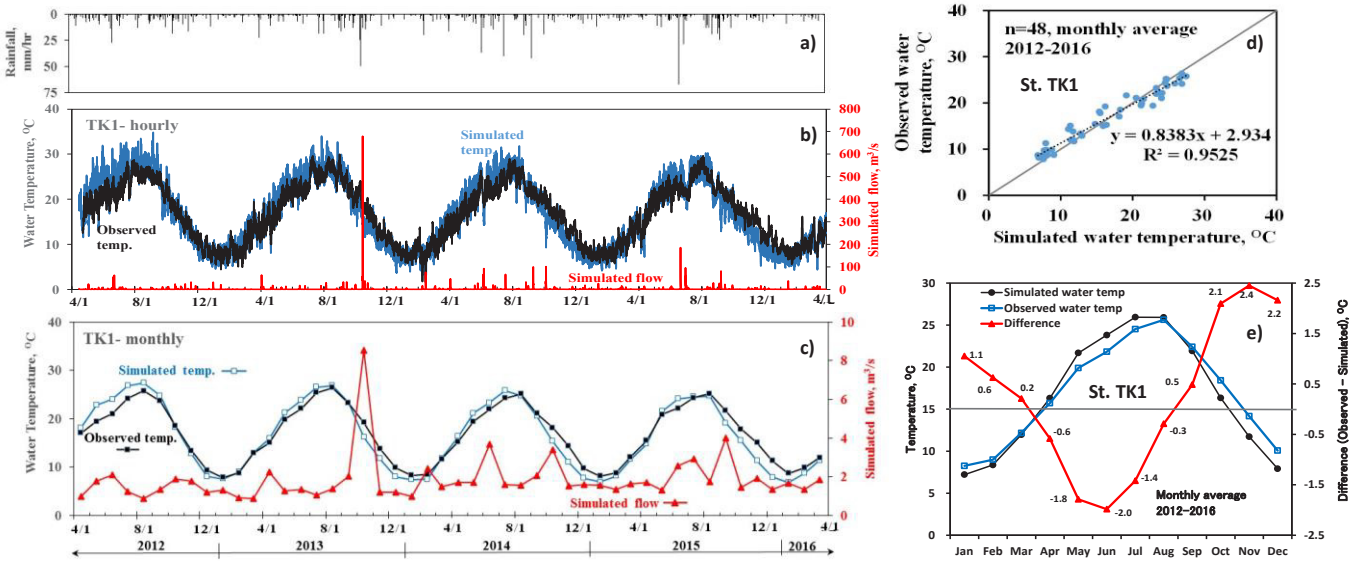

Fig. 2. Rainfall (a), hourly (b), and monthly average (c) simulated and observed temperature and flow rate; and average (d), and monthly (e) variation of observed and simulated temperature

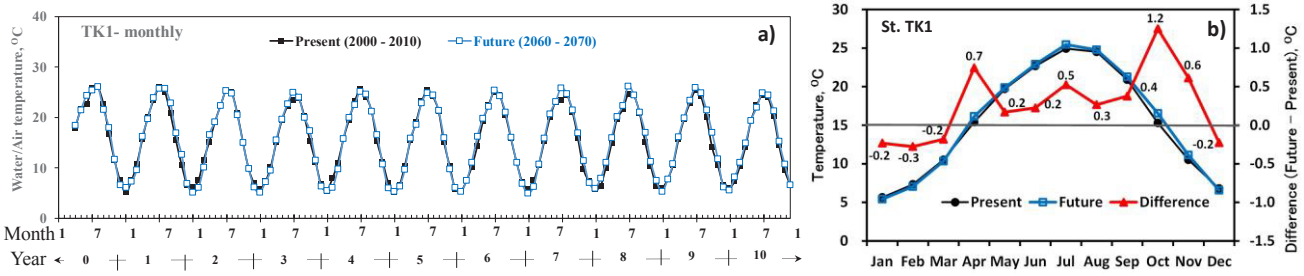

Fig. 3. a) Simulation of the present decade (2000 – 2010) and future decade (2060 – 2070) water temperature, and

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Assessment of Stream Flow Using Soil and Water Assessment Tool (SWAT) In Loktak Lake Catchment

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Keywords: Stream flow, Hydrological modelling, SWAT, Loktak, ungauged

ABSTRACT

Stream flow is very important in water cycle and a useful water resource to sustain human life. However, estimation of stream flow in an ungauged catchment still poses a challenge. Hydrological models are one of the commonly used techniques for the discharge simulation in ungauged stations. This paper focusses on the estimation of stream flow in the Loktak Lake catchment (part of the Manipur river basin) using Soil and Water Assessment Tool (SWAT). SWAT, developed by the United States Department of Agriculture which analyzes the stream flow based on Digital Elevation Model (DEM), soil map, land use map and meteorological dataset. The SWAT tool was run for the year 1999-2002 on 2 gauged sub-catchments (Nambul and Iril), which are calibrated and validated using the observed discharge. Calibration was carried out using manual iterative process and the evaluation of the model was done using Nash-Sutcliffe model efficiency (NSE) coefficient. The results between observed and modelled flow showed agreement with NSE value 0.837 for Iril River and 0.796 for Nambul River. These results were used to estimate the ungauged sub-catchment flows. The results show high variation in discharge of all the rivers with high discharge during monsoon season and low in the other month of the year. The highest flow was found in Iril followed by Thoubal. This assessment can be helpful in generating the water balance of Loktak Lake.

1. INTRODUCTION

Water resources are essential renewable resources that are the basis of existence and development of society. Proper utilization of these resources requires assessment and management of the quantity and quality of water resources. Water crises caused by shortage, floods and diminishing water supply are increasing in all parts of the world. Mismanagement and increasing pressure from human activities like water diversion, pollution and reclamation of area has added to pressure of the water resources.

Surface water being easy and direct is therefore easy to exploit as compared to other water resources. Surface water in the form of Lakes and River runoff (discharge) is predominantly obtained from rainfall after being generated from the rainfall runoff process. In order to make decision in planning of water resources long runoff data series is required. However, in most cases, this is not feasible due to a variety of reasons such as financial, logistics or purely due to lack of intent [2]. This leads to the fact that a large portion of the total number of river basins present around the globe are either poorly gauged or completely ungauged.

A rainfall-runoff model can be therefore used to estimate the streamflow. Soil and Water Assessment Tool (SWAT) is a most commonly used model for hydrological modeling which gives reliable results. SWAT is a physically based, continuous, long-term, semi distributed hydrologic model, developed by the U.S. Department of Agriculture. It is a conceptual model that works both on daily and sub daily time steps [1]. It can simulate surface and subsurface flow, soil erosion, nutrient cycling and transport, and sediment deposition, and has been applied worldwide in hydrologic and water quality modeling [9].

The objective of this study is to analyze the daily rainfall-runoff study of the basin, analyze the performance of the model with the observed data and stimulate the streamflow of the ungauged rivers in the basin.

2. METHOD

Study Area Description

Loktak wetland complex (LWC) (area 470.15 km2) is the largest freshwater wetland in North east India located in the southern part of Manipur valley along the Manipur river. Spanning between 24.400 to 24.720 latitudes and 93.760 to 93.990 longitudes, the wetland is located in the interfluvial areas as different tributaries, and hill stream connect with the main channel[9]. The complex comprises Loktak lake (the largest wetland of the complex, area 287 km2), Ikop- Kharung and Pumlen- Khoidum. The complex has a catchment area of 5203.65 km^2 which is divided into 8 sub-catchments (Figure 1)

LWC is located in the central valley of the catchment. Hills varying from 900m to 3000m amsl fringe the valley area with steep slopes [8]. The Manipur valley is made up of alluvium of fluvio-lacustrine origin, with clay being the main form of origin followed by silt and sand.

The valley is characterized by a tropical monsoon climate. During 1954-2011, the rainfall within the state varies from 956.5 to 2269.9 mm, with monsoon months (June to October) accounting for 63% of the total rainfall. With mean temperature at 4° C, January was recorded as the coldest month and July as the hottest at 29° C. [3].

Due to its rich biodiversity and its socio-economic importance, Loktak Lake was designated as a wetland of internationally importance under the Ramsar Convention in 1990. However, the Loktak Multipurpose Project for generating 105 MW of hydro-electric power, have resulted in major modifications to the lake's hydrological regime leading to raised mean water levels and reduced the magnitude of seasonal fluctuations.

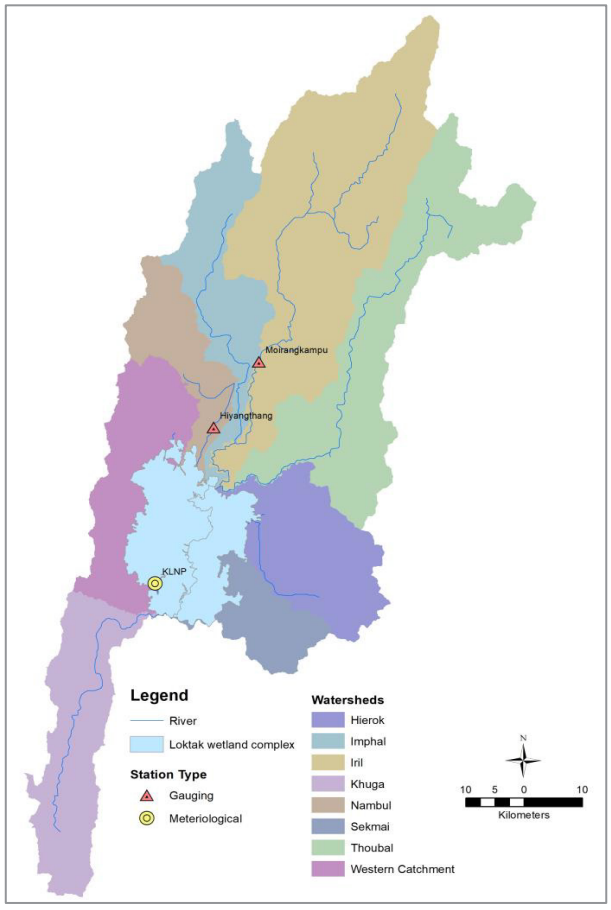

Figure 1 - Loktak Lake, its sub-watersheds and gauging stations

SWAT Model Description

To analyze the stream flow of all the rivers in the catchment Arc SWAT (version 2009) was selected. SWAT is a semi-distributed, continuous hydrological model which functions on a daily time scale to predict the impact of land management on water, sediment and water quality of large basins. This model divides a large watershed into sub-watersheds, which are further sub-divided into a series of hydrological response units (HRUs), a unique combination of land use, soil, and slope. When parameters are simulated, they are first estimated for each HRU and then accumulated for the whole watershed as a weighted average [7].

Soil water balance is the primary consideration by the model in each HRU which is represented by equation below:

$$SW_t = SW_0 + \sum_{i=1}^{t} \left(R_i + Q_{surf} + E_a + w_{seep} + Q_{gw}\right) \qquad (1)$$

Where SW_t is final soil water content; SW_0 is the initial soil water content, R_i is the amount of precipitation, Q_{surf} is the amount of surface runoff, E_a is the amount of actual Evapotranspiration, w_{seep} is the percolation from the soil profile, and Q_{gw} is the amount of return flow on day i

Dataset

SWAT requires Digital Elevation Model (DEM), Soil Map, Landuse Map and daily meteorological data as input to run the model. A brief description of the data is shown in Table 1. The location of Weather station and Gauged streams in Fig 1

Table 1-Data used for SWAT modelling

Data	Data Source	Year
DEM	SRTM DEM	Feb 2000
Soil Map	NBSS&LUP[6]	2001
Landuse Map	Landsat 8	Feb 2017
Weather Data	LDA	1999-2002
Gauged Station	LDA	1999-2002

(LDA- Loktak Development Authority, NBSS&LUP – National Bureau of Soil Survey and Land Use Planning)

Modelling Process

For the purpose of modelling the catchment of LWC has been sub-divided into eight sub-catchments namely the Thoubal, Iril, Imphal, Khuga, Hierok, Sekmai and Western sub-catchment and Nambul. Out of these sub-catchments, Iril and Nambul is gauged while the others are ungauged. The modelling of the sub-catchment was undertaken using the hydro meteorological data available for the three year (June 1999–May 2002).

Given the paucity of data, the approach to model calibration and validation was to initially calibrate the model of the Iril sub-catchment with available observed discharge data and then to apply the same calibrated parameter values to models developed for the Nambul sub-catchments as validation. The dataset set for Iril and Nambul is clipped from that of the Loktak catchment.

This form of validation exercise was considered appropriate given the similar geology, soils and vegetation cover within the sub-catchments in addition to similar flow regime with high monsoon and low dry season flows. Discharges for the ungauged sub-catchment were subsequently estimated by using the same parameters as used in validation and running the model on the whole catchment.

Model Calibration & Evaluation

The calibration needs to be taken place to identify the optimized parameter set which might have an impact on the catchment response. These parameters may or may not have any physical meaning, but they have a high level of uncertainty associated with them [4]. The calibration process takes place by adjusting the values of soil parameters, land use parameters and flow parameters like Manning's 'N' and soil saturated conductivity 'k'.

The model calibration and validation is evaluated using Nash & Sutcliffe Efficiency (NSE) method. NSE is a measure of correlation, bias and variability [5], which is one of the most widely used criteria for performance evaluation all over the world. NSE varies from -∞ to 1. A value of 1, points towards a perfect match between observed and simulated value. The expression for NSE is:

$$NSE = 1 - \sum_{t=1}^{T} \left(\frac{Q_0^t - Q_m^t}{Q_0^t - Q_0\ mean}\right)^2 \qquad (2)$$

Where Q_0^t-Observed Discharge at time t, Q_m^t-Modelled Discharge at time t and $Q_0\ mean$-Mean Observed Discharge

3. RESULTS AND DISCUSSION

Model Calibration

The calibration was carried out in Iril sub catchment as

described in the previous section. Calibration was carried out using manual iterative process. Manning's 'N' was the most sensitive parameter and the model was run changing the value of N and evaluating the results using NSE. The final Manning's 'N' value was calibrated to 0.014 from default value of 0.04.

Figure 3 shows the observed and projected discharge in the Iril sub-catchment for the period May 1999 to Dec 2002. The graph shows that the model is generally successful in reproducing the observed daily flows. The model is considered good with NSE value being 0.837.

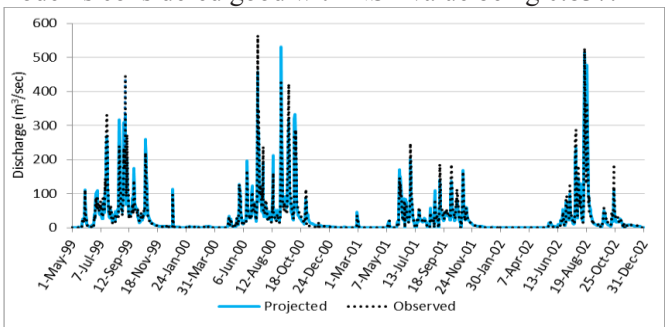

Figure 3 - Observed and Projected discharge of Iril watershed

Model Validation

The validation of the model was carried out using the calibrated parameters of the Iril model in Nambul model. The model was validated by comparing the observed and projected discharges in the Nambul sub-catchment (Figure 4). The model showed good results and was successful in reproducing the observed daily flows with NSE value being 0.796.

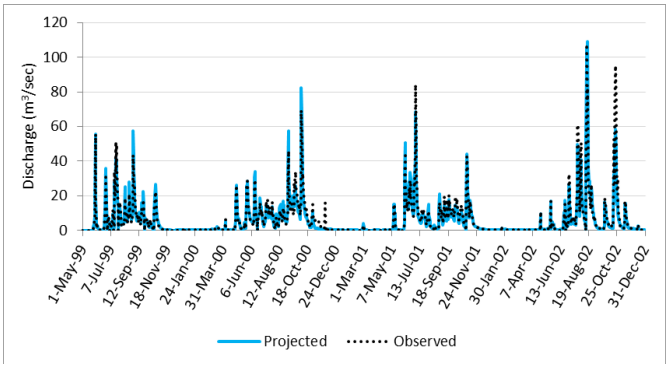

Figure 4 - Observed and Projected discharge of Nambul watershed

Runoff for Ungauged Catchment

After the validation is complete the same parameters are run the model for the whole catchment to analyze the runoff from the whole catchment as all the other sub-catchments are ungauged. The monthly stimulated discharge of all the catchments is shown in Figure 5.

4. CONCLUSION

In this study the SWAT model was applied to evaluate the streamflow in the direct catchment of the Loktak wetland Complex. The daily flow was calibrated for Iril sub-catchment and then validated in Nambul sub-catchment. Then the parameters were used to estimate the flows of the ungauged catchments.

The daily discharge in the calibration and validation

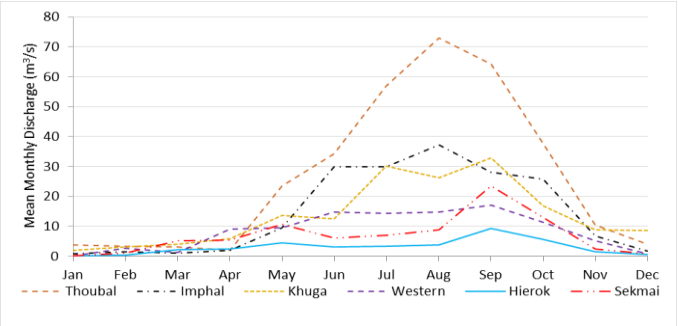

Figure 2 - Mean Monthly discharge for Ungauged watershed

models showed good performance with NSE values which is calculated from equation (2) of 0.837 in the calibration model and 0.796 in the validation model. Iril has the highest mean monthly discharge of 30.416m3/sec followed by Thoubal having 26.318 m3/sec. The minimum discharge is from Hierok and Nambul sub-catchment discharging 3.057m3/sec and 6.612m3/sec. These discharges form the ungauged catchment can be used for calculation of water balance of the lake.

Therefore, the SWAT model can be used to estimate the streamflow in the study area. But the present study is carried out using scarce data as there is no continuous metrological data management in the catchment since 2002 for the analysis of the present scenario. However detail analysis needs to be carried out to estimate the exact flow into the Lotak Lake.

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O6-24

Developing A Model for Estimating Secchi Disk Depth using Landsat TM and ETM+ in Indonesian Lakes

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Keywords: Secchi Depth, Landsat, Water quality, Monitoring, Lake

ABSTRACT

A simple data pre-processing to minimize the atmospheric effects and improve data quality was proposed to build a model for estimating Secchi Depth (SD) from Landsat TM and ETM+ data. The model intended to be simply applicable without requirement of in-situ data for both atmospheric correction and model recalibration. Rayleigh scattering effects were removed using 6S software. Median filters were applied iteratively to improve the low Signal-to-Noise Ratio. Aerosol scattering effects in visible bands were reduced using the SWIR band. The reflectance extracted from pre-processed Landsat images and corresponding in-situ SD measurements from 9 lakes collected from 2011 to 2014 (ranging from 0.5 m to 18.6 m) were used for model calibration. Other in situ SD measurements from 31 Lakes collected in 1992-1993 (ranging from 0.4 m to 20 m) were used to validate the developed model. A long-term change of SD in Lake Maninjau estimated from the model was also compared with in situ data collected from 2001-2017 for another validation. Results show that the developed model provides acceptable result and robust estimates SD for both several different lakes in 1992 and long-term change SD of Lake Maninjau with determination coefficients of 0.81(with RMSE of 2.59 m, n=31) and 0.46 (with RMSE of 1.22 m, n=17) respectively. These results indicate that the developed model is simply applicable and has a potential to fill the SD data gap for further water environment studies.

1. INTRODUCTION

Lakes are habitats of great human importance as they provide water for domestic, industrial and agricultural use as well as providing food [1]. Despite their fundamental importance to humans, freshwater systems including lakes have been affected by anthropogenic disturbances. The disturbances cause the eutrophication, acidification and contamination by toxic substances. This problem is predicted to continue to increase, especially in developing countries where the developments prioritize other than environmental conservation [1]. Monitoring the environment is necessary to ensure the management practices achieve the sustainability [2]. For effective lake management, it is essential to have long-term water quality information on a broad regional and spatial scale [3].

One of important water quality parameter is secchi depth (SD). SD is the simplest and most often used for limnological measurements because its values are easily understood [4]. Assessing the SD is one of the key issues in environmental monitoring and management, because it can affect both ecosystems and water amenities [5].

Since conventional water-monitoring methods (e.g., water sampling from a boat) are very time-, labor-, and cost-consuming, the maintenance of steady monitoring is remain challenging for local and national governments with meager financial resources, especially in developing countries [6]. As the result, the number of in situ water quality data is very limited. On the other hand, the satellite remote sensing is a powerful supportive tool for assessing the spatial and temporal variation in water quality parameter such as SD [7, 8, and 9]. Combination of in situ and remote-sensing can be used to provide comprehensive data solutions to address sustainability issues because satellite technologies have the potential to provide better spatial and temporal coverage compare with traditional field sampling [2].

In general, studies on SD estimation using Landsat TM images can be classified into two major groups. The first group used the band ratio and the second group used the combination of single band plus band ratio as the SD predictor. Further, the studies can be differentiated whether they perform atmospheric correction or not. Previous models were built based on empirical relationship. Different band and band ratio combinations that were suggested from previous research may relate with the differences in image quality or limnological condition of the water body [10].

The existing models require to be recalibrated for other image from different time or other location. This is a significant challenge for the study areas which lack of in situ SD data. Kloiber et al. [11] mentioned that, ideally a

single (standard) relatively simple equation with constant coefficient values would be used to calculate SD or a phytoplankton abundance index. Their study indicated that if the atmospheric effect can be removed, then one set of coefficients can be applied for different images across time and space. However, the other challenge is the meteorological data to perform the atmospheric correction for the historical image are not always available. Therefore the objectives of this research are to develop a model for estimating SD from Landsat TM / ETM+ data, to test the model if it is simply applicable without requirement of in situ data for recalibration and to provide a showcase for long term SD estimation using the developed model.

2. METHOD

All 64 Landsat Images were downloaded from the USGS website [15] for model calibration and validation. The images were pre-processed to reduce the atmospheric effect and improve the data quality. The water bodies were extracted using the combination of Normalized Different Water Index (NDWI)[12] and Modified Normalized Different Water Index (MNDWI) [13], then area of a buffer of 150 m from the shoreline were excluded. Rayleigh scattering effects were removed using 6S with tropic atmospheric model. Median filters were applied iteratively to improve the low Signal-to-Noise Ratio. Aerosol scattering effects in visible bands were reduced using the SWIR band.

The reflectance extracted from 7 scenes pre-processed Landsat images and corresponding in-situ SD measurements from 9 lakes in Indonesia collected from 2011 to 2014 (ranging from 0.5 m to 18.6 m) were used for model calibration. Following Kloiber et al. [11] and Olmanson et al. [3] least-square multiple regressions were used to obtain the model coefficient. The model using the general form:

ln SD = a + b (single band) + c (band ratio), where a, b and c are model coefficient which can be obtained from the multiple regression analysis.

Second in-situ SD data set from 31 Lakes collected in 1992-1993 [14] (ranging from 0.4 m to 20 m) were used to validate the developed model. A long-term change of SD in Lake Maninjau estimated from Landsat using the developed model was also compared with in situ data collected from 2001-2017 for another validation.

3. RESULTS

The atmospheric correction resulted in Rayleigh and Aerosol corrected reflectance as shown in Fig. 1. It shows that over the water surface the proposed method gave better performance compare to surface reflectance standard products [15]. The aerosol effect at the longer band (TM5 & TM7) can be mitigated pixel by pixel.

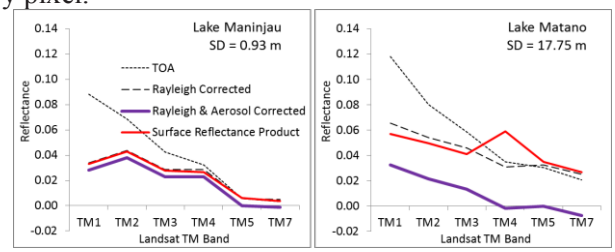

Fig. 1. Atmospherically corrected reflectance

In order to develop the model, wide ranges of in situ SD (0.5 – 18.6 m) were utilized in this research. It was limited in numbers (31 measurements from 9 Lakes), but covered a wide range of optical properties which are represent the variety of limnological conditions. The combination of filtered atmospherically corrected satellites data and the wide range in situ SD data were expected to be the optimum input for model development. All possible band combinations were tested as the result we select 6 models with best performance for further analysis, as shown in Table 1.

Table 1. Model Calibration performance

Model	Band Configuration	R^2	RMSE (m)	NMAE (%)
A1	TM1 & TM1/TM3	0.987	1.17	6.41
A2	TM2 & TM1/TM3	0.981	1.17	12.01
A3	TM3 & TM1/TM3	0.993	0.57	13.15
B1	TM1 & TM1/TM2	0.958	1.29	29.13
B2	TM2 & TM1/TM2	0.958	1.40	31.36
B3	TM3 & TM1/TM2	0.959	1.27	30.30

The accuracy of the selected models (A3 and B3) were plotted in Fig.2. The estimated SD is the average value which calculated from 90% of total water pixels (due the sampling site coordinate were not available). It was observed that the over estimation of model A3 are too large especially for clear water. Model B3 provide more acceptable result.

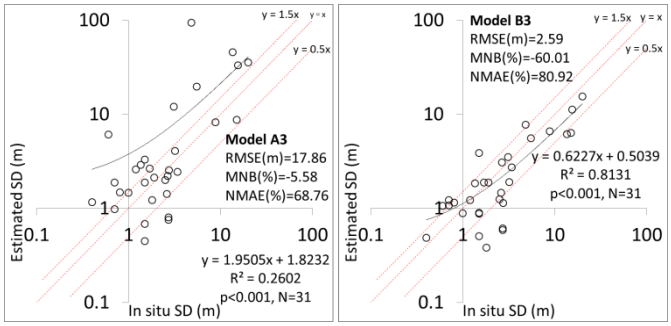

Fig. 2 Scatter plot of in situ versus Estimated SD

The water quality in lake can change over a short or long-time period. Model B3 then was used to estimate

SD of Lake Maninjau during 2001-2017 (Fig.3). The result showed that 30 years ago the average SD in Lake Maninjau was estimated around 5 m. However, starting from 2009 the SD values were steady lower than 2 m and both from measured and estimated. In-situ observation in August 2006 ranged from 2.25 m to 5.8 m, it showed that the SD in Lake Maninjau sometime was heterogeneous. From fig.3, we can also see that the estimated long-term SD from Landsat matched well with in-situ data.

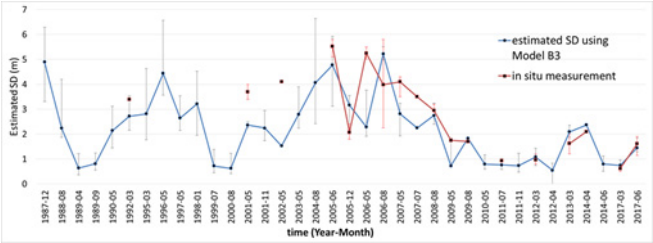

Fig 3. A showcase of long term SD estimation of Lake Maninjau using Model B3

4. DISCUSSION

The sources of estimation errors in this research are generally propagated from the time gap and the geographic location error. The validation data set 1 were collected from the field surveys conducted during 1992-1993. At those periods, the corresponding Landsat images were not always available. To make use of all in situ data we set the wider time window. Narrowing the time window into less than one month for validation data set 1, reduced the number of data which can be used into 11 data. The RMSE can be reduced to 1.21 m with the MNB = -21.23% and NMAE = 42.82%. This result indicates that a narrower time window can provide better accuracy.

The next limitation is that the sampling locations information is not available. Match-up between in situ and estimated SD from the model is not an ideal comparison. In this research, we compare the single value of in situ SD data and the average of the SD value from the whole water bodies.

5. CONCLUSION

In this study, a model for estimating SD using Landsat TM/ETM+ data has been developed. It uses TM3 and ratio of TM1/TM2 with fixed coefficient. It was proved to be consistent predictors of SD and more robust from noise.

The model can be simply applicable without requirement of recalibration on each image. Neither required atmospheric conditions information. It has been validated using two validation data set. Both estimated SD for several different lakes at the same period and time series of a lake showed reasonable result. However, the applications for another different environment such as tempered lakes in mid or higher latitude are required to be further studied.

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O6-25

PEGモデルを視点とした琵琶湖水質と植物プランクトン遷移の関係解析について

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キーワード:湖沼・河川モニタリング技術

抄録

滋賀県琵琶湖環境科学研究センターでは、30 年以上にわたり琵琶湖の理化学的な調査に併せて植物プランクトンの調査を実施している。これまでの調査結果の解析において、植物プランクトンの減少や藍藻類の増加など様々な知見が明らかとなっている。しかし、これらのほとんどは群集全体の経年変化に注目したものであり、プランクトン遷移が長期的にどのように変化してきたかについては十分に議論されていない。そこで本研究では植物プランクトン分類群の生物量から Bray-Curtis 類似度指数を用いて植物プランクトン遷移の類型化を行った。その結果、植物プランクトン遷移は5パターンに分類され、そのパターンはPEGモデルに示される富栄養型のモデルから貧栄養型のモデルへと経年変化していた。この傾向は琵琶湖における栄養塩類の抑制傾向と一致し、植物プランクトン遷移が琵琶湖の栄養状態を評価する指標して有用である可能性が示唆された。

1. はじめに

湖沼において植物プランクトンは湖内生態系の原動力であるとともに有機汚濁や湖底の低酸素化など水質形成に大きく寄与しており、異臭味やろ過障害など水利用の面でも大きな影響を与えている。このため、水質とプランクトンの動態を併せた総合的な水質評価を行う必要があり、当センターでは、30 年以上にわたり琵琶湖の理化学的な調査に併せて植物プランクトンの調査を実施している。これまでの調査結果の解析において、植物プランクトンの減少や藍藻類の増加など様々な知見が明らかとなっている。しかし、これらのほとんどは群集全体の経年変化に注目したものであり、その季節的消長が長期的にどのように変化してきたかについては十分に解明されていない。そこで本研究では植物プランクトン遷移を解析するために、季節遷移の類型化をおこない、水質の栄養状態の関係性を解析した。

2. 方法

調査は、北湖の今津沖中央(北緯35° 23′ 41″ , 東経135° 07′ 57″)(図1)における水深0.5mにおいて月2回の頻度で採取した湖水を用いて行った。植物プランクトンは湖水1mLを界線スライドグラス型式S6300(松浪硝子工業株式会社)に取り、湖水中に含まれる藻類について、光学顕微鏡下で同定および細胞数(藍藻類については群体数)の計数を行った。計数した細胞数を一瀬ら[1]の方法で容積換算を行った。

計数した植物プランクトンを藍藻類、黄色鞭毛藻類、珪藻類、渦鞭毛藻類、褐色鞭毛藻類、緑藻類およびその他の計7分類群に分別し、各分類群の生物容量(Biovolume:mm^3/L)を調査毎に算出した。算出した生物容量は対数変換(log10(x+1))した後にBray-Curtis指数[2]を用いて植物プランクトン遷移の類似度を求め、クラスター分析(Word法)によりデンドログラムを作成した。



図 1　調査地点

3. 結果

琵琶湖における植物プランクトン遷移について、年間での類似性を Bray-Curtis 指数により算出しクラスター分析を行ったところ、遷移パターンはまず、G1 型と G2 型の大きく2つに分類され、さらに G2 型は G2A 型と G2B 型に分けられた。これら各型の遷移パターンをみると、G1 型では植物プランクトンの季節遷移に大きな変化は見られないが、G2 型では夏と秋に植物プランクトン生物量の増加が見られた。また、G2 型のうち、G2B 型は夏に大きな増加をもつパターンであり、G2A 型は秋に植物プランクトンが増加するパターンであった。G2A 型のパターンはさらに2つに分けることが出来、春に黄色鞭毛藻類の増加を持ち秋の緑藻類の増加が大きくなる G2A α 型と、春に黄色鞭毛藻類の増加を持たず、秋の緑藻類ピークをもつ G2A β 型に分けられた。また、G2B 型も2つに分けられ、夏の緑藻類の増加に加え、晩秋に緑藻類が増加する G2B α 型と初秋に緑藻類が増加する G2B β 型の合計5パターンに分類された(図2)。さらに植物プランクトン遷移パターンがどのような順で経年変化しているかを調べるために、クラスター分析によって各パターンに分類された年の分布状況を求めた。この結果、遷移パターンは 1978 年から 2014 年にかけて G2A α 型、G2B β 型、G2A β 型、G2B α 型、G1 型の順にパターンが変化していることが示された。

4. 考察

PEG(Plankton Ecology Group)モデル [3]の富栄養湖型のモデルでは植物プランクトンの明瞭なピークが2つあり、貧栄養湖型のモデルでは、植物プランクトンの明瞭なピークが見られないモデルとなっている。琵琶湖における植物プランクトン遷移は明瞭なピークを示すG2型と明瞭なピークを示さないG1型に分類され、これらのパターンは過去からG2型からG1型に変化していることが示された。これらは、栄養塩類の長期的な変動とも合致した。このことから、植物プランクトン遷移は湖沼の栄養塩状態を示す有用な指標であると考えられた。今後はPEGモデルに見るようにプランクトン遷移がどのような要因により生じているかを解析することで琵琶湖における植物プランクトン遷移モデルを作成していきたい。

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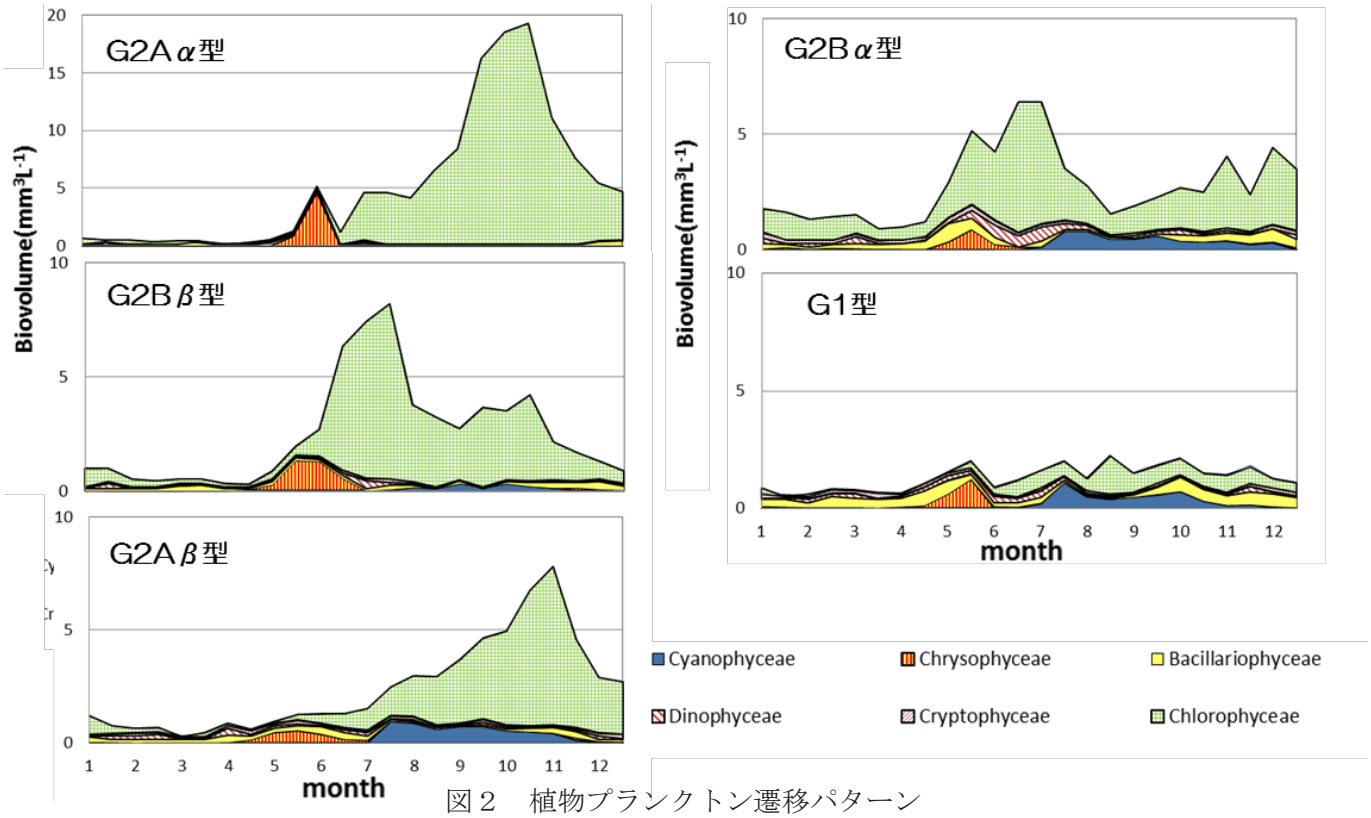

図２　植物プランクトン遷移パターン

O6-26

琵琶湖北湖におけるウイルス・ホットスポット

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キーワード:琵琶湖, ウイルス, 空間分布、表面混合層、紫外線

抄録

本研究では、琵琶湖北湖を対象に、ウイルス数および宿主である細菌数と植物プランクトン(クロロフィル *a* 濃度)を14か月間追跡し、ウイルス数の分布が形成される要因について考察した。スピアマンの順位相関係数解析では、ウイルス数と細菌数($r = 0.47$、$n = 126$、$p < 0.01$)およびクロロフィル *a* 濃度($r = 0.40$、$n = 126$、$p < 0.01$)との間には正の相関がみられたが、ウイルス数の分布を説明するには不十分であった。また、ウイルス数の分布の極大点(ウイルス・ホットスポット)が宿主の分布の極大ではない水深20〜40 m付近に出現していることを確認し、これが表面混合層のすぐ下であることを見出した。これはウイルスの分布が宿主の分布だけでなく、物理的な要因(紫外線や鉛直混合)も関わっていることを示唆するものであった。

1. はじめに

ウイルスは水中で最も多い生物学的存在であり、細菌や植物プランクトンの死亡要因としても重要な役割を担っている[1]。ウイルスによる宿主への感染と細胞破壊を通じて、微生物ループを介した高次への栄養伝達や粒子の沈降フラックスが抑制されることが理論的にも実験的にも明らかになった[2, 3]。これらのことから、物質循環におけるウイルスの役割とその重要性に関する議論は国際的に活発化している[1]。

海洋においてウイルスの宿主はほとんどが細菌および植物ピコプランクトンであると考えられている[4]。そしてウイルス数は宿主の現存量に強く依存していることが知られている[5, 6]。しかし、湖沼において季節と水深を考慮したウイルス数の分布についての研究例は乏しく、どのようにウイルスの分布が形成されるのかは不明な部分が残されている。

本研究では、琵琶湖北湖(全水深約 90 m)を対象に、9水深で14か月間調査を実施した。そして宿主であるクロロフィル *a* 濃度と細菌数の分布に加えて、表面混合層と紫外線という物理的な要因からウイルスの分布がどのように形成されるのかについて考察を試みた。

2. 方法

2.1 採水地点

採水は琵琶湖北湖沖帯の水深(0.5、5、10、15、20、30、40、60、80 m)で2016年8月から2017年9月の間に毎月実施した。サンプルは採水してすぐに船上で化学固定(グルタルアルデヒド、最終濃度 1vol%)を行い、氷冷して実験室に持ち帰った後、観察まで冷凍保存(-30 °C)した。

2.2 細菌数およびウイルス数の計数

化学固定した試料を、Anodisc フィルター(孔径 0.02 μm、GE Whatman)上に捕集し、SYBR Gold(核酸染色試薬)で染色した[7]。その後、フィルターを褪色防止試薬(0.1% 1,4-phenylenediamine dihydrochloride)とともにスライドガラスとカバーガラスの間にマウントした。ウイルスと細菌の数は落射蛍光顕微鏡を用いて測定した。

2.3 その他の水質項目

水温およびクロロフィル *a*(Chl. *a*)濃度については、平成 29 年度公共用水域・地下水水質測定計画(滋賀県)およびそれに準じて、滋賀県琵琶湖環境科学研究センターにより測定されたものであり、本論文執筆時点では速報値である。また、表面混合層の厚さは、表層(0.5 m)の水温から1 °C 低い水深までとした[8]。

3. 結果と考察

細菌数は観測期間を通して、$0.3〜4.5 \times 10^6$ cells/mL を推移し、表水層(水深 0〜20 m)で高く、水深とともに低下する傾向がみられた(Fig. 1C)。また、ウイルスは $1.0〜12.3 \times 10^7$ VLPs/mL を推移し、表水層で高く、水深とともに減少する傾向がみられた(Fig. 1D)。またウイルス数と細菌数またはクロロフィル *a* 濃度との相関係数(スピアマン順位相関係数、n=126)はそれぞれ 0.47 と 0.40 と正の相関はみられたが、強い相関ではなかった。さらに、VBR(virus-to-bacteria ratio、ウイルス数を細菌

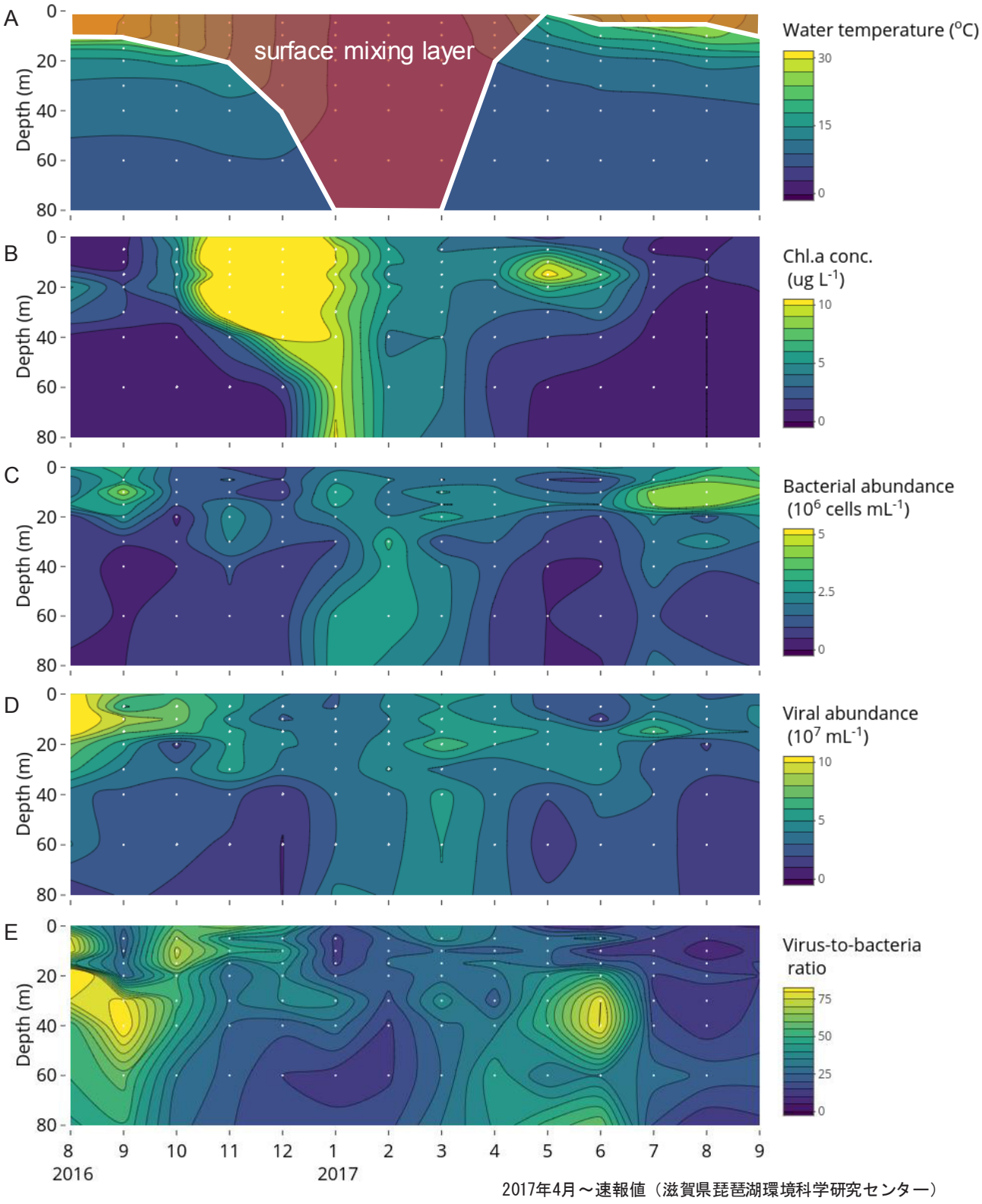

Fig. 1 Distribution of (A) water temperature, (B) Chl. *a* concentration, (C) bacterial abundance, (D) viral abundance, and (E) virus-to-bacteria ratio at Northern Lake Biwa

数除した値）は 7.8～124 を推移し、その極大点は表水層だけでなく水深 40 m 付近にもみられた（Fig. 1E）。この VBR の極大点は細菌やクロロフィル *a* 濃度（Fig. 1B）の分布と一致しなかった。

表面混合層は成層が形成される 4 月から夏季の 9 月頃まで 5～10 m を推移した。その後、循環期直前の 12 月には 40 m に達し、全循環期である 1 月から 3 月は全水深と同じ厚さ（約 90 m）となった。表面混合層とともに図示した水温プロットから（Fig. 1A）、いくつかの VBR の極大点が表面混合層の下に現れることが明らかとなっ

た。表面混合層中に存在するウイルスは、鉛直混合により表層付近で紫外線照射を受けるが、逆に表面混合層より以深に存在するウイルスは表面混合層と隔離されているため、紫外線照射により不活化・消失するリスクが低いと考えられる。また、宿主である細菌や植物プランクトンの現存量は水深とともに減少する傾向がみられることから、VBR の極大点より以深では十分な宿主が存在せず、ウイルス数が高濃度で維持されることが難しい可能性が考えられる。したがって、季節とともに形成される表面混合層の直下がウイルスにとって「住みやすい」水深（ウイルス・ホットスポット）であることが示唆された。

4. 結論

ウイルスは宿主である細菌や植物プランクトンと異なる分布を持つことが明らかとなった。今後は、ウイルスの現存量を決定する要因である一次生産速度や細菌の生産速度に加えて、紫外線照射への耐性や粒子への吸着速度なども同時に観測し、どのパラメータがウイルスの分布を規定するのかを明らかにしていく必要がある。

謝辞

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O6-27

Comparisons between the Characteristics of Natural Organic Matters in Upstream Inflowing Rivers and Discharging Sources of a Drinking Water Reservoir with or without the Transbasin Diversion

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Keywords: water quality problems and pollution concerning water use, water quality management and monitoring technologies for lakes and/or rivers

ABSTRACT

The characteristics of natural organic matter (NOM) in the Agongdian Reservoir (AGD) and its inflowing rivers and discharging sources during the periods with or without transbasin diversion are compared using dissolved organic carbon (DOC) measurements and fluorescence spectroscopy methods. The fluorescence excitation-emission matrices (FEEM) method was applied to characterize the NOM into five organic groups, including type I simple aromatic protein (API), type II simple aromatic protein (APII), fulvic acid-like substances (FA), soluble microbial by-product-like material (SMP) and humic acid-like substances (HA). Although the main fractions of NOM are FA and HA during both periods, the average fluorescence intensity (AFI) of each group as well as the levels of DOC obtained during transbasin diversion are lower, indicating that the transbasin diversion water may not be a significant source of NOM. The total AFI of API, APII and SMP links well with the levels of human activities, and shows that discharging sources in the Wanglai tributary are the hotspots of NOM. Comparing to the non-transbasin-diversion period, the levels of total AFI are easier to be explained by the levels of DOC during transbasin diversion. Characterizing the distribution patterns of NOMs in a catchment area of source water provides useful information for identifying potential NOM sources.

1. INTRODUCTION

NOMs such as humic/fuvic substances from wetlands and farmlands, proteins from organic wastes, and microbial byproducts from metabolism of algae, are commonly found in reservoirs providing raw water to water treatment plants (WTPs)[1]. Carcinogenic or mutagenic DBPs are formed when NOMs in raw water react with oxidants or chlorine disinfectants[2]. NOM found in natural waters often has various properties and is composed of complex mixture of compounds[3] which can be linked to important information of potential sources of contamination. However, very indicators are shown by water quality parameters that are commonly used to assess the level of NOM, e.g., DOC, 5-day biological oxygen demand (BOD_5) or chemical oxygen demand (COD).

Fluorescence spectroscopy and indexes have been applied to characterize NOM based on the measurement of absorption and emission of energy by organic matter molecules. The FEEM method is sensitive with the possibility of single-molecule detection and provides discrimination between chromophoric organic matter absorbing at similar wavelengths. Characterizing NOM from samples in a water treatment train provides information for reducing the risk of the formation of DBPs[4]. Consequently, understanding the distribution patterns of NOMs in a catchment area of source water or tracking changes of NOM in a river network[5] may further help identifying and controlling potential sources through management practices.

Therefore, this work uses the FEEM method that combines both quantitative and qualitative approaches to obtain main NOM characteristics in water samples from organic matter sources of a drinking water reservoir, including inflowing rivers, discharging and transbasin diversion sources. Resolving the spatio-temporal patterns of NOM in source waters could help to remove such material at the source or evaluate purification methods during water treatment.

2. METHOD

Figure 1 shows the locations of seven NOM sampling stations in the catchment of AGD. Five stations coded from upstream to downstream as W1 to W5 are located in the northern tributary basin (Wanglai Creek) of the AGD, and two stations coded as Z1 and Z2 are located in the

southern tributary basin (Zhuoshui Creek). Both tributary basins have similar land use, which consists of mainly forest (40%), fruit plantations (35%), built-up areas (10%) and farmland (10%). The W2, W4 and Z1 stations are positioned in the drainage outlets of main sub-catchments which collect wastewater and polluted runoff. The AGD provides 30,000 m^3 of raw water per day to the Luzhu WTP that supplies drinking water for Luzhu District and Luzhu Science Park in Kaohsiung City, Taiwan. The AGD activates the empty flushing operation annually during the rainy season (June to early September) to remove the deposited sediments in the reservoir. After the empty flushing, the reservoir is refilled by the catchment runoff during the late rainy season, and discharges from transbasin diversion (path of transbasin diversion shown on Fig. 1). Notably, the Luzhu WTP experienced serious DBPs and odor problems in the produced tap water during the empty flushing period in 2013, due to high levels of DOC (2.6±0.26 mg/L) and 2-MIB (>> 10 ng/L) of the raw water.

Fluorescence spectroscopy of water samples was analyzed by the Perkin Elmer LS-55 fluorescence spectrometer. The spectrometer uses a xenon excitation source, and slits were set to 10 nm for both excitation and emission. To obtain fluorescence EEMs, excitation wavelengths are incremented from 200 to 400 nm at 10-nm steps; for each excitation wavelength, the emission is detected from 280 to 600 nm at 0.5-nm steps. Instrumental parameters are controlled by Perkin Elmer FL WinLabTM software and the fluorescence intensity and the excitation/emission wavelengths can be displayed in real-time.

First, the intensity measurement of excitation at 370 nm (Ex370) and emission at 450 nm and 500 nm (Em450 and Em500) were applied to calculate the fluorescence index (FI):

$$FI = \frac{Ex370/Em450}{Ex370/Em500} \quad (1)$$

McKnight et al.[6] suggested that NOM is mainly contributed by terrestrial sources (autochthonous source) when FI approximates 1.4, and by microbial sources (allochthonous source) when FI approximates 1.9. Second, from the FEEM spectroscopy (Fig. 2), five organic fractions were divided according to the research of Chen *et al*.[7]. Region I is known as API such as tyrosine. Region II is related to APII such as tryptophan and BOD_5. Region III is identified as FA. SMP material is classified as Region IV. Region V is represented by HA. Additionally, the EEM contour plot was analyzed using fluorescence regional integration method to perform quantitative information. The intensity of each group of organic matters are quantified using the AFI method on each region of the FEEM spectroscopy. Samples for DOC (or NPDOC) quantification were measured by NIEA W530.51C method with Shimadzu TOC-5000.

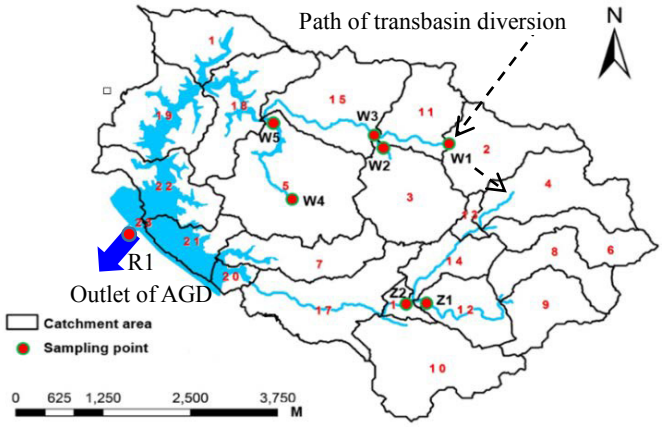

Fig. 1 The NOM sampling locations in study area

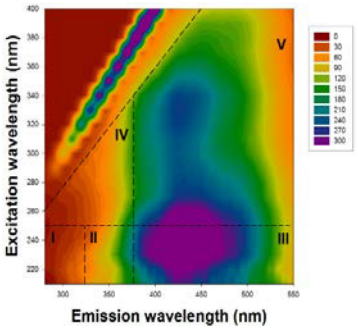

Fig. 2 A typical 2D FEEM spectroscopy showing the fluorescence emission intensities (colored contours), and emission-excitation wavelengths of a water sample.

3. RESULTS AND DISCUSSIONS

The comparisons between results of FEEM collected during the periods with and without transbasin diversion show that the main fractions of NOM are both FA and HA (Fig. 3), however, the AFIs as well as the levels of NPDOC obtained at the period of transbasin diversion are much lower. It indicates that the level of five NOM components in transbasin diversion water are lower (Fig. 4), although its NOM characteristics are similar to that of the inflowing waters (Fig. 3). Additionally, the spatial distribution of NOM intensities reflect a typical water pollution path during the period without transbasin diversion: NOMs were accumulated from up- to down-stream in both Wanglai Creek (W3>W1) and one of its main drainage (W5>W4), and diluted from drainages to receiving creeks (W3<W2 and Z2<Z1).

Figure 5 shows that the NOM in inflowing rivers and discharging sources of AGD are mainly contributed by terrestrial sources for both the periods with and without transbasin diversion. The relationships between human activities and the resulting NOM levels are obtained by comparing the fruit plantation (agriculture) and residential (human) areas in the catchments of each sampling points

(W1 is excluded) to the NOM measured by different approaches. Comparing to commonly used water quality parameters (Fig. 6b), the NOM intensity in terms of FEEM-AFI has a higher correlation with the human pollution strengths (Fig. 6a), especially the correlations between human and AP (API and APII) + SMP, and that between agriculture and HA + FA.

As shown on Fig. 7, because the NOM characteristics are simpler and the levels of DOC are lower during transbasin diversion (dilution effects), the levels of total AFI at different sites are well to be explained by the levels of DOC. In the other hand, DOC concentration may not be a good indicator of NOM characteristic during the non-transbasin-diversion period.

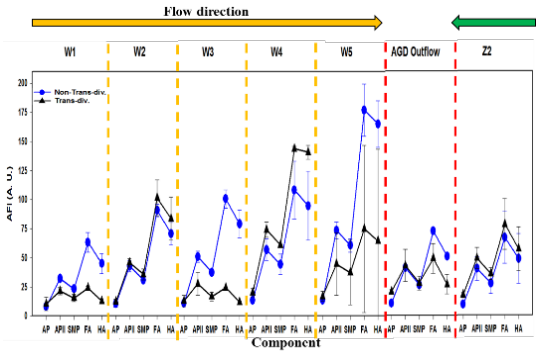

Fig. 3 Comparisons between 5 component AFIs for 7 sampling sites during the periods with and without transbasin diversion

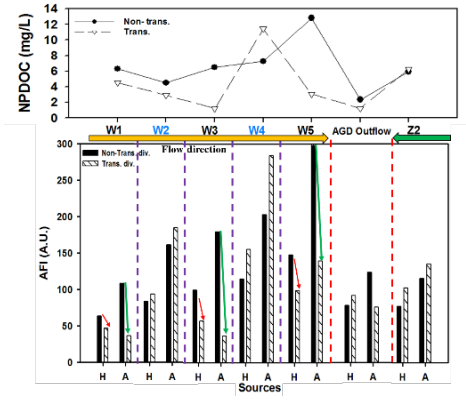

Fig. 4 Comparisons between total AFIs for 7 sampling sites during the periods with and without transbasin diversion

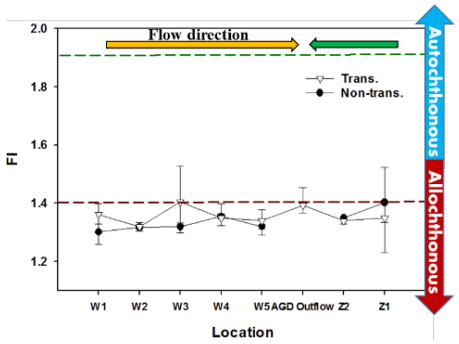

Fig. 5 Comparisons between average FI for 8 sampling sites during the periods with and without transbasin diversion

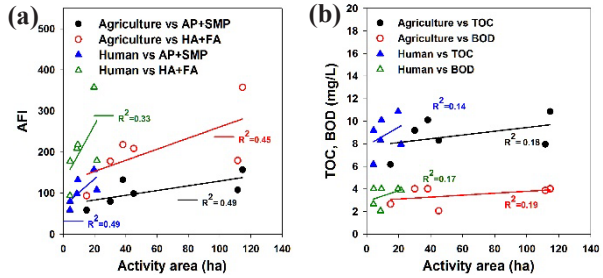

Fig. 6 The relationships between human activity strengths and the resulting NOM intensities obtained by (a) FEEM-AFI, and (b) DOC and BOD concentrations.

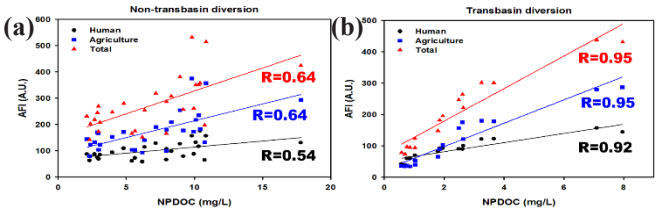

Fig. 7 Comparisons between the correlation relationships between total AFI and NPDOC during the periods (a) without transbasin diversion, and (b) with transbasin diversion.

4. CONCLUSION

Results indicated that the NOM fractions of simple aromatic proteins and soluble microbial byproducts in AGD may source from municipal wastewaters. Additionally, the high level of humic/fulvic acid-like substances shown by FEEM and AFI, as well as the high DOC concentrations, may be the result of high density planting of fruit trees in the catchment of AGD.

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O6-28

琵琶湖・淀川流域における難分解性有機物に関する調査研究のための流域連携

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キーワード:難分解性有機物, モニタリング体制, 流域連携, GIS

抄録

琵琶湖・淀川水質保全機構水質浄化研究所は, 琵琶湖の BOD と COD の乖離について 1997 年から難分解性有機物の問題および削減対策の研究に取り組んできた。一方, 各研究機関もそれぞれの研究目的で進められているが, 測定方法が確立されていないこと, また測定に時間を要するため, 既往知見や測定データが少ないことが課題であった。そこで, 琵琶湖・淀川流域の関係研究機関(滋賀県, 京都府, 大阪府, 兵庫県)の協力を得て2年間にわたるワーキングを実施した。そして, 各流域の水質状況や影響, 自治体の取り組みなどを整理し, 難分解性有機物に関する手引書となるよう, 対象水ごとの知見を体系的にとりまとめた。とくに, 今後データを活用する際には, 統一した生分解性試験の方法が重要と考え, 「標準的な生分解性試験方法」を検討し提案した。この分析手法により多くのデータの蓄積が進み, 流域全体での難分解性有機物の状況把握等が可能になると期待できる。

1. はじめに

琵琶湖を含む淀川水系の有機汚濁問題は, 近年では改善傾向にある。これらはおもに下水道整備によるものであり, 河川の BOD 濃度の減少に大きく寄与した[1]。一方, 湖沼や閉鎖性海域は, COD 濃度が漸増傾向にあり, その要因の一つとして難分解性有機物の関与が指摘されている[2]。この難分解性有機物の問題は, これまでも種々の知見が得られてはいるものの全容は解明されていない。しかし, 環境基準であるこれら有機物を水域で管理する場合, 対象水域およびその流域における濃度や負荷量の実態, 時空間分布などの特性, 水質保全対策との応答等を調査・検討することが必要である。今後, 「環境の時代」にふさわしい水質管理が求められる中で, 難分解性有機物の取り扱いは重要となっている。さらに, 難分解性有機物は微生物によって容易に分解しないことから, 生態系への影響や流域全体に蓄積していくことが懸念される。

このような背景から, COD に関する今後の効果的な行政対応に資するために, 琵琶湖・淀川流域および大阪湾への影響が顕在化してきた「難分解性有機物」について, 流域研究者の協力を得て連携した取り組みを実施することを目的に検討会を行った。本発表では, 琵琶湖・淀川流域の難分解性有機物に関して体系的にとりまとめた手引書(案)の概要およびデータ蓄積や流域内でのデータ解析の比較を推進するために「標準的な生分解性試験方法」を提案したのでこれらを紹介する。

2. 方法

2.1 難分解性有機物

琵琶湖・淀川流域を構成する当研究所や自治体の研究機関等では, これまでに様々な研究目的で「難分解性有機物」の調査を行ってきた。それらの既往調査・研究成果をもとに, 琵琶湖, 淀川流域, 大阪湾, その他の水域の有機物指標の動向とCODとBODの乖離現象などについて整理した。また, 難分解性と易分解性有機物を定義し, 各水域(河川, 湖水, 海域)や各排水中での難分解性有機物の指標等について示した。

2.2 難分解性有機物の分析方法

難分解性有機物の捉え方には様々な方法があり, 各分析方法による有機物に関する指標の考え方を取りまとめた。さらに, 各水域における難分解性有機物の生分解試験方法はそれぞれ条件が異なることから, 今後, 水質管理や実態把握等を行う際の難分解性有機物のデータ取得では, 統一した方法が重要であり, 生分解性試験の条件を明示することが必要と考えた。そのため, まず先行して実施されている琵琶湖や大阪湾などの淡水や海水の環境水, 路面排水などの各種排水等で行われた方法を整理した。それらの条件を踏まえて, 対象水別に基本となる生分解性試験の条件をとりまとめ, 前処理や培養条件などを示した「標準的な生分解性試験方法」を手引書(案)として策定した。

3. 結果および考察

3.1 難分解性有機物の動向と定義

本研究での難分解性と易分解性有機物の定義を図1に示す。

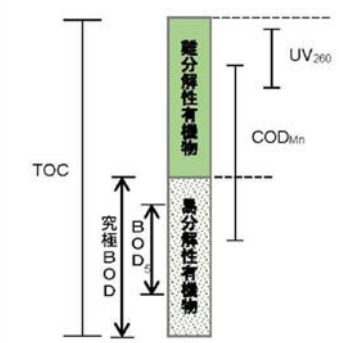

図 1 難分解性と易分解性有機物の定義

水中の有機物総量を炭素量で表したものが TOC (Total Organic Carbon)であるが，難分解性有機物自体は直接的に表す指標がないため，これまでも様々な方法で定性的・定量的に把握する研究がなされてきた。例えば，DOM (Dissolved organic matter) を指標としてその分画分布による特性評価[3]や三次元励起蛍光スペクトル測定による難分解性有機物起源の把握[4]などがある。ここでは，流域全体の湖沼や河川の 20 年間の変化を COD/BOD 比で検討した。図 2 に示すように，琵琶湖北湖で明確に現れており，BOD と COD の乖離現象が進行していることがわかる。また，琵琶湖のみならず下流の淀川等においても問題が顕在化していることが明らかであった。

3.2 難分解性有機物の分析方法

これまで当研究所や各研究機関が測定に供した方法を踏まえ，種々の方法や条件を整理し，流域での難分解性有機物の測定を推進するために重要である生分解性試験について検討した。おもな内容は，①試料採取量，②前処理，③培養容器容量・材質や洗浄作業，④培養機材の準備，⑤培養条件の設定（培養期間、分析頻度、水温、光条件、曝気や振とうの有無，植種添加の有無，栄養塩および緩衝液添加の有無，ブランク試験の実施），⑥水質分析方法　の条件である。培養時のイメージを図 3 に示した。詳細は手引書(案)[5] に記す。

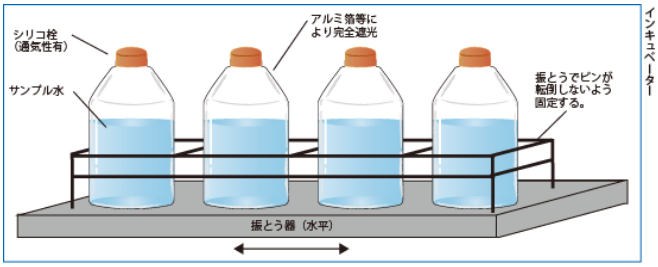

図 3-1 曝気を考慮しない場合の培養機器構成例の概要

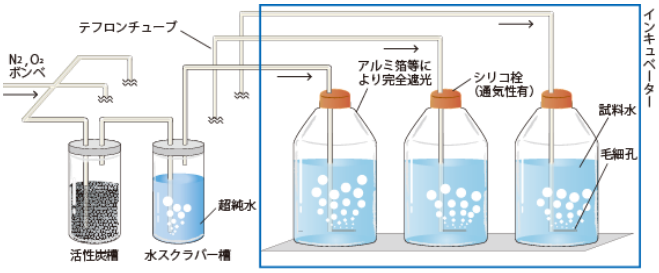

図 3-2 曝気を考慮する場合の培養機器構成例の概要

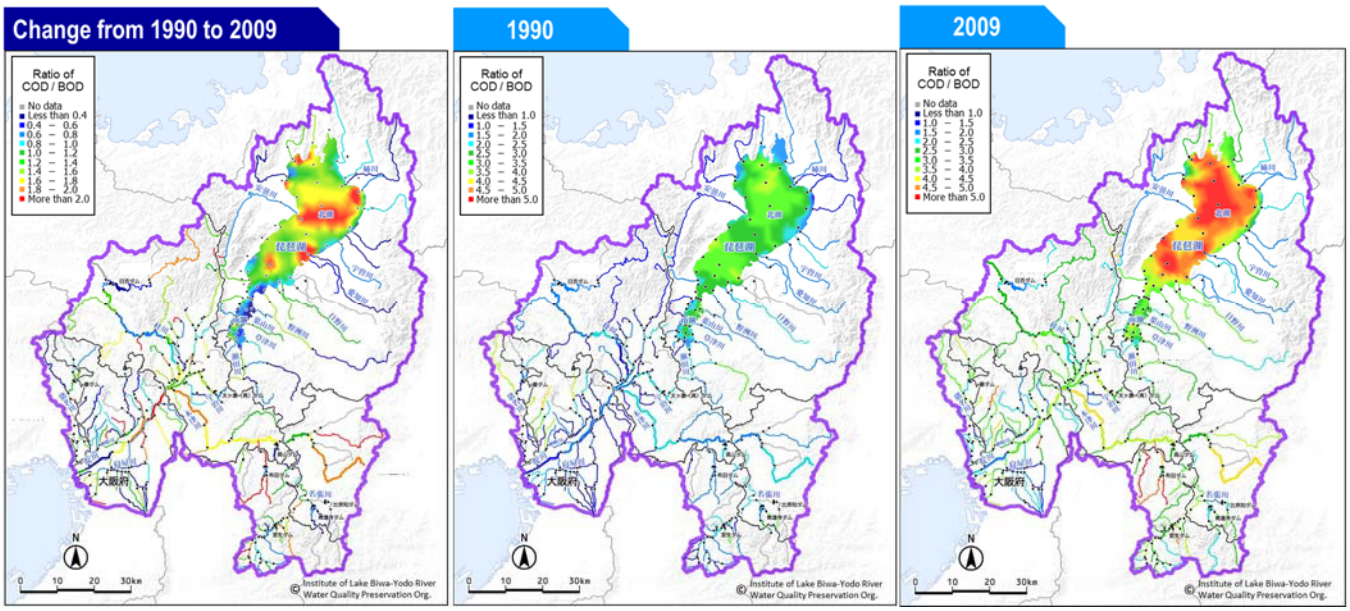

図 2 琵琶湖･淀川流域の COD/BOD 比の 1990 年から 2009 年までの 20 年間の変化

4. 結論

環境基準である「有機物 (BOD・COD)」を対象に，「難分解性有機物」に焦点をあて，琵琶湖・淀川流域や他の湖沼にて得られた知見や文献情報を収集整理し，流域全体の現在の実態把握や事例を体系化してとりまとめた。さらに，流域の研究機関のメンバーとともに生分解性試験の方法等について検討し，各水域や培養条件などを考慮した「標準的な生分解性試験方法」を立案した。この方法を参考にすることで，難分解性有機物のさらなる調査・測定データの蓄積や流域内の他の結果との比較解析などが進み，より一層の難分解性有機物に関する知見の充実が期待できると思われる。

謝辞

本研究は，琵琶湖・淀川水質保全機構の調査研究事業における特別調査研究にて実施した。とりまとめに際しては，流域の研究機関に所属する関係者による検討会を立ち上げ2年間にわたり勉強会を行った。滋賀県琵琶湖環境科学研究センター 早川和秀氏ならびに岡本高弘氏，(地独)大阪府環境農林水産総合研究所 相子伸之氏，(公財)ひょうご環境創造研究会兵庫県環境研究センター 松林雅之氏，京都府保健環境研究所水質課 北野隆一氏ならびに木南敬之氏には本検討会メンバーとして多大なるご協力を頂いた。ここに謝意を表します。

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TS7-1

Restoration of Loch Leven: sustaining ecosystem services

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Keywords: Lake restoration; phosphorus; pesticides; BMPs; diffuse pollution; ecosystem services

ABSTRACT

The pollution and restoration history of Loch Leven has been variously described in earlier papers. The nature and basis of the controls implemented during the recovery period included work with a textile mill, and determining appropriate best practice discharge standards for the municipal sewage effluents. The regulatory effort included enforcement actions with various polluters in the catchment to raise awareness of the requirements for better quality in the tributary watercourses and hence the loch (lake). From the mid 1990s, awareness of the nature and importance of diffuse sources of pollution increased and a series of initiatives with local farmers, agricultural advisors and the River Purification Board (later SEPA) led to the establishment of a suite of diffuse pollution controls. Creativity in finding means to fund measures such as buffer strips and reduced nutrient additions was a feature of effective work during that period. Whilst an EQS approach to discharge standards to a tributary watercourse was taken, setting standards for discharges into the loch was more challenging, and a best practice approach was adopted. That was extended to measures to manage diffuse sources too. The experiences at Loch Leven subsequently informed the development of diffuse pollution regulations and strategy in Scotland.

1. INTRODUCTION

Loch Leven is the largest lowland lake (loch) in Scotland (13.3km^2) and is relatively shallow (mean depth 3.9m) with a large surface area in relation to its catchment[1]. Historically, water quality was good at the turn of the 20th century, but deteriorated as industrial development and increases in the size of the villages and town in the catchment, resulted in phosphate rich effluents draining into the loch. A condition of hyper-eutrophication developed, with varying periods of improvement followed by slippage in quality. The catchment of the loch is mainly mixed agricultural, with some forestry in the hills. Diffuse sources of nutrients became increasingly important as restoration efforts focused on the effluent discharges were successful, leaving diffuse pollution as the principal challenge.

Social and economic activities provided by the loch have included:

- Drainage and effluent disposal
- Nature conservation
- Angling (trout)
- Bird-watching (an RSPB reserve adjacent)
- Informal recreation (walking and cycling)
- Hydropower generation (downstream industries)
- Local economic benefits (tourism)

Ecosystem services (provisioning, regulating, supporting services and cultural) have been discussed in relation to Loch Leven by May and Spears[1], exploring the inter-related impacts of various factors and actions, including unintended consequences. The years of deteriorating water quality adversely affected the above in varying ways; perhaps primarily by establishing a public image of the loch as being badly polluted with health risks from toxic algal blooms and decomposing scum along the beaches. The realities were somewhat different, but the negative messages were consistently stated.

2. POLLUTION CONTROL ACTIONS

2.1 Pollution abatement strategy

There were 3 steps in the strategic approach to achieving reductions in pollution in Loch Leven:

a) Review existing discharge permits and use published environmental quality objectives for specified pollutants in effluents discharging to the tributary watercourses of the loch

b) Adoption of a pragmatic best practice approach to P-removal at municipal sewage treatment works (STWs), and to the control of diffuse pollution sources across the landscape.

c) Support continuing monitoring of the loch and seek evidence of consequential improvements; that required development of strategic water quality goals for the loch.

2.2 Pollution abatement at major point sources

The first step was to seek compliance with the discharge limit for P which had been agreed some years earlier at the textile mill in Kinross, and to begin a review of the permit to also cover moth-proofing chemicals and toxic metals. Enforcement action was taken, followed by a strategic decision at the mill in relation to P use, which since 1987 has made the mill typically no more relevant to P issues in the loch than any other business. Subsequently, new discharge limits were agreed which precluded use of moth-proofers, and protected the S. Queich (and hence the loch too) from pollution from toxic metals. The review also reduced the permit P limit to 2 mg/l, consistent with new limits being agreed for the remaining discharges by then[2]. Prior to the actions at the mill, that P load had been estimated at 30.6% of the external load of total P into the loch[3].

In parallel with the work at the Mill post 1985, the effluent discharges from STWs in the catchment were re-appraised. The principal discharge was from Kinross North STW; a relatively new works designed to remove as much P as was possible by conventional treatment with enhanced sedimentation. Wedge wire screens in the final clarifier polished the effluent to a high standard (limits were for BOD, ammonia and total suspended solids; indirect benefits for P-removal). A 2,000 population septic tank input from South Kinross was draining directly into Loch Leven in 1985; transferring that input for treatment to Kinross North was a priority and achieved as the first stage of STW progress (agreed for some years prior to the review post 1985, and already in the capital programme of the water utility (Tayside Regional Council, then East of Scotland Water, later part of Scottish Water). That action addressed a TP load of 6.7% of the total external TP budget in the 1985 study (Bailey Watts *et al* 1987). Two other sewage discharges comprised the rest of the major point source inputs: Kinnesswood - a village on the east side of the loch; and Milnathort, the second largest village in the catchment and served by an old combined sewer network and an old treatment works. A new works was completed for Milnathort, designed with P-stripping, in 1995[4], and Kinnesswood was pumped to the neighbouring village which was just outside the loch catchment (discharging to the Leven Valley Sewer) [1]. The standards for TP in the sewage discharges (2mg/L) were determined by participating in a European workshop on appropriate best practice discharge standards for municipal sewage effluents. The regulatory effort included enforcement actions with various polluters in the catchment to raise awareness of the requirements for better quality in the tributary watercourses and hence the loch. That work included a focus on combined sewer overflows and pumping station discharges too.

2.3 Managing diffuse pollution

From the mid 1990s, awareness of the nature and importance of diffuse sources of pollution increased and a series of initiatives with local farmers, agricultural advisors and the River Purification Board (superseded by SEPA) led to the establishment of a suite of diffuse pollution controls[5]. A national 'Buffer Strips Initiative' was launched by the partnership, and Loch Leven tributaries became part of that. Creativity in finding means to fund measures such as buffer strips and reduced nutrient additions was a feature of effective work during that period. Evidence of the efficacy of those measures was published in 2006[4]. Nutrient budgets were important and popular with farmers.

2.3 The impact of 'Scum Saturday', 1992

13th June 1992, became known locally as 'scum Saturday' when an algal bloom at Loch Leven coincided with a major nature reserve open day and attracted a lot of media attention. A combination of anglers and locals formed an action group. The statutory bodies involved, together with the loch owner and the principal scientific research organisation at that time working on the loch (now CEH), responded by forming a Loch Leven Area Management Advisory Group (LLAMAG) in 1992. Of several options identified, the principal options were P-stripping (£2M) and diversion of the town effluents around the loch into the Leven Valley sewer (£3.2M). There can be little doubt that the crisis accelerated agreement on the implementation of P-stripping at public STWs (Kinross was the first town in Scotland to have this retrofitted).

3. SUSTAINING ECOSYSTEM SERVICES

The improvements in water quality began to restore the reputation of the loch. A walking/cycling trail around the loch was completed and attracts many visitors and locals. Numbers of visitors to the RSPB bird reserve have increased from 40,000 p.a. to 70,000. The Mill has allowed access through their property for the trail and re-opened a shop and café. Two additional café/restaurant developments have grown significantly too. The Mill has strengthened its position in international markets and has had a positive environmental impact on suppliers as well. Biodiversity has greatly recovered in the loch. Conversely, the native trout fishery[1] has been greatly reduced in size, as a business decision by new managers of the estate.

4. DISCUSSION

The intervention of a crisis into the abatement decision-making process had consequences. The urgency cut-short consideration of long term benefits of diversion, with its advantage of total reduction and allowance for population increases and growth in influent loads. Often limited or false information was seized upon in the press. The main beneficial consequences were the acceleration of actions to reduce the sewage P-load, and to support for diffuse pollution partnerships with farmers and their advisors[4]. Efforts to persuade local authority planners to target sewered areas for development instead of piecemeal development in the rural areas largely failed. The belief that treatment technology should prevent a problem, ignores widespread professional experience of small private treatment systems. For the main water utility STWs, the discharges are well within limits; should their concentrations be allowed to rise? Should there be an upper limit to growth of the settlements? Abatement success brings new challenges too; tourist facilities need to consider P losses more effectively.

5. CONCLUSIONS

A mixture of approaches needs to be used for pollution prevention and control, and these have been well demonstrated in Loch Leven:

1. Environmental goals need to be simple and clear
2. Cessation of a discharge in perpetuity is better than investment to achieve a percentage reduction by a treatment process.
3. Setting discharge limits based on published environmental quality standards for tributary rivers and streams, rather than allowing piped effluents into the lake, provided better control of pollution for the lake than setting limits based on debatable in lake mixing zones and dilution concepts (c.f. coastal water discharge practices).
4. For industry, environmental improvements are consistent with business efficiency and cleaner technology.
5. Many pollution incidents are avoidable; fair and reasonable enforcement actions are often needed to underline the importance of environmental protection in a community or catchment.
6. Good will from local business sectors, the public, and the water utility and local council, can accelerate progress beyond the scope of regulatory actions. Catchment management plans are one mechanism to achieve that.
7. People in a lake catchment respond well to a campaign or initiative, since they identify with their local rivers and lakes. That is especially important for diffuse pollution control, which relies on widespread uptake of best practices.
8. The sewered catchments of Milnathort and Kinross, drain to modern STWs with P-removal; those areas are therefore preferable for development to areas outside those sewered areas, when allowing development in the lake catchment.
9. Drainage from Kinnesswood and Scotlandwell is pumped into the Leven Valley Sewer, discharging after treatment into the Firth of Forth. That is therefore the least impact area for development, as long as it is connected to the sewer.
10. Success brings new challenges; tourism.

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TS7-2

A perspective on water environment management in Japanese lakes

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Keywords: environmental water quality standards, COD_{Mn}, bottom dissolved oxygen, climate change

ABSTRACT

The management of water environment in Japanese lakes and reservoirs started in 1970's by the environmental water quality standards (EWQS) such as COD_{Mn} to prevent serious problems in water uses caused by organic pollution. Effluent regulations were also started by the Water Pollution Prevention Act to satisfy with the standard. However, percent compliance of the EWQS on COD_{Mn} did not improve and various problems associated with eutrophication were reported. Additional EWQS and related effluent regulations both for nitrogen and phosphorus started in 1982 to cope with eutrophication. Also, the Law Concerning Special Measures for Conservation of Lake Water Quality (1984) was enacted to control non-point sources, to regulate total loading of pollutants and to protect lakeshore ecotone vegetation. However, only a half of lakes and reservoirs could satisfy with the EWQS even in 50 years. Also, COD_{Mn} increased in some lakes irrespective of the reduction of loadings. The new EWQS on benthic dissolved oxygen concentration and littoral zone Secchi Disk transparency were enacted as new targets of comprehensive water environment management. Also, adaption to climate change is a new challenge in Japanese lakes and reservoirs.

1. ENVIRONMENTAL WATER QUALITY STANDARD FOR LAKES AND RESERVOIRS

Japanese management for water environment started by the adoption of the environmental water quality standards (EWQS) in 1970s. EWQS define desirable quality of environmental water necessary and sufficient for various water uses based on the Basic Law for Environment and are administrative targets and criteria for promotion of comprehensive measures to cope with water pollution.

Table 1 shows one of EWQS for lakes and reservoirs to conserve living environment, i.e. to protect all the water uses for daily human life and the living environment for aquatic plants and animals closely related to human life[1]. The following are examples of definitions of the water uses in the table on drinking water supply:

>class 1 – can be treated by simple purification process such as filtration

>class 2 – can be treated by conventional purification processes such as coagulation, sedimentation and filtration

>class 3 – can be treated by advanced water purification processes with pretreatment.

In the EWQS, the most important parameter to be achieved has been COD_{Mn} to cope with organic pollution.

2. EFFLUENT STANDARDS

Regulations of wastewater discharge into public water bodies from the specified facilities started by the Water Pollution Prevention Act to satisfy with the EWQS[2].

Table 1 EWQS for Lakes and Reservoirs (mg l^{-1}, volumes > 10 x 10^6 m^3)

category	water use	pH	COD_{Mn}	SS	DO
AA	water supply class 1, fishery class 1, conservation of natural environment, and uses A-C	6.5-8.5	1	1	7.5
A	water supply class 2 and 3, fishery class 2, bathing, and uses B-C	6.5-8.5	3	5	7.5
B	fishery class 3, industrial water class 1, irrigation water, and use C	6.5-8.5	5	15	5.0
C	industrial water class 2, conservation of environment	6.0-8.5	8	No floating matters	2.0

The effluent standards are uniform and national minimum criteria on effluent quality being applied for facilities with daily discharge more than 50 m^3. Local, i.e. prefectural governments, therefore, can enact more rigorous standards than the national standards by local ordinance if the national standards are not enough to satisfy with the EWQS for local waters.

3. WATER QUALITY IMPROVEMENT

The comprehensive efforts to control wastewater discharges resulted in the improvement of water quality. As shown in Fig.1, water quality in rivers improved and percent compliance on BOD significantly increased from ca. 50% in 1970s to more than 95 % in recent years[3]. However, those for lake and reservoirs on COD are not satisfactory. They remain between 40 % and 60% showing little improvement irrespective of the similar regulation for wastewater discharge.

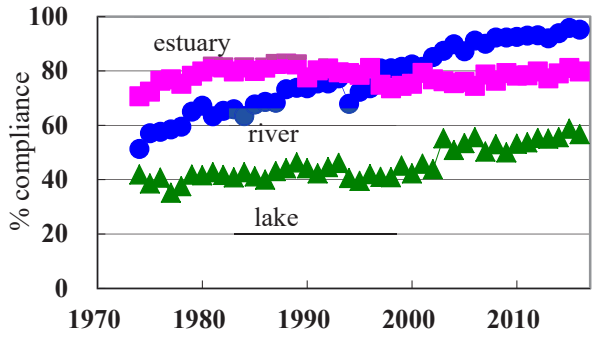

Fig. 1 Percent compliance for EWQS

4. EUTROPHCATION CONTROL

The fact that little improvement both in lakes and estuaries suggested that internal production of COD, i.e. organic production in receiving water by primary production of phytoplankton, is responsible for the non-compliance of EWQS in COD. Also, typical phenomena in eutrophication such as water bloom formation by cyanobacteria and sand-filter clogging in drinking water treatment plant have been reported. Nutrient control, therefore, is necessary in addition to organic pollutants. Additional EWQS and effluent regulations both for nitrogen and phosphorus started in 1982 to cope with eutrophication as shown in Table 2.

Fig. 2 shows percent compliance for EWQS on T-N and T-P in lakes and reservoirs. They are less than 20 % for lakes where EWQS on T-N are applied. Other lakes with T-P and both T-N + T-P are applied are also low and show little improvement irrespective of nitrogen and phosphorus regulation for wastewater discharge.

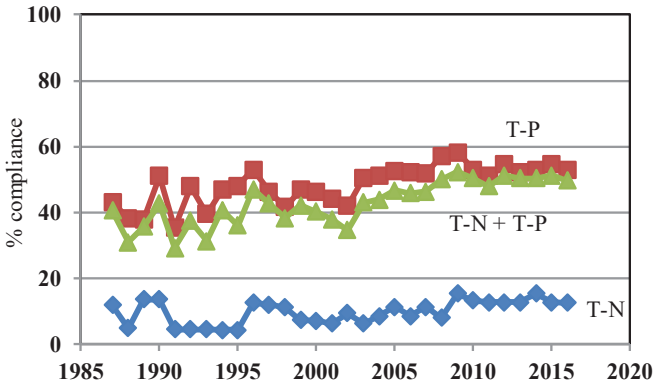

Fig. 2 Percent compliance for EWQS on T-N and T-P

In addition to the effluent regulations, the Law Concerning Special Measures for Conservation of Lake Water Quality (1984) was enacted to control non-point sources, to regulate total loading of pollutants and to protect lakeshore ecotone vegetation. However, only a half of lakes and reservoirs could satisfy with the EWQS on COD even in 50 years. Also, COD_{Mn} increased in some lakes irrespective of the reduction of both organic and nutrient loadings.

Table 2 EWQS on nitrogen and phosphorus for Lakes and Reservoirs (mg l^{-1})

category	water use	T-N	T-P
I	Conservation of natural environment, and uses listed in II-V	0.1	0.005
II	Water supply classes 1, 2, 3 ((except for special types), fishery class 1, bathing, and uses listed in III-V	0.2	0.01
III	Water supply class 3 (special types), and uses listed in IV-V	0.4	0.03
IV	Fishery class 2, and uses listed in V	0.6	0.05
V	Fishery class 3, industrial water supply, irrigation, conservation of living environment	1.0	0.1

Table 3 EWQS on benthic dissolved oxygen (DO) concentration (mg l^{-1})

category	designated use	DO
Habitat 1	・Area to protect and restore habitats for adult species sensitive for low DO ・Area to protect and restore habitats for species sensitive for low DO in reproductive stages	4.0
Habitat 2	・Area to protect and restore habitats for most adult species except for sensitive species for low DO ・Area to protect and restore habitats for most species in reproductive stages except for sensitive for low DO in reproductive stages	3.0
Habitat 3	・Area to protect and restore habitats for adult species tolerant for low DO ・Area to protect and restore habitats for species tolerant for low DO in reproductive stages ・ Area for the survival of most tolerant benthic organisms	2.0

5. EWQS ON BENTHIC DISSOLVED OXYGEN AND TRANSPARENCY

The comprehensive efforts for more than 50 years to restore lake water environment, however, cannot satisfy with the EWQS, i.e. lake environment is not satisfactory. Fishery production remains low compared to 1960s and has not recovered yet. Also, wide and frequent anoxia in lake bottom have been reported. Many circles claim that the current EWQS was good to remediate serious water pollution in 1970s, whereas they might not be appropriate as targets of the current management of lake water environment.

The Japanese government started to reconsider the current EWQS and proposed new EWQS for the better management of water environment. The new EWQS have two parameters on water quality, i.e. dissolved oxygen concentration (DO) at the bottom to secure survival and reproduction of aquatic organisms (Table 3) and littoral zone Secchi Disk transparency (SD) as local criteria for the conservation and restoration of submerged vegetation and recreation.

Designation of water area types for benthic DO in lakes will be discussed based on expected fish species for conservation. Different from COD, T-N and T-P where the same parameters were applied for effluent regulation, DO standard may require effluent regulations on organics and/or nutrients depending on local conditions.

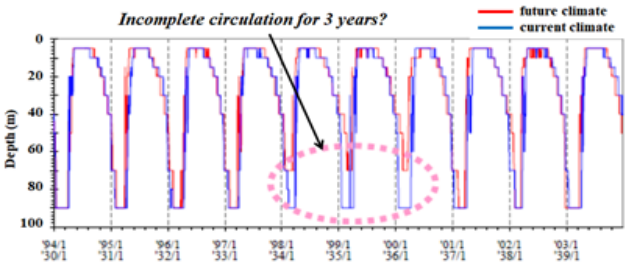

Fig. 3 Predicted incomplete circulation in the Lake Biwa

6. CLIMATE CAHNGE: ADAPTAION IN LAKES

It is well known that global surface temperature will increase several degrees and current climate will be changed in near future. Although various measures have been proposed and carried out to prevent the change, it is well known that the increase and change will be inevitable.

In addition to these mitigation, i.e. decrease in greenhouse gases emission, therefore, measures for adaptation has been studied in three Japanese lakes[4].

Changes in water temperature and precipitation were not significant in the Lake Biwa even in the most pessimistic scenario, RCP 8.5. However, depths of overturn in autumn were predicted to decrease in some years and area of DO deficit in the bottom increased by a climate model as shown in Fig. 3. This may damage benthic fish population.

However, another climate model did not show any reduction of overturn depth. The more intensive studies are required to evaluate effects of climate change on lake ecosystem and efficient measures for adaptation.

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O7-1

水道原水として見た霞ヶ浦の水質について

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キーワード:浄水・排水処理技術

抄録

霞ヶ浦は茨城県企業局にとって重要な水道水源であるが，有機物やかび臭物質が他の水源に比べて高い傾向にあり，浄水処理をする上ではこれらの物質の低減化を図ることが大きな課題となっている。そこで，当企業局が実施してきた霞ヶ浦水源調査に係る，過去 22 年間のデータを 4 つのフェーズに分けて解析した結果，溶解性有機物は各フェーズで夏期に高くなり，フェーズが進むにつれて値が低くなる傾向であることがわかった。また，霞ヶ浦におけるかび臭物質は冬期から春期にかけて高濃度に発生するという特有の傾向が見られるとともに，ジェオスミンと濁度に正の相関があることが明らかとなり，かび臭物質の発生を予測できることが示唆された。全体的な傾向としては近年，最悪なフェーズから改善の傾向が見られるが，有機物やかび臭物質は他の水源より依然として高い傾向にあるため，今後も霞ヶ浦水源調査を継続し，霞ヶ浦の水質について注視していく考えである。

1.　はじめに

茨城県企業局は，全 10 浄水場で用水供給事業を行っており，2016 年4月から2017 年3月までの給水実績は約 1.3 億㎥となっている。この全 10 浄水場のうち6浄水場が霞ヶ浦を取水源としており，当局にとって霞ヶ浦は貴重な水源である。

一方，我が国の水道用水は，水道法において塩素消毒が義務付けられているが，その塩素が有機物と反応することにより，発癌性が疑われるトリハロメタンを生成する[1]。このため，トリハロメタンを生成する有機物を如何に低減するかが，水道事業体において大きな課題の一つであるが，霞ヶ浦湖水中の有機物は，河川等に比べ高い傾向にある。

また，水道原水中には藻類が多種存在するが，環境因子等の条件によって特定の藻類種がかび臭物質（ジェオスミン及び 2-メチルイソボルネオール（以下，「2-MIB」という）を産生する[2]。このかび臭物質の閾値は 5ng/L[3]と言われており，極微量でも水道用水中に含まれると苦情の原因となるため，この物質の低減がもう一つの大きな課題であるが，霞ヶ浦においては，このかび臭物質濃度も，他の水源に比べ高い傾向にある。

当局では 1965 年から霞ヶ浦の水質調査を行っているが，この様な背景を踏まえ，電子データとして整理可能であった 1995～2016 年の調査結果について解析を行ったところ，幾つか知見が得られたので報告する。

2.　霞ヶ浦水源調査概要

(1) 調査地点

霞ヶ浦水源調査は図 1 のとおり全 14 地点で実施しているが，当局が管理する浄水場のうち，日最大給水量が最も多い霞ヶ浦浄水場が取水している西浦の木原取水塔の水質調査結果について整理したものを報告する。なお，調査は 1 回/月の頻度で行った。

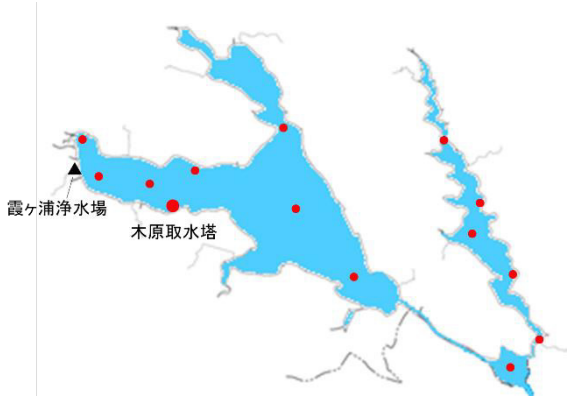

図 1 霞ヶ浦水源調査地点

(2) 調査項目

水温，水深，透明度，濁度，色度，過マンガン酸カリウム消費量，pH 値，電気伝導率，溶存酸素，浮遊物質，COD，溶解性 COD，アンモニア態窒素，亜硝酸態窒素，硝酸態窒素，総窒素，総りん，溶存りん，塩化物イオン，臭化物イオン，総アルカリ度，蒸発残留物，総硬度，総鉄，溶存鉄，総マンガン，溶存マンガン，溶性ケイ酸，クロロフィル a，TOC，DOC，2-MIB，ジェオスミン，E260，アルミニウム，溶存ア

ルミニウム，放線菌，藻類，ミクロキスチン-LR，トリハロメタン生成能

3. 解析方法

霞ヶ浦においては利水上の観点から，4月から 10 月中旬までは上限水位を Y.P.＋1.10m，11 月中旬から2月末までの期間は Y.P.＋1.30m として水位管理を行っていた。しかし，周辺環境への影響等を考慮し，2000 年 10 月からは全期間，上限水位を Y.P.＋1.10m で，2004 年 10 月からは，2月に Y.P.＋1.30m を確保し，それ以外の期間は Y.P.＋1.10m で管理するとの方針変更があった。また，西浦においては，富栄養化対策の一環として 1975 年から 2013 年4月まで底泥の浚渫工事を行ってきた[4]。

これらのことを鑑み，次のとおり4つのフェーズに分け，データ解析を行った。

フェーズ1：1996 年4月～2000 年 10 月

フェーズ2：2000 年 11 月～2004 年 10 月

フェーズ3：2004 年 11 月～2013 年4月

フェーズ4：2013 年5月～2017 年3月

4. 結果と考察

(1) 濁度の状況

各フェーズにおける濁度の経月変化を図 2 に示す。

濁度はフェーズ1・2に比べ，フェーズ3・4の方が低い傾向が見られており，水位管理による影響が示唆された。

更に濁度は，浚渫工事を終了したフェーズ4の方が，フェーズ3より低い値を示していることから，浚渫工事による影響が示唆された。

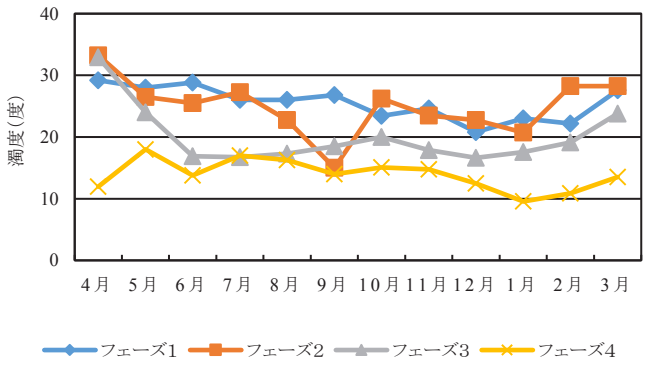

図 2 濁度経月変化

(2) 溶解性有機物及び臭化物イオンの状況

各フェーズにおける溶解性有機物の経月変化を図 3 に，臭化物イオンの経月変化を図 4 に示す。

溶解性有機物については，フェーズ1からフェーズが進むに従い，値が低くなる傾向が見られた。また，各フェーズとも夏期に高くなる傾向が見られ，フェーズ3・4については，9月に最大値を示した。

トリハロメタンは塩素と溶解性有機物（フミン酸等）の濃度，温度，臭化物イオン濃度等に依存して増加する[5]。霞ヶ浦の有機物や臭化物イオン濃度（2017 年平均値で TOC4.0mg/L，臭化物イオン 0.14mg/L）は，霞ヶ浦流入河川である利根川を取水源とする利根川浄水場原水（前述と同様に 1.8mg/L，0.04mg/L）よりも高い濃度である。また，図 3 のとおり夏期に溶解性有機物の濃度が高くなることから，トリハロメタンの低減化を図る上で，より困難な状況となっている。

この様に，霞ヶ浦を取水源とする浄水場においては，トリハロメタンの生成が非常に懸念されるが，当局は粒状活性炭処理を行っており，霞ヶ浦浄水場の浄水中のトリハロメタン濃度は 2017 年の平均値で 0.018mg/L と，基準値の5分の1以下に処理し，給水している。

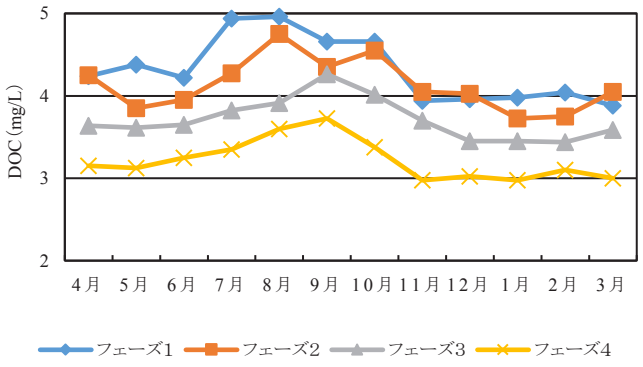

図 3 溶解性有機物経月変化

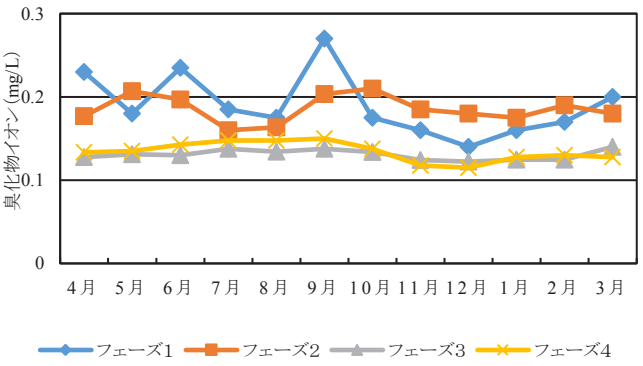

図 4 臭化物イオン経月変化

(3) かび臭物質の状況

各フェーズにおける 2-MIB の経月変化を図 5 に，ジェオスミンの経月変化を図 6 に示す。

他県の湖沼等においては夏期にかび臭物質が発生する事例が多いが，図 5 及び 6 のとおり霞ヶ浦においては，冬期から春期にかけて発生する傾向にあり，霞ヶ浦における特徴的な傾向である。しかし，フェーズ3のよう

に，夏期に発生する場合もある。また，2-MIB 及びジェオスミンとも，フェーズ2が最も低く，フェーズ3が最も高い値を示した。

このかび臭物質に対しても主に粒状活性炭処理により処理しており，霞ヶ浦浄水場浄水中のかび臭物質濃度は 2017 年の平均値で 2-MIB，ジェオスミンともに 1ng/L 未満で給水している。

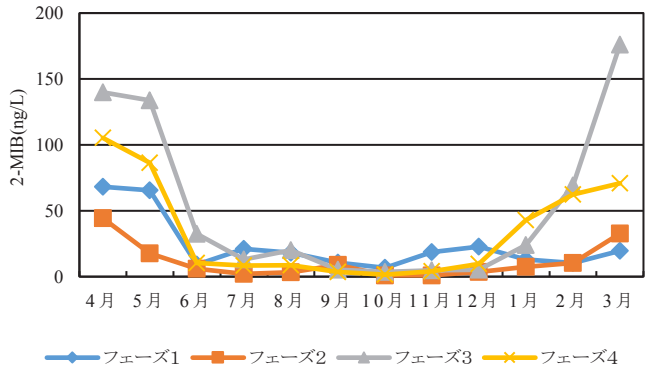

図 5 2-MIB 経月変化

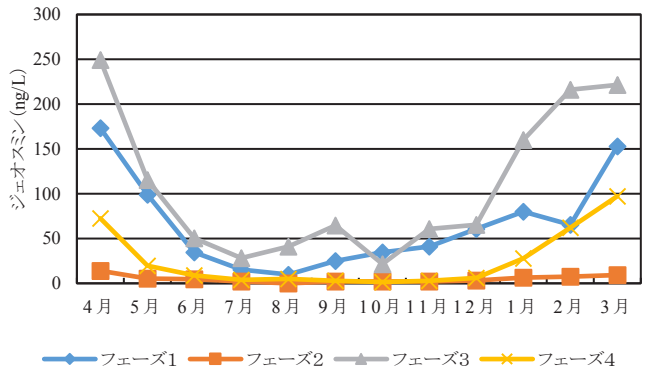

図 6 ジェオスミン経月変化

(4) かび臭物質の発生予測

かび臭物質の発生時期は年によって異なり，また過去には 1,000ng/L を超える極めて高い濃度で発生した事例もある。前述のとおりかび臭物質は，主に粒状活性炭処理により行っているが，粒状活性炭は使用期間の進展に伴い，吸着性能が低下する。このため，劣化状況やトリハロメタンの生成状況，かび臭物質発生時期等を考慮の上，再生を行っている。しかし，粒状活性炭の再生には一定期間が必要であることから，突発的にかび臭物質が高濃度に発生した場合は，その対応が遅れることも予想される。

このため，どの様な状況の時に，かび臭物質が発生するか解析を行ったところ，フェーズ4において図 7 のとおり，ジェオスミン最大濃度と濁度最大値との間に，一定の相関関係が見られた。また，風速と濁度最大値との間にも正の相関が見られるとともに，西風よりも東風の方が，濁度が上昇しやすいことが明らかとなった。

以上のことから，東風が強く吹くと底泥の巻き上がり等によって濁度が上昇し，それに伴いジェオスミンの濃度が高くなると予想される。

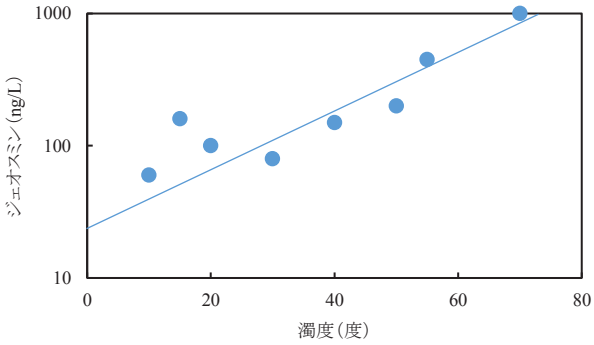

図 7 ジェオスミンと濁度の関係

5. 結論

以上のとおり，霞ヶ浦水源調査結果を各フェーズに分け整理すると，浄水処理における大きな課題であるトリハロメタンの生成要因である溶解性有機物質や，かび臭物質の濃度は，最悪なフェーズより改善していると示唆されるが，依然として他の水源に比べて高い傾向にあるため，今後も霞ヶ浦水源調査を継続していく考えである。

また，これらの物質に対し，当局は粒状活性炭処理によって低減化し，対応を図っているが，消費者ニーズの高まり等により，その再生費用は年々増加傾向にあるとともに，突発的な高濃度のかび臭物質の発生も懸念される。

この様な課題に対し，より効率的に対処するため，霞ヶ浦浄水場において現在，帯磁性イオン交換樹脂及び促進酸化処理を組み合わせた浄水処理の実証実験を行っているところである。この実証実験の成果等については，本会議の分科会で報告していることから，そちらについても参照されたい。

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O7-2

凝集磁気分離型水処理装置を採用した霞ヶ浦直接浄化実証施設

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キーワード:湖内浄化対策, 浄水・排水処理技術

抄録

霞ヶ浦直接浄化実証施設は, 霞ヶ浦湖水を汲み上げ, 水中の浮遊物質(SS)およびりんを除去する事を目的とした実証施設である。実証施設の主要装置として採用された凝集磁気分離型水処理装置は,「凝集」と「磁気による固液分離技術」を組合せる事で, 処理時間が従来方式の約 1/30 である約 2 分 40 秒という非常に短い時間の中で効率的に水中の SS およびりんを除去することが可能な水処理装置である。実証施設は処理能力 10,000m^3/日であり, 閉鎖性水域である土浦港内の湖水を取水後, 実証施設へ送水し, 水中の SS およびりんを除去し, 処理水を再び土浦港に放流する施設である。処理水目標値は SS:5 mg/L 以下, T-P:0.03 mg/L 以下である。2013 年度～2017 年度にかけて実証運転を実施し, 全期間を通じて SS およびりんの処理目標を概ね達成することが出来たので報告する。

1. はじめに

霞ヶ浦では, これまで 7 期にわたり「湖沼水質保全計画」[1]に基づいて, 湖に流入する汚濁負荷の削減対策など, 総合的かつ計画的に対策を実施しており, さらなる湖水の水質改善を目指している。

このような背景より, 茨城県は霞ヶ浦の湖水を汲み上げ, 水中の浮遊物質(SS)および植物プランクトン増殖の一因であるりんを除去する「霞ヶ浦直接浄化実証施設」の導入を決定した。霞ヶ浦直接浄化実証施設(以降実証施設)とは茨城県が 2012 年度にプロポーザルとして公募した浄化実証施設であり, 2013 年度～2018 年度にかけて実証運転を行っている。

今回, 実証施設の主要装置として採用された「凝集磁気分離型水処理装置」は, 限られた設置面積の中で効率的に水中の SS およびりんを除去することが可能な水処理装置である。

2013 年度～2017 年度の実証運転にて SS およびりんの処理目標を概ね達成することが出来たので報告する。

2. 凝集磁気分離型水処理装置の概要

凝集磁気分離技術は,「凝集」と「磁気による固液分離」技術を組合せたコンパクトな水処理技術であり, その概要を図 1 に示す。

原水に無機凝集剤と磁性粉を添加し, 水中の SS および固形性りんを取込んで磁性粉を核としたマイクロフロックを生成させる。その後高分子凝集剤を添加しフロックを成長させる。成長したフロックは磁性を有しており, 後段の磁石により水中から吸着・分離される事で処理水を得る。

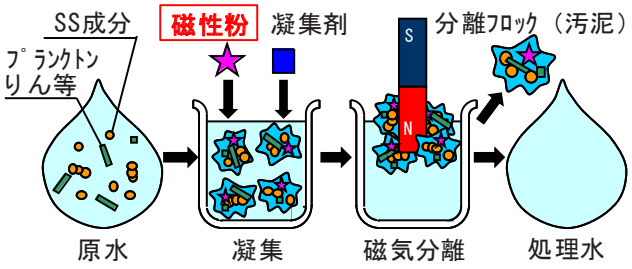

図1　凝集磁気分離技術の概要

この処理方式は固液分離のための沈殿操作が不要となり, 処理時間を従来の 1/30 に短縮できる。また磁石によって吸着・分離された汚泥は濃度 3～4%と, 通常の凝集沈殿方式で発生する汚泥濃度よりも高く, 直接脱水することができ, 汚泥濃縮槽が不要となる。凝集磁気分離型水処理装置の概要を図2に示す。

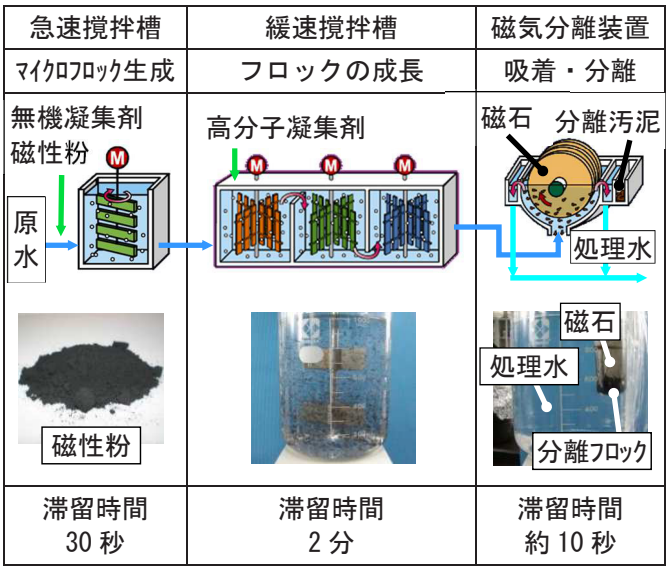

図2　凝集磁気分離型水処理装置の概要

3. 実証運転の方法

運転は，霞ヶ浦の中でも植物プランクトンが堆積しやすい閉鎖性水域である土浦港内の湖水を取水後，実証施設へ送水し，水中の SS およびりんを除去し，処理水を再び土浦港に放流した。施設設置場所状況を図3に示す。

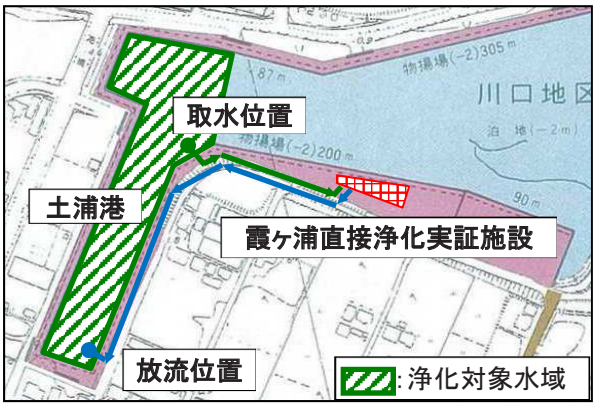

図3 施設設置場所状況

処理水量は最大 10,000m^3/日とし，処理性能評価は水処理装置の入口および出口の SS およびりんの水質によって行った。サンプリングは運転開始後概ね10日間隔で実施し，各年度合計 12～13 回実施した。実証施設の運転条件を表1に示す。

表1 実証施設 運転条件

項目	仕　様
処理方式	凝集磁気分離方式
対象原水	霞ヶ浦土浦港内湖水
処理能力	最大 10,000m^3／日
装置内滞留時間	約 2 分 40 秒（全体処理時間）
処理水目標値	SS　：　5 mg/L 以下 T-P　：　0.03 mg/L 以下

各薬品の注入率については以下のとおりである。

無機凝集剤は原水 SS 濃度および原水 pH 値によって 3～6 mg-Al/L の範囲で注入率を設定した。

磁性粉は，運転開始初期の 2013 年度～2014 年度は設計標準注入率で固定注入とした。一方，2015 年度～2017 年度は磁性粉注入率低減を目的とし，分離汚泥の一部を水処理装置内で回収・循環し，再利用磁性粉として急速撹拌槽に再添加した。この時の新品の磁性粉注入率は設計標準値から再利用分を差引いた値とした。（磁性粉再利用率約 30%）

高分子凝集剤は 0.6～0.7 mg/L を標準とした。

なお発生した汚泥については後段の脱水機で脱水後場外搬出とし，脱水脱離液については水処理装置急速撹拌槽に返送し再処理するクローズドシステムとしている。

4. 結果

(1) SS 処理性能

原水および処理水の SS 濃度の推移を図4に示す。2013 年度は実証施設の建設に伴い運転は 11 月～3 月の冬季に行った。原水 SS 濃度は 7.0～13.2 mg/L と比較的低濃度に対し，処理水 SS 濃度は 2.2～5.3 mg/L と概ね目標値を満足した。

ただし 12 月から 1 月にかけては原水水温が 6～8℃，原水 SS 濃度が 7.0～9.0 mg/L 程度と低水温・低 SS 濃度となり，凝集に不向きな条件となった。そこで凝集核確保のため磁性粉注入率及び，高分子凝集剤注入率を各々増加させたが，凝集反応の安定性を確保する事が難しく，処理水量を 5,000m^3/日とし，滞留時間を 2 倍とする事で処理性能を確保した。

2014 年度～2017 年度は SS，りん濃度共に年間で最も高くなる 6 月～9 月の夏季に運転を行った。原水 SS 濃度 5.0～30 mg/L に対し，処理水 SS 濃度は 1.3～5.6 mg/L と概ね目標値を満足した。特に 2015 年度～2017 年度に実施した磁性粉の循環再利用運転においても，安定した処理性能を得る事ができた。

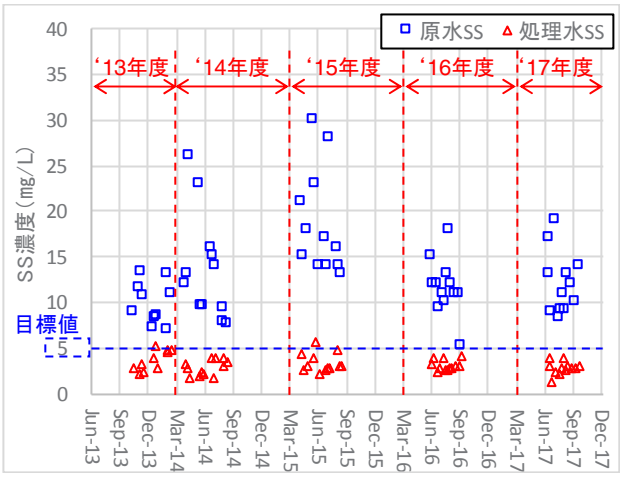

図4 SS 濃度推移

(2) りん処理性能

原水および処理水の T-P 濃度の推移を図5に，PO_4-P 濃度の推移を図6に示す。2013 年度の冬季運転では，原水 T-P 濃度 0.037～0.1 mg/L に対し，処理水 T-P 濃度は 0.002～0.041 mg/L と概ね目標値を満足した。また溶解性のりんである PO_4-P 濃度は，原水で 0.003～0.016 mg/L と非常に低濃度であり常時目標値以下であった。

2014 年度～2017 年度の夏季運転では，原水 T-P 濃度 0.048～0.22 mg/L に対し，処理水 T-P 濃度は 0.003～0.061 mg/L と，原水濃度上昇に伴い一時的な処理水 T-P 濃度上昇はあったが，概ね目標値を満足した。一方で原水 PO_4-P 濃度 0.003～0.11 mg/L に対し，処理水 PO_4-

P 濃度は 0.003～0.027 mg/L となり，溶解性のりんについても処理できることが解った。

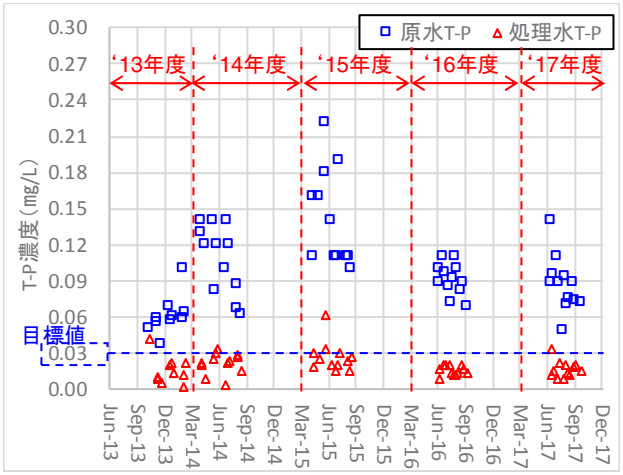

図５　T-P 濃度推移

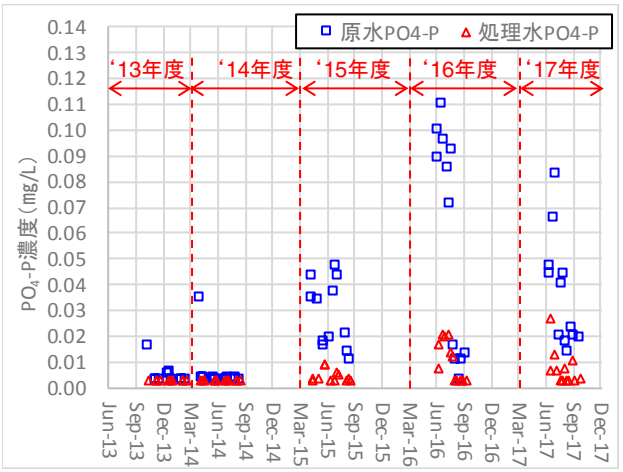

図６　PO_4-P 濃度推移

5.　考察

(1)SS 処理性能と無機凝集剤注入率について

凝集剤注入率の評価として，凝集剤のアルミニウム添加量と原水 SS 濃度の比（AL/SS 比）および処理後 pH 値に着目した。各々の関係を表2に示す。

表２　原水 SS 濃度に対する AL/SS 比，処理後 pH 値

原水 SS 濃度	10 mg/L 前後	20 mg/L 前後	30 mg/L 前後
AL/SS 比	0.3～0.35	0.17～0.2	0.13～0.17
処理後 pH	6.8～7.2	6.8～7.2	6.8～7.2

原水 SS 濃度上昇に伴い AL/SS 比は小さくなっており，相対的なアルミニウム添加量が少なくても良好な処理水を得ることが解った。処理後 pH 値については中性付近が最適であった。土浦港は夏季に原水 pH 値が著しく上昇する傾向がある。よって凝集剤注入率の管理指標は，表3に示す AL/SS 比を基本とし，処理後 pH 値により注入率を調整する事で安定した処理性能を得ることが出来ると考えられた。

(2)りん処理性能と無機凝集剤注入率について

りん処理性能については，原水りんの形態によって処理過程が異なる事が解った。2013 年度～2014 年度では原水りんのほとんどが SS 性のりんであり，SS を除去することでりんも除去されていたと考えられるため AL/SS 比による注入率管理が適用できると考えられる。

一方 2015 年度～2017 年度は原水りんの内，溶解性のりんである PO_4-P の割合が平均で 40%程度であり，2016 年度においては PO_4-P の割合が最大 90%以上であったが，安定して処理水 T-P 濃度 0.03 mg/L 以下で運転継続可能であった。溶解性のりんに対する処理性能として，この期間における凝集剤のアルミニウム添加量と原水 T-P 濃度のモル比（AL/P モル比）に着目し評価した。安定運転時の原水 T-P 濃度に対する AL/ P モル比の結果を表3に示す。

表３　原水 T-P 濃度に対する AL/P モル比の結果

原水 T-P 濃度	(2015 年度) 0.1～0.22	(2016 年度) 0.08～0.11	(2017 年度) 0.05～0.14
AL/P モル比	25～52	31～44	20～34

実証運転における凝集剤注入率は原水 SS 濃度および処理後 pH 値から決定していたため，表3に示す AL/P モル比は結果値であるが，処理目標 T-P 濃度 0.03 mg/L という極低濃度域において，溶解性のりんについても安定して処理するためには比較的高い AL/P モル比での凝集剤注入が必要であると考えられる。

(3)磁性粉の循環再利用運転について

2015 年度～2017 年度に実施した，磁性粉の循環再利用運転では安定した処理性能を得る事が出来た。新規磁性粉注入率を 30%低減しても，今回の原水では処理可能であった。

6.　結論

今回設置した「凝集磁気分離型水処理装置」は，処理時間約 2 分 40 秒という非常に短い時間の中で，SS およびりんの処理目標を全期間を通じて概ね達成することが出来た。また，磁性粉の循環再利用運転を実施し，新規磁性粉の注入率を 30%低減することが出来た。

本施設の設置及び運転管理は，茨城県の「霞ヶ浦直接浄化対策検証事業」に基づき，茨城県から株式会社日立製作所への発注・委託により行われたものである。

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O7-3

Value-chain analysis - An assessment approach to estimate Lake Nasser fisheries performance

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Keywords: Fisheries, Lake Nasser, value chain, tilapia and pebbly fish

ABSTRACT

Although, the fishery in Lake Nasser has existed for more than 40 years, the economic and financial performance of its fisheries-based businesses not well understood. The current study aimed to improve understanding of fisheries value chain performance in Lake Nasser. Individual interviews and focus group discussions with fishers, traders, and processors were used to collect quantitative and qualitative information about financial performance, employment creation and critical factors impacting performance of each node throughout the chain. Tilapias account for 75%, while pebbly fish and tigerfish account for 13% of capture. Fish processing is an important subsector as some fish species (mainly tigerfish and pebbly fish) are only consumed after going through a salting process. Fishers obtained a relatively low percentage (49%) of the final consumer price. Average catch per fisher per day was 20 kg and average total cost in the three fishing harbours was EGP 5210/t. One hundred tons of fish caught and sold provides an average 29.99 Full-Time equivalent jobs (FTE). The current study suggests that the fishery is under pressure from overfishing. Critical factors facing the fisheries sector and impacting profitability are numerous. This value chain study improve our understanding of the performance of fisheries sector in Lake Nasser and identified limiting factors and action needed to support fisheries development in the Lake.

1. INTRODUCTION

Lake Nasser is an important source of fish for the Egyptian markets. Lake Nasser has a diverse fishery with 52 fish species belonging to 15 families [1]. During recent decades, the lake's ecosystem has undergone change and species diversity has declined [2, 3]. Tilapias, comprise 75% of the total catch by weight and are sold as fresh fish, while pebbly fish (*Alestes* spp.) and tigerfish (*Hydrocynus* spp.) are also important and are used as raw material to produce a traditional salted fish product. Other fish species in the catch are Nile perch, squeaker catfish, sharptooth catfish, Bagrus catfish and Nile carp. The statistics indicate that fish catches declined in the last 5 years mainly due to reduced tilapia and Nile perch catches [4]. Value chain analysis (VCA) has become increasingly prominent as a form of analysis in the fisheries and aquaculture sectors [5 - 7]. The particular aims of this study were to: Map the fisheries value chain and the flow of products through the chain; identify the various actors, their functions, and existing linkages across the chain; conduct a preliminary analysis of the input-output structure and the distribution of margins, return on investment and job creation along the chain; identify the problems and opportunities facing different actors in the fisheries value chain.

2. METHOD

The work for this study consisted of three main stages: planning, data collection and data entry. Three main target groups were identified in this study: fishers, traders (intermediaries, wholesalers, and retailers) and fish processors. Three questionnaires designed to be used in the study (one for fishers, one for processors, of both fresh and salted fish, and one for the postharvest subsector; i.e. intermediaries, wholesalers and retailers). The questionnaires tested and revised and simplified wording for the interviewees.

Fishers were selected on a stratified random basis in the three fish landing sites (Aswan, Garf Hussein and Abu Simbel). Fish processors are based in Aswan and the sample selected randomly from a list of fish processors. While, fish traders were selected to represent different trading activities (intermediaries, wholesalers, and retailers). The number of interviewees for each category considered in this study are as follows; fishers 162; processors 22 (fresh and salted processors); and traders 23 (intermediaries, wholesalers and retailers). A total of 207 respondents (fishers 162, processors 22, and traders 23) were interviewed. Data collected allowed the estimation of a number of key indicators for each link in the value chain.

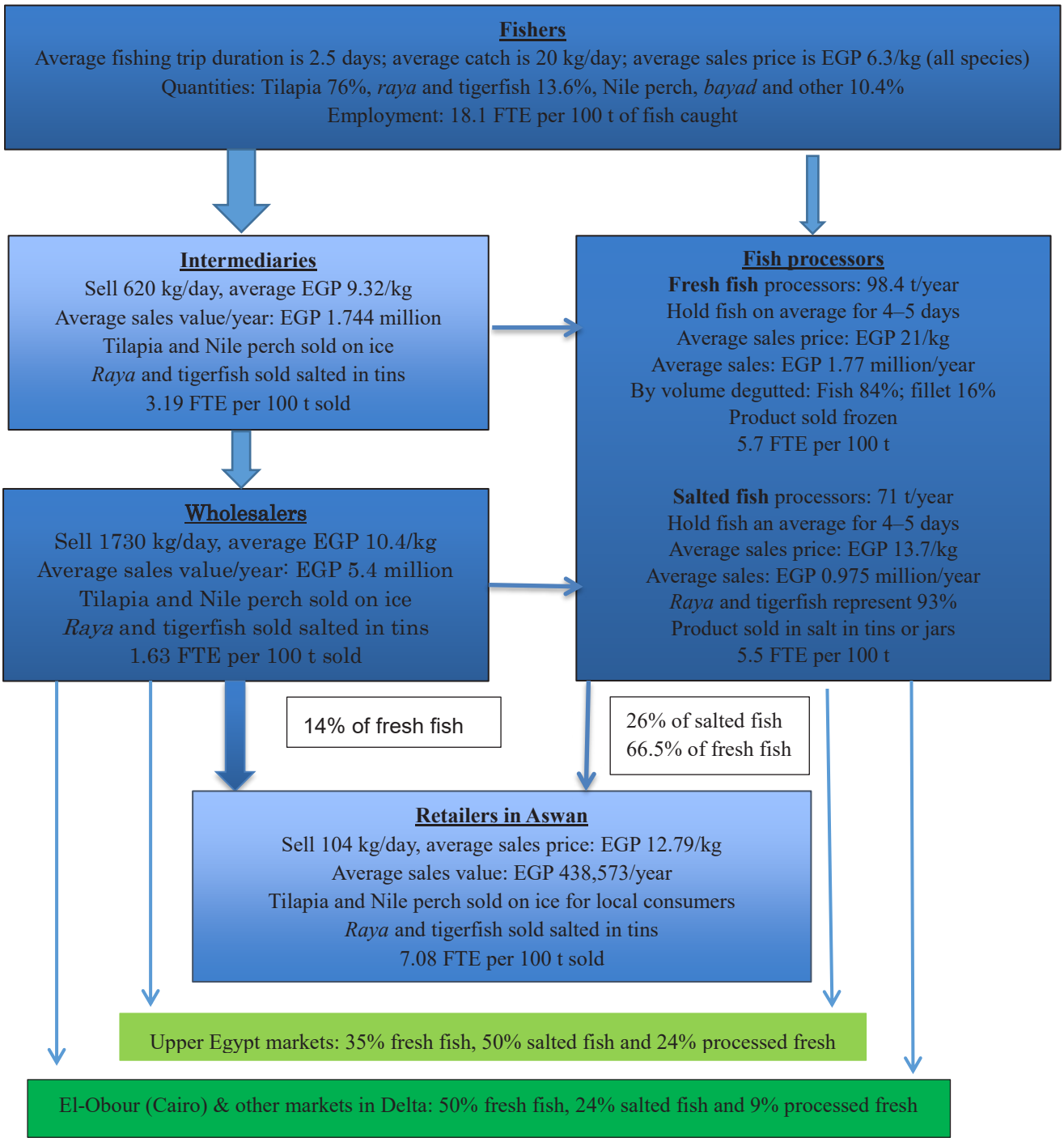
The data collected allowed for the construction of costs and earnings models for each respondent across the chain. The data collected on employment was converted into Full-Time Equivalent (FTE) jobs. FTEs were estimated based on 1 FTE being the equivalent of 300 days per year in fishing and processing sub-sectors, and 330 days FTE in the trading sub-sector as described by Macfadyen et al. [6].

3. RESULTS AND DISCUSSION

4.1. Lake Nasser fisheries value chain mapping

Results of the value chain mapping and analysis revealed that the average catch per fisher per day was 20 kg and average sales price is EGP 6.3/kg, Fishers obtained a relatively low percentage (49%) of the final consumer price, due to the long supply chain compared to aquaculture value chain [6]. Tilapias represent 76% of catch and pebbly fish and tigerfish represent 13.6%. Intermediaries play an important role in collecting catches from fishers in their fishing camps and selling on to wholesalers at landing sites or in the market. Fish processing is an important subsector of the fisheries value chain in Lake Nasser. Fresh fish processing generates 5.7 FTE/100t processed, while salted fish processing generated 5.5 FTE/100t processed. Also, fresh fish processing led to higher value added (EGP 3652/t) than salted fish processing (EGP 2507/t). Salted fish (*muluha*) is a product that is unique to Upper Egypt and comes mainly from Lake Nasser. *Muluha* is made from tigerfish (*Hydrocynus* spp.), pebbly fish (*Alestes* spp.), Nile carp (*Labeo* spp.) and other species that cannot be sold as fresh fish.

Figure 1. Schematic chart for Lake Nasser fisheries value chain.



4.5. Data summary

Changes in the average product price across the value chain indicate the average sales price for each link in the value chain (i.e. the basket price) (Table 1). The data indicates that fishers receive just below 50% of the final retail price.

Table 1 Gross output values (average prices) for the Lake Nasser fisheries value chain

Subsector	Price EGP/kg	% of Retail prices
Fishers	6.29	49
Intermediaries	9.32	73
Wholesalers	10.40	81
Retailers	12.79	100

4.6. Job creation in fisheries value chain

This study found that the fishing subsector resulted in total employment of 30 jobs (FTE) per 100 t of fish caught in Lake Nasser (Table 2). The highest employment level was in fishing followed by retailing, and intermediaries and wholesaling. More than 90% of fishers working in Lake Nasser are from Upper Egypt governorates. Meanwhile, 50% of wholesalers and 65% of retailers are also from outside Aswan. This indicates that the fisheries sector is an important source of job creation not just for Aswan but also for other governorates, including those of Upper Egypt. The current study found that most work was full time (>79%) indicating that fish businesses generate a good level of income across all subsectors. Furthermore, in fish retailing and wholesaling, almost all employment was full time (97% and 95% respectively). Youth (30 years old) represented 49–59% of total FTE indicating that working in the fisheries value chain is an acceptable option for young men.

Table 2 Employment creation in the Lake Nasser fisheries value chain

Employment	Fishers	Inter[1]	Ws[2]	Re[3]	Total
Jobs (FTE)/100 t sold	18.1	3.19	1.63	7.08	29.99
% across the chain	60	11	5	24	100
Full-time (% of FTE)	79	78	95	97	
Youth (% less than 30 years old)	57	53	59	49	
Source of labor					
Aswan %	9	47	50	35	
Other governorates %	91	53	50	65	

[1]Intermediators; [2]Wholesalers; [3]Retailers

4.7. Analysis of critical factors limiting fisheries development

Focus group discussions (FGD) resulted in identification of a series of challenges categorized into; livelihood challenges; inputs availability challenges; operation challenges include; post-harvest and marketing challenges.

4.8. Recommended actions to improve fisheries value chain performance

Suggested recommendations are based on the critical issues identified during the FGD and issues raised by fishers during interviewing.

- Establish new service organizations to provide inputs.
- Capacity building on recent fishing methods, improved handling and fish processing technologies.
- Facilitate affording operations inputs (food, fuel and ice).
- Ensure enforcement of security on and around the lake
- Adopt community-based fisheries management approach
- Improve living standards in the fishing camps in the lake and provide health service and social insurance service.
- Local authority should support establishing fish auctions in both Aswan and Abu Simbel to regulate fish prices.

4. CONCLUSION

The Lake Nasser fishery is an important source of food and job creation in Aswan and Upper Egypt. The fisheries sector contributes significantly to direct job creation, including for youth. No women were employed in the fishers or fish processing sectors in Aswan.

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O7-4

水草の持続的利活用を通した湖沼生態系の保全

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キーワード:水草, 持続的利用, 里湖循環型社会, メタン発酵, 微細藻類培養

抄録

近年, 世界中の多くの閉鎖性水域において, 水生植物(以下, 水草)の異常繁茂が様々な環境問題を引き起こしている。一方で, 水草は水質を浄化し湖沿岸に生息する生物に産卵・育成場所を提供する湖沼生態系になくてはならない存在と認識されている。実は, 1950 年以前には水草(主に沈水植物)は農地に施用する肥料として利用されており, 「循環型」の社会構造を形成していたと考えられている。今日, 便利で安価な化学肥料が利用されるようになり, 水草は全く利用されなくなった。これらのことは, 水草の効果的な利活用方法を開発することが, 異常繁茂した水草に関する問題を解決する最も良い方法であることを暗示している。ここでは, 水草をメタン発酵してエネルギー変換し, 発酵液分残渣を使って微細藻類を培養し利益還元することで刈り取られた水草を有効活用する取り組みについて紹介する。

1. はじめに

近年，水草の大量繁茂による環境問題が世界各地で報告されるようになっており[1-5]，日本国内でも社会問題となって久しい[6-7]。例えば，琵琶湖南湖では，沈水植物が湖面の 90%以上を覆うまでに至っており，複合的な環境問題を引き起こしている[8]。

一方で, 水草は元来, 水質浄化あるいは魚類の産卵場所や仔稚魚の生育場所として機能しているため[9], 適度に存在することで水域生態系を健全に保つことに貢献している。日本では僅か 60 年程前まで，水草は農地施用の肥料として刈り取られ利用されていたことが分かっている[10]。琵琶湖においても 1930～1938 年の滋賀県統計全書によれば，藻類の販売量は 2～3 万トンと記されている[10]。もしかするとこのように定期的に刈り取られることによって，過去において水草は適度な現存量に保たれていた可能性がある。水草は肥料として農地に施用され, 農作物として人間社会へ還元されることによって,「里湖循環型社会」と呼べるリサイクルシステムが形成されていたと考えることができる[10]。

今日，安価で便利な化学肥料の台頭により水草を肥料として利用することはまったくない。琵琶湖などで異常繁茂する水草に関連した問題とは, 即ち, 水草が利用されなくなったことで生じているのかもしれない。今日的な利活用の方法さえ見出すことができれば，過去に行われていたような水草の循環利用が可能となり, 水草問題も解決し, ひいては水域生態系の保全に役立つものと期待できる。

現在, 琵琶湖では水草は, 主にマンガンと呼ばれる道具を用いて，根こそぎ除去される[8]。しかし，これは水草の生態学的役割や水草除去に伴う環境への影響をまったく考慮していない。水草の刈り取り方法, および適正な現存量を策定することは，これを管理する上で極めて重要な知見を提供する。

我々は，2014 年～2016 年の 3 年間，環境省の環境研究総合推進費の助成を受け，琵琶湖環境を保全するために，過剰繁茂した水草類の持続可能な管理基準を策定し，加えて除去した水草バイオマスを有効利用する基盤技術を確立するための研究を行った。ここでは，メタン発酵と微細藻類培養による水草バイオマスを利用した現代版里湖循環型社会を実現するための研究および技術開発の概要について紹介する。なお，本発表の内容はすでに環境技術[11]に掲載された内容を含む。

2. 持続可能な水草刈り取り量および刈り取り方法

水草を持続的に利活用するためには，適正な刈り取り量を推定する必要がある。滋賀県が 2002 年から継続して行っている水草バイオマス調査によると，水草群集としての成長期は 5～9 月であり，9 月の現存量は湿重量でおよそ 10 万トンと見積もられている[12]。これは，月当たりにして湿重量で 2 万トンずつ増加している計算になる。

2015 年に行われた琵琶湖南湖での調査によると，湖底直上での溶存酸素量が，魚介類の成長・生理活性が低下するレベル（4.3 ml/L 以下）まで減少した地点は全調査地点の 8%を占めた[13]。これらの地点は水草の水柱当たり占有率が 60%を上回るところと良く一致していた。一方，水草に付着する微小動物の種数は，水草占有率が 30%を下回ると急激に減少傾向を示した。このことは，湖底直上の溶存酸素量と水草に関連する生物の多様度を指標にすることで適正な水草量を推定できることを暗示する。

今日，琵琶湖での水草除去は，刈り取り船を用いた表層刈り取りとマンガンを用いた根こそぎ除去がおこなわれている。しかし，これら刈り取り方法の違いが湖沼生態系に及ぼす影響については，これまであまり検討されてこなかった。我々の研究では，湖底堆積物中の化学物質の鉛直分布より，湖底堆積物表層の短期的な攪乱は，ある種の化学物質が湖底から溶出する可能性を示唆した。一方で，刈り取りによる長期的な有機物堆積量の減少は，これら化学物質の溶出を抑制する効果があることを示した。これらの結果は，水質・底質を保全するには水草の除去がある程度有効だが，根こそぎ刈り取るのではなく，表層のみ刈り取る方法がより適切であることを示す。

3. 刈り取った水草の有効活用方法

琵琶湖における水草の有効活用については，これまでにバイオエタノールや堆肥化など様々な試みがなされてきたが，有効な解決手段は見出されてこなかった。我々は，メタン発酵によって水草バイオマスを処理し，効率的にメタンガスに変換することでエネルギー転換し，廃液として生成される発酵液分残渣（消化液）を用いた微細藻類培養を行うための研究開発を行った。

水草は種によってリグニン含量が異なり，そしてこれに伴ってメタン生成量の変動することが分かった。従って，メタン発酵の前処理としてアルカリ加熱処理が必要であることを明らかにした。また，微細藻類培養において Mg が不足していることを見出し，消化液の pH を下げることでこれを解消できることも分かった。これらの実験結果を踏まえてベンチスケールでの実験を実施し，60%以上のメタン変換率と水草 1kg 当たりクロレラ 6-8g 乾重量の生産を達成することができた。

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O7-5

Assessment of Ecosystem Services of Water Reservoirs/HPP dams in the Kura-Araz Basin

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Keywords: sustainable ecosystem management, targeted scenario approach, irrigation, flood management

ABSTRACT

This study focuses on freshwater ecosystem services that support hydropower plants (HPP)/dams development in the Kura-Aras River Basin in Azerbaijan. The study assesses the HPP/dams sector, and reviews additional sectors including nature-based tourism, irrigated agriculture, and drinkable water supply. In addition, the study briefly discusses the role and value of ES that help to mitigate natural hazards related to poor ecosystems management.

The study used a basic Targeted Scenario Analysis (TSA) approach. The TSA assesses current "business as usual (BAU)" ecosystems management practices and its current value of ecosystems services under BAU. It uses sector output indicators and compares with potential "sustainable ecosystems management (SEM)" outputs to assess losses and potential gains (or losses) of shifting from BAU to SEM. The BAU approach is characterized by a focus on short-term gains (e.g., < 10 years), externalization of impacts and their costs, and little or no recognition of the economic value of ES, which are typically depleted or degraded. Under SEM, the focus is on long-term gains (> 10 years); also under SEM, the costs of impacts are internalized. Ecosystem services are maintained, thus generating potential for a long-term flow of ecosystem goods and services that can enter into decision making. SEM practices tend to support ecosystem sustainability as a practical and cost-effective way to realize long-run profits.

1. INTRODUCTION

The hydropower dams/ reservoir in Azerbaijan provide a preferred cultural, regulatory, and provisioning ecosystem services [1]. The study aims at: 1) Demonstrate the value of contribution of biodiversity and ecosystem services to hydropower/dams development in the Kura-Aras River Basin; 2) Support the introduction a Sustainable Dams Assessment and Planning Methodology; and, 3) Mobilize key stakeholders, secure their support and launch the Caucasus Sustainable Dam Initiative [9].

The study stresses that joint-effort of key stakeholders at the river-basin-scale can support sustainable ecosystems management to ensure that the benefits of the hydropower sector, both financial and economic are secured for the long-term.

The study assesses the HPP/dams sector, and reviews additional sectors including nature-based tourism, irrigated agriculture, and drinkable water supply. In addition, the study briefly discusses the role and value of ecosystem services that help to mitigate natural hazards related to poor ecosystems management.

2. METHOD

The study used a basic Targeted Scenario Analysis (TSA) approach. The TSA assesses current "business as usual (BAU)" ecosystems management practices and its current value of ecosystems services under BAU. It uses sector output indicators and compares with potential "sustainable ecosystems management (SEM)" outputs to assess losses and potential gains (or losses) of shifting from BAU to SEM. The BAU approach is characterized by a focus on short-term gains (e.g., < 10 years), externalization of impacts and their costs, and little or no recognition of the economic value of ES, which are typically depleted or degraded. Under SEM, the focus is on long-term gains (> 10 years); also under SEM, the costs of impacts are internalized. Ecosystem services are maintained, thus generating potential for a long-term flow of ecosystem goods and services that can enter into decision making [4]. SEM practices tend to support ecosystem sustainability as a practical and cost-effective way to realize long-run profits.

It is expected that the TSA approach will serve multiple purposes:

1.Analyze the HPP/dams sector and determine the potential economic gains or losses of undertaking productive activities by comparing "poor" with "sound" environmental management practices.

2.Inform policy makers and businesses about the economic risks and opportunities of undertaking productive activities that impact ecosystem services.
3.Assist government officials and the private sector to incorporate ecosystems' management policy into economic planning, corporate business plans, and investment policies at sectoral level.
4.Provide economic (and social) arguments to mobilize political will to increase financial support to improve fresh water and forestry ecosystems management [2].

3. RESULTS

During 2005-2009 large investments were made in HPP sector, including new and advanced generators installed in several HPP. Contribution of these new generators rapidly increased electricity production, however, over the last two years a considerable reduction of the electricity produced is noticeable. However, during this period, little or nothing was invested in watershed management (the water factory). This is typical BAU scenario; it may include deforestation, intense silting, and poor dam management. Despite the increasing trend for this period, total amount of investments is rather low [6]. Under BAU, investment in infrastructure and equipment is high; Economic losses in electricity production for the period of 2003-2012. Actual production of HPPs in Azerbaijan is much lower than the installed capacities of all HPP. E.g. the Mingechaur HPP the installed capacity is 402 Mw, while actual production in 2012 was only 159 Mw. This difference may be explained by the impact of various factors. One and very simple explanation is related to the effective dam management. This large difference between installed capacity and actual production is considered as an indicator that HP dam management in Azerbaijan is under BAU.

A total economic loss 2003-2012 under BAU makes nearly 4.5 billion USD (for 2000-2012 it makes 6.4 billion USD), which is considerably higher than market value of produced electricity for that period. The optimal annual level of productivity assumed under SEM is nearly 2000 kWh per year, while under BAU we observe sharp fluctuation of productivity.

Comparison of total actual productions and total installed capacity of HPP and Economic loss from reduced HP generation sector 2003-2012 under BAU

The current BAU situation contributes to create conflict amongst stakeholders; i.e. reduced electricity production, less water available for irrigation leads to a decrease in agricultural output, and inadequate flood management that leads to flooding in downstream regions. For instance, the Mingechaur dam and reservoir has a purpose of hydropower generation, irrigation, and flood management. So, at least three stakeholders have an interest on management of the dam and reservoir.

Well-managed reservoirs should be operated to be able to storage water during high flows [5]. However, state owned HPP/Dams operators are interested in maintaining energy flow and little is invested in maintenance on dams. For example, during the high flow seasons, Mingechaur Reservoir serves as a flood prevention depository, reducing the risk of floods. However, in 2010, before high flow season, Mingechaur reservoir was not emptied to prevent reduction in electricity generation. Thus, during the high flow the reservoir did not function as a depository and it resulted in floods and inundation of 50 ha of irrigated lands, and destruction of homes. By the end of 2013, Azerbaijani hydro power plants decreased electricity generation by almost 75%. This is a strong case for promoting a shift from BAU to SEM.

Simultaneously, the government reported that the hydropower plant crisis in Azerbaijan started in the end of 2012 and continued in 2013. According to the information, power generation at HPPs for January-October 2013 reached only $1.209 \bullet 10^6$KW/h that is by 24.5% below that for the 2012 same term[1]. According to estimations, this makes additional economic loss equal to USD 184,292.000 only in 2011-2012. Estimated total economic loss in hydropower sector over the period of 2002-2012 is nearly USD 4.5 billion.

Poor dam and watershed management started to cause big floods since 1993. Recently, floods in the target region affect lives of 200,000-250,000 people on average per year. E.g. in May 2010, more than 240,000 people were affected, with tens of thousands of homes flooded or destroyed and 50,000 hectares of farmland inundated. The damage was estimated at $591 million. The main reason for this flood damage was a combination of poor upper basin management and dam management (flow regulation).

In 2010, the GoA increased its state budget up to USD 425 million to eliminate consequences of flooding. In 2013 USD 180 million has been spent to reduce consequences of floods. In 2014, the projected costs will be nearly USD 185 million. Total spending over the last four years slightly exceeds USD 1 billion. The Figure 12 shows the annual costs for elimination floods. The high cost of the 2010 flood is linked to BAU. This cost could be reduced by shifting to SEM management; for instance, only USD 20

million annually. The data to support this estimation was provided by the government.

4. DISCUSSION

BAU practices in fresh water ecosystem management have a high cost to the economy of Azerbaijan. Part of this high cost can be avoided by shifting to low cost SEM practices. Despite the availability of several laws and regulations governing the administration and management of HPP and Dams in Azerbaijan, enforcement is weak. The legal framework is also incomplete, there are no means for law enforcement, and no measurable indicators or means to collect and evaluate it. Therefore no results of evaluation are fed into policy making or to improve HPP/Dams management.

5. CONCLUSION

Because of different priorities, poorly planned BAU management generates conflict amongst fresh water ecosystems' stakeholders [3].

The current environmental impact assessments of HPP/Dam projects (small and large) neglect to assess the potential impact of current ecosystems management practices in the upper river basin. This in turn will have a negative impact on HPP/Dams performance that may result in additional negative externalities affecting other sectors such irrigated agriculture, tourism, fisheries, and drinkable water supply. The aggregated cost of these negative externalities often surpasses the current benefits deriving from the HPP/Dams sector.

Because improving ecosystem management in the upper watershed requires the participation of multiple sectors, e.g., HPP/dams, agriculture, forestry, fisheries, tourism, water supply, a comprehensive package of interacting policy reform measures is needed, both at national and at regional level. This is defined as a "policymix" package that is indispensable to introduce sustainable HPP/Dams development in the Southern Caucasus [10].

The lack of information and data limited the scope of this study; therefore, further research is needed, and it may include developing of primary data baselines. However, basic scenarios (BAU/SEM) were constructed where possible to inform policy makers and businesses about the economic risks and opportunities of undertaking productive activities that impact ecosystem services.

It is evident that BAU scenario causes huge economic losses in all sectors, reducing long-term gains. In contrast, the SEM could help to gradually increase ecosystem values and related benefits. For illustration purposes, a rough aggregate of the economic losses in various sectors under BAU and shows how costly BAU management can be, USD 18,6 billion. It also shows how economic losses may continue to increase, unless SEM management is provided.

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O7-6

Climate change impact assessment on ecosystem services of West Lake, Hanoi capital and suggestion a system of mitigation and adaptation measures

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Keywords: climate change, ecosystem services, West Lake, mitigation, adaptation, Hanoi capital.

ABSTRACT

West Lake is the freshwater lake in the Red River Delta in Vietnam, located in Hanoi capital. The lake is one of the few natural freshwater largest lake in the country. West Lake is listed as one of the lakes to be preserved in the world. Due to this such important role of lake, this research has analyzed current status of natural and socio-economic conditions of the West Lake, Hanoi capital and surrounding areas. From there, assess the ecosystem services that the West Lake ecosystem brings. There are four ecosystem services groups of West Lake: provisioning services, regulating services, supporting services and cultural services, in which the group of cultural services is crucial. By analyzing climate change scenarios of Vietnam in general, climate change scenarios of Hanoi capital in particular to assess the impacts of climate change on each group of ecosystem services of West Lake. From that point of view, proposals will be made to mitigate and adapt to climate change impacts for conservation and sustainable development of lake ecosystem services. A system of mitigation and adaptation actions has been proposed to restore West Lake as natural wetland as previous time for strengthening the resilience of West Lake to climate change.

1. INTRODUCTION

Analyzing the impact of climate change on ecosystems in Viet Nam is a country-wide requirement and based on these results of this analysis to propose mitigation and adaptation measures with climate change.

West Lake is the largest lake in the Red River Delta. The lake has an area of about 527ha, average depth of 1.5m, capacity of lake $7.5x10^6$m3. Lake is one of the few natural freshwater largest lake in the country. West Lake is listed as one of the lakes to be preserved in the world. Besides, ecosystem services of West Lake play an important role for Hanoi capital.

2. METHOD

This research uses method of document synthesis and methods which authors used for the previous researches listed in references.

3. RESULTS AND DISCUSSION

3.1. Current status of water quality, environment and aquatic biodiversity of West Lake

There are so many surveys on water quality, environment and aquatic biodiversity of West Lake since 1960. The most recent and more in details is the report of Institute of Ecology and Biological resources (IEBR) in 2012:

- ***Water quality***: all the water quality parameters are in the limit of tolerant of National Technical Regulation on surface water quality of QCVN 08-MT 2015 BTNMT with category B1 i.e. for living aquatic organisms but not so good in comparison with the past time (1960).

- ***Water and sediment layer depth***: after a half century, the water layer depth is shallower around 0.5m (in 1961 the deepest point is 3.5m and 2.5m in 2012. The sediment depth is more deeper, around 1m.

- ***Heavy metals of water, sediment layers and in living organisms***: there are so many heavy metals in presence of water and sediment layers such as: arsenic, cadmium, chromium, copper, iron, lead, zinc… The above heavy metals are also in presence (contamination) on aquatic plant species and commercial animal species such as fishes, shrimps, molluscs…

- ***Aquatic biodiversity***: is originally very diverse (1961) but rather poor now. There are many exotic (alien) species, cultured species (for fish species). No aquatic plant species. For other species such as shrimps, crabs, clams, snails…are decrease in species number and in stock (biomass).

3.2. Climate change in Vietnam in general and in Hanoi capital in particular

The ministry of Natural resources and Environment has deliberated two scenarios for global climate change 2009 and 2016. The followings are some data of Hanoi capital in the recent scenario 2016:

Annual average temperature: The change in mean annual temperature (^oC) over the baseline period (1986-

2005) (The value in parentheses is the variation around the mean value for the lower bound 10% and the upper bound 90%):

- RCP4.5 scenario: 2016-2035: 0,6 (0,2÷1,1); 2046-2065: 1,7 (1,2÷2,5); 2080-2099: 2,4 (1,6÷3,4);
- RCP8.5 scenario: 2016-2035: 1,1 (0,6÷1,6); 2046-2065: 2,2 (1,4÷3,4); 2080-2099: 3,9 (3,0÷5,7);

Annual average precipitation: The change in mean annual precipitation (%) over the baseline period (1986-2005) (The value in parentheses is the variation around the mean value for the lower bound 20% and the upper bound 80%):

- RCP4.5 scenario: 2016-2035: 12,6 (3,1÷22,9); 2046-2065: 17,0 (10,8÷23,8); 2080-2099: 24,0 (14,3÷35,3);
- RCP8.5 scenario: 2016-2035: 9,9 (2,7÷17,0); 2046-2065: 17,8 (9,8÷25,9); 2080-2099: 29,8 (18,0÷40,9);

Extreme weather phenomena in Hanoi: It can be said that with the people of Hanoi, the phrase climate change is no longer strange, because the unusual evolution of the weather in recent years has had a great impact on the life and environment in the capital. The issue for Hanoi is the response to climate change and extreme weather, such as colder winters, hotter summers, drier seasons and more rainy seasons. There are six rivers and dozens of natural lakes in Hanoi, which have suffered from climate change, such as erosion, lower water levels in recent years.

3.3. Ecological services of West Lake and climate change impacts

3.3.1. Provisioning services

Food supply (aquaculture, vegetables and fruits); Water supply (for irrigation and domestic use). Every year, West Lake is put into raising from 2.2 to 2.5 million, equivalent to about 5 tons of fingerling. Estimated, the yield of fish is supplied to Hanoi market over 400 tons per year. Genetic resources includes the genes and genetic information used for animal and plant breeding and biotechnology. Flora and fauna in the West Lake is very diverse and abundant. Therefore, this is the place to store biological genetic resources with many rare genes. Under extreme heat conditions at certain times of the year, surface water is heated up and the absorption of oxygen into the water is reduced. When surface water oxygen levels decrease, some of the surface water species are affected. In addition, warm waters, oxygen-deficient and excess CO_2 are favorable for algal blooms. After the algae blooms, the water will be contaminated by dead aquatic organisms, along with decaying algae causing odors, pollution in the lake area, affecting the air environment as well as lake water quality. Highly polluted species will overwhelm low-polluted species. Increasing temperatures during intense summer heat, or longer deep cold in winter can affect the organisms inside the lake as well as on the lake shore. Some species that do not suffer from prolonged colds can die and cannot be recovered without protection, such as the Bach Diep lotus species in lake. In addition, invasive alien species will rapidly overwhelm the native species.

3.3.2. Regulating services

Climate control (air conditioning, micro-climate of the city); Hydrological regulation (under groundwater collection and exchange); Pollution control (receiving and keeping of sediment, solubilizing nutrients and pollutants, waste). Disaster control (flood control). In the context of climate change, storms with high intensity, heavy rainfall in short time, change in precipitation intensity and frequency, increase flooding in the lake and surrounding areas. Floods associated with rainwater combined with domestic effluent spills from the sewage system, along the lake can be turned into the disease outbreaks associated with stagnant water environment, pollution. In addition, when rainwater runs over sewers with high concentrations of inorganic substances, organic matter can cause eutrophication in the lake and can cause odors. This phenomenon not only affects the organisms in the lake but also affects the people living around as well as visitors. Besides, due to the increased rainfall, however, not frequent, therefore, it will cause sometimes floods, sometimes drought and the erosion and sediment will be increased, the life expectancy of the lake will decrease as the depth of the lake will be shallow gradually with faster speed.

3.3.3. Cultural services

Spiritual values (belief and trust of the people); Landscape value, entertainment (opportunities for tourism and leisure activities, sightseeing); Educational value (opportunities for education, formal and extracurricular training). Due to the harsh climate, unusually hot sunshine, high temperatures in summer and winter, people often prefer to live around the lake. Land price in the West Lake (Tay Ho district) is the most expensive of Hanoi. Human activities have encroached, separating the lakes into areas that serve different purposes: restaurants, hotels, houses.., water surface area is shrinking. Crowded population will cause pollution from the discharge of the basin due to tourism activities on the lake, including solid waste. Many construction works are not suitable to lose the beauty of West Lake. Urbanization process of rapid development, especially in the northern, northeastern together with the population density is on the development. This process reduces the risk of rapid area "green" of the natural ecosystems in the basin.

3.3.4. Supporting services

Support biodiversity (habitats of species); Nutrition cycle support (take / hold and nutrient handling). Supporting services are those that are necessary for the production of all other ecosystem services. Extreme weather makes rare species listed in the Vietnam Red Data Book. Described species and new species (possibly endemic) will disappear. Southern species will dominate the northern species. Gradually, primary production, atmospheric oxygen production, soil formation and retention, nutrient cycling, and primary production will be reduced.

3.4. Suggestion a system of mitigation and adaptation measures of climate change impacts on ecosystem services of West Lake

Climate change will put negative impacts on ecosystem services of West Lake. The issue is: should preserve/restore the natural biodiversity of the West Lake, as wetland. The best way, in view of this research is: to conserve the maximum biodiversity, minimize and adapt to climate change while limiting human activities affecting the natural biodiversity/ecosystem of West Lake. Here are the proposed actions in this direction:

- Making a system of floating treatment wetlands and near coast wetlands.
- Removing the toxic microalgae.
- Destroying/catching the invasive aquatic species.
- Reconstructing 3 islands in the centre of the lake as formerly.
- Making the lotus plantation and submerged aquatic plants as formerly.
- Better bio-manipulation of lake.
- Integrating lake and water management.
- Enhancing the community participation.
- Adaptation with climate change by construction. The canal connecting with Red river – sustainable biodiversity development.

4. CONCLUSION

West Lake is one of the most famous natural lakes in Vietnam, so the locations around West Lake always attracts a large number of visitors. West Lake has high level of biodiversity and there are four ecosystem services groups in which the group of cultural services is crucial. Climate change affecting the ecosystem services of West Lake has made them degradation. If combined with the inadequate economic, social and cultural activities of human, the ecosystem services that West Lake supports is likely to be at risk and destroyed by the end of the 21st century. To better preserve ecosystem services of the West Lake, a set of actions has been proposed and should be implemented.

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O7-7

Which of zebrafish or Japanese medaka is suitable for the WET test for the evaluation of sewage effluent?

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Keywords: Whole Effluent Toxicity (WET), Zebrafish (*Danio rerio*), Japanese medaka (*Oryzias latipes*), Sewage treated water

ABSTRACT

To establish the whole effluent toxicity (WET) test specific to evaluation of sewage effluent, we examined the sensitivities of Zebrafish (*Danio rerio*) and Japanese medaka (*Oryzias latipes*). In the test of sensitivities to three chemicals (nickel chloride, ammonium chloride, and sodium hypochlorite), differences of NOEC values by these two fishes were the extents of 0.5-2 fold. These results showed that the sensitivities to chemicals were similar in *D. rerio* and *O. latipes*. In the WET test for the sewage effluent, NOEC values of the influent were the same (40%) as *D. rerio* and *O. latipes*. The NOEC value was over 80% in the test of second effluent using *D. rerio.* On the other hand, the NOEC value of secondary effluent could not be obtained from the test by *O. latipes*, because surface of eggs allowed microorganisms to grow in water samples diluted in 20 and 40%. From these reasons, we suggest that *D. rerio* is recommended to be used to evaluate wastewater in the WET assay.

1. INTRODUCTION

The whole effluent toxicity (WET) test is useful to evaluate effluents from the two points of view; firstly, the WET test can evaluate chemical toxicities including unknown compounds, while conventional methods using chemical analysis are restricted to detect known chemicals. Another is that WET test can evaluate multiple-chemical effects by using biological responses. In the late 20th century, the U.S. EPA has started WET test to monitor effluents, and the method has been followed by many other countries including Canada and Germany to protect environments from pollutions. Recently, Japanese government is considering the application of WET test for environmental conservation [1]. The WET test is suitable for evaluating wastewater because various kinds of pollutants are discharged into sewage treatments from many sites such as residential and industrial areas.

Zebrafish (*Danio rerio*) and Japanese medaka (*Oryzias latipes*) are recommended to evaluate water samples in WET test [1]. In acute toxicities, *D. rerio* have similar sensitivities to *O. latipes* [2]. However, there are few reports on comparisons of chemihal-sensitivities between *D. rerio* and *O. latipes* in subchronic toxicity test used in WET test. Because WET test using fishes takes a lot of time and labor, more convenient methods are needed to promote WET test for evaluation of sewage treated water.

Here, we examined sensitivities of three chemicals (nickel chloride, ammonium chloride, and sodium hypochlorite) using *D. rerio* and *O. latipes* firstly. To establish the WET test method specific for evaluation of sewage treated water, secondly, influent and secondary effluent water were examined using *D. rerio* and *O. latipes.*

2. METHOD

D. rerio and *O. latipes* were obtained from the National Institute for Environmental Studies in Japan (NIES).

For chemical test, nickel chloride (3.75, 7.5, 15, 30 mg/L), ammonium chloride (12.5, 25, 50, 100, 200 mg/L), and sodium hypochlorite (chloride concentration; 0.03, 0.06, 0.125, 0.25, 0.5, 1.0 mg/L) were used in this experiment. We examined the water quality base on the WET test [1]. In each beaker, 10 eggs and 50 ml test solution were added, and incubated for 8 (*D. rerio*) and 13 (*O. latipes*) days, respectively (Experiments were carried out until 5 days after hatching). Four replicates were performed for each treatment and control. Hatch of eggs and viability rate of larval fish were documented every day. All the beakers were stored in an incubator at 26±1°C (*D. rerio*) and 24 ±1°C (*O. latipes*), respectively. Exchanging water was performed every other day.

Wastewater samples (influent and secondary effluent) were obtained from a waste water treatment plant employing conventional activated sludge process in November 2017. The water samples were filtered with 60 μm mesh and stored at a dark cold place (4°C). Secondary effluent was used after treatment with chlorine (2.5 mg/L) for 30 min to simulate final effluent. Eggs of *D. rerio* and *O. latipes* were exposed to each diluted wastewater (0% (control), 10%, 20%, 40%, and 80%). Dechlorinated water was used to dilute water samples and control.

Experimental conditions were the same as the above method.

Statistical analysis was performed using the statistical package R [3]. The homoscedasticity of viability and hatching rate were examined by Bartlett test ($p<0.05$). Statistically significances were evaluated using Dunnett test ($p<0.05$), because of the rejection of homoscedasticity in the all tests. The highest concentration with no differences between a samples and control was determined as the No Observed Effect Concentration (NOEC).

3. RESULTS and DISCUSSION

Comparisons of sensitivities for three chemicals (nickel chloride, ammonium chloride, and sodium hypochlorite) between *D. rerio* and *O. latipes* were examined based on hatching and survival rate. As shown in Table 1, NOEC values calculated from survival rates were lower than those of hatching rates both in *D. rerio* and *O. latipes*. These results suggest that egg has more chemical tolerance than larval fish. Differences of NOEC values by two fish-species were the extents of 0.5-2 fold, though NOEC value were different among chemical types in these fishes (Table 1). These results suggest that sensitivities to chemicals were similar in *D. rerio* and *O. latipes*.

Table 1 Comparison of NOEC values for three chemicals derived from *D. rerio* and *O. latipes*

Chemical	NOEC from hatching	NOEC from viability
	D. rerio / *O. latipes*	*D. rerio* / *O. latipes*
Nickel chloride	30 mg/L> / >30 mg/L	15 mg/L / 7.5 mg/L
Ammonium chloride	100 mg/L />200 mg/L	25 mg/L / 12.5 mg/L
Sodium hypochlorite*	1.0 mg/L> / 0.5mg/L	0.5 mg/L / 0.5 mg/L

* Total chlorine concentration

Interestingly, characteristics of chemical sensitivities were observed in hatching times of *D. rerio* and *O. latipes*. Delay in hatching was observed in *D. rerio* treated with nickel chloride, which was not observed in *O. latipes*. Acceleration in hatching was observed both in *D. rerio* and *O. latipes* treated with sodium hypochlorite. These results may suggest that hatching time is important factor to judge water quality in addition to conventional criteria including hatching and survival rate.

Water samples of influent and secondary effluent (addition of chlorine 2.5 mg/L) taken from a wastewater treatment plant were evaluated by the WET test using *D. rerio* and *O. latipes* (Fig. 1). Both NOEC values of the influent were the same (40%) between *D. rerio* and *O. latipes*. The NOEC value of secondary effluent was over 80% derived by the test of *D. rerio*. On the other hand, it was difficult to obtain the NOEC value of secondly effluent from the test of *O. latipes* because treatment with 20 and 40% diluted secondary effluent resulted in annihilated eggs, though 80% diluted secondary effluent was not effect on them. These results may be due to the differences in the hatching time between *D. rerio* (8-9 days) and *O. latipes* (13-14 days). Low concentrations of chlorine may be a reason of microorganism growth on egg membrane, though further studies are needed to appear these phenomenon.

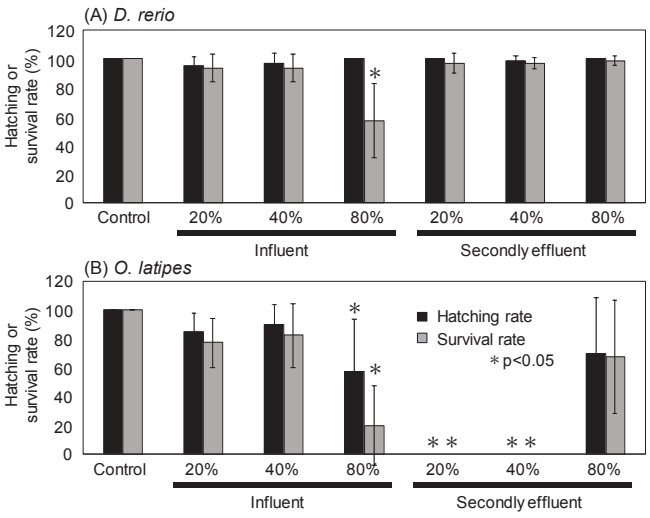

Fig. 1 Evaluation of wastewater samples (influent and secondary effluent) using *D. rerio* and *O. latipes*

4. CONCLUSION

Our study demonstrated that sensitivities of *D. rerio* exposed to chemicals are similar to those of *O. latipes*. Egg haching of *D. rerio* was more stable than that of *O. latipes* both of the cases in the treatments with standard chemicals and actual wastewater. From these reasons, *D. rerio* is recommended to be used to evaluate wastewater in the WET assay.

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O7-8

Effects of Sediment and Water Quality on Antioxidant Response of Brackish Bivalve *Corbicula Japonica*

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Keywords: Clay/silt, *C. japonica*, Multiple regression analysis, ORAC, Salinity, Turbidity

ABSTRACT

This paper deals with field experiments conducted in actual brackish environment (Hinuma lake/river and Naka river) to investigate the effects of sediment and water quality on antioxidant capacity of *Corbicula japonica*. For sediment experiments, clams were cultivated on sediments with adjusted contents of clay/slit (3.7, 20.2 and 33.1%). For water quality experiments, clams were placed in water of totally five sites. It is observed that sediment with clay/silt content of 33.1% decreased in oxygen radical absorbance capacity (ORAC) within two weeks, while sediments with those of 3.7 and 20.2% had no changes. The results indicate that the effects of sediment with up to ~20% of clay/silt content can be neglected on ORAC assay. On the other hand, Naka river had a large variation in salinity, which was different salinity condition to Hinuma lake/river. ORAC assay showed that there were significant differences between Naka River and Hinuma River (p<0.05). To estimate the water quality parameters that affect ORAC, multiple regression analysis was carried out. The results revealed that ORAC values were affected by variations in salinity and turbidity. In particular, variations in the two parameters during the past two days determined ORAC of brackish bivalve *C. japonica*.

1. INTRODUCTION

Recently for environmental assessments, application of biomarkers is becoming an important topic in aquatic organisms as indicators of pollution effects [1]. For sustainability of ecosystem, countermeasures and technologies based assessment is required. Oxygen radical absorbance capacity (ORAC) has been widely accepted as a biomarker for the direct assessment of antioxidant capacity. The ORAC assay measures peroxyl radical–induced oxidations of a fluorescent probe through the change in its fluorescence intensity with a microplate reader. This enables rapid and simple assessment of total antioxidant capacity.

There are limited findings on the effects of sediment and water quality on antioxidant capacity of bivalves in brackish environment. Present study focuses on brackish water clam *C. japonica* [2] available in Hinuma lake/river and Naka river. The research objectives can be described as follows; (1) to investigate the effects of different sediment composition on ORAC; and (2) to find out the water quality parameter affecting on ORAC.

2. MATERIALS AND METHOD

2.1 Experimental conditions and sampling

2.1.1 Sediment experiment

Field experiment was carried out in Hinuma lake from October to December 2017. Plastic cage (35×65×30cm) of three different sediment particles of (3.7, 20.2 and 33.1%) were fixed in the site. These sediment particles were obtained by blending bottom quality of the field (experiment site) and clay sediment obtained from Naka river shown in Table 1. For each run, 50 individuals were placed, out of which 10 individuals were taken out once in every two weeks. 5 individuals were used for ORAC analysis and others for NADH analysis. Both analyses were conducted for six weeks from the start of experiment.

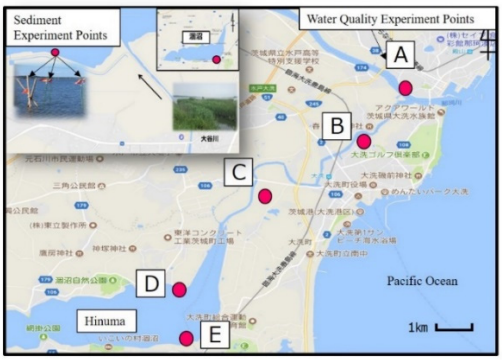

Fig. 1 Experimental site

Table 1. Composition of sediment for experiment

No.	Clay / silt content (%)	Ignition loss (%)
Run 1	3.7	2.8
Run 2	20.2	20.2
Run 3	33.1	10.4

2.1.2 Water quality experiment

Field experiment was conducted at the survey points A, B, C, D and E shown in Fig. 1 from October to November, 2017. Clams were placed in a basket once every two weeks on each survey points for ORAC and NADH assays. At the same time, water quality parameters such as temperature (°C), Salinity (psu), DO (mg/l), Turbidity (FTU) and chlorophyll a (µg/l) were measured every 30 minutes interval at the survey points A, C, D and E.

2.1.3 Biochemical analysis

Each soft tissue of five clams was homogenized in 20mL of buffer solution (20mM Tris-HCL, 1mM EDTA, 50mM KCl) for 1min (GLH-115, Yamato Scientific, Tokyo) and centrifuged at 10,000g for 10min at 4°C. The supernatant was subjected to total antioxidant capacity and protein assays as a sample. Total antioxidant capacity was assayed as ORAC [3] with minor modification. 30µL of sample was added to each well and mixed with 150µL of fluorescein (40nM) as a fluorescent probe and 60µL of 2,2-azobis (2-amindinopropane) dihydrochloride (AAPH) (100mM) as a source of peroxyl radicals. Fluorescence was continuously measured with a microplate reader (Infinite F200 PRO, Tecan Japan, Tokyo). Total antioxidant capacity was expressed as micromoles of trolox equivalent per milligram of protein [4]. Protein was quantified by the Bradford method [5] using a Protein Assay CBB Solution (Nacalai Tesque, Kyoto, Japan). Oxygen Radical Absorbance Capacity is given by the following equation;

$$\text{ORAC (µmol-TE/mg-Protein} = \frac{Sample\ Area}{Trolox\ Area} \times \frac{Trolox\ Concentration}{Sample\ Value} \times \frac{Dilution\ Factor}{Protein} \quad \text{eq (1)}$$

2.1.4 Statistical analysis

Water quality data at the survey points A, C, D and E were analysed by principal component analysis and cluster analysis. To understand the independent water quality variables affecting ORAC, each water quality variable; average, standard deviation, maximum, minimum and median were calculated as 1 day, 2 days and 3 days before the measurement day of ORAC respectively and then ORAC and the extracted water quality data were subjected to multi-regression analysis. Tukey's test was conducted to detect significantly different means (p<0.05).

3. RESULTS AND DISCUSSION

3.1 Sediment and ORAC in *C. japonica*

The three-different composition of sediment particle with respect to ORAC is shown in Fig. 2. Sediment particle that of 33.1 % decreased in ORAC, while those of 3.7% and 20.2% had no changes. It was revealed that the influence of bottom sediment up to ~20% of clay/silt content can be neglected in ORAC assay for *C. japonica*.

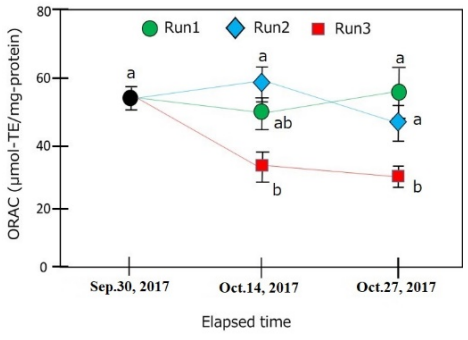

Fig. 2 Antioxidant Response to Sediment

3.2 Water quality characteristics and ORAC responses

3.2.1 Evaluation of water quality parameters

Remarkable variation in salinity at points A and C was observed as shown in Fig. 3. Also, turbidity was seen highest at points C, D and E. It rapidly increased in approximately one-week span. Chl.a, was seen highest at point E. Principle component analysis and cluster analysis demonstrated that points D and E were found to have similar characteristics and points A and C have a separate feature. In terms of salinity, the average value is almost same at points A and C. Value of turbidity at point C have greater influenced than point A. Also, the value of standard deviation shows that points A and C have high salinity variation compared to the points D and E. Value of Chl.a was seen higher at points D and E. This is due to the growth of phytoplankton in Hinuma lake as compared to rivers.

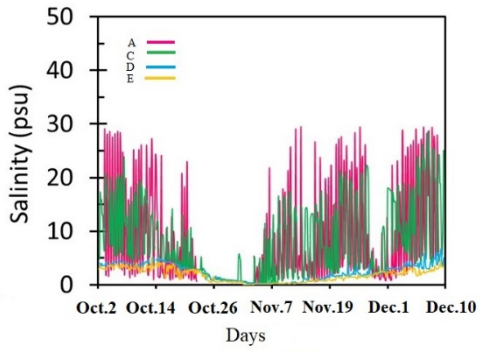

Fig. 3 Salinity variation in experiment points

3.2.2 Impacts of water quality factors on ORAC

The differences in ORAC were found in experimental sites (Fig. 4). Significant difference (p<0.05) was observed in ORAC value at points A and C in the brackish river zones where salinity variation was large. Multi-regression analysis revealed that two water quality factors salinity and turbidity were the most affective to ORAC. The highest value of R^2 was observed in 2 days (R^2 = 0.87) analysis, compared with 1 day (R^2 = 0.49) and 3 days (R^2 = 0.43) analyses. t values were highest in salinity and turbidity that suggests variable highest impact on ORAC.

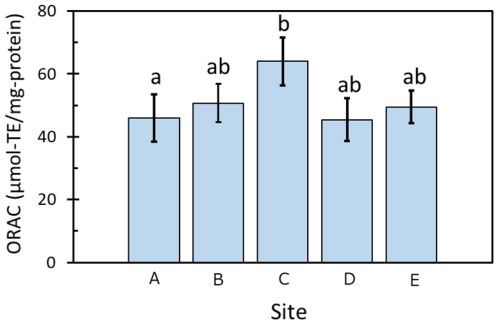

Fig. 4 Differences in ORAC in experimental sites

4. CONCLUSIONS

Clay/silt content of sediment is very important to evaluate the responses of ORAC in *C. japonica*. Also, salinity and turbidity have an influence on ORAC responses. Particularly, variations in the two parameters during the past two days determined ORAC values. We conclude that natural environmental factors should be considered in ORAC assay for *C. japonica*.

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O7-9

汽水域における自然的・人為的水質要因がヤマトシジミの成長力に及ぼす影響

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キーワード：汽水性二枚貝, 成長力, 総抗酸化力, 水質汚濁, 都市下水

抄録

汽水域の自然的水質要因として浮遊物質（SS），塩分，水温，人為的水質要因として都市下水（5 倍希釈）の 4 要因各 2 水準を組み合わせた合計 16 系をヤマトシジミに実験的に与え，成長力と総抗酸化力を評価した．その結果，成長力に対しては，都市下水（5 倍希釈）の単一効果が認められた。また，塩分と都市下水の交互作用も認められた。塩分が時間変動する汽水域において，都市下水の影響が加わると，ヤマトシジミの成長力に対して複合的な影響を及ぼすことが明らかとなった．また，自然的水質要因に曝されたヤマトシジミの成長力と総抗酸化力の間には負の相関がみられた。一方，自然的水質要因に都市下水の影響が上乗せされた条件では，両者には明確な相関がみられなかった。

1. はじめに

欧州では沿岸海域の包括的な環境影響評価のために，水生生物の生体内バイオマーカーを用いた調査が行われている[1), 2)]。環境ストレスを受けた生物は，生体内に生成される過剰な活性酸素種を除去するために，抗酸化成分を合成する[3)]。この抗酸化成分は，抗酸化力の指標（ストレスバイオマーカー）として評価されている。近年では，簡便な蛍光分析に基づく ORAC（Oxygen Radical Absorbance Capacity）法を用いた研究も行われている[4), 5)]。

汽水域では，自然的水質要因と人為的水質要因が生物に対して複合的に作用していると考えられる。こうした複合作用を明らかにできると，水生生物保全に基づく水環境評価に繋げられると考えられる。また，抗酸化力等の生化学レベルの応答を生体成長等の個体レベルの応答と関係づけることができると，抗酸化応答に対する理解や解釈が可能になる。

海洋性二枚貝の成長力を評価する手法として，SFG（Scope for growth）法が提案されている[6)]。生体成長を評価するためには年月を要するが，SFG 法では数時間で成長に利用できるエネルギーを成長力として評価することができる。しかし，既存の方法[8)]では測定項目が多いことから，著者らはこれまでに炭素収支に基づく成長力評価手法を検討してきた[7)]。

そこで本研究では，筆者らが確立した炭素収支に基づく簡便なヤマトシジミの成長力評価手法を用いて，汽水域の自然的・人為的水質要因がヤマトシジミの成長力に及ぼす要因や複合作用を明らかにした。さらに，成長力と総抗酸化力などの生体内バイオマーカーとの関係を整理した。

2. 方法

2.1 炭素収支に基づく成長力評価手法

炭素収支に基づく成長力評価手法では，ヤマトシジミが摂取または排出する炭素量を測定した。**式 1** に示すように，摂餌（C）による炭素摂取量と擬糞（P），排泄（U），呼吸（R）による炭素排泄量をそれぞれ実験に基づいて算出し，その差分を成長力（SFG）として評価した（**図 1**）。 SFG>0 であれば摂取した炭素を成長に使用可能であり，SFG<0 であれば炭素を成長に使用できない環境であると判断できる。

$$SFG\ (\mu gC/individual \cdot h) = C - (P + U + R) \qquad (1)$$

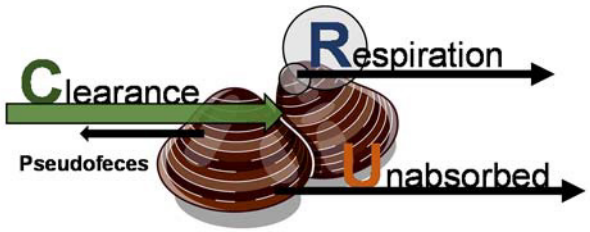

図 1 炭素収支に基づく成長力評価手法の概念図

(1) 摂餌実験

有効容積 4.5 L プラスチック製容器に，培養珪藻類 20 mg-SS/L に調整した人工海水 3 L とヤマトシジミ 30 個体を投入し，循環ポンプを用いて十分に曝気と攪拌を行った。実験中はウォーターバスの中で水温を一定にした。

事前検討により，ヤマトシジミが摂餌中に排泄する擬糞は試験水中に拡散すると，摂餌量の測定に影響を及ぼすことが明らかとなっている。そのため，擬糞の拡散を防ぐために，ヤマトシジミは開き目 50 μm のプランクトンネットに入れて実験を行った。プランクトンネット内で捕集した擬糞は採取後，超純水を加えてホモジナイズ処理し，全有機炭素（TOC）を測定した。そして，この擬糞由来の TOC をヤマトシジミの排泄量とした。ヤマトシジミを投入した時間を実験開始時刻とし，1 時間で減少した粒子態炭素（POC）量を摂餌量とした。

(2) 排泄実験

摂餌実験で使用したヤマトシジミをよく拭き，0.5 L の人工海水に投入した。実験中は水温を一定に保ち，

十分に曝気を行った。ヤマトシジミが排出する糞（POC）を排泄量とした。

前検討より，糞（POC）は 1 時間程度で溶出率が高くなり，排泄量の過小評価となることが明らかとなっている。そのため，炭素溶出率の低い 30 分毎に試験水を交換し，既存の方法と同様に 1 時間の排泄量を算出した。

(3) 呼吸実験

アルミホイルで遮光した 1L 三角フラスコにヤマトシジミを 30 個体投入後，珪藻類 20 mg-SS/L に調整し十分に酸素を溶存させた人工海水を満水まで投入し密閉した。実験中は水温を一定に保った。密閉した時刻を実験開始時刻とし，1 時間で増加した溶存無機炭素（DIC）量を呼吸による炭素排出量とした。採水した試料への CO_2 溶解を防ぐために，流動パラフィンを試料に重層した。そして，すみやかに DIC を分析した。事前の検討により，流動パラフィンを使用することによる試料の DIC は変化しないことを確認している（p>0.05）.

2.2 汽水域の自然的水質要因と都市下水に対する成長力の応答実験

室内水槽で飼育しているヤマトシジミ（殻長 : 20.5 ± 1.5 mm）90 個体を水温 20 ℃，塩分 10 psu の実験水槽に移し，室内培養している珪藻類を 1 日 1 個体あたり 1 mg-SS となるように 1 時間毎に等分量を給餌して馴致した。馴致後，汽水湖の自然的水質要因として餌源（SS），水温，塩分と人為的水質要因として都市下水（5 倍希釈）の濾水の合計 4 要因各 2 水準の組み合わせで合計 16 系の室内実験を実施した。実験条件を**表 1** に示す。各系 3 日間暴露した後，成長力と総抗酸化力（ORAC）を評価した。ORAC 分析は既報 [5]に従った。応答実験の期間は，事前の検討実験の結果に基づいて決定した。応答実験期間は馴致時と同様に，培養珪藻類を給餌した。都市下水は人工海水で 5 倍希釈した。

要因の主効果および交互作用を明らかにするために実験計画法を用いた。条件の割付には $L_{16}(2^{15})$直行表を用いた。分析にあたり，各要因のみの効果（主効果）および 2 因子間の複合作用（交互作用）をみることとし，3 因子以上の交互作用は誤差 e として扱った。

3. 結果と考察

3.1 汽水域の自然的水質要因と都市下水に対する成長力の応答

図2に汽水域の自然的水質要因と都市下水に対する炭素収支と成長力を示す。自然的水質要因に上乗せして都市下水を与えた系は，自然的水質要因のみを与えた系と比較して摂餌量がより少なくなる傾向がみられた。一方で，排泄量や呼吸量はより多くなる傾向がみられた。その結果，成長力が抑制される傾向を示した。つまり，都市下水はヤマトシジミの成長に対して負の影響を与えていることがわかった。また，餌源（SS）の給餌量が少ない系（Run9～16）は，給餌量の多い系（Run1～8）と比較して，摂餌量が少なくなり，成長力も低く見積もられる傾向がみられた。高塩分の系（Run5～8，Run13～16）の系と比較して低塩分の系（Run1～4，Run9～12）の成長力は，低く見積もられる傾向がみられた。ヤマトシジミは濾過摂食性の二枚

表 1 汽水湖の水質に対する成長力・総抗酸化力の評価実験条件

Run	Feeding (mgSS/ind.d)	Sal. (psu)	Water Temp. (℃)	W.W (DF=×5)	Run	Feeding (mgSS/ind.d)	Sal. (psu)	Water Temp. (℃)	W.W (DF=×5)
1	5	5	25	−	9	0.5	5	25	−
2	5	5	25	○	10	0.5	5	25	○
3	5	5	15	−	11	0.5	5	15	−
4	5	5	15	○	12	0.5	5	15	○
5	5	20	25	−	13	0.5	20	25	−
6	5	20	25	○	14	0.5	20	25	○
7	5	20	15	−	15	0.5	20	15	−
8	5	20	15	○	16	0.5	20	15	○

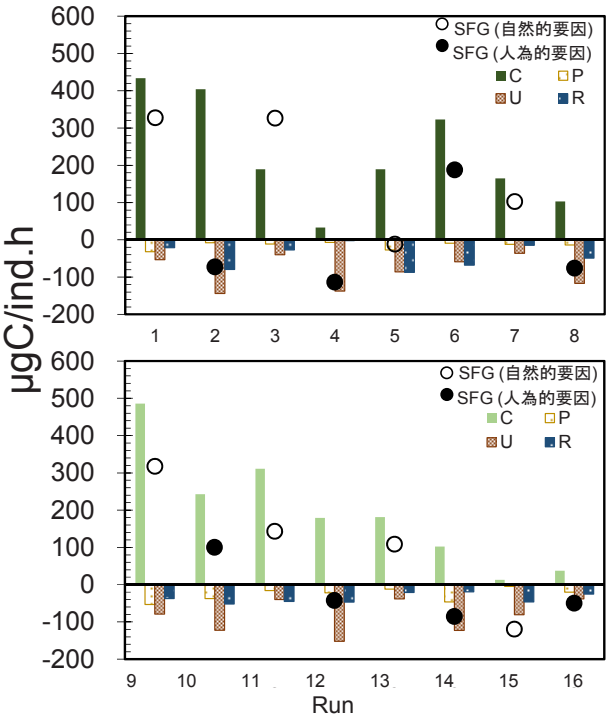

図 2 汽水域の自然的水質要因と都市下水に対する成長力の応答

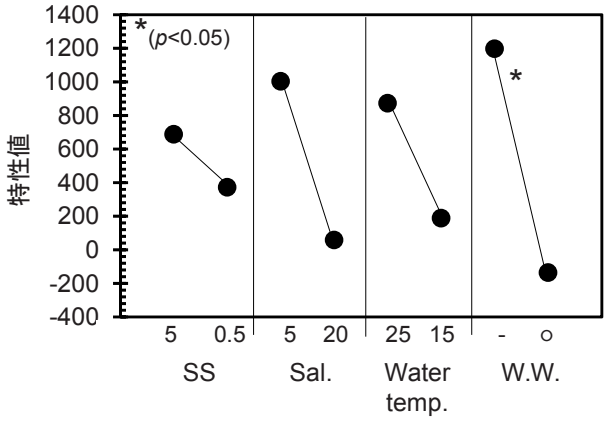

図 3 効果推定図

貝であり，開殻をともなった給水とともに，摂餌や呼吸を行う[9]。しかし，高塩分に曝されると開殻する時間が短くなる[10]。ヤマトシジミは高塩分に曝されて開殻する時間が短くなり，炭素摂取量が少なくなったと考えられる。

以上のことから，確立した成長力の評価手法を用いると各要因やそれらの組み合わせによって成長力に違いがみられた。水質要因が成長力に及ぼす影響にはおおよその傾向がみられたが，条件の組み合わせによってその傾向とは異なる応答も確認できた。これは，水質要因を組み合わせることによる複合作用の効果であると考えられる。

3.2 水質要因が成長力に及ぼす効果と複合作用

成長力の応答値を各要因の水準毎に累積して算出する特性値に基づいて，要因がヤマトシジミの成長力に及ぼす効果の有意性を判断した。効果推定図を**図 3** に示す。成長力は 5 倍希釈した都市下水に影響を受けることが明らかとなった（p<0.05）。池田ら（2017）[11]は，10 倍希釈の都市下水に曝したヤマトシジミの細胞に損傷が起こることを明らかにしている。本実験で条件として与えた 5 倍希釈の都市下水も，ヤマトシジミに負の影響を与えていると考えられる。一方で，SS や塩分，水温の影響は受けないことがわかった（p>0.05）。

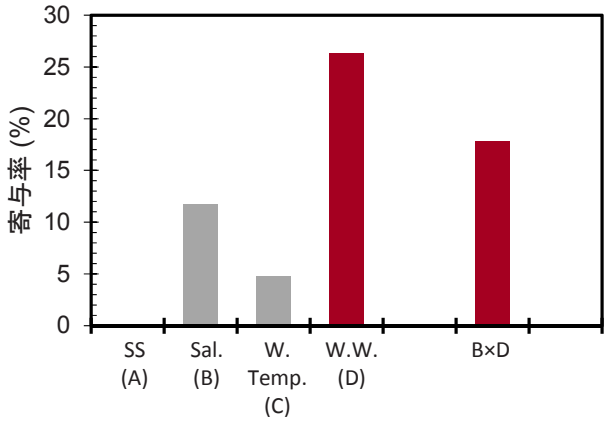

図 4　成長力に対する汽水域の自然的水質要因と都市下水の寄与率

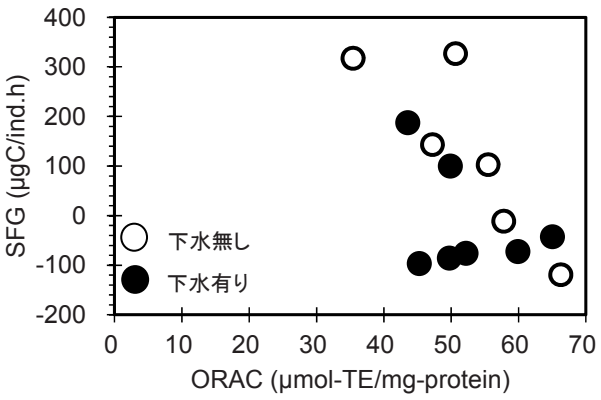

図 5　成長力と総抗酸化力の関係

また，各要因の主効果に加えて要因間の複合作用を明らかにするため，交互作用も考慮した分散分析を行った。成長力に対する効果の分散分析結果とその寄与率をそれぞれ**図 4** に示す。成長力は都市下水の主効果及び都市下水と塩分の交互作用を受けることが明らかとなった（p<0.05）。自然的水質要因の一つである塩分に主効果はないものの，都市下水に曝された場合は交互作用が発生し，塩分も成長力に影響を与える要因となることが明らかになった。

3.3 成長力と生体内バイオマーカーの関係

図 5 に SFG と総抗酸化力（ORAC）の関係を示す。ORAC が高くなると成長力は低くなる傾向を示した（p<0.05）。ここでは，成長力に寄与する都市下水の有無に着目してみる。自然的水質要因にのみ曝した系では，ORAC と SFG に強い負の相関性が得られた（p<0.01）。一方で，都市下水に曝した系では，ORAC と SFG には相関がみられなかった（p>0.05）。二枚貝はアンモニアに曝されると体内の活性酸素種の生成が促進されることが知られている[12]。より多くの活性酸素を消去するために抗酸化成分が消費されて，合成した抗酸化成分を維持することができず，ORAC 値が低くなったものと考えられる。このように，成長力と総抗酸化力の関係から ORAC の解釈が可能になると考えられる。

4. 結論

本研究では，炭素収支に基づく成長力評価手法をヤマトシジミに適用し，汽水域の水質がヤマトシジミの成長力に及ぼす影響を調べた。また，ヤマトシジミの総抗酸化力（ORAC）と成長力の関係を整理した。得られた知見を以下に示す。

1) 自然的水質要因（SS，塩分，水温）はヤマトシジミの成長力に影響しなかったが，都市下水（5 倍希釈）は影響を及ぼした。また，成長力に対して，塩分と都市下水の交互作用が確認された。
2) ヤマトシジミの成長力と総抗酸化力の間にはおおむね相関がみられた。ただし，都市下水が存在する場合については，今後さらに整理する必要がある。

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O7-10

題名:製鋼スラグを用いた藍藻類沈降処理法の検討

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キーワード:製鋼スラグ, *Microcystis aeruginosa*, *Daphnia magna*, 酸抽出液,遊泳阻害試験

抄録

閉鎖性水域の富栄養化により引き起こされる藍藻類の大量発生(アオコ現象)は, 景観の悪化, 魚の斃死, 水道水のろ過障害による経済損失を引き起こすため, 改善が求められている. 本研究では, 製鋼スラグから抽出した成分(抽出液)によって, 藍藻類 *Microcystis aeruginosa* への沈降効果の有無を検証した. 同時に, 藍藻類への沈降効果が現れる添加量の検討も実施した. さらに, 製鋼スラグからの抽出液による水生生物への影響を確認するために, *Daphnia magna* を用いた遊泳阻害実験を実施した. 藻類沈降実験の結果, 製鋼スラグでは, 酸抽出中和液 0.8 mL を添加したときに高い沈降除去効果を得られた. *Daphnia magna* を用いた遊泳阻害実験の結果, 製鋼スラグ酸抽出中和液において影響が無いとは言えなかった. これより,製鋼スラグを用いた藍藻類の沈降処理が可能であることが提案できたが, 実用するためには毒性を弱める工夫が必要となる.

1. はじめに

閉鎖性水域の富栄養化により引き起こされる藍藻類の大量発生(アオコ現象)は, 景観の悪化, 魚の斃死, 水道水のろ過障害による経済損失を引き起こすため, 改善が求められている[1][2]. 現状のアオコ対策では, ほぼ全てが湖沼付近に施設建設が必須であり, 維持管理コストがかかることが問題点として挙げられる[3]. しかしながら, 中国の大湖で$\mathbf{Mg(OH)_2}$を散布することでアオコの沈降が報告されたことや[4], PAC(ポリ塩化アルミニウム)とカゼインを用いて, *Microcystis aeruginosa* を凝集除去できた報告[5]があることから, 閉鎖性水域に薬剤を散布する対策が有効であると考えられる. また, 鉄を用いた凝集沈殿も実施されており, ポリシリカ鉄(PSI)を用いて懸濁質を凝集させた報告がある[6]. そこで本研究では, 薬剤と比較してより安価に入手が可能であり, 既存研究より沈殿凝集に寄与する可能性がある Mg, Al, Fe を含む産業廃棄物である製鋼スラグに着目し, その中に含まれる成分により沈降除去が可能であるかを実験室にて検討することにした. また, 閉鎖性水域への散布を仮定した場合, 水生生物への影響が懸念される. そこで本研究では, 動物プランクトンである *Daphnia Magna* を用いて影響評価を行うことで, 産業廃棄物中の成分が生態系に及ぼす影響を評価した.

2. 実験方法

2.1 藻類沈降実験

まず, 製鋼スラグを用いて藻類の沈降除去が可能であるかを検証するために, 藻類沈降実験を実施した. 表 1 に示す異なる形態の製鋼スラグを, 藻類懸濁液 50ml が入っている試験管に添加することで, 沈降効果の有無を検討した. 実験条件は, 対数増殖期に該当している *Microcystis aeruginosa*(NIES-102 株)の細胞を使用した. また, 初期クロロフィル a 濃度を 1,500~2,500 μg/Lとした. 添加後 1, 2, 24 時間後の水温, pH, 藍藻類の細胞を含んでいる懸濁液(以下藻類懸濁液とする)の上澄み 10 mL におけるクロロフィル a 濃度を測定した.

表 1 添加方法

ケース1	直接添加
ケース2	水抽出産廃混液-中和後懸濁液 (以下水抽出中和液)
ケース3	酸抽出産廃混液-中和後懸濁液 (以下酸抽出中和液(A液))
ケース4	酸抽出ろ液-中和後懸濁液 (以下酸抽出中和液(B液))
ケース5	酸抽出ろ液-中和後ろ液 (以下酸抽出中和液(C液))
ケース6	酸抽出ろ液-中和後ろ過物懸濁液 (以下酸抽出中和液(D液))

次に, 藍藻類の沈降効果が確認された製鋼スラグの形態について, コスト削減を目的として, 藍藻類の沈降除去が見られる製鋼スラグの最少添加量の推定を実施した. 実験条件は, 初期クロロフィル a 濃度を 500 μg/L に統一し, 水温 25 ℃と設定した. また, 光による沈降効果のばらつきを排除するために暗条件で実験を実施した. 添加後 24, 48 時間後の水質(水温, pH, ORP, 藻類懸濁液の上澄み 10 mL におけるクロロフィル a 濃度)を測定した. 本実験において, 48 時間後の上澄み 10 mL におけるクロロフィル a 濃度が富栄養湖の基準となる 10 μg/L 以下である状態を沈降除去効果があると見なした.

2.2 *Daphnia magna* を用いた遊泳阻害実験

藍藻類の沈降除去効果が確認できた形態において，最少量と推定された前後の量を添加し，水生生物に影響を及ぼさないかを確認することを目的として実施した．実験条件は，温度を 25 ℃，照度を 2500 lux，明暗周期を 16 L/8 D とした．実験には，生後 24 時間以内の *Daphnia magna* の個体を 1 つのコニカルビーカーにつき10匹用いた．*Daphnia magna* に産業廃棄物中の成分を暴露して 0，24，48 時間後に水質(水温，pH，DO)および遊泳阻害が生じた *Daphnia magna* の個体数を測定した．

3. 実験結果と考察

まず，製鋼スラグの形態の違いによる藍藻類沈降実験の結果を表 2 に示す．

表 2 形態の違いによる藻類沈降実験結果

	ケース1	ケース2	ケース3
0.8ml	×	○	○
1.6ml	×	○	○
4.0ml	×	○	○
＼	ケース4	ケース5	ケース6
0.8ml	○	○	×
1.6ml	○	○	×
4.0ml	○	○	×

表 2 より，ケース 2~5 において，沈降効果が確認された．沈降効果が見られた理由として，産業廃棄物に含まれるカオチン(陽イオン)が抽出され，中和の過程で生じた金属水酸化物が藍藻類沈降効果に影響している可能性が考えられる．また，今後の実験結果についてはケース 3 およびケース 4 について記述する．

次に沈降が確認されたケースについて最小添加量の推定実験を実施した．製鋼スラグ酸抽出中和液(A 液)を藻類懸濁液に添加した実験結果を図 1 に示す．

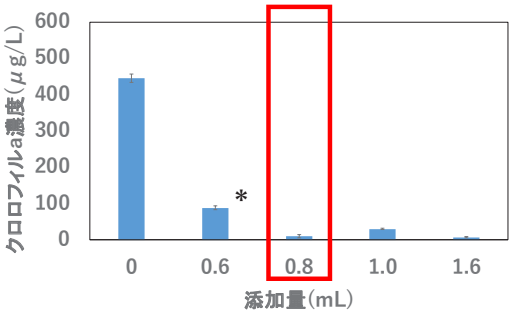

図 1 製鋼スラグ酸抽出中和液(A 液)での実験

(n=2～4, AVE.±S.E.) ＊:Dunnett 法にて 5%有意

製鋼スラグ酸抽出中和液(A 液)を添加した場合において，48 時間後のクロロフィル a 濃度が 10 μg/L 以下を達成している区間は，0.8 mL 添加した場合であった．0.8 mL 添加した場合における 48 時間後のクロロフィル a 濃度を対照区として，多重比較(Dunnett 法)を実施した．製鋼スラグ酸抽出液(A 液)を添加した区間において，0.6 mL 添加した区間と 0.8 mL 添加した区間との間で，有意水準 5%において有意な差が見られた．この結果から，本研究において，藻類の沈降除去効果が見られる製鋼スラグ酸抽出中和液(A 液)の量は，0.8 mL と推定できた．

最後に，遊泳阻害実験を製鋼スラグ酸抽出中和液(A 液)を添加し実験を実施した．添加 48 時間後の反応率(遊泳阻害率)を確認した結果，50mL のカルキ抜き水道水に対して製鋼スラグ酸抽出中和液(A 液)では，1.0 mL において 38.3%を示した．この結果を用いて probit 法を用いることで *Daphnia magna* に対しての EC50 に相当する天下量の推定を実施した．その結果，1.2mL と推定できた．

4. 結論

形態の違いによる藻類沈降実験の結果，産業廃棄物を酸抽出した場合において，高い藍藻類沈降効果が見られる結果となった．このことより，製鋼スラグから抽出したカチオンおよび中和の過程で生じた金属水酸化物が藻類の沈降に強く影響している可能性が示唆された．さらに，藍藻類が沈降した形態において，藻類の沈降除去効果が見られる最少添加量の推定を実施し製鋼スラグ酸抽出中和液(A 液)に関しては，0.8 mL と推定できた

遊泳阻害実験の結果，製鋼スラグ酸抽出中和液において，Daphnia magna に影響を及ぼしたことより，製鋼スラグ酸抽出中和液(A 液)の水生生物に対しての影響は無いとはいえない結果となった．

製鋼スラグを用いた藍藻類の沈降処理が可能であることは提案できたが，実用するためには，毒性を抑える工夫が必要となる．

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O7-11

霞ヶ浦を水源とする新たな浄水処理システムの実証実験（Ⅰ）

－促進酸化処理の処理性及び運転条件の検討－

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キーワード：浄水・排水処理技術

抄録

茨城県企業局では 10 浄水場で用水供給事業を行っており，その内 6 浄水場が霞ヶ浦を取水源としている。この霞ヶ浦は，流域人口の増加や地形的要因等により，1960 年代から富栄養化が進行し，有機物濃度が高い状況で推移していることから，各浄水場においては，夏期のトリハロメタン対策と，冬期から春期に発生するかび臭物質対策が大きな課題となっている。そこで，当局では，2009 年から 2011 年にかけて民間企業との共同研究を実施した結果，帯磁性イオン交換樹脂処理及び促進酸化処理が霞ヶ浦を水源とする浄水処理に有効であると判断した。この結果を踏まえ，霞ヶ浦浄水場に，これらの処理を組み合わせた新たな浄水処理システムの実験プラントを建設し，2014 年 12 月から実証実験を行っている。今回，これまでの実験によって得られた，本処理システムにおける処理効果，特に促進酸化処理の処理性について報告する。

1. はじめに

茨城県企業局が運営する全 10 浄水場のうち 6 浄水場が霞ヶ浦を取水源としているが，富栄養化を起因とする様々な浄水処理障害が生じている。中でも冬期から春期にかけて発生する高濃度のかび臭物質（1993～2017 年における 2-メチルイソボルネオール（以下，「2-MIB」という。）の最大値 910ng/L）への対応，また塩素との反応によってトリハロメタン（以下，「THM」という。）を生成するとともに夏期に高い値となるトリハロメタン生成能（以下，「THMFP」という。）の除去が大きな課題となっている。

このような霞ヶ浦を取水源とする霞ヶ浦浄水場においては前段に生物処理，後段に粒状活性炭処理を導入して対応してきた。しかし，生物処理は維持管理費用が高額であるとともに冬期にその処理性が低下する等の課題があり，また，粒状活性炭処理も年々再生費用が増加する傾向にある。こういった課題に対応するため，当局は 2009 年から 2011 年まで民間企業との共同研究を行い，溶解性有機物（以下，「DOC」という。）の高い除去能を有する帯磁性イオン交換樹脂処理（以下，樹脂処理）と，低水温期においても高いかび臭除去能を有し，かつ臭素酸生成抑制効果を併せ持つ促進酸化処理（以下，「AOP」という。）が有効であると判断した。この結果を踏まえ，既存の凝集沈殿・砂ろ過処理に加え，樹脂処理と AOP を導入することを目的に 2014 年 12 月から実証実験を行っているところである。

2. 実験・調査方法

2.1 実験プラント運転条件等

実験プラントの処理フローは図 1 のとおりである。

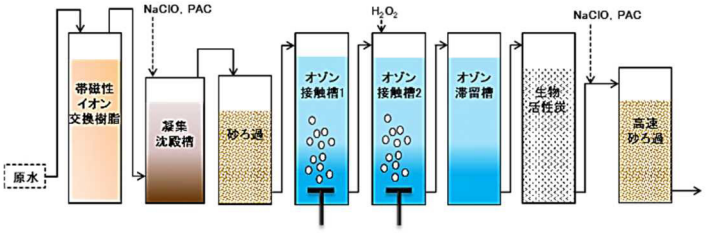

図 1　実証実験における処理フロー

帯磁性イオン交換樹脂は，イオン交換によって原水中の DOC を除去するものであり，塩水で再生し，繰り返し利用が可能である。なお樹脂は，処理水量に対する再生樹脂量の比（BVTR：Bed Volume Transfer Rate）が 10,000 となるよう引き抜き，再生，投入を行った。AOP はオゾンと過酸化水素の併用により，オゾンよりも酸化力の強いヒドロキシラジカルの生成を促進し，有機物の酸化分解力の向上を図るものである。このため，原水におけるかび臭物質濃度が高くなる冬期から春期にかけては AOP を，その他の期間はオゾン単独処理を行うこととした。AOP における過酸化水素の添加はオゾン接触槽

2（図 1）のみとした。なお，過酸化水素はオゾン注入率に対する物質量比（以下，「モル比」という。）で制御し添加しており，オゾン接触槽全体に対する過酸化水素の注入率は式 1 のとおりである。

$$H_2O_2\text{注入率}\ (\text{mg/L}) = \frac{34}{48} \times \text{モル比} \times O_3\text{注入率}\ (\text{mg/L}) \times \frac{1}{2} \quad \text{（式 1）}$$

また，本実験における目標値は，表 1 の通りである。

表 1 実証実験における目標値

項目	対象処理水	目標値
2-MIB	オゾン又は AOP 処理水	1 ng/L 以下
臭素酸	BAC 処理水	0.005 mg/L 以下
THM	高速砂ろ過水	0.03 mg/L 以下
72hrTHM※	高速砂ろ過水	0.07 mg/L 以下

※高速砂ろ過水に次亜塩素酸ナトリウムを添加し，恒温槽で 72 時間静置した後の THM 濃度

2.2 かび臭物質添加実験

当該処理システムにおける高濃度かび臭物質の処理性を調査するため，冬期にかび臭物質添加実験を行った。添加実験は市販の 2-MIB 及びジェオスミン標準品を超純水に溶解し，実験プラントの凝集沈殿槽（図 1）に想定した濃度（冬期 250～2,000ng/L，夏期 10～1,000ng/L）となるように添加し，オゾン注入率（1.0～3.0mg/L）及び過酸化水素のモル比（0～10）を変化させ，かび臭物質の処理性，臭素酸の抑制効果等を調査した。なお，当該実験においては，高濃度かび臭物質による負荷を避けるため，生物活性炭（以下，BAC）処理塔以降へは通水しなかった。

2.3 給水末端を想定した 72hrTHM

給水末端を想定した 72hrTHM 調査を夏期（7~9 月）は月 2 回，他の期間は月 1 回の頻度で行った。なお，72hrTHM は，100mL ガラスびんに高速砂ろ過水を満水に採り，次亜塩素酸ナトリウムを採水から 72 時間後の残留塩素濃度が 0.2mg/L 程度となるように添加し，採水時の水温で暗所で 72 時間恒温静置し THM 濃度を測定して求めた。

3. 結果及び考察

3.1 かび臭物質添加実験

かび臭物質添加実験は前述のとおり 2-MIB 及びジェオスミンを添加して行ったが，ここではより除去性が低い 2-MIB について考察する。2-MIB 添加濃度 1,500ng/L，オゾン注入率 3.0mg/L の条件における，AOP とオゾン単独処理を比較すると，図 2 のとおり，オゾン単独処理では滞留槽で 577ng/L 残留したのに対し，AOP（モル比 5.0）では定量下限値（1ng/L）以下まで処理された。

一方，臭素酸濃度は，図 3 のとおりオゾン単独処理では 0.008mg/L 生成したのに対し，AOP では 0.003mg/L と，半分以下の生成量であった。これらのことから，オゾン単独処理と比べ，AOP の方が 2-MIB 除去能が高く，臭素酸抑制に優れることが明らかとなった。

これらの条件の他にオゾン注入率及びモル比を変化させてかび臭物質添加実験を実施した結果，冬期においては，モル比 5.0，オゾン注入率を 3.0mg/L とすることにより 2-MIB 添加濃度 2,000ng/L まで目標値を達成することが可能であった。

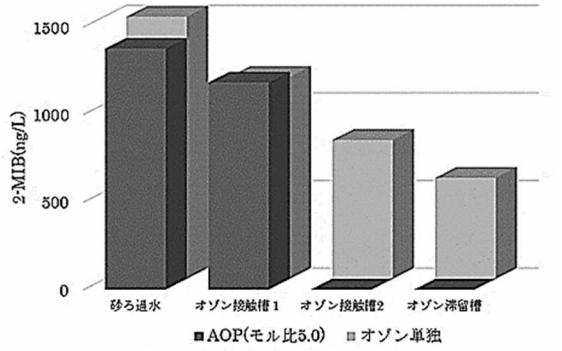

図 2 かび臭添加実験における 2-MIB 除去効果（2-MIB 添加濃度 1,500ng/L，オゾン注入率：3.0mg/L）

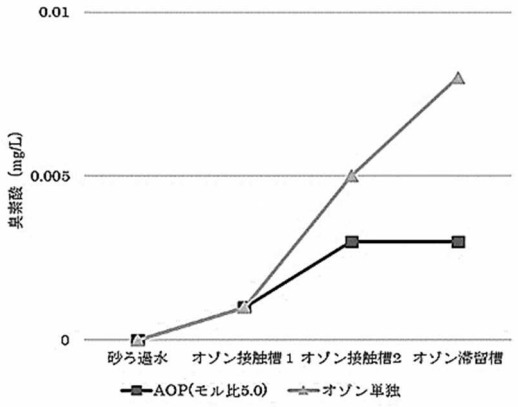

図 3 かび臭添加実験における臭素酸抑制効果（2-MIB 添加濃度 1,500ng/L，オゾン注入率：3.0mg/L）

3.2 72hrTHM 調査等結果

72hrTHM の推移を図 4 に示す。72hrTHM は水温の高い夏期（7~8 月）に高くなり，目標値（0.07mg/L）を超

過する結果となった。また，夏期の 72hrTHM は年々増加傾向にあり，2017 年 7 月には水質基準値（0.1mg/L）を超過した。

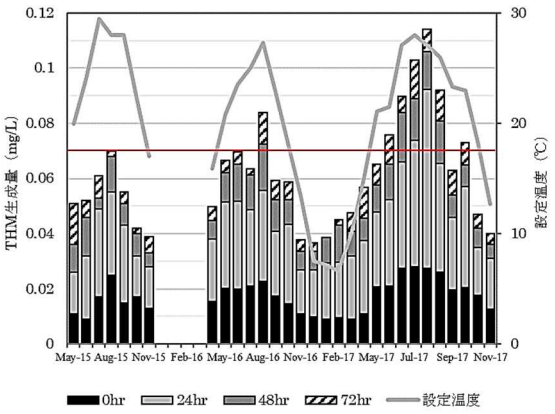

図 4　72hrTHM 調査結果

また，2017 年の夏期にオゾン単独処理と AOP における THMFP の比較結果を表 2 に示す。なお，砂ろ過水の THMFP は，0.036mg/L であった。

表 2　2017 年夏期における THMFP 調査結果

運転条件	AOP	オゾン単独
O_3 注入率(mg/L)	2.5	1.0
モル比	5	―
臭素酸濃度(mg/L)	0.003	0.003
THMFP(mg/L)	0.055	0.033

AOP 及びオゾン単独処理のいずれも臭素酸濃度は 0.003mg/L であった。夏期はオゾン単独処理を基本とするが，夏期に高濃度のかび臭物質が発生した場合は，臭素酸の抑制等の観点から AOP への切り替えが必要になると考えられる。しかし，表 2 のとおり，AOP の方が THMFP が高くなることから，この点について注意が必要である。

3.3　日常運転の結果（かび臭物質，臭素酸）

以上の実験結果を踏まえ，表 3 の運転指標を定め，かび臭物質濃度が高くなる冬期から春期の期間を AOP，その他の期間をオゾン単独処理として，連続運転した。その結果を図 5 に示す。全期間において 2-MIB 及び臭素酸の目標値を概ね達成することができていることから，AOP とオゾン単独処理を適切に切り替えて運転することで，かび臭物質の除去及び臭素酸の抑制が安定的且つ効率的に行えることが明らかとなった。

表 3　実証実験結果に基づく運転指標

かび臭濃度 (ng/L)	水温 (℃)	運転条件	O_3 注入率 (mg/L)	モル比
1,500 以上	10 未満	AOP	2.0~3.0	5~10
500~1,000			2.0~2.5	5
100~500			1.5~2.5	2.6~5
10~100			1.6~2.0	5~10
5~10	10 以上		1.5	2.6~5
1~5		O_3 単独	1.0~1.1	―

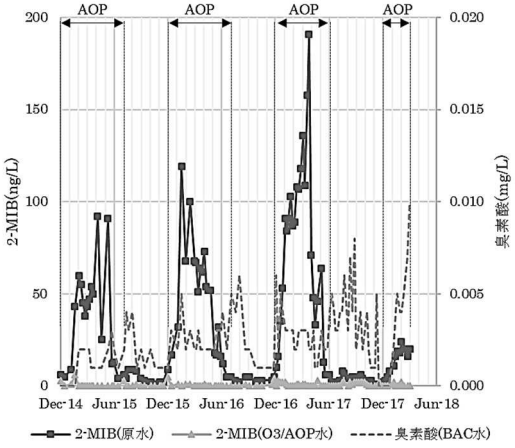

図 5　日常運転におけるかび臭及び臭素酸の推移

4. 結論

かび臭物質添加実験及び 72hrTHM 等の調査から，以下のことが明らかとなった。

(1) AOP はオゾン単独処理と比較して，かび臭物質除去及び臭素酸抑制に優れているが，処理水中の THMFP 及び 72hrTHM が高くなる傾向が見られる。

(2) 冬期においては AOP 処理により臭素酸の生成を抑制しながら最大 2,000ng/L の 2-MIB を除去することが可能である。

(3) 給水末端を想定した 72hrTHM は夏期に目標値を超過しており，さらに経年的に高くなる傾向が見られる。

AOP のかび臭物質除去及び臭素酸抑制に対する有効性は確認できたが，夏期における 72hrTHM の抑制対策が課題である。このため，今後，溶解性有機物の低減対策について検討するとともに，実運転を見据えた運転条件等について検討したいと考えている。

O7-12

霞ヶ浦を水源とする新たな浄水処理システムの実証実験（Ⅱ）

−帯磁性イオン交換樹脂の処理特性−

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キーワード：浄水・排水処理技術

抄録

茨城県企業局では10浄水場で用水供給事業を行っており，その内6浄水場が霞ヶ浦を取水源としているが，霞ヶ浦の富栄養化の進行により，各浄水場では夏期のトリハロメタン対策と冬期のかび臭物質対策が大きな課題となっている。このため，霞ヶ浦浄水場において，帯磁性イオン交換樹脂処理及び促進酸化処理による実証実験を行っているが，帯磁性イオン交換樹脂処理がトリハロメタン生成能の除去に有効であることを確認した。

1. はじめに

茨城県企業局では 10 浄水場で用水供給事業を行っており，その内6浄水場が霞ヶ浦を取水源としている。この霞ヶ浦は，流域人口の増加や地形的要因等により，1970 年頃から富栄養化が進行し，有機物濃度が高い状況で推移していることから，霞ヶ浦を取水源とする浄水場においては，夏期のトリハロメタン対策と，冬期から春期に発生するかび臭原因物質対策が大きな課題となっている。

そこで，茨城県企業局では，2009 年から 2011 年にかけて民間企業との共同研究を実施した。その結果，当局は，帯磁性イオン交換樹脂処理（以下，「樹脂処理」という。）と促進酸化処理が，霞ヶ浦を水源とする浄水処理に有効であると判断した。この結果を踏まえ，霞ヶ浦浄水場に，これらの処理を組み合わせた新たな浄水処理システムの実験プラントを建設し，2014 年 12 月から実証実験を行っているところである。今回，この実験によって得られた樹脂処理の効果について報告する。

2. 方法

実証実験の処理フローは図1のとおり，樹脂処理（124 ㎥/日）→凝集沈殿処理（80 ㎥/日）→砂ろ過処理（50 ㎥/日）→促進酸化（オゾン）処理（40 ㎥/日）→生物活性炭（以下，「BAC」という。）処理（40 ㎥/日）→高速砂ろ過処理（40 ㎥/日）となっており，本実験の目標値は表 1 のとおりとした。

樹脂処理に使用する樹脂は平均粒径 200 μm 程度の磁性を帯びたイオン交換樹脂で，溶解性有機物の選択性が優れるとともに，磁性によって集塊化するため，沈降性に優れる。なお，樹脂（110L）は，処理水量の比（BVTR：Bed Volume Transfer Rate）が 10,000 となるよう一定量引き抜いた（12L/日）。引き抜いた樹脂は，10%塩化ナトリウム水溶液で再生し，繰り返し使用した。

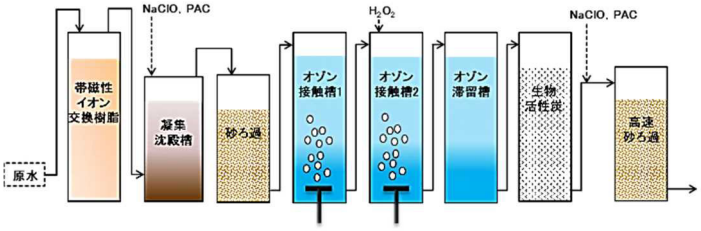

図 1　実証実験における処理フロー

表 1　実証実験目標値

項目	対象処理水	目標値
2-MIB，ジェオスミン	オゾン処理水	1ng/L 以下
臭素酸	BAC 処理水	0.005mg/L 以下
THM	高速砂ろ過水	0.03mg/L 以下
72hrTHM※	高速砂ろ過水	0.07mg.L 以下

※高速砂ろ過水に次亜塩素酸ナトリウムを添加し，恒温槽で72時間静置後の THM 濃度

3. 結果と考察

(1) 樹脂処理の処理性

図2のとおり，原水中のトリハロメタン生成能（以下，「THMFP」という。）は0.054～0.094mg/L で推移したのに対し，樹脂処理水は 0.032～0.068mg/L で推移し，除去率の平均は 30%であった。また，原水中の DOC は 2.6～3.8mg/L で推移したのに対し，樹脂処理水は 1.9～

2.8mg/L で推移し，除去率の平均は 23%であった。

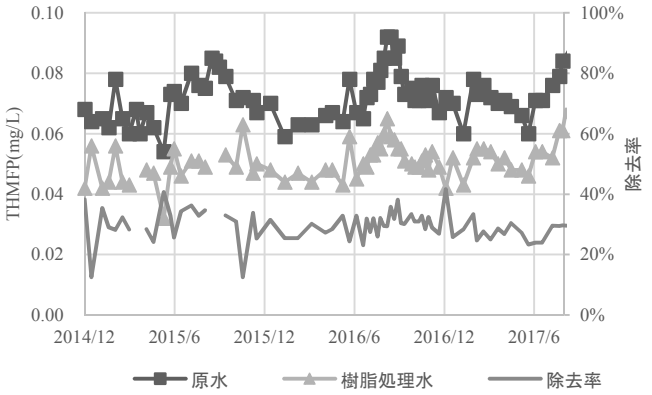

図 2　THMFP の変動

促進酸化処理及びオゾン単独処理について，それぞれ約2週間程度，樹脂処理を停止し，各処理工程における THMFP の挙動を調査した。その結果を図3に示す。原水濃度に対する各処理工程までの除去率は，どちらの処理も樹脂処理を行った方が高い傾向が見られた。このことから，樹脂処理によって BAC への流入負荷を減らすことが出来ると考えられるため，BAC の交換サイクルも長く出来ると考えられた。

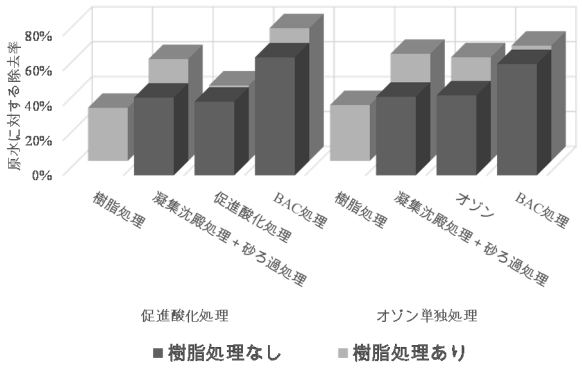

図 3　処理過程ごとの THMFP 除去率

(2) BVTR の影響

給水末端を想定したトリハロメタン生成量を調査するため，高速砂ろ過処理水に必要な次亜塩素酸ナトリウムを添加し，採水時の水温で3日間，恒温静置した際のトリハロメタン生成量（以下，「72hrTHM」という。）を調査した。その結果，夏期における 72hrTHM は，図 4 のとおり年々増加傾向を示した。オゾン処理水までの THMFP の除去率等の指標については，経年的な低下傾向は認められていないことから，BAC の THMFP の除去能が低下していると考えられた。

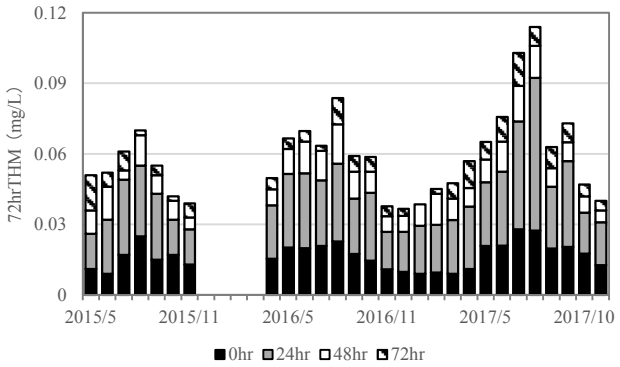

図 4　72hrTHM の変動

このため，夏期におけるトリハロメタン生成量の抑制が必要であると考え，樹脂処理における THMFP 等の除去率の向上について検討を行った。

テーブル試験によって所定の BVTR となるよう原水と樹脂を接触させ，BVTR の変化が THMFP の除去量に，どの様に影響するか調査した結果を図 5 に示す。BVTR が低くなる程，THMFP の除去量が大きくなっていることから，現状の BVTR10,000 より低い条件で運転することにより，夏期のトリハロメタン生成量の低減化が図れると考えられた。

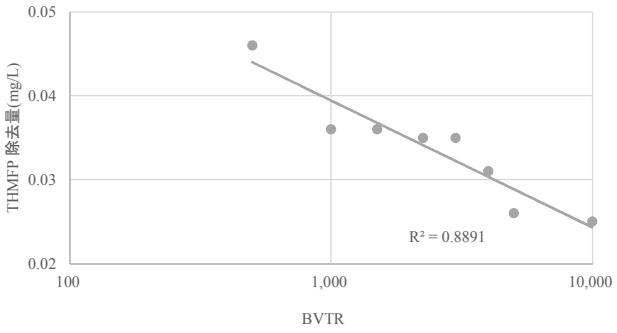

図 5　BVTR と THMFP 除去量の関係

更に，前述の樹脂接触水に対し段階的に PAC を添加し，THMFP の除去量の変化を調査した結果を図 6 に示す。なお，THMFP の除去量は，原水の THMFP から，各 PAC 処理後の THMFP を減じて算出した。全ての BVTR 条件において，PAC 注入率を増加させるに従い，THMFP の除去量が増加する傾向が見られた。これらのことから，BVTR 及び PAC 注入率を適切に設定することにより，更なる THMFP の低減化が図れることが明らかとなった。

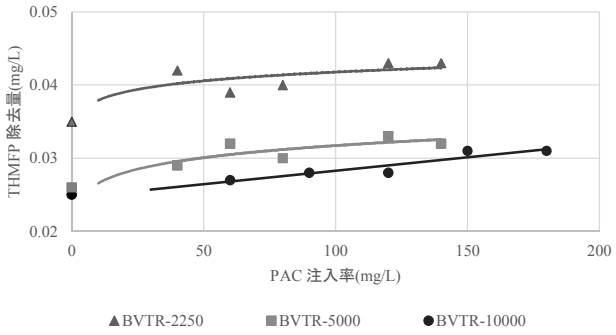

図 6　PAC 注入率と THMFP 除去量の関係

以上の結果を踏まえ，2017 年8月 28 日から 11 月 20 日の間（9月 11～28 日を除く），実証実験プラントの樹脂処理の BVTR を 2,500 に変更し，調査を行った。

BVTR の変化が 72hrTHM にどの様な影響を及ぼすか調査するため，水温が同程度となるよう考慮し，2017 年８月 21 日に BVTR10,000 で，同年９月４日に BVTR2,500 で 72hrTHM を調査した結果を図７に示す。

図のとおり，BVTR10,000 における 72hrTHM が 0.092mg/L と目標値を超過しているのに対し，BVTR2,500 では 0.063mg/L と目標値を満足した。

前述のとおり，BAC は通水開始時と比べ，溶解性有機物等の除去能の低下が見られており，BVTR10,000 の条件では BAC の使用期間は約3年と評価している。有効使用期間は，72hrTHM の濃度も考慮して評価するが，BVTR を 2,500 にすることによって 72hrTHM の低減が図れることが明らかとなったことから，BAC 使用期間をより延長することが可能であると示唆された。

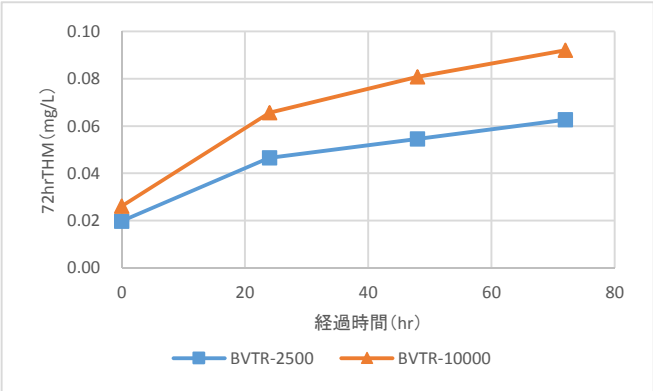

図 7　BVTR が 72hrTHM に与える影響

4. 結論

以上のことから，次のことが明らかとなった。

(1) 樹脂処理により，原水中の THMFP を平均で 30％除去出来る。

(2) 促進酸化処理，オゾン単独処理のいずれにおいても，樹脂処理を行うことにより，各処理工程での THMFP 除去率が高くなる。

(3) BVTR を低くする（再生サイクルを早くする）ことにより，樹脂処理における THMFP の除去率が向上し，高速砂ろ過水の 72hrTHM も低くなる。

樹脂処理は THMFP 等，溶解性有機物の低減化に有効であるとともに，BVTR を下げることにより，THMFP 等の除去率が向上し，BAC の有効使用期間の延長が期待出来る結果となった。

しかし，BVTR を下げると，樹脂の再生回数が増えるとともに，再生費用や廃液の処理費用が増加する。

このため，今後，BVTR を低くした連続運転を行い，データを蓄積するとともに，BAC の交換費用や樹脂処理の運転費用等を考慮し，安定的で且つ効率的な運転条件を確立したいと考えている。

O7-13

UF膜ろ過装置におけるオンライン差圧予測システムの開発

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キーワード:浄水技術, 膜ろ過, 予測, モニタリング

抄録

UF（限外ろ過）膜ろ過は素材、運転方法など様々な面から研究開発が進められ、UF 膜を用いた水処理技術は飲料水製造だけでなく、海水淡水化の前処理、廃水処理など世界各地に普及している。膜ろ過システムは既存の浄水技術と比べ維持管理が容易であるものの、原水水質や環境が刻々と変化する中、適正な運転状態を実現するにはノウハウや経験が必要である。そこで、既に開発した UF シミュレーション技術を活用し、原水や環境条件が変化した際にも UF 膜装置の差圧上昇をリアルタイムで定量的に予測する運転監視システムを開発した。これにより、差圧上昇時に必要な薬品洗浄（CIP）のタイミングを事前に把握可能となるため、生産水計画の調整や薬液・作業員の事前手配を可能とし、さらに適切なタイミングでの CIP 実施により、過度な CIP による膜の化学劣化の抑制や CIP 遅延による膜性能の悪化を抑制可能となる。

1. はじめに

UF(限外濾過)膜ろ過は素材、運転方法など様々な面から研究開発が進められ、UF 膜を用いた浄水処理は世界各地に広く普及している。

外圧型中空糸 UF 膜モジュールのろ過イメージを Figure 1 に示す。原水をモジュールに加圧供給することによって、原水中のコロイド物質、細菌、病原性微生物などの懸濁物質は中空糸膜表面に捕捉され、中空糸膜内側から清澄な膜ろ過水が得られる。このとき、同時に膜表面および細孔内部にて、目詰まり（ファウリング）が起こり、膜の運転性能指標の一つである膜間差圧（以下、差圧）が上昇し、性能が低下してしまう。

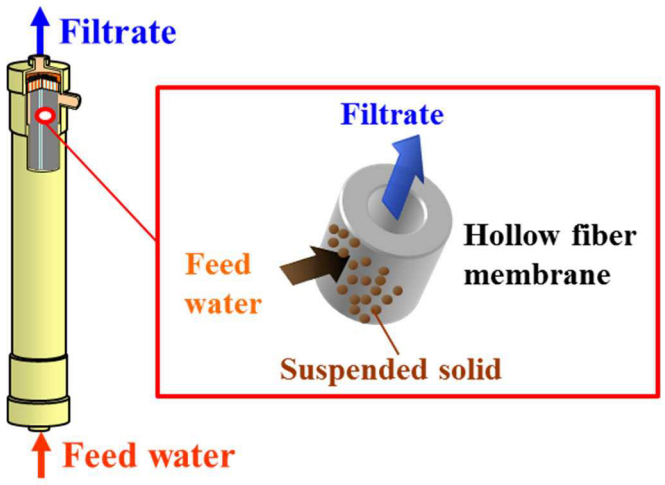


Figure 1 Image of UF membrane filtration

そこで、ろ過水などの清澄水を膜のろ過水側から原水側へ逆流させる「逆圧洗浄（Backwash）」や空気を膜の一次側に供給して膜の汚れを取る「空気洗浄（Air wash）」などの物理洗浄を定期的に実施し、膜性能の回復・維持を図るのが一般的である。しかし、物理洗浄のみでは洗浄が不十分であり、ファウリング物質の完全除去が困難な場合が多い。その際には、1 日 1 回程度の頻度で、有効塩素濃度(以後、塩素)300 mg-Cl_2/L 程度の次亜塩素酸ナトリウムを含む薬液で実施する薬液強化逆洗（CEB）、運転日数の経過と共にさらにファウリングが進行している際には、1 年に数回程度の頻度で、高濃度の塩素 3,000 mg-Cl_2/L や塩酸 0.1 N などを用いた薬液洗浄（CIP）を行い、膜の透水性能を回復させる。このように UF プロセスの設計は、膜とファウリング物質の複雑な相互作用、物理洗浄、及び化学洗浄の頻度に起因しているため、ファウリング成長を予測することは容易ではなく、深刻かつ敏感な問題である。 そこで我々は少量(約 5L）の原水を用いたラボ膜ろ過試験により、ろ過中に蓄積した抵抗である δA、逆洗で回復しない抵抗の上昇度 δB_{bw}、空洗で回復しない抵抗の上昇度 δB_{aw} といった原水由来のファウリングパラメータ（Figure 2 参照）を取得し、ファウリングパラメータをろ過理論や化学反応速度論などの

様々な理論を考慮したシミュレーションプログラムに組み入れることで差圧上昇予測を実施する手法を開発した[1]。

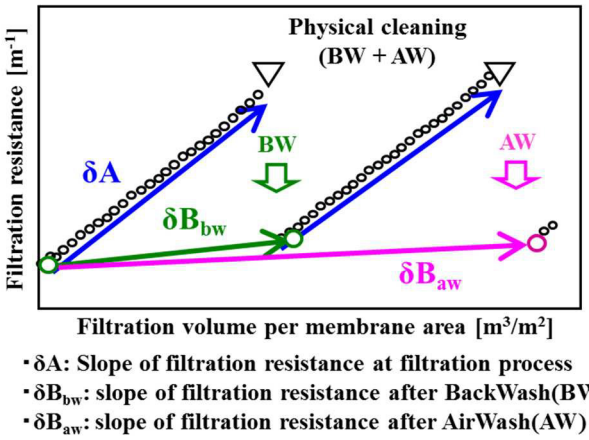


Figure 2 Fouling parameter with lab filtration test

しかし、刻々と変化する原水水質に対してオンラインで UF 膜装置の運転状況に併せて差圧予測を実施するためには、高頻度のラボ膜ろ過試験によるファウリングパラメータ取得が必要となるが、現場で実施困難である。

そこで今回、原水および運転状況においてオンラインで差圧予測を可能とする手法を開発した。

2. 方法

中空糸 UF 膜と膜モジュールの基本特性を Table 1,2 に示す。この膜モジュールには分画分子量 150,000 Da の低ファウリング性 PVDF 中空糸 UF 膜を用いた。ここで、UF 膜モジュールは外形寸法が直径 216 mm で長さ 2,160 mm、有効膜面積は 72 m^2 であり、ろ過方式は外圧式のデッドエンドろ過である。

Table 1 Specifications of PVDF Hollow Fiber UF Membrane

Item	UF membrane
Membrane material	PVDF
Molecular Weight Cut Off	150,000 Da
Outer / Inner diameter	1.4/0.9 mm

Table 2 Specifications of Membrane Module

Item	Membrane Module
Flow direction	Outside-In
Module size	216 mm(8") dia. × 2,160 mm
Membrane area	72 m^2

Figure 3 には試験に用いた UF 装置の概略図を示す。UF 装置に設置されている圧力計 PT1 と PT2 の差分を取ることで算出する実差圧データと Darcy の法則から、Figure 4 に示す 1 回のろ過工程のろ過抵抗上昇度 ΔR_A、物理洗浄後のろ過抵抗上昇度 ΔR_{aw} を算出し、それらの算出値からろ過モデルに基づき可逆ファウリングパラメータ δA と不可逆ファウリングパラメータ δB_{aw} を取得した。また UF 膜ろ過装置の物理洗浄では通常逆洗と空洗を連続で実施するため、実差圧データから δB_{bw} を直接算出できないため、これまでの知見に基づいて算出することとした。

本手法で算出したファウリングパラメータを用いてシミュレーション結果と実運転データを比較検証した。

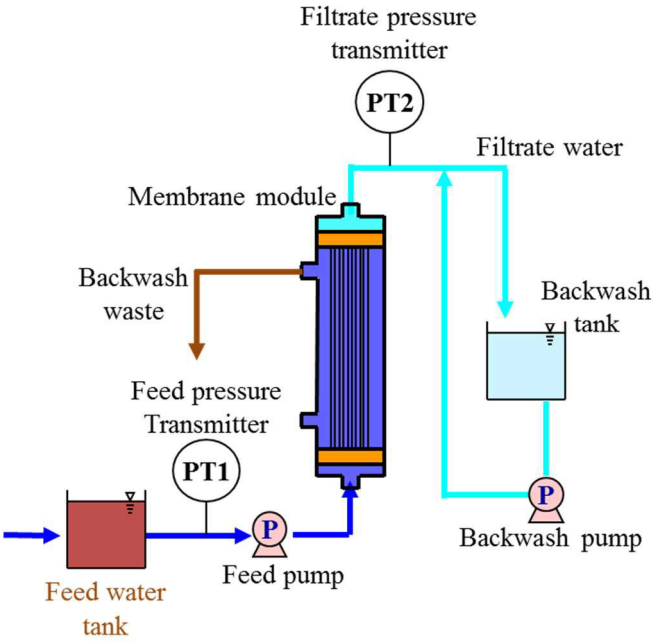
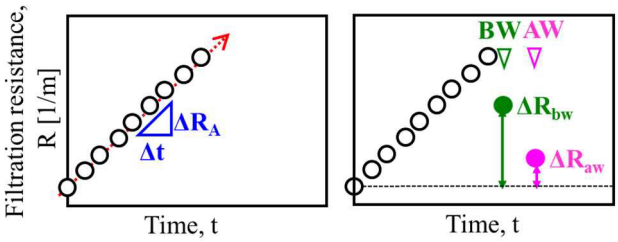


Figure 3 Schematic flow of UF test equipment



$$\Delta P = \mu \cdot J_{filt} \cdot \Delta R$$

$$\delta A = \frac{\Delta R_A}{\alpha \cdot J_{filt} \cdot \Delta t} \qquad \delta B_{aw} = \frac{\Delta R_{aw}}{\beta_{aw} \cdot J_{filt} \cdot \Delta t}$$

J_{filt} : Filtration Flux ($m^3/m^2/s$)

μ : Viscosity (Pa・s)

t : Operation time (s)

Figure 4 Calculation of UF filtrate resistance

3. 結果と考察

Figure 4, 5 と 6 には 6/19～9/20 までの UF 実差圧データとトラブル発生前、トラブル発生時、トラブル対策後のシミュレーション結果を示した。Figure 4 の通りトラブル発生前の予測結果は実差圧データと概ね一致していることが分かる。一方、Figure 5 では UF 装置の洗浄不良トラブルが発生し、実差圧が大きく上昇したが、Figure 6 のトラブル対策後、洗浄不良を解消することにより実差圧も低下した。このようなトラブル発生時とトラブル発生後の実差圧データの上昇に対し、シミュレーションも追従し、実差圧データと概ね一致した。即ち、実差圧データに基づいてファウリングパラメータを算出することで刻々と変化する原水水質及び膜のファウリング状態を把握可能であることを確認した。本シミュレーション技術とオンラインによる運転状況のデータ取得は、膜ろ過システムのトラブル発生時には要因解析に活用することも可能である。

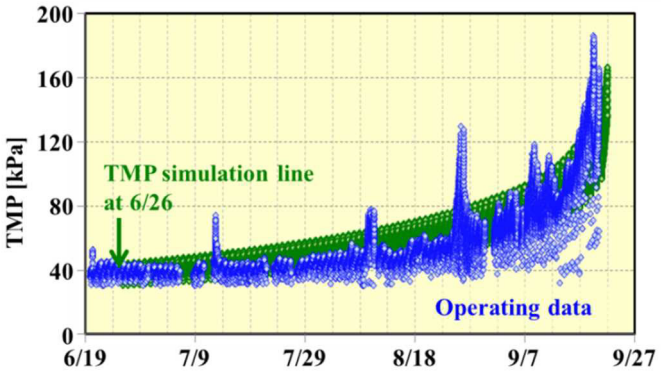


Figure 4 TMP operation and simulation prior to UF trouble

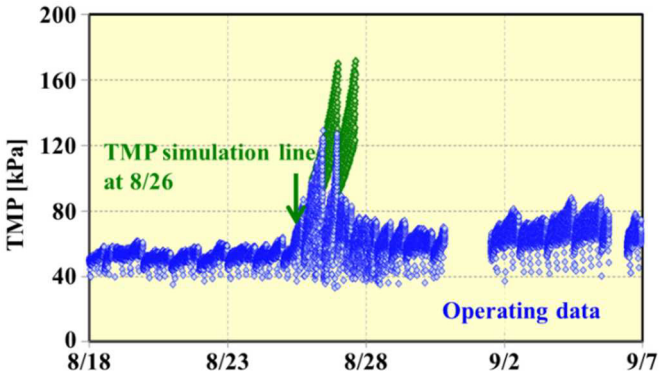


Figure 5 TMP operation and simulation at the time of UF trouble

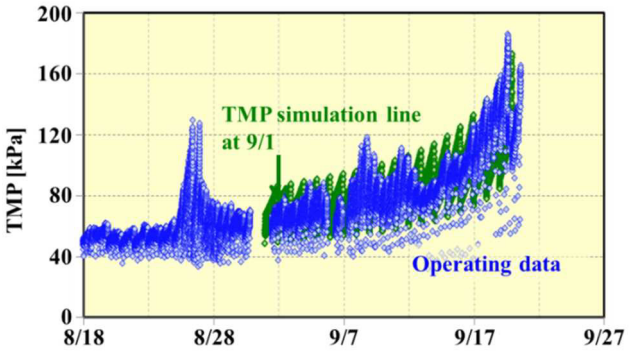


Figure 6 TMP operation and simulation after troubleshooting

4. 結論

実差圧データからファウリングパラメータをオンラインで取得する手法を構築し、取得したファウリングパラメータをシミュレーション計算式に組み込み、算出された UF 膜装置の差圧上昇予測と実差圧データが概ね一致することを確認した。本手法を搭載したオンライン差圧予測システムを開発し、刻々と変動する原水性状,UF 膜装置運転状況に合わせて定量化した CIP 実施日予測が可能となった。これにより、適切なタイミングで CIP を実施し、過度な CIP による膜の化学劣化や CIP 遅延による膜性能の悪化を抑制可能となった。

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O7-14

Process, Organizational, and Operational Developments in Putatan Water Treatment Plant 1 from 2015 to 2017

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[1]Maynilad Water Services, Inc.

Keywords: water purification, wise use and development of water resources, water quality and pollution concerning water use

ABSTRACT

Putatan Water Treatment Plant 1 (PWTP 1) is vital in Maynilad's aim of providing new water sources to the south of Metro Manila's West Concessionaire Zone. The plant obtains its waters from the brackish Laguna Lake, which has a turbidity of 100-200 NTU and a seasonal taste and odor problem, among others. The plant has a design capacity of 150 million liters per day (MLD) at the end of 2015, but it only reached and exceeded this nameplate capacity by the middle of 2017. The challenges in lake water quality, as well as other difficulties, were addressed by these five general aspects: (1) inculcating the safety culture in the plant such as implementation of self-evaluation of the safety of the personnel's tasks, (2) improvement of process streams such as the inclusion of biological aerated filters (BAF) to address ammonia, (3) re-organization of personnel such as the addition of the technical wing, (4) maintenance schedules, which cater to the production demand, and (5) changes in operational philosophies, especially in cleaning of ultrafiltration (UF) membranes. These developments have increased the total treated water to the reservoir by a 36% difference from the 2015 to the 2017 yearly average, which means more water is provided to the community.

1. INTRODUCTION

PWTP 1 taps the Laguna Lake as its source in order to provide potable water to the residents and establishments located at the southern part of the West Concessionaire Zone of Metro Manila, such as in Las Piñas, Muntinlupa, and certain areas of Cavite.

The Laguna Lake has brackish water, with turbidity ranging from 100-200 NTU, and a total dissolved solids (TDS) level greater than 400 mg/L. Its waters may have seasonal taste and odor problems, and algal blooms may occur in it. Laguna Lake water also has high levels of total organic carbon (TOC) and ammonia.

The process of PWTP 1 in 2015, which addresses these concerns, can be divided into two major sections: the Pretreatment Section, which consists of a basin called the Forebay and the Dissolved Air Flotation (DAF) system; and the Membrane Section, which is composed of Microfiltration (MF) and then Reverse Osmosis (RO) Membranes. After the treatment process, the water is chlorinated for potable use. Figure 1 shows a simplified block flow diagram of PWTP 1 in 2015.

With this set-up, problems in water quality (such as high TDS and discoloration of product water) are almost always solved by running the RO Membranes, which only had a capacity of 30 MLD. The RO permeate is blended with the MF filtrate, in ratios depending on the water quality. It is possible that the product of the plant reaches as low as 30 MLD due to unpredictable lake water quality.

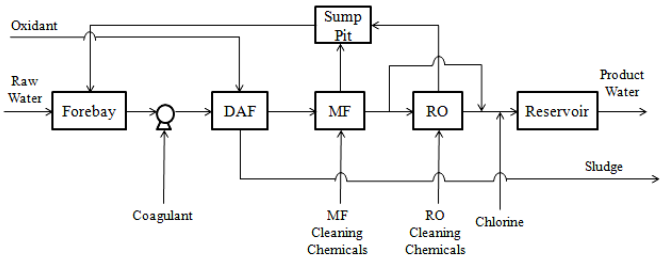

Fig. 1 Simplified block flow diagram of PWTP in 2015.

However, due to the changes which will be discussed in this paper, in 2017 the plant has even exceeded its nameplate capacity of 150 MLD, as seen in Figure 2.

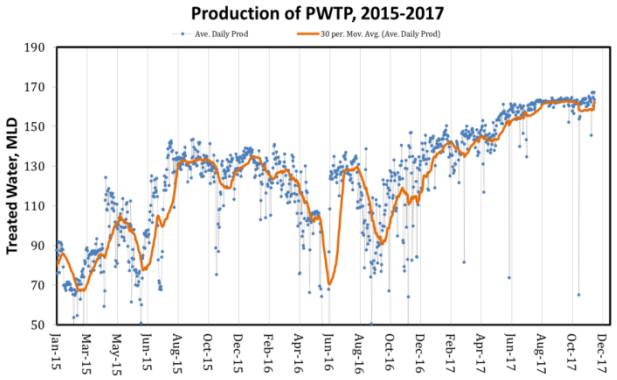

Fig. 2 Average daily production of PWTP 1, 2015-2017.

This paper tackles the programs placed in order to address high water volume demand and lake water quality issues, which can be outlined in five major areas: (1) inculcation of safety culture among the personnel, (2) process improvements, (3) specialization of the organizational hierarchy, (4) arrangements in the maintenance schedule, and (5) improvement in the operational philosophies. These areas constitute the following sections in this paper.

2. SAFETY CULTURE

PWTP 1 has inculcated into the personnel three simple and effective means in order to maintain their safety: First, the Take 5 Form, which was put in place to address the knowledge gap and skills gap of the personnel. One stops for five minutes to consider whether the personnel knows what he/she will be doing, the hazards and risks involved, and the PPEs required while doing the activity. This has caused a decrease in the mishandling of the operations of the plant.

Second, the Near Miss Reporting has been set up to address hazards. PWTP 1 has been recognized for making its company reach a thousand near miss reports in a year. Third, the personnel are assigned an area for housekeeping in order to keep the place neat and safe. Other risk management tools have also been introduced in the plant, such as Job Safety and Environment Analysis (JSEA) and Quantitative Risk Assessment (QRA).

3. PROCESS IMPROVEMENTS

Each of the circuits have been improved and upgraded. First and foremost, the biological aerated filters (BAF) have been added and the dissolved air flotation (DAF) has upgraded its capacity both in 2015, and the membranes have been replaced in the span of 2015–2017. Figure 3 shows the simplified block flow diagram of the improved process of PWTP 1.

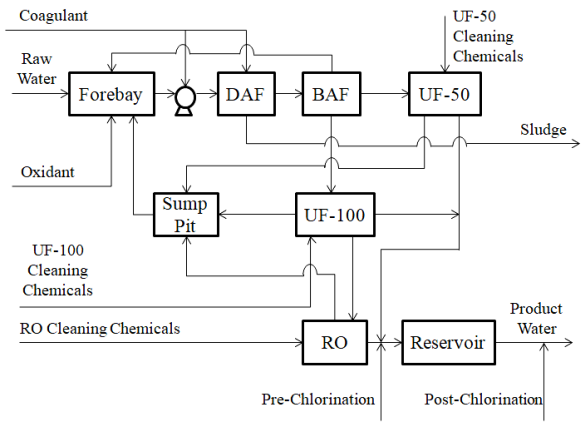

Fig. 3 Block flow diagram of the updated PWTP 1.

Before, the issues in lake water quality, particularly high manganese and high ammonia have been both addressed mainly by a decrease in production. This is the least viable option both in terms of the business and the benefit of the customers. Now, each of this has been addressed by the proper solution. High manganese has been resolved by changing the dosing points and increasing the aerators; meanwhile, high ammonia has been addressed by the BAF.

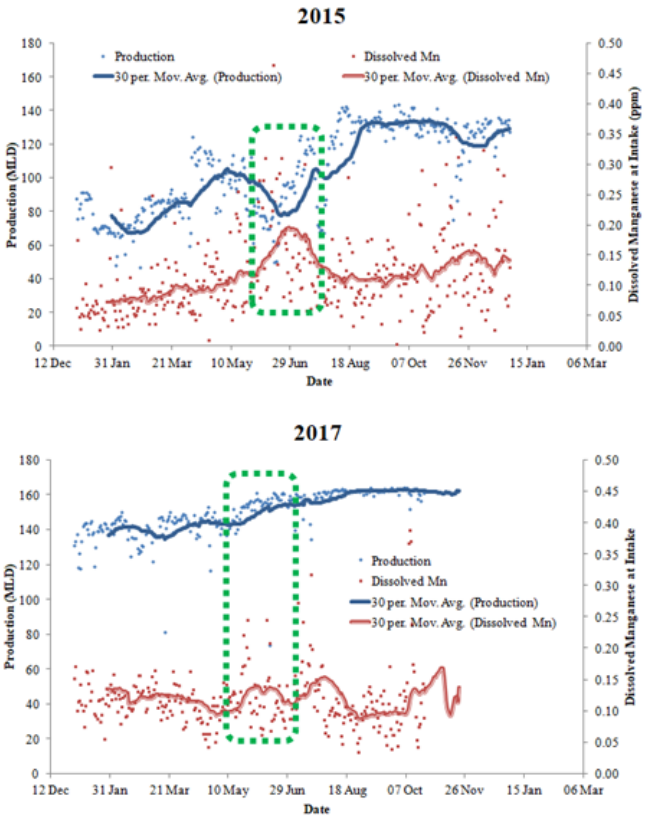

Fig. 4 Before (2015) and After (2017): Effect of Manganese Levels in Production.

In 2015 (refer to top part of Figure 4), the manganese spike (red line) causes a drop in production (blue line). On the other hand, the production is not affected by the manganese spikes in 2017.

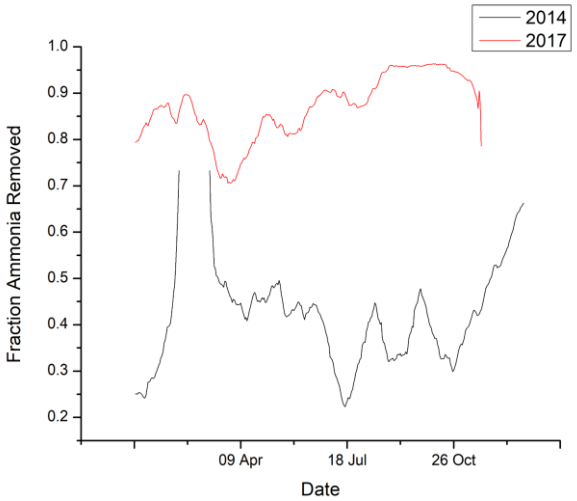

Fig. 5 Fraction of Ammonia Removed.

When the BAF has not been operational (i.e., in 2014), the ammonia removal averaged at 40%. In 2017, this removal has increased to around 85%. This removal is measured based on the difference in ammonia levels between the lake water and the filtrate.

An additional process control system was also installed in the lake water feed to the plant. This reduced the noise of the input to the plant, as shown in Figure 6. As seen in this figure, the plant noise was abruptly reduced; thus the level of the DAF was disturbed less, which encouraged the formation of flocs. Figure 7 shows the effect of this process improvement: a change in the process control has increased the turbidity reduction of the DAF.

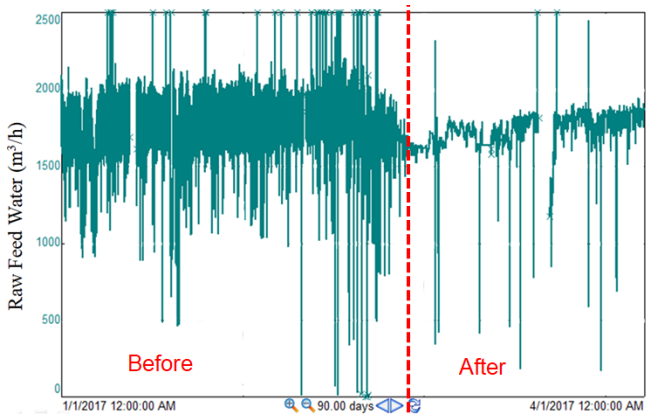

Fig. 6 Lake Water Feed to PWTP1, Jan – Apr 2017.

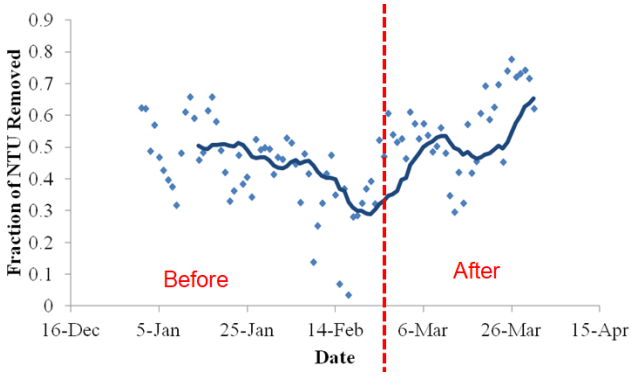

Fig. 7 Turbidity Removal in the DAF, Jan – Apr 2017.

4. ORGANIZATIONAL HIERARCHY

Before, the six complex circuits of the PWTP 1 were controlled by one shift officer. This shift officer acted both as a supervisor and as the control room operator. Now, the control room engineers have been instituted, who were also trained in field operations. PWTP 1 has also introduced the technical wing, who watches the overall process on a day-to-day basis, because lake water quality changes every hour and PWTP 1 has to be proactive in addressing these issues.

5. MAINTENANCE SCHEDULE

The community's demand for water is low at certain moments of the day. PWTP 1 has taken advantage of this low demand in order to perform prolonged cleaning of the BAF cells and the ultrafiltration membranes, as well as the maintenance of pumps and valves. Therefore, PWTP1 has achieved performing maintenance schemes without stopping the plant.

6. OPERATIONAL PHILOSOPHIES

PWTP 1 has installed heaters for chemical cleaners. This is in alignment with the thinking that the UF membranes serve as polishers, not as pretreatment.

Operational limits for residual alum entering the UF membranes have also been established, since an aluminum-based coagulant is used upstream of the UF membranes.

Operation of the UF membranes has also changed. Before, the feed setting to the UF was according to the capacity as indicated by the designers, i.e., 100 MLD for UF-100 and 50 MLD for UF-50. However, the filtrate production will be less than these feed settings since some of the water will be used in the flushing scheme. Therefore, upon discussion with the consultant and design review, the feed setting to the UF membranes was increased. Production in some days of November 2017 even reached an average of 165 MLD, which is beyond the nominal capacity of PWTP.

7. CONCLUSION

PWTP 1 has consistently achieved the high production rate in 2017 by improvements in the safety culture; process streams; organizational structure, which was more specialized depending on the needs of the plant; maintenance schedule, which was adjusted based on the demand for water; and operational philosophies, especially with regards to the ultrafiltration system.

Detailing the developments in the process streams, the BAF has been added in the Pretreatment Section in order to address high ammonia levels in the lake water. In order to address high manganese, aerators were added and oxidant dosing points were placed further upstream to allow prolonged reaction. The lake water feed's controls were also improved in order to stabilize the incoming flow rate, thus lessening the disturbance in the floc formation of the next process stream.

These improvements have strengthened water security in the south of Metro Manila, and the spirit with which it was done will be reflected in future projects of water production.

O7-15

Characterization and Treatment of Stormwater Runoff from the Nainital Lake Catchment in the Himalayan Region of India

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Keywords: Stormwater runoff characterization, runoff treatment, ballasted sand flocculation, Nainital lake

ABSTRACT

Stormwater runoffs are one of the primary causes for deteriorating water quality in the Nainital Lake, a lake of national importance in Himalayan region of India. The Nainital lake is a prominent tourist attraction and the sole drinking water source for the habitants of Nainital city. The aim of this study is to investigate the characteristics of pollutants of Lake's catchment area and performance assessment of Ballasted Sand Flocculation (BSF) technology during monsoon season of year 2017. A 1 MLD capacity pilot plant was installed (land space: 54 sq.m.) and applied for treatment of stormwater runoffs from Nainital Lake's catchment. A conventional treatment method would require large land footprint, which is a big constraint in the Nainital because of hilly region. The water quality results showed marked variation during different storms especially for TSS, TP, COD, FC, Cu, Pb and Zn with maximum concentration of 864 mg/l, 1.2 mg/l, 388 mg/l, $14x10^4$ MPN/100 ml,73µg/l, 83 µg/l and 890 µg/l respectively. The performance analyses result of the pilot plant revealed that the contaminants including trace metals in the stormwater runoff were reduced appreciably. The removal efficiency of Turbidity, TSS, Total Phosphorous, COD, FC, Cu, Pb and Zn are 86-96%, 69-93%, 75-95%, 41-82%, 61-96%, 40-82%, 56-87% and 51-77% respectively. The performance analysis results of BSF system have been found to be a promising technology for treatment of storm runoff.

1. INTRODUCTION

Stormwater runoff is an important transporting medium for various pollutants to transport from land to surface water bodies such as lakes. Urban storm runoff pollution problems are more difficult to manage than steady-state point discharges because of the sporadic characteristic of rainfall and runoff. Urban runoff pollution has been studied in developed countries [1,2]. However, little information is available on storm runoff pollution from urban area in developing counties, including India. There are very few reports or research papers are available about the characterization of surface runoff in an urban catchment environment in India including stormwater inflow to the Lake of national importance such as Nainital Lake. Nainital Lake (India) receive polluted runoff and thus face the deteriorating water quality problem [3,4]. The Nainital Lake is one of the major sources of water supply to the Nainital city, and also attracts thousands of tourists every year due to its scenery beauty. The economy of Nainital region is directly or indirectly dependent on this lake. Therefore, there is a need to devise an appropriate storm-water runoff treatment plant to improve the lake water quality. Availability of land is a critical factor in Nainital to adopt a conventional treatment plant. One of the technologies, which proven to be effective for surface water and combined sewerage overflow (CSO) is ballasted sand flocculation, also known as high rate clarifier which require very less space [5]. There are hardly any attempts to employ the BSF technique at full scale or laboratory scale in India as per author's best of knowledge. In the present paper, stormwater runoff was characterized and treatment efficiency of BSF technology was evaluated.

2. METHOD

Study Area

Nainital Lake, India (Latitude-29^0 23.127' and Longitude-79^0 27.656') has a crescent shape and is situated in Nainital district of Uttarakhand, India. The maximum length of lake is 1.4 km and maximum width is 0.45 km and maximum depth 27.32 m with mean depth of 18.5 m [4]. The catchment area of lake is 4.9 sq. km and average annual rainfall in the basin is 203 cm. The pilot plant of 1 Mld (42 m^3/hr) capacity was installed near storm water drain (locally called Naina Devi drain) Nainital, India. Naina Devi drain is the major drain in the Lake's catchment, which contributes 60% of runoff to the Nainital Lake (NIH, 2000).

Description of pilot plant

The ballasted flocculation technology is mainly based on physical-chemical treatment process that uses a continuous recycled medium along with chemicals to improve the settling properties of suspended solids through improved floc bridging [6,7].

The BSF unit involves three-stage process i.e injection, maturation and settling. The technical design detail of BSF pilot plant has been given in Table 1. The total

hydraulic retention time (HRT) of the plant was 16 min, which corresponds 2-2-6-6 design that means 2 min retention time in coagulation tank, 2 min in flocculation tank, 6 min in maturation tank and 6 min settling time. The coagulation, flocculation and maturation tank were equipped with mixers, which provides high mixing speed (160-180 rpm) in the first two tanks and low mixing speed in the maturation tank (40-60 rpm). The different processes is shown in Fig. 1. and actual experimental set-up (1 Mld pilot-plant) has been shown in Fig 2.

Table 1 Technical design detail of BSF pilot-plant

Parameters	Unit	Value
Design flow	m^3/hr	42
Coagulation tank size	m^3	1.62
Flocculation tank size	m^3	1.62
Ballastation tank size	m^3	5.76
HRT	minutes	16
Rise rate	m/hr	40

The inlet and outlet samples of BSF unit were collected during nine different storm events. Number of samples for each storm event varied from three to seven depending upon the duration of event. Samples were collected after 10 minutes of rainfall initiation and then after, at every twenty minutes interval till the flow in Naina devi drain reach to its initial flow.

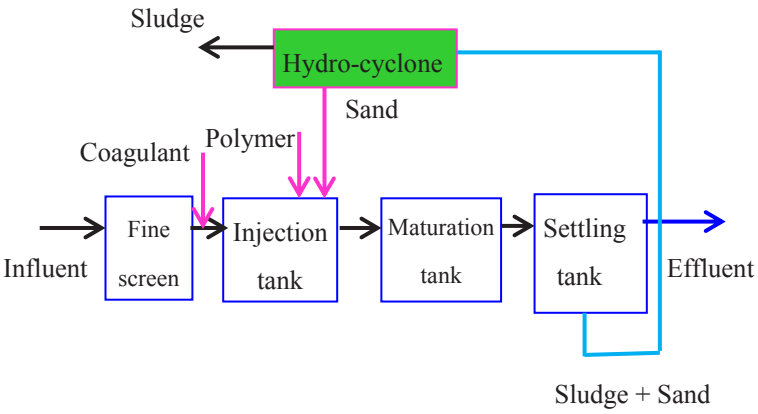

Fig. 1 Schematic diagram of BSF unit



Fig. 2 Actual Experimentation set-up at Nainital

3. RESULTS AND DISCUSSION

Table 2 summarizes the results (influent-effluent concentration and removal rate of pollutants) obtained during the study period. There are large fluctuations in the influent concentration for all the parameters. The value of COD and BOD reached upto 388 and 224mg/l respectively (Table 2) indicates that there may be mixing of sewage due to bursting or choking of sewer pipeline during some events. Total phosphorous concentration ranges from 0.08- 1.2 mg/l, which is much higher than the threshold value causing eutrophication in the lake. Most pollutants in the storm runoff are characterized by the tendency that the concentrations increase with the increased runoff flow rate at rising limb of hydrograph and then concentration decreases following the trend of hydrograph.

Figure 3 indicates that the peak concentrations reaches near the peak runoff flow rate for both storm events and after the peak, the pollutant concentration rapidly reduced. This characteristic of pollutograph is reported to hold true when the watershed area is small (Lee and Bang, 2000).

The chemical dosages of the plant were optimized by conducting modified jar test in the laboratory before the field application of the plant. The optimum chemical dosages ranged between 20 - 80 mg/l of alum ($Al_2SO_4.18H_20$); 30-120 mg/l of ferric chloride ($FeCl_3.6H_2O$) and 8 g/l of micro-sand.

The removal efficiency of pilot plant is presented in Table 2. Results showed that BSF unit is highly efficient in removing particulate matter and phosphorous and it also exhibit a significant removal of other pollutants. Turbidity, TSS and TP removal rates ranged from 86 to 96%, 69-93% and 75-95% whereas COD and BOD removal rate ranged between 41-82% and 29-82%. The average removal rate of ammonical nitrogen is 8 % but no removal of nitrate nitrogen was found out. Phosphorous removal is

important, as phosphorous is the limiting factor for eutrohication of Nainital Lake. The removal efficiency of pollutants is comparable with other reported studies based on the performance of BSF systems for CSO/surface water of similar characteristic of influent [6,7].

Table 2 Influent and Effluent concentration with removal efficiency of BSF unit

Parameters	Influent Concentration Average (min-max)	Effluent concentration Average (min-max)	% Removal Average (min-max)
pH	7.54(6.8-8)	7.31(6.9-7.8)	-
Turbidity (mg/L)	135(21-635)	2.45(1.2-4.8)	95(86-96)
TSS (mg/L)	185(38-864)	14(6-45)	88(69-93)
COD (mg/L)	118(21-388)	30(12-78)	71(41-82)
BOD (mg/L)	46(7-224)	08(3-34)	72(29-82)
NH_4^+-N (mg/L)	1.53(0.26-3.55)	1.3(0.12-3.50)	8(0-46)
NO_3-N (mg/L)	0.62(0.10-2.25)	0.75(0.13-2.71)	No removal
TP (mg/L)	0.47(0.08-1.2)	0.07(0.02-0.22)	83(75-95)
FC (MPN/100 ml)	$19x10^3$($15x10^1$-$14x10^4$)	$59x10^1$($2x10^1$-$39x10^2$)	84(61-96)
Cu(µg/l)	38 (5-73)	12(3-32)	65(40-82)
Pb(µg/l)	25(7-83)	8(2-32)	67(56-87)
Zn(µg/l)	625(368-890)	226(126-327)	64(51-77)

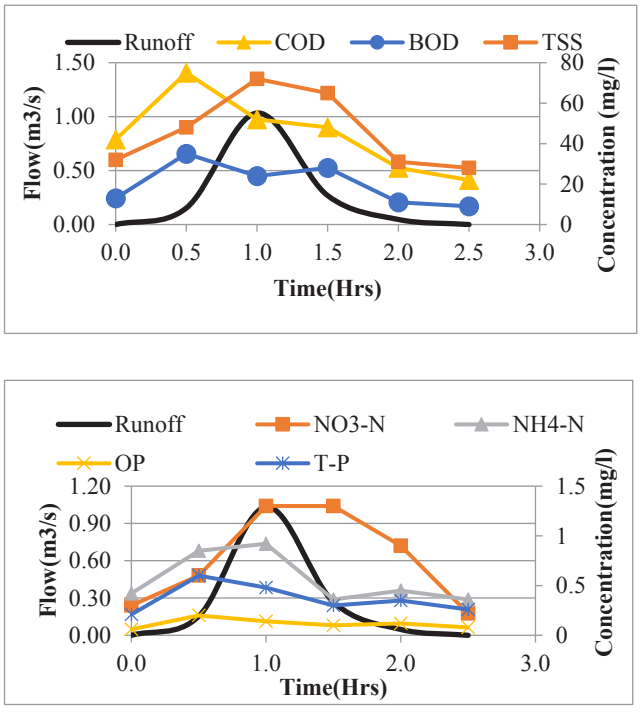

Fig. 3 Typical hydrograph and pollutograph for a storm event

4. CONCLUSION

The characterization and performance of BSF unit was evaluated for stormwater runoff of a hilly catchment area i.e Nainital, India. A 1 Mld pilot-plant was installed near Naina devi storm-water drain which carries variety of pollutants. The pollutants showed a marked variation during different storm events. The particulate matter, phosphorous, COD and BOD showed a very good removal during the overall experimental campaigns. The treatment of storm water runoff with average removal rate was found out to be 95% for turbidity, 88% for TSS, 83% for T-P, 71% for COD and 72% for BOD. Findings of present study suggest that the BSF unit can be suitable for treatment of urban runoff.

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O7-16

Field Experiments on Runoff Reduction Using Terrestrial Alga as Topsoil Nutrient Absorber

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Keywords: control of point and non-point source pollution, nitrogen and phosphorus cycle, nutrient dynamics

ABSTRACT

Nutrient runoff into aquatic systems leads to eutrophication. The Institute for Clean Earth developed a new technology using terrestrial microalga (a drought-tolerant cyanobacterium *Nostoc* sp.) that could reduce the amount of nutrients in surface runoff. The field-scale experiments examined whether the technology would reduce the water-soluble nutrients in the topsoils in water's edges. The experimental approach consisted of the following: assessment of the topsoil nutrient runoff risk, application of the technology, and evaluation of the efficacy. For the assessment, the topsoils were collected from various types of water's edges. Unexpectedly, most unfertilized topsoils around lakes (Biwa-ko, Imba-numa and Kasumiga-ura) and in planting beds, contained high amounts of water-soluble inorganic nutrients: above 1.2 kg N/ha and above 0.2 kg P/ha. Algal inoculated plots and the control (plots without algal inoculation) were used in the application experiments. The reduction values of N and P amounts in the topsoils were estimated to be from 1.3 to 5.4 kg N/ha, and 0.4 to 1.6 kg P/ha. Judged these values from the published information, the results suggest that the algal inoculation onto the topsoil is a promising technology for reducing water-soluble inorganic N and P in surface runoff.

1. INTRODUCTION

There are few technical measures to reduce the nonpoint pollution[1, 2]. Many microalgae including cyanobacteria (blue-green algae) can utilize inorganic nitrogen (N)[3] and inorganic phosphorus (P)[3] during efficient photosynthetic CO_2 fixation[4]. Some terrestrial cyanobacteria absorb ammonium (NH_4^+), nitrate (NO_3^-), nitrite (NO_2^-), urea and phosphate in the topsoil, and produce organic matters such as proteins and saccharides during photosynthesis. These matters have very long term mean residence time (ca. 40 years) in soil[5]. Considering these facts, the Institute for Clean Earth (ICE) developed a new technology against the nutrient runoff from the topsoils, using photosynthetic terrestrial cyanobacterium. This technology was registered on March 2016 (No. KT-150125-A) in the NETIS of the Japanese Ministry of Land, Infrastructure and Transport.

2. METHOD

Assessment of the nutrient runoff risk

Surface soils from 0 to 2 cm depth[6] were collected from water's edge plots around lakes (Biwa-ko, Imba-numa, and Nishi-ura in Kasumiga-ura), around ponds and/or on bayshore (in Tokyo Metropolitan Parks), and in planting beds (near gutter gratings in Tokyo and Saitama Prefecture).

Water-soluble NH_4^+[7] and inorganic P[6] may be the most appropriate estimators of the concentrations in runoff water. NO_3^- can be easily extracted from most soils[8]. Therefore, the amount of water-soluble nutrients (Table 1) was used as the relative index of the nutrient runoff risk for giving priority level. The deionized water extraction procedure[9] was performed at 24~26C: Soil to water mass ratio in centrifugation tube was 1 to 5, and the extraction time on a reciprocal-shaker at 90 rpm was 30 min. After centrifugation at 1,000 g for 10 min, the floating debris was eliminated, and the resulting supernatant was used as the extracted solution. First of all, the measurement of pH and electrical conductivity (EC) of the extracted solution was performed. Quantitation of NH_4^+ and phosphates in the extracted solution was performed using indophenol blue and molybdenum blue, respectively. NO_3^- was quantitated using the Griess reagent after removal of NO_2^- in the extracted solutions.

Application of the technology

Nontoxic terrestrial cyanobacterium *Nostoc* sp. was autotrophically cultured in 1,000 L liquid medium, collected, mixed with sterile perlite particles, and followed by drying. A part of the mono-algal production system for the quality maintenance was developed by the support from the Zenkoku Chûôkai grant in Japan. The dry alga-perlite particles ($\varnothing \leq 3$ mm) were inoculated onto the following plots: lawn soil surface of 40, 100 or 300 m^2 (at the rate of 0.6 mg chlorophyll *a*/m^2) in the river levees of Ara-kawa, Maruyama-gawa (an upper stream of Ramsar wetlands in Hyogo Prefecture), Tone-gawa and Watarase-gawa (an upper stream of Ramsar wetlands and the Tone-gawa), and the planting beds of 8 m^2 (at the higher rate of 2.3 mg chlorophyll *a*/m^2).

Evaluation of the efficacy

At the start and end (α months later: $0.6 < \alpha \leq 2.5$) of the experiments, the topsoils were collected from inoculated and uninoculated plots, and sieved with 2 mm mesh to remove rock debris including moss-covered clod and crust. Chlorophyll *a* (Chl*a*) content was spectrophotometrically determined in the ethanol fraction[10] extracted from the sieved soil. The algal biomass can be expressed using Chl*a* amount. The Chl*a* increment during α months ($\delta_{\alpha\ months}$) was calculated as follows: $\delta_{\alpha\ months}$ = (Chl*a*-e − Chl*a*-s), where Chl*a*-s is Chl*a* amount per area at the start of the field experiments and Chl*a*-e at the end. Preliminary experiments at the ICE in spring and fall showed that the alga grew linearly on the outdoor soil surface during 2.5 months. Therefore, $\delta_{2.5months}$ was calculated from $\delta_{\alpha\ months}$. In order to offset the effects of native algal species and unknown factors, the values of the alga inoculated plot ($\delta_{2.5months\text{-}A}$) and uninoculated control ($\delta_{2.5months\text{-}C}$) were used. The increment of Chl*a* ($\delta_{2.5months}$) by using the present technology was calculated as follows: $\delta_{2.5months} = (\delta_{2.5months\text{-}A} - \delta_{2.5months\text{-}C})$. The reduction of N and P amounts (Table 2) were estimated from $\delta_{2.5months}$, the algal protein N content, and Redfield stoichiometry: N/P = 16.

3. RESULTS

EC and pH values in the extracted solutions varied by location and with seasons. The average EC values (mS/cm) were as follows: over a range of 0.14~0.34 at Imba-numa and Kasumiga-ura; 0.09 at Biwa-ko; 0.07 at Saitama (Kurihashi and Okabe). Most extracted solutions from the plots showed around neutral pH. The average concentrations (mg/L) of inorganic N ($NH_4^+ + NO_3^-$) and P in the extracted solutions were above 1.2 and above 0.2 (Table 1).

Table 1 Water-soluble N and P concentrations of topsoils in water's edges

Water's Edges	(no. of plots)	*Sampling date	N (mg/L) NH_4^+	N (mg/L) NO_3^-	P (mg/L) PO_4^{3-}
around Lakes [unfertilized plots]					
Biwa-ko	(13)	11 Nov.	0.8	0.4	0.6
Imba-numa	(12)	29 Jun.	0.8	8.0	0.2
	(12)	29 Aug.	1.8	1.7	0.3
	(12)	29 Dec.	1.3	8.9	0.7
Kasumiga-ura	(12)	30 Jun.	1.4	4.5	0.6
	(12)	1 Sep.	0.1	1.2	0.7
	(12)	28 Nov.	1.5	6.0	0.4
in Planting Beds [unfertilized plots]					
**Saitama	(12)	13 Sep.	4.8	1.4	1.0
Unoki	(1)	5 Dec.	3.5	1.3	0.2

*Samples obtained in 2016 (Imba-numa, Kasumiga-ura, Unoki in Tokyo) and in 2017 (Biwa-ko, **Kurihashi and Okabe in Saitama Prefecture).

Assuming that specific gravity of the soils was 2.0 and the topsoil consists from 0 to 2 cm depth, then the amounts per area (kg/ha) of water-soluble topsoil inorganic nutrients were estimated to be above 1.2 of N and above 0.2 of P. No relationship was found between EC and NO_3^- concentration in the extracted solutions from the unfertilized water's edge.

Several weeks after the algal inoculation, sparse spots of algae including cyanobacteria (*i.e.*, algal crust) on the soil surface became visible to the naked eye. This corresponded to very early stage of ecological succession on land. Culture experiments *in vivo* by using each extracted solution as algal medium showed that *Nostoc* sp. efficiently absorbed NH_4^+, NO_3^- and phosphate during photosynthetic growth. Similarly, the algal cells on outdoor plots probably absorbed these inorganic nutrients, and reduced these amounts (Table 2).

Table 2 Reduction of N and P amounts of topsoils in water's edges after using the present technology

Water's Edges	(no. of plots)	N (kg/ha)	P (kg/ha)
around Lake [unfertilized plots]			
Kasumiga-ura	(4)	*2.1	*0.6
in River Levees [fertilized plots]			
Ara-kawa	(1)	3.1	0.9
**Maruyama-gawa	(1)	1.6	0.5
Tone-gawa	(3)	*2.0	*0.6
**Watarase-gawa	(1)	1.3	0.4
in Planting Beds [unfertilized plots]			
Saitama	(2)	4.9	1.5

* One ineffective result is included: Two heavy rain events (Typhoon No.21 & 22 in 2017) caused the sediment accumulation on the soils during the study period, and hindered the algal growth.
**An upper stream of Ramsar wetlands.

4. DISCUSSION

There are strong linear relationships between EC and NO_3^- concentration in the extracted solutions from agricultural soils[11]. NO_3^- amount can be estimated from EC value in such a case. Whereas, nitrate ion-meter is better choice to measure NO_3^- amount in the solutions from water's edge around lakes.

N and P pollution in runoff is caused primarily by agricultural and urban activities[1]. Land use can disrupt the surface water balance[12]. Atmospheric deposition[13] may affect the topsoil fertility. Some agricultural chemicals degrade into NH_4^+ and/or phosphate by the action of microbes[14]. If limited to the lakes, storm waves may carry the lake nutrients over to the topsoils. However, the real cause of the high amounts of N and P (Table 1) in unfertilized plots remains to be clear.

Fertilizers were applied globally in 2013 at 74 kg N/ha and 12 kg P/ha[15]. River levees (Table 2) are covered with fertilizing lawn soil surface (annual rates in the plots: ca. 30 kg N/ha and ca. 10.5 kg P/ha). Generally, fertilizer N and P losses in runoff are below 5% of that applied[1]. These values suggest that the annual N and P amounts in surface runoff from worldwide croplands are below 3.7 kg N/ha and 0.6 kg P/ha. Those from the river levees may be below 1.5 kg N/ha and 0.53 kg P/ha. These estimated nutrient runoff values roughly match with the reduction amounts by "one-time use of the algal inoculation" (Table 2). In the experiments, the inoculation was performed not in whole

but in limited area. Therefore the nutrient inflow from the surrounding area to the experimental plots could occur naturally. Additionally, runoff water contains particulates[1, 16] and organic matters, which are rich in nutrients[17]. The algae in the experimental plots might utilize these nutrients as well as water-soluble ones. It is no wonder that the reduction of P amounts on planting beds in Saitama (1.5 kg P/ha, Table 2) exceeded the estimated amounts of water-soluble inorganic P (1.0 kg P/ha) in the same plot.

5. CONCLUSION

The treatment of wastewater with aquatic microalgae to remove inorganic nutrients was proposed over 60 years ago[18], and many experimental studied on the process have been constructed[19,20]. Meanwhile, terrestrial microalgae have been used in the eco-friendly tools in soil fertilization and desertification reversal[21]. No technical measure of nutrient runoff was proposed using terrestrial algae. Field experiments showed that the present technology using terrestrial cyanobacterium could reduce the nutrients in surface runoff.

Some microalgae can utilize hardly-soluble materials as their nutrients (N of uric acid; P of $AlPO_4$; K of potassium feldspar; Mg of $Mg(OH)_2$; S of $BaSO_4$) as well as water-soluble ones during photosynthetic growth[22]. At present, the efficacy of the technology against nutrient pollution from the eroded soil remains to be clear. Improvement of the technology is now in progress at the ICE.

The riparian buffer zone removes efficiently inorganic N and P of runoff from agricultural fields[1]. Judged from the plant community, the soil is likely to remain uncovered by the terrestrial algae during several months after its installation. The present technology could synergistically reduce surface inorganic nutrients in the zone. Now is the time to take action against the non-point source pollution, by using various measures including the present technology.

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O7-17

水質安定化と省エネルギーを実現する硝化制御技術の実証

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キーワード:硝化制御、アンモニア計、ICT

抄録

アンモニア計を活用し、水質安定化と省エネルギーを実現する硝化制御システムを国土交通省 B-DASH プロジェクトにて実証した。硝化制御システムによる制御運転の結果、98 日間の運転の平均として処理水 NH_4^+-N 濃度を 0.33 mg-N/L（目標 1.0 mg-N/L 以下）、風量削減率 16.9%減（従来 DO 一定制御比、目標 10%以上）を達成した。また、異なる処理水目標値での運転においても、目標を満足する水質に制御できた。アンモニア以外の有機物、窒素、リンに関しては、従来 DO 一定制御と同等以上の処理性能を示した。以上の結果より、硝化制御システムは良好な水質を維持しつつ、消費エネルギーを低減できることを実証した。

1. はじめに

国内では閉鎖性水域などを中心に水質汚濁防止のため、窒素・リン除去といった高度処理化が推進されている [1)]。また、近年は、冬期に下水処理水中の栄養塩類濃度を上げ、ノリの生育を促進させるなど、豊かな海の形成を図る季節別運転管理も注目されている [2)]。このように放流先水域の多様なニーズに応じた下水処理制御技術の重要性が高まっていくと考えられる。

同様に、地球温暖化防止を目的とした CO_2 排出量抑制も水環境や生態系の保全には重要となってくる。下水処理過程での CO_2 発生源としては、ブロワでの消費電力が大きな割合を占める。ブロワからの送風は活性汚泥に酸素を供給するものであり、生物処理性能に大きく影響する。そのため、水質と消費電力低減の両方の観点から適切に送風量を制御する必要がある。

以上の背景を踏まえ、本研究では窒素除去の重要な工程であり、酸素消費量も大きい硝化を対象とし、安定的かつ効率的な下水処理制御技術（以下、開発制御）を開発・実証したので、報告する。なお、実証は国土交通省の下水道革新的技術実証事業（B-DASH プロジェクト）「ICT を活用した効率的な硝化運転制御の実用化に関する技術実証研究」（2014~2015 年度）において、国土技術政策総合研究所の委託研究として日立製作所・茨城県の共同研究体により実施した。

2. 開発制御の概要

2.1 特徴

図 1 に開発制御の概要を示す。本制御は2台のアンモニア（以下、NH_4^+-N）計（第1 NH_4^+-N 計：好気槽よりも上流側、第 2 NH_4^+-N 計：好気槽中間地点）による水質計測と情報通信技術 (ICT; Information and Communication Technology)を組み合わせた3つの機能により、水質安定化、消費電力低減、維持管理業務の軽減を図る技術である。以下、各機能について述べる。

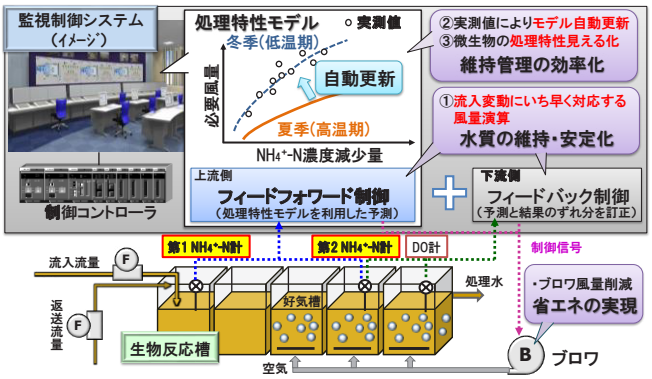


図 1 開発制御の概要（仮）

1つ目の機能として、流入負荷変動にいち早く対応する風量制御機能がある。本機能では第 1 NH_4^+-N 計の計測値に基づくフィードフォワード(FF)制御風量と、第 2 NH_4^+-N 計の計測値に基づくフィードバック(FB)制御風量を重みづけして足し合わせ、硝化制御風量として出力する。FF 的要素と FB 的要素をバランスすることで、流入変動にいち早く対応し、送風量の適正化、処理の安定化を実現する。

2つ目の機能は、風量演算モデルの自動更新機能である。例えば、低水温となる冬季には生物活性が低下するなどして、処理に必要な風量は年間を通じて変化する。そこで、本機能では、FF 制御風量の演算において、運転実績に基づき自動更新する処理特性モデルを用いる。処理特性モデルは NH_4^+-N 濃度の減少量に

対する必要風量の関係を表しており、運転実績として NH_4^+-N 計設置区間の NH_4^+-N 濃度減少量と供給した風量から、所定周期ごとにモデル式を自動更新する。この自動更新機能により、必要風量の予測精度を自動的に担保し、処理水質の安定化を図る。

3つ目が処理特性の見える化機能である。活性汚泥の性状の急変や運転異常の傾向を早期に検知することは、安定した運転には重要である。そこで、本機能では、処理特性モデルの自動更新機能と連携し、モデル式やグラフ上のプロット値の変化を追跡することで、活性汚泥のもつ処理特性の変動を見える化する。

2.2 風量制御方法

FF, FB 制御では、処理水 NH_4^+-N 目標値までの通過点として、第 2NH_4^+-N 計設置位置での予測値（以下、中間 NH_4^+-N 予測値、式(1)参照）に基づき風量を演算する。式(1)の中間処理率は、処理水目標値に対して好気槽上流側（第 2NH_4^+-N 計まで）でどれだけ処理するかを表す制御パラメータである。FF 制御では、流入濃度（第 1NH_4^+-N 計計測値）と中間 NH_4^+-N 予測値との差分を処理特性モデルに入力し、必要風量を予測する。一方、FB 制御では、第 2NH_4^+-N 計計測値と中間 NH_4^+-N 予測値とを流下時間を考慮して比較し、その偏差から風量を演算する。このように、制御パラメータとして、中間処理率と処理水 NH_4^+-N 目標値を設定することで、硝化制御を適用できる。

また、開発制御では、過度な DO 低下を防ぐため、運用管理上の DO 下限値に基づく DO 制御を硝化制御と並行して演算し、より大きい風量を採用する。

$$NH4_{md_tgt} = NH4_{in} - \mathrm{R_{up}}\left(NH4_{in} - \mathrm{NH4_{out_tgt}}\right) \qquad (1)$$

ここで、$NH4_{md_tgt}$(mg-N/L)：中間 NH_4^+-N 予測値、$NH4_{in}$(mg-N/L)：流入 NH_4^+-N 濃度、$\mathrm{R_{up}}$(-)：中間処理率、$\mathrm{NH4_{out_tgt}}$(mg-N/L)：処理水目標値とする。

3. 実証実験方法

3.1 実験施設

実証実験は、茨城県流域下水道事務所霞ケ浦浄化センターの2つの処理系列（No.5 池、No.6 池）にて実施した。どちらの系列も凝集剤併用型循環式硝化脱窒法であり、2つの無酸素槽、3つの好気槽から構成される。実証では、No.5 池を実証系列として開発制御を適用し、No.6 池は対照系列として従来の DO 一定制御を継続した。No.5 池、No.6 池の設備構成を図 2 に示す。No.5 池では、無酸素槽1、好気槽2に新設した NH_4^+-N 計を用いて、開発制御により風量を制御した。

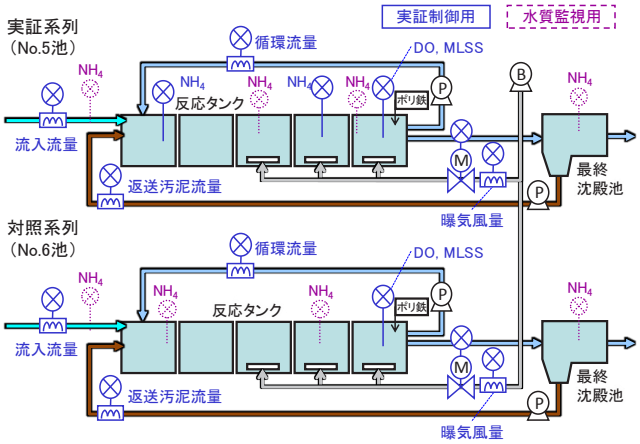


図 2 実証設備の概要

3.2 運転条件

B-DASH プロジェクトでは、平均処理水 NH_4^+-N 濃度を 1.0 mg-N/L 以下に制御しつつ、従来 DO 一定制御と比べて風量を 10%以上削減することを実証目標とした。2015 年度の実証条件を表 1 に示す。実証では、処理水 NH_4^+-N 目標値を実証目標の 1.0 mg-N/L のほか、0.1, 2.0 mg-N/L にも設定し、複数の目標値に対する制御効果を検証した。

表 1 実証実験における運転条件

ID	実験期間（日数※）	処理水NH_4^+-N目標値	DO下限値
No.1	2015/6/4-/7/14 (38日)	0.1 mg-N/L（想定：完全硝化）	0.50 mg/L
No.2-1	2015/7/18 - 8/4 (15日)	1.0 mg-N/L（実証目標）	0.50 mg/L
No.2-2	2015/8/5 - 12/27 (83日)		0.30 mg/L
No.3-1	2016/1/7 - 1/17 (11日)	2.0 mg-N/L（想定：硝化抑制）	0.15 mg/L
No.3-2	2016/1/25 - 2/3 (8日)		0.30 mg/L

※ 既設運転、工事期間、非定常運転時をのぞく

3.3 採水調査

実証研究では、NH_4^+-N に加えて BOD など他の項目の処理性能も比較するため、両系列で通日採水調査を実施した。調査は 2015 年 9 月、11 月、12 月の計 3 回実施し、最初沈殿池流出水（以下、初沈流出水）、生物反応槽、処理水、返送汚泥において BOD や全窒素、NH_4^+-N、全リン濃度などを分析した。

4. 結果および考察

4.1 採水調査結果

採水調査における流下方向の水質変化の例として、図 3 に 2015 年 11 月調査での全窒素(T-N)、NH_4^+-N 濃度の通日平均値を示す。対照系列に比べて実証系

列では硝化をより適正化し、過剰曝気の領域を削減できた。全窒素については、実証系列の方が好気槽内で低くなった。これは、開発制御適用により従来DO 一定制御と比べて低 DO での運転となり、同時硝化脱窒が進行したためであると考えた。

採水調査における両系列の処理状況を比較するため、各項目の除去率を表2に示す。実証系列のBOD、全リン、NH_4^+-N の除去率は対照系列と同程度であり、全窒素の除去率は高くなった。以上の結果から、実証実験条件では、開発制御により従来制御と同等以上の処理性能を達成できることが分かった。

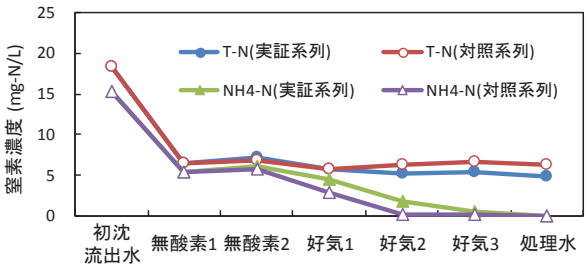


図 3 採水調査における窒素濃度の推移

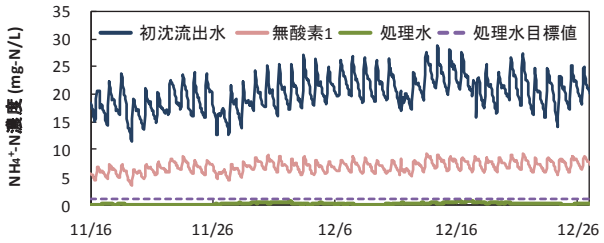
表 2 採水調査結果まとめ

項目	系列	第1回 (2015/9)	第2回 (2015/11)	第3回 (2015/12)
水温 (℃)	実証・対照	27.0	22.9	21.8
BOD除去率 (%)	実証	98	96	95
	対照	98	96	95
T-N除去率 (%)	実証	74	77	78
	対照	68	70	71
NH_4^+-N除去率 (%)	実証	99	100	98
	対照	100	100	100
全リン除去率 (%)	実証	100	99	96
	対照	96	97	94

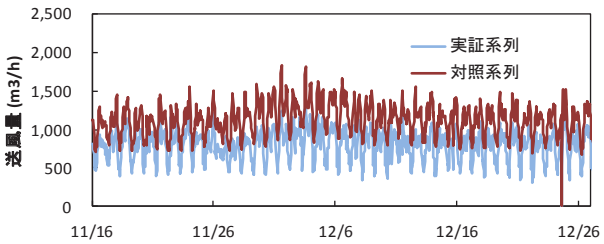
4. 2 開発制御による連続運転結果

開発制御による制御結果の例として、2015 年 11 月 16 日～12 月 27 日を対象に、図 4 (a)に NH_4^+-N 濃度、図 4 (b)に送風量の 1 時間平均値の推移を示す。流入水質が変動する中、処理水 NH_4^+-N 濃度は目標値以下に制御しつつ（図 4 (a)）実証系列の方が送風量は低くなった（図 4 (b)）。以上の結果より、開発制御により安定的に水質目標を満足しつつ、従来制御と比べて送風量を削減できた。

次に、複数の目標値に対する運転結果として、処理水 NH_4^+-N 濃度と DO 濃度、風量削減率の関係を表 3 に示す。本研究では 0.1~2.0 mg/L の範囲で処理水 NH_4^+-N 目標値を設定したが、どの目標値に対しても満足する処理水質が得られた。実証目標の処理水目標値 1.0 mg-N/L に対しては、実証期間中（No.2-1, 2-2）の平均値として処理水 NH_4^+-N 濃度 0.33 mg-N/L、風量削減率 16.9%となり、目標を達成した。



(a) NH_4^+-N 濃度



(b) 送風量

図 4 実証実験における NH_4^+-N，送風量の変動例

表 3 実証実験での処理水質と風量削減率の結果

ID	期間 (日数)	処理水NH_4^+-N (mg-N/L) 目標値	実測値		DO (mg/L) 下限値	実測値	風量削減率	
No.1	2015/6/4 - 7/14 (38日)	0.1	0.09 (平均)		0.50	0.85	12.9% (平均)	
No.2-1	2015/7/18 - 8/4 (15日)	1.0	0.14	0.33 (平均)	0.50	0.58	12.5%	16.9% (平均)
No.2-2	2015/8/5 - 12/27 (83日)		0.36		0.30	0.45	17.7%	
No.3-1	2016/1/7 - 1/17 (11日)	2.0	1.20	1.19 (平均)	0.15	0.44	22.0%	20.2% (平均)
No.3-2	2016/1/25 - 2/3 (8日)		1.18		0.30	1.06	17.8%	

5. 結論

NH_4^+-N 計を活用した効率的な硝化制御システムを国土交通省 B-DASH プロジェクトにて実証した。2015 年度の実証では、複数の処理水 NH_4^+-N 目標値に対して処理水質を満足しつつ、従来 DO 制御と比べて風量を削減できた。また、採水調査の結果、BOD, 全窒素、全リンにおいても開発制御では従来制御と同等以上の処理を実現した。以上の結果より、水質・省エネルギーの両面で開発制御の効果を実証できた。

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2) 国土交通省：栄養塩類の循環バランスに配慮した運転管理ナレッジに関する事例集, http://www.mlit.go.jp/common/001033458.pdf (2018/04/09 アクセス)

O7-18

下水処理における窒素除去を向上させるための曝気プロセスの検討

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キーワード:浄水・排水処理技術, 霞ケ浦, 下水道, 窒素除去, 同時硝化脱窒

抄録

茨城県の潮来浄化センターは霞ケ浦流域に処理水を放流している。霞ケ浦への窒素負荷を低減するため, 活性汚泥による下水処理における窒素除去率を向上させる検討を行った。6 槽からなる反応タンクにおける処理フローを, 嫌気-無酸素-無酸素-無酸素-好気-好気から嫌気-無酸素-好気-無酸素-好気-好気に変更し, 3 槽目を好気槽とすることで硝化を促進し, 4 槽目での脱窒を促す試みを行った。その結果, ねらいどおり, 3 槽目で生じた硝酸性窒素が 4 槽目で脱窒されることによる窒素除去が確認できた。さらに, 3 槽目の好気槽においても脱窒が見られ, その窒素除去量は 4 槽目の無酸素槽での脱窒よりも多かった。好気槽における脱窒は, 低 DO 条件で起こる同時硝化脱窒によると考えられる。無酸素槽での脱窒のほか, 好気槽での同時硝化脱窒も考慮した DO 設定の最適化により, 窒素除去率のさらなる向上が期待できると考えられる。

1. はじめに

茨城県潮来市に位置する潮来浄化センターは, 処理能力 11,230 m^3/日(A 系 7,450 m^3/日, B 系 3,780 m^3/日)の流域下水処理場である。処理水を霞ケ浦流域へ放流しているため, 閉鎖性水域への排出源対策が必要とされている。

本研究では, 霞ケ浦において富栄養化の原因物質となる窒素を対象とした除去率向上の検討として, 反応タンクの処理フローにおいて A_2O 法の槽配置から無酸素槽中央部に曝気槽を設置する槽配置に変更し, 窒素の硝化, 脱窒をさらに促す試みを行ったので報告する。

表 1 霞ケ浦水郷流域下水道事業概要

系列	A系	B系
処理開始	昭和52年	平成10年
処理面積(ha)	921.0	
処理人口(人)	23,691	
処理能力(m^3/日)	7,450	3,780
放流先	霞ケ浦	

2. 方法

下水処理における生物学的窒素除去法では, まず曝気を行っている好気槽(O)で硝化菌の働きによりアンモニア性窒素を亜硝酸性窒素, 硝酸性窒素に硝化した後, 無酸素槽(AO)で脱窒菌の働きにより窒素をガスとして放出する。

潮来浄化センターでは図 2 で示したように反応槽を嫌気槽, 無酸素槽, 好気槽の順に配置し, 好気槽から無酸素槽に循環させる A_2O 法を利用しており, 第 5,6 槽の好気槽で硝化した硝化液を第 2 槽の無酸素槽に循環させて, 第 2～4 槽の無酸素槽で脱窒し, 窒素を除去している。

本研究では平成 29 年 6 月初旬～8 月末を対象期間として, 反応槽における処理フローを嫌気-無酸素-無酸素-無酸素-好気-好気から嫌気-無酸素-好気-無酸素-好気-好気に変更し, 3 槽目を好気槽とすることで硝化を促進し, 4 槽目での脱窒を促して, 窒素除去の向上を図った。運転変更後, 各反応槽での各態窒素(アンモニア性窒素, 亜硝酸性窒素, 硝酸性窒素)を測定し, その効果を評価した。

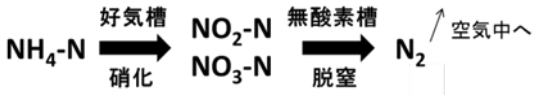

図 1 窒素除去反応の過程

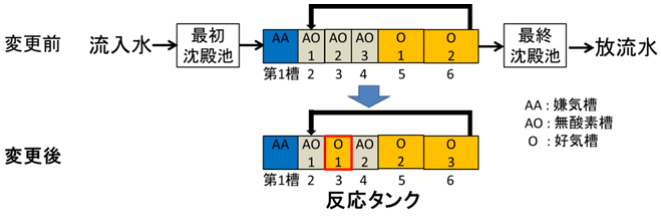

図 2 潮来浄化センター反応タンクの概要図

3. 結果

・COD 除去率

本研究では窒素除去の向上を対象としているが，その際，有機物の処理も問題なく行える必要がある。今回の運転変更における有機物処理状況を確認するため，図 3 に平成 27～29 年度の COD 除去率を示した。

COD 除去率

=(最初沈殿池の COD/最終沈殿池の COD)×100

6 月に運転変更をしてから，運転変更前の平成 27，28 年度と比べ，除去率に大きな差はなく，90%以上で安定していた。以上より，本研究の水処理運転では，有機物処理への影響が出ることはないと考えられる。

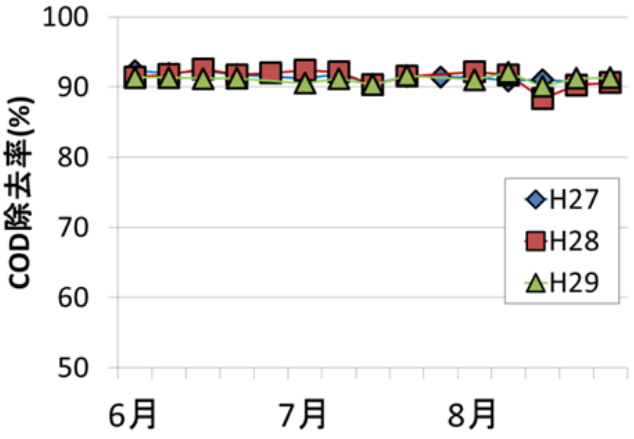

図 3 COD 除去率

・窒素の除去状況

運転変更後の窒素除去の状況を評価するため，図 4 に反応タンクの各反応槽における溶存無機窒素濃度(アンモニア性窒素，亜硝酸性窒素，硝酸性窒素濃度の和)を示した。本研究で新たに設置した 3 槽目の好気槽(O1)から 4 槽目の無酸素槽(AO2)にかけて，溶存無機窒素濃度の低下がみられた。

また，3 槽目は好気槽であり硝化がおきる場であるため，窒素除去を期待する槽ではないが，本研究ではこの 3 槽目の好気槽(O1)においても溶存無機窒素の低下がみられた。日によって差はあるが，3 槽目の好気槽(O1)の方が 4 槽目の無酸素槽(AO2)よりも窒素除去がよい傾向にあった。

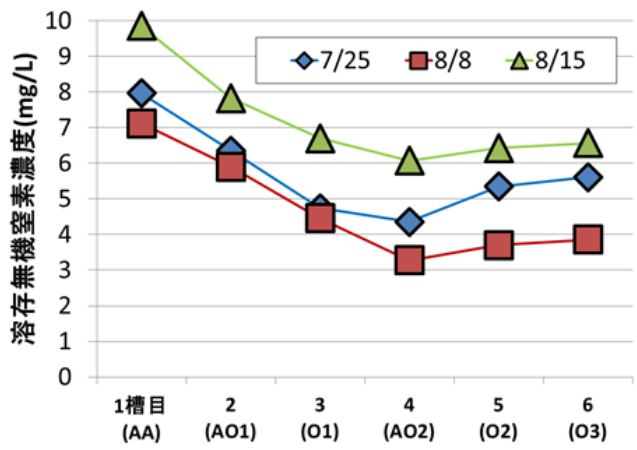

図 4 各反応槽の溶存無機窒素

・各反応槽の形態別窒素濃度

この窒素除去の挙動の原因を調べるため，各槽における形態別窒素濃度を調べた。図 5 にその結果の代表的な例である 8 月 15 日の結果を示した。硝化促進のため導入した3槽目の好気槽(O1)では，ねらいどおり硝酸性窒素の増加がみられた。また，4 槽目の無酸素槽(AO2)においても，3 槽目の硝化分が脱窒されて減るだけではなく，それ以上の硝化が確認できた。

さらに，2 槽目の無酸素槽(AO1)では硝酸がないのにもかかわらず，3 槽目の好気槽(O1)では溶存窒素濃度が減っていた。このことから，好気槽である 3 槽目でも脱窒が起きていると考えられた。

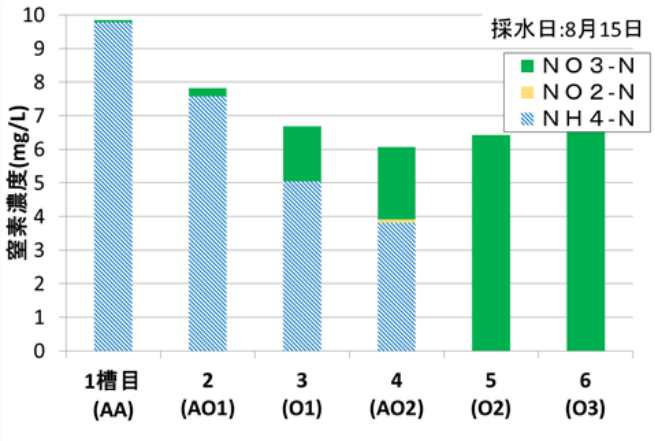

図 5 各反応槽の形態別窒素濃度

4. 考察

3 槽目を好気槽にすることにより，本研究のねらいどおり硝化がおこり，4 槽目で脱窒によるさらなる窒素除去をおこせたと考えられる。ただし，4 槽目でも硝化が進ん

でおり，3 槽目からの DO の持ち込みがおきていることが示唆された。本研究では 3,4 槽目の DO は確認していないため，3 槽目から 4 槽目への DO の持ち込み状況の定量的な確認はできないが，これにより 4 槽目の無酸素槽における脱窒の能力は低減されており，窒素除去の条件として最適化できていなかったと考えられる。このことより，3 槽目の硝化槽で硝化を促進すれば窒素除去が促進されるとは限らないことが示唆される。

次に 3 槽目にて好気槽であるにもかかわらず窒素濃度の減少がみられたが，これは好気槽内での同時硝化脱窒によるものと考えられる。同時硝化脱窒の考え方として，図 6 に周囲の DO 値により変化する活性汚泥フロックの内部モデル[1]を示す。周囲の DO 値が高い場合，好気槽では活性汚泥フロック全体で硝化が進行する。一方，好気槽であっても周囲の DO 値が低い場合，活性汚泥フロックの内部に無酸素領域が形成され，外側で硝化，内側で脱窒が同時に起こるため，窒素除去がおこる。本研究では，3 槽目の DO 値がこの同時硝化脱窒がおきる領域の値であったものと考えられる。同時硝化脱窒では，フロック内での硝化と脱窒のバランスが脱窒量に影響するため，そのバランスが適切になるような DO の最適化が必要になると考えられる。

これまでの結果より，本研究の反応槽の処理フローでの窒素除去の向上においては，3 槽目の好気槽で硝化し 4 槽目の無酸素槽で脱窒する反応を促進することのほか，3 槽目の好気槽内での同時硝化脱窒の影響も大きく，その促進もあわせた 2 つの要素を考える必要があることがわかった。これは，そのそれぞれの反応について単独に最適化をはかるのではなく，両方の反応をあわせた結果の窒素除去量が最大となるような最適化が必要であることを示唆する。平成 25 年度に北見らが行った調査研究[2]では無酸素-無酸素-無酸素-好気-好気-無酸素-好気の処理フローでの検討において，5 槽目の好気槽での窒素の硝化率を 3 段階に設定して窒素除去率を評価したところ，高硝化率または低硝化率ではなく，中程度の硝化率のときに窒素除去量が最大になることを報告しており，本研究と同様に，同時硝化脱窒と無酸素槽での脱窒をあわせて考えることの必要性を指摘している。

以上より，本研究の処理フローでは 3 槽目の好気槽の曝気の仕方が重要であり，その最適化により，窒素除去の向上が期待できることがわかった。

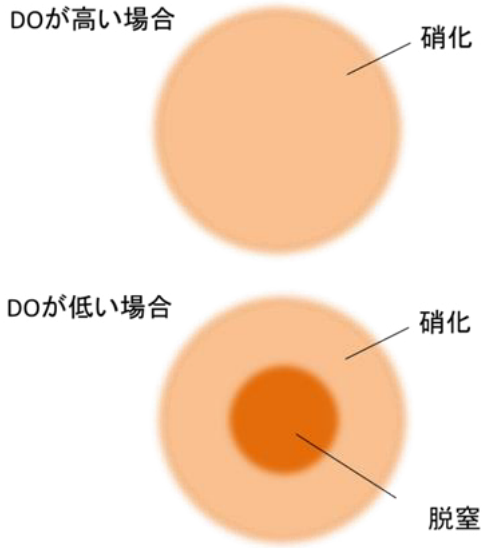

図 6 活性汚泥フロックの内部モデル

5. 結論

・下水処理場の反応槽において，嫌気-無酸素-無酸素-無酸素-好気-好気から嫌気-無酸素-好気-無酸素-好気-好気に変更することで，3 槽目の好気槽での硝化，4 槽目の無酸素槽での脱窒により窒素除去が向上すると考えられる。

・さらに，4 槽目の無酸素槽だけでなく 3 槽目の好気槽でも窒素除去がみられ，その量は 4 槽目の無酸素槽での除去率よりも大きかったことから，好気槽の同時硝化脱窒が窒素除去に寄与する影響が大きいことも確認された。

・好気槽で硝化し，無酸素槽で脱窒するプロセスに加え，好気槽での同時硝化脱窒も考慮した DO 設定の最適化により，窒素除去率のさらなる向上が期待できると考えられる。

6. 謝辞

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O7-19

Realization of partial nitritation for mainstream deammonification

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Keywords: sewage, nutrient, denitrification

ABSTRACT

Performance of novel nitritation process using gel entrapment carrier for municipal waste water treatment (mainstream anammox with gel-carrier) was investigated. Purpose of the study was to assess the stability of this process under low ammonium concentration (40 mg-N/L) and low water temperature (20 degrees C) condition. We applied heat-shock treatment to some portion of the nitritation gel carrier frequently for suppressing nitrite-oxidizing bacteria (NOB), and as a result, we succeeded to operate the process stably more than 3 months with suppression of the activity of NOB. In addition, it was confirmed that half-nitritation is possible at a high rate of HRT 1 hour, and that the concentration ratio of ammonium and nitrite can be maintained optimally by DO control.

1. INTRODUCTION

It is important to remove nutrients such as nitrogen from wastewater for improving the water quality in closed water area. Anaerobic ammonium oxidation (anammox) process is a novel biological denitrification process for nitrogen wastewater treatment. Since both ammonium and nitrite are needed for the anammox reaction, part of the ammonium in wastewater has to be oxidized to nitrite with pre-treatment, such as nitritation process. This nitritation-anammox (deammonification; N-A) process is less-energy and cost-effective way to remove ammonium nitrogen compared with conventional nitrification-denitrification process.

However, this N-A process has only been applied to the sidestream municipal wastewater (digester supernatant) treatment and some specific industrial wastewater treatment with high ammonium concentration and high temperature, yet not to the mainstream municipal wastewater treatment with low ammonium concentration and low temperature.

The main challenge for applying N-A process to mainstream treatment is to keep the appropriate ratio between nitrite and ammonium concentrations stably under low ammonium concentration and low temperature condition, because nitrite easily changes to nitrate under that condition.

In our previous works, the full-scale nitritation-anammox plant using gel entrapment technology was successfully operated for industrial wastewater treatment [1]. Especially, it is possible to keep nitritation without nitrate production by giving the intermittent heat load (heat-shock) for gel [2].

In this study, heat-shock technology was applied to the nitritation process under low ammonium concentration and low temperature condition for investigating the possibility of applying N-A process to mainstream municipal wastewater treatment.

2. METHOD

In this study, gel entrapment technology was applied to immobilization of bacteria. For the nitritation process, gel carriers that immobilized ammonium-oxidizing bacteria (AOB) and nitrite-oxidizing bacteria (NOB) inside were used. The size of the gel carrier is 3 mm cubes and the base material is Polyethylene Glycol. A complete mixing tank having volume of 0.5L was prepared as the nitritation reactor, and 0.05L of gel carriers (10%) was charged therein. Synthetic wastewater adjusted to ammonium concentration of 40 mg-N/L with ammonium sulfate was continuously fed to the reactor. The HRT was kept 1hour. In order to suppress the activation of NOB, 4% of the gel carriers were immersed in hot water at 60 degrees C for 60 minutes once a day. Dissolved oxygen (DO) concentration was controlled to achieve the appropriate ratio between ammonium and nitrite concentrations during the experiment.

Temperature of the feed water and the reactor was kept 20 degrees C. In order to evaluate nitritation performance, influent and effluent water were analyzed for ammonium, nitrite and nitrate.

3. RESULTS and DISCUSSION

Heat-shock technology was applied to the nitritation reactor from start-up period for investigating the

effectiveness of suppressing the nitrate production. Figure 1 shows the nitrogen concentrations in nitritation reactor with heat-shock technology. After 20 days, the ammonium and nitrite concentrations maintained both approximately 20 mg-N/L stably. It was an appropriate ratio for anammox process. In contrast, nitrate was not produced for 3 months. NOB in the gel carrier could be completely inactivated by the heat-shock treatment effect. Moreover, it was confirmed that the nitritation process was operated with a short HRT of 1hour, and half-nitritation was achieved. DO concentration during the experiment was controlled about 1 to 4 mg/L for controlling the concentration ratio of ammonia and nitrite to be 1:1. This ratio is appropriate for the anammox phenomena. In this test, the ammonium loading rate and nitrite production rate were approximately 0.9 and 0.4 kg-N/m3-reactor/d, respectively. Very fast nitrification performance was observed even though the packing ratio of the carrier was 10 percent.

4. CONCLUSION

In this study, nitritation performance using gel entrapment technology at low ammonium concentration and low water temperature was investigated for the purpose of applying N-A process to mainstream municipal wastewater treatment.

In the nitritation process, it was clarified that NOB can be inactivated stably by periodic heat-shock treatment to a part of the gel carrier. In addition, it was confirmed that half-nitritation was achieved at a high rate of HRT 1 hour, and that the concentration ratio of ammonium and nitrite can be maintained optimally by DO control.

As mentioned above, it was concluded that partial nitritation process under low ammonium and low temperature condition was substantiated by applying the gel entrapment technology and heat-shock technology to the nitiritation process. This conclusion suggests that it is possible to apply the N-A process using gel carriers to mainstream municipal wastewater treatment.

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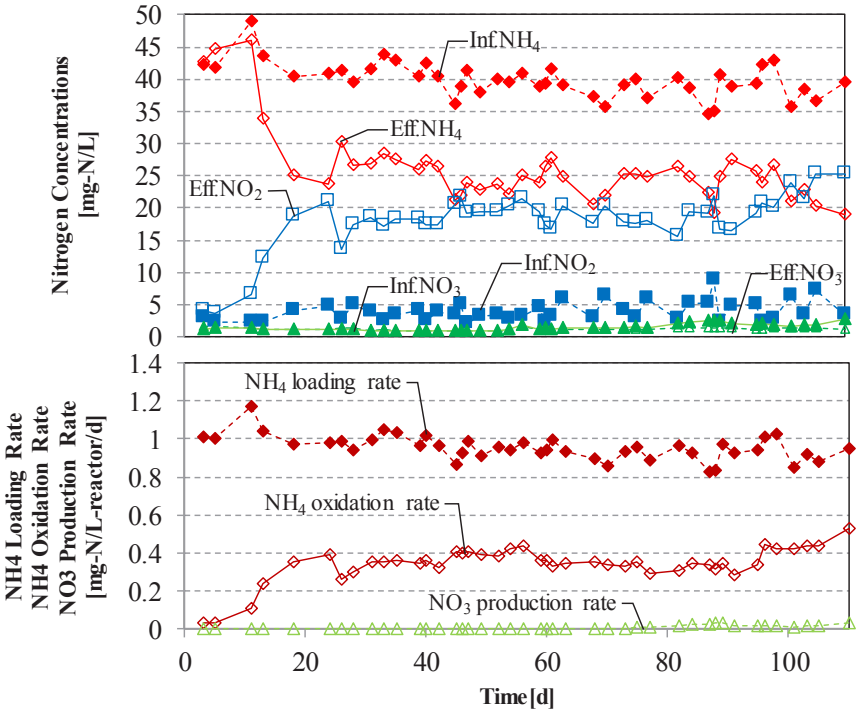

Fig. 1 Performances of the nitritation reactor using heat-shocked gel carriers.

O7-20

Simultaneous removal of nitrogen and priority phthalates from municipal wastewater for management of fresh water sources

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Keywords: Emerging contaminants, Fate, IFAS process, Phthalates, Removal, Wastewater treatment.

ABSTRACT

The study was focused on pilot scale experiments in order to understand the impact of carbon removal and nitrogen removal configuration on phthalate removal in an integrated fixed film activated sludge (IFAS) system which can be used to save lakes and fresh water sources from pollution. To achieve these objectives, four priority phthalates (DEP, DBP, BBP and DEHP) were chosen. Run I was carbon removal process and run II was nitrogen removal process. It was observed that during run I when there was intensive carbon removal process, the percentage removal was in the range of 40 – 78% (DEP), 64 – 85% (DBP), 40 -98% (BBP) and 65 – 90% (DEHP) respectively. Comparatively to run I, the percentage removal in run II, the percentage removal of phthalates varied over a smaller range. The range of percentage removal in run II increased to 84 - 96% (DEP), 83 – 97% (DBP), 85 – 99% (BBP) and 87 – 95% (DEHP). During run I, there were fluctuations in the removal of DEP, DBP and BBP with average removal of 60±13%, 75±8% and 76±21% respectively. During run II, when the anoxic zone was developed with inlet diversion, the removal of all four phthalates was steady and higher. The maximum contribution to the overall removal was observed in the secondary oxic tank in both operational runs. Biodegradation was observed a main contributor to the overall removal. Mass balance calculations showed that during run I, 62% of influent DEP, 65% of influent DBP, 68% of influent BBP and 61% of influent DEHP was removed by biodegradation while as during run II, 90% of influent DEP, 90% of influent DBP, 91% of influent BBP and 89% of influent DEHP was removed by biodegradation.

1. INTRODUCTION

Large usage of phthalate acid esters (PAEs) or phthalates in manufacturing of polyvinyl resins, wall coverings and car coatings etc. and their release into the environment have made their presence ubiquitous in the environment [1,2]. Their release into the environment is because most of the phthalates are not chemically bound to the product. High concentration of phthalates is detected in influents of wastewater treatment plants and the inefficient removal of these compounds in the treatment plant is considered as one of the main source of their presence in fresh water sources [3, 4]. Our earlier study Gani and Kazmi [5] with full scale wastewater treatment facilities observed that phthalate removal was highest in nutrient removal based sequencing batch reactor (SBR) based wastewater treatment plant. Fate study also confirmed that the biodegradation was also highest in this treatment configuration compared to conventional activated sludge process and upflow anaerobic sludge blanket reactor followed by polishing pond.

The objective of this study was to investigate the impact of nitrogen removal configuration and carbon removal sequence on phthalate removal. To achieve these objectives, four priority phthalates (DEP, DBP, BBP and DEHP) and an integrated fixed film activated sludge (IFAS) process was chosen because IFAS process has mounting market attention and contain features of both activated sludge process and attached growth process.

2. METHOD

2.1 IFAS process based reactor

A 35 L bioreactor composed of three reaction tanks and a settler was used in the study (Figure 1). The three reaction tanks were 1) media tank with aeration 2) an anoxic tank 3) an oxic tank and the reaction volume was 10 L each. A 5 litre settling tank with rotating scraper was installed at the end of treatment process. The media used in first tank was polyvinyl alcohol gel beads occupying 10% or 1 L of reactor volume. Aeration in media tank and oxic tank was provided with diffusers placed at bottom. Continuous mixing was carried out in anoxic tank with the help of rotating shaft. Initially for 64 days the raw sewage inflow was completely fed to media tank. After that 20% of raw sewage was fed into anoxic tank for external BOD loading for denitrification. Total HRT of

the wastewater in the reactor system was 6 hours with 2 hours in each tank. Sludge recirculation was carried into the anoxic tank with flow rate of 60 L/d (Table 1).

Table 1 Operational information of the PVA gel based IFAS pilot plant.

Parameter	Run I	Run II
HRT (hours)	6	6
Flow (L/d)	120	120
SRT (days)	7.3	7.5
External carbon source flow rate (L/d)	-	24

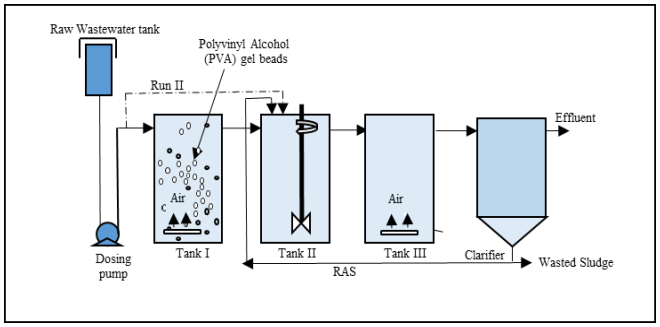

Fig. 1 Flow diagram of the IFAS pilot plant.

3. RESULTS AND DISCUSSIONS

3.1 Treatment performance of the IFAS bioreactor

Figure 2 and Table 2 shows the COD and BOD removal performance of the IFAS reactor system in different stages. It took almost 40 days for the bio reactors to get stable and perform at steady rate. However, stability of the bioreactor with respect to carbon removal (COD and BOD) was comparatively faster than nitrification. COD in the effluent of the bioreactor continued to be less than 100 mg/L from 15th day of start of operation while as the ammonia removal stabilized after 40 days. The longer time for nitrification to get stabilized was due to washout of biomass from the media tank and attachment to the media. It was observed that the biomass in mixed liquor reduced to less than 500 mg/L after inoculation with 1500 mg/L of MLSS in the beginning and the trend was not changing till 40th day of operation. From 45th day to 50th day, the wasted sludge was manually recirculated to media tank which enhanced nitrification to a steady rate of more than 90%.

Table 2 Performance of wastewater treatment in IFAS reactor.

	Startup	Phase 1	Phase 2
Influent COD (mg/L)	388±211	375±65	435±124
Efficiency (%)	77±18	91±3	93±3
Influent BOD (mg/L)	185±74	199±47	188±59
Efficiency (%)	82±11	91±6	96±2
Influent TSS (mg/L)	-	250±86	313±45
Efficiency (%)	-	94±4	98±1
Influent NH_4^+-N (mg/L)	47±25	43±9	17±8
Efficiency (%)	31±30	97±2	95±5
Influent TN (mg/L)	59±28	68±1	39±11
Efficiency (%)	31±30	71±9	70±15
Influent PO_4^{3-}-P (mg/L)	14±3	7±2	8±1
Efficiency (%)	49±15	37±13	25±24

3.2 Phthalate removal performance of IFAS bioreactor

Figure 2 shows the removal of phthalates in the IFAS process during two different operational scenarios. Phthalate monitoring in the samples from IFAS process was carried out after stabilization of carbon and nitrogen removal. During run I i.e. unavailability of anoxic zone, there were fluctuations in the removal of DEP, DBP and BBP. The average removal of DEP, DBP and BBP in this run was 60±13%, 75±8% and 76±21% respectively. During run II, when the anoxic zone was developed with inlet diversion, the removal of all four phthalates was steady and higher. The average removal of DEP, DBP, BBP and DEPH was 89±4%, 93±4%, 95±5% and 94±5% respectively. The steadiness in removal during run II may be due to availability of different reaction environments which enhanced the removal by providing different metabolic pathways. Enhanced removal of micro pollutants in a membrane bioreactor (MBR) having several aerobic and anoxic zones was observed by Phan et al. [6] than a pilot scale MBR having only one aerobic and anoxic reactor.

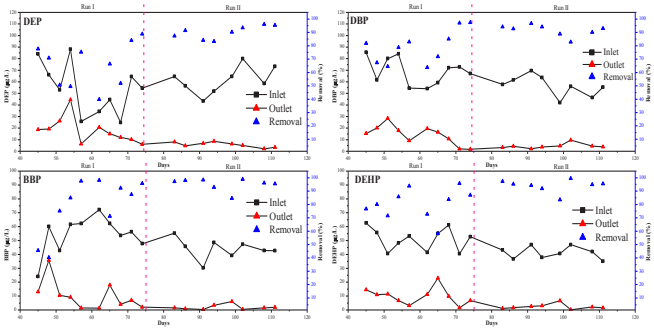

Fig. 2 Phthalate removal in IFAS pilot plant.

3.3 Phthalate mass balance

From fate calculations the contribution of the sorption to the overall removal was very less (Figure 4). The reasons for this was less wastage of sludge from the pilot plant

rather than low sorption of phthalates to suspended bio solids. The average concentration of four phthalates attached to bio solids in three tanks was in confirmation with previous studies such as that of Gao et al. [3] and Gani et al. [5].

Biodegradation was observed a main contributor to the overall removal. Mass balance calculations showed that during run I, 62% of influent DEP, 65% of influent DBP, 68% of influent BBP and 61% of influent DEHP was removed by biodegradation while as during run II, 90% of influent DEP, 90% of influent DBP, 91% of influent BBP and 89% of influent DEHP was removed by biodegradation. This implies that the increase in removal of the phthalates during biological nitrogen removal configuration (run II) was due to enhancement is microbial degradation rather than sorption. Earlier field scale studies such as that of Gani et al. [5] have also observed the higher contribution of biodegradation to the overall removal in nutrient removal treatment technologies.

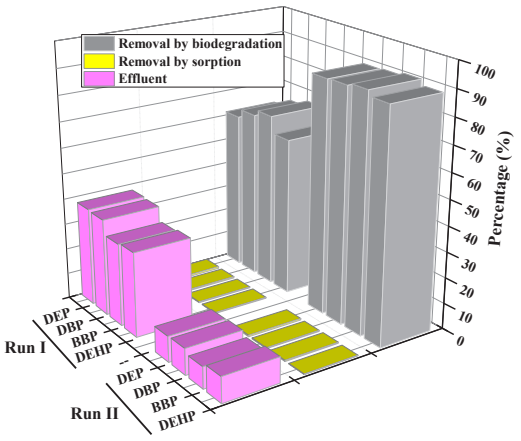

Fig. 3 Mass balance of phthalate removal in IFAS pilot plant.

4. CONCLUSIONS

This study was aimed to investigate and report the treatment of phthalates in biological wastewater treatment under carbon and nitrogen removal conditions. After start of the operation of the pilot plant, stability of the IFAS bioreactor with respect to carbon removal (COD and BOD) was comparatively faster than nitrification and the treatment performance was conforming the discharge criteria of India. The removal of phthalates during nitrogen removal configuration (run II) was more than the removal during intensive carbon removal configuration (run I). Not only there was increase in average removal of phthalates in run II but there was steadiness in the removal performance of these compounds which can be owed to the different reaction environments in run II. The removal of phthalates in the presence of external carbon source enhanced in anoxic zone. Finally, fate studies were carried out in this study from which it was observed that under similar operating parameters, main process of removal of phthalates in IFAS reactor is biodegradation.

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O7-21

Comparison of Effluents Characteristics from Full-Scale Wastewater Treatment Plants in Thailand, USA, and Japan before Discharging to Lakes

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Keywords: Effluents; Thailand; USA; Japan; Lake

ABSTRACT

Three full-scale systems wastewater treatment plants (WWTPs) from Thailand, United States of America (USA), and Japan were used as study sites. All of these WWTPs were designed and operated for biological nitrogen removal (BNR) by using nitrification-denitrification processes. In general, the WWTPs in Thailand operated at higher values of temperature, HRT and SRT comparison to USA and Japanese WWTPs. Influents and effluents from these sites are compared and discussed in terms of BNR, dominant nitrifying and ammonia oxidizing archaea (AOA) microorganisms, and WWTP engineering design. Polymerase chain reaction coupled with denaturing gradient gel electrophoresis was used to identify dominant bacteria involved in nitrogen transformations: ammonia-oxidizing bacteria (AOB), nitrite-oxidizing bacteria (NOB), and nitrate reducing bacteria (NRB). AOB Nitrosomonas sp. was found only in Thailand where aerobic HRT was ≥ 4 hours and SRT was ≥15 days. Furthermore, AOB Nitrosospira sp. were found only in Japan at aerobic HRT ≤ 4 hours and SRT≤ 13 temperature (21-27°C). NOB Nitrospira sp. was found at aerobic HRT ≥ 4 hours and SRT ≥ 6 days. Interestingly, Nitrotoga sp. was found in the aerobic tank one in Thailand and one in Japan and co-occurred with NRB Burkholderia denitrificans. The higher wastewater temperature and lower influent nitrogen concentration in Thailand appear to promote a different AOB and NOB community structure than in Japan. The conditions at the Thai WWTP promoted the dominance of AOA amoA genes over AOB amoA genes, while conditions at the WWTPs in Japan and USA promoted growth of AOB. The Thai WWTP is a unique system that can be used to better understand.

1. INTRODUCTION

Nitrogen in municipal wastewater is source of water pollution which reduces oxygen concentration. Nitrogen should be removed before it is discharged into the environment. Nitrogen forms can have deleterious effects on human health, aquatic life, and environment. For example, ammonia (NH3) is toxic to fish and many other aquatic organisms. Nitrate (NO3-) is a significant potential public health hazard in drinking water which presents the risk of methemoglobinemia (blue baby syndrome) in infants. Nitrogen is the major nutrient that enhance eutrophication of freshwater and lakes. Domestic sewage, agriculture, and industries are sources of nitrogen. In Thailand, domestic sewage is a main source of nitrogen. In Japan and USA, runoff from agriculture is significant source of nitrogen. However, it is quite different to control runoff from agriculture because there are more land and area. Also standard of effluent discharging from agriculture is not too rigid. In general, WWTPs in Japan and USA report higher nitrogen removal than WWTPs in Thailand. However, there is little information available to elucidate the factors responsible for the lower nitrogen removal efficiency of WWTPs in Thailand (humid tropical climate) relative to the WWTPs in Japan and USA (humid subtropical climate). Potentially important differences include climate, influent wastewater characteristics, WWTP design and dominant bacteria that oxidize or reduce nitrogen.

2. METHODS

Influent and effluent wastewater quality was determined

according to *Standard Methods for the Examination of Water and Wastewater* (APHA et al. 1995). All effluent samples were collected every day for one year. All samples were kept at 4°C until analysis. Effluent characteristic quality was determined by measuring biochemical oxygen demand (BOD), organic nitrogen, ammonium, nitrate, and total nitrogen and phosphorus. All the effluent samples from points from each WWTP were taken in duplicate.

DGGE analysis and sequencing of DGGE fragments

For DNA analysis effluent samples from three WWTPs were collected twice in one year. All the samples of DNA analysis from this work were only collected in the aerobic basins because of focus on nitrifying and ammonia oxidizing archaea (AOA) microorganisms.

3. RESULTS

These WWTPs were selected as study sites because each WWTP has biological nutrient removal (BNR) (nitrification and denitrification process) and had been designed and similar operation for municipal treatment system. Average physical and chemical characteristics of influent and effluent of these three WWTPs are shown in Table 1. The qPCR results show the relative abundance of AOA and AOB amoA genes at the three WWTPs.

Table 1 Characteristics of the activated sludge systems at the WWTPs in Thailand, USA, and Japan.

Parameter	unit	Wastewater Treatment Plants		
Treatment Process		Thailand OD	USA OD	Japan AO
Flow rate	m^3/day	28,735	15,160	92,300
Temp.	°C	30	16	22
pH		7.2	6.7	6.2
BOD_{inf}	mg/L	174	336	110
$BOD_{eff.}$	mg/L	3.7	3.7	2
$NH_4^+{}_{inf}$	mg-N/L	15.9	35.8	15.9
TN_{inf}	mg N/L	25.3	56*	24.7
$NH_4^+{}_{eff}$	mg-N/L	8.7	0.7	6.5
$NO_3^-{}_{eff}$	mg-N/L	3.2	3.2	12.2
MLSS	mg/L	7,180	2,330	920
Organic Loading rates	Kg/day	5,000	5,094	10,153

4. DISCUSSION

The levels of AOA amoA gene in the WWTPs in Japan and USA were below the quantification limit of 1.0×101 copies/ng-DNA, corresponding to 7.6×102 and 3.9×102 copies/mL-sludge, respectively. In contrast, the copy number of AOB amoA gene averaged 2.4×105 copies/ mL-sludge for both the WWTPs in Japan and USA. This indicates that ammonium oxidation was conducted by AOB but not AOA in Japanese and USA WWTPs.

5. CONCLUSION

The effluent characteristics quality both chemical and biological quantity from USA and Japan are lower than the standard. For Thai's effluent on quantities of fecal coliform and E-coli are significantly lower than Thai's and US EPA's standards. The effluents could not usage as an indirect potable water reuse.

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O7-22

Development of Design Method for Localization of Japanese Johkasou to EU Area

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Keywords: small-scale wastewater treatment facility, localization, performance evaluation test, domestic wastewater solution, design method

ABSTRACT

For environmental conservation of closed water bodies such as lakes and bays, the promotion of wastewater treatment facilities that can remove not only BOD but also nitrogen, one of the causes of water-bloom and red tide, is desirable. To apply Japanese johkasou to other countries, it is necessary to modify the design of johkasou to harmonize with the local life style and environmental characteristics. For this purpose, this study examined the localization of Japanese johkasou for the EU region where the performance evaluation method for such facilities has been established. Focusing on the amount of wastewater and the pollutant load which differ in the performance evaluation tests between EU and Japan, an EU-oriented facility was designed with BOD volumetric load equal to Japanese facility. This facility was experimented in France, and the results were compared to those of the Japanese prototype model. As a result, the effluent quality of the EU-oriented facility was maintained at the same level as the Japanese model even when the influent BOD load increased to 120% of the preset value. This result indicates that the most common design method in Japan using BOD volumetric load is effective for designing EU-oriented facilities, but there is a possibility that the volume of the facility may be over-designed. Furthermore, to maintain the ability to remove nitrogen, it is important to the keep the water temperature in the facility above 13°C.

1. INTRODUCTION

The Sustainable Development Goals (SDGs) entered into force on 1 January 2016. To achieve one of the targets to halve the proportion of untreated wastewater, countries need to improve their wastewater treatment facilities correspondingly over the next 15 years. Moreover, in the event that domestic wastewater is discharged into a closed water body, such as a lake or a bay, it is desirable that in addition to BOD, the treatment facilities are able to remove nitrogen and phosphorus, two of the causes of water-bloom and red tide.

Wastewater treatment infrastructure in Japan includes centralised treatment – the sewerage system, and decentralised treatment – johkasou. Centralised treatment suits densely populated areas, whereas decentralised treatment is suitable for sparsely populated mountainous areas. Currently, johkasou is expected to be the solution for the latter areas as they have lower population coverage of wastewater treatment. Johkasou is a type of wastewater treatment facility uniquely developed in Japan. Furthermore, new types of johkasou that can remove nitrogen and phosphorus have been developed in recent years. For these reasons, johkasou has been drawing attention from other countries, and a number of technology transfers have been accomplished. On the other hand, in regions with an established performance evaluation method for johkasou and other small-scale wastewater treatment facilities, these facilities cannot be installed if their performance test results using the established method failed to meet local effluent standards. Regarding the testing method, differences exist between EU and Japan in influent conditions such as influent volume and pollutant load, and testing conditions such as water temperature and maintenance interval. Also, different effluent standards exist among EU member states. Due to these facts, no significant progress has been made for localization of johkasou. If a design method that allows redesigning Japanese johkasou to meet standards of various countries can be discovered, johkasou's contribution towards the popularization of wastewater treatment facilities that harmonize with local features could be further expected.

In this study, an EU-oriented small-scale wastewater treatment facility and a Japanese johkasou were put into operation in France and Japan respectively for a period of more than one year to investigate and analyze the influence of different performance evaluation methods on the treatment performance.

2. METHOD

(1) Method of examination

In EU, EN12566-3+A2 regulates the performance evaluation method for small-scale wastewater treatment facilities. In Japan, on the other hand, johkasou performance testing standard was established based on the Building Standard Law. A brief description of the testing methods in EU and Japan is shown in Table 1.

Analysis of the performance of the EU-oriented small-scale wastewater treatment facility (the "EU model") was carried out with the following steps in this study: (1) clarify the differences in performance testing method between EU and Japan, then review the design of johkasou (the "Japanese model") for use in the EU region; (2) regarding testing the effluent, prolong the testing duration designated in EN12566-3+A2 for the EU model, meanwhile, test the Japanese model in Japan using the testing method for johkasou; (3) based on the results from (2), comparatively analyze the BOD and nitrogen in the effluent, and examine the influence of different testing methods on treatment performance.

(2) Testing method for the EU model

Testing for the EU model, carried out by a French testing institute, lasted for 63 weeks (442 days) in total, including a 38-week (263 days) test based on EN12566-3+A2 shown in Table 2, and an additional test, which included a 2Q overload test to examine the performance in the overloading condition. Water volume 1Q was 750 L/day. Influent quality, effluent quality as well as water temperature were measured 38 times each throughout the test. In terms of maintenance during the test, based on the local testing method, desludging was set to be conducted when settled sludge reaching 1/3 of the designed volume of primary process chamber, whereas maintenance and operation would be carried out in the event of a malfunction, such as a breakdown. This test will be referred to as the "EU test".

Table 1 Testing methods in EU and Japan (5 P.E)

		Unit	EU test	Japanese test
Inflow rate		(L/day)	750	1,000
Influent	BOD	(mg/L)	150 ～ 500	200（180 ～ 220）
	TKN	(mg/L)	25 ～ 100	45（40 ～ 50）
	NH_4-N	(mg/L)	22 ～ 80	-
Water temperature		(℃)	-	20, 13 (low temperature test)

※(　　): range; ※※T-N measured in Japanese test was substituted for TKN

Table 2 Details of the EU test

Items	Testing duration (days)			Times of measurement		
	EN12566-3+A2	Additional	Total	EN12566-3+A2	Additional	Total
Start-up(1.0Q)	34	0	34	0	0	0
Routine(1.0Q)	205	95	300	25	0	25
Low load(0.5Q)	28	0	28	3	0	3
Low stress	14	41	55	0	3	3
Overload(1.5Q)	16	0	16	2	0	2
Overload(2.0Q)	0	43	43	0	5	5
Total (excl. Start-up)	263	179	442	30	8	38
Total	297	179	476	30	8	38

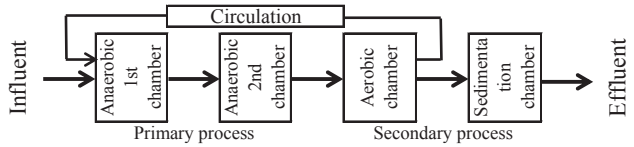

Fig.1 Treatment process of the EU model

(3) Testing method for the Japanese model

As shown in Table 1, standard duration of a johkasou test is 16 weeks which is considered difficult for comparison with the 63-week EU test. For this reason, actual duration of the performance test in Japan was adjusted to 52 weeks (to match the once/year desludging interval regulated by Johkasou Act). Moreover, for comparison with the EU model, a 5 P.E facility was chosen as the Japanese model to be used in the test, with an influent volume of 1.0Q (1,000L/day). Objects being tested were set the same with the EU test and measured 26 times in the test. This test will be referred to as the "Japanese test".

3. Design of the EU model

(1) Summary of the design

The prototype of the EU model was chosen from johkasous qualified in the Japanese performance test. The design was then reviewed based on the differences in testing method between EU and Japan. The reviewed design is described below.

(2) Effluent quality and treatment process

Effluent standards in the EU regions are different from the Japanese standard for johkasou (BOD≤20mg/L; T-N≤20mg/L). However, as the objective of this study is to examine the appropriateness of the method of johkasou localization, the Japanese standard was adopted as the preset value for the EU model, except for T-N which was not measured in the EU regions. In response, TKN was used as the nitrogen indicator for the EU model. Moreover, taking account of maintainability, a combination of two simplified anaerobic chambers without flow adjustment or filtration, an aerobic chamber and a sedimentation chamber (Fig.1) was chosen as the treatment process (structure) of the EU model. Moreover, as disinfection was not required in EU, the disinfection chamber was deleted.

(3) Volume of the EU model

In Japan, the most common method to design the necessary volume of treatment facilities with various inflow rates was to calculate pollutant volumetric load and wastewater volumetric load of the influent, separately, then adopt the higher value [1]. In this study, volumetric loads of BOD, TKN and wastewater of the Japanese model were used for the calculation for the EU model. As a result, the highest value was 2.838m^3, calculated from the BOD volumetric load, and was adopted as the necessary volume (necessary volume of the Japanese model is 1.892m^3). Moreover, assumed influent quality

Table 3 Effluent results of EU model and Japanese model

Items		Inflow rate	BOD (mg/L)		Removal rate	TKN (mg/L)		Removal rate
			Influent	Effluent		Influent	Effluent	
EU test	Condition	1.0Q	400	20.0	95%	80	20.0	75%
	EU model	average	481	10.7	98%	102	20.2	80%
		1.0Q	488	11.1	98%	104	20.5	80%
		0.5Q	493	12.0	98%	105	16.1	85%
		1.5Q	335	9.5	97%	83	52.2	37%
		2.0Q	492	7.4	98%	101	11.5	89%
Japanese test	Condition	1.0Q	200	20.0	90%	45	20.0	56%
	Japanese model	1.0Q	207	11.9	94%	47	16.3	65%

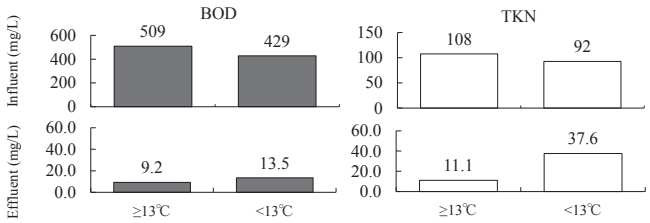

Fig.2 Effluent results by water temperature

of the EU model in this calculation was BOD 400mg/L and TKN 80mg/L, taking into account variations.

4. RESULTS

(1) Effluent results of EU model and Japanese model

Effluent results of the EU model and the Japanese model were shown in Table 3. As shown, in the EU test, the average BOD in the influent (481mg/L) was 1.2 times the preset value - close to the maximum value of the testing condition, meanwhile, the average TKN in influent (102mg/L) exceeded the maximum value. As a result of the fluctuating inflow rate between 0.5Q and 2Q, the average effluent BOD (10.7mg/L) was at the same level with the Japanese model, and was below the preset value (20mg/L), however, average effluent TKN (20.2mg/L) exceeded the preset value slightly.

(2) Maintenance in the EU test

In the EU test, it took 476 days to reach the requirement for desludging. During this period, no functional deterioration had been observed, thus no need for maintenance work.

5. DISCUSSION

(1) Design method based on volumetric load

As the EU test had a higher influent BOD concentration than the preset value, the BOD volumetric load (0.13 BOD-kg/m^3・day) was higher than the Japanese model (0.11 BOD kg/m^3・day). In addition, the inflow rate fluctuated intentionally. Considering these facts, analysis of the influence on effluent BOD load was made with a non-exceedance probability of 90%. The BOD in the effluent of the EU model was 17.2 mg/L, which was almost the same as the calculated value of the Japanese model (17.0 mg/L). It indicates that using the same BOD volumetric load is an effective design method for calculating the necessary volumes of facilities with various influent loads. However, it is also suggested that this method may cause over design. In terms of TKN volumetric load (TKN-kg/m^3), the EU model (0.028) was higher than Japanese model (0.025). It is considered that the EU did not meet the preset value of TKN.

(2) Influence of water temperature on performance

Water temperature in the low-water-temperature test in Japan was set to 13°C. In the 26 measured results, only one result was below 13°C (12.7°C). On the other hand, results from the EU test were categorized into <13°C and ≥13°C (Fig.2). Effluent BOD, TKN at <13°C were worse than at ≥13°C, regardless of influent pollutant concentrations being lower. Also, although variation of effluent BOD stayed below the effluent preset value, TKN at <13°C significantly exceeded the preset value. As a result of analysis, nitrification rate (mg-N/g-SS・hr), which is the decreasing rate of ammonia nitrogen, of the Japanese model was 1.70, similar to the EU model at ≥13°C (1.65). However, the rate at <13°C fell to 0.88. Therefore, in order to maintain the ability to remove nitrogen throughout a whole year, water temperature needs to be kept above 13°C.

6. CONCLUSION

This study aimed to find out the design method that allows redesigning the Japanese johkasou to meet various standards in different countries for its overseas application. And the following conclusions were made.

1) As a method that allowed Japanese anaerobic-aerobic johkasou to meet the low-volume and high-concentration loading condition in the EU regions, an EU-oriented wastewater treatment facility with the same BOD volumetric load was designed. As a result, the effluent BOD in the EU test met the preset value based on the Japanese model. Moreover, during the 476 days of the test, no desludging or maintenance work was required.

2) Although influent BOD in the EU test was higher than the preset value, the effluent was at the same level as the Japanese model. As a design method for wastewater treatment facilities for various influent loads, using the same pollutant volumetric load is effective. However, it is suggested that this may cause over design.

3) In the EU test, effluent TKN worsened when the water temperature was below 13°C. As this was caused by decreased nitrification rate under low water temperature, keeping the water temperature in the facility is considered important in order to maintain the ability to remove nitrogen.

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O7-23

印旛沼流域におけるナガエツルノゲイトウ問題
～治水リスクの軽減にむけた外来種管理の持続可能な取り組み～

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キーワード:印旛沼開発事業, 利水施設, 特定外来生物, SDGs, 地域活性化

抄録

千葉県北西部に位置する印旛沼では, 出水時に治水対策として大和田排水機場よりポンプ排水を行っている. しかし, 印旛沼の流入支川に大量に繁茂している特定外来生物ナガエツルノゲイトウ(以下, ナガエ)が, 出水時に大和田排水機場に漂着し, スクリーンに詰まることによるポンプ排水への影響を回避するため, 重機や手作業で漂着したナガエの駆除活動を実施している. このような状況を未然に防ぐために, 千葉県では市民や学生ボランティアとともに駆除活動を行っている. 本論文では, 印旛沼におけるナガエの問題について経緯と現状, 今後の課題を整理するとともに, ナガエに関する取り組みの中で培われてきた地域との連携や, 課題解決が地域活性化に繋がる可能性について考察した. また, このような活動は SDGs の達成に向けた具体的な施策である生物多様性の保全にも関連していると考えられ, 分野を超えた連携強化の必要性が示唆された.

1. はじめに

グローバルリスク報告書 2018 によれば, 発生確率の予測が難しく, ひとたび発生すれば甚大な被害をもたらす「異常気象」が高リスクの自然災害として挙げられている[1]. 国や自治体はこうした気象災害への備えとして, 河川や湖沼における治水対策の強靭化を図っているが, 流域における土地利用の変化, 特に表面流出量の増加をもたらす森林や草原・湿地環境の減少という想定項目に加え, 侵略的外来種の侵入定着がさらなる阻害要因として顕在化し, 自然災害の防止・低減方策の実現が困難さを増している.

本論文は, 気候変動下における総合治水を念頭に, 印旛沼流域水循環健全化会議(印旛沼流域における課題解決のため千葉県が 2001 年に設立)が行ってきた特定外来生物ナガエツルノゲイトウ(以後, ナガエと略称する)対策の取り組みを紹介する. それによって, 類似の課題に直面する地域や自治体との情報交換・経験の共有を図り, 実行可能かつ効果的な解決策への道筋を見出すことを目的とする. なぜならば, 印旛沼流域におけるナガエの何が問題であり, だれが利害関係者(ステークホルダー)なのか, そしてなぜ河川管理者が様々な協力者とともにこの課題に取り組まなければならないのかは, ナガエの存在が知られてからしばらくの間, 曖昧模糊とした状態であり, 駆除活動も手探り状態であった. そして, 現在もナガエ問題の本質がどこにあるのか, 明らかになったとは言い難いからである. そのため, ナガエ問題の経緯と現状, 今後の課題を可能な限り整理し, 見える化させる意義は小さくない.

2．ナガエの生態的特徴と印旛沼流域での生育状況

ナガエは水際に生育する南米原産の多年生植物であり, 水際に大群落をつくる. 茎断片からの栄養繁殖が旺盛で, 流下した断片が漂着した先でも群落を

形成する．日本では 1989 年に近畿地方で初めて記録され，印旛沼地域では 1990 年に，西沼に流入する鹿島川でナガエが確認された．1997 年には西沼に分布を拡げ，2000 年頃までに周辺河川，水路や農地にも侵入がみられた．現在では，西沼・北沼およびすべての流出入河川と水田での生育が確認されている．

3．ナガエによる被害の本質

印旛沼は利根川の下流域にある霞ヶ浦，北浦，手賀沼と同様に，縄文海進後に形成された海跡湖である．江戸時代から始められた印旛沼開発事業が昭和 44 年に完成し，湖沼の開水面の面積が大幅に減少し、多くの水利施設（排水機場，揚水機場）によって水位調節される広大な干拓農地が創出された．現在の印旛沼は，農業用水，工業用水，飲料水の水源として人為的に管理されている湖沼である．

印旛沼におけるナガエ問題は，主に利水，治水，そして農業に及ぼす影響である．繁茂した群落が開水面を塞ぎ，内水面漁業への航路障害については，定かではない．利水上の悪影響は，揚水機場に漂着した大量の群落がスクリーンに張り付くため，清掃作業の負担が増え，取水障害を起こしていることである．治水上の悪影響は，台風や大雨による増水時に排水機場を通じて東京湾にも強制排水を行う際に発生している．

排水ポンプ稼働時にスクリーンに張り付いた大量のナガエを取り除き，処分するためには，多額の経費が生じるばかりでなく，清掃作業時に排水ポンプを停止しなくてはならない.そのため，強制排水が制限され，沼の水位を下げることが出来なくなり，内水氾濫が発生する可能性があり、治水対策としてナガエの適切な管理の重要性が増している[2]．実際に，2015 年 9 月には台風に伴う排水時にナガエが大和田排水機場に漂着し，重機や人員による駆除作業を行ったもののポンプ全台の緊急停止が発生し，水位は計画高水位にせまり，堤内の水田が調節池の様相を呈し，一部の地域では農業揚水機場のポンプが水没する事態が発生した．

流域の水田へは，用水施設を通じて，沼や河川内に生育するナガエの群落からちぎれた茎断片が侵入して繁茂し，水稲との生育競合のほか，コンバインによる収穫作業の障害となっている．水田畦畔に蔓延したナガエが除草作業によって断片化した茎が排水路を通じて河川や湖沼に流出し，散布体の供給地となってしまうことも懸念される．

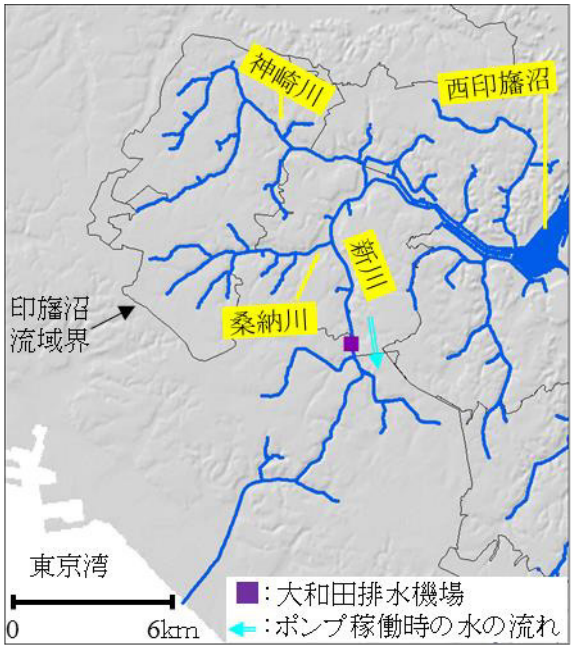

図 1 印旛沼流域に位置する大和田排水機場

4. ナガエ群落防除体系確立にむけた基礎研究

湖内における群落や茎断片の漂流，漂着，さらには水質改善の目的で行われる循環灌漑によって，ナガエは印旛沼流域の隅々に配られ，生育適地に群落を形成している．そのため，現在はすでに初期防除の段階を過ぎ，根絶は現実的な目標とはなり得ない．したがって，求められる現実的な対応とそのための基礎研究は，主に以下の4つに絞られる．

1）治水リスク軽減に資する効率的な駆除方法を確立する． 2）河川や湖内に生育する群落の成長と脱落・漂流量をあらかじめ低減するための効果的な駆除方法を確立する． 3）降雨時にナガエ群落が排水機場に漂着するタイミングと量を予測し警告を発する予報システムを構築する． 4）水利システムを介して流域内で侵入と定着を繰り返しているナガエの循環を断ち切るための効率的な駆除方法を確立する．

印旛沼環境基金の助成によって，平成 18 年から継続して行われてきたナガエ群落の分布モニタリングは，上記基礎研究の進展に不可欠な貴重なモニタリングデータを提供してきた．今後は，担い手の確保を考慮し，河川の流況データと連動する定量的なナガエ群落の挙動データの自動的取得システムの開発研究も含めたモニタリング体系の構築が不可欠である．

現在の印旛沼が農業用水，工業用水，飲料水の水源として人為的に管理されている湖沼であることを認めつつも，気候変動下における気象災害の予測可能性の低下，地盤沈下による堤防高の低下，流域の開発による土地利用の変化，施設維持費の社会コストの増加を考慮し，花見川への強制排水に大きく依存する体制からの脱却，生態系を活用した減災・防災を展望しつつ，印旛沼の在り方そのものを再検討する意義は小さくない．生物多様性の保全と生態系サービスを享受する地域社会の実現に向けた基礎研究を進め，賢明な合意形成のための社会知を蓄積することの重要性はますます大きくなるであろう．

5. ナガエ群落の体系的・組織的な防除を地域で持続的に実現する組織のあり方

外来植物の駆除については，重機や人員等の費用面に加え，外来種の取り扱いや仮置き場等の運営面が挙げられるが，財政状況や人口減少・高齢化を踏まえると，外来種への対応は後手となる可能性が高い．2015 年に国連で採択された SDGs の達成に向けて，具体的な目標として生物多様性の保全が位置づけられている社会情勢を考慮すると[3]，これらの課題解決は必要不可欠である．

印旛沼流域水循環健全化会議では，2016 年より NPO 法人国際ボランティア学生協会（以下，IVUSA）[4] とともにナガエの駆除活動を行っている[5]．

参加者の多少，経験者の参加状況，重機の有無，駆除対象とする群落サイズにより様々な駆除方法について試行錯誤され，河川区域内における群落の効果的な駆除方法については確立されてきた。



写真　水域班、陸上班、船班に分かれた多様な主体による駆除活動

状況に応じたナガエ駆除手法を取り入れながら，ナガエ駆除活動の経験者が多くなるにつれて，ナガエ駆除量の増加に繋がる事が予想される．

2018 年度は，学生・行政・企業・NPO 等が参加しやすい時期を関係者と調整しながら設定しており，さらに広報活動の工夫により，より多くのナガエが駆除される事が期待される．

7. まとめと今後の課題

効率のよい駆除手法については確立されてきたものの，治水上，管理可能な駆除量については明らかになっていない．そのため，前述の基礎研究を進める必要がある．

また，駆除した植物は現在焼却処分となっているが，印旛沼流域水循環健全化会議では，駆除植物の堆肥化について実現性を確認し，ナガエ由来の堆肥活用に向けた営農計画への適用について検討を進めており，今後は農業分野との連携強化が重要と考える．

さらに，SDGs の目標達成を念頭に置いた場合，課題解決に取り組むには関係者との連携が重要である．

多様な主体が駆除というイベントに参集し，駆除活動を通じて現地状況や課題を実感することは，持続可能性を考慮した上で重要である。また，駆除活動というイベントに「楽しい」、「達成感」といった要素が見いだせれば，ナガエの駆除活動自体が地域活性化に繋がる可能性も含め，特定外来生物の駆除問題への関わり方の良好事例となり得る可能性がある．

本論文に発表者として名を連ねた関係者が一体となってナガエ問題に取組む事により，幅広い繋がりが構築された．今後はいっそう連携を強化し，ナガエの駆除活動自体が地域活性化の一端となる事を願っている．

謝辞：本論文では，印旛沼流域水循環健全化会議委員やアドバイザー，桑納川流域において調査研究等を進められている方々から有益なご助言を頂いた．ここに記して深甚なる謝意を表します．

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O7-24

印旛沼に自生するヒシの機能性と活用について

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キーワード:ヒシ、化粧品、有効利用、ポリフェノール

抄録

千葉県の印旛沼で繁茂しているヒシ(図 1)は富栄養化により年々増え続け、従来使用されていた漁場や観光航路が確保できなくなるだけでなく、水質の悪化や悪臭なども問題となっている。これにより、毎年刈取り陸揚げ作業(図 2)が行われているが、廃棄処理コストが嵩むことも問題となっている。[1]本研究は、印旛沼に繁茂しているヒシに含まれるポリフェノールが、美容効果があると言われている緑茶カテキンより効果が高いことを明らかにした。これを化粧品に利用することで印旛沼周辺の活性化につなげていく。

1. はじめに

昭和 38 年の印旛沼開発干拓事業が行われた。その結果、面積の半減と沼が二分化されたことにより、水の流れが悪くなり水質が悪化し始めた。また昭和 59 年頃から漁業に影響が出るほどヒシが異常に繁茂し始めた。

ヒシは、池や沼に自生する一年生の浮葉植物で、2 本または 4 本の棘を持つのが特徴である。(図 3) 昔から、ヒシの実は食用とされるほか、民間薬としても利用されてきた。[2]これまでの研究で、ヒシの外皮(図 4) には、ポリフェノールが多く含まれていることが明らかになっている。[2]本研究では、印旛沼ヒシ外皮に含まれるポリフェノールの化粧品素材としての機能性について検討した。



図 3



図 4



図 1



図 2

2. 方法

① ポリフェノールの成分分析

ヒシ果皮を粉砕し、1:9～2:8 の混合抽出液に漬込み、これを濾過後、濃縮させた。吸着剤に濃縮液を通液させ、溶媒で粗ポリフェノールを脱着させ、純化したヒシ果皮ポリフェノール抽出物を作製。さらにヒシ果皮ポリフェノールそれぞれを成分分析するとトラパイン、オイゲニイン、TGG（1,2,3,6-tetra-O-galloyl-ß-D-glucopyranose）の 3 成分が特に抗酸化力を強くし示していることが分かった。(図 5)

② コラゲナーゼ活性阻害試験

シミ抑制や抗シワ効果としてコラゲナーゼ活性阻害試験とエラスターゼ活性阻害試験を行なった。試料サンプルとして、印旛沼オニビシ外皮から抽出した粗ポリフェノール、オイゲニイン、Tetra-GG、トラパイン、そして、ポジティブコントロールとしてEDTA、比較検討としてしわたるみ効果で知られている緑茶のポリフェノール（カテキン）の一種である（－）-エピガロカテキンガレートEGCGを用いた。実験方法は、次のとおりである。マイクロチューブ（2mL）にサンプル溶液15 ・lを入れ、コラゲナーゼ酵素溶液（0.1mg/ml、pH7.1）15 ・l を加えた。基質（Pz-Pro-Leu-Gly-Pro-D-Arg-OH, Trifluoroacetate、0.5 mM、pH7.1）溶液を120 l を入れ、37℃で30 分間インキュベートした。その後、25 mM クエン酸（反応停止液）300 lを入れ、酢酸エチルを1.5mL 入れ、激しく振とうし、抽出させた。さらに、遠心分離（3000rpm、10 分）を行い、上清の酢酸エチル層をセルに入れ、分光光度計（Ubest-V560、日本分光）にて320nm における吸光度の測定を行った。

③ エラスターゼ活性阻害試験

ポジティブコントロールとしてオレアノール酸、比較検討として同じくEGCGを用いた。実験方法は、次のとおりである。マイクロプレートに試料溶液50 ・l を入れ、エラスターゼ酵素溶液（10・g/ml、pH7.5）50 ・l、基質溶液（1mM のN-Succinyl-Ala-Ala-Ala-p-nitroanilide、pH7.5）を100 ・l を加えた。さらに、25℃で50 分間インキュベートし、マイクロプレートリーダー（Synergy HT、Bio Tec）にて波長415 nm における吸光度を測定した。

2. 結果

○コラゲナーゼ活性試験結果について

コラゲナーゼ活性阻害が50%の時のサンプルの濃度を示すIC50 値をまとめた。IC50 値が小さいほど高いコラゲナーゼ阻害活性を示すことから、粗ポリフェノール、オイゲニイン、Tetra-GG、トラパインは、ポジティブコントロールであるEGCG やEDTA に比べて、高い値を示した。特に、トラパインのIC50が最も小さく、高いコラゲナーゼ阻害活性を示すことがわかった。【表1】

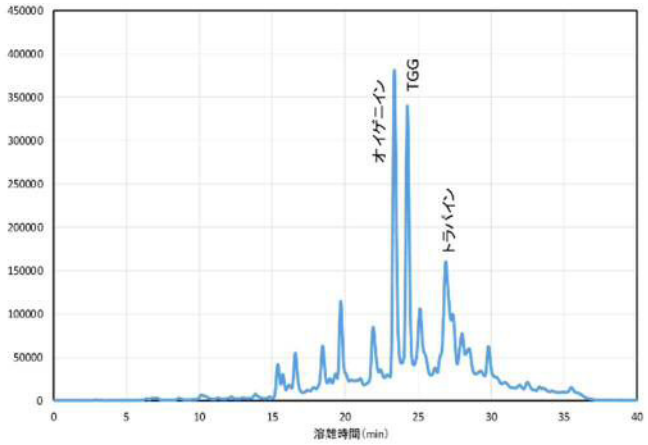

図 5 グラフを表す図

表 1　コラゲナーゼ阻害活性を示す IC50

No	化合物名	IC_{50}	
		μg/ml	μM
1	粗ポリフェノール(20170331製造)	120	-
2	オイゲニイン	104	110
3	TGG	114	145
4	トラパイン	52	54
5	EDTA・2Na（ポジティブコントロール）	556	1494
6	EGCG（(-)-エピガロカテキンガレート）	622	1356

○エラスターゼ活性阻害試験について

また、エラスターゼ活性阻害が50%の時のサンプルの濃度を示すIC50 値をまとめた。IC50 値が小さいほど高いエラスターゼ阻害活性を示すことから、粗ポリフェノール、オイゲニイン、Tetra-GG、トラパインは、ポジティブコントロールであるEGCG に比べて、高い阻害活性を示した。特に、オイゲニイン

とトラパインのIC50 が小さく、ポジティブコントロールのオレアノール酸よりも高いエラスターゼ阻害活性を示すことが明らかになった。【表2】

表２　エラスターゼ阻害活性を示す IC50

No	化合物名	IC_{50}	
		μg/ml	μM
1	粗ポリフェノール	55	-
2	オイゲニイン	1.2	1.2
3	TGG	115	146
4	トラパイン	4.5	4.7
5	オレアノール酸	44	96
6	EGCG	288	628

3. 考察

印旛沼ヒシの実は栗のように甘く、小動物などの外敵も多い。その自衛策として、外皮に多くのポリフェノールを含有し、苦味を感じさせることで外敵から身を守っていると考えられる。そうした防御本能から、抗酸化力の強いポリフェノールが精製されているのではないかと推測される。もともとヒシは美白効果としてチロシナーゼ活性阻害効果、ヒアルロニダーゼ活性阻害効果[3]が低い濃度で効果があったことから、同じようにコラゲナーゼ活性阻害効果、エラスターゼ活性阻害効果があるのではないかと推測する。

4. 結論

エラスターゼおよびコラゲナーゼの阻害活性は肌のハリや弾力性に効果を示す。したがって、印旛沼に繁茂するヒシは機能性化粧品素材として、有用なものであることが分かった。

この結果を踏まえ、今まで廃棄されていたヒシに新たな価値を生み出させることができる。ヒシの存在価値が見直されれば印旛沼流域においても、ヒシ事業を通して地域が活性化し、印旛沼流域をさらに豊かにすることができると考える。

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O7-25

Hygiene and Sanitation of people living on and around Tonle Sap Lake: Comparison of water based, water-land based and land based zones

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Keywords: Tonle Sap Lake, Water base, Water-landed base, Land base, and waterborne disease

ABSTRACT

This study aimed to collect the information on water use, hygiene and sanitation and waterborne diseases among people living on the lake and the lakeshore. The stratified sampling survey was conducted in three regions around Tonle Sap Lake (TSL) involving a total of 542 families, which were randomly selected for the interview, comprised of 202 Land base (LB) households, 132 Water-landed base (WLB) households and 208 Water base (WB) households. The results of the survey showed that TSL water was the principle drinking water source of WB population (52.9%). For populations in LB, well water was the main drinking water source (71.8%). Related to water treatment systems, 53.5% of LB, 34.9% of WLB and 22.6% of WB used filtration system to treat their drinking water. Boiling of water for drinking was done by 37.1%, 20.5% and 32.7%, of LB, WLB and WB, respectively. Diarrhea and severe diarrhea were waterborne diseases frequently found in this study. Diarrhea disease was found in 60.4%, 80.3% and 79.8%of adults, 39.8%, 61.3% and 75.3% of children under 5 years old and 42.4%, 67.1% and 72.9% of older children and adolescents, for LB, WLB and WB, respectively. People living in WB and WLB zones seems to have high incidence of diarrhea disease as compare to that living in LB zone. This may be due to the drinking water source, water treatment systems and flooded experiences.

1. INTRODUCTION

Cambodia is one of countries which are most famous for freshwater fisheries in the world since the permanent wetlands cover more than 30% of total national land represented by Tonle Sap Lake (TSL)[1]. The TSL is an invaluable natural resource of inland water for agriculture, fish production, biodiversity, water supply and sanitation, transport, and hydropower[2][3], supporting more than 1.7 million people living around it[4]. Communities in the TSL have adopted their living system based on the specific hydrological conditions of the lake, which form three different human settlement communities: “LB villages,” “WB villages,” and “WBL villages.” In LB ones, villagers are engaged more in farming and less in fishing depending on the distance from the lake. WB villages are floating villages on the lake, where fishing is the primary occupation for villagers. The third type is the WLB villages, which is usually located six months on water and six months on land, and both agriculture and fishing are the main activities for the villagers[2][5]. In recent year, the increases of agriculture activities, industrial development, numerous tourists and other human activities in/around the lake has been threatening the ecosystem and human health via pollution and contamination of lake water[6]. The aim of studies is to collect the necessary information on water use, hygiene and sanitation, waterborne and food borne diseases among people living on and around the TSL, focusing on the types of villages.

2. METHOD

Target population

The primary data has been collected through surveys implemented questionnaire to people at LB, WBL and WB areas around TSL. The target population is the completed set of people identified for the investigation according to the research objectives. The studied regions were purposively stratified selected from three provinces (Kompong Chhnang, Kompong Thom and Battambang province) around TSL (Fig.1). And in each province, the households and participants were randomly selected for the interview. In total, 27 villages were selected for the interview, in which 13 villages from LB areas, 6 villages from WLB areas and 8 villages from WB areas.

Survey conducted

The survey conducted questionnaire interview was face to face since the target people lack of access to the internet and literature[7]. A total of 542 families were randomly selected in this study where 202 households from LB, 132 households from WLB and 208 households from WB. The interview was completed at the

households considering the age groups (0-5 years old, 6-17 years old, and older (adult)) and sex of correspondents.

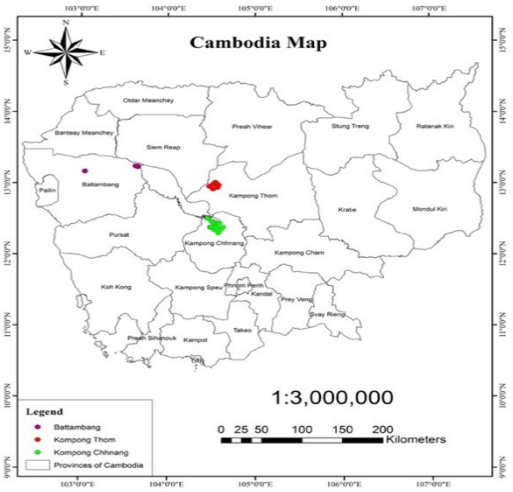

Fig. 1 Map of Tonle Sap Lake with three surveyed provinces

3. RESULTS

Hygiene and Sanitation

Currently there are no affordable sanitation options available for the floating communities of the TSL, and many other communities that live in challenging sanitation environments in Cambodia. Concerning hygiene section, among the surveyed households, 58.2% in WB area, 28.8% in WLB and 75.7% in LB did not have toilets. Interestingly, for the households in WB areas that have toilets in this survey, almost all of these toilets were the open toilet directly discharge into the lake. However, these results showed that the awareness of sanitation and hygiene practice in the communities is low. On the other hands, using soap was found in WB zone more frequently (80.3%) than WLB (68.9%) and LB (69.8%) zones. According to the data of baseline survey with children who live in LB, WB and WLB of TSL, the hygiene practice of children in WLB areas were very low compared to those in WB and LB areas. The percentage of children under five year olds who washing hand with soap before eating and after defecation were similar in these three different zone. But, the percentage of WLB children from 6-17years old who wash hand with soap before eating food and after defecation was 56.72%, while there were 69.57% and 75.56% for WB, and LB children, respectively.

Solid waste management

The surface water and ground water source were contaminated by leaching of non-disposed burned substance and impacted to population health such as air and water-borne disease. In this study was found that people in WLB (more than 50%) and WB (more than 80%) zones were directly disposed their waste into lake surrounding their living areas where they take the water to be use every day as their domestic water source and drinking water.

Waterborne diseases

Data reveals that most of waterborne diseases were diarrhea with level of 80.30% and 79.81% were found of people living in WLB and WB areas, respectively; while the lowest rate was from LB areas (60.40%). In the meantime, severe diarrhea happened in the rate of around 23% in WLB areas and the lowest was found in LB (11.88%) areas. The percentage of less than five years old children got diarrhea was 75.25%, skin problem was 69.31%, eyes problem was 64.40%, and severe diarrhea was 18.81% for these studied population. For children aged between 6-17 years old who faced with diarrhea was 72.90%, skin problem was 69.31%, eyes problem was 64.49% and severe diarrhea was 12.15% (Table 1). Children in these three different zones: LB, WLB and WB of TSL areas were suffered diarrhea, followed by eyes and skin problem and also severe diarrhea. These diseases were highly prevalence for children under five years old and aged between 6-17 years old who live in WB zone.

Table 1 Common disease in studied areas

Diseases (%)	LB	WLB	WB
Diarrhea	60.40	80.30	79.81
Severe diarrhea	11.88	23.48	23.08
Cough	47.03	68.18	69.23
Fever	53.96	78.03	79.33
Eye Problem	24.75	31.06	46.15
Skin problem	25.74	38.64	41.83
Others	30.20	33.33	28.37

4. DISCUSSION

The target of the Millennium Development Goals of Cambodia was to halve the proportion of people without access to sanitation by 2015. Cambodia's National policy on rural water and sanitation envisions that every person in rural communities has sustained access to safe water supply and sanitation services and lives in a hygienic environment [8]. However, the studied results showed that less than 15% of mothers wash their hands with soap after defecation, before preparing food, before feeding their child, before eating, before cleaning the child's bottom [9]. The very low awareness of hygiene awareness

of communities, especially of hygiene practice of children in WLB areas might be due to poor education and lack of support from related ministry and non-government organizations (NGOs). Most of NGOs and government have been focusing on people who live in WB zones by improving education, hygiene, and installed drinking water treatment system for some community. There is only a few of NGOs could access and supporting WLB community because this area is far from the province and lack of transportation that could access these communities.

In Cambodia, one of seven deaths of children was caused by diarrheal disease. Every day, 50 Cambodian children under five years old died from preventable disease such as diarrhea and pneumonia[10]. Children in these three different zones: LB, WLB and WB of TSL areas were suffered diarrhea, followed by eyes and skin problem and also severe diarrhea. These diseases were highly prevalence for children under five years old and aged between 6-17 years old who live in WB zone.

5. CONCLUSION

Considering hygiene and sanitation, adults in all three zones had used soap before eating and after defecation (it can be found most frequently in WB area).Among children, only 6-17 year-old children performed more this habit than those at 0-5 years old. The diarrhea disease was the main disease found in people living around TSL, especially children under five years old (75.3%). According to data analysis, improper water treatment, water storage system, hygiene and sanitation, and flooding were identified as the main causes of diarrhea in these studied zones.

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O7-26

The Challenge for Lake Victoria Protection by the Ecological Sanitation Approach in Kenya

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Keywords: ecological sanitation, Lake Victoria, water pollution, income increase, women activity, village development

ABSTRACT

Lake Victoria faces serious water pollution by point and non-point sources. As to point pollution control, it is all most impossible to construct sewerage systems to all communities. House-hold sanitation system is instead affordable and preferable. Nippon International Cooperation for Community Development (NICCO) with the support of Kyoto University implemented an ecological sanitation project in Bushiangala Village of Kakamega County, Kenya, since 2014. It is a comprehensive village development, but water supply and ecological sanitation are key components to boost agricultural products and improve income. Along the comprehensive development project, women are strongly involved in the project so that women status is elevated. Nitrogen and phosphorus of point sources are derived from 35 million people of the entire catchment of Lake Victoria. Total construction cost of one million Eco-san toilets is estimated to be 300 US$ x one million which is most economical solution for water and sanitation issue that is the number six target of SDGs, clean water and sanitation.

1. INTRODUCTION

Lake Victoria faces serious water pollution by point and non-point sources. As to point pollution control, it is all most impossible to construct sewerage systems for all village communities in the catchment of Lake Victoria. House-hold sanitation systems are instead affordable and necessary. Nippon International Cooperation for Community Development (NICCO) with the support of Kyoto University has successfully implemented ecological sanitation (Eco-san) projects in Malawi during 2007-2014 [1]. It is necessary to repeat the similar Eco-san project to village communities in Kenya, because the conditions of Kenya villages are different from those of Malawi, in terms of climate, soil, crops, sanitation culture, education levels, and religions, etc. It was decided to introduce Eco-san project with a comprehensive development programs to Bushiangala Village of Kakamega County, Kenya, since 2014. The project covers 1,6,14 families with 8,203 people.

This paper discusses success and challenges of the project that shows similar as well as different from the results of the Malawi projects that are discussed in another paper of this conference. Upon the success of the Kakamega project, NICCO propose extension of the ecological sanitation projects to communities that locate around coastal countries of Lake Victoria, namely Kenya, Uganda, Tanzania, Rwanda and Burundi.

2. WATER AND SANITATUON IMPROVED HEALTH CONDITION

NICCO newly installed two suction pipe and pump systems of deep ground water for Bushiangala village. Pipes are extended to 12 km covering 5,887 people, including 6 schools, 4 churches, 2 clinics, and 334 households and five water kiosks. The village community realized the importance of maintenance of the water supply system, so that the water supply committee was established, which collect water fees, employed a water engineer to operate pumping station, and extend service pipes, etc. The water supply committee became a core

group for introducing Eco-san project. The restoration and extension of water supply system changed life style of the community in terms of labor time, school time and household management, etc. NICCO constructed total 216 units of Eco-san toilets (87 private houses and 129 public houses).Buyemi Health Center of Kakamega investigated the results of installation of Eco-san toilets in Mukongolo community of Kakamega comparing pit-latrine toilets, in terms of the people health relating diarrhea cases (2 Nov. 2017). The center gave a certification paper telling that (1) Eco-san toilets had improved public health compared to pit latrines, evidenced by reduction of diarrhea cases; (2) zero diarrhea cases were observed due to improved hygiene and reduced flies in Eco-san toilets; (3) the reduction number of flies in Eco-san toilets compared to that of pit latrines was the ration at 5:16.

3. URINE AND SANITIZED FECES (HUMANURE) WERE EXCELLENT ORGANIC FERTILIZER

The people of Bushiangala first did not believe in that urine and feces were organic fertilizer, as the people of Malawi project villages. In order to show safety of sanitized feces that were disinfected and fermented by ash application and stored in a feces compartment of an Eco-san toilet. NICCO asked the Laboratory Department of Kakamega County General Hospital to examine Eco-san manure in terms of infectious microbes. The results showed that Salmonella and Coliforms/E.Coli, were not detected, and Ovarian cysts were not seen (18 Sept, 2017). The nutritional value of Eco-san manure (Humanure) was analyzed by Non-ruminant Research Institute of Kakamega, Kenya Agricultural and Livestock Research Organization for different items. There was no analysis of K, but P, Ca and Mg were well included to fertile soil. Total nitrogen is low for fertilization of soil, due to decomposition of protein and dissipation of ammonia during fermentation. In order to improve soil condition of C/N without chemical fertilizer of N, P, K, it was recommended to use much urine in practical way.

Maize crop test was done using urine and humanure and chemical fertilizer in the test fields of Bushiangala, Kakamega, Sep.2015. It is obvious that soil condition is very important and without fertilizer it is difficult to get crop yield. It shows dramatic improvement of crop yields specially combination of urine and humanure. Nitrogen supply with urine was important as indicated N shortage in humanure. However, this test indicates another important improvement of soil condition, that is improvement of soil acidic condition by ash supply in disinfection of feces, as indicated pH 10.65 of the humanure. The people participated in this field test satisfied the results and got confidence to using Eco-san toilets and agriculture use.

4. CHANGES IN COMMUNITY ACTIVITIY

Bushangala community has changed its activity triggered by revitalization and extension of water supply systems, establishing four committees such as (1) Water supply committee (3 men and 2 women members), (2) Eco-san construction committee (6 men and 4 women members) (3) Agri-livestock committee (13 men and 9 women members), and (4) Women status elevation committee (2 men and 24 women members).

Eco-san construction committee promoted many workshops for propagation. They faced financial problems and established loan system. However, farmers must increase income to pay back to the construction fee. Based upon crops yields improvement, they started different crop culture than before introducing new types of crops and started processing the crops to more market oriented products. Soybean, sunflower seeds, and peanuts are such newly introduced. The committee asked women and elderly persons work for processing business, that increased income for those people. The agri-livestock committee started raising chickens at home. Chicken is good market item to increase income. The women status elevation committee started energy efficient oven construction, and seed & seedling business. Pot seedling business does not require heavy labor works. They select

vegetable, crops and tree seedlings and conduct pot seedling that help a lot farmers to avoid unsuccessful seedling in the fields.

Trees are essential for cooking, etc. Reforestation around the village is a key to survive. The pot seedling of useful trees is very important and good business. Many other ideas came to the committee and income for the participants remarkably increased. Based upon those Bushangala committee activities, NICCO think great potential of expanding Eco-san projects to village communities of other part of the catchment of Lake Victoria.

5. THE CHALLENGE FOR PROTECTION OF LAKE VICTORIA

Lake Victoria is shared by five countries in terms of lake surface are, catchment area, shoreline and population. Waste waters are generated by the people activities in the manner of point source and non-point source including agricultural activities. Pollutants such as BOD, COD, nitrogen and phosphorus cover all human activities. Lake Victoria Basin Committee estimated reginal point source loads of TP, TN and BOD for Tanzania, Uganda and Kenya. The point loads are proportional to population of the countries.

Eutrophication of Lake Victoria is caused by nitrogen and phosphorus loadings which are necessary for agriculture and food production. Nitrogen and phosphorus control is very difficult issue. We propose that the recycle of nitrogen and phosphorus from urine and humanure is the best solution for controlling eutrophication, reducing application of chemical fertilizer in agricultural fields. Eco-san toilets are the solution of recycling nitrogen and phosphorus.

NICCO propose the challenging project that if one million Eco-san toilets are provided to the people along coastal areas of Lake Victoria, point source loads of BOD, TN and TP are cut, that is equivalent 6 million population (6membaers per family) of 35 million of the catchment. Construction cost is estimated from Malawi and Kenya experiences to be around 300 US$ x 1 million, which is much less cost compared to any other sanitation systems.

6. CONCLUSION

Water supply systems were installed in Bushiangala, Kakamega, Kenya, which dramatically improved life style of the people. Eco-san project was introduced constructing for 216 units of the toilets (87 private houses and 129 public houses), which clearly showed improvement of health condition to the people who enjoyed clean water and good sanitation. Urine and sanitized feces were proved to be excellent fertilizer and soil amendment. Crops yields were increased to help income increase of the farmers of the village. The people want to install Eco-san toilets to their homes. Construction cost must be borne by the people in addition to some external subsidies or donation. They set up Eco-san committee to start a loan/ship system that is a new idea to disseminate the Eco-san project other part of the village communities around Lake Victoria Coastal countries. If one million Eco-san toilets are constructed in the catchment of Lake Victoria, 6 million people may enjoy good sanitation and practice recycling of nitrogen and phosphorus which are eutrophication pollutants. Nitrogen and phosphorus of point sources are derived from 35 million people of the entire catchment. Total construction cost of one million Eco-san toilets is estimated to be 300 US$ x one million which is most economical solution for water and sanitation issue that is the number six target of SDGs, clean water and sanitation.

ACKNOWLEDGEMENT

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O7-27

Successful Results of the Ecological Sanitation Approach toward Harmonious Coexistence of the People and Lake Malawi, Africa

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Keywords: ecological sanitation, Lake Malawi, water pollution, humanure and comprehensive village development

ABSTRACT

Lake Malawi collects surface and ground water from the west bank. Water pollution of the lake is mainly caused by poor sanitation, domestic and agricultural waste waters. The rural communities still face famine, due to poor infrastructure hindering from their economic growth. Malawi rural communities need comprehensive development models that could solve the problems of infrastructure such as safe drinking water supply, proper hygiene and sanitation, and agricultural food security. Nippon International Cooperation for Community Development (NICCO) with Kyoto University implemented the comprehensive development projects for seven years.in two prefectures of Malawi covering about 3,600 families of 18,000 people, in the support of Mitsui & Co .Environment Fund, JICA and Ministry of Foreign Affairs of Japan. The programs of safe water supply and eco-logical sanitation (Eco-san) were essential to protect water environment of Lake Malawi. This paper discusses success, failure and the further problems of the ecological sanitation approach.

INTRODUCTION

Ecological sanitation (Eco-san) toilets were introduced two decades ago to Africa by many NGOs of Europe and North America. However many of them were abandoned facing difficulty of proper maintenance. Most important points of maintenance are, understanding of hygiene and proper practical use of the urine and feces separation toilets, and sanitation of feces and urine for agricultural use as fertilizer.

NICCO implemented comprehensive village development projects in Malawi since 2007 until 2014 [1].The ecological sanitation program is a key of the comprehensive projects that consist of seven programs such as (A) agriculture technology, (B)grain storage-seed bank, (C)reforestation - moringa tree, etc., (D)measures for infection—malaria, HIV/AIDS and schistosomiasis, (E)human-resource development-education, (F)water supply and (G)ecological sanitation. In order to overcome famine in under-developed villages, agricultural development is the major target. However, there are many obstacles to promote agricultural development. The seven programs were introduced in the good manner of coordination. Due to limitation of this paper room, we would like to focus on the ecological sanitation program, and analyses it in terms of success, failure and further problem.

NICCO PROJECTS OF ECOLOGICAL SANITATION IN MALAWI

NICCO constructed ecological sanitation (Eco-san) toilets in three Districts of two Prefectures such as Nkhotakota and Lilongwe for the family of about 1000 with about 5000 people. NICCO also constructed shallow wells with supplying safe water for about 3600 families. Safe water supply and sanitation provision are minimum requirement. However, NICCO could not provide Eco-san toilets for all families due to limit of construction finance. The partial construction cost of Eco-san toilet must be borne by the families of the project. NICCO provided half of the total cost, and the half should be borne by the families. Financial problems still remain for expansion of ecological sanitation in rural areas.

BENEFITS OF ECO-SAN TOILETS FOR VILLAGE COMMUNITIES IN MALAWI

It is obvious that most villages in Malawi do not have proper water supply systems and sanitation. The people need safe drinking water, which can be provided by shallow water well systems, because water quality of the well is so far meeting to safe drinking standard. However, the contamination of shallow ground water is caused by poor sanitation such as dig-hole toilets namely pit latrines. In spite of that, Government of Malawi needs to introduce ground water supply systems for all villages. The question to good sanitation is very difficult to answer, because there are many obstacles to find good solutions. NICCO invited Mr.Uno Winblad who introduced the thought of ecological sanitation and edited two books, Ecological Sanitation by Sida (1998) and Ecological Sanitation, revised and enlarged edition by Stockholm Environmental Institute (2004). NICCO concluded to introduce Eco-san toilets in Malawi. We think the following problems must be overcome for the introduction of Eco-san toilets as a sanitation solution; (A) scientific understanding of urine and feces by the people, (B) proper disinfection of feces, (C) understanding of nutrient values of urine and feces by the people, (D) practical demonstration of treated feces and urine for agriculture, (E) health improvement such as less diarrhea, (F) agricultural yields increase with more income, and (G) other indirect benefits.

SUCCESFUL RERSULTS

In order to construct many Eco-san toilets, NICCO asked a Japanese specialist of architect to design the Malawi style urine-feces toilet and teach how to build

the toilets to village people. The construction work must be contributed by the owner of the toilet. NICCO organized a program, of Eco-san toilet builder workshops in which the specialist taught techniques of the buildings 14 people who later became a licensed builder by NICCO. In the end 1000 units of Eco-san toilets were constructed.

In general for Malawi people, human urine and feces are dirty untouchable matters, so that they practice open defecation or sanitation by dig-hole toilets that easily fed up and abandoned contaminating shallow ground water and surface streams. Maintenance of the toilets needs urine and feces recycle for agriculture activities. It was necessary for the people to understand urine is safe to touch after holding in tanks for a week, even urine comes from HIV/AIDS patients. HIV viruses are weak in infection through urine. Urine contains all necessary nutrient for agricultural cultivation, specially N, P, K , S, and other minerals such as Ca. Mg, Fe, Mn, and others. Human nutrition requires I, Zn, Cu. Co, Cr. and Se for hormone regulations. Dilution of urine is necessary for application to plants, that are very important knowledge for Malawi farmers to understand in practice. The problem is feces disinfection. NICCO decided to select the method of ash disinfection, in which the ash from oven was not at all utilized in families of the villages. They just discarded the ash elsewhere. However, the ash is excellent strong alkaline agent to kill any germ, viruses and eggs of intestinal worms. In addition to that, alkaline minerals such Ca, Mg, K are best soil improvement matters to acidic and poor soils of Malawi. NICCO asked Physics and Biological Department of University of Malawi to examine microbial analysis for Eco-san manure (humanure) and the result is shown in Table 1.
Organizing many workshops of Eco-san toilets and organic farming of application of urine and humanure, farmers gradually accepted Eco-san toilets.

Table I Microbial examination of Eco-san manure (Humanure) by University of Malawi

Parameter	Result
Salmonella	Not detected
Fecal Streptococcus	40 colonies/100g
Crystopordia	Not done, special microscope not working
Ascaris eggs	Not detected
pH	8.78
Moisture content	7.28%
Temperature	27°C

CONDITIONS OF PROJECT SITES BEFORE AND AFTER THE PROJECT

Generally the adoption of the Eco-san toilets technology gave an immediate solution to the problems on waterborne diseases which rise death from lack of proper disposal mechanisms of feces and urine. Comparative data were obtained at the inception of the project through the midterm reviews, which revealed a drop in water born disease cases and raised household incomes, showing a positive impact to the communities.

The other immediate result was from the use of urine on crops which would readily be used when diluted and applied to soils in the gardens or around homes kitchen garden. Such helps communities to earn income and nutrition from the crops in the home gardens. The project area of low income immediately improved outbreaks of waterborne diseases when the toilets are used. While the condition of increasing crop yields by the use of humanure would be realized after six months cultivation, the stabilization, decomposition and disinfection of feces required six months in the climate condition of Malawi, before applying the humaure to gardens where crops grow. Table 2 shows the results of maze harvest between application of Eco-san fertilizer (urine and humanure) and no fertilizer application. It was 2.4 times more harvest with Eco-san fertilizer.

Table 2 Results of maze harvest between application of Eco-san fertilizer (urine and humanure) and no fertilizer application.

Harvest place	Harvest date	Fertilizer conditions	Maize yield (kg)		
			Seed	Food	Total
Kalusa (100 ㎡)	14 April, 2012	Eco-san Fertilizer	5.0	31.5	**36.5**
		No fertilizer	2.5	20.0	**22.5**
Chiuzuula(100 ㎡)	18 April, 2012	Eco-san Fertilizer	3.5	58.7	**62.2**
		No fertilizer	0.0	8.0	**8.0**
Njumbla (100 ㎡)	14 April, 2012	Eco-san Fertilizer	1.5	29.3	**30.8**
		No fertilizer	1.0	22.5	**23.5**
Eco-san fertilizer yield					**129.5**
No fertilizer yield					**54.0**

PROBLEMS REMAINIG FOR FUTURE DEVELOPMENTP

Physical maintenance of the toilet structure is important for sustainability of Eco-san project. Although the brick and cement structure of the toilet is very robust and heavy, it may stand for 20 years, but there are problems remained such as roof broken, door broken and leaning of the toilet due to ground sinking by heavy weight. The toilets are strong to stand challenges of collapsing of soils in communities whose soils are sandy and soft, or weak and collapsing during rainy season as they are built on top of the ground.

Fourteen Eco-san toilet builders were established with their skills. Training on care and maintenance of the toilets has to be provided to the benefitting communities. Local masons who are trained to support the construction of the toilets in the project area also bring a rich pool of technicians who support the adoption of the technologies, when the project phased out. Eco-san builders can help other communities where the people require new construction of toilets. It is important that the owners of the toilets show a strong sense of ownership that requires good maintenance of the toilets.
Some religious groups such as Muslims use water for anal cleansing after defecation, which is a challenge to promote the current style Eco-san toilet. When water is introduced to a feces containment compartment, it delays the process of drying, disinfection and fermentation of the feces. However NICCO have the solution for this problem, providing another model of Eco-san toilet that allowed to use small water to anal cleaning for Muslims and Hindus communities.
In Malawi, there are still some traditional myths in pregnant mothers who stop using Eco-san toilets during pregnancy, because they feel a fear or think losing their fetuses during defecation. This kind of thought deprives them of the benefits in improved sanitation in the home forcing them to use alternatives ways. They are not good thereby bringing diseases and also not able to realize the use of Eco-san products in agriculture, which leads to increased crop yields when they are applied to soil where the crops grow.
In order to promote the Eco-san toilet model throughout village communities of Malawi, there needs a massive propagation of the information on the benefits. Many benefits are given by introduction of the system of Eco-san toilet and agricultural profits with good health and good water environment connected Lake Malawi. On the other hand, financial problems are most important to be solved. Governments of Malawi must seek for international aids one hand, but on the other hand, subsidies of the toilet construction by governments is also necessary. Furthermore, farmers must bear partial cost of the construction. It is estimated roughly to be total 300 US$/unit for a family. If introduction cost is provided by a community bank in a manner of loan, any project could start for the community. The loan could be paid back by increase profits form organic farming with humanure and urine. Financial problem is still a big problem remained for the future of Eco-san toilet model.

CONCLUSION

NICCO successfully constructed 1000 units of Eco-san toilets in two prefectures of Malawi during 2007 and 2014. Eighty percent of them is in use and successfully connected with agricultural production. The good practice of sanitation protects Lake Malawi from contamination of both shallow ground water and surface streams by discharging human feces and urine. It is expected to expand the Eco-san toilet model for other parts of village communities of Malawi. Technology of construction needs the solution of constructing heavy toilets over soft and weak ground soil. Financial problems are most important. Poor farmers need subsidies from governments and international aids for the construction with their own bearing the cost.

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O7-28

傾斜土槽法を用いた低エネルギー消費型の上下水処理

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キーワード:浄水・排水処理技術, 発展途上地域における適正技術, 傾斜土槽法, 自浄作用, 生物学的吸着作用

抄録

大気と接する土壌の表層は、自浄作用の強い場所である。傾斜土槽法は、この自浄作用を水質浄化に応用したものであり、底面が傾斜した薄層構造体に担体を充填し、これに原水を浸透流下させる方式である。様々な有機性排水浄化の実験結果より、本法の浄化特性は、(1)曝気が不要の低エネルギー消費型の好気性浄化、(2)有機性汚濁物質と栄養塩類の同時浄化、(3)汚濁物質と水の分離による滞留時間の短縮、(4)槽内の有機性汚濁物質の強い分解作用、(5)高次の食物連鎖による汚泥発生量の少なさ、等である。本法による飲料水のための浄水試験は、スリランカとバングラディシュで行われた。前者は、緩速ろ過法では処理不可能な平均 BOD37mg/L の原水を処理し、良好な処理水が得られた。後者は、重金属類で汚染された井戸水を処理し、鉄、マンガン、ヒ素の浄化が確認された。一連の実験結果は、傾斜土槽法が低コストで低エネルギー消費型の上下水処理技術であることを示している。

1.　はじめに

本研究の目的は、無曝気で好気性浄化を行う低エネルギー消費型の水質浄化技術の開発である。

水の飽和溶存酸素濃度は、僅かに 10mg/L 前後で、水には酸素が溶けにくい性質がある。水中での好気性浄化は不自然であり、この不自然さを補うために大量の電力とコストを消費して曝気を行っている。水を自然に好気性浄化するには、水中以外の場所が望ましい。水中以外の場所とは、水が不飽和状態の場所である。

水中以外での水質浄化では、陸上の浄化装置に原水をどのように流すのかがポイントとなる。流す方向には、(1)鉛直方向、(2)水平方向、(3)斜め下方の 3 通りがある。(3)の方式として、底面が傾斜した薄層構造体に担体を充填したものを傾斜土槽、これを用いた水質浄化法を傾斜土槽法(以下、本法という)と名付けた。

本法の浄化は、原水を層厚が 0.2m 程度の担体中に強制的に浸透流下させる方式であり、多段積みでコンパクトな浄化装置となる(図 1 参照)。本報では、本法を用いた上下水処理の実証試験で得られた知見について報告する。

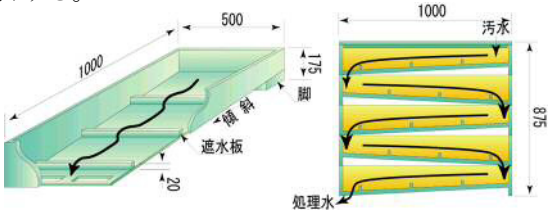

図 1　傾斜土槽と多段積みでの運用

2.　有機性排水の浄化実験と結果

2.1　台所排水の浄化

(1)国内での実験

図 1 の傾斜土槽の 3 段積みで 4 人家族の台所排水の浄化を行った。流し台からの落差を利用して、無動力で台所排水が最上段の傾斜土槽に流入するようにした(図 2 参照)。[1]



図2　台所排水の浄化実験

実験は、2001 年 7 月に通水を開始し、4 年 4 ヶ月間、毎月 1 回の水質調査を行った。この期間の総処理水量は 143.6m^3、日平均処理水量は 92L であり、この期間中は担体（鹿沼土）の交換等の維持管理は何もしていない。設備費用は、工事費を含めて約 5 万円で、2018 年 5 月時点で運用を継続している。浄化結果を表 1 に示す。この結果より、本法では有機性汚濁物質と栄養塩類の同時浄化が可能で、浄化効果は長期間持続することがわかった。

表 1　国内の台所排水の浄化結果

項　目	水温 (℃)	SS (mg・l^{-1})	BOD (mg・l^{-1})	COD_{Mn} (mg・l^{-1})	T-N (mg・l^{-1})	T-P (mg・l^{-1})
原　水	18.1 ±5.7	153 ±80	819 ±820	542 ±671	30.6 ±25.4	5.88 ±4.7
処理水	16.4 ±7.4	34 ±21	86 ±69	51 ±40	5.3 ±2.8	0.70 ±0.4
除去率	－ －	74% ±17%	83% ±13%	80% ±16%	73% ±16%	81% ±14%

※)±は、標準偏差を示す。

(2)インドネシアでの実験

インドネシアのジョグジャカルタ特別州の一般家庭で、図 1 を模した 4 段積みの木製の傾斜土槽で台所排水の浄化を行った。担体は 4 槽で 90L 分のスポンジで鶏糞肥料を種植した（図 3)。この材料費は、約 2,600 円（314,500 ルピア）であった。[2]

実験は、前日の夕方から実験日の朝にかけて採水貯留した原水を、落差を利用して 4 段積みの傾斜土槽を通過させ、通過前後の水質を測定した。



図3 インドネシアでの台所排水の浄化実験

実験は、2017 年 8 月から 9 月にかけて 13 回行った。この結果を表 1 に平均値で示す。また、原水と各段を通過した処理水の状況を図 4 に示す。

総リン(T-P)以外はよく浄化されていた。T-P は、槽内に投入した鶏糞肥料のリンが処理水に出ていた。

表 2 インドネシアでの台所排水の浄化結果

項目名	BOD	CODcr	T-N	T-P	SS
原水 平均値 (mg/L)	2091	3804	33.7	9.40	350
処理水 平均値 (mg/L)	223	376	5.5	30.0	8
平均除去率 (%)	88	87	73	-	95



図4 原水と各段通過の処理水の外観

2.2 各種の有機性排水の浄化実験

本法を用いた各種の有機性排水の浄化を行った。本法は、大気からの酸素供給で好気性浄化を行っている。単位 BOD 負荷量あたりの表面積が増えれば処理水は良好となり、逆に単位表面積あたりの BOD 負荷量が増加すれば除去率は低下する。

図 5 に各種の有機性排水の BOD 面積負荷量と BOD 除去率の結果を示す。この結果より、BOD が浄化しやすい排水（ドレッシング製造工場排水等）と浄化しにくい排水（バルク排水（搾乳設備洗浄排水）や製麺工場排水等）があることがわかる。[3]

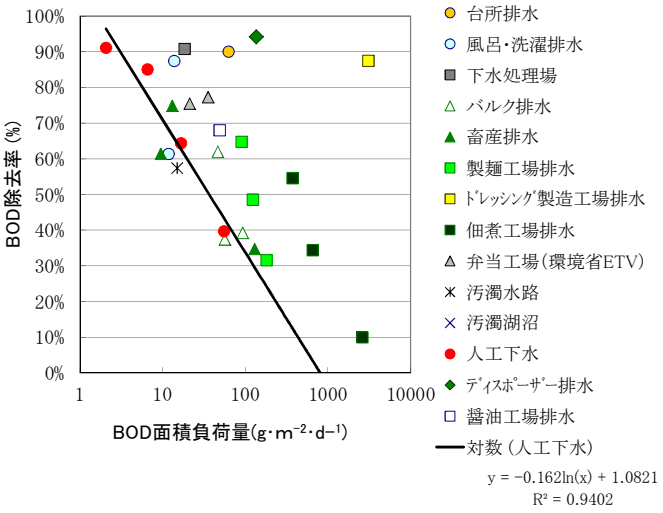

図 5 BOD 面積負荷量と BOD 除去率

3. 有機性排水の浄化機構の解明

3.1 滞留時間と BOD 除去率

スポンジを担体とした図 1 の傾斜土槽 9 段積みで、醤油製造工場排水の浄化実験を行った。原水は、毎分 1L でほぼ毎日 3 時間 180L を最上段に注水した。原水と 3 段、6 段、9 段の各段を通過した処理水の水質及び、注水開始から 9 段目の処理水が出るまでの滞留時間を測定した。原水の平均 BOD は 527mg/L、平均溶解性 BOD は 425mg/L で、BOD の多くは溶解性であった。[4]

図 6 に BOD 除去率、滞留時間の変化を示す。当初の BOD 除去は、物理学的なろ過や付着によるものである。時間経過に伴って 9 段と 6 段の除去率が上昇するのは、生物学的吸着作用の強化による。生物群が十分に育てば、滞留時間は約 30 分程度で BOD 除去率は 100%近くになることがわかる。

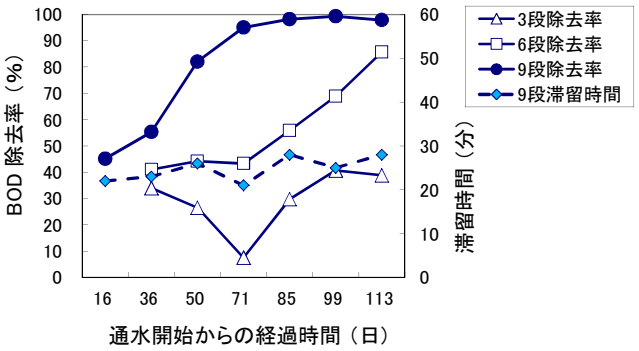

図 6 滞留時間と BOD 除去率

活性汚泥法のBOD浄化には8時間程度の滞留時間が必要といわれている。本法の短い滞留時間は、BOD成分と水とが生物学的吸着作用等によって 30 分程度で分離されるためである。捕捉された BOD 成分は、槽内で本来の浄化である有機物の無機化が進行する。

3.2 傾斜土槽の重量変化

前述3.1の9段積みの傾斜土槽の各段の重量変化を図7に示す。[4]1・2段目は、ろ過作用の重量増加があるので除いた。12 月から 4 月は重量が増加したが、連日の原水注水にもかかわらず 5 月に重量は減少した。これは温度上昇に伴い、微生物以上の高次の生物を含む食物連鎖が活性化し、冬季に溜まった過剰の有機物や生物膜が分解されるためである。この機構によって本法の汚泥発生量は少ない。また、過剰に有機物が蓄積した槽は、浄化系外に放置して有機物分解を促す養生操作を行うが、これも同じ食物連鎖によるものである。

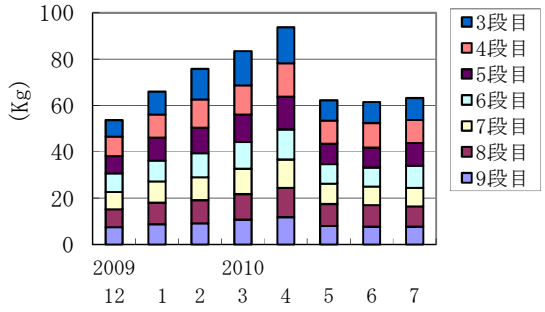

図 7　傾斜土槽の重量変化

4.　浄水処理への応用と結果

4.1 スリランカでの浄水処理

開発途上国では、河川等の水源の汚濁が進行し、緩速ろ過法では浄水が困難な事例も起きている。スリランカで平均 BOD が 37mg/L の原水について、緩速ろ過法の前処理として傾斜土槽法での浄水処理を行った。処理の流れは、原水→傾斜土槽①→傾斜土槽②→緩速ろ過→最終処理水である。傾斜土槽の仕様と日処理水量を表 3 の下部に示す。[5]

本法の酸素の供給能力は、緩速ろ過法よりも優れているために同法では浄水処理が不可能な原水についても浄水処理が可能である。なお、現在の本施設では、本法のみで浄水処理が行われている。

表 3　スリランカでの浄水処理の結果

試料名＼項目		濁度 (n.t.u)	BOD (mg/L)	COD_{Mn} (mg/L)	総無機態窒素 (mg/L)
原　水		13.5	37.1	10.0	11.6
処理水	傾斜土槽①	0.1	9.9	5.0	10.3
	傾斜土槽②	0.0	7.1	4.0	3.6
	緩速ろ過	0.0	2.1	2.3	3.6

（注）傾斜土槽①②は、各2×10m、担体は①は砂利、②はアンスラサイト、処理水量は$8m^3 \cdot day^{-1}$

4.2 バングラディシュでの浄水処理

バングラディシュでは地下水のヒ素等の重金属汚染が深刻である。同国チャンドプール県において、本法による汚染井戸水の浄化実験を行った。傾斜土槽は、図 1 を模して鮮魚運搬用の発泡スチロール容器を加工して作成し、担体はスポンジとした。実験は、実際に使用中の井戸の近傍に5段積みの傾斜土槽を設置し、無電源のため人力で井戸水を最上段に入れ、最下段の処理水を利用してもらった。水質が悪化すると、住民自らが汚れたスポンジを手洗いする維持管理を行った。[6]

表 4 に実験結果を示す。除去率は、鉄とマンガンはほぼ 100%で、ヒ素は 70%であったが、現地の上水基準は達成できた。ヒ素の除去機構は、鉄バクテリアによる酸化鉄との共沈作用と本法の汚濁物質と水との分離作用によるものである。なお、本実験の処理水によって、この村では初めて白いご飯が炊けたと喜ばれた。

表 4　バングラディシュでの浄水処理の結果

		ヒ素 (mg/L)			鉄 (mg/L)			マンガン (mg/L)		
上水基準	ﾊﾞﾝｸﾞﾗﾃﾞｨｼｭ	0.05			0.3 － 1.0			0.1		
	日本	0.01			0.3			0.05		
水質浄化結果	調査日	原水	処理水	除去率	原水	処理水	除去率	原水	処理水	除去率
	2015.7.4	0.22	0.15	31%	6.17	0.65	89%	0.76	0.17	78%
	2015.10.4	0.20	0.06	70%	3.45	0.00	100%	0.63	0.03	95%
	2016.3.23	0.18	0.06	66%	5.29	0.07	99%	0.64	0.03	95%
	2016.4.27	0.21	0.07	66%	5.81	0.05	99%	0.70	0.03	96%
	2016.5.29	0.13	0.05	63%	3.60	0.49	86%	0.60	0.16	74%
	住民が担体のスポンジを洗浄									
	2016.7.31	0.18	0.05	72%	5.64	0.00	100%	0.60	0.00	100%

5.　結論

本法は、低エネルギー消費と低コストで良好な上下水処理が可能なことから、開発途上国の水環境と水に係る衛生問題の改善に寄与することが期待される。また、湖沼の水質保全には、簡易な浄化方式で窒素・リンが浄化可能な本法は有効な対策の一つと考えられる。

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TS8-1

Community Participation in Integrated Water Resource Management in Northern Thailand

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Keywords: community participation, water resources, check dam, agricultural area

ABSTRACT

Water problem is one of the most severe global problem. Thai people have been facing both quantitative and qualitative problems of water for decades. Northern region is the main headwater of Thailand where Ping, Wang, Yom and Nan are the main watersheds. Therefore, the heads of those 4 rivers are extremely important for Thai people. The four communities including MaeLaOop, MaeChiangRaiLum, PhaTang and DongPhapoon are selected as case studies which located in Ping, Wang, Yom and Nan watershed respectively. Each watershed locates in different geographic condition. Therefore, those communities analyzed and solved their own problems by different ways of management. MaeLaOop community, representative of Ping watershed, came across the drought and flood seasonal problems by designing and constructing three-layer check dams. These check dams worked also as "wet firebreak" to limit the forest fire area. PhaTang community, representative of Yom watershed, has been facing flooding and soil erosion problems in rainy season. The local people constructed numbers of local material-based check dams to come across those problems with friendly atmospheric community. MaeChiangRaiLum community from Wang watershed and DongPhapoon community from Nan watershed have been facing severe logging problem which lead to drought and landslide problems. The local people constructed numbers of low cost and local material check dams along the mountainous slope with creating and effective forest restoration project. The "highland wet forest" could narrow down the problems. Not only adult activities, but also local teenagers, as youth power, keep running their activities under the concept of environmental sustainable development.

1. INTRODUCTION

Thailand is located on South-East Asia Region, in what is known as the Indochina Peninsula. The climate is tropical, with three distinct seasons: a hot season from March to mid-May, a rainy season caused by the southwest monsoon, which generally runs from mid-May to October, and a dry and relatively cool season from November to February, when the north-east monsoon, coming from the Asian continent, prevails. As same as other countries in the tropical zone, Thai people face the water-related seasonal problems along the year. The six months of rainy season annually damage huge areas of northern, central and southern part of Thailand by flooding, whilst the 3 dry months damage most area of north-eastern and northern part of Thailand according to severe drought problem. Thailand is an agriculture country. Approximately 34 % of total Thai population are farmers (agriculturists)[1]. Therefore, drought and flooding are the most important national problems. The geographic information including river length, watershed area and annual precipitation (Table 1) of the 4 watersheds are very important to do the research design.

Table 1 Geographic information of Ping, Wang, Yom and Nan watersheds.

	Watershed			
	Ping	Wang	Yom	Nan
Length (Km.)	715	460	735	740
Watershed area (sq.km.)	34,534	10,793	24,047	34,682
Annual precipitation (mm.)	1,132	1,100	1,204	1,287

This project was designed together between University researchers, government organization so-called Hydro and agro informatics institute and members of the local communities. The project was aimed to use scientific and technology application to solve or at least minimize the water-related problems in the 4 areas of northern Thailand

where upstream of the 4 main rivers, Ping, Wang, Yom and Nan Rivers are located. In addition, community forest and youth activities were also included in the process of implementation and environmental awareness to keep these outputs of the project sustainably transfer after ending the project.

2. METHOD

2.1 Community selection criteria

According to the 4 main river basins of Thailand, one active and successful community was selected from each river basin. The main criteria were consisted of 1) located in both drought and flooding problem area 2) located outside the national irrigation area 3) low income community 4) community members have high concern in environmental aspect.

2.2 Participatory project planning

The meeting along University researchers, Hydro and agro informatics institute researchers and community leaders and committee were conducted at each community locations. The area analysis including Geographic information, water balance (water budget, water demand), forest cover, soil types, agricultural activities and so on, were collected and analyzed for the next step of management.

2.3 Data collection

Man survey and Geographic Information System (GIS) survey were used to obtain the area GIS position and slope. The general information, including agricultural activities, local people attitudes, history and background of the community were obtained by direct interview. Annual precipitation data was collected from Hydro and Agro Informatics Institute Report [2]. Hydrologic data including stream water level, velocity, depth, discharge, stream width and substrate types were collected *in situ* seasonally.

2.4 Implementation

After obtaining all data, the water resources management was designed and constructed. The mountain irrigation pipeline, check dams [3, 4], ponds and water storage were constructed under the community need, geographical, ecological and hydrological criteria.

The community forest and youth environmental activities were also designed for local community utilization and environmental awareness.

3. RESULTS

After field survey and exhaustive consideration, the four communities were selected as Mae La Oop from Ping Watershed, Mae Chiang Rai Lum from Wang Watershed, Pha Tang from Yom Watershed and Dong Phapoon from Nan Watershed (Figure1).

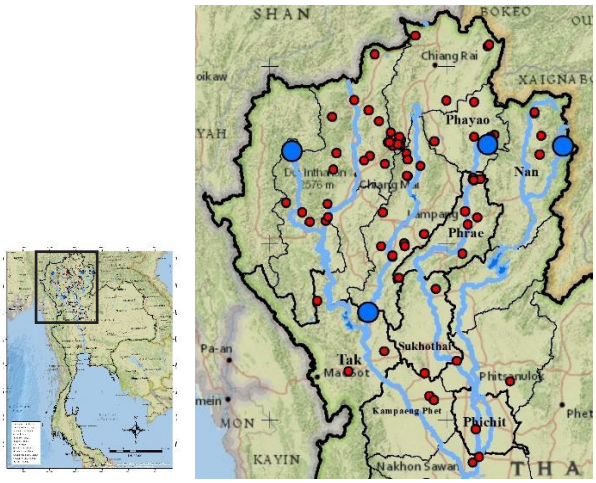

Figure 1 Thailand map with the selected communities in Ping, Wang, Yom and Nan Watersheds (indicated in larger circles)

The 4 selected communities have been facing problems as annual drought in dry season and flood in some year as shown in Table 2.

Table 2 Annual water problems occurring in the four selected communities

Mae LaOop	Mae Chiang Rai Lum	Pha Tang	Dong Phapoon
Drought and flooding without water storage	Drought and soil erosion with sandy substrate	Flooding in rainy season with soil erosion	Drought without water storage

According to the geographic, ecological and hydrological data analysis, the integrated water resource management was discussed and designed how to solve the problems based on area data and community benefit.

Mae La Oop Community, Ping Watershed: eight rock check dams were participatively constructed along the stream. In addition, the connecting pipe lines were laid to connect the irrigation pond to newly constructed concrete storage (Figure 2). These systems are used for agricultural and household purposes. 1,230 residents have been receiving benefit from the project. There is enough water for household use.

Mae Chiang Rai Lum Community, Wang Watershed: ten rock-bamboo check dams (Figure 3) were constructed along upstream area of stream tributaries according to increase the humidity to riparian areas of the stream, whilst three concrete-bamboo check dams were constructed

downstream for water storage in stream. The storage water was used for agriculture purposes. 1,200 residents in 293 houses have been receiving benefit from this project. In addition, more water and higher humidity was increased in huge forest area which resulting higher biodiversity.



Figure 2 Concrete water storage



Figure 3 Rock-bamboo check dam

Pha Tang Community, Yom Watershed, five onsite material check dams were constructed by local people with friendly help from the officers of Doi Phu Nang National Park. These check dams are used for community forest and agriculture purposes. The collaboration between residents, University researchers and national park officers created very friendly relationship with green and moisture forest output.

Dong Pha Poon Community, Nan Watershed, two old concrete check dams and two old rock check dams were re-constructed and 3 new rock check dams were constructed. In addition, 5 concrete water tanks were also constructed. These water supply systems are used for agriculture and household purposes. After project, the residents could come across the drought problem with higher humidity of their community forest.

Environmental Awareness from Youth Activities

The young generation members of each community discussed with the adult residents and University researchers for planning on environmental/ecological activities. The University researchers and national park staff created ecological/biodiversity workshops which aimed to educate and train local youths and adults to create their own project for natural streams and forest. Most youths from each community planned and started the forest restoration project. Thousands of seedlings of native trees have been prepared for planting in the forest where the water resource management adult projects were conducted. Long term water and tree growth monitoring projects have been carried on with local adults, youths and local government.

4. CONCLUSION

The key successes of this participatory integrated watershed management are the continuous collaboration between local communities (adult and youth residents), government organization (Hydro and Agro Informatics Institute, National parks and local government) and University researchers. This collaboration sincerely runs by ecological, science and technology and indigenous living concept.

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TS8-2

ESD & SDGs beyond environmental education: Awareness through networks

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Keywords: Network

ABSTRACT (a maximum of 250 words, 248 words)

Many networks have been organized among civilian groups to accomplish their Education for Sustainable Development (ESD) activities effectively. Here, I describe two examples of the difficult process of organizing networks. The first is at the school level, and the second at the local area level. (1) **School level:** ESD was promoted by UNESCO ASPnet schools (UNESCO-School Network) in Japan, because the ideas and purpose of ASPnet correspond well with those of ESD. At the beginning, universities supported the activities of ASPnet schools in neighboring regions; later the number of member schools increased. The universities then formed an alliance called the ASPUnivNet to support ASPnet schools all over Japan. The alliance served as a driving force to increase the number of schools to over 1,000. Recently, these universities and schools joined other stakeholders in creating a consortium. (2) **Local area level:** The Kabukuri-marsh area (Tajiri area) in Osaki City in northeast Japan is one example. The area was recently certified by Globally Important Agricultural Heritage Systems (GIAHS). People made great efforts to conserve the environment of rice fields in groups including NPOs, NGOs, institutions, and companies. This area, the "Great Sendai area RCE", is one of the UN's Regional Centers of Expertise, with the Sendai City and Kesen-numa City areas in Miyagi Prefecture. The activities and collaboration led to this area's GIAHS certification. The ESD Resource Center was recently founded as the central institution in Japan. We expect it to be an information center for networks of ESD collaboration.

1. INTRODUCTION

Japan experienced serious pollution, "Kogai", at the end of the 20th century and overcame due to the efforts of people and the unexpected "oil shock". In the process, many activities were carried out in groups, which were organized into networks. Environmental education (EE) grew out of this movement, and Education for Sustainable Development (ESD) was begun after the World Summit on Sustainable Development in Johannesburg (2002). Despite a decade of ESD (DESD, 2005–2014), however, we still face issues regarding sustainable development. The Global Action Programme (GAP) on ESD, a follow-up to the DESD programme is currently being conducted. The UN adopted SDGs (Sustainable Development Goals) in 2015. I believe that ESD will become even more important in the effort to achieve the SDGs by 2030.

ESD encompasses a wide range of fields. Many groups (NPOs, NGOs, institutions, companies, etc.) have newly organized to promote ESD in Japan. It is important for these groups to communicate and collaborate to achieve the SDGs. From the viewpoint of civilian activism on ESD, we here consider the organization process of networks in Miyagi prefecture.

2. Collaboration network centered on a school

In 2002, the year the UN adopted the DESD, Omose elementary school in Miyagi Prefecture began EE with the Fulbright Memorial Fund (FMF) Master Teacher Programme offered by the Japan FMF (JFMF), established in 1997. This programme aimed to bring schools in the United States and Japan together in a collaborative exchange and education process. Omose elementary school had a plan to collaborate with Lincoln elementary school in Wisconsin, USA, and needed academic support to help implement the international collaboration on environmental education. The Environmental Education Center

(EEC) of Miyagi University of Education (MUE) began support of the school's activity at the request of the Kesen-numa Board of Education, which supervised the Omose school, and collaborated with the Science Education Center of the University of Wisconsin-Madison to conduct the project effectively.

From this experience, we learned of two things necessary for collaboration with a network centered on a school. First, there should be a school leader to promote the project in the school and colleagues ready to cooperate with that leader. The principal should endorse the teacher's activity and be a good facilitator. In addition, the role of superintendent is important in Japan, as that individual supervises the principal. Second, it is important for the school to open its doors to stakeholders, and for each stakeholder to gain a better understanding of the school.

In order to meet the school's expectations, MUE developed a new support system. The EEC of MUE founded the Environmental Library for Education (ELFE) in 2006 to support EE activities at school. The ELFE distributes teaching materials, offers temporary staffing, provides information on education, and holds teacher-training seminars on EE. MUE often held meetings on EE and ESD. One of conclusions after the 2004 meeting was that it is necessary for schools to establish a network, and to receive adequate support from local stakeholders, including NPOs, NGOs, universities and the local government [1]. The network of the Omose school was ideal for ESD implementation, and eventually led to this area being declared a Regional Center of Expertise (RCE).

3. Drastic increase of UNESCO ASPnet

The UNESCO Associated Schools Project Network (ASPnet) was founded in 1953. In Japan, there were few member schools by 2005. However, the Japanese government MEXT and Japanese National Commission for UNESCO expected ASPnet schools to fulfill their leading function on ESD, because the education ideals are very similar. In Japan, ASPnet was called the UNESCO School Network. MEXT and the national commission encouraged schools to join the ASPnet. The number of member schools increased drastically during the period of the UN DESD, mainly because a network of universities (ASPUnivNet) strongly supported the membership application of schools and assisted with ESD activities at those schools [2]. In Kesen-numa, almost all schools became ASPnet members during the DESD. The affiliation influenced the entire country. ASPUnivNet, the university network to support ASPnet schools, is a unique network. ASPnet activities contributed to improving the quality of ESD at each university.

4. Sustainable development activities based on regional characteristics

The Kabukuri-numa marsh area in Osaki City is located about 60 km inland from the seashore area of Kesen-numa City. The marsh, which is surrounded by rice fields, is small but very famous as a wintering ground of the greater white-fronted goose. About 70,000 birds come to the Kabukuri-numa. This represents about half of the birds that come to Japan in one season. Many bird watchers have visited here for the past 50 years. Some particularly enthusiastic visitors were called Kabukuri-Genjin (primitive man), because they looked like curious foreigners in the eyes of residents. The Genjin knew well the value of nature of this area. People often say "native people do not always notice the value of their hometown, but *youth*, *aliens*, and *cranky people* often notice the real value of the region." In this area, residents are learning the value of the Kabukuri-marsh from the *aliens* called Genjin and are accepting of them.

There appear to be three reasons for the acceptance of *aliens* in this area. First, under the leadership of the mayor at that time, Mr. Mineura, a few young farmers traveled to Germany for agricultural training for a short period every year. Therefore, many youth gained an international perspective. Second, the area has a culture of regarding environmental conservation as important. Kabukuri-marsh has been used as an anti-flood and irrigation pond. People in this area have treated nature well for a long time. Third, residents make a point of generously accepting foreign visitors, probably because young leaders have had the experience of agricultural study in Germany.

The EEC of MUE nominated the Kabukuri area as

a learning model field for wetlands under the Field Museum Concept, while Kesen-numa was selected as a seacoast field, and Sendai as a model field of consumptive urban city. EEC did research on the environment and often held training sessions for school children in the area [3]. Through these sessions, children enriched their understanding of the nature of wetlands. People in the area protecting the wild goose received materials from MUE to form a group, the "Numakko-club", in 2000. The club often held field trips to convey environmental education in the Kabukuri-marsh. They held informal gatherings to discuss what the local government should do to conserve the marsh. Such gatherings played an important role in the conservation of the marsh.

In this way, collaboratiive groups and networks were organized in the Osaki City area. As a result, the area was certified as a RCE and inscribed as a registered wetlands under the Ramsar Convention. In 2005, RCE became a regional center for promotion of ESD all over the world. Also that year, the Izu-numa and Uchi-numa area, including Kabukuri-numa marsh (Miyagi Prefecture) was registered under the Ramsar Convention.

A change then occurred in farmer residents. In 2012, they started "Green tourism", a kind of agritourism. Visitors can now take a relaxing holiday in a rural area and experience farm work. In this way, the people of this area increased awareness of and openness toward sustainable development. In 2018, Osaki City (including the Kabukuri-marsh) was certified as a Globally Important Agricultural Heritage Systems, GIAHS by the FAO. The accumulative power of citizens led to the success of this GIAHS.

5. UN Regional Centers of Expertise

The UN University proposed the idea of RCEs in 2004. "The great Sendai area RCE" was originally organized by MUE, Sendai City, Tajiri-Town (currently Ohsaki City) and Kesen-numa City, and certified as one of the initial seven RCEs in the world [4]. Sendai City was known as advanced administration, for example, de-spike tire movement. Kesen-numa was famous for ESD and afforestation activity for oyster farming. Before the RCE designation, people in the three cities performed their activities independently, and did not feel the need to collaborate. However, they seemed to recognize the meaning of RCE through information exchange after it was established, because they were able to cherish the features that made their area different from other areas. UNU currently has 164 RCEs listed globally [5].

6. Strengthening networks for SDGs

In 2015, the UN adopted 17 SDGs (Sustainable Development Goals) to be achieved by 2030. ESD is vital for the implementation of these SDGs. The issues of sustainable development can sometimes result from technological development, while some issues will be cleared by the science itself. The development of sustainable science is required. ESD covers a very wide range of academic disciplines. Therefore, information exchange between networks is important. Recently, the ESD Resource Center was founded as the central institution in Japan. The center has 8 regional branch-offices. We expect it to serve as a hub for networks of ESD collaborating with each other. Toward the realization of SDGs, we raise awareness and conduct ESD activities effectively through the networks.

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O8-1

茨城県土浦市宍塚の里山における，市民による広範な保全活動

及川 ひろみ，森本 信生
認定 NPO 法人宍塚の自然と歴史の会

キーワード：市民参加，協働，里山保全，水辺ふれあい，自然保護

抄録

茨城県土浦市宍塚と隣接する地域は，生物多様性や埋蔵文化財に恵まれた関東平野でも有数の里山である。ここに魅せられた近隣住民は宍塚の自然と歴史の会を 1989 年に発足させ，保全活動を 30 年間継続してきた。すなわち，自然環境調査，地元住民からの聞き書き調査，雑木林，草原，竹林，湿地，小川の保全，畑での耕作、谷津田農家の耕作支援，自然田んぼ塾による有機水田耕作の実践などの活動がおこなわれている。また，テーマ別観察会，毎週の観察会，探鳥会，田んぼの学校の開設，学習会などの環境教育活動も進められている。さらに，会報の発行，地元学校への案内配布，シンポジウム開催などの普及活動も実施されている。その結果，生物多様性の向上や様々な団体による協働作業が活発化し，市民の関心も高まっている。地元自治体は，現時点では，この地域の将来を市街地開発と保全の両論併記の形としているが，ここで展開されている活動を活かした将来設計が望まれる。

1. はじめに「宍塚の里山」

JR 土浦駅・つくば TX つくば駅から，いずれも約 4km にある「宍塚の里山」は，東京駅から 50 ㎞，土浦市宍塚側が 100ha，つくば市側が約 80ha，東京から筑波山麓までで最大級の里山であり，環境省「生物多様性保全上重要な里地里山」に選定されている。中央にある宍塚大池は，広さ約 3.3ha の溜め池で，「ため池百選」（農林水産省）に選定されている。この里山は雑木林・谷津・田や畑・草原・湿原，昔ながらの小川や湧水など，多様な自然環境によって構成されている。多様な環境要素が幾多の生き物を育む場となり，レッドデータブックに掲載されている数多くの種が確認でき，この里山の重要性の根拠の一つとなっている。

また，里山は人の暮らしと共に利用されてきた場所であり，大池を囲むように旧石器時代から近代までの遺跡，遺構が高密度に散在し，池の北側には宍塚古墳群，南西側には国指定遺跡である上高津貝塚が存在する。また，宍塚の集落には国指定重要文化財の銅鐘を有する般若寺があるなど，史跡の多さも特徴となっている。まさに自然環境，歴史的な環境に恵まれた里山となっている。

土浦市第7次総合計画（2008年）では，「宍塚大池周辺などのまとまりのある緑地や本市の特色である水辺環境を生かした公園・緑地の整備・維持管理に努めます。」とあるものの「宍塚大池周辺地区の一部は、環境に配慮しながら、筑波研究学園都市に隣接しているといった地理的優位性や交通条件を生かした研究・業務拠点として位置づけ、適切な機能配置や、広域的かつ長期的な視点に立った整備を検討します。」と位置づけられ、宍塚の里山全域の保全する方針は示されていない。

2. 宍塚の自然と歴史の会の諸活動

1989 年，会はこの自然と歴史的遺産をより深く理解しながら，地域の特性に即した姿で未来に受け渡すことを目的に活動を開始した。「宍塚の里山」全体としての保全・利活用を主眼とし，生き物の保全，農業の維持を目指し，里山の保全活動，環境教育，レクリエーション，ゆとり，生き甲斐，情操教育，自然・歴史的な環境調査など，活動は多岐にわたっている。都市近郊という立地条件を活かし，地域住民・市民にとどまらず，大学，専門学校，地元小中学校，企業等と連携し，国，茨城県，土浦市等の行政，筑波研究学園都市の研究機関の研究者の協力も得て活動を実施している。

① 自然環境調査

環境省が実施しているモニタリング 1000 調査(重要生態系監視地域モニタリング推進事業)は，100 年間自然を見つめ，環境の変化を把握し保全に役立てるための調査でありる。宍塚は，この事業の「里地里山」調査の中心的な場所として，「コアサイト」に選定され，植物・野鳥・チョウ類・哺乳動物・水質・カヤネズミ，カエルの卵塊調査を本会が

実施している。

また，森林・池・湿地・草原・谷津・田畑・小川・竹林・針葉樹林など多様な環境を対象に，水質，キノコ，サシバ（鷹），湿地植生調査などの自然環境調査を行っている。

これらの調査で得られた情報をもとに，専門家の指導を仰ぎ，保全目標・計画を立て，再生・保全に取り組む努力を続けている。

② 聞き書き―里山の暮らし

農業や日常の暮らしと自然とが深く結びついて生み出された里山は，先祖の知恵の結晶，まさに文化遺産である。この 40～50 年で農業も暮らしも急激に変わった。昔を知るということは，今を位置づけ，未来を展望するために不可欠なことであり，里山の未来を考える時，これまでの人と里山との関わりをその土地に則して学ぶことが，重要で急がれる課題になっている。会発足当初から，この課題に取り組み，今の暮らしに至る努力，がんばり，たくさんの知恵と技，里山の幸，豊かな文化・伝承，人と人の繋がり，一人一人の誇り，さらには，これからの暮らしや農業，自然と人間，人の生き方が聞き書きによって浮き彫りにした。この成果は，2 冊の単行本，リーフレットとして取りまとめている。

③ 保全活動

・雑木林：1990 年からの植生の管理活動を開始した。目的は生物の多様性を求めた森づくりであり，基本は明るい森づくりであり，毎年下草刈り・落ち葉掻き，大木となったコナラ・クヌギ，常緑広葉樹の伐採，現在 16 か所で実施している。

・草原：地元専業農家が 1947 年から冬季，落ち葉掻きが続けてきたコナラを主体とする明るい林があり、オミナエシ等の草原性の絶滅危惧種が多数生育している。2009 年から農家に代わり，草刈り・落ち葉掻きを継続し，多様な植物・生き物の生息地になっている。

・竹林：モウソウ竹林・マダケ竹林が年々拡大していることから，モウソウ竹林 4 か所，マダケ林 3 か所の伐採・整備を行い，刈った竹は，大形機械でチップ化し，土壌改良材として活用している。

・溜め池：宍塚大池は周囲の雑木林や湿地などが水源となり流入河川はない。堤防を除き護岸されていないため，森林，湿地等連続的につながりが保たれている。1990 年からオニバスを保全することを目的に，ハスの葉の刈取り，2006 年からは外来生物の駆除活動を行っている。

・谷津田環境：半溜谷津：カヤネズミ保全のために，冬季ヨシ・スゲ等湿地性植物を刈り取っている。刈取り後はフクロウ・タカ類の採餌場所にもなっている。

・湿地：茨城県自然博物館と年 3 回の合同調査を行い，その結果から翌年の保全計画を立て，保全を行っている。

・小川：貝等の保全，水流確保のため冬季落ち葉掻きを実施している。

・田畑：自然農田んぼ塾により，「生き物いっぱいお米ザクザク」を合言葉に，無農薬・無化学肥料・不耕起によるコメの栽培を実施している。また，収穫した米を都会の人が購入し，谷津田での水田耕作農家の支援する「宍塚米オーナー制」を 20 年間継続している。また，地元が栽培していた地場の大豆を系統保存し，水田畦畔などで栽培した大豆で，味噌・豆腐などの加工を行っている。さらに，4 か所の畑での野菜などの耕作，2ha3 か所の果樹園の管理も行っている。

④ 観察会・環境教育

・観察会：専門家を講師に招いた月例テーマ観察会，毎週土曜の観察会，日本野鳥の会との月1回合同探鳥会，月1回子ども探偵団を実施している。

・田んぼの学校：稲作，里山の自然，田んぼの環境，稲作に伴う伝統文化行事の伝承、実施をしている。

・学習会：里山の自然・歴史・保全手法を学ぶ土曜学習会や，：県や土浦市の職員と保全策を学ぶ保全学習会を主催。

・シンポジウム：オニバス・里山・サシバ，ため池，モニタリングなどをテーマとしたシンポジウムを開催。

・安全講習会：労働安全衛生法に基づいたチェーンソー・草刈り機の取り扱い安全講習会を実施。

⑤ 広報

・広報・出版：「宍塚大池のお知らせ 1990 年から「宍塚のお知らせ」の配布を開始し，現在土浦・つくばの小学生に約 17,000 枚/1 回，年 11 回配布し，観察会・里山子ども探偵団・生きもの調査・収穫祭などの行事開催を伝えている。・会報「五斗蒔だより」，「どんなところ宍塚大池」，「宍塚地域自然環境調査報告書」など。

・イベント：収穫祭，里山の春を楽しむ会・ 伝統行事 青

屋箸，さなぶり，お十八夜のお月見，ならせ餅等

2. つながり・ひろがり

地元：里山の土地，利活用するために無償で提供を受ける。収穫祭等，祭りへの参加者が増加，地元農家 9 軒と連携し，宍塚地区農地・水・環境保全会協働活動を実施。地元との交流が深まり，林・田畑，駐車場など，約 40 名の方から活動の場，協力が得られるようになっている。

学校教育：地元土浦小学校による観察会，中学校，竹林調査（里山に広がる竹林の脅威）および保全・お楽しみ活動，高校，大池で貝を使った水質改善や保全活動他，新たな取り組みを 2 件を行っている。

大学：筑波大学，筑波学院大学などの学生実習の他，宍塚を訪れる大学生が増えている。法政大学のサークル活動の受け入れは 16 年継続している。放置されてきた畑の復元し耕作するほか、地元を訪問しかつての暮らしの話を聞き，お年よりから藁ない等の技術を学び，収穫祭などで子ども達の指導者になっている。地元 2 軒が，学生の宿泊を受け入れている。

企業：富士通，LIXIL，積水樹脂，関彰商事などと協働した保全活動，寄付を賜る企業 5 社であり，会員だけでなく，多彩な陣容の協働活動によって目的を果たしている。

社会福祉：引きこもりの青年・不登校の子ども達，体に障害のある若者達の受け入れをおこなっている。

3. 里山が生み出したもの

これまで宍塚の多様な環境について，さまざまな生物が生息できる環境づくりを目指し，保全手法の蓄積を 30 年間進めてきた。地権者約 40 数名の協力を得，保全が進んでいる。ニホンアカガエルの産卵を促すために田んぼの溝を産卵に適した深さにし，また湿地の保全を進めた結果，2005 年，ニホンアカガエルの卵塊数がそれまでの6倍に増えた。その後ヘビが増え，サシバの繁殖が毎年確実なものとなり，最近は複数のつがいが繁殖に成功している。

アライグマの確認した際は，調査，防除の計画策定を求めた請願を茨城県議会に提出し，「茨城県アライグマ防除計画」が策定されるなど，政策へ反映されている。国際的にも SATOYAMA が注目され，JICA による研修の受け入れなど，評価も明確になってきた。

表に地域に関わる指定や当会の褒賞をまとめた。

結論　未来へ

表　地域に関わる指定、当会の受賞

年次	主催　指定団体など	事項
2015	環境省	宍塚の里山を「生物多様性保全上重要な里地里山」に選定
2015	茨城県森林保全協議会	「グリーンフェスタ・森林保全2015」優秀賞
2015	日本自然保護協会	「日本自然保護大賞」入選
2014	茨城県森林ボランティア団体協議会	奨励賞（茨城県森林ボランティア団体協議会長賞）
2014	内閣官房及び農林水産省	農山漁村活性化の優良事例「ディスカバー農山漁村の宝」
2013	国連生物多様性の１０年日本委員会	連携事業として認定
2012	地域環境資源センター　農林水産省	第10回 田園自然再生活動コンクール「農林水産大臣賞」
2010	日本ユネスコ協会連盟	プロジェクトクト未来遺産に選定
2010	日本水大賞委員会	日本水大賞「大賞（グランプリ）」
2010	農林水産省	宍塚大池を「ため池百選」に選定
2009	関東建設弘済会　日本生態系協会	「関東・水と緑のネットワーク拠点百選」に選定
2007	コカコーラ環境教育財団	コカコーラ環境教育賞「主催者賞」
2006	茨城県	茨城県表彰　功績団体表彰　受賞
2006	環境省	宍塚をモニタリングサイト1000のコアサイトに指定
2005	日本自然保護協会	第5回沼田眞賞「里山の自然と文化の保全に対する貢献」
2005	あしたの日本を作る協会	ふるさとづくり賞「内閣総理大臣賞」
2005	環境大臣表彰	「みどりの日」自然環境功労者
2005	日本水環境学会	水環境文化賞
2004	農林水産省	田園自然再生活動コンクール「朝日新聞社賞」
2004	読売新聞、環境省	「日本の里地里山30」に選定
2003	ソロプチミスト日本財団	受賞
2003	文化庁	「農林水産業に関連する文化的景観重要地域」に選定
2003	常陽新聞厚生文化事業団	福祉・文化団体顕彰
2002	マイマップコンクール	優秀賞
2000	日本昆虫学会	「昆虫類の多様性保護のための重要地域」
2001	農村整備環境センター	「田んぼの学校」企画賞
1997	環境庁	「生物多様性保全のための重要地域」に指定
1995	イオン環境財団	奨励賞
1989	朝日新聞社水戸支局	宍塚大池を「茨城の自然100選」に選定
1978	環境省	「特定植物群落」に選定

農業と暮らしに欠かせなかった里山の存在価値が，いったん失われたかのように考えられたが，今，また新たにその値打ちが見出され始めている。

生物の多様性の観点から，人が環境について学び，自然と係りながら育つ場として，里山の価値，里山の必要性が明確になってきている。大切にしていくべき里山の宝は何か。どのような人々の力とつながりで，どんな里山にしていくのか，地元，市民，行政等，大勢の人達で考えいかなければならない。そして私有地が 3/4 を占めるこの里山の保全は，地権者の了解なくして保全はできない。今後も行政・地権者・市民・専門家・企業等々と知恵を絞り，展開が求められるが。そして行政が宍塚の里山の価値を深く認識し，保全が必要であることを認められることが必要である。

将来的には，市民活動のみならず，行政が果たすべき役割は，きわめて大きい。土浦市は里山の保全の方針を明確にし，この地域で展開されている諸活動を活かした策が，行政や地権者，農業従事者，市民による知恵の集結により施されることが望まれる。

O8-2

印旛沼源流域の里山における環境教育

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キーワード:里山保全, 人材育成, 意識啓発

抄録

印旛沼の源流域である千葉県富里市で活動する私達「NPO 富里のホタル」は, 市内に自然発生するホタルを守りたいという動機から活動が始まった。その後, ホタルを守るためには, その生息域を取り巻く里山全体を健全な状態にする必要性に気付き, それと共に, 里山の持つ多面的な価値を実感する事となった。それらを将来にわたって守り続けるためには, 子供達への環境教育が何よりも大事と考え, 様々な取り組みを行っている。里山で遊ぶ・食べる・感じることで楽しい原体験を得て, その子供達が成長した時, 里山を守る動機になれば, と願っている。現在, 1 年間に延 3000 人以上の子供達を私たちの里山に迎え入れており, 里山の空間や生き物が好きな子供が, 多数誕生している。これらの取組から, 場を提供すれば, 現代の子供達でも活発に野で遊ぶことが実証されており, この子達がいずれ印旛沼源流域の環境保全の担い手となることが大いに期待される。

1. はじめに

千葉県富里市は千葉県の代表的な湖沼である印旛沼の源流域に位置する。私達は市内の谷津田に自然発生するホタル(ヘイケボタル・ゲンジボタル)を守り, それを次世代に引き継ぎたいという想いから,「NPO 富里のホタル」を 2007 年に設立した。

私達はホタルの生息環境を整える為に草刈りなどを行ったが, やがて, 耕作放棄されて陸地化が進行していた谷津田の復田, それを取り巻く斜面林の整備, それに連なる森林や耕作地との関りなどが重要な要因ではないかと, ホタルについての理解が進むにつれて気付き始めた。

それと共に, 畑作が盛んな富里市では, 施用される肥料により湧き水の窒素濃度がとても高いことと, それが印旛沼に流れ着き, 水質に影響を及ぼしていることを知った。その一方で, 谷津に湧き出した窒素濃度の高い水が, 田んぼを下るにつれて脱窒されていくデータを得て, ホタルを保護するための活動が, 水質浄化という思わぬところに影響を及ぼすことを実感することとなった。

このような谷津田を含めた里山の持つ多面的な価値を知るにつれて, これらを将来にわたり守り続ける為には, 通常の整備・保全活動と共に, 子供達への環境教育がとても大事であろうということに思い至り, 力を注いでいる。

2. 方法

市内の教育施設に打診し, 先方の要望に沿って以下のような取り組みを行っている。

・絵本の読み聞かせ(幼稚園等)

市内 5 か所の幼稚園等で毎月 1 回, 主に生き物に関わる絵本・紙芝居の読み聞かせを行っている。身近な生き物に対する興味の入り口となることを目的としている。



写真 1 絵本の読み聞かせ

・生き物出前教室(幼稚園等)

年 3 回, 市内 5 か所の幼稚園等で, 谷津で採取した生き物を持ち込み, 手で触れてもらっている。併せて, 生き物クイズを出題したり, 園児達の素朴な質問に答えたりして, 生き物に親しみを持つ機会としている。



写真 2 生き物出前教室

・自然観察会，昔遊びの伝承（小学 3 年生）

地元小学校の 3 年生に，春・秋の 2 回行っている。住む地域の自然や文化を知るきっかけになることを目的とする。



写真 3 自然観察会

・稲作体験学習（小学 5 年生）

地元小学校の 5 年生に，代掻き・田植え・稲の生長観察・稲刈り・昔の農機具体験・収穫米での食事を行っている。各作業の際は，地元の農家の方に講師を務めて頂いている。



写真 4 稲作体験学習

・里やま塾

「里やま塾」と称して参加者を募り，年 5 回開催している。春の野草の試食，田植体験，ホタル観賞，稲刈体験，伐採・植樹体験を行い，併せて，楽しい遊びに競技性を加味したサブイベントを行っている。また，参加者と私達スタッフが一緒に，その場で調理した昼食を食べることを恒例としている。

以上の他，近隣中学校と高校の生物部の生徒達が，生物調査やボランティア活動の場として私達の活動拠点を，毎週のように訪れている。

3. 結果

以上のような取り組みを続けた結果，現在，1 年間に延 3000 人以上の子供達と接することとなった。

幼稚園児とは顔馴染みとなり，私達の来園を心待ちにしてくれているとのことで，大きな励みになっている。ザリガニ・カブトムシ・ドジョウ・カエルなどは大人気で，はじめは怖がっていた園児達もすぐに平気で手で触れるようになる。



写真 5 里やま塾「田植体験」



写真 6 里やま塾「植樹体験」



写真 7 里やま塾「泥玉鬼退治」

小学生は，田んぼを訪れた後には教室に戻ってからも興奮が続き，そのあまり，その後放心状態になると担任の先生から報告を頂く。子供達の感想も「楽しかった」「また行きたい」というものがほとんどで，なかには「田んぼの生き物を守りたいです。私は頑張ります。」という感想まであった。

定期的に谷津を訪れる中学生の保護者からは，「谷津に通うようになってから積極的になり，明るくなった」という声がいくつも寄せられている。

軽度の障害を持ち，今までほとんど笑ったことのない子が，谷津を訪れたら大きな声で笑うようになったり，登校しても教室に入れなかった子が，生き物に触ることをきっかけに教室に入れるようになったりと驚くべきことが起きていて，自然環境や生き物たちの持つ潜在力を実感している。

4. 考察

私達が子供達を相手にするときに強く心掛けていることは，「里山は楽しい・面白い」と心に刻んでもらうことである。知識を与えることはその次の段階と考えている。このように意識してイベントを企画するようにしたところ参加者が一気に増え，一度参加した人達はリピーターとなる。

子供達が「楽しい・面白い」と感じる要素は，遊ぶこと・生き物を捕まえることなどいろいろとあるが，食べるということも大きな要素だと取り組みの中で気付き，可能な限り里山で皆で食べる機会を作るようにしている。

現代の子供達は自然環境の中で遊ぶことをしなくなったと言われるが，里山で遊ぶときの子供達のみずみずしい感性や意外な目線に触れると，場と機会を与えれば，とても活発に遊びまわることが実証されているように思う。

このようなことが子供達にとって楽しい原体験となり，その原体験を持って成長した時，そこがいつまでもあの頃のままであって欲しいと思うはずで，それが環境保全の動機になると考えている。

5. 結論

現在活動に携わっている私達の根源的な動機は，子供時代の懐かしく楽しい思い出が元になっていると，日頃の話し合いの中で確信している。私達が関わっている子供達も，そのような道筋を辿ってくれるものと期待している。

ホタルを守りたいという動機から始まった私達の活動が里山保全に行き着き，印旛沼の源流域であることから，ここから送り出される水が下流の環境にまで影響を及ぼすことを知ることになった。環境については，ある行動が思いもよらぬところと関りを持つということ， 成長した子供達も， 当然そのような視点を持つことになると考えている。

どのような立場の大人になっても，「里山は楽しい，様々な価値がある，守るべきもの」と言う観点をもって行動して欲しいと望んでいる。それが富里の里山を守ることであり，つまり印旛沼の源流域の環境保全につながると考えている。

O8-3

次世代に残そう「ふるさとの水辺」

金﨑 いよ子 [1],河野 芳明 [1],中 明子 [1]

[1] 認定 NPO 法人びわこ豊穣の郷

キーワード:水辺ふれあい，人材育成，市民参加，意識啓発

抄録

びわこ豊穣の郷は「琵琶湖・赤野井湾」の再生を目標に 1996 年設立。現在個人 431 名と 80 の団体で構成している。赤野井湾には守山市内から 8 河川が流入し、これらの河川環境改善が、赤野井湾再生につながると考え、2000 年より長年手入れがされていなかった市内を流れる**目田川**で河川整備や維持活動を始めた。多くの市民や会員が毎月 1 回作業を行い、水質も安定し、生物多様性の河川となり地域の憩いの場となっている。

河川整備活動は今も続いているが、参加者の減少が現在の課題となっている。これには河川保護への関心の薄れも大きく関係しているのではと懸念している。

一方、私たちは目田川で、親子対象に環境保全のための学習会を行なっている。この活動も 18 年目となり、インターンシップでスタッフとして参加した学生の中には、会員として活動する人材も現れた。今後、幼かった参加者の中からスタッフとして活動できる人材が現れるのではと期待している。

1. はじめに

NPO 法人びわこ豊穣の郷は、滋賀県南部にある、赤野井湾流域の守山市を中心に、「赤野井湾」の再生を目的に活動している。



図 1 赤野井湾流域図

1970 年代、赤野井湾は琵琶湖の中でも最も汚染が進んだ水域とされているが、以前は、生物多様性の豊かな入り江だった。高度成長の時期に、環境汚染が進み、赤潮の発生などの問題が発生した。ここで立ち上がったのは、県民であり、特に主婦層を中心に繰り広げられた「せっけん運動」は有名である。この時期に赤野井湾再生のために地元自治会や各種団体、企業、行政などで設立されたのが、びわこ豊穣の郷の前身となる「豊穣の郷流域協議会」である。その後 2004 年には特定非営利活動法人となり、現在に至っている。

2. 赤野井湾再生のために

赤野井湾には守山市内から8本の河川が流入している。そこで、市内河川の保全と改善が赤野井湾の再生につながると考え、そのモデルとなる河川づくりを始めることにした。実践の場として「目田川」を選定し 2000 年から守山市のからの委託事業として整備を始めた。それまでの目田川は、ゴミが散乱し、護岸も崩れたままで、ほとんど管理がされない河川だった。



写真 1 2000 年当時の目田川

その後、当法人の会員を中心に、多くの市民の協力を得て、毎月 1 回の整備、清掃活動、水質調査を行い、現在では水質も安定し、多くの生き物が生息する河川へと変化した。



写真 2　2018 年の目田川

3.　環境学習の場としての役割

この整備された目田川は、現在では市民の憩いの場となり、初夏にはゲンジボタルの飛翔する公園になっている。昔ながらの小川の姿を残すこの河川では、近隣の住民や幼稚園や保育園児が水辺でくつろぐ姿も見られるようになった。

また、当法人でも川遊び体験、水生生物調査などの環境学習を行っている。この学習会は、水辺の生き物と触れ合い、河川に親しむことで生まれる水辺への興味を喚起し、環境保全の大切さや、水辺を守ることの思いを伝えることで、将来の環境保全・改善活動の担い手の育成に繋ぐことを目的としている。

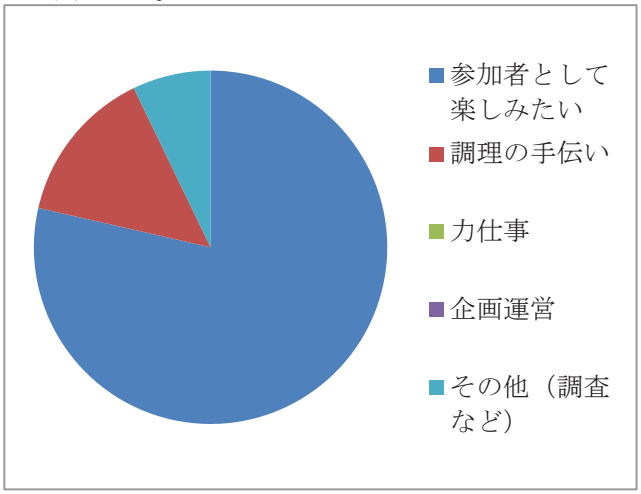


写真 3　環境学習（水辺の楽校）の様子

4.　課題

河川整備を始めて 18 年目を迎え、現在も毎月 1 度の整備活動は続いているが、最近では活動の参加者の減少が目立っている。また環境学習についても、スタッフが固定化し、人手不足が問題となっている。

これは、当法人が活動を始めて 22 年の年月を経て、会員の高齢化が進み、活動への参加が困難になってきていることに加え、新しい会員の加入数が減少しているためでもある。また、川遊びは楽しいが、河川整備や保全活動にはあまり興味がない保護者も多くアンケート結果にも出ている。



グラフ 1　環境学習参加保護者対象
ボランティアに関する意識調査

5.　考察

この環境学習に参加した 20 代～30 代の保護者は、レジャーとして河川で遊びたいが、環境保全活動やボランティアへの関心が薄い。

一方同じ年齢層でも、環境学習や保全活動にインターンシップでスタッフとして参加した学生が、就職後、数年経って会員として戻り、活動を始めたという事例がある。

懐かしい小川の姿が残る目田川を見て、守山市への転入を決めたという住民の話もあることから、河川整備や環境学習の活動が、少しずつ次世代を引きよせているのではないかと考察する。

6.　結論

継続した活動が 14 年経った今、ようやく実を結び、成果が出始めたようだ。

今後、幼かった環境学習参加者の中からスタッフとして活動できる人材や水環境保全の担い手が現れるのではと期待している。

また、その保護者層をどのように巻き込み、親子で環境改善やボランティアへの意識づけができるかが課題となってくる。

今後も、ふるさとの水辺づくりを通し、琵琶湖・赤野井湾の再生に向けて、持続可能な地道な活動を続けたい。

O8-4

地域全体で日本三景の天橋立・阿蘇海とその流域を護り未来に繋げるための取組

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キーワード:・市民参加, 協働,里山保全, カキ殻活用

抄録

天橋立で外海と隔てられている阿蘇海は閉鎖性水域（汽水湖）であり、高度成長期頃から人々の生活様式の変化などにより富栄養化が進み、水質・底質が急速に悪化した。その結果、悪臭の発生やカキの異常繁殖によるカキ島の形成、アサリ漁場喪失などの問題が生じた。これに対して地域の関係団体や行政、専門家で構成する阿蘇海環境づくり協働会議を立ち上げ、地域一丸となり海岸清掃や啓発等の取組を進めた。 また、平成 27 年に「阿蘇海流域ビジョン」を策定、平成 28 年には宮津市と与謝野町が同時に「美しく豊かな阿蘇海をつくり未来につなぐ条例」を施行し、流域全体で取組を進めていく基盤を整備した。そうした中で、平成 27 年から国際ボランティア学生協会の大学生が、カキ殻回収活動等に参画し、大規模な活動を実施されるとともに、回収したカキ殻を活用する取組も進んだ。このように、地域の「宝」である、阿蘇海の環境を未来に繋げるためにボランティアの協力も得ながら地域一丸となって取り組んでいる。

1. はじめに

天橋立は宮津湾と阿蘇海を南北に隔てる長さ 3 キロ以上に伸びる砂嘴であり、その砂嘴の上には松並木が広がり、美しい景観を見せています。何千年もの歳月をかけて自然がつくりだした神秘の造形は、日本三景の一つに数えられ、この景観を見ようと、毎年多くの観光客が訪れその美しさに魅了されています。

その一方で、外海である宮津湾と天橋立で隔てられた閉鎖性水域（汽水湖）である阿蘇海（面積 約 500 ha、最深部約 14m）は、昭和初期頃まで宮津湾とほとんど水質に差はありませんでしたが、高度成長期頃から工業生産の増加、森林の手入れ不足、農地への化学肥料の転換、人々のライフスタイルの変化などにより、流入負荷（生活・農業排水、山林の土砂等）が増え、阿蘇海の富栄養化が進行した結果、水質・底質が急速に悪化しました。これに伴い、有機物が沈積し、底質付近では無酸素・貧酸素状態になるとともに、浅瀬ではアオサやオゴノリなどの藻類やカキの異常繁殖が生じ、それらが腐敗し悪臭を放つとともに、海面を超えてカキ殻が堆積し、「カキ島」が形成され、景観の悪化、カキの浸食によるアサリ漁場喪失などの多くの課題が生じています。

これらの課題に対し、天橋立と一体である美しく恵み豊かな阿蘇海とその流入河川流域の保全と活用を地域が一丸となって進め、未来へ継承していくための取組を進めていますので、その活動について紹介します。

2. 取組内容

阿蘇海の環境改善については、流域の下水道の整備を進め流入負荷を軽減するとともに、平成 5 年から京都府において、阿蘇海の浅い海域を清浄な砂で覆う（覆砂）ことにより海底に堆積したヘドロ層の海中への汚濁物質の溶出を低減し、二枚貝などの生物生息環境を改善するシーブルー事業などのハード事業も行われてきました。

しかし、環境を改善していくためにはハード整備だけでなく、阿蘇海の流域全体で環境改善の取組気運を高め、具体的なプロジェクトの実施を通じて取組の場づくり、人づくり、環づくりを推進し、持続可能な阿蘇海流域の環境改善活動を進めていく必要があります。そこで平成 19 年 5 月に活動の推進母体となる阿蘇海環境づくり協働会議（以下「協働会議」）を立ち上げました。この協働会議は、京都府や地元市町などの行政だけでなく、環境分野を専門とする団体や地域企業をまとめる商工会議所、観光協会、農業団体、水産団体、まちづくり団体、教育関係者などで構成されており、加えて大学などの専門家が委員として参画し、技術的な支援等も受けながら進めています。これにより、地元の関係者が一堂

に会して、懸案や取組内容を検討・実施する体制がつくられ、地域が一丸となって取り組んでいくことが可能となりました。

協働会議の設立以降、構成団体を中心に海岸清掃などの環境改善の取組を行う他、地元住民や次代を担う地域の子ども達に「自分たちのまちの環境は自分たちで守る」という意識を醸成するため、環境改善のチラシの配布、小学校等への講師派遣、環境ポスターコンクールの実施・展示など様々な取組も実施してきました。地元で徐々に気運が高まる中、さらなる展開を目指し平成 25 年に「阿蘇海流域ビジョン」の策定に向けて、計 4 回の住民ワークショップを開催しました。ワークショップでは、延べ 151 名の参加者による熱心な議論が行われ、流域全体の将来像や課題、今後の取組について住民が考えた原案を元に、平成 27年 3 月に「阿蘇海流域ビジョン」を策定しました。このビジョンは、「みんなの力で取り戻そう！未来へ注ぐ阿蘇の海」をスローガンに海だけでなく、流域である山、里、川と海の繋がりを大切にしながら、美しく恵み豊かな流域全体を守り、未来へ伝えていく強い意志を地域全体で共有する指針となりました。

さらにこのビジョンを実現するため、平成 28 年 2 月に阿蘇海流域の自治体である宮津市長と与謝野町長とが「美しく豊かな阿蘇海をつくり未来につなぐ共同宣言」を発表し、美しく豊かな阿蘇海を取り戻し、次世代に継承していくため、最大限努力していく決意を宣言するとともに、平成 28 年 4 月には住民・事業者及び行政が一体となって実施する行動規範として、「美しく豊かな阿蘇海をつくり未来につなぐ条例」を両市町で制定し、同時施行しました。これらの施策により流域全体で取組を進める基礎が確立し、阿蘇海と流域の環境保全に地域全体で取り組むこととなりました。

また、環境悪化の象徴であるカキ殻堆積による「カキ島」については、表出している部分だけでもカキ殻の堆積量は推計で約1千トンもあり、さらに年々新たに堆積することから、平成 21 年度から協働会議構成団体を中心に除去活動を実施していましたが、年間で約 10 トン程度の回収にとどまり、改善するところまでには至りませんでした。

このような中、平成 27 年度にマスコミ報道などでこの活動を知り、内容に共鳴した NPO 法人国際ボランティア学生協会（略称：IVUSA）の大学生から活動への参画の申し入れがあり、以降、協働会議と大学生が協働してカキ殻回収を開始することとなりました。

夏と冬の年 2 回、毎回 100 名を超える大学生が全国から参加する際に、協働会議が宿泊先や地元関係者との調整、許認可手続き、回収用具の一部負担などを行い、大規模な体制でのカキ殻回収活動の実現にこぎ着けました。さらには、地元の多くの高校生などの参加もあり、平成29年度末までに約 245トンのカキ殻の回収を行うことができ、この結果、懸案であったカキ島が年々確実に小さくなってきている状態です。

この取組は、TV、新聞等でも大きく報道され、カキ殻でできた「カキ島」が環境悪化をもたらしていることと共に、カキ殻回収が環境改善活動の象徴としての良いイメージで報道されるなど、多くの人の知るところとなり、その効果は非常に大きなものとなっています。さらには、この活動を通じて地域住民・地域団体に阿蘇海を守る意識がさらに醸成されるなど、地域にも大きな影響を与えています。

しかし、一方で大量に回収したカキ殻をどうするかが新たな課題となりました。これに対しては、地元のワイナリーで栽培されているブドウ畑で石灰の代わりとなる肥料としての活用が進められている他、回収作業を行った大学生ボランティアと共同で地元の桑畑、ミカン畑などでもカキ殻を肥料として活用する取組が始まっています。これらの取組により、膨大な処分費用がかかるカキ殻を再資源化する仕組みを構築することにより大幅なコスト削減に結びつけることができました。さらに、カキ殻を活用したレンガや漆喰の試作など建築資材への応用や、カキ殻と放置竹林の整備で出た竹を混合した土壌改良資材づくりの試作など、地元の事業者や町おこし団体などとの新たな協働によるカキ殻の新たな資源化に向けた取組も拡大しています。

その他、牡蠣自体を食べて減らそうとする取組も始まっています。水質悪化やそれに伴う阿蘇海のイメージ悪化に伴い、阿蘇海産天然真牡蠣の消費・販売を躊躇する声も地元にありましたが、大学生ボランティアの「熱意」と「行動力」に触発され、阿蘇海産天然真牡蠣の商品化に取り組む地元事業者が現れ、地産地消の取組が始まりました。さらには、大学生と協働で阿蘇海産天然真牡蠣を活用した新商品の開発も進められています。

また大規模なカキ殻回収だけでなく、阿蘇海への流入河川である野田川の美化活動を大学生ボランティアと地元自治会、農業団体で協働実施するなど、協働会議と大学生ボランティアの活動領域を上流域にまで拡げ、流域全体での取組も進んでいます。その結果もあり、野田川では、近年サケや鮎が自然遡上する様子が観

察されています。

3. 今後の展開

このように、阿蘇海環境浄化の取組は、阿蘇海環境づくり協働会議を中心に地元と地域外の大学生ボランティアなどとの協働により実施してきましたが、10 年にわたり活動の輪を広げつつ取組を進めてこられたのは、協働会議に地元のステークスホルダーとなる団体が概ね参画しており、地域一丸となって、取組が進められてきたことにあり、地域全体を巻き込んだ事業展開が可能となりました。

さらには地元での協働が進んだことを契機として、関係する市町が同時に条例を制定したことは全国的にも珍しく、毎年、阿蘇海の日を設け、市町域を越えて啓発事業を行うなど、大きな取組につながっています。

また、NPO 法人国際ボランティア学生協会に所属する多くの大学生が全国から活動に積極的に参画してもらえることとなり、協働会議は、学生と地元の交流の場づくりにも力を入れています。協働会議構成員である NPO 法人や漁業者などの有志がコーディネーターとなり、大学生ボランティアと地元との連携、上流域での新たな連携方法の模索、カキ殻の新たな資源化・上流域での活用など、山、里、川と海を繋げる取組の実施や機運の向上に努めています。

平成 29 年 8 月には NPO 法人国際ボランティア学生協会と地域の協働をより進めていくため、阿蘇海を含む丹後地域を所管する京都府丹後広域振興局と同協会とで包括連携協定を締結しました。この協定により、大学生と地域との繋がりを一層深めるとともに、更なる活動の展開を目指していくこととしています。

一方では、課題として、「阿蘇海流域ビジョン」の策定や条例制定により基盤整備はできたものの、この取組を関係団体や大学生ボランティアだけでなく流域の一般住民全体へ浸透させていくことが挙げられます。そのためには、一層の啓発活動が必要です。「地域の環境は地域で守る」意識を住民全体で共有していくため、協働会議では構成団体と連携した啓発活動や海岸清掃への参加の呼びかけ、地元小中高校生の環境学習の場づくりを一層進めていくこととしています。

また、阿蘇海における環境改善を促進するため、産官学民が一体となったカキ殻回収・資源化プロジェクトを更に推進し、景観破壊や悪臭、アサリ漁場の喪失等環境に悪影響が出る部分の大規模なカキ殻回収を今後も進めていく必要があります。

協働会議では、カキ殻回収が進んだ箇所は、美しく豊かな「里海づくり」の活動にシフトし、景観や漁場づくりなど、地元が主体となった持続可能な海浜空間づくりに取り組んでいきます。これらの実現に向け、流域全体で取組の「環」ができるよう、大学生ボランティアの「若い力」も借りながら、カキ殻回収・資源化プロジェクトをはじめ、アサリ漁場の復活試験や牡蠣を活用した新商品開発など、地域を広く巻き込んだ活動を推進していくこととしています。

また、平成 30 年 3 月に環境省が「地域が主体となる閉鎖性海域の環境改善の手引き」を発刊されました。その手引き書の中で、環境改善のケーススタディの一つとして「阿蘇海の取組」が取り上げられるとともに、これまで取り組んできたカキ殻回収や覆砂などの他、ポンプ排水を行った場合や作澪などを実施した場合やそれらの取組を複数組み合わせた場合など、環境改善の手法ごとに低層の貧酸素化に対する改善予測シミュレーションが掲載されました。今後、この結果を踏まえながら、効果的な取組等について有識者等と検討していくこととしています。

4. 終わりに

天橋立は、世界遺産登録を目指して地元で取組が進められています。世界的に珍しい地形でもあり、歴史的にも、雪舟の国宝「天橋立図」に描かれたほか、全国各地の日本庭園などにも大きな影響を与えてきました。この風光明媚な天橋立を守り、次世代に残していくためにも、流域全体で阿蘇海に関心と危機感を共有しながら世界遺産にふさわしい環境づくりを進めていく必要があります。

引き続き、協働会議では、大学生ボランティアなど地域外の方々と協働しながら流域住民と一緒に一層の環境改善活動に取り組んで行くこととしております。



O8-5

M.A.T.H. for Yaman ng Lawa: Strategies for Sustainable Development of the Wealth of the Lake The Case of Laguna De Bay, Calamba City, Philippines

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KEYWORDS: citizen participation, lake conservation, wise use and development of lake resources, advocacy

ABSTRACT

Yaman ng Lawa (YNL) or Wealth of the Lake Project started as a research project funded by the Research Institute of Humanity and Nature, Japan and implemented by the LakeHEAD Research Team from Japan and University of the Philippines. It primarily aims to provide avenue for exchange of ideas between the scientists and local fisherfolks.

The City Government of Calamba adopted the YNL concepts and principles; used them in designing programs for fishery resource management. The project was implemented using the adaptive community-based management approach, wherein the "technology" used comes from the fisherfolks, adapting to their needs, and was backed-up by scientific principles.

To ensure the sustainability of the YNL project impact, the City Government of Calamba through the City Agricultural Services Department designed the M.A.T.H. in Adaptive Co-Management of Fishery Resources as implementing strategies of the project. M.A.T.H. stands for: M – Mentoring the future generation; A – Accessing partnership; T – Technology and Information Dissemination; H – Home and Family-Based Approach.

For almost six (6) years, through the implementation of M.A.T.H. strategies, YNL continuously became a project that celebrates environmental success and embodied social commitment of the City of Calamba that can also be adopted and implemented in other lakeshore communities in the Philippines. Through M.A.T.H. lakes and humans can co-exist harmoniously, leading to sustainable development of the wealth of lake resources, benefitting the community around it.

1. INTRODUCTION

Laguna de Bay, formerly known for its economic and historical value, is now characterized in its extremely stressed ecological state[1] With the current status of Laguna De Bay, there is an urgent need for projects that will focus on conservation and management of fishery resources in the city.

In 2012, the City of Calamba, particularly the fishery sector experienced a series of tragedy that cause great loss to livelihood of fisherfolks. First, the fish kill in May 2012 that reduced the aquaculture production. Second, the damages caused by the heavy flooding brought by Habagat (southwest monsoon) that lasted for three long months.

The incidence of fishkill and heavy flooding paved the way for the local fishermen to meet the research team from RIHN, Kyoto, Japan and the University of the Philippines Los Baños (UPLB) who are part of the LakeHEAD (Lake Health, Environment, Agriculture and Diversity) Project. The series of meetings gave birth to the idea of Yaman ng Lawa (YNL) Project. The project's purpose was to be a venue for exchange of ideas between the local fishermen and scientists; harnessing the wealth of the lake stored in the indigenous knowledge of the local fisherfolks.

2. METHOD

The study was conducted at Calamba City, Laguna, Philippines from January to April 2018. Calamba City is one of the 27 municipalities around Laguna De Bay, is located in the southwestern part of the lake. Case study approach was used to focus on the dynamics present within the case of fishery resource management of Calamba City. Key informant interview and focus group discussion with city officials, barangay (village) leaders and fisherfolk leaders (FARMC) were conducted. Secondary data from 2011 to 2018 were collected from available records at different agencies in the City government and BFAR.

3. RESULTS AND DISCUSSION

Fisheries in Calamba City

Ten (10) out of the 54 barangays of Calamba were located in the shore of Laguna De Bay. Fishery was a major source of livelihood by more than 1,700 families in Calamba City. Fishing activities includes capture fisheries, aquaculture, fish vending, fish processing, and fish workers.

The Yaman ng Lawa Project

The Yaman ng Lawa or Wealth of the Lake Project is a research project that served as a platform for sustainable management and utilization of the Laguna Lake resources.[2] The project was conducted by the LakeHEAD (Lake Health, Environment, Agriculture and Diversity) Research Team composed of the researchers from Research Institute for Humanity and Nature (RIHN), Kyoto, Japan and the University of the Philippines Los Baños (UPLB) from 2011 to 2014. In the City of Calamba, the project was implemented from December 2012 to November 2013. The main objective of the project is to harness the wealth of Laguna Lake stored in the indigenous knowledge of the local fisherfolks through series of dialogues, seminar and joint field works. The fisherfolks, through the Calamba City FARMC (Fisheries and Aquatic Resources Management Council), functioned as the community based researchers in action (COBRA). They provided valuable assistance to the researchers in the studies under the Yaman ng Lawa Project. Studies include the following: survey of fisheries production data, early warning system for fishkill, interpretation of biosignals, identification of indigenous aquatic plants, and observation of traditional fishing practices.

Yankaw Fish Garden and Fish Protected Area

One of the traditional fishing practices that were highlighted is the effect of yankaw (a fish aggregating device) in the fish behavior. Yankaw, composed of tamarind (*Tamarindus indica*) or kamatsili (*Pithecellobium dulce*) branches, were used as traditional fishing gear in Laguna De Bay. Yankaw was then used as part of the management strategies of the Fish Protected Area, thus giving birth to the Yankaw Fish Garden and Fish Protected Area (YFG). Since, Laguna de Bay is a freshwater body and there is no mangrove area, the yankaw placed inside the fish protected area simulates the functions of the mangrove roots, providing shelter for the fish. In addition, the yankaw also released tannins and flavonoids that improved the quality of the water around it and is favorable for the growth of aquatic plants in the area, thereby providing a ground conducive for the breeding and reproduction of fishes.[3]

M.A.T.H. for Yaman ng Lawa

Yaman ng Lawa Project becomes a platform for sustainable management and utilization of Laguna Lake Resources. The City Government of Calamba adopted the YNL concepts and principles; used them in designing programs for fishery resource management. The project was implemented using the adaptive community-based management approach, wherein the "technology" used comes from the fisherfolks, adapting to their needs, and was backed-up by scientific principles. Programs implemented under the YNL Project includes activities towards environmental conservation, law enforcement and livelihood upliftment of the fishing families.

To ensure the sustainability of the YNL project impact, the City Government of Calamba through the City Agricultural Services Department designed the M.A.T.H. in Adaptive Co-Management of Fishery Resources as implementing strategies of the project. M.A.T.H. stands for: M – Mentoring the future generation; A – Accessing partnership; T – Technology and Information Dissemination; H – Home and Family-Based Approach.

Mentoring the future generation

Advocacy to conserve and protect Laguna De Bay should not stop in the present generation of fisherfolks. Calamba City FARMC continuously shares their knowledge and advocacy to the students from different schools and universities. Educational tours, environmental researches, dialogues and seminars were conducted regularly.



Fig. 1 Learning by Doing: Educational exposure trips of students includes actual hands-on fishing experience, demonstrations and dialogues with local fisherfolks.

Accessing partnership

Conservation of fisheries resource is not a one-man-job. It's a responsibility of everyone, young and old, private and government, students and professionals, civic and religious, local and international. Calamba City is continuously tapping every networks and partnership available for any type of support. Figure 2 showed the networks and partnership formed through the YNL Project between government institutions, local government unit, scientists and academe, private sector, community and fisherfolks. Support received includes technical assistance, trainings and capability building seminar, provision of fishery inputs, livelihood support, financial assistance, insurance program, cash/food for work program, law enforcement and legal assistance, disaster preparedness and emergency response, among others.

Technology and Information Dissemination

Appropriate technology and correct information were disseminated to the local fisherfolks and communities

through the conduct of regular FARMC meetings at barangay levels. IEC materials which includes pamphlets and tarpaulins were prepared and distributed to the fisherfolks and concerned communities. The use of social media in fast and wider information dissemination were also used effectively.

Home and Family-Based Approach

The goal of the YNL Project does not end in lake conservation but ultimately to alleviate the fishing families from poverty. Calamba City FARMC designed strategies to include all the members of the family in its advocacy such as livelihood upliftment programs such as training on value adding of fisheries products, and establishment of fisherfolks cooperative; values formation and moral recovery program for fisherfolks children, marriage course and counselling for couples; and family day celebration.

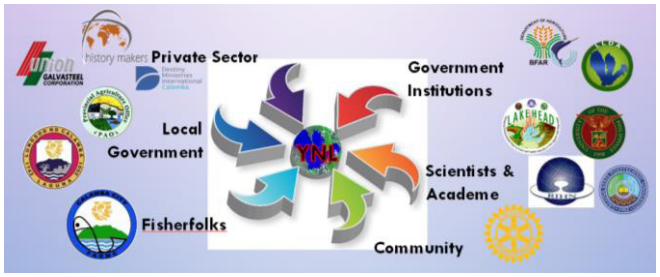

Fig. 2 Convergence for Yaman ng Lawa

Impact of M.A.T.H. for Yaman ng Lawa

Environmental Impact

The declaration of a portion of the lake that was closed for fishing activities, is one of the known effective management strategy in fishery management. The area chosen by the fisherfolks and the LGU greatly considered the water flow and presence of aquatic plants. By closing the area and declaring it as fish protected area, a "sanctuary" was provided for the fish species, thereby increasing fish population and simultaneously increasing the fish production.

Water quality on that part of the lake was observed to improved, as indicated by the different biosignals. There was improved growth of aquatic plants (*Hydrilla verticillata*), not just inside the FPA but also in its surrounding waters.

Impact in Fish Production and Food Security

The effects of Yankaw Fish Garden and Fish Protected Area in the improvement of water quality, enriched growth of aquatic plants and conducive breeding and reproduction of fishes; as well as the intensive campaign against illegal fishing; have direct impact on the amount of fish production. There were increasing trend in annual fish production from capture fisheries observed from 201 to 2017 as shown in Figure 3. Daily fish catch of fisherfolks increased from average of 5-10 kg per fishing effort to average of 15-25 kg. Fisherfolks reported fish catch of as high as 100-150 kg during the peak season (July to October).

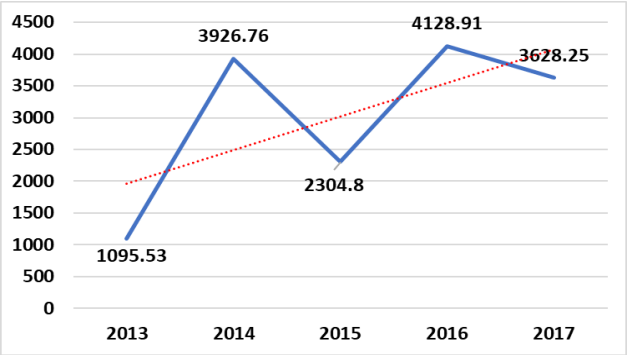

Fig. 3 Annual Municipal Fish Catch 2013-2017 (in MT)

Promotion of people's participation and empowerment

Yaman ng Lawa does not only address the environmental issues and food security, but also empowers the fisherfolks to be responsible and to be part of the solution in fishery management.

4. CONCLUSION

For almost six (6) years, through the implementation of M.A.T.H. strategies, YNL continuously became a project that celebrates environmental success and embodied social commitment of the City Government of Calamba that can also be adopted and implemented in other lakeshore communities.

1. Mentoring the younger generation will ensure that genuine concern for the conservation of lake resources will continue in the future.
2. Accessing partnership with all agencies, government and private, will greatly ease the implementation and of programs and will complement one another in attainment of development goals, environmental conservation and economic benefit.
3. Technology and Information dissemination must be done effectively, harnessing the use of updated technology for a wider impact and benefits.
4. Home and Family-Based approach will guarantee the active participation of the whole family in the advocacy and programs.

MATH is a strategy that can be learned and implemented, not just in schools, but also in lake conservation. Through M.A.T.H., lakes and humans can co-exist harmoniously, leading to sustainable development of the wealth of lake resources, benefitting the community around it.

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O8-6

My Lake Lanao Project: A Clean Lanao for a Peaceful Mindanao

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Keywords: citizen participation, collaboration, capacity building, awareness.SDGs

ABSTRACT

Lake Lanao in Mindanao, the southern part of Philippines, is one of the world's ancient lakes. It is a cultural heritage of the Meranaws and a strategic economic resource of the country being a major source of hydropower. The lake is an important source of water, subsistence and livelihood for the Meranaws. However, unsustainable agricultural practices, pollution, illegal logging, as well as the series of dams constructed along the Agus River, the lone outlet of the Lake, have caused deterioration of the Lake. If left unabated, the livelihood, health, and food security of Měranaws will be seriously affected. Following the sustainable human development framework, the My Lake Lanao Project (MLLP) attempts to addresses these multiple and interconnected problems of the Lake and lakeshore communities. Interventions include community-based development projects integrating livelihood and Lake conservation, education and awareness campaigns mobilizing school-based and community-based youth. MLLP adopts collaborative participatory processes, evidence-based approaches and need-responsive programs. Employing a modified *action research* approach, this study examines the social processes of MLLP implementation, focusing especially on the responses of local communities and their level of awareness on existing programs for the protection of the Lake. The research reveals the crucial role of collaboration among local communities, non-government organizations, local governments and the academe, as a *collective agency*, in attaining the objectives of poverty alleviation, environmental conservation and peace advocacy.

1. INTRODUCTION

Lake Lanao in Mindanao, the southern part of Philippines, is one of the world's ancient lakes. It is a cultural heritage of the Meranaws, the Muslim peoples inhabiting the area since precolonial times. It is a strategic economic resource of the country being a major source of hydropower. The lake is an important resource for subsistence and livelihood of the Meranaws. However, unsustainable agricultural practices, pollution, illegal logging, as well as the series of dams constructed along the Agus River, the lone outlet of the Lake, have caused the Lake to deteriorate. If left unabated, the livelihood, health, and food security of Měranaws will be seriously affected. Many fears that this will be a factor which increases their vulnerability to recruitment by extremist groups.

Cognizant of these realities, and the priorities of Millineum Sustainable development goals (SDGs) the project *My Lake Lanao for a Peaceful Mindanao* (MLLP) was drafted. US Embassy in Manila provided the funds while the College of Arts and Social Sciences (CASS) of the Mindanao State University-Iligan Institute of Technology provided management backup and direction-setting. Following sustainable human development framework (Hasnat 2009, Pelenc *et al* 2013) , the project had the following objectives: (1) to empower local communities to protect and develop Lake Lanao; (2) to create a cadre of environmental advocates that promote the conservation and protection of Lake Lanao. (3) Facilitate production of locally-adapted materials for environmental advocacy and awareness and cultural heritage campaign. The project sought to improve the quality of life of the people in the communities and widen their choices through community-driven responses which would thwart the destruction of the environment, generate sustainable livelihood opportunities, and reduce sources of conflict, thus enabling them to not only provide for their own needs, develop their human capabilities, and live long and healthy lives but also to ensure that future generations will also be able to do the same.

2. METHOD

The actors, termed stakeholders, in this research are the implementers of the MLLP - a collaborative undertaking among the following: the funder[1], the academe[2], the partner non-government organizations and people's organizations (NGOs & POs). Traditional action research requires that the "actors" themselves conducts the inquiry with the primary reason that the actors can automatically improve or refine interventions as deem fit with the changes and shifts of social conditions (see Sagor 2009). In this case, research is carried out by the academe but with close contact with field implementers, the NGOs and POs. Data gathering are done during regular meetings with collaborators, field visits of the academe and exchange of e-mails, texts (SMS) and phone calls among them. Action research gives primal importance to *relevance* and *effectiveness* of the interventions to the project participants who are themselves the users of the data or information.

[1]The US Embassy in Manila provided funding support for the first year of this program.

[2] A composite team from the Department of Sociology and Department of English of the College of Arts and Social Sciences, Mindanao State University-Iligan Institute of Technology, a university very close to the study/project area. This university is well-known to the locals in the Lanao areas.

3. RESULTS

Following the MLLP components, the following are the outcomes of the project:

Pre Project Planning and Partnership Building

MLLP started with pre-project meeting where collaborators met and leveled-off on the MLLP's aims, processes and intended outcomes. In these preliminary meetings, collaborators agreed on general project process, identification of project and community partners, logistical arrangements and reporting.

MLLP Summit-Workshop

A 3-day workshop participated by government representatives, law enforcers, youth leaders, academics, NGOs, religious leaders, legal aid clinicians, environmental experts, and community representatives identified factors which contribute to the degradation of the Lake Lanao watershed area and came up with possible solutions. To aid participants in proposal making and project pitching, lectures on Strategic Thinking and Visioning were conducted. Participants were given time to craft proposals, with the assistance of the CASS MLLP team and legal aid clinicians[3].

A Facebook Group (*My Lake Lanao Project*) was created which served as a venue for participants to share their ideas and experiences. Proposals were posted on the group page and subjected to peer review prior to final submission.

Rapid Appraisal Study

CASS spearheaded the conduct of a baseline study on the beliefs and attitudes of communities in the Lake Lanao watershed area regarding lake conservation, livelihood opportunities, and sources of conflict. Also, the baseline study inquires on the existing policies on Lake Lanao conservation and development. Results of the baseline study served as input in the design of the MLLP awareness campaign and community mini-projects.

Community Development Projects

Ten communities have been the recipients of MLLP development project. Each was given a grant of Php250,000.00 (US$5,000). The following are community-based projects facilitated by five (5) partner NGO/PO:

a. *Livelihood & Environmental Conservation* - through Recycling, establishment of Abaca nursery and production of organic fertilizers like vermi-composting. Implemented in (4) communities by the Al-Mujadilah Development Foundation, Inc (AMDFI)

b. "*Fish for Peace"* - a livelihood project with care for waters and environmental advocacy facilitated by the NGO partner , Dansalan College (1DC) Alumni Association.

c. *Agro-reforestation Project* in the uplands of Lake Lanao watershed. This is facilitated by the Department of Sociology & Anthropology of the sister-university, Mindanao State University-Marawi City.

d. *Sab't Lanao Project,* an awareness campaign for saving Lake Lanao with components in (1) Multi-sectoral Seminar Workshop on Solid Waste Management (2) Community Clean-Up Drive and (3) Art for Earth Day activity. This is implemented by a youth organization, the Inspired Young Optimistic Guild (IYOG)

e. *Assisted Natural Regeneration Project* with components: (1) agroforestry (2) livelihood (3) establishment of Herbal and Vegetables garden facilitated by NGO partner, ABAG Inc.

f. *Fish Cages* with three components: (1) Waste Management and Disposal projects ("May Pera sa Basura"); (2) livelihood support project, fish cages, (3)establishment of herbal and vegetable gardens facilitated by NGO partner, ABAG Inc.

Awareness Campaign and Advocacy

Advocacy initiatives, on the other hand, focused on the critical role of Lake Lanao as a cultural heritage and an economic resource. It consisted of four subprojects: (1) *Ranao* Monster, a large format children's book written in English and Měranao; (2) advocacy training for 37 elementary public school teachers in Marawi City and Lanao del Sur; (3) a short film making contest; and (4) a documentary on MLLP. The first two were implemented by advocacy partners from MSU-Marawi, with CASS supervision, while the other two were directly implemented by CASS. The book was distributed to elementary schools in Lanao del Sur while the two winning entries for the film competition were shown in classrooms in various schools in the province.

Culminating Summit of MLLP

A two-day culminating summit was conducted at the end of project period. This was attended by representatives of project communities, partner NGOs and POs, academics, LGU officials and students. Some environmental activists were also invited. Project implementers shared about their experiences, the projects and activities they have embarked, shared their plans for sustainability, including possibilities of replication of successful projects to other similarly-situated communities. A reflective session was also conducted which helped identify the *facilitating factor*s - supporting and hindering factors - and challenges encountered.

Project Evaluation

[3] This is a group of Filipino lawyers who have been beneficiaries of a program under the US Embassy in Manila.

A private group, *Future by Design Pilipinas* facilitated the post project evaluation of MLLP. The process involved reflective sessions where participants reflected on their learnings and experiences over the past year. They shared how the situation in their respective communities has changed with the implementation of MLLP.

4. DISCUSSIONS

At the outset, MLLP ensured a mechanism that will be effective in bringing the project into its intended outcomes. A collaborative team was organized which then decided to gather all actors in the project to have a pre-project summit to do leveling-off - on the conditions of the Lake and the communities, and affirm the project's intentions, and to decide on project interventions that will address social and environmental issues they collectively decide to pursue. In like manner, a culminating summit was done at the end of first year of the project where stakeholders presented outputs and learnings from their engagements.

(1) To empower local communities to protect and develop Lake Lanao .

Community-based projects is the flagship component of MLLP. Ten communities embarked on a project they themselves collectively identify. They created livelihood opportunities, thus contributing to the poverty situation and the attainment of food security. Moreover, the project helped facilitate proper garbage disposal instead of throwing them into the lake. Instead, the people use the garbage to make *vermi* compost which is sold as organic fertilizer. Quarrying which has resulted in the siltation of Lake Lanao, has been minimized as people with an alternative source of income through *tilapia* cage farming. The use of floating fish cages is important because it ensures that other fishes in the lake are not affected by the presence of *tilapia*.

(2) To create a cadre of environmental advocates that promote the conservation and protection of Lake Lanao.

MLLP has facilitated the establishment of a network of advocates for environmental conservation for Lake Lanao. Aside from developing environment-conscious income-generating projects in the communities, the youth group was able to embark on an active advocacy on environmental enhancement like the "clean up" activity of *Sumpitan Falls*, which rivers flows into the Lake. The public school teachers and students produced several information, education campaigns (IEC) materials - short films, large-format book for children, advocacy materials for schools. During the Culminating Summit of MLLP, stakeholders brainstormed and decided on strategies of sustainability of their respective projects. [4]

(3) Facilitate production of locally-adapted materials for environmental advocacy and awareness and cultural heritage campaign.

The talents and skills of the young Meranaws artists were tapped and given mileage in the production of short films, story books and posters for the MLLP. These were well-appreciated by the communities as their art carries Meranaw cultural symbols and messages. On another realm, the cultivation of abaca in some project sites has served as an effective deterrent to cutting trees. Agro-reforestation efforts have contributed to combatting the effects of climate change. Recycling projects have helped promote sustainable consumption and production patterns. More than 80% of stakeholders or actors - community-based - are women.

5. CONCLUSION

The project was able to facilitate an empowering realization among stakeholders that Lake Lanao is not just an economic resource but is actually an integral part of the identity of Meranaw as a people. Inspired by sustainable human development framework, communities committed to continue efforts to save Lake Lanao. As the MLLP experience has shown, attaining the objectives of both poverty alleviation and environmental advocacy require the collaborative effort of government, civil society, the academe, and the community, as a collective agency, with the capacity to to decide and implement corresponding strategies to make change they desire.

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[4] The Culminating Summit was conducted in February 2017. In the succeeding month of May, an ISIS-connected siege occurred in Marawi City. This famous "Marawi Siege" caused the massive evacuation of all Marawi residents and nearby communities, including all the project areas of MLLP. The war lasted for one year. At present, initial steps are undergoing to regain many communities, including the areas covered by MLLP.

O8-7

Paper title：The changing role of community in the management of reservoirs in Jakarta

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Keywords: reservoirs, role of community, management, water resources

ABSTRACT

The reservoirs made by the Dutch colonial government in Jakarta have undergone drastic changes in the role of the community over the last one hundred years. The purpose of this study was to find out how the communities negotiate with the government and compete with private business interests. The research method is observational and depends on an in-depth interview as a key informational source. The results of the study indicate that the changing role of the community is caused by, (1) water resource laws do not provide space for the participation of local communities; (2) the land around the reservoir is controlled by the private sector for urban expansion; (3) the reservoirs have changed in function from agricultural irrigation to flood control; and (4) many reservoirs are polluted and silted. Some communities that demonstrate the capability of managing the reservoirs are largely dependent on the following factors, (1) social ties within communities that affect solidity in determining the importance of managing reservoirs; (2) the role of village community leaders in establishing relations with the government as a crucial step toward the success of negotiations in the management of reservoirs; and (3) the combination between the two factors already listed affects the success of a community competing with private developers in reservoir management. This study concludes that the community's ability to maintain relationships with stakeholders demonstrate their capability in taking on the role of managing reservoirs also influence the continuity of the respective reservoir’s function as a water source.

1. INTRODUCTION

Artificial reservoirs constructed in the Dutch colonial era in the capital region of Jakarta and its surrounding areas have changed drastically in numerous ways over the last one hundred years or so. This study examines some communities around the reservoirs that have remained in the last few generations, who are trying to maintain their management of the reservoirs in order to take advantage of water resources. This community effort is no easy feat, as the government has regulated the management of reservoirs through laws that restrict access to them and the opportunities to participate in their maintenance as members the public. The purpose of this study is to find out how local communities can survive for the following generations, negotiate with governments and compete with private business interests.

2. METHOD

This research project uses the following method (1) reviewed regulatory documents related to the management of reservoirs; (2) observed the relationship between the community and the reservoirs; and (3) conducted in-depth interviews with key informants who live around the reservoirs.

3. RESULTS

Reservoirs in the Greater Jakarta area are land and water controlled by the state. Management of reservoirs is the responsibility of the local government, which in this case is the Department of Public Works. Meanwhile, the people who live around there generally have a historical relationship both in terms of development, utilization, and mythology. The history of the relationship between society and reservoirs are generally formed from the colonial period to the present. However, management of reservoir at this time by the Department of Public Works generally places less emphasis on community involvement.

Table 1. The role of community of seven reservoirs in Jakarta

Situ	Role and involvement	Problems in the management of Situ
Pluit, North Jakarta	Workers root out *Eceng Gondok* and utilize the plant for craftmaking within a community project based. They also utilize the reservoir as a household waste disposal.	There is a large number of households living around the reservoir. Their relationship with the reservoir tends to degrade and reduce the function of reservoir. Resettlement to flats that are being built are not enough to accommodate all households.
Babakan, South Jakarta	Their role in the management and utilization reservoir was large enough in the past but not currently.	Betawi Cultural Village being built by the provincial government of Jakarta. However the people are not involved in the process of development.
Gintung, South Tangerang	After flash floods due to the dam collapse, the surrounding community is more concerned with the management of reservoir. A community has been formed to maintain the reservoir	After the governor of Banten and South Tangerang mayor's husband was arrested by KPK, funding assistance to communities that manage reservoir are reduced, so the community is rather inactive
Cihuni, South Tangerang	The community plays a role in the retention of the reservoir's presence there as "common property," in conflict with the Sumarecon	Reservoir management threatened by Sumarecon's involvement and used as a private facility
Cipondoh, Tangerang City	The community acted to manage it in the past but not at present, because it functions as an agricultural irrigation which is not working anymore	Land around the reservoir has been dominated by Alam Sutera and housing will be built. Residents will be relocated and the area of the reservoir will be used as a tourist site as part of the Alam Sutera residential area.
Binong, Bekasi	The Binong community has built a non-governmental organization called Walatra, which has established rules in the management and preservation of reservoir, including planting trees, making water installations, and maintaining public participation in its management	Land around the reservoir has been controlled by the Delta Mas and waste water generated from residential areas, markets, and households is dumped into the territory around the reservoir.
Tonjong, Bogor	Community's role in managing reservoir has decreased along with the diminishment of its irrigational function. The role of management is practiced by the village government, among others, through the planting of trees, and the involvement of the community in the form of a working relationship in wages.	Land on the edge of reservoir to be taken over by private residential and restaurant business. Household waste goes into the reservoir, and community participation in the management of reservoir is declining

Community involvement in the management of reservoirs have existed towards: the overall development of reservoir, their maintenance in an infrastructural as well as environment sense, the use of clean water as a daily source, the irrigation of rice fields, aqua-culture, and tourism, as well as the ritual of *sedekah bumi* (thanking-earth rituals) as a form of internalizing cultural values in the management of reservoir. Several communities around the reservoirs also formed organizations to preserve the container reservoir, such as the Walatra in Binong reservoir area; other communities created organization-based on community neighborhood institutions (*Rukun Tetangga/Rukun Warga*). Various forms of community involvement in the management of reservoirs have declined. These changes happened, among others, by the land use changes around reservoirs during the period of the 1980s until now.

At this time, communities' involvement in the management of reservoirs are declining in correlation

with the reduced utilization of reservoirs for their daily needs. Less intensive communities' involvement have led to the changes of reservoirs management responsibility, being allocated solely to the Department of Public Works. Meanwhile, the communities around reservoirs are increasingly being subject to urbanization, affecting reservoirs conservation in general. Many reservoirs in Jakarta area are declining in their functions as a result of the weakness of local community involvement.

4. DISCUSSION

The role of the community in the management of *Situ* has changed, with the overall tendency being that it is less instrumental and less involved. This is caused partly by: (1) Rules established by the government do not provide space for public participation in the management of *Situ*; (2) Land around the *Situ*, particularly outside Jakarta, is increasingly dominated by the private sector, especially housing, offices, malls and other forms of infrastructure that comprise a "new town/city"; (3) *Situ* in Greater Jakarta have changed in function from rice irrigation system to flood control; and (4) Many *Situ* in Jakarta have simply not been cared for properly. Among other problems, many *Situ* are experiencing pollution and are silting up because the involvement of local communities in the management of the *Situ* is very low.

Table 2. The parameters of the role of community in the management of reservoir

Criteria for participation		Parameter				
		5	4	3	2	1
A	Relations with the community	Managed by community	Maintained by the community	Defended by a small number of group	Not maintained by a community	Condoned by the community
1	Pluit					■
2	Babakan				■	
3	Gintung			■		
4	Cihuni			■		
5	Cipondoh			■		
6	Binong		■			
7	Tonjong				■	
B	Stakeholder involvement	Multi-stakeholder involvement	Multi-stakeholder involvement is less	Only a small group of stakeholders' involvement	Stakeholders involved only government	There is no involvement of stakeholders
1	Pluit					■
2	Babakan		■			
3	Gintung			■		
4	Cihuni				■	
5	Cipondoh				■	
6	Binong		■			
7	Tonjong				■	
C	Benefits for the community	Provide benefits for many parties	Provide benefits to the local community	Provide benefits to a small number of people	Less provide benefits to the local community	No benefit
1	Pluit					■
2	Babakan			■		
3	Gintung				■	
4	Cihuni				■	
5	Cipondoh				■	
6	Binong		■			
7	Tonjong				■	

Some communities that demonstrate roles largely depend on the following factors are (1) social ties within the community, especially those established through kinship, brotherhood and hereditary history, affect the solidity of the community in determining the interests around the control of the reservoirs; (2) the role of village community leaders, especially the village head in establishing communication and good relations with the local government. This is crucial to the successful negotiation in the control of the dam; and (3) the combination of solidity and cohesiveness contributes to the success of a community competing with private developers in terms of reservoir control.

5. CONCLUSION

This study concludes that the community's ability to maintain relationships with stakeholders, especially the government and the private sector, affects the role of the community in the management of reservoirs. Some communities that fulfil their role in the management of reservoirs also influence the continuity of reservoir function as a water source.

O8-8

Stakeholder Participation for Determining Research Direction of Phayao Lake, Thailand

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Keywords: lake management, stakeholder participation, research direction, sustainable development

ABSTRACT

Phayao Lake is one of the most important lake in Thailand and provides many benefits to the city of Phayao and lake basin. Settlements, agriculture, tourism and fishing are some of the major uses of the lake basin, making community involvement a necessary component of its management. The aim of the study was to explore the knowledge and perceptions of local communities regarding; the critical problems, situation of the lake management and possible future research direction Three key processes were carried out including 1) collect and synthesize available knowledge from previous research articles and publications, 2) integrate lake development plans with available knowledge, and 3) determine strategic research directions for the lake using stakeholder participation. More than 200 research articles have been published in the past decade. Most of the studies were related on the lake but only a few of them have been used in policy making process or development plan. Future lake strategic research directions could be determined in four main areas; development of ecosystem balance for sustainable use of natural resources; development of economic potential especially tourism competencies; restoration of social issues and management deregulation; improvement of inhabitant health status. The vision and strategies of the lake research and development were also pointed out by participatory process. Lesson learned from this study was lake management should include the integration of academic research, local government development plan, and stakeholder participation.

1. INTRODUCTION

Phayao Lake is the international recognition wetlands situated in the northernmost of Thailand. It is a semi -natural wetlands including a permanent freshwater lake covering an area of approximately 1,980 hectares with a mean depth of 1.7 m and located at an altitude of 380 meters above sea level. It is a significant residence for freshwater fishes and water birds[1]. The lake is fed by 13 small channels. Phayao city is situated on the southeastern fringe of the lake. The lake empties to the east, via the lng river which empties into the Mekong river in Chiang Rai Province[2]. Phayao Lake is a habitat for diverse aquatic living groups and services as a community source of freshwater fish, water supply, freshwater irrigation, and is also used for recreation and tourism. There are 1 3 local fishery communities around the lake. Forty-seven species have been recorded[3]. Recently, Phayao lake has experienced water quality problems due to population expansion in and around Phayao municipality. Moreover, many cultivations surrounding the lake, mainly rice crop, are also sources of agricultural pollutants. The lake itself is gradually becoming shallower as a result of high particulate deposition from inflow streams and the accumulation of aquatic detritus. In some places, poor water quality, particularly low dissolved oxygen, is near a critical level for the survival of fish[4]. Apart from ecosystem degradation, Phayao lake has been subjected to management problem, which is threatening the habitat diversity and recreational opportunities. Although many research works have been done by many researchers, only a few of them were considered for lake development planning process by policy makers. To avoid research redundancy and encourage people participation in lake management, we used research methodology as a tool for bringing policy makers, community, and academia to work together. This research aims to explore the knowledge and perceptions of local communities regarding; the critical problems of the lake; technical and political situation of the lake management; possible future strategic research direction for ensuring positive change towards the sustainability of the lake.

2. METHOD

Three key processes were carried out in this study including 1) collect and synthesize available knowledge from the previous reports and publications, 2) current situation review and integrate lake development plans, and 3) identify the research directions of the lake

by various stakeholder participation. Literature review of previous lake research was done from 21 research databases. Collected articles were analyzed for their contexts and findings which can be utilized for development plan. Current status and lake development plans of lake related government organizations were also reviewed by Ad Hoc committee. Focus group meetings of 10 stakeholder groups from upstream to downstream were conducted. These groups comprise of policy makers (governor and head of provincial public organizations), water users in upstream, midstream and downstream areas, upstream forest conservation network, fish farmers, local fisherman, researchers, private business associations and tourism business operators, local industries, NGOs, and youth group. Total people participated in these activities were 874. SWOT analysis, Space matrix technique, Strategic Position & Action Evaluation matrix, and gap analysis were used to determine research direction from stakeholder opinions. Overall results from these activities were used to define the lake sustainable developmental goals and research directions.

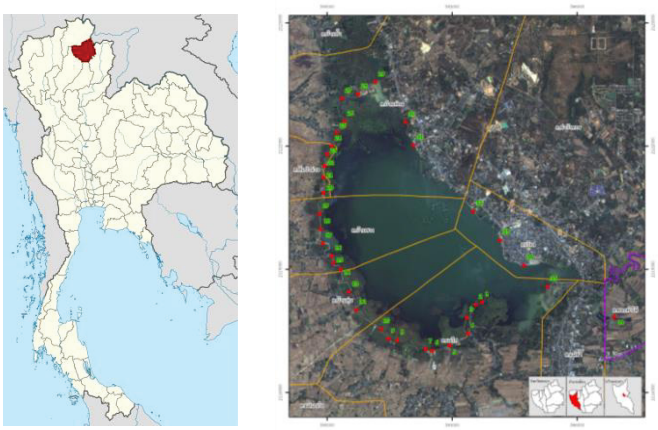

Fig. 1 Map of Thailand and satellite image of the studied area Phayao Lake, Thailand.

3. RESULTS

From literature review of 21 research database, more than 200 publications/research articles related to Phayao lake and vicinity areas have been recorded. These research works were done by more than 120 researchers from many universities and research institutions in Thailand. Most of the lake available researches were related on natural ecosystem, social issues, economics, and health studies, respectively. There had been rapid development in Phayao lake research since 2004 and a sharp increase in papers since 2008. A keyword analysis showed that "fishery", "biodiversity", "water quality" "sediment", "eutrophication", "*Microcystis aeruginosa*", "cyanobacterial blooms", "tourism" and "participation" were the most frequently used keywords of the study subject. Owing to its significant impact on aquatic ecosystems and economic problems, crucial emphasis has been placed on climate change and tourism activities recently. It was found, from stakeholder opinions, that recent critical problems of the lake are the shallower by sedimentation, aquatic weeds accumulation, and a conflict on lake boundary and land used. Strategic positioning was then created from overall processes and can be defined as 4 research directions. The first direction is the proactive strategy for the development of ecosystem balance in natural resources and environment. The second direction is the conservative profile strategy for the development of economic potential and tourism competence. The third direction is the defensive strategy to restore the state of society and deregulations. The fourth direction is the proactive strategy of inhabitant health status development. Considering the research directions of the watershed areas of Phayao lake in the upstream area, the lake surrounding area, and the downstream area, it can be proposed that the upstream area should be targeted on natural resource conservation and restoration. Lake surrounding area should be emphasized on the ecosystem balance with resources utilization. Downstream area should be focused on water resource management from upstream toward downstream.

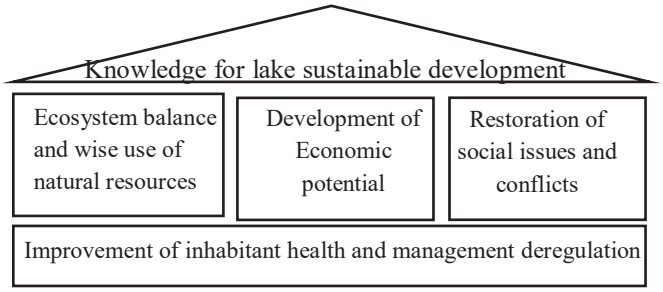

Fig. 2 Phayao lake research directions from stakeholder Involvement

4. DISCUSSION

Phayao lake is one of the most important freshwater lakes in Thailand. It is an attractive site for researchers to conduct their research. However, most of the research results have been ignored in policy making and development planning processes. In this work, we have brought diverse groups of stakeholder participated from the beginning so a good cooperation was received. Due to the complexity and uncertainty of lake environmental problems, reliable scientific and research information is needed to inform stakeholder deliberation. This has been identified as an essential ingredient in any participatory

process[5]. The knowledge and perceptions of local communities regarding to the critical problems of the lake, technical and political situation of the lake management, possible research strategies ensuring positive change towards the sustainability of the lake should be integrated for pointing out the lake development goal. The research processes can be used as a tool for encouraging stakeholder participation in lake management. A combination of local and scientific may empower local communities to monitor and manage environmental change easily and accurately[6]. Participatory processes should lead to higher quality decisions, as they can be based on more complete information[7]. From this study the results revealed that local communities were aware of the lake's problems and contribution of the participatory approaches to lake management. Also, collaboration between the communities, public and academic institutions was accepted as key to successful lake management[8]. There are a large number of researchers and government agencies working on the Phayao lake issues. Although numerous government organizations have public participation included in their agendas their actions often focus on public relations efforts to gain citizen approval on specific projects rather than incorporating citizens into the decision-making process.

5. CONCLUSION

In order to design more effective and appropriate participatory processes, further research is needed to better understand and prioritize the factors that make stakeholder participation lead to stronger and more durable decisions in different contexts. It can be suggested from this study that to restore and solve the problems of Phayao lake, the integrated management from upstream to downstream should be adopted. The important issues should be prioritized for the efficiency of problem solving and achievement of the substantial outcomes. Participatory approaches using research methodology can improve policy-making processes by providing a role for reasoned and transparent dialogue between interested parties. In turn, successful participation promotes active citizenship, greater social capital and increased trust in political decisions.

ACKNOWLEDGEMENT

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O8-9

Implementation and Evaluation of the "Tirta Budaya Situ" Water Culture Program Established for Urban Lakes Within the Jakarta Metropolitan Area

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Keywords: citizen participation, community revitalization, awareness, get-close-to-water activities, culture

ABSTRACT

A water culture program titled "Tirta Budaya Situ" was implemented in and around several urban lakes (*situ*) within the Jakarta metropolitan area (*Jabodetabek*). The program encouraged communities situated nearby to urban lakes to hold activities for maintaining the lakes by launching cultural or sports events in which direct involvement with the lakes and their surrounding land were practiced. The hypothesis is that community activities taking place near the lakes will increase people's awareness of the lakes' healthy ecosystems and functions. If communities need an urban lake in their area, they will maintain the urban lake. The implementation was conducted at Situ Rawa Badung in East Jakarta, Situ Bojongsari in Depok, Situ Binong in Bekasi, Situ Bungur in Tangerang Selatan, and Situ Gintung in Tangerang amongst others. "Tirta Budaya Situ" supported the community in striving toward a better environment and has thus far added more greenery to the land surrounding the lake by planting trees. Community activities such as cleaning the surrounding lake, cultural festivals, and sport events were supported by us behind the program by, for example, helping communities find sponsorships for such events. After several years of implementation, we drew up an evaluation of how the "Tirta Budaya Situ" program managed to support community activities and strengthen the relationship between community activities and the maintenance of urban lakes. The results demonstrated that, for certain lakes, the more community activities taking place around them, the more the lake is likely to be well maintained.

1. INTRODUCTION

Urban lakes (called *situ* and *waduk* in Bahasa, *tameike* in Japanese), which are natural or man-made lakes, in the Jakarta Metropolitan area (*Jabodetabek*) have played important roles in irrigation, flood control and groundwater storage for a long time. Urban lakes in Jakarta Megacity are in severe condition due to unplanned rapid economic development, unplanned urbanization, no proper land use/zoning planning, illegal occupancy and pollution. Many problems such as land conversion, sedimentation, domestic & industrial waste/wastewater pollution, and eutrophication have appeared. Urban lakes filled with untreated sewage and solid waste are perhaps the most visible problems, with waste from households and factories being dumped into urban lakes, leading to their contamination. Also of note is the total abandonment of some urban lakes, which generally leads to an excessive weed growth taking place on the water's surface. Every year, flooding occurs, with the water level having reached up to four meters in 2002, 2004, and 2008.

In order to improve the quality of life of the *Jabodetabek* residents, it is urgent to enhance the functions and ecosystems of urban lakes and their surroundings.

"Tirta Budaya Situ" is a program for the community-based management of urban lakes in *Jabodetabek*. The involvement of local people is promoted by the program, with the intended outcome being the increase in benefits and services to local people. After several years of implementation, we drew up an evaluation of how the "Tirta Budaya Situ" program managed to support community activities and strengthen the relationship between community activities and the maintenance of urban lakes.

2. METHOD

In this research we evaluated the urban lake condition before and after the implementation of "Tirta Budaya Situ". The examined urban lakes fell within eight types of urban ecosystems within *Jabodetabek* as described by Henny and Meutia (2014) [1]. Several urban lakes were selected as representative of their wider location (Table. 1). All data obtained was analyzed using the Cobweb chart evaluation method. A detailed interview with local residents was conducted for each lake. Pictorial questionnaire sheets were also used for the identification of both fauna and flora

within the urban lakes and their surrounding environment. The hypothesis is that community activities taking place near the lakes will increase people's awareness of the lakes' healthy ecosystems. If communities need an urban lake in their area, they will maintain the urban lake.

Table 1 Location of Urban Lake

No.	Name of *situ*	Location	Area (ha)
1	Rawa Badung	East Jakarta	3.80
2	Babakan	South Jakarta	32.00
3	Binong	Bekasi	13.98
4	Bungur	South Tangerang	3.00
5	Gintung	Tangerang	21.40
6	Bojongsari	Depok	28.25
7	Baru	Depok	2.00
8	Tonjong	Bogor	14.44

3. RESULTS

Before the implementation of "Tirta Budaya Situ", Situ Rawa Badung in East Jakarta was in very poor condition with all aspects considered (Fig.1) while Situ Baru in Depok City was in better condition in terms of water quality, biodiversity, and waterside condition. Situ Bojongsari in Bogor City proved itself to have good water quality, biodiversity and hosted beneficial human activity, although other aspects were very poor (Fig. 2).



Fig. 1 Cobweb results of Situ Rawa Badung.

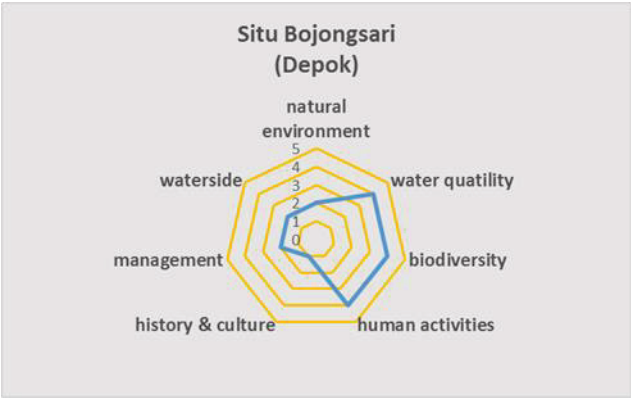

Fig. 2 Cobweb results of Situ Bojongsari.

Situ Babakan in South Jakarta scored excellently for the maintenance of history, culture and human activities, although other aspects such as water quality and biodiversity were poor. Meanwhile, water quality and management scored well. Management of Situ Babakan is conducted by a foundation set up by the local government. Situ Gintung in South Tangerang boasted high human activity but other aspects were not as satisfactory and the management was insufficient, although the lake is managed by the central government under BBWS. The management is organized according to a top-down system and allows for less than adequate community involvement. Situ Binong in Bekasi Regency scored the highest points within the following five criteria: natural environment, waterside, management, history & culture, and human activities. Meanwhile the criteria of water quality and biodiversity were good. Situ Binong is managed well by the local community surrounding the urban lake. Situ Tonjong, which the local government within the Bogor Regency attempts to manage, has good natural environment conditions, although community activities are considerably less strong. The result demonstrated that central/local government activity alone does not guarantee the high quality condition of such lakes, and that the commitment of the local community is required for sufficient practices of management overall.

The "Tirta Budaya Situ" program supported the urban lake and community in striving toward a better environment by planting trees, made links with private sector to find sponsorships through CSR and gave an environmental training to increase people awareness. The evaluation results after the "Tirta Budaya Situ" program was implemented showed that in Situ Rawa Badung almost all aspects improved except water quality which remained in the same condition (Fig. 3). Various events were conducted by the community such as fishing competition, tree planting around the *Situ*, a bazar, and hydroponic training amongst other events. The local government supported the community in their management of the *Situ*.



Fig. 3 Situ Rawa Badung after "Tirta Budaya Situ".

Figure 4 showed that in Situ Bojongsari, human activity, management and natural environment conditions were slightly improved. The community held a cleaning event

called *Gemes* that proved to be a short-term means for community movement in cleaning up garbage in the *Situ,* as well as the weeds that cover its surface. Although local government provided insufficient effort in supporting community activities.

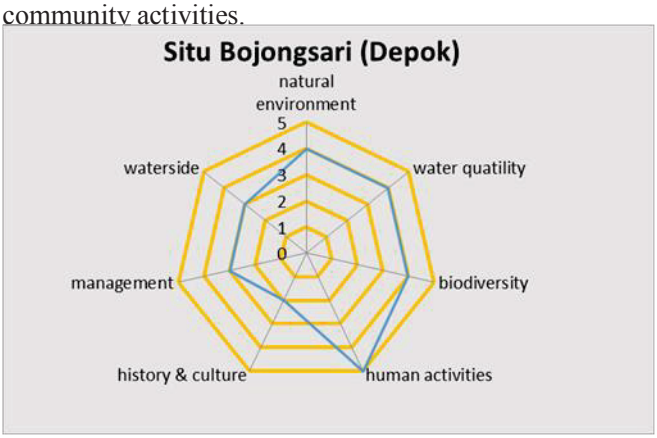

Fig. 4 Situ Bojongsari after "Tirta Budaya Situ".

Table 2 show the activities of several urban lakes. The Table show that few urban lakes host cultural events and almost all urban lakes are used for fishing activity. Situ Babakan is located within a Betawi cultural preservation area, so many events surrounding the lake are related to Betawi culture. Situ Bungur is similarly characterized by Betawi culture as the surrounding area is home to Betawi residents. Situ Binong preserves Sundanese culture by holding an annual event called *Sedekah Bumi*. In the case of Situ Rawa Badung, the community can push the local government to assist in the management of their urban lake by policing illegal occupancies around the urban lake.

Table 2 Community Activities at Urban Lake

No.	Name	Cultural Event	Sport Event
1	Rawa Badung	none	fishing
2	Babakan	Betawi culture	fishing, boating, martial art
3	Binong	Sundanese culture	fishing, cycling
4	Bungur	Betawi culture	fishing, rowing
5	Gintung	none	fishing
6	Bojong Sari	none	fishing
7	Baru	none	fishing
8	Tonjong	none	fishing

4. DISCUSSION

Urban lakes within the greater Jakarta area have lost their primary function as irrigation for rice fields. In their current condition, many urban lakes in Jakarta are incapable of supporting their intended functions to prevent flooding, provide water sources for drinking water, as well as their capacity to act as water purification sites. We found there were slight changes in the role and involvement of the community due to the increase in the awareness of people regarding the functions of the urban lakes due to recent flooding, but still this level of consciousness was insufficient. The participation of local people is essential considering the failings of government regulations and policies.

"Tirta Budaya Situ" encourages the participation of local people to increase their awareness of urban lake maintenance via a forum established in 2015 for the communities around urban lakes within the *Jabodetabek* area called "Forum Persahabatan Situ-Situ Jabodetabek". The forum allows communities to network and learn from other community's experiences in how to conduct regular activities prior to the holding of events such as folklore festivals, fishing contest or sports events amongst others.

A discussion of two case studies can elucidate our research: Situ Rawa Badung in East Jakarta and Situ Bojongsari in Depok city. In the case of Situ Rawa Badung, after the "Tirta Budaya Situ" program was introduced to the community, it seemed that the community became more active and, as a result, the surroundings of the urban lake improved significantly. Before the "Tirta Budaya Situ" program was introduced in Situ Rawa Badung, the community surrounding the lake did not know how to deal with the urban lake. Although, they had good intentions for the lake, they lacked the know-how to realize them. After attending several meetings with the "Forum Persahabatan Situ-Situ Jabodetabek" with support from the program, the community of Situ Rawa Badung was inspired to contact the local government and asked them to support them in managing the *Situ*. The same outcome also occurred with Situ Bojongsari. However, the response of the local government differed.

5. CONCLUSION

We applied a new water program titled "Tirta Budaya Situ" for maintaining and protecting urban lakes within the *Jabodetabek* area. The idea promoted participation and collaboration amongst the local community, the private sector and local government. The results demonstrated that, for certain lakes, the more community activities taking place around them, the more the lake is likely to be well maintained.

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O8-10

The ways to increase environmental awareness of the Aral tragedy and its ecology today

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Keywords: awareness, curriculum development, nature conservation, collaboration, citizen participation

ABSTRACT

Today's current textbooks contribute to the development of future specialists, but while teaching any environmental problems, it is important for the trained, competent, qualified specialists to develop their vision of the use of the student's self-study. Therefore, the purpose of our research is to study and analyze a specific environmental problem from a scientific research point of view. At present, it is already recognized that it is impossible to restore the Aral Sea in the same state and size. Therefore, we can only talk about stabilizing and improving the already existing situation. Although the governments of Kazakhstan and Uzbekistan have already responded appropriately and implemented projects that have partially stabilized the situation in the Aral Sea area, but further concrete actions are still need to improve the complex environmental situation in the Aral Sea basin, taking into account socio-economic development. September 9-17, 2017 the teachers of the University of Tsukuba organized a joint expedition of Kazakh and Japanese scholars where they were acquainted with life, educational institutions and discussed conducting joint research works. Therefore, it is advisable to make specific decisions, if possible, use space data, unite states and international organizations dealing with this problem and positively resolve this issue, because today the tragedy of the Aral Sea is not only an internal problem of Central Asian countries and Kazakhstan.

1. INTRODUCTION

In the teaching of environmental problems, the reasons for its occurrence, based on concrete scientific and practical information, contributes to the training of future conscious and qualitative specialists. Today's current textbooks contribute to the development of future specialists, but while teaching any environmental problems, it is important for the trained, competent, qualified specialists to develop their vision of the use of the student's self-study. Therefore, *the purpose of this work* is to study and analyze a specific environmental problem from a scientific research point of view; it is possible to train competent specialists and access to improve its competence. Guided by these principles, we believe that the formation of the educational process will be able to solve many issues.

Based on this we can be said that the reason for the emergence of the "Aral tragedy" is politics in an effort to become an independent state of cotton in Central Asia. In addition, if we look at the basics, causes and consequences of the Syr Darya and Amu Darya rivers until 1991 and after Kazakhstan's independence, we can see that human makes the causes. Currently, 51 reservoirs and gas-power stations are built up to the Aral Sea, with 13 of them being along the Syr Darya River, and 38 of them are built [1] along the Amu Darya River. Currently, the state of the Aral Sea is divided into three stages. The first phase of today is from 1920 to 1965, the second stage is from 1966 to 1991, and the third stage is from 1992 to 2018, should be considered up to these days.

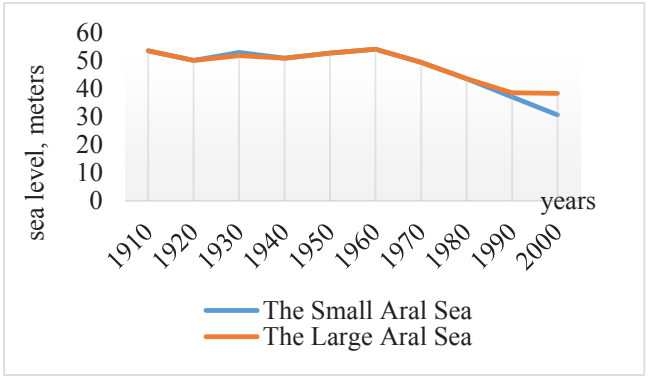

Fig. 1 Reducing the level of the Aral Sea in the XX century

Since the middle of the XIX century, for the development of the national economy, ponds and dams of the Syr Darya and Amu Darya have been divided into two reservoirs, such as the main arterial artery of the Aral Sea, without taking into account the possibility of nature. *In the first stage* (1920-1965), eight reservoirs were constructed in the Syr Darya River: two of them are located in Tajikistan (Kairankum, Kattasai), Kyrgyzstan (Ushkorgan), Uzbekistan (Toyabugas, Farhad, Karkidon, Kassansay), and in Kazakstan - Bogen Reservoir and in the river basin The Amudarya has a total of 15 large reservoirs, which are twice as large as the reservoir. *The second phase* (1966-1991) included 11 eleven reservoirs along the Syr Darya river basin, five in Kyrgyzstan, the other five in Uzbekistan, and one in Kazakhstan - Shardara reservoir, and nine large reservoirs along the Amu Darya River.

Analyzing this we see that 23 reservoirs were built at the first stage and at the second stage there were built

another 20 reservoirs with a capacity of not less than 23 reservoirs. Comparing these two stages - with each other the Aral Sea water decreased 2.5 times [3]. In fact, the Amu Darya river flow in the Aral Sea from 1920 to 1960 was about 4 times smaller than in 1990, and today the Amu Darya River does not pour into the Aral Sea [1]. The reservoirs and dams built on the Amu Darya and Syr Darya Rivers, the ponds, were three times as big as the river Amu Darya compared to the Syr Darya River, and the river was blocked.

Today, the well-known small Aral Sea is being restored. By the efforts of the Republic of Kazakhstan in 1999, the current Kokaral dam was built and it is known that it was washed away with water. In 2005, with the support of the World Bank along the "Aklak" hydrosystem with a length of 13 km, the North Aral hydroelectric power station was built along the Kokaral River, so the small Aral Sea appeared, this complex was launched in 2005 in August 7, at 20.47, the water began to fill, and in 2006 on February 2, the water level reached a 39 meter unit in six months, but it had to be filled within 36 months.



Fig. 2 The level of the Aral Sea in the 2018 y.

2. METHOD

Let us look at the question of the current state of the Large Aral Sea. The Great Aral Sea is divided into two parts: the West and the East Sea; its water is strongly salted and mineralized from 130 to 350 g/l. Until 2008, there was a channel with a hydraulic link with a depth of 7 meters, i.e. it flows along the eastern sea to the West Sea together with bottom sediments. Therefore, we need to study the eastern and western parts of the Greater Aral Sea, and consider that it is necessary to supply water to the West via a dedicated channel to the east or to the west.

In general, the results of a study of the radiological state of the Syr Darya-Aral basin that have been conducted since 2008, teaching environmental problems such as the tragedy in the Aral Sea in higher education institutions or conducting research can be trained by competent specialists. Sampling and research are conducted in accordance with the norms of the Republic of Kazakhstan. The results of these studies can be summarized as follows. The water of the investigated basin is shown in the contamination of rivers with radioactive nuclides, especially in settlements near the uranium industry, whereas α-activity is twice as high as the lowest (minimum) by 250 times. (The reason for this is the impact of uranium mining by underground leaching). In 2000 transitions in transboundary waters of the Republic of Kazakhstan, where α-activity was 2 times higher, and in 2016 river water in Shardara reservoir increased from 2 to 5.45 times, and these radionuclides can accumulate in the Shardara reservoir [2].

Anthropogenic polluting radionuclides in the waters of the Syr Darya River in the spring of 2003 increased by 5-6 times in Aman-Koy and Bogen settlements near the Aral Sea, whereas in 2017 α-activity in the Aral Sea increased 8-fold, i.e. the concentration of radionuclide residues in the river water accumulated in the Aral Sea [4].

3. RESULTS

So, we can say that a new life has begun for people of the local villages of northern Aral. The reason for this is that water has come to the suburbs. Thanks to the Kokaral dam, more than 20-30 lakes and ponds have appeared.

In the Aral Sea, there are 75 472 people (10.1% of the population) with a population of 1.4 people / m^2. Of these, 50.8% of men and 49.2% are women. There is a steady increase in the population in the Aral Sea area. Over the past 3 years, the region's population has grown by 4.5% or 3232 people. As of January 1, 2018, the number of pre-school institutions is 85 (including 1 kindergarten, 19 kindergartens, 9 private kindergartens, 19 full mini-centers, 37 half-day mini-centers).

Fish production was re-launched and fish farms emerged. In the processing of fish are 4 enterprises. More than 300 people work in 4 modern fish processing plants. The area of fishing, its processing is growing every year.

At present, it is already recognized that it is impossible to restore the Aral Sea in the same state and size. Therefore, we can only talk about stabilizing and improving the already existing situation. Although the governments of Kazakhstan and Uzbekistan have already acted appropriately and implemented projects that have partially stabilized the situation in the Aral Sea area, but further concrete actions are still needed to improve the complex environmental situation in the Aral Sea basin, taking into account socio-economic development. We research provides data on the dynamics of the processes in the bottom of the sea and the dry Aral Sea area changes, as well as socio-economic status of the residents of this region.

4. DISCUSSION

In general, we have drawn up a curriculum as well as a program course for schoolchildren, where the discipline "Ecology and sustainable development" is studied, the Aral Sea problem is considered as a special chapter and can be used to raise awareness of environmental education in all higher educational institutions of Kazakhstan.

Scientific research institutes (geography, geology, ecology, etc.) and scientists of universities in natural sciences and mathematics conduct scientific works on the basis of grants from universities, international INTAS and various foundation's on arbitrary and initiative topics about the situation in the Aral-Syrdarya basin, for example: every academic year in our university, under our leadership, 1-2 master's and diploma works are defended. The state is mainly focused on scientific topics on the applied and business-market economy. That is why they cannot be satisfied with the fact that drinking water has come to the Aral region, and the small Aral Sea is filled with water, international organizations together with the Central Asian countries should develop a plan and work towards development of the Aral Sea, including the Great Aral Sea. The reason is that today's small Aral Sea is only 6-10% of the former Aral Sea.

September 9-17, 2017 the teachers of the University of Tsukuba organized a joint expedition of Kazakh and Japanese scholars where they got acquainted with life, educational institutions and met with the students of the Aral region, they discussed the teaching of the Aral tragedy in secondary school and higher educational institutions, shared opinions and also discussed conducting joint research works.

5. CONCLUSION

Therefore, it is advisable to make specific decisions, if possible, use space data, unite states and international organizations dealing with this problem and positively resolve this issue, because today the tragedy of the Aral Sea is not only an internal problem of Central Asian countries and Kazakhstan, but also the environmental problem of the whole world, because it attracts the whole world. Currently, more than 60 million people, including Afghanistan, live in this region, about 4 million of them live in the Aral region. This is mainly residents of Karakalpakstan, Khorezm, Uzbekistan, Dashowuz district, Turkmenistan and Kazakhstan, Kazalinsk and Aral regions of Kyzylorda oblast and Aktyubinsk region.

At the same time, the ecology of the Aral Sea region will be improved if the following measures are implemented:

- it is very important that the mouth of the Amu Darya River be brought to the Aral Sea, for this it is necessary to open other jobs and provide financial assistance instead of water coming from Tajikistan and Uzbekistan.

- the location of military scientific grounds located on the islands of the "Vozhrozhdenie", "Barsakelmes" and "Lazarev" in 1991-1992, the detection of toxic burials of toxic substances buried in cemeteries with the help of state or international organizations (registers), and it is necessary to control it.

- it is necessary to develop a long-term program "Green Aral", growing on dry, relief lands plants and haloxylon plantations, adapted to growth in sandy and desert regions.

- at present, the Big Aral Sea takes 12-13 billion cubic meters of water a year, many of these waters evaporate becoming salty islands, exploring the Great Aral entirely, from the border of Kazakhstan and Uzbekistan, i.e. taking into account the geographic technical structure of the relief, by studying the East Sea of the Great Aral and growing haloxylon plantations, then gradually to completely turn the East Sea to the West Sea, it is necessary to build a second dam and hydraulic system, which is a very complex and expensive project, and this can extend to several kilometers.

- to work with universities and schools located in the local area (for example, in South Kazakhstan and Kyzylorda oblasts), establish partnerships, create joint projects and discuss their results at a special round table, symposium and conference - for environmentally sustainable development it is necessary to jointly conduct environmental research with the younger generation.

- The Aral Sea, which has now been restored from the present Aral Sea, is about 10-15% of the former Aral Sea and the current situation of the Great Aral Sea needs to be published in local, national and international media and scientific mass publications.

In conclusion, higher education institutions teach environmental problems not only through analysis, but also through practical and laboratory researches, and only then qualified specialists are trained.

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O8-11

Initiative by Maharashtra State Angling Association (MSAA) to conserve Powai Lake, Mumbai, India

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Keywords: Powai lake, conservation.

ABSTRACT

Powai lake situated 55 meters above the mean sea level (msl) is known as 'Anglers Paradise'. It is meant exclusively for angling and sports and is located about 27 Km away in the north-east of Mumbai city. This lake came into existence in the year 1891, when Mumbai Municipality got constructed a masonry dam of 10 meter height between two hillocks across Powai basin to conserve the rain water for drinking purpose, which later was commonly known as Powai lake, since it impounded in Powai area. Subsequently, the water in the lake was found unpotable because of indiscriminate use of the lake for various purposes by the local people and also due to discharge of domestic sewage from the surrounding localities. Initially this lake was open for the general utilization of the natives and is leased out to Maharashtra State Angling Association (MSAA), Mumbai - an NGO registered in 1955 under the Society's Registration Act 1860 for angling in addition to conservation

1. Introduction

Lakes and Ponds are one of the landscape features that significantly contribute to increase the quality of life in urban centres, by increasing amenity, providing recreational and educational activities and even contributing to migrate the urban climate (Martinez-Arroyo and Jauregui E, 2000). Moreover, the watershed of these ecosystems is part of the urban tissue and thus they tend to emphasize the environmental problems affecting the metropolitan areas, by collecting and accumulating large amount of nutrients and pollutants, including microbial contaminants. Toxic cynobacterial blooms, as well as bacterial contamination and heavy metal pollution, may significantly impair all the water users and represent a health risk for the urban populations, which may require costly management and restoration plans.

Powai Lake is situated in metropolitan city of Mumbai, the financial capital of India, and has total water spread area of 210 hectors. It is a man-made impoundment built in 1891. Powai lake (19^0 8' N and 72^0 54' E) situated 55 meters above the mean sea level (msl) is known as 'Anglers Paradise'. From the very beginning, its water was not meant for human consumption, nevertheless, even today, it is used by industrial areas including big industry like Larsen and Turbo and the lake apart from supporting recreational needs, is also a source of flourishing fishery. The immediate lake environment is well protected by Dr Babasaheb Ambedkar Udyan (Garden) and world famous Indian Institute of Technology on the eastern side. The lake is extensively used for washing & bathing activities and exhibits characteristics of a eutrophicated ecosystem. The Lake Powai has been the subject of intensive limnological and fishery studies over the past few years, being the site of one the oldest Angling Association in India (Established in 1939). The value of lake today lies in its being one of the most sought after recreational spot and lung spaces for the ever-growing population of the Mumbai city.

2. Issues and Problems in the Powai lake Basin

Water quality issues in Powai Lake can be summarized as follows:

1. The main factors responsible for degradation are heavy siltation, pollution due to anthropogenic activities and

reduction of lake spread due to encroachments.
2. Constantly recurring toxic cyanobacterial blooms in the summer
3. Nutrient enrichment from sewage.
4. Deforestation in the watershed.

3. **Awareness**

MSAA has invited people by organizing educational or recreational events. MSAA has connected local environmental NGOs, local governments and residents efficiently and its staff members work hard to keep their momentum in activities. There is no more effective, longer-term and preventative approach towards protecting the lakes than teaching children to value the very resources that they will need in the future. Children, who are inspired at an early age, will take small, but continual actions that will make the world a better place for the environment and the people. The children's enthusiasm in doing their voluntary work can even sometimes put an adult's lethargy and apathy to shame.

4. The objective of the Maharashtra State Angling Association

The objective of the association was angling as a sport. In 1991, realising the rapidly deteriorating environment and fast disappearing beauty spots in Mumbai, the Maharashtra State Angling Association Decided to amend its constitution and involve itself in environment work to preserve Powai Lake from the innumerable destructive influences working against it.

5. Environment work by MSAA

a) Removal of weeds like water hyacinths.
b) Introduction of fish fry (2 to 5 lacs every year)
c) Monthly water analysis by DR PRAMODH SALASKAR
d) Security and patrolling of Powai Lake 24 hours by MSAA to prevent stealing of fish and other malpractices.
e) Interaction with angling and environment bodies in India (MSAA have reciprocal membership with other associations in India).
f) Introduction and replenishment of the great Indian Mahaseer. Powai Lake is the home of the great Indian Mahaseer - a famous Indian fish which is facing extinction. MSAA have introduced this fish with the help of Tata Hydro, Walvan, Lonavla and are protecting its survival. Introduction of weavils to control aquatic weeds (work with R.R. Labs Hyderabad).
g) MSAA have also published a book called "Powai -the anglers paradise" to create public interest in Powal lake and MSAA activities.

6. Initiative by MSAA to preserve Powai Lake

Maharashtra State Angling Association (MSAA) was the first NGO to raise the issue of lake protection. It approached the State and Central Governments with a request to protect the lake. In response to representation of MSAA, in 2001 Ministry of Environment & Forests (MOEF), Government of India, New Delhi, included Powai Lake in the National Lake Conservation Mission (NLCM) with allocation of Rs. 26 Crores to the Bombay Municipal Corporation (BMC) for conservation and management of the lake.

7. Objectives of the National Lake Conservation plan

Main objectives under the programme would include the following:
* Prevention of pollution from point and non-point sources.
* Catchment area treatment.
* Desilting and weed control.
* Research & Development studies on floral and faunal activities and related ecological aspects.
* Other activities depending on the lake specific conditions such as integrated development approach, including interface with human populations.

8. Anglers as Environmentalists

Angling is internationally accepted as being an Environment friendly activity since it is intended to conserve aquatic life "It should be evident that the true Angler has a vital role to play in the conservation of sport fish and its habitat" (Dr. P.V. Dehadrai - Director of Fisheries ICAR, New Delhi). In all examples given in Dr. Dehadrai's paper it should be noted that the lead

in conservation of aquatic life has been given by the sporting angler. He further states that "unless immediate measures are taken to protect our great sport fish, MSAA will loose irretrievably one of our major sources of food supply and tourist attractions - The Mahseer. There seems to be active participation of Anglers Association/Clubs in all schemes undertaken by the authorities for the conservation of game fish from the outside. Sport fishing is a multibillion dollar industry and Angling as a sport has potential for not only attracting our own foreign tourist but, also for stepping into a highly lucrative international market engaged in the manufacture of fishing (angling) gear". MSAA at Powai introduce every year anywhere between 2 to 5 lac fish fingerlings. MSAA members catch about 5 to 6 thousand fish which are recorded and logged in our ledgers. The bulk of the fish are stolen by poachers but, fortunately many prize specimens still live at Powai because MSAA release back many of the fish which are caught as per Association Rules.

10. Conservation plan for Powai as recommended by MSAA

a) Angling
b) Fish Breeding Farm to cater to interior Maharashtra fisheries as well as Powai Lake.
c) Picnic Site with Cabanas for Indian and Foreign tourist.
d) Nature Trek path
e) Boating in a selected area of the lake.

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O8-12

霞ヶ浦における放射能汚染への私たちの対応

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NPO 法人霞ヶ浦アカデミー

キーワード: 市民参加、放射能汚染、東日本大震災、漁業被害、常陸川水門、

抄録

2011.3.11 の東日本大震災時の福島第一原子力発電所の爆発により、霞ヶ浦も放射能汚染に見舞われた。私たちは、霞ヶ浦の魚類と漁業への影響を観察および実験、底泥および魚類の放射性セシウムを測定し汚染状況を判断した。魚類の放射性セシウムが基準値(50Bq/kg)を下回るのには 1～5 年を要した。堆積物中の放射性セシウムの減衰速度が小さいと考え、下流常陸川水門の管理放射性セシウ排出速度を水理額的に試算、対策案として公開の場で提案し、議論したが、下流や沿岸域への影響に配慮して受け入れられなかった。本報告で、この経緯につて報告する。

1. はじめに

東北地方太平洋沖地震は湖岸堤の損傷や海水の湖内への浸入等によって様々な被害をもたらしたが、常陸川水門の倒壊や越波は免れた。しかし福島原子力発電所の爆発による霞ヶ浦への放射性物質は漁業に大きな被害をもたらした。私たちは魚類の観察と実験、堆積物および魚類の放射性セシウムを測定し、問題解決策案を策定、公開の場で提案、議論した。

2. 方法

(1) フナ類卵のふ化率および生残率

2011 年 4 月 17 日に霞ヶ浦湖岸に生みつけられたギンブナの卵 1000 個体を室内の水槽に収容、ふ化率と 1 年後の生残率を 2 つの水槽で実地した。

(2) 魚類の異常形態観察

2011年4月から2012年12月の間に毎月一回定置網で漁獲された採集魚を観察し異常がないかを観察した。

(3) 放射性セシウムの測定

堆積物はエクマンバージ〈20x20 ㎝〉で採取し乾燥させた試料につてでセシウム 134,137 を測定した。

魚類については、三枚におろした試料を直接ゲルマニウム半導体検出器で測定した。

3. 結果

(1) ギンブナのふ化率および1年後生残率

ギンブナのふ化率、生残率は表1のおとりであった。このふ化率は、当地区の養殖池でのゲンゴロウブナのふ化率や生残率と遜色ないもので放射能汚染が魚類のふ化や生産には影響を及ぼさなかったものと判断した。

表 1 ギンブナのふ化率と 1 年後生残率

No.	ふ化率 (%)	生産率 (%)
1	68.2	22.5
2	72.6	26.8

2011 年 4 月～2012 年4月

(2)魚類の形態的異常

アメリカナマズ、フナ類、ワカサギ、ハゼ類、モツゴの形態〈体表、背びれ等〉的特徴を1年8ヶ月にわたって観察したところ 2011 年 4 月から 2012 年までの期間には異常は確認されなかったが、2012 年 4 月から 2012 年 6 月までの期間に定置網で漁獲されたアメリカナマズ 56 尾中 25 尾の体表にアナアキ病状の症状が認められた。これが放射能汚染と関係あるかどうかについては確認できなかった。

(3)魚類の放射性セシウム(134＋137)含有量

図1にワカサギとアメリカナマズの放射性セシウム含有量の推移を図示した。ワカサギでは約 1 年前後で基準値(50Bq/kg)を下回る程度に減衰した。しかし、アメリカナマズでは 6 年を経過してもなお基準値前後で推移しており、アメリカナマズについては、なお、漁獲規制が解除されていない。なお、ウナギについて2016年2月に規制が解除されている。

(4)湖内堆積物中の放射性セシウム

湖内堆積物の放射性セシウムの分布を図2に図示した。

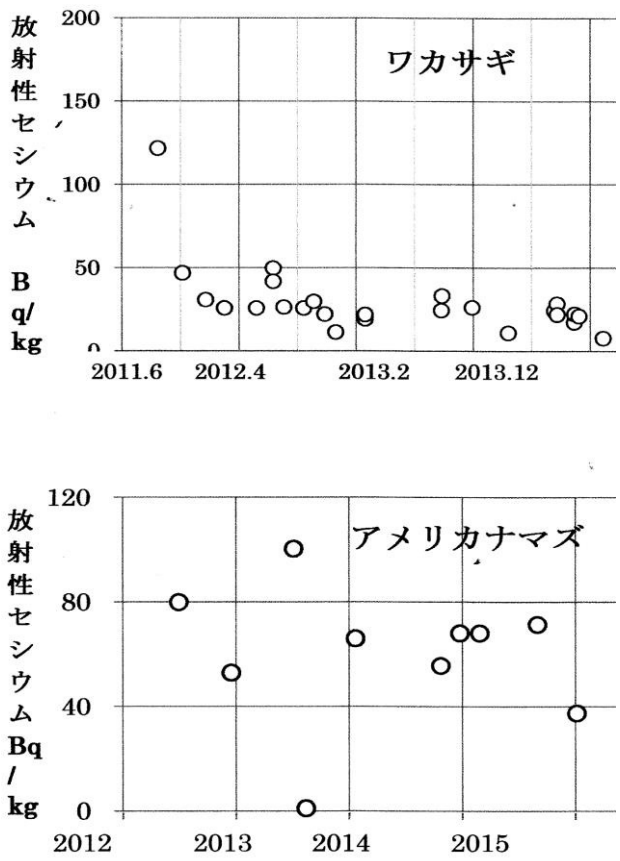

図１　魚体の放射性セシウム含有量（Bq/kg）

図は土浦港を起点をとした放射性セシウムの水平分布を示したもので 2012 年 9 月には土浦入中心部で 900Bq/kg であるが、湖尻（麻生沖）に向って減衰している。一年後の2013年9月の調査では土浦入中心部では約 70%に低減しているが、湖尻では逆に上昇した。

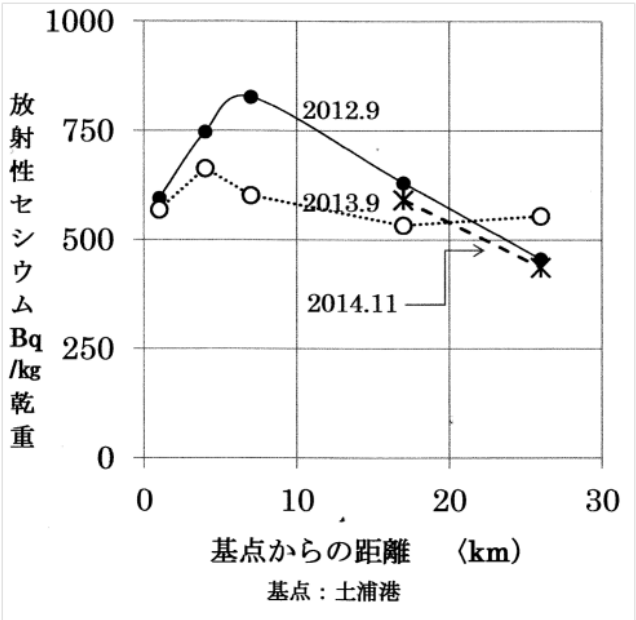

図２　堆積物中の放射性セシウム（134＋137）

湖奥側から湖尻側へ移動したおのと見られた。事故から3年8ヶ月後の調査でも湖心から湖尻付近では依然として 500Bq/kg 前後で減衰は大きくは進んでいなかった。

鉛直分布

霞ヶ浦（霞ヶ浦大橋下流 500m 地点）の堆積物の鉛直方向の分布をみたのが図3である。

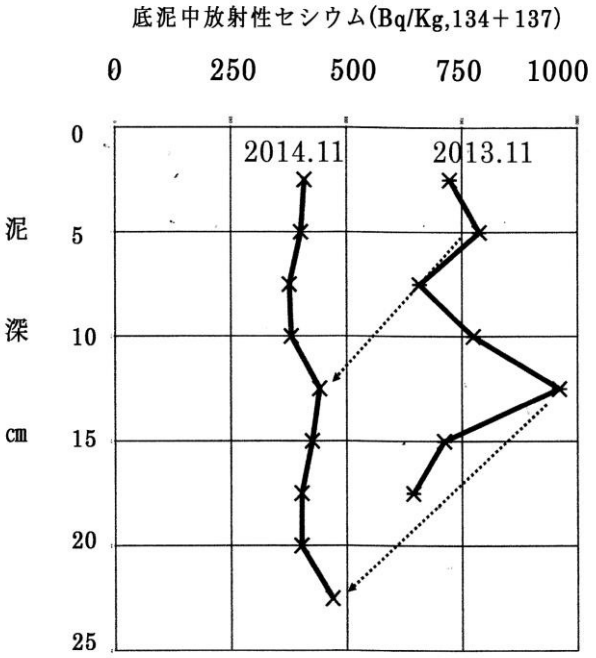

図３　堆積物中の放射性セシウムの鉛直分布

2013 年には 750Bq 程度の値で特に泥深 12.5cm 層にピークがあるが、1年後には全体に値が小さくなり、半減している。ピークは 22.5cm の深度にあるようで鉛直方向へ拡散したのではないかと考えられた。

図中に点線で示したようにＩ年間で鉛直方向にピークが 5～10 ㎝移動しているようである。

4　考察および事態への対処

(1) 汚染状態の判断

環境省の観測値（湖水）から上水への影響はないものと判断し魚類および漁業被害に焦点を絞った。堆積物中の分析値から湖奥から湖尻への水平移動が小さく湖内への蓄積が進むのではないかと考えた。しかし、鉛直方向への拡散速度が大きいようで湖底泥表層の濃度は高くはならなかった。

一方、魚体の含有量は、アメリカナマズとギンブナで高値が維持されていたので漁業被害を軽減するためには湖内に蓄積した放射性セシウムを常陸川水門操作で下

流へ流出させる対策案を検討することとした。

(2) 対策案の策定

対策案　常陸川水門操作による放射性物質排出

湖内堆積物を漁業者のトロール漁船で湖底表層を撹拌懸濁させ放射性物質懸濁状態で大潮時 6 日間、全８門２m の開放で排出 する。

予測式

堆積物中の放射性物質の濃度を Y, 湖内からの排出水量を Q, 大潮時の水門操作回数(6 日/回)を X、懸濁した放射性物質が完全混合状態にあると仮定すると放射性物質の濃度変化は次式となる。ただし、k は放射性物質の懸濁率である。

$$V.dY/dt = -k.Q.Y$$

積分して

$$Y = Y_0 \exp(-k.Q.X/V) \qquad (1)$$

を得る。

放流水量の推定

一般に水門からの流出量は下流水位が低い場合の自由流出と高い場合の潜り流出分けられるが常陸川水門の場合には後者の例と考え Henry の公式を適応する。

湖の水位変換につては、

$$(Qi_t - Qo_t)\ \Delta t/F = H_{t+\Delta t} - H_t$$

放流水量については

$$Q = CaB\sqrt{2gh_0} \qquad (2)$$

を用いる。ただし、Q 、C、a、B、gおよびh_0 は、それぞれ放流水量、流量係数、水門開度(m)、水門の幅員、重力加速度 9.8m/s^2 および水門上流側水深である。ここで C として a/h_i および a/h_0の条件から 0.15 を用いた。水門諸元は全通水幅 228m(28.5m×8 門)、水門の敷高 -3.35m とした。

常陸川水門操作による放流水量と湖水の変動量を表２に示した。厳密には、流域からの流入等を考慮しなければんらないが、短期的には、放流水量と湖内の放射性物質の懸濁状態から上式から湖内の放射性物質の相対値の変化を予測できる。ここでは水門開門 2.0m の相対値の変化を図４に図示した。

表２　常陸川水門操作による放流量予測（大潮 6 日合計）

水位	フラッシュ流量（10^8m^3）			湖水位低下量Δh（m）		
YPm	a:1.0	a:2.0	a:3.0	a:1.0	a:2.0	a:3.0
1.07	1.078	2.156	3.236	0.49	0.98	1.47
1.30	1.104	2.210	3.312	0.50	1.00	1.51
1.50	1.128	2.257	3.385	0.51	1.03	1.54
1.80	1.163	2.326	3.488	0.53	1.06	1.59

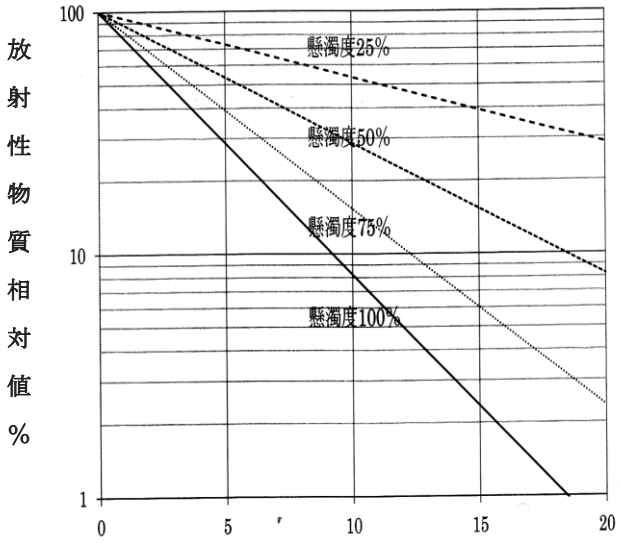

図４　常陸川洲門を大潮時に 6 日間開放した場合の操作回数と放射性物質相対値の関係
懸濁状態は、人為的撹拌も考慮する.

懸濁状態 50%の場合、10 回の大潮、したがって約半年で 30%、1 年で 10%以下にまで低減させることができると推定される。

5 結論

2回の公開討論会ではいずれも下流域や沿岸水域の汚染を引き起こすことになるという理由で合意を得ることはできなかった。今回の事故では放射能汚染は直ちに人命にかかわるまでにはいたらなかったが、そうした事態にどうのように対処すべきか。また、常陸川が倒壊、あるいは海水が越波する危険性もあった[2]。霞ヶ浦は汽水湖を上水水源した唯一の例でこの点でも再検討が迫られる。新しい時代に相応しい水資源開発管理と生物多様性保全をめざすシステム構築について議論を深めたい。

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[2] 浜田篤信 2012.大震災を踏まえた霞ヶ浦共生論. 霞ヶ浦研究会報 15:88-89.

O8-13

地域の中小企業連携で進める小規模都市河川での生物多様性保全の取り組み

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中井克樹[4]　　宮城成和[5]

キーワード：生物多様性、中小企業連携、小規模都市河川

抄録

滋賀経済同友会に加盟する湖南地域の企業を中心とした 17 社は、「湖南企業いきもの応援団」を組織し、各企業の特性を生かした業務・活動の一環として、地元の「狼川」をフィールドとした生物・環境調査を 2010 年度から年4回の頻度で開始した。調査の内容は、河川の魚を中心とした生き物と水質で、調査に持続性を持たせるため、特に①参画のしやすさ、②環境調査・社員教育としての質の高さ、③学術的に正確なデータの取得の3点を考慮して、滋賀県と草津市と連携しながら継続している。地域の中小企業が始めたこの活動は、河川周辺地域の学校の環境学習の支援や、地域のまちづくりへの協力という形で、身近な環境保全を通じて地域をつなげる展開になってきている。

1. はじめに

滋賀経済同友会では 2009 年に発表した「琵琶湖イニシアティブ～生物多様性の恵み豊かな社会を未来に引き継ぐために～」で、滋賀の経済人として「企業は持続可能な経済活動」「地域の自然再生への貢献」を両輪とした活動の展開を宣言し、経営者自らが活動の先頭に活動することとした。この取り組みに賛同した湖南地域の企業 17 社は、「湖南企業いきもの応援団」を組織し、各企業の特性を生かした業務・活動の一環として、地元の身近な河川である「狼川」をフィールドとした生物・環境調査を、2010 年度から開始し、市や県の環境施策に貢献するとともに、近年は小学校や自治会などを通じて地域をつなぐ活動へと展開している。

2. 方法

狼川は草津市内を流れ琵琶湖に流入する、里山、工業地域、住宅地、市街地を流れる総延長約 7km の小規模な都市河川である。調査場所は、流入支流や用途地域を考慮して、河川の上流から下流まで 6 ポイントを選定した。なお、最下流のポイント 6 は、1980 年代に草津市環境課の生活排水対策の調査ポイントの近傍に設置した。各ポイントでは、水中の生き物（魚・大型底生動物）のタモ網とモンドリによる捕獲、目視による流量、透視度の記録と、パックテストによる pH、COD、リン酸イオン、亜硝酸性窒素の簡易測定を行った。透視度は独自に作成した透視度計を用いた。調査時間は比較的河川の水質が安定する 13:30 から 15:00 とした。生き物の同定は滋賀県（琵琶湖博物館）の専門家が確認し、水質調査は草津市の行政担当者が指導した。この調査は、2010 年度から年4回の頻度で開始し、2017 年度末現在で調査回数は 32 回となった。

3. 結果

1）確認した生き物

8 年に渡る 32 回の調査で確認された生き物の種数を分類群ごとに表 1 に示す。魚類ではカワムツとヌマムツの同属 2 種が優占種で流程に沿った分布傾向に差が見られた。他に、フナ類、オイカワ、ドンコ、オウミヨシノボリ等がよく見られ、稀にミナミメダカやウツセミカジカも確認された。昆虫類では大型で発見しやすいこともあり、トンボ類の幼虫が 11 種以上確認されたのが特筆され、特にハグロトンボは上流から下流まで最優占種であった。

表1　確認生き物の種類

分類群	確認種数	うち外来種数
魚類	14 種	2 種
両生・爬虫類	5 種	2 種
昆虫類	30 種以上 （トンボ類 11 種以上）	0 種
貝類	9 種	3 種
甲殻類等	6 種	3 種

調査では外来種も確認され、特に甲殻類ではアメリカザリガニに加えて、カワリヌマエビ属の一種とフロリダマミズヨコエビ（2014 年に県の指定外来種に追加指定）は、調査期間中に増加傾向が確認された。カワリヌマエビ属の一種は在来種のスジエビと置き換わる勢いで激増し、フロリダマミズヨコエビは 2012 年に初確認された後、継続的に確認されている。特定外来生物のオオクチバスは最下流のポイント 6 だけでなく上流側のポイント 5 まで確認区域が拡大し、ポイント 4 との間にある落差工までは生息域を拡げるものと予想される。

2)水質

調査結果からは、ポイント3の手前で流入している支流からの流入負荷が大きく影響していることがわかった。草津市による水質測定は毎月行われているが、ポイント6の近傍に限られ、本調査の年4回の調査は、河川の流域全体での健全性の確認に役立っている。

本調査による各調査ポイントにおける水質測定の結果を図2に、草津市によるポイント6における過去の測定結果を図3に示した。

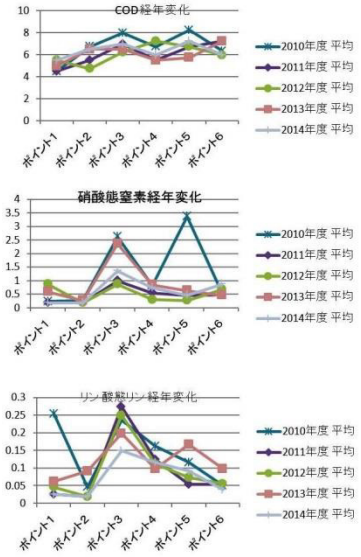


図1. 各調査地点における水質調査結果.

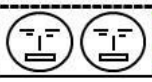
年度	2001	2011	2012	2013
BOD 単位(mg/L)	C(3.2)	B(2.1)	B(2.1)	A(1.6)
T-N 単位(mg/L)	C(2.8)	C(1.6)	C(1.2)	C(1.6)
T-P 単位(mg/L)	C(.24)	C(.21)	C(.13)	C(.12)
顔による評価				

図2. ポイント6における水質データ(草津市調査).

3)参加企業の従業員の意識の変化

参加企業は調査開始当初の11社から17社に増え、毎回12社程度から約30名の参加者がある。参加者の意識は、当初は「なぜこんなことをしなければならないのか、企業として儲からない」など否定的な意見が多かったが、回数を重ねるに従い、身近な河川環境や生物多様性の重要性が認識されるようになり、CSR 意識も高まってきた。

4) 地域貢献の広がり

調査で採集した生き物については、毎回、ポイント4に持ち寄って同定を行っているが、小学生の下校時と重なる時間帯のため小学生が集まってくるが、我々より魚に詳しい子供がいることもある。また、地域の大人からも「こんなに魚がいるの？」「一緒に捕まえたい」などの声が聴けたため、夏休みに地元小学校による「狼川学習」を地域の方々を対象として実施するようになっている。また、校内には「狼川水族館」と題した水槽群が設置され、子供たちが面倒を見ている。先日も、ハグロトンボが幼虫から羽化して学校の中を飛び回ったという。また、地元自治会による地域のふれあい祭りには、応援団がブース展示して狼川で採集した生き物を展示し、企業と地域の方々との連携を進めている。

4 考察

応援団を構成する中小企業は、かつては排水を狼川へ流し、それが琵琶湖へと流れ込んでいたが、工業排水の規制が強化され、排水の流れ込みは止まった。しかし、一方で、河川環境は企業にとっても近くに存在しながら縁遠いものになってしまっていた。

異業種の中小企業が連携して、身近な都市河川を調査する応援団の調査活動は、滋賀県経済同友会の「いきものイニシアティブ」宣言に呼応する形で、地域の企業が調査を始めてみたことがきっかけであった。そして、せっかく企業が社員を職務として派遣して活動を行うからには、活動内容を有意義なものとし、単発的なものでは終わらさないよう、取り組みが進められることになったが、結果として、調査は年4回の実施頻度を保ちながら、すでに8年もの間が継続している。

調査の結果としては、まず、小規模な都市河川にもさまざまな生き物が生息していることが明らかとなり、調査自体に「楽しみ」をもたらしてくれた。また、新たな外来種の発見は滋賀県の外来種対策を後押しすることにもなり、水質調査の結果は草津市による環境調査を補完するものとなっている。さらに、調査活動の経験と成果を携えて、地元の小学校の環境学習の支援や自治会の活動への協力など、地域の方々と共にまちづくりにも寄与する活動として広がりをみせている。

保全上価値の高い絶滅危惧種はほとんど見つけることはできない小規模な都市河川にも、さまざまな生き物たちの暮らしやその変化がある。**「ないものねだりより、あるものさがし」**の大切さを認識し、身近な自然を「地域の宝物」として将来に引き継いでいくことこそが、私たちに課せられた重要課題であると考えている。

参考資料

湖南企業いきもの応援団報告書 vol.1～3.

＊1 湖南企業いきもの応援団 初代団長
＊2 湖南企業いきもの応援団 前団長
＊3 湖南企業いきもの応援団 現団長
＊4 滋賀県立琵琶湖博物館(連携団体) 専門学芸員
＊5 草津市役所(連携団体) 元職員・現個人会員

O8-14

びわ湖の環境問題の歩みと次世代へのメッセージ

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[1]株式会社ヒロセ

キーワード:環境学習, 富栄養化

抄録

水道水源としての「びわ湖」の重要性について、幼少の頃から体験してきたこと、研究してきたことを、次世代に継承していく使命を持って活動を続けています。

高度経済成長期に、びわ湖の水質の悪化に対して周辺住民が立ち上がり、「粉せっけん運動」を住民主導で行政と折衝し、「琵琶湖富栄養化防止条例」の施行となりました。 その条例の検証結果を元にこの市民運動の意義を伝承しています。

その後に生じている、びわ湖の環境問題の現状と今後の課題について、次世代の市民・子供たち・研究者に理解してもらうと共に、多くの人たちがびわ湖の水道水源としての重要性に気付いて頂いて、びわ湖の水質保全に関わって頂けることを期待しています。

1. はじめに

琵琶湖・淀川流域の現状と今までに取り組まれた行政施策について述べると共に、次世代の研究者に琵琶湖をケーススタディーとして、取り組んでもらいたい研究課題について問題提起を行い、将来のあるべき水環境の姿について示唆したい。

1）琵琶湖淀川流域

琵琶湖・淀川流域は、滋賀県・三重県・京都府・奈良県・大阪府・兵庫県にまたがっており、水道水源として重要な役割を果たしています。

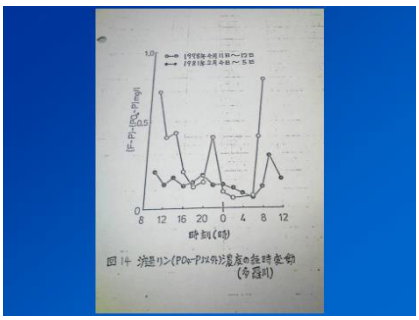


2. 高度経済成長期のびわ湖の現状

琵琶湖流域の人口増加に伴い、琵琶湖においては富栄養化が進行し、淡水赤潮等の問題が顕在化してきました。

そこで、滋賀県の主婦は、「琵琶湖を守るために、少し不便だが、リンの入ってない粉石鹸を使おう」という石鹸運動を始めました。この取り組みは窒素リンを規制する富栄養化防止条例を制定につながりました。このような取組は、県民と行政が一体となり、成果につながった最初の事例と考えられます。





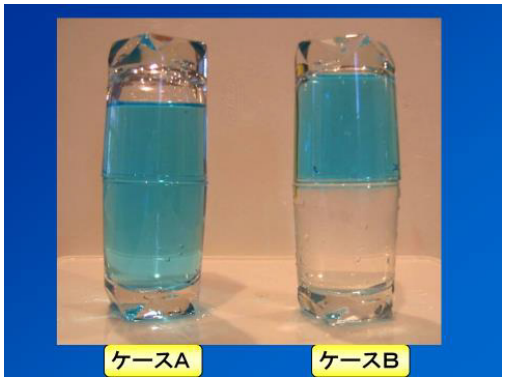
「琵琶湖富栄養化防止条例の効果の検証結果」

3. 現在のびわ湖の現状と今後の課題

1）地球温暖化による琵琶湖の鉛直循環（琵琶湖の深呼吸）への影響

琵琶湖では、春から秋にかけての成層期、秋から春にかけての循環期があり良好な水質が保持されています。2007 年の暖冬の年に、琵琶湖の深呼吸が遅れました。

今後、このような現象がしばしば起これば、琵琶湖の水質や生態系への多大な影響が考えられます。



琵琶湖の鉛直循環と成層（環境教育）

2）琵琶湖沿岸帯の生態系への影響並びに外来生物の琵琶湖固有種への影響

琵琶湖沿岸帯での外来水生植物大繁茂やブラックバス等の外来魚類の琵琶湖固有魚類への影響が問題となっています。



住民視線のびわ湖沿岸帯の第一印象

3）琵琶湖流域の地下水汚染・土壌汚染対策

琵琶湖集水域の地下水は、一部を除いてほとんどが琵琶湖に流入してきます。

県内のいくつかの市の水道水源は、地下水や河川伏流水を原水としているため、浄水処理に地下水汚染物質の除去工程を導入しています。

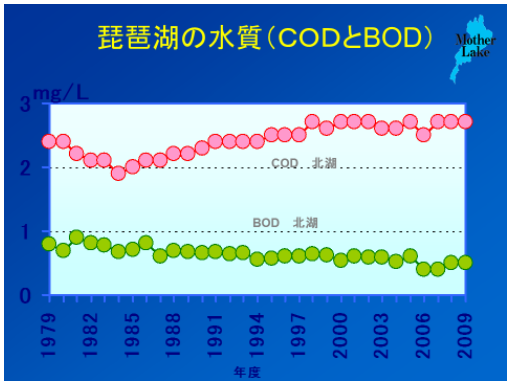
地下水汚染・土壌汚染は、面的な広がりを把握することは極めて困難であるため、対応策が遅れており、今後の調査研究・対応施策が望まれます。



琵琶湖集水域の土壌汚染・地下水汚染

4）ＣＯＤとＢＯＤの乖離現象

琵琶湖では、1984 年以降、ＢＯＤが低下してＣＯＤが増加する乖離現象が続いており、　この現象は琵琶湖水中の難分解性有機物の蓄積が考えられ、ＣＯＤの増加の原因について研究が行われてきています。



ＣＯＤとＢＯＤの乖離

4. 取り戻そう碧いびわ湖

最後に、これからの次世代の研究者への質問です。

今の琵琶湖の水をそのままで飲めると想う人！！！

答えは、飲めます！　ただし現在は、琵琶湖北湖の水深の深い所に限られます。

夏でも､8℃くらいの冷たくて美味しい琵琶湖水

が頂けます。

琵琶湖を心より愛して研究者する私たちへの「天使のおもてなし」ともいえる瞬間を湖上の上で堪能させて頂いています。

来たれ、次世代の研究者！

琵琶湖の未来は、これからの皆さんのハートに受け継がれるものと信じています！



家庭での湧水（伏流水）の有効利用



70 年前の琵琶湖（南湖）の水泳場

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O8-15

田村･沖宿･戸崎地区自然再生事業の取組について

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キーワード: 自然再生, 湖岸植生, 維持管理, 自然攪乱, 市民参加

抄録

霞ヶ浦田村･沖宿･戸崎地区自然再生事業は, 自然再生推進法に基づき実施している事業である。2004 年 10 月に協議会が設立されて以降, 2018 年 3 月までに 29 回の協議会を開催している。養浜やワンド, 消波施設などの自然再生施設整備が, 2017 年度に概成している。これらの施設や植生帯の保全等の維持管理を, 協議会として委員がどのようにして協働し活動していくかを議論しながら, 草刈り及びゴミ拾いなどの環境管理活動を年2回程度実施している。2016 年度には植生等の保全手法の1つとして火入れを行う管理方法について試験的に実施した。本報告では, 霞ヶ浦の湖岸植生帯の保全･再生の取組状況について報告する。

1. はじめに

霞ヶ浦[常陸利根川, 横利根川, 霞ヶ浦(西浦), 鰐川及び北浦の5河川の総称]は, 茨城県南東部の平地に位置し, 湖面積約 220km^2 と全国第二位の広さを有する, 平均水深約 4m の海跡湖である。霞ヶ浦の湖岸には, かつては抽水植物･浮葉植物･沈水植物に代表される湖岸植生帯が広く分布していた。しかし, 抽水植物は 1972 年に約 400ha あったものが 2011 年では約 120ha と大幅に減少し, 浮葉植物は同約 28ha あったものが 2011 年では約 3ha に減少, 沈水植物は同 750ha あったものが 1993 年以降は群落面積としてはほぼゼロとなっている(**図 1**)。

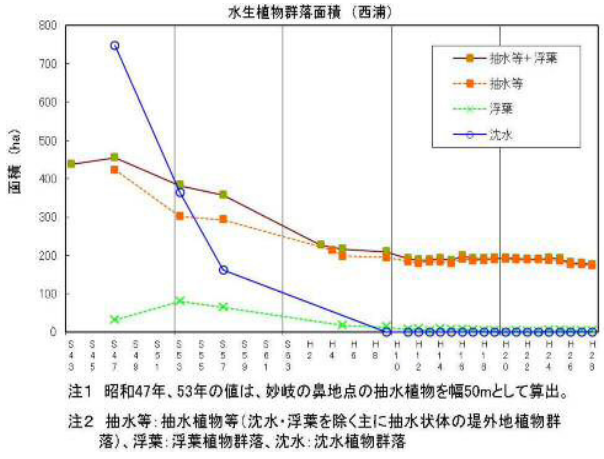

図1 霞ヶ浦湖岸の植生帯面積の変化

2. 湖岸植生帯の保全･再生の取組について

2.1 湖岸植生帯について

霞ヶ浦全体の湖岸植生の減退傾向を踏まえ, 多様な主体の参加や環境学習などでの活用が期待出来る湖岸として, 茨城県土浦市とかすみがうら市の霞ヶ浦湖岸沿いを事業対象地(**図 2**)として, 自然再生推進法に基づき湖岸環境の再生を図ることとした。2004 年 10 月に霞ヶ浦田村･沖宿･戸崎地区自然再生協議会が設立され, 2005 年度に策定された自然再生全体構想に基づき, 湖岸植生帯を含む湖岸環境の保全･再生に取り組んでいる。

協議会は, 学識者, 市民団体の代表者, 企業の代表者, 公募の個人, 市, 県関係部局の担当者等で構成され, 事務局が霞ヶ浦河川事務所となっている 。本地区においては, 現状の植生の状況等から9区間に分け(**図 3**), 養浜やワンド, 消波施設などの自然再生施設整備を実施し, 2017 年度に概成している。



図 2 事業対象地 位置図

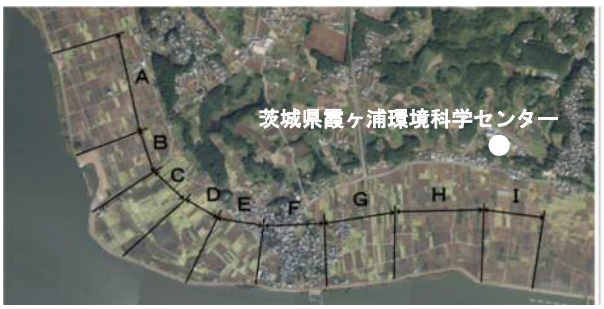

図 3 自然再生事業の事業区間

2.2 自然再生事業が目指すもの

かつての霞ヶ浦の湖岸帯は，抽水植物，浮葉植物，沈水植物からなる良好な湖岸環境（エコトーン）が成立していた。湖岸には湿地，幅のある植生帯，複雑な水際線が分布していた。湖岸から台地にかけては，植生帯（ヨシ原），水田や湿地帯，エンマ（水路），斜面樹林などが連続し，霞ヶ浦の代表的な環境要素を顕著にみることができた（図4）。

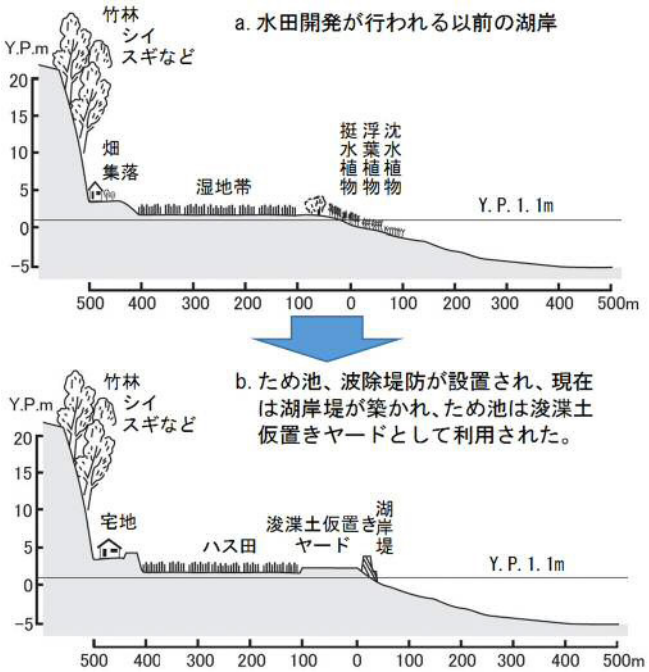

図 4 エコトーンの変化

自然再生事業では，多様な動植物が生育・生息し，里と湖の接点を形成する湖岸帯の保全・再生を図るものとして，2005年度に自然再生全体構想が策定されている（図5）。

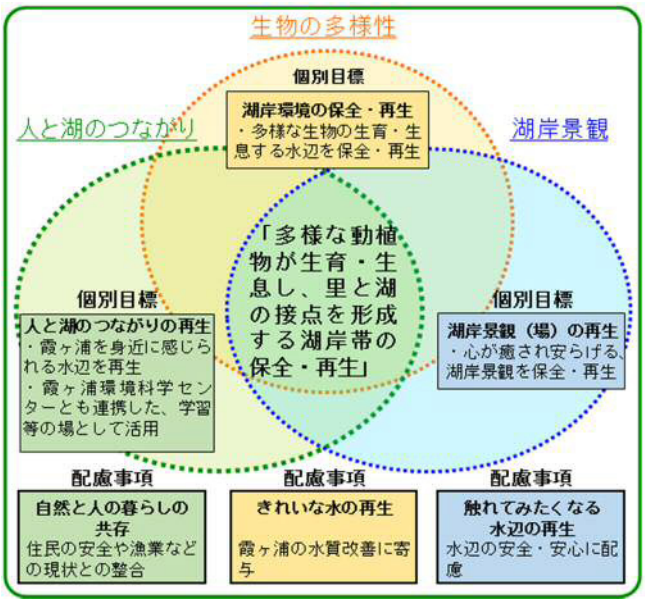

図5 自然再生全体構想における目標設定

2.3 実施区間の現状

2.3.1 A区間の現状と課題

事業区間 A～I の内，先行して事業が実施されている A 区間（2007 年度施工）は，かつては霞ヶ浦の浚渫土砂の処理ヤードとされていた箇所で，湖側を矢板で仕切り，その中に浚渫土砂が置かれている。事業は，矢板の一部（2 箇所）を切断・開口して湖と接続させ，切断部の内側を掘ってワンドとして整備し，2 つのワンド間を素掘り水路で接続したものである（図 6）。

整備当初は水路部に沈水植物が出現するなど，抽水植物，浮葉植物，沈水植物からなる良好な湖岸環境（エコトーン）となったが，抽水植物の繁茂拡大に伴って徐々に水路やワンドが縮小し，沈水植物は見られなくなった。また，ワンドにアクセスするための通路も草本に覆われるなど景観が大きく変化した。この通路や水路･ワンド周辺の除草作業は，協議会委員の手作業により行われているが，草本の繁茂が著しく，作業が追いつかない状況である。



図6 A区間のワンド（2007年）

3. 環境管理の現状

3.1 草刈りとゴミ拾い

自然再生協議会では，例年 6 月と 10 月に自然再生地区の草刈り及びゴミ拾いを実施している（図 7）。



図7 草刈りとゴミ拾いの実施状況

協議会委員への実施案内及び参加確認の連絡は，遅くても 3 週間前には行うとともに，草刈機などの作業に必要な機械類の手配は，事前に委員である市民団体，県・市と調整し準備している。

3.2 火入れ管理の試行

自然再生地を放置すると，大きな自然撹乱がない

場合には，陸域では外来の高茎草本(セイタカアワダチソウなど)に覆われ，湿地環境ではヤナギなどの木本が過度に繁茂し，暗くうっそうとした環境になりやすい。そうして日光が届かない暗い環境になると，光を得られなくなった地表付近の植物が減少し，魅力のない単調な環境になることが懸念される。このことは植物の専門家からも同様の助言を得ている。

また，協議会でも「ヨシ地の伝統的な維持方法として，ヨシを刈り取った後に火入れをする方法がある。これを将来的にシンボリックなイベント，行事に展開していくことを期待する。」との意見があり，人為的な手入れの一つとして火入れ管理の検討を行い，2017 年 2 月及び 2018 年 2 月に試験的に実施した。

火入れを実施した個所では，春季において水際付近に明るい湿地に生息するウキヤガラの出芽を多数みることができた。まだ 1 シーズンしか経過していないため植生の顕著な変化は確認できていないが，植生の状況を観察しながら，規模を拡大して実施していく方針である。

4. 環境管理の担い手を確保するための取組はじめに

4.1 環境管理活動範囲の拡大

昨年度（2017年度)整備した自然再生事業地（G～I地区）においては，自然撹乱を適度に取り入れることで抽水植物等の過度な繁茂を抑えつつ水辺植生のエコトーンの保全・再生，維持管理作業の軽減という方針に基づき計画を行った。しかし，維持管理作業を軽減する設計としたものの，環境管理活動を行う対象範囲は，完成済みのA，B区間を含め拡大している。このため，継続した環境管理活動を行うための担い手を確保する工夫や維持管理作業を低減させる既存自然再生地の改良などにより，良好な自然環境の保全･再生を継続させる必要がある。

4.2 持続可能な取組とするために

自然再生地の維持管理作業には，膨大な労力が必要です。現在行っている年 2 回程度の環境管理の実施では追いつかないボリュームであるため，回数及び参加者の増加が必要となっている。

自然再生事業は，協議会が主導で行っているが，基盤整備があるため，霞ヶ浦河川事務所が協議会の事務局を担っている。自然再生地の基盤整備が概成したことにより，今後の協議会活動の軸足は，維持管理作業や環境学習などの自然再生地の利活用に移行していく段階に入っている。

このため，維持管理作業や利活用に係る事務局の機能について，より一層委員が参画するよう段階的に移行して行く必要がある。環境管理活動の実績から持続可能な事務局機能を整理した（図 8)。

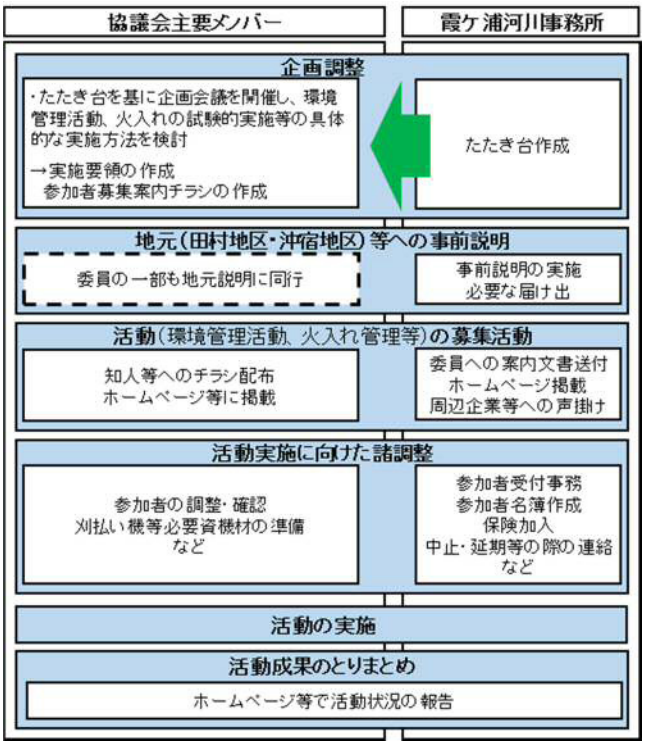

図 8 持続可能な事務局機能案

5. おわりに

これまで自然再生地の維持管理活動として，草刈りやゴミ拾い，試験的な火入れなどを実施してきた。委員の意識は，活動に対する必要性を理解され，協力的である。火入れについても，地元の理解や委員の期待も大きなものである。

自然再生事業では，事業地における植生等の環境モニタリング調査を継続的に行い，植生の状況を把握するとともに，委員が協働で実施する草刈りやゴミ拾いを継続的に実施していく。また協議会では，火入れを含めた効果的な植生保全，環境管理などについて議論していく予定である。

O8-16

滋賀県野洲市“須原せせらぎの郷”による「魚のゆりかご水田」の取り組み

堀　彰男, 冨田　眞至, 赤松　喜和
須原せせらぎの郷

キーワード：市民参加、地域活性化、意識啓発

抄録

滋賀県野洲市須原地区において“須原せせらぎの郷”を中心に、水田で稲作と魚の生育を同時に行う「魚のゆりかご水田」が取り組まれている。農業基盤整備事業により一度破壊された生態系を回復する取り組みであり、滋賀県内の琵琶湖周辺の約 20 地域において実施されており、須原地区はその一つに当たる。“須原せせらぎの郷”では魚の遡上・生育を支える魚道の設置や減農薬・無農薬栽培といった田の整備だけでなく、ゆりかご水田で生産されるゆりかご米の促進販売や環境教育、都市農村交流の場の提供に取組んでいる。こうした活動により多くの消費者や理解者を増やし、持続的に活動することを目指している。

1.　はじめに

日本最大面積を有する琵琶湖の周囲には農村が広がっており、野洲市須原地区もその一つである。1960 年頃までこの集落は琵琶湖から流入した水が駆け巡るクリーク地帯であったため、水路から灌漑用水を人力で引っ張っていた。しかし、増水時に田畑へ大量の水が流れ込み、生産者は作物への損害や排水作業への過大労働に悩まされていた。

1960 年以降、国内では田の生産性を向上するための圃場整備が広く行われ、須原地区でも同時期より地区内の水路の埋め立てと田の圃場整備が開始された。その結果、農業機械の導入により生産効率が高まったが、一方で農地環境に変化が見られた。田に魚が見られなくなったことである。須原地区は琵琶湖辺から概ね 1km 以内に位置しており、産卵期に遡上習性のあるフナやナマズ、コイ等が水路を通り、増水時に田へ入っていたのだが、圃場整備により田が嵩上げされ、用排水も分離されたため、構造上水路から田へ魚が入ることが出来なくなってしまったのである。

琵琶湖固有種にニゴロブナがあるが、琵琶湖内の環境変化や先述した湖辺環境の変化といった複合的な要因により個体数は減少した。そこで、滋賀県は漁業資源保全や農村環境における生態系保全の観点から、田へ魚を呼び戻す「魚のゆりかご水田プロジェクト」を発足し、2006 年より農業生産者の下で実践されるようになった。

須原地区では生産者が「子どもの頃、田で魚採りをした遊びをもう一度取り戻し、将来世代へと受け継いでいきたい」との思いのもと“須原せせらぎの郷”を立上げ、2008 年より「魚のゆりかご水田」に取り組むに至った。須原で実践されているゆりかご水田は、魚が田へ遡上しやすい排水路魚道の設置や魚の生育を阻害しない減農薬・無農薬栽培の実施、また生育した稚魚が排水路へ流下しやすい溝切り等の取り組みがある。また、せせらぎの郷はこういった田の環境整備だけでなく、活動普及のために田植えや稲刈り、魚の観察会等のイベントの企画・開催とゆりかご水田で生産された「ゆりかご米」を使った商品開発を行っている。次章で須原でのゆりかご水田の活動について具体的に取り上げる。

2.　須原のゆりかご水田

•　魚のゆりかご水田づくり

毎年、魚が遡上する少し前、4 月下旬に排水路に魚道を設置する。須原では田と排水路の高低差を無くすため、堰板を使用し、約 10cm ずつ高さをずらして設置することで田と水位の高さを調整する。また、魚が遡上しやすいように、堰板の中央に V 字の切り込みを入れる。遡上期は排水路を満水状態に保ち、排水路から落水道を通って田への流入が可能な環境に整える。そして田植え後は、魚が田へ入ってくるため、畦畔の除草は薬品を散布せず手作業で行い、田の中は魚毒性の低い除草剤を 1

回のみ使用する。また、機械除草といった手押車のような機械を用い、草の根をかき回して繁殖を抑える。さらに、化学合成農薬・化学肥料は慣行の 50%以上減に抑え、魚の生育を阻害しない。親魚は産卵を終えると、再び琵琶湖へ戻る。稚魚が 5cm 以上に育ったことを確認して中干しをするが、その際排水路へ流下しやすいように魚の通り道を作る“溝切り”を実施する。須原では、フナ、コイ、ナマズを見ることができる。

- イベントの実施

せせらぎの郷はゆりかご水田の取組を地域内外の人へ伝えるために、年に数回イベントを開催している。手作業の田植え体験、魚の観察会、鎌を使った稲刈り体験がある。家族連れで来られる方が多く、子供たちも一生懸命取り組む。田んぼのオーナー制と言って、一区画を田のオーナーとして登録するとイベントの参加費無料と新米が提供される制度があり、馴染みのオーナーさんもいる。イベントの前後には必ずゆりかご水田の説明とその意義を発表し、ゆりかご米も食べて頂く。手を動かし、考え、味わうことを通して、一面的な体験に終わらせないことが狙いである。 魚の観察会は、中干しをするために田から水を引くときに行う。落水道にアミを添えておくと、たくさんの稚魚が入ってくる様子が伺える。また魚の生態に詳しい研究者を招き、観察できた魚の説明をして頂く。魚採りの体験から離れた子供も大人も皆夢中になるイベントである。



写真 1　稲刈り体験の様子（2017.9.7）

- ゆりかご米の販売

須原のゆりかご水田で生産した「ゆりかご米」はイベント時に参加者へ直接販売を行っている。また、インターネットを通した販売も行っている。玄米、白米はもちろん、ゆりかご米を使用した日本酒「月夜のゆりかご」の開発・販売にも取り組んでいる。ゆりかご水田のような生態保全的農業は減農薬、無農薬により収量が減少するため、生産者にとっては経済的損失が生じる。しかし、「水田で魚を育てる」という環境サービス（付加価値）を提供しているため、その価値を価格に上乗せすることができる。直接販売は環境保全や食の安全に理解関心のある消費者と出会う機会であり、コミュニケーションを図ることでリピーターの確保につながっている。

3.　ゆりかご水田活動の効果

昨今、農業の機械化が進むなかで、田んぼに来ることのない地域の若い父母が子ども達と一緒に参加することで、世代や地域を超えた交流も増え、地域全体が元気になり、環境意識が高まった。また、最初は役員のみで取り組んでいたが、若い人が進んで魚道の管理、田植え、観察会や遡上風景の撮影を行うなど、世代を超えた交流活動をする場にもなっている。自治会の子ども達も家で田んぼの話をするようになるとともに、30 代、40 代で 2 名の若者が農業を始めるきっかけにつながるなど、農業への関心が高まってきている。

2017 年度は魚のゆりかご水田を 13ha で実施したが、生態系に配慮した水田(40 筆)において、フナ、ナマズ、ドジョウなどの数百匹の稚魚を確認することができた。

2016 年からはゆりかご水田において「無農薬・無化学肥料のお米づくり」を開始し、一層関心を持っていただく消費者の輪が広がった。県外から農作業を体験しにやってくる大学生や活動の視察にくる環境NPOの存在が生産者の励みになり、楽しみながら作業が出来るようになった。さらに、地元小学校の子供達が魚のゆりかご水田米を食べる際に活動の出前講座を実施したり、大学等の依頼により環境保全に資する本活動の視察の受入れなど環境学習の場となっている。

須原のゆりかご水田の活動は、生態系保全が主要目的であり、琵琶湖から遡上してきた魚が水田で産卵・生育する環境を取り戻した。他方で、それがきっかけとなり、地域内外で無かった新たな人のつながりの形成や子供、学生の意識啓発の場へと発展した。

O8-17

緊急に求められる外来水生植物対策と市民にできること

半沢 裕子[1], 小倉 久子[1], 竹内 順子[1],八鍬 雅子[1],中野一宇[1]
美しい手賀沼を愛する市民の連合会

キーワード:協働、自然保護、里山、水辺ふれあい

抄録

千葉県北部に位置する手賀沼で、2017 年 6 月、侵略性の高い外来水生植物(特定外来生物)のオオバナミズキンバイが見つかった。完全駆除できたと安心したのもつかのま、実はすでに定着初期の段階を過ぎ、大量繁茂段階に入りつつあることが判明した。手賀沼ではすでに、市民団体と周辺自治体・企業が協働して、ナガエツルノゲイトウ(特定外来生物)の駆除活動や遮光法による繁茂抑制実験を行っている。オオバナミズキンバイについても大繁茂の「先輩地」、滋賀県琵琶湖の対策手法を参考にしながら、市民主導で駆除活動を模索中だ。手賀沼では今後、ナガエツルノゲイトウ・オオバナミズキンバイの異常繁茂によりどんな事態が起こりうるのか。それに対し、どのような対策をどのタイミングでどの主体が行えばよいのか。市民団体はどんな役割を果たせばいいのか----手賀沼の事例を検証し、今後全国すべての湖沼で起こりうる事態として警鐘を鳴らしたい。

1. はじめに

侵略性の高い外来生物の防除の基本は、定着初期における早期発見、早期防除とされている[1]。とりわけ、基本動かない植物については、地域住人が見つけ次第同定し、駆除できれば最も効果的と言える。半面、侵略性の高さから外来生物法で特定外来生物に指定されている生物種の場合、移動や管理にきびしい規制がかかることから、市民は防除に手が出せず、せっかく発見しながら早期防除の機会を逃してしまうことも少なくない。千葉県北部に位置する手賀沼(面積約 6.5 ㎢)でも、ナガエツルノゲイトウ *Alternanthera philoxeroides* およびオオバナミズキンバイ *Ludwigia grandiflora* subsp *grandiflora* の侵入に際し、当初はそれに近い展開があった。

その一方、手賀沼には手賀沼に関わる市民団体の連合会「美しい手賀沼を愛する市民の連合会」(通称美手連、現在 21 団体)があり、この両種の侵入についても地域住人に広報したり、行政や関係機関に働きかけるなど「できること」を通じて防除・対策への足かがりを作ってきた。我田引水ではあるが、ここでは手賀沼における約 6 年間の外来水生植物防除・対策と、そこで美手連が果たしてきた役割を整理してみたい。と同時に、早期防除段階を過ぎ、大量繁茂段階に入りつつある外来水生植物対策に、市民ができることについて考えてみたい。

2. 水質ワーストワン連続 27 年の中で

手賀沼では行政と市民団体の距離が比較的近く、水質や生物多様性の保全などについて市民団体が主導的に活動できる素地は早くからあった。背景には 27 年という長きにわたった水質汚濁ワーストワンの時代(1974 年～2001 年)を通じて、「きれいな水辺を」という目標を共有してきた歴史がある。利根川の水を引き込む北千葉導水路の効果などでワーストワンは返上したが、水質最悪の時期にはアオコで緑色をしており、悪臭もひどかったと聞く。ワーストワンを脱するまでの国、県、市町、市民団体などの動きを簡単にまとめてみよう。

1974 年　国が湖沼の水質データ公表を開始すると同時に手賀沼がワーストワンに。

1975 年　手賀沼水環境保全協議会(手水協)設立。千葉県、流域市町、土地改良区や漁協などの利水団体参加。

1979 年　COD 値 28mg/L の最高値を記録。

1981 年　手賀沼流域市町が資金を出し合い、手賀沼浄化事業連絡会議を結成。のち手水協に統合。

1983 年　環境保全市民団体「湖北座会」発足。

1984 年　国が汚濁法の特別措置として湖沼水質保全特別措置法制定。

1985 年　同特別措置法の「指定湖沼」に手賀沼が指定される(全国で 5 湖、現在は 11 湖)。

1986 年～1990 年　同特別措置法に基づき、第1期湖沼水質保全計画策定(現在は第 7 期)。

1995 年　「湖北座会」を核に市民団体の連合会として美手連が発足。手水協のメンバーに。

2000 年　北千葉導水路完成、運転開始。

2002 年　手賀沼ワーストワンを返上。

2003 年　千葉県が手賀沼水循環回復行動計画を策定。手水協を中心に計画を微修正しながら今日に至る。

3. ナガエツルノゲイトウからオオバナミズキンバイへ

このように、水質改善というむずかしい課題を行政や市民が共有してきた手賀沼に、外来水生植物という新たな難題が顕在化したのは 2010 年前後のことで、最初はナガエツルノゲイトウだった。ナガエツルノゲイトウは南アメリカ原産のヒユ科ツルノゲイトウ属の多年草植物で、強い生命力、繁茂力を有する。茎や葉の切片からも増殖し、除草剤により他の植物とともに消滅しても最初に復活するため、たちまち占有状態で繁茂すると言われている。

最初に流域で確認されたのは 1998 年、亀成川流域の水田水路だった。発見者の千葉県立中央博物館学芸員の林紀男氏は、手賀沼に隣接する印旛沼から農業用灌漑用水に植物体の断片が混入して拡散したと推察し、灌漑用水にトラップを設置。茎などの破片を確認している[2]。同植物は 2002 年に水田から亀成川の河川に侵入したと考えられ 、2007 年には手賀沼全流域に拡大。2012 年には確認地点が急増し、2013 年に爆発的に増殖した。手賀沼北岸西側に位置する手賀沼公園では、ボート店桟橋にナガエツルノゲイトウの大群落が流れ着き、船が出せなくなる被害も。美手連では大阪府立環境農林水産総合研究所水生生物センターが遮光シートによる駆除実験に成功したとの情報を得たため、千葉県柏土木事務所に勧められ、千葉県河川海岸アダプトプログラムの認可を受け、2014 年 3 月、同土木事務所と協働でナガエツルノゲイトウ遮光実験を開始した。

この実験は 2017 年まで継続的に行ったが、一定の効果は認められるものの、ヨシなどの植物がシートに穴を開け、そこから日光が入ってナガエツルノゲイトウが繁茂する事態が繰り返された。そのたびにシートの張り直しなどを行ってきたが、ナガエツルノゲイトウが沼全体に繁茂する今日、遮光による駆除は現実性に乏しいという結論に至りつつある。

2016 年 11 月には千葉県柏土木事務所、柏建築業会との協働、柏市の協力で重機による駆除を実施。事後、取り残したナガエツルノゲイトウを人力で繰り返し駆除したところ、翌年春にほぼ再生しないことが確認できた。水田におけるナガエツルノゲイトウ実態調査も行っている。手賀沼流域では亀成川のほか、金山落周辺の田んぼでもナガエツルノゲイトウの侵入がすでに確認されている。

これらの活動を通じて県や市の行政、手水協メンバー、農家、一般市民などへの広報を行い、外来水生植物問題への注意を喚起してきた。

しかし、2017 年の春～夏、手賀沼および流入河川の大津川におけるナガエツルノゲイトウの繁茂はすさまじく、どう対策すべきか、今後の道筋が見えない状況に陥った。そんな中、遮光実験地で 6 月、市民が見慣れない植物を発見。千葉県立中央博物館により、滋賀県の琵琶湖で猛威を振るっているオオバナミズキンバイと判明した。

南米・北米南部原産のオオバナミズキンバイはアカバナ科チョウジタデ属の水生植物で、侵略性はナガエツルノゲイトウよりさらに強いと言われている。琵琶湖では 2009 年に初確認され、2012 年に対策を開始。2016 年度と 2017 年度には年間 3 億円を超える対策費を投じて駆除を行い、ようやく「管理可能な状態をめざす」方向性が固まったと聞いている。この最強植物が手賀沼で発見されたのは衝撃だったが、美手連では 8 月、発見地の徹底した駆除を行い、すべて駆除できたものと安堵した。

ところが、駆除後まもなくの 9 月 4 日、琵琶湖で外来水生植物対策を担当している滋賀県琵琶湖環境部自然環境保全課主幹の中井克樹氏が手賀沼を来訪。駆除地を見てもらったところ、オオバナミズキンバイを多数確認した。手賀沼公園東端のヨシ帯の中にも大規模な群落を発見。中井氏に「残念ながら早期防除の段階は過ぎました」とのコメントをいただく結末となった。

もうひとつ、中井氏来訪に先立ち、「手賀大橋の西側にある植生帯(水草復元のための木造建造物)付近でも、8 月末にオオバナミズキンバイを確認した」との情報も美手連は得ていた。中井氏来訪の 2 日後、美手連では船による手賀沼調査を予定していたため、手賀大橋西側の植生帯を見に行ってみると、いたるところにオオバナミズキンバイが繁茂し、ナガエツルノゲイトウ大群落の奥まで入り込んでいることが確認された。岸と植生帯の間の水路が完全にふさがっている場所もあった。続いて北岸の西側をつぶさに調査すると、オオバナミズキンバイがナガエツルノゲイトウに置き換わっている群落が無数に見られた。きわめつけは利根川の水を手賀沼に注ぎ込んでいる北千葉導水第2機場前で、ヨシ帯の中から沖へ外来水生植物の巨大群落がみっしりと形成され、島ならぬ大陸と化していた。私たちがナガエツルノゲイトウと認識し、「すさまじい繁茂」と心配していた外来水生植物群落の多くが、すでにさらに強力なオオバナミズキンバイに駆逐されようとしているところだったのだ。

そこで、美手連では 11 月に緊急勉強会を企画。中井氏より琵琶湖の現状について講演していただくとともに、同じく 2017 年にオオバナミズキンバイを確認・駆除した霞ヶ浦の事例、2015 年の発見・駆除後、今のところ再発見報告のない印旛沼の事例、そして、手賀沼の現状について関係者に報告をいただいた。勉強会当日午前中

には再度船による視察も行っている。わずか 2 ヵ月強の間にオオバナミズキンバイはさらに増殖していた。

勉強会翌日には千葉県柏土木事務所、我孫子市手賀沼課、我孫子建設業会との協働による2回目のナガエツルノゲイトウ駆除が計画されており、市民を含む 60 人体制でナガエツルノゲイトウの大群落(400 ㎡)を駆除したが、ここでもオオバナミズキンバイが入り込んでいることを間近で確認した。つまり、手賀沼はまさしくオオバナミズキンバイ爆発前夜にある。来春の芽吹きどきがこわいと思ったのは私だけではないだろう。

4. すでに繁茂している水域の防除・対策はどうするか

今年、ナガエツルノゲイトウとオオバナミズキンバイの群落は明らかに昨年と比べてより大きく、より沖側に張り出しつつある。第２機場前には再び大陸が出現するかもしれない。私たち市民団体はどんな活動をとせのように行えばいいのだろうか。

そもそも、ナガエツルノゲイトウやオオバナミズキンバイが殖えて大変という話をすると、「何が困るの」と言われることが多い。たしかに、増えても実害がなければ、放っておけばいいともいえる。あれだけの質量がまとまって出現すれば、何かしらの影響は必ずあるはずだが、現状実害と推定できるのは、①洪水、②洪水予防対策に費用がかかること、③水田に入り稲と混生し米の収量を落としたり耕作機械を壊すこと、④他の水域に流出し、そこで殖えて同様の問題を起こすこと、などである。

①は今のところ起きていないが、①につながる②はすでに起きている。2017 年 10 月に台風 21 号と 22 号が相次いで来襲した際、手賀排水機場のスクリーンにナガエツルノゲイトウが大量に漂着。スクリーンの詰まりによる洪水を防ぐため、土地改良区では 4 日間にわたり重機による駆除を実施した。その費用は 100 万円弱に上ると推計されている。とはいえ、ひとたび洪水が起きたら、その被害総額は②とは比較にならないはずである。

③も今後が大いに心配される。現在、水田への侵入が確認されているのはナガエツルノゲイトウのみだが、実はオオバナミズキンバイの脅威は段違いと言われている。この植物は他の植物より高く伸びて日光を遮り、一人勝ちする習性がある。琵琶湖や手賀沼において、ナガエツルノゲイトウという強力な水生植物までもが駆逐されつつあるのもそのためと推察されている。外国には米の収量が大きく減ったという報告もすでにあるという。

④他地域への流出も問題だ。2018 年 2 月、再び船上調査を行ったところ、第 2 機場前の「オオバナ大陸」が忽然と消え失せていた。群落は刈れてもオオバナミズキンバイは水面に浮かび、漂っていくので、枯死して水没・沈殿したとは考えにくい。あれほどの大群落がバラバラになり、手賀沼全域に散ったことになる。手賀沼を出て利根川に入り、別な水系にたどり着く可能性もある。現に、第二機場下流のボート店に訊くと、大きな群落がたびたび流れ着き、作業に支障をきたすため、竿などで突いて下流に送り出しているとのことだった。手賀沼は被害を受けるだけでなく、他地域に対して害をなす可能性もあるのだ。

では、早期防除に間に合わず、外来水生植物大繁茂寸前と思われる手賀沼は何をしたらいいのだろうか。私たち市民団体にできることは何だろうか。これだけの面積、これだけの群落の駆除となれば、市民団体にできることは少ない。最優先で取り組むべきは行政が経費を投入できるよう対策を強く要望することだろう。繁茂面積を増やさないためには、重機による大規模な駆除と駆除後にこまめに行う巡回・監視・小規模駆除が欠かせない。必要経費もかけてもらわなければならない。裏付けとなる情報を増やすことも大切だ。地域住人に外来水生植物の脅威を知ってもらい、多くの人に関心を持ってもらうことも必要となる。啓発活動やマスコミへの情報提供も欠かせない。せっかくよく機能している協議会があるのだから、協議会を核にして琵琶湖の事例を参考に駆除計画を立ててはどうだろうか。幸い、手賀沼水環境保全協議会でも来年度以降の手賀沼水循環回復行動計画に、外来水生植物対策を明確に盛り込んでくれた。

手賀沼での防除・対策は正直、失敗する可能性も高い。しかし、成功しても失敗してもひとつの先進事例となる。それこそが手賀沼に課された使命といえるだろう。※手賀沼の外来水生植物防除の実働を担っているのは美手連だが、ほぼすべてで共催しているのは手賀沼流域フォーラム実行委員会である。これは手水協や流域市町、市民団体などから成り、手水協が協働している団体で、調査やイベントなどを通じて、市民に手賀沼の魅力や情報を体験してもらうことを目的としている。

引用文献

[1] 環境省:外来種被害防止行動計画　第 1 部第 2 章第 1 節 (p.54-p.62) 2015

O8-18

題名：大学生による多様な主体との協働による琵琶湖の侵略的外来水生植物の除去の取り組み

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キーワード：侵略的外来植物,オオバナミズキンバイ,多様な主体との協働,早期発見・早期除去

抄録

琵琶湖では、新たな侵略的外来水生植物であるオオバナミズキンバイ(以下,オオバナ)の異常繁茂が深刻な課題となっている。本稿では、1)学生がオオバナ除去活動を始めたきっかけ、2)守山市での多様な主体との連携した活動の手順と各主体の役割分担、3)学生主体による琵琶湖南部全域での活動について紹介する。また、認知度向上と危機意識の共有のための啓発・広報活動について取り上げ、行政の動きの迅速化や企業、地域住民などとの協働の輪の広がりに繋がってきたのかを紹介する。

1. はじめに

1-1 石けん運動

琵琶湖は滋賀県に位置する日本最大の湖であり、日本最古の湖でもある。約 400 万年もの歴史を持つ古代湖である琵琶湖は 60 種を超える固有種も生息する生態系豊かな湖である。[1]

しかし、1977 年 5 月、琵琶湖に淡水赤潮が発生した。その原因の一つが、合成洗剤に含まれている「りん」であることが分かり、主婦層を中心に「粉石けんを使おう」と石けん運動が行われた。行政に対策を講じるように要求した結果、1980 年 7 月にりんを含む合成洗剤の販売、使用、贈答の禁止、工場排水規制を盛り込んだ「滋賀県琵琶湖の富栄養化の防止に関する条例」が制定され、近年は赤潮発生などの問題は終息しつつある。[1]

2016 年に実施された総務省の「社会生活基本調査」によると過去一年間の滋賀県のボランティア活動の行動者率は、33.9%で全国1位であった。[2]石けん運動をきっかけに市民活動が活発になり、琵琶湖を守る運動が広まった。自分たちの住む地域を改善しようという精神が県内各地での環境保全に繋がっている。[1]

1-2 侵略的外来水生植物オオバナ

侵略的外来水生植物であるオオバナが、2009 年 12 月の滋賀県守山市の琵琶湖赤野井湾で初めて定着が確認された。当時の生育面積は 142 ㎡であったが、3 年後の 2012 年 12 月には、琵琶湖南湖全体で約 18,000 ㎡へと急速に拡大した。オオバナの増殖により、漁船の航行障害や魚の産卵場所である内湖を覆いつくなど水産資源への悪影響が懸念されていた。[3]



写真 1-1 内湖に繁殖するオオバナ

2013 年 4 月より本協会では、オオバナ完全除去と認知度向上を目的として活動を始めた。本論文では、多様な主体との協働による除去活動と、認知度向上に向けた啓発・広報活動について紹介する。

2. 除去活動

2-1 オオバナ除去活動の始まり

2013 年 2 月に守山市で開催された川づくりフォーラムに参加した本協会の学生が、近江ウェットランド研究会の基調講演を聞き、オオバナの問題を知った。2013 年 3 月に守山市で開催された赤野井湾・小津袋クリーン大作戦に参加して、船上から水草を引き揚げる重労働作業を体験し、また除去に従事するのは、漁師を中心とした高齢者であることに危機感を覚え、「学生の力で琵琶湖を守りたい」と除去活動の企画を行った。

初めてのオオバナ除去活動は、2013 年 4 月に大津市の膳所城跡公園の湖岸で、本協会 14 名の学生と滋賀県、近江ウェットランド研究会、(株)ラーゴを含む 17 名で 4 時間程度実施され、湖面やヨシに絡みついていた約 150 ㎡のオオバナを陸揚げし袋詰めを行った。

滋賀県より、公園の使用許可、乾燥させるための仮置き場の確保、焼却処分の手続き、水中作業のための胴長やゴム長手袋などの援助があったことで、学生の参加の負担を軽減でき、また重労働ではあったが、目に見えて琵琶湖が綺麗になることにやりがいを感じることができ、活動の発展の足がかりとなった。

2-2 守山市での多様な主体と連携した活動

琵琶湖に繁殖するオオバナの 90%が守山市にあり、赤野井湾では、航路障害や内湖を埋め尽くすなど漁や生態系への被害が深刻で、地域の認知度も低かった。

この状況に対して 2013 年 6 月に NPO 法人びわこ豊穣の郷が中心となり、守山市、玉津小津漁業協同組合、住民、本協会参画による「オオバナ除去大作戦プロジェクト」が結成され、除去活動と異常繁殖の危機や除去の必要性を呼びかける啓発活動を実施した。初年度は計 5 回の除去活動を実施し、延べ 261 名が参加した。

除去活動の手順(①調査②事前学習③活動実施会議④活動実施⑤天日干し⑥焼却処分⑦反省会)を解説する。①分布状況の調査として、研究機関や地域環境団体、漁師の方と現地に訪れ、オオバナ繁殖状況の調査を行う。②本協会の学生には、除去活動に向けて、外来水生植物に関する知識や除去作業における注意点を事前学習する。③分布調査の結果を踏まえ、活動場所や効果的な除去方法について、行政も交えて活動実施会議を行う。④関係機関や地域住民と共に除去活動を行う。⑤水草は多くの水分を含むため、仮置き場に運搬して、天日干しを行う。⑥行政や環境団体と乾燥させたオオバナの回収作業と焼却処分を行う。⑦関係機関と活動を振り返り、今後に向けての反省会を行う。

このようなサイクルを行政、研究機関、環境団体、漁師、住民、学生が互いの強みを活かして実施することで、地域一体となった持続的な除去活動を行っている。



図 2-1 除去活動の手順



写真 2-1 赤野井湾での除去活動の様子

2-3 学生主体による琵琶湖南部全域での活動

オオバナは守山市だけでなく、草津市、大津市の琵琶湖湖岸、琵琶湖から流れ出る河川である瀬田川でも生育が確認されていたが、防除対策がされておらず、オオバナの爆発的な繁殖力による被害の拡大が懸念されることから、滋賀県全体での対策が急務であった。

滋賀県は、この状況に対し、2014 年 3 月に関係者による情報共有と連携体制の整備を図り、オオバナの効果的・効率的な防除方法の確立と除去を目指して琵琶湖外来水生植物対策協議会を設立した。

本協会はこの協議会の構成員として守山市での除去活動で得たノウハウを共有し、関係機関のハブとなることで大規模活動を展開している。

2014 年の 9 月には、初の学生主体で「琵琶湖外来水生植物除去大作戦」を企画・実施した。この活動では、学生 570 人が 3 日間に渡り、琵琶湖南部の大津市、草津市、守山市の 3 市に渡る湖岸線全長約 20km を徒歩で除去作業していくもので、地元行政の他、地域環境団体、漁師、民間企業など多様な主体を巻き込みながら、連携して実施した。この琵琶湖南部全域での活動を企画・実施するうえで難しかった点と、各主体がどのような役割を果たして実施したのかを説明する。

草津市、大津市では、航行障害や漁業障害などの被害がなかったため危機意識がなく、認知度も低かった。本協会の学生が、被害が拡大し手遅れになる前に対策すべきだと行政や各管理者に話をしたが、認知度や危機意識が低く、また除去したオオバナを天日乾燥させる仮置き場の確保や焼却処分の管轄や費用負担の問題があることから、行政や各管理者との連携した対策を実施することが難しかった。しかし、オオバナ除去作業に参加して、その脅威を一番肌で感じていた学生が、行政や各管理者への説明や理解を仰ぎ、行政と行政、行政と管理者の連携・協働のつなぎ役になったことで、関係者から仮置き場や焼却処分の理解・協力を得ること

ができ、行政や各管理者、学生が横断的な連携した活動を行うことができた。

各主体の役割として、行政や管理者は活動実施と仮置き場、焼却処理の許可を与え、地域環境団体は地域とのハブとなり一般参加者の巻き込みや自治会への調整を行った。漁師は繁殖状況の共有、除去作業時の船出し、水辺作業の安全管理を行い、企業は協賛品、社員の活動参加などによる支援を行い、活動を支えた。

この大作戦は毎年夏に実施されている。当初は、初期群落から大規模群落まで除去対象であったが、行政による大規模な機械駆除の対策が強化されていることから、近年は、関係機関と活動領域を検討しながら、人の手による作業が必要とされる石積み護岸、ヨシ群落内の初期群落を中心に実施している。

表 2-1 琵琶湖外来水生植物除去大作戦の実績(人数は延べ)

活動日	本協会(人)	関係者(人)	除去面積(㎡)	除去重量(t)	除去地点数
2014年 9/15-17	1710	12	6000	120	-
2015年 9/11-13	1206	66	4000	42	-
2016年 9/9-11	1152	85	5820	48.7	855
2017年 9/8-10	1542	82	3075	23	553



写真 2-2 除去大作戦の様子

3. 啓発・広報活動

3-1 積極的な発信が社会を動かす

2013 年 4 月に本協会が除去活動を始めた頃は、オオバナが 3 年で 100 倍の勢いで異常繁茂している実態が明らかになっていたが、行政や地元住民には、ほとんど認知されていない状況であった。

この課題に対して、本協会では、啓発・広報活動を 実施してきた。環境団体への講演や意見交換会の開催、子どもへの環境学習の提供、日本全国の大学学園祭の他、イナズマロックフェス、県主催のびわコミ会議、各市主催のこども環境会議、環境フォーラムなどで展示、発表をしている。また、マスコミの取材としてラジオ出演、新聞掲載、全国放送のニュースで放映されるなど、オオバナによる現状や被害、課題を社会に訴えかけてきた。



写真 3-1 フォーラムでの展示

この問題に対する危機意識を共有したことで、対策の動きが加速する一助となった。2014 年 6 月にはオオバナが、環境省より特定外来生物に認定され、滋賀県主導での琵琶湖外来水生植物対策協議会の設立、機械駆除等の迅速な動きにも繋がった。

また滋賀県議会の定例議会、琵琶湖再生法に関する衆議院の環境委員会でも本活動が取り上げられ、防除に関する対策への強化に繋がった。

3-3 協働の輪の広がり

継続的かつ積極的に啓発・広報活動をすることにより、この問題を取り巻く協働の輪が広がっている。これらをきっかけとして新たに環境団体、中学生・高校生・大学生、国土交通省の職員、水草の有効利用を研究する民間企業などと除去活動を実施するなど、滋賀県内の協働の輪を広げることに繋がっている。

4. 今後の課題

今後の課題として、オオバナが京都府の宇治川、千葉県の手賀沼、茨城県の霞ヶ浦など日本各地で確認されている。大繁殖して多大な労力・機械駆除・仮置き場・処分など多額の経費が発生する前に、早期発見・早期除去を実施することが重要である。

そのために、外来生物を取り扱う行政や管理者への具体的な措置を明らかにし、また環境学習の提供により行政、環境団体、企業や地域住民の基本的な理解を高め、行政から住民まで協力した早期発見の監視体制、早期除去の連携体制の構築が重要である。

謝辞:本協会の活動には、認定NPO法人びわこ豊穣の郷を中心とした守山市の「オオバナ除去大作戦プロジェクト」、滋賀県庁をはじめとした滋賀県琵琶湖外来水生植物対策協議会の構成員の皆さま、また多くの関係者の皆さまに、多大なる御理解、御協力、御指導、応援を頂いた。ここに記して、心からの感謝を申し上げる。

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O8-19

Education for Sustainable Development (ESD)の視点を取り入れた、生涯にわたって段階的・継続的に取り組む体系的な環境学習について

滋賀県琵琶湖環境部琵琶湖保全再生課
赤﨑　好近

キーワード:環境学習、市民活動、持続可能な社会

抄録

環境に関する様々な課題を解決し、持続可能な社会を実現するには、それらの課題と自分たちの暮らしとのつながりを理解し、県民一人ひとりが主体的に行動を起こすことが欠かせません。

本県では、毎年 7 月 1 日の「びわ湖の日」に併せて実施される一斉清掃に 10 万人を超える県民に参加いただくなど、主体的に環境を守ろうとする県民の意識が高い県であると言えます。

持続可能な社会を築くためには、このような高い環境保全意識をより多くの県民に広げ、次世代の県民へと受け継いでいくことが必要であり、そのために大きな役割を果たすのが「環境学習」です。

そこで県では、ESD（Education for Sustainable Development）の視点を取り入れ、様々な環境課題に対し、気づき、学び、考え、行動することができる人を育てるとともに、その人たちが課題解決に向け主体的に行動を起こし、それにより持続可能な社会づくりが進むことを目指した環境学習に取り組んでいます。

1.　はじめに

環境学習や環境教育の推進に向けて、県は平成 16 年(2004 年)に全国初の環境学習に関する条例となる「滋賀県環境学習の推進に関する条例」(以下、「条例」という。)を制定し、平成 28 年(2016 年)3 月に条例に基づく「第三次滋賀県環境学習推進計画」を策定しました。

この計画では、環境学習によって気づきや学びを得た個人が主体的な行動を起こすとともに、行動を始めた人たちがつながって社会の課題を解決してくことで、持続可能な社会づくりが進展すること、いわば「人育て」と「社会づくり」の双方がかみ合った歯車のように連動して進むことを、環境学習の推進にあたっての基本的な考え方としています。

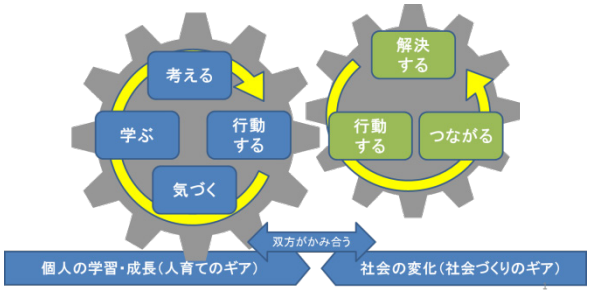

図１　人育てと社会づくりがかみ合って進む「ギアモデル」

こうした環境への学びや行動は、生涯にわたって段階的・継続的に取り組むことが重要であり、以下の事例のように、県ではライフステージに応じた体系的な環境学習を推進しています。

2.　幼児期における自然体験

幼児期における自然体験を通じて、自然を大切に思う気持ちをはぐくむことが大切であることから、県では幼稚園教諭や保育士等を対象とした幼児の自然体験プログラムに関する学習会を行っています。

平成 23 年度から 29 年度まで、延べ 228 園が学習会に参加されました。



写真１：幼児の自然体験指導者実践学習会

3. 学校での環境教育・環境学習

(1) 自然を生かした体験型環境学習

子どもたちの身の回りの全てを環境ととらえ、実感・納得・感動のある環境学習を推進しており、特に、滋賀らしい環境教育・環境学習の取組として、びわ湖フローティングスクール「うみのこ」、森林環境学習「やまのこ」、農業体験学習「たんぼのこ体験事業」などの自然体験型の環境学習を実施しています。

〈「うみのこ」参加実績〉 約 53 万人(35 年間)

(2) ESDカレンダー(年間指導計画)

県では ESD の視点に立った学習指導を実践しています。ESD カレンダー(年間指導計画)の作成により、人や社会とのつながりや他教科との関連を俯瞰的に示すことができ、学習内容を教科横断的に把握し、体系的な学習を視野に入れた教科指導、他教科で学習したことを活かした体験的な学習を進めることができます。

(3) 地域課題の解決に向けた「エコ・スクール」活動

「エコ・スクール」は、将来の社会づくりの主役となる児童生徒が主体的に環境学習や環境保全活動に取り組む力を身につけることを目指した、学校全体の活動プログラムです。

小・中・高の児童生徒たちが、地域の人たちの協力を得て、エコ・スクール活動を推進していく組織(グループ)を立ち上げ、身の回りの生活環境の調査探検、計画づくり、実行と評価といったプロセスを学校全体で取り組むものです。〈平成 29 年度実績〉 認定校 18 校



写真 2 : エコ・スクール活動 (草津市立笠縫東小学校)

4. 大学生の琵琶湖学習

県内の大学生のうち主に他府県出身者を対象として、琵琶湖体験クルーズを行い、琵琶湖の価値や地域の課題について学んでいただく取り組みを、大学と連携して行っています。

〈平成 29 年度実績〉 事前学習出席者 約 400 名



写真 3: 大学生による近江八幡市沖島での地引網漁体験

5. 生涯にわたって学び、行動する

大人が地域の課題解決に向けた学習を通じて、積極的に社会に参画し、活力ある地域づくりの活動をするため、大学やコミュニティ、民間団体との連携のもと、大人が学ぶ場を創出しています。

毎年、マザーレイクフォーラム(びわコミ会議)では異世代、多分野、県内外の参加者が琵琶湖のことを話し合い、7月1日「びわ湖の日」周辺では 10 万人以上の方が清掃活動等に参加しています。



写真 4 : マザーレイクフォーラムの様子

6. まとめ

以上、幼児期から大人まで、ライフステージに応じた環境学習の事例を紹介しました。

私たちが琵琶湖の恵みを享受できるのは、40 年前の琵琶湖での大規模な淡水赤潮を克服した石けん運動の精神をもとに、多様な団体や市民などが琵琶湖を守る運動を続けてきたからです。

環境学習を通じて、琵琶湖と人とのつながりに気づき、琵琶湖の多様な価値を認識するとともに、琵琶湖や地域を愛し、地域を守る人々を育てていくことは、琵琶湖を次の世代に引き継いでいくことにつながると考えます。

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O8-20

Educational program of the Center for Water Environment Studies, Ibaraki University

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Keywords: common use facilities, Lake Kasumigaura, Educational program

ABSTRACT

The Center for Water Environmental Studies (CWES) consists of common use facilities where environmental education and research are performed on Lake Kasumigaura all facilities are on the lakefront of the town of Kitaura. In 2013, CWES was recognized as an education-related joint usage facility by the Ministry of Education, Culture, Sports, Science and Technology. In this paper, we introduce the history of CWES and our educational program in water environmental studies.

1. History of the CWES

The Center for Water Environmental Studies (CWES) consists of common use facilities where environmental education and research are performed on Lake Kasumigaura; all facilities are on the lakefront of the town of Kitaura. Our center consists of two specialized fields with five permanent researchers and four staff members. The organization is an experimental laboratory of Ibaraki University and was established in 1949. Therefore, CWES has an approximately 70-year history of education and research focused on the area around Kitaura. In addition, in 2013, CWES was recognized as an education-related joint usage facility by the Ministry of Education, Culture, Sports, Science and Technology. The joint usage by the CWES of Ibaraki University in Japan focuses on the lake and marshes, and the annual number of users exceeds 3,000 people (2014–2016). Figure 1 is a satellite image observing the area around CWES. The center consists of a reinforced concrete building (2F: main building) and accommodations. In addition, an exclusive wharf exists on the Kitaura lakeside and three training ships are operated from the wharf.

2. CWES educational program

Figure 2 is a conceptual diagram of the educational core of the water environment studies program. The educational staff at CWES conducts practical programs in the educational core for water environment studies, as well as department lectures and a graduate school. In this paper, we introduce the educational program of the educational core. The educational core is managed by a common use conference that consists of 12 researchers including an extramural researcher, a local government officer, and a high school teacher. In addition, an educational program is being considered by the educational consortium of the Kasumigaura watershed. The training contents address the fields of ecosystems, geology, and environmental surveying. All students need to choose an educational field when applying to our program. Occasionally, a diligent student will attempt more than two programs. Accommodation charges range from 500 yen to 900 yen, and with board included, it is possible to study one program for approximately 9,000 yen. Our educational program has been evaluated and it is possible for students to learn substantial content such as limnological surveys, the investigation of hydrobiology, and the analysis of radioactive materials.



Fig. 1 CEWS and Lake Kitaura

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https://www.google co.jp/intl/ja/earth/

3. Landscape of the practical training at Kitaura

Photograph 1 shows the landscape for the practical training at Kitaura. Here, students are performing sampling of bottom sediments and making terrain measurements. Basic security measures such as sailing with more than one ship and the use of life jackets are observed by the program. It is possible to experience surges and wind swells at Kitaura; therefore, a dynamic environment can be experienced. Photograph 2 portrays an analysis of a sample extracted from the lake bottom near Kitaura. Students identify the biota using microscopes and filtration work. In addition, analytical instruments such as germanium semiconductor detectors, laser diffraction particle size analyzers, and GNSS survey instrument are used at CWES. CWES can offer various observation and analysis environments to students and researchers studying a lake and it's shore.

4. Future Aims of CWES

CWES is planning to arrange a training program for foreign students and oversea researchers via collaboration with the Institutes for Global Change Adaptation Science, Ibaraki University. In addition, CWES plans to cooperate with various institutes focused on water environment studies in the Ibaraki Prefecture.

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Photo. 1 Practical training at Kitaura



Photo. 2 Lecture in the Meeting Room



Photo. 2 Analysis of a sample extracted from the lake



Fig. 2 Conceptual diagram of the educational core

O8-21

アジア湿地シンポジウムにおけるユースセッションの開催とその成果

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キーワード:コミュニケーション,人材育成,意識啓発,ラムサール条約,ユース

抄録

中学生から大学院生が中心となり、ラムサール条約が目指している湿地保全のための CEPA（コミュニケーション、能力養成、教育、参加、普及啓発）活動を行なう「ユースラムサールジャパン」は、2017 年 11 月7日～11 日、佐賀県佐賀市で開催された 8th Asia wetlands Symposium（AWS： 第 8 回アジア湿地シンポジウム）において、「湿地と若者（Wetlands and Youth）」セッションを行なった。「湿地と若者」セッションは、将来にわたって意見交換を行える関係を築くことを目的に、アジア各地の湿地で活動するユース世代が湿地の課題についてディスカッションを行った。「湿地と若者」セッションには7カ国から 34 人のユースが参加し、日頃行っている湿地での活動を紹介し、代表者 21 人により、ユースならではの視点から活発な議論が行われ、セッションに参加したユースで Facebook グループを創設し、継続的に意見や事例を交換できる場を作ることができた。また、AWS で採択された“Saga Statement”には、若者が湿地保全へ参加する重要性が明記された。

1. はじめに

ユースラムサールジャパン（YRJ）は、中学生から大学院生までのユース世代によって組織される NGO 団体である。YRJ は、ユース世代が湿地について学び、湿地保全活動を実践し、湿地保全を通してラムサール条約が目指すワイズユースなどを市民に広くCEPA することを目的として 2013 年に設立された。これまで全国 13 ヶ所のラムサール条約登録湿地で活動を行い、その地域の魅力や湿地の情報を「ユースの視点」から捉え直し、発信する活動を行なってきた。

AWS は、1992 年に第一回目が開催され、湿地に関わる NGO、研究者、行政、市民などが参加し、アジアの湿地における問題点や今後の保全に向けた話し合いが行われるシンポジウムである。これまで、ラムサール条約が目指している湿地を次世代に引き継ぐためには若者の参加が重要であるが、学生や若者の参加が少なく課題の一つとされていた。そこでアジア規模において、湿地で活動するユース世代が交流や意見交換を行い今後、湿地保全に向けた意見交換を行える関係を築くことを目的に、第8回 AWS で「湿地と若者（Wetlands and Youth）」セッションを行なった。

2. 開催準備と当日の活動

2017 年 2 月に韓国順天市で AWS を準備するための第一回国際運営会議が開催された。その会議において、若者の参加が課題として挙げられ、YRJ として、「湿地と若者」セッションの実施を要望した。「湿地と若者」セッションで発表とディスカッションをおこなう、日頃から湿地の保全、管理、賢明な利用に関連する活動や研究に携わっている 15～25 歳前後のユースを募集し、34 人が参加した。

「湿地と若者」セッションは、プレゼンテーションパートとディスカッションパートの2部構成で行った。第1部はプレゼンテーションパートで、参加者の活動事例を共有することを目的に行われた。第2部はディスカッションパートで、今後、ユース世代が湿地を保全するためにどのような活動をおこなうべきかディスカッションを行った。

プレゼンテーションパートでは、英語により口頭発表とポスター発表が行われ，口頭発表では約 50 人が公聴する中 5 ヵ国から 13 件、ポスターセッションでは 4 ヵ国の 12 件の発表が行われた。

ディスカッションパートでは、「今後、ユース世代が湿地を保全するためにどのような活動をおこなうことができるか？」をメインテーマとし、①湿地に関心がない人をどのように巻き込んで行くか？②知識や技術をユース世代が将来的に獲得していくために必要なことは何か？③ユースは他の世代やステークホルダーにどのような影響を与えられるか？④ユース世代が情報や知識や経験などを

共有するために何が必要か？をサブテーマとして議論を交わした。ディスカッションパートでも英語で行われたが，日本語－英語の同時通訳が付いたほか、事前にディスカッションのテーマの共有を行なった。

3. 成果と課題、今後の活動

それぞれのサブテーマに対しては、①もっと若者が楽しめる活動にする必要がある②ボランティアやインターンシップに参加し、経験豊富な大人から学ぶ③ユース世代がリーダーシップを発揮することで、大人や子どもの世代に影響を与えられるはずである④SNS などのネットワークを用いたプラットフォームで情報のやりとりができるなどの意見が出た。その為，SNS のネットワークツールとして Facebook グループ「Global Youth Ramsar Network」を開設し、継続的に意見や事例を交換するプラットフォームが作られ、今後このプラットフォームを通じた情報交換を行う予定である。

「湿地と若者」セッションでは、湿地保全活動の情報や将来的なビジョンを共有し、それらを自分が日頃活動している湿地へ持ち帰り、継続的に活動を行うことが確認された。

「湿地と若者」セッションでの議論の内容は、AWS で採択された Saga Statement（佐賀ステートメント）の第7項「Ensure Youth Leadership in Wetland Conservation（湿地保全における若者のリーダーシップを確保する）」に反映され、同項目では「We recognize the capacity of youth to exchange ideas between various stakeholders, build networks, and actively participate in various wetland conservation actions. We expect youth leadership to enable the AWS to continue its vital contribution to effective wetlands management.（我々は、若者達が多様なステークホルダーと意見交換を行い、ネットワークを構築し、様々な湿地保全のための活動に積極的に参加する力を有していることを認識する。AWS が引き続き湿地の効果的な管理に核心的な貢献しうるよう、若者達が今後の AWS の開催において、更なるリーダーシップを発揮することを期待する。[1]）」と宣言された。

今回の成果を受け，2018 年 10 月にドバイで開催される第 13 回ラムサール条約締約国会議（COP13）で、Youth Forum の開催と Youth Statement の作成が検討されている。また AWS は、2020 年に韓国順天市で第9回が開催される予定である。今後、YRJ は、Saga Statement の実行のため、ユース同士で情報共有を活発に行い、次回 AWS に向けて、湿地保全分野でリーダーシップを発揮しながら広くユース世代に普及・啓発活動を行っていく。

1.

4. 結論

中学生から大学院生が中心となってラムサール条約の CEPA 活動を行なっている NGO 団体「ユースラムサールジャパン」は、2017 年 11 月に佐賀県佐賀市で開催された 8th Asia wetlands Symposium（AWS：第 8 回アジア湿地シンポジウム）において、「湿地と若者」セッションの運営を行なった。「湿地と若者」セッションは、湿地で活動するアジアのユース世代が知見と課題を共有し、意見交換を行い、その後も意見交換などを行える関係を築くことを目的に開催された。7カ国から 34 人のユースが集まり、代表者 21 人によるディスカッションを行った。これらの実施により、AWS 全体の宣言文である“Saga Statement”には、湿地保全におけるユースのリーダーシップの重要性が明記された。またユース同士でネットワークを継続的に維持するため Facebook グループを創設し、意見や事例を交換する場を作ることができた。

これらの成果を受けて YRJ は今後の湿地保全活動でもリーダーシップを発揮し、アジアにおいて CEPA を実践していく予定である。

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図 1 活動報告の様子



図 4 YRJ メンバーがセッションの議長を務めた（右）



図 2 AWS の若者参加者による記念撮影



図 5 ディスカッションの様子

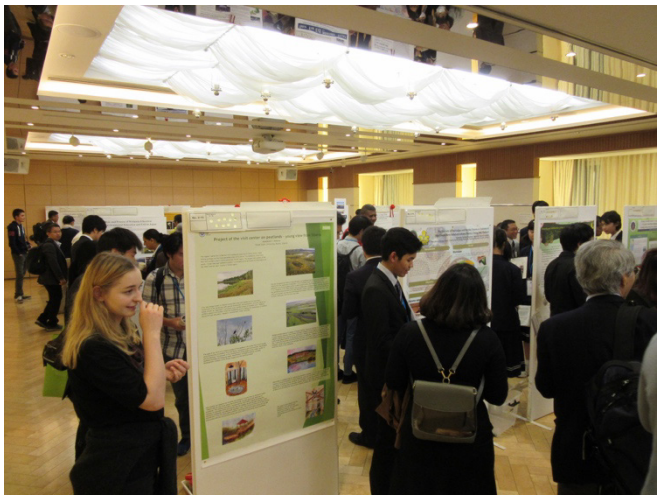

図 3 ユース参加者によるポスターセッションの様子

O8-22

バーチャルリアリティ(VR)技術による湖沼環境教育

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キーワード:バーチャルリアリティ, 全天球映像, 環境教育

抄録

北海道大学 CoSTEP では 2017 年 10 月 15 日にバーチャルリアリティ(VR)技術による環境教育イベント「没入!バーチャル支笏湖ワールド」を、札幌市青少年科学館で小中学生向けに実施した。水平、垂直の全方位を映像化できる全天球撮影カメラを用いて受講生らと支笏湖で水中撮影を行い、あたかも水中を泳いで観察しているような感覚が得られるよう工夫した。VR を環境教育に活用する場合、再現性が重要であり、流れのない静水システムである湖沼は撮影しやすい環境といえる。また VR の場合、受動的な平面映像と異なり、能動的に参加したくなる仕掛けが必要となる。制作にあたり「人々が対象物を探す動機づけ」「観察空間の位置関係を理解させること」「視線を誘導するためのテロップ配置」という重要な 3 点を見出した。また取材した大学生、院生には現場でのリアルな体験が得られ、VR を体験した小中学生には仮想空間での教育効果という、二重の意味での環境教育効果がある。

1. はじめに

筆者の所属する北海道大学科学技術コミュニケーション教育研究部門(CoSTEP・コーステップ)メディアデザイン実習は、2017 年 10 月 15 日にバーチャルリアリティ(VR)技術を活用した湖沼環境教育イベント「没入!バーチャル支笏湖ワールド」を、札幌市青少年科学館で小学 2 年生から中学 3 年生までを対象に実施した。

実習に所属する学生 7 名(大学院生 4 名、学部生 3 名)が主体となって、活動の一環としてイベントを企画、実施した。支笏湖の自然を伝える平面のハイビジョン映像を1本、会場での常時上映用として制作した。またゴーグルを装着して体験する VR 映像 2 本(地形編と生物編)に関しては、筆者が撮影、編集した。なおこの VR 映像(生物編)は 2018 年 1 月に朝日新聞社が主催する朝日 VR アワードの自然部門賞を受賞した[1]。

近年、インターネット動画サイトの普及や撮影機材の低価格化、軽量化によって、アマチュアにも映像制作の可能性が広がっている。また映像は動き、音、文字などの組み合わせによって一瞬で本質を受け手に伝えることができるという特質があり、水中環境のプレゼンテーションに適している[2]。中でも VR 映像は没入感と臨場感において通常の平面映像では得られない効果がある。

2. イベントの概要

北海道千歳市の西端、支笏洞爺国立公園に位置する支笏湖に潜って水中環境及び生物の生息状況の観察と撮影を行った。専門のインストラクターと筆者が学生らに水中撮影を指導した(筆者は元科学番組のディレクターであり、水中撮影の経験がある)。イベントの流れは表 1 に、イベントポスターは図 1、会場の様子は図 2 に示した。

当日は全体で 30 分のイベントを入れ替え制で 4 回繰り返して実施し、あわせて 43 名の小中学生(うち 91%が小学生)が来場した。参加者は支笏湖の環境に関するクイズや VR 映像などを通して、地形や生物相、外来種問題について学んだ。VR 映像を視聴する中で、流木や湧き水、ハゼ、ウチダザリガニといった対象物を探して、イラスト化したシールをシートに貼るというワークを行った。

こうしたプレゼンテーション、クイズ、VR 映像の視聴、シールシートのワークといった作業を通して、以下の内容について来場者に理解してもらうことを目標とした。

表 1 「没入!バーチャル支笏湖ワールド」の流れ

No.	項目	時間
1	注意事項と概要紹介	1:30
2	「支笏湖探検隊長」役のプレゼンターより、クイズを交えた透明度、地形の解説	5:00
3	没入タイム～VR1. 地形編～	5:30
4	シールシートのワーク 1	2:00
5	「支笏湖探検隊長」役のプレゼンターより、生物、外来種問題に関する解説	3:30
6	没入タイム～VR2. 生物編～	5:30
7	シールシートのワーク 2	2:00
	計	25:00

(1) 支笏湖に特有な水の透明性と、その地形的要因

(2) 外来種の生息状況、在来種への影響

(3) 文化資源、観光資源としての支笏湖の価値



図 1　学生が作ったイベントポスター



図 2　イベントの様子

3.　VR 映像化しやすい環境とは

VR 技術は仮想空間における疑似体験を得ることできるため、様々な教育現場への活用が始まっている [3]。湖沼は身近な環境ではあるが、水温の低さやダイビングスポットの少なさ等から、小中学生が実際に水中を見ることは容易ではない。特に支笏湖は水温も低く 8 月の最高値でも 20 度ほど、平均水深は 265.4m もあり、地形的に切れ落ちていて子供では潜水できない場所もある。

しかし逆に、こうした環境では VR 技術の体験価値は高い。実体験が困難な場所として水中の他に、高山地帯、冬山、数百～数千mの上空、人を寄せ付けない断崖などの地形があげられる。現場に行くことが難しい場合では、特に VR 技術は環境教育に有効である。

VR 用の全天球映収録に Nikon の KeyMission 360 を使用した。平面映像の収録には、GoPro のウェアラブルカメラ HERO4、SONY の HDR-GW66V を使用した。図 3 に制作した映像の一部を示す。

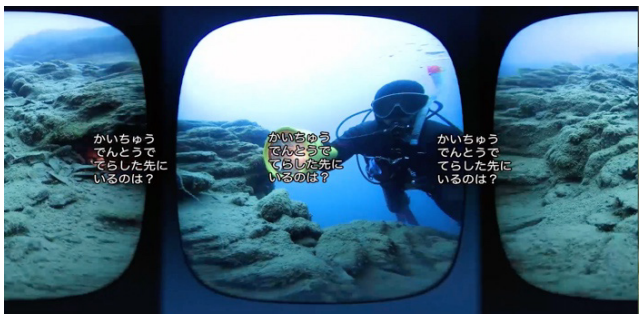

図 3　VR 映像（VR ゴーグルで見ると立体的に見える）

4.　能動性を引き出す仕掛け

VR 映像を使う上で重要なポイントとなるのが、体験者の能動性をいかに引き出すかというイベント全体の設計である。博物館、ビジターセンターに常設されている平面の映像も、来場者が興味を持って足を止めてもらう意味では効果がある。しかし、VR の場合はゴーグルを使って完全に、仮想世界に没入してもらうため、ある種の強い動機づけが必要となる。

VR では身体を動かすことで視点方向を変えることができるため、360 度空間全体を見渡してみて初めて没入感や参加感が得られることが特徴である。そこで図 4 のように参加者の小中学生がゴーグルをつけた際に、視聴範囲内で湧き水や魚、ザリガニといった対象物を探すように学生から指示を出した。こうして、何かを探すというアクションを入れることで集中力を高めてもらった。

こちらの意図が伝わるように、支笏湖の環境をイラスト化したシールシート（図 5）を学生が作成し、6つの対象物を探して、見つかった場合にそこにシールを貼るというワークを取り入れた。これによって子供たちは首を回して対象物を見つけようとする結果、VR の世界に没入することになる。こうしたゲーム性によって子供たちの能動性を引き出せることが分かる。

また VR ゴーグルを装着している時、視聴者が現在、観察範囲のどこに位置しているのかが分からなくなり混乱することがある。この位置関係をイラスト化したシールシート（図 5）に常に立ち返ることで、参加者が観察空間の位置関係を理解する手助けとなる。

とはいえ湧き水や流木、足元でじっとしている魚程度なら探すのは容易であるが、岩陰に隠れているウチダザリガニや深い場所にいるアメマスなどは探し出すのは難しく、大学生、院生らがテストしたときでもほとんど見つけられなかった。そこで、見つけるのが難しい対象物に関しては、図 3 のように文字テロップで適切に視線を誘導することが重要である。文字は全天球映像であることを考慮して 3 箇所くらいに入れておけばまず見落とすこと

はない。ただ文字の位置や大きさ等はいったん画面上に入れてみて、動画ファイルに書き出し、ゴーグルを装着して確認するという作業が繰り返し必要となる。

このように VR の編集は、多視点に対応する必要があるため、通常の平面映像の編集よりかなり手間がかかる。全体の動画構成はシンプルにすることがポイントである。



図 4 ゴーグルをつけ視線方向の映像を見る参加者



図 5 支笏湖の環境を表現したシールシート

5. VR 環境教育イベントへの評価

小学 2 年生から中学 3 年生まで参加者 43 名のうち 39 名からアンケートの回答を得た。イベントに参加しようと思ったきっかけ（複数回答可）としては「VR を体験してみたかった」（32%）が最多で、「支笏湖を知りたかった」（3%）より圧倒的に多かった。しかし自由記述欄には「VR を体験して支笏湖に行きたくなりました」「ウチダザリガニが凶暴だということがわかった」「わきみずを見てもっと調べたいと思った！」「湖にもともといた生物はどうやってきたのかきになった」といった様々な意見が出た。VR 技術そのものが入り口となって、支笏湖の環境についても強く興味を持ってもらえたことが分かる。

また参加した感想として「VR の科学イベントにまた参加したい」（66%）「もっと VR を体験してみたくなった」（46%）「実際に支笏湖に行ってみたくなった」（29%）「実際に支笏湖でダイビングしてみたくなった」（26%）といった意見が上位に上がった。VR 技術への関心とともに、支笏湖そのものへの関心もあわせて高まっていることが伺える。実際に自分でもダイビングをしてみたいといった意見からは、VR 映像が実体験に踏み出す重要なステップになり得ることを示唆している。

6. VR 技術の教育効果に関する考察

VR コンテンツの作成において、参加者の能動性を引き出すためには「人々が対象物を探す動機づけ」「観察空間の位置関係の理解」「視線を誘導するためのテロップ配置」という 3 点が重要であることが分かった。こうした仕掛けによって、それまで支笏湖に興味が無かった子供たちの興味や関心を引き出すことができた。こうした結果から、VR 技術は、湖沼における環境教育に非常に有効だったと考える。

このイベントを通して、北海道大学 CoSTEP の大学生、大学院生らも実際に支笏湖でダイビングを行い、ビジターセンターを見学するなどしてリアルな経験を積んだ。学生らは「今回の撮影を通して支笏湖の地形や生物環境に対してとても興味がわいた」と述べており、作り手である学生自身への環境教育の効果もあったといえる。

このようにバーチャルなコンテンツを制作する過程で得られるリアルな体験は、大学生や院生にとっても非常に貴重なフィールド経験となる。アマチュアでも扱えるようなアクションカメラが増えてきたことで、VR 技術は「体験する」だけでなく、「作る」という行為も教育に応用できる時代となった。今後も、VR 技術によって「作る」「体験する」という2つの教育要素をうまく生かした自然環境教育を行っていきたい。

謝辞

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O8-23

「印旛沼学習」 －印旛沼のふるさと 船穂の里山－

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キーワード：カリキュラム開発, 里山保全, 意識啓発

抄録

千葉県の印西市立船穂小学校は明治 6 年創立の歴史のある小学校で，隣接した千葉ニュータウンとは対照的な農村地域の児童数 50 名前後の小規模校である。校歌に歌い込まれているほど印旛沼とは関係が深かったが，干拓で沼が小さくなったため，船穂地区は沼から距離的に遠ざかるとともに，住民の暮らしや意識も沼から離れてしまった。そこで「印旛沼のふるさと 船穂の里山」を統一テーマとした環境学習を実施し，水源涵養の場として今でも印旛沼と深くつながっていることを学んだ。子供たちは，地元のお年寄りなどに昔の暮らしの話や伝説を聞く，校外学習で湧水を自分の眼で確かめる等，体感しながら学び，学習の成果は「ふなほまつり」（文化祭）で地域の方たちの前で発表した。子供たちはこの学習により，印旛沼をより身近に感じるとともに，「印旛沼のふるさと」である地元に誇りを持つようになった。また，地域と学校との結びつきがより深まった。

1. はじめに

千葉県の代表的な湖沼である印旛沼は，涵養域が台地という非常に開発しやすい地形的特殊性をもつ。このため富栄養化が進行し，水質（COD）は非常に悪化している。2000 年度に立ち上げられた印旛沼流域水循環健全化会議[1] では，直接的な水質改善対策だけでなく，幅広い見地から，多くの主体がそれぞれの視点で印旛沼流域の水循環・水環境をより良くするために活動している。

健全化会議の中では現在 8 つのワーキンググループ（WG）が活動しているが，その 1 つである「学び WG」では，2005 年度から流域内の小中学校の中からモデル校を指定して，3 年間にわたり講師派遣や校外学習の支援をしながら環境学習（印旛沼学習）を行っている。

ここでは，2015～2017 年度にモデル校となった印西市立船穂小学校において実施した印旛沼学習の概要について報告する。

船穂小学校は明治 6 年（1873 年）に創立された歴史のある小学校で，隣接した千葉ニュータウンと対照的な農村地域の児童数 52 名（2018 年度 4 月現在）の小規模校である。当初の校舎は沼を見下ろす高台に位置し，校歌にも「沼」や「森」，「水鳥」などが歌い込まれているが，1969 年に竣工した印旛沼総合開発による干拓で沼が小さくなったため，沼から距離的に遠ざかるとともに，住民の暮らし・意識も沼から離れてしまった。

船穂小学校の学区の一部である結縁寺地区は「にほんの里 100 選」[2]にも選ばれた豊かな里山であり，歴史や文化の多く残る地であるが，子供たちもその親の世代も隣接した千葉ニュータウンの高層マンション群や大規模商店街に，とかく目が行きがちである。

そこで，印旛沼学習のテーマとして「印旛沼のふるさと 船穂の里山」を取り上げた環境学習プログラムを構築・実施し，船穂の里山が古くからの豊かな土地で、水源涵養の場として今でも船穂地区が印旛沼と深くつながっていることを気づくための一助とした。

2. 印旛沼学習プログラムの構築

印旛沼学習の対象は 3，4 年生，総合的な学習の時間を使って実施することとし，学校の教員の方たちと協働で，4 段階に分けて組み立てた。

(1) 見出す段階：

・里山ってどんなところだろうか？
　⇒人が住んでいた。山（森，木）もある。
・里山から何が得られる？
・里山には水がある。・・・⇒印旛沼

(2) 調べる段階：

・地図の土地利用の色分けから，この地区には谷津が多く，そこには水田が広がっていることを知る。
　⇒なぜ水田が多いのだろうか？
・地域の湧き水や井戸の位置について調べる。
・湧き水や井戸のお宅に伺って，実際に湧き水を観

察するとともに，そのお宅の人に質問して調べる。（湧き水の用途，昔と今の湧出状況，湧水にまつわる伝説等など）

・地域のお年寄りに，昔の農業や沼での漁業の話，沼とつながった暮らしの話などをお聞き（取材）する。

(3) 深める段階

・調べたこと，取材して分かったことを整理し，さら自分たちの「知りたいこと」について，調査，踏査，取材を行う。

・その中から「ふなほまつり」で発表するための内容を検討して，まとめる。

・掲示物や説明文を作ることにより，調べたことを咀嚼して理解する。

(4) 表す段階

・毎年秋に開催する文化祭である「ふなほまつり」で，掲示物，スライド，紙芝居等を使って，学習したことを在校生や地域の方たちの前で発表する。

これらの一連の学習のうち，3 年生では主に里山と水の関係について学び，船穂の里山が印旛沼の水源地（ふるさと）となっていることを知った。また，4 年生では主に聞き取りによる学習により，稲作や（昔の）漁業について，また水害の歴史や伝説などについて学び，昔の人々と印旛沼との深い関わりについて知ることができた。

上記 4 段階のうち，外部講師としての筆者は 3 年生の(1)の導入の部分について担当し，Google Earth や昔と現在の印旛沼の地図を使って，船穂地区と印旛沼の位置関係を明示した。そして子供たちの考える「昔の人々が里山から得る恵み」を補足しながら，里山の持つ生態系サービスについて言及した。様々な生態系サービスの中で，「水」に注目し，印旛沼と船穂の里山の関係につなげた。

さらに，スポンジを使った保水能力の簡単な実験を行うことにより，コンクリートで被覆された地面と樹木の生えた里山との大きな違いを体感してもらうことができた。

この導入部に引き続く授業は担任の先生にお任せし，地元の人材や自然・文化を活用した地域ぐるみの印旛沼学習が行われている。

3. 実施とその成果

成果は，毎年秋に開催する「ふなほまつり」で，家族＝地元住民に発表する形でまとめ上げた。小規模校の良さで，まさに全員が主役の発表会である。参加者のほうも，おじいちゃん，おばあちゃんを含めた家族総出で楽しんだイベントである。

子供たちはこの学習により，印旛沼をより身近に感じるとともに，「印旛沼のふるさと」である地元に誇りを持つようになったと考えられる。

これらの成果は，地元住民，すなわち地域全体と小学校との結びつきも強めることに働き，学校の統廃合が進む中において，地元の伝統ある小学校の存続の必要性をアピールする良い機会にもなっている。

4. 終わりに

以上のように，3 年間のモデル校実施期間において，船穂地区という地域特性を活かした環境教育プログラムを構築することができた。本プログラムは子供たちの自主的な意思に基づく調べ学習であるが、とかくありがちな，web 情報やむずかしい書籍・資料を未消化のままに丸写しするのではなく，地に足の着いた真の Active Learning になっていると自認している。

船穂小学校で行われたモデル校としての印旛沼学習は 2017 年度で終了したが，その間に学校の総合学習の通常のカリキュラムに組み入れられて，モデル校が終了した今年度も継続して行われている。下級生の中にも，「ふなほまつり」で上級生の印旛沼学習の発表を聴くことによって、次は自分たちが印旛沼のことを学習するのだという漠然とした自覚が芽生えているようである。

印旛沼の里山というすばらしい環境をしっかりと引き継いでいく子供たちに，大いに期待したい。

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O8-24

霞ヶ浦市民協会の受託事業

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キーワード：水辺空間、協働、意識啓発、生活、文化

抄録

1993（平成 5）年9月「世界湖沼会議市民の会」が発足し、第 6 回世界湖沼会議に行政・産業界・研究者・市民の 4 者パートナーシップのもと積極的に参加した。閉会後、世界湖沼会議で採択された「霞ヶ浦宣言」の精神を尊重し「社団法人霞ヶ浦市民協会」を設立、今なお浄化対策が多岐にわたり継続する霞ヶ浦へ人々の関心を高めようと23年間活動を重ねてきた。ここでは市民協会の取り組んできた 1. 霞ヶ浦流入河川一斉水質調査と2. 茨城県霞ケ浦環境科学センター、交流サロン促進事業の2つの受託事業について検証する。受託事業は制約が多く、苦労の多い事業であるが県内外の住民の意識高揚はもちろん、市民協会内では組織強化、会員拡大という目的もある。2 つとも行政に関わる受託事業という点で引き受けるにあたり市民協会内で行政とは「緊張感のある協調関係」を保持しながら持続可能な活動を展開することにした。

1.　はじめに

汚れた霞ヶ浦しか知らない世代が圧倒的に多くなってしまった中で現状を学び　個人としてどう動くかの認識を持ってもらうこと、湖の恩恵に気づいてもらうこと等を目的に 2 つの受託事業にしぼり検証する。

2.　方法、

霞ヶ浦生活関連汚濁水路浄化対策調査の受託

1998（平成 10）年度 11 月 22 日に茨城県より受託した「霞ヶ浦生活関連汚濁水路浄化対策調査」は霞ヶ浦市民協会の実践研究事業担当者が中心になり，霞ヶ浦流入河川 56 本の内、清明川、高橋川、小野川、桜川の 4 河川の水質を調査した。流域の市町村と地元の参加者を募り、250 名の協力を得て実施した。その結果は1999年3月に3会場で「市民による水質調査報告会及びシンポジウム」で茨城県と参加者と情報共有し問題点の改善方法について討議した。

2年目の1999（平成 11）年度も5河川を調査し同じく「市民による水質調査報告会」を開催し2会場で140名の参加があった。

3年目の2000（平成 12）年度は11月23日に潮来町・麻生町の前川、夜越川を中心に5河川・160地点を250名の参加者で調査をした。「ふるさとの川シンポジュウム」を2会場で開催し、170名の参加で開催した。

4年目の2001（平成 13）年度は北浦方面の巴川、山田川、他調査を5河川、9市町村、260名の参加で調査をした。「ふるさとの川シンポジウム」は3会場、350名の参加で開催した。

5年目の2002（平成 14）年度は土浦市内を流れる桜川、備前川、新川を180地点　310名の参加者の協力を得て調査を行い報告会は「みんなの桜川シンポジウム」で180名の参加者で開催された。

霞ヶ浦流域の主な河川を5年かけて調査しその情報の共有と市民参加の中で個々に問題点を考え、参加者より情報を発信していくことに少しずつ手ごたえを感じている。参加者の中には小学生を含む若い世代がたくさん含まれており、3世代にわたり幅広い年齢の交流と啓発が行われたことにこの事業の意義を感じた。



写真 1　採水の様子

2003（平成 15）年度より事業主体が茨城県から霞ヶ浦の流域市町村で組織されている霞ヶ浦問題協議会に移ったが、続けて霞ヶ浦市民協会が受託した。名称も「霞ヶ浦流入河川一斉水質調査」に代わり、10月25日に恋瀬川水系を399地点で調査した。水質の分析も霞ヶ浦市民協会の研究室が中心となり昨年の2017（平成

29)年度まで調査結果解析報告書を作成し提出、継続している。

特質すべきはこの市民による水質調査をきっかけに霞ヶ浦の流入河川の4本(巴川、桜川、恋瀬川、小野川)でそれぞれの河川名を冠に探検隊ができた。水質の調査と故郷の河川とその周辺の魅力を探るため茨城県・市町村、市民団体が一体となり活動を開始した。各探検隊は2003(平成平成 15)年より巴川探検隊をはじめ1年ごとに発足した。

調査方法

調査基準日を設ける(降雨後の影響の大きい日は避ける) 採集時間はなるべく午前中に行い、採水地点での現場状況の記録(天候、気温、水温、水のにおい、色、にごり、透視度、汚濁物、川の様子など)

簡易水質検査法(パックテスト)によりCOD、PH、アンモニア態窒素、リン酸態リンの測定を行った。

パックテストによって、1 検体につき 3 回測定し、平均値をとり測定値のばらつきを少なくし、平均化することで真値に近づけた。

調査参加者について

流域住民、各市町村家庭排水浄化推進協議会員、水質監視員、環境保全団体、小学校児童、小学校教員、市町村環境担当課職員、茨城県環境科学センター職員、国土交通省霞ヶ浦河川事務所職員、霞ヶ浦問題協議会職員等 324 名参加(2017 年)



写真 2 パックテストの実施

茨城県霞ケ浦環境科学センター交流サロンの受託

事業受託について

1995(平成 7)年に開催された第 6 回世界湖沼会議において、当時の橋本知事が「国際湖沼環境政策フォーラム」で(仮称) 霞ケ浦環境センターの設立を提唱された。翌年からセンター設立に向け具体的にスタートし、2005(平成 17)年 4 月 22 日に茨城県霞ケ浦環境科学センターがオープンした。センターは環境保全に取り組むため、市民・研究者・企業・行政が手をつなぎあって、調査研究・技術開発、環境学習、市民活動との連携・支援、情報・交流の 4 つの機能を果たすことを担っている。

(一社)霞ヶ浦市民協会は、開館前から市民団体の立場からセンターの在り方、運営等に意見を具申してきた。2006(平成 18)年交流サロン運営の入札に応募し、運営受託した。内容は交流サロンの運営、事業の企画運営と幅広い内容である。2013 (平成 25)年より業務の見直しによりプロポーザルによる応募となり、委託業務の内容も交流サロン交流促進事業業務と事業の企画運営となったが、毎年応募し採用されている。

受託業務の内容

交流サロン交流促進事業業務として、(1)団体間の交流促進のための催事(シンポジウム等)の開催が 2 回、(2)水辺環境に対する関心を深めるための催事の開催が 5 回となっている。2017(平成 29)年度の実施事業として、 (1)のシンポジウムについては、①2018 年1月 13 日(土)に第 17 回世界湖沼会議に向けてシンポジウム「行政、市民から いま伝えたいこと」、②2018 年 3 月 3 に(土)に第 17 回世界湖沼会議に向けてシンポジウム「里浜・里川・里山がつなぐ湖」を開催。2015 年から 3 年間、第 17 回世界湖沼会議に向けてと題し。シンポジウムを開催し、一人でも多くの市民の方々に会議への参加を促し、参加の機運醸成を図る成果をあげることができた。



写真 3 シンポジウム「行政、市民から今伝えたいこと」

(2)の事業として、①2017 年 6 月 3 日(土)センター環境月間に「エコ・グッズづくり」。②8 月 26 日(土)霞ケ浦環

境科学センター夏まつり 2017 に「手作り工作教室」「アクリルたわしづくり教室」。③2018 年 2 月 17 日（土）環境学習フェスタに「どんぐりのおひな様づくり」を開催。いずれも体験型イベントして来場者の多くの方に参加してもらった。④学習型イベントして、「霞ヶ浦水系の歴史と文化」を 8 月 5 日（土）、12 日（土）に座学として開催、⑤バスによる現地見学会として、9 月 9 日（土）、23 日（土）には、座学で学んだ現地を実際に見学した。継続して霞ヶ浦をテーマに取り上げ、好評のシリーズとなっている。



写真4　アクリルたわしつくり教室の開催

今後の事業

2018（平成 30）年シンポジウムについては、第 17 回世界湖沼会議を終えて―その成果と課題を探る―、世代をつなぐ環境学習はどうあるべきか―環境学習の問題点―を取り上げる。これから交流、啓発を通じて次世代を育てること、第 17 回世界湖沼会議後の参加団体の地域交流を図ることをテーマとして取り上げたシンポジウムを開催する。センターイベントに参加する事業についても、マンネリに陥ることなく新規イベントの取組みを図っていく。学習型イベントも霞ヶ浦をテーマにさらに内容を深め、参加者の参加意欲を高める。今後も限られた予算の中で、茨城県霞ケ浦環境科学センターの認知度アップ、来館者の増加につながる事業を取り上げていく。

3.　結果

両事業とも単に環境学習だけでなく多くの住民の交流の中で水辺空間がもたらす多様な暮らしを知ることができる。それは、新たな地域文化を醸成する場づくりともなっている。

4.　考察

無関心であることの問題発生、全てに関わることを知り、学び、どう動くかの啓発を大切にしていく、そのために葉活動に関わる側の自己研鑽が求められる。

5.　結論

各事業を通じて世代間の霞ヶ浦への思いに大きな隔たりがある。その意識をどう繋いでいくか今回の世界湖湖沼会議終了後の課題となる。

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霞ヶ浦流入河川水質調査結果解析　報告書

O8-25

桜川探検隊連絡会議の活動

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キーワード:市民参加、意識啓発, 水辺空間, 協働, 地域づくり

抄録

桜川は長さ 63km、流域面積 350km^2 で、霞ヶ浦に流入する 56 河川の中で最大の河川である。2003（平成 15）年 6 月、桜川流域の子どもたちや住民の水環境への関心を高め、上流から下流に至るまで相互に連携して、桜川流域及び霞ヶ浦の水質浄化に取り組む機運の醸成を図ることを目的に「桜川探検隊連絡会議」が結成された。構成メンバーは、流域の市町村、市民団体、県の出先機関など 23 団体。探検隊の活動は、『探検交流』『水質調査への参加』の二つに大別できる。探検交流は桜川流域への関心を高めることを目的に年 3 回開催、水質調査への参加は水質の状況を把握するため市町村が中心となり年 2 回実施している。子どもたち、多くの住民に参加を促しながら、身近な川である桜川の水質浄化が霞ヶ浦の水質浄化につながることへの理解と、さらなる浄化への意識を高める活動を進めている。

1. 桜川探検隊連絡会議とは

1995（平成7）年に開催された第6回世界湖沼会議で採択された「霞ヶ浦宣言」 を受け、その精神を具体化する取り組みがスタートした。その一つとして、霞ヶ浦への流入河川の代表格である桜川、恋瀬川、巴川、小野川の 4 つの河川それぞれに探検隊連絡会議を置き、流域の子どもや住民が水環境への関心を高めるための取組みを始めた。桜川は、長さ 63 ㎞、流域面積 350 ㎢で、霞ヶ浦（西浦・北浦・常陸利根川）に流入する56河川の中では最大。桜川市北部、岩瀬地区の鍬柄峠付近にある鏡ヶ池に源を発し南へ流れ、土浦市の常磐線桜川鉄橋の下流で霞ヶ浦に注ぐ。昔から舟運や漁業の場、あるいは農業用の水源として重要な役割をはたし、人々に親しまれてきた。2003（平成 15）年 3 月 3 日に流域の行政、市民団体等の関係団体が集まり、桜川探検隊連絡会議設立準備会議が開催され、3 月 25 日につくば市北条市民研究センターで設立総会を開催、参加者の承認を得て桜川探検隊連絡会議が発足した。桜川探検隊連絡会議（略称:桜川探検隊）の目的は、桜川流域並びに霞ヶ浦の水辺、動植物、風土、文化などと直接ふれあうことを通じて、流域の子どもたちや住民の水環境への関心を高め、上流から下流に至るまで相互に連携して桜川流域並びに霞ヶ浦の水質浄化に取り組む機運の醸成にある。

事業活動としては、(1)桜川流域及び霞ヶ浦の水環境に関わる探検・調査・啓発事業 (2)桜川流域及び霞ヶ浦の情報交換に関すること (3)その他、目的を達成するために必要な事業を行う。 構成員は、(1)桜川流域市町村市民団体　(2)桜川流域市町村の企業・産業関係の団体　(3)桜川流域市町村　(4)桜川流域、霞ヶ浦を管轄区域とする行政機関　(5)霞ヶ浦問題協議会　(6)一般社団法人霞ヶ浦市民協会　(7)茨城県生活環境部霞ヶ浦対策課　(8)その他目的に賛同する者とし、幅広く目的に賛同される方をもって構成し、入会・退会も事務局に申し出ればよいという緩やかな団体となっている。設立メンバーは市町村が9、市民団体等が14、県の出先機関等 10 の合計 33 団体だったが、その後の市町村合併等に伴い、現在は市町村4、市民団体 6、県の出先機関等 8 の合計 18 団体となっている。（一社）霞ヶ浦市民協会は当探検隊設立以来、16 年間事務局を務め、探検事業の運営に当たってきた。

2. 探検交流活動について

2003（平成 15）年、桜川探検隊は、運営規約を作成し活動をスタートした。まず探検交流を実施する市町村等を決定。市町村等は、主管する団体を決定し、地元の市民団体の方、市町村の方々を交えて検討す

るとしたが、主管する団体がなかなか見つからず、結局、市町村が主管する形となり、委員長の選任をメンバーの中から行うこととした。実施日の２ヶ月前頃までにメンバーで原案をまとめ、参加市町村、参加団体に配布し､参加者の募集を行った｡そして、実施日の１ヶ月前頃に関係者に呼びかけて現地を下見し、本番での問題点等を話し合った。

2004（平成 16）年度、2005（平成 17）年度まで、運営規約に基づき活動をしてきたが、幾つか問題点が出てきた。その一番の問題は平成の大合併による市町村の合併である。岩瀬町・大和村・真壁町が合併して桜川市に、下館市・明野町が合併して筑西市にと、７市町村が、桜川市・筑西市・つくば市・土浦市の４市に統合された。当初は地元の市民団体が主体となっての運営を想定していたが、想定通りにはならず担当市町村が主体となって運営に関わらざるを得なくなり、負担となってしまった。また、茨城県からの助成金が年々少なくなり、市町村の持ち出しが発生することも起きてきた。そこで 2005 年（平成 17）年総会において協議の上、①第１回探検交流事業は、４市が順番に持ち回りで担当する。すなわち４市とも４年に１回探検交流事業を担当する ②第２回探検交流事業は、(一社) 土浦青年会議所が霞ヶ浦キャンピングスクールとして毎年担当する ③第３回探検交流事業は、(一社) 霞ヶ浦市民協会が毎年担当する、ことに決定し、以降、このやり方で運営している。では、第１回探検交流事業を担当した各市の事業、第２回を担当した土浦青年会議所の事業、第３回を担当した霞ヶ浦市民協会の事業の様子を紹介する。

【第１回探検交流事業】

・2013(平成 25)年８月３日(土)桜川市主管。「桜川の源流を探検しよう」をテーマに、桜川の源流である鏡ヶ池での動植物学習のほか、生葉染め体験などを実施。鏡ヶ池で動植物についての学習を受けたあと、岩瀬中央公民館に移動し、桑の生葉の液汁でハンカチを染める生葉染めを体験した。また、桜川源流、下流、水道水のパックテストを行い、水質調査を体験した。



写真１　桜川市／鏡ヶ池での動植物のお話

・2010(平成 22)年８月 28 日(土)筑西市主管。「ふるさと明野町の歴史を知ろう！」をテーマに、宮山ふるさとふれあい公園を会場に開催。明野町の宮の杜里山を中心とした地勢・歴史の話、平安時代の陰陽師安倍晴明の伝説を聴き、観音川で採水した水をパックテストで水質調査した。また桜川の魚、漁具の説明を受け、住民が昔からいかに桜川の恩恵に預かってきたかを理解した。

・2015(平成 27)年８月３日(月)つくば市主管。「桜川に入って魚たちと遊ぼう」をテーマに、つくば市松塚地先を会場に開催。子どもたちは水着に着替えて投網見学をし、そのあと自由に川に入って水遊びを楽しんだ。漁協で用意してくれたフナの稚魚を放流して川遊びを終了。この会場は桜川で唯一川に入って水遊びのできる場所であり、子どもたちはなかなか川から出ようとしない。昼食タイムでは漁協提供のエビ、雑魚を天婦羅、佃煮にしていただいた。



写真２　つくば市／桜川に入っての水遊び

・2012(平成 24)年 8 月 4 日(土)土浦市主管。「霞ヶ浦湖上を楽しもう！」をテーマに、土浦市川口町のラクスマリーナを会場に開催。アクセスディンギーヨットやカヌーの試乗体験、投網見学をした後、班ごとに分かれてドラゴンボートの競争を楽しんだ。最後にホワイトアイリス号で霞ヶ浦に出て湖上体験スクールに参加した。



写真３　土浦市／霞ヶ浦湖上体験スクール

【第２回探検交流事業】

・2016(平成 28)年 8 月 20 日(土)～21 日(日)土浦青年会議所主管。美浦村の光と風の丘公園のバンガローに 1 泊 2 日で「かすみがうらキャンピングスクール 2016」を開催。ファームイシイでのレンコン掘り体験、同公園での水鉄砲サバゲーを楽しみ、グループに分かれて夕食のカレーを作った。翌日は清掃活動、流しそうめん、夏の映像学習教室、水のクイズ、とプログラムを楽しんだ。



写真４　美浦村／レンコン掘り体験

【第３回探検交流事業】

・2017(平成 29)年 10 年 28 日(土)霞ヶ浦市民協会主管。「霞ヶ浦名産とどんぐり細工を楽しむ」をテーマに開催。㈱出羽屋の佃煮工場（かすみがうら市）を見学し、霞ヶ浦の魚、漁業等について質疑応答。同市加茂のどんぐり山では、どんぐりや落ち葉を集め、霞ケ浦環境科学センターにてどんぐり細工を楽しみ、森の大切さ、霞ヶ浦と森林の関係を学んだ。

３．今後の展開について

桜川探検隊連絡会議も設立 16 年目を迎え、今後の活動を展開していく上で、下記の課題が考えられる。

（１）企画内容のマンネリ化　…桜川流域と考えるとかなり広範囲に考えられるが、意外に探検交流の対象となる場所が少ない。前回開催した内容の焼き直しに過ぎない企画が多い。特に川に入って遊ぶとなると、つくば市松塚の河原しかなく、水に入ることが楽しみな子どもたちを喜ばせられるような場所の確保が求められる。

（２）参加者への広報活動の強化　…参加者数が減っている。参加者が多く集まればいいというものではないが、事業を実施する以上は 50 人以上の参加者が欲しい（スタッフ・講師等を除いて）。従来の市報頼りの募集方法でいいのか、ホームページの活用をどう考えるか、広報活動のあり方、強化も大きな課題である。

（３）資金難への対応　…現在１事業当たりの助成金は三万円である。この金額では講師代だけで終わってしまう可能性があり、不足分は各団体の持ち出しとなる。必要な資金は提供するのが事務局の務めとは思うが、全体予算の枠の中で身動きが取れない。窮状を訴えていくしかないのであろうか。

（４）他探検隊との探検交流の実施　…恋瀬川、巴川、小野川の各探検隊がどのような活動をしているのか、お互いに情報を共有し合い理解する。例えば桜川探検隊が恋瀬川の探検場所を、恋瀬川探検隊は桜川をというように、交互に探検場所を変え、担当者の視野を広げ、参加者に別の視点から学ぶ場を提供する。

今後の展開については、各団体の担当者が集まり検討を進める。桜川探検隊連絡会議の目的である、桜川流域並びに霞ヶ浦の水質浄化に取り組む機運の醸成を図るための努力を、これからも続けたい。

O8-26

地方環境研究所が行う河川環境学習が児童の自然環境に対する意識・理解に与える影響

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キーワード:河川環境学習，イメージマップ，意識・理解

抄録

子どもたちの豊かな人間性の育成や持続可能な社会の実現を目指すために，現在の学校教育の中では，学校内外における自然体験活動の必要性や環境教育・環境学習の重要性が叫ばれている。しかし現実には，学校内では学習の場が確保できない，教師が十分に指導できないなどの問題があったり，学校外では子どもたちの自然体験活動への参加率が年々減少傾向にあったりすることから，環境教育・環境学習の低迷，子どもたちの自然離れや環境意識の低下が懸念されている。そこで今回，地方環境研究所である茨城県霞ケ浦環境科学センターが学校と連携して河川を対象とした環境学習を行うことで，教師の負担を減らすだけでなく，児童の自然環境に対する意識・理解にどの様な影響があるのかを学習前と学習後に行った質問紙調査とイメージマップの結果から分析したところ，学習後に児童の調査河川に対する興味・関心や有用感の向上，知識の増加，理解の深まりが見られたため，その結果と考察について報告する。

1. はじめに

社会的な変化が激しい昨今，子どもたちに豊かな人間性や社会性などを培っていく必要があることから，社会奉仕体験活動や自然体験活動を始めとする，各種体験活動の場を提供していくことが求められている。その中で，自然体験活動について焦点をあて見ていくと，学校教育においては，平成 19 年に改正された学校教育法第21条の二の中に「学校内外における自然体験活動を促進し，生命及び自然を尊重する精神並びに環境の保全に寄与する態度を養うこと。」という目標が掲げられており，学校だけでなく，家庭・地域・企業・行政が互いに連携し合い，様々な機会において子どもたちに自然体験活動を行わせていくことの必要性や環境教育・環境学習を意識した活動の重要性が示されている。

しかし，内閣府が作成している平成 29 年度版「子供・若者白書」[1]によれば，児童の学校以外の団体などが行う自然体験活動への参加率は年々減少傾向にあり，独立行政法人国立青少年振興機構が平成26年度に調査した「青少年の体験活動等に関する実態調査」[2]においても，学校の授業や行事以外での「昆虫や水辺の生物を捕まえる」「植物や岩石を観察したり調べたりする」といった自然体験活動を何度も行ったことがある児童の割合は低いことから，子どもたちが自然と接する機会はまだまだ少ない状況にあることが分かる。

また，国立環境研究所が平成 16 年に行った，小中学校の教職員を対象にした「環境教育・環境学習の推進に関するアンケート調査」[3]では，環境教育・環境学習に取り組むときの問題点として，「時間の確保が困難である」「適当な教材が少ない」「取り組み方法が分からない」などがあげられていることから，現在においても学校で環境教育・環境学習の充実を図っていくには多くの課題があると思われる。

こうした子どもたちの自然との関わりの希薄化や環境教育・環境学習が低迷している状況は，地域の自然や生き物への関心，理解，愛着，更には環境問題に対する危機意識や保全意識の低下を招く恐れがある。

そこで，地方環境研究所である茨城県霞ケ浦環境科学センター（以下，「センター」と記す）が学校と連携し，多様な自然体験活動の機会を提供したり，自然環境に対する専門性を持った職員が学習を行ったりすることで，教員の負担を減らし，尚且つ，子どもたちの自然環境に対する意識を高めたり，理解を深めたりすることができればと考え，今回は河川環境学習を通しての児童の自然環境に対する意識・理解に与える影響について調査した。

2. 方法

実施対象は，2017 年 12 月 12 日～15 日，19 日の5日間に分けて河川環境学習を行った茨城県内にあるA

小学校の5年生児童（5クラス 147 名）である。実施内容は学習前と学習後に，調査河川についての質問紙調査とイメージマップ作成を行った。

3. 学習の実際

学校や家庭における安全指導の影響などから，川に行った経験がある児童は意外に少ない。そこで，センターが行う河川環境学習では，「自然に親しむ」「川を多面的に捉える」「川と私たちとのつながりを考える」「知識と体験を結び付ける」ことなどを意識して実施している。そのため，調査場所については可能な限り上流域，中流域，下流（河口）域の3か所を辿れるようにしたり，調査内容については環境省が作成した「水辺のすこやかさ指標」をセンター用にアレンジしたものを共通して行う活動にしたりし，河川環境の変化を比較しやすくしている。

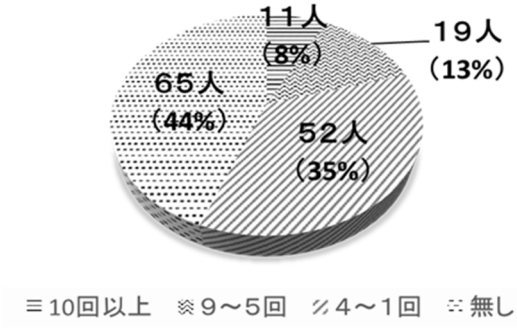
また，それ以外にも学校の要望や調査場所の特徴に応じて，生き物や自然の観察を行ったり，川と関わりが深い人の話を聞いたり，できるだけ多様な活動を取り入れている。

今回の河川環境学習では，連携する学校の学区近くを流れる河川の中で、桜川市北部に源を発し，土浦市で霞ヶ浦に流入する一級河川の桜川を対象とした。

4. 結果

(1) 質問紙調査

図 1 は学習前の桜川に行った回数と主な目的についての設問の結果である。これによると，学区の近くを流れる大きな川であるにもかかわらず，一度も行った経験が無い児童が 65 人（44%）もいた。一方，10 回以上行ったことがある児童はわずか 11 人(8%)であった。これまでに桜川へ行った経験のある児童の主な目的としては，景色を見る，花火大会，釣りなどであった。



＜主な目的＞※複数回答可
・景色を見る 43 人 ・花火大会 28 人
・魚釣り 12 人 ・散歩 10 人 ・花見 6 人 等

図 1 今までに桜川に行った回数と主な目的

また，表1は学習後の河川環境学習や桜川に対する興味・関心を問う設問の結果である。参加した児童の多くが，今回の学習を「とても楽しかった」「どちらかといえば楽しかった」と感じていたり，「桜川にまた行ってみたい」「桜川について，いろいろ調べてみたい」と思っていたりすることが分かった。

更に，「桜川は私たちの生活に役立っていると思うか」という有用感を問う設問では，表2のように学習後に「とても役立っている」と答えた児童の人数が大きく増加していた。

表1 河川環境学習や桜川に対する興味・関心

	とてもそう思う	どちらかといえばそう思う	どちらかといえばそう思わない	思わない
桜川の学習は楽しかったか	141人	4人	0人	0人
桜川にまた行ってみたいと思うか	113人	30人	2人	0人
桜川についていろいろ調べてみたいと思うか	80人	59人	4人	2人

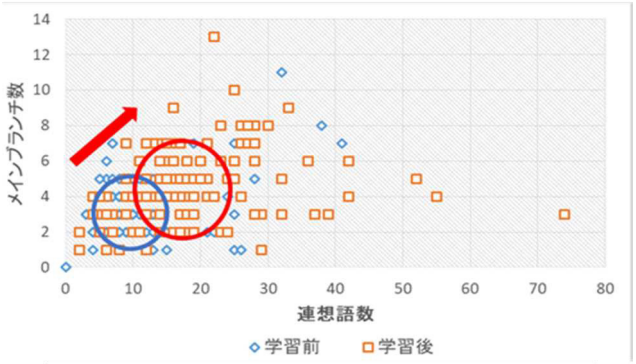
	たくさん話をした	少し話をした	話をしていない
帰ってから桜川についてお家の人と話したか	70人	71人	4人

表2 桜川に対する有用感

	とても役立っている	どちらかといえば役立っている	どちらかといえば役立っていない	役立っていない
学習前	64人	76人	4人	3人
学習後	108人	36人	1人	0人

(2) イメージマップ

図2は学習前と学習後に作成した桜川のイメージマップに記述された連想語数と主題から出ている一階層目のブランチ（メインブランチ）数を表したものである。学習前は連想語数もメインブランチ数も少ない児童が多かったが，学習後は両方とも増加していた。



	連想語数の平均	メインブランチ数の平均
学習前	11.0語	3.2本
学習後	17.4語	4.3本

図2 連想語数とメインブランチ数の変化

そして，図3は桜川の自然環境に関する連想語を書いた児童数を表したものである。学習後に水の状態や既習事項である5年生理科「流れる水のはたらき」に関する内容の言葉が特に多くなっていた。

更に，図4のように学習後の連想語のつながりは，縦方向だけでなく横方向にもブランチの分岐が増え，より複雑化している児童が多くなっていた。

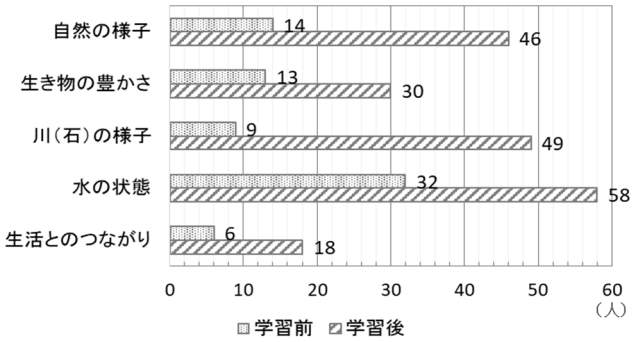
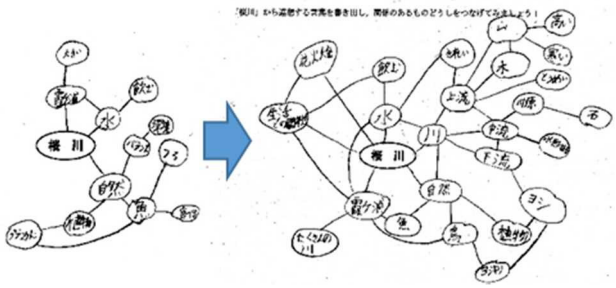


図3　桜川の自然環境に関する連想語を書いた児童数



学習前
分岐数の平均 4.9 回

学習後
分岐数の平均 9.6 回

図4　学習前後のイメージマップの変化

5. 考察

(1) 児童の意識の変化

学習後の質問紙調査で，95％以上の児童の興味・関心に関わる評価が高かったことから，河川環境学習は，自然環境への興味・関心を維持したり，高めたりするのに有効であったと考えられる。そして，このような自然体験活動は，継続的に実施していくことで更に効果が上がるものである。その機会を増やすためには，当然家庭の協力も必要になってくるが，今回の調査では，参加児童の約半数が桜川について「お家の人にたくさん話した」と回答していることから，児童の興味・関心を高めるような体験活動を工夫することで，子どもが親に「連れて行って」と頼む場面や，親が子どもに「一緒に行ってみよう」「○○が今度あるから参加してみたら」と誘ったり，促したりする場面も期待できると考える。

また，学習後に桜川に対する有用感が高まった理由としては，憩いの場としてや何となく役立っていると感じていただけの児童が，河川環境学習で川を上流から河口付近まで辿ったことで，水道水に使われている霞ヶ浦の水の一部が桜川の水であったことを意識したり，中流にある堰で貯められた水が昔から田畑の水に利用されていることや桜川が育んだ水生植物が水の浄化に役立っていることなどを新たに知ったりし，生活の基盤としての桜川の恩恵を感じることができたことが大きかったと考えられる。

(2) 児童の理解の変化

児童は，これまでの学習経験や生活経験から桜川についてある程度の知識・理解があると考えられる。ところが学習前のイメージマップに書かれた連想語を見ると，既習事項と関わる内容が少なく，言葉の分野的広がりもあまり無かった。この傾向は，これまで桜川に 10 回以上行ったことがあると回答した児童でも同様であった。このことから，既有の知識やその場所を訪れた回数が，直接自然環境の理解に結びつくとは限らないと言える。

また，今回児童が書いたイメージマップにおいて「連想語数は知識の量」「メインブランチ数は視点の広がり」「分岐数は理解の深まり」を表していると考えられるため，河川環境学習後は多くの児童が桜川に関する知識を増やしたり，理解を深めたりすることができたと言える。そこで，少ない体験であっても新たな見方や考え方を与えたり，多様な自然体験活動をさせたりすることで，自然環境を多面的に捉えたり，知識を「実感を伴った理解」へと変えたり，様々な知識を相互に関連付けて捉えたりすることができるようになると考える。

6. 結論

学校とセンターが連携し行う自然体験活動は，教師の負担を軽減するだけでなく，児童の自然環境に対する意識や理解に影響を与える効果があった。そして，多様な自然体験活動の機会は，教科書では学べない多くの気づきを児童にもたらすことも分かった。

今後も原体験の少ない現在の子どもたちに，自然体験活動の機会を提供できるよう，多くの学校と連携を図る努力をしていきたい。

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O8-27

地域対話が河川流域住民の水環境に対する意識に与える影響

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抄　録

平成 23 年 3 月の東京電力 (株) 福島第一原子力発電所事故以降，福島県民の水環境への関心の低下が課題となっている。今回，福島県いわき市を流れる 2 つの河川流域をモデルとして，各河川流域の住民等を対象者とした水環境に関するワークショップを実施した。また，その前後にワークショップ参加者に対し，「イメージ」，「良さ」等に関するアンケートを 5 件法で尋ね，前後を比較することにより，参加者の意識に与える影響を検証した。その結果，ワークショップ前後で参加者が河川に対して抱く意識に良好な変化が見られた。これは，様々な利害関係者が集い，話合うことによって，改めて身近な河川環境について様々な視点や考え方等を共有し，再認識すること等によってもたらされた効果と考えられる。河川に対する関心の高さや上下流域の区分けに関わらず，地域対話の場に参加してもらうことが，水環境に対する意識の向上に繋がるものと期待される。

1. はじめに

平成 23 年 3 月の東京電力　(株) 福島第一原子力発電所事故　(以下「事故」という。) 以降，福島県では，事故以前は日本一であった水生生物調査の参加者数が回復していない等，県民の水環境に対する関心の低下が課題となっている。

これに対し福島県では，「福島県水環境保全基本計画 (平成 25 年 3 月) 」等において，水を介した地域交流の推進等の施策を展開している。これら施策をより一層効果的に進め，地域の水環境に対する意識の高まりや自主的な環境保全活動等の取組みに繋げていくためには，水に関する地域住民の意識を把握するとともに，水を介した地域交流がもたらす効果の検証，さらには検証結果を踏まえた行政の支援のあり方を検討することが必要であると考えられる。

そこで今回，県内の 2 つの河川流域をモデルとして，各河川流域の住民等を対象者とした水環境に関するワークショップを実施し，その前後に対象者に対してアンケート調査を行うことにより，地域対話が河川流域住民の意識に与える影響を検証した。

2. 方法

(1) 対象河川

夏井川水系新川及び好間川を対象とした。両河川ともにいわき市を主流域としている (図 1) 。

(2) 対象者

各河川流域の住民又は各河川流域で地域活動を実践している団体等の関係者から 16 名 (新川) 及び 17 名 (好間川) を対象者とした。後述のアンケートから，対象者の性別構成は両河川ともに男性の方が多く，年齢構成は新川に比べて好間川で高かった (表 1) 。また，河川の利用頻度は両河川ともに週 1 回以上が 7 割程度を占め，その目的はウォーキングや通勤・通学等の活動が 6 割程度を占めていた。

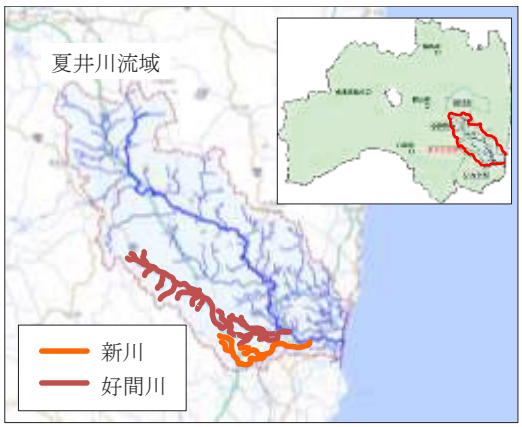

図 1　夏井川水系新川及び好間川の位置図

表 1　対象者の性別及び年齢構成

		新川		好間川	
		人数	割合	人数	割合
性別	男性	11	69%	13	76%
	女性	5	31%	4	24%
年齢	30 代以下	1 (0)	6%	1 (0)	6%
	40 代	5 (1)	31%	1 (0)	6%
	50 代	2 (0)	13%	7 (2)	41%
	60 代	4 (2)	25%	5 (2)	29%
	70 代以上	4 (2)	25%	3 (0)	18%

※年齢のカッコ内の人数は女性の人数 (内数)

(3) ワークショップ

平成 29 年 9 月に新川及び好間川の各流域において，河川流域の対象者を参加者とした水環境に関するワークショップを開催した。ワークショップは参加者を 4〜5 名ずつ 3〜4 グループに分け，はじめに河川の「魅力と課題」をテーマとしてグループで話合い，意見をまとめた。各グループ代表者がまとめた内容を発表し，参加者全体で共有した。次に，「地域で関心を高めるための取組み」をテーマとして同様の流れで話合い等を行った。最後にファシリテーターが全体を総括した。




図 2 ワークショップの様子

(4) アンケート

地域対話による意識の変化を調査するため，ワークショップ前後に対象者に対して，対象者の属性 (年齢層，職業，居住地等) のほか，各河川流域の「利用頻度」，「利用目的」，「イメージ」，「良さ」及び「地域で必要な取組み」に関するアンケートを行った。アンケートは既往調査 [1] を参考に設問内容を設定し，設問内容に応じて選択式 (単一又は複数) 及び自由記述の回答方法を採用した (表 2) 。集計にあたって，イメージ，良さ及び地域で必要な活動の設問については，「そう思う」，「ややそう思う」，「どちらともいえない」，「あまり思わない」，「思わない」の 5 件法で尋ねているが，各設問の回答を「そう思う」から「思わない」の順に 5 点から 1 点と評点し，その合計を回答者数 (対象者数) で割って平均点を算出し，評価した。

3. 結果

(1) ワークショップ

ア　魅力と課題

新川のワークショップにおいては，「魅力」として，ホタルが生息している等の「豊かな自然」，散策路が整備されている等の「空間利用」及び石炭との関わり等の「歴史・文化」に関する意見が上位を占めた。また「課題」としては，川に植生が繁茂している等の「豊かな自然」，水質が悪いイメージがある等の「水質・水量」及び河川氾濫の不安等の「安全性・治水」に関する意見が上位を占めた。他方，好間川のワークショップにおいては，「魅力」として，水質が良好である等の「水質・水量」，多様な生き物が生息している等の「豊かな自然」及び川を身近に感じる等の「親水性」に関する意見が上位を占めた。また「課題」としては，雑草の繁茂等の「豊かな自然」，洪水時の土砂堆積への不安等の「安全性・治水」及び水量が減った等の「水質・水量」に関する意見が上位を占めた。

イ　地域で関心を高めるための取組み

新川のワークショップにおいては，歴史や自然等に関するブランディング戦略，魅力を発信するマップ作成等の「地域振興」に関する意見が上位を占めたほか，新川の魅力や基礎知識の学習を行う等の「講座」，笹舟競争等の「川を利用した体験」に関する意見があった。他方，好間川のワークショップにおいては，桜並木の整備等の「整備」，源流探検やマラソン大会等の「ウォーキング等，運動」，芋煮会やバーベキュー等の「地域振興」に関する意見が上位を占めた。

(2)　アンケート

ワークショップ前後に行った、河川に対するアンケート結果の一例として、「イメージ」、「良さ」及び

表 2 アンケート設問の構成（属性を除く）

分類	設問概要	回答方法	事前※	事後※
利用頻度	−	選択式 (単一)	○	
利用目的	−	選択式 (複数)	○	
イメージ	水環境のきれいさ／ごみ量／豊かな自然／身近さ／利便性／安全／水量／歴史・文化／過去との比較／若者の集い	選択式 (単一)	○	○
良さ	安全な水の提供／自然災害の緩和／生き物の生息環境の提供／自然との触合いの場の提供／地域住民の交流の場の提供／歴史や文化の実感	選択式 (単一)	○	○
良さや課題	自由回答	自由記述	○	○
地域で必要な取組	水質や水生生物調査等の活動／河川美化活動／水辺の観察会等の活動／川について学ぶ活動／意見交換や地域交流を行う活動／水源地を守る活動	選択式 (単一)	○	○
	自由回答	自由記述	○	○

※事前及び事後アンケートにおける設問項目

「地域で必要な取組」に関する項目の新川流域を対象とした調査結果を図 3，図 4 及び図 5 に示す。ワークショップ前後で対象者が抱く各河川に対する意識に良好な変化が見られた。まず，「イメージ」及び「良さ」について，新川では，「きれいな水環境である」，「安全な飲み水等の提供」及び「歴史や文化を感じることができる」の項目においてワークショップ前後の平均点が有意に上昇していた。好間川では，「豊かな自然を感じる」，「歴史・文化を感じる」，「若い人たちが集う」，「安全な飲み水等の提供」，「地域住民の交流の場の提供」及び「歴史や文化を感じることができる」の項目においてワークショップ前後の平均点が有意に上昇していた。また，「地域で必要な取組」に関するアンケート結果においても，特に好間川で「水について意見交換や地域交流を行う活動」がワークショップ前後の平均点が有意に上昇していたほか，両河川のワークショップに対する感想においても，「改めて河川を見つめ直す機会となった。」，「自分では気づけない良いところをたくさん知った。」といった意見が多く寄せられていた。

4. まとめ

今回，2 つの河川をモデルとしたワークショップを実施し，その前後の意識の変化をアンケート調査した。その結果，流域住民の河川に対する意識に良好な変化をもたらした。これは様々な利害関係者が集い，話合うことによって，改めて身近な河川環境について様々な視点や考え方等を共有し，再認識すること等によってもたらされた効果と考えられる。今回のワークショップは，これまで積極的に河川と関わりのある方だけでなく普段は身近な河川を意識せず利用している方も対象としたこと，河川を流域全体として捉えて広域的に参加者を集めたこと，さらには各地域の核となる代表者の多くを対象としたことに意義がある。河川に対する関心の高さや上下流域の区分けに関わらず，地域対話の場に参加してもらうことが重要であり，さらには，地域の核となる利害関係者の参加が，水環境に対する意識の地域全体への広がりや主体的な活動に繋がるものと期待される。

謝辞

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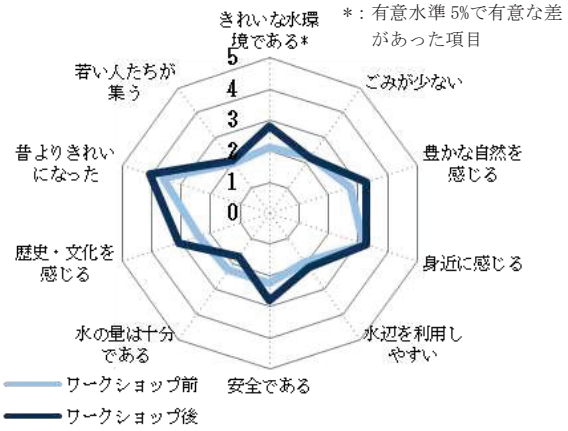

図 3 ワークショップ前後の河川に対するイメージの平均点比較 (新川流域)

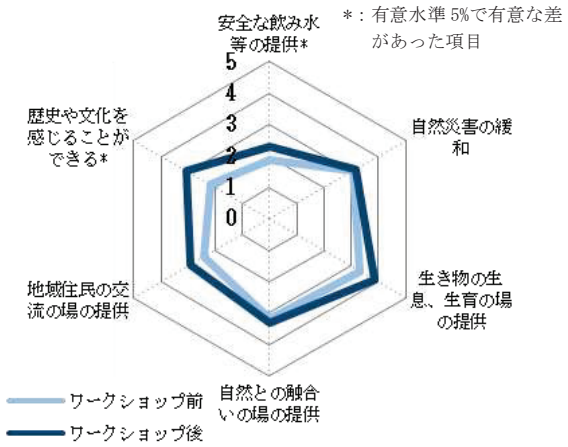

図 4 ワークショップ前後の河川に対する良さの平均点比較 (新川流域)

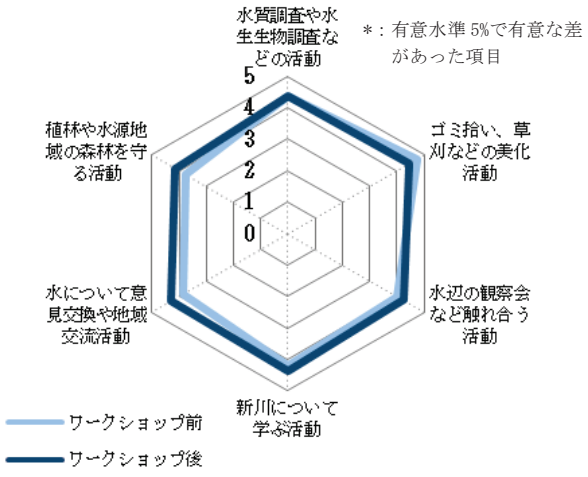

図 5 ワークショップ前後の河川の関心を高めるために必要な取組みの平均点比較 (新川流域)

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O8-28

NHK テレビ番組で放映された霞ケ浦の環境問題

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キーワード:湖沼環境問題, テレビ番組, 社会的関心,環境意識

抄録

本研究は NHK で放映したテレビ番組のうち日本の湖沼の環境問題を主題にした番組を調査し、その中から特に霞ケ浦の環境問題を主題にした番組の内容を分析したものである。霞ケ浦の環境問題が最初に放映されたのは 1973 年で、きっかけはその年に発生した魚の大量死とアオコの大発生だった。それ以降 1995 年まで数年おきに水質を取り上げた番組が放映され、その内容は漁業への影響、生活水への影響、環境問題への対応へ変化した。これらの対応は、世界の湖沼環境の持続的な改善と保全に対する提言として世界湖沼会議の関連番組(1995)で放映された。1995 年以降の番組は水質以外の問題を取り上げて環境問題の多様性を示唆した。番組には当時の霞ケ浦の状態や人びとの行動、意見が映像で残されていた。これらは貴重な資料であり時代や世代に通じた共通の情報である。今後の環境学習や人びとの環境意識啓発の参考になると考えられる。

1. はじめに

霞ケ浦の水質改善のために周辺の人びとは長期的な努力を継続している。しかし、明確な水質の改善は見られない[1]。加えて近年は外来種の脅威や 3.11 後の放射性物質の残留など環境問題の多様化が報告されている[2]。NHK(Nippon Hosou Kyokai)では 1960 年代から湖沼の環境問題に関するテレビ番組が作成され、その中で霞ケ浦の環境問題も取り上げられた。映像には当時の霞ケ浦の状態や人びとの様子が残されていた。霞ケ浦の環境問題は、これまでも先行研究 [3]や新聞記事[4]で公表されたがテレビ番組で放映した内容の分析例はない。マス・メディアの発する情報は、社会情勢に従い時代とともに変化する。そのため同じ話題は持続性に欠けるという特徴があるが、発せられた過去の現象や人びとの対応の事実がその都度関連付けられて、人びとがその事実に基づいて考え、行動できるようになるという役割もある[5]。本研究は番組の内容を用いて過去からの霞ケ浦の環境問題の内容と人びとの対応を調べた。それらから霞ケ浦の環境問題の変化を分析した。そして霞ケ浦への一般的な関心と人びととの関わりを考察した。

2. 方法

本研究は「NHK アーカイブス学術利用トライアル研究」(以下、トライアル研究)を利用した研究である[6]。NHK アーカイブス(以下、アーカイブス)は、NHK に保管されたすべての放送資料を学術振興のために提供する試みで 2010 年から開始された。この放送資料のうち、湖沼に関するテレビ番組(以下、番組)を調査し、特に霞ケ浦の環境問題を主題にした番組の内容を分析対象とした。

研究方法を以下にまとめる。(1)番組はアーカイブスの検索機能を使用して検索した。アーカイブスの検索機能において、キーワードが番組名、番組紹介内容、番組副題に含む番組が検索される。検索キーワードは湖とした。検索期間は 2015 年 12 月までとした。これは本研究のアーカイブス閲覧期間が 2016 年 6 月から 8 月だったためである。(2) 検索結果には同じ番組の再放送が含まれていたが再放送は対象としなかった。よって、同じ番組の中で一番早い放送日時のものを対象とした。(3) 選出した番組を視聴して、番組内容、インタビュー、ナレーションのメモを取った。(4) 番組内容から霞ケ浦の水環境または環境問題を主題にした番組を選出した。

3. 結果

図 1 に日本の湖沼に関する番組数、その中で湖沼環境問題を主題にした番組数をまとめて年代別に示した。湖沼に関する番組または湖沼環境問題に関する番組は、1970 年代から 1990 年代にかけて増加し、2000 年代以降は減少した。湖沼に関する番組のうち湖沼環境問題に関する番組の割合は、1990 年代が最も多かった。初めて湖沼環境問題を主題にした番組が出現したのは 1969 年 11 月、番組名は「ある湖の物語」(1969)で諏訪湖の富栄養化を主題にした内容だった。また、番組の対象になった湖は、琵琶湖(滋賀県) 約 43%、霞ケ浦

(茨城県) 約 11%、諏訪湖 (長野県)、猪苗代湖 (福島県)、宍道湖と中海(ともに島根県) 約 0.3%などだった。

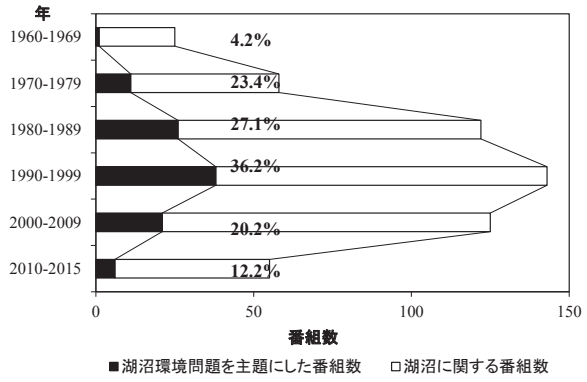

図 1 湖沼に関する番組数と湖沼環境問題を主題にした番組数:グラフ内の数値(%)は湖沼環境問題を主題にした番組が占める割合を示す(川村, 2017[7]をもとに作成)

表 1 に霞ケ浦の環境問題を主題にした番組の一覧を示した。霞ケ浦に関する番組が初めて出現したのは 1973 年の「明るい農村 村の記録」だった。副題は「アオコの湖～霞ケ浦の1年～」である。番組の冒頭では、この年の夏におこった魚の大量死とアオコ大発生の映像ときれいな霞ケ浦を取り戻そうと書かれたビラを土浦駅前で配布する漁業関係者の映像があった。漁業関係者は、魚の大量死とアオコ大発生の原因は水門を閉鎖したことによる湖沼の環境変化だと主張して水門開放を行政に求めた。しかし、行政はその主張を受け入れず両者は対立した。ナレーションでは、霞ケ浦が淡水化された経緯が説明され、淡水化後の漁業の変貌が漁民へのインタビューで語られた。そして、ナレーションで霞ケ浦は死の湖になったと語られた。漁業関係者と行政との対立は膠着状態のまま番組は終了した。

それ以降の番組の概要を以下にまとめる。番組は副題で示す。「大都市圏の水資源」(1975)では、飲み水の悪臭を取り上げ、霞ケ浦と琵琶湖周辺の住民がやかんに炭を入れるなど活性炭で水道水をろ過する様子が放映された。「茨城県霞ケ浦 昭和38年」(1981)では「アオコの湖」(1973)のその後が取り上げられた。ゲストで漁業関係者をスタジオに招き、インタビューにより霞ケ浦の現状を紹介した。この時期には漁業関係者と行政との和解が成立していた。しかし、霞ケ浦の水質は変わらず、水門も閉鎖中という現状だった。ゲストへのインタビューでは霞ケ浦を淡水化した当時は水質のことは誰も考えなかった、という発言があった。この番組のナレーションでもかつての霞ケ浦の環境は戻らないと語られた。「リポート‘82」(1982)、「湖・再生への道」、「霞ケ浦」(ともに1984)、「リポート くらし」(1990)、「水草が消えていく」、「湖は今」(ともに 1995)では、飲み水の悪臭、アオコの発生、死んだ魚など水質悪化による霞ケ浦の現状状態を放映したが漁業関係者よりも周辺住民の生活が取り上げられた。特に「リポート‘82」(1982)からは、環境問題へ対応する周辺住民の様子が取り上げられた。一部をあげると行政による条例の制定、ビオトープ設備の設置、住民による家庭油流出の制御運動や定期的な水質測定調査、大学や研究所による環境モニタリングなどである。「水草が消えていく」(1995)のナレーションでは、霞ケ浦は死の湖といわれても再生しようとしている、と語られた。

表 1 霞ケ浦の環境問題を主題にした番組:○は番組名、●は副題

放送年月日	○番組名 ●副 題	放送時間 (分:秒)
1973 年 12 月 17 日	○明るい農村 村の記録 ●アオコの湖 ～霞ヶ浦の1年～	024:30
1975 年 7 月 5 日	○教養特集 ●「大都市圏の水資源」 ―霞ケ浦・びわ湖開発の周辺―	060:00
1981 年 10 月 13 日	○ふるさとの証言 ●茨城県霞ヶ浦 昭和38年	030:00
1982 年 2 月 17 日	○明るい農村 ●リポート‘82 「霞ヶ浦条例と農業」 茨城県出島村ほか	024:00
1984 年 8 月 26 日	○視点 ●湖・再生への道(霞ケ浦)	025:00
1984 年 11 月 2 日	○日本新地図 ●霞ケ浦 ～汚染と環境保護～	020:00
1990 年 8 月 28 日	○イブニングネットワーク ●リポートくらし 水をきれいにせよ ～霞ヶ浦水質浄化作戦～	010:00
1995 年 8 月 28 日	○いのち輝け地球 ●水草が消えていく(霞ケ浦)	020:00
1995 年 9 月 18 日	○こんにちは いっと6けん ●湖は今・霞ケ浦ほか	記載なし
1995 年 10 月 23 日	○ETV特集 ●霞ケ浦はよみがえるか 第1回 汚染報告 湖は何を失ったか	045:00
1995 年 10 月 24 日	○ETV特集 ●霞ケ浦はよみがえるか 第2回 対策報告 私たちに何ができるか	045:00
2002 年 10 月 8 日	○ETV2002 ●NPOの時代 湖よ よみがえれ ～アサザ・プロジェクトの挑戦～	044:00
2004 年 1 月 30 日	○10min. ボックス ●湖沼と酸性雨 (霞ケ浦)	010:00

「霞ケ浦はよみがえるか」(1995) は、1995 年に霞ケ浦周辺で開催された第 6 回世界湖沼会議の特集番組だった。この番組では、第1回・汚染報告と第2回・対策報告として環境問題の現状と対応について有識者と市民代表などがスタジオで議論した。そして、人びとの環境意識啓発の重要性を訴え、霞ケ浦の環境問題への対応は世界の湖沼環境問題への提言として番組で発表された。「NPO の時代」(2002)では水生植物・アサザの復

活への取組み、「湖沼と酸性雨」(2004) では酸性雨が主題だった。

4. 考察

4.1 霞ケ浦の環境問題の変化

最初に、番組が作成された背景について考察する。「アオコの湖」(1973)では魚の大量死の映像と同時に駅でビラをまく漁業関係者が映された。魚が大量死して壊滅的な打撃を受けた漁業関係者の訴えが背景となり、これらの訴えや漁業関係者と行政との対立が社会的関心を触発したと考えられる。しかし、漁業が注目されたのはこの番組と「茨城県霞ケ浦 昭和38年」(1981)の 2つの番組で、他の番組では周辺住民の生活が取り上げられていた。この背景は、霞ケ浦の湖水が生活水、特に飲料水で使用されており、水質が広い地域に影響を与えたためと考えられる。「大都市圏の水資源」(1975)では霞ケ浦と琵琶湖周辺での水道水の汚臭を取り上げており、これらの背景から水道水の安全性、すなわち湖沼環境の安全性に社会的関心が向けられたと考えられる。次に、霞ケ浦の環境問題の主題については、結果から1995 年ころまで水質が注目されたといえ、それ以降は水質以外の問題への移行が示唆された。その内容は、漁業への影響、生活水への影響、環境問題への対応と変化していた。これらの背景には、湖沼の水資源的価値に向けられた社会的関心が、発生した事象へと焦点を変化させたことが考えられる。番組の減少が社会的関心の減少とはいえないが、今後は環境問題の多様化とともに社会的関心の焦点も多様化していくと考えられ、環境問題の解決には焦点の大小に関係なく人びとの環境意識を啓発する努力が必要と考えられる。

4.2 霞ケ浦の環境問題と人びととの関わり

「アオコの湖」(1973)、「茨城県霞ケ浦 昭和38年」(1981)では漁業関係者と霞ケ浦との関わりが放映された。漁業関係者は淡水化される以前から霞ケ浦で漁業を営んで生活をしてきた人びとである。人が霞ケ浦から受ける恩恵の原点といえるかもしれない。水質悪化による漁業の衰退は古来の霞ケ浦の環境消失を示唆し、ナレーションでも霞ケ浦は死の湖と決定づけられていた。その後、漁業関係者と行政との和ぼくが成立したが、漁業にかつての隆盛が戻るには至らなかった。「リポート‘82」(1982)以降の番組では霞ケ浦の湖水を生活水で使用する人びとが取り上げられ、霞ケ浦と人びととの関わりは漁業関係者から住民へ移行した。水質改善に取組む霞ケ浦周辺の住民、行政、研究所の人びとの様子が取り上げられ、官民産学が協力して環境問題に取り組む態度や行動が取り上げられた。そして「霞ケ浦はよみがえるか」(1995)では官民産学の代表者がスタジオに集合した。これらから、霞ケ浦と関わる人びとは漁業関係者、周辺の住民、行政や研究所などの専門機関、最後は世界の人びとへと変化したといえる。これは、霞ケ浦の環境問題が霞ケ浦湖内から周辺地域、そして世界へと拡大していく様子を示唆している。こうして最初は死の湖と言われた霞ケ浦は再生に挑み、世界の湖沼環境へ提言を発信するまでになった。過去に行われた水質改善への取組みには、現在も継続するもの、すでに終了したものとあるが、近年は環境問題への対応として小学校の環境学習の義務化など新しい取組みが開始されている。多様な人びとの協力を得ることは、霞ケ浦だけでなく世界の湖沼環境問題解決への持続的な努力へつながると考えられる。

5. 結論

本研究は NHK で放映したテレビ番組の中で霞ケ浦の環境問題を主題にした番組の内容を分析したものである。その結果、1973 年に初めて霞ケ浦の水質悪化の様子が放映され、霞ケ浦では 1995 年頃まで水質が最も注目されていた環境問題とわかった。また、内容は漁業への影響、生活水への影響、環境問題への対応と変化し、それぞれに霞ケ浦と関わる人びとも変化した。変化の背景には湖沼への社会的関心があると考えられ、近年多様化する霞ケ浦の環境問題の解決には、人びとの環境意識の啓発と多様な人びとの協力を得るための努力の継続が必要と考えられる。これらの番組は多様な人びとが共有できる情報のひとつである。

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TS9-1

琵琶湖・淀川流域圏における統合的流域管理の実現に向けたガバナンスのあり方

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キーワード:関西広域連合,琵琶湖・淀川流域,統合的流域管理,ガバナンス,客観的根拠に基づく意思決定

抄録

本報告は琵琶湖・淀川流域を対象に,顕在化する課題解決に向けた関西広域連合の取り組みについてである.琵琶湖・淀川流域における課題の多くは,既存の政策的枠組みでは積極的に取り組みにくい“はざまの問題”であることを明らかにするとともに,その解決のためには流域各主体の自発的取組や連携・協働を促進するガバナンスが重要であることを示す.また,ガバナンス向上のためには政策決定に資する客観的根拠が重要であり,流域の状態を地先レベルで計量できかつ流域全体で俯瞰できる指標の活用が効果的であることを示す.そのうえで,関西広域連合が,流域の知識・知恵を集積し,調整役として裏方となり,流域各主体間が「現状の認識－課題の認知－連携・協働の枠組みと取組方針の設定－取組の実施」を繰り返しながらガバナンスを徐々に向上させ,結果として政策統合を進める方策を示す.本報告では,関西広域連合での統合的流域管理に関するこれまでの検討内容と取組を報告する.

1. 関西広域連合とは

関西広域連合は,地方自治法第 284 条に基づき 2010 年 12 月に設立された特別地方公共団体である.2017 年 3 月時点で,滋賀県,京都府,大阪府,兵庫県,奈良県,和歌山県,鳥取県,徳島県,京都市,大阪市,堺市,神戸市の 8 府県 4 政令市が参加している.関西広域連合は,広域行政の責任主体となることを設置目的に掲げ,防災,観光・文化・スポーツ振興,医療,産業,環境保全,資格試験・免許等,職員研修の 7 分野での広域事務を進めるとともに,国出先機関の権限移譲を求めるなど分権型社会の実現を目指している.関西広域連合は流域管理に関する直接的な権限・財源を持たないが,その一方で,連合委員会・連合議会の合意に基づき,構成団体間で共通政策の実施が可能である.

2. 背景

地球規模の気候変動や人口減少などに伴い,これまでの高度経済成長を支えた伝統的な政策的枠組みの中ではそれほど関心を示されなかった課題が顕在化するようになってきた.こういった新たに顕在化してくる課題の解決には,旧来の地域的・分野的・組織的“縦割り”を越えた対応が求められることも多く,それゆえ“縦割り”を克服する努力が各所で続けられている.流域関連政策の中でも水害リスク管理や環境リスク管理に関しては,“ガバナンス”の重要性が強調され,ガバナンスのあり方や向上方策について多くの研究が報告されている.

このような中で,関西広域連合は,2014 年 7 月に「琵琶湖・淀川流域対策に係る研究会(座長:中川博次京都大学名誉教授)」(以下「研究会」)を設置,同研究会の助言を得ながら,統合的流域管理を進めるための望ましい流域ガバナンスのあり方を検討し,2017 年度より段階的に実践しはじめている.

3. 統合的流域管理のための流域ガバナンス

(1) 琵琶湖・淀川流域に顕在化する課題とその特徴

流域 75 市町村を対象に実施したアンケート調査(2014 年 10 月)[1],各種白書などを基に流域圏の抱える課題を漏れなく可能な限り幅広く収集し,8 分類で約 50 課題を整理した.具体的な分類は、①流域治水・総合治水の推進,②利水システムの多重化,③ 地下水の保全,④水インフラの老朽化対策,⑤流域生態系サービスの総体的な維持・向上,⑥ 総合土砂管理の推進,⑦水の危機管理の強化,⑧流域文化の個性と繋がりの再生である。例えば,分類①の総合治水・流域治水を考える場合にも,河川部局・都市部局・農林部局・防災部局などの連携が必要であり,既存の枠組みではどの部局にとっても主要な課題として取り扱われ難い“はざまの問題”である.

(2)　統合的流域管理の必要性“はざまの問題”の解決

“はざまの問題”をこれまで以上に効率的に解決していくには，分断された地域・分野・組織に対して，流域単位で適時適切に縦串・横串を通して課題解決にあたる“統合的流域管理”を実現することを目指す．

(3)　統合的流域管理の目的

統合的流域管理の目的を，流域圏(集水域に氾濫域や給水域を加えた範囲)をひとつの単位として，①生態系サービスの総体的な維持・向上を図りながら，②水に起因するさまざまなリスクを軽減するとともに，③持続可能な水の利用を実現することによって，将来にわたって流域に暮らす人びとが享受する福利を最大化することとしている．

(4)　ガバナンスのあり方

統合的流域管理の実現のためには，現在では想定し得ない将来の課題に対し，行政区画や政策分野にとらわれることなく，適時適切に関係各主体(ステークホルダー)が集まり，その都度必要な合意形成・意思決定ができる“ガバナンス”を整える必要がある．

流域管理が適切に進められるよう，ビジョン(あるべき将来像)や課題の共有と関係主体間の連携・協働がより着実に進められる社会の構築を目指す．

4.　流域ガバナンスの社会実装

(1)　統合的流域管理の政策評価指標の提供

社会的インセンティブを与える政策手段として，政策決定に資する客観的(科学的)根拠を調達し，流域社会に提供することを通じて，関係各主体の自発的な行動や連携・協働を誘起していく．

＜客観的根拠となる指標の例＞

・治水・防災　水害リスク(発生確率別水理量など)

・水利用　　水循環　代替水源数，年水源涵養量等

・自然環境・生態系サービス

漂着ごみの発生源・フロー　等

(2)　主体的参加を誘起するコミュニケーション

流域ガバナンスを向上させていくうえで，流域の諸課題を他人事ではなく自分事として捉え，自発的・内発的に行動していただくことが欠かせない．それが統合的な流域管理の原動力となる．

(3)　流域ガバナンスの調整役

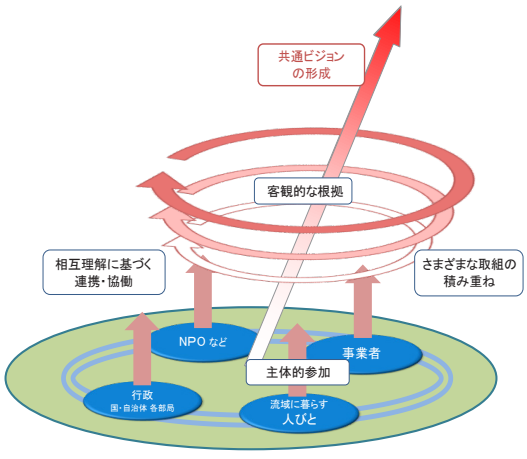
～関西広域連合が担うべき役割～

a)　調整役の役割

関西広域連合は，流域ガバナンスの向上のために，俯瞰的な視点(全体最適の視点)から“はざまの問題”を浮き彫りにし，流域社会に投げかけ，関係者間の相互理解を図り，それぞれの自主的な取組や連携・協働を促進する“調整役”としての役割を担うべきと考えている．この“調整役”の役割はA　流域に関する知識と知恵の収集・構成，B　現状分析と課題抽出，C　具体的な解決方策の検討，D　議論の機会づくり・場づくり，E　共有可能なビジョンの逐次とりまとめの5つである。

b)　調整役の留意事項－プロセスマネジメント

「D．議論の機会づくり・場づくり」は，関係各主体間で折り合いをつけながら一定の合意形成に至るまでのプロセスマネジメントであり，慎重な対応が必要と考えている．　この合意形成に至るまでのプロセスについては，取り組む課題の性質や，関係各主体の組み合わせ，時々の社会情勢，あるいは調整役自身の社会的立場



図−1　流域ガバナンスのイメージ，琵琶湖・淀川流域水環境会議 [1]を参考に加筆・修正

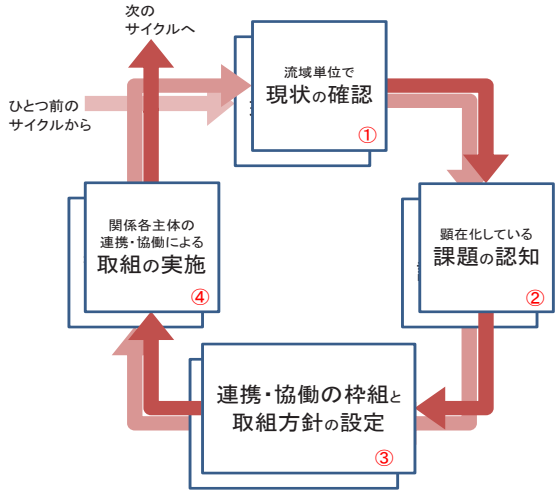


図-2　課題解決のフロー(1サイクル)

や信用能力なども十分に考慮し，柔軟に設計されるべきと考えている．

また，合意形成の過程において重ねられた議論が覆ることがないよう，客観的(科学的)根拠に基づく意思決定を丁寧に積み上げ，透明性を確保しなければならないと考えている．

c) 調整役の要件

流域ガバナンスの調整役は，政策決定に資する客観的(科学的)根拠を用意し，さまざまな工夫をしながら関係主体間の創造的コミュニケーションをお膳立てする舞台回し，裏方である．表-2 に，調整役に求められる要件を整理しておく．

表-2 調整役に求められる要件

信用	中立性・公平性が確保され，関係各主体からの信用があること．
課題設定能力（先見性）	全体最適の視点から適時適切な課題を抽出する能力があること．
課題解決能力（技術力）	技術的(科学的・制度的)に実現可能な解決策を見出す技術力があること．
課題解決能力（調整能力）	関係各主体の関心事に留意しつつ，連携・協働に導く調整能力を持つこと．

5. 適用状況と課題

流域ガバナンスの社会実装に向けて、関西広域連合は 2017 年度より以下 3 点に着手している．

・流域の状態(各種リスクやサービス等)に関する調査，および 8 つ課題に関連する国内外の取組事例の収集・整理を行い，定期的にレポートを作成

・流域管理に関連する既存のさまざまな議論の場に積極的に担当者が参加し，俯瞰的な視点と知識・知恵を駆使して，合意形成・課題解決に貢献すること

・流域の状態に関する客観的な根拠に基づき，既存の枠組みでは積極的に取り組まれて来なかった課題を取り上げ，議論の機会・場のお膳立てをし，事務局として具体的な解決方策を提案する

そこで，約 50 課題について，(i)広域性，(ii)分野横断性，(iii)実現性・実効性，(iv)既存取組の進捗状況といった観点から絞り込み，再編し，①水害に関する広域的なリスクファイナンス，②便益の帰着構造に基づく広域的な水源保全制度，③大阪湾海ごみ削減のための広域的な発生源抑制対策などを優先課題とした [2]．2017 年度は，①～③の実現化を図る準備として，流域各地点の水害リスクや水源涵養能力などの性能評価，大阪湾の海ごみの発生源を把握するための基礎調査に着手した．さらに調査結果をもとに，各課題解決の手段として，公的洪水保険・共済制度や，広域森林環境税・水源涵養税，ペットボトルのデポジット制度などについて制度化の可能性を探ろうとしている．

例えば仮に，水害リスクに応じた料率設定で保険制度が導入されれば，応分のリスク移転が進むだけではなく，副次的には水害リスクを考慮した土地利用・住まい方も誘導され，結果として都市計画や防災計画，河川計画にも反映されるかもしれない．これは，本稿で論じた流域ガバナンス，すなわち，流域全体を俯瞰しつつ課題抽出を行い，関係各主体の連携・協働による課題解決を図るプロセスに一歩踏み出すことに他ならない．

6. 結語

本報告は，琵琶湖・淀川流域を対象に，既存の社会的枠組みを前提としつつ，統合的な流域管理を実現するための望ましい流域ガバナンスのあり方を明らかにし，あわせて，関西広域連合が果たすべき役割を明らかにしたものである．

持続可能な流域社会の実現に向け流域政策の全体最適を図るには，既存制度や枠組の足らざるを補うアプローチが有効で，組織統合ではなく連携・協働を基調とした流域ガバナンスが必要である．さらに，流域全体を俯瞰する視点を持ち，客観的根拠を示しながら，関係主体間の合意形成・意思決定を促す“調整役”の存在がそのポイントとなる．

関西広域連合は，流域ガバナンスの中で，“調整役”の要件を現段階では十分に備えていないが，流域の状態に関する調査を定期的にレポートとして作成するとともに、流域の状態に関する客観的な根拠に基づき、既存の枠組みでは積極的に取り組まれて来なかった課題を取り上げ、議論の機会・場のお膳立てをし、具体的な解決方策を提案することを積み重ねることで、実務能力と信用を得る努力をすべきと考えている。

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TS9-2

Integrated Lake Basin Management (ILBM) as an integral part of Transforming the Malaysian Water Sector

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Keywords: Integrated Water Resources Management, Integrated Lake Basin Management, Water Resources Management, Water Services Management, the Malaysian Water Sector,

1. INTRODUCTION

The ASM Water Committee (AWC) was initiated and led, sometime in 2007, by the first Chair of the AWC, Tan Sri Shahrizaila Abdullah with the focus to assist the authorities in developing a National Integrated Water Resources Management Plan (National IWRM Plan or NIWRMP). In undertaking this task, the main IWRM paradigm were divided into some 24 sub-sets and sub-themes, of which ILBM was one of them. ASM benefited from the invaluable support from IAP and ILEC. Similar parallel studies on the other sub-themes identified, also progressed and study reports on some 10 key areas were completed and published by the end of 2015.

In early 2016, the time was opportune to carry out a synthesis of the outcomes and outputs from the detailed thematic studies to formulate a coherent National IWRM Plan and accompanying Strategies and Road Map for implementation. For the remaining 14 other sub-themes of the original 24 earlier identified, expert reviewers were commissioned on each, to complement the knowledge base in ensuring a more inclusive National IWRM Plan. Tan Sri Shahrizaila Abdullah led the Editorial Team to draft the synthesis report entitled *"Transforming the Water Sector: National IWRM Plan - Strategies and Road Map" [1].* It has since been published and formally launched by the Honourable Minister of Science, Technology and Innovation, Malaysia (MOSTI) in mid-December 2016. The report is in 2 volumes, Volume 1 being the Main Report and Volume 2, the set of Appendices. The report has since been presented to the Economic Planning Unit (EPU) of the Prime Minister's Department and other relevant ministries

2. LAKE MANAGEMENT IN MALAYSIA

Through its involvement in the Global Water Programme initiated by the Inter Academy Panel (IAP), ASM since 2004, has taken special interest in lake and reservoir management. IAP, with some 60 academics from around the world, identified the topics of Eutrophication of Lakes and Groundwater Management as 2 priority areas for its initial focus. ASM supported these two initiatives. For lake management ASM together with its partners, planned and initiated several studies and workshops to develop an information base line for an ILBM (Integrated Lake Basin Management). Some of these reports are detailed below.

2.1 A Desk Study on the Status of Eutrophication of Lakes in Malaysia [2]

NAHRIM (National Hydraulic Research Institute of Malaysia), with the support of ASM, commissioned UTM (Universiti Teknologi Malaysia) to carry out the above study in 2004.

This was a base line study with the objectives to

review existing information and status of the lakes, identify threats – both water quantity and quality, provide recommendations for remedial measures & environmental management strategies and for future planning, management, restoration and conservation

Among the findings of the 397-page report were

- There were at least 85 reports on lakes and reservoirs that have been documented
- In general, these studies can be classified into seven categories i.e.
  Aquatic flora, Fish & aquatic fauna, Dam & regulated rivers, Economic development, Management & tourism, Lake information system and Modelling & Water quality
- 62% of the 90 lakes surveyed were found to be eutrophic or nutrient rich, with the rest considered mesotrophic
- Major areas of research identified include
  Physical characteristics, Hydrology of lakes & reservoirs, Hydrologic & Chemical budget, Monitoring &assessment methods, Lakes & reservoir modelling and Environmental problems
- The national strategy for research and capacity building programs, requires funding mechanism and institutional & human resource

development

2.2 Lakes and Reservoir Management in Malaysia [3].

A Colloquium on Lakes and Reservoir Management was subsequently organised in August of 2007, and the proceedings were published, featuring articles related to ILBM such as by Prof Mahahisa Nakamura from Japan, Prof Maciej Zalewski from Poland, Prof Eduardo Mario Mendiondo from Brazil and nine other local papers. The output of this colloquium became another important document in preparing the next step of the required lake and reservoir management.

2.3 Strategies for the Sustainable Development and Management of Lakes and Reservoirs in Malaysia [4]

A Technical Committee jointly hosted by ASM and NAHRIM, were set up to develop a strategic plan for Lake and Reservoir Management in Malaysia, through a multi-stakeholder consultation process with an initial conceptual framework report and several detailed thematic component plans. These reports were later synthesised to produce a three-volume publication on the "*Strategies for the Sustainable Development and Management of Lakes and Reservoirs in Malaysia*" [4]. This publication recommended that lakes and reservoirs be sustained, restored and protected through the adoption of an ILBM approach, supported by the 8 strategies below:

- *To identify and empower a Lead Ministry/Agency*
- *To establish a National Lake Resource Centre*
- *To establish a Standing Committee on Lakes within the purview of the National Water Resources Council*
- *To establish Lake Management Committee at State Level*
- *The development of a Detailed Action Plan*
- *To support the Role of Local Communities in Lake Management*
- *To pass Appropriate Legislation to Strengthen Existing Legal Framework*
- *To enhance Networking and Strengthen International Strategic Alliances*

Since then, there have been other publications by ASM and partners before the preparation of the NIWRMP. These included the 3 series on lake briefs and several coffee table books.

3. PREPARATION OF THE NATIONAL INTEGRATED WATER RESOURCES MANAGEMENT PLAN (NIWRMP)

Ten component-plan water sub-sector studies were carried out prior to the development of the synthesis report on NIWRMP, entitled "*Transforming the Water Sector: National IWRM Plan - Strategies and Road Map" [1].* Each component plan was chaired by a Fellow of ASM in the specific Task Forces. Members of these Task Forces are drawn from experts in the public and private sectors as well as from the academia. The output from each Task Forces were prepared as rigorous as that for the Lake Management. Some Task Forces run in parallel, with some studies stretching to 2 to 3 years, and most running from 2007 to 2015. These Task Forces were on sub-sectors as shown below:

- *Integrated Lake Basin Management*
- *Integrated Aquifer Systems Management*
- *Water Demand Management*
- *Water Supply and Wastewater Management*
- *National Agenda for Integrated Water Research*
- *Climate Change and Water*
- *Integrated River Basin Management*
- *Agriculture Water Services for Water Business*
- *NKPA (National Key Priority Area) in the Water Sector*
- *ASM Mega Science Study: Water Sector*

Fourteen water sub-sector reports were invited from subject matter experts to complement the component plan studies and to ensure inclusiveness. These were

- *Integrated Flood Management*
- *Integrated Flood Management*
- *Water Quality Management*
- *Water and Land Use (National Physical Plan)*
- *Water and Health*
- *Water and Green Growth*
- *Water and Gender*
- *Virtual Water and Water Footprint*
- *Water Financing*
- *Water-Food-Energy Nexus*
- *Awareness, Advocacy and Capacity Building*
- *International Networking and Collaboration*
- *Integrated Urban Water Management*
- *NWRP Action Plan*

4. OUTPUT OF THE "TRANSFORMING THE WATER SECTOR: NATIONAL IWRM PLAN - STRATEGIES AND ROAD MAP" [1]

The report is published in 2 volumes, Volume 1 being the Main Report and Volume 2, the set of Appendices. Chapter 6 of volume 1, the centre-piece of the report, provides an overview of the Malaysian water scenario, highlighting the issues and challenges, followed by a synthesis of the strategies, organized into a coherent National

IWRM Plan. The Plan comes with a Road Map for implementation over a 15-year period until 2030, the end of the Sustainable Development Goals.

Twenty-five recommendations were provided, organised into 7 groups as shown below:

- 2 overarching recommendations

Adoption and implementation of NIWRMP together with the Component Plans nationwide by the key ministries and respective state administrations.

- 10 Enabling Environment recommendations,

addressing policies, legislation, regulations and finance among which is the need for an over-arching Integrated Natural Resources Policy; a contemporary National Water Resources Act to be expedited; and the need for funding arrangements and protocols especially pertaining to environment rehabilitation works.

- 5 Institutional Framework recommendations,

focusing on the review and strengthening of governance through institution of oversight and implementation of management structures at national, state, river basin and local hierarchical levels, and calls for greater intra-ministerial integration.

- 5 Management Instruments recommendations

Stresses on the establishment of a central IWRM database built around river basin platforms; the use of economic, financial and technical instruments for greater water use efficiency and accountability and to curb abuse; implementing a national agenda for integrated water research; mechanisms for promotion of green growth; and the pooling of resources to establish one-stop capacity building centres to improve skills and raise competency at all levels

- 1 recommendation on Investments in Water Infrastructure

A central recommendation for urgent Investments in Water Infrastructure to cater for the national water sector needs and to spur the transformation of the water sector. 15 major programmes with corresponding 95 Entry Point Projects were proposed.

- 1 recommendation on NIWRM Plan implementation Management Structure

Recommending the plan be managed nationally at the highest political level by the National Water Resources Council (MSAN), and at the state level by the State Water Resources Council (MSANg) with the support of a National Steering Committee (NSC) to oversee the implementation and assisted by a National Technical Committee (NTC) to resolve technical issues. Formation of a dedicated IWRM Implementation Unit (IWRM-IU) reporting to the NSC to ensure the timely and coordinated implementation of the Plan.

- 1 recommendation for champion/s

*The need for "**champion(s)**" to actively pursue "NIWRMP" initiative and the transformation processes.*

5. CONCLUSION

All the water sub-sectors, including that for Lake Management, are important and are integral parts of NIWRMP. The 25 recommendations are ***inclusive solutions.*** They should be implemented immediately and concurrently to overcome the challenges in the water sector, in ensuring sustainable water resources and to build resilience from the increasingly negative impacts of climate change, urbanisation and rapid development. NIWRMP implementation will contribute to Malaysia's target in achieving SDG no. 6 by 2030

New Task Forces will be set up for other water sub-sectors, such as identified in the 14 Complementary Reports, on a priority basis, for e.g. the Task Forces on Integrated Urban Water Management (IUWM), Water-Food-Energy Nexus (WEF Nexus) and on Awareness, Advocacy and Capacity Building (AACB)

The change in Malaysian government as of 9 May 2018 has resulted in the reorganizations of federal ministries. Primarily, many of the agencies under MoNRE and KeTTHA has been moved into a single ministerial entity, KATS (Kementerian Air, Tanah dan Sumber Asli or Ministry of Water, Land and Natural Resources). Other agencies such as energy, environment and climate change have been moved to the new MESTECC (Ministry of Environment, Science and Technology, Environment and Climate Change, the revamped MOSTI (Ministry of Science, Technology and Innovation)
As the detail strategies and action plans are based on responsibilities of specific ministries, the Editors of "*Transforming the Water Sector: National IWRM Plan - Strategies and Road Map" [1]* are currently relooking at this report to review and realign proposed strategies and action plans to current relevant ministries.

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O9-1

Governance gaps and prospects in the Sta. Rosa Watershed of Laguna Lake, Philippines

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Keywords: basin governance, collaboration, wise use and development of water resources

ABSTRACT

While bringing economic success, urbanization processes have resulted in stress and undesirable consequences such as pollution and depletion of water sources, sedimentation, flooding, biodiversity loss and degradation of lake and river systems that impact public health, food security, livelihoods and well-being. Using Sta. Rosa Watershed in Laguna Lake Philippines as a case study, this paper examines the evolution of local institutions that aim to mitigate these issues at the watershed scale. Challenges to watershed governance are examined using institutional and stakeholder analysis. Prospects for expanding and sustaining the capacity of the existing institutions are articulated to address multiple issues and mitigate concerns in this urbanizing landscape.

1. INTRODUCTION

The Santa Rosa Watershed is one of the 24 sub-watersheds draining to Laguna Lake, the biggest inland water in the Philippines. Due to its proximity to Metro Manila, this area experienced rapid industrialization and urbanization over the past 3 decades. The Sta. Rosa Watershed (hereinafter, SW) covers the whole city of Santa Rosa, 11 villages of Cabuyao City, 8 villages of Binan City and 24 villages of Silang Municipality. The fairly extensive and productive aquifers observed in this watershed[1] is said to be a critical factor for industrial companies to relocate in this area. About 97% of water permits granted by the National Water Resources Board (NWRB) in this area is for groundwater extraction pumped from shallow and deep wells[2] that supply domestic and industrial needs. Conservative estimates indicate water demand to exceed groundwater recharge by 2026[3]. Concerns due to vulnerability of groundwater resources to contamination have been raised[3], as warned by high nitrate concentration of groundwaters in some parts of the SW[4]. Furthermore, drastic changes in vegetated areas and impervious surface covers have been observed[5] and increased flooding risks due to increasing run off have been projected[3,4].

In order to address these threats in the SW, various types of institutions have been created. This paper examines the evolution of different institutions that can address issues at the watershed scale and sifts through lessons and ways in which to strengthen governance processes in the area.

2. METHODS

This is a descriptive study making use of document reviews, semi-structured interviews, focus group discussions and participant observation. Interviews were conducted with key informants from the national, local government agencies, river councils, NGOs, local communities and the private sector in the SW during the period September to December 2017. Various policy documents, project reports, organizational meeting minutes and online articles were reviewed and analyzed.

Diagnosis of governance gaps was undertaken, according to the OECD multi-level governance framework[6] that has been used to appraise water governance challenges in OECD countries (presented in Section 4.1). A participatory stakeholder workshop undertaken on December 2017 together with members of the Sta. Rosa Watershed Management Council informs the analysis in Section 4.2.

3. 3. EVOLUTION OF INSTITUTIONS IN THE STA. ROSA WATERSHED

Sta. Rosa Watershed has a history of rule-making dating as far back as 18th century [7] but this paper focuses on the 3 main phases towards institution building in Sta. Rosa watershed from the late 1990s to the present.

3.1 Formation of River Councils

In 1997, to improve environmental quality of river systems, Laguna Lake Development Authority (LLDA) organized the Save Silang Santa Rosa River Council (also known as S3R2) and Cabuyao River Rehabilitation Foundation. These multi-sectoral groups composed of the business sector, academic institutions and civic society have since then initiated environmental awareness campaigns, river clean ups, adopt-a-river projects and seminars on waste management. The S3R2 continues to be active and is

known for organizing *Silakbo*, a bike, walk and run event attended by about 2000 participants yearly, aimed at raising funds and awareness for river protection. The river council in Cabuyao City became inactive and was revived by the office of the Cabuyao CENRO and the LLDA as the Cabuyao River Protection Associates (CaRPA) in 2015. As a new organization, CARPA's members are quite eager and enthusiastic. While the S3R2 has evolved into a primarily business-sector membership, the CARPA has an expanded base composed of not just businesses but academic institutions, and local community organizations.

3.2 Profiling and characterization of the watershed

A number of scientific assessments have been conducted in the area starting in 2005, when the Local Environmental Action Planning under a World Bank project provided a baseline ecoprofile characterization of the watershed[1]. From 2008 onwards, the Sta. Rosa watershed became the focus of a number of projects by NGOs, research institutions and funding agencies. Hydrological assessments, water balance studies were undertaken by WWF Philippines in partnership with Coca Cola Philippines. The Research Institute for Humanity and Nature (RIHN) examined the impact of ecological hazards on the inter-relations of food production and public health. The Institute for Global Environmental Strategies conducted participatory land use planning incorporating climate change scenarios. RIHN through its new project, *e*-REC, has now conducted biodiversity and nutrient assessments, groundwater studies, and social research towards enhancing watershed governance.

3.3 Formation of the Sta. Rosa Watershed Management Council (SWMC)

The various projects implemented since mid-2000, involved a number of feedback sessions and workshops with different stakeholders in the area. These meetings brought into fore, the issues identified by stakeholders e.g. water pollution, water depletion and flooding—that shifted their attention from river systems to watershed boundaries. In 2014, after a series of intergovernmental workshops, the 4 local government units (LGU) decided to sign a Memorandum of Agreement for the implementation of an Integrated Watershed Management Program with the vision of unifying efforts to manage water resources at the scale of the Sta. Rosa watershed. In 2017, the Sta. Rosa Watershed Management Council (SWMC) was formalized with an initial composition of 4 LGUs of Santa Rosa, Binan, Cabuyao and Silang, Water Service providers and the 2 River Councils.

4. CHALLENGES IN WATERSHED GOVERNANCE

Institutionalization of a management body which can operationalize plans and programs for watershed conservation is a welcome development, however there remain various challenges for watershed governance and this section examines these gaps and the degree of stakeholder engagement in the SW.

4.1 Governance Gaps

The OECD multi-level governance framework [8] is adapted here in order to organize the analysis for diagnosing governance gaps in the SW. This includes looking at administrative, information, policy, capacity, funding, objective and accountability gaps for coordination (Table 1) in the Watershed.

Table 1. Governance gaps in the Sta. Rosa Watershed

Administrative. The formation of the SWMC which is an institutional body transcends 4 local administrative units and currently matches the hydrological boundary of the watershed.
Information. Wealth of scientific information exist whose results have been presented via various fora, meetings and discussions but asymmetry with regard to access to this information is observed. The data is also not being synthesized and no repository identified.
Policy. Environmental policies at the local government level (mainly on solid waste management and sewerage and septage) have been enacted. LGUs have varying policies especially on development, water management and land use which are relevant at the watershed scale and harmonization of policies has been identified as a priority
Capacity. Limited capacity for taking on administrative, technical, information dissemination and coordination responsibilities have been observed. Facilitative skills will be important in mobilizing the council and engaging more stakeholders into the process.
Funding. The Clean Water act sets the establishment of an Area Water Quality Management fund but no experience to date about how to access this or how to set it up for the SW. The LLDA has provided a meager USD3800 as start-up funds for the council. Financing mechanisms need to be set up in order to implement action plans.
Objective. Contradictory interests between stakeholders. Silang in the upstream wants to pursue development while downstream LGUs are afraid of the consequences. Water districts seem to be concerned about water sustainability but are primarily focused on protecting their interests. Common aspirations for all the key stakeholders have yet to be clearly identified and clear goals and objectives for the watershed council have yet to be articulated.
Accountability. Transparency processes have yet to be observed in this watershed due to limited representation and information flows in the SWMC even while the constituent base has not been clearly defined. For the SWMC action plans to have legitimacy, there is a need for a wide variety of stakeholders impacted by loss or degradation of the watershed functions to be engaged.

4.2 Participatory Stakeholder Analysis

The participatory stakeholder analysis identified the key impacting sectors, key impacted sectors, enablers and influencers pertaining to the issues of water pollution and depletion and flooding in the SW. These stakeholders were then prioritized and categorized according to their level of interest (priority ascribed to) and influence in (with power/actions that can affect)[8] watershed governance (Figure 1).

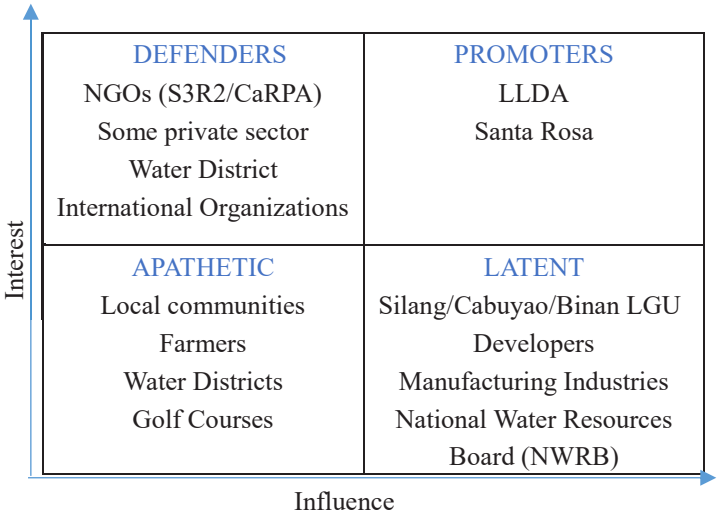

Figure 1. Characterizing Interest vs. Influence of key stakeholders in Sta. Rosa watershed

The framework for public participation is very much in place in the SW but this analysis revealed that actual participation in watershed governance has been limited. The LLDA and Santa Rosa LGU are the main promoters having high interest and high influence. Despite being key stakeholders considered to have a high impact on the watershed, 3 LGUs have low interest while developers and manufacturing industries have not been engaged for action. The NWRB who has the mandate for managing water resources was identified as crucial to be engaged. Influencers and enablers such as the river councils, some private sectors, Laguna water district were also identified whose strengths and capacities can be tapped and optimized for governance processes. The group currently labeled as "apathetic" has capacity to contribute considerably (e.g. water districts' businesses revolve around water). Local communities and farmers groups that are highly impacted need empowerment in order to participate in governance processes.

The need to engage multiple stakeholders as crucial to watershed governance[9] has been acknowledged which is the reason why a Watershed Forum is being developed for the SW. The forum is envisioned as a platform for stakeholder participation and information exchange, a hub where multiple actors can interface in order to participate in watershed governance as well as implement actual activities. A shared vision and plan for sustainability of the watershed will be facilitated and activities by different sectors that can be aligned to the watershed plan will be determined. It will be crucial that the key stakeholders previously identified, be a part of this governance process.

6. CONCLUSION

Governance in the Sta. Rosa Watershed has evolved from river conservation to collaboration at the watershed scale. This makes sense especially since issues on water pollution, depletion and flooding need to be addressed at the watershed scale. Governance gaps pertaining to information, capacity and funding are currently being compensated by external projects. However, the capacity needs to be built up locally to ensure continuity of initiatives. Accountability also needs to addressed by increasing involvement of various stakeholders, especially of local communities. Prospects are high for the development of a watershed forum which is hoped to engage the key stakeholders in the watershed governance and facilitate co-creation of a vision for sustainability of the SW that will help address the policy and objective gaps. The challenge is the realization of watershed plans that will lead to actual improved environmental and social well-being outcomes.

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O9-2

Paper title：Integrated Lake Basin Management in Malaysia – a decade of evolution

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Keywords: Governance, ILBM, lake management, sustainable

ABSTRACT

Integrated Lake Basin Management has been adopted in Malaysia for over a decade. This paper provides a review of the various national initiatives and studies concerning lake and reservoir management that have been undertaken in Malaysia. It detailed the evolution of ILBM implementation in the country over more than a decade since its inception in 2005 in particular the governance improvement as well as areas of lake research and management. The paper concludes with challenges that need to be addressed as the way forward to enhance ILBM implementation.

1. INTRODUCTION

Managing inland water resources such as lakes and reservoirs has been one of the agendas of Malaysia to ensure its waterbodies can be sustainably use for the future generation. The major issues of lake management in the country has been eutrophication, siltation, sedimentation, introduced species, and management challenges [1, 2, 3,4]. The integrated lake basin management (ILBM) approach has been adopted by Malaysia to address the issues. The National Water Resources Policy which was approved in 2012 also imbedded Integrated Lake Management as one of the management approaches for managing lakes and reservoirs in the country.

2. KEY PROGRESS

This work was based on reviews of various national initiatives that have been carried out throughout its inception in the year 2004 to 2018 (Table 1). The first 5-years (2005 – 2010) was dedicated to developing the strategic plan for sustainable lake basin management in the country. The second 5-year (2011 – 2015) phase involved fine-tuning and preparing a more detailed action plans and governance instruments. The third 5-year plan was focused on implementing the strategic plan.

3. GOVERNANCE IMPROVEMENT

The ILBM progress in Malaysia has been focusing on improving governance. The strategic and detailed action plan generally attempted to provide strategic direction in developing and managing lake resources based on the basin scale. The policy framework identified is "***Lakes and reservoirs will be sustained, restored and protected through the adoption of an Integrated Lake Basin Management (ILBM) approach***".

Seven strategies were identified in the strategic plan namely the lead agency to be driven by the Ministry of Natural Resources and Environment Malaysia (NRE). Two other departments namely the Drainage and Irrigation Department (DID) was identified as the implementing agency while the National Hydraulic Research Institute of Malaysia (NAHRIM) as the research agency entrusted for the lake resource research[1]. The creation of permanent lake committee known as the Catchment, Reservoir and Lakes Sustainable Management Permanent Committee chaired by NRE provided a platform to monitor progress in implementing the action plan. Similarly, the Lake Research Committee of Lakes, Reservoir and its catchment has successfully developed a blueprint for the lake research and development (R&D). A committee that foresee the implementation of the action plan such as at state levels, however, remains partially implemented and varied between States.

Development of scientific understanding on lakes and their issues are important in the lake management. A blueprint on lake R&D which was developed in 2014 identified research areas much needed to support lake management. Seven themes were identified namely (i) governance (ii) ecosystem services and socio-economic (iii) water quality (iv) ecohydrology and basin management, (v) biodiversity and natural products (vi) physical limnology and hydrodynamic and (vii) technology[4].

To strategically promoting monitoring of water quality of

lakes, National lake water quality standards was developed in 2015 and approved by the National Water Resources Council for implementation in August 2017. The standard promotes monitoring of parameters important for lakes and of concern to human health or ecosystem[5]. The standardized criteria are based on lakes uses with the aim to understanding the water quality conditions for lake management. Roadshows to various States in the country are in progress to brief and improve understanding on the application of the new standard at State's level.

To further aid management, a guideline for ILBM plan has been prepared by NAHRIM in 2017. The guideline provided step by step guide for lake managers in developing the ILBM Plan for their respective lakes[6].

Table 1 ILBM progress in Malaysia

Period	Initiatives
2005-2010	• Desk study on lake eutrophication in Malaysia • Colloquium on lakes and reservoir status and issues • Multi-stakeholders' workshops • Strategies for the Sustainable Development and Management of Lakes and Reservoirs in Malaysia • Lake Inventory Database • Lake Brief Series 1
2011-2015	• Endorsement of Strategic Plan • Lake Brief Series 2 & 3 • National Lake Research Blueprint • National Lake Water Quality Criteria & Standards (NLWQS) • Establishment of Lake Research Committee • Establishment of Lake Permanent Committee • Development of Detailed Action Plan for ILBM
2016-2018	• Integrated Lake Basin Management – component plan studies in National IWRM Plan (Strategies and road map) • Integrated Lake Basin Management Plan for Sembrong and Batang Ai lakes • Endorsement of NLWQS • Guideline for Developing ILBM Plan

4. CHALLENGES

Fragmented management has been the biggest challenge in Integrated Water Resources Management implementation including the ILBM in Malaysia[7]. The implementation of any plan formulated at national or Federal level depends on State's acceptance or adoption since management of land and water resources falls under their purview. Only few States has dedicated institution to manage water resources at basin levels including lakes (Table 2). With the exception of Selangor and Kedah, many of these agencies have limited capabilities to sustainably manage lake at basin scale. For Putrajaya Lake, transboundary challenges remain as the drainage basin transcends over two states namely FT of Putrajaya and Selangor[8].

Table 2 State and/or Lake Authorities in Malaysia

State	State or Lake Authority
Selangor	Selangor Water Management Authority (LUAS)
Negeri Sembilan	Water Regulatory Bodies of Negeri Sembilan
Melaka	Water Regulatory Bodies of Melaka
Johor	Water Regulatory Bodies of Johor
Pahang	Water Regulatory Bodies of Pahang
Kedah	Kedah Water Management Authority
Perlis	N/A. (Drainage & Irrigation Department)
Kelantan	N/A. (Jabatan Air Kelantan/ Drainage & Irrigation Department)
Terengganu	N/A. (Jabatan Air Terengganu/Drainage & Irrigation Department)
Penang	Badan Kawal Selia Air Pulau Pinang
Perak	N/A. (Lembaga Air Perak/ Drainage & Irrigation Department)
Sabah	Sabah Water Resources Council
Sarawak	N/A. (State Water Authority)
FT Putrajaya	Perbadanan Putrajaya
FT Kuala Lumpur	Kuala Lumpur Municipal Council (DBKL)
FT Labuan	Perbadanan Labuan

N/A – not available

To date, only a few management plans or basin management plan are in place or have been developed by

agencies to improve the governance framework in respective lakes (Table 3). Some of these plans are institutionalized with legal instruments such as the enactment for Control of Activities in the Putrajaya Lake (the By-Laws 2004) which aid the lake management by prohibiting or zoning certain activities and entrusting enforcement powers. Other management plans such as Chini, Jor and Batang Ai have yet been implemented.

Management plan is generally a tool to aid in decision making and developing strategies for the management. A success in integrated lake basin management depends on the capacity of the targeted central authority to enhance their management role as well to understand the specific lake basin issues. It also requires a long-term commitment from every stakeholder to achieve a common goal in managing lakes. To ensure success, awareness and capacity building of ILBM principles is required at all levels of stakeholders.

Table 3. Status of Lake Management Plan in Malaysia

Lake	Management Plan
Putrajaya	Putrajaya Lake Catchment Development and Management Plan (2000)
Bera	Tasek Bera Integrated Management Plan (2004)
Loagan Bunut	Loagan Bunut National Park Management Plan (2007)
Chini	Strategic Implementation Plan (2007), Lake Chini Management Plan (2014)
Jor & Mahang	Integrated lake management plan for Jor and Mahang reservoirs, Districts of Batang Padang, Perak Darul Ridzuan (2015)
Sembrong	Integrated Lake Basin Management Plan for Sembrong Lake (2016)
Batang Ai	Integrated Lake Basin Management Plan for Batang Ai Lake (2016)

5. CONCLUSION

ILBM implementation in Malaysia has undergone more than a decade of development. Progress are in place to strengthen governance framework and successful implementation of the ILBM strategies/action plans.

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O9-3

Conservation of Wetlands in Bhutan: Policy and Practice

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Key Words: Wetlands conservation in Bhutan; Ecosystem based conservation; Watershed management; Wetland Policy; and upstream-downstream linkages.

ABSTRACT

Benevolent leaders and associated strong environmental policy is the impetus of environmental conservation in Bhutan. Never – the – less, greater challenge exists today with faster paced modernization, as Bhutan advents into the 12th five-year planning cycle. Changing ecosystems and their services, is more visible and challenges in the water sector with the cascading phenomenon in the food-energy-climate nexus is escalating. In the past, an ecosystem-based approach to conservation was rarely visible as a common policy directive in the sustainable management of environmental resources in the country. The roadmap for wetlands conservation, followed by the Royal Government of Bhutan is envisaged to build information on wetlands, achieve the sustainable development goals, assess wetlands, build management plans for significant wetlands, and continuously monitor and evaluate the conditions of wetlands in the country. With this roadmap, the country envisions to add value to Bhutan's legacy to environmental conservation through an ecosystem based approach with an effective wetlands conservation program.

1. INTRODUCTION

The importance of wetland ecosystems in the watershed is crucial. The wetlands functions and benefits are well known and adopted globally as an important link in the overall health of the watershed. Wetlands such as lakes, streams, springs, rivers and marshes are common types of wetlands in Bhutan and also important water sources for both rural and urban settlements.

Benevolent leaders and associated strong environmental policy is the impetus of environmental conservation in Bhutan. Never – the – less, greater challenge exists today with faster paced modernization as Bhutan advents into the 12th five-year planning cycle.

Despite the fact that wetlands provide vital ecosystem services, loss of wetlands is observed in the country, especially in growing urban settlements. They are filled in, drained, or impounded by a variety of human influences including stream channelization, urban development, growing transportation sector or conversion to other land uses. Symptomatic issues of water sources drying are most urgent and the country is grappling with the cascading phenomenon in the food-energy-climate nexus.

This paper covers the road map to wetlands conservation in Bhutan. It looks into the enabling factors and unravels why there is loss in wetlands in the country, despite strong environmental policies. It then outlines the major steps taken to curb the problem and how Bhutan is moving forward with strategies for wetlands conservation in the country.

2. ENABLING FACTORS TO WETLANDS CONSERVATION

Bhutan is bestowed with numerous wetlands because of its complex underlying geology and its strategic location in the eastern fringes of the Himalayas. Natural conditions for fresh water storage and discharge are created. The summer monsoon, from the Bay of Bengal during June, July, August and mid September, provides precipitation in the form of rainfall. The annual average precipitation ranges between 2,500 and 5,550 mm per year at the southern foothills; 1000mm in the central inner mountains and 400mm in the northern regions with subtropical, temperate and alpine agro-ecological zones respectively[1].

From a period of strong traditional and cultural ethos to a much modern society where a unique development philosophy is revered, Bhutan has since then tried to maintain a balanced loop between conservation and development. Gross National Happiness, as a development philosophy has been adopted since the early 1970's in the country. Benevolent leaders and associated strong environmental policy through the constitutional requirement to maintain at least 60 percent forest coverage for all times to come and the responsibility of "every Bhutanese as a trustee of the natural resources and environment… " is the impetus of environmental

conservation in the country[2]. Bhutan has a total of 2,730,889 ha, amounting to 71% of its total geographical area as forest coverage [3].

3. STATE OF THE WETLANDS

There is no complete data on how much wetland the country has and how much has been lost. With no comprehensive record of the country's wetlands, there is no way of knowing - at what rate Bhutan's wetlands are being converted or lost.

However, there are persistent reports from many parts of the country; those wetlands, mostly springs and lakes are drying [4]. Wetlands in and around growing cities and town are the most significant wetland loss noticed in Bhutan. The rate of loss of - wetlands - is not as pronounced in other parts of Bhutan as it is in the capital city, *Thimphu*. This phenomenon is replicated in other urban centers in Bhutan. Many of the critical watershed management plans also report the drying of water sources in rural settlements. The Mid term review report of the 11th Five Year Plan also highlights drying up of water sources in the country and has created flagship programs in the water sector to curb this issue.

Until 2010, in the absence of a common strategy in wetlands management in the country, conservation activity was mostly through habitat enrichment (plantation) and water source protection (fencing). The Water and Wetlands Program was established in 2010 when the interdisciplinary Watershed Management Division was created in the Department of Forests and Park Services. Until then, an ecosystem-based approach to conservation was rarely visible as a common policy directive in the sustainable management of environmental resources in the country.

Most of the environmental conservation activities then, addressed forest coverage and not the protection of wetlands in the landscape. Wetlands conservation was not mainstreamed in the overall environmental policies and plans, resulting to loss in wetlands in the country.

4. STRATEGIES FOR WETLANDS CONSERVATION

In the absence of an ecosystem-based approach to environmental conservation, a Ministerial Notification was issued by the government in 2011; requiring all forestry clearances to consider the significance of wetlands and the need to retain it in its natural conditions. The only protection until then was the 30 m buffer from riverbanks and 100m buffer from lakes. However this was not adequate, because other type of wetlands in the country was oftentimes ignored, especially marshes. To address the lack of policies specific to wetland conservation, the Forest and Nature conservation regulations, incorporated a chapter on wetlands conservation. Simultaneously, the need for a guideline for wise use of wetlands was found crucial to implement the regulations in place. However, the tools necessary to implement the regulations require a comprehensive inventory of wetlands in Bhutan, encompassing the type and extent, which is currently not available.

Therefore, the entire 12th FYP focus for the wetlands program has been designed to carry out the National Wetlands Inventory of Bhutan. Numerous wetlands assessments carried out in the country will be used to develop the Framework for wetlands classification. The framework will then be used to adopt a standard methodology to comprehensively map the wetlands type and extent in the country. The information will be generated as a layer to the Atlas of Bhutan, to be used as a sieving mechanism in land allocation for development.

The implementation of the Forest and Nature Conservation Rules of 2017 is envisioned to be successful with the use of the comprehensive wetlands inventory map. The major conversion of wetland to other land use in the country will be regulated. This roadmap followed by the Royal Government of Bhutan is envisaged to build information on wetlands, achieve the sustainable development goals, assess wetlands, advocate for wetlands as important ecosystems deemed necessary for protection, build management plans and continuously monitor and evaluate the conditions of wetlands in the country.

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O9-4

Construction of partnerships to improve Integrated Management of Lake Chapala basin, Mexico

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Keywords: Integrated Lake Basin Management(ILBM), basin governance, basin management policies.

ABSTRACT

From 2002 to 2017 a series of 94 projects have been completed in the Lake Chapala basin (Mexico) by the Institute Corazon de la Tierra; they were directed to improve the conditions of terrestrial and aquatic ecosystems and the Environmental Services they provide. Creating partnerships has been a core part of this process, to properly deal with complex ecological, social and economic aspects, including conflicting activities and points of view regarding access and use of natural resources, most importantly, water and forests. This paper reviews the features of the strategies used to create effective partnerships, the challenges that were faced and how they were dealt with, in order to create a deeper involvement of stakeholders beyond their particular location and socio-political position, to involve them as a conglomerate into the integrated management of Lake Chapala basin, a strong collaborative effort that still has a challenging way ahead.

1. INTRODUCTION

The Lake Chapala basin includes the water body of same name, the largest one in Mexico and the third in size in Latin America. Most forest ecosystems at the basin present degradation processes derived of land use change, erosion, overgrazing and forest fires. This situation has resulted in water table lowering, reduced soil fertility and loss of biodiversity, which as a result has generated reduced agricultural production and increased levels of poverty, altogether with associated problems such as migration. According to data reported by the National Institute of Ecology-INE[1] and several researchers (Juarez et al., 2010)[2] the phreatic level has decreased dramatically during the last 50 years: in 1970 it was common to find underground water at depths of 5 meters (15 feet), while now sometimes it's necessary to drill more than 100 meters (300 feet) to find it. On the other hand surface runoff has increased, causing flooding and mudslides during the rainy season (May-September).

Lake Chapala basin, together with another 18 basins, composes the Lerma-Chapala basin (a macro-basin of 53,500 km²)[1]. This area is characterized by the diversity of ecosystems, related to changes in altitude and climate as well as the extent of topographic forms (mountains, plains, canyons and valleys), which in turn has generated a rich biodiversity and a set of environmental services[2], quite essential for a population of more than 15 million people dwelling in the basin and 6 million external users.

Alongside 15 years (2002-2017) a series of 94 projects have been completed in the Lake Chapala basin (Mexico) by the Institute Corazon de la Tierra, most of them following the Integrated Lake Basin management Platform[3] and its Six Pillars of Governance. Those projects were directed to improve the conditions of terrestrial and aquatic ecosystems and the Environmental Services they provide, strengthening the basin governance, mostly working with local communities and municipal authorities. Creating partnerships has been a core part of the process, to properly deal with complex ecological, social and economic aspects, including conflicting activities and points of view regarding access and use of natural resources, most importantly water and forests.

Even if some projects have been very specific in their territorial range, each one has been designed to work as part of an integrated basin vision, using a collaborative approach in order to create and strengthen a basin network in the medium and long terms. To help guiding

all projects on this collaborative way, four Methodological Criteria were defined (Juarez et al, 2007) [4] being these: 1) Dialogue of knowledge, 2) Questions engine, 3) Clarification of responsibilities and 4) Conflict as an opportunity.

Wanting to identify lessons about the way how partnerships were designed and the way they worked, a workshop was conducted in order to organize and analyze the projects' partnership information.

2. METHOD

First, a list of all 94 projects was prepared, altogether with a descriptive file for each one of them, describing their goals, location, period and particular outcomes. Also the participant partners (institutions and groups) that were involved in each project. Eight categories of partner roles were identified.

Then a workshop was organized to analyze the data. Participants were projects leaders, technicians and directives of the institute, besides partners' representatives. The Multistakeholder Platform (MPS) structure[5] was used to identify how partners interacted, the conflicts that emerged alongside the projects and the way how they were dealt with. Complementarily, a matrix of Conflict-Collaboration was created for each case. With those outputs, a group of "good partnership practices" were identified and later discussed, in order to propose ways to improve partnerships in a medium and long term.

RESULTS

As mentioned, eight categories of partner roles were found (shown in Table 1)

Table 1 Partners involvement

No.	Categories	Number of projects
1	Decision-making process	26
2	Design of the project	11
3	Financial support	82
4	Institutional support	32
5	Networking-Communication	16
6	Public divulgation	17
7	Research	6
8	In-kind	63

Four challenges were identified as the most common and difficult to solve along the projects, being these:

1. Communication breaks: refers to situations when information didn't flow properly or didn't reach its right audience.
2. Uncertain information: use of not reliable info to guide decision-making processes and project field activities.
3. Organizational problems: reduced capabilities to understand information, limited decision-making experience, abridged representativeness, leadership conflicts.
4. Lack of continuity: change of administrative representatives, funding discontinuity, people abandoning the process (due to conflicts, immigration and other causes).

The way how those challenges were solved showed an interesting variation. In summary, a set of alternatives were identified, including: Informative meetings, involvement of mediators, open public reunions, community research, printed announcements, radio invitations, promotion of local business, women empowerment, definition/improvement of rules, broadening of partnerships, involvement of universities and NGOs, legal procedures, field demonstrations, among others.

The matrices of Conflict-Collaboration showed that even when initial positions of partners were coincident, there were difficulties that arise as part of the development of the process, related with the four challenges identified.

Interestingly, several alternatives were used to address more than one challenge, depending of the context. For each of these a descriptive file was integrated..

3. DISCUSSION

A set of valuable features was identified as core

components to create successful partnerships.

- Creation of common goals.
- Definition of precise outcomes and times.
- Precise responsibilities and benefits for each partner.
- Use of effective communication tools.
- Transparency and accountability.
- Identification of current/potential conflicts between partners and/or with project beneficiaries.
- Frame the project within a vision of the basin.
- Use of dialogue mechanisms.
- Clear closure of the projects, informing all partners.
- Count with a record of meetings, discussions, and agreements.
- Integration of diverse-sectors working groups, to promote practical information exchange and to reduce risks of administrative changes.
- Raising awareness among beneficiaries of Environmental Services to foster support for next stages of projects.

There is agreement that such aspects are difficult to achieve by a single institution, requiring by themselves the use of partnerships.

The whole set of workshop outputs proved to be both rich and complex. Even if integrating the descriptive files was an important advance, it's necessary to organize them as a Tool Box, which could be used to improve current and future partnerships, reducing times, effort and costs.

There would be interesting to compare partnership processes of Lake Chapala basin with those of other Mexican lakes, as Patzcuaro and Cuitzeo. Besides there is interest of other institutions allocated at the Lerma-Chapala macro-basin to compare information and it's also a common interest with members of the Mexican Basin Management Network and watershed managers from Costa Rica, Guatemala, Colombia, Bolivia and Peru.

The strengthening of Participation is one of the six pillar of ILBM Governance, we hope to contribute to this participatory platform with this ongoing process.

4. CONCLUSION

Despite the step forward that this analysis represents, the integration of a Tool Box will require a good deal of time and resources. It's necessary to continue assessing and evaluating partnerships to maintain the upgrading of this aspect of projects, which represents a key component to deepen the reach and transcendence of the integrated management process of the Lake Chapala basin.

Creating successful partnerships it's not an easy task, given frequent conditions of shattered information, competition, distrust, overlapping of functions and others. For this reason is extremely important to foster experience exchanges, divulge ongoing and concluded projects, promote the replication of success cases and raising public awareness. Informing previous and current partners in order to create a more extensive network to achieve integrative programs and to better existing basin management policies and institutions is a long term goal.

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O9-5

Peace & Governance: Challenges for Sustainable Development of Lake Lanao, Southern Philippines

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Keywords: basin governance, ecosystem services and basin management policies, sustainable development, cultural heritage

ABSTRACT

One of the world's ancient lakes, Lake Lanao in the province of Lanao Sur, southern Phiippines, is home to the Meranaws, a Muslim group who inhabit the area since precolonial times. Lake Lanao is also a major economic resource of the country being the source of water of six hydropower plants, the *Agus Powerplant Complex*, which provide a big bulk of electricity to Mindanao, the country's southern most island and home to more than 30% of Filipinos. Lanao Sur is one of the poorest province and known to be hotbed of violent conflicts in the country, ranging from clan violence to historical Moro/Muslim armed secessionist rebellion and other forms of "shadow economy". Against this social backdrop, the study inquires on the state of sustainable development of Lake Lanao. From a survey of 500 respondents, key informant interviews and on-site observation, the study reveals that Lake Lanao matters has not trigger conflict among the locals. However, the professional groups and development actors in the area, private and government alike, deplore the absence of, or poor, governance of Lake Lanao which, they argue, abetted the socially and environmentally damaging monopolistic control and utilization of the Lake by a government-owned and controlled corporation. The study highlights the (a) challenges of competing resource use, between local - subsistence and cultural - versus national, highly economic ; and (b) effective governance in addressing peace and security in the locality as pillars of sustainable development.

1. INTRODUCTION

Lake Lanao is not just a cultural heritage of the Meranaws; it is likewise a major economic resource for both Lanao areas and Mindanao, in general. As a cultural heritage, the Lake is crucial to the daily life of the Meranaws in terms of food for consumption and livelihood, as well as for religious practices in Islam. However, since the 50s until present, the National Power Corporation (NPC) has the monopolistic role in the industrial utilization of the lake through its seven-power generating plants, the Agus Hydropower Project. NPC provides more than 50% of the electricity power base of Mindanao.

The construction of the NPC regulatory dam in 1978 already has some changes on the Lake as NPC now controls the outflow of the Lake. Prior to this, NPC only harnessed the natural flow of the Agus River to feed its turbines in the Agus 6 Hydorpower Dam which is more than 30 kilometers away from the lake. But it was only in 1991, where Agus 1 Hydropower Plant, constructed along the side of the Lake and with turbines at the bossom of Lake, will have been operational that a popular contestation against NPC's utilization of the Lake, particularly protesting against the operation of Agus 1 plant. This was the condition which paved the way for the creation of SALAM (Save Lake Lanao Movement, composed mostly of Meranaw professionals and traditional leaders, which embarked on an advocacy to bring justice, transparency and equity of Lake Lanao utilization. SALAM argues that Agus 1 operation will directly and radically affect Lake Lanao and its corresponding ecological and economic roles. To date, NPC still holds the monopolistic reign over the Lake.

This study explores and documents cases of conflict that have occurred in the region which are directly or indirectly related to Lake Lanao. Moreover, this study inquires on the challenges on governance in the context of sustainable peace, both as experienced and perceived by the various stakeholders in the area.

2. METHODS

A case study research design employing mixed method of qualitative and quantitative approaches. 500 community respondents were covered in the random survey and some 15 key informants for the in-depth unstructured interviews, and nonparticipant observation. Key informants are community personalities and officials of the municipality and NPC.

3. RESULTS & DISCUSSIONS

Experiences of Conflict

The Lanao region is popularly known to be a hotbed of violent conflicts between clans and family traditionally called *rido. Rido* has become the most important conflict issue facing the Philippines' Autonomous Region of Muslim Mindanao (ARMM) as this is the leading contributor of violent conflicts in the region *(Ferolin & Constantino 2014).* Table 1 below shows

cases of of violence in Mindanao with *rido* gaining a gigantic lead.

In several studies conducted about *ridos*, the following are identified as causes and triggers for the development of *ridos* in Lanao del Sur, as follows (in random order): land disputes, political rivalry, homicide, business rivalry, non-payment of debts, sex crimes (eg rape, physical contact, elopement), pride/ disgrace/shame/affront to *maratabat,* accidents and drug-related cases.

Table 1. Cases of Violence in Mindanao

Cases of Violence in Mindanao	%
Between families & clans "rido"	17
Between farmers and landowners	4
Between Muslims and Christians	0.3
Between the AFP and Abbu Sayyaf, a Muslim extremist group	2
Between the Armed Forces of the Philippines (AFP) and the New Peoples Army (NPA)	3
Due to crime	3
Due to Muslim rebels	2

Source: Social Weather Station 2005

Respondents ascertained that the utilization of Lake Lanao by the locals has never been a cause or a source of conflict, trouble or problem among the locals. They explain that the Lake is accessible to all of them; they all have access to the lake and has been using the lake their entire life, especially for their daily needs. On a similar vein, majority of the respondents have not heard of any news or information about occurrence of conflicts between Meranaws nor between anybody in their communities and nearby areas that concerns or relates to the Lake.

However, contrary to the experiences and perceptions of community-based respondents, key informants reported of a harrowing experience in 1990 in the National Power Plant, (NPC), the only industrial utilizer of Lake Lanao since 1950s. This involved the killing of some personalities connected with NPC by Meranaws who were formerly NPC employees. Key informants expressed dismay over the seemingly unfair practice of NPC in terms of employment, where Meranaws are rarely provided the chance even if they are qualified (Naga 2010).

Activities that Threaten the Lake

More than half of the survey respondents report they are well aware of on-going activities that can harm Lake Lanao. Most identified logging as a major threat to the Lake as it causes denudation of forests in the uplands of the area (see Table 2). Other activities identified are agriculture, quarrying and garbage dumping into the lake. These activities have been existing for a long time already and many respondents perceive them as "normal" practices. They recognize though that these practices must be controlled and regulated in order to safeguard the integrity of the Lake Lanao's ecosystem.

Table 2. Activities Threatening the Lake

Activities	Frequency
> Logging in the forests	50-66%
> Dynamite fishing	21%
> Other destructive fishing	20%
➢Agriculture	9%
➢Quarrying	8%
➢Garbage throwing, no toilets	5%

Existing Laws and Ordinances For Lake Lanao

A big majority of the survey respondents said they are not aware of any law or policy or ordinance, whether local, regional or national, that are existing for the protection of Lake Lanao. Key informants, however, report that there are issuances on the maintenance of the water quality of the lake, especially controlling pollution. However, there are no documents as proofs of these issuances. Key informants from the government and private sector explained that policies regarding lake protection usually stem from programs implemented by either by NGOs or government agencies in specific communities. Few key informants though asserted that there exists no local policies as the lake is entrusted to the NPC.

Members of the Save Lake Lanao Movement (SALAM) reiterate their long-standing woes and complains on the non-implementation of laws and national policies regarding Lake Lanao. This non-implementation has been to the detriment and deprivation of the Meranaws of the gargantuan bounties of the Lake. They identify the following national policies and enabling laws that are existing for the protection and development of Lake Lanao and the Meranaws:

> Environmental Compliance Certificate of NPC which mandates NPC to deliver services akin to a corporate social responsibility;
> Presidential Decree Declaring Lake Lanao Watershed for the protection and conservation of the lake
> National Integrated Protected Area System 1992- for the protection of Lake Lanao watershed
> Water Code of the Philippines - protection and conservation of Lake Lanao watershed

Secondary data also shows the existence of other nationally mandated laws and policies and for the protection of Lake Lanao and the Meranaws, as follows:

> 1992 Presidential Memo No. 30 - a decree stopping the issuance and operation of all forms of timber cutting in Lake Lanao watershed
> 1997 Republic Act 8435 - for the implementation of the Integrated Riverbasin Management and Development Master Plan for the Ranao (Agus) River Basin, for watershed conservation, river basin rehabilitation, flood control/mitigation, and water security for domestic, irrigation and industrial use, livelihood and economic opportunities in the area.
> 2001 - A Republic Act 9054 enforces total log ban in watershed areas.
> Republic Act 7160 - mandates NPC to provide monetary benefit to host local government. The share of host LGU to national wealth tax shall be applied to lower the cost of electricity and to finance local development and livelihood projects.

Existing Programs and Projects for Lake Lanao

*Integrated Natural Resources and Environmental Management Program (INREMP) for Lake Lanao - a*ims to address the dual goals of poverty reduction and watershed conservation reducing forest denudation, unsustainable farming practices, loss of environmental services and loss of agricultural productivity.

National Greening Program is a massive forest rehabilitation program of the government. NGP seeks to enhance the country's forest stock to absorb carbon dioxide, reduce poverty by providing alternative livelihood activities for marginalized upland and lowland households relating to seedling production and care and maintenance of newly-planted trees. In 2011, two communities in Lanao del Sur are beneficiaries.

The My Lake Lanao Project (MLLP) is a one-year partnership between Mindanao State University, especially the College of Arts and Social Sciences being the lead implementer, and the NGO , ABAG sa Kalambuan Inc. The project was funded by the US Embassy in Manila Cultural Affairs Division. MLLP project focussed on advocacy on Lake conservation and raising awareness of the young generation on the role of the Lake, as well as community-based livelihoods with environmental enhancements.

Issues and Concerns and Experiences of Governance of the Lake

a] The survey show that following urgent concerns about the Lake:

> Maintain the quality of water of the lake

> restore the beauty of the lake

> Build fish port for easy access for the fishers

> establish fish ponds for fish production

> Establish public toilets

b] *The National Power Corporation: The "Lord of the Lake"*

National Power Corporation (NAPOCOR or NPC) is a government owned and controlled corporation has started operation since early 1950s using the natural outflow of lake water through the Agus River. In 1978, it constructed a regulatory dam which affected the water of the lake, locals argue (Naga 2010). Five power plants are built along this river producing a total of more than 746MW. The company has been operating without any significant opposition from the communities until 1990's hostage taking-incident[1]. This incident opened up employment opportunities for Meranaws to replace the Christian employees who refused to report back to work. Moreover, this incident spurred in the office. to spurred In 1991, NPC claims it has complete jurisdiction and control over watersheds surrounding its powerplants and energy sources, referring to national laws issued.

c] Recommendations from Local Stakeholders on the following:

> Management of the Lake: A tripartite co-management among DENR, ARMM and the LGU-Lanao del Sur. With co-management, NPC will have stronger basis to participate in watershed management and to attend to the eastern side of the lake where the tributary rivers are.

> Awareness-raising among the youth on the role of Lake Lanao - maximization of the roles of schools. Also, to further study Sharia Law, especially on the context of "Khalifa" - stewardship of man to nature.

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O9-6

Mexican Watershed Network, a proposal to work on the integral management of lakes in México

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Keywords: network, Mexico, watershed, synergies,

ABSTRACT

Mexican Watershed Network (MWN) was formed in 2007 as a result of the 1st. Nacional Watershed Congress which was held in the city of Santiago de Querétaro in Mexico. In 2011 the Network began a systematic and voluntary work with a new Strengthening Strategy focusing on four axes: dissemination and communication of information, generation of synergies, linkage, coordination and collaboration, strengthening technical capacities and systematization of national information on integrated management of watersheds in Mexico. The Network is formed today by more than six hundred members, 30 % of them with a complete update of basic individual information in a database. The Governance structure of the MWN is shaped by a Directive Board, an Advisory Board, an operational group and specific technical groups. One of this groups, with Integrated Lake Basin Management (ILBM) approach, is being generated in order to develop a better understanding and diagnosis of Mexican lakes, and its watersheds, and then build the appropriated synergies and capabilities towards the 18th World Lake Conference to be held in Mexico in 2020. This technical group must base its work on an interdisciplinary and multi-institutional fundaments and will present its first results in different forums of the 5th National Watershed Congress and its corresponding 1th Latin-American Congress to be held in 2019 at Mexico.

1. INTRODUCTION

The main objective of this paper is to describe the strengths and opportunities to promote the Integrated Lake Basin Management (ILBM) through the Mexican Watershed Network (MWN) and outline the great potential and next efforts that Mexico will do nationwide and in Latin America, all of this in the context of the 18th World Lake Conference.

The organization of a networked task to develop in Mexico a strategy proposal for the ILBM is based on the work carried out in the Chapala Lake basin, in Jalisco, Mexico by the *Instituto de la Tierra A.C.* In addition to the adoption and strengthening of capabilities of the MWN to align efforts with the ILBM, exist also the possibilities of amplification and construction of synergies with strategic allies that the Network has built since 2011: WWF Mexico, the Gonzalo Rio Arronte Foundation, the Fund for Communication and Education, A.C., through the Virtual Water Information Center [1] and the "*Nuestra Agua*" application [2] and the governmental institutions in charge of environmental and water issues in Mexico, these are the Ministry of Environment and the National Water Commission.

The Governance structure of the MWN is formed by a Directive Board, an Advisory Board, an operational group and the specific technical groups (Fig. 1).

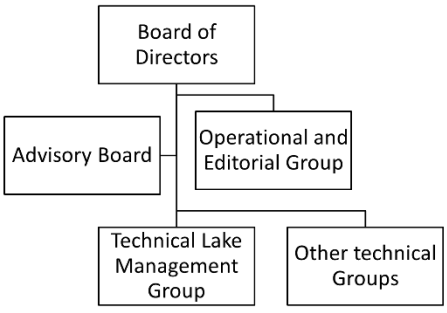

Fig. 1 Governance structure of the MWN.

Synergies from this structure could be triggered by the active participation of at least 60 organizations of the current projects of the Water Program of the Gonzalo Rio

Arronte Foundation, a Private Assistance Institution working since 2000 with the mission of influencing the revaluation of water, by supporting projects promoted by organizations, public or private, that, for purposes of social benefit, develop activities to promote a culture of water, care of bodies channels and watersheds, of control-correction or optimization of the use of water, of minimization of negative effects of excess water and in projects particularly directed to marginalized rural communities.

Also, synergies and technical capabilities can be amplified by the collaboration and coordination with the Socioecosystems and Sustainability Network [3] a Thematic Network financed by the Nacional Center for Science and Technology (CONACyT).

2. METHOD

The MWN has designed a networking procedure on its platform [4] and will invite to collaborative specialists registered in its database and researchers from the CONACyT thematic networks, specifically the Socioecosystems and Sustainability Network, to discuss the application of the ILBM approach in Mexican lakes.

The coordination and collaboration bases will be established in addition to the necessary agreements to make an articulated and transparent work.

A diagnosis, the state of the art of knowledge about lakes and the gaps between current work and that based on the ILBM approach will be requested as products of the technical group's discussion.

With the experts involved in this process, the spaces will be designed to present results and advances in 5th National Watershed Congress and its corresponding 1st Latin-American Congress to be held in 2019 as well as 18th World Lake Conference to be held in 2020, in Mexico.

3. RESULTS

The MWN is the perfect vehicle to implement the ILBM approach through a technical group of specialists with an interdisciplinary approach.

A group of specialists in lakes, formed for the first time in Mexico at the invitation of the MWN, with a database and a digital platform will exchange experiences and articulate future actions in favor of lake basins.

The results of the process will be available in the digital tools and the MWN page: networking, discussion forum and blog, and all will be obtained from the technical group.

In addition, the topics to be worked on in the development of the 2019 Congresses and the World Conference in 2020 in Mexico will be discussed in coordination and with the guidance of International Lake Environment Committee Foundation (ILEC).

4. DISCUSSION

The collaborative work supported with the technologies to develop a networked work will be essential to register Mexico within the countries that develop and commit to the ILBM approach**.**

A technical group, generated into the MWN, with an interdisciplinary and multi-institutional fundaments will be responsible for establishment of new era in the future of Mexican lakes.

The results and advances of this effort will be presented in the next important congresses in Mexico related to integrated watershed management, including the lakes.

5. CONCLUSION

The MWN will be the key player to introduce the ILBM approach throughout Mexico and a point of contact for future efforts of International Lake Environment Committee Foundation (ILEC)

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O9-7

Impacts of recent environmental changes on the livelihoods of fishing communities in the Tonle Sap Lake (TSL)

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Keywords: environmental changes, fisheries, livelihoods, socio-economic, Tonle Sap Lake

ABSTRACT

The Tonle Sap Lake (TSL) is among the most productive freshwater ecosystems, and one of the most fish-abundant lakes in the world. It is connected with the Mekong River by the Tonle Sap River. The TSL absorbs a huge volume of water, which helps to reduce flooding in the Mekong River floodplains during the peak flooding season, then releases water into the Mekong River during the dry season, which vital to maintain ecological flows and to prevent salt intrusion into the Mekong delta. Local communities who live in or around the TSL are well adapted to this hydrological phenomenon of the Mekong River and TSL. Local livelihoods are also deeply dependent on natural resources and services that the lake and its floodplains provide, including agriculture, trade and fishing, three most important livelihood sources. This study investigated impacts of and the recent environmental changes on the livelihoods of the fishing communities in and around the TSL. More specifically, the study intends: (i) to examine socio-economic and environmental changes occurred in and around the lake and its causes; (ii) to explore the impacts of these changes on the livelihoods of fishing communities; (iii) to identify the strategies that could enhance the resilience of the local communities and reduce their vulnerability.

1. INTRODUCTION

The Tonle Sap Lake (TSL) is the largest freshwater lake in Southeast Asia and is the seventh largest lake in the world, in terms of size in the wet season (ILEC, 2005). The lake size varies from approximately 160 km long and 35 km wide (250,000-300,000 ha) during the dry season (Somony, and Schmidt, 2004) to 250 km long and 100 km wide (1.0-1.3 million ha) during the peak wet season (Matsui et al., 2005). The Tonle Sap River connects the lake to the Mekong River and is known for its rich biodiversity and extraordinary hydrological phenomenon characterized by a huge seasonal variation in term of both water level and volume. The TSL absorbs a huge volume of water during wet season when the Tonle Sap River flows into reverse direction. This helps to reduce excessive flooding in the Mekong River floodplains and maintains beneficial inundation. In dry season, water is gradually released, when the Tonle Sap River flows into normal direction, and helps to maintain vital flow in the Mekong River prevent salt intrusion into the Mekong Delta. This process is referred as the "flood pulse", which causes the lake to swell 5-6 times larger, with water depth increasing from 1.5 m in the dry season to 9-10 m in the wet season (Kummu et al., 2006). The "flood pulse" transforms both the physical and the human landscape of the Lower Mekong and TSL. In the dry season, the water level of the TSL recedes and exposes the areas naturally fertilized by sedimentation of nutrients ready for regeneration of plants, farming and home to terrestrial species. As one of the most productive freshwater fisheries in the world, the Lake yields 230,000 tons fish annually; it has been estimated that approximately half of the country's population benefits, either directly or indirectly, from the lake's resources (Van, Zalinge, et al., 2000). Unfortunately, due to several negative changes have occurred due to human induced drivers which has led to the disruption of the TSL water environment. Cascade of hydropower dams developed along the Mekong River is one of the distinct interventions to TSL unique flood pulse system. The socio-economic context of the TSL is quite varied and the unsustainable pattern of resource exploitation, expansion of settlements, and discharge of wastes and pollutants into the lake has severely affected the lake environment. Deterioration of environmental condition of the TSL could have significant impacts on the livelihoods of communities directly relying on fishing, farming and other resources of the TSL. An insightful understanding of socio-economic and environmental changes occurred in and around the lake is critical for the

sustainable management of the lake and its basis as well as for enhancing the resilience of communities living in and around the lake.

2. METHODS

The study employed both qualitative and quantitative methods for data collection and analysis from both primary and secondary sources. The secondary data relies on published literature and statistical data (e.g. Cambodia Socio-Economic Survey 2014, 2015; Cambodia Inter-Census Population Survey 2013). Primary data were collected using following qualitative approaches in land-based, land-water based and water based (floating village) communities: (a) ethnographic-type fieldwork, in particular, participant observations in the selected study sites; and (b) semi-structured interviews with local residents; and (c) focus group discussion with local NGOs and communities, and village chiefs. Before conducting household interviews in each studied site, a Focus Group Discussion (FGD) was carried out targeting local residents, fishers, local NGOs and village chiefs, in order to get general understanding of the village and its livelihood situations. Totally, 3 FGDs have been conducted. In addition, altogether 253 interviewing samples have been carried out at households in 4 studied villages located in 4 major provinces around Tonle Sap Lake, namely Rohal Suong (land-based village) in Battambang Province, Muk Wat (water-land based village) in Siem Reap, Kampong Luong (water-based village) in Pursat, and Chhnok Trou (water-based village) in Kampong Chhnang Province (Fig. 1). The interviews were conducted using a semi-structured questionnaire. Main issues discussed in the interviews included household characteristics; geographical landscape of the community; linkages between TSL and their livelihoods; household income; farming and fisheries and their impacts on the livelihoods; access, availability and uses of water; changes in socio-economic conditions, living standards and surrounding environment during the past decade.

3. RESULTS

It is estimated that about 1.7 million were living in 1037 villages of TSL and surrounding floodplains (Sithirith 2011). They have learned to adapt to the hydrological changes and live in close relation with the environment. Fishing villages in the TSL are organized into three different groups situated in three different ecological zones, namely land-based village (948 villages), water-based village (53 villages), and water-land based village (36 villages) (Sithirith, 2011). In land-based villages, people are primarily engaged in farming with occasional fishing activities depending on water level. In water-based villages, often referred to as floating villages, local people are primarily relied upon fishing, which is an important activity for local livelihoods since they have little or mostly no access to land. Meanwhile, in water-land based villages, people often spend approximately six months of the year on land and six months in water. In the wet season,

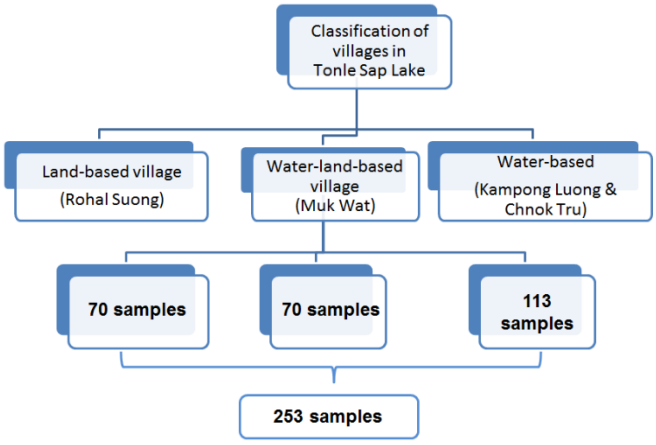

Figure 1. Sampling locations and sample size for household questionnaire surveys

the water floods the area around the village and surrounds the houses, which are built 6-8 meters above ground. Although fishing is a primary occupation for local livelihoods, villagers also supplement their incomes through small-scale farming. These villages are in the ecological zone mostly affected by seasonal water level changes. The livelihood setting of the TSL area is well adapted to its flood pulsing system and are deeply dependent on the resources and services that the lake and its floodplains provide such as agricultural products, fish and other aquatic animals, and plants. Local people also engage in several off-farm income generating activities, depending also on the seasons.

Declining fish catch and socio-economic impacts

Fisheries in all surveyed communities are crucial and forms their main or secondary income sources. (Kampong Luong and Chhnok Trou; Muk Wat). For example, in Chhnok Trou, 74% of households heavily rely on small-scale fishing as the main income source. The income is directly dependent of daily fish catch which is equivalent to 3-20 US$/day, and often the only revenue for household expenditure. Meanwhile, in land-based and water-land based villages, besides small-scale fishing as the secondary income source, rice cultivation is the main livelihood and income sources for majority of households living here. In this delicate situation, rapid fall in the fish catch (both quantity and quality) is one of the critical issues identified from the surveys. As a result the fishermen are unable to adequately support essential households' expenses. Fish catch has declined despite an intensification of fishing effort at the household level, which also means added time, financial and energy expenditures, and opportunity costs.

According to the local communities, the decline in fish catch can be attributable to several factors, including the use of illegal fishing methods, lack of control of fishing gear, unequal access to fishing grounds, an increase in the number of fishers, deterioration of fish habitat, hydrological changes in the flood pulse, and climate change. In particular, the construction of cascade of hydropower dams on the upstream countries as well as impact of climate change is believed to alter hydrological cycle affecting seasonal inundation of the lake, sedimentation and nutrient transport. Continuation with the disruption in the hydrological cycle and declining fish catch will increase people's vulnerability, especially, those with low assets base and relying on income from daily fish catch.

The impacts of environmental changes

The findings from the interviews showed that the most recent environmental changes is the deterioration of water quality in both the TSL and Tonle Sap River. The main causes of water quality decline are discharge of untreated wastewater and disposal of solid waste in the tributaries flowing towards the lake, runoff of agro-chemicals and poor water, sanitation and hygiene (WASH) and waste disposal within the floating villages. Houses in floating villages discharge effluents from toilets directly into the lake, which increased the risk of microbial contamination in the surrounding waters. Due to the nature of housing, people come under frequent direct contact with polluted water such as through washing raw food and fish, bath, hand wash and swimming. Due to primary and secondary contamination paths, at least some family members, especially children, had water borne illness and need to visit doctor frequently.

Climate change and low adaptive capacity of fishing communities

The local livelihoods and people's lives in and around Tonle Sap Lake are directly affected by the impacts caused by climate change, especially, through disruption on the hydrological cycle of the TSL. Number of extreme weather or unexpected events such as heavy storms causing high waves, severe floods (e.g. the flood events in 2000 and 2011) and droughts seem to occur more frequently and have huge economic impacts particularly to the poor households. This is highly critical for a large population dependent on the resources and services of the TSL basin floods and droughts mitigation (Grundy-Warr and Sithirith, 2016), agriculture and food security, terrestrial and freshwater ecosystems, and human health. Among 3 types of surveyed villages, the water-based communities (Kampong Luong and Muk Wat village) as such are physically less affected than those living in land. However, too high water level or waves caused by heavy storms cause many difficulties for their small-scale fishing activities. Meanwhile, too low water level will induce severe water pollution, therefore affecting to fish population, as a result the communities have to travel afar in search of better fishing ground adding fuel cost of the fishing boats, extra physical labour, and risk of accidents.

4. WAYS FORWARD TO IMPROVE THE RESILIENCE OF COMMUNITIES AROUND THE LAKE

Findings from the study indicated that in order to improve the resilience and to cope with unexpected environmental and climate change, diversification of income sources is one of the common options adopted by the households such as seasonal migration to cities, industrial estates for jobs, part-time or short-term workers or helpers in other villages or provinces, off-farm business (groceries). Improve and strengthen their housing structures, either using bamboo or woods, is another coping measure against rising tides and storms. The study found that micro-credits with low interest rate is also an important factor that help local communities to initiate supplementary livelihood sources and for buying new fishing gears.

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O9-8

Role of Local Authority in Integrated Lake Basin Management: Experiences from Malaysia

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Keywords: Water Pollution, Drinking Water, Socio-economic, Sustainable Development

ABSTRACT

ILBM (Integrated Lake Basin Management) is relatively a new concept in Malaysian context if it is compared to IWRM (Integrated Water Resources Management) and IRBM (Integrated River Basin Management), however, it can be fit in nicely and quickly because of relatively good understanding and buy-in from stakeholders at various levels in Malaysia. ILBM is quite a natural approach for Malaysia because there are so many lakes in the country such as natural lakes, ex-mining lakes, man-made lakes, and other multi-purpose lakes including for HORAS (hybrid off-river augmentation system) uses in Selangor State, etc. There are already active committees at the policy level on lakes as well as research and development levels too, including those chaired by several government agencies. Therefore, lakes may quickly and efficiently bring ordinary people closer to proper water management because of aesthetics and recreational attractions of lakes including for fishing, relaxation and retention purposes for water discharged or runoff from residential and business areas and estates. The key success factors for ILBM, based on literature review and informal interviews, is community buy-in along with embracement and enculturation of ILBM principals as well as aspirations for human and ecosystems health. In Malaysia, if there is a bold and sincere leadership of local authority, then the maximum of the implementation of ILBM can be won. Moreover, if there is support by academia and business professionals for expertise sharing and knowledge transfer, then the ILBM can be achieved entirely to promote the sustainable development in Malaysia.

1. INTRODUCTION

Integrated Lake Basin Management (ILBM) is a new approach in Malaysia in line with the integrated water resources management (IWRM) and integrated river basin management (IRBM), however, it can significantly contribute to the socio-economic development of the country since it is considered as the important reservoirs of fresh water [1]. For instance, Putrajaya lake is a successful example of operational UNESCO-IHP Ecohydrology Demonstration project out of seven such projects implementing globally since 2010 incorporating ecohydrology principals and relevant stakeholders [2]. Putrajaya lake which is a man-made lake of 600 hectare serves as a micro-climate moderator as well as serves as the sport and recreational purposes. However, the shortcomings in sustainable water resources management in Malaysia are reported mainly because of inadequate enforcement of policies and public participation along with the inadequate emphasis on non-structural measures [3;4].

11th Malaysia Plan (2016-2020) has also emphasized the water security in Malaysia for the green growth. Off River Storage (ORS) is an approach to tackle the pollution problem of the river for drinking water purposes. For instance, the Labohan Water Plant is following Off River Storage (ORS) which is storing water from the Langat River, Malaysia to supply drinking water at the household level after treatment [5]. Ex-mining ponds in Kampung Sungai Darah, Selangor has already been converted to special water storage for 600 million litres per day raw water supply for drinking purposes in Selangor. The particular water storage is termed hybrid off river augmentation system (HORAS) which is the combination of the off-river storage and horizontal collector well such as stormwater and underground water. The Selangor state government has already invested about RM300 million for the two HORAS projects to get 600 million litres and 700 million litres per day (MLD), respectively from Selangor River to meet up the growing demand of drinking water [6].

Although the water quality in the ex-mining pond is questionable concerning metal and radionuclide contaminants, however, Kusin et al. [7] reported the water quality regarding metal in the abandoned mining ponds including sediment at Selangor are within safe limit. Meanwhile, several best management practice projects have been carried out in line with the IWRM and IRBM

by the government of Malaysia over the last decade; however, Sukereman & Suratman [8] reported that the implementation of these projects remained in doubt and was unfamiliar by many parties. Therefore, the study proposed the leadership of local authority to implement the integrated lake basin management in Malaysia since they can involve the stakeholders effectively at all levels.

2. METHOD

The study is based on the review of the secondary literature as well as informal interviews with the public, private and civil sectors in 2017.

3. RESULTS AND DISCUSSIONS

National Hydraulic Research Institute of Malaysia (NAHRIM) is leading the lake management along with the monitoring of water quality in collaboration with Department of Environment (DOE), local authorities, universities, and as such [9]. NAHRIM has also already published the "National Lake Water Quality Criteria and Standards" for Malaysia, and the agency has arranged several stakeholder's participation from different ministries and departments through the workshop, seminars, etc. DOE [10] has also included the management of lake in the Environmental Management Plan and Environmental Monitoring of Malaysia. Although the present conventional approach to managing the water quality of Lake has not become successful to minimize the pollution of the lake through the Environmental Quality Act 1974 and the limitation to implementing Malaysia Waters Act 1920, however, the Local Government Act 1976 can be effective in reducing the pollution since the local authorities have got the mandate to punish the polluters economically through the act.

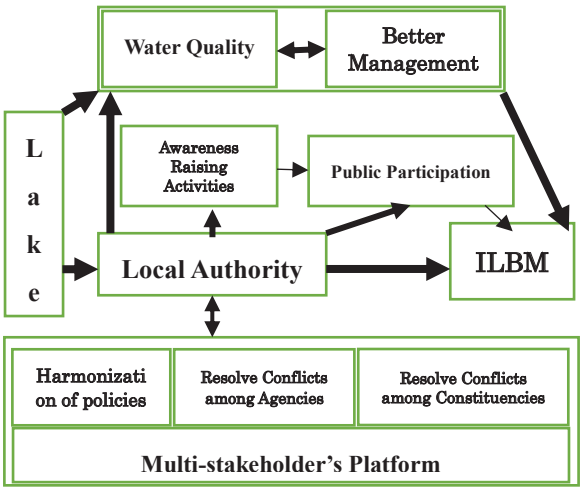

Fig. 1 Flowchart of better implementation of ILBM

Sharip et al. [11] also reported that all the important lakes in Malaysia (Table 1) are eutrophic and they could experience algae blooms or macrophyte problems due to enriched nutrients and can result in poor water quality. Therefore, to improve the water quality largely depends on the sustainable catchment practices along with the active collaboration among the public, private and civil sectors [1]. Hence the proactive leadership of local authority can lead to successful implementation of ILMB through involving the public in the decision-making process (Figure 1).

Although the beat management practice projects have potential in improving water quality status of the lakes in Malaysia (Table 1), however, the improvement of water quality highly depends on the active promotion of these projects incorporating various stakeholders to enhance the implementation of ILBM in line with the IWRM [8]. The challenges of lake basin governance are associated with the conflicts among many agencies and different constituencies not only in Malaysia but also in Canada and USA [12]. Similarly, the Great Lakes Basin, Canada is also getting chemical pollution for the rapid urbanization and which is a threat for the fresh water reservoir including the groundwater for drinking water supply purpose [13].

Table 1 Important lakes of fresh water reservoirs in Malaysia [1;11]

Lake	Area (km²)	River Basin	Water	Lake Type	Land Use
Talang	3.7	Pahang	Clear	Man-made	75% Forested
Kelinchi	1.9	Pahang	Clear	Man-made	75% Forested
Sg Terip	2.25	Linggi	Clear	Man-made	90% Forested
Bukit Merah	41	Kurau	Clear	Man-made	46% Forested
Chenderoh	25	Perak	Clear	Man-made	33% Agriculture
Raban	0.375	Perak	Clear	Man-made	33% Agriculture
Chini	2	Pahang	Coloured	Natural	50% Agriculture
Sembrong	8.5	Batu Pahat	Clear	Man-made	84% Agriculture
Kenyir	369	Terengganu	Clear	Man-made	99% Forested
Bera	6	Pahang	Coloured	Natural	50% Agriculture
Ulu Lepar	4.69	Pahang	Mixed	Natural	Mixed
Durian Tunggal	3.5	Melaka	Clear	Man-made	75% Agriculture
Ayer Keroh	0.5	Melaka	Clear	Man-made	Mixed
Aman	0.0224	Kelang	Clear	Man-made	Mixed
Layang	6.6	Johor	Clear	Man-made	50% Agriculture
Putrajaya	6	Langat	Clear	Man-made	Mixed

In Thailand, the local people perceived that the governance performance of lake basin management was below average mainly due to the institutional and agency fragmentation, inadequate coordination and integration of stakeholders as well as enforcement and compliance of policies [14]. However, the governance performance can be improved through integrating local people's perceptions in governance and management decision-making.

Similarly, the Lake Chini in the Pahang River Basin, Malaysia is not only a famous location of eco-tourism but also one of the largest freshwater reservoirs in the country [15]. However, the integrated and holistic management of the Lake Chini in line with the IWRM and IRBM largely depends on the inclusion of the local and indigenous people's livelihood in the lake ecosystem. Therefore, lakes

are not just for aesthetic beauty but also contribute significantly to the socio-economic development of the country. These lakes can also be used for freshwater storage to meet up the growing raw drinking water demand. Therefore, ILBM will be very pertinent for the Selangor and Kedah State of Malaysia since there is no reserve margin of fresh water during 2016 by the water treatment plants (WTPs), while other states in Malaysia have at least some reserve margin of fresh water [16].

4. CONCLUSION

The proactive leadership of local authority could be effective in implementing ILMB in Malaysia to promote the socio-economic transformation of the country in line with the IWRM. Hence, the leadership of local authority can be achieved via special training and education since the performance of all the local authorities in Malaysia is not equal. Besides, these inland lakes in Malaysia are also providing provisioning as well as regulating services. However, the success of ILMB largely depends on the meaningful participation of communities in collaboration with public and private agencies as well as harmonization of policies to enforce effectively. Therefore, under the proactive leadership of local authority, the implementation of ILMB can efficiently arrange the adequate stakeholders' participation through top-down and bottom-up approaches. However, the awareness raising activities, e.g. seminar, workshop, fair, etc. by the local authorities are required to encourage the people for willingness to participate and willingness to pay for lake basin management.

ACKNOWLEDGEMENT

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O9-9

River/Lake Chief, a new concept proposed by China to improve water environment

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Keywords: River Chief, top officials, sustainable development, water environment

ABSTRACT

With an aim to promote better coordination among government departments to protect the water bodies, the central government of China has decided to establish a nationwide river and lake chief system to cover all rivers and lakes by the end of 2018. It is expected to cover the provincial, city, county and township levels. Heads of provincial-level regions will be general chiefs responsible for all rivers and lakes in the region, other top officials at provincial, city, county and township levels will act as chiefs responsible for different parts of the water bodies. Responsibilities of the chiefs include water resource protection, pollution prevention and control, and ecological restoration. Their job performance will be assessed, and they will be held accountable if environmental damage occurs in the water bodies they oversee. Information including names and responsibilities of the chiefs will to be made public to ensure public supervision. China firstly appointed local government officials as chiefs in 2007 to address problem of blue-glue algae bloom in Lake Taihu, Jiangsu Province. Zhejiang Province began testing this new system in 2008 and expanded it across the whole province from 2013. In this presentation, we'd try to introduce this new concept and also its the achievement and challenges we've seen.

In China, along with fast development of economy, balancing economic development and ecological protection is becoming a major challenge. The central government of China has long realized the necessity and urgency to protect the environment. "Interplay between development and environmental protection is an intrinsic requirement of sustainable development, and the fundamental principle of modernization", "To protect the environment is to protect productivity, and to improve the environment is to develop productivity", as said by Chinese President Xi Jinping.

On 11 December, 2011, the general offices of the Communist Party of China Central Committee and the State Council, China's Cabinet, jointly issued a document to implement a river keeper system nationwide. According to the document, heads of provincial-level regions will be general chiefs responsible for all rivers and lakes in the region, other top officials at provincial, city, county and township levels will act as chiefs responsible for different parts of the water bodies. Responsibilities of the chiefs include water resource protection, pollution prevention and control, and ecological restoration. Their job performance will be assessed, and they will be held accountable if environmental damage occurs in the water bodies they oversee. Information including names and responsibilities of the chiefs is supposed to be made public to ensure public supervision.

The concept develops from a successful experience in Changxing County, Zhejiang Province in 2003. China firstly appointed local government officials as chiefs in 2007 to address problem of blue-glue algae bloom in Lake Taihu, Jiangsu Province. Zhejiang Province began testing this new system in 2008 and expanded it across the whole province

from 2013. The central government of China has decided to establish the nationwide river and lake chief system to cover all rivers and lakes by the end of 2018.

A similar scheme has been proposed in Australia in 2010. A chairman of Murray-Darling Basin Authority was appointed by the government, to restore the Murray-Darling river system. The chairman was asked to ensure the restoration plan balanced ecological outcomes with the socioeconomic impacts. However, such an ambitious scheme came to its end when the chairman resigned two months after the release of the draft plan, which prompted protests from the region's farm.

Although no systematic assessment has been done on the effectiveness of the river/lake chief system, some advantages of the new system can already be seen since after the release of the document and appointment of the chiefs. "The system helps to tackle tough challenges", as said by the director of the Department of Water Environment management at the Ministry of Environmental Protection. The efficiency of coordination among departments has been greatly improved. In the system, all the government departments related to waterbodies are members of a leading group and the top official acts as the chief. Such a hierarchy enables the system to coordinate their activities efficiently.

Due to the achievement the river/lake chief system has obtained, the newly proposed concept has been introduced to management on coast in Hangzhou, Zhejiang and street in Beijing, i.e. where the top officials are named coastal chief and street chief.

O9-11

琵琶湖流域の環境評価に影響を与える要因

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キーワード:・湖沼流域保全, 参加型評価, 滋賀県

抄録

琵琶湖は, 水資源としてだけでなく豊かな生態系を育み, 固有の文化や景観が形成されるなど多様な価値を持っている。滋賀県では2020年に琵琶湖の総合保全計画を再策定するため, 現行計画の評価を踏まえて次期計画の検討が始められている。本研究では, 公共政策において住民参加型評価が求められているという観点から, アンケート調査によって個人における琵琶湖流域の湖内, 河川, 農地, 森林の現状評価を把握し, 評価に影響を与える要因を検討した。その結果, 50歳以上の回答者は50歳未満の回答者に比べて全ての項目の満足度が顕著に低く, 田と森林について問題があると評価している, 滋賀県に10年以上住んでいる回答者は川と田に問題があると回答している, 湖に関わる頻度が多い人ほど田や森林に対して問題を認識し, かつ, 満足度が低い, 滋賀県住民は県外住民よりも森林の評価が低く満足度も低い傾向がある, などの傾向が明らかになった。

1. はじめに

琵琶湖は, 水資源としてだけでなく豊かな生態系を育み, 流域に住む人々によって固有の文化や景観が形成されるなど, 多様な価値を持っている[1]。しかし, 湖とその流域の環境は様々な要因が絡み合っており, また, 社会情勢の変化とともに新たな問題や課題も顕在化してきている[2]。このような背景を受け, 滋賀県では琵琶湖の多様な価値を次世代に引き継ぐための指針として2000年にマザーレイク21計画(以下, ML21計画)が策定された。同計画では, 2050 年頃の琵琶湖のあるべき姿と合わせて, 2010年度までを第1期, 2020年度までを第2期として, 琵琶湖を保全するための幅広い取り組みが進められている[1]。現行計画では,「暮らしと湖の関わりの再生」と「琵琶湖流域生態系の再生・保全」を掲げ[2], 進行管理として, ①計画の策定, ②事業・施策・活動の実施, ③琵琶湖総合保全の方向性の確認・評価, ④改善・対応策の検討, 協働への発展, のプロセスを組み込んだPDCAサイクルを実行することが想定されている[1]。

PDCAサイクルのCheckの段階では, 行政の評価だけではスムーズに改善が進まない可能性もあり[3], 外部の視点や考え方を取り入れる参加型評価が有効である[4]。参加型評価の導入によって, より多様な意見を得られる, 評価の透明性が上がる[5]など評価プロセスを通じて利害関係者自身に変化をもたらすことができる[6]。このような住民参加型評価の視点からML21計画では第2期策定の際, 琵琶湖やその保全に関する県民意識を把握するためのアンケート調査や琵琶湖流域の将来像を探るためのワークショップ等が実施された[7]。現在, 次期計画検討のために現行計画を見直す段階にあるが, 行政による一定の評価はされているものの, 流域住民(利害関係者)の評価は把握されていない。現段階では参加型評価を十分実行できていない状況である。

本研究では, 公共政策において住民参加型の評価が求められているという観点から, まずは琵琶湖流域住民の琵琶湖流域の現状評価とその理由を把握する。さらに, 住民と行政の評価結果の差異を明らかにするとともに, 現在の琵琶湖流域の課題や目指すべき姿について考察する。本研究の意義は, ML21計画の第3期計画へ反映させるべき内容の参考資料となることである。

2. 方法

上記の目的を達成するため, 2016年8月20日に開催された琵琶湖の環境活動に関する催事, 11月22日に開催された滋賀県内小学校教師を対象とする研修会, 11月30日に滋賀県立大学環境科学部の学生を対象とした授業において, それぞれ42名, 16名, 36名を対象にアンケート調査を実施した。調査方法は, まず, 図1に示すシートを用いて琵琶湖, 川, 田畑, 森林それぞれの現状について満足度および問題と感じる程度を評価し, シート上にプロットすることとした。また合わせて, 評価の際にイメージした場所と評価理由を尋ねた。次に, 現状評価に影響を与える要因を把握するため琵琶湖と

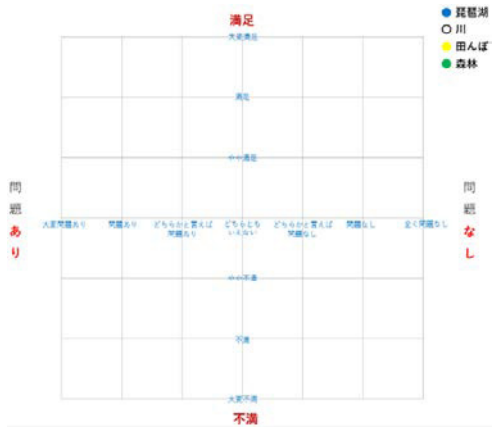

図 1 現状評価の記入シート

関わる頻度を，回答者の属性として性別，年齢，職業，居住地，滋賀県内居住年数を尋ねた。調査は対面で依頼し回収数は 94，回収率 100%であった。また，評価結果は大変満足を (0,1) ，大変不満を (0,-1)，問題なしを (1,0)，問題ありを (-1,0) として，原点からプロットされた位置までの距離によって数値化した。

3. 結果と考察

現状評価の結果を図 2 に示す。図より問題なしで満足（第 1 象限）および問題ありで不満（第 3 象限）は問題の程度と満足度が関連している結果であるが，問題があるが満足である（第 2 象限）との回答も多かった。この理由を確認したところ，問題があるが自分自身の生活に影響がない，保全活動の取り組みがされているため不満はないなどであった。これらの結果より，問題の程度と満足度は関連している回答が多数であるが，自分自身への影響の有無や自然環境そのもの以外に市民活

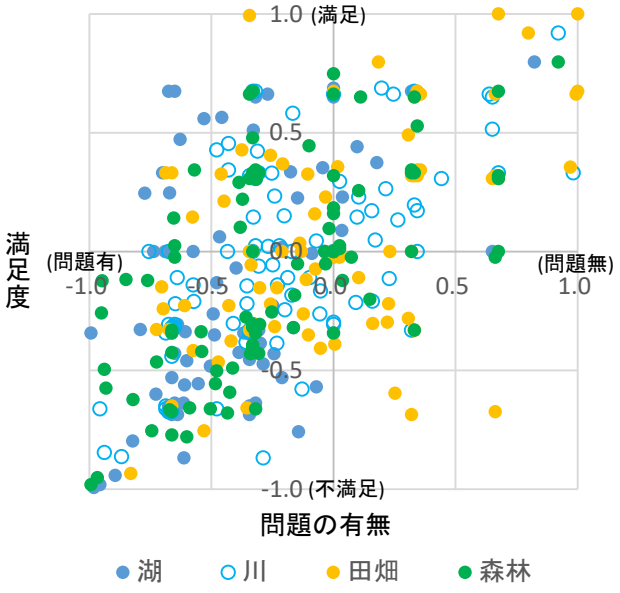

図 2 評価結果（N = 94）

表 1 現状評価の平均値

	湖	川	田	森林
満足度	-0.17	-0.03	0.05	-0.09
問題の程度	-0.41	-0.20	-0.01	-0.25

動や地域への愛着などが満足度に影響している可能性が考えられる。

次に，各項目の満足度と問題の程度の平均値を表 1 に示す。満足度については田のみ 0.05 で正，それ以外は負の符号となりどちらかというと不満に思っている人が多いことが分かる。特に湖については-0.17 とそれ以外の項目よりも顕著に低い。また，問題の程度については全て負の符号となり問題ありと評価している人が多いことが分かる。特に湖は-0.41 と最も評価が低く，川と森林もそれぞれ-0.20，-0.25 と低い評価であることが分かる。また，各項目における満足度と問題の程度の関係については，全ての項目で問題の程度よりも満足度が高く，また，湖の評価について，問題の程度と満足度が共に最も低い評価であること等から，問題の程度によって満足度に影響があることが考えられる。

最後に，属性や湖と関わる頻度による評価の違いについて検討するため，平均値の差の検定を行い 5%水準で有意に差があることを確認できた結果を表 2 に示す。表中では有意に低い値（評価が低い）のセルを灰色で示す。表より，50 歳以上の回答者は 50 歳未満の回答者に比べて全ての項目の満足度が顕著に低く，田と森林について問題があると評価している。また，滋賀県に 10 年以上住んでいる回答者は川と田に問題があると回答している傾向がある。湖に関わる頻度が多い人ほど田や森林に対して問題を認識し，かつ，満足度が低い傾向にある。滋賀県住民は県外住民よりも森林の評価が低く満足度も低い傾向がある。

以上の結果より，比較的滋賀県や琵琶湖に関わりが深い回答者ほど問題を認識している，もしくは満足度が低い結果となった。この理由として，まず，居住期間が長いもしくは年齢が高い回答者は，滋賀県や琵琶湖の過去の状態や変化を認識しており，過去と現在の自然環境を比較していることが考えられる。また，湖との関わる頻度が高いほど，問題を把握し保全活動を実施している，もしくは愛着があるためにさらに良い環境を求めていることなどが考えられる。

表 2 属性等による評価結果の違い

		湖	川		田		森林	
		満足度	問題の程度	満足度	問題の程度	満足度	問題の程度	満足度
年齢	50 歳以上	-0.32	—	-0.17	-0.25	-0.22	-0.40	-0.31
	50 歳未満	-0.08	—	0.04	0.12	0.20	-0.13	0.05
県内居住期間	10 年以上	—	-0.23	—	-0.10	—	—	—
	10 年未満	—	0.13	—	0.28	—	—	—
湖との関わり	多い	—	—	—	-0.31	-0.16	-0.49	-0.33
	少ない	—	—	—	0.08	0.11	-0.16	-0.01
居住地	滋賀県内	—	—	—	—	—	-0.32	-0.16
	滋賀県外	—	—	—	—	—	-0.02	0.12

p<.05

4. 結論

本研究では 97 名を対象として琵琶湖流域の湖内，河川，農地，森林の現状について評価を把握し，評価に影響を与える要因を検討した。その結果，次のことが明らかとなった。

・50 歳以上の回答者は 50 歳未満の回答者に比べて全ての項目の満足度が顕著に低く，田と森林について問題があると評価している。

・滋賀県に 10 年以上住んでいる回答者は川と田に問題があると回答している傾向がある。

・湖に関わる頻度が多い人ほど田や森林に対して問題を認識し，かつ，満足度が低い傾向にある。

・滋賀県住民は県外住民よりも森林の評価が低く満足度も低い傾向がある。

今後，個人の評価に至る心理構造などを明らかにするとともに，行政評価や政策への反映方法について明らかにする必要がある。

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O9-12

Perceptions, attitudes and preferences for wetland ecosystem services: a case study of Tampara, Odisha

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Keywords: wetlands wise use, ecosystem services, perceptions, lake basin management, ESSVA

ABSTRACT

Wise use of wetlands is predicated on the extent to which primary stakeholders, especially local communities participate in the management of these ecosystems. Limited empirical data on behavioural dimensions of ecosystem services and communities' response to management of these services impedes effective integration in management. We used Ecosystem Services Shared Value Assessment (ESSVA) tool to assess community perceptions, preferences and attitudes for ecosystem services of Tampara, a freshwater lake located along the eastern coast of Odisha State in India. Data from 278 structured questionnaire survey of basin communities and eight focal group discussions indicated that the demographic, socioeconomic and spatial heterogeneities within these communities had a significant influence on attitudes and preferences for 19 ecosystem services identified as being derived from the wetland. Relative significance for ecosystems services, mainly provisioning services varied when communities responded as a group as compared with when responding as an individual. Spatial location in the basin, gender, occupation and ownership of assets had a significant bearing on the preferences for ecosystem services. Communities directly dependent on the wetland perceived their role in restoration and management as being more prominent as compared with governments or other management agencies. A segmented and spatially nuanced understanding of ecosystem services, as enabled by the ESSVA tool, provides the basis for broadening stakeholder engagement in management for wise use of wetlands.

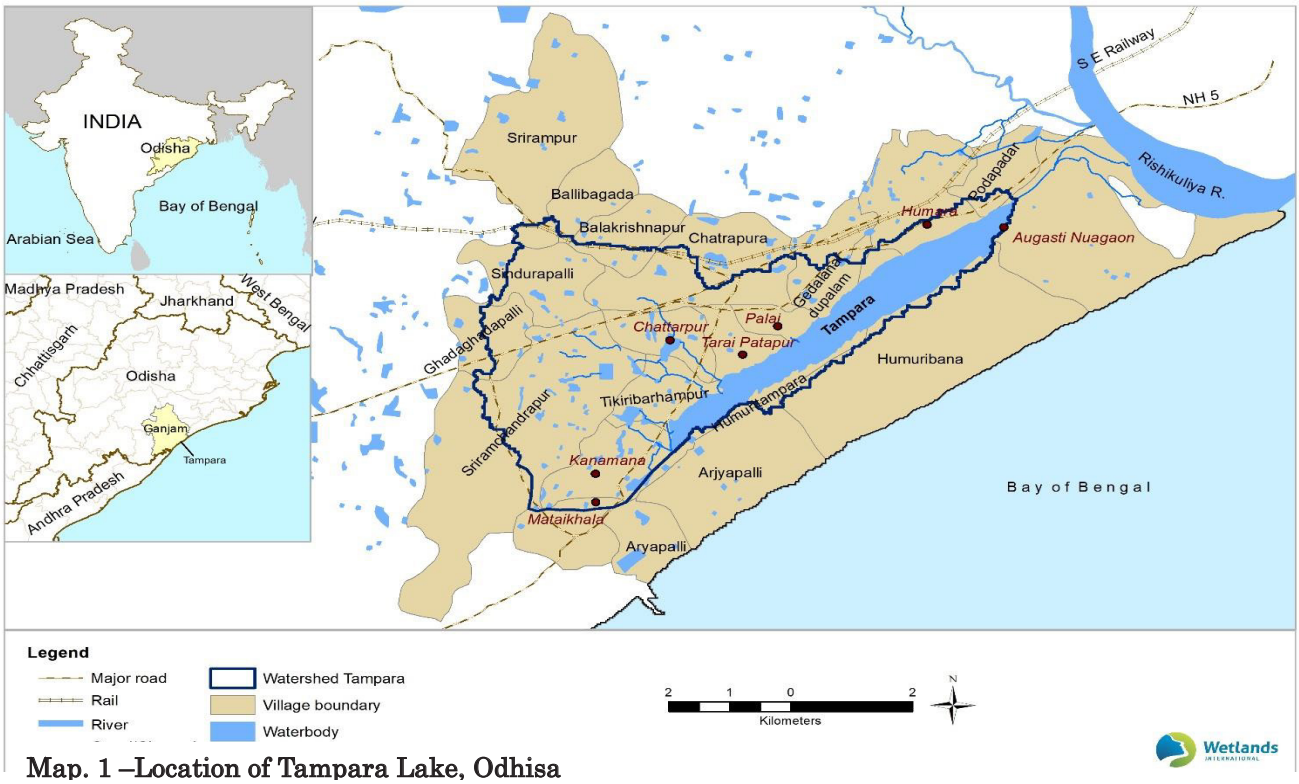
1. INTRODUCTION

The Ramsar Convention's wise use approach is premised on ensuring compatibility of human use of wetlands with the goal of maintenance of ecological character. The ecosystem services have been included in the definition of ecological character as a means of bridging wetland ecosystem functioning and their human use for well-being (Finlayson 2012). In a human-dominated world, it is increasingly appreciated that ecosystem services are not generated only by ecosystems, but by social-ecological systems of which human form an integral part. The perceptions, attitudes and preferences humans hold for ecosystem services are important institutions in themselves to engender changes in the ways stakeholders engage with management of ecosystems (Ostrom 2008; Jacobs 1997) by acting as a societal feedback mechanism, alerting the society on the consequences of consumption choices and behavior (Zavestoski 2004). However, there is a paucity of research on understanding the behavioural dimensions of ecosystem services (Asah et al. 2014), thus limiting their effective integration in management planning and decision making. The paper aims to present use of a participatory tool to uncover individual as well as societal attitudes and preferences for ecosystem services, through application in a wetland located in east coast region of Odisha State, India.

2. METHOD

We used Ecosystem Services Shared Values Assessment Tool (ESSVA) developed by International Lake Environment Committee (ILEC) to assess stakeholder perceptions, attitudes and preferences for wetland ecosystem services. The tool enables engagement with communities living around the wetland, and its upstream and downstream reaches, linking ecosystem services with various drivers of change and implications for well-being. Behavioural data is elicited through a structured questionnaire, options of which are represented mostly through photographs. A training workshop on the use of ESSVA tool was jointly conducted by ILEC and Wetlands International South Asia in December 2017.

Tampara, a freshwater lake on the east coast of Odisha State (Map 1) was selected as a demonstration site, wherein Wetlands International South Asia is formulating an integrated management plan for wetland wise use. The wetland, spanning 409 ha within a basin of 2,200 ha, is the primary source of water for over 25,000 households living in Chattarpur Municipality, and irrigation in and around. The lake is also an important source of fish, and aquatic aromatic Pandanus, sustaining livelihoods of over 700 households. Overall, 1% of the basin population living



Map. 1 –Location of Tampara Lake, Odhisa

within eight of the 15 basin villages was selected for ESSVA questionnaire survey. The households were selected based on stratified random sampling to ensure an appropriate representation of stakeholder occupations, geographical location and asset ownership. The questionnaire was developed through focal group discussions in three villages conducted during February 2018, and further modified through pilot testing in 30 households. The surveys were conducted during March – April 2018 by a group of trained surveyors.

3. RESULTS

The communities identified 19 ecosystem services (6 provisioning 6 regulating and 7 cultural services) as being derived from the wetland. When eliciting as a group, the respondents ascribed statistically significant higher values for 5 of the 6 provisioning services. Similarly, differences in mean scores for disaster risk reduction functions and select cultural services (religious values, aesthetic values, and education values) were statistically significant (Fig. 2).

Factor analysis (principal components with variance maximising rotation and Kaiser normalisation) of demographic, socioeconomic and environmental relationship data led to identification of eight variables which accounted for 68% variability within the data. The rankings ascribed to provisioning services mapped with the occupation categories (a fisher ranked fishing as the highest and a farmer to the provision of water for irrigation). However, communities which had a lesser direct dependence on the wetlands for livelihoods (such as business owners, wage labourers and private sector employees) ranked the regulating and cultural services as a highest preference. Respondents within the age group of 30-60 years scored almost all ecosystem services higher than those falling within a lower and more upper age group. Men scored provisioning services higher than the women (95% significance), whereas women scored cultural services higher than the men. Spatial location was observed to have a distinct influence on ecosystem service preferences. Awareness of ecosystem services amongst upstream communities was higher in the upstream reaches as compared with downstream reaches (99% significance). In general, the scores for provisioning and regulating services were higher for the communities located in the downstream (statistically significant with 99% and 90% significance), whereas the scores for cultural services were comparable. Scores ascribed to provisioning and regulating services by communities living within 500 meter from the lake shoreline (both 99% significant) than those living further away.

Regarding roles in the management of wetland, communities having a direct dependence on the wetland raked their role as an individual to be higher as compared to that of the municipality or the state and central government. Communities with lesser direct dependence on wetlands (those engaged in businesses and private service) felt that the state government had a major role to play in ensuring that wetland ecosystem services are sustained.

4. DISCUSSION

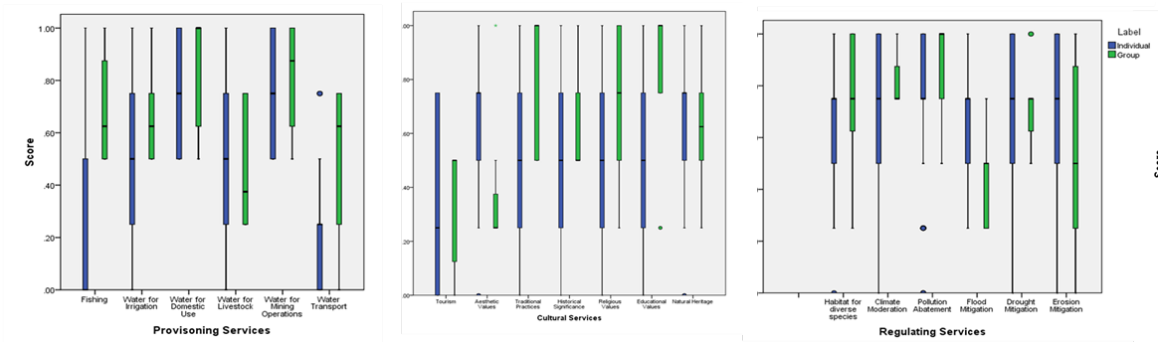


Fig. 2 - Ranking of preferences as a household and as a community group for 19 ecosystems of Tampara on a scale of 0 (=no preference) to 1 (=highest preference).

The valorised view of community as a contiguous spatial unit, similar social structure sharing similar norms has often been challenged (Agrawal and Gibson 1999; Lemos and Agrawal 2006). The case study of Tampara revalidates that the ways in which communities benefit from a set of wetland ecosystem services would tend to vary according to their interests (occupation), level of environmental awareness, location within a basin and related socioeconomic conditions. When ranking as a group, the importance of provisioning services was overestimated as compared with when ranking as an individual household, as group dynamics tend to vary with the social and physical environment in which discussions are held. A significant ramification of such difference is that perceptions and attitudes towards ecosystem services would change by the method of elicitation. Concordance of ecosystem services preferences with occupation maps with the Maslow's hierarchy of needs (primary preference to survival needs, followed by psychological and spiritual needs). The upstream communities, being urbaner and higher density of assets has accordingly placed the impacts of the decline in wetland ecosystem services as being higher than downstream communities (which have a higher concentration of farmers and fishers, with comparatively lower incomes than the upstream communities).

5. CONCLUSION

Technocratic and expert-driven assessments of ecosystem services are likely to render a simplistic view of ecosystem services, without indicating underlying social factors which have a bearing on the perceptions, preferences and attitudes towards ecosystem services. Gaining such a nuanced understanding is crucial to engage communities systematically in management for wise use of wetlands. Through the use of tools such as ESSVA, it is possible to dive deeper into factors which define the relationship communities have with wetland ecosystem services and use the assessment outcomes to develop a shared view of ecosystem services, trends therein, and possible restoration options. A critical application of the results is in developing targeted messages for various stakeholder categories while eliciting their participation in wetland management, and deciding on priority socioeconomic and demographic variables likely to influence participation.

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O9-13

Ecosystem Health Card for Laguna de Bay and its Tributaries

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Keywords: water quality, water pollution, ecosystem management, ecosystem health card, scorecard

ABSTRACT

An Ecosystem Health Card (EHC) provides simple and clear presentation of the current ecosystem health of a water body based on certain indicators. The first Ecosystem Health Card for Laguna de Bay was for 2013, where the lake scored a low passing mark of C- which is equivalent to 76%. In 2016, the EHC assessment was extended to the rivers that drain into the lake and it was named as LGU scorecard, with reference to the Local Government Units in a river basin. The same water quality parameters used in the 2013 assessment were used in the lake and river assessment. The score attained in 2016 was even lower at 72 % or a failing mark of D attributed to high phosphate concentrations and high chlorophyll a content. The East Bay garnered the highest score among the lake stations for having the least built-up areas. With the issuance of the new Effluent Standards where nutrients are already among the regulated parameters for industrial and commercial sources, the increasing nutrient loading into the lake can be effectively addressed.

1. INTRODUCTION

The Laguna de Bay, more commonly known as Laguna Lake, is the largest inland water body in the Philippines and the third largest in South East Asia. It has a surface area of 900 km^2 with an average depth of 2.4 meters (2014). Around 100 rivers and streams drain into the lake. The Pasig River through the Napindan Channel is the only outlet of the lake and drains into Manila Bay.

Laguna de Bay is a multiple use resource. The lake provides livelihood to the fisheries sector, supplies water for domestic use and irrigation purposes and supports hydropower production. The lake is also used for recreation, industrial cooling, navigation and as waste sink. Over the past decades, population expansion, urbanization, industrialization, deforestation and land conversion have led to the degradation of the lake water and the watershed.

In February 2016, the first Laguna de Bay Ecosystem Health Card (EHC) was launched by the LLDA. However, the data used was from to 2013 because of complete data set during this period. It was developed through the support of the Partnership in Environmental Management for the Seas of East Asia (PEMSEA) and patterned after the health cards of Chesapeake Bay and Chilika Lake in India. The health card was designed to easily convey information on the state of health of the lake environment to decision makers and stakeholders. The indicators used in the EHC were water quality and fisheries. Laguna de Bay scored a low passing mark, 76%, a C-, in water quality and 48 % or an F in fisheries. The lake's water quality consistently conformed with the Water Quality Criteria for Class C Waters for DO, BOD, NO_3, and total coliform but always scored poorly for chlorophyll *a* and phosphate. Laguna de Bay scored an F for fisheries due to low ratings on catch per unit effort, low ratio of native to introduced/invasive species, and dominance of invasive calanoids to cyclopoid species. Water quality and fisheries are negatively impacted by the increasing population and industrialization in the watershed.

The 2013 Ecosystem Health Card focused on the lake. Under the Wealth Accounting and Valuation of Ecosystem Services (WAVES) Project of the World Bank, the EHC assessment was extended to the river systems within the watershed using the results of the Ecosystem Accounts developed. The same water quality parameters in the EHC were used except for chlorophyll a. Instead of fishery indicators, other indicators such as waste management and ecosystem management were also included.

The scores in the EHC and Local Government Units (LGU) scorecard could serve as basis for the issuance of necessary policies and implementation of programs and projects, and encourage serious engagement of local executives for a more effective management of the lake, its watershed and resources.

2. METHODOLOGY

The EHC assessment on the water quality of the lake and river stations in 2016 was done using the LLDA

monitoring data. The different parameters were assigned scores and grades based on their compliance with the Water Quality Criteria for Class C Waters, which is fit for fisheries.

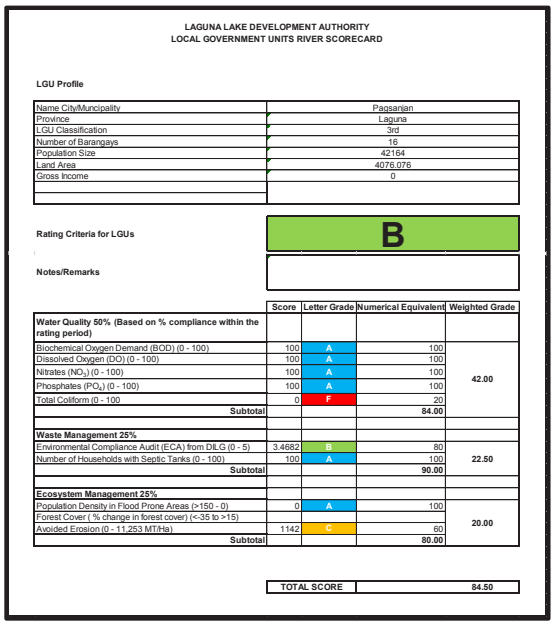
For the LGU Scorecard, the data on waste management such as the solid waste practices of Local Government Units (LGUs) and the number of households with septic tanks were taken from the Department of Interior and local Government (DILG). Assessment on ecosystem management specifically on population density on flood prone areas, percent change in forest cover and avoided erosion was based on the results of the WAVES Project.

3. RESULTS

Figure 1 shows the 2016 scores on water quality while Figure 2 shows an example of an LGU scorecard.

2016 Report Card Water Quality				
Region	Indicator	Score	Overall Score	Grade
West Bay	Nitrate	100.00	70.14	D
	Phosphate	25.00		
	Chl a	0.00		
	BOD	97.92		
	DO	97.92		
	Total Coliforms	100.00		
Central Bay	Nitrate	100.00	71.21	D
	Phosphate	27.27		
	Chl a	0.00		
	BOD	100.00		
	DO	100.00		
	Total Coliforms	100.00		
East Bay	Nitrate	100.00	75.76	C-
	Phosphate	54.55		
	Chl a	0.00		
	BOD	100.00		
	DO	100.00		
	Total Coliforms	100.00		
Southern Bay	Nitrate	100.00	71.21	D
	Phosphate	27.27		
	Chl a	0.00		
	BOD	100.00		
	DO	100.00		
	Total Coliforms	100.00		
Laguna de Bay	Nitrate	100.00	72.08	D
	Phosphate	33.52		
	Chl a	0.00		
	BOD	99.48		
	DO	99.48		
	Total Coliforms	100.00		

Figure 1. Water Quality Scores for the 2016 Ecosystem Health Card



LAGUNA LAKE DEVELOPMENT AUTHORITY
LOCAL GOVERNMENT UNITS RIVER SCORECARD

LGU Profile

Name City/Muncipality	Pagsanjan
Province	Laguna
LGU Classification	3rd
Number of Barangays	16
Population Size	42164
Land Area	4076.076
Gross Income	0

Rating Criteria for LGUs: B

Notes/Remarks:

	Score	Letter Grade	Numerical Equivalent	Weighted Grade
Water Quality 50% (Based on % compliance within the rating period)				
Biochemical Oxygen Demand (BOD) (0 - 100)	100	A	100	42.00
Dissolved Oxygen (DO) (0 - 100)	100	A	100	
Nitrates (NO_3) (0 - 100)	100	A	100	
Phosphates (PO_4) (0 - 100)	100	A	100	
Total Coliform (0 - 100	0	F	20	
Subtotal			84.00	
Waste Management 25%				
Environmental Compliance Audit (ECA) from DILG (0 - 5)	3.4682	B	80	22.50
Number of Households with Septic Tanks (0 - 100)	100	A	100	
Subtotal			90.00	
Ecosystem Management 25%				
Population Density in Flood Prone Areas (>150 - 0)	0	A	100	20.00
Forest Cover (% change in forest cover) (<-35 to >15)				
Avoided Erosion (0 - 11,253 MT/Ha)	1142	C	60	
Subtotal			80.00	
TOTAL SCORE			84.50	

Figure 2. LGU Scorecard

4. DISCUSSION

The water quality of rivers has deteriorated mostly at the western portion of the lake where there has been significant increase in the built-up areas which led to higher pollution loads to the lake.

The Laguna de Bay in 2016 scored a lower mark at 72 % or a D in water quality when compared to the 2013 rating of 76 % or C-. Results showed increasing trend in phosphate concentrations.

5. CONCLUSION

The low rating of Laguna de Bay and its tributaries in 2016 scorecard attributed to high phosphate and BOD levels and high coliform counts is indicative of pollution from domestic wastes that include laundry and untreated sewage. The findings call for the putting-up of centralized sewage treatment plants by the concerned LGUs and other agencies.

Areas with low ratings on avoided erosion and forest cover are identified as priority areas for the Greening Program.

In May 2016, the Department of Environment and natural Resources (DENR) issued Administrative Order No. 2016-08 which provides the new water quality guidelines and effluent standards. In the effluent standards, nutrients such as nitrate, phosphate and ammonia are already among the regulated parameters for specific industry sectors. With the new standards, it is expected that the nutrient loading in the lake will be effectively addressed.

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O9-14

Main Outcomes, results and lessons learnt from the international Workshop on Integrated Lake Basins Management with an emphasis on the importance of ESSVA in the ILBM framework in West Africa

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Keywords: basin management for sound water circulation, basin governance

ABSTRACT

From February 27 to March 2018 in Dakar, ILEC organized an International Workshop on Integrated Lake Basins Management (ILBM) with a focus on West African Lakes status and the current patterns for integrated lake basins management in Africa.

Discussions on lakes and wetland ecosystems were held and conducted in the framework of multiple crisis recorded in the sub-region, such as: climate change and extreme events, population growth, cities expansion, ecosystems degradation and poverty, pollution, etc. The objective of workshop was to develop guidelines in terms of research and collaboration with the African scientists and managers in order to develop knowledge and initiate research action especially in the area of the preservation and development of integrated lake basins management and ecosystems. One particular area of focus was the compliance with laws and regulations and the need to develop areas of cooperation between West African countries and experts in order to adopt common approach on research and methodologies in the area of lake basins, watersheds and wetland ecosystems integrated management.

Today's challenges are mostly focused on drinking water supply to large coastal cities populations, food self-sufficiency of lakeside villages and cities and the improvement of living conditions of populations living around lake basins. Thus the importance of integrated management of lake basins systems that takes into account the interface between the different pillars of ILBM process and the role of ecosystem approach in the context of improving the governance of lake basins, as largely discussed during the workshop.

As results, rainfall deficit observed in West African region for decades has strongly impacted the hydrological functioning of lake basins and water resources within West African countries. This situation has been exacerbated by the high pressure generated by economic activities of populations such as, agriculture, fishing with the use of illegal fishing gear, wastewater discharges and other forms of pollution that altered characteristics and biogeochemical processes of water resources. As overall consequences, poor water quality has negatively impacted agricultural activities, including fisheries resources in terms of abundance, size and spatial distribution. One can noticed as well that there are in some places development of aquatic plants, siltation/sedimentation phenomena and reduced fish production, saline intrusion into surface and groundwater as well as problems of drinking water supply to populations living around some lakes.

Today's challenges are mostly focused on drinking water supply to large coastal cities populations, food self-sufficiency of lakeside villages and cities and the improvement of living conditions of populations living around lake basins. Thus the importance of integrated management of lake basins systems that takes into account the interface between the different pillars of ILBM process as well as the role of ecosystem approach in the context of improving the governance of lake basins, as largely discussed during the workshop.

For the restoration and preservation of lake basins and ecosystems in West Africa, it will be necessary to improve existing overall management framework as well as to further strengthen and provide respect to legal and

institutional framework that govern lake basins and water ecosystems. Promoting training and capacity building on ILBM as well as generating scientific knowledge to underpin the integrated management of lakes and the interactions between lakes and surrounding watersheds are critical for the sustainable management and development of lake basins systems in Africa in general, West Africa in particular.

O9-15

Paper title : Ecosystem Services Valuation for urban lake and wetland - a case of Putrajaya

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Keywords: ecosystem services, urban, lake, wetland

ABSTRACT

The man-made lake and wetlands in Malaysia's Government Administrative City of Putrajaya has created a unique healthy ecosystem within the new city. This encourages many other cities to duplicate the same water body design. To ensure continuous financial support for its management, its economic values of this achievement need to be monitored and assessed. What benefit are we getting from such a healthy urban ecosystem? It is an important enquiry that needs to be carefully answered and understood by the city dwellers that benefit greatly from the existence of the ecosystem. This paper describes the valuation of the ecosystem services provided by Putrajaya Lake and wetland based on various economic assessment methods. Understanding of the value of this urban ecosystem, especially related to water body will enable the authorities or owner of the lakes to determine the source of financial assistance for a better management of the water body. This is crucial to ensure everybody will benefit appropriately with their contribution to the well-being of the areas.

1. INTRODUCTION

The construction of Putrajaya Lake and Wetland in the middle of a city has created various views. Some critics say it will not be easy to make sure the water is clean. While some others are more optimistic that Malaysian will rise to the occasion when common issues such as water quality at stake.

Innovative management approach is important to change the common people attitude towards a better status of our surface runoff water quality and common environment at large.

In this project, Perbadanan Putrajaya with the support of UNESCO-IHP, Jakarta has implemented the exercise of determining the 'economic value' of the 'Ecosystem Services' (ES) for Putrajaya Lake and Wetland.

The value of ES will allow the authority to start working on the source of funding the management of a large wetland and lake in the middle of an urban area.

This is almost impossible as of trying of getting large amount of fund to maintain a small ecosystem in a city.

It will only be possible if we can understand its value and will be able to share our understanding of the values with all other stakeholders.

Getting various related ministries (with actual interest) into action of sharing the management fund can be another main reasons of accessing the Ecosystem Services' Economic Value of the beautiful lake in the center of a city.

2. METHOD

There are many economic assessment methods used in this study. They are:

i. Direct Market Value (DMV);

ii. Benefit Transfer Method;

iii. Indirect Value of Economic Assessment

Direct Market Value (DMV)

Direct Market Value (DMV) method was applied to get the value of consumable water, fish and boat ridership. Direct Market Value (DMV) methodology is applied for the following assessment:

- The water value for supply (assuming the water available is made usable for domestic consumption);
- The Cruise Tasik Putrajaya ridership benefit; and

– The fish value (data taken over the five years of sampling exercise)

Benefit Transfer Method (DTM)

For other ecosystem services that are not conducted in this study, the Benefit Transfer Method (DTM) will be used. In this study, the Benefit Transfer Approach refers to the "estimating the value of an ecosystem service at a 'policy site' by assigning an existing valuation estimate for a similar ecosystem at a study site".

Indirect Value of Economic Assessment

The data collection is done for the basis of the three (3) components of the project implementation methods:

i. Contingential Value Method (CVM);

ii. Total Cost Method (TCM) and

iii. Hedonic Pricing Method (HPM) – Aesthetic value

3. RESULTS

As listed in Table 3.1, the total value of Putrajaya Lake and Wetland (as 31 of October 2015) is RM 5.89 Billion or equivalent to USD 1.38 Billion (conversion rate at that time).

According to Perbadanan Putrajaya Report [2], the estimated amount cost for the construction of the lake and wetland in 2000 is about RM 1.2 Billion. This shows that the Putrajaya Lake and Wetlands actual value (in terms of its ecosystem system value) is getting higher than it was previously developed or constructed.

This findings also provide some understanding of getting the proper ecosystem into a city may finally provide a better world and significantly assured that the lifestyle and well-being of the communities will be upgraded.

Table 3.1: the list of value of Putrajaya Lakes and Wetlands according to the various ecosystem values.

ITEM	VALUE IN RM
DIRECT MARKET VALUE	
Selling the lake water for drinking - Water Rent /Provisional/ Direct Value	19,162,500.00
Use of the Cruise Tasik Putrajaya boating service / Cultural/ Direct Value	24,176,000.00
Fish harvest / Provisional/Cultural/ Direct Market Price	4,866,600.00
Sub Total DIRECT MARKET VALUE	**48,205,100.00**
BENEFIT TRANSFER METHOD	
Water quality improvement / Regulating/ Waste Treatment	2,363,334.00
Local climate influence / Regulating/ Climate regulation	6,167,416.00
Nuisance prevention / Regulating/ disturbance modernation	37,737,511.00
Reduce flow energy/ Regulating/ Regulation of water flow	70,849,460.00
Slowing down the flow/ Regulating/ Erosion prevention	32,947,653.00
Retention time control /Regulating/ Nutrient Cycling	21,649,148.00
Pest or disease control / Regulating/ Biological Control	11,980,965.00
Breeding ground/Habitat/ Nursery Service	16,265,297.00
Genetic materials and resources/ Habitat/ Genetic Diversity	14,761,357.00
Education and research /Cultural/ Inspiration	8,846,704.00
Sub Total BENEFIT TRANSFER METHOD	**223,568,845.00**
INDIRECT VALUE – SURVEY	
WTP - *Conservation efforts ILBM/ Regulating/Cultural/ CVM- Contingent Valuation Method*	1,027,356,375.00
Events - *Recreational in lake / Provisional/Cultural / TCM – Travel Cost Method*	2,254,018,125.00
Aesthetics - *Lake front house price / Provisional/ Hedonic Pricing Model*	2,331,176,630.00
Sub Total INDIRECT VALUE – SURVEY	**5,612,551,130.00**
TOTAL ESTIMATION – 31 October 2015 (USD)	**5,884,325,075.00 (1,381,296,965.96)**

4. DISCUSSION

The method of assessment has produced reasonable value of the Putrajaya Lake and Wetland. The applications of Direct Value Method as well as the Indirect Value Method has given the opportunities for Perbadanan Putrajaya of getting good results in terms of the value of their lake and wetland.

Benefits of economic assessment

The findings of lake and wetland economic values from the research will enable the custodian of the water body to benefit especially for enhance the management of the water body. The following matters are important and will be useful:

– Sustainable source of management allocation;

– Multiple source of operation fund;

– Capacity building and training;

– Payment for ecosystem services

However, there are also opportunities for further assessment to be made such as:

i. The value of recreational benefit;

ii. Value of pollination and rare species of birds;

iii. Hedonic Pricing for all other housing, commercial and even for the government services.

iv. Applying the Ecosystem Services Shared Value Assessment (ESSVA) – non-monitory

5. CONCLUSION

Value of ecosystem services need to be assessed to provide the real values of our environment and ecosystem which will finally be handful for further discussion and negotiation with the administrative and political leaders.

From the discussion above, it is encouraged that another economic assessment with the approach of getting the total economic value should be done for Putrajaya Lake and Wetland, including the non-monitory assessment (ESSVA).

It will be useful for the owner of each lake and wetlands in Malaysia to start assessing the ecosystem services economic values of their water bodies. The process of making the assessment will also be an important matter to the custodians of such water body because it chartered the proper parameters and methods of making appropriate monitoring of data and information collection system.

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O9-16

Paper title：'Enhanced hydrological connectivity' facilitated improvement of LULC status in the catchment area of Lake Chilika: a case study from Partner's for Resilience (PfR) project in India.

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Keywords: Integrated Lake Basin Management, Ecosystem Management, Disaster Risk reduction.

ABSTRACT

Worldwide wetlands are suffering from various issues due to development initiatives. Also Natural disasters change the pattern of ecological services provided by the wetlands to the adjacent communities. Chilika is one of the important Ramsar site and largest wetland system of India. The changes in land use and land cover patterns have affected the creeks and natural canals of the lake. The occurrence of frequent floods and cyclones has also blocked the natural passage of water in to it and exacerbated the natural functioning of the wetland. 'Enhanced hydrological connectivity' has taken as a planned ecosystem based measures in building resilience of the communities. It has also taken as a key approach to rejuvenate the water bodies, revival of the creeks and mitigate water logging issues. Moreover this helped in the promotion of sustainable irrigation to 350 acres of crop land, increased flood water absorption capacity as a buffer zone of Lake Chilika and renovation of 3 ponds. The women of the community could gain economic profits from the pond aquaculture. This ultimately promoted the improvement of the LULC (Land Use and Land Cover) status of the area. The scientific LULC study conducted by Integrated Coastal Zone Management Project and Chilika Development Authority (CDA) in 2013 confirms the gain of ecosystem services due to such intervention. The recent LULC status shows 112.7 hectares of creek and 5158.6 hectares of aquaculture promotion in the area.

1. INTRODUCTION

Introduction-

Chilika Lake is the largest wetland system in India and an important Ramsar site. It is lake of 1135 sqaure km in size. The lake can be segregated in 3 sectors as per the water quality and salinity.

The upper catchment of sector of the lake towards the north-west zone is that of fresh water. This catchment area covers 3987 sq. km. Hydrologically the catchment area is influenced by two sub systems; one is Mahanadi river system (Bhargabi, Daya, Makara, Luna rivers) and another western catchment (Kusumi, Tarimi, Mangalajodi, Kantabaia, Badanai, Kansari and Kalajhar rivers). There has been frequent change in the land use and land cover pattern across the catchment area of the lake with time. Due to human interference and frequent occurrence of disasters like floods in these areas has changed the Land use and Land cover (LULC) status of the area. The local communities have been facing low ecosystem service and benefits for this from their adjacent wetland.

Land use and land cover (LULC) change is a major issue of global environment change. Land use refers to man's activities and the varied uses which are carried on over land and land cover refers to natural vegetation, water bodies, rock/soil, artificial cover and others noticed on the land. Land cover is that which covers the surface of the earth and land use describes how the land cover is modified. The Land cover reflects the biophysical state of the earth's surface and immediate subsurface, thus embracing the soil material, vegetation and water. Land use refers to man's activities on land which are directly related to the land. Land use and land cover are dynamic. The change happens due to human activities and natural processes. The LULC in the catchment of Chilika has shown several variability and changes with time.

The Intervention

NETCOAST was an implementation partner in PfR project in the Lake Chilika, which is also categorised as a Lentic water system. The goal of the project was to build the resilience of the local communities who were been facing the issues related to recurring occurrence of flood and water logging. These areas at Kanas of Puri district lies on the head of the lake, where fresh water pours into the lake system through its tributaries. Over the period of time, mouths of these rivers got chocked, due to several reasons. During the flood season this caused transversal stretching along the villages. There were several canal/ creek systems which were working as natural buffer zones to carry these excess flood waters. Due to lack of proper maintenance and slits carried by flood in regular years choked these natural passages of water. Gradually some of these canals were blocked by some vested people and transferred to aquaculture ponds. This eventually increased the risk in the area with water logging.

The model intervention planned to mitigate the issue through clearing of inlet and outlet of the creeks. These creeks were more vulnerable since they are worst vulnerable than other linked water systems to the river. Participatory consultative assessment was carried out along with the communities living around the lake. There were some of the vested individuals who have blocked the original path of these creeks and developed it into their aquaculture ponds illegally. In the beginning they were opposing, but later agreed internalizing the long term benefits even for their own crop fields. It was then finally concluded that de-siltation work will be carried.



Fig.1: Renovation of canal & de-siltation work

The work finally ended with renovation of old creek / canal system with 1.5 km length at river Daya. This virtually helped in the entry of fresh water to the crop fields. During the rainy period all the rain water drains to this system and thus water logging in the crop field minimized (record of water logging and reduction due to intervention please mention). The water from the creek was later used for irrigation purpose, in around 200 acres of land. No need for extraction ground water for the crops during the dry periods, since river water from Daya could easily flow to this with the use of a 5 HP motor. The canal itself serves as a mini-water reservoir for these fields. This success was again replicated in another such drain which was suffering a similar chocking. Both these creeks are now actively managed by the village committees. 3 ponds could be rejuvenated at the tail end of these creeks. This also helped in ground water recharging in the area. Most importantly, the old Creeks could started providing services as the buffer zones in the flood and water logging periods. The use of water from the canal thus increased the productive of the land and thus crop production in the area. 350 acres of the crop land get benefits from this, round the year.



Fig. 2: Irrigation helped in getting 2 crops from 350 acres of the land in the adjacent field.

Further, it helped in recharging water into 3 adjacent ponds, which were not functional for years. This helped in diversification of livelihood of 120 women from 4 SHGs, thus enhanced income from pond pisciculture.



Fig. 3: Rejuvenation ponds helped in promotion of pisciculture activities in the ponds by the women group.

The scientific data evidencing the recent change –

There was an assessment study on the LULC pattern of Chilika lake catchment conducted by Integrated Costal Zone Management Project (ICZMP) and Chilika Development Authority (CDA) in the year 2013. It used the Land use and land cover (LULC) assessment data and empirical observations which has revealed remarkable change in land use -land cover classification in Chilika Catchment. In this paper an attempt has made to study the changes in land use and land cover in this Catchment over 37 years period (1975 -2012). The study has been done through Remote sensing approach using SOI top sheet and Land Sat imageries of 1975 and 2009, 2012. GIS software is used to prepare the thematic maps.

The study has brought to light on the land use and land cover exhibited considerable influence on the various hydrologic phenomenon. In that study land use/land cover maps of Chilika catchment for the years 1975, 1999 and 2012 was prepared by Image processing and visual interpretation technique. The following table shows the differences, which confirms the achievements.

Table 1: LULC study summery; demonstrating the periodic differences (from 1975 to 1999 and 2012).

LULC indicators	1975		1999		2012	
	Area (ha.)	Area in %	Area (ha.)	Area in %	Area (ha.)	Area in %
Agriculture Land	87952.6	18.18	168608.4	34.84	125730.1	26.05
Chilika Lake	103410.7	21.38	91048.3	18.81	88734.6	18.38
Dense Forest	67904.6	14.04	43666.6	9.02	61377.7	12.72
Open Forest	13632.8	2.82	14674.7	3.03	24252.3	5.02
Plantation	2410.6	0.50	4830.5	1.00	3471.01	0.72
Water Body	1263.2	0.26	7484.6	1.55	2273.8	0.47
Aquaculture	0	0	1760.6	0.36	5158.6	1.07
Creek	0	0	0	0	112.7	0.02

In the year 1999 the 'double crop' area converted to 'agricultural land' and some new land use / land cover category created like 'aquaculture area' and some settlements are covered with vegetation, it means vegetation and agriculture area is increased but 'dense forest' decreased because of population growth here urban population increased in comparison with the year 1975.The Chilika lake also reduced its area because of sedimentation from its catchment area. The agriculture land converted partially to aquaculture ponds in 2012, which was found to be suitable and profitable income model by the community. There is evolution of creek systems in those areas in the year 2012.

Conclusion-

The restoration measures in the northern region have contributed in the revival of the catchment area of the lake and further provided livelihoods to the communities around the intervention areas. The catchment area could gain the original ecosystem service as the buffer zone to the issue of flood and water logging. The crop production of the area increased. This simultaneously illustrates the increase of the fertility of the adjacent crop fields. The women of the community also gained in terms of recharging the old and dysfunctional pond systems. Estimation showed the investment of Rs. 90000.00 from the project, resulted in the income generation of Rs. 200000.00 annually for the local communities for the subsequent years. The LULC study confirms the land use and land cover changes that have occurred in Chilika catchment in the last 37 years and considers as well as relates different components responsible for the change. Further restoration measures need to undertaken for conserving the lake. Community based initiatives need to firmed up to mainstream wetland protection.

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O9-17

Paper title: Participatory Basin Management and Biodiversity Conservation in Ansupa Lake, India

Mr. Durga Prasad Dash, PALLISHREE, Odisha, India

Keywords: Integrated Lake Basin Management, Basin Governance, Eco-system Services

ABSTRACT

Ansupa is the largest freshwater lake in Odisha, with a catchment area of 5231 hectares. During the last 2 decades the Lake was under threat due to huge amount of sand, soil and debris flowed from the catchments and the river Mahanadi. The average depth of the Lake is 4 metre. Chilika Development Authority initiated participatory lake basin management and sustainable livelihood along with activities for weed management in the lake.

About 30,000 populations in 28 villages around the lake were depending on the Lake for their livelihoods, 70% on agriculture and 25% on fishing. 1836.99 hectares of agricultural crop (paddy and vegetables) depends upon its water. The capacity of the farmers have been enhanced through training programmes to increase the yield in agriculture with organic inputs and the yield increased significantly. Various plantation programmes in 132 hectares were carried out including soil conservation measures like continuous contour bond, staggered and half moon trenches. 8 nos. of new rain water harvesting structures (4.2 hectors) saved the needs of crops in stress period. Special skill building training was provided to fishers. Women SHGs helped in de-weeding the lake.

As a result the biodiversity improved in the lake ecosystem, development of favorable micro climatic conditions for wildlife viz. rabbit, small Indian civet cat, deer, python, hyena, elephants and tiger. Community based institutions like Watershed committees (7), women SHGs (30) and Primary Fisherman Cooperative Society (1) were promoted in the Lake Basin management which contributed significantly in the eco-system and economic growth.

1. Introduction

Ansupa is a freshwater lake by inflow of flood-water from the river Mahanadi and geographically located between 20.459142° latitude North and 85.603709° longitude East. It is a horseshoe-shaped lake situated in Banki Block of Cuttack district, Odisha India. The area of the lake is spread over 152 ha. (380 acres). It is a wetland of national importance with 152 ha. water spread area. 27 species of resident and 32 species of migratory birds, 9 species of submerged aquatic plants, 12 species of floating plants and 26 species of emergent aquatic plants, 33 species of fish, 3 species of prawns & 10 species of reptiles are seen in this lake. It covers 7 nos. of micro-watersheds in 28 villages in the catchment area having about 30,000 populations. The stakeholders were depending on the Lake eco-system for their livelihoods, 70% on agriculture and 25% on fishing. 1837 ha. of agricultural crop production depends upon its water.

The Issue

The lake faces soil erosion from Saranda hill (west) and Gunjar hill (north-east) and about one lakh metric ton of silt enters the lake every year. The lake was silted up and encroached by farmers for conversion to agricultural fields by the local stakeholders. The tourism stopped and the lake was almost dying. Excess use of chemical fertilizers and pesticides in the catchment increased weed infestation and eutrofication in the lake. Un-sustainable agricultural practices coupled with soil erosion and forest fires have degraded the lake eco-system. Despite several initiatives to clean up the lake, weed infestation could not be controlled. The "*Mayurinala*" is choked due to weed infestation and raising of its bed have diminished both water flow and flush out process. This resulted in the lake to behave like a closed pond and disturbed the water holding capacity. Revival of the lake was undertaken by the State Government on 2003

under the control of District Administration. Subsequently the renovation work was transferred to Chilika Development Authority (CDA), an independent Authority of Odisha Government as the nodal agency in 2010 which continued rejuvenation activities.

The Intervention & the Results:

Holistic approach for the restoration of Ansupa Lake has been carried out by the participation of the watershed committees, Primary Fisherman Cooperative Society and women Self Help Groups. Following conservation measures were taken and results have been achieved :-

* Reclamation of water spread area from encroachment: - 12 ha. of encroach area is made free and pillars are posted permanently for demarcation of the boundary.

* Re-delineations of mouth channel and its renovation:- The channel is fixed and capable of both entering and discharging flood water from river Mahanadi. Again the floating weeds like water hyacinth could be discharged through the mouth automatically which control the weed growth in the lake.

* Formation of watershed committee by the local stakeholders and involvement to the lake reclamation:- 7 micro watershed committees are formed. Total micro-plan and its implementation is executed in the Public Private Partnership mode under the guidelines of 2012 of Watershed Mission, Government of India. This increased the yield for their sustainable livelihood.

* Soil conservation measures taken in the catchment: - Different types of soil conservation measure like staggered trenches, half moon trenches, continuous bonding are executed in 129 ha. Staggered trenches over an area of 104 ha. in the catchment area increased the crop quality of cashew plantation both by Government and private. This helped in recharge of ground water table and saved the agricultural field from water logging. 8 nos. of rain water harvesting structures (4.2 ha.) saved the agricultural crop during the stress period. Fish farming training including necessary inputs have been provided to the stakeholders to increase their skill on pisciculture in these water bodies.

* Enrichment of forest through plantation and rehabilitation:- Plantation programme have been undertaken in the catchments covering 25 hectors cashew nut plantation, 20 Bald-hill plantation, 5 ha. eco-garden on the lake embankment, 2 ha. plantation in Saranda-hill for restoration of historical places. The suitable plant species such as 10 nos. of forest, 4 nos. of horticulture, 6 nos. of avenue, 11 nos. of medicinal and 23 nos. of ornamental plants and the local stakeholders also raised 80 ha. cashew nut plantation as cash crop in their own fields. All the planted area has been covered with different type of soil conservation measures which created around 100 workdays per day for 200 days per annum for continuously 3 years.

* Creation and development of eco-garden around the embankment and hillocks:- The soil erosion around the embankment is arrested through creation of eco-garden over 2 ha. Besides the erosion from the Saranda hill is arrested through creation of eco-garden in the hillock over 3 ha. Both the eco-garden is maintained in the Public Private Partnership mode with the women SHGs with the revenue collected from the tourists.



Fig.1: De-weeding by women SHG members

* De-weeding of lake manually and biologically:- Women SHG members were engaged in de-weeding to create an area of 22500 sq. meter water spread area for boating and generated 151 workdays. Organic manure around 125 tons produced in 3 years with the same weeds which is subsequently used by the farmers in agriculture resulting in decrease of chemical flow into the lake. Fingerlings of different carps for fish production through PFCS was

provided to enhance their livelihood and supplemented fingerlings of grass-carp variety as a pilot basis. In the first year, 2000 nos. of fingerlings of grass carp variety was released and subsequently the number has been increased up to 5000 per annum. In the 1st year the yield of fish of grass-carp variety was 3650 Kg. and also the production enhanced up to 6900kg. per annum subsequently.

* Dredging of lake mechanically:- The Authority has excavated the lake which resulted in increased depth up to 6 meters at places. The excavated earth is mounted in the embankment creating a smooth configuration resulting creating of tall tree plantation.

* Monitoring of lake: Lake-water quality, hydrology and migratory birds are monitored by the experts of CDA and ornithologist of BNHS, Bombay, India. This programme is being carried out by NIO, Goa, India and CDA jointly. 47 species of Hydrophytes, 27 species of residential birds, 32 species of migratory birds are seen in the lake.



Fig.2:Migratory Birds during winter in the lake

* Creation of animal friendly micro climate:-Many more species of birds, jackal, hyena, rabbit, small Indian civet cat, deer, python, elephants etc. have appeared in the catchment area since last 5 years. Tiger is also temporarily visiting the area is the indicator of creation of favorable micro climate in catchment of Ansupa lake.



Fig.3: Eco-tourism managed by women SHG

* Eco-tourism promotion: The Government provided the SHGs four boats and to run boating activity under ecotourism development programme in the lake in Public Private Partnership (PPP) mode. In the first year, 15,000 INR revenue was generated by the SHGs and this has been increased to 50,000 - 60,000 INR in the subsequent years.



Fig.4: Local women have access over lake resources

Conclusion:

As a result the biodiversity improved in the lake ecosystem, including development of favorable micro climatic conditions for wildlife. The LULC status of the lake has been increased remarkably. Community based institutions like Watershed committees (7), women SHGs (30) and Primary Fisherman Cooperative Society (1) were promoted to build participation in the Lake Basin management. It has got a new lease of life through holistic intervention initiated by CDA through the local stakeholders. The results are sustainable which provide protection to the life and livelihood of the local community and eco-system services from the wetland. This intervention and its impact is one of the most successful case study on Basin Governance and Integrated Lake Basin Management.

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O9-18

Paper title：Vulnerability and Ecosystem Services Assessment of Muda Lake Basin under the impact of Changing Climate

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Keywords: climate change, ecosystem services, lake management, tropical lake, vulnerability

ABSTRACT

Climate change influenced hydrological pattern in reservoir subsequently altered their ecosystem services. Muda Lake Basins support valuable ecosystem services and irrigate the largest paddy fields for the country. This study assessed the vulnerability of Muda Lake Basin to climate change using the Probability Distribution Model rainfall-runoff model and InfoWorks two-dimensional Integrated Catchment Model. The hydroclimate simulation was based on the downscaled global circulation model data to Peninsular Malaysia. Future hydroclimate model showed that the lake catchment will received slightly lower and higher rainfall amount at the mid of 21st century. A much severe rainfall pattern over a long period was projected at the end of 21st century. Simulation results provided pattern of lake hydrologic and hydrodynamic in association to future climatic changes. Long drought at the end of century will be affecting the lake services to supply water for irrigation and domestic. Economic valuation of the impact of climate change on the main ecosystem services during drought and flood events will enable identification of strategies to reduce the associated potential losses to infrastructure and communities.

1. INTRODUCTION

Many studies showed that climate change will be impacting water resources by altering rainfall pattern and water balance. Any changes in hydrological cycle may have ramifications to lakes and reservoirs hydrodynamic subsequently impacting water quality and ecosystem services. Climate warming were reported to intensify the eutrophication symptoms including by reducing lake levels, increasing internal nutrient loadings and supporting cyanobacteria blooms [1]. Climate change impacts will also be impacting forest and freshwater wetland ecosystems including shrinking the wetland area coverage and threatening endangered terrestrial and aquatic flora and fauna species[2,3]. Assessment on the vulnerability of Prairie wetlands to climate change showed that, under a drier climate, most wetland areas would be drained while the habitat for breeding waterfowl would be shifted from the most productive areas to the less productive but wetter areas[4].

Muda Lake Basin is one of the most endangered lake basin in Malaysia as it is located in the water stress area in the country. The lake which was constructed in 1965 and completed in 1969 was designed for irrigation of Muda Irrigation Scheme, Kedah. The lake has large catchment encompassing 984 km^2 of the Ulu Muda Forest Reserve. The lake surface area is about 15.5 km^2 with lentic ratio of 63.5[5]. The maximum depth of the lake is 25.9 m while the lake volume is 160 million cubic meters. The lake supply water to the Pedu Lake located in the north through a 6.8 km Salong tunnel. Both reservoirs were managed by the Muda Agriculture Development Authority (MADA). The Muda Lake Basin forms part of the Muda River Basin which is the largest river basin (4249 km^2) in Kedah and one of the transboundary rivers in the country.

Hydroclimate projection study has been undertaken by the National Hydraulic Research Institute of Malaysia (NAHRIM) since 2005. The study involved downscaling of the Global Climate Model (GCM) to the peninsular

region and simulated based on coupled atmosphere-ocean global climate models ECHAM5, CCSM3 and MRI[4]. The extension study on the impact of climate change in the Peninsular Malaysia that has been carried out in 2014 provided 15 projection scenarios data based on 6 by 6 km grid simulation of A1B, A2, A1F1 and B1[6]. Hydroclimate projection studies by NAHRIM indicate that Muda River Basin will experience a significant increase in rainfall amount[4]. The increase in mean monthly flows in this watershed associated to the expected climate change during 2040–2100 was reported to be statistically significant from April to May and from July to October [5]. This study aims to evaluate and simulate the impact of these climate changes using the downscaled hydroclimate data on Muda Lake Basin in particular to assess the vulnerability of the lake to changes in future hydrological pattern. Muda Lake Basin, which is situated at the most upstream of the Muda River Basin is a major water catchment for Kedah and Penang State.

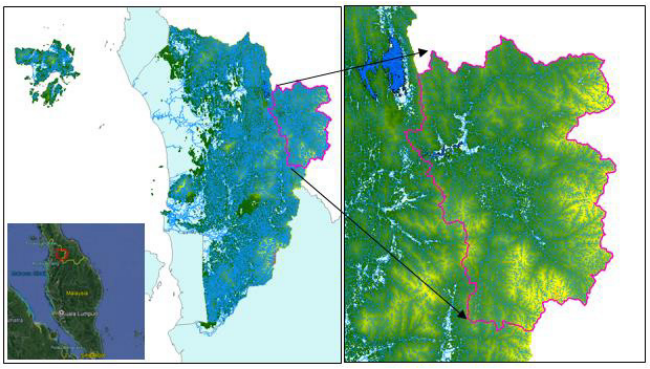

Fig. 1 Muda Lake Basin within the Kedah State, Malaysia

2. METHOD

Hydrological and hydrodynamic modelling using Probability Distribution Model (PDM) rainfall-runoff model[7] and Infowork 2-Dimensional Integrated Catchment Model is used to analyze the impact of climate change on Muda Lake Basin. The PDM was based on long duration continuous rainfall runoff and calibrated using rainfall and water level data for the period 2012-2017. Rainfall data was obtained from MADA and DID. In general, the main rivers that flow into Muda reservoir are Muda, Teliang, Che Song and Nipis Kulit. The catchment can be divided into 5 main sub-basins. The main sub-basins are the Ulu Muda and Teliang river basins that contain more than 85% of the rainfall amount that flows into the catchment areas. The hydroclimate scenarios were based on baseline data and future land use with hydrological pattern varied between scenarios. Climate impact assessment is carried out based on 3 slices period: early 21st century (2010-2040), middle 21st century (2040-2070), and end 21st century (2070-2100). Future hydroclimate projection from 35 grids were used in hydrological model (Figure 2).

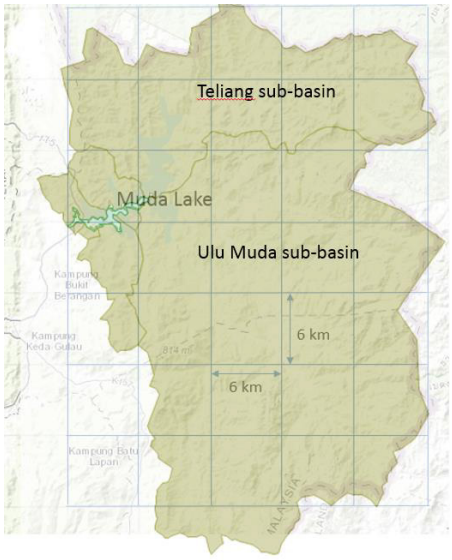

Fig. 2 Catchment model and grid of hydroclimate model

3. RESULTS

The mean annual rainfall in Muda Lake basin is 3150.4 mm. This value is much higher than the mean annual rainfall between the period of 1970 to 2015 that is 2419.6 mm. Driest month is February while wettest month is September. Future hydroclimate projection data showed varied rainfall pattern between scenarios with increasing annual rainfall by end of century. Mean 30-year basin average by end of 21st century is still below 3000 mm. Preliminary simulation results showed Muda reservoir is sensitive to hydrological changes in particular drought. Existing water storage in Muda lake varied about 30 Mm^3.

Future climate projection during 2040-2070 show mild decrease and increase in rainfall amounts: dry trend (2040-2064) and wet trend (2064-2070). Such changes may be affecting slightly the water level and lake volume. In contrast, future climate projection during 2070-2100 will lead to sharp decrease and increase in rainfall amounts: long period droughts will be experience during 2070 to 2083 while long wet periods will be experience during 2083 to 2100. Due to the large catchment basin, hydrologic and hydrodynamic model of Muda Lake are being calibrated to ensure that the baseline model will adequately provide sound simulation to predict the impact of future hydroclimate projection. The expected results from this

research is an integrated catchment model that are able to predict the impact of future climate to lake water balance and its ecosystem services.

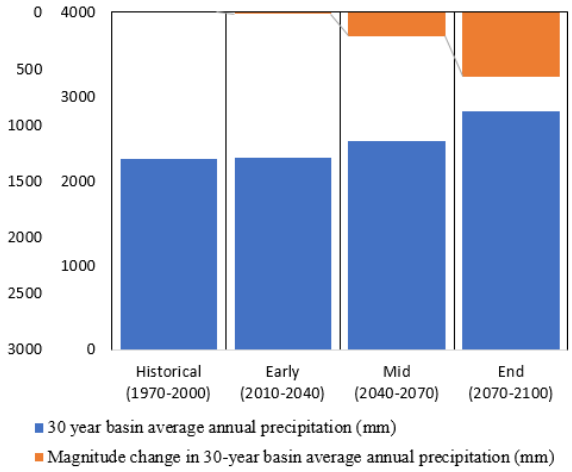

Fig. 3 30-year mean basin average annual precipitation and their magnitude of change

4. DISCUSSION

Changes in hydrology affects the water level and hydrodynamic pattern in the reservoir and its ecosystem services namely resource provision of water supply for irrigation and domestic. Due to its large drainage basin, Muda reservoir function as main collector of rainwater to channel to Pedu reservoir prior releasing to the Muda Irrigation Scheme which is also the largest paddy field in Malaysia and located about 80 km to the east. The paddy irrigation field encompass an area of 100, 685 ha, adopt double cropping of rice per year and involve a total of 68,000 farmers are dependent on the water supply from Muda and Pedu reservoirs. Water that flows downstream of Muda lake are extracted for water supply for both Kedah and Penang States. Climate change projection indicate significant increase in rainfall amounts during 2040-2100 in the inter-monsoon periods in the Muda Lake Basin consistent with prior findings in the larger river basin[6,8]. Significant changes in rainfall amount during these periods provide excess water for irrigation that can be stored during drought.

Long drought by end of 21st century will affect water storage needed for irrigation. To ensure minimum environmental flow is required for river to sustain water extraction, water transfer to Pedu Lake for irrigation will be reduced during long droughts and affect the double cropping cultivation. Increasing future rainfall indicate excess water and flood to downstream areas. The targeted findings of this work are to identify strategies to reduce the vulnerability of Muda Lake Basin to climate change including measures and policy to enhance infrastructure development and stakeholder management and cooperation at the catchment scale to sustain the overall lake ecosystem services. This will covers estimating the associated values related to the provisioning and regulating services and potential losses of crops, foods and water supply associated to floods and drought.

5. CONCLUSION

This study documents the vulnerability and ecosystem services assessment of Muda Lake Basin to climate change using the downscaled regional hydroclimate data. The study will enable identification of additional measures to reduce the climate change impacts.

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O9-19

Paper title : Government disaster response to flood and utilization of remote sensing to river observation ; An investigation in the Asia Pacific region

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Keywords: climate change, disaster prevention, mitigation

ABSTRACT

Among the natural disasters in the world, The largest number of afflicted countries among the natural disasters is " Hydro-meteorological disasters" such as floods, storm surges and landslide in the world. Important elements in river and lake disaster prevention are the diversity of gathering information of to the observation network by various sensors such as rain gauge, water gauge, weather radar and AMEDAS, in recent years it has been widely used for observation of information by remote sensing using satellite, UAV, drone and access It is recognized as an effective means for observation of difficult remote areas and afflicted areas. Consequently, based on the existing survey in Japan and Myanmar, Vietnam, we will describe the application and the problem to the disaster prevention field in each country river observation system and remote sensing

1. INTRODUCTION

There are many countries affected by disasters caused by natural disasters in the world, but most of losses due to natural disasters are hydro-meteorological disasters. Of the 22,200 events recorded between 1980 and 2011, 17, 400 (78.4%) caused the storms, floods, landslides, droughts etc. [1] and the number of affected countries is large. The observation system in Vietnam and Myanmar, which is a country susceptible to human and economic impacts due to climate change in the Asia-Pacific region, is weak compared with Japan, which is a disaster-prone country and advanced disaster prevention country. Under the circumstances under consideration, in order to investigate disaster prevention and mitigation in rivers and lakes, existing river management facilities and disaster prevention systems in each country and the possibility of utilization of observation data in UAV, drone and satellite remote sensing 1) Japan, (2) Myanmar, and (3) Vietnam.

2. METHOD

Investigate on the actual situation of river management facilities and disaster prevention systems in each country on-site survey and interview to relevant government agencies. We will also examine availability of observation data in UAV, drone and satellite remote sensing. Specific methods are as follows. (1) Information gathering by existing documentation,(2) On-site survey government related disaster prevention, listening to staff in charge,(3)Consideration of utilization of observed data in satellite remote sensing

3. RESULTS

Disaster prevention consist of three categories, such as “Information Gathering”, “Data Analysis” and “Information Delivery”.(1)At first, various information is gathered by using many kinds of sensors.(2)The gathered information is analyzed, and shared with disaster related ministry and other states and prompt and proper countermeasures are decided.(3)The decisions are sent to residents and other states through various devices.

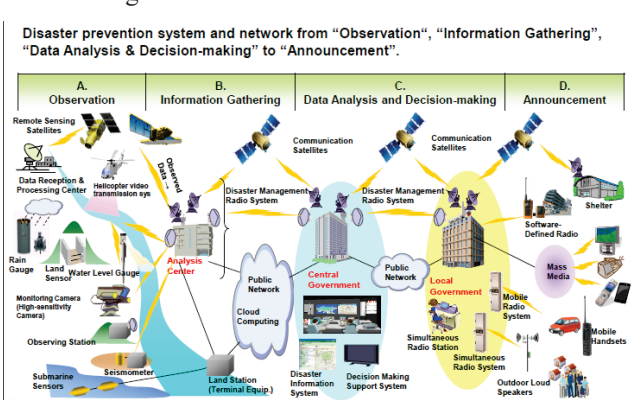

Fig. 1. Overview of Disaster Prevention in Japan

(1) Japan

Japan is globally known for a lot of natural disasters as well as advanced knowledge and technology of disaster prevention. Based on such a knowledge and technology, disaster prevention equipment such as various sensors, redundant network for disaster prevention, various monitoring and simulation systems are developed.

(2) Myanmar

The Republic of the Union of Myanmar has long history of suffering wide-scale disaster such as Cyclones, Floods, and Earthquakes. Especially in 2008, Cyclone Nargis caused devastated damages on Myanmar. More than one hundred and thirty thousand (130, 000) people are dead or missing, and two point four million (2.4 Million) people are affected. Also, cyclone “Komen” in 2015 wide-ranging and serious flood damage occurred across the country, 1.6 million people and 450,000 houses were affected. [2] With regard to Myanmar, excluding urban areas such as Naypyidaw, Yangon, traffic and communication infrastructure is still underdeveloped, international donor agencies and NGOs support to gather various information related disaster.

Based on the above, in order to investigate the existing disaster prevention system of Myanmar, visited DMH (Transportation Meteorological Hydrology Bureau) , RRD (relief of social welfare and relief and reconstruction Ministry) at Naypyidaw and Yangon in 2015.We conduct survey on Observation Facility and Emergency Operation Center as below.

1) Observation facility

Regarding the meteorological weather station, implemented 120 stations throughout the country.

Observation is operated manually, and observation data is taken five times / day every 3 hours from 6 am, and it is sent to DMH head office by telephone / FAX. Apart from that, a water level gauge and a telemetry system are introduced to each river and dam by country support including JICA. Also, at the time of 2015, observation facilities of the weather radar are under construction in Japan's ODA, further improvement of weather observation accuracy is expected.

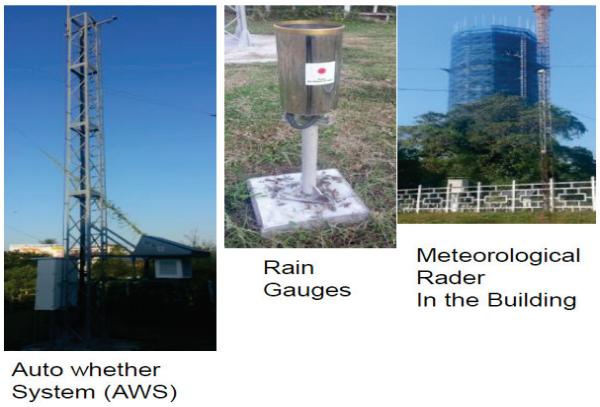

Fig. 2. meteorological weather station；DMH at Yangon

2) EOC；Emergency Operation Center

RRD governs EOC. Essentially, disaster information is gathered and decision making done by Heads of Administrative at EOC. In Myanmar, disaster response is handled by National Natural Disaster Management Committee (NNDMC) which chaired by vice-president accordance with the NNDML. The RRD is mainly responsible for (1) acceptance for international organizations and NGO support personnel in the times of disaster, (2) acceptance of emergency relief goods, (3) release situation report on disasters, etc.

Moreover, data collection in RRD is relay on telephone and fax. It contains a lot of potential errors and consumes much more human resources. Therefore it is very difficult for RRD to provide accurate information on time.

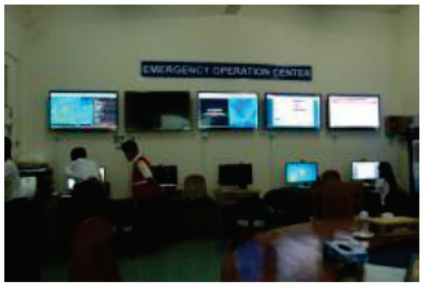

Fig. 3.EOC；RRD at Naypyidaw

(3) Vietnam

In this survey, we investigated Rainfall and water level observation facility in HCMC and SCFC (flood control center) building and existing system. All observation facilities we surveyed, managed by NHMS (National hydrological Meteorological Agency) South District Meteorological Center which is under MoMRE (Ministry of Natural Resources and Environment). The meteorological and hydrological observation office we investigated as below.

- Moc Hoa Weather and water level observation station (Manual)
- Kenh N79 Weather and water level observation station (Automatic)
- Long An meteorological hydrological observation station
- DongNai Province Bien Hoa Level Observatory (Manual)
- Dong Nai Province Meteorological Hydrology Bureau
- Tan Son Hoa weather station (manual)

1)Observation facility (meteorological hydrological information)

1) hydro-meteorological observation (Manual)

NHMS is conducting observations of hydrological weather related to disasters. The system of observation within the range heard is visually read from the recording paper twice a day. Loggers taking rainfall record are almost made in China. The tide level gauge that takes record of the water/tide level is a float type, made in the USA. According to the JICA survey report [3], there was a statement that tide level observations will be made 24 times a day in areas affected by the tide level. As for the ground weather, observation at least 4 times / day, 8 times / day.



Fig. 4.Rainfall observation station

2） Hydrological and meteorological observation (automatic)

Automatic hydro-meteorological observation station was equipped with a water level gauge and a rainfall gauge, and observation information was collected via satellite communication. Observed data is confirmed at the branch office, and data collected in nearly real time (delay of about 10 to 15 minutes) was displayed(Made by CAE Italy). Unfortunately, noises are found in the tide level data, and it is considered that there is a problem in the implementation system of maintenance.

3) Water level observation network

SCFC is conducting to observe only 7 water level gauges installed along the Nhieu Loc Thi Nghe (New Rottingge) waterway in HCMC. The observation device is installed on a pillar standing on the sidewalk along the water channel. The observation data is automatically collected in the data aggregation server via the GSM / GPRS communication module. Since it was a reply that the system handling observation data was not arranged in the server room installed in the office building of SCFC, management of observation equipment was left to external institutions such as Urban Drainage Company (UDC).SCFC is monitoring only at the observation result.



Fig.6.Water level observation station

4. DISCUSSION

Disaster prevention systems for hydro-meteorological disasters require gathering information, decision making quickly and accurately. In Japan, budget for disaster prevention infrastructure as well as maintenance are sufficient, but it is not sufficient for Vietnam and Myanmar.

They have been given top priority for the development of social infrastructure which contributes to the economy. Many observation equipment in their countries has been provided by Japan and other countries' donation and maintenance is not sufficient.

Meanwhile, an observation system based on vulnerable communication infrastructure, such as utilizing GSM / GPRS / SSB as infrastructure for sending disaster information, has implemented.

Regarding large-scale flood disasters such as Cyclone ·

Komen in Myanmar, remote sensing from artificial satellite or UAV is effective in times of disaster. It's possible to (1) instantly observe a wide range, (2) grasp the situation without going directly to the site, and (3) near infrared rays and microwaves which can't be confirmed by human eyes Observation. However, remote sensing by artificial satellites is expensive for developing countries.

Based on the above, it's convinced that remote sensing by utilizing drone is effective to grasp disaster information in real time. (There was also a question from the Director of RRD of Myanmar after the disaster cyclone "Komen" in 2015.

Consequently, based on considering the size of the economies of each country and the disaster prevention literacy, we should consider to implement a disaster prevention system.

5. Conclusion

Based on the results of on-site survey, we discussed the disaster prevention system for "Hydro-meteorological disasters" in Japan, Myanmar and Vietnam.

Although disaster infrastructure in Myanmar and Vietnam are vulnerable, we convinced that it will be improved their infractracture supported by JICA or multilateral assistance both hard and soft, and budget for disaster prevention infrastructure due to economic growth of our country will be improved.

Although the disaster prevention infrastructure in Myanmar and Vietnam is weak, although disaster prevention system in flood damage in Japan, Myanmar and Vietnam was discussed based on the on-site survey results, both JICA and multilateral assistance. Moreover, it will be improved by the increase of budget for disaster prevention infrastructure due to economic growth in their country.

Meanwhile, concerning Pacific islands, which are also areas where natural disasters such as cyclones, floods, earthquakes and tsunamis frequently occur, and which are susceptible to serious impacts of climate change, their "Narrowness", "Isolation", "Remotability" and "Maritime", there are many disaster prevention issues before disasters. Based on the discussion Japan, Myanmar and Vietnam, we try to investigate the hydro-meteorological observation and disaster prevention system in the Pacific islands.

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O9-20

Management of a Tropical Freshwater Lake under a Changing Climate and Environment

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Keywords: Sasthamkotta Lake, water quality, climate change, socio-economic

ABSTRACT

Lakes are under threat from the impact of environmental degradation and changing climate in India, a country with fast rising population and with several social, economic and political hurdles in manangement. The Sasthamkotta Lake , a designated wetland is the only freshwater lake in the tropical state Kerala. This spring-fed lake is the source of drinking water for 0.5 million people and residence of nearly 27 freshwater fish species. Input of chemicals, fertilizers and pesticides from farms carried through rivers, and the detergents and untreated domestic effluents from urban areas contaminate the lake's water. Rising needs in water and the extremes in local climate as part of global anomalies worsen the situation. Increasig rainfall intensity causes large-sclae erosion in the upper hills and the sediment load carried by rivers threatens the existence of the lake. Degradation of the lake leads to socio-economic issues such as pricing of water, migration, and conflicts. Rules and regulations for the protection of lake become farce bcause of various social and political reasons. This paper analyses the water quality of the lake, various factors leading to the degradation of the lake and the socio-economic issues associated with the degradation of the lake.

1. INTRODUCTION

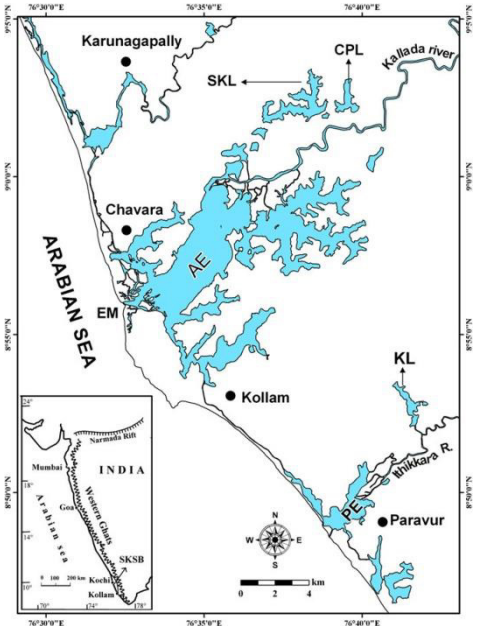

Fig. 1Location map

Sasthamcotta Lake, a designated Ramsar site is the largest natural fresh water lake in Kerala located in Kollam District between 9º 0′-9º 5′ N latitude and 76º 35′-76º 46′ E longitude, with an average depth of 6.5m. Except for an earthen embankment of 1.5 km length which separates the lake from the paddy fields on its southern side, bordering the alluvial plains of the Kallada River, all other sides of the lake are surrounded by hills which are steep and form narrow valleys. In the south and southwestern parts of the lake there are a number of smaller water bodies and waterlogged areas. This lake has an area of 3.75 km2 and volume of 22.4 km 3 (Vishnu Mohan et al., 2016). The lake receives water mainly from rainfall of (nearly 2500 mm/year) and surface runoff (3.54 million m3/ year) (Nair, 2015). In addition, it receives water from underwater springs. The wetland supports 27 species of freshwater fishes and two genera of prawns. It is the drinking water source for about 0.8 Million people. Inland navigation, tourism and fishing are the major source of income for the lake depending communities. Erosion associated with climate change and pollution from domestic, agricultural and industrial sectors deteriorates the water quality of the lake. Sand mining in the nearby Kallada, overexploitation of water, unscientific engineering constructions etc also badly affect the water quality (Sujayakumari & Lisy 2017). Floodplain area is becoming fallow lands because of indiscriminate sand mining, reducing the groundwater replenishment of the lake. Encroachment has reduced the depth and surface area of the lake considerably. Large tracts of land around the lake have been cleared off trees for paddy, plantain and tapioca cultivation. The lake is losing its water level at an alarming rate of 1 cm per day. Water level in the lake fell from around 16m in 2010 to 11.5m in 2018. Area of the lake fell from about 4.60 sq km in 1970 to 2.5 sq km in 2018.

2. METHOD

Quality of water in the lake was analysed during summer and monsoon seasons during 2016 & 2017. Data and reports from various government agencies and NGOs have been collected for the study. Meteorological data procured from the India Meteorological Department was analysed to find changes in rainfall characteristics over the area.

3. RESULTS

Analysis of the rainfall data shows that total rainfall during the study period was not much different from the

climatological normal, but intensity and seasonality of rainfall over the area is increasing. Surface water temperature of the lake is increasing. The total dissolved solids (TDS) shows a monthly range of 88.4mg/L to 55 mg/L, much below safety limits. The TDS values are high during monsoons due to the input of organic matter and wastes from rivers and canals. Surface water temperature of the lake ranged from 26.5C to 32.3C. Turbidity values varied from 14 NTU to 19 NTU, the dissolved oxygen values varied from 5.46 to 8.53 mg/L and the BOD varied from 0.68 to 5.3 mg/L. COD from 3.2 to 110.7 mg/Ltotal hardness from 7 to 25 mg/L (within desirable limits). High value of total coliforms (19 to 23700 count / 100mL indicates that water quality is unsafe to humans. COD, BOD, pH, and turbidity and coliform of the water samples were exceeding the desirable limit, though there is large seasonal variations. Microbial contamination was detected in all samples, which is a serious threat to human health. Water quality analysis shows that water is acidic, especially during the non-rainy months (December to May) when the pH values were always below 5.5.

4. DISCUSSION

As the rainfall is becoming more seasonal and intense, erosion and sediment input into the lake are increasing. Long gap in rainfall reduces groundwater recharge and adds to the deterioration of water quality. Rate of evaporation increases with the rise in water temperature, adding to decreasing summer water level. Main reasons for the degradation of water quality are: encroachment/reclamation for agriculture (mainly paddy, plantain, and tapioca), unauthorised sand and clay mining in the surrounding hillocks which serves as catchments, acacia plantation that consumes large water quantity, soil erosion on the banks and accumulation of eroded materials at the bottom of lake, dumping of agricultural and domestic wastes, dumping of wastes by restaurants and butchers, dumping of hospital wastes, dumping of municipality sewage via gutters, debris input from construction, coconut husk retting and, bathing (humans and animals) and washing clothes.



Fig. 2 Change in lake area 2011 & 2017

State government has started an action plan for the sustainable utilization and conservation and to address the threats faced by the lake. The forest department has planted trees to prevent soil erosion at some places along the embankments. Efforts had been made to control cultivation along the banks of the lake. It was proposed to rejuvenate the lake fishery by ranching with the seeds of indigenous fishes. Local NGOs are working actively to restore the lake. But, the progress is very slow.

Degradation of water quality leads to several socio-economic and health issues such as: local water crisis and hiking price of reliable water, migration and conflicts over allocation of water, spread of water-borne diseases and increasing poverty of lake depending communities.

Major challenges to the lake are changing climate, (especially the trends in rainfall and temperature), the national river linking programme to interconnect major rivers that may reduce flow into the lake, rising population, agricultural expansion, urbanization and industrialisation. Fall in water level allows nutrient-rich water from the nearby marshes to flow into lake. This will trigger algal bloom in the lake, causing eutrophication that may trigger anaerobic conditions, threatening the lake ecosystem. A good portion of the 3.73-sq km lake has turned lush grassland which is now being utilised for grazing livestock. When the grass gets decayed during monsoons, it will produce methane and result in eutrophication. Increasing use of surface water will lead to increased use of groundwater that may result in salinity intrusion, as the lake is not so far from the Arabian Sea. Another major challenge is the tourism development. Oil spills from houseboats is becoming a threat to the aquatic life. Fishing boats with outboard engines release large quantity of hydrocarbon in to the lake.

Recommendations for the protection of lake and to mitigate the impacts include public awareness to protect and improve the aesthetic environment near the lake, ensuring safe drinking water though domestic water purifiers, rainwater harvesting, enhancing groundwater recharge in the surroundings through traditional and environment friendly techniques, strict banning on the discharge of human wastes sewage and other pollutants directly into the lake, control of agriculture on the immediate vicinity of the lake, relocation of polluting industries, periodic evaluation of water quality and prohibition of bathing and direct washing of cloths in the lake.

5. CONCLUSION

Water quality as well as the water quantity of the lake is decreasing fast, as a result of encroachment, input of chemicals from domestic, agricultural and industrial sectors and the changes in temperature and rainfall patters associated with global climate change. This has seriously affected the availability of reliable water and livelihood of lake depending poor communities. Deterioration of water quality leads to serious health issues. The lake is receiving increasing pressure with requirements in land and water for the fast rising population. All these factors lead to several socio-economic issues. Current policies and strategies for the

conservation of wetlands are inadequate the implementation mechanism often fails due to various administrative, political and financial reasons. The state should develop an appropriate policy that includes social, economic and environmental factors and climate change adaption and a strong guideline for the implementation of the policy. Increased public awareness can be made with cooperation of NGOs. Financial crisis can be overcome with private sector participation with a strong control by the government.

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O9-21

気象条件の変動に対する近隣湖沼の水質応答特性に関する研究

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キーワード:近隣湖沼,気候変動,水質応答,ILBM,水質管理

抄録

霞ケ浦,手賀沼,印旛沼は利根川流域における同様の気象特性のエリア内の近隣湖沼である.気象条件の変動に対する近隣湖沼の水質応答特性には,気象変動特性による同期性と湖沼特性に応じた個別性がみられ,近隣湖沼における気象特性,湖沼特性に応じた水質応答特性の分析は,近隣湖沼の統合的な利水管理,環境管理に有効と考える.日平均水質の応答特性として,手賀沼は降水後の COD 低下,霞ケ浦は強風時の COD 上昇が顕著である.近隣湖沼の月平均の水質変動には同期性と個別性が見られる.近隣湖沼の年平均水質の応答特性として,手賀沼は年降水量,霞ケ浦,印旛沼は年降水量,年日照時間による年平均 COD の変動量が大きい.

1.　はじめに

図 1 に示す霞ケ浦, 手賀沼, 印旛沼（以下 3 湖沼と言う.）はいずれも利根川水系に属する近隣湖沼である.ここで近隣湖沼とは,集水域の気象特性（降水,日照,風速,気温の年間変動特性）が同様の湖沼で,概ね半径 30km の円内に集水域が位置する湖沼を言う.表 1 の 3 湖沼の諸元のとおり,3 湖沼の容積,年平均回転数等,湖沼特性は大きく異なる.ここで 3 湖沼の流出係数は,手賀沼の日雨量と日平均自流量（利根川下流河川事務所データ）の相関式から求めた手賀沼流出係数を他の 2 湖沼にも準用した.3 湖沼における気象条件の変動は近隣であることから同期性がみられ,気象条件に対する湖沼水質の応答には湖沼特性の差異が反映される.本論は近隣湖沼における気象条件の変動に対する水質応答特性を分析し,近隣湖沼の統合的な利水,環境管理に資する.

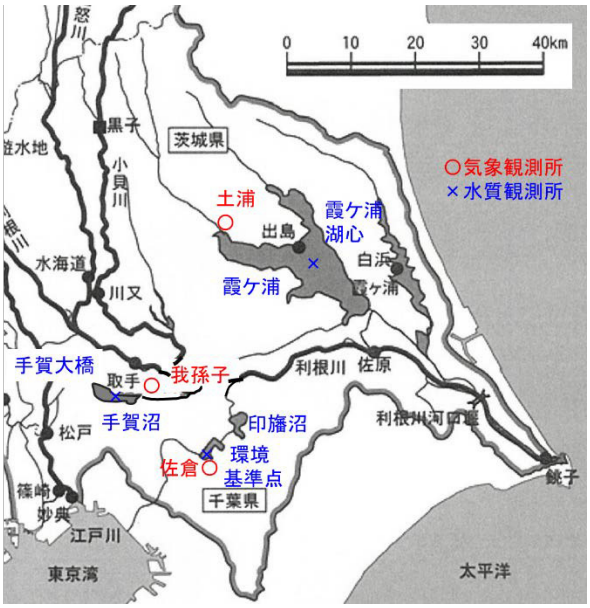

図 1　 3 湖沼の位置図

表 1　3 湖沼の諸元

		手賀沼	印旛沼	霞ケ浦
COD75%値(mg/L)	環境基準	5	3	3
	27年度現況	9.3	14	8.6
湖沼面積(100ha)		6.5	11.6	218.6
平均水深(m)		0.86	1.7	4
湖沼容積(百万m^3)		5.6	19.7	850
流域面積(100ha)		150.5	505.4	2156.7
年平均雨量mm（1984～2017年平均）		1407	1404	1210
年平均回転数		27.8	26.4	2.3

・手賀沼流出係数＝(1.407＊0.7335＊流域面積＋1.8941＊365日)/流域面積/1.407＝0.734

・年平均回転数
＝年平均雨量＊流域面積＊流出係数／湖沼容積

2.　近隣湖沼における日平均水質応答特性

湖沼の日オーダの水質変動要因として,強風による底泥巻き上げに伴う COD 上昇,降水時の汚濁負荷流出に伴う COD 上昇,降水後の湖水の流出交換に伴う COD 低下,気温低下による光合成の抑制に伴う COD 低下,日射による光合成に伴う COD 上昇が考えられる.図 2 は 2011 年 4 月の霞ケ浦近傍の土浦における日気象値（日平均気温,日日照時間,日平均風速,日降水量）と,水質指標として霞ケ浦湖心の日平均 COD 値を示す.日平均 COD の変動と気象値の対応から,日平均 COD の変動要因を推定し,気象要因別に丸印で示した.日照時間,DO ともに高い場合は日照による光合成に伴う COD 上昇と推定され,気温、水温ともに低い場合は気温（水温）低下による光合成減少に伴う COD 低下と推測さ

れる.複数の気象イベントが同時発生の場合は,複数の丸印を同日に示し,件数,COD 変化量は按分した..表 2 の定義により手賀沼と霞ケ浦の日平均 COD の変動要因と推測される気象イベント件数をカウントし,気象イベントによる COD 変化量の合計値を算定し,図 3 に示す.手賀沼は降水後の COD 低下,霞ケ浦は強風時の COD 上昇が顕著である.

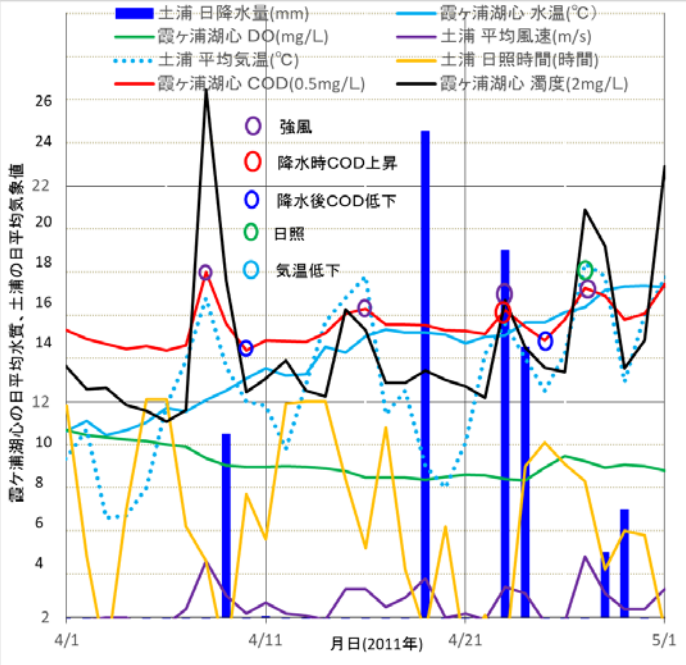

図 2　３湖沼の年平均ＣＯＤの経年変化

表 2. 気象イベントによる日平均ＣＯＤの変動量の定義

気象イベント	気象イベント前	気象イベント後（カッコ外の数値は手賀沼、カッコ内の数値は霞ケ浦）
強風	気象イベント直前のCOD値	日平均2m/s以上の風速後１日（２日）以内のCODピーク値
日照		３日連続8時間以上の日照後１日以内のCODピーク値、またはDOのピークから0日（２日）以内のCODのピーク値
降水時		日10mm以上の降水後１日（２日）以内のCODピーク値
気温		１０日で2℃以上の水温または気温低下後２日以内のCOD最低値
降水後		日10mm以上の降水後２日以内のCOD最低値

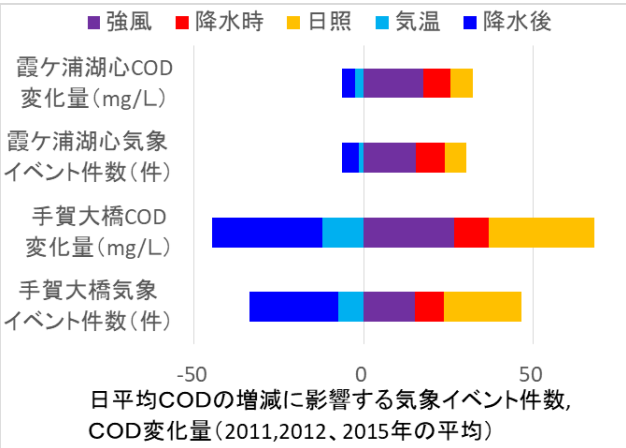

図 3　手賀沼、霞ケ浦の気象イベント件数、COD 変化量

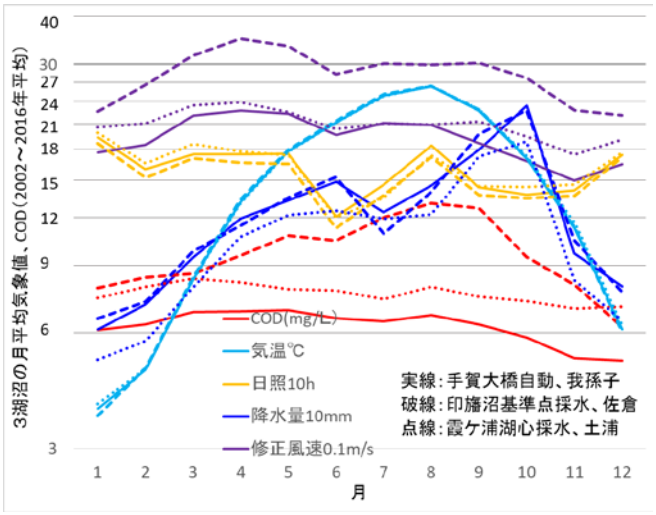

図 4　３湖沼の月平均気象値, COD

3. 近隣湖沼における月平均水質応答特性

図 4 は 3 湖沼の月平均気象値,COD 値を示し,表 3 は 3 湖沼の月別の COD の高低と図 4 における気象値と水質値の対応から推定される COD の変動要因を示している．3 湖沼とも秋雨以降の 10～12 月は COD が低い.印旛沼は夏季の 7～9 月の COD が高いが,霞ケ浦,手賀沼は 3～4 月頃の COD が高い．COD の高低は,年間上位 3 位までを＋,下位 3 位までをーで表示した.1～2 月は概ね弱風で COD は低く,3 月は少雨,強風,日照が強まり COD 上昇,5 月は強風で COD 上昇,6 月は梅雨,弱風で COD 低下,7～9 月は強風,日照,少雨により COD 上昇,10 月は梅雨により COD 低下,11～12 月は弱風等で COD 低下し、3 湖沼で月平均水質には,同期性と個別性がみられる.

4. 近隣湖沼における年平均水質応答特性

3 湖沼の年平均 COD,年平均気象値間の単回帰分析を行い,表 4 に示す.なお,2009 年以前の我孫子,土浦の風速は観測環境悪化による経年的な線形低下トレンドを修正した.図 5 に 3 湖沼の年気象値の変動（2＊標準偏差σ）による年平均 COD の変動幅（各気象要因は独立ではないため,合計で COD の 2σとなるように比例配分）を示す.手賀沼は年降

水量による COD の年変動量が大きく,降水流出により汚濁負荷が効率的に排出されていると考えられる.印旛沼、霞ケ浦は年日照時間,年降水量による COD の年変動量が大きい.

表 3　３湖沼の月別の COD の高低と COD 変動要因(2002～2016 年平均)

湖沼	区分	1月	2月	3月	4月	5月	6月	7月	8月	9月	10月	11月	12月
霞ケ浦	CODの高低		＋	＋	＋						－	－	－
	COD変動要因		少雨	日照、強風	日照、強風						多雨、日照少、弱風	弱風	弱風
手賀沼	CODの高低			＋	＋	＋					－	－	－
	COD変動要因			強風	日射、強風	日射、強風					少雨、弱風、日照少	弱風、日照少	弱風
印旛沼	CODの高低	－						＋	＋	＋		－	－
	COD変動要因	弱風						高温	高温、日照	高温		弱風、日照少	弱風

表 4　３湖沼の年平均 COD、気象値間の単相関、COD 変動幅

		年日照時間hr	年平均気温℃	年降水量mm	年平均風速m/s	年平均CODmg/L
導水前手賀沼	係数	0.0066	0.213	−0.0088	−1.173	
	決定係数	0.09	0.00	0.60	0.00	
導水後手賀沼	係数	−0.0005	0.206	−0.0036	−2.48	
	決定係数	0.00	0.00	0.19	0.03	
印旛沼	係数	0.004	0.513	−0.0034	−1.29	
	決定係数	0.32	0.04	0.30	0.02	
霞ケ浦	係数	−0.0011	−0.067	−0.0014	1.18	
	決定係数	0.13	0.00	0.15	0.01	
平均値	前手賀沼	1634	14.58	1418	1.98	19.44
	後手賀沼	1909	14.81	1462	1.92	9.03
	印旛沼	1771	14.70	1434	2.49	9.72
	霞ケ浦	1818	14.70	1241	2.07	7.72
標準偏差σ	前手賀沼	132	0.51	260	0.05	2.95
	後手賀沼	207	0.39	174	0.1	1.44
	印旛沼	189	0.5	222	0.15	1.36
	霞ケ浦	219	0.5	200	0.07	0.71
2σのCOD変動幅	前手賀沼	1.54	0.20	4.06	0.11	5.90
	後手賀沼	0.29	0.22	1.70	0.68	2.88
	印旛沼	1.05	0.35	1.05	0.27	2.72
	霞ケ浦	0.54	0.08	0.63	0.19	1.42
・1988～2016年データで解析						
・手賀沼は導水前1988～1999年、導水後2000～2016年						
・各気象値によるCOD変動幅＝係数＊各気象値の標準偏差						
＊実際のCOD変動幅／(各気象要因による計算COD変動幅)						

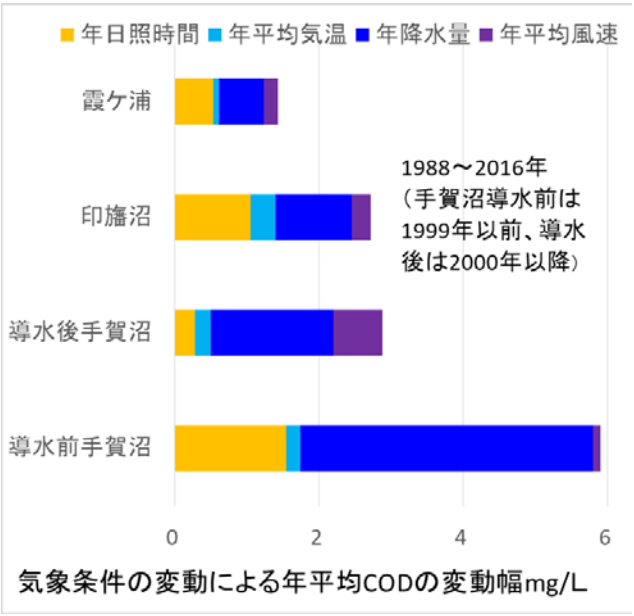

図 5　３湖沼の気象イベントによる COD 変動幅

5. おわりに

気象条件の変動に対する近隣湖沼の水質応答特性に関する結論は以下のとおりであり,近隣湖沼の比較により適格な湖沼水質変動特性の分析が可能となり,近隣湖沼の統合的な利水管理,環境管理に有効と考える.

1．日平均水質の応答特性として,手賀沼は降水後の COD 低下,霞ケ浦は強風時の COD 上昇が顕著である.

2．月平均水質の応答特性として,近隣３湖沼の月平均水質には同期性と個別性がみられる.

3．年平均水質の応答特性として,手賀沼は年降水量,霞ケ浦,印旛沼は年日射時間と年降水量による年平均 COD の変化量が大きい.

O9-22

Water availability and demand under climate change and population growth in Lake Guiers, Senegal

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Keywords: climate change, water resources, population growth, Lake Guiers, Senegal

ABSTRACT

During the last three decades, increasing population, changing patterns of water demand, and concentration of population and economic activities in urban areas has pressurize Senegal's freshwater resources. To overcome this deficit, Senegal turned to the exploitation of Lake Guiers. It is the sole water reservoir in the country and its water is use for irrigating crops and sugar refinery, as well as a drinking water resource for urban centres. To address the challenges that climate change and population growth poses in Lake Guiers water resources, it is necessary to consider its potential impacts on different dimensions of water resources. In this study, future water availability and demand has been modelled under scenarios of climate change and population growth until 2030, based on the representative concentration pathways (RCPs) 4.5 and 8.5 by applying the Water Evaluation And Planning System model (WEAP). The results show that the pressure on Lake Guiers's water resources will increase, leading to greater competition between agriculture and municipal demand site. Decreasing inflow due to climate change will aggravate this situation. WEAP results offer basis to Lake Guiers water resources manager for an efficient long-term planning and management.

1. INTRODUCTION

In Senegal, the supply of drinking water to satisfy population needs is one of the biggest issue. To overcome deficit on water supply, Senegalese authority turned to the exploitation of the Lake Guiers. It is a shallow reservoir located on the right bank of Senegal River, between latitudes 16°23'N and 15°55'N, and longitudes 16°12'W and 16°04'W. The Lake Guiers is mainly fed by Senegal River through Taouey canal (Figure 1). Its water is used for irrigating crops (90,000 ha) and as a drinking water resource for urban centres (165,000 m3/days for a population of 5 Million inhbts).

In the last decades, the Lake Guiers basin was subject to several changes. These changes concern socio-economic factors like growth of population and increased agro-industrial farming as well as hydrological changes in the Senegal River basin and the impacts of climate change.

Despite all these emerging issues, there is limited knowledge of the Lake's resources and how it might respond to global changes. Statistics on water use and supply are sparse and incomplete. There has been little assessment of the impacts of climate change and population growth in Lake Guiers which has much relevance for the formulation of climate adaptation policies. Many studies carried out in the Lake Guiers [1]-[2] provided only qualitative information. The lack of observations and studies limits our understanding of the dynamic relationship between the resources of the Lake and climate change and demographic change. In the future, increasing water abstraction will cause problems for downstream riparian communities and ecosystems [3], not only at the local, but also the national scale. The high spatial and temporal variability of water resource availability and its uneven spatial distribution and the further stress on this resource due to population growth, means that Lake Guiers water supply is at risk [4]

Therefore, this study aims to assess water availability and demand in Lake Guiers under scenarios of climate change and population growth until 2030, based on two IPCC scenario: the representative concentration pathways (RCPs) 4.5 and 8.5. To achieve research objective, we apply the Water Evaluation And Planning System model (WEAP).

2. METHOD

2.1 Data Set: We used hydrological data (discharge), climate data (Pmm T°C Etpot), and water demand and population growth rate. For scenarios analysis we use 2 IPCC scenarios: RCP 4.5 and RCP 8.5. Data are from CORDEX (Coordinated Regional Climate Downscaling Experiment) with 50km x 50km gridded and a length period of 2002-2030; 2051-2100

2.2 Water Evaluation and Planning System (WEAP): The main program that was used is WEAP, a management

program that is focused on the optimal distribution of water supply. WEAP is developed to combine water management and watershed hydrology [5]. The structure of demand and supply sites is created. Lake Guiers was characterized by the storage capacity, the initial storage and the netto Evaporation (ET_{net}).

The demand sites each got their annual water use rate by an activity level that means the population, the number of livestock or for agro industrial activities, the expand of cultivated land in hectares.

3.3 Scenario analysis**:** Three main scenarios have been developed on the basis of the current account year 2005 and the reference period from 2006-2030. The following Table 1 shows the structure of the scenarios created in WEAP.

The first scenario assumed the climate change in two of the RCP scenarios. The second scenario in WEAP is a growth scenario including the Lake Guiers region as well as the capital Dakar. The third scenario was created to test in which time the water in the reservoir will be exploited without a refill. It is based on the climate change scenarios and the growth scenario.

Table 1 Structure of the scenario created in WEAP

Current Account (2005)			
Simulation period (2006-2030)			
1	**Climate change scenario RCP8.5 or RCP4.5**		
Change in ET_{net} following change in RCP8.5 or RCP4.5			
2	**Growth scenarios on the basis of climate change scenario RCP8.5 or RCP4.5**		
Et_{net}	Population growth Implementation of introduced projects		
3	**Water supply from reservoir, Lake Guiers**		
ETnet	Population growth	Implementation of projects	Stopped inflow from Taouey canal

3. RESULTS

3.1 Water supply

The modeled stream flow in Taouey Canal into Lake Guiers show a distinct variation throughout the year representing the influence of Senegal River. Furthermore Figure 2 illustrates the distinct increase in inflow from 2006 - 2030 in both scenario RCP 4.5 and RCP 8.5 compare to current account year. The increasing differences between the two combined scenarios are very slight.

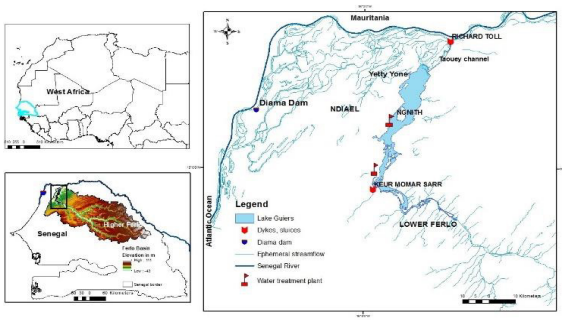

Fig. 1 Study area: Lake Guiers

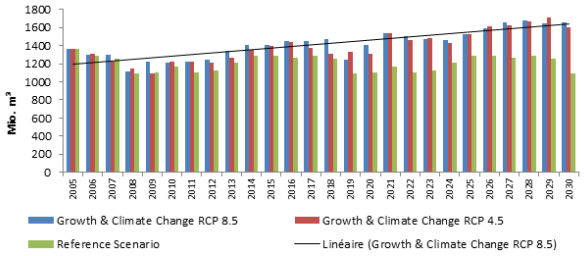

Fig. 2 Annual stream flow in Taouey Canal under RCP 8.5 and RCP 4.5 scenarios

3.2 Reservoir

It was tested, in case of a limitation of inflow (4,177,274.8 m^3/day) from the Senegal River, how long the water stored in the reservoir (655,616,099.3 m^3) will be sufficient when all projects are implemented. The water supplied by the reservoir (Figure 3) will not suffice for more than twenty months in RCP 4.5 scenario and nineteen months in RCP 8.5.

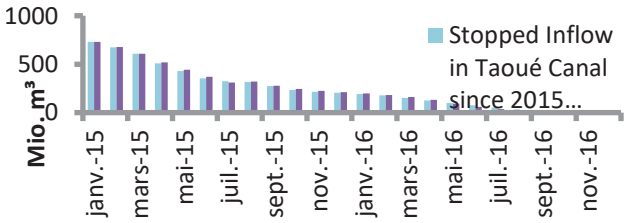

Fig. 3 Storage Volume in Lake Guiers with stopped inflow beginning in January 2015, combined scenarios of growth and climate change RCP 4.5 and RCP 8.5.

3.3 Water availability and demand

The total water demand (Figure 4) of the different demand site types is increasing throughout the study period and in all of the applied scenarios. Hereby, RCP8.5 shows the highest growth rates.

Results show that CSS (Sugar cane refinery), the biggest agro-industrial units, water demand is the highest. In 2005, it was estimate to 175 million m^3 and by 2030 the demand

will increase up to 25% in total. Furthermore, Senhuile, the second big agro-industrial units and private irrigation (others agro-industrial units) will face an increasing water demand by 2030. It was estimated that their demand will increase up to 20%.

For domestic demand the water demand in Dakar was estimate to 70,810,000 m^3 in 2005. This demand will increase up to 116,800,000 m^3 /year by 2030.

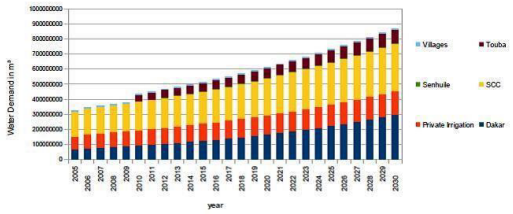

Fig. 4 Total water demand per user type in m^3

Unmet demand (Figure 5) is found in all scenarios, however, its amounts vary. Some demand sites will suffer unmet demand due to their dependency of Taouey canal which in turn depend on the inflow from Senegal River

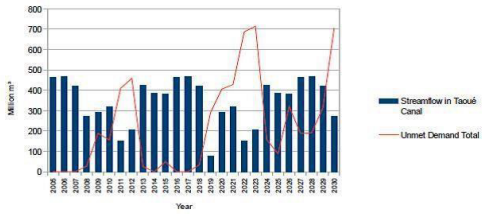

Fig. 5 Annual streamflow in Touey canal and Total Unmet demand

4. DISCUSSION

Like most of modelling tools, WEAP requires a large number of input data. Therefore, it faces uncertainties and constraints. One of the limits of the model is that it has not a quality assurance module [6]. Therefore, the challenge for a user applying WEAP model is to identify errors and to judge of the model results accuracy.

Data input uncertainties and constraints apply to both water supply and water demand data. The CORDEX data (spatial resolution 0.25°; rasta data) has been used for simulating evapotranspiration. The modelled demand might be underestimated as we don't take account to ground water data, livestock watering, industrial water demand, due to the lack of data availability.

Water availability and water supply situation could be ensured and achieved by using different management methods. Taouey canal should be adjusted in order to mitigate or anticipate unmet demand. In addition to increasing the reservoir capacities, other efficiency measurements should be applied: Adopt a basin approach, taking into account the adjacent ecosystems. Another efficiency measure is to establish water laws and allocations. This option imply water pricing and other market-based incentives to motivate further improvements in water use efficiency in agriculture dominated by private agro-industrial unit. Water evaporation mitigation is also another efficiency measure that could be used. Reducing the amount of water lost to evaporation would improve water security for Lake Guiers and lead to increased irrigation production. Substantial research and commercial testing on practical methods to reduce evaporation in a reservoir were completed recently [7] [8]. These methods use new technologies. Some of these new technologies are cost efficient solution to reduce evaporation each year and to maintain the highest quality drinking water.

5. CONCLUSION

The results show that the available amount of water in the reservoir is potentially high enough to satisfy users demand. However, the scenario analysis with WEAP reveal potential conflicts about water shortage. These shortages occur in both climate scenarios RCP 4.5 and RCP 8.5 with the decreasing of Taouey canal inflows. To ensure water security supply this research recommend to integrate the results in a DPSIR as an analyzing tools to help water resources managers to mitigate or anticipate future impacts.

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O9-23

Lake Basin Environment of the Lake Cluster Pokhara Valley (Ramsar Site), Nepal

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Keywords: Ecosystem, Lake-Basin, Biodiversity, Encroachment and Pollution

ABSTRACT

Lake Cluster of Pokhara Valley comprises nine lakes in Pokhara Valley in the Province-4, and 10th Ramsar Site (Site No.: 2,257) of Nepal covering the basin area of 262 km^2 with 9 km^2 of surface water across the Chitwan Annapurna Landscape. Each lake supports significant biodiversity, provides important ecosystem services and sustains local livelihoods and make Pokhara the globally known tourism destination in Nepal.

All lakes are sub-surface drainage basin type, and noteworthy with 362 species of plants comprising 286 terrestrial, 61 aquatic species and 32 species of orchid including 10 endemic one so it considered as the O*rchid Garden*. *Dischidia bengalensis* and *Phreatia elegans* are new plant species recorded where >146 plant species are valuable as NTFPs including key 82 agrobiodiversity species. Among wildlife 128 species are vertebrates (Mammal: 32 sps; Birds: 40 terrestrial and 52 water dependent sps; Reptile: 24 sps; Amphibian: 11 sps; Fish: 27 sps including 6 alien sps). The cluster hosts a wide variety of globally threatened migratory birds like the critically endangered Baer's pochard and Indian vulture, and mammals like the vulnerable clouded leopard, and the endangered Indian pangolin.

Anthropogenic activities associated to climate change has noted impacts to distress the structure, function and stability of lake ecosystems such as encroachment, siltation, pollution, and invasion by exotic species, so lakes are conditioned to degrade. Implementation of integrated lake cluster basin plan yet developed by government that stakeholders foresee instrumental document in improving lake condition in those lakes.

1. INTRODUCTION

The Lake Cluster of Pokhara Valley (LCPV) is located in the mid-hill region of Nepal in Pokhara-Lekhnath Metropolis (PLM), Province number-4 (Figure 1). It is designated as the 10th Ramsar Site in February 6, 2016. The cluster consists of nine small lakes i.e., Phewa, Kamalpokhari, Gunde, Khaste, Neureni, Dipang, Maidi, Begnas, and Rupa; which bequeathed Pokhara valley a title of the *'Garden of Lakes'*, at the panoramic setting of Chitwan Annapurna Landscape (Table 1).

Table 1 Location and areas of nine lakes under lake cluster of Pokhara valley (Source:

SN	Name	Latitude	Longitude	Altitude (m)	Area (km^2)	Water (Km^2)	% Water body
1	Phewa	28.1943-28.2902	83.8004-83.9898	763-2482	119.39	4.33	3.6
2	Begnas	28.1621-28.2167	84.0814-84.1332	647-1447	18.6	3.13	16.8
3	Rupa	28.139-28.2061	84.1004-84.1699	580-1420	26.02	1.11	4.3
4	Khaste	28.1908-28.2115	84.0449-84.0603	739-1186	2.69	0.13	4.8
5	Dipang	28.1777-28.2025	84.0645-84.0821	687-1269	2.39	0.14	6.2
6	Maidi	28.1753-28.1952	84.0785-84.0895	672-1123	1.6	0.007	0.4
7	Gunde	28.1889-28.2001	84.0392-84.0476	741-948	0.61	0.08	13.1
8	Neurani	28.1889-28.195	84.0465-84.0533	742-866	0.18	0.027	15.0
9	Kamalpokhari	28.2169-28.2377	84.0102-84.0217	822-1440	1.35	0.013	1.0
				Total	**172.8**	**9.0**	**5.2**

All lakes are subsurface drainage basin types that covers a total area of 262 km^2 of basin and about 9 km^2 of core water bodies. Phewa is the largest lake in cluster and 3rd largest lake of Nepal. Other lakes are shallow and smaller. Lakes are scattered across the valley at varying altitudes, Rupa at the lowest (582 masl) and basin peak of Phewa at the highest (2,483 masl).

The lakes and waterways are important sources of drinking water and water for biodiversity, navigation, fishery, irrigation, and hydropower. The cluster also have recreational, religious, spiritual and inspirational values. Overall economy of Pokhara is to some extent dependent on lakes resources. Pokhara fetches a significant amount of foreign currency which align to the lake tourism. Despite these values, the lakes are degrading from encroachment and reclamation, siltation, pollution and invasion of alien invasive species the prominent proximate threats. Siltation is widespread. Phewa alone had 269,752 m^3 sediment load from road networks and induced landslides [6 9,10,15]. The substantial evidences *E. colii* [19] and eutrophication are common [22]. The spread of invasive is increasing with colonizing plants water hyacinth, *Lantana* and *Parthenium spp* etc, and fauna the African Catfish and Tilapia [2]. Climate change impacts have been perceived at all levels

After designation as the Ramsar, local concerns are well versed for a need of effective measures in restoring lakes' environ. PLM has Phewa project more to the engineering works. Rupa is under community managed cooperative.

This paper is based on the assessment by CODEFUND while preparing Integrated Management Plan of LCPV (2016), and examines the basin biodiversity, lake basin governance and climate change impacts in the cluster.

2. METHODS

The consistent review of literatures like relevant policies; rules; regulations; assessment of biodiversity and climate; reports from national/international entities; and other relevant literatures were done followed by the series of focus group discussions, and direct and indirect

interview with communities of particular group interest in different locations in reference of Wetlands Inventory, Assessment & Monitoring Tool/Government of Nepal [3]

3. RESULT AND DISCUSSION

3.1 Change in launduse of the cluster in past 20 years

There is a significant spatial changes in landuse from 1996 to 2016[16]. The cultivated land has reduced from 88 km^2 to >71.2 km^2, forests land increased from 66.9 km^2 to 73.5 km^2, shrubland from 2.2 km^2 to 6 km^2, and grassland from 1.3 km^2 to 2.2 km^2 in the basin. Water bodies in Phewa, Begnas, Maidi, Kamalpokhari, and Gunde have decreased with the trend greatest in Phewa and Begnas by 4% and 17% respectively. Water cover in Rupa, Dipang, Khaste, and Neureni have increased with such extent almost doubled in Dipang (0.06 to 0.15 km^2).

3.2 The cluster as the biodiversity the basket

Ecoregions and vegetation. Of Nepal's 12 ecoregion, LCPV demonstrates the dynamics of Eastern Himalaya Temperate Broadleaf Forests, Himalayan Subtropical Pine Forests, and Himalayan Subtropical Broadleaved Forests (MoFSC 2014) [18]. It is the domain of four key forest types in a range of sub-tropical and lower temperate forests dominated by *Shorea robusta* (Sal), *Schima* spp. *Castanopsis* spp., *Daphniphyllum himalense* and *Alnus nepalensis* [12,21]. The aquatic vegetation is featured by macrophyte, hydrophyte and helophyte [6,7,8].

Floral diversity. A total of 362 species of plants are enumerated, with 286 terrestrial species (83 families), and 61 aquatic sps (22 families) including 32 sps of orchids with 10 endemic sps. Over 146 species are fund valued as NTFPs and 82 species important as agrobiodiversity. There is a record of new species of plants i.e., *Dischidia bengalensis* from the Phewa basin.

Faunal diversity. The cluster hosts 128 species of vertebrates comprised of 32 spp. mammals (17 families), Felidae and Muridae the most mammal rich families. Over 140 birds' spp. (including 52 wetlands dependent) from 37 families are found here with diversity most from Corvidae, Accipitridae, Passeridae, and Silviidae. Similarly, 24 reptile species (10 Families), 27 species of fishes, and 11 amphibian species in 3 families are reported [42] including 21 native and 6 alien fish species.

Endemism. There are a number of endemic species like Spiny babbler and Wren babbler. The Panchase area is famed for natural garden of endemic orchid like Fairy orchid, Terete Vanda, and Foxtail orchid [12].

Biodiversity significance. The cluster hosts numbers of nationally and globally significant flora and fauna such as 2 species of mammals Clouded leopard, and Indian Pangolin, and 3 species of nationally protected plants like Devil pepper, Red cotton tree, and Indian Dammer.

One endangered and two vulnerable mammals, four critically endangered and two endangered birds, and two vulnerable plant species occur in cluster. It also hosts some species under CITES-I (5 species of mammals and 2 species of reptiles, and CITES-II (14 birds' spp., 3 mammals' spp., 2 spp. of reptile and 1 of amphibian, and 33 spp. of plants).

Some birds of higher conservation value are spiny babbler, Wren babbler *Panoepyga immaculata*, Indian Vulture, and the globally threatened Comb duck and nationally threatened Ferruginous Duck. Rupa and Begans report for near threatened Eurasian otter. Smooth coated otter occurs along Seti River in Vijayapur Khola [1]. Some indigenous fishes are the Mahseer, Golden Mahseer, Katle, and Rewa in Phewa, Begnas and Rupa.

Rupa, Begnas, Dipang and Khaste are habitat of the wild rice, and wild gene pool of cultivated brownbeard rice is noticed in lakes. Other significant agrobiodiversity of the cluster includes Chinese Tinospora and monogeneric species of Hornwort, Devil pod and Common cattail.

3.4 Climate changes impacts now visible in the cluster

There has been visible changes in climate pattern in the cluster [4,5]. Kaski district, where the cluster is located, ranked low in the drought vulnerability index [17] and modest vulnerability index but high for landslides [22]. In addition, anthropogenic activities have increased the risk of climate vulnerability and disaster. The moderate vulnerability does not mean healthy socio-ecological system, it may add complexities to the *Himalayan Dilemmav* [14,24]. The community perceived about the risk of climate vulnerability, and identified 6 indicators with their corresponding scenario, sensitivities and impacts. The climate change has been contributing enormousness stresses to the lakes, and exerted pressure to the communities for extra effort, energy and investment in measures adapting over the stresses.

3.5 Evolving lake basin governance

The lake falls within the Ministry of Forests and Environment at the federal level. This ministry coordinates through the National Wetlands Coordination Committee but execute through the Department of Forests, and Department of National Parks and Wildlife Conservation in case if lakes are the Ramsar sites within protected areas. National Lake Conservation Development Committee as government agency has annual fund for some lakes. At the State, the cluster has direct link with PLM but also with the Ministry of Tourism, Industry, Forests and Environment. Over 2 dozen policies crosscut lake issues with the most relevant ones, the National Wetlands Policy (2012) and the National Ramsar Strategic Plan (2018-2024). No specific wetlands/lake Act prevail. Within these frames, lake is divided as open access resource to many other agencies like fishery, irrigation, drinking water supply, energy etc.

At grass-root, each lake has community organization, mostly the cooperative, and figure 2 indicates about their governing capacities. Though, lake basin governance is still evolving [11,20], communities' insitution in the cluster are weak in a view of institutional capacity, enforcement of formal/informal policies, stakeholders' participation, generation/dissemination of information and financial capabilities. Community responded very positive in the preparation of integrated plan of LCPV, which they think

will be instrumental to improve lake basin governance for the sustainability of the cluster.

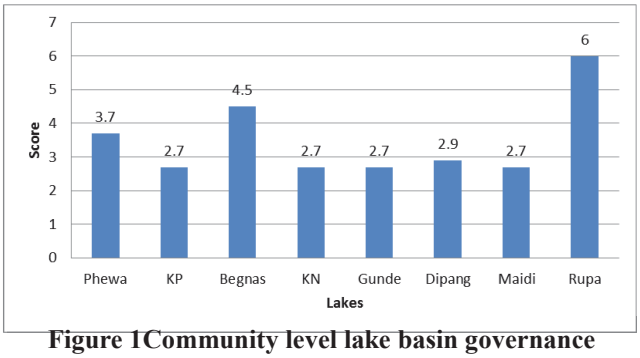

Figure 1Community level lake basin governance

4. CONCLUSION

Lake Cluster of Pokhara Valley is the 10th and only Ramsar site in the mid-hill region of Nepal, and adds value on making Pokhara the top lake-tourism vantage, *'City of Lake Garden'* also frequently referred *'Nepal's Tourism Capital'*. Each lake differs in habitat mosaics, water body and species diversity. The cluster is important biodiversity hotspots for globally and nationally protected, endemic, indigenous and monogeneric many species and so on which formed the basis of the cluster to enlisted in the Ramsar site.

In the past 20 years, the cluster has been experiencing impacts of climate change together with the significant spatial change in landuse. The core water bodies in Phewa, Begnas, Maidi, Kamalpokhari, and Gunde have decreased but increased in other lakes, Dipang almost doubled in area. The significant change in landuse in the past might have implications in characteristics of lake ecosystem and biodiversity which needs further enquiry.

All lakes are degrading due to anthropogenic activities leading to the encroachment, siltation, pollution and invasion of alien species in parallel with impacts of climate change. And, people are making new efforts adaptive to cope against climate vulnerability.

Institutional arrangement and policy unclarity among the government structures at all tiers and weak lake governance at communities level persist intact, which needs consolidation toward improving lake basin governance. In this context, the strength of Integrated Lake Management Plan of LCPV is understood the basis in managing the cluster (Ramsar site) in a sustained way.

5. ACKNOWLEDGEMENT

Authors are thankful to the Hariyoban Program/WWF Nepal/USAID for the opportunity given to CODEFUND for the preparation of plan of the cluster, and to all experts and communities for their outstanding contributions.

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Stakeholder's account of the social and environmental challenges in the Lake Victoria Basin

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Keywords: Lake Victoria, stakeholder engagement, problem analysis

ABSTRACT

It is important that policymakers are aware of stakeholder's account of societal challenges to develop policy that is relevant and supported. This paper reports on a problem analysis that was conducted stakeholders in the Lake Victoria Basin. A thorough stakeholder analysis was followed by semi-structured interviews with businesses, NGO's, governmental organizations and communities. The analysis resulted in 12 key challenges that were raised by the stakeholders covering social, environmental, health, economic and institutional issues. This paper concludes that a strong partnership between policy makers and stakeholders is crucial in order to mitigate of these challenges.

1. INTRODUCTION

In order to manage a Lake basin well, it is important to know what local stakeholders perceive as pressing challenges in the region so that policymakers can align their policy or adapt information provision accordingly. The world's second largest lake, Lake Victoria, would particularly benefit from mapping stakeholder's perceptions due to the diverse types of stakeholders spanning a large geographical area across three riparian countries. Indeed, local scientists have called for stakeholder involvement to address the issues as Lake Victoria [1], [2]. In order for stakeholders to be engaged properly, the first step is an assessment of their views.

A lot of research has been dedicated to understand the social and environmental challenges at Lake Victoria. These include: sanitation and health [3] hazards and disasters around the lake such as floods, droughts [4], water hyacinth [1], poverty [5], governance issues [4], overexploitation of immature fish [1], food security [1], corruption [1], water pollution and eutrophication [2]. climate change [6] and the prevalence of HIV/AIDS [7].

However, little research has reported on Lake Victoria's stakeholder's perceptions on the challenges in the area. An exception is a study that explored Ugandan fisher's perspective on the most important problems in the fishery [8]. This study reported that the biggest issue was perceived to be the use of illegal fishing method (arguably a cause of an issue rather than an issue itself), followed by corruption and gear theft. Nevertheless, no research has mapped out perspectives of different types of stakeholders at Lake Victoria. Therefore, this paper reports on a problem analysis that has been conducted with stakeholders in the Lake Victoria Basin. and will lay out their perceptions of the most pressing social and environmental issues in the Lake Victoria Basin.

2. METHOD

The stakeholder's of Lake Victoria were first identified through a comprehensive stakeholder analysis [9]. The stakeholder analysis process consisted of three steps: 1) identification of stakeholders, 2) categorization of stakeholders and 3) understanding (relations between) stakeholders. A 'snow sampling' technique was used as a first step in which individuals are identified through current contacts, who then identify further contacts until enough stakeholders were selected or no further stakeholders were identified. Next, the stakeholders were categorizes in terms of priority and role (e.g. businesses, NGO's, communities, government) to facilitate the selection of a diverse set of stakeholders, ensuring that different views were included.

The stakeholders that were interviewed for the problem analysis are reported in table 1. A total of 26 groups of stakeholders were interviewed, of which 14 located in Uganda, 3 located in Kenya and 9 located in Tanzania. These include 7 governmental organisations, 10 NGO's, 3 business organisations, 3 research institutions and 3 communities. Together these organisations cover a diverse set of stakeholders representing different interests and nationalities.

Table 1: overview of patriating stakeholders

	• Counties Cooperation • Fisheries Training Institute • Ministry of Agriculture, Animal Industry & Fisheries • Lake Victoria Fisheries Organization	Commission	• Environmental Management Programme • National Environment Management Council
NGO's	• Katosi • WWF • Association of Fishers and Lake Users of Uganda • Ugandan Fisheries & Fish Conservation Association • Young woman's Christian Association	• Osienala	• Environmental Management and Economic Development Organisation • Fishers Union Organisation • Kagera Development And Credit Revolving Fund • Naturland
Business	• East African Industrial Fishing & fish processors Association • East African Tourism Platform • Ugandan Fish Processors & Export Association		
Research institutions	• National Fisheries Resources Research Institute	• Kenya Marine and Fisheries Research Institute	• Tanzania Fisheries Research Institute
Communities	• Fishers, traders and boat owners in Mpunge		• Mshikamano Women's group (fisherwomen, boat owner and traders) • Beach Management Unit Kigoto

Structured interviews were conducted to learn about the perceived challenges in the region from each stakeholder. Stakeholders were interviewed about the key benefits, challenges, drivers of the challenges and mitigation of the challenges. Follow-up questions were asked to get the stakeholders to discuss the process of the issue and how different factors affect the issue. Participatory tools were used to aid the discussions and to visualise complex processes.

A coding scheme was developed to analyse the discussion from the interviews. This coding scheme facilitated the identification of recurrent issues discussed by the stakeholders. The analysis resulted in a matrix of issues discussed across stakeholders, and what particular aspects of the issue were discussed by each stakeholder.

3. RESULTS

The problem analysis resulted in a list of 12 issues that the stakeholders discussed. These challenges are not necessarily independent and may overlap or influence each other. These challenges will be discussed in the following sections in order of the frequency with which this challenge was raised (starting with the most frequently raised challenge), but it is acknowledged that this does not necessarily reflect the relative importance of the challenges.

1. Reduced fish catch

With 20 groups of stakeholders, the most frequently discussed challenge was a declining fish catch and stock as one of the most pressing issues in the Lake Victoria Basin. This mainly referred to the Nile perch. Stakeholders reported that too much immature Nile perch is currently being caught which causes a decline of the stock. They also expressed that a lack of monitoring results into noncompliance to fishing regulations meaning the use of destructive fishing gear. The stakeholders discussed how a high demand of Nile perch on the one hand, and a lack of alternative livelihoods on the other hand means that the fishery continues to draw people. Other causes of the decline of fish catch were also ascribed to climate change, poor water quality and corruption.

2. Water pollution

The second challenge that was often discussed was the water pollution in Lake Victoria which was mentioned 17 times. Many stakeholders reported that industry discharge waste water in the Lake and that the government is not sufficiently monitoring this. Mining practices around Lake Victoria were also discussed to contribute greatly to the water pollution, as well as an increase use of fertilizers for agriculture. Furthermore, stakeholders also discussed how a growing population, deforestation, poor sanitation practices, use of poison by fishers and unsustainable waste disposal by local communities continue to exacerbate the issue of water pollution

3. Soil erosion

Soil erosion and deforestation were discussed by 9 stakeholder groups. Most of these discussions focused on local communities cutting trees to use for fuel, to build houses and to clear land for cultivation. Stakeholders explained that a consequence of the soil erosion is the removal of a buffer zone that functioned to filter water mounting to Lake Victoria, meaning that deforestation contributes to the issue of water pollution.

4. Governing Lake Victoria

Various governance issues were raised by 8 stakeholder groups during the interviews. Stakeholders reported to not feel sufficiently involved in the mitigation of issues at Lake Victoria, wanting to see more partnership with the government. It was also discussed how regulations among the three riparian countries were harmonized on paper but how in practice this is not (yet) the case. The stakeholders also discussed how corruption prevented an effective approach to tackle the challenges in the region. A lack of an effective intuitional framework and unclear water borders further complicate successful governance in the region according to the stakeholders.

5. Water hyacinth

The water hyacinth that grows on Lake Victoria was mentioned by 8 stakeholder groups as a significant challenge in the region. Some stakeholders discussed how the growth of this plant is a result of poor sanitation practices, industrial waste and use of pesticides in the basin. Fishers often discussed how the growth of water hyacinth can prevent access to the lake. Nevertheless, many stakeholders also discussed that many mitigation strategies have been successful and that this challenge is not as big as it used to be.

6. Alternative livelihood

Six stakeholder groups reported that there were few alternative livelihood options for people living in the Lake Victoria Basin (besides fishing). The stakeholders discussed how people experience a large barrier to move away from fishing and into other professions due to a lack of capital, skills or knowledge or because of a strong fishers identity.

7. High prevalence of HIV/AIDS

Another challenge that was raised was the high prevalence rates of HIV/AIDS infection in the region, this was mentioned by 6 stakeholder groups. It was reported that HIV/AIDS prevalence is particularly high around Lake

Victoria, much higher than national average of the riparian countries. The stakeholders discussed how poverty and a lack of employment forces women into the sex industry. It was also discussed that the nature of the pay-out (daily wages) causes many fishers to spend their wages on alcohol and prostitution, which increases the chance of HIV/AIDS contraction. Stakeholders also mentioned that many men in the region are polygamous, which further increases the spread of HIV/AIDS.

8. Poverty

The issue of poverty in the region was discussed by 5 stakeholders. Most of these ascribed a lack of a savings culture among the fishing community to the continued poverty in the basin. The government was also said to not address this issue sufficiently and a lack of education opportunities were further proposed to exacerbate this issue.

9. Spread of diseases

Four stakeholder groups discussed how poor sanitation practices in the region result in a high prevalence of diseases such as malaria, cholera, diarrhea and typhoid. Particular attention was paid to a lack of access to clean drinking water in these discussions, reporting that many riparian communities drink untreated water from the lake.

10. Landownership

The issue of landownership, meaning that many citizens do not legally own the land they live on, was discussed by 4 stakeholders. The stakeholders discussed how the government owns a large share of the riparian land and is starting to sell this land to foreign investors, which means that the occupants are evicted or uncertain about their future.

11. Gender inequality

A lack of gender equality was discussed by one stakeholder who reported that women do not have equal opportunities and right in the Lake Victoria basin. Specifically, increase in scale and regulations has driven many women out of the fishing industry who tended to dry the fish for a living.

12. Food security

One stakeholder discussed that food security is increasingly becoming a challenge. This is because climate change is affecting the weather which in turn affects the harvest.

4. DISCUSSION AND CONCLUSION

This paper aimed to map out the most important challenges in the Lake Victoria Basin as reported by local stakeholders. The results show that stakeholders believe that the region suffers from many serious issues, which are affecting millions of lives in the region. The issues comprise a diverse set, including social, environmental, health, economic and institutional issues. It is therefore clear that addressing these issues is a challenging task and that not one solution can mitigate such a varied set of challenges.

However, it is clear that these stakeholders are aware, knowledgeable and engaged in these issues. Many stakeholders reported that they feel insufficiently consulted by policy makers even though they demonstrate to be keen to be part of the solutions to address these challenges. A key recommendation that therefore follows from this research is that a stronger partnership between stakeholders and policy makers should be build. This partnership will be mutually beneficial as this gives stakeholders the opportunity to voice their concerns and needs, and policy makers can develop policy that is relevant and supported by society.

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O9-25

Limnological Studies of Lonar Lake, Buldhana District, Maharashtra, India

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KEYWORDS – Lonar crater, Limnlogical characteristics, Eutrophication

ABSTRACT

The Lonar Crater Lake situated in Buldhana District, Maharashtra is a natural crater lake formed by hyper velocity meteoritic impact in basaltic rock before some 50,000 years ago. It has an area of 256.15 hectares and declared as a wildlife sanctuary in 2002. The Lonar crater is said to be the world's oldest and the third largest meteoritic crater. It is surrounded on all sides by a rim ejecta blanket formed from the blocks of basalt, and a steep escarpment to an even height of about 150 m deep. The present study was undertaken to focus the need of its conservation because of its unique ecosystem all over the world. Unique aquatic ecosystem was developed in the Lonar Lake due to the high pH of lake water. Hence there is urgent need to conserve this world heritage by applying the seven principles, advocated by WLV (World Lake Vision) by which we can successfully achieve the goal to maintain ecological balance thus resulting into conservation of Lonar Lake.

1. INTRODUCTION

Limnology is the study of the geological, physical, chemical and biological aspect of all natural fresh water ecology. Whether an animal lives in water or on land its protoplasm holds about 70 to 90% of water. Lonar Lake (19° 59'N, 76° 31'E) is located at Buldhana, Maharashtra, India (see map below). The lake was discovered by a British officer J. E. Alexander in 1823. The lake is estimated to be about fifty-two thousand years old (Fredrikson *et al.*, 1973). Lonar crater is said to be the world's oldest and third largest meteorite crater. It is surrounded on all sides by a rim called as ejecta blanket formed from the blocks of basalt, and a steep escarpment (circulatory index <0.9) to an even height of about 150 m deep, having 6 km diameter from outer side and 3.5 km from inner side, whereas the depth of the brine is 5.5 m.



Fig.1 Map of Lonar Lake

2. MATERIAL AND METHODS

Water samples were collected seasonally at a depth of 2 feet from the surface of the water body from four sampling stations between 7 to 11 a.m. Water samples were collected in airtight and opaque plastic containers of five litre capacity, which were thoroughly cleaned, washed and rinsed before every collection. Separate containers were used for each station. Samples were labelled properly according to their location and date of sampling. Samples were stored and protected from heat and exposure to sunlight during transportation and stored in the refrigerator until analysis.

3. RESULTS AND DISCUSSION

The present study area - Lonar Lake is one of the best example of man's disregard towards nature. The rapidly growing population and increasing urbanisation, industrialisation and agricultural activities have resulted in over exploitation of the water body leading to degradation of its water quality.

Temperature

The temperature of Lonar lake water ranged from 21.6° C to 29° C and overall view showed fluctuations in accordance with atmospheric temperature.

pH (*Potentia hydrogenii*)

pH is the measure of intensity of acidity or alkalinity and refers to the concentration of hydrogen ions in water. The Lonar Lake was found to be alkaline. pH was found to be descending order viz., summer > winter > rainy season which may be due to dilution of alkaline substances by rain waters.

Electrical Conductivity
Lonar lake water showed high electrical conductivity which ranged from 14258 µmhos/cm to 20400 µmhos/cm at different sampling stations. The values of electrical conductivity observed by other researchers range between 11600 µmhos/cm to 15100 µmhos/cm reported by Siddiqui (2008).

Total Solids (TS)
In summer, higher values of TS were recorded due to the increase in evaporation resulting into high salinity and higher amounts of solids in the lake water. The water in the crater was observed to be very salty, may be carbonates, sulphates and magnesium, which together contribute to the dissolved solids in the water (APHA, 1992).

Total Dissolved Solids (TDS)
Ions such as potassium, sodium, chlorides, carbonate, sulphate and magnesium all contribute to the dissolved solids in the water (APHA, 1992). The total dissolved solid of lake water ranged from 11025 mg/litre to 15230 mg/litre at different sampling stations.

Total Suspended Solids (TSS)
The mean values of TSS ranged from 712.33 mg/litre to 787.33 mg/litre in monsoon, 580.66 mg/litre to 679 mg/litre in winter and 660.66 mg/litre to 732.66 mg/litre in summer.

Total Alkalinity
Alkalinity of water is caused by the presence of bicarbonates, carbonates, hydroxides and phosphates. The present study shows that maximum values of alkalinity ranged from 2404.9 to 2886.5 mg/litre which are far much greater as compared to the maximum permissible limits of ISO and BIS (200 mg/litre) as well as WHO (120 mg/litre).

Dissolved Oxygen (DO)
DO is required to maintain the health of aquatic ecosystems. Oxygen is produced during photosynthesis, but is also used by plants, animals and microorganisms that thrive in water. The DO of lake water ranged from 1.01 to 1.05 mg/litre at different sampling stations.

Biochemical Oxygen Demand (BOD)
BOD is the amount of oxygen required for microbial metabolism of organic compounds in water. In the present study, the BOD of the lake water ranged from 228 to 384 mg/litre at different sampling stations.

Chemical Oxygen Demand (COD)
COD is a measure of the total amount of oxygen required to oxidise all the organic matter in a sample into CO_2 and H_2O. In the present study, chemical oxygen demand of lake water ranged from 730 mg/litre to 1155 mg/litre at different sampling stations. Earlier investigators have observed COD of Lonar lake to be in the range of 263 mg/litre to 285 mg/litre and 0.01 mg/litre to 0.04 mg/litre (Babar, 2010).

Ammonia and Nitrate
Ammonia is dissolved in water to produce ammonium hydroxide and further dissociated to ammonium and hydroxyl ions. In the present study, ammonia content of the lake water ranged from 225 mg/litre to 386 mg/litre at different sampling stations. Nitrogen is an essential plant nutrient found in fertilisers, human and animal wastes, yard waste and the air. In the present study, the nitrate content of lake water ranged from 7.68 to 12.5 mg/litre at different sampling stations.

Phosphate and Sulphate
Phosphorous is an essential plant nutrient and most often controls aquatic plants (algae and macrophytes) growth in the freshwaters. In the present study, the phosphate content of lake water ranged from 2.18 mg/litre to 6.84 mg/litre at different sampling stations. The main source of sulphate in water is various sedimentary rocks which include gypsum and anhydride. In the present study, sulphate of lake water ranged from 45.5 to 76.4 mg/litre at different sampling stations.

Chloride
In the present study, chloride ranged from 2471.7 to 3153.42 mg/litre which is much greater than the maximum permissible limit of 250 mg/L as per WHO (1992) and ISO (2004), and 1000 mg/L as per BIS (1991).

Hardness
In the present study, hardness of lake water ranged from 110 mg/litre to 149.2 mg/litre at different sampling stations. Earlier investigators observed hardness of Lonar lake water in the range of 120 mg/litre to 140 mg/litre.

4. CONCLUSION

The parameters like pH, TSS, alkalinity, chlorides, sulphates, potassium, DO and BOD were found to exceed the maximum permissible limits as given by WHO (1991), BIS (1992) and ISO (2004) for human consumption and other domestic purpose. Nitrates and phosphates are essential for the growth of primary producers of the aquatic ecosystem. But excess of these nutrients has led to eutrophication, thereby causing an algal bloom which is disrupting the natural ecosystem of the lake.

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O9-26

Property Regime Change and Lake Degradation: an Institutional Analysis of Lake Rawapening, Indonesia

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Keywords: property right regime, lake governance, Rawapening, Indonesia

ABSTRACT

Debate over the effects of different property regimes on natural resource systems has long been controversial. A large body of literature has investigated the links between different property rights regimes and environmental outcomes and shown that common, state, and private property rights regimes are each capable of yielding sustainable environmental outcomes. However, the existing evidence is highly mixed. This study examines how the alteration of property regimes at local level leads to the degradation of the lake by using the perspectives of institutional economics, in particular property-rights approaches. Lake Rawapening is a multifunctional semi-natural lake which is currently in environmentally degraded condition. Nearly 70% of its surface is covered by water hyacinth and its depth is in the process of shallowing. As consequences, the lake is not able to provide ecosystem services at optimum level. This research using a case study approach and used data collected from in-depth interviews with informants as well as reports and documents related to the lake. The study shows that the current property rights regime in the lake and its catchment area associated with social change is driving local resource users toward greater degradation of the lake. The opportunity exists to build on existing village level institutions to develop a collaborative management system to help protect the lake ecosystem.

1. INTRODUCTION

The linkage between property regimes and environmental outcomes has been controversial since seminal paper of Garett Hardin [1]. Property rights affect access to and distribution of natural resources, which in turn affects the level of poverty and long-run quantity and quality of resources. However, most of the studies of property rights effect on natural resources degradation focus on open access. A large body of literature has shown that common, state, and private property rights regimes are each capable of yielding sustainable environmental outcomes. However, the existing evidence is highly mixed. The failure to distinguish between common property and open access has been identified as a main reason of natural resources nationalization that can speed exploitation of the resources due to lack of local control over the resources[2, 3]. This study examines how the alteration of property regimes at local level leads to the degradation of the lake by using the perspectives of institutional economics, in particular property-rights approaches.

2. METHOD

This research applied a case study method. As the case is the alteration of property regime applied in Lake Rawapening, starting from Dutch colonial era in 1830s to current era of 2010s. Data were collected from in-depth interviews arranged in 2017. The interviewees included government officials, village elders, villagers and local non-governmental organizations concerned to the sustainability of the lake. In addition, for the purpose of this research we also collected reports and documents pertaining to the lake. Data and information were then analysis using qualitative approach.

3. RESULTS AND DISCUSSION

Lake Rawapening was converted from a marsh to a lake in 1912-16 and enlarged in 1939 by dams on the Tuntang River. When full, at 463 m above sea level, the lake covers 2500 ha but, in the dry season, may be as small as 620 ha at 460 m. The lake provides water for irrigating about 24,000 ha of rice fields and for generation of 20 MW of hydroelectric power. Rawapening has 9 inlets which are Galeh,Torong, Panjang, Legi, Parat, Sraten, Rengas, Kedung Ringin dan Ringis and 1 outlet: Tuntang River [4].

The construction of dams on Tuntang River was mainly motived by Dutch colonial interests in providing water irrigation for the cash crops of Cultivation System and electricity of Dutch people living in Salatiga. This is a

point of the beginning of property regime change of Lake Rawapening, from common property regime to state-property regime. At that time, 28 hamlets of 4 sub-districts was submerged and its inhabitants were moved to nearby villages. The Dutch also introduced water hyacinth brought from Bogor botanical garden as ornamental aquatic plant on the lake. Since then, the plants proliferated quickly and spread over almost the surface of the lake.

Following the operation of the dams, the Dutch colonial administrator imposed strict rules that deteriorated village-level social conventions that had previously acted to control lake ecosystem. It became increasingly difficult to take necessary, and customary, collective actions to address lake degradation.

Once the Dutch colonial transferred the governance to newly independent state, Republic of Indonesia, the prevailing property regime of the lake did not change much. The government has shown little interest in revitalizing local-level system of authority. This means that the lake has become the "property" of the national government.

The change of regime of the lake property into state-property regime was not followed by the managerial capability of government in managing the lake and its catchment area. A number of plans and programs have been initiated by government to reverse the trend of degradation. However, most of them were failed due to lack coordination and capability of government officers. This practically makes the lake, and especially its shoreline area, to be open access. Communities began to occupy the shoreline area and construct buildings and houses. Agricultural cultivation is also increasingly intensive by using modern inputs, such as nitrogen fertilizers, which further accelerate the degradation process of the lake. The most visible consequences are the decline in fish populations and the quality of lake water. Currently most fishermen can no longer rely their living from the lake, but instead get income from harvesting water hyacinth.

Nevertheless, both government and local communities still see opportunities to improve situation. One of the solution arise during the discussion is collaborative management between government and local community in managing the lake. From the government perspective, co-management systems are attractive because it open avenues for local participation in lake governance and more equitable benefit sharing while maintain some level of state control.

4. CONCLUSION

This paper highlighted the change of property regime of the Lake Rawapening from common property regime to state-property regime. The study shows that the current property rights regime is driving local resource users toward greater degradation of the lake. The opportunity exists to build on existing village - level institutions to develop a collaborative management system to help protect the lake ecosystem.

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P1-1

Plankton Community Structure in Saguling Dam

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Keywords: Saguling Dam, plankton biodiversity, Floating Net Cage, fisheries, organic waste

ABSTRACT

Saguling Dam is a semi natural man-made ecosystem which is located at Bandung District, West Java. For the time being, the characteristic of Saguling Dam is changing because of human activity, such as floating net cage (FNC) activity. FNCs on Saguling Dam increase organic waste level at Saguling Dam. This causes plankton communities to change around the FNCs on Saguling Dam. Plankton communities can be used as an aquatic biologic parameter. Aspects that were inspected are the composition, abundance, and diversity of plankton species. This research's goal is to compare plankton communities at 3 different state of FNC: dense, distant, and vacant; at three different lake depths: 0, 3, and 6 meter(s) below the surface. Plankton communities on each point of point sample is tested using Sorensen's index. This research's conclusion is that the diversity index at Saguling Lake is at medium level; the highest plankton abundance is at 3 meters depth, and the highest predominant genus for phytoplankton is *Trachelomonas* and for zooplankton is *Paradileptus*. Sorensen's index results show that there are similiarities of plankton communities at several point samples.

1. INTRODUCTION

Saguling Dam is a semi-natural man-made ecosystem which is located at Bandung District, West Java. The construction of Saguling Dam is done by stemming the flow of Citarum River. The condition of Saguling Dam is constantly changing over time, both naturally and based on human activities in the riparian (DAS) mainly due to the activity of floating net cages (FNC)[1]. The existence of FNC increases waste content of Saguling Dam, which took shape in the form of organic waste dominated by nitrogen and phosphorous compounds that derived from fish feed [2].

All accumulated organic waste can affect the community of plankton living in the Saguling Dam. These wastes can increase the content of nitrogen and phosphorus compounds in the waters that affects the abundance and plankton community structure [6]. Therefore, this study was conducted to determine the effect of FNC on plankton community structure as the biological parameter of waters in Saguling Dam.

2. METHOD

Study Area

The research took place at the Saguling Dam, Bandung District, West Java. In the Citarum River cascade dam system, Saguling Dam is located in the most upstream area compared to the other two Dams, namely Cirata Dam and Jatiluhur Dam. Geographically, Saguling Dam is located at 107°21'58.42" E and 6°54'46.3" S [3]. At the study area, we sampled a total of 9 sites in the three different types of FNC: dense, distant,and vacant. Description of research area is shown in **Fig. 1.**



Fig. 1 Map of Saguling Dam[3]

Activities Description

Data sampling was done on November 14th, 2017 at three different types of FNC: dense, distant, and vacant. Data analysis was done at Laboratory of SITH ITB on 15 - 30 November 2017.

Plankton Sampling & Water Sampling and Physical-Chemistry Parameter

Plankton sampling was done by towing method using water sampler then filtering water using plankton nets. Sampling was conducted in 3 sites with three different lake depths: 0, 3, and 6 meter(s) below the surface. The samples were poured into the film bottle and preserved later identification. Dissolved oxygen (DO), temperature, pH, ammonium, nitrite, nitrate, and orthophosphate were measured as physical-chemistry parameter of water.

Determining the Abundance, Diversity, and Dominance of the Plankton

1 mL of water sample containing plankton from each location and each depth was dropped into Sedgewick rafter, then observed under microscope. Plankton abundance was determined by the following equation that were developed by APHA [4],Plankton diversity index was determined by the formula of Shannon-Wiener index [5] .Plankton dominance index was determined by the formula of Simpson index

[6].The similarity of planktons in the two locations was determined with the formula of Sorensen Similarity Index (Is) [10].Further analysis was done by using multivariate analysis with MVSP software.

3. RESULTS

Plankton Community Analysis

Fig. 2 showed that the highest total phytoplankton abundance was found on distant stage of FNC region in 0 m depth (74.875 cell/mL).

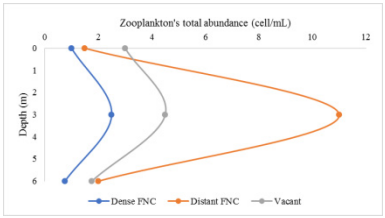

Fig. 2 Total phytoplankton abundance in three FNC stations

Total abundance of zooplankton in Saguling Dam is shown on **Fig. 3**.

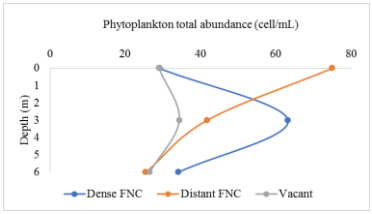

Fig. 2 Total phytoplankton abundance in three FNC stations

The highest total abundance of zooplankton (11 cells/mL) was found at distant stage of FNC in the depth of 3 meters.

Biological indexes

Phytoplankton's biological indexes that could be analyzed from the results are shown on **Table 1**. Zooplankton's biological indexes that could be analyzed from the results are shown on **Table 2.**

Table 1 Summary of phytoplankton biological index

Depth (m)	High Density FNC				Moderate Density FNC				Non-FNC			
	H'	S	D	E	H'	S	D	E	H'	S	D	E
0	1.92	21.00	0.28	0.63	2.25	22.00	0.14	0.73	2.48	21.00	0.13	0.81
3	2.91	33.00	0.08	0.83	2.08	17.00	0.16	0.74	2.98	36.00	0.08	0.83
6	2.68	23.00	0.08	0.85	2.71	21.00	0.08	0.89	2.10	24.00	0.07	0.66

Table 2 Summary of zooplankton biological index

Depth (m)	High Density FNC				Moderate Density FNC				Non-FNC			
	H'	S	D	E	H'	S	D	E	H'	S	D	E
0	1.54	6.00	0.27	0.86	1.55	5.00	0.22	0.96	1.61	6.00	0.22	0.90
3	2.03	8.00	0.14	0.97	0.33	4.00	0.87	0.24	1.10	5.00	0.41	0.68
6	0.00	1.00	1.00	-	0.94	3.00	0.42	0.86	0.95	3.00	0.44	0.86

Similarity Coefficient

The points of observation which has the most similar phytoplankton are the high density FNC at 3 m depth with 6 m depth. Its similarity coefficient (Is) value is 0.691. The points of observation which has the most similar zooplankton is the dense FNC in 3 m depth with the vacant FNC in 3 m depth with 0.667 as its similarity coefficient (Is) value.

Waters Physical and Chemical Condition Analysis

The water temperature at Saguling Dam decreases along with usage of the water for FNC. Water temperature in Saguling Dam was approximately at 30°C. Temperature was declining at 0 m – 3 m, and at 3 m – 6 m. Water pH in Saguling Dam was approximately at 6.5 – 7.3. The DO level at Saguling Dam was approximately at 2.5 – 5 ppm. The area with the highest DO concentration was distant FNC area. The highest concentration of ammonium was at 6 m depth in the non-FNC area and lowest ammonium concentration was at 0 m depth in the dense FNC area, and highest nitrate concentrations were found in non-FNC areas and the nitrite concentrations were not stable.

4. DISCUSSION

Plankton Community Analysis

The depth of 0 m in the lake ecosystem belongs to the epilimnion layer or 'mixed layer'. This layer gets the best light intensity especially during the daytime. Phytoplankton tends to move on the water surface (horizontal movement) to get enough light to support the process of photosynthesis. If supported with adequate nutrients such as in the distant type of FNC region, the phytoplankton will have a high abundance in the epilimnion layer [7][8].

The highest total abundance of zooplankton (11 cells/mL) was found in Station 2 in the depth of 3 meters. This is due to the vertical migration pattern of zooplankton; in daytime, zooplanktons tend to stay at the epilimnion layer of the lake (0-5 meters deep) and will move towards hypolimnion layer (5-10 meters deep) at nighttime [9].

Biological Indexes

The three stations generally have moderate diversity. This explains that Saguling Dam's phytoplankton community structure has enough productivity, balanced ecosystem, and currently under moderate ecological pressure [10]. This is in line with the fact that the Saguling Dam is the location of many human activities (e.g. fisheries and aquaculture, also recreation) – this may be the cause of the 'ecological pressure' mentioned before [11]. Index of phytoplankton evenness in all three stations indicates that all phytoplankton are distributed quite evenly until almost evenly [12]. Therefore, it can be concluded that the stability of a community in different spots and depth of sampling is moderate [12], due to no existence of a species that dominates the others [13] (equal proportions of individual numbers). There are no dominance existed – dominance exists if the value of the index of dominance is close to 1[15].

In all three stations, zooplankton community generally have low to moderate diversity. This is caused by the fact that the Saguling Dam is the location of many anthropogenic activities – the same thing that affects phytoplankton's diversity [11]. On the other hand, zooplankton's index of evenness is similar with phytoplankton's. On stations with greatly even distribution of individuals, the index of evenness will be greater – and vice versa [13]. There was one spot with exactly only one species of zooplankton (High density FNC in 6 meters deep); therefore the evenness index of this spot cannot be calculated. There are also some

sampling spots with dominance of one species at each spots: high density FNC in 6 meters deep and moderate density FNC in 3 meters deep. In high density FNC 6 meters deep, the dominance was due to the existence of only one species of zooplankton; and in moderate density FNC 3 meters deep, the dominance was of the species *Brachionus* sp.

The relative abundance of species is used to determine the predominant phytoplankton species. It was found that the genus of predominant phytoplankton in dense FNC station at 6 m, 3 m and 0 m depth respectively are *Trachelomonas* (13,776%), *Chroococcus* (21,505%), and *Trachelomonas* (50%). *Trachelomonas* are quite common in freshwater environments, because euglenids are commonly found in water habitats containing both high and low soluble minerals with varying pH and light levels, especially in swamps and wetlands that have a lot of organic matter [16]. In moderate density FNC station, the predominant genus that was found at 6 m, 3 m and 0 m depth respectively are *Dictyosphaerium* (15.574%), *Cryptomonas* (21,939%) and *Euglena* (22,286%). In non-FNC stations, the predominant genus at 6 m, 3 m and 0 m depth respectively are *Trachelomonas* (19,412%), *Trachelomonas* (19,412%) and *Cryptomonas* (29,6%). Overall, the predominant genus on this station is *Trachelomonas* that were found at a depth of 6 m and 3 m. This fact is possible because at this point in this station the nutrient content is high enough. *Trachelomonas* is a cosmopolitan organism that could become a good indicator to identify moderately contaminated waters [30].

The relative abundance of species is used to determine the predominant zooplankton species. The predominant zooplankton genus that was found in the Saguling Reservoir area in dense FNC station at 6 m and 3 m could not be concluded – the genus that was predominant at 0 m depth is *Paradileptus* (45.455%). In distant FNC station, the predominant zooplankton genus at 6 m, 3 m and 0 m depth respectively are *Paradileptus* (50%), *Brachionus* (93.023%), *Anuraeopsis* (28,571%). At vacant-FNC station, the predominant zooplankton genus at 6 m, 3 m and 0 m depth respectively are *Glochidium* (60%), *Askenasia* (54.167%) and *Cestum* (28.571%). *Paradileptus* is the genus that has the highest frequency of appearance, which appeared at 2 out of 9 observation points. *Paradileptus* can be identified with the existence of cilia that contained on part or all of the body surface[31].

Similarity Coefficient

Combination with other observation points made the Sorensen's similarity coefficient score lower: below 0,5. This phenomenon indicated that the environmental condition and difference of depth will represent different species too, because every species in nature develops different adaptation mechanisms and tolerance towards their habitat[14].

5. CONCLUSION

The index of diversity in the three stations in Saguling Dam is at medium level. The highest abundance of plankton is at 3 m depth. The predominant genus of the Saguling Dam is *Trachelomonas* for phytoplankton and *Paradileptus* for zooplankton. Sorensen's index result show that are similarities of plankton communities at the dense FNC at 3m with 6m depth, distant FNC station with non-FNC station at 0 m depth, distant FNC station at 3 m depth with 6 m depth, dense FNC station at 3 and 6 m depth with distant FNC station and vacant FNC station at 0 m depth, and finally at those points above with vacant FNC station at 6 m depth.

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P1-2

Microbial competition for acetate: an important factor to mitigate methane emission from *Sasa*-invaded wetland soils

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Keywords: *Sasa*-invaded wetland soil; stable isotope probing; acetate; uncultured microorganism

ABSTRACT

Acetate is the most important precursor to CH_4 during anaerobic degradation of organic matters. Wetland soils are a significant source of atmospheric CH_4 and their invasion by *Sasa* (bamboo) species results in the decrease of the CH_4 emission. However, the microbial interspecies competition for acetate is largely unknown. Here, we identified actively acetate-assimilating microorganisms by ultra-high-sensitivity rRNA-stable isotope probing with ^{13}C-labeled acetate. The *Sasa*-invaded soil slurry was amended with ^{13}C-acetate at a concentration of 5 mM and afterwards incubated anaerobically in the dark at 25°C for 2 weeks. A gradual degradation of the acetate amended was accompanied with the production of CH_4 and CO_2 during the incubation. RNA was extracted from the slurries at week 2 and density-separated by isopycnic centrifugation according to molecular weight. Microbial communities in density fractions of rRNA were comprehensively screened by high-throughput Illumina sequencing. *Methanosaeta* spp. responsible for aceticlastic methanogenesis were significantly labeled with the acetate ^{13}C. Notably, 34 different species of Bacteria were identified as the active ^{13}C-acetate assimilators. One of them was closely related to the dehalo-respiring *Dehalogenimonas alkenigignens* with acetate-oxidizing activity. The others were phylogenetically novel, exhibiting quite low sequence similarities (i.e., 77.8%−92.5%) of 16S rRNA genes from cultured relatives. The result of this study demonstrated for the first time that hitherto unidentified bacterial species as well as a known dehalogenating bacterium significantly assimilated acetate, thereby being competitive with aceticlastic methanogens in the *Sasa*-invaded wetland soils.

1. INTRODUCTION

Acetate is an important precursor to CH_4 during anaerobic degradation of organic matters, and it is mostly utilized by aceticlastic methanogens [1]. Wetland soils are a significant source of atmospheric CH_4 and their invasion by Sasa (bamboo) species results in the decrease of the CH_4 emission (Table 1)[2] . The potential competitors of aceticlastic methanogens are microorganisms catalyzing anaerobic acetate oxidation. However, this reaction is highly endergonic ($\Delta G^{o\prime}$=+105 kJ mol^{-1}). The diversity and ecology of the acetate-oxidizing microorganisms are largely unknown.

Table 1 Environmental characteristics in the study site [2]

Gas flux (g-C m^{-2} y^{-1})	*Sasa*-invaded wetland (Vegetation type: *Sasa palmata*)	Wetland (Vegetation type: *Sphagum* spp.)
CH_4	6.6 ± 6.2	13.2 ± 3.5
CO_2	223.8 ± 3.5	5.8 ± 31.1

Recently, we have developed ultra-high-sensitivity stable isotope probing of rRNA (rRNA-SIP) to thoroughly characterize the metabolic function of uncultured microorganisms in natural environments [3]. The objective of this study was to identify actively acetate-assimilating microorganisms in anoxic *Sasa*-invaded wetland soil by ultra-high-sensitivity rRNA-SIP with ^{13}C-labeled acetate.

2. METHOD

A *Sasa*-invaded wetland soil was collected in Bibai, Hokkaodo, Japan. Soil slurry was prepared by mixing the soil with sterilized water at a ratio of 1:4 (v/v). Aliquots (20ml) of the homogenized slurry were transferred anaerobically into 50-ml serum vials. The head space of each sample vial was flushed with N_2. Four soils were produced: (i) a non-autoclaved soil amended with ^{13}C-labeled acetate to a final concentration of 5 mM (^{13}C treatment), (ii) a non-autoclaved soil with amended with unlabeled acetate to a final concentration of 5 mM (unlabeled treatment), (iii) a non-autoclaved soil with addition of sterilized water in place of acetate (no acetate addition), and (iv) an autoclaved soil amended with unlabeled acetate to a final concentration of 5 mM (heat-

killed treatment). All treatments were run in triplicate with static incubation for 4 weeks at 25 °C in the dark.

Samples of the head space gas, slurry water and solid-phase soil were taken at week 0, 1, 2, and 4 from each vial. Total CH_4 and CO_2 in the head space gas were analyzed by dual-detection gas chromatography (GC) with both thermal conductivity and flame ionization detectors as described previously [4]. The carbon isotopic composition of gaseous CH_4 and CO_2 were measured with GC-combustion-isotope ratio mass spectrometry [5]. The concentration of acetate from the slurry water was determined by high-pressure liquid chromatography [4].

RNA was extracted from the slurries at week 2 and density-separated by isopycnic centrifugation (128,000 g for >60 hours at 20°C [3]). Gradients of density-separated RNAs were fractionated in triplicate. The heaviest (1H), second-heaviest (2H), and light (L) fractions of RNA with buoyant density of 1.796–1.798, 1.788–1.791 and 1.769–1.772 g ml^{-1}, respectively, were subjected to RT-PCR. Microbial communities in density fractions of RNA were comprehensively screened by high-throughput Illumina sequencing of V4 region of 16S rRNA transcripts. The sequences in each sample were characterized phylogenetically using the QIIME software [6].

DNA was extracted from the slurries at week 0 of the ^{13}C treatment and was used as PCR template for PCR amplification of the V4 region of 16S rRNA genes. Then, Illumina sequencing was conducted.

3. RESULT AND DISCUSSION

Under both the ^{13}C and the unlabeled treatments, biogeochemical activities were almost same. With respect to the slurry water of the both treatment samples, the acetate concentration decreased to 1.44−1.64 mM at week 2 and was completely depleted at the end of the incubation. On the other hand, the acetate concentration kept constant in the heat-killed treatment. In the gaseous phase of the two treatments, CH_4 and CO_2 were produced after the beginning of the incubation. The concentrations of CH_4 and CO_2 increased by 0.778−0.784 mM and 1.986−2.106 mM, respectively, at week 2. The production of CH_4 and CO_2 in the control treatment (no acetate addition) was less than those in the ^{13}C and unlabeled treatments. These data indicated that acetate was converted to CH_4 and CO_2 by soil microbial communities. The fate of ^{13}C-labeled acetate was traced by monitoring the ^{13}C atom percentage of the gaseous products CH_4 and CO_2 over the incubation time. $^{13}CH_4$ and $^{13}CO_2$ were produced from the start of the incubation and increased by 1.14 mM and 0.74 mM at week 2, respectively.

We phylogenetically characterized the 1H, 2H, and L fractions of RNA from the ^{13}C and unlabeled treatments by high-throughput Illumina sequencing. The total number of 16S rRNA molecules analyzed in 18 density fractions was around 3.1 million, corresponding to an average of 173,000 sequences per library. Phylum and class level phylogenetic analysis indicated that no significant changes with the increase in BDs were observed in either treatment. Nevertheless, high-resolution operational taxonomic unit (OTU)-level survey identified 36 microbial OTUs exhibiting significantly higher relative abundances in the ^{13}C treatment than in the unlabeled treatment. *Methanosaeta* spp. responsible for aceticlastic methanogenesis were significantly labeled with the acetate ^{13}C. Notably, 34 different species of Bacteria were identified as the active ^{13}C-acetate assimilators. One of them was closely related to the dehalo-respiring *Dehalogenimonas alkenigignens* with acetate-oxidizing activity. The others were phylogenetically novel, exhibiting quite low sequence similarities (i.e., 77.8%−92.5%) of 16S rRNA genes from cultured relatives. As a result of analyzing the relative abundances of the 36 ^{13}C-incorporating OTUs at week 0, the identified acetate oxidizer OTUs were low-abundance (< 0.15% of the total).

4. CONCLUSION

This study demonstrated for the first time that hitherto unidentified low-abundance bacterial species as well as a known dehalogenating bacterium significantly assimilated acetate, thereby being highly competitive with aceticlastic methanogens in the *Sasa*-invaded wetland soils.

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P1-3

A New Hypothesis for the Declining Cause of the Japanese Eel.

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Keywords: Japanese Eel, Declining Cause, L. Kasumigaura, The Tone R., Water gates, Water resource Development.

ABSTRACT

A hypothesis to explain the cause of the decline in Japanese eel *Anguilla japonic*a is proposed ,based on the analysis of catch trends and information on environments downstream of the Tone River. It was evident that the Tone River used to contribute more than 80% of the total spawning. Spawning migration was inhibited by a water gate constructed in 1963, and by the complete closure in 1975. Based on this, a hypothesis was proposed, stating that the Japanese eel decline was caused by the inhibition of spawning and upstream migration of eels into lakes, which were used as habitats, due to the water resource development projects. Support for this hypothesis was obtained by examining the parent-child relationship and the influences of the project on catches in areas other than the gate.

1. INTRODUCTION

The catch of Japanese eel, one of the most important fishery resources in Japan, has declined greatly since around 1970. The causes have been studied focusing on the three hypotheses: excessive fishing, regime shift of the ocean [1,2], and the environmental destruction of rivers and lakes [3], but the exact cause has not yet been determined. .This study attempted to obtain a new hypothesis for the causes of the resource decline in the Japanese eel *A. japonica* by studying fishery information downstream of the Tone R., the greatest fishing ground and once shared about 30% of the eel catch and 80% of glass eels. First, a hypothesis on the decline cause was suggested by examining the characteristics of temporal changes in catches in two different sections of the Tone River system and in other areas. The hypothesis was examined using the parent–child relationship and the influences of development projects on catches in areas other than the Tone Rover system..

2. METHOD

The location downstream of the Tone River is shown in Fig. 1. The Tone River is 322-km long, has a drainage area of 16,840 km^2. Lake Kasumigaura is the second largest shallow eutrophic lake in Japan with a drainage area of 2,157 km^2.

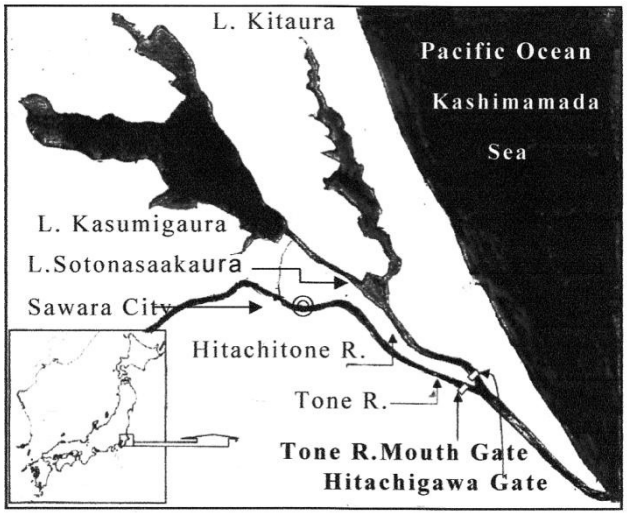

Fig.1. Location of douwnstreem of the Tone R.

Approximately 1000 fishermen fish for eel, pond smelt, gobies, and shrimp so on in the lake, which was originally brackish with indirect connections to the Pacific Ocean via the Hitachitone and Tone Rivers. In 1963, the Hitachigawa gate was constructed at the outlet of the lake to accelerate water resource utilization The construction of the gate started in 1959 and was completed in 1963. The gate was occasionally closed from 1964 to 1974, and has been completely closed to all but downward flow since 1975. Since then, the water in the lake has been maintained 0.3-m higher than before the water resource was supplied, in accordance with the development plan, from 1996.

Catch data. The data are from "The Annual report of catch statistics on fishery and aquiculture" (Ministry of Agriculture, Forestry and Fisheries..In "The Annual report of catch statistics on fishery and aquiculture", catches are recorded as "eel" or "seed." Here, "eel" represents individuals weighing over 150 g, which are edible, and "seed" represents glass eel.

3. RESULTS

The changes in catches and the ratio of the Tone R. system to the total catch The catches are shown in Fig. 2 and the ratio of the Tone R. system to the total catch in Fig. 3. The proportion of the Tone River system catch to the total eel catch fluctuated around 30% until 1975, began to decline in 1976..The ratio of total glass eel was 84% in 1962, but declined since 1970.

Relationship between the eel catch in Lake Kasumigaura and the total glass eel catch. The relationship between the eel catch in Lake Kasumigaura and the total glass eel catch is shown in Fig. 4.There was a positive correlation between both. The relationship is given by the following equation:

$$Y_{GW} = 0.69X_{EK} + 13 \ (R^2 = 0.92).$$

This suggests that Lake Kasumigaura may provide a large proportion of parents for spawning.

4. DISCUSSION

Characteristics of the Tone River system. The ratio of the Tone River system catch to the total glass eel catch exceeded 70% before the construction of the gates..In addition, the total glass eel catch is proportional to the eel catch in Lake Kasumigaura. Therefore, the main decline cause may be attributed to the use of Lake Kasumigaura for water resource development.

A new hypothesis. There may be another more likely reason than conventional ones. Thus, the hypothesis states that the decline was caused by the Kasumigaura Development Project.

Verification of the hypothesis. Evidence to support this is needed to verify the following two examinations.

A. Use of the Hitachigawa Gate caused the decrease in the eel catch in areas other than the Tone River system.

B. The correlation exists between the parent of the Tone River system and the total glass eel catch, and no correlation between eel in other areas and the total glass eel catch.

Examination A. The effect of the gates on catches in other areas could be caused by the decline in glass eel recruitment, because recruitment is dependent on a common origin of spawning [4], which is largely influenced by the eel resource of the Tone River system. Therefore, the catches in other areas must have declined in 1963 (completion of the gate), 1975 (start of complete closure of the gate), and 1996 (start of water resource administration). Fig. 5 shows the temporal changes in the total eel catch in other areas except for the Tone River system. The eel catch decreased drastically in 1970, 1982, and 2003. The times 7 years exceed these fallings agree with these.. Two of those 7 years are for spawning and transportation of larvae to the Japanese archipelago, and for growing to parents. Hence, there is evidence to support examination A.

Examination B The second examination aims to confirm that a correlation exists between parent fish of the Tone River system and glass eel recruitment. The relationship between the eel catch in the Tone River system and the total glass eel catch 2-years later across the whole country was examined in Fig.6 (left). In Fig. 6 the open circles represent the catches in 1964–1970, during the construction of the Tone River Mouth Gate. Hence, the correlation was estimated using logistic regression, with the exception of data from the construction period of the gate. This is given by the following equation (R^2=0.89):

$$Y = Y_{\max} /(1 + exp(aX + b)) \qquad (1)$$

where Y, $Y_{\max}$, X, a, and b represent the glass eel catch 2-years later, the maximum of Y, the eel catch in the Tone River system, and coefficients. . The values X, a, and b are 247, -0.0060, and 3.53, respectively. This relationship confirms that the parent fish in the Tone River system result in larvae recruitment across the whole country. Fig.6 (right) shows the relationship between the glass eel

catch in the whole country 2-years later and the eel catch in other areas except the Tone River system. There is no clear correlation between the both. This shows that the other areas have little effect on the recruitment of glass eel. However, a detailed analysis revealed that a weak correlation exists when the catch is below 1250 t.

This relationship can be also expressed by equation (1), and Y_{max}, *a,* and *b* are 24, -0.002, and 1.24, respectively. The relationship between the eel catch and the glass eel catch corresponds to the parent-child relationship of the Japanese eel, and can be estimated using a logistic curve. The Y_{max} values and the coefficients correspond to the carrying capacity, and the population growth rate.

The carrying capacities of glass eel in the Tone River system and the other areas were estimated to be 247 and 24 t. Hence, the effect of the other areas will be essentially less. Therefore, it can be concluded that the new hypothesis mentioned above may be effective.

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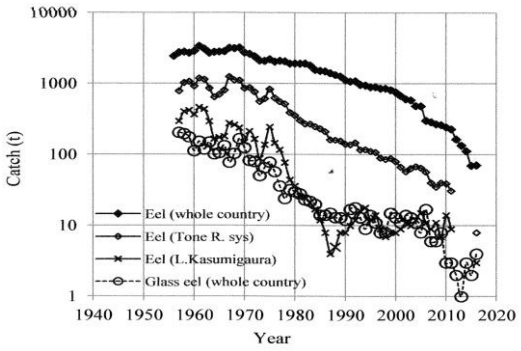

Fig.2 Changes in catches.

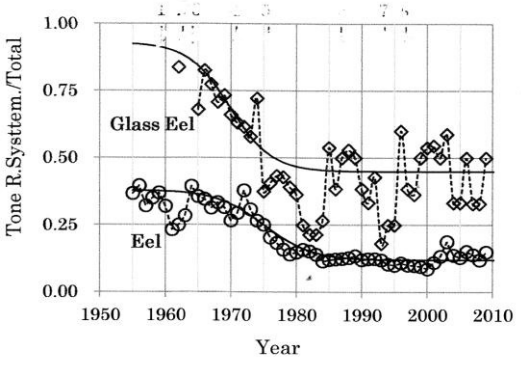

Fig.3. [Tone R. System] / [Total] in catches.

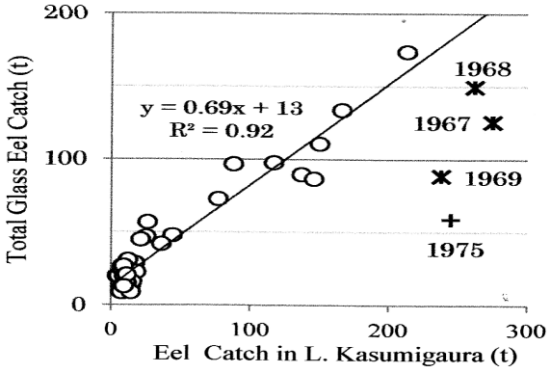

Fig.4. Relation between eel catch in L.Kasumigaura and total glass eel catch.

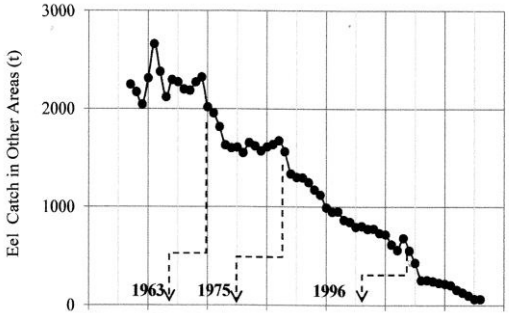

Fig.5. Changes in total eel catch in other areas except the Tone R. system.

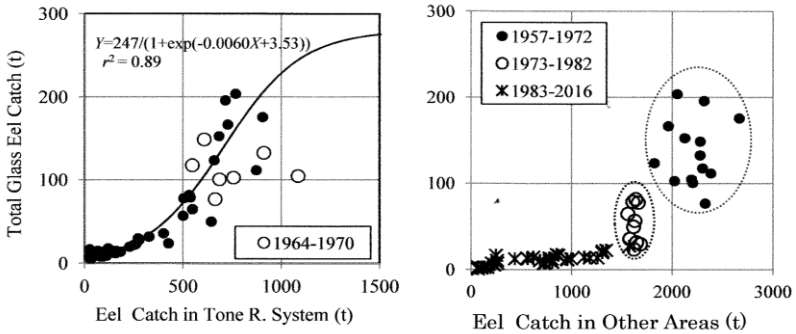

Fig.6. Relation between total glass eel catch and eel catch in Tone R. System (left), and in other areas (right).

P1-4

レンコン品識別法開発とポリフェノール含量の多様性

Development of a method for lotus variety identification and variations in polyphenol contents

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キーワード: 生物利用, 農業, 食糧生産, レンコン, DNA マーカー

抄録

ハス（*Nelumbo nucifera*)の肥大した根茎はレンコンと呼ばれ野菜の一つとして消費される．レンコン生産のために栽培されるハスの品種群もレンコンと称される。霞ヶ浦周辺はレンコン生産が非常に盛んな地域であり，日本の生産量の約半分を出荷している。レンコンは主に根茎で増殖するため、品種の識別が困難であることから、DNA マーカーによる品種識別法の開発を行った。一塩基多型を HRM 法によって識別したところ、レンコン品種群は 6 個のマーカーで２８の遺伝子型に識別された。また、レンコンの食品としての機能性向上を目的として、東京大学が保有する観賞用ハス（花蓮）のコレクションにおいて根茎のポリフェノール含量を調査した。節と節間を凍結乾燥した後、ポリフェノールを抽出し、フォーリンチオカルト法で濃度を測定したところ、花蓮はレンコン品種群と比較して多様性が高く，有望な育種素材であることが明らかとなった。

1. はじめに

ハス のうち地下茎が肥大する品種群はレンコンとして食用に栽培されており、観賞用である花ハスと区別される。レンコンの生産出荷額は茨城県が1位であり、霞ヶ浦周辺で栽培されている。日本の各産地ではそれぞれ特徴のあるレンコン品種群が栽培されているが、ハスは地下茎で増殖するため、他の品種の混入、種子からの実生に由来する個体の混入を把握することが困難であり、品種の維持管理が容易ではない。そのため、レンコンでも DNA マーカーを開発し、品種識別法の開発や類縁関係の解明を行う必要がある。そこで本研究では、近年、報告されたハスゲノムの概要塩基配列情報（Ming *et al.* 2013[1], Wang *et al.* 2013[2]）を活用し、ddRAD-seq 解析を行って得られた一塩基多型(SNP)情報に基づく DNA マーカーを作製し、栽培されているレンコン品種における品種識別法を開発した。以上に加え、花ハスのポリフェノール含量を調べることにより高ポリフェノール含量を持つレンコンの育種材料の探索も行った。

2. 方法

ハスゲノム概要配列から SNP を含む塩基配列を得て BLAST 検索し、ゲノム内で複数コピー存在しないものを選抜した。次に、Primer3 を用い PCR 産物のサイズが 80 bp から 110 bp となるよう SNP を挟むプライマー対を設計した。プライマーの塩基配列は再度 BLAST 検索を行い、標的配列がユニークであるものを用いた。実験にはレンコン 42 系統、花ハス 2 系統、キバナハス (*N. lutea*) 1 系統を用いた。遺伝子型の決定は、LightCycler 96 システム（ロッシュ）を用い、High Resolution Melt (HRM)解析によって行った。得られた各 DNA マーカーの遺伝子型をもとにデータマトリックスを作成し、ソフトウエア Past 3.18 (Hammer 1999-2017)を用いて UPGMA 法によるクラスター解析を行った。

ポリフェノール含量の測定に関しては、東京大学大学院農学生命科学研究科 附属生態調和農学機構で維持・栽培されている花ハス54品種の節と節間をそれぞれさいの目状に切り出したのち、凍結乾燥させ粉状にした。その後 80%メタノールを用いてポリフェノール抽出を行い、これを試料とした。ポリフェノールの測定はフォーリンチオカルト法を用い、100, 200, 300, 400, 600, 800 ppm クロロゲン酸を標準とし、750nm での吸光度をマイクロプレートリーダー（FlexStation 3 Microplate Reader, Molecular Device Japan Co., Ltd.）を用いて行った。

3. 結果

ddRAD-seq 解析で検出された 4901 箇所の SNP のうちレンコンの系統間で多型のあった 1248 箇所を調査した。作製した 351 個の DNA マーカーのうち 191 個の DNA マーカーで多型識別が可能であった。開発された DNA マーカーのうち遺伝子型の識別が良好であった 6

マーカーを栽培されている45系統に用いたところ、28の遺伝子型に識別することができた。ハスの系統はクラスター解析で、花ハスとレンコンに分かれたあと、レンコン内で4つのクラスターに分類された。茨城県および新潟県で栽培される系統群と主に西日本で栽培されるレンコンの系統群が異なるクラスターとして分類された。54 系統の花ハスで節間部で生重量当たりのポリフェノール含量を測定したところ、最も少ないものは 62.91 mg/100 gfw (漁山紅蓮)で最も多いものは 735.58 mg/100 gfw (紅ガニ) であった。また、節でも同様に測定したところ 1458.72−2929.55 mg/100 gfw の範囲でポリフェノールが含まれていた。

4. 考察

調査した 10 マーカーでは品種名が異なるにもかかわらず遺伝子型が同一、または極めて類似したグループが 6 つあった。逆に、遺伝子型が異なるにも関わらず、同一の品種名を持つ例もあった。このような品種名と遺伝子型の不一致は本研究で開発された品種識別法を適用することにより解消することが可能である。ポリフェノール含量については、今回測定した花ハスコレクションの結果はレンコン品種群(節間部 41.0-131.0 mg/100 gfw、節部 793.1−1866.0 mg/100 gfw) と比較して多様性が高く、より濃度の高いポリフェノールを含む系統が存在することが明らかとなった。

5. 結論

本研究の結果、少数の DNA マーカーセットで既存レンコン品種の多くを識別可能であることが実証された。また、花ハスはレンコン品種群と比較してポリフェノールを多く含む系統が存在し、有望な育種素材であることが明らかとなった。

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P1-5

Water quality and fisheries of the Bui Reservoir, Ghana: Five years after impoundment

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CSIR-Water Research Institute, Ghana

Keywords: Limnology, dams and reservoirs, fisheries, ecology, biology, water quality

ABSTRACT

Ghana has derived many useful benefits from reservoirs including hydroelectric power generation, potable water supply, fisheries, irrigation, transportation and raw water supply for domestic, industrial and agricultural use. The Bui Dam is the third to be created in the Volta River System for hydroelectric power generation after the Akosombo and Kpong dams and has a surface area of 444 km^2. The study is the first assessment of the water quality and fisheries of the Bui Reservoir five years after impoundment. Field visits were undertaken between October and December 2016. Profiles of pH, temperature, dissolved oxygen, chlorophyll-a and turbidity were measured *in situ* using the YSI EXO II Sonde. Total Nitrogen and Total Phosphorus were determined using the Hach digestive methods. The fishery assessment was undertaken using a battery of multifilament and monofilament gill nets of laterally stretched mesh sizes of 12.5 mm – 40.0 mm and 38.1 mm - 177.8 mm respectively. The water quality profile assessment showed that the reservoir was thermally stratified. Mean temperature difference between surface and bottom water was 4.5º C. The water quality in the epilimnion was distinctly varied from that in the hypolimnion in relation to the physical parameters and chlorophyll-a but the nutrients showed minimal variation in concentrations between the surface and bottom water. The fisheries assessment revealed a decline in fish species composition by 57 % and a shift from riverine to lacustrine species as well as a shift in trophic dominance from piscivores to benthic omnivores when compared to the pre-impoundment results.

1. INTRODUCTION

The construction of dams for hydroelectric power and irrigation tends to alter the ecosystem from riverine to lacustrine conditions leading to major changes in water quantity, quality and flows, nutrient inputs and balances as well as fish habitats and fish assemblage [1,2]. Due to their storage, dams are believed to change river discharges to a much greater extent than any adjustment expected from global climate change [3].

The Bui Dam is the third to be created in the Volta River System for hydroelectric power generation after those at Akosombo and Kpong in Ghana, West Africa. The dam is built on the River Black Volta at the Bui Gorge and has a surface area of 444 km^2 at full supply level with capacity to generate 400 Megawatts of electricity. The dam was impounded in June 2011 and commissioned for operation in December 2013. Although the dam has been in existence for about five years, very little information exists on its water quality status and impacts the modification in habitat may have had on the fisheries of the dam. The study assessed the water quality and changes in fisheries of the reservoir. The fish species composition data were compared with results obtained from the pre-impoundment study carried just before impoundment.

2. METHOD

Seven sites were selected on the Bui Reservoir (Fig 1) for water quality assessment in the post-rainy season between October 2016 to December 2016. Two water samples were collected per site: 1m below the surface and 1m from above the bottom of the reservoir using a Van Dorn water sampler.

Depth profiles of water temperature, pH, dissolved oxygen (DO), conductivity, turbidity and Chlorophyll-a (Chl-a), and Total Dissolved Solids (TDS) were measured in situ using the YSI EXO II Sonde. Total Nitrogen (TN) and Total Phosphate (TP) were determined using the Hach persulphate digestion and Molybdovanadate with Acid Persulfate Digestion Methods respectively.

Sampling for fish assessment was undertaken at sites 1, 2 and 3 (Fig 1) which were selected to coincide with sites for the pre-impoundment study. Multifilament and monofilament gill nets of laterally stretched mesh sizes of 12mm – 40.0 mm and 38.1 mm - 152. 4 mm were used in sampling fish. The nets were set at dusk and retrieved at

dawn the following day at each station.

The catch at the end of each sampling session was identified with the keys of [4, 5 ,6], sorted into various species, and counted. Each individual fish was weighed to the nearest 0.1 gramme (g) using a measuring scale while standard length and total length were measured to the nearest 1.0 millimetre (mm) using a measuring board. The catches of local fishermen were also observed.

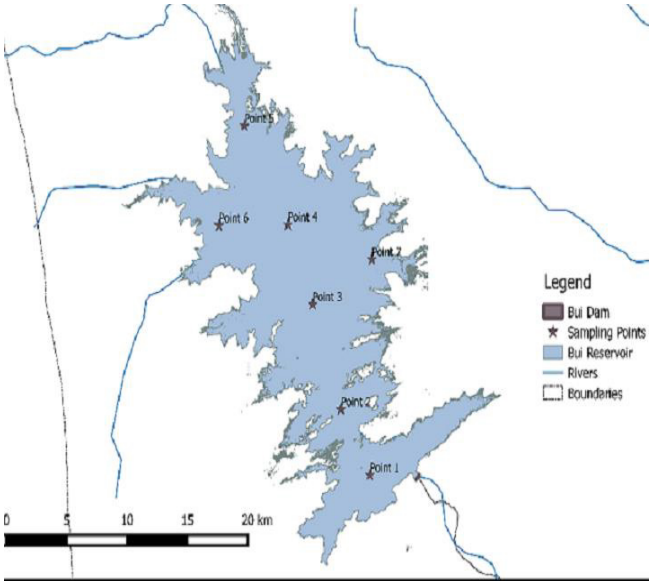

Fig 1: Sampling sites on the Bui Reservoir

3. RESULTS

The depth of water at the sampling sites ranged from 33.8 m to 86.0 m bringing the mean depth of the reservoir to about 50m. Results from the water quality profiles showed the dam was thermally stratified and the water quality in the epilimnion was distinctly varied from that in the hypolimnion in relation to the physical parameters. Surface water temperatures ranged from 29.1 ºC to 31.4 ºC whiles of the bottom temperature ranged from 25.3 ºC to 28.8 ºC with an average difference between surface and bottom water of about 4.5 ºC (Fig 2). The pH was slightly more alkaline at the surface than at the bottom with values ranging from 7.48 - 7.92 and 6.40 to 7.0 respectively (Fig 2). DO concentrations ranged from 7.93 to 8.78 mg/l at the surface water and declined rapidly with depth till about 20 to 30 m depth, after which the water becomes completely anoxic (Fig 3 and Fig 4). Chlorophyll-a concentrations were typically less than 5 mg/l at all the monitoring sites.

Minimal variations were observed in nutrient concentrations. TN concentrations ranged from 0.56-0.87 mg/l at the surface and 0.82 to 0.87 mg/l in the bottom water (Fig 5). Whiles TP ranged from 0.07 to 0.14 at the surface and 0.07 to 0.09 mg/l at the bottom.

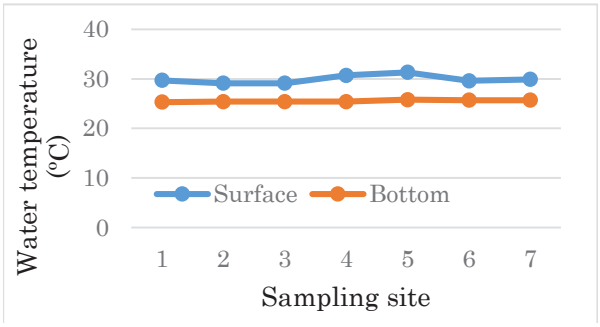

Fig 2: Mean water temperatures at the sites

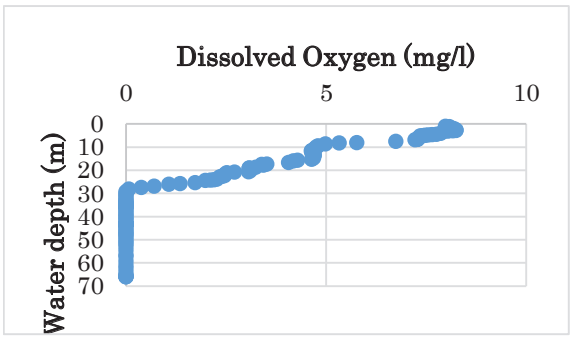

Fig 3: Dissolved oxygen profile at one of the sites

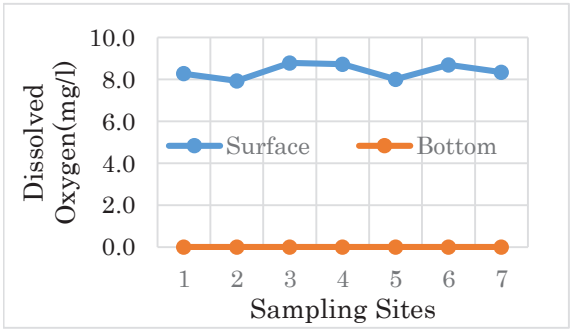

Fig 4: Mean dissolved oxygen at the sites

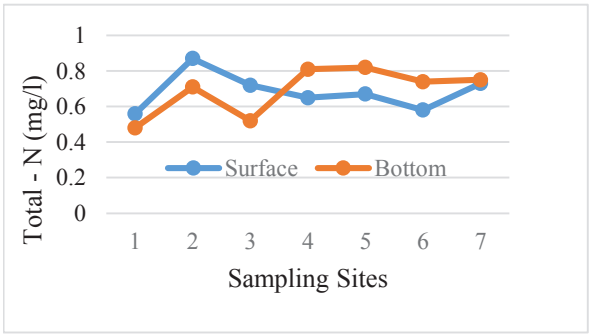

Fig 5: Total Nitrogen concentrations at the sampling sites

Thirty-Six (36) fish species belonging to 23 genera and 10 families based on a total of 356 fish samples were recorded in the study area. The major families by numbers and weight are presented in Fig 6 and Fig 7. Cichlidae were dominant by number and Cyprinidae dominant by weight

(Fig 6 and 7). The trophic composition was made up of benthic omnivores (42.12 %) semi pelagic omnivores (25.84 %), piscivores (24.15 %) and aufwuch-detritus and herbivores (7.58 %) based on number and by weight was semi pelagic omnivores (37.61 %) piscivores (29.15 %), benthic omnivores (25.52 %) and aufwuch-detritus & herbivores (6.30 %).

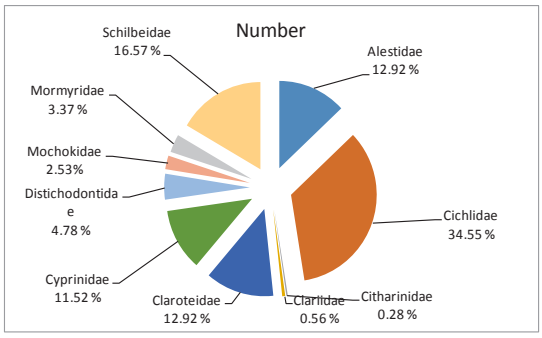

Fig 6: Fish species composition by number

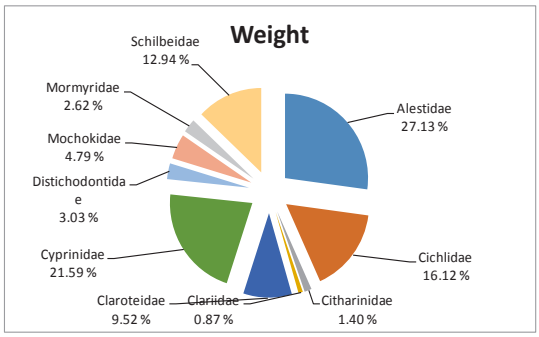

Fig 7: Fish species composition by weight

4. DISCUSSION

Tropical lakes are typically warm monomictic [7]. Water density however responds very well to changes in temperature thus a high temperature results in adequate density difference between the top and bottom water of lakes to maintain seasonal stratification as observed in the Bui Reservoir. Mixing could, however, be expected at a later period as only few lakes are persistently stratified by temperature gradients alone [8]. DO levels in a lake is an important indicator of overall lake health. Although DO concentrations were high at the surface, the levels declined rapidly with depth and this could be attributed to decomposition of submerged vegetation. Per the Chl-a levels, of which they were mostly less than 5 µg/l but greater than 3 µg/l, the reservoir water may be described as mesotrophic [9].

The reservoir exhibited very low fish species diversity, very good species richness and very low species evenness indicating a generally weak ecological stability. Compared to pre-impoundment fishery studies, there was a general decline in the number of fish species by about 57 %. The abundance of Tilapia, a member of the *Cichlidae* family has increase from 1 % before impoundment to 45.09 % and 24.55 % based on number and weight respectively after impoundment. The presence of Cichlids (*A. guntheri* and *H. fasciatus*) as well as Claroteids (*C. nigrodigitatus* and *C. auratus*) at the levels of importance recorded is an indication that the two families are becoming very important in the Bui Reservoir as it occurred in Lake Volta and Kpong Reservoirs. The abundance of *A. guntheri* could be attributed to its preference for calmer habitats with submerged cover such as tree roots and fallen branches.

5. CONCLUSION

Water in the Bui reservoir is good quality at the surface but anoxic at the bottom. The number of fish species have declined and there is a shift in fish species composition from typically riverine species to lacustrine species.

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P1-6

Comparison of Environmental Condition using Biological Indicators in Yatsu Tidal Flat locating in Tokyo Inner Bay

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Keywords: Yatsu Tidal Flat, Environmental conditions, Green tide, Biological index, Water quality

ABSTRACT

From the water quality of the Yatsu Tidal Flat (Funadamari/ Sankaku Tidal Flat),we aimed at to consider to about environment transition of the characteristics of water quality and pollution load factor of Yatsu tidal flat from the results of the water quality . And from the appearance situation of benthos organisms and attached diatoms. Characteristics of the water quality of the Yatsu Tidal Flat Characteristics of the water quality of the Yatsu Tidal Flat were estimated as being polluted progressing because high COD value in Funadamari and Daisankaku ② and ③were high. This is thought to be caused by weak flow than other site. T-P of Shosankaku is high because domestic wastewater was flowing in there. As water quality analysts, COD of Sankaku tidal flats(2.4mg/l) was almost stmilar to that of Tokyo Bay (2.7mg/l). From the results of benthic organisms overall the Funadamari is often evaluated as somewhat dirty in the degree of environmental preservation Ⅱ, and Sankaku Tidal Flat is evaluated as somewhat clean in the degree of environmental preservation Ⅲ. The results of DAIpo show that the value of DAIpo decreased in the Funadamari ④ from spring to autumn , but the value of DAIpo rose due to the increase in the number of saproxenous in other points. The Funadamari which is the most inner part of the Yatsu Tidal Flat shows the past figure of Yatsu Tidal Flat and the Sankaku Tidal Flat near Tokyo Bay shows the future of Yatsu Tidal Flat.

1. INTRODUCTION

Yatsu Tidal Flat (Narashino city, Chiba prefecture) is connects with Tokyo Bay by the two canals of the Yatsu River and the Takase River and closedness water area by changes due to the filled of the tide. In recent years, irregular growth *Ulva* sp. become a problem.

Water quality is evaluated using pH, BOD, SS, DO etc. of the environmental standard value set by the Ministry of the Environment, Japan. Water quality is evaluated by instantaneous value at sampling At the same time, advantages of biologically to investigate water quality can know in the chemical analysis, cannot judge long-term change of the water environment ,by observing creatures living there can know the degree of the ecological pollution tendency of mentioned

In this research, we aimed at to consider to about environment transition of the characteristics of water quality and pollution load factor of Yatsu tidal flat from the results of the water quality . And from the appearance situation of benthos organisms and attached diatoms.

2. METHOD

2.1 Survey site

The survey sites were set to 10 places in total including the Funadamari ① to ④,Daisankaku ①to ③ and Shosankaku ①, ② as shown in Fig.1.

2.2 Survey period

On Fiscal Year 2016 – 2017, we conducted in spring, summer, autumn and winter.

2.3 Field survey

At each site, water samples were collected using a heyroht water sampling device and poly bin, and NO_2-N, NO_3-N, PO_4-P, and COD were measured by pack test. As the observation parameters, temperature, water temperature, pH, DO, transparency, weather, water depth, flow rate were

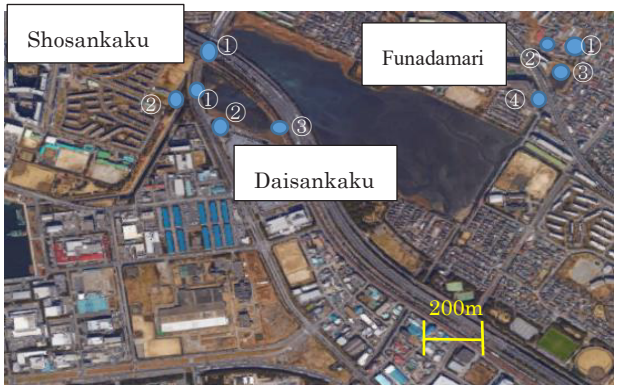

Fig. 1 Survey site

measured. Benthic organisms (higher - level consumer) were collected together with sediments four times using an Eckman-purge bottom sampler machine or a quadrat frame of 15 cm × 15 cm and a scop. Sediment was also collected to measure IL, but because there are points where only gravel and shells are collected, only seven site were collected. Adhered diatom (producer) was collected from the surface of shellfish or the like using a 5 cm × 5 cm quadrate frame and a brush.

2.4 Analysis parameters

The sampled water was brought back to the laboratory immediately and were analyzed for pH, DO, COD, Chl.a, Cl^-, NO_2-N, NO_3-N, T-N, PO_4-P and T-P.

2.5 Evaluation method by benthic

From the harvested benthic organisms, according to the method of Kyutokenshi (Table 1), scores were assigned to the four criteria of crustacean ratio, ignition loss, dominant indicator organism in total number of occurrence types ,and we calculated the total points of them.

The evaluation was divided into 5 stages, and the total points were fitted to the score table of the evaluation point evaluation classification (Table 2),

and the environment condition was evaluated. The point where sediment can not be collected was evaluated by applying it to another scoring table (Table 2) excluding score by ignition loss. Table 3 shows the classification with provisional expressions each evaluation.

2.6 Evaluation method by diatom

Adherent diatom was collected from the surface of shellfish using a 5 cm × 5 cm quadrate frame and a brush. DAIpo (Diatom Assemblage Index to Organic Water Pollution), which is an organic pollution index based on adherent diatom assemblage, classified, identified and counted and The river comprehensive evaluation RPId (River Pollution Index based on DCI) was calculated.

$$DAIpo = 50 + ((A - B)/2) \cdots (1)$$

A : The sum of the relative frequencies of all the saproxenous that appeared at that point.
B : The sum of the relative frequencies of all saprophilous that appeared at that point.

$$RPId = A/L \cdots (2)$$

A : The area of the part surrounded by the vertical axis and the line connecting the plotted points.
L : Extension of flow path of investigated river.

3. RESULTS AND DISCUSSION

The water quality date of COD,Chl.a,Cl^-, NO_2-N, NO_3-N, NH_4-N, T-N, PO_4-P in T-P in spring, summer, autumn and winter are shown in Table 5 toTable 8.

Evaluation by the benthic organism at each point in spring, summer, autumn and winter are shown in Fig.2. Evaluation by the attached diatoms at each point in spring, summer, autumn and winter are shown in Fig. 3.

From spring to autumn, Funadamari and Daisankaku ②,③ were polluted. At any point, there are fewer flows than other point and it is thought is easy to accumulate organic matter. The result of DAIpo value of Funadamari ④decreases from spring to autumn. The result of the benthic organism was less species and Environmental preservation degree was lowered.

The bottom mud of Funadamari is sludge. Therefore, it is understood that it is an environment where living things are difficult to live. As a cause, it was suggested that the flow of wastewater from Funadamari ④ may have flowed in. On the other hand, Shosankaku of Sankaku Tidal Flat is connected to Tokyo Bay, and the value of COD was the closest that of to Tokyo Bay. There is no flow in Funadamari, and nutrient salts accumulate and are polluted, but In Shosankaku and Yatsu River, it is thought that it became near the water quality of Tokyo Bay by being mixed with the purification action such as shell and *Ulva* .sp and water of other sites. However, the value of T-P was high.

DAIpo has increased overall value to Funadamari ④, and the water quality has been improved.

As a result of the benthic organisms, environment al preservation degree is higher than Funadamari except for Daisankaku ③, and is considered to be inhabit than Funadamari. From these outcomes, an environment Funadamari which is the most inner part of Yatsu Tidal Flat is thought to represents the appearance of the past of Yatsu

Table 1 Evaluation by Kyutokenshi Method

①	Number of occurrence types in benthic organisms	More than 30 species	20～30species	10～19species	Less than 10 species	No biological
	Scores	4	3	2	1	0
②	Percentage of Crustaceans in ①	More than 20%	Less than 10～20%	Less than 5～10%	Less than 5%	0%
	Scores	4	3	2	1	0
③	Loss on ignition of sediment	Less than 2	Less than 2～5	Less than5～10	Less than 10～15	More than 15
	Scores	4	3	2	1	0
④	Dominant pointer biology	A		B	C	D
		Organisms other than B and C		Lumbrineris longiforia	Paraprionospio sp.(typeA)	No biological
				Raeta rostralis	Theora lata	
				Prionospio pulchra	Sigambra hanaokai	
	Evaluation by dominant species of the top three species	Dominant species of the top three species other than B and C		Not classified as A, C and D rank	More than two species of C	No biological
	Rank	A		B	C	D
	Scores	3		2	1	0

※ 1 : If the total number of occurrences types is less than four, the grade is 1 regardless of the ratio.
※ 2 : If the total number of occurrences types is less than two species, the rank C.

Table 2 Evaluation division by Kyutokenshi Method

Evaluation classification	Score
Environmental conservation degree Ⅳ	14～
Environmental conservation degree Ⅲ	10～13
Environmental conservation degree Ⅱ	6～9
Environmental conservation degree Ⅰ	3～5
Environmental conservation degree0	0～2

(considering IL)

Evaluation classification	Score
Environmental conservation degree Ⅳ	12～
Environmental conservation degree Ⅲ	9～11
Environmental conservation degree Ⅱ	6～8
Environmental conservation degree Ⅰ	3～5
Environmental conservation degree0	0～2

(not considering IL)

Table 3 Evaluation Expression by Kyutokenshi Method

Evaluation classification	Interim(Expression)
Environmental conservation degree Ⅰ	Clean
Environmental conservation degree Ⅱ	Slightly clean
Environmental conservation degree Ⅲ	Slightly polluted
Environmental conservation degree Ⅳ	Polluted
Environmental conservation degree Ⅴ	Extremely polluted

Table 4 Relationship of DAIpo,BOD and pollution level

DAIpo	BOD	Pollution level
100~85	0~0.0625	Extremely poor water area
85~70	0.0625~1.25	βpoor water area
70~50	1.25~2.5	αpoor water area
50~30	2.5~5.0	βmedium toxic water area
30~15	5.0~10.0	αmedium toxic water area
15~0	10<	Extremely toxic water area

Table 5 Water quality(spring)

Spring	Unit symbol	Funadamari①	Funadamari②	Funadamari③	Funadamari④	Daisankaku①	Daisankaku②	Daisankaku③	Shosankaku①	Shosankaku①
COD	mg/l	5.2	6.4	14.8	16	6.0	5.2	5.6	6.8	6.4
T-N	mg/l	10.9	6.7	7.0	7.6	4.1	2.1	2.9	3.9	3.9
NH4-N	mg/l	0.40	0.50	0.50	0.30	0.29	0.35	0.30	0.40	0.33
NO2-N	mg/l	0.005	0.0097	0.006	0.000	0.0377	0.0175	0.0187	0.0155	0.0349
NO3-N	mg/l	2.2	2.8	2.1	1.1	2.0	1.3	1.5	1.1	1.4
T-P	mg/l	3.33	3.25	1.10	5.53	1.09	2.32	1.80	6.90	6.30
PO4-P	mg/l	0.97	0.96	0.88	0.30	0.30	0.63	0.49	1.88	1.72
Cl-	mg/l	9749.6	4077.1	5318	10104.1	5140.7	5052.1	4697.5	2481.7	2942.6
Chl.a	μg/l	3.0	3.0	1.8	2.8	2.5	2.5	2.7	3.0	4.6
SS	mg/l	21.05	18.10	0.05	0.25	22.10	38.25	56.45	27.90	13.25

Table 6 Water quality(summer)

Summer	Unit symbol	Funadamari①	Funadamari②	Funadamari③	Funadamari④	Daisankaku①	Daisankaku②	Daisankaku③	Shosankaku①	Shosankaku①
COD	mg/l	6.0	10.4	8.8	7.2	4.0	8.4	8.4	4.4	4.4
T-N	mg/l	7.9	5.8	10.6	6.5	4.9	3.8	4.5	3.6	3.7
NH4-N	mg/l	0.19	0.30	0.40	0.21	0.36	0.24	0.32	0.36	0.34
NO2-N	mg/l	0.0533	0.1396	0.035	0.0825	0.0167	0.0083	0.0101	0.01	0.0094
NO3-N	mg/l	2.5	1.5	3.1	1.6	1.0	0.8	0.9	1.3	1.2
T-P	mg/l	0.36	1.66	0.40	0.41	2.02	1.43	1.43	1.15	2.05
PO4-P	mg/l	0.93	0.92	1.58	1.46	1.87	1.94	2.05	2.24	2.00
Cl-	mg/l	10281.4	18081.0	12408.6	17017.4	16414.7	15953.9	19499.2	18612.8	17584.7
Chl.a	μg/l	0.9	0.9	1.6	1.5	15.2	3.6	7.3	5.2	5.9
SS	mg/l	37.75	45.55	25.45	21.70	4.10	24.00	16.35	4.25	12.55

Tidal Flat, and Sankaku Tidal Flat near Tokyo Bay represents the figure of the future of Yatsu Tidal Flat.

4. CONCLUSION

1) Characteristics of the water quality of the Yatsu Tidal Flat were estimated as being polluted progressing because high COD value in Funadamari and Daisankaku ② and ③ were high. This is thought to be caused by weak flow than other site. T-P of Shosankaku is high because domestic wastewater was flowing in there.

2) As water quality analysts, COD of Sankaku tidal flats(2.4mg/l) was almost stmilar to that of Tokyo Bay (2.7mg/l).

3) From the results of benthic organisms, the Funadamari is often evaluated as somewhat dirty in the degree of environmental preservation Ⅱ, and Sankaku Tidal Flat is evaluated as somewhat clean in the degree of environmental preservation Ⅲ.

4) The results of DAIpo show that the value of DAIpo decreased in the Funadamari ④ from spring to autumn , but the value of DAIpo rose due to the increase in the number of saproxenous in other points.

5) The Funadamari which is the most inner part of the Yatsu Tidal Flat shows the past figure of Yatsu Tidal Flat and the Sankaku Tidal Flat near Tokyo Bay shows the future of Yatsu Tidal Flat.

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Table 7 Water quality(autumn)

Autumn	Unit symbol	Funadamari①	Funadamari②	Funadamari③	Funadamari④	Daisankaku①	Daisankaku②	Daisankaku③	Shosankaku①	Shosankaku①
COD	mg/l	4.4	5.2	4.8	3.2	4.0	6.4	8.4	4.0	3.6
T-N	mg/l	10.3	8.3	9.1	4.3	5.7	6.1	3.9	4.1	5.0
NH4-N	mg/l	0.65	0.57	0.64	0.20	0.31	0.19	0.15	0.16	0.24
NO2-N	mg/l	0.0778	0.055	0.0609	0.0261	0.0351	0.0266	0.0194	0.0353	0.0296
NO3-N	mg/l	3.8	2.9	3.1	1.6	1.1	1.5	1.4	1.6	1.6
T-P	mg/l	3.32	3.68	2.44	0.60	0.48	0.15	0.19	1.51	1.98
PO4-P	mg/l	1.81	0.96	1.61	0.22	0.48	0.15	0.19	1.51	1.98
Cl-	mg/l	9040.5	10547.3	10104.1	18258.3	12231.3	11699.5	14003.9	14358.5	16485.6
Chl.a	μg/l	3.2	4.3	4.6	6.5	2.1	3.7	3.8	1.6	1.3
SS	mg/l	21.05	18.10	0.05	0.25	22.10	38.25	56.45	27.90	13.25

Table 8 Water quality(winter)

Winter	Unit symbol	Funadamari①	Funadamari②	Funadamari③	Funadamari④	Daisankaku①	Daisankaku②	Daisankaku③	Shosankaku①	Shosankaku①
COD	mg/l	3.2	4.4	4.4	3.2	4.4	4.0	5.6	2.4	3.2
T-N	mg/l	12.9	15.4	6.4	4.1	11.0	13.7	4.9	4.7	5.3
NH4-N	mg/l	0.58	0.37	0.32	0.19	0.44	0.51	0.16	0.16	0.16
NO2-N	mg/l	0.0474	0.0376	0.0321	0.028	0.0293	0.0318	0.0275	0.0287	0.0457
NO3-N	mg/l	3.8	2.3	1.7	1.7	3.0	3.4	1.3	2.5	1.6
T-P	mg/l	0.36	0.52	0.28	0.26	0.09	0.09	0.48	0.39	0.31
PO4-P	mg/l	1.50	1.67	1.59	1.59	1.37	1.32	0.03	0.03	0.03
Cl-	mg/l	6972.4	5790.7	8804.2	14358.5	16840.2	16072.0	16485.6	16131.1	16840.2
Chl.a	μg/l	7.7	5.6	4.3	7.4	20.3	11.2	3.2	1.6	3.2
SS	mg/l	24.20	23.05	18.00	23.25	54.95	57.15	74.55	41.85	36.90

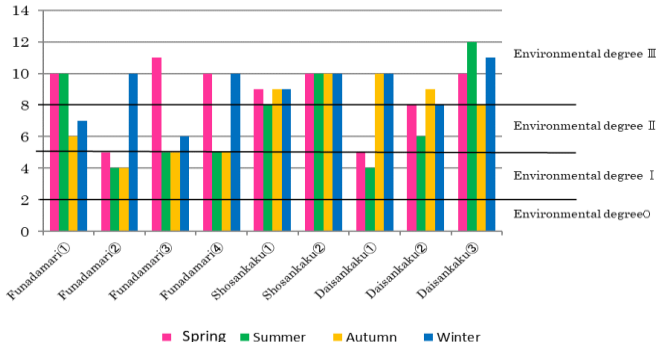

Fig. 2 Evaluation by benthic organism (Kyutokenshi Method)

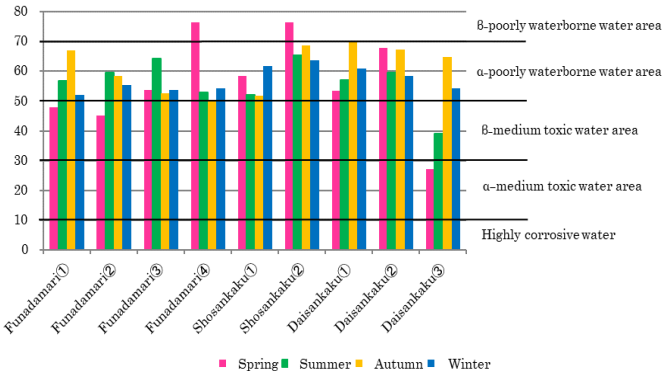

Fig. 3 Evaluation by adhered diatom (DAIpo)

P1-7

Diversity Models of Plankton in Gold Coast Ornamental Lake, Pantai Indah Kapuk, North Jakarta

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Keywords: abundances models, plankton, Gold Coast Ornamental Lake, water quality

ABSTRACT

Plankton diversity can be calculated through a model of species abundance. This study aimed to describe the structure of plankton communities using various models of diversity and coherence of the water quality. The study was conducted from July to December 2015, using the method of APHA, 2012. Based on water quality data, the five stations are grouped into three zones. Zone 1 consists of Station 1, Zone 2 consists of stations 2, 3, and 5, Zone 3 consists of Station 4. The difference in the water quality at each station causes differences plankton diversity. The results showed that the model of geometric and broken stick was not suitable for use in all zones. Log normal model was appropriate using in Zone 1 for data phytoplankton and zooplankton all zones to the data. Log series model was an appropriate model to describe the plankton communities throughout the zone. This model describes the waters were disturbed and their dominance.

1. INTRODUCTION

Gold Coast Ornamental Lake is located in Pantai Indah Kapuk Residence, North Jakarta. The waters is relatively small with total area about 7359 m2 and 1 m in depth. It has unique net-shape, The small and shallow condition lead a dynamic physical and chemical condition that infkuence the appearance of plankton community. The combination of relationship between water quality and plankton community could show the role of plankton as bioindicator of lake water condition [1].

Density and richness (number of genera) can be used as factors in calculating diversity index. Diversity index can be determined with three approached, i.e. index of richness, index based on spesies/genera relative abundance, and model of spesies/genera abundance [2].

This study emphesized on the third approach that usualy used to describe the community structure [3], especially plankton community. The model of spesies/genera abundance consist of several models, such as geometric, log series, log normal, and broken stick model [2]. The research was aimed to describe plankton community structure in Gold Coast Ornamental Lake, based on several diversity models.

2. METHOD

The research was done in six month, from July to December 2015, with monthly sampling periods at five sites. Station 1 was close to sewage treatment plant and pump station (outlet). Station 2 set at the north western part, before the Sewage Treatment Plant. Station 3 was inside of 'net' curve of waters. Station 4 was in southern part, close to inlet that receive input from next cluster residence, Bukit Golf Mediterania. Station 5 was at south eastern part of waters.

Water quality was observed and measured in situ and in laboratory, based on water quality analysis reference [4]. Identification of plankton was based on several references ([5], [6], [7], [8], [9]). The density of plankton was counted using SRC (Sedgewick Rafter Counting Chamber) [4].

Pre-analysis was done to set spatial cluster of station, based on water quality information, using clustering analysis of Canberra Index value [10]. Furthermore, for each clustered stations, there were calculation of plankton diversity with spesies/genera abundance model tah consist of geometric, log series, log normal, and broken stick models ([11]; [2]). Chi square test was used to fit the model in describing plankton Community structure in Gold Coast Ornamental Lake.

3. RESULTS

Water quality that illustrated by temperatur, is relatively warm (31,22-32,30 °C); high pH (8,73-8,87), existance of salinity (3,45-4,40 ‰), and high dissolved oxygen (9,42-13,23 mg/L). The condition of dissolved oxygen expressed supersaturation condition. Based on water quality, there were clustered Three groups of stations.

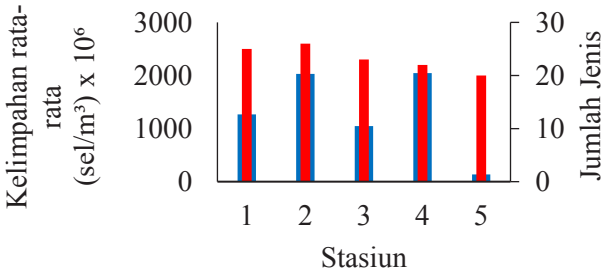

Figure 1. Abundance and number of taxa

The comparation value between χ2 calculation (χ2c) and χ2 table (χ2t) (Table 2) shows that values of Zone 3 are higher than other zones; related to high density of plankton. The values of χ2c for geometric model were higher than other models. The value of χ2c for log seriesmodel were lower than χ2t. There were a consistance pattern of χ2t of each model of all zones.

Table 2 The comparation of χ2 calculation and χ2 table of each zone

Zone	Geometric Model		Log series Model		Log normal Model		Broken stick Model	
	χ2 calculation	χ2 table	χ2 calculation	χ2 table	χ2 calculation	χ2 table	χ2 calculation	χ2 table
Phytoplankton								
Zone 1	341454,6	36,4	21,2	28,9	19,3	26,3	5804,9	28,9
Zone 2	263613,1	36,4	22,6	27,6	25,3	25,0	13406,6	27,6
Zone 3	379934,6	32,7	26,6	28,9	27,8	26,3	8191,6	28,9
Zooplankton								
Zone 1	36,8	9,5	3,5	12,6	4,2	9,5	17,4	12,6
Zone 2	468,3	11,1	11,6	12,6	11,4	15,5	31,6	12,6
Zone 3	476,9	9,5	10,3	19,7	11,9	16,9	108,5	19,7

Table 3 The result of fit test for models toward data of phytoplankton and zooplankton

Zone	Uji keseuaian model			
	geometric Model	*log series* Model	*Log normal* Model	*broken stick* Model
Phytoplankton				
Zone 1	Not suit	suit	suit	Not suit

Zone 2	Not suit	suit	Not suit	Not suit
Zone 3	Not suit	suit	Not suit	Not suit
Zooplankton				
Zone 1	Not suit	suit	suit	Not suit
Zone 2	Not suit	suit	suit	Not suit
Zone 3	Not suit	suit	suit	Not suit

4. DISCUSSION

In those water quality condition, there were found 27 genus from five classes of phytoplankton and seven taxa from two groups of zooplankton (Figure 1). In detail, the richness and density of plankton of each station were varied. The highest density was found at Zone 3 (2044 x106 cell/m3) and 1177 x103 individu/m3, for phytoplankton and zooplankton, respectively. The highest number of genera was found in Zone 2 with 26 genera and Zone 1 with five genera, for phytoplankton and zooplankton, respectively. The fit test for models is shown in Table 3. If the value of χ^2_c is lower than χ^2_t, it means that the model is fit, vise versa. It is shown that log series model is the most suitable model for all zone of Gold Coast Ornamental Lake, while log normal model suits in Zone 1 for phytoplankton data, and in Zone 1, 2, and 3 for zooplankton data. Furthermore, geometric and broken stick model were not suit for all zones.

5. CONCLUSION

The most suitable diversity model for phytoplankton and zooplankton data in Gold Coast Ornamental Lake was log serie model

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P1-8

Antifungal Activity of Actinomycetes Isolated from Surface Sediments of Lake Lanao against *Candida albicans* and *Aspergillus niger*

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Keywords: Actinomycetes, Antifungal activity, Lake Lanao

ABSTRACT

Antibiotic resistance is not only a national problem but a global dilemma. There are many reasons why this type of resistance exists including inappropriate use of antibiotics. The search for novel antimicrobial compound is still a priority goal in drug discovery. Thus, actinomycetes from lake sediments are being explored. This study was conducted to determine if the isolated actinomycetes could exhibit antifungal activity against two test microorganisms namely *Candida albicans* and *Aspergillus niger*. A total of 34 actinomycetes was isolated from the western part of Lake Lanao specifically in the municipalities of Wato-Balindong, Tugaya and Bacolod-Kalawi, Lanao del Sur. Antifungal screening using Filter Paper-Disc Diffusion Method revealed that out of the 34 actinomycete isolates, only eight (23.53%) have inhibitory effect against *Candida albicans* with the mean zone of inhibition greater than the positive control. These actinomycetes, with their corresponding mean values, were A3 (26.39 mm), A9 (21.83 mm), A11 (22.66 mm), A18 (26.63 mm), A21 (24.74 mm), A25 (22.76 mm), A31 (14.76 mm) and A32 (16.88 mm). Whereas, only two (5.88%) of the actinomycete isolates inhibited the growth of *Aspergillus niger* with mean zone of inhibition greater than the positive control. These potential actinomycetes, with their corresponding mean values, were A11 (23.83 mm) and A31 (30.13 mm). Generally, isolates were found to be more effective against *Candida albicans*. Thus, this study concludes that Lake Lanao harbors potential actinomycetes that could be a source for the search of new and effective drugs against pathogenic fungi.

1. INTRODUCTION

Some bacteria, fungi, virus and other pathogenic microorganisms are resistant to their own antibiotics nowadays. As stated by Prabakarana *et al.,* (2011), bacteria lived on earth for several billions of years. During this long period of time, they encountered range of naturally occurring antibiotics to which by now, they combated these and became resistant by the drugs synthesized today. Supported by the study of Spadari *et al*., (2013), *Candida albicans*, a pathogenic fungus which causes candidiasis is found to be resistant to its antibiotic (Fluconazole) by Disc-Diffusion method. Antimicrobial resistance is not just a national issue but a global problem and so, finding new and effective drugs is major challenge to the field of medicine. One possible candidate in the search of new and effective drugs is from the actinomycetes. Some actinomycetes form branching filaments that look like the branching hyphae formed by fungi and so, it was erroneously classified as fungi before. Actinomycetes are actually bacteria under the phylum, Actinobacteria. Under this phylum, actinomycetes tend to produce secondary metabolites; many of which have been successfully isolated and turned into useful drugs. It was in the fifties and sixties that the antibiotics discovered were mainly isolated from Streptomyces. Primarily, Streptomyces were active against bacteria and fungi (Prabakarana and Raja, 2011). The purpose of this study is to screen the 34 actinomycetes isolated from the surface sediments of Lake Lanao specifically from Wato Balindong, Tugaya and Bacolod- Kalawi for its antifungal activity against *Candida albicans* and *Aspergillus niger*.

2. METHOD

Thirty-four actinomycete isolates obtained from Lake Lanao were cultured in nutrient broth for 48 hours

and tested against the two test fungi, *Candida albicans* and *Aspergillus niger*. Inoculation of test fungi were done following the agar over-lay technique. The antifungal assay was done using filter paper disc diffusion method. Filter paper discs were impregnated with the 48 hour-old broth culture of the actinomycete isolates were then placed each on the surface of the pre-labeled plates. Petri plates were then incubated at 28°C for 7 days. The mean for every seven-day observation was calculated in three replicates of each isolate. Distilled water and nystatin were used as negative and positive control, respectively. One-way ANOVA and DMRT were used to analyze the zone of inhibition effect of the isolates against the two test-fungi.

3. RESULTS

Candida albicans

Out of the 34 actinomycete isolates that were tested for antagonistic screening, only eight isolates (23.53%) were found to inhibit the growth of *Candida albicans*. Among the actinomycete isolates, A18 has the highest mean zone of inhibition of 26.63mm other isolates ranges from 14.76 to 26.39 mm (Figure 1).

There is a statistically significant difference in the mean zones of inhibition among the actinomycete isolates (p value of <0.001). Duncan's Multiple Range Test results showed that the inhibitory effect of A3 and A 18 are comparable and were significantly different from the other bioactive isolates (Fig. 1). The mean values of the zone of inhibition of the positive control were less than of the bioactive isolates. The mean value of the actinomycete isolate, A3 (26.39mm) was greater than the positive control (13.89mm) and so with the other bioactive isolates, A9 (21.83mm>13.57mm), A11 (22.66mm>13.14mm), A18 (26.63mm>14.40mm), A21 (24.74mm>14.12mm), A25 (22.76mm>12.52mm), A31 (14.76mm>14.29mm) and A32 (16.88mm>13.63mm) .

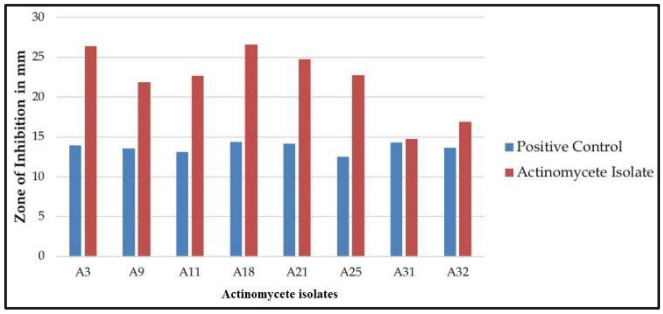

Figure 1. Antifungal activity of the bioactive actinomycete isolates vs. positive control (Nystatin) against *Candida albicans.*

Aspergillus niger

Out of the 34 isolates, there were only two (5.88%) bioactive isolates that shows inhibitory effect against *A. niger*. These bioactive actinomycete isolates were A11 and A31 only. Results showed that the zone of inhibition between the bioactive isolates, A31 has the highest mean value of zone of inhibition of 30.13mm followed by A11, with a mean value of 23.83mm (Figure 2). Results also shows that there is a statistically significant difference in the mean zone of inhibition between the actinomycete isolates ($p<0.001$).

Moreover, from the raw data, the mean values of the zone of inhibition of the positive control were less than of the bioactive isolates. The mean value of the actinomycete isolate, A11 (23.83mm) was greater than the positive control (10.14mm). Likewise, A31, with a mean value of 30.13mm was greater than the mean value of the positive control (8.86mm).

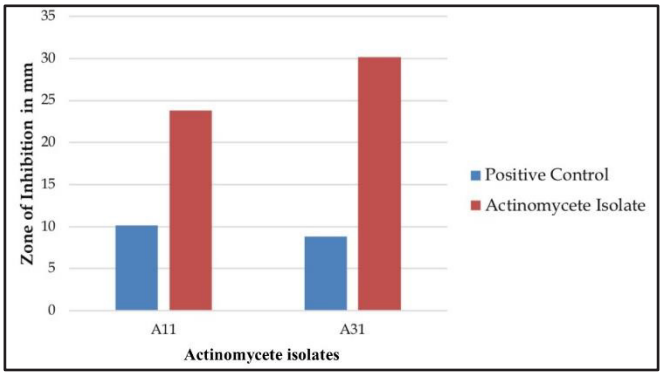

Figure 2. Antifungal activity of the bioactive actinomycete isolates vs. positive control (Nystatin) against *Aspergillus niger.*

4. DISCUSSION

Results showed that Lake Lanao has bioactive actinomycetes with antifungal activity. Unlike *Candida albicans*, the growth of *Aspergillus niger* is more difficult to inhibit (Das *et al*., 2014). Thus, it correlates with the results that only two actinomycetes isolates (A11 and A31) inhibited the growth of *A. niger*. This is similar to the findings of Jiang and Xu (1996), in which only 118 (6.78%) out of 1741 actinomycete isolates inhibited the growth of *A. niger*. These 118 bioactive actinomycetes were isolated from Yunnan Middle Plateau lakes that are said to be clear and not as densely polluted by human activities. Supporting this study, the active actinomycetes

that inhibited the growth of *A. niger* with a percentage value of 5.88% were isolated from the lake sediments that are not densely polluted by the local residences of Wato-Balindong.

Antifungal activity of the bioactive actinomycetes may be described either having a fungistatic effect or fungicidal effect. Fungistatic effect explains the effect of inhibiting the growth of the fungi that may result to thinning of growth of the certain fungi. Fungicidal effect on the other hand, totally eliminates or kills the fungi. In the study of Bonjar *et al*., 2005, it was determined that clear zones were indicative of fungicidal effect and the zones bearing only mycelial growth had fungistatic effect. Bacteria are known to produce substances with fungistatic and fungicidal effects (Barbosa *et al*., 2017) just as actinomycetes produced in various studies. All of the bioactive actinomycetes that inhibited the growth of *C. albicans* have fungistatic effects as shown in Figure 3. We observed thinning of the growth of the test fungi as seen in the surroundings of the growth of the actinomycete isolate. Though fungistatic effects do not totally inhibit the growth of the test fungi, fungistatic effects still weakened the growth of the said fungi. Welsch (1942), showed that the independence of bacteriolytic and bacteriostatic properties is highly improbable or unlikely. As for inhibiting the growth of *A. niger*, the two bioactive actinomycete isolates clearly showed fungicidal effects as shown in Figure 4.

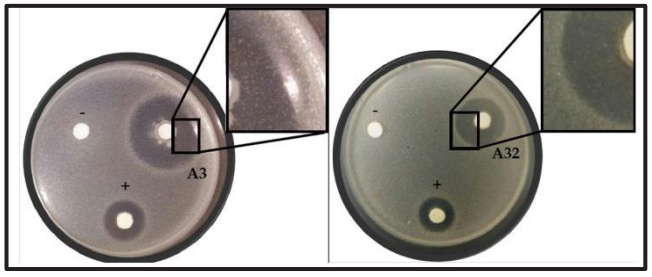

Figure 3. Zones of inhibition of the bioactive actinomycete isolates A3 and A32 with its – (negative control) and + (positive control) against *Candida albicans* at 28°C after 7 days.

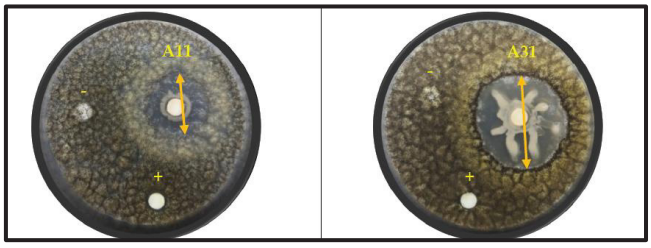

Figure 3. Zones of inhibition of the bioactive actinomycete isolates A11 and A31 with its – (negative control) and + (positive control) against *Aspergillus niger* at 28°C after 7 days

5. CONCLUSION

Findings on this research conclude that the western part of Lake Lanao has bioactive actinomycete isolates. Thus, the lake is a potential ecosystem for antagonistic actinomycetes which deserves bioprospecting or to search for substances that are produced by these bacteria that may be of helpful to medicinal research in the future. Considering the above-mentioned results, eight isolates, A3, A9, A11, A8, A21, A25, A31 and A32 exhibited antifungal activity against *Candida albicans* and only two isolates, A11 and A31 exhibited antifungal activity against *Aspergillus niger*. These bioactive actinomycete isolates have the potential to contribute in the search for new and effective drugs.

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P1-9

Environmental Impact Risk Assessment of Alien Species using Microcosm System

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Keywords: alien species, environmental impact risk assessment, microcosm, prey-predator interaction, food chain

ABSTRACT

From the biota (structural parameter) and the P/R ratio (functional parameter), utilizing the microcosm, which is a microbial ecosystem capable of constructing the basic ecological structure of general lakes, *Daphnia* (*Moina macrocopa*, the top-level predator species in the food chain) and bacteria (*Escherichia coli*, the lowest-level prey species in the food chain) as foreign species invading from outside the lake ecosystem and conducted ecological risk assessment. When introducing the top-level predator species in the food chain into the microcosm, there would be a risk that existing top-level predators would increase due to invasion of foreign organisms that would become higher predator. When introducing the lowest-level prey species in the food chain, it was evaluated that there would be no major impact on existing ecosystems. The influence of alien species on existing ecosystem depends on which trophic stage the alien species are located, and the influence on existing ecosystem is shown to be stronger in high-level predator species in food chain more than low-level prey species in food chain.

1. INTRODUCTION

One of the factors that have a serious effect on ecosystems and biodiversity is invasion of alien species into existing ecosystems such as microbial pesticides, ballast water, abandonment of pets, etc. Some these alien species which cause damage and destruction of existing wildlife due to genetic disturbance and disruption of balance of food chain, which causes damage to primary industry, it has become a problem in recent years.

In this study, we used the microbial ecosystem (microcosm) that can construct the fundamental ecological structure of general lakes, and from the biota (structural parameters) and P/R ratio (functional parameters), *Moina macrocopa* (the top-level predator species in the food chain) and bacteria (*Excherichia coli*, the lowest-level prey species in the food chain) were evaluated as foreign species invading from outside the lake ecosystem, and the purpose was to evaluate the ecological risk impact.

2. EXPERIMENTAL PROCEDURE

2.1 microcosm

Microcosm is a simulated ecosystem that cut out a part of natural ecosystem, and it consists of basic components of ecosystem such as decomposer, producer, predator and their biological interaction, material circulation, energy flow. It is a microbial ecosystem that contains elements and is capable of constructing a stable ecosystem. In the Gnotobiotic type microcosm used in this study, the constitutive species is completely known, two producers of green algae *Chlorella* sp., *Scenedesmus* sp., one blue-green algae *Tolypothrix* sp., one protozoan ciliate *Cyclidium glaucoma* (primary consumer), two metazoan rotiferas *Lecane* sp., *Philodina erythrophthalma*, one metazoan oligochaetes *Aeolosoma hemprichi* (top consumer), four kinds of bacteria (*Bacillus cereus*, *Pseudomonas putida*, *Acinetobacter* sp., coryneform bacteria) as decomposer, consisting of eleven species in total. It has been shown that this microcosm system (N-type) has a high correlation with the natural ecosystem.

2.2 Culture method

200ml of TP (Taub's basal medium + polypeptone) medium was poured into a 300ml Erlenmeyer flask, and 10ml of subcultured microcosm seed was added, and cultivation was carried out for 30 days under a static condition of a temperature of 25℃ and an illuminance of 2,400 lux (light/dark cycle 12hr./12hr.).

2.3 Introduced organisms

As a transferred organism (alien species), *Moina macrocopa* (the top-level predator in the food chain) and *Escherichia coli* HB101/pBR325 (the lowest-level prey in the food chain) which were not constructed in microcosm were supplied.

Moina macrocopa is filtration feeding minute crustaceans belonging to *Daphnia* with a physical condition of 0.6-1.2 mm and is usually parthenogenetic only in female, but males appear due to deterioration of the environment due to water pollution and the like to form resisting egg. Also useful as organisms are living baits for ornamental fishes, usefulness of toxicity testing of chemicals, attention as a biomanipulation introduced species, and so on. In this study, focusing on the competitive relationship with *Aeolosoma hemprichi* which is the top predator in the microcosm, *Moina macrocopa* is added at 1, 5 and 10 times the introduction amount of *Aeolosoma hemprichi* individuals, and the structure of the ecosystem and its effect on function.

Escherichia coli is gram-negative bacteria and belongs to facultative anaerobic bacteria and is one of the major species of bacteria present in the environment. This bacteria is also an intestinal bacterium and inhabits the large intestine in the digestive tract of warm-blooded animals (birds, mammals), especially humans. Its size is usually 0.4-0.7 μm on the short axis and 2.0-4.0 μm on the long axis, but the long axis is shortened, and some are nearly spherical. It is one of the model organisms as a representative of bacteria, and it is used as a material in various research such as genetic engineering, and it is also used for the production of chemical substances by

incorporating genes. In this study, we focused on the competitive relationship with the four species of bacteria which are the lowest species in the microcosmic food chain. *Escherichia coli* HB101/pBR325 was added at 1, 10 and 100 times the number of indigenous bacteria in the microcosm, and the influence on the structure and function of the ecosystem was examined.

2.4 Evaluation method

Evaluation items were two, number of individuals (structural parameter) and DO (functional parameter). The number of individuals was observed on days 0, 2, 4, 7, 14, 16, 18, 20, 23 and 30 from the start of cultivation using an optical microscope, and the ratio of the number of organisms on the 30th day to the control system evaluated from N_{30}. DO was continuously measured from the 16th day, and the P/R ratio was calculated from the production amount (P) and the respiration amount (R) and evaluated.

3. RESULTS AND DISCUSSION

3.1 Impact of top-level predator introduction

3.1.1 Evaluation by individual number (structural parameter)

In any of the addition systems, the producers *Chlorella* sp. and *Tolypothrix* sp. were decreased from immediately after introduction of *Moina macrocopa*. The cause was thought to be because the predation pressure increased by *Moina macrocopa* invasion and the latter could not grow sufficiently due to the swimming behavior of *Moina macrocopa*. In predators, *Lecane* sp. and *Cyclidium glaucoma* showed a decreasing tendency, and in the 10 times addition system, extinction was confirmed on the 18th day immediately after addition. This is thought because the competitive relationship of consumers in the microcosm became severe due to the predation pressure of *Moina macrocopa* and the difference in superiority or inferiority of predation ability occurred. In addition, *Moina macrocopa* added as a foreign organism in all additive systems converged on the 30th day by the time of measurement. In the 10 times addition system assuming the invasion of a larger amount of alien species, the number of individuals of *Aeolosoma hemprichi*, which is the top indigenous predator in the microcosm system, increased dramatically on the 30th day. This is because the existence of metabolites generated by the remains of *Moina macrocopa* and molting is a physical obstacle to filtering feeding zooplankton in predation behavior and only *Aeolosoma hemprichi* which is opening feeding intake advantageously can prey green algae *Chlorella* sp..

3.1.2 Evaluation by DO (functional parameter)

From the P/R ratio, which is the ratio of the production and consumption of dissolved oxygen, the consumption activity of dissolved oxygen (DO) increases as the addition amount of *Moina macrocopa* increases, and immediately after the start of continuous measurement in the 10 times addition system After the DO value attenuated for about 70 hours, it stabilized. For this reason, introduction of ten times amount determined that the ecosystem was affected by the variation of the structural type of the structural parameter and the attenuation of the DO value of the functional parameter, and the top category of the food chain (higher predator) invaded in the microcosm the

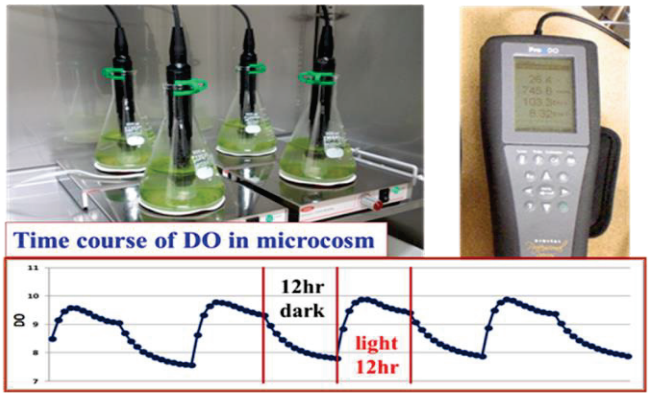

Fig.1 Microcosm (microbial ecosystem model)

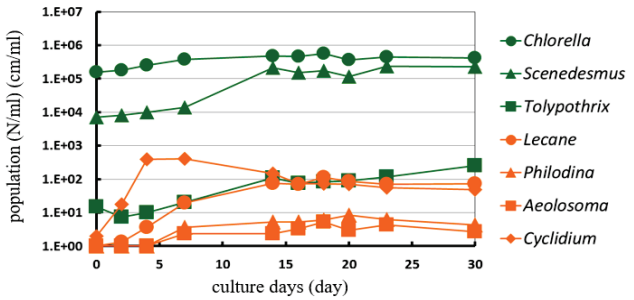

Fig.2 Population succession in microcosm (control system)

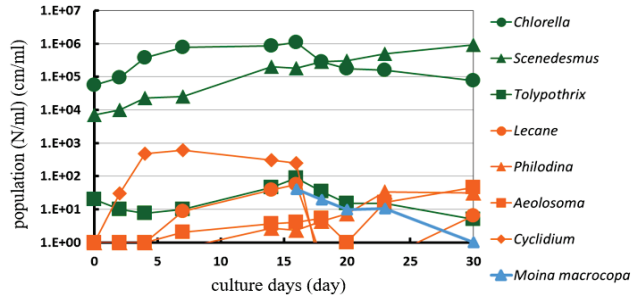

Fig.3 *Moina macrocopa* (the top-level predator species in the food chain) addition system

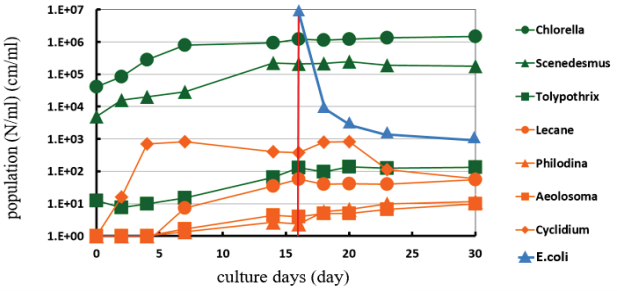

Fig.4 *Escherichia coli* (the lowest-level prey species in the food chain) addition system.

maximum no effect concentration (NOEC) was estimated to bebetween 5 and 10 times the existing top-level predator. Furthermore, since the *Lecane* sp. is drastically decreased in the 5 times addition system from the structural parameter, the m-NOEC (microcosm maximum effect free

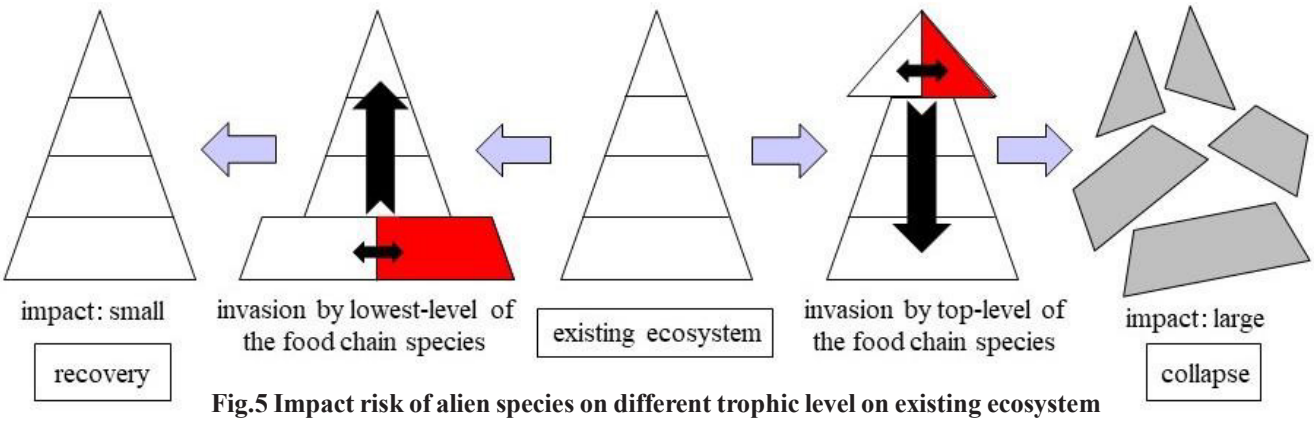

Fig.5 Impact risk of alien species on different trophic level on existing ecosystem

concentration) is considered to be at a relatively low concentration among 5 to 10 times.

3.2 Impact of lowest-level prey introduction

3.2.1 Evaluation by individual number (structural parameters)

Escherichia coli rapidly decreased at 1, 10, or 100 times inoculation concentrations in viable counts by the selective media method after microcosm inoculation, and the number of small animal groups (in particular, it is a primary consumer, protozoan ciliate *Cyclidium glaucoma*) in the microcosm increased. *Escherichia coli* has been shown to be a suitable food source for microcosm-constituting micro animal group such as protozoan ciliates including *Cyclidium glaucoma* and *Philodina erythrophthalma* and *Aeolosoma hemprichi* in prey-predator interaction test, it was considered to be dominated by these predatory actions. In N_{30} comparison, no significant difference was observed between *Escherichia coli*-added system and non-added system (control system).

3.2.2 Evaluation by DO (functional parameter)

In the P/R ratio, which is the ratio of the production and consumption of dissolved oxygen, the consumption activity of dissolved oxygen (DO) increased as the amount of *Escherichia coli* added increased, but eventually the non-additive system (control system) converge same level, And the P/R ratio was also stabilized at about 1. For this reason, the introduction of *Escherichia coli* judged that there is no influence on the ecosystem from the variation of the structural type of the structural parameter and the decline of the DO value of the functional parameter, and even if the lowest species of the food chain invades microcosm, it was evaluated that there was no major impact on the ecosystem.

4. CONCLUSIONS

1) In the case of the top-level predator species in the food chain (*Moina macrocopa*) was introduced into the microcosm, two predators were confirmed to extinct in the 10 times addition system. There was a risk that existing top level predators would increase due to invasion of alien species that would become higher predator. The possibility of collapse of the system was indicated.

2) In the case of introducing the lowest-level prey species in the food chain (*Escherichia coli*) was introduced into the microcosm, both the structure and function parameters converged to the same extent as the control system (non-additive system) and the system recovered, and it was evaluated that there would be no big impact on existing ecosystems.

3) The influence of alien species on existing ecosystem depended on which trophic stage the alien species are located, and the influence on the existing ecosystem was shown to be stronger in high-level predator species more than low-level prey species in its food chain.

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P1-10

ヨコエビ類を用いた久慈川流域水質環境の生物学的評価

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キーワード:ヨコエビ類, 指標生物, 侵入外来生物, 生態系管理

抄録

久慈川流域で水質とヨコエビ類の生息を調査した. 少し汚れている中・下流域で, ヨコエビ類が 5 地点で採取された. この結果, ヨコエビ類はきれいな水の指標生物になりにくいことがわかった. そこで, ヨコエビ類の種の同定を行った結果, 4 地点で侵入外来生物のフロリダマミズヨコエビ(*Crangonyx floridanus* Bousfield, 1963)が確認された. 残りの1地点では, 関東地方の低地の河川, 湖沼に生息する在来のアゴトゲヨコエビ(*Jesogammarus (J.) spinopalpus* Morino, 1985)であることが分かった. 上流域には, 関東・北陸・東北地方の山間部の渓流に生息する在来のヒメヨコエビ(*Jesogammarus (J.) paucisetulosus* Morino, 1984)を確認した. ヨコエビ類の種の同定を行うことで, 久慈川流域の水質環境の生物学的評価が可能になった. 今後, 生態系管理の指標生物として利用できる可能性も期待できる.

1. はじめに

河川の水質環境評価の指標生物として用いられているヨコエビ類は, きれいな水に生息するとされている. しかし, 1989 年に千葉県我孫子市と茨城県取手市の県境にある古利根沼から利根川に流出する小河川で, 侵入外来生物の北米原産のフロリダマミズヨコエビ(*Crangonyx floridanus* Bousfield 1963) が採取れた. その後, 全国各地でフロリダマミズヨコエビが報告され, 特に在来のヨコエビがほとんど生息しないやや汚濁の進んだ水域や水温が高い下流域で採取されている(多摩川, 鶴見川等)[1]. これらの結果はヨコエビ類が従来の指標生物になりにくいことを示している. そこで福島県南部と茨城県北部及び栃木県東部に流域を持つ久慈川のヨコエビ類の生息に関する報告を調べたが見つけられなかった. これらの背景から久慈川流域の水質とヨコエビ類調査を一定の期間に行って, 生態系管理の指標生物として, 利用できる可能性も視野に入れ, ヨコエビ類を用いた久慈川流域水質環境の生物学的評価を試みた.

2. 方法

1)水質調査

(1)調査期間と調査地点

水質調査は 2017 年 12 月 2 日～2018 年 3 月 18 日に行った。調査地点(図1)は以下(川・用水路:地点, 地名, 標高)のとおりである.

a.下流域: 標高 2～50m

久慈川:①,落合,2m. ②,辰ノ口,25m. 用水路:町下,19m.

b. 中流域: 標高 100～200m

久慈川:③,大子,100m. ④,米山下,200m. 川上川:⑥,中塚,200m. 八溝川:⑧,川山,115m. 矢祭川:⑨,牧野,144m.

c. 上流域: 標高 300～600m

久慈川:⑤,戸中,400m. 那倉川:⑦,川辺,400m.

(2)測定項目と方法

気温・水温はアルコール温度計で測定した. 化学的酸素消費量:COD, アンモニウム態窒素:NH_4^+-N, 亜硝酸態窒素:NO_2-N, 硝酸態窒素:NO_3-N, りん酸態りん:PO_4^{3-}-Pは, 水質調査セット(TZ-RW,(株)共立理化学研究所)を用いて測定した. pHはコンパクトpHメーター(ツイン:B-211:ホリバ(株)), 透視度は透視度計(TO-100:ケニス(株))で測定した.

3)ヨコエビの生息調査と種の同定

(1)調査期間と調査地点

生息調査は 2017 年 12 月 2 日～2018 年 3 月 11 日に行った. 調査地点(図1)は以下(川・用水路:地点, 地名, 標高)のとおりである.

a.下流域: 標高 2～50m

久慈川:1,落合,2m. 7,辰ノ口,25m. 10,西金,50m. 山田川:3,上河合町,4m. 浅川:5,松栄町,12m. 枇杷川:8,山方, 36m. 用水路:2,下河合町,7m. 4,小島町,7m. 6,下町,19m. 9,舟生,45m.

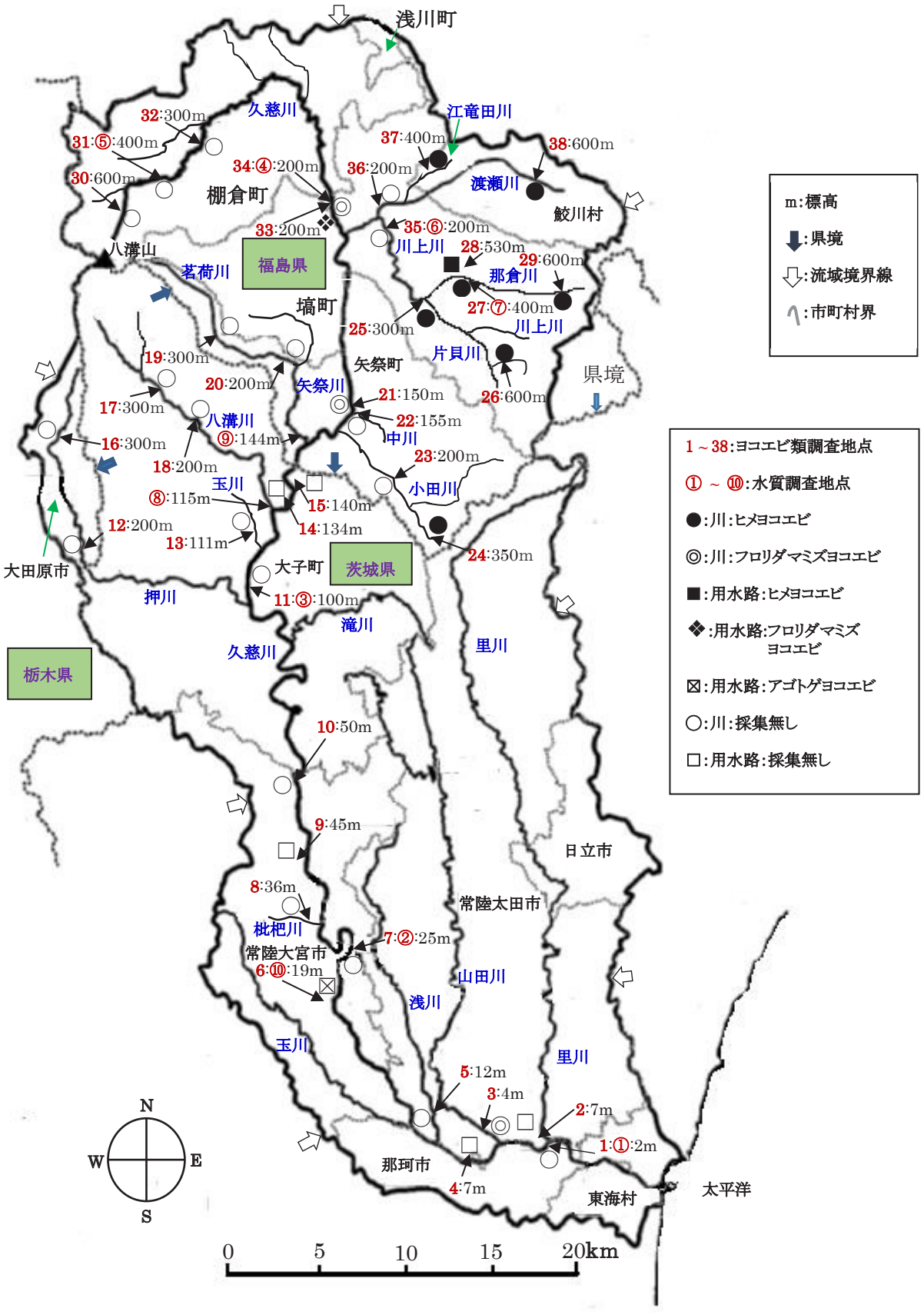


図1. 久慈川流域の水質とヨコエビ類の調査地点

b. 中流域: 標高 100～200m

久慈川:11,大子,100m. 21,江戸塚,150m. 34,米山下,200m. 押川:12,中居,200m. 玉川:13,岩花,111m. 八溝川:18,宮本,200m. 茗荷川:20,歯朶平,200m. 中川:22,小田川,155m. 小田川:23,仲町,200m. 川上川:35,中塚,200m. 渡瀬川:36,赤坂,200m. 用水路:14,田中,134m. 15,仲野,140m. 33,米山下,200m.

c. 上流域: 標高 300～600m

久慈川:30,戸中,600m. 31,戸中,400m. 32,大岩平,300m. 押川:16,如来,300m. 八溝川:17,磯神,300m. 茗荷川:19,上茗荷,300m. 小田川:24,明神,350m. 川上川:25,前田,300m. 片貝川:26,片貝,600m. 那倉川:27,川辺,400m. 29,鳩の宮,600m. 江竜田川:37,江竜田,400m. 渡瀬川:38,丸谷地,600m. 用水路:28,小田井田 530m.

(2)ヨコエビ類の採取

各調査地点で主に落葉の蓄積や水草があるところにタモ網を入れた. 採取したヨコエビ類は消毒用エタノールに入れて固定した.

(3)種の同定

ヨコエビ類は富川[2]などに従い, 種の同定を行った.

3. 結果

1)水質調査

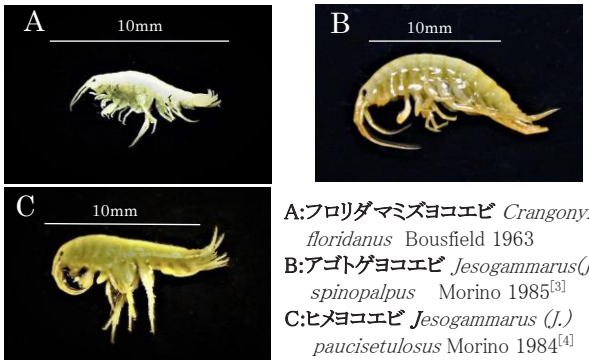
調査期間の気温は4～14℃, 水温は2～8℃であった. 下流域の地点①,②,⑩,中流域の地点③,④,⑥,⑧,⑨のCOD 値は 2～4mg/L で少し汚れた水であった. 上流域の地点⑤,⑦の COD 値はほぼ 0mg/L できれいな水であった. 下流域の地点②の NO_2-N 値は 0.02mg/L であったが, 他の地点は 0.005mg/L で最低値あった. 下流域の地点②, ⑩,上流域の地点⑦の NO_3-N 値は, それぞれ 1 mg/L, 5mg/L, 0.5mg/L であったが, 他の地点は 0.2mg/L で最低値であった. 全調査地点の NH_4^+-N 値と PO_4^{3-}-P 値は, それぞれ最低値の 0.2mg/L, 0.02mg/L, pH 値はpH6.9～7.3, 透視度は 100 度以上であった.

2)ヨコエビ類の生息調査

下流域の地点 3 でフロリダマミズヨコエビ(図 2,A), 地点 6 にアゴトゲヨコエビ(図 2,B) が採取された. 中流域の地点 21, 33, 34 でフロリダマミズヨコエビ(図 2,A)が採取された. 上流域の地点 24, 25, 26, 27, 28 29, 37, 38 でヒメヨコエビ(図 2,C)が採取された. その他の地点では採取されなかった.

4. 考察

久慈川流域の水質とヨコエビ類の生息を調査した結果, 少し汚れている中・下流域(地点 3,6,21,33,34)でもヨコエビ類が採取された. この結果, ヨコエビ類は, きれいな水の指標生物になりにくいことがわかった. ヨコエビ類の種の同定の結果, 4 地点で侵入外来生物のフロリダマミズヨコエビであることが分かった. 残りの1地点 6 で



A:フロリダマミズヨコエビ *Crangonyx floridanus* Bousfield 1963
B:アゴトゲヨコエビ *Jesogammarus(J.) spinopalpus* Morino 1985[3]
C:ヒメヨコエビ *Jesogammarus (J.) paucisetulosus* Morino 1984[4]

図2. 久慈川流域で採取されたヨコエビ類

関東地方の低地の河川, 湖沼に生息する在来のアゴトゲヨコエビ[3]であった. その地点の水質はきれいな水とは言えない水であった. 上流域には関東・北陸・東北地方の山間部の渓流に生息する在来のヒメヨコエビ[4]であった. 以上の結果, ヨコエビ類の種の同定を行うことにより久慈川流域水質環境の生物学的評価が可能になった. 今後, 生態系管理の指標生物として利用できる可能性も期待できる.

5. 結論

ヨコエビ類を用いた久慈川流域水質環境の生物学的評価を行った結果, ヨコエビ類の種の同定を行うことで、久慈川流域の水質環境の生物学的評価が可能であることが示唆された.

謝辞

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P1-11

Distribution of Phytoplankton and Water Quality in Chiang Mai Moat, Thailand

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Keywords: Biodiversity, Chiang Mai Moat, Phytoplankton, Water Quality

ABSTRACT

The distribution of phytoplankton and the water quality of the Chiang Mai Moat, Thailand were investigated over a period of 4 months (September-December 2017). Samples were collected from 4 sites within the Chiang Mai Moat. The distribution of phytoplankton was found to be of the highest abundance at the Chang Phueak Gate site with thirty-nine species found, while the most abundant species were *Chlamydomonas* sp., *Trachelomonas* sp. and *Microcystis* sp. Thirty-four species were identified at the Suan Dok Gate site and the most abundant species were *Lepocinclis* sp. and *Trachelomonas* sp. Thirty-two species were identified at the Tha Phae Gate site and the most abundant species were *Aulacoseira granalata*, *Pediastrum biradiatum* and *Merismopedia* sp. Twenty-five species were identified at the Chiang Mai Gate site and the most abundant species were *Pseudanabaena* sp., and *Peridinium* sp., respectively. In addition, the trophic status of the Chiang Mai Moat was classified as meso-eutrophic status.

1. INTRODUCTION

The Chiang Mai Moat was built in 1839. It has a square shape and surrounds the old city of Chiang Mai, which is located in Chiang Mai Province. It was originally built to protect the city from the Burmese army. At present, the Chiang Mai Moat is considered a famous tourist attraction of the city and is associated with both the Loy Kratong and Songkran Festivals. It is particularly important in the Songkran Festival (Thai New Year's festival) when people pour or splash moat water to one another as part of the cleansing ritual to welcome the New Year. However, around the moat there are many markets and a thriving community, which have affected the water quality in the moat. Moreover, phytoplankton is one of organisms that are sensitive to water quality because each species can grow in different types of water quality. For this reason, phytoplankton can be used to monitor water quality [1]. Our present investigation focuses on the distribution of phytoplankton and water quality in the Chiang Mai Moat by examining samples collected from four sampling sites.

2. METHOD

The samples were collected from 4 sites, namely Tha Phae Gate, Chiang Mai Gate, Suan Dok Gate and Chang Phueak Gate, within the Chiang Mai Moat (Figure 1). The collection period involved the months of September, October, November and December in 2017. The physical and chemical factors of the water including pH, conductivity, DO, BOD_5, nitrate nitrogen, ammonium nitrogen and Orthophosphates values were measured according to the methods described by APHA, AWWA and WEF [2]. The trophic status of the water was classified using the Applied Algal Research Laboratory-Physical and Chemical Score (AARL-PC Score) [3].

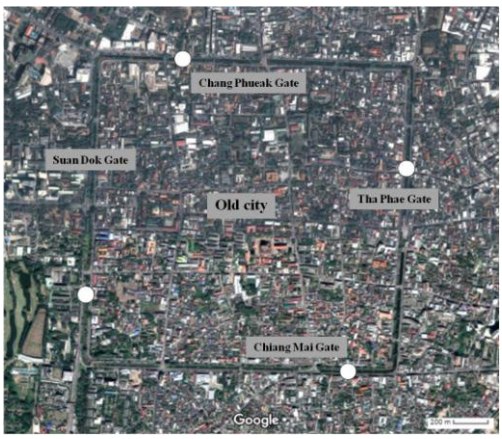

Fig. 1 Aerial photograph of the Chiang Mai Moat and 4 sampling sites (O).

Phytoplankton samples were collected by filtering 10 liters of water with a 10 µm mesh size plankton net in the field. The samples were then preserved by Lugol's solution. The samples were identified and counted according to relevant resource references [4-6]. The abundance of the phytoplankton species found was also determined for calculation of the diversity index using the Shannon method [7]

3. RESULTS

A total of sixty-eight species of phytoplankton were found in the Chiang Mai Moat. Thirty-two species were identified at the Tha Phae Gate site and the most abundant species (more than 10% of relative abundance) were *Aulacoseira granalata*, *Pediastrum biradiatum* and *Merismopedia* sp. Twenty-five species were identified at the Chiang Mai Gate site and the most abundant species were *Pseudanabaena* sp., and *Peridinium* sp. Thirty-four species were identified at the Suan Dok Gate site and the most abundant species were *Lepocinclis* sp. and *Trachelomonas* sp. Thirty-nine species were identified at the Chang Phueak Gate site and the most abundant species were *Chlamydomonas* sp., *Trachelomonas* sp. and *Microcystis* sp.

The diversity index ranged from 0.58-2.87 and the evenness ranged from 0.16-0.87. At the Suan Dok Gate site during the month of October, a total of 22 species were present. This was where the highest diversity index of 2.87 (evenness 0.80) was recorded. The trophic status of the Chiang Mai Moat was classified as meso-eutrophic status. The maximum and minimum values of the physico-chemical factors, trophic level, Total number of species, Diversity index, Eveness and Richness of each sampling site are shown in Table 1.

4. DISCUSSION

The distribution of phytoplankton and water quality revealed differences at each sampling site due to the different activities taking place around the moat. The most dominant species of each sampling site was similar to what was reported by Bicudo et al. [8], Solórzano et al. [9], Wołowski and Grabowska [10] and Komárek and Jankovská [11]. The species that are typically found in water bodies that are rich in organic matter and nutrients could be used to indicate the meso-eutrophic species. This was relevant to determining the trophic level of the Chiang Mai Moat according to the AARL PC score. In addition, *Microcystis* sp. were found to be in high abundance at the Chang Phueak Gate site and this species could produce Microcystins, which are a group of hepatotoxins that can actively affect fish, birds and mammals [12]. Therefore, water bodies should be considered in the investigation of water quality.

Table 1 Minimum and maximum values of the physico-chemical factors, trophic level, Total number of species, Diversity index, Evenness and Richness in Chiang Mai Moat between September to December 2017.

Physico-chemical factors	Tha Phae Gate	Chiang Mai Gate	Suan Dok Gate	Chang Phueak Gate
pH	7.01-7.52	6.93-8.15	7.05-7.41	6.87-7.59
Conductivity (µs/cm^{-1})	212.5-299.1	194.3-234.3	203.5-228.9	198.9-241.3
DO (mg/L)	5.4-7.0	4.4-7.4	5.6-6.8	4.4-6.4
BOD_5 (mg/L)	5.2-7.6	5.4-7.8	4.8-10.8	3.2-6.8
Nitrate nitrogen (mg/L)	0.6-1.7	0.2-1.9	0.4-4.7	0.7-4.0
Ammonium nitrogen	0.07-0.50	0.13-0.42	0.82-1.93	0.73-1.52
Orthophosphates (mg/L)	0.07-0.58	0.05-0.31	0.07-0.23	0.21-0.57
Trophic level*	Meso-eutrophic	Meso-eutrophic	Meso-eutrophic	Meso-eutrophic
Total number of species	32	25	34	39
Diversity index	0.58 - 1.97	0.73 - 2.37	2.16 - 2.87	2.13 - 2.80
Evenness	0.16-0.71	0.42-0.76	0.68-0.87	0.36-0.68
Richness	10-19	4-18	10-22	13-24

Note: * Trophic level was calculated by conductivity, DO, BOD_5, nitrate nitrogen, ammonium nitrogen and Orthophosphates

5. CONCLUSION

Sixty-eight species of phytoplankton were collected from the Chiang Mai Moat. The distribution of phytoplankton revealed differences at each sampling site. The dominant species are commonly found in the meso-eutrophic level of lentic ecosystems and could be used to indicator species. In addition, the water quality of the Chiang Mai Moat was classified as meso-eutrophic status.

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P1-12

Biodiversity Assessment in and around the Museum Lake in Govt. Botanical Garden and Museum, Thiruvananthapuram India

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Keywords: Biodiversity, Museum Lake, Avifauna, Ecosystem Health, India

ABSTRACT

Lakes perform several hydrological, biological, biogeochemical and other ecological functions both at ecosystem and landscape level with high aesthetic values. They significantly influence the microclimate and thereby influence the biodiversity in that aquatic ecosystem. An ecological survey carried out on the riparian flora and fauna around the Museum Lake recorded sixty bird species, thirty seven butterflies, twelve Odonates, forty six varieties of plants, five fish species, six varieties of reptiles and two varieties of amphibians. As urbanization is making depletion of the natural habitats, this *ex situ* conserved area well nourished with exotic and indigenous floras and perennial water body inside provides shelter for diverse fauna. The survey results will helps in highlighting the importance of this inland lake ecosystem and suggesting recommendations for the better conservation and management of the aquatic ecosystem as a whole.

1. INTRODUCTION

Freshwaters come under the lentic ecosystems are fundamental for life on Earth, and yet freshwater biodiversity remains poorly documented, understood, and protected (Ajayan et al., 2018). Lakes forms a significant source of precious water, it provides valuable habitats to a variety of flora and fauna. They influence the microclimate, improve the aesthetic beauty of the landscape and extend many recreational opportunities.

The restoration, conservation and management of lakes require a thorough understanding of all the components of that ecosystem. Ecological monitoring and assessment provides baseline information about the condition of the aquatic systems. A lake in an urban ecosystem forms an integral part of it performing significant environmental, social and economic functions ranging from as a source of drinking water, recharging groundwater, and acting as sponges to control flooding, supporting biodiversity and providing livelihoods. While cities are facing challenges of unplanned rapid urbanization, these water bodies plays an important role in maintaining environmental sustainability irrespective of whether they are natural or artificial wetlands.

2. METHOD

Thiruvananthapuram Government Botanical Garden and Zoo is one of the oldest of its kind in India which is located at the heart of the temple city (08˚30' N, 076˚57'E). It is well known for its vivid collection of plants and variety of animals in collection. The tropical trees, water body and its associated shores serve as a ground for many faunal species. It is a perennial water body but an artificial one with 159 year old since from its construction in 1859, has never lost its water level even in the scorching summers. The waterbody complete with an island, lush vegetation and the consequent abundance of winged visitors - has never failed to arrest the attention of visitors. This is a source of water for the Zoo Animals.

Ecological survey of the birds, butterflies, dragonflies, riparian vegetation, reptiles and amphibians associated with the water body has been carried out during February 2013 to October 2016. Field studies were carried out during the early morning hours from 6.30 am to 9.30 am and in the evenings from 4.30pm to 5.30 pm. Data were collected by direct observations, random walks and opportunistic observations and photographed in the study area. The field guides used for biodiversity assessment is

given in Table.1

Table.1 Field guides for the ecological survey

Avifauna	(Ali and Ripley, 2007; Grimmet *et al*., 2015 and Kazmierczak, 2000).
Flora	Gamble, 1986
Ichthyofauna	Jayaram, 1999
Odonates	Kunte (2000) and Kehimkar (2008), Kiran and Raju (2013)
Amphibians and reptiles	Palot (2015) and Das (2015)

3. RESULTS

During the study period a total of 60 bird species belonging to 33 families and 14 orders were recorded around the Museum Lake. Among them 51 of the birds recorded were included in the Schedule I and IV of the Wildlife Protection Act (WPA) 1972. 53 bird species in them are resident breeders, 14 of them are winter migrants. Little Grebe (*Tachybaptus ruficollis*), Black-crowned Night-heron (*Nycticorax nycticorax*), Lesser Whistling-duck (*Dendrocygna javanica*), Indian Pond-heron (*Ardeola grayii*), Cattle Egret (*Bubulcus ibis*), Intermediate Egret (*Mesophoyx intermedia*), Little Egret (*Egretta garzetta*), Little Cormorant (*Phalacrocorax niger*), Indian Cormorant (*Phalacrocorax fuscicollis*) are the waterbirds recorded from Museum Lake. A good but varying population of Cormorant type species and the Oriental Darter (*Anhinga melanogaster*) a bird enlisted in the Red Data Book of IUCN as a RET species, the Museum Lake within the zoo provides a potential habitat for the bird. Sighting of Asian Openbill Stork (*Anastomus oscitans*) is significant, which shows the availability of necessary resources from the water body.

A total of 37 butterfly species belonging to five families were observed from the riparian zone. One of them is endemic to the Western Ghats and three species are protected under various schedules of the Indian Wildlife (Protection) Act, 1972. Family Nymphalidae (brush-footed butterflies) dominated the butterfly fauna 15 species followed by Papilionidae (swallow-tails) 9 species, Lycaenidae (blues) 7 species, Pieridae (whites and yellows) 3 species and Hesperiidae (skippers) 2 species. Malabar Rose (*Pachliopta pandiyana) endemic to Western Ghats was also observed from this area. Among the butterfly species Danaid Eggfly* is protected under schedule - I of Indian Wildlife Protection Act 1972. Grey Count and Gram Blue are included under Schedule - II.

Twelve varieties of dragonflies and damselflies were recorded from the study period. Long Legged Marsh Glider (*Trithemis pallidinervis*) was very common. The life cycle of odonates are closely associated with water bodies (Kannagi *et al*., 2016) and their occurrence can be taken as an indicator of a healthy ecosystem and for quality of water (Emiliyamma *et al*., 2005).

The fishes in the Museum Lake has been introduced and only five varieties of fishes - *Oreochromis mossambica* (Mozambique Tilapia), *Ctenopharyngodan idella* (Grass Carp), *Catla catla* (Catla), *Labeo rohita* (Rohu) and *Xiphophorous maculates* (Southern Platyfish) were observed. The fish species which was listed as some of the "100 of the world's worst invasive alien species" (Lowe *et al*., 2000) - Egyptian Mouthbreeder or Tilapia was recorded from here. In conservation areas invasive fishes are a notable stressor for the ecosystem (Russell, 2011). Since the primary aim of zoos and conservation parks are protection and conservation, stocking of these invasive fishes in water bodies are to be prevented (Raghavan *et al*., 2016).

A number of rare and exotic floras are associated with the lake and are kept as part of conservation and beautification in mind. The bamboo varieties serve as host plants for *Telicota ancilla (Dark Palm Dart)*. Seasonal flowering varieties like *Pongamia pinnata, Pteocarpus marsupium* and *Peltophorum peltocarpum* are attracting these nectar feeding butterfly groups. The rain tree- *Samanea saman* serves as the host plant for Common Grass Yellow (*Eurema hecabe hecabe*). *Mangifera indica* and *Barringtonia acutangula* along the riparian zone forms the host plant for Monkey Puzzle (*Rathinda amor*) variety of butterfly. The host plants for Common Cerulean and Lemon Emigrant was *Butea monosperma.*

From the ecological survey, six varieties of reptiles and two varieties of amphibians have been documented from the Museum Lake. The Indian Rat Snake (*Ptyas mucosa*) and Checkered Keelback (*Xenochrophis piscator*) are listed in the Schedule II under the Wildlife Protection Act of India (1972) and Travancore Kukri Snake (*Oligadon travancoricus*) endemic to Western Ghats and Travancore Wolfsnake (*Lycadon travancoricus*) listed in the Schedule IV of the WPA are the reptile varieties sighted around the Museum Lake.

4. DISCUSSION

The dense growth of different species of trees and water bodies and the resources provided for various exhibited animals offer diverse habitat and favorable conditions which are being used by the native and urban population of fauna. These flora and fauna are significant in maintaining the balance of this ecosystem. A serious issue of mismanagement in fish stocking with invasive carps and tilapias and southern platy fish was noticed during the study. The high density population of grass carps and tilapias can alter the water quality of the lake.

5. CONCLUSION

The associated flora and fauna of the Museum Lake confirms it as a diversified ecosystem. These flora and fauna are significant in maintaining the balance of this ecosystem. Regular monitoring of the biodiversity associated with this area and scientific management and conservation measures will help from degradation. This study stresses on the need for conservation of this aquatic ecosystem and a right management measure as the need of the time. The survey also points out towards the meaningful role in educational, entertainment, scientific and conservation activities of Thiruvananthapuram Zoo.

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P1-13

Diversity of Fishes in Laguna de Cagayan Lake, Philippines: Status and Conservation Needs

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Keywords: species composition, abundance, IUCN, Red List status, diversity indices

ABSTRACT

Assessment of ichthyofauna and habitat stability of Laguna de Cagayan Lake is a pioneer study to document diversity and conservation towards sustainable ecosystem services. The study was conducted to characterize species composition, abundance, IUCN Red List status, and diversity of fishes caught in the lake from September, 2017 to March, 2018. Species composition revealed 1,714 individuals belonging to 14 species from 9 families. The dominant species *Trichopodus pectoralis* consisted 41.94% and the least 0.06% of the population is *Leiopotherapon plumbeus*, Family Osphronemidae dominated the catch followed by Cichlidae and Anguillidae .*Cyprinus carpio* VU is the only Red List species. But *Anguilla celebesensis*, *A. bicolor pacifica* and *Clarias macrocephalus* are NT fishes. Diversity T-test showed significant differences ($P<0.05$) on fish abundance between two sites and species richness of Luga, Margalef Index d= 1.77 is higher than Bangalao d= 1.34. Shannon-Weiner index H=1.59 revealed that the lake is fairly stable. Simpson's Reciprocal Index showed 1/D= 3.34- 4.29 means there are 3-4 commonly caught species and suggest good result of the study. Pielou's Evenness (J=0.69) observed more equal distribution of individual. Furthermore, Sorensen's Index Cs=2.67 showed more than half of the fishes identified in both sites are of the same species. Results of this study could serve as a baseline data in coordination with concerned line agencies to formulate sound-community based management strategy.

1. INTRODUCTION

The Philippine archipelago belongs to the world's richest mega diverse countries and one of the biodiversity hotspots worldwide with high diversity of endemic species significantly altered by human activities. The province of Cagayan (capital: Tuguegarao City, 17^0 37'N $121^0$43'E) lies in the northern part of Region II. Cagayan is endowed with rich biodiversity. In the recently conducted Philippine Biodiversity Conservation Setting, the region has been one of the priority conservation sites and identified as Key Biodiversity Areas.

Species richness and relative species abundance describe key elements of biodiversity. Diversity is maximum when all species that make up the community are equally abundant or have similar population sizes [1]. Diversity indices are commonly related to studies on species composition and distribution to evaluate stability of aquatic ecosystems.

Documentation of species composition and abundance of fishes at Laguna de Cagayan (LDC) Lake is important because this freshwater ecosystem has never been scientifically assessed. There is no detailed investigation on species diversity to date thus, this study was conducted. Proper documentation of the area is needed for policy formulation and proper management of the ecosystem.

This study generally aimed to assess the diversity and abundance of fishes along Laguna de Cagayan Lake. Specifically aimed to determine the species composition and evenness, Red List conservation status, and diversity indices of fishes caught.

2. METHODS

2.1 Study Area

Laguna de Cagayan Lake is bounded in the north by Bangalao Elementary School, in the south by Namunit hills and caves, in the west by a wide landmass uninhabited and the east by rice fields towards the Sierra Madre Mountains. LDC Lake has rich ecosystem diversity and natural scenic attractions promote the famous annual "National Eco-tourism Festival". Laguna De Cagayan (LDC), the town's premiere lake also known as Bangalao Lake is one of the most productive inland waters having diverse aquatic flora and fauna. Various aquatic vegetation's like the emergent native bakong grass, *Hanguana malayana* surrounds the lake abundantly, which is widely used in making expensive barongs, bags, and wall decors. The lake has an estimated area of 200 ha. located at Brgy. Luga, Sta. Teresita, Cagayan North. Three sampling points each were used in site 1-Sitio Bangalao and site 2- Barangay Luga.

2.2 Data Gathering and Analysis

Fishing practices used passive gears like fish corral in shallow portion. Gill net and hook and line were used at depths of 5-10 m. Specimen were collected at random from the catch of three fishermen/ cooperators each from the different fishing gears. Only two fishermen have skiff boat. Sampling was done thrice a month in the landing sites between 6:00 – 8:00 am from September 2017-March 2018. Fishes were counted and weighed fresh and classified to the lowest possible taxon. Some were preserved in ice packed cooler and brought to COFMS-Aparri laboratory for further identification.

Classified species were further verified at FishBase 2018[2]. The conservation status of fishes classified were cross referenced with IUCN Red List of Threatened Species 2018. Species richness was determined by the number of freshwater fishes classified and abundance the number of individuals per species. Five indices were used to estimate the various measures of diversity using the formula as follows: (a) Margalef's diversity index - d=S-1/$logeN$ where S is the number of species and $logeN$ is the natural logarithm of all individuals found. (b) Shannon-Wiener Index - H'=Σ - $(Pi * ln\ Pi)$ where Pi is the fraction of the entire population made up of species i and ln is the natural logarithm to determine how diverse the ecosystem in terms of species composition. (c) Simpson's-Reciprocal Index- $1/D=1/\Sigma\ (n/N)^2$ where n is the number of entities belonging to the ith type and N is the total number of entities in the data set. (d) Pielou's Measure of Evenness - J' = H'/ln (S) where H' is the Shannon-Weiner index value and S is the number of species. (e) Sorensen's Similarity Index - $CS=2j/\ a+b$ where j is the number of species common to a given pair of locations and b are the number of species occurring in either of the two locations. T-test was used to analyze diversity indices between sites using the SPSS version 19 program.

3. RESULTS

Table 1 presents a total of 1,714 individuals belonging to 14 species. The most dominant species is *Trichopodus pectoralis* 719 individuals (41.94%), *Oreochromis niloticus* 420 (24.05%) and *Channa striata* 121 individuals (7.06%). Least species are *Leiopotherapon plumbeus,* a rare fish in the lake and *Acanthopagrus latus*, a transient species from Buguey Lagoon, a nearby brackishwater water.

Table 1. Species Composition, Abundance and IUCN Red List Status

Species	Pcs	%	Status
Anguilla celebesensis	94	5.47	NT
A. bicolor pacifica	25	1.46	NT
A. marmorata	2	0.16	LC
Clarias macrocephalus	9	0.53	NT
C. batrachus	95	5.54	LC
Cyprinus carpio	19	1.10	VU
Ctenopharyngodon idella	80	4.66	NE
Trichogaster trichopterus	117	6.83	LC
Trichopodus pectoralis	719	41.94	LC
Oreochromis niloticus	420	24.50	NE
Channa striata	121	7.06	LC
Anabas testudineus	11	0.63	DD
Acanthopagrus latus	1	0.06	DD
Leiopotherapon plumbeus	1	0.06	NE

Diversity Indices of Fishes

Margalef's diversity index showed that Luga (d=1.77) is significantly richer than Bangalao (d=1.34) together with fish abundance. Significant difference revealed that Bangalao (1/D=4.29) has more number of common fishes caught than Luga (1/D=3.34). This implies that in every fishing activity, there are 3 – 4 commonly species caught. Pielou's evenness values range from J'- 0.60 to 0.77 both near to 1, the distribution of fish assemblage described as high evenness Furthermore, Sorensen's Similarity index showed that more than half of the species caught in both sites (Cs=2.67) are of the same species.

Table 2. Diversity Indices of Fishes Caught

Diversity Indices	Sitio Bangalao	Brgy. Luga	Pooled
Number of Species	8	14	14
Fish Abundance	186[a]	1,528 [b]	1,714
Margalef's Diversity Index *(d)*	1.34 [a]	1.77 [b]	1.56
Shannon-Weiner Index (H)	1.60 [a]	1.58 [a]	1.59
Simpson's-Reciprocal Index (1/D)	4.29[a]	3.34 [b]	3.82
Pielou's Measure of Evenness (*J'*)	0.77 [a]	0.60 [a]	0.69
Sorensen's Similarity Index (Cs)	2.67	2.67	2.67

4. DISCUSSION

Species Composition and IUCN Red List Fishes

In this study, 14 fish species were classified belonging to nine (9) families and four (4) orders. In Bangalao, eight (8) species were commonly caught while Luga has 14 species where anguillids and clariids are more abundant here. Most eels, catfishes and mudfishes were caught by hook and line fishers with skiff boat. Result showed lower species composition than Lake Taal River Systems with 37 species belonging to 19 families [3] but higher than Tikub Lake [4] with 9 species from 7 families, both in Luzon Island, Philippines. The most dominant family is Osphronemidae followed by Cichlidae, Anguillidae, Channidae and Clariidae. In River Ore, Nigeria, clariids and channids were the most abundant and dominant groups. [1] The result showed almost similar in species composition on the preliminary study at Aparri Cagayan River Estuary [5] with 15 finfishes caught by filter net due to the geographical location.

The Philippines is one of the world's major hotspots for the conservation of biological diversity. It hosts about 3,010 fish species with only 344 (10%) occurring in freshwaters, of which are 83 (24%) are endemic, 206 (62%) are native, 44 (15%) are introduced in the country, and 42 are of certain of status [2].The *L. plumbeus* caught by gill net is endemic in the lake and other freshwaters of the country including Laguna de Bay, the largest lake in the Philippines. The presence of single specimen caught suggest that it is rare and endangered in the lake. And according to the fishermen, they can only encounter once or twice in a year. It was once abundant in the Tikub Lake but due to sulfur upwelling, the entire population of this rare species was totally wiped out [4]. It is is suspected to be threatened already but no data in CITES 2017 [6] and recorded as

Not Evaluated (NE) by IUCN Red List of Threatened Species.

Some 20 years ago, according to fishermen of LDC Lake, *Clarias macrocephalus* was once abundant but due to the introduction of Thailand hito, *C. batracus* an invasive alien species (IAS) is now more dominant species therefore, reduced the population of the native catfish. Further research across the species range is needed into the impacts of hybrids on the wild. Thus, the conservation efforts should ensure minimization of anthropogenic impacts, like the introduction of IAS.

Cagayan River, the longest river in the Philippines, is also habitat of the above two Near Threatened (NT) eel species including vulnerable (VU) species *Cyprinus carpio.* Although no population data exists, it is suspected that in the past 60 to 75 years within the native range, major threats are river channelization which impacts the species. Common carp needs flooded areas at very specific times to successfully spawn, and hybridization with introduced stock, has caused a population decline of over 30% [2]. Due to rising concerns over the increased exploitation of elvers, the Philippines issued a ban in 2012 on the trade of juvenile eels. Aside from this ban, which was largely driven by fisheries concerns, there are other conservation measures being taken for *Anguilla spp.*

LDC Lake has recently joined select areas in the country in the implementation of the Restoration and Enhancement of Fisheries in Lakes and Reservoirs, to capacitate the residents surrounding the lake on fisheries management, protection and conservation.

Diversity Indices

Results showed that Margalef's diversity index in Laguna de Cagayan varies from d=1.34 to 1.77. Diversity T-test results showed that Luga is significantly higher in species richness and abundance than Bangalao. Shannon—Weiner index H=1.59 means that the habitat structure is fairly stable and quite balanced. Comparing the diversity to Buguey Lagoon of a nearby town has higher species composition (n=43) with a stable ecosystem H=2.0 (author's unpublished paper presented WLC 2016, Bali, Indonesia). Lake Geriyo, Nigeria [8] with H=2.48 indicated a fair fish diversity and Lake Taal River Systems [3] with a range of H=2.32-3.05 as high diversity. The fair diversity estimate of this 200ha. lake could be explained by the very few fishermen with lesser fishing effort because they are busy with other livelihood like farming. They are not interested even in buying a motorized banca nor constructing one, again only two used a skiff boat. Most of the fishermen are about two km. away from the isolated deeper portion of the lake. However, because of the scenic beauty of this biodiverse lake including nearby verdant hills and numerous caves, it is where the said municipality celebrates the opening program and other fisheries activities of the national annual festival. Its theme emphasizes the management and conservation of terrestrial and aquatic ecosystems biodiversity.

High evenness values J'=0.69 was observed. The distribution of fish assemblage can be therefore described as high evenness, reflecting fish assemblage co-existing within the lake. Result is quiet lower than Lake Taal River Systems [3] of which values ranged from J'= 0.7 - 0.85.

5. CONCLUSION

Fourteen (14) species of freshwater fishes with a total of 1,714 individuals were classified at LDC Lake with good species richness and abundance *Trichopodus spp.* dominated the catch followed by cichlid, anguillids, channids and clariids. *Cyprinus carpio (VU)* is the only Red List species. More ever, native *Anguilla celebesensis, A. bicolor pacifica* and *Clarias macrocephalus* are Near Threatened (NT) fishes already. Shannon-Wiener index estimate of fair habitat stability is for further study. Simpson's Reciprocal Index significantly showed 3-4 common fishes caught every fishing in Laguna de Cagayan Lake and suggest good result of the study. Consequently, Pielou's Evenness revealed more equal distribution of individuals or high evenness. Furthermore, Sorensen's Similarity Index showed that more than half of the fishes identified between sites are of the same species.

Further study should be conducted and coordinated to government line agencies like DA- BFAR and DENR for funding and better documentation. The generated data base will be presented to the Local Government Unit (LGU) of Sta. Teresita for information dissemination to increase awareness among fisher folks on the importance of conserving threatened, native and endemic fishes in maintaining ecosystem integrity and promote sustainable fishing. This study could serve as a baseline data in formulating management plan and conservation of fisheries resources of this water body.

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P1-14

Bird abundance in the rice fields of Chor-Lae community, Mae Rim District, Chiang Mai Province in Thailand

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Keywords: Bird abundance, Biodiversity evaluation, Wetlands, Rice fields

ABSTRACT

The objective of this study was to investigate the abundance of birds in the rice fields and its surroundings during farming season. The survey was conducted from September to December 2016, by using the line transect technique along the rice fields. Data were collected from 0600 h to 0900 h and/or 1500 h to 1800 h, 16 times in total. Overall, seven orders consisting of 45 species within 24 families of birds were found. Thirty-two species were resident birds and 13 species were migratory birds. Passeriformes was the most common order of birds found in the area. Twelve bird species were categorized as abundant, for instance, Common Myna (*Acridotheres tristis*), White-vented Myna (*Acridotheres grandis*), Spotted Dove (*Streptopelia chinensis*), Rock Pigeon (*Columba livia*) and Eurasian Tree Sparrow (*Passer montanus*). Seven species were common; for example, White-breasted Waterhen (*Amaurornis phoenicurus*) and White Wagtail (*Motacilla alba*). Thirteen species were moderately common, such as Bronzed Drongo (*Dicrurus aeneus*). Other 13 species were uncommon, such as White-throated Kingfisher (*Halcyon smyrnensis*) and Intermediate Egret (*Mesophoyx intermedia*). The Shannon diversity index was 3.16 and the evenness index was 0.88. The data from this research will be useful for those interested in studying birds in the rice fields, wetlands or fresh water sources, and it would build good source of knowledge for community for planning conservation of natural resources in the future.

1. INTRODUCTION

Chor-Lae community is located in the basin of the Mae Ping and Mae Ngad River. It is an agricultural area with extensive vegetable gardens, fruit orchards and rice fields which are the good sources of food and habitat for birds. Many birds help to eliminate insects, worms and pests or help to spread pollination. During rainy and winter seasons, between August to December of every year, the large part of Chor-Lae community will become rice fields. When rice is planted, various living species, such as insects, mollusks, mice, etc., will come into the area due to the abundance of food and water. These organisms are abundant sources of food for many species of birds. Therefore, the objective of this study were to explore the diversity and abundance of birds in the rice fields and its surroundings, to gain knowledge for the use of community and those who are interested later on.

2. METHOD

Bird surveys were conducted along the rice fields in Chor-Lae community **(** 19°08'30.5"N 99°00'48.2"E**)** by using the line transect technique. This technique is suitable for a complex environment or large areas with open spaces such as rice fields, wetlands, lowlands, etc., where birds are easily visible. The total distance observed was approximately 850 meters. The data were collected 16 times across the period of four months (four times every month) during September to December 2016, from 0600 h

to 0900 h and/or 1500 h to 1800 h. The surveys were designed to explore both left and right sides vertically to the path not over 30 m**.** Binoculars and a digital camera were used to search for the location of birds from the ground level, in grass, bushes and up to the tall trees[1]. Species, numbers and behaviour found were recorded. Bird species were identified by using the bird guide. The relative abundance[2], Shannon diversity index (H′) and Pielou's evenness index (J′) were then calculated.

3. RESULTS

From the survey of birds found in the area from September to December 2016, there were seven orders consisting of 45 species from 24 families. Thirty-two of them were residents, such as Red Collared Dove (*Streptopelia tranquebarica*), White-throated Kingfisher (*Halcyon smyrnensis*), Green Bee-eater (*Merops orientalis*), White-breasted Waterhen (*Amaurornis phoenicurus*), Bronzed Drongo (*Dicrurus aeneus*), Scaly-breasted Munia (*Lonchura punctulata*), Little Spiderhunter (*Arachnothera longirostra*), Olive-backed Sunbird (*Nectarinia jugularis*), Eurasian Tree Sparrow (*Passer montanus*), Baya Weaver (*Ploceus philippinus*), Streak-eared Bulbul (*Pycnonotus blanfordi*), Red-whiskered Bulbul (*Pycnonotus jocosus*), Sooty-headed Bulbul (*Pycnonotus aurigaster*), Black-collared Starling (*Sturnus nigricollis*) and Common Myna (*Acridotheres tristis*). The other 13 species were migratory birds or winter visitors, such as Chinese Pond Heron (*Ardeola bacchus*), Asian Openbill (*Anastomus oscitans*), Common Kingfisher (*Alcedo atthis*), Sand Martin (*Riparia riparia*), White Wagtail (*Motacilla alba*), Red-throated Flycatcher (*Ficedula parva*) and Japanese White-eye (*Zosterops japonicas*) (Fig.1). When considering the abundance of individual birds, across five categories of the abundance, 12 species were categorized as abundant, seven species were common, 13 species were moderately common and 13 species were uncommon (Fig.2). When analyzing the data drawn out from the recorded information, the diversity index was 3.16 and the evenness index was 0.88.

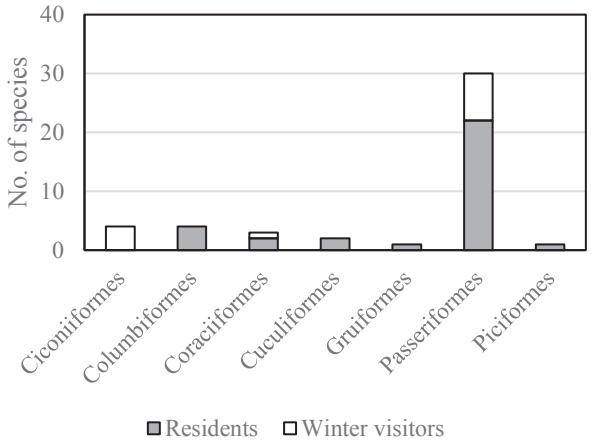

Fig.1 Orders and status of birds found in the rice fields of Chor-Lae community during the farming season.

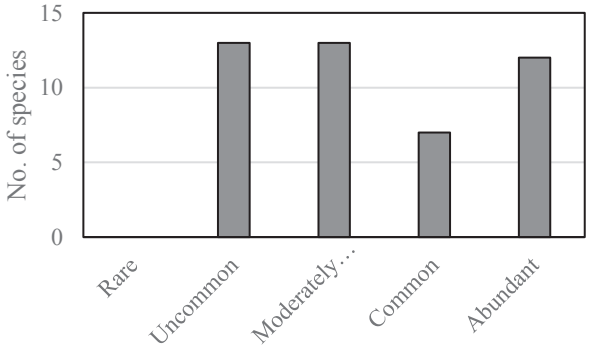

Fig.2 Relative abundance of birds found in the rice fields of Chor-Lae community during the farming season.

4. DISCUSSION

The most common bird species recorded are in order Passeriformes. They live in this area all year long and do not move or migrate to other areas. Thailand is in the tropical zone where warm weather is stable throughout the year. More than half of the birds found in Thailand are endemic. Each species adapted themselves to suit different habitats and adaptable birds are found in almost every season and habitat. However, the results shown that several species are abundant than others. They are Common Myna, White-vented Myna, Spotted Dove, Rock Pigeon and Eurasian Tree Sparrow. These birds are able to adapt to the changing environment, communities' livelihoods and the development of the country. By living in the suburbs where food and water sources are plentiful, the species can spread more widely[3]. These birds also eat

a variety of food and that makes more chance of survival than other species that eat specific kinds of food. Also, close to the rice fields, there are vegetable gardens, orchards and several ponds where food, fruits, seeds, grains, insects and small mollusks are abundant for them to eat. However, around the beginning of December, rice was harvested. There were more kinds of grains, insects and reptiles under the ground which brought more birds coming into the area, especially migratory birds such as White Wagtail, Common Kingfisher, Red-rumped Swallow, Sand Martin, Barn Swallow, Intermediate Egret and Little Egret.

Birds of interest in the area are Asian Pied Starling and Asian Openbill. Asian Pied Starling can be found in all parts of Thailand except the south and northeast. In the past, this species were rarely found in the north. However, this bird has successfully spread due to the breeding programme. Besides, this may be due to the abundance of resources in the northern part of Thailand, the species can find food more easily. The study area is also near the water sources and rice fields which are suitable for them to find food. We found the migration of Asian Openbill in the early period of the study. They will travel to Thailand around September or October and continue to live throughout the winter (November-February). This bird usually live by the rice fields, swamps, marshes, wetlands or fresh water sources where they feed on fish, mollusks, etc[4].

Seasons in the year usually affect the number and density of birds. Overall, the Shannon diversity index of this study was 3.16. First couple of months of the study were the beginning of the rainy season and the area was generally watered. As a result, the abundance of bird habitats and food sources had increased. It caused more birds to spread out of the area and to other wetlands. By the end of the study, it was the beginning of the winter season and rice was harvested. The diversity of birds had increased because of the reproductive season of the resident birds and there were groups of migrant birds joined. Birds that eat grains and insects would be easily found such as Green Bee-eater, Sand Martin, Barn Swallow, Ashy Woodswallow, Red-throated Flycatcher and Common Tailorbird. For the species evenness, it was generally 0.88. Birds, that are living on top of tree canopy, by the roof of the house or walking along the ground and farmland, usually live together as a group. Most of them are found throughout the season, such as Eurasian Tree Sparrow, Scaly-breasted Munia, Black-collared Starling and Spotted Dove, resulting in high consistency. In open spaces and meadows, there were many small birds that were found in both grouped species and isolated species, such as Green Bee-eater, Common Tailorbird, Barn Swallow and Ashy Woodswallow. This makes them a little less consistency.

5. CONCLUSION

There are 45 species found in Chor-Lae community consisting of both resident and migratory birds. Most of them are in order Passeriformes. Each species has a different abundance caused by types of food, water sources, habitats, seasons and migration.

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P1-15

青森県姉沼におけるイシガイ科二枚貝の脱落後の生態に関する研究

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キーワード:生物多様性評価, 生態系機能, 絶滅危惧種

抄録

イシガイ科二枚貝は, 世界各地に広く分布し, 国内では 15 種 1 亜種が確認されているが, 近年, 湖沼流域環境の劣化の影響で 15 種中 11 種が絶滅を危惧される状態にある。そこでイシガイ科の保全を考慮し, 本研究では, 脱落後の稚貝の生息適地に必要な餌料の解明を目指すことを目的とした。宿主魚類から稚貝を採取し, この稚貝を餌料が異なる底質で飼育することによって, その成長可否について調べた。解析の結果, 底質にバイオフィルムが存在すると成長量が大きくなる傾向がうかがえた。また, 乾燥させたバイオフィルムも餌料として機能することが示唆された。足と消化管内に繊毛を確認し, それらを用いて足弁摂餌およびそれらで水流を起こして周囲の餌料を摂食している様子が確認された。これらのことから, イシガイ科稚貝は, バイオフィルムを餌料とし, 足弁摂餌により摂食していると考えられる。

1. はじめに

軟体動物門に属するイシガイ科二枚貝(イシガイ科: *Unionidae*)は, 世界各地に広く分布し, 日本国内では 15 種 1 亜種が確認されている[1]。近年, 湖沼流域では, 開発や人工の増加等の社会・経済的な構造の変化によって汚濁負荷が増加し, それと密接に関連した湖沼の水域環境が損なわれてきており[2], これらの水域環境の劣化によって 15 種中 11 種が絶滅を危惧される状態にある[3]。本科二枚貝は, 特定の宿主に対して寄生や産卵場の提供を通じた共生関係[4]や大量の有機物を短期的な物質循環のサイクルから取り除いて底土に集積するなど生態的機能を有しているとともに, 浮遊物・金属イオンを取り除く[5]ことで水質浄化を行っているため, その保全は必須である。本科二枚貝の保全を考慮した場合, 脱落後の稚貝の好適な環境を確保することで稚貝の生残率を向上させることが重要な課題だが, 稚貝の生態に関する知見は, 成貝の生態に関する知見に比べて極めて少ない。中でも脱落後の稚貝の生息適地に必要な餌料については, 具体的にどの成分を吸収し, 栄養分としているかは未だに不明な点が多い[4]。そこで本研究では, 脱落後の稚貝を蓄養し, 成長量を把握することで, 底質に含まれる自然環境下の餌料の解明および形態観察により摂餌方法の解明を目指した。

2. 方法

対象地は, 青森県東部に位置する姉沼とし, 2017 年 6 月 27 日, 11 月 7 日に宿主魚類の採捕を行った。宿主魚類は定置網(周囲長 30 m, 目合い 5 mm)を用いて採捕した。採捕する宿主魚種は, 水質変化に比較的に強く, 長期的な飼育が容易なハゼ科(ウキゴリ, ジュズカケハゼ, ヌマチチブ)の魚種に限った。持ち帰った宿主魚類は標準体長に合わせて 10～15 個体ずつ虫籠(190 mm×95 mm×90 mm 間隙寸法 2 mm)に入れ, それをエアーポンプ(Suisaku 水心 SSPP-2S)で曝気を行っている円筒形容器(直径 20 cm, 高さ 205 mm)に収容した。円筒形容器は水温(20～23℃)を一定に保ったトロ箱(700 mm×410 mm×200 mm)に収容した。採捕日の翌日から毎日, 円筒形容器内の稚貝を含む沈殿物をプランクトンネット(目合い 112 μm)で濾し取った。濾し取った沈殿物は, プラスチック製のシャーレー(直径 60 mm)に移した後, 実体顕微鏡(SHIMIZU)で沈殿物から稚貝を探し出し, パスツールピペット(先端直径 1 mm, 長さ 143 mm)を用いて採取した。採取した稚貝は, 採取時期により異なる方法で飼育を行った。稚貝の餌料には, 姉沼の沿岸域の底質に堆積し, シルトが含まれるバイオフィルム(biofilm)を利用した。2017 年 6 月 28 日, 6 月 30 日, 7 月 6 日に宿主魚類から採取した稚貝(イケチョウガイ: *Hyriopsis scblegeli*)は, 採取日ごとに地下水のみの飼育ケース(以下, 底質無し), 姉沼で採取した砂礫・少量の採取した状態の生のバイオフィルムから成る土を入れた飼育ケース(以下, 姉沼の土), 採取した状態の生のバイオフィルムを入れた飼育ケース(以下, 生バイオフィルム)の 3 種類に等分し, 計 9 個の飼育ケースで飼育を行

った。2017 年 11 月 8 日～11 月 17 日に宿主魚類から採取した稚貝（カラスガイ: *Cristaria plicata*）は，個体ごとに底質無し，加熱処理を行った砂礫を入れた飼育ケース（以下，砂礫），生バイオフィルム，乾燥させたバイオフィルムを入れた飼育ケース（以下，乾燥バイオフィルム）の 4 種類に等分し，計 27 個の飼育ケースで飼育を行った。6 月，7 月に採取した飼育個体（イケチョウガイ）は 4 日おきに，11 月に採取した飼育個体（カラスガイ）は 3 日おきにデジタルマイクロスコープ（HIROX KH-8700）を用いて殻長，殻高を記録した。そこから，稚貝を四角で囲った殻面積を算出し，稚貝の成長量とした。脱落時に斃死した個体や飼育中に斃死した個体は，電子顕微鏡（HITACHI TM3030Plus）を用いて形態観察を行った。観察は，稚貝の腐敗を避ける為に稚貝の斃死を確認した当日に行った。また，稚貝の成長量の観察を行う際に，デジタルマイクロスコープでも稚貝の形態観察を行った。

3. 結果

イケチョウガイ稚貝の成長観察について，脱落後 12 日目の成育条件ごとの成長量を図 1 に示した。イケチョウガイの脱落時の殻高×殻長は，271×227 μm である[1]。観察の結果，姉沼の土で飼育した稚貝の成長量は，底質無しで飼育した稚貝の成長量に対して，有意に大きいことが示された（Scheffe 検定，$p<0.05$）。一方，姉沼の土で飼育した稚貝の成長量と生バイオフィルムで飼育した稚貝の成長量には，有意な差は示されなかった（Scheffe 検定，$p>0.05$）。同じく，底質無しで飼育した稚貝の成長量と生バイオフィルムで飼育した稚貝の成長量にも，有意な差は示されなかった（Scheffe 検定，$p>0.05$）。

カラスガイ稚貝の成長観察について，成育条件ごとの成長量を図 2 に示した。なお，図 2 では 18 日目の稚貝の成長量が最大値の個体の成長過程を線で結んだ。カラスガイの脱落時の殻高×殻長は，317×292 μm である[1]。図 2 に示した折れ線グラフから，脱落 18 日目の稚貝の成長量は，生バイオフィルムで飼育した個体が最も大きく，殻面積 0.24 mm^2 であった。次いで，乾燥バイオフィルムで飼育した個体は，殻面積 0.23 mm^2 となり，生バイオフィルムの殻面積に近い値となった。砂礫で飼育した個体は，殻面積 0.18 mm^2 であった。底質無しで飼育した個体は，最も小さく殻面積 0.11 mm^2 であった。

電子顕微鏡およびデジタルマイクロスコープでの観察の結果，稚貝の足と消化管内に繊毛を確認した。さらに，デジタルマイクロスコープでの稚貝の形態観察では，足に触れた泥状バイオフィルムは繊毛を利用し，足の表面上を移動させて殻内部へ取り込む様子が確認された。また，消化管上にある繊毛で水流を起こし，周囲の浮遊物・泥状バイオフィルムを殻内部へ取り込む様子が確認された。

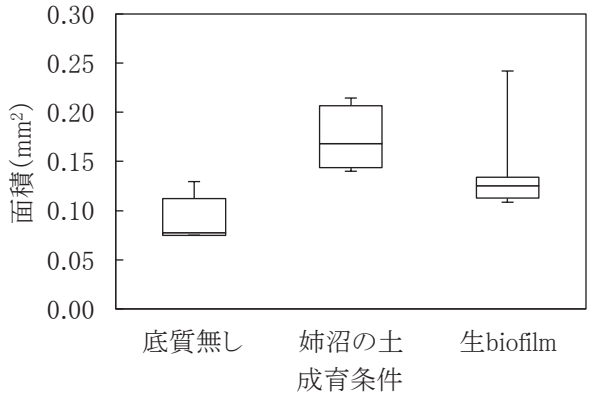

図 1 イチョウガイ（脱落後 12 日目）の成長量

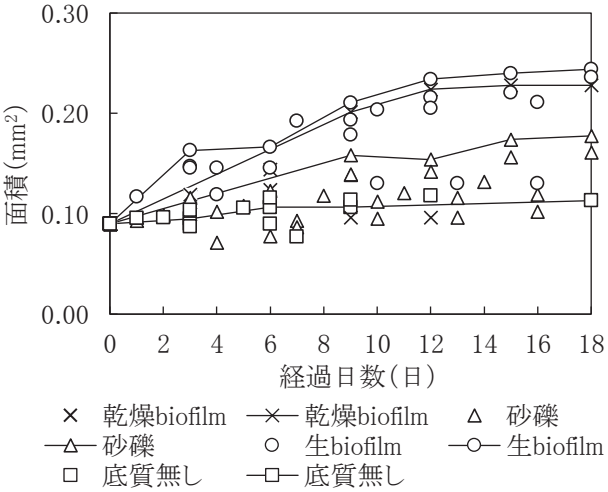

図 2 カラスガイ（脱落後 18 日目）の成長量

4. 考察

イケチョウガイ稚貝の成長観察およびカラスガイ稚貝の成長観察から，底質に生バイオフィルムが存在すると稚貝の成長量が大きくなる傾向がうかがえた。したがって，イシガイ科稚貝の餌料はバイオフィルムの可能性がある。また，乾燥バイオフィルムで飼育した稚貝は，生バイオフィルムで飼育した稚貝に近い成長量を示したことから，乾燥させたバイオフィルムも餌料として機能することが示唆された。イケチョウガイの成長観察では，餌料に加え

て砂礫があると成長量が大きくなる傾向が示された。また，カラスガイにおいても砂礫で飼育した稚貝は，餌料が存在しない環境であるものの，脱落直後の２倍近い成長量を示した。底質（細砂）がある条件下で *Epiobasma copsaeformis* と *Villosa iris* の稚貝を飼育した場合，底質が存在しない場合に比べて成長率と生残率が高いとされ，これは底質（細砂）がバクテリアなどの餌料の供給源となっている可能性があることが報告されている[6]。このことから，砂礫が稚貝の餌料となる生物・物質の発生・付着する基質となり，それを稚貝が摂食したことで成長したと考えられる。イシガイ科稚貝の摂餌方法として，Yeager et al.[7]によると *Villosa iris* は足で餌料を集めていることが示唆されており，Akiyama[8]では，脱落直後のタガイは粘性の強い粘液を吐き出し，周囲のデトリタスを軟体部の周辺に吸着させる行動を行うとしている。また，鰓の発達が十分でないアサリは足弁摂餌[9]を行うことが報告されている。電子顕微鏡の形態観察およびデジタルマイクロスコープでの観察の結果を踏まえると，イシガイ科成貝に対し消化管が未発達なイシガイ科稚貝は，足と消化管内にある繊毛を利用し，足弁摂餌により餌料を摂食していると推察される。

5. 結論

脱落後のイシガイ科稚貝の餌料は，バイオフィルムの可能性が示唆され，底質に付着・堆積しているバイオフィルムを少なくとも足弁摂餌によって摂食していると考えられる。

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P1-16

Biodiversity evaluation using Nature Index tool in Chilika Lake, Odisha, India – A case study

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Keywords: Biodiversity evaluation and ecosystem services

ABSTRACT

Biodiversity is crucial for human well-being; it provides food, nutrition and livelihood security. In 2010, parties to the Convention on Biological Diversity (CBD) adopted the Strategic Plan for Biodiversity 2011-2020, a ten year framework for action by all the countries to safeguard biodiversity and halt biodiversity loss. A pilot study was carried out in Chilika Lake for evaluating the status of biodiversity using the **Nature Index (NI)** tool developed by the Norwegian Institute for Nature Research (NINA). Chilika is one of the largest lagoons in Asia and this is the first Ramsar site of India and boasts of rich floral and faunal diversity. For evaluating the biodiversity status in Chilika Lake, 25 indicator species were selected (15 species of fish & 10 species of birds) and the time series data of these indicator species were fed into the NI database. The NI values were calculated using the R-package and the status of biodiversity was visualized though a colour coded map (e.g. red-very poor; orange, yellow and green-gradual improvement; and blue-good). NI is a well-designed policy tool that synthesizes biodiversity data and helps in monitoring the status of biodiversity. This monitoring tool can be used for identifying the threat status of species/ecosystem and guides the policy makers to take important policy decisions towards conserving the biodiversity. NI tool can be used for assessing the biodiversity status of the an ecosystem, protected areas, lakes, rivers, hotspots etc.

1. INTRODUCTION

India is a mega diverse country harbouring 7-8% of all recorded species of the world, which includes 48,000 species of plants [1] and more than 97, 708 species of animals [2] India has 10 bio-geographic zones and is home for 8.6% of mammalian species, 13.7% avian species, 7.9% reptiles, 4.7% amphibians, 11.7% fishes and 11.8% plants in the world. India has more than 15,042 species of marine diversity [3]. Biodiversity plays a crucial role in the functioning of the ecosystems on which human beings depend for food, water, health, recreation and protection from the natural disasters. The loss of biodiversity affects cultural and spiritual values that are integral to human well-being. The global mission of the Strategic Plan for biodiversity 2011-2020[4] is advocating countries to halt the loss of biodiversity and ensure that ecosystems are resilient and continue to provide essential services, thereby securing the planet's variety of life.

The objective of the present study is to test the Norwegian Nature Index (NI) tool in Chilika Lake for evaluating the biodiversity status in collaboration with the Norwegian Institute for Nature Research and Chilika Development Authority. The NI is a policy tool provides an overview of the state and trend of biodiversity and it can be used for taking important policy decisions for conserving and managing the biodiversity in an ecosystem[5]. The status of an indicator is calculated through a scaled value (ranging from 0 to 1) where the value zero means that the species is extinct and the value 1 means that the status of the indicator is very good. The NI is then calculated as the average over many such indicators. This tool can be applied in both data-rich and data-deficient areas and helps

the policy makers and administrators to monitor the biodiversity status in an ecosystem.

2. METHOD

The NINA has developed a web-based information system for recording, storing and presenting NI data. The system consists of SQL relational database connected to a web server and the database has various modules such as (i) indicator type; (ii) type of organisms (mammals/reptiles/birds); (iii) red list status (critically endangered/vulnerable/ near threatened/least concern); (iv) reference value; (v) pressure factors (e.g. eutrophication, pollution, climate change, habitat destruction, human pressure and hydrological changes); (vi) ecosystem affinity [5]. The time series data collected from various secondary sources were fed into these modules. The Reference value for the indicators species were determined with the help of experts (expert judgement/opinion) and the catch data were collected during 2003 was used as a reference year. The NI values were analysed by NINA using R-scripts and the status of biodiversity is visualised using colour coded map. For example, red shows a very poor state and the blue a very good state. Orange, yellow and green signify gradual improvements towards blue [6](Fig.1).



Figure 1 - Scaled value expressed on a 0-1 scale

For monitoring the status of biodiversity in Chilika, 25 indicator species were selected which includes 15 fish species (Flat head mullet, Large scale mullet, Sea bass, Bengal corvine, Four finger threadfin, Pearl spot, Hilsa shad, Grey eel-catfish, Spot tail needle fish, Bloch's gizzard shad, Small Bengal silver-biddy, Long whiskers catfish, Gold lined sea bream, Soldier catfish and Striped snakehead and 10 bird species (Northern pintail, Eurasian wigeon, Gadwall, Black-tailed godwit, Brown-headed gull, Asian open-bill stork, Purple swamp hen, Common coot and Lesser whistling-duck). The polygon map of Chilika was divided into 5 regions *viz* (i) Southern Sector (SC); (ii) Central Sector (CS); (iii) Northern Sector (NS); (iv) Outer Channel Sector (OSC) and (v) Island based on salinity variation.

3. RESULT

In the Chilika lake the maximum NI value of (>0.8) of bird population was recorded in OSC, CS and Nalabana Island and the moderate values of >0.7 (SS) and >0.6 (NS) was recorded in other sectors. In the case of fish diversity, the OSC has recorded the maximum value of >0.8 and in other sectors the NI values have declined {SS (from >0.9 to <0.7); NS (from >0.7 to <0.6); CS (from >0.7 to <0.6)} between 2005 to 2015. The status of the biodiversity can be visualised through the colour coded maps depicted in Fig.2.

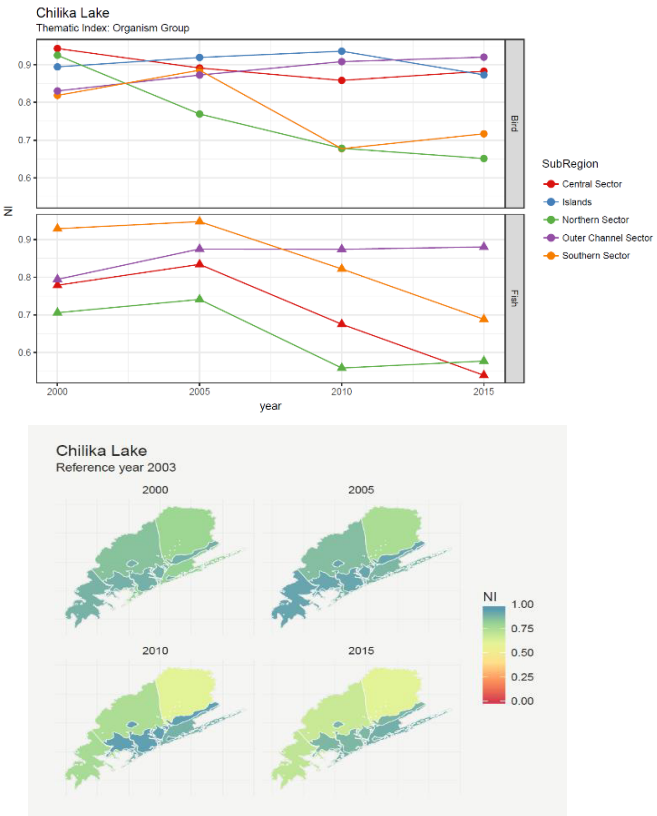

Figure 2 -Thematic value for the five areas of Chilika and the map showing the colour rang

4. DISCUSSION

The biodiversity wealth of Chilika Lake has tremendously increased after the ecological restoration of the Lake (by opening a new mouth to the Bay of Bengal) during the year

2000. This has resulted in rejuvenation of lost species (6 species of fish, 4 species of prawn, 7 species of crab and 2 species of Indian spiny lobster have reappeared) and the Irrawaddy dolphin population was increased from 89 to 160 individual.

The present study has reported that in Chilika the bird population was showing an increasing trend in OSC, CS and Nalabana Island regions. Birds such as the Brown headed gull, Asian open bill stock, Purple swamp hen, Common coot, Lesser whistling duck and Little cormorant is showing a good population trend in all the sectors studied.

In the cases of fishes, the Pearl spot and Grey eel showed a maximum aggregation in all the sectors and it was noticed that, the Spot tail needle fish was maximum in the OSC and the Hilsa population was high the NS. The figure indicates that there is a declined in the biodiversity in the NS (fresh water zone) and this be due to various anthropogenic pressure and over harvesting of fish resources by the local fishers. In the other sectors the good biodiversity trend was maintained due to the some biodiversity friendly initiatives by the CDA which includes: (a) protection of migratory waterfowl from poaching; (b) eviction of the Illegal prawn gherries from Chilika;(c) maintenance and dredging of the feeder channel and creeks, which facilitates for migration of fish juveniles; (d) catchment area treatment; (e) weed control; (f) restoration of feeding and roasting habitat of water fowl; (g) pollution control and (h) encourage community participation.

5. CONCLUSION

The pilot study carried out in Chilika Lake helped us in monitoring the status of birds and fishes (Sector wise in Chilika Lake) from the year 2000 to 2015. The NI tool provides an overall picture of the changes in biodiversity over a period of time and provides details about the causative factors for taking corrective measures. This scientific tool can be used for evaluating the impact of climate change; monitoring the implementation of National Biodiversity Targets (NBTs) and Sustainable Development Goals (SDGs) etc.

This NI tool can be extensively used for assessing the biodiversity wealth of the Protected Areas (PAs) in the forestry sector. Similarly, NI can be used for evaluating the wealth of marine/inland and agriculture ecosystems. This scientific tool provide visual clarity (maps and graphs) to the policy makers for taking important policy decisions on species and ecosystem conservation related issues. Currently there is no other scientific tool is available to store, synthesis the time series biodiversity data showing the trends over time for assessing the biodiversity.

Hence, the Nature Index tool can be extensively used in evaluating biodiversity in national parks, sanctuaries, biodiversity hotspots, etc. The PA area managers can use this tool to monitoring the status of wildlife biodiversity inside the PAs. The NI methodology and database is very well suited to assess the state of biodiversity. The data generated under this study can also be used for the preparation of national reports, and Climate Change action plans and for undertaking studies for the Inter-governmental science-policy platform on biodiversity and ecosystem services, etc. As India pledged under several International agreements, the NI study can be used for monitoring the progress of the various global and national biodiversity targets (e.g., Aichi, National Biodiversity Action Plan and Sustainable Development Goals) towards addressing the biodiversity loss.

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P1-17

Terrestrial and Freshwater Mollusks on the University of Tsukuba Campus

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Keywords: biodiversity evaluation, introduced species, nature conservation, education

ABSTRACT

Terrestrial and freshwater mollusks comprise one of the most diverse groups of animals. The mollusks are generally known as good ecological indicators and, because they are slow-moving and easy to observe, they have great potential for use in education. To describe the species composition and diversity, we surveyed terrestrial and freshwater mollusks on the University of Tsukuba campus in Ibaraki Prefecture, Japan. Between May 2017 and April 2018, we recorded 22 terrestrial and five freshwater molluscan species in 15 surveys at 28 sites. Commonly observed species were *Euhadra brandtii brandtii* (local name, Hitachimaimai), *Zonitoides arboreus* (Kohakugai), and *Acusta despecta sieboldiana* (Usukawamaimai) in terrestrial ecosystems and *Pseudosuccinea columella* (Habutaemonoaragai) and *Physa acuta* (Sakamakigai) in freshwater ones. Introduced species were also observed: six were terrestrial and two were freshwater species, accounting for about 30% of the total recorded species. The molluscan species are threatened globally by anthropogenic disturbances. Our results will be used for science and environmental education, management of introduced species and identification of important areas for biodiversity conservation.

1. INTRODUCTION

Although terrestrial and freshwater mollusks (i.e., nonmarine mollusks) are one of the most diverse groups of animals, they are threatened by anthropogenic disturbances worldwide [1]. The main causes of their decline are habitat loss, predation by introduced species, and overuse by humans [2]. Yet terrestrial and freshwater mollusks are generally known as good ecological indicators. In addition, because they are slow-moving and easily observed, they are good study organisms for education.

Here we describe our field surveys of terrestrial and freshwater mollusks at the University of Tsukuba in central Japan. Our aims were to describe their species composition and diversity on the campus and use the data for student education and conservation planning. This project is still ongoing, and we report the preliminary results here.

2. METHODS

Between May 2017 and April 2018, we conducted field surveys of terrestrial and freshwater mollusks on the University of Tsukuba campus in Tsukuba city, Ibaraki Prefecture, Japan. The campus is approximately 257 ha and contains various types of ecosystem, such as forests and grasslands, as well as street trees, gardens, ponds, artificial drainages, and land/water ecotones. We explored 28 sites during 15 field surveys and recorded the molluscan species observed by at least one of the authors.

3. RESULTS

Twenty-two species of terrestrial mollusk from nine families were recorded in total. Commonly observed species were *Euhadra brandtii brandtii* (local name, Hitachimaimai), *Zonitoides arboreus* (Kohakugai), and *Acusta despecta sieboldiana* (Usukawamaimai). We found relatively high species diversity in forest and grassland ecosystems, despite them being fragmented into small pieces by road and building construction. On the other hand, five species of freshwater mollusk were observed at three aquatic sites: *Sinotaia quadrata historica* (Himetanishi), *Pseudosuccinea columella* (Habutaemonoaragai), *Physa acuta* (Sakamakigai), *Corbicula* sp. (Mashijimi or Taiwanshijimi), and *Laevapex nipponica* (Kawakozaragai). Individuals of *Corbicula* sp. could not be distinguished between *C. leana* (native) and *C. fluminea* (introduced) because they are morphologically similar and we found only shells of dead individuals. With regard to introduced species, we recorded six terrestrial and two freshwater species, accounting for approximately 30% of the total recorded

species.

4. DISCUSSION

The University of Tsukuba campus was constructed approximately 45 years ago. Today many areas have been developed with roads and buildings, and more than 10,000 students attend the campus. The observed mollusks consist largely of native species, some of which (e.g., *E. brandtii brandtii*) are characteristic to the Kanto plain. We also recorded introduced species that are common in urbanized areas. These findings can be used for science and environmental education, management of introduced species, and identification of important areas for biodiversity conservation.

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P1-18

Isolation, screening, and identification of potential antibiotic-producing fungi from surface sediments of Lake Lanao in Lanao del Sur, Philippines

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Keywords: biodiversity evaluation, lake ecosystem functions, biological resource use, sediment release

ABSTRACT

To keep abreast with the need to discover new antibiotics and help address problem on antibiotic-resistance, this study was conducted to isolate, screen, and identify potential antibiotic-producing fungi from Lake Lanao along Ditsaan Ramain, Taraka, and Marawi City, Lanao del Sur, Philippines. Isolation of fungi from sediment samples followed Serial Dilution Pour Plate Method resulting to the isolation of 126 kinds of fungi based on colony, hyphae and reproductive spores in slide cultures. Antibiotic screening was done using Cotton Swabbing Technique which showed 10 (7.94%) isolates with antibiosis activity based on the zone of inhibition (ZOI) around each fungal isolate against *Escherichia coli* and *Staphylococcus aureus*. *Acremonium* sp., *Pestalotia* sp. 1, *Sporotrichum* sp., and *Cladosporium* sp. inhibited both test bacteria with average ZOI of inhibition of 2-17.5 mm. *Pestalotia* sp. 2, *Scopulariopsis* sp., and *Aspergillus* sp. 2 inhibited *S. aureus* only whereas *Curvularia* sp., *Aspergillus* sp. 1, and *Penicillium* sp. inhibited *E. coli* only with 7-9.5 mm and 2.75-6.25 mm average zone of inhibition, respectively. The fungal isolates will be further tested against other pathogens and their antibiotics produced will be later purified and utilized for drug development, thus, could be of economic and medical importance.

1. INTRODUCTION

Antibiotic resistance has increasingly become a problem in recent years because the pace at which we are discovering novel antibiotics has slowed drastically, while antibiotic use is rising. Therefore, we will always need new antibiotics to keep up with resistant bacteria. And the most common source of antimicrobial compounds was isolated from soil but in the last two decades, however, the rate of discovery of novel compounds from this source has significantly declined, as demonstrated by the fact that extracts from soil-derived microorganisms have yielded high numbers of clinically unacceptable metabolites. The aquatic environment is now becoming increasingly recognized as a rich and untapped reservoir of useful novel natural products. Fungal habitats in lake ecosystems are numerous, diverse, and often hidden and due to the specific habitat of freshwater fungi, they might have biosynthetic capabilities different from those of terrestrial fungi. Hence, there is a high possibility of obtaining new antibiotic metabolites of medical importance from freshwater fungi. Thus, this study was conducted to isolate, characterize, screen for antibiosis activity, and identify up to the genus level the untapped pool of microbial sources from Lake Lanao, the second largest lake in the Philippines.

Fungi that displayed antibiosis can be potential sources of new antibiotics that can be

further tested against other microbial pathogens. These antimicrobial substances can then be further purified, elucidated and developed as new drugs for the treatment of various infectious diseases.

2. METHOD

This study made use of experimental research design and was conducted at the Microbiology Laboratory of the Biology Department, Mindanao State University, Marawi City, Lanao del Sur, Philippines. All glasswares and autoclavable materials were sterilized at 121ºC, 15 psi for 15 minutes.

Sediment samples were collected from the littoral zone of Lake Lanao which lies between 8° N. Latitude and 124° E. Longitude. Three sampling sites were at the bank of barangays Ditsaan-Ramain, Taraka, and Marawi City (see Figure 1). Surface sediment samples were analyzed within 24 hours of collection.

Isolation of fungi from sediment samples was done using Serial Dilution Pour Plate Method with dilutions plated into Potato Dextrose Agar (PDA) with Cefalexin and then incubated for five to seven days. Fungal colonies were characterized, coded, and maintained in PDA slants [1].

Antibiosis assay was done through direct inoculation of each fungal isolate into nutrient agar plates. After four days, the test bacterium was swabbed around fungal growth and incubated for 48 hours at 30ºC. Antibiosis activity was based on the presence of the zone of inhibition around each fungal isolate against *Escherichia coli* and *Staphylococcus aureus*.

Characterization and identification (up to the genus level) of antibiotic-producing fungi were done using both cultural and microscopic features of these isolates from slide culture. Manuals by Hauser (2006) [3], and Woodward (2001) [5], were used. Data on the zone of inhibition of the fungal isolates against the two test bacteria were analyzed statistically.



Figure **1**. Map showing Lake Lanao in the Philippines with the three selected sampling sites (Taraka, Ditsaan-Ramain, Marawi City) in red boxes (https://images.search.yahoo.com/search/images

3. RESULTS

A total of 126 kinds of fungal colonies were isolated, characterized, and tested for antibiosis activity against *Staphylococcus aureus* and *Escherichia coli.* Results showed that only ten (7.94%) exhibited growth inhibition to both or either of the test bacteria (see Table 1). These fungi belong to eight genera that include *Acremonium* sp., *Pestalotia* sp. 1, *Sporotrichum* sp., and *Cladosporium* sp. which showed average zone of inhibition of 3.25-17.5 mm and 2-13.75 mm against *S. aureus* and *E. coli*, respectively. Among the fungal isolates with antibiosis activity, *Acremonium* sp. showed relatively the widest inhibition to the growth of the two test bacteria. *Pestalotia* sp. 1, *Sporotrichum* sp., and *Cladosporium* sp showed comparable but lower antibiosis activity.

Pestalotia sp. 2, *Scopulariopsis* sp., and *Aspergillus* sp. 2 inhibited the Gram-positive *S. aureus* only with average ZOI of 7-9.5 mm. On the other hand, *Curvularia* sp., *Aspergillus* sp. 1, and *Penicillium* sp. inhibited the Gram-negative *E. coli* only with 2.75-6.25 mm average zone of inhibition.

Table 1. Zone of inhibition (in mm) of the ten fungal isolates against the two test bacteria after 48 hours of incubation.

FUNGAL ISOLATES	TEST BACTERIA		MEAN
	Staphylococcus aureus	*Escherichia coli*	
Acremonium sp.	17.5	13.75	15.62
Pestalotia sp. 1	7.25	3.5	5.38
Sporotrichum sp.	3.25	2	2.63
Cladosporium sp.	3.25	2	2.63
Pestalotia sp. 2	9.5	0	9.25
Scopulariopsis sp.	9	0	9
Aspergillus sp. 2	7	0	7
Curvularia sp.	0	6.25	6.25
Aspergillus sp. 1	0	4.25	4.25
Penicillium sp.	0	2.75	2.75
Grand Mean	8.107	4.929	**6.50**

The 10 fungal isolates which showed antibiosis are maintained as pure cultures in PDA slants. Slide culture and microscopic examination showed their colony, hyphae, and spore features (Figure 2).

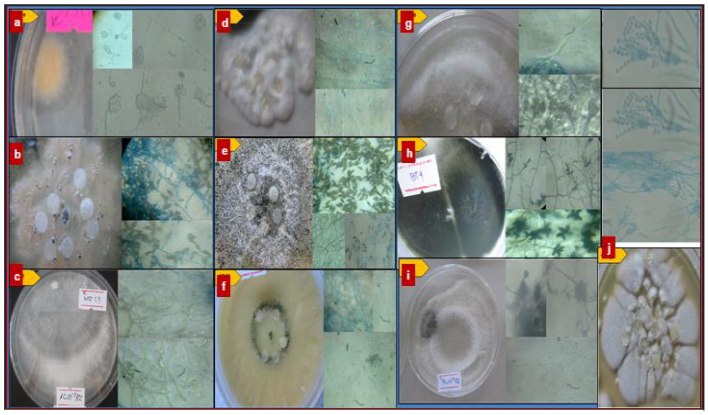

Figure **2**. Colonies and spores (1,000x) of the 10 kinds of fungi which showed antibiosis (*Acremonium* sp.(a), P*estalotia* sp. 1 (b), *Sporotrichum* sp. (c), *Cladosporium* sp. (d), *Pestalotia* sp. 2 (e), *Scopulariopsis* sp. (f), *Aspergillus* sp. 2 (g), Cu*rvularia* sp. (h), *Aspergillus* sp. 1 (i), and *Penicillium* sp. (j).

4. DISCUSSION

The 10 fungal isolates inhibited growth of *S. aureus* and/or *E. coli* through a mechanism called antibiosis. Antibiotics act by either inhibiting synthesis of peptidoglycan in the cell wall and/or proteins and phospholipids in the cell membrane resulting to cell lysis; or may also inhibit enzyme activity, thus, causing cessation in metabolism resulting to cell death [4].

Four genera (*Acremonium, Pestalotia, Cladosporium, Sporotrichum)* that inhibited both *S. aureus* and *E. coli* are potential sources of broad-spectrum antibiotics effective against both Gram-positive and Gram-negative bacteria being comparable with streptomycin (ZOI:15 mm) and cephalosporin (ZOI:18 mm)[2]. *Pestalotia* sp. 2, *Scopulariopsis* sp., and *Aspergillus* sp. 2 that inhibited *S. aureus* as well as *Curvularia* sp., *Aspergillus* sp. 1, *and Penicillium* sp. that inhibited *E. coli* could be possible sources of narrow-spectrum antibiotics.

5. CONCLUSION

With the main purpose to find sources of new antibiotics, this study was able to isolate *Acremonium* sp. with antimicrobial activity comparable to commercially sold antibiotics followed by *Pestalotia* sp. 1, *Cladosporium* sp., and *Sporotrichum* sp.; all these four fungal isolates are potential sources of broad-spectrum antibiotics. Six other isolates that include two species of *Aspergillus, Curvularia* sp., *Penicillium* sp., *Pestalotia* sp.2, and *Scopulariopsis* sp. could be sources of narrow-spectrum antibiotics. Further tests, however, should be done to establish safety in the use of these antimicrobials for future drug development. Also, more studies must be done on Lake Lanao particularly of its microbial community to assess its ecological status and safety for human uses.

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P1-19

Evaluation of River Environment by Biological Indicators in Boso Peninsula

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Keywords : river environment, biological index, attached diatom, benthos, water quality, Boso peninsula

Abstract

In this study, rivers that flow down the Boso peninsula using biological indicators for river environmental assessment was conducted, and river environment map in the Boso peninsula drew up at the same time, aimed at the construction of biological environment information in Chiba Prefecture. The Boso peninsula is shown to be divided into three areas in the Northwestern (urban area), Northeastern (plains) and Southern parts (hilly area). The Northwest (urban area) and the Northeast (plains) were estimated as "dirty" and the South (hilly area) was estimated as "clean". In addition, there is the great gap on biotic assessment between benthos and attached diatom. In the future, traditionally from individuals, populations and water quality assessment and environmental assessment environmental DNA analysis be conducted from biological habitat quality and quantity and ecosystem composition, structure and functions point of view. Furthermore, development of the database is expected to the characteristics of environment information for ecosystem restoration and conservation by linking with evaluation based on sensibility such as Water Environmental Soundness Index.

1. INTRODUCTION

Utilization of biological indicators for water environmental evaluation is different from water quality indicator by chemical analysis. It has the advantage of reflection a relatively long-term environmental change and easy to convert as a influence to human. On one hand, there is a big problem that they require skill in the classification, identification and counting, and susceptible to the influence of analysis of individual differences and method of investigation. In Japan, when evaluating rivers, chemical water quality survey is main investigation but biological water quality survey is not, as well as in Chiba prefecture. Then, it is thought that comprehensive biological water quality survey in Chiba prefecture will be possible by using attached diatom as a producer and benthos as higher-level consumers. In this study, rivers that flow down the Boso peninsula using biological indicators for river environmental assessment was conducted, and river environment map in the Boso peninsula drew up at the same time, aimed at the construction of biological environment information in Chiba prefecture.

2. RESEARCH METHODS

2.1 Rivers to survey

Kikuta River (2005), Koito River (2009), Obitsu River (2010), Yoro River (2011), Inba marsh inflow and outflow Rivers(Shinkawa River, Hanami River, Kashima River) (2012, 2016), Tega marsh inflow and outflow rivers(Ohori River, Ohtsu River, Someiiriotoshi, Tega River) (2013), Yatsu tidal flats inflow in and out Rivers(Yatsu River, Takase River) (2013), Kuriyama River (2014), Ebi River (2014), Isumi River (2015), Sakuta River (2016), Ichinomiya River (2017), Minato River (2018), and their watershed were surveyed. It was carried out four times a year at each of three to seven points of each river by season. The parentheses are the years studied.

2.2 Attached diatom investigation as a producer

Attached diatom was collected using a quadrate frame of 5 cm × 5 cm from the bottom of the river, and It was classified, identified and counted using a biological microscope (Nikon Ecripse E 800).

DAIpo (Diatom Assemblage Index to organic water pollution) and RPId (River Pollution Index based on DCI) were calculated, and the river environment was evaluated by these indicators.

1) DAIpo

DAIpo is an organic pollution index based on attached diatom community, and is used as a biological index for organic contamination, common to still water areas (lakes) and running water areas (rivers).

Attached diatom is decided to investigate belong to what a biotic community (good clear water species, wide adaptability species, good pollution species), and calculated from equation (1).

$$DAIpo=50+((A-B)/2) \quad \cdots\cdots \quad (1)$$

Here,

A: The sum of the relative frequency (%) of all saproxenous taxa at the survey site

B: The sum of the relative frequency (%) of all saprophilous taxa at the survey site

Table 1 shows the relationship between DAIpo, BOD, and pollution class.

2) RPId

RPId is a total evaluation value of river based on DAIpo, and by calculating the RPId, it is possible to compare the pollution of rivers different flow

path length. It is calculated the area of the trapezoid created by plotting the value of DAIpo on the graph and drawing a perpendicular from the plot and flow path length, by equation (2)

$$RPId=S/L \quad \cdots\cdots \quad (2)$$

Here,

S: The area of figure consisting of DAIpo (horizontal axis) at each survey site and channel length (vertical axis) of the survey river

L: The flow path length of the river surveyed (Distance between the most upstream point and the most downstream point among the surveyed points)

2.3 Benthos survey as higher-end consumers

The benthos was collected by D-frame net or Ekman-Birge mud sampler, and classified, identified, and counted using a substantive microscope (Nikon smz445). ASPT (average score per taxon) value was calculated the by BMWP score (Biological Monitoring Working Party score) method, and evaluated for the river environment.

1) BMWP score method

The BMWP score method is improved BMWP method for Japan. The Working Group organized in the United Kingdom (Biological Monitoring Work Party) advocated standardize biological water quality evaluation methods. This method is a new indicator for biological water quality survey "River Water Environmental Evaluation Manual (draft)" created by the Ministry of Environment, Japan.

2) ASPT

ASPT (Average Score Per Taxon) identify and classify enthos into the family, apply the benthos of 62 families to the score table classified as a score of 1 to 10. ASPT is obtained by calculating from equation (3).

$$ASPT = TS / TF \quad \cdots\cdots \quad (3)$$

Here,

TS: Total score

TF: Total number of families

The survey point was evaluated from 1 to 10 points by the ASPT value (Table 2).

2.4 Water quality survey as a nutritional substrate

The surface water was collected with a heyroht water sampler and measured BOD, COD, nutrient salt, Chl.a, SS, pH, DO, water temperature, transparency degree according to JIS-K0102 of the factory wastewater test method and the ocean observation guidelines.

3. RESULTS

Figs. 1, 2, 3, and 4 show the results of RPId at each research site, BOD as a nutrient substrate,

Table 1 Relationship between DAIpo, BOD, and pollution class

DAIpo	BOD	The pollution class
100~85	0~0.0625	Destitute water
85~70	0.0625~1.25	β-Oligosaprobic water
70~50	1.25~2.5	α-Oligosaprobic water
50~30	2.5~5.0	β-Mesosaprobity water
30~15	5.0~10.0	α-Mesosaprobity water
15~0	>10	Polysaprobity water

Table 2 Evaluation of water environment from ASPT value (provisional)

ASPT value	Expression(Provisional)
> 7	Clear water
6~7	Somewhat clean water
5~6	Somewhat polluted water
< 5	Polluted water

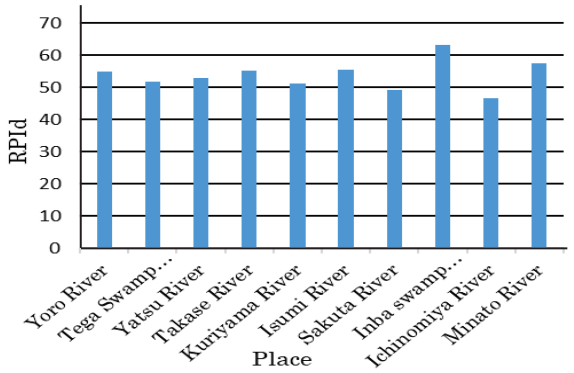

Fig.1 RPId value in each research point

attached diatom as a producer, and benthos as a high-level consumer.

The Boso peninsula was shown to be divided into three areas, that is the Northwestern (urban area), Northeastern (plains) and Southern parts (hilly area). The Northwest (urban area) and the Northeast (plains) were estimated as "dirty" and the South (hilly area) was estimated as "clean", and it was shown that rich nature was left in the Boso hills.

Although, the BOD was evaluated as "slightly clean" in the Northwestern part (urban area), Northeast (plain), it was not consistent with the evaluation by indicator organisms.

In addition, there was the great gap between the evaluation benthos and attached diatom.

4. DISCUSSION

The Northwest (urban area), where many large cities are gathered, were evaluated as "polluted". It was considered due to the pollution caused a vibrant urban economy. Despite the big city does not exist, Northeast (Plains) was assessed as "polluted". It was considered nonpoint sources from paddy fields because fluctuation of pollution connected farm work. BOD becomes somewhat clean reputation in the Northwest (urban areas), and Northeastern (Plains), and BOD and biological indicators were not consistent. The water quality

is evaluated from instantaneous sampling, however, biological indicators are for the evaluation of long-lasting water quality of river. The difference between benthos and attached diatom assessment are time lag before change of water quality was reflected by bottom material, because water quality of rivers had a big-time change but bottom material had an influence for a long term. Therefore, it may show improvement from pollution state.

5. CONCLUSIONS

1) The Boso peninsula was shown to be divided into three areas of the Northwestern (urban area), Northeastern (plains) and Southern parts (hilly area).

2) The Northwestern part (urban area) and the Northeastren part (plains) were estimated as "dirty" and the Southern part (hilly area) was estimated as "clean", respectively.

3) There was the great gap between the evaluation by benthos and attached diatom as biological indicators, and from this reason, it is necessary to evaluate both indicators comprehensively.

6. FUTURE PROSPECT

In the future, using assessment by existing individuals, population and water quality and analysis by DNA (eDNA), more detailed environmental assessment will be conducted considering quality/quantity of existing creature and construction/structure/function of ecosystem. Furthermore, conducting assessment by sensitivity like Water Environmental Soundness Index at the same time, it is anticipated that construction of database relating to acquisition environmental information to ecosystem restoration and characteristic of location become possible.

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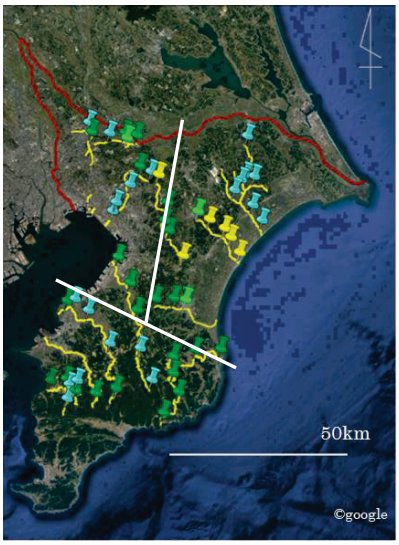

Fig.2 Environmental condition map of Boso peninsula by BOD

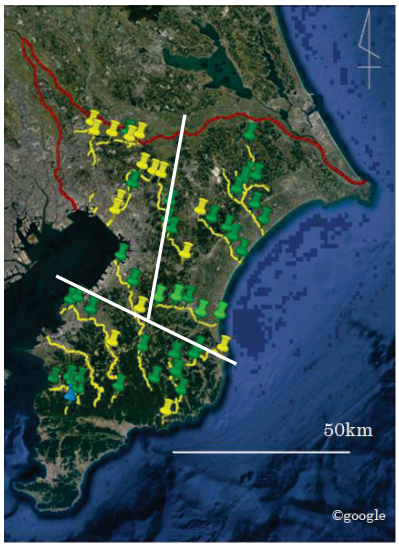

Fig.3 Environmental condition map of Boso peninsula by diatom

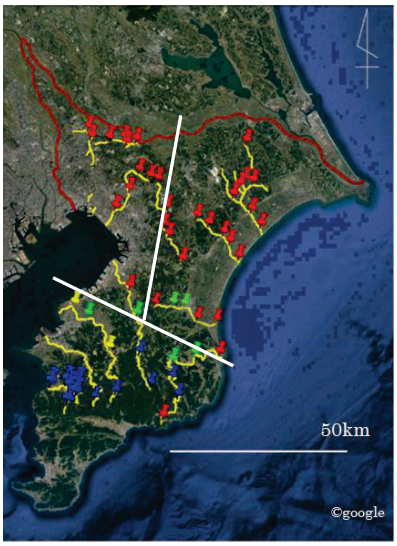

Fig.4 Environmental condition map of Boso peninsula by benthos

P1-20

The Diversity of phytoplankton in some check dams of Chiang Mai Province

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Keywords: Diversity, Phytoplankton, Check Dams

ABSTRACT

The study aims to explore the diversity of phytoplankton and their relationships with some environment parameters such as physical and chemistry properties. Ten different type of check dams in Chiang Mai province were selected. The results showed that 5 divisions of phytoplankton were found including Bacillariophyta (66%), Chlorophyta (28%), Cyanophyta (3%), Euglenophyta (2%) and Chrysophyta (1%) respectively. The phytoplankton diversity and their abundance were able to reflex the environments varieties. Not only the physical and Chemical parameter that impacted to the check dams but the other factors such as seasonal variation, type volume and size of check dams were also influence to the distribution of phytoplankton

1. INTRODUCTION

The current natural resources problems is getting worse as deforestation, expansion and pollution. The natural resources were extremely negatively impact not only represent in the term of environmental loss but also impact to the human as flooding, drought and water shortage. Therefore, one of those problem solutions was the check dam project. The check dam was support not only storage water in dry season but help in the replenishment of water resources and restore moisture to the local ecosystem. The check dam was acting as the natural water tank that can be used to modify the velocity of stream flow which can be help to reduce erosion. Moreover, the check dam were prevent to solved the flooding problem in rainy season as well as the drought in dry season.

Check dams refer to the construction that lay cross section or block on the stream. bed check dams is usually blocked the gully brook in the area or that is highly slope. The water flow was slowed down and the sediment was settled down to the bottom. However, the check dams might have an impact to the environment. The most impacted of check dam to environment were slowing flow and increasing the matter sediment accumulation. Another impacted were the water level. The water level usually raised up, which will affect to the living things no only producer as an algae, phytoplankton but the consumer as zooplankton and small invertebrate. The migration of organisms might obstruct check dams wall. The impact might more or less depend on the type of check dams such as the height and shapes, etc. Therefore, prior to building check dams to get the maximum positive and minimal negative effects were needed to analyzed those impact caused from check dams throughout by research. One to the potential assess of impact is aquatic bioindicator such as phytoplankton as this organism that sensitivity to water quality.

Therefore, this research study were focused to the diversity of phytoplankton and their relationship with the environment and physical- chemical parameters and were evaluated the impacted of the check dams in the area of upstream in Chiang Mai province. The result might use as a basic information for other check dam construction.

2. METHOD

The water and phytoplankton samples were collected from middle points of the all 10 check dams.(Fig 1, Table 1) The water quality as physical and chemical properties were investigated at sites as water temperature, air temperature, color, velocity, pH, conductivity, DO, TDS, turbidity, BOD, volume of water, surface area, nitrate-nitrogen, ammonia – nitrogen and orthophosphate. 10 liters of water sampled was filtered through 10 μm mesh plankton net and keep it in a bottles and preserved with Lugal's solution. The phytoplankton was identified and counted in the laboratory. The diversity index, species evenness, species richness and the relationship between the physical and chemical diversity of phytoplankton were investigated by Past3 version 3.14 program.

Table 1 Type and description totals 10 check dams

Type of check dam	Description	Check-dams code
Indigenous (A)	- Use the natural materials such as bamboo rock, etc. - Appropriate to the gully, twigs, creek, small stream size.	PY, PK, DK
Semi-permanent (B)	- The combination of the natural materials and the material that is not a natural such as concrete with a stone - Appropriate to the stream or small rive	OR, SNG, YK, YK2
Permanent (C)	- Reinforced concrete - Appropriate to the streams and small river (large size with fast water flow)	MH, MHL, MLM



Figure 1 Example of different type of the check dams

A: The local indigenous check dams (PK, PK, DK)

B: The integrated check dams (OR, SNG, YK, YK2)

C: The modern check dams (MH, MHL, MLM)

3. RESULT

Five division of phytoplankton were found in Division Bacillariophyta (66%), Division Chlorophyta (28%), Division Cyanophyta (3%), Division Euglenophyta (2%) and Division Chrysophyta (1%) respectively. The highest amount of individual phytoplankton belong to Division Baciilriophyta except upstream check dams as sites YK2, MH, MHL that the Division Chlorophya were found as the dominant group. (Fig 2)

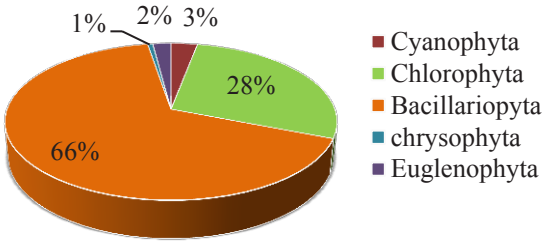

Figure 2 The number of phytoplankton totals 10 check dams

The diversity index, evenness and number of species of phytoplankton in 10 check dams were investigated. Site DK was a highest diversity index, species evenness and number of species richness as 3.21503, 0.93624 and 31 respectively. (Table 2)

Table 2 Diversity index, Species evenness and Species richness totals 10 check dams

Type of check dams	Name	Diversity index	Species evenness	Number of species
Indigenous	PY	2.57978	0.82277	23
	PK	2.56334	0.88685	18
	DK	3.21503**	0.93624**	31**
semi-permanent	OR	2.41727	0.85319	17
	SNG	0.42685*	0.23823*	6
	YK	0.76684	0.47646	5*
	YK2	2.00226	0.80577	12
permanent	MH	2.49162	0.80608	22
	MHL	2.61448	0.84583	22
	MLM	1.13827	0.38658	19

** Maximum * Minimum

The relationship of the physical and chemical and diversity of phytoplankton in 10 sampling sites were investigated. The relationship between the water quality physical and chemical properties could be grouped by the cluster distance 1.0 as divided to two. Firstly turbidity had a positive relationships with site MH and MHL. Thus the conductivity and TDS has a positive relationships with sites SNG and OR in second group. (Fig. 3) On the other hand, the diversity of phytoplankton to check dams could be grouped by the cluster distance 7.5 as 8 groups. Each group has a difference dominant phytoplankton such as site MH, MHL were *staurastrum tetracerum*, MLM was Navicula sp., PY, YK2 weas *Coelastrum reticulatrum* (dangeard) Senn, DK was *Pandorina* sp. and PK was *Cyclotella* sp. (Fig. 4)

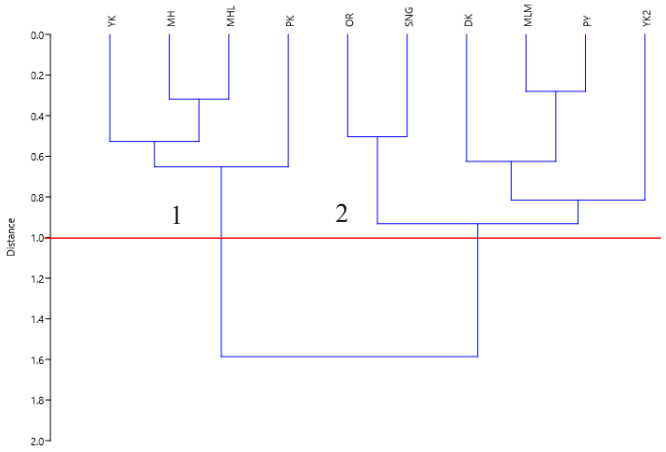

Figure 3 The cluster plot show the relationship between water quality Physical and Chemical of 10 check dams.

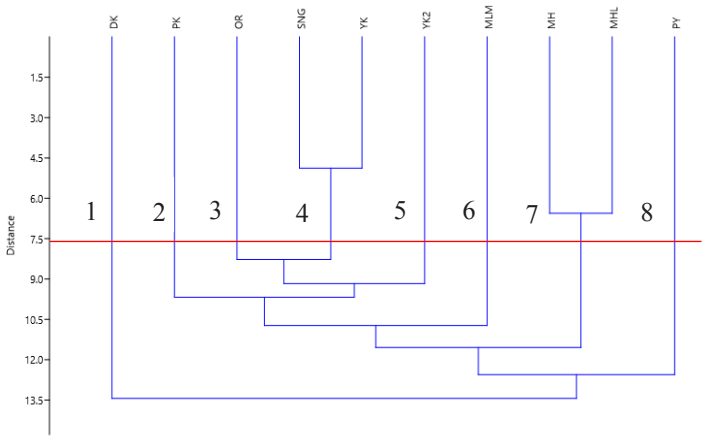

Figure 4 The cluster plot show the relationship diversity index of phytoplankton in 10 check dams.

4. DISCUSSION

The diversity and distribution of phytoplankton in sampling sites were different as well as the water condition.[1] The water composition from each sampling point were unique characteristics and influence to the phytoplankton communities.[2] The other factor as a seasonal condition might impact to check dams especially, small size and low volume capacity. Moreover, the seasonal influenced to the distribution of phytoplankton as higher abundant in rainy season as well as the richness more than the dry season. [3]

In this research the relationship between the physical and chemical and some algae were investigated. The sites MH MLM that had a high turbidity would found *staurastrum tetracerum* as the dominant species. (Fig. 3, 4)

5. CONCLUSION

The physical and chemical properties of all 10 sampling check dams sites that had and unique and different characteristics. The other factors such as the season, the volume and size of check dams were also impact to the diversity of phytoplankton were also different depended on the characteristic of the check dams. Thus, the construction of the check dams should be aware about the impacted to ecosystem and environment.

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P1-21

A brief introduction of biodiversity in Dongting Lake

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Keywords: Dongting Lake; Biodiversity; Invasive plants; Poplar plantation

ABSTRACT

Dongting Lake, the second largest freshwater lake in China, locates in the northern Hunan Province and connectes to the Yangtze River. The lake has three Ramsar wetlands of international importance and shows rich biodiversity.

The vegetation in Dongting Lake composes by 229 seed plants belong to 58 families and 150 genera. Among these plants, 97% of species belongs to herbs. However, the number of the invasive plants reaches 43 species, belong to 34 genera and 19 families. The most typical invasive plant in the Dongting Lake is poplar plantations and their effects on the native plant diversity were investigated. On the whole, large-area of poplar plantations increased species richness and diversity index. However, they changed the species composition and decrease the number of aquatic species and native species. Therefore, biodiversity protection must be enhanced in the Dongting Lake wetlands.

1. INTRODUCTION

Dongting Lake (28°30′–30°20′N, 111°40′–113°10′E), the second largest freshwater lake in China (2,691 km^2), is located in northern Hunan Province in a basin south of the Yangtze River and is connected to the Yangtze by distributary channels. Three major sections of the lake (eastern, southern, and western) have been designated as Wetlands of International Importance by the Ramsar Convention. The mean water depth is 6.7m and with deepest 30.8m, the mean annual runoff is 312.6 billion m^3. The lake has seven water inlets, including three channels of the Yangtze River (Songzi, Taiping and Ouchi) and four rivers (Rivers Xiang, Zi, Yuan and Li). The lake has only one outlet, which discharges into the Yangtze River at Chenglingji. Annual fluctuation in water level is approximately 12–14 m, with the maxima in August and minima typically in January or February, which provides the basic hydrological regime for maintaining large areas of beach wetlands, the most dynamic landscape within the Dongting Lake area. The mean annual temperature in the area is 16.4–17℃, with the coldest temperatures in January (3.9–4.5℃) and the hottest in July (28.6–29.1℃). Annual precipitation is 1,382 mm, with more than 60 % falling during the period from April to August. Alluvial soil is the primary soil type in the Dongting Lake wetlands.

The region has also been recognized as one of the 200 global conservation priority eco-regions proposed by the World Wide Fund for Nature, due to its valuable and exclusive biodiversity. The catchment has 1428 herbaceous species, 114 fish species, and 217 bird species.

2. METHOD

The nested quadrats sampling design suggested by Avery and Burkhart33 was used to form sampling units to determine plant diversity. In each vegetated area, three plots (20 m 330 m) with equal spacing were established as replicates. In each plot, five quadrats (2 mX2 m) with equal spacing (5‑6 m) were chosen for investigation.

3. RESULTS

With the field investigation, totally 235 species were found in the Dongting Lake wetland. Among these species, 97.9% were herbaceous plants. The number of seed plants was 229 species, belonging to 58 families and 150 genera.

Additionally, we analyzed the floristic type according to the floristic areal-type method. In family level, the plants contents 38 families belonging to cosmopolitan type. Poaceae is the biggest family, followed by *Asteraceae*. In genus level, the plants contents 52 genera belonging to cosmopolitan type and Polygonum is the biggest type. From the observation results, most plants in Dongting Lake belong to the cosmopolitan type and temperate flora.

Then, we would introduce the invasive plants in Dongting Lake and take poplar as an example. Totally, we found 43 invasive plant species from 19 families and 34 genera. The biggest invasive family is *Compositae* and contents 7 species, which accounts to 16.2% of the total species. Among these invasive species, 24 species are originated from America. The 17 species, including *Erigeron annuus*, *Alternanthera philoxeroides*, and *Populus euramevicana* are most common invasive plants in Dongting Lake. 27 species distribute along the flood control levee and road edge. 37 species belong to herbaceous type, in which, 29 species are annuals or biennials. The invasive species are adaptable and short in growth cycle and easy to be spread by water flow in Dongting Lake. On the whole, 48.8% plant species were introduced by intentional human activities and or 37.2% by unconscious human activities.

Now, we take Poplar (*Populus deltoides*) as an example. In 1970s, *P. deltoides* was introduced into the Dongting Lake area for making paper. In 2007, the area increased from 87 km^2 in 1983 to 640 km^2 (accounting for 26% of the total lake area). The study shows that although species number and Shannon's diversity were higher in young poplar versus reedy areas, poplar plantations had different effects on relative proportions of species composition: a higher ratio of mesophytes but a lower ratio of hygrophytes, and a higher ratio of heliophytes but a lower ratio of neutrophilous or shade plants. Changes in relative proportions of species also reflect the changes in understory environmental conditions. Therefore, species richness alone is incomplete and species composition of different ecotypes or life forms cannot be neglected when evaluating the extent to which understory plant diversity is affected by fast-growing tree plantations. Additionally, poplar plantations might also have far-reaching effects on the diversity of animal species. In the South Dongting Lake wetlands, poplar plantations have led to a significantly lower diversity of migratory birds.

4. CONCLUSION

Considering the wetland of international importance, the biodiversity in Dongting Lake region should be protected or strengthen by taking artificial and natural measures to restore the degraded habitat

P1-22

Paper title：Do winter-flooded paddies serve as overwintering sites for aquatic animal communities?

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Keywords: eco-friendly rice paddy, biodiversity, winter-flooded rice cultivation, aquatic animal community

ABSTRACT

For successful reintroduction of storks, winter-flooded rice cultivation has been introduced widely in paddy fields in the Toyooka Basin of the Hyogo prefecture, Japan. We studied the overwintering status of aquatic animal communities in winter-flooded paddies (WFP). The number of taxa of aquatic animals in winter-flooded paddies did not differ from that of conventional water management paddies (CWMP), fallow-field biotopes (FFB), and canal-type biotopes (CTB). Aquatic animals were more abundant in CWMP than in WEP. In addition, community structures of Odonata, Hemiptera, and Coleoptera were roughly divided into CWMP and WFP, and FFB and CTB, respectively. Our results show that winter-flooded rice cultivation is not very effective for the overwintering of aquatic animals, compared with conventional paddies and fallow-field biotopes. Therefore, it may be necessary to develop various types of overwintering environments at the regional scale in paddy fields for conservation of the aquatic animal communities.

1. INTRODUCTION

The Oriental white stork (*Ciconia boyciana*) inhabits open freshwater wetlands, such as paddy fields and floodplains, and preys on various animal species (e.g., fish, insects, frogs, tadpoles, snakes, crayfishes, and small mammals) there [1]. The Japanese wild population of the Oriental white stork became extinct in 1971. One major reason for this extinction was the sharp decrease in the number of aquatic animal species in paddy fields due to the spread of agrochemicals and agricultural field improvements in the 1960s [2]. Since 2005, Oriental white storks have been continuously reintroduced in the Toyooka Basin, the final habitat of wild storks in Japan. Reintroduced storks have bred every year since 2007. For successful reintroduction of storks, various eco-friendly rice farming, i.e., “White Stork-friendly Farming Method”, have been introduced in paddy fields of the Toyooka Basin. Among them, winter-flooded rice cultivation is especially believed to contribute to the conservation of paddy biodiversity and restoration of feeding habitats of storks in winter; however, to our knowledge, no study has quantitatively analyzed its effects. Therefore, we examined the impact of winter-flooded rice cultivation on overwintering in aquatic animal communities.

2. METHOD

We studied one paddy field area (35°55 N, 134°86 E) in the Toyooka Basin, of the Hyogo prefecture, Japan. This area is one of the main habitats of reintroduced storks and has approximately 50 modernized structural paddy fields. Small streams are utilized for irrigation, and water is supplied to each paddy through concrete creeks spread throughout the district. Winter-flooded rice cultivation is carried out in half of all paddies in this area. Conventional water management paddies (CWMP) are flooded only during the cropping period (from late April to late August), but some puddles remain in each paddy because of poor drainage and heavy precipitation during the non-cropping period (**Fig. 1a**). On the other hand, winter-flooded paddies (WFP) are flooded not only during the cropping period but also during the non-cropping period (from early December to late March, **Fig. 1b**). Besides WFP, 20 fallow-field biotopes (FFB) and eight canal-type biotopes (CTB) adjacent to paddies have been developed for conservation of aquatic animal habitats and as foraging sites of storks. FFB are flooded during all seasons and CTB are flooded during the same season as WFP. Four types of study sites were selected: (1) WFP, (2) CWMP, (3) CTB, and (4) FFB. We set three control sections for each site type to have 12 study sites in total. To capturing aquatic animals, we conducted sweeping survey with a D-frame hand net (35-cm frame diameter, 1-mm mesh size). At each study site, we set eight sampling points and swept approximately 30 cm toward the shoreline. Aquatic animals were counted for each taxon and were discharged into the sampling point. All surveys were conducted from January 19 to January 30, 2015.

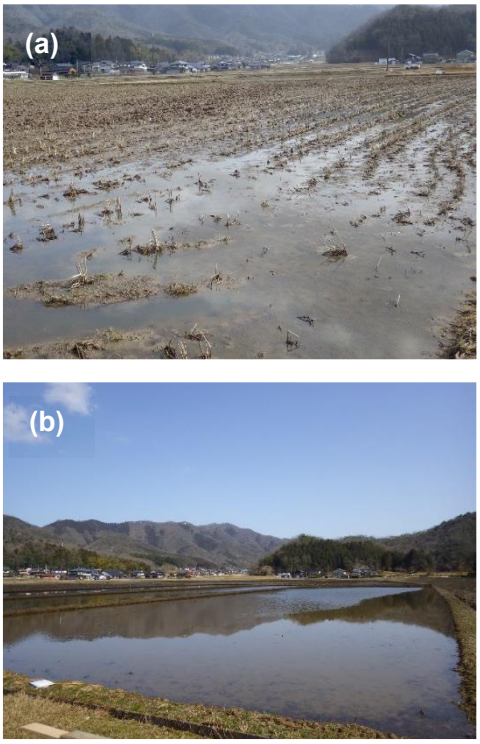

Fig. 1 Pictures of study paddies during the non-cropping season (January 30, 2015) in the Toyooka Basin, (a) the CWMP and (b) the WFP.

3. RESULTS

A total of 2,915 aquatic animals belonging to 38 taxa were collected at the 12 study sites. The number of Oligochaeta and Chironomidae larvae were 1349 and 754, respectively, which accounted for 72% of captured aquatic animals. In terms of taxa, aquatic insects were dominant (24 taxa, 63%). The number of taxa of aquatic animals in WFP did not differ from that in other study sites. Community structures of Odonata, Hemiptera, and Coleoptera, which are the indicator fauna in paddy fields (Nakanishi et al., 2009[3]), were roughly divided into CWMP and WFP, and FFB and CTB, respectively (**Fig. 2**). Oligochaeta, Chironomidae larvae, and Hirudinea were more abundant in CWMP than in other study sites. Aquatic Hemiptera *Sigara* spp. showed a similar abundance in CWMP and WFP, they did not appear in FFB and CTB. Viviparidae were more abundant in CWMP, WFP, and CTB than in FFB, while Veneroida showed the opposite trend.

4. DISCUSSION

Aquatic animals in WFP were not more diverse than those in other study sites. Tawa et al. (2013) [4] reported that ill-drained paddy fields where water puddles of various depths remain during the non-agricultural period can serve as wintering habitats for aquatic animal communities. In the WFP, the whole surface was filled with water after flatting the field, so a water environment of constant depth was formed there. Hence, the WFP plays a role as an overwintering habitat for the aquatic animals, but it is considered to be less likely to function as an effective overwintering site than the CWMP.

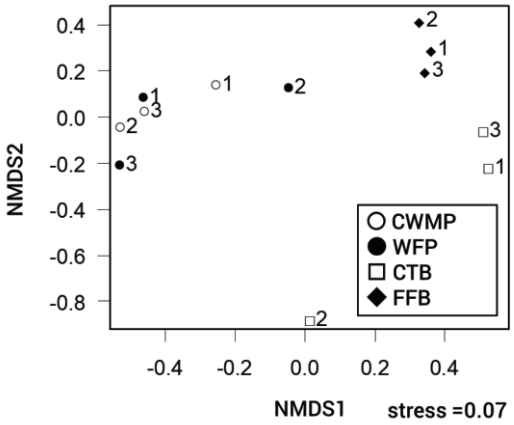

Fig. 2 Nonmetric multidimensional scaling (NMDS) plot of aquatic insect communities in study sites. Different types of study sites are denoted by different symbol shapes.

5. CONCLUSION

For conservation of aquatic animal communities in paddy fields at the regional scale, it is necessary to create various types of overwintering environments rather than introducing specific environmentally friendly farming methods (e.g., WFP). Even in modernized structural paddy fields, water puddles that serve as overwintering habitats for aquatic animals may be formed depending on topography. Therefore, it is also important to not only implement new eco-friendly rice farming but also make use of existing paddy fields as overwintering sites for aquatic animals.

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P1-23

Paper Title: Estimation of ecological carrying capacity of tilapia (*Oreochromis niloticus*) cage culture in Lake Volta using phosphorus mass balance.

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Keywords: Ecological carrying capacity, phosphorus mass balance model, cage fish farm, Lake Volta, Tilapia.

ABSTRACT

Development of intensive fish cage farming in reservoirs and lakes could pose threats to the environment. Ecological carrying capacity assessment is useful for sustainable aquaculture production and rational use of water bodies. The current study estimated the ecological carrying capacity for a tilapia cage culture on Lake Volta. The ecological carrying capacity was predicted using Dillon and Rigler mass balance model, taking into account water quality data and average production data of feed and fish compositions and feed conversion ratio (FCR). The phosphorus load to the environment estimated per tonne of fish produced was 22.77 kg P t^{-1} for the farm. The calculated capacity was 6,363 ty^{-1} for the farm area. The estimated capacity was about 14 times higher than the present production (450 ty^{-1}) in the zone. This suggests that further cage culture of tilapia could be established in the lake without compromising the water quality and the ecosystem. However, monitoring of water quality should be undertaken periodically to accurately determine the state of the lake in order to both confirm and refine predictions.

1. INTRODUCTION

Lake Volta, a multipurpose water body supports a range of interests including wild capture fisheries, hydropower, irrigation and water supply. Currently, cage fish farming of tilapia is fast expanding on the lake. Large quantities of waste (uneaten food and fish faeces) are produced as a result of intensive cage fish culture[1] . Excess phosphorus loading from fish feed can cause eutrophication in lakes. Thus, mismanagement of intensive cage farming can negatively impact the lake water.

The estimation of ecological carrying capacity of a specific site is essential to sustain culture, protect the environment and reduce risks of eutrophication that may occur[2]. A phosphorus mass balance model for freshwater lakes by Dillon and Rigler is widely used for estimating phosphorus levels in lakes and reservoirs in different areas, as well as other waters with cage fish culture. The carrying capacity of Lake Volta is unknown. There is a need to have estimates for the lake's carrying capacity for aquaculture development.

The study is aimed at estimating the ecological carrying capacity of important areas for aquaculture development in Lake Volta. This is done as a basis for planning, decision making and integrated management of sustainable aquaculture in the lake.

2. METHOD

The Lake Volta is a tropical man-made lake that was created by damming River Volta in 1964 to provide hydroelectric power. Geographically, it lies between longitude 1° 30° W and 0° 20° E and Latitude 6° 15′ N and 9° 10′ N (Figure 1). At a maximum level, the lake has a volume of 149 km^3, a surface area of about 8,500 km^2 and its length is 400 km.

For the purposes of estimating the ecological carrying capacity, a medium-scale farm with 80 cages of 5m x 5m x5 m was chosen. The farm is located close to the dead end of a side channel of Lake Volta, near to Akosombo, an

inland port with a mean depth of 20 m. (Figure 2). The farm practiced intensive system of farming and used predominantly locally manufactured extruded feed. The total production of the farm was estimated at 106 tonnes in 2014 with feed input of 211 tonnes per annum and FCR of 1.99.

The Dillon and Rigler model states that at steady state "the concentration of total-P in a water body, [*P*], is determined by the P loading, the size of the lake (area, mean depth), the flushing rate (i.e. the fraction of the water body lost annually through the outflow) and the fraction of P lost permanently to the sediments" [1]

$$[P] = \frac{L(I-R)}{Z\rho}$$

Where [*P*] is in µg/L total-P or TP; *L* = the total-P loading in gm^{-2} per year; Z= is the mean depth in m; *R* = the fraction of total-P retained by the sediments; and ρ = the flushing rate in volumes per year.



Fig. 1: Map of L. Volta showing the study area

3. RESULTS

The results of ecological carrying capacity estimation using Dillon Rigler phosphorus mass balance are shown in the steps below:

i. Determination of the steady-state total-P concentration. In tropical lakes and reservoirs, [P] is taken as the annual average total P concentration of surface waters



Fig. 2: Google map of section of L. Volta (marked yellow) where carrying capacity determined

and should be based on a number of samples taken during the year. The average phosphorus concentration of the lake water samples was $[P]_i$ = 46µg/L at the reference site in the study period in 2013.

ii. The capacity of lake or reservoir for intensive cage culture is the difference [ΔP] between $[P]_i$ prior to exploitation and the final desired/acceptable level of productivity,$[P]_f$. A 100 µg/L is chosen as the value for maximum acceptable $[P]_f$ in tropical inland water bodies used for the culture of tilapia [3]

iii. Determine Δ [P];

$\Delta [P] = [P]_f - [P]_i = 100 - 46 = 54$ µg/L

$L_{fish} = \Delta [P]\, z\rho/(1 - R_{fish})$

Table 1: Morphometric, hydrodynamic and phosphorus load of cage farm on Lake Volta.

Characteristics	Units	Symbols	Values
Surface area	km^2	A_o	5.365
Lake volume	$10^6 m^3$	V_o	107.3
Mean depth	m	Z	20
Total outflow	$10^6\ m^3$	Q	939
Flushing rate	y^{-1}	$\rho=Q/V_o$	8.75
Residence time	y	T_w	0.1143
Phosphorus retention coefficient		R	0.308
Phosphorus in feed		%	1.35

Feed conversion ratio (FCR)		1.99
Phosphorus content in fish	%	0.41
Phosphorus load to environment	kgt^{-1}	22.77
Tot. Phosphorus load to environment	kgy^{-1}	2,416

R_{fish} is the most difficult parameter to estimate. At least 45-55% of the total-P wastes from cage rainbow trout are likely to be permanently lost to sediments as a result of solids deposition. In the absence of any other data, these values are also used for cage tilapia and carp, and calculated as $R_{fish} = x + [(1 - x) R]$

Where x is the net proportion of total-P lost permanently to the sediments as a result of solids deposition (0.45-0.55) and R is proportion of dissolved total-P lost to the sediments i.e. phosphorus retention coefficient.

X was calculated to be 0.50

Thus, R is calculated from equation $R = 1/1 + 0.747\rho^{0.507}$

R= 0.308

Thus, using above equation, R_{fish} is calculated as 0.65.

z = 20 m (Table 1)

ρ= 8.75 y^{-1} (Table 1)

$L_{fish} = (54 \times 20 \times 8.75) / (1 - 0.65)$

= 27,000 mg m^{-2} y^{-1}

Equivalent to 27.0 g m^{-2} y^{-1}

iv. Since the area under operation (Farm area) of the lake has a surface area of 5.365 x 10^6 m^2, the total loading, L_a, is

L_a = 27.0g m^{-2} y^{-1}x 5.365 x 10^6 m^2

L_a = 27.0g y^{-1}x 5.365 x 10^6

L_a = 144.86 x 10^6 g y^{-1}

v. Having calculated the total acceptable P loading L_{fish}, this value is divided by the average total P waste to the environment per tonne fish production as a result of the cage culture to obtain the carrying capacity of the area.

The tonnage of fish of P loading from Farm was calculated as 22.765 kg t^{-1} (Table 1). Therefore,

Carrying capacity of Farm area of lake = 144.86 x $\mathbf{10^6}$ g y^{-1}/ 22765 g t^{-1}

= 6,363 t y^{-1}

4. DISCUSSION

The present production levels of tilapia of 450 t for the farm is over 14 times higher than the predicted ecological carrying capacity. Despite the rapid expansion of cage culture, the present biomass and impact to the lake's ecosystem is still acceptable. Cage aquaculture has the potential to continue on its current trend and increase without substantially altering the lakes ecosystem. With the government's proposal to increase aquaculture production from 10, 200 tonnes to 100,000 tonnes, and from the results of this study, this may be still within acceptable ecological limits, since there are other zones in the lake to accommodate the required expansion. .

5. CONCLUSION

The results of this work indicated that the carrying capacity of the zone studied on the lake has not yet been reached. Further cage culture of tilapia could be established in the lake without compromising the water quality and the ecosystem. This calculated value can be taken as an indicator of a possible ecologically sustainable aquaculture production level for Lake Volta area. However, monitoring of water quality should be undertaken periodically to accurately determine the current state of the lake in order to both confirm and refine predictions.

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P1-24

青森県姉沼におけるイシガイ科の生息環境評価

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キーワード:生態的機能, 生物多様性評価, 絶滅危惧種

抄録

イシガイ科の持つ生態的機能は, 水域生態系において重要な役割を担っている。イシガイ科は, 国内で15種確認されており, 内, 11 種が環境省レッドデータブックに指定されている。国内において, イシガイ科の保全は急務である。本研究では, 日本の本州北部に位置する姉沼を対象水域とした。Habitat Evaluation Procedure（以下, HEP)を用いて, イケチョウガイ *Hyroipsis schlegeli*, ヨコハマシジラガイ *Inversiunio jokohamensis*, ドブガイ属 *Sinanodonta* spp.を対象に, 生息分布が成立する環境を評価した。HEP を用いて評価を行う際, 6 つの因子（水深, DO, クロロフィル a, ヨシ帯からの距離, 底質の粒度)を選定し評価を行った。その結果, HEPを用いて作成したイシガイ科3種の生息分布モデルは, 現地での生息分布とおおむね一致した。本研究で, イシガイ科の生息環境評価手法の開発事例が得られたのでここに報告する。

1. はじめに

イシガイ科は, 雌雄異体の卵胎生であり, 繁殖時期になると, 雄個体の出水管から放出される精子球が, 雌個体の入水管に取り込まれることで, 雌個体の育児嚢中の卵が受精し, グロキディウム幼生が発生する。その成熟したグロキディウム幼生が水中に放出され, 宿主となる魚類の鰓や鰭などに寄生する。寄生期間を終えると, グロキディウム幼生が変態して稚貝となり, 宿主魚類から脱落, 底生生活を送り, 幼貝, 成貝へと成長する。また, イシガイ科は生態的機能としてコイ科タナゴ亜科（*Acheilognathinae*）の産卵母貝としての利用や, 貝殻による隠れ場など, 他生物の生息場所の創出, 貝殻の内側に魚類の産卵場所の提供, 排泄物や偽糞の供給による低質への堆積, 移動による低質変化・攪乱などを介して, 水域生態系において重要な役割を担っている。イシガイ科は, 国内で15種確認されており, 内, 11種が環境省レッドデータブックに指定されている[1][2][3][4]。イシガイ科の保全は急務であり, 本科が豊富に残存している水域で良好な生息環境について調べることは, 本科の保全にとって重要である。

本研究の対象水域である青森県東部に位置する姉沼では, イケチョウガイ *Hyroipsis schlegeli*, ヨコハマシジラガイ *Inversiunio jokohamensis*, カラスガイ *Cristaria plicata*, フネドブガイ *Anemina arcaeformis*, タガイ Sinanodonta japonica, とヌマガイ *Sinanodonta lauta* を含むドブガイ属 *Sinanodonta* spp. といった多くの種が生息し, 種によっては多数の生息分布が確認されている[6][7][8]。本水域では, 前述の複数種にとって良好な環境が担保されていることがうかがわれるが, 種ごとの生息環境の違いや, 分布の要因は明らかになっていない。種数および種ごとの生息個体数が多い水域での生息環境を把握することは, 生息環境が劣化している他水域の本科の保全に役立つ。

本研究は, 湖沼のイシガイ科の生息環境評価法の開発を目指した基礎研究と位置づけ, 青森県東部に位置する姉沼を事例として, 夏季における宿主魚種の把握および分布の推定, 水質, 物理条件, 餌条件を把握し, Habitat Evaluation Procedure （以下, HEP)を用いて, イシガイ科の生息分布が成立する環境を評価することを目的とした。

2. 対象水域および方法

対象水域を, 青森県東部に位置する姉沼（40°42’ N, 141°20’ E)とした。総面積1.56㎢, 湖岸長7.6㎞, 最大水深 4.3m, 平均水深 1.3m, の淡水湖である[9]。本水域は, 南側から姉沼側と中津川が流入し, 下流側で汽水湖である小川原湖につながっている。沿岸には人工護岸が施されておらず, ヨシ *Phragmites australis* やガマ *Typha latifolia* が多数繁茂しており, 沿岸帯からやや離れた地点には, ヒシ *Trapa japonica* の小群落が点在する。

本研究では, 評価手法として HEP 用いた。HEP は環境要因ごとの適正指数（Suitability Index 以下, SI)と,

それらを結合したハビタット適正指数（Habitat Suitability Index 以下，HSI）で表される。また，適正指数はそれぞれ 0（不適）～1（最適）で表される。

HEP の手順に従い，姉沼で採取した，イシガイ科 3 種（イケチョウガイ，ヨコハマシジラガイ，ドブガイ属）を対象に，生息に必要な生存条件を既存の資料や文献によって整理し[1][10][11][12][13][14][15][16][17]，SI の適正値を決定した。また，SIを目的変数とし，生存必須条件（水深，DO，クロロフィル a，ヨシ帯からの距離，底質の粒度）を説明変数とした。

姉沼全域（36 地点）にて，説明変数である生息必須条件について測定を行った。生存必須条件の一つである「ヨシ帯からの距離」には，宿主魚種の生息分布が反映されている。イシガイ科は植物プランクトンを餌資源としている可能性が高いため，クロロフィル aを生息必須条件の1つとした。イケチョウガイ，ドブガイ属とヨコハマシジラガイでは，底質粒度において生存必須条件が異なっている知見を得ため，異なる SI の適正値を設定した。なお，水深は，2016 年 7 月 12 日，9 月 27 日に超音波ドップラー流向流速計（SonTek/YSI 社 Hydro Surveyor M9）を用いて測定し，DO およびクロロフィル a は，2016 年 9 月 16 日に多項目水質系（Hydrolab/DS5X）を用いて測定を行った。底質粒度は，2016 年 9 月 16 日にエクマンバージ採泥器（15×15×15 ㎝）を用いて底質を採取し，採取した底質を乾燥機で約 110℃，24 時間乾燥させた。乾燥させた底質を，篩にかけ，粒形ごとの重量構成割合を構成した。篩はそれぞれ，19mm（粗礫），4.7mm（中礫），2mm（細礫），0.85mm（粗砂），0.25mm（中砂），0.075 ㎜（細砂）を用いた。

前述の方法で得られた測定値を用いて，SIを算出し SI モデルを作成した。これらの SI を結合させる際に，生存必須条件のどれか一つを欠けるとなると，本科の生息地に不適であると評価できるように，本研究では幾何平均法を用いて HSI を算出し，HSI モデルを作成した。また，6 次メッシュ（1 区画 125×125m）で作成した姉沼マップを図示し，グリッドごとで評価値に応じて色分けを行い，イシガイ科3種の生息分布ポテンシャルを評価した。

本研究で行った評価が適切かどうか判断するため，検証可能なグリッド，すなわち，HSI 評価されたグリッドにおいて，イシガイ科が実際に採捕されたか否かを，既存のデータを踏まえて検証した。

3. 結果および考察

SI の適正値は，水深 0m の時に SI を 0 とし，40 ㎝以上の時 SI を 1 とした。DO は 0mg/lの時に SI を 0 とし，5mg/l以上では DO が高く，本科の生息密度が高いという知見を得たことから，SI を 1 とした。クロロフィル a が 5μg/l未満の地点では本科は生息しないとの知見から，クロロフィル a が 5μg 以上の時は SI が上昇し，10μg/l以上を 1 とした。宿主魚類のヨシ帯との距離は，宿主魚類がヨシ帯から離れるほど本科の生息密度が低くなることから，ヨシ帯からの距離が 770m 以上では，SI を 0 とし，0m では SI を 1 とした。底質の粒度は，イケチョウガイとドブガイ属は泥質環境を好むことから,シルト，砂では SI を 1とし，礫では 0.2 とした。ヨコハマシジラガイは，砂礫底の環境を好むので，砂，礫では SI を 1 とし，シルトでは SI を 0.3 とした。

SI を結合させ，姉沼の 36 地点各々の HSI を算出した結果，イケチョウガイ，ドブガイ属は HSI が 0～0.77（標準偏差 0.29）であり，ヨコハマシジラガイでは 0～0.91（標準偏差 0.30）であった。これらの値を用いて，HSI モデルを作成し，イシガイ科を評価した結果（図 1, 2），沿岸帯では HSI が高く，特に南西部はイシガイ科 3 種類において HSI が高かった（0.77～0.91）。また，ヨコハマシジラガイは北部において生息しにくい環境であるという評価となり，イケチョウガイ，ドブガイ属はやや沖帯では，生息しにくいという評価となった。イシガイ科 3 種において沿岸帯からグリッドまでの距離が離れるほど HSI が低くなることが分かった。また，グリッドごとで沿岸帯から沖帯にはなれるほど SI 値が低くなったため，沖帯の環境ではイシガイ科の生息分布ポテンシャルは低いと考えられた。

本研究の評価が適切かどうか判断するため，イシガイ科が，実際に採捕されたか否かを検証した結果，沿岸帯で確認されたイシガイ科 3 種は HSI モデルに概ね適合すると考えられた。ただし，姉沼側河口付近は適合しなかった。これは，姉沼川が増水する際にこの範囲の掃流力が高まり，貝が沖帯へと流されている可能性，もしくは河口付近は貧栄養によって貝にとって生息に適さないためであると考えられる。

SI モデル作成時に他水域の知見データが組み込まれているため，本研究で得られた HSI モデルは，他水域においても，本科の生息分布が成立する環境を評価できると考えられた。

4. 課題

本研究では，南東の姉沼側のような外部の水域による影響を考慮しておらず，今後その影響に対する補正が必要である。また，より正確なモデルを作成するために，生息必須条件に挙げられている宿主魚種の分布についてより詳細なデータを得ることが今後の課題である。

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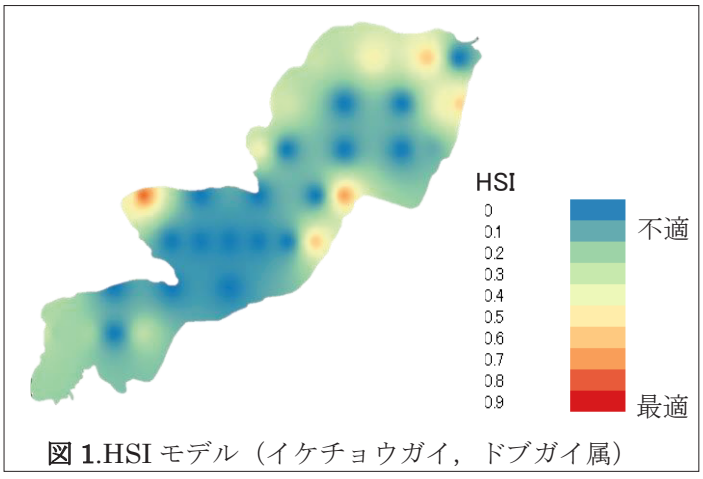

図 1.HSI モデル（イケチョウガイ, ドブガイ属）

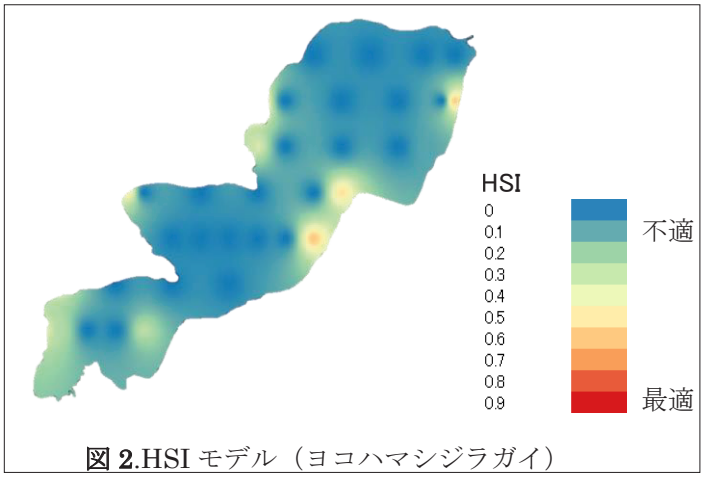

図 2.HSI モデル（ヨコハマシジラガイ）

P1-25

茨城県つくば市の都市地域周辺における野生動物の出現と土地被覆の関係

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キーワード:生態系ネットワーク、生態系管理、GIS、ロードキル

抄録

都市地域とその周辺では，野生動物は限られた区域を生息域としていると考えられる。従って，どのような特徴を持つ場所に野生動物が出現するかを明らかとすることは，都市における生物多様性保全に繋がる。そこで，本研究は，土地被覆の分類における「陸水」という特徴に着目する。河川や湖沼などの陸水環境が，都市地域とその周辺においては野生動物にとって好適な生息域であると仮定し，その検証を試みる。そのために，茨城県つくば市の都市地域とその周辺を事例とし，野生動物の出現地点と土地被覆の関係を分析する。野生動物の出現地点は，つくば市におけるロードキルのデータを用いた。また，土地被覆は国土数値情報の提供するデータに従う。GISを用いた解析により，アライグマ，イタチ，ノウサギ，タヌキ，ハクビシンの357件のロードキル記録による出現地点と，森林地域，農業地域，都市地域，陸水の土地被覆との関係を明らかとする。

1. はじめに

本ポスターは，筆頭著者の博士論文の一環を発表するものである。報告者は，人口が密集し，人工物が土地被覆の多くを占めるような，都市地域とその周辺に生息する野生動物を対象とした研究をしている。都市地域とその周辺では，野生動物は限られた区域を生息域としていると考えられる。従って，どのような特徴を持つ場所に野生動物が出現するかを明らかとすることは，都市における生物多様性保全に繋がると考える。本ポスター発表は，そのような目的で進めている研究の内，土地被覆の分類における「陸水」という特徴に着目する。河川や湖沼などの陸水環境が，都市地域とその周辺においては野生動物にとって好適な生息域であると仮定し，その検証を試みる。

2. 方法①：野生動物出現地点の収集

本研究では，茨城県つくば市を事例とした。つくば市は，東京から50kmの距離に位置する面積283.72平方メートルの市である[1]。北方は水郷筑波国定公園に指定される筑波山地域が位置するが，その他は標高 20～30メートルの平坦な地形であり，多くの河川が霞ヶ浦・牛久沼に注いでいる。

事例地における野生動物の出現データとして，つくば市廃棄物対策課が収集した，道路上で死亡した動物の回収報告に着目した。つくば市は，私道・高速道路を除く，全ての道路で発生した死亡動物個体を回収の対象としている。実際には，1月1日を除く08:30～17:00の間に市民から通報があった場合に出動し，死亡個体の出現地点，日時，動物種，写真を記録している。一部を除き，ほとんどの個体はロードキル（自動車との交通事故）によって死亡したものと推定される。

本研究では，この報告をその動物が確実にその場に出現したデータとみなすことができると考えた。そこで，2017年4月1日～2018年3月31日の期間において収集された記録から，筑波山地域を除いた都市地域とその周辺で発生した，野生の中型哺乳類（アライグマ，イタチ，ノウサギ，タヌキ，ハクビシン）の記録を抽出し，分析の対象とした。

3. 結果①:野生動物出現地点の収集

2017年4月1日～2018年3月31日の期間において収集された記録は1091件存在した。この内から，地点が特定できないなどの無効データ188件（17.2%）を除くと，903 件の記録があげられた。分析対象となるアライグマは 5 件，イタチは 14 件，ノウサギは 76 件，タヌキは143 件，ハクビシンは 119 件の計 357 件の記録があり，その他はほとんどをネコの記録（438 件）が占めた。

4. 方法②:出現地点と土地被覆分類のGISへの入力

①で明らかとした野生動物の出現地点をもとに，地点周辺の土地被覆分類との関係を分析した。土地被覆の分類は，国土数値情報ダウンロードサービス[2]から得られる「森林地域」,「農業地域」,「都市地域」,「河川」,「湖沼」のデータを用いた。これらのデータと野生動物出現地点のデータを QGIS(Version 2.18.6)に入力し，地図化した。同時に，対象とした動物種毎に出現地点の密度分布をヒートマップによ

り可視化した。

5. 結果②:出現地点と土地被覆分類の GIS への入力

結果を図 1 に示す。ポスター発表では，これらの図についてより詳細な分析結果を示す。

6. 方法･結果③：土地被覆との関係の分析

出現地点ひとつひとつについて，QGIS を用いて最も近くにある森林地域，農業地域，都市地域，陸水までの距離を算出する。この値を用いて，動物種毎に特徴的な土地被覆の特徴について，特に陸水環境との関係をふまえ考察する。詳細な結果と，結果からの考察についてはポスター発表において報告する。

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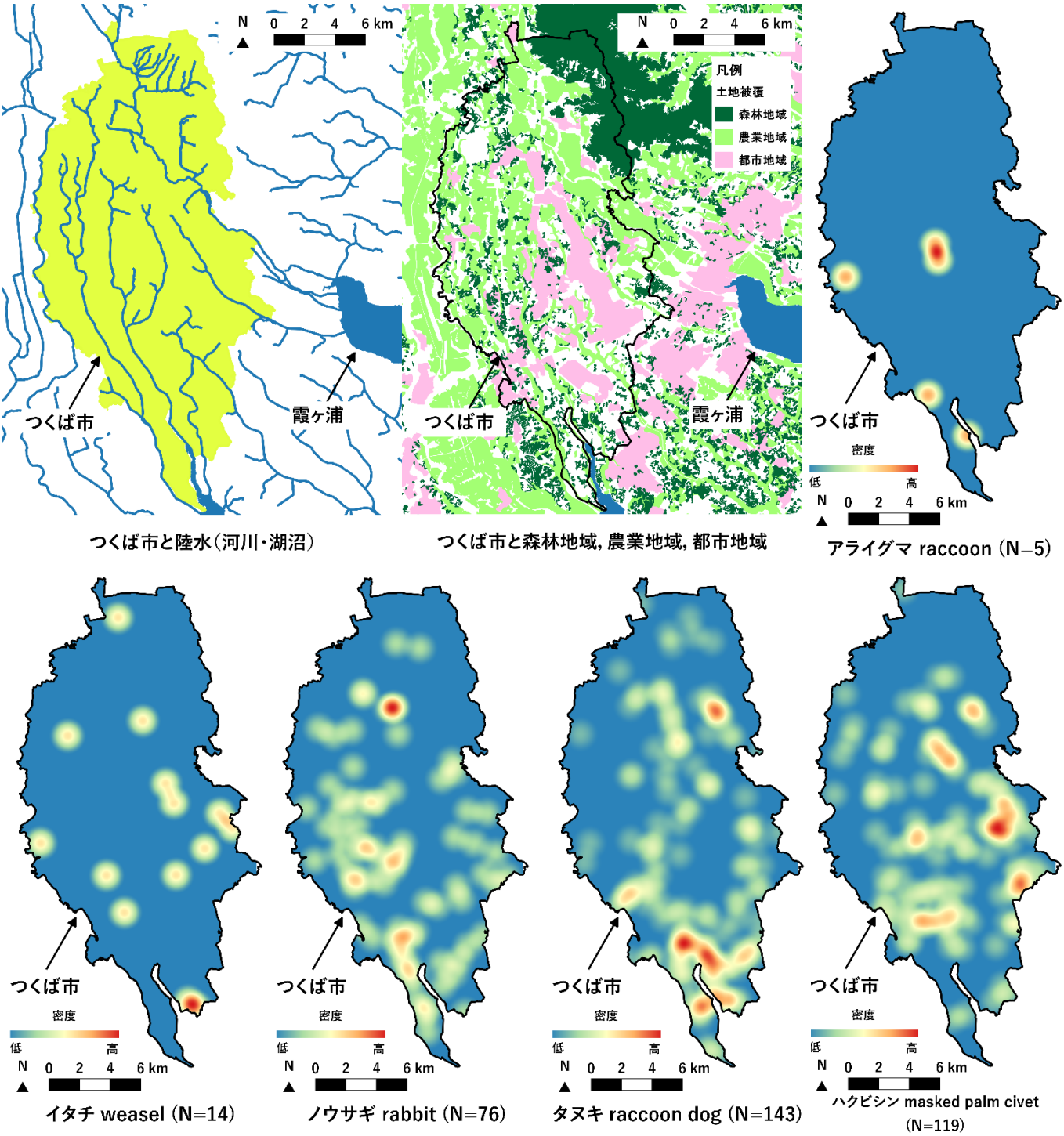

図 1 つくば市における土地被覆分類の分布と動物種毎の出現地点の密度分布

P1-26

AQUATIC ECOSYSTEM SERVICE PERCEPTIONAL PROFILE ASSESSMENT: Focus on Regulating Services and Impact to Human Health in Baloi Lake, Baloi Lanao del Norte (Philippines)

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Keywords: Ecological stress, Aquatic ecosystem, Regulating services, Health impact

ABSTRACT

This study was conducted to probe the stakeholders' perception based on their socio-economic characteristics of stress exerted to the regulating services provided by Baloi Lake and its impact to the respondents' health employing structured interview technique. Study results showed that most of the respondents are young, having blue collar job, and an old time resident in the area. They have low weekly income, who reached high school level/graduate, and residing near the lakeshore. Most respondents perceived regulating services as degraded. There existed direct relationship between the respondents' residency years in the municipality and pollution absorption by wetland perception. Also, a direct relationship is observed between their perception of impact on the respondents' health and the distance of their residence to the lakeshore.

1. INTRODUCTION

Ecosystem services are defined as the benefits that people acquire from ecosystems and the direct and indirect contributions of ecosystems to human well-being (Grizzetti *et al*., 2016; Alassaf *et al*., 2014; Millennium Ecosystem Assessment (MEA), 2005; Guerry *et al*, 2015).

Crucial aquatic ecosystem services such as in lakes include fish production, water provisioning, and recreation, and key ecosystem services connected to the hydrological cycle e.g. water purification, water retention and climate regulation. Most of these water related ecosystem services can be quantified and directly appreciated by people (Alassaf *et al.*, 2014). Understanding the connections between the natural and socio-economic systems can lead to improved and more sustainable management of ecosystems. In order to frame and craft appropriate policies and management plans that will address environmental problems and maintain ecosystem health, together with sustainable livelihood, ecosystem analysis should include aspects related to human behavior, activities, and perceptions.

Studies (*cf*. Alassaf *et al*., 2014; Cooper *et al*., 2016; Pandeya *et al*., 2016; Reynaud and Lanzanova, 2017; Quintas-Soriano *et al.*, 2016; David Allan *et al*., 2017; Guerry *et al*., 2015) on ecosystem services have been undertaken around the globe. However, very few, if not none at all, has been done on Philippine lakes, much more in Baloi Lake. Thus, this study was conducted. The socio-economic characteristics of the respondents were profiled to determine if they influence the respondents' perception on the ecosystem services provided by Baloi Lake and its impact on human health.

2. METHOD

This study was conducted in Baloi Lake, Baloi Lanao del Norte (Fig.1a and 1b). This man-made impoundment was built as National Power Corporation's Agus IV Hydroelectric Power Plant reservoir. Lying at latitude 8°7'39"N and longitude 124°11'55"E, Baloi Lake has been the water source, both for domestic use and agricultural purposes, source of freshwater fish for human consumption, and hydropower for Mindanao and some part of Visayas.



Fig. 1a. Map of Lanao del Norte (center map) showing the Municipality of Baloi. Map of the Philippines (inserted lower map) and neighboring countries emphasizing Mindanao Island (red pointer). Map of Mindanao (inserted upper map) where the Province of Lanao del Norte is situated (red pointer) (http://news.pecojon.org).

Fig. 1b. Map of Baloi Lake showing the three barangay sampling sites.

This descriptive-correlational research used respondents who were locals residing in the three barangays (i.e., Matampay, Abaga, and Nangka) located along the lake

shore. Forty (40) respondents were subjected to the structured interview.

The data collected in the study was analyzed using Systat version 13.1 and the statistical tools employed are: 1.) Descriptive statistics and 2.) Multiple linear regression. The H_o states that there is no relationship between the compared variables. The significance level is set at 0.05.

3. RESULTS

The respondents' socio-economic characteristics frequency is graphically presented in fig. 2. As reflected, most of the respondents are young (65%), having blue collar job (fisherman or unemployed), and an old time resident in the area (15 to above 25 years residency). They have low weekly income (65%), who reached high school level, or high school graduate (62.50%), and residing near the lake shore (57.50%).

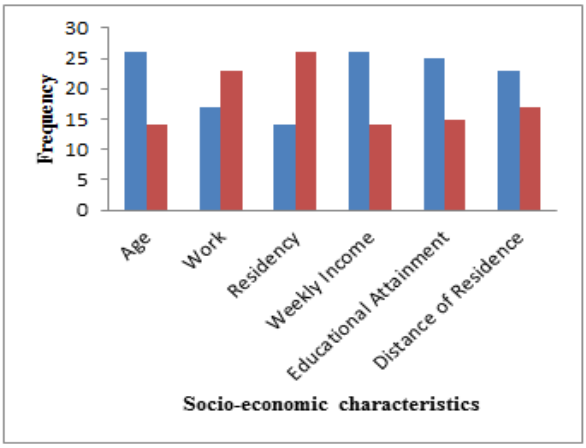

Fig. 2. The frequency distribution of the respondents' socio-economic characteristics

Table 1 reflects the summary statistics of the respondents' socio-economic characteristics.

Table 1. The summary statistics of the respondents' socio-economic characteristics

Socio-economic characteristics	N	Mean	Range	cv
Age	40	33.5±11.3	19-61	33.70
Work	40	3.3 ±1.5	1-5	46.88
Number of years living in the municipality	40	2.8±0.8	1-4	31.33
Weekly income	40	6.5±1.8	5-11	27.96
Educ. attainment	40	4.6±1.5	3-7	34.25
Distance of residence from the lake	40	2.5±0.6	2-5	27.17

The respondents' perception on the lake regulating services and the impact on human health is graphically presented in figure 3. Most of them perceived regulating services as degraded. However, these environmental degradations were moderately affecting them, their families, and the municipality.

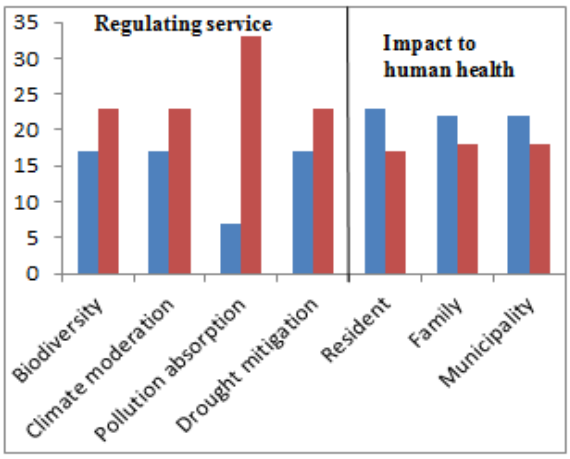

Fig. 3. The respondents' perception on the regulating services and the impact to their health

The summary statistics of the respondents' perception on the regulating services and the impact to their health is revealed in table 2.

Table 2. Summary statistics of the respondents' perception on the regulating services and the impact to their health

Range legend: 1-Not so degraded (even with some improvement of the river), 2-Not degraded, 3-Neutral, 4-Moderately degraded, 5-Strongly degraded				
Regulating Services	N	Mean	Range	cv
a. Biodiversity, food chain, plant and animal habitats	40	2.83±0.81	2-4	28.78
b. Climate moderation	40	3.57±0.50	3-4	14.00
c. Pollution absorption by wetlands	40	2.95±0.55	2-4	18.72
d. Drought mitigation	40	3.58±0.51	3-4	14.00
Range legend: 1- Not much affected, 2-Moderately Affected, 3-Neutral, 4- Affected, 5-Very much affected				
Human health impact	N	Mean	Range	cv
a. Resident	40	2.48±0.51	2-3	20.56
b. Family	40	2.51±0.50	2-3	20.43
c. Municipality	40	2.43±0.50	2-3	20.64

Table 3 revealed the respondents' socio-economic characteristics relationship with their perception on the regulating services. As shown in the table, a direct relationship ($p<0.05$) is observed between the respondents number of year residency in the municipality and their perception on pollution absorption by wetlands. The rest of the compared data did not yield relationship ($p>0.05$).

Table 3. Multiple linear regressions between the respondents' socio-economic characteristics and their perception on the regulating services (i.e. A- Biodiversity, food chain, plant and animal habitats, B. Climate moderation, C. Pollution absorption by wetlands, and D. Drought mitigation)

Socio-economic characteristics	Regulating services			
	A	B	C	D
Age	0.82	0.64	0.49	0.76
Occupation	0.68	0.26	0.29	0.75
Number of years living in the municipality	0.07	0.11	0.01**	0.38
Weekly income	0.06	0.64	0.77	0.70
Educational attainment	0.53	0.58	0.48	0.96
Distance of residence from the lake	0.31	0.09	0.08	0.48

*** highly significant at 1%*

The relationship between respondents' socio-economic characteristics and their perception of impact on their health is shown in table 4. As reflected in the table, no relationship ($p>0.05$) is observed between the compared variables except between their perception of impact on respondents' health and their residence distance from the lake ($p<0.05$).

Table 4. Multiple linear regressions between the respondents' socio-economic characteristics and their perception of impact on their health (i.e. A-. Respondent's health, B- Respondent's family health, and C- Municipality's health

Socio-economic characteristics	Impact on Human health		
	A	B	C
Age	0.30	0.06	0.33
Occupation	0.97	0.09	0.18
Number of residency years	0.42	0.76	0.84
Weekly income	0.77	0.62	0.28
Educational attainment	0.25	0.70	0.29
Distance of residence from the lake	0.01**	0.24	0.81

***highly significant at 1%*

4. DISCUSSION

Amongst the respondents' socio-economic characteristics, only their length of residence in the area was directly related to their perception on lake regulating service of pollution absorption by wetlands. That is, the greater the years that they resided in the area, the more that their perception of the pollution absorptive capacity by the lake as being greatly degraded. It is expected that the longer the respondent resided in the lake area, the more that he would be aware of the lake characteristics, that is, the lack of shoreline vegetation that can function for pollution absorption.

Lakes can have an impact on human health in relation to their being used as a water source, and being a source of pollution itself due to excessive quantities of decomposing aquatic vegetation, and the like. Amongst the respondents' socio-economic characteristics, only the distance of their residence to the lake showed a direct relationship with their perception on the lake's impact to human health. It is expected that the respondent residing near the lake would observe better some aspects of the lake that he thinks can affect his health. In Baloi Lake, the practice of the National Power Corporation is to harvest the massive amounts of floating water hyacinth and dump these hyacinths onto the shoreline. These rotting hyacinths give a foul odor most discernible to the near-shore residents. They have interpreted this foul odor as having a great impact on their health, which explains the observed relationship.

5. CONCLUSION

In conclusion, the theoretical perspective which states that the respondents' socio-economic characteristics influence their perception on regulating services and impact to human health is partially supported by this study. This is evidenced by the direct relationship revealed between residency years in the municipality and pollution absorption by wetlands perception. Also, direct relationship is shown between their residence distance from the lake and their perception of impact to their health. Other compared variables did not yield relationship.

To provide further credence to the findings of this research, replication studies should be conducted in lakes found in the provinces of Lanao del Sur and Lanao del Norte i.e. Lakes Lanao, Dapao, and Nunungan.

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P1-27

琵琶湖のハスはなぜ減ったのか？過去と現在の生態比較からの検討

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キーワード：*Opsariichthys uncirostris uncirostris*，魚食魚，成長，外来魚，環境改変

抄録

本研究は 1970 年代以降の琵琶湖の生態系変化が同湖に生息するコイ科魚食魚のハス（*Opsariichthys uncirostris uncirostris*）個体群に与えた影響について検討することを目的として，1960 年代および 2010 年代に行われた本種に関する既往研究を比較して，約50年間での同種の生態の変化を明らかにした。両期間においてハスは魚食性を示したが，現在の琵琶湖に生息するハスは 1960 年代に主要な餌であったコイ科魚類を全く捕食しておらず，ハゼ科魚類についても捕食頻度・重量ともに大きく減少した。体長・体重関係については 2010 年代の研究において特に雌の繁殖個体の体型変化が示唆された。さらに，成長に関しては成魚となる 3 歳以上の個体について 1960 年代と比べて 2010 年代では雌雄とも小型化したことが明らかとなった。以上のように，琵琶湖に生息するハスの生態は過去 50 年間で大きく変化したことが明らかになった。この原因の一つとして，湖岸環境の人為改変や魚食性外来魚の侵入等による餌資源の減耗が，ハスの食性変化を通じて成長や体型を変化させた可能性が考えられた。

1. はじめに

琵琶湖固有亜種であるコイ科ダニオ亜科の魚食魚ハス（*Opsariichthys uncirostris uncirostris*）の漁獲量は 2000 年代以降大きく減少し（図 1），個体数減少が懸念されている。現在は環境省レッドリストの絶滅危惧 II 類に掲載されている。琵琶湖の生態系は 1970 年代以降の琵琶湖総合開発事業による湖岸環境の改変や外来魚類の侵入などの影響を受けて大きく変化してきたと考えられており，ハスの漁獲量減少も過去の生態系変化と関連する可能性がある。ハスの保全策を検討するためには，過去の生態系変化によって個体群がどのような影響を受けてきたのかを明らかにする必要がある。

琵琶湖に生息するハスの基礎生態は 1960 年代初頭に詳細な調査が行われたが[1,2]，2010 年以降研究事例が再び増えている[3,4,5]。そこで本研究では，1960 年代および 2010 年代に琵琶湖のハスを対象とした食性，体型および成長を扱った既往研究の結果を比較して，ハスの生態が約 50 年間でどのように変化したのかを明らかにし，1970 年代以降の琵琶湖の生態系変化がハス個体群に与えた影響を検討することを目的とする。

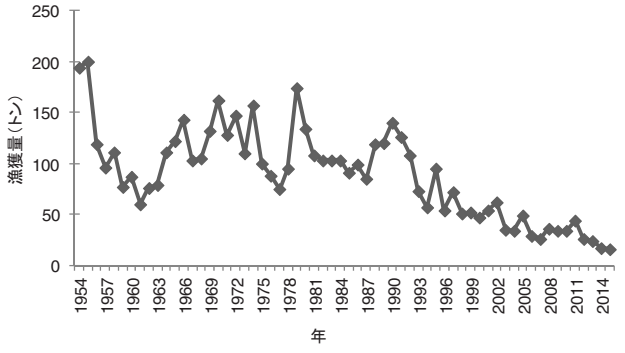

図 1 琵琶湖におけるハスの漁獲量の推移
（滋賀県水産統計より作成）

2. 対象とした先行研究と比較の方法

異なる研究から得られた結果を直接比較するために，調査の季節，期間，場所，方法，得られた標本数等の詳細が記述されている既往研究 5 件（表 1）を対象に，食性，体長・体重関係，成長に関する共通の指数や数式とその係数を比較した。具体的には，食性に関しては供試個体の消化管内容物から得られた餌種ごとの出現比（ある餌種を捕食していた個体の割合）と重量比（消化管内容物総重量に対するある餌種の総重量の割合），および供試個体の空腸率（供試個体における餌を捕食していなかった個体の割合）を，体型については供試個体の標準体長と体重（湿重量）から推定した体長・体重関係の回帰式（対数変換）を，成長に関しては供試個体の鱗の年輪を用いた齢査定から推定した von Beltaranffy の成長式における各係数と各齢における推定体長をそれぞれ比較した。

3. 結果

1960 年代の成長に関する研究[2]および 2010 年代の研究[3,4,5]の実施期間は夏季または秋季が中心であったため，本研究では上記季節を比較対象とした。

表 1 比較対象とした先行研究の概要

（文献 No.は末尾の引用文献の番号と一致する）

文献 No.	調査年	調査項目
1	1963	食性, 成長, 体型
2	1963-1968	成長（雌雄別）
3	2013	食性
4	2013	成長（雌雄別）, 体型
5	2015	食性（空腸率）, 体型（雌雄別）

食性：1960 年代、2010 年代共にハスは魚類を主に捕食しており, 成長に従って魚食率が増加する点も両期間で共通した。しかし, 個々の餌種に着目すると, 1960 年代に中・大型個体（標準体長 120mm 以上）において主要な餌であったコイ科魚類（出現比：0～37.5%, 重量比：0～81.8%）が[1], 2010 年代の調査では全く確認できなかった[3]（図 2, 3）。また, 1960 年代には中小型個体（標準体長 180mm 以下）において主要な餌種であったハゼ科魚類（出現比：17.4～78.9%, 重量比：9.9～66.9%）は[1], 2010 年代は出現比（0～4.5%）・重量比（0～0.7%）[3]ともに少なかった（図 2, 3）。空腸率は 1960 年代では 27.2%[1]であったが, 2010 年代では 51.7%[3] および 83.1%[5]であった。

体型：対数変換した体長・体重関係式を比較した結果は図 4 のようであった。1960 年代と比較すると, 複数の年齢群を対象とした 2013 年の研究では体型に差が見られなかったが[4], 産卵群を中心とした 2015 年の研究では体型に関する定数の推定値が小さく, 特に雌の産卵個体に関しては体型の小型化が示唆された[5]。

成長：von Beltaranffy の成長式における成長係数は 1960 年代には雄 0.41, 雌 0.40 であったが[2], 2010 年代には雄 0.25, 雌 0.22 であった[4]。また, 同式における推定最大体長は, 1960 年代では雄が 277mm, 雌が 254mm であったが, 2010 年代での研究では雄が 274mm, 雌が 269mm と推定された。von Beltaranffy の成長式によって推定された年齢別の標準体長を比較した結果, 特に 3 歳以上の個体に関して雌雄ともに 2010 年代では 1960 年代よりも小型化していた（図 5）。

4. 考察

食性に関してはハスが魚食性である点は共通したが, コイ科魚類やハゼ科魚類など 1960 年代にハスの主要な食物であった魚類の利用が近年では減少したことが明らかとなった。1970 年代以降, これらの魚類は湖岸開発による抽水植生帯の減少や魚食性外来魚であるオオクチバス（*Micropterus salmoides*）等の侵入の影響によって個体数減少が指摘されている[6,7]。在来魚類の資源減耗が魚食魚であるハスの食性変化をもたらした可能性が示唆された。

体型および成長については, 1960 年代に比べて大型魚（3 歳魚以上あるいは標準体長 130mm 以上[5]）における小型化が示唆された。ハスにおける成長は若魚期におけるプランクトン食から魚食への食性変化が重要であると考えられており[1], 餌資源の減耗による食性変化が近年の成長低下につながった可能性が考えられる。琵琶湖のハスの産卵群を構成する繁殖個体は 3 歳以上の個体が中心であるため[2,5], 成長の低下は繁殖機会の減少につながる可能性が懸念される。

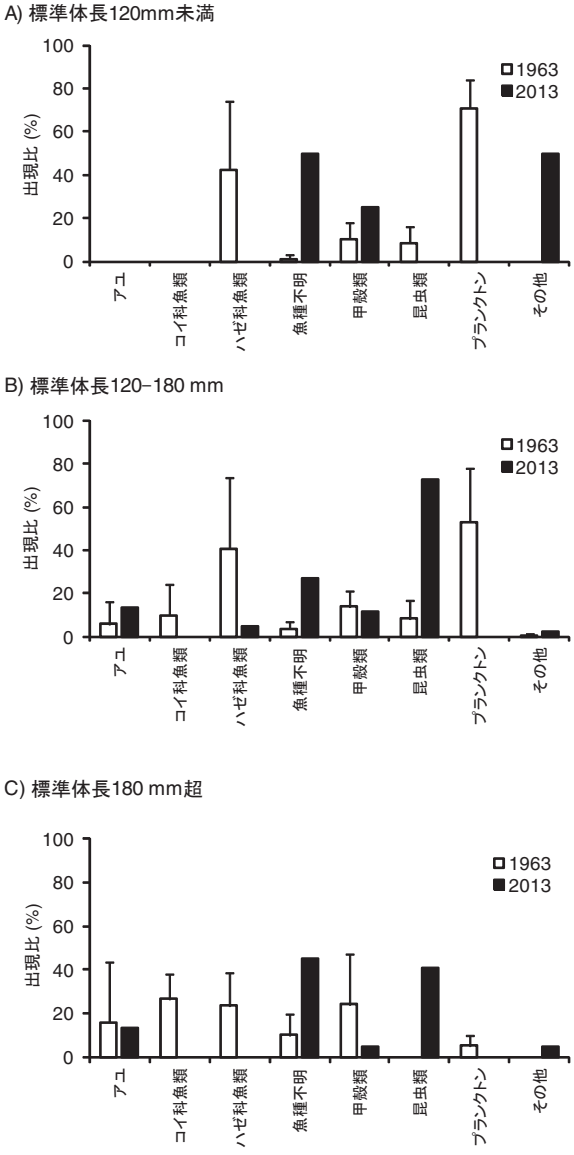

図 2 ハスの消化管内容物に関する出現比の比較

（引用文献[1,3]より作成, エラーバーは標準偏差）

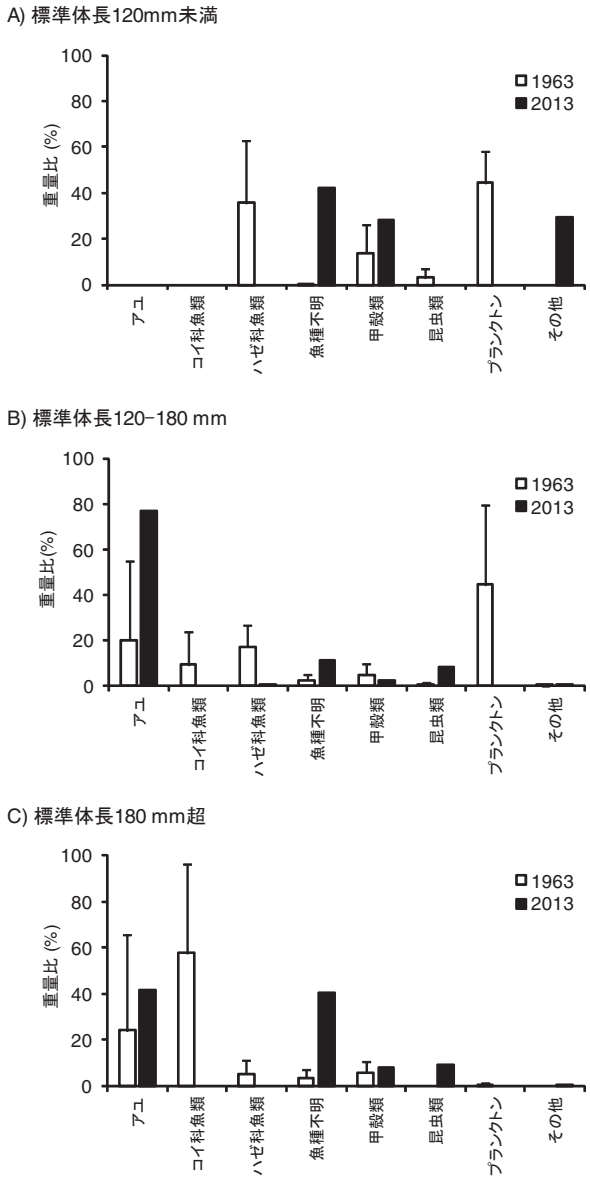

図 3 ハスの消化管内容物に関する重量比の比較
（引用文献[1,3]より作成，エラーバーは標準偏差）

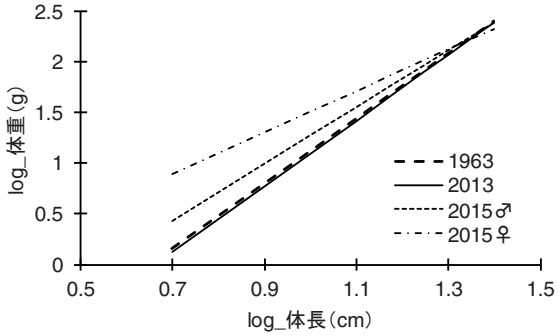

図 4 ハスの体長・体重関係式（対数変換）の比較
（引用文献[1,4,5]より作成）

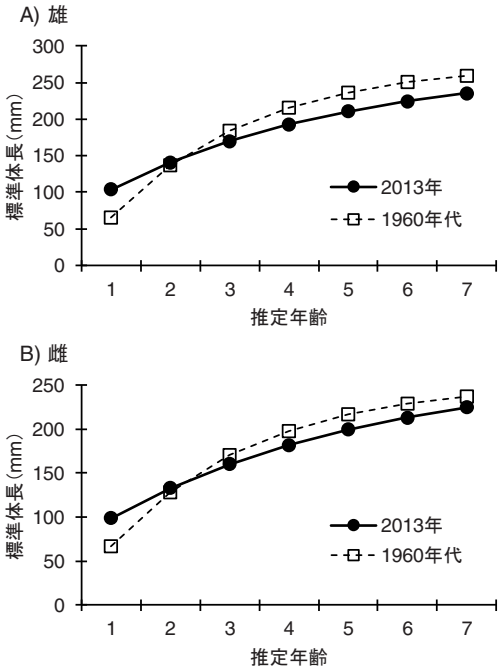

図 5 ハスの von Beltaranffy の成長式の比較
（引用文献[2,4]より作成）

5. 結論

本研究では，1970 年代以降の生態系変化に伴う在来魚類の資源減耗が魚食魚であるハスの餌資源利用を変化させ，さらに産卵群を構成する大型魚の小型化につながった可能性を示唆した。今後，具体的な保全策を検討する上で，本研究が示唆した生態変化が個体群動態に及ぼす影響を明らかにする必要がある。

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P1-28

Environmental condition, distribution, and structure of aquatic plant communities of the rivers and irrigation channels around the Lake Suwa, Nagano Prefecture, central Japan

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Keywords: endangered species, invasive alien species, aquatic plant, Lake Suwa, irrigation channel

ABSTRACT

Latterly, the loss of biological diversity of aquatic plants has become an important issue by water pollution and development in the Lake Suwa. For the conservation of the aquatic plant communities, it was necessary to grasp the condition of the rivers and irrigation channels around this lake, but there was little knowledge. Therefore, the purpose of this study was to know the environmental condition, distribution, and structure of aquatic plant communities of the rivers and irrigation channels around this lake to conserve particularly these endangered species. We chose two investigation areas from the northern part and the southern part of the lake. Vegetation and environmental conditions of the riverside communities were investigated in 2015. All investigation plots were 661, and the area of one quadrat was 1square meters. The dominance of the appearance species in each plot were measured. And, the environmental conditions were measured and recorded as follows; water quality, agricultural and dredging managements and so on. Furthermore, we carried out hearing investigation about the management situation. All of the number of appearance species was 75. Particularly, the number of endangered species was 17. Eleven types of communities were distinguished by a TWINSPAN classification. These were primarily classified into three river types, four spring water types, and four lowland weed types. The environmental condition such as quality of bottom or the quality of the water was different in the northern part and the southern part of the lake. It was thought that they influenced difference in species composition.

1. INTRODUCTION

In Japan, decrease and the extinction of the aquatic plant become the problem now. Lake Suwa is the biggest lake in Nagano Prefecture (Fig. 1). Therefore, many aquatic plants have ever grown it in the Lake Suwa. However, recently, the loss and decrease of biological diversity of aquatic plants has become an important issue by water pollution and development in this lake. In addition, there are few studies on aquatic plant of the Nagano Pref. middle southern district. For the conservation of the aquatic plant communities, it was necessary to grasp the condition of the rivers and irrigation channels around lake Suwa, but there was little knowledge [1], [2]. Consequently, the purpose of this study was to know the environmental condition, distribution, and structure of aquatic plant communities of the rivers and irrigation channels around this lake to conserve particularly these endangered species.

2. METHOD

We chose two investigation areas from the northern part and the southern part of the lake Suwa. The northern part is in Suwa city. And the southern part is in Okaya city and Shimosuwa-machi. The altitude of this study area is 750m from 790m. And, the native vegetation of the lowland of Suwa district is summer green Broad-leaved forest.

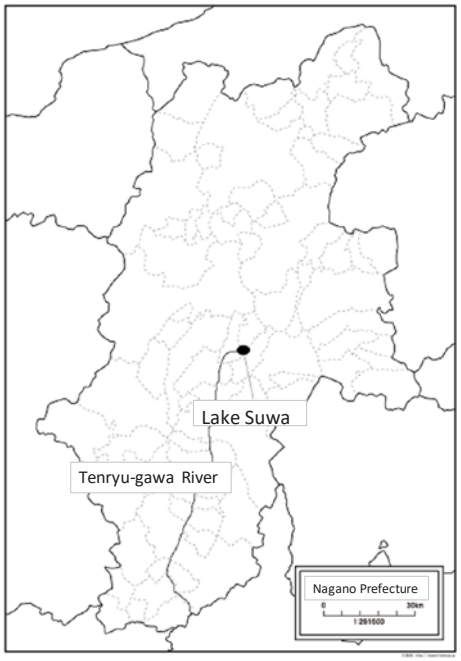

Fig. 1 Location of study area

We carried out distribution of aquatic plant, vegetation, and environmental conditions survey in autumn from summer of 2015. The number of investigation plots were 661. Each quadrat plot size was 1 ㎡. We recorded all appearance species name in study plot. And, the dominance of the appearance species in each plot were measured. The environmental conditions were measured and recorded as follows; water quality, flow velocity, structure of channel, quality of bottom, agricultural and dredging managements and so on. In addition, we carried out hearing investigation about the management situation.

Statistical analyses

We carried out the community analysis by a TWINSPAN classification and a detrended correspondence analysis (DCA).

3. RESULTS

The number of all of appearance species was 75. Particularly, the number of endangered species was 17, such as *Sparganium japonicum* Rothert, *Hydrilla verticillata* (L.f.) Royle, *Potamogeton oxyphyllus* Miq., *Potamogeton octandrus* Poir. var. *octandrus*, *Potamogeton wrightii* Morong, *Ranunculus nipponicus* Nakai *var. submersus* H.Hara. On the other hand, invasive alien plants such as *Elodea nuttallii* (Planch.) St.John and *Cabomba caroliniana* A.Gray were cofirmed. The number of alien plant was 8.

All investigation plots were classified mainly three types; river type, lowland weed type, and spring water type by TWINSPAN (Table. 1). River type had 3 sub types (①, ②, ③). Those types were established in the river with some width of rivers in mainly the southern part of the lake (Table. 2). Particularly, in river types, submerged plants such as *Potamogeton octandrus* Poir. *var. octandrus* and *Hydrilla verticillata* (L.f.) Royle appeared and dominance. But, invasive alien plant *Cabomba*

Table. 1 Composition and structure of aquatic plant communities in each type. The numerical value shows the frequency of appearance.

number of appearance species	15	26	36	17	26	18	29	36	13	14	11
Main community type	Rriver type			Lowland weed type				Spring water type			
species name ＼ community type	①	②	③	④	⑤	⑥	⑦	⑧	⑨	⑩	⑪
indicater species											
Hydrilla verticillata (L.f.) Royle	5	1						1			
Potamogeton wrightii Morong	3										
Potamogeton crispus L.	4	1	1		1			3	+		+
Cabomba caroliniana A.Gray	2	1						+			
Potamogeton oxyphyllus Miq.	+	2		1							
Potamogeton octandrus Poir. var. octandrus	2	2	1	1	5		+	1	+		
Trapa japonica Flerow	2	2	1								
Phragmites japonicus Steud.			4		1	1		1			
Lemna aoukikusa Beppu et Murata		1	1	5	3	2	1	1	+	1	
Persicaria thunbergii (Siebold et Zucc.) H.Gross		1	1		1	3	4	2	+		
Murdannia keisak (Hassk.) Hand.-Mazz.				1	+	4	3	+			
Commelina communis L.			1	1	1		3	1	1	+	
Sparganium japonicum Rothert	1	1	1	+	1		+	3	1	3	
Myosotis scorpioides L.					+			1	2	+	
Callitriche palustris L.				+			+	1		3	
Glyceria depauperata Ohwi var. depauperata						+				2	
Ranunculus nipponicus Nakai var. submersus H.Hara			+				+	1	+	2	+
Nasturtium officinale R.Br											2
Cardamine lyrata Bunge			+				+	1			2
common species											
Phragmites australis (Cav.) Trin. ex Steud.		2	3	+	1	5		2	+		
Zizania latifolia (Griseb.) Turcz. ex Stapf	1	5	2	+	1	5	1	1			
Elodea nuttallii (Planch.) St.John	+	1	1	1	1		1	3		1	+
Bidens frondosa L.		+	1		1		3	1	5	1	2

caroliniana A.Gray dominanced in this type ①. In this type, quality of bottom was mud or gravel .

Then, lowland weed type had 4 sub types (④, ⑤, ⑥, ⑦), and spring water type was similar, too (⑧, ⑨, ⑩, ⑪ Table. 1) . Lowland weed types were established in paddy field and the irrigation channel in mainly the southern part of the lake. Therefore, some lowland weed and hydrophyte such as *Lemna aoukikusa* Beppu et Murata and *Persicaria thunbergii* (Siebold et Zucc.) H.Gross appeared. In this type, quality of bottom was mostly mud .

Spring water types were established flashy stream or narrow irrigation channel in mainly of the northern part of the lake. In spring water type, *Sparganium japonicum* Rothert and *Ranunculus nipponicus* Nakai var. submersus H.Hara dominanced. On the other hand, invasive alien plant *Elodea nuttallii* (Planch.) St.John dominanced in only one type. Quality of bottom in spring water was gravel or cement.

4. DISCUSSION

As a result of investigation, we were able to confirm that many endangered aquatic plants still grew in the rivers and irrigation channels around the Lake Suwa. River type was important community to conserve aquatic plant in the southern part of the lake. On the other hand, in the northern part, spring water type was most important one. The environmental condition such as quality of bottom or the quality of the water was different in the northern part and the southern part of the lake. It was thought that they influenced difference in species composition. However, we confirmed the predominance of invasive alien plants.

5. CONCLUSION

It was thought that it was important that we maintained a variety of location environment to conserve aquatic plant communities. And, we confirmed that the extermination of invasive alien plants was most important problem.

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Table 2. Environmental conditions. The numerical value shows the mean. Means, in a column, are statistically different at $P<0.05$, when they share no common letter. The comparisons were made using the scheffe.

Main community type	River type			Lowland weed type						Spring water type		nonvegetation
Community type	①	②	③	④	⑤	⑥	⑦	⑧	⑨	⑩	⑪	⑫
width of channel (m)	17.12a	0.81c	1.83c	9.30ab	1.45bc	6.58b	2.44bc	0.92c	0.98bc	1.28bc	1.15bc	1.5c
water depth (m)	1.20a	0.13ce	0.21ce	0.44b	0.08de	0.32bc	0.27cd	0.09ce	0.08ce	0.16ce	0.07ce	0.13e
water temperature (℃)	9.9	8.7	11.2	9.5	8.2	13.1	13.1	9.7	12.4	14.2	14.9	12.7
pH	7.6	7.1cd	7.2c	7.5cd	7.3	7.7abd	7.9a	7.2bcd	7.6	7.8abd	8.0	7.8ab
EC (μs/cm)	195abcd	455fg	368cdefg	258cdef	498g	183a	248abcf	402bcdefg	291	237abcf	231	241ab
DO (mg/cm)	11.41	6.21	7.82	9.41	7.22	9.38	9.16	6.73	8.68	8.45	8.32	9.11
oxygen saturation (mg/L)	104.2a	54.6d	73.7	84.7	63bcd	91.5abc	89.7abc	61.4d	83.0	84.8	84.6	87.9ab
flow velocity (m/s)	0.06	0.01bc	0.03c	0.03c	0.03bc	0.45a	0.15bc	0.04bc	0.10	0.27	0.41	0.27ab

P1-29

Paper title : Fishing Grounds and Closed Fishing Areas of Lake Baringo, Kenya

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Keywords: Fish resources maps, closed fishing areas, geographical migration

ABSTRACT

A monthly sampling exercise was carried out twice in February–June 2011 and February-April 2012 in Lake Baringo to identify and map the fishing, breeding and nursery grounds. The ultimate goal was to set aside closed fishing areas for fish breeding and wildlife conservation, thus enhancing sustainable management and mitigate conflicts in the lake. Fishing grounds were identified by visiting the sites where fishing gears had been set and establishing the geographical positions where gears were set using a GPS.

In the southern zone of lake there were three major fishing grounds during the 2011sampling period. These were: i) along the eastern shoreline of lake between the mouths of Rivers Ngasotok and Molo, ii) along the western shoreline between the mouths of Rivers Perkerra and Kapthurin and iii) there area between Lesukut Island and mouth of River Ngasotok. During the same period, fishing ground in the central zone was identified around Kampi ya Samaki, Kokwa and Samatiany islands towards the north. In the northern zone, fishing grounds was located between Rongena Island and Komolion.

During the high lake water level (2012), there was a substantial geographical migration of the fishermen particularly to the intermittent lake and areas which were hitherto land. The geographical migration of the fishermen was probably motivated by migration of fish in large numbers to the intermittent lake.The fact that some fishing grounds fall within the legal closed fishing areas implies that enforcement of fisheries laws is not effective or is not being done at all.

1. INTRODUCTION

Lake Baringo is a shallow equatorial lake is located on the eastern arm of the Rift Valley in Kenya. The lake situated between latitudes 0° 30'and 0° 45''N and longitudes 36° 00'and, 36° 10''E at altitude of 975 m (Figure 1). It is has a surface area of 137 km^2 and drains a total area of 6820 km^2 (Ssentongo, 1974).

Until 1970 the fishery used to be the economic mainstay of the local population and supported a fish processing factory at Kampi ya Samaki market. The fish factory collapsed in 1986 and has not been revived up to date due to lack of adequate fish catch from the lake for processing (R. Chelagat, pers. comm.). In the 1960s the annual total landing for tilapia was over 600 tonnes and by 1984, it had declined to less than 3 tonnes (Hickley *et al*., 2004). To revive the fishery and increase production, mainly two regulatory measures were applied before: closed fishing season and use of fishing gear of certain minimum mesh size (gillnet) and hook size. The regulatory measures were meant to allow fish stocks to recover and for sustainable exploitation. However, the efforts to improve the fish stock by closing lake did not yield much. The lake stakeholders' suggested that closed fishing areas as management technique to improve the stock should be applied (Muli *et al*., 2009). The stakeholders suggested that maps of the lake resources be developed showing among others things, the fishing grounds, closed fishing areas and their geographical positions for gazetting by the ministry in charge of fisheries management. At the moment there is no gazetted map showing the closed fishing areas as is the case for Lake Naivasha (Fisheries Act, 1991). Fishing grounds in this paper is defined as

place where fishermen catch fish in the lake. These are the areas where fishermen know; on the basis of empirical knowledge and expect to catch commercial fish species and on a daily basis set their fishing gears (W. Chepkir Fisherman L. Baringo pers. comm.). Major conflicts in the fishery are between wildlife conservationist, hospitality industry players and fishermen on the other hand. The conservationist's objective is to preserve wildlife and to keep the lake healthy. On the hand, fishermen complain that wildlife should be eradicated from the lake as they destroy their fishing gears and maim and kill human beings. In addition motorised boats which ferry tourists to view the lake and wildlife destroy their gear. The aim of the study was therefore to map the fishing grounds *vis-a-vis* the designated legal closed fishing areas as defined by fisheries act (Fisheries Act, 1991).

2. METHOD

A monthly sampling exercise was carried in Lake Baringo twice in February–June 2011 and February-April 2012 to identify and map the fishing grounds. The two periods represented the wet and dry seasons respectively.

To ensure that the sampling was representative of the whole lake area, transects were taken covering all geographical grids of the lake. All major zones of the lake i.e. south, central and north were sampled. In addition, all river mouths and bays were also sampled. The sampling was done between 8 am and 2 pm because that is the time when most fishermen are in lake. Generally, after 2 pm the lake is rough due to high waves, making navigation difficult and hard to locate fishing gears. All the fishing grounds were identified by visiting the sites where fishing gears had been set. Fishing sites were accessed using a boat powered by an outboard engine. The sites where the gears were set were located visually from a distance by their buoys. This technique was adopted following the Fisheries Act article 44 (1) which states that: "Any fishing gear set or placed in or on water shall be marked with a clearly visible buoy so that it can be seen both during the day and night by a vessel a hundred and fifty metres away from the position of the gear'' (Fisheries Act, 1991). Once at site, the gear was lifted, examined and the following information recorded: i) Type of fishing gear (gillnet, long-line, hand-line), and ii). Geographical positions where gears were set were identified using GPS (Model Garmin 72H). Other data which was collected was abundance and geographical positions of wildlife. The wildlife recorded included Hippopotamus (*Hippopotamus amphibius*) and Nile crocodiles (*Crocodylus niloticus*). Data on wildlife was used to map wildlife territories. This is important as there are human-wildlife conflicts in the lake as wildlife destroy fishing gears.

In laboratory, the computer program Arc-View GIS (Environmental System Research Institute, Inc., Redlands, CA) was used to develop a map showing location of various gears in lake. Fishing gear locations and wildlife location in the lake were plotted on the geo-referenced map. The areas with high concentration of fishing gears set were delineated by drawing polygons covering the larger extent around them. Thus a map showing the major fishing grounds were developed (Figure 1). According to the Fisheries Act (Fisheries Act, 1991) the legal closed fishing areas are the areas within a three kilometre radius of the river delta and estuary.

3. RESULTS

Overall, 216 and 135 fishing gears were recorded in the study in 2011 and 2012 respectively. The fishing gears observed were long lines, gill nets and hand lines. Long lines and gill nets were the dominant gears used in the fishery. There was no significant difference in gear composition in the two different sampling periods ($\chi 2$ 0.05, 2 = 4.8827, P > 0.05). However, there were substantial differences in geographical location setting of various fishing gears and also changes in size (area) of the major fishing grounds in the lake over the between the two sampling periods. Fishing takes place in the entire lake, with a concentration of fishing effort in particular areas as depicted by high concentration of fishing gear set (Figure 1). In the southern zone of lake there were three major fishing grounds during the 2011 sampling period. These were: i) along the eastern shoreline of lake between the mouths of Rivers Ngasotok and Molo, ii) along the western shoreline between the mouths of Rivers Perkerra and Kapthurin and iii) there area between Lesukut Island and mouth of River Ngasotok. During the same period, fishing ground in the central zone was identified around Kampi ya Samaki, Kokwa and Samatiany islands towards the north. In the northern zone, fishing grounds was located between Rongena Island and Komolion. During the high lake water level (2012), there was a substantial geographical migration of the fishermen particularly to the intermittent lake and areas which were hitherto land. The geographical migration of the fishermen was probably motivated by migration of fish in large numbers to the intermittent lake. Figure 1 shows that legal closed fishing areas are located in the southern zone of the lake only. Most of the large wildlife (hippopotamus and crocodiles) territories lay within the legal closed fishing area (Figure 1).

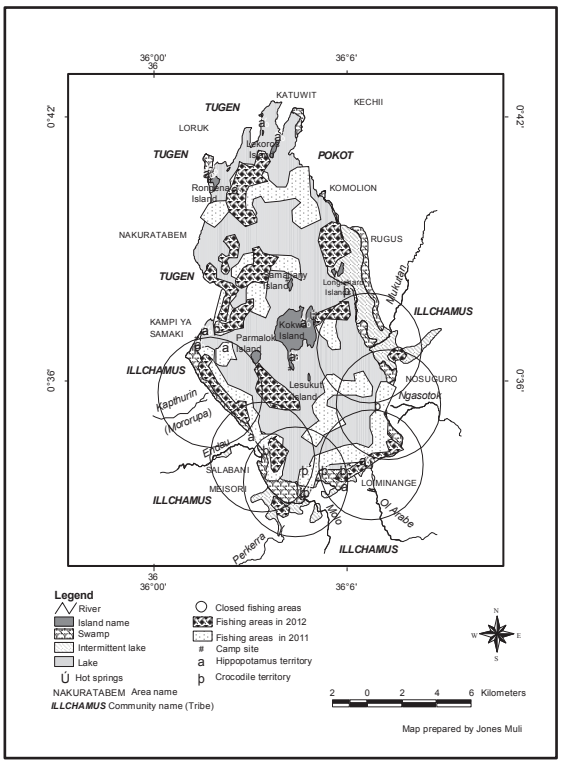

Fig. 1. Fishing grounds and legal closed fishing areas

4. DISCUSSION

Delineation of fishing grounds and closed fishing grounds in the maps provided distinctive visual representation of where fishing takes place in the lake which is easy to understand at a glance. Moreso the map can be easily understood by stake-holders of different backgrounds and education levels. The maps among others, i) show the areas where fishermen fish illegally and need to be persuaded to stop fishing, ii) guide fisheries department where to conduct patrols to protect the legal closed fishing grounds, iii) can be used for future delineation of the lake for various purpose e.g. areas for closed fishing areas, fishing areas, wildlife zones. The maps can be used as a management tool and would be important in sensitization and drawing of management/conservation measures.

Distribution pattern of fishing gear set in lake may reflect fish distribution in lake. The largest concentration of fishing gear in central zone around Kampi ya Samaki, Kokwa and Samatiany islands towards the north is indicator of higher density of fish in this area compared to other zones. Incidentally, the area of high fish density is also the deepest in the lake. These findings are in conformity with findings of Mlewa *et al.* (2005).

Since some of fishing grounds fall within the legal closed fishing areas (Fisheries Act, 1991), they are therefore potential sites of conflict between the commercial fishers and biodiversity conservationist (hoteliers, tour guides, wildlife conservationist, fishery's managers and research scientists). Some of the closed fishing and biodiversity conservation area are also territories of large wildlife namely Hippopotamus and Nile crocodiles which attract tourist to the lake. Boat rides to view wildlife is major source of revenue for the local hospitality and tourism investors. Fishing immature fish in the closed fishing areas that are breeding and nursery grounds contribute to the depletion of fish stock and is an unsustainable practice which should be done away with. Respecting the role of closed fishing areas to protect immature fish, spawn or spawning fish such as lungfish which breed in the swamp (Mlewa and Green 2006) and potamodromous fish such as *Labeo* and *Barbus* spp could partly assist the stock to recover and for sustainable exploitation. Maintenance of closed fishing and biodiversity conservation areas is of mutual benefit to all the lake users and therefore is a priority.

5. CONCLUSION

County government of Baringo department of fisheries should mark clearly the closed fishing area for ease identification by the fishers. Sensitization of fishers should be done so that closed fishing area can be respected and reduce conflicts in the fishery. All the three indigenous communities Illchamus, Pokot, and Tugen that fish in lake should be involved. This would ensure no one community would feel alienated from fisheries activities, as all will participate in protecting and conserving part of their heritage.

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P1-30

魚類による湖沼から流入水路への移出状況とその関連要因

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キーワード: ため池, 魚類, 移動, 生態系ネットワーク

抄録

本研究では, 湖沼生態系の状態に強い影響を与える魚類を対象とし, 湖沼から流入水路への移出状況とその関連要因について把握することを目的とした。12の農業用ため池を対象に流入水路口においてトラップ調査を実施した結果, 最も多くの移出個体が採捕されたのはモツゴであり, 池での出現率上位 5 種で全移出個体数の約 96%を占めた。移出に関わる最も重要な要因としてコンクリート護岸率が抽出され, 護岸率が高まるほど移出が増加する傾向が確認された。また, 移出関連要因は魚類の生活様式によって異なる部分もあり, プランクトン食の遊泳魚に関する移出個体数は水路中のプランクトン密度と正の関連を示した。本研究から, 護岸など湖沼環境の人的改変が湖沼内に生息する魚類の行動に影響を及ぼしうることが示された。また, 魚類による湖沼からの移出は, 湖沼内の環境条件だけでなく, 流入水路の環境条件による影響もうけることが把握された。

1. はじめに

これまで貯水池を含む多くの湖沼において, 透明度の高い状態からアオコなどを伴う濁った状態へと変化する湖沼生態系のレジームシフトが観察されてきた。レジームシフトは多大な生物多様性消失を伴うだけでなく, 栄養塩などを変化前の水準まで戻しただけでは回復しないという特徴を持つ。このため, 各状態の維持機構や変化プロセスの解明は, 湖沼生態系の保全・管理上極めて重要な課題となっている。魚類はプランクトンへの捕食を介してレジームシフトと強く関連しており, 魚類の大量導入や除去が湖沼のレジームシフトを引き起こした事例も報告されている。一方で, 魚類個体群が湖沼外へと移出を行うケースが知られており, 近年こうした移動の有無が湖沼生態系に大きく影響することが示されている。しかしながら, こうした移出のメカニズムや関連要因に関する実証的研究は全く進んでいない。

そこで本研究では, 湖沼に生息する魚類による移出の実体を把握するとともに, 移出に関連する環境条件の把握を目的とした。

2. 方法

調査は岩手県南部に位置する農業用ため池群を対象とした。調査対象ため池の規模は水面面積にして約 0.1ha～5.6 ヘクタールであり, 周辺の主要な土地利用は水田である。いずれのため池も造成から少なくとも 100 年程度以上は経過していると思われる。

2.1 魚類の移動状況

ため池からの魚類の移出状況を把握するため, 12 か所のため池において移出個体の採捕を行った。移出個体の採捕は, ため池とその流入水路の接続口に小型のトラップを設置し, 24 時間後に回収することで行った。トラップによる採捕は 6 月, 8 月, 10 月に実施し, すべての対象池において各月 2 回ずつ行った。

2.2 ため池内の魚類相

ため池内に生息する魚類相の把握を目的として, 調査対象とした全てのため池において, 投網及び手網を用いて採捕を行った。ため池間における採捕努力量が等しくなるよう, 池の水面面積に合わせて採捕時間を調整した。

2.3 環境調査

移出に影響を及ぼしうる要因として, 池内および流入水路の環境条件について記録を行った。池内環境については水面面積, 水深, コンクリート護岸率, 植物被覆率, 溶存酸素量及び動物プランクトン密度について計測を行い, 水路環境については, 流量, 水温, 動物プランクトン密度を計測した。

2.4 分析方法

本研究ではGeneralized linear mixed model（GLMM）及び Model averaging を用いた解析によって魚類の移出に関連する環境条件の抽出を行った。解析は移出種

数及び移出個体数を目的変数とし，上記環境条件及び各池における魚食魚の在不在を説明変数とした。ランダム変数には調査月及び Principal coordinates of neighbour matrices によって作成した空間変数を用いた。また，移出種数を対象とした解析の際は池内の生息種数もランダム変数に加えた。

3. 結果

3.1 採捕概要

魚類相調査の結果，14 種の魚類が確認された。もっとも広く分布していたのはトウヨシで，対象としたすべての池で生息が確認された。2 番目に高い出現率を示したのはフナ類であり，続いてドジョウ，モツゴ，タイリクバラタナゴとなった。

トラップ調査の結果，12 種 1912 個体の池から移出する魚類が採捕された。各池の一回当たりの移出種数は 0~6 種，移出個体数は 0～651 となった。最も多く池で移出が認められたのはヨシノボリ類であり，対象としたすべての池で移出が確認された。一方で最も多くの移出個体が採捕されたのはモツゴであり，池での出現率上位 5 種だけで全移出個体数の約 96%を占めた。以下の解析では，当該 5 種（タイリクバラタナゴ，モツゴ，フナ類，ヨシノボリ類，ドジョウ）を対象とする。

3.2 移出に関わる要因

移出個体数は調査季節間で大きな差はなく，ANOVA の結果いずれの魚種個体数，種数についても季節間で有意な差は認められなかった。Model averaging の結果，池からの移出に影響を及ぼす 要因として護岸率が抽出され，種数・個体数いずれについても護岸率が高まるほど移出が増加するという傾向が確認された（表 1）。さらに，流入水路の流量も全体的に移出と正の関係にあることが示された。また，遊泳魚に関しては流入水路の水に含まれるプランクトン量も関連要因として抽出され，移出に対して正のインパクトを及ぼしている傾向が確認された。一方で，既往研究で報告されている酸素条件や捕食者の影響については，タイリクバラタナゴにおいて魚食魚の存在による正の影響が認められたものの，本研究においては確認されなかった。

表 1　GLMM 及び model averaging による推定結果

Model	Variable	Estimate	Adjusted SE	z	P
移出種数					
	コンクリート護岸率	**2.227**	**0.361**	**6.176**	**< 0.001**
	水深	**-0.711**	**0.245**	**2.901**	**0.004**
	水路流量	**0.201**	**0.074**	**2.729**	**0.006**
	水路水温	0.407	0.405	1.004	0.315
移出個体数					
タイリクバラタナゴ					
	コンクリート護岸率	**3.125**	**0.720**	**4.338**	**< 0.001**
	水路水温	0.864	1.006	0.859	0.390
	魚食魚の生息	**0.255**	**0.109**	**2.339**	**0.019**
	水深	0.620	0.469	1.321	0.187
	水路流量	**0.322**	**0.161**	**2.001**	**0.045**
モツゴ					
	コンクリート護岸率	**5.518**	**1.037**	**5.323**	**< 0.001**
	水路プランクトン密度	**0.263**	**0.089**	**2.948**	**0.003**
	水路水温	**3.729**	**1.387**	**2.689**	**0.007**
フナ類					
	水路プランクトン密度	**0.109**	**0.041**	**2.626**	**0.009**
	水路水温	-0.669	0.638	1.049	0.294
	溶存酸素量	0.433	0.287	1.512	0.131
ヨシノボリ類					
	コンクリート護岸率	**3.531**	**0.623**	**5.669**	**< 0.001**
	水路水温	1.181	0.624	1.891	0.059
	水路流量	**0.317**	**0.112**	**2.829**	**0.005**
ドジョウ					
	コンクリート護岸率	**1.648**	**0.700**	**2.352**	**0.019**
	水路水温	1.304	0.875	1.490	0.136
	水深	**-1.010**	**0.365**	**2.770**	**0.006**

4. 考察

本研究結果から，ギルドによる違いは認められたものの，湖沼内に生息する魚類による周辺水式への移出には主に湖沼の護岸状況が影響を及ぼしており，コンクリートによる護岸割合が高まるほど移出は増加することが把握された。これまで湖沼外への移出を扱った研究では捕食者の存在や貧酸素からの退避が関連要因として指摘されていたが，本研究により湖沼環境の人為的改変も魚類の移出に大きな影響を及ぼしうることが明らかとなった。

湖沼における自然湖岸は，植生帯の発達や環境の異質性創出を促すものであることから[1]，湖沼沿岸の改変は魚類にとって重要な生息環境の喪失をもたらすと考えられる。また，本研究では池内における分布状況について把握していないものの， 護岸化は湖沼内における魚類の分布変化及び集合を引き起こすことが指摘されている[2]。これらのことから，本研究で確認された護岸率と移出の関係は，護岸化に伴う好適な生息環境の消失及びそれに伴う魚類の行動変化が湖沼外への移出を促進する可能性を示唆していると考えられる。

遊泳魚の 2 種（フナ類，モツゴ）では，水路におけるプランクトン量が移出と正の関係にあることが確認され

た。本研究で対象とした池の中には，魚類の成長には不十分であるほど動物プランクトン密度が低い池がいくつか認められた。加えてプランクトンとの関係が認められた 2 種はいずれもプランクトン食者であることから，両種は餌環境を求めた移動を行っていたと推察され，これは湖沼内の魚類による採餌目的の移出を報告した既往研究を支持するものであると考えられる。

本研究では，タイリクバラタナゴ，ヨシノボリ類及び種数について流入水路の流量が移出と正の関連を示した。流入水が湖沼内の魚類に及ぼす影響についての研究例は多くないが，季節的な増水などが移動を促す事例が知られている[3]。しかしながら，本研究においては調査月間に移動量の差は認められなかったことから季節的移動による影響はないものと思われる。一方で，水の流れは多くの場合に魚類の移動を促すことが知られており，河川性の魚類については流量と移動の関係について多く報告されている[4]。こうした傾向は河川生活への適応を反映していると解釈されており，本研究においても移出と流量の関連が認められた上記の 2 種は当該地域において湖沼よりも水路に多く生息する種であった[5]。また，湖沼内において好適な生息場や餌を求めて探索的な行動をとる個体にとって，大きな流量を持つ水路は発見しやすいということも示唆しているのかもしれない。

5. 結論

・湖沼沿岸の護岸化が魚類による湖沼から移出に強い影響を与える

・移出メカニズムは魚類のギルドによって異なる

・魚類による湖沼から移出は，湖沼内の環境条件だけでなく，流入河川・水路の条件による影響も受ける

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P1-31

外来魚チャネルキャットフィッシュは流れに応じて遊泳方法と浮力を調節する

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キーワード:侵入外来生物

抄録

特定外来生物チャネルキャットフィッシュ(アメリカナマズ)の野外における遊泳行動を、日本国内の3つの水域(霞ヶ浦・利根川・矢作川)で、動物搭載型の行動記録計を用いて調査した。湖のチャネルキャットフィッシュは、うきぶくろ内にためる空気の量を減らして体を水より重く保ち、尾びれを振らずに潜降するグライド遊泳を活用して効率よく泳いでいた。河川のチャネルキャットフィッシュではグライド遊泳はほとんどみられず、うきぶくろに空気を保持し、体密度を水と同程度に保って泳いでいた。本種は、流れの有無やエサ環境の異なる湖と河川で、それぞれに適した浮力状態と泳ぎ方を選択することで、エネルギー消費を抑えていると考えられる。

1. はじめに

水中を泳ぎまわる多くの魚類は、鰾(うきぶくろ)に空気をためて浮力を得ることで自らの体重を支え、泳ぐ際のエネルギー消費を低く抑える一方、十分な浮力の得られない状況下においても、尾びれを振らずに潜降する「グライド遊泳」を活用することで、移動コストを低く抑えるとされる[1, 2]。

日本国内の複数の水系で近年定着しつつあるチャネルキャットフィッシュ(アメリカナマズ)[3]は、気道とつながった鰾をもつ開鰾魚(かいひょうぎょ)で、口から空気を飲み込んだり吐き出したりすることで、鰾内の気体量を速やかに変化させて自身の浮力を調節できる。過去に行なわれた研究で、チャネルキャットフィッシュはグライド遊泳により移動コストを大幅に抑えられると予測されており[4]、この効率的な遊泳方法をもつことが、本種が国内で湖沼から河川まで幅広い環境に分布を広げられた要因のひとつと考えられる。

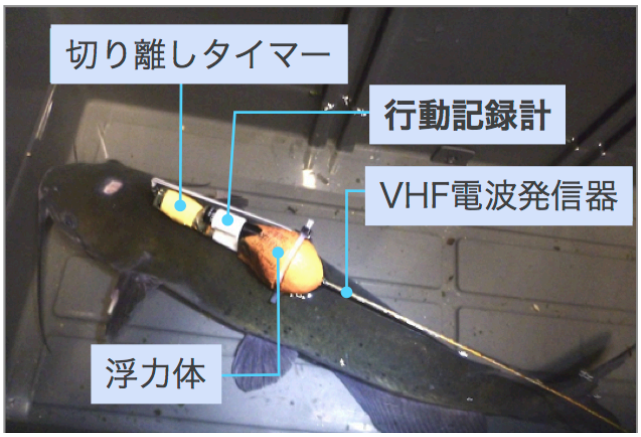

図 1 記録計を装着したチャネルキャットフィッシュ

2. 方法

本研究では、行動記録計(ORI400-D3GT または W190-PD3GT; Little Leonardo 社製)を装着したチャネルキャットフィッシュ(図 1)を霞ヶ浦、利根川、および矢作川で放流し(図 2)、自動切離しシステム[5]を用いて、数日後に記録計のみを回収した。記録計から得られた、遊泳時の深度(1Hz)および3軸方向の加速度(10Hz ないし 16Hz)のデータを元に、鉛直移動に伴う浮上・潜降時の遊泳強度(動的体加速度; ODBA[6])を算出して比較することで、本種がどのような浮力状態を選択し、どの程度の頻度でグライド遊泳を活用していたかを解析した。さらに、流れのある河川(利根川・矢作川)と流れのない湖(霞ヶ浦)で魚の浮力状態や遊泳行動を比較し、異なる環境でどのように振る舞っているかを検証した。

3. 結果

2012-2015 年に行なった野外実験により、霞ヶ浦で 6 個体、利根川で 2 個体、矢作川で 3 個体のチャネルキャットフィッシュ(全長 42.0-59.1cm, 体重 1.24-4.16kg)から、9-100 時間の行動データを取得した。

浮上時と潜降時の尾びれの振りの強さを個体ごとに比較した結果、霞ヶ浦の個体は自重を支えるだけの浮力をもたず(負の浮力)、体が水より重い状態にあった一方、河川の個体は自重を支えるだけの浮力をもち(中性浮力)、体密度は水とほぼ同等であった(図 3)。

グライド遊泳の起こる頻度を応答変数とした一般化線形混合モデル(GLMM)を用いて、AIC に基づくモデル選択を行なった結果、グライド遊泳は、潜降時に、泳ぐ

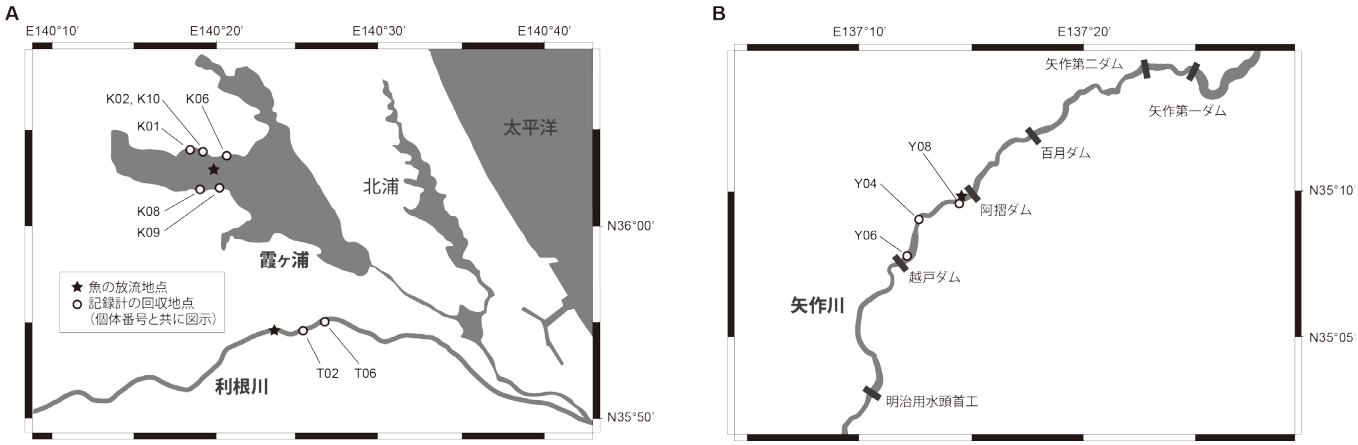

図 2　霞ヶ浦、利根川（A）および矢作川(B)における個体の放流地点と記録計の回収地点

深度が深くなるほどより多くみられた（表 1）。また、湖のチャネルキャットフィッシュはグライド遊泳を頻繁に行なっていた一方、河川の個体ではグライド遊泳はあまり見られなかった（表 1，図 4）。

4.　考察

一般に、深場で高い水圧がかかって鰾内の空気が圧縮されたり、個体がやせていたりすると、浮力が小さくなり、水中で受ける重力が大きくなる分、楽にグライド遊泳できる。グライド遊泳が河川よりも湖で多くみられたことから、湖のチャネルキャットフィッシュは体を水より重い状態に保ち、積極的にグライド遊泳を活用していると考えられる。いっぽう、河川にすむチャネルキャットフィッシュは、流れに逆らって尾びれを振り続ける必要があり、グライド遊泳で尾びれを振らずに受動的に泳ぐことは困難だと想定される。そもそも、体が水より重い状態で尾びれを振り続けるには体を持ち上げるエネルギーが余分に必要となることから、流れのある河川では、中性浮力を保持することで消費エネルギーを抑えていると考えられる。

流れ環境の異なる湖と河川でみられたチャネルキャッ

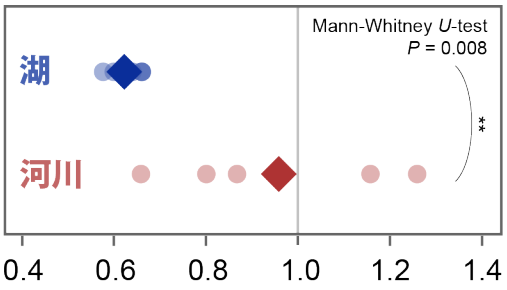

図 3　遊泳努力量から推定した個体の浮力状態

表 1　AIC 最小となったグライド頻度予測モデル

Variables	Coefficient	s.e.	*z*	*P*
Depth	**0.15**	**0.02**	**8.79**	**< 0.001**
Descent phase	**2.21**	**0.07**	**33.6**	**< 0.001**
Condition Factor	0.26	0.13	1.93	0.053
Lotic habitat	**-2.52**	**0.71**	**-3.57**	**< 0.001**

（リンク関数: log，誤差分布: 二項分布）

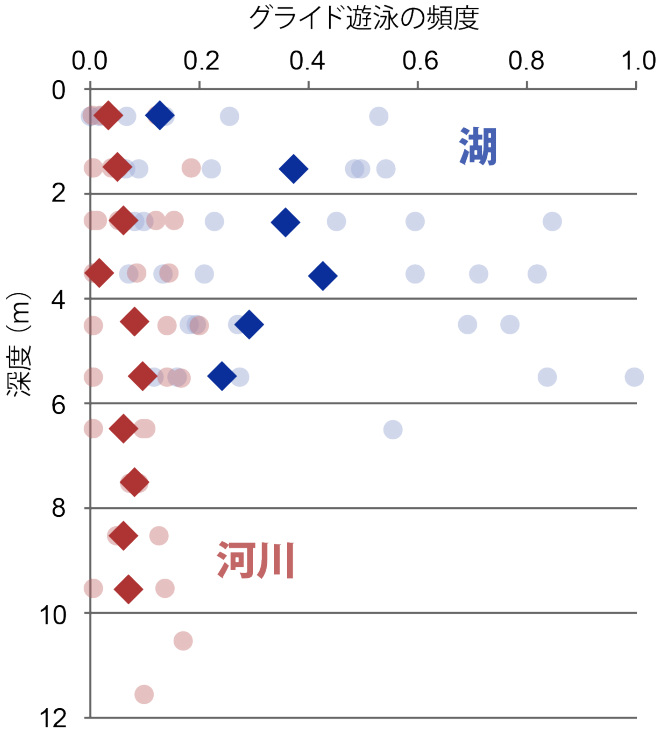

図 4　深度別にみた潜降時のグライド遊泳頻度

トフィッシュの行動の違いは、水域ごとの採餌生態の違いを反映するものと考えられる。湖底付近で底生動物を採餌する、本種の霞ヶ浦における採餌生態[7]を反映するものと考えられる。河川では上流から流下する生物が食性の中心と報告されており[8, 9]、水面から川底まで鉛直方向に広く探索する必要があるために、体を支えるのに余分な力を必要としない中性浮力の状態を選択していると考えられた。

過去に淡水魚を対象として行なわれた研究では、うきぶくろの形態的な特徴から、流水にすむ種は体を水より重くして川底にじっと留まり、止水にすむ種は中性浮力で体を支えて遊泳コストを下げるとされてきた[10]が、本研究では逆の結果となった。これは、より多くの餌を得られる遊泳戦略をとることが、遊泳コストを上回るだけのエネルギー獲得を可能とし、その余剰分を成長および繁殖に投資することで適応度の向上に貢献すると考えられる。これは、魚類の河川環境への適応を考える上で、遊泳にかかるエネルギー消費だけではなく、摂餌によるエネルギー獲得もふまえたエネルギー収支に基づく考察が重要であることを示唆する。

5. 結論

チャネルキャットフィッシュは流れの有無に応じて浮力を調節し、生息水域の餌環境に適した遊泳方法ならびに浮力状態を選択することで、淡水環境に広く適応していると考えられる。

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P1-32

Effects of upstream reservoir regulation on the intra-annual distribution of benthic invertebrates in a large floodplain lake (Dongting Lake, China)

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Keywords: Intra-annual distribution; Benthic invertebrates; Upstream reservoir regulation; Dongting Lake; TGR

ABSTRACT

Hydrological controls from damming upstream heavily affect the flow-sediment regime and water chemistry of floodplain lakes downstream, and thus cause profound impacts on lake ecosystems, which have been widely proven. However, with this series of disturbances, the intra-annual distribution of benthic invertebrates may be affected but it is not clear by now. This research aims to explore benthic invertebrates (BI) response to hydrological process variation induced by upstream reservoir regulation, using three years (1995, 2004 and 2014. The Three Gorges Reservoir started operating in 2003) paired hydrological database and monitoring data of BI in Dongting Lake. The results showed that: the intra-annual distribution of BI significantly responded to upstream reservoir regulation, but this response was not sustained. Hydrological variation in dry season and in wet season seemed to have greater impacts on *Aquatic Insecta* while the variation in wet season has greater impacts on *Mollusca*. Sediment concentration and water chemistry were proven to be the critical variables. Sediment concentration was positively correlation with the intra-annual distribution of *Aquatic Insecta*. Flow and water level were closely related to *Mollusca* and *Oligochaeta*. Water chemistry was most closely related to *Other Taxa*. This work would provide valuable information for design of lake management strategies and upstream reservoir regulation rules.

1. INTRODUCTION

In recent years, climate variability and anthropogenic river regulation by hydraulic projects (HP) have constantly changed hydrological regime, in turn caused aquatic habitat variation in rivers and their floodplain lakes[1]. Floodplain lakes even become one of the most threatened landscapes worldwide[2]. For the conservation and management of aquatic ecosystems, many researches have tried to link hydrological variation induced by the operation of HP to the response of aquatic biota. Benthic invertebrates (BI) are often used as a target community in such researches[3]. Within this effort, most researches have focused on the positive or negative effects of the HP construction and operation, such as comparison of biological response before and after the upstream reservoir operation[4], or paired comparison of community parameters between regulated and unregulated sites[5].

However, the most significant change caused by HP is the change in intra-annual hydrological process. In order to meet the needs of flood control and water utilization, water level in non-flood season is raised and that in flood season is reduced. Besides, variations of hydrological process will inevitably result in the variations of sediment transport and water chemistry[5]. With this series of disturbances, the intra-annual distribution of benthic invertebrates may be affected. Furthermore, due to community recolonization, this effect may exhibit differences among years. But studies on this effect still remain scarce by now. This fact inhibits the development of quantitative relationships between ecological responses and anthropogenically induced hydrological alterations, which is critical important for design of lake management strategies and upstream reservoir regulation rules.

Dongting Lake, the second largest freshwater lake in China, is the first large lake downstream of the Three Gorges Reservoir (TGR). The flow-sediment regime of Dongting Lake is highly affected by hydrological controls from reservoir regulation of the main stream, which in turn contributes to affect lake biodiversity. Hydrological processes in Dongting Lake have been proven to be highly altered temporally[6]. This lake is therefore an ideal study lake for assessing hydro-ecological effects. Given these contexts, this research aims to explore BI response to hydrological process variation using three years (1995, which is before the operation, 2004; which is just after the operation and 2014, which is after 175m water storing of TGR) paired hydrological database and monitoring data of BI in Dongting Lake. The current study had two main purposes: (1) to investigate the intra-annual distribution of BI response to upstream reservoir regulation; (2) to examine the relationship between flow-sediment regime and water chemistry properties and community metrics, aiming to select key variables affecting BI.

2. METHODS

2.1. Data resources

Data of BI was collected from literatures[7-9]. All of the sample collections and treatments have been finished by the Ecological and Environmental Monitoring Center of Dongting Lake of Hunan. The sampling sites, located on the typical section in the East, South and West Dongting Lake, could reflect the overall and regional characteristics of BI in Dongting Lake. Sampling occurred in dry season (December to next March), normal season (April to May and October to November) and wet season (June to September) within each year, respectively.

Measured data of control hydrological stations in Dongting Lake, included flow, sediment concentration, water level and water chemistry properties (Nemerow index) of Chenglingji Hydrological Station, was collected from the Changjiang Water Resources Commission.

2.2. Data anylysis

Redundancy analysis (RDA) was used to examine the relationship between flow-sediment regime and water chemistry properties-community metrics (carried out in CANOCO version 4.5). RDA and Monte Carlo permutation test with 499 permutations were performed to evaluate the significance of variables separately.

3. RESULTS

3.1. Total abundance of BI in different seasons

The numerical difference of the richness among these 3 years was not significant. *Mollusca* and *Aquatic Insecta* were most abundant, accounting for approximately 41.70% and 28.90% of the total respectively.

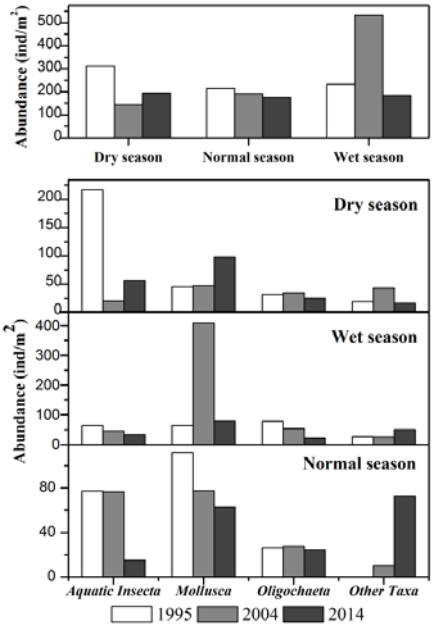

Fig. 1 BI abundance of different season and different taxa in 1995, 2004 and 2014.

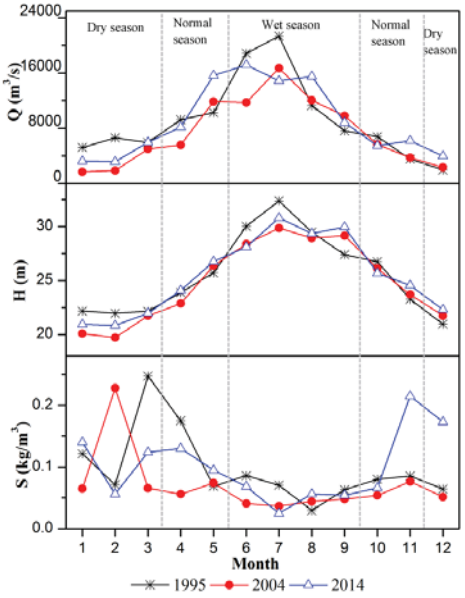

Fig.2 Flow, water level and sediment concentration of Chenglingji Station in 1995, 2004 and 2014.

Comparing the total abundance of BI in three seasons, it could be found that the difference between 1995 and 2014 was not obvious, reflected as highest in dry season and the lowest in wet season. The difference between 2004 and the other two years was significant, showing the highest abundance in wet season and the lowest in dry season. For BI composition in different seasons, the inter-annual difference in normal season was the smallest. In dry season, the abundance of *Aquatic Insecta* and *Mollusca* differed significantly. In wet season, the abundance composition in 2014 was close to that during wet season in 1995. In 2004, the abundance of mollusca was 300ind/m^2 more than that in the other two years. In addition, the abundance of *Aquatic Insecta* and *Mollusca* also differed greatly among the three seasons (Fig. 1).

3.2. Variation of hydrological properties before and after the operation of TGR

For flow and water level, the significant inter-annual differences existed in the dry season and the wet season. For sediment concentration, the significant inter-annual differences existed in the dry season and the normal season (Fig. 2).

3.3. Correlation analysis

The all canonical axes explained approximately 69.5% variance of species data, among which the cumulative explanation of the first two axes reached 69%. Monte Carlo permutation tests for the first and all canonical axes were significant (P=0.042，P=0.027, respectively). The biplot of the overall species distribution and hydrological variables was shown in Fig. 3.

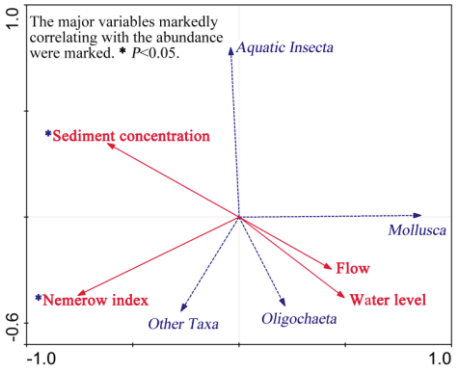

Fig. 3 RDA ordination diagram of species distribution and explanatory variables in Dongting Lake.

4. DISCUSSION

Total abundance of BI did not immediately decrease after the operation of HP or the loss of natural hydrological regime, inconsistent with the description of previous studies. Instead, it increased significantly during the wet season after the TGR operation, which may be attributed to the peak clipping effect of TGR, reducing the impacts of high flow events on BI. The short-term beneficial effects of TGR on BI couldn't be ignored. However, the peak clipping effect of TGR was sustained (flow during wet season in both 2004 and 2014 was less than that in 1995), the beneficial effects on BI was unsustained.

Abundance of *Aquatic Insecta* in dry season and that of Mollusca in wet season showed significant inter-annual differences. Hydrological variation in dry season seemed to have greater impacts on *Aquatic Insecta* while the variation in wet season seemed to have greater impacts on *Mollusca*. As organic matter carried by suspended sediment was main food source of aquatic insects, the abundance were closely linked with sediment. Flow inputs changed greatly during wet season, Mollusca showed susceptibility to flow and water level. This result was consistent with previous studies. In addition, the greater sediment content, the less stable the lake basin became. Sediment content in Dongting Lake decreased sharply due to the operation of TGR and the deposition/erosion regimes changed from a deposition-dominant to an erosion-dominant state after 2008. Although sediment content during dry season upswung in 2014 due to substratum erosion, the differences of substratum conditions might cause different responses of aquatic insects.

Sediment concentration and Nemerow index were checked out to be the major variables markedly correlating with the abundance of taxa. RDA analysis also provided further evidences that sediment concentration was positively correlation with the intra-annual distribution of *Aquatic Insecta* and flow and water level were closely related to that of *Mollusca* and *Oligochaeta*. Besides, water chemistry was most closely related to *Other Taxa*.

5. CONCLUSION

Upstream reservoir regulation could heavily affect the intra-annual distribution of BI. Hydrological variation in dry season seemed to have greater impacts on *Aquatic Insecta* while the variation in wet season seemed to have greater impacts on *Mollusca*. Sediment concentration and water chemistry were proven to be the critical variables affecting the intra-annual distribution of BI. This work would provide valuable information for design of lake management strategies and upstream reservoir regulation rules.

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P1-33

特定外来生物オオバナミズキンバイを侵入初期段階で駆除

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キーワード:特定外来生物、オオバナミズキンバイ、維持管理、外来種被害防止行動計画

抄録

2016 年度に実施した河川水辺の国勢調査(植物分布の現地調査)によりオオバナミズキンバイ群落を土浦市の霞ヶ浦(西浦)で初めて確認した。今後の河川管理に多大な影響を及ぼすと考えられたため、関係機関(学識者、茨城県、土浦市、水資源機構等)との協働により、緊急的に駆除作業を実施した。駆除作業は、学識経験者の意見と琵琶湖での現状や駆除活動を参考として、流出や拡散する前に完全除去を目標に実施した。

1. はじめに

2016 年度に実施した河川水辺の国勢調査(植物)において、特定外来種オオバナミズキンバイ(以下、「本種」という。)群落を霞ヶ浦(西浦)で初めて確認した。

本種は、南アメリカ及び北アメリカ南部を原産とする水生多年草であり、これまで琵琶湖等西日本の湖沼や河川等にて確認されている。特に琵琶湖では著しく繁茂して船舶の航行障害等の原因となっており、滋賀県が予算を確保し駆除対策を実施している。侵略性の高い外来種を根絶させるためには、一時的な侵入段階や定着初期段階における防除の重要性が強調されており、速やかな対策が必要である[1] 。

本種は、茎の断片から発根する繁殖力が非常に旺盛な水生生物で、ヨーロッパやアメリカでは水上や水中で繁茂し、他の植物の生育を阻害するなど侵略的な外来植物と位置付けられている。日本においても近年定着し、急速に分布面積を拡大しており、在来種の駆逐など生態系に係る被害が発生しつつある[2]。

このように侵略的性質が極めて高い本種を「外来種被害防止行動計画」の考えに則り、侵入初期と考えられる段階にて、霞ヶ浦から根絶させることを目指し駆除作業を実施した。

2. 駆除の必要性

2-1. 霞ヶ浦における生育環境の想定(琵琶湖との比較)

平成 25 年度より駆除を実施している琵琶湖と霞ヶ浦の生育環境を比較すると以下のようになる。

・琵琶湖南湖の平均水深は4mで、霞ヶ浦(西浦)の平均水深4mと等しく、遠浅となっている。

・本種の初期確認位置は琵琶湖が南湖下流側、霞ヶ浦は西浦上流側となっている。(図-1)

・水位変動は、琵琶湖は夏期の水位低下が大きいが、霞ヶ浦(西浦)は年間の水位変化が約 20cm と小さい。



出典:国土地理院ウェブサイト(http://maps.gsi.go.jp/)

図-1 霞ヶ浦(西浦)と琵琶湖南湖の比較 (地理的要因)

・霞ヶ浦(西浦)は琵琶湖南湖より富栄養状態にある。(図-2)

・年間の平均気温は、大津が 14.9℃、土浦が 14.4℃とほぼ等しい。

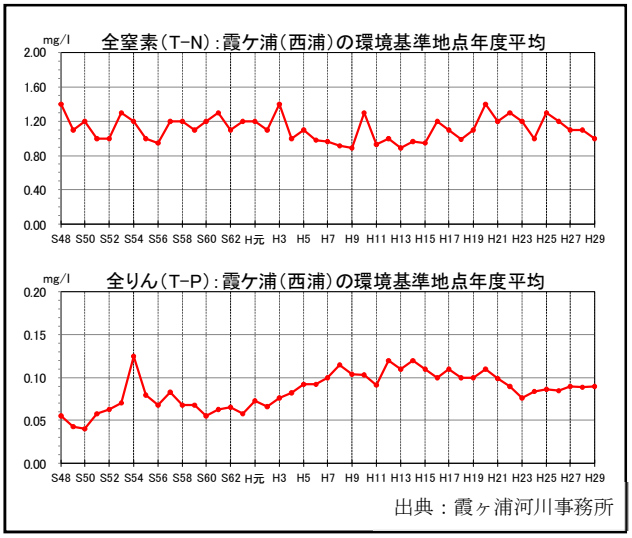
2-2. 霞ヶ浦での定着の可能性について

霞ヶ浦(西浦)は、琵琶湖の南湖と同程度の面積ながら、水質は富栄養状態にあり、遠浅で水位変動が小さいため、本種の生育には琵琶湖より適していると考えられる。また、確認場所が土浦入り最上部であり、支川桜川からの流入による湖流の影響や筑波おろしに代表される北西風により、駆除を行わない場合には、琵琶湖の例により2～3年程度で西浦右岸全域への拡大が懸念される。このように霞ヶ浦における本種の生育環境として、マイナス要因は見当たらず、むしろ琵琶湖南湖より分布拡大に対する条件がそろっており、定着し分布を拡大する可能性が非常に高いと考えられた。

2-3. 関係機関との情報共有

外来種は、定着が進むにつれて対策にかかる費用や

霞ヶ浦の水質変化



琵琶湖の水質変化

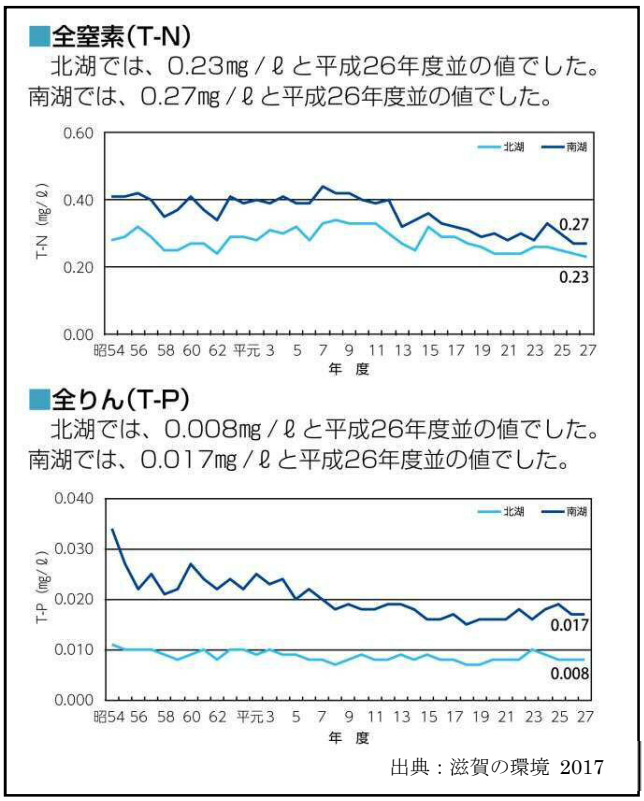


図-2　霞ヶ浦(西浦)と琵琶湖南湖の比較（水質的要因）

労力等のコストが大きくなり、対応が困難になる[1]。また、本種の分布が広がると、漁業被害、水質悪化、取水障害や排水障害などの社会的被害が発生することが懸念されたことから、茨城県、地元土浦市及び水資源機構などの関係機関と情報共有し早急な駆除対策を連携して講じることとした。

3.　駆除作業

3-1. 生育状況

生育状況等を詳細に確認し駆除作業計画に反映するために、現地調査を実施した。現地調査は、当事務所の河川水辺の国勢調査アドバイザー及び茨城県生物多様性センター職員と行い、繁茂状況（生育範囲、茎及び根の状況、開花・結実状況、在来種の混成状況、水深など）の確認を行った。本種群落が最も広範囲に密生する地点で、群落の広がりは 10m×8m 程度であった。湖面側の廃棄ボート付近では密な群落を形成していた。堤防側一帯では抽水植物のマコモやドクゼリ等と混成していた。廃棄ボートにより湖面側への拡散が抑えられていたが、湖面上に伸び出した茎が一部確認された（図-3）。

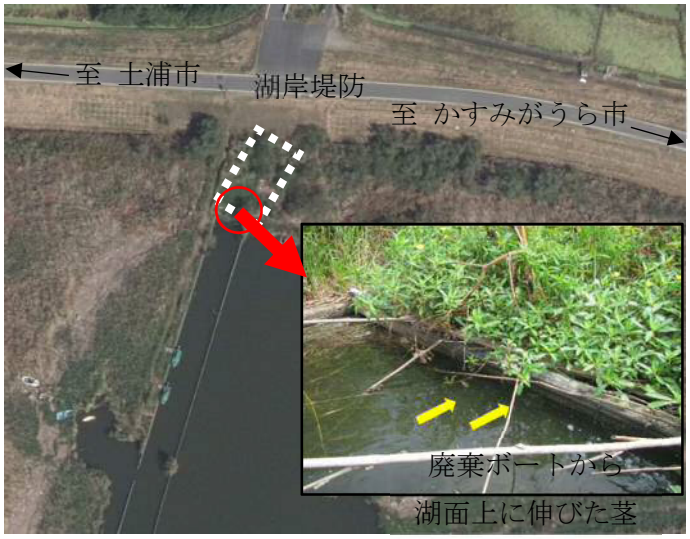


図-3　オオバナミズキンバイの生育状況

3-2. 駆除作業

駆除作業は、琵琶湖での現状や駆除活動の例を参考にするとともに、学識者にご指導いただき実施した。実施時期は、台風などの影響により水位が上昇して流出・拡散する前の平成 29 年 8 月に行った。

本種は、ちぎれた断片から植物体が再生して拡大する性質をもっているため、駆除作業は特に丁寧な除去が必要であり、人力を主体とした手作業による抜き取りを基本として実施した。群生している範囲は、湿地状で足場が悪いことや地表面を効率よくはぎ取る作業性も考慮し、重機（パワーショベル）による掘削を併用し駆除した。掘削等により細分化された葉、茎、根等の流失を防止するためオイルフェンスを設置して作業を実施した。飛散、流出した植物片は、タモ網等により速やかに回収・対応が出来るように作業員を配置し対応した。

駆除した植物は、逸脱防止シートを敷設した集積所に一旦集め、順次仮置き場へ運搬した。仮置き場にて乾燥させることにより、焼却処分の負担の軽減を図った。

乾燥させた植物は、土浦市の協力により、一般廃棄物として運搬し、焼却処分を行った。

4. 経過状況

駆除作業により、霞ヶ浦への侵入初期段階での駆除は達成できたと思われたが、作業後1ヶ月もすると、抜ききれなかった根などから再生したとみられる個体が確認された(図-4)。また、今年の 4 月にも 1cm 程度の小さい



図-4 平成 29 年 9 月の状況



図-5 平成 30 年 4 月の状況

葉を付けた芽生えが 30 株ほど確認されている(図-5)

5. まとめ

侵略的外来種オオバナミズキンバイの発見から早期に駆除することにより、台風などによる流出・拡散することなく、駆除費用、生態系への影響を最小限に抑えることが出来た。

発見後から、学識者及び茨城県自然博物館とは、本種の生育状況、駆除方法や駆除時期について助言をいただくなど情報共有に努めた。駆除作業に際しては、茨城県、地元土浦市及び水資源機構等の関係する機関と連携することにより、早急な駆除対策を講じることが出来た。

侵略的外来種の分布拡大を阻止するためには、侵入初期段階による駆除が有効であるため、今後とも関係機関との情報共有に努め、経過観察状況により連携して駆除作業を行うなど拡散防止に努めていきたい。

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P1-34

霞ヶ浦における特定外来生物オオバナミズキンバイ(アカバナ科)の防除とその後の生育状況

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キーワード:侵入外来生物, 生態系管理, オオバナミズキンバイ, 霞ヶ浦, 防除

抄録

2017 年 5 月に霞ヶ浦湖岸の排水路内にオオバナミズキンバイの生育が確認された。オオバナミズキンバイは特定外来生物に指定されており, 西日本では問題となっているが, 東日本における記録は初めてである。発見されたその年の 8 月に国土交通省を中心に, 各関係機関が集まり防除作業を行った。その後, 9 月, 10 月, 11 月, 翌年の 1 月, 4 月に経過観察を行った。その結果, 防除作業を行った場所で, 切れ端から発生したと考えられる小さな個体が少数見つかり, 走出枝から成長した個体も観察された。現在のところ大規模に分布が広がった様子は確認されていないが, 今後も継続して経過観察を行い, 必要に応じて防除作業を行い, 分布の拡大に注意を払っていく予定である。

1. はじめに

オオバナミズキンバイ *Ludwigia grandiflora* (Michx.) Greuter et Burdet subsp. *grandiflora* (アカバナ科, Onagraceae)は, 南米および北米南部原産の多年生植物である。国内では水質浄化や観賞用として流通していたものから逸出して繁茂し, 2014 年に特定外来生物に指定された[1]。2007 年に兵庫県加西市のため池で野生化が確認され[3], その後, 琵琶湖南湖で異常繁茂し[4], 和歌山県でも報告例がある[2]。本種は, 茎の断片から発根し, 繁殖力が非常に旺盛で, 日本だけでなく, ヨーロッパやアメリカでも侵略的な外来種となっている。希少種の生育地を奪うほか, 絶滅危惧の在来種ミズキンバイ *Ludwigia peploides* (Kunth) P.H.Raven subsp. *stipulacea* (Ohwi) P.H.Raven 等と交雑し, 遺伝的攪乱を引き起こすことが危惧されており[5], 早急な対策が必要である。

今回, 茨城県土浦市霞ヶ浦で, オオバナミズキンバイが初めて確認された。本報では, 発見当初の状況を報告するとともに, 国土交通省関東地方整備局霞ヶ浦河川事務所が中心となって行った防除作業後の経過について報告する。

2. 対象地および方法

オオバナミズキンバイが発見された場所は, 霞ヶ浦の北西の湖岸(土浦市手野町出島排水樋門, 田村川排水路)(図 1)である。2017 年 5 月 4 日に著者の一人である吉川によって発見された。2017 年 6 月 12 日に生育状況を調査した。その後, 2017 年 7 月 30 日に結実状況を確認した。2017 年 8 月 28 日に, 河川管理者が中心となって, 重機を用いた大規模な防除作業を行った。防除作業後の経過観察は, 9 月 27 日, 10 月 11 日, 11 月 9 日, 翌年の 2018 年 1 月 27 日, 4 月 20 日に行った。

なお, 防除作業については, 国土交通省関東地方整備局霞ヶ浦河川事務所を中心に, 国土技術政策総合研究所, 茨城県県民生活環境部自然環境課生物多様性センター, ミュージアムパーク茨城県自然博物館, 環境省関東地方環境事務所野生生物課, 国立環境研究所, 土浦市環境保全課, 農研機構農業環境変動研究センター, 霞ヶ浦漁業協同組合, その他関係者の協力を得て実施した。

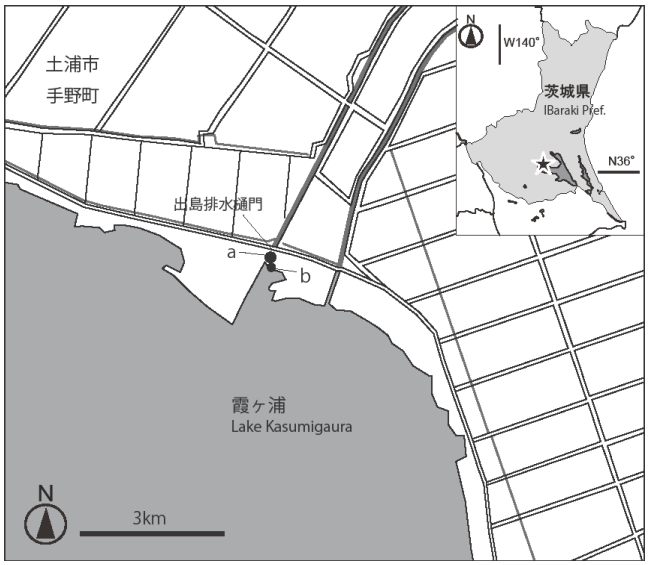

図 1. オオバナミズキンバイの生育地(a および b).



写真 1　防除前の排水路内（2017 年 6 月）



写真 2　排水路内の群落（2017 年 6 月）



写真 3　排水路内の防除の様子（2017 年 8 月）



写真 4　防除直後の排水路内（2017 年 8 月）



写真 5　排水路左岸の小さな葉をつけた個体（2017 年 9 月）



写真 6　走出枝を広げ排水路内に侵入した個体（2017 年 11 月）



写真 7　防除後の排水路左岸（2018 年 1 月）



写真 8　防除後の排水路左岸（2018 年 4 月）

3. 結果

2017 年 6 月 12 日，オオバナミズキンバイは，堤防の直下の入り江に作られたボートの停泊所横の排水路内に，約 10m×8m に一面に群生していた（写真 1-2，図 1a）。隣接して群生するドクゼリ *Cicuta virosa* L.やマコモ *Zizania latifolia* (Griseb.) Turcz. ex Stapf とともに，停泊所に停められた，使われていないボートの中へと進入していたが，そこで群落が途切れていた。また，付近のヨシ *Phragmites australis* (Cav.) Trin. ex Steud 群落内や湖の水際にも，数個体が点々と生育していた（図 1b）。しかし，その周辺ではほかに生育がみられず，広く分布が拡大していく様子はなかった。ボートの停泊所横の排水路内では，オオバナミズキンバイは，沈水部が水中で絡まるように茎を伸ばし，マット状に密に生育して，そこから

水上に伸びた茎に多数の花をつけており，2017 年 7 月 30 日には，開花個体の一部が若い果実をつけていた。ヨシ群落内から水際にかけてのオオバナミズキンバイは，小さな個体がヨシの隙間から伸びながら生育しており，開花は確認されなかった。

2017 年 8 月 28 日にオオバナミズキンバイの防除作業が行われた（写真 3-4）。作業の際は，湖岸側にオイルフェンスを設置して，切れ端の流出を防いだ。排水路内に生育するものは，重機を用いて泥ごと持ち上げて除去したほか，人力によって残った茎や根の切れ端を網ですくい取り除いた。ヨシ群落内に生育するものは，事前にヨシを刈り取った上で，人力によって根から抜き取った。抜き取った個体は，排水路左岸のヨシ群落を刈り取った場所に敷いたブルーシートの上で乾かし，乾燥したのちに，焼却処分を行った。重機による防除作業と根からの抜き取り作業は約 40 名で約 2 時間かけて行い，その後残った切れ端を網ですくう作業を 4 名で約 1 時間 30 分かけて行った。

防除作業後，2017 年 9 月 27 日～2018 年 4 月 20 日に経過観察を行った。2017 年 9 月 27 日は，排水路左岸とその周辺の裸地に，茎や根の切れ端から発生したと考えられる 1cm 程の小さな葉をつけた個体が点々と見つかった（写真 5）。これらは，防除作業の際にブルーシートを敷いた場所付近で多く確認された。排水路内には，同様に切れ端から発生したと考えられる，やや大きめの個体が水面に浮かび生育していた。その後，10 月 11 日には左岸に発生した個体が走出枝を伸ばし，排水路内侵入していた。10 月下旬に大規模な台風が到来した後，11 月 9 日には，走出枝を伸ばし排水路内に侵入した個体が，排水路右岸でもみられた（写真 6）。翌年，2018 年 1 月 27 日には，排水路内と右岸の個体はなくなっており，排水路左岸には氷が張って，個体数が急激に減少していた（写真 7）。4 月 20 日には，排水路左岸に再び，小さな個体が約 30 株見つかった（写真 8）。

オオバナミズキンバイの生育地付近で特筆すべき外来種として，防除作業前の 2017 年 6 月には，ヨシ群落内には特定外来生物に指定されているアレチウリ *Sicyos angulatus* L.の芽生えがみられたほか，防除作業の際に水際に，ツルノゲイトウ *Alternanthera sessilis* (L.) R.Br. ex DC.が生育し，防除作業後の 2018 年 4 月には，ツルノゲイトウはみられなかったが，排水路左岸の裸地にアレチウリ，セイタカアワダチソウ *Solidago altissima* L.，オオブタクサ *Ambrosia trifida* L.，オオフサモ *Myriophyllum aquaticum* (Vell.) Veldc.の芽生えがみられた。

4. 考察

オオバナミズキンバイが見つかった生育地は，堤防から降りてすぐのところであり，人が立ち入りやすい場所であることから，人為的に持ち込まれた可能性も考えられる。発見後，早急に防除作業を行ったことにより，大部分の生育個体は防除され，現在のところ広範囲の分布拡大は認められていない。

ただし，防除作業後数か月で，茎や根の切れ端から発生したと考えられる個体が，走出枝を伸ばし，排水路内へと侵入していたことから，今後も分布が拡大していく可能性が十分にある。また，10 月下旬の台風による増水によって，茎や根の切れ端が流されて対岸などに渡った可能性も考えられる。

今回，冬場に個体数が減少したため，オオバナミズキンバイは冬の寒さに耐えられなかったと考えられる。しかし，春には再び小さな個体が観察されたことから，今後の成長が心配される。

5. 結論

以上のことから，霞ヶ浦湖岸の排水路内で生育が確認されたオオバナミズキンバイは，防除作業により，そのほとんどが取り除かれたが，茎や根の切れ端から発生した個体が残り，完全に防除することはできていない。今後も，関係者で協力して定期的に経過観察を行い，必要に応じて防除作業を行い，分布の拡大に注意を払っていくことが重要である。併せて，生育地付近に生育するその他の外来種についても，注意を払う必要がある。

今回採集されたオオバナミズキンバイの標本は，ミュージアムパーク茨城県自然博物館に収蔵されている（INM-2-97947，INM-2-97949）。

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P1-35

The Invasive Alien Species of Freshwater Crayfish: Ecological and Economical Impacts

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Key words: invasive alien species, biodiversity evaluation, fisheries

ABSTRACT

The presence of invasive alien species in freshwater ecosystems, such as freshwater crayfish, can give a significant influence to native species and humans. This study aims to confirm species, distribution, and impact of freshwater crayfish. The study was conducted in the lake, reservoir (artificial lake), and situ (small lake) in West Java area on May to October 2017 with survey methods and descriptive analysis. Morphologically, there are two invasive alien species of freshwater crayfish in West Java, namely *Cherax quadricarinatus* and *Procambarus clarkii*. *Cherax* has been widely distributed in inland waters of West Java region. *Cherax* has been found in all lakes in altitude < 1000 meters above sea level. Meanwhile, *P. clarkii* is only found in ornamental fish traders in Bogor, which is originated from cultivation activities in Sukabumi area. Ecologically, the presence of freshwater crayfish, especially *Cherax quadricarinatus*, has decreased the population of native species of small crustaceans, such as in Lake Lido, meanwhile, in other sites it has not occurred. During the study, there has never been any incidence of freshwater crayfish as a plague vector on human. Economically, the presence of both freshwater crayfish can give a positive impact to local people, both for consumption and ornamental fish.

INTRODUCTION

The existence of invasive alien species or non-native species in aquatic ecosystems has attracted many interest, because the inclusion of invasive species into an ecosystem can effect the ecological system of its life, even also can effect the economic and social of human culture[1]. The influence of invasive species on living environments may lead to changes, such as changes in trophic interactions[2], community structure, food webs, and key species[1].

One of the most common taxa found as non-native species in freshwater ecosystems is group of freshwater crayfish. Some species of freshwater crayfish commonly found in the world as invasive species are *Procambarus clarkii* or red swamp crayfish from the northeastern regions of Mexico and southern of USA[4], *Cherax quadricarinatus* or red claw crayfish from Australian waters[5], *Pacifastacus leniusculus* from the northwestern continent of America[6], and *Orconectus limosus* originating from USA[7].

The impact of invasive species has been shown to have a significant effect on the ecosystems, specially on primary and secondary productivity in the waters[8][9]. Feeding habit of freshwater lobsters as grazer and self-burying activities can also change the condition of the waters, such as decreasing the closure of benthic algae and macrofita so clear waters become turbid because the waters are dominated by phytoplankton [10]. Another impact, the introduction of freshwater crayfish can lead to a decrease in fish abundance in aquatic ecosystems[11], as well as a decrease in the diversity and abundance of native invertebrates[11][2].

Freshwater ecosystems in Indonesia, particularly in West Java are inseparable from the phenomenon of invasive freshwater crayfish such as *Cherax quadricarinatus* and *Procambarus clarkii*. These invasive species are not only found in waters, but are also traded and widely used as ornamental lobsters. This group of freshwater crayfish is believed to give a change to trophic interaction of freshwater ecosystem in West Java. Both freshwater crayfish of *P. clarkii* and *C. quadricarinatus* are also known as vectors of plague disease for another freshwater crustacean. This disease is caused by the parasite *Aphanomyces astaci*

which can be a deadly disease and the cause of the decrease of population of native freshwater crayfish in Europe[12][13][14]. *P. clarkii* also has the potential to bring other pathogens, such as *Batrachochytrium dendrobatidis* which is responsible for a deadly skin infection for amphibians[15]. Therefore, the study on distribution and impact of invasive freshwater crayfish, particularly is important to do. This study is expected to be a source of information for the management of invasive freshwater crayfish and to prevent or to minimize the negative impact of this species.

METHODS

This research has been conducted from May to October 2017 in freshwater ecosystem of West Java Province, include lake, artificial lake (reservoir), and small lake (situ). Identification of species of freshwater crayfish is done morphologically. Identification of the presence of freshwater crayfish was conducted through direct observation and interviews. Confirmation the presence of plague was analyzed using molecular analysis and collaborated with researchers from the Czech University of Life Science and the University of South Bohemia, Czech.

RESULTS

Morphologically, there are two invasive alien species of freshwater crayfish in West Java Province, namely *Cherax quadricarinatus* (red claws crayfish) and *Procambarus clarkii* (red swamp crayfish). Red claw crayfish is native species from southern of New Guinea and northeast of Australia, and red swamp crayfish is native species form America continent. *Cherax* or red claw crayfish has been widely distributed in inland waters of West Java region, so this species is found in almost all research area, particularly at altitude < 1000 meters above sea level (msl). In some research locations that have altitudes > 1000 msl, red claw crayfish is not found there. Meanwhile, *P. clarkii* is only found in cultivation activities in Sukabumi. Both freshwater crayfish are found as consumption commodities and ornamental fish.

Ecologically, the presence of *Cherax* is suspected to have decreased the population of other crustacean species, like *Macrobrachium sintangensis* in Lake Lido. Even according Dr. Achmad Farajallah (Biologist from IPB – personal communication), the presence of *Cherax quadricarinatus* in Lake Lido is suspected to have caused the loss of two species of native shrimp waters, namely *Macrobrachium sintangensis* and *M. pilimanus*. In some other research locations, the presence of *Cherax* has not decreased the population or eliminated species of other crustaceans. However, we should always be aware of the existence of these freshwater crayfish because of the nature of these species as invasive alien species and has been proven to be an invasive alien species in some freshwaters in Indonesia.

Samples of *P. clarkii* collected from cultivation activities in Sukabumi area and from ornamental fish traders indicated carry plague pathogen. In Europe, *P. clarkii* has been the cause of extinction of native freshwater crayfish species due to the infection of crayfish plague (Souty-Grosset *et al.* 2016). During the study, there has never been any incidence of freshwater crayfish as a plague vector on human. However, we should always be aware and avoid being in direct contact with this species.

Economically, the presence of both freshwater crayfish can give a positive impact for local people as additional income from trading activities, both for consumption and ornamental fish.

CONCLUSION

Morphologically, there are two species of freshwater crayfish in West Java, namely *Cherax quadricarinatus* and *Procambarus clarkii*. *Cherax quadricarinatus* has been found in all lakes in altitude < 1000 meters above sea level. Meanwhile, *P. clarkii* is only found in ornamental fish traders in Bogor, which is originated from cultivation activities in Sukabumi. Ecologically, the presence of freshwater crayfish has reduced the population of native species, especially small crustaceans, such as in Lake Lido, but in other sites it has not occurred. During the study, there has never been any incidence of freshwater crayfish as a plague vector on human Economically, the presence of both freshwater crayfish can give a positive impact for local people, both for consumption and ornamental fish.

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P1-36

Development of a management method for the invasive water primrose (*Ludwigia grandiflora*) in Lake Biwa

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Keywords: invasive alien species, water primrose, *Ludwigia grandiflora*, herbicide, glufosinate,

ABSTRACT

Although the precise introduction route of the water primrose in Japan is still unknown, it was first recorded in Kasai city of Hyogo prefecture in 2007. And then it was found in Akanoi Bay, Lake Biwa in 2009. Water primrose has expanded rapidly and has become one of the most damaging invasive plants, currently extending to about 300,000 m^2. In the water, its dense stem becomes a habitat for mosquitoes; moreover, sediments accumulate and inhibit the flow of water. A number of physical measures have been used to control the expansion of the water primrose, including mechanical harvesters, rotovators, and hand removal, but results have largely been poor.

In order to develop measures to counter the expansion of invasive alien aquatic plants in Lake Biwa the present project aimed to identify new techniques for the removal of aquatic plants and methods for suppressing the spread of effluent water from industries. The purpose of this project is to support the development of new technologies by subsidizing those adopted by Shiga prefecture. We applied the project program and adopted an herbicide management method for water primrose control. We used Basta® as an herbicide and its effects were tested using water primroses cultured in a plastic bucket, and as expected it was completely eliminated. In addition, acute toxicity tests for aquatic organisms were conducted using Medaka (*Oryzias latipes*), Daphnia (*Daphnia pulicaria*), and Honmoroko (*Gnathopogon caerulescens*) from Lake Biwa. High safety conditions were confirmed.

1. INTRODUCTION

Lake Biwa is a lake in Shiga Prefecture with an area of about 670 km^2 in area and is the largest lake in Japan. One hundred seventeen primary rivers flow directly into Lake Biwa. However, the Seta River and the artificial Lake Biwa canal are the only rivers that discharge from Lake Biwa. The biota of this lake is very rich, as it is inhabited by around 1,100 species of animals and plants. There are also many indigenous species found only in Lake Biwa. Furthermore, Lake Biwa represents an important landing spot for nearly 50,000 waterfowl species that visit the lake every year. For this reason, it became, in 1993, one of the few wetlands in Japan registered by the Ramsar Convention.

There are records stating that the aquatic plants of Lake Biwa had been used as fertilizer and soil conditioner for agricultural land more than 1000 years ago.

Moreover, about 400 years ago, algae disputes occurred in various places with respect to the right to collect water plants from the lake.

About 150 years ago, the right to collect water plants was treated as a type of permitted fishery subject to tax payment.

As aquatic plants of Lake Biwa are also an important spawning place for fishes and shellfishes, a harvesting ban period was implemented by law in 1890, but after that, food production increase was advocated and harvesting was encouraged.

In 1930, sales from water plant (algae) were the main income for farmers, exceeding even that from shellfish and prawn harvest.

Since the mid-1950s, owing to the spread of chemical fertilizers as a result of the modernization of agriculture, algae removal and muddy algae removal is no longer performed except by some farmers practicing organic agriculture.

More recently, Lake Biwa's aquatic plants started to increase rapidly in the South Lake in the wake of the drought in 1994. In recent years, about 90% of the lake bottom of the South Lake is covered with aquatic plants during the summer, and abnormal conditions were present, owing to which natural environments, ecosystems, living environments have been considerably affected.

Therefore, in Shiga prefecture, we are promoting water

grass cutting and removal measures and the effective utilization of harevested aquatic plants in order to reestablish the conditions for aquatic plants that existed about 80 years ago.

Hiyoshi Corporation, located in Omihachiman City of Shiga prefecture, is a company that provides comprehensive support for environmental projects in a wide range of fields, such as measurement and analysis and environmental conservation. Particularly in the field of environmental analysis, we are proud to contribute greatly to the maintenance and management of natural environments such as water, soil, and air in Shiga prefecture and Lake Biwa.

To develop measures to counter the expansion of invasive alien aquatic plants in Lake Biwa, this project aims to identify new techniques for the removal of aquatic plants and methods for suppressing the spread of effluent water from industries. The purpose of this project is to support the development of new technologies by subsidizing those technologies that are being adopted by the Shiga prefecture. Hiyoshi Co. received subsidies for the "Aquatic plants management technology development support project" from Shiga Prefecture in 2017.

There is no simple way to control the spread of water primrose. A number of physical control measures including hand-pulling, rotovation, and mechanical harvesting may be used to control water primrose; however, all fragments and roots must be removed to prevent re-establishment. It is likely that mechanical treatment of large populations would provide only a temporary solution[1].

Water primrose has been used in the past to absorb herbicide residues in runoff water. Several herbicides have been used with reported success, including halosulfuron-methyl, glyphosate and triclopyr[1]. Some researchers have also reported the evaluation of six herbicides (2,4-D, Glyphosate, Imazamox, Imazapyr, Penoxsulam, and Triclopyr) for the control of water primrose[2].

Agricultural chemicals are agents or natural enemies that can affect organisms and the environment if used incorrectly. A registration system for agricultural chemicals ensures that the standards for residues in crops and the effects on aquatic organisms are established, and their usage is specified not to exceed those standards, based on which the agricultural chemicals are examined and their safety is guaranteed[3].

The safety of agricultural chemicals is ensured by complying with the usage rules specified for the registered agricultural chemicals.

2. EXPERIMENT

We made the decision to use Basta® (active ingredient; glufosinate) as it is less toxic to aquatic life than Roundup® (active ingredient; glyphosate).

Water primrose samples were collected on the lakeshore of the Karasuma peninsula in Lake Biwa (under the permission of Ministry of Environment), and the stem, from which the leaves had been removed, was cut to 30 cm, inserted into the sedimentary soil of a test water prepared in a plastic bucket, and grown and cultured for 23 days.

The herbicide was administered at a dose of 18.5 mg / strain (glufosinate) using an herbicide applicator (PAKPAK PK 98 L).

Leaves began rolling up after only one day of the herbicide treatment. The whole plant including the stem became brown and withered by 10 days after the beginning of the treatment, and the root was confirmed to be dead 29 days after the beginning of the treatment. Thus, our experiments confirmed that glufosinate is, in the short-term, sufficiently effective as a chemical control for water primroses.



Fig. 1. Herbicidal effect of glufosinate on water primrose

In addition, the amount of glufosinate flowing from the plant into the water of the plastic bucket was measured using an LC / MSMS (Table 1).

Table 1. Concentration of glufosinate in water from the plastic bucket (mg/L).

Days	Control	Treated
1	< 0.001	1.65
3	< 0.001	3.04
5	< 0.001	2.79
10	< 0.001	1.61
14	< 0.001	0.72

Some of the herbicide administered to the surface of the stems and leaves of the water primrose fell into the water, but seemed to be decomposed by the action of glufosinate-degrading bacteria in the water.

In order to investigate the effects of the herbicide on aquatic organisms, we conducted experiments on the acute toxicity of glufosinate using Daphnia (*Daphnia pulicaria*: photo by Dr. S. Ichise of Lake Biwa Environmental Research Institute), Honmoroko (*Gnathopogon caerulescens*), and Medaka (*Oryzias latipes*: source of photo http://www.akb.jp/fs/tojaku/1126) from Lake Biwa.



Fig. 2 Photos of Daphnia, Honmoroko and Medaka

Daphnia were obtained from Lake Biwa Environmental Research Institute. The 48 hour acute immobilization test for daphnia was carried out using the static exposure condition method without exchange of test water. The results revealed a 48-hour EC_{50} value of 112 mg/L and confirmed that glufosinate is a safe herbicide for these organisms.

Honmoroko fishes were acquired from the “Yamasho Honmoroko Youshoku Koubou Co., Ltd.”, and acclimatized to test water temperature in the breeding room and then bred for two weeks under the same water quality and water temperature conditions. Glufosinate's 96-hour acute toxicity test on Honmoroko was carried out using the static exposure condition method without exchange of test water. The 96-hour LC_{50} value of 117 mg/L was calculated; we confirmed that this herbicide is safe for adult Honmoroko fish.

A 96-hour acute toxicity test on Medaka juveniles was carried out using the static exposure condition method without exchanging test water. Medaka got parent fish from the Oda branch of “The School of Medaka” and tested juveniles were hatching and breeding by us.

The results showed that death or abnormal swimming behavior was not observed even with the maximum test concentration of 120 mg/L conducted in this test, and Basta was thus confirmed to be safe for Medaka.

3. CONCLUSION

We confirmed that the use of glufosinate as a chemical control is effective for the management of water primrose and its use as an herbicide could have little effect on aquatic organisms. In future experiments, we plan to use a larger experimental system and devise a dosing regimen, and will try to conduct experiments with a system that is more reflective of real-world conditions.

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霞ケ浦における魚類相の変遷とその保全

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キーワード:霞ケ浦, 魚類相と保全, 環境の変遷, 自然再生, 侵入外来生物

抄 録

霞ケ浦は縄文海進によって関東平野東部にできた内湾に由来する。湾口部に土砂が堆積して閉鎖が進み, 17 世紀までにはほぼ淡水化した。近代に入ると治水・利水目的で大きな改変を受けると共に, 流域人口の増加などによって富栄養化した。古くは汽水性と淡水性の魚類が共存したが, 1974 年, 常陸川水門によって海水の流入が遮断されると湖内は完全に淡水化した。そのためクルメサヨリ, マハゼなどの汽水性魚類は減少し, 水門閉鎖はウナギやスズキなど回遊性魚類の激減をもたらした。しかし, ワカサギ, シラウオなどは陸封化し, 湖内で再生産している。湖岸堤による植生の衰退もコイ科などの淡水魚類に影響を与えた。また, 富栄養化による低層水の酸欠で二枚貝が減少しタナゴ類が衰退した。さらに, 1900 年代初頭以来, 多くの外来魚の導入や侵入があり生態系に深刻な影響を与えている。これらの状況を踏まえて, 霞ケ浦の魚類など水生生物の保全を考察する。

1. はじめに

霞ケ浦は関東平野の東側に海跡湖として成立した, 日本で2番目の広さをもつ湖である。湖沼水質保全特別措置法では, 西浦, 北浦, 外浪逆浦, 北利根川, 鰐川, 常陸川の各水域を合わせた水域を霞ケ浦と呼ぶが, 西浦と北浦, 外浪逆浦のみを湖沼と呼ぶことも多い(図 1 右)。その総面積は 220 km^2 に及ぶが, 湖沼部については, 西浦が 172 km^2 で大半を占め, 北浦は 36 km^2, 外浪逆浦 6 km^2 と小さい。平均水深は 4 m, 最深部でも 7.1 m と浅く, 構造湖である国内最大の琵琶湖(670 km^2, 平均水深 41.2 m, 最大 103.6 m)と比べ水環境は随分異なる[1]。

霞ケ浦は, 霞ケ浦は, 古くは「常陸風土記」(713)の中で, 流海(ながれうみ)として言及されている。近世に入ると, 湖は流域に住む人々が水産物の漁獲や移動や輸送の場として利用するようになった。さらに, 第二次世界大戦後の経済成長期に入ると, 輸送の需要は減ったが, 農耕や飲用, 工業用に水の需要は劇的に増加し, 人間活動にとって湖の存在は一層重要になった。そのため, 湖は構造的にも運用面からも大きな改変を受けることになり, それが湖内や周辺に住む生物にも大きな影響を与えつつある。

著者らは, 近世から現在に至るまでの霞ケ浦の構造や水環境の変遷と, それに伴って変化した生態系の構成要素のうち魚類に焦点を当てて論じる。その上で, 今後における魚類相の修復や保全についていくつか提言を行う。

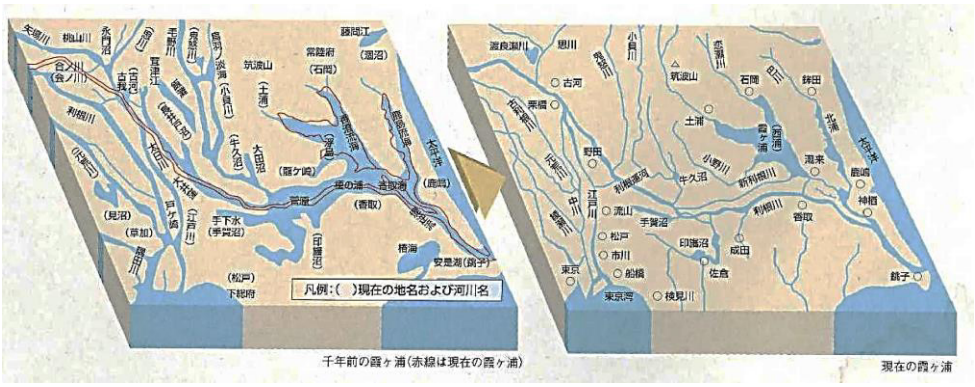

図 1 1,000 年前(利根川東遷以前)と現在の霞ケ浦.
(国土交通省 2009 より引用)

2. 霞ケ浦の成り立ちと構造・水環境の変遷

霞ケ浦の概形は, 最終氷期の最中, 海退の起こった 3～2 万年前に古鬼怒川によって刻まれた谷によって形成された。氷期の終わった 6000 年位前には, 縄文海進によって内湾化したが(図1左), 次第に湾口部に土砂が堆積し湾の閉鎖が進んだ。さらに江戸時代(1594～1654 年頃)に洪水対策と新田開発を目的に行われた利根川東遷事業が大きな変化を与えた。東遷した利根川は鹿島灘に注ぐようになったが, 下流で起こる洪水の土砂が

堆積して湾部はほぼ淡水化し，「霞ケ浦」と呼ばれるようになった。さらに，1783 年の浅間山の噴火で降り積もった火山灰が河床を埋めて利根川下流の氾濫が頻繁に発生すると共に湖の淡水化もさらに進んだ[2]。

利根川下流域から霞ケ浦にかけての洪水を防ぐため，国は 1948 年から常陸利根川の拡幅・浚渫を実施したが，今度は海水の遡上が頻繁になり湖は汽水化した。そのため，潅漑に霞ヶ浦の水を利用する水田では塩害が発生するようになり，塩害防止と治水を目的に，国は 1963 年に常陸川水門を建設（図2），洪水発生時など状況に応じて水門を開閉した。この段階では開門時間が長く，湖水はいくらか塩分を含んだ汽水の状態が維持され，回遊性魚類や他の水生動物も海と湖を行き来することができた。しかし，流域の農業用水や上水，工業用水の需要が高まり，1975 年以来，水門はほぼ完全に閉鎖されて湖はほぼ完全に淡水化した。同時に，コンクリート製の湖岸堤が全周にわたって築堤され，1996 年の完成後は湖の水位を上げて水瓶化が進んだ。現在，通常は水門を閉門し，湖水の水位が上がった時のみ開門して下流に流している。そのため，魚類やカニなどの水生生物が遡上あるいは降下できるように，魚道が設置されている[1]。

3. 魚類相の変遷

縄文時代，霞ヶ浦周辺に住む人々は海産の魚介類を採捕して食べていたことが，多数存在する貝塚からもうかがえる。17 世紀に淡水化してから生息するようになった魚類については知見が乏しい。戦後行われた常陸利根川の拡幅・浚渫による汽水湖への回帰によって，ヤマトシジミが上流側に分布を拡大した。1958～1977 年にかけてかなりの漁獲を記録していたが，淡水化後は激減している。現在の魚類など水生動物相は，1975 年の水門閉鎖による淡水化と水路遮断に加え，富栄養化の進行や護岸堤による湖岸植物相の衰退，外来種の導入・侵入などの要因が複雑に絡み合って成立した。

霞ケ浦の魚類は，これまでに海産魚，汽水魚，淡水魚を合わせ，104 種が記録されている。近年確認されているのは 60 種弱だが，その中に海産種は含まれない。汽水種の中には，淡水化によって消滅したものもあるが，陸封化して湖内で再生産している種も多い。また，外来種は 24 種（約 4 割）を占めるが，そのうち国外外来種は 14 種，国内外来種は 8 種，不明 2 種である。近年は外来種が勢力を広げ，生態系に大きな影響を与えている。

3-1. 回遊魚

降河回遊魚のウナギは，稚魚のシラスウナギが海から湖や川の上流に遡上し，そこで成長した個体が産卵のために海に下る。しかし，常陸川水門による流路遮断が稚魚の遡河を妨げている。水門には魚道が附設されているが，そこを通過して遡河する個体は少なく，霞ケ浦のウナギ資源量は減少した。1960 年代には年間 400 t あった漁獲が，現在は 10 t 程度に減っている[3]。

図２　常陸川水門



遡河回遊魚のシロザケは，今でも 100 個体前後が霞ケ浦まで遡上する。しかし，現在の環境では湖内での繁殖は困難とされ，実際，稚魚はほとんど見られない。霞ケ浦で捕獲されるのは，利根川を群馬・埼玉方面に向かうべき遡上個体が迷入したものと推測される[3]。

3-2. 陸封化した回遊魚・汽水魚

ウナギとシロザケ以外にも，湖と海を行き来する魚には，遡河回遊魚のワカサギ，イトヨ，両側回遊魚のアユなどがある。これらは 1950 年代にはかなりの遡上が見られたが，水門閉鎖後は激減した。しかし，近年の調査で、これらの魚種が陸封化して湖内で再生産していることが明らかになった。例えば、アユは 1990 年台に入って漁獲量が増えており，桜川や恋瀬川，巴川などの流入河川で再生産していることが判明した[3]。

また，本来汽水域に住むクルメサヨリは，水門閉鎖後も少数ながら湖に残留して生活している。一方，ボラとスズキは海で産卵し，稚魚が利根川を経て湖に上がってくる。マハゼは淡水化以前には霞ヶ浦でも繁殖していたが，現在は利根川河口域などで産卵し，増水時などに水門を経て少数が湖に入る程度である。

4. 外来魚による攪乱

霞ケ浦における最初の外来種は，1918 年に琵琶湖から移殖されたコイ科のビワヒガイである[3]。その後も，戦前には蛋白源としてコイ科のソウギョ，ハクレンなどが中国から移殖され現在も定着している。1970 年代に入ると

北米原産のブルーギルやオオクチバス(サンフィッシュ科)などが，ゲーム用に移入される事例が増えた。

現在，霞ケ浦に定着している外来魚のうち，生態系に深刻な影響を与えているのは，ブルーギル，オオクチバス，チャネルキャットフィッシュ(アメリカナマズ科)など，中・大型の肉食性魚類であろう。オオクチバスは 1925 年にカリフォルニア州から芦ノ湖に移入された。霞ケ浦では 1975 年に初めて確認されたが，爆発的に増えて釣り客を集めた。在来のタナゴ類やワカサギ，コイやフナの稚魚などが捕食されて急減した。2000 年代に入ってオオクチバスやブルーギルは漸減している。チャネルキャットフィッシュは現在も漁網により多数混獲されており，生態系や漁業に深刻な影響を与えている。

魚食性はないが，近縁のタナゴ類と競合して在来のタナゴ相に悪影響を与えているのがオオタナゴ(コイ科)である。この種は 2000 年頃，中国より移入・定着した。霞ケ浦ではタイリクバラタナゴとカネヒラに次ぐ 3 番目の外来タナゴ類だが，特に産卵母貝をめぐって他種と競争関係にある可能性が高く，近年，霞ケ浦や周辺水域にも分布域を広げている。在来タナゴ類が激減している背景に本種の勢力拡大が関係していると推定される[4]。

5. 護岸築堤による湖岸植生の衰退

護岸堤は垂直のコンクリート製であるため，従来，陸地から湖岸にかけて生育していた移行帯の植生は大きく失われ，壁の湖内側にはヨシの群落がわずかに残ったのみである。しかも，それらの多くは強い波に洗掘されて流失した。そのため，湖岸植生帯で産卵していたフナやコイなどは産卵場所を失った。さらに，湖岸壁は湖に流入する小河川や水路への魚の移動も妨げている。

6. 考察―霞ケ浦における魚類相の保全

霞ケ浦における近年の魚類相の変化は，いくつかの要因が複合して起こっている。その経過を見ると，第二次世界大戦後の一時的な汽水化によって海水魚や汽水魚が生息するようになり，生息種数は増加したと考えられる。その後，常陸川水門の設置によってほぼ完全に淡水化し，在来の魚種は減少したが，外来魚がそれに置き換わっている。

魚類相を修復し今後安定的に維持するために，以下の対策が必要と考える。

6-1. 魚道の改良による回遊生物の通過量の増加

現在の魚道では回遊性生物の遡河・降河が十分に行われていないので，特に絶滅危惧種に指定されたニホンウナギの稚魚の遡河習性を調べて，より通過しやすい魚道に改良する必要がある。

6-2. 湖岸における自然再生の促進

これまで，国交省を中心に多自然型護岸，ウェットランド，ワンドなどの整備が湖岸各エリアで実施されてきた。コンクリート護岸によって衰退した湖岸植生が部分的でも再生されれば，フナなど，特にコイ科魚類の産卵場ができる。これまでの成果を点検しつつ，さらにエリアを広げて実施することが望まれる。

6-3. 常陸川水門の弾力的運用

水門の操作は国交省が行っているが，湖岸植生帯や浮葉植物の再生のため，それらの生態により配慮した水位の調節が望まれる。

6-4. 外来生物の制御

湖全体に分布を広げたオオクチバス，チャネルキャットフィッシュなどの魚食性外来魚を完全に駆除するのは困難であろうが，在来魚類にかかる強い捕食圧を少しでも軽減するため積極的に漁獲し，食用や肥料などに活用する方法を開発したい。漁業関係者や釣り人の協力をいかに得るかが課題である。

6-5. 水質の浄化による低層の酸欠防止

過度な富栄養化によってアオコが形成され，それが湖底に沈んでしばしば低層水の酸欠を起こしている。それが原因で多くの二枚貝が消滅し、タナゴ類の衰退の一因となっている。富栄養状態を改善するため，窒素や燐の流入をさらに低減し水の浄化を図ることが望ましい。

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富栄養化した調整池におけるアメリカザリガニの生息状況

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キーワード:アメリカザリガニ, 生態, 駆除

抄録

岩手県滝沢市に位置する常時湛水型の調整池において、要注意外来生物であるアメリカザリガニ *Procambarus clarkii* の生息状況調査を行った。個体数推定の結果、当池に生息するアメリカザリガニはおよそ 300~1200 個体であると推定された。採捕調査の結果、当池の浅い部分で多く採捕されることが確認できた。これは、富栄養化による低層 DO の低下傾向がみられ、底生生物であるアメリカザリガニの生息に影響を与えたためと考えられる。採捕調査では抱卵個体が採捕されなかったが、9 月 7 日にセメント腺が現れた個体と 10 月 3 日に抱稚仔個体を採捕したことから、当池のアメリカザリガニのおおよその産卵時期が 9 月であることを特定した。今後は抱卵個体の採捕による効率的な駆除を行うため、判明した産卵時期にトラップを集中して設置することを試みたい。また、当池の食物網を調査し、アメリカザリガニの生態的地位を明らかにした上で適切な個体管理方法を模索していきたい。

1. はじめに

常時湛水型である岩手県立大学第一調整池(以下「調整池」)には、要注意外来生物(環境省)や日本の侵略的外来種ワースト 100(日本生態学会)に指定されているアメリカザリガニ *Procambarus clarkii* が生息している。本種は日本の在来生物の捕食などを通じて日本の生態系に大きな被害をもたらすことから、効率的な駆除方法が必要とされている。

白石ほか[1]は、アメリカザリガニの駆除方法として、複数の餌とトラップを用いた採捕実験により、練り餌とエビ籠(本調査における籠トラップ)が効果的なことを明らかにした。また、牛見ほか[2]は、本種が巣穴を掘って隠れる習性を利用し、塩ビ管を用いて巣穴を模したトラップ以下「塩ビ管トラップ」による採捕実験を行った。その結果、塩ビ管トラップが餌を用いず継続的に採捕可能であること、および採捕に適したトラップの諸元を明らかにした。このように、アメリカザリガニの採捕に関する知見の蓄積は行われているものの、提案された捕獲方法の汎用性や、生態の地域性に関する情報は少ない。そこで本研究では、調整池における本種の生息状況や産卵期等の生態を明らかにすると共に、効率的な駆除方法に関するさらなる知見の収集を目的とした実験を行った。

2. 方法

2-1. 調査地概要

本研究の調査地である調整池は、雨水と学内排水用浄化槽処理水が流入する(図 1)。主な水源は浄化槽処理水であり、富栄養化が進行している。また、池の中央部の水深は 1~1.2m(以下、深部)、他方で岸近くは水深 30~50cm であり浅く、スイレンやガマが群生している(以下、浅部)。池の周囲はヤナギ等の樹木で囲まれている。

調査は 2016 年 9 月 24 日から 2017 年 10 月 7 日の間で行った。調査項目ごとの実施日を表 1 に示した。なお、2017 年 5 月 18 日の採捕調査は、試作したトラップの設置可否確認のための予備的調査である。

2-2. 採捕方法

採捕調査は籠トラップと塩ビ管トラップの 2 種類を使用して行った。籠トラップは市販品を利用し、誘引用の練り餌を入れた。設置時間は、前日の 16 時から翌日の 9 時 30 分とした。塩ビ管トラップは、牛見ほか[3]を参考に製作した(図 2)。二ホンザリガニが夜行性であること[4]から本種も夜行性であると仮定し、日中に潜む際に採捕できるよう、時間は前日 16 時から翌日の 16 時とした。採捕した

表 1 各調査項目の実施日

調査項目	2016年			2017年													
	9/24	10/1	10/8	5/18	6/2	6/16	6/30	7/14	7/28	8/12	8/25	9/7	9/22	9/29	10/3	10/7
採捕(塩ビ管のみ)					●		●		●		●		●			
採捕(塩ビ管と籠)				●		●		●		●		●				
個体数調査	●	●	●											●	●	●
移動調査	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●

個体は採捕した位置を記録した上でメジャーによる体長計測を行い、雌雄を確認し、ホワイトマーカーで通し番号によるマーキングをした後に採捕された地点に放流した。個体数推定は標識採捕法の Petersen 法を用いた。

3. 結果

4 回の個体数推定は、それぞれ 311 個体、675 個体、そして 1224 個体、527 個体であった。すなわち、当池に生息するアメリカザリガニはおよそ 300～1200 個体であると推定された。

本調査で採捕された個体の体長のヒストグラムを図 3 に示した。成体であると思われる 91～110mm の個体が 152 個体であるのに対し、80mm 未満の個体は 15 個体と少なかった。また、当池で採捕されたアメリカザリガニの体長の平均は 98mm であった。

籠トラップと塩ビ管トラップの総採捕個体数の浅部と深部における平均値を比較すると、浅部で多く、深部では少ない傾向が見られた（図 4、マン・ホイットニの U 検定、$p<0.05$）。

籠トラップ、塩ビ管トラップの総採捕個体数はそれぞれ 193 個体、9 個体であり、塩ビ管トラップの採捕個体数は少なかった。トラップ設置地点毎の総採捕個体数（図 5）を見ると、籠トラップは A1、C1、C4 の地点で多く採捕された。

籠トラップにおける雌雄別総採捕個体数の変化を見ると、全体的にメスの採捕個体数が少なかった（図 6）。9 月 7 日にメスの採捕個体数が最も少なくなり、10 月 7 日に最も多くなった。また、9 月 7 日に産卵期のメスに現れるセメント腺が発達した個体を 2 個体採捕し、10 月 3 日には親を 1 個体採捕した。なお、採捕された子の大きさは 7mm 程度であった。

個体の移動について図 7 に示した。2016 年は 9 月 24 日から 10 月 1 日において C4 から B1、10 月 1 日から 10 月 8 日で B1 から C2 と移動している個体のほか 10 月 1 日から 10 月 8 日で A3 から A1 に移動する個体が見られた。2017 年は A1 から A2、A1 から B1、A4 から C1 に

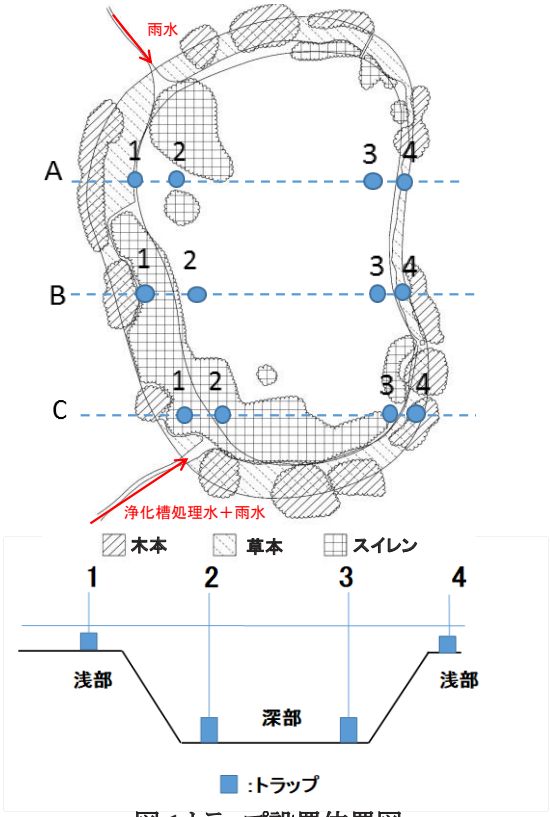

図 1 トラップ設置位置図



図 2 製作した塩ビ管トラップ

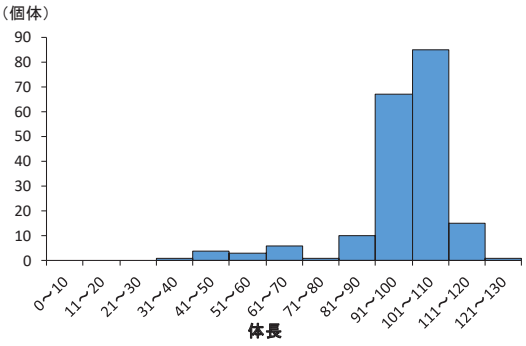

図 3 採捕された個体の体長のヒストグラム

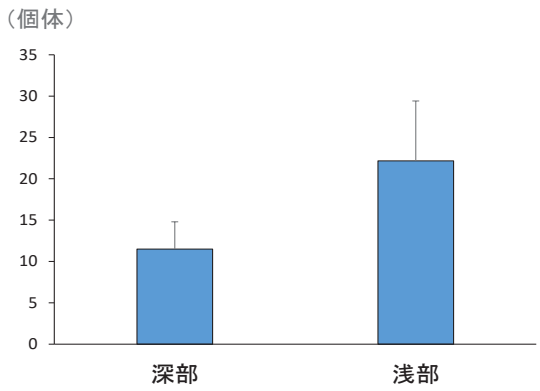

図 4 浅部と深部の各調査日の平均採捕個体数
（エラーバーは標準偏差を示す）

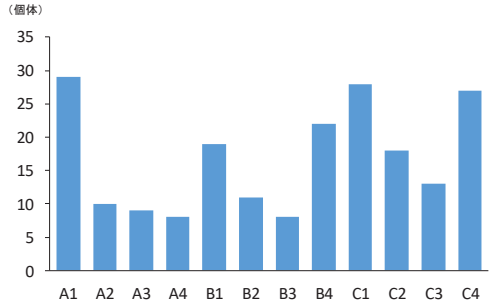

図 5 トラップ設置地点毎の総採捕個体数

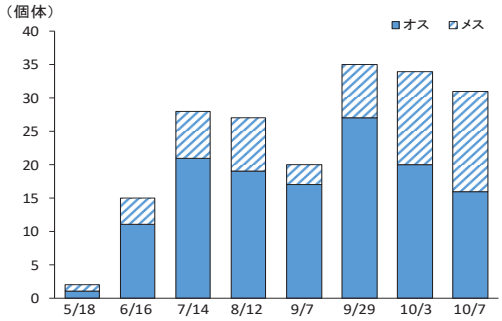

図 6 籠トラップにおける雌雄別総採捕個体数の変化

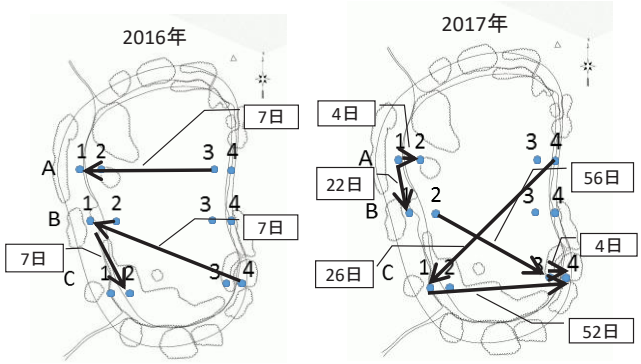

図 7 アメリカザリガニの個体移動

移動する個体が見られた。

4. 考察

当池で採捕されたアメリカザリガニの採捕個体数を浅部と深部で比較した結果、浅部で多いことが確認された。深部で採捕個体数が少なかった要因として、深部の溶存酸素濃度が低かったためと推察された[5]。一方で、C2、C3 地点では他の深部の地点と比べて多くの個体が採捕される傾向が見られた（図 5）。これは C 地点にアメリカザリガニの鉛直方向の移動手段や隠れ家となるスイレンが繁茂していることが関係している可能性がある。

9 月 7 日にセメント腺の現れた個体、および 10 月 3 日に抱稚仔個体を採捕したことから 9 月頃に産卵期を迎えることが考えられた。したがって、9 月 7 日のメスの採捕個体数の減少（図 6）は、メスが産卵期に入り活動が抑えられたためと考えることができる。

また、抱稚仔個体を確認したことから、当池でアメリカザリガニは再生産をしていることが確認された。しかし、未成個体と考えられる 80mm 未満の個体数は総採捕個体数の役 12%と少なく、再生産が活発ではないことが示唆された。稚仔個体には低い DO や富栄養化している当池の環境条件が厳しく、生き残れる個体が少ないという可能性が考えられる。

個体の移動で最も長距離移動したのは 2016 年に、7 日間で C4 から B1 地点と対岸に移動した個体だった。他の個体も個体差はあったが、活発に移動していることが確認できた。また移動経路は、当池の深部は DO が低く、生物の生息に不適な環境であることから、DO がある程度確保されている浅部を移動していると考えられた。

5. 今後の課題

本調査では抱卵個体を対象とした塩ビ管トラップでの採捕効率は低かった。要因として抱卵したメスのザリガニは池周辺の草木の影や巣穴等に隠れ、産卵に向けて不活発になったためだと考えられた。本調査でおおよその産卵時期を特定することが出来たことから、産卵期の直前にトラップを集中的に設置することや、設置時間を延長することで周囲の環境に馴染ませるなどの対策を講じ、塩ビ管トラップによる抱卵個体の採捕を調査する必要があると考える。

本調査中に池外で多数のアメリカザリガニの死骸を発見した。このことからアメリカザリガニを捕食している種が存在していると考えられた。捕食者を特定すると共に、当池のアメリカザリガニの生態的地位を確認する必要がある。

また、周辺では本種が確認されていないため池も見られることから、周辺の生息状況を調査すると共に、域外への侵出を防ぐためにも、当池におけるアメリカザリガニの適切な個体数管理方法を模索していきたい。

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浄水処理施設におけるカワヒバリガイによる被害と対策について

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キーワード:侵入外来生物

抄録

特定外来生物であるカワヒバリガイは，霞ヶ浦においては2005年に初めてその存在が確認された。茨城県企業局は全10浄水場のうち6浄水場が霞ヶ浦を取水源として用水供給事業を行っている。このうち，霞ヶ浦西浦を取水源とする霞ヶ浦浄水場においては，2016年から取水場において大量のカワヒバリガイの塊によるバースクリーンの閉塞が確認されており，計画水量が確保出来なくなる恐れが生じている。このため，当浄水場においてはこれまでに，取水パターンの変更や，閉塞したカワヒバリガイの人力による除去等の対策を講じ，安定的に水道用水の供給を行っている。また，霞ヶ浦西浦及び北浦の取水場内でカワヒバリガイの発生状況を調査したところ，西浦に比べ北浦の方がカワヒバリガイの発生数が少ないことが明らかとなった。

1. はじめに

特定外来生物であるカワヒバリガイは，霞ヶ浦においては 2005 年に初めて存在が確認され[1]，生息範囲が年々拡大する傾向にある[2]。また，大量発生した貝が死滅・腐敗し，悪臭を発生する等の被害も報告されている。

霞ヶ浦は大きく分けて西浦，北浦，外浪逆浦からなるが，当局が管理する全 10 浄水場のうち4浄水場が西浦から，2浄水場が北浦から取水し，用水供給事業を行っている。

当局が管理する浄水場の一つである霞ヶ浦浄水場は，図 1 のとおり浄水場から南東約 10km にある木原取水場で霞ヶ浦西浦の湖水を取水し，浄水処理を行っているが，近年，カワヒバリガイによる取水障害等が発生している。

今回，当浄水場におけるカワヒバリガイによる被害状況を報告するとともに，当局の対応について報告する。



図 1 霞ヶ浦水場及び木原取水場位置図

2. 霞ヶ浦浄水場の概要

霞ヶ浦浄水場は茨城県土浦市に位置し，1960 年に給水を開始した浄水場であり，1 日最大給水量は 155,675 ㎥，計画給水人口は 322,700 人と，当局が管理する全 10 浄水場のうち最も給水量が多い浄水場である。また，当浄水場の処理フローは図 2 のとおりであり，生物処理槽や粒状活性炭ろ過池といった高度浄水処理施設を有している。

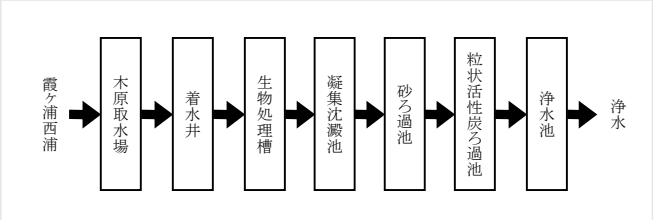

図 2 霞ヶ浦水場処理フロー

3. 霞ヶ浦浄水場における被害状況

(1) 霞ヶ浦浄水場における実態調査

2007 年の新聞記事に霞ヶ浦におけるカワヒバリガイによる被害に関する記事が掲載されたことを踏まえ，木原取水場の水位を通常運転水位より 1.7m 下げて調査した結果，壁面やバースクリーン等にカワヒバリガイの付着は見られなかった。

2012 年に取水場の電力量が大きくなっていることから調査したところ，揚水量が設定値よりも少ない状況であることが確認できたが，原因の特定には至らなかった。

2013 年に木原取水場内の導水管の耐震化工事の一環で，既設管の一部を切り出し確認したところ，カワヒバ

リガイが一面に付着していることが確認された。

また 2014～2015 年にかけ，取水塔から取水場までの一部区間約 550m の取水管内を，潜水士による目視調査を行った結果，カワヒバリガイの付着が確認されたが，取水量に影響を及ぼす量ではないことが明らかとなった。

更に，2017 年には取水塔から取水場までの全区間約 655m の範囲について，潜水士による目視調査を行った。その結果，前回の目視調査結果に比べ，上流（取水塔）側で付着量が倍増し，下流（ポンプ場）側で半減していることが明らかとなった。

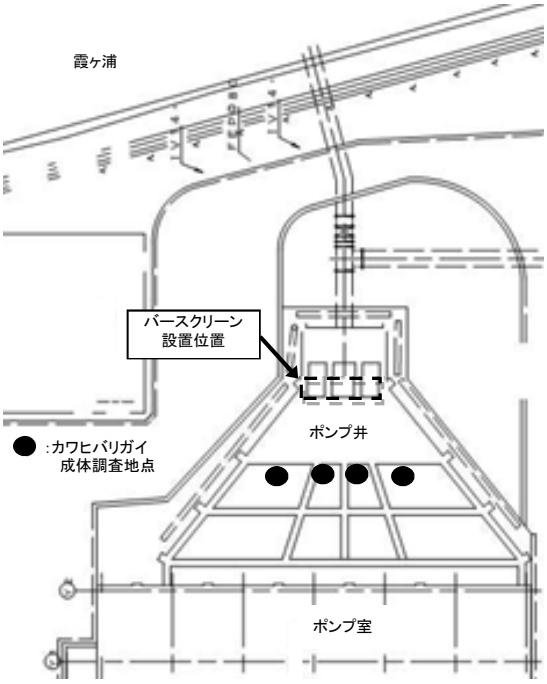

図 3 木原取水場平面図

(2) 被害状況

2016 年に取水場のバースクリーン（目幅 50mm）がカワヒバリガイの付着によって閉塞し，取水ポンプが緊急停止する事態が発生した。バースクリーンを引き揚げ点検したところ，バースクリーンの水中部一面にカワヒバリガイが付着していることが確認できた。なお，付着状況を確認したところ，カワヒバリガイはバースクリーンに着床しているのではなく，大きな塊となって流下してきたものが，バースクリーンを塞いでいる状況であった。

更に，2017 年の春から秋にかけても，同様の閉塞が確認されている。

4. 霞ヶ浦浄水場の対応

(1) 導水管揚水流速

カワヒバリガイの発生により，最大取水量が1割程度低下したが（計画最大取水量 6,660 ㎥/h に対し，6,000 ㎥/h 程度に低下），週1回，約 30 分間，最大取水量で取水することにより，計画最大取水量と同程度の揚水量を確保出来るようになった。これは，流速を上げることにより，導水管内にカワヒバリガイの幼生が着床しにくくなると共に，着床しても剥離しやすくなり，損失が低減したためではないかと推測している。

(2) バースクリーンの清掃

2016 年9月にバースクリーンを引き上げ，その状態を確認するとともに，カワヒバリガイの除去・回収を手作業で行った。しかし，木原取水場は長時間取水を停止することが難しく，バースクリーンを頻繁に引き上げて清掃することが出来ない。このため，2017 年4月からは，取水（堤内）ゲートを絞り，水位を約1m下げ，図 4 の様にバースクリーンの水面から上部の範囲のみ手作業で清掃を行った。なお，清掃回数は1週間に1回程度実施してきたが，付着量が多くなった8～9月については，ほぼ毎日清掃を行った。この清掃によって除去・回収した量を図 5 に示す。回収量は8～9月をピークに年間で約 15t のカワヒバリガイを回収した。なお，回収したカワヒバリガイは取水場内で天日乾燥し，死滅させた後，処分した。

バースクリーンの清掃は，夏期は付着量が多くなるため，毎日，人力を割かなければならず，なおかつ作業者の負担も大きい。このため，機械式の自動除塵機を設置し，作業の効率化を図りたいと考えている。



図 4 バースクリーンの清掃状況

(3) ポンプ井の浚渫

バースクリーンより下流のポンプ井にも，バースクリーンを通過したカワヒバリガイが推定で 200 ㎥堆積しており，2017 年 11 月に重機で約 40 ㎥のカワヒバリガイを試

験的に回収した。現状，浄水処理に障害がある程の堆積量ではないと考えるが，対策を考慮しておく必要があると考えている。

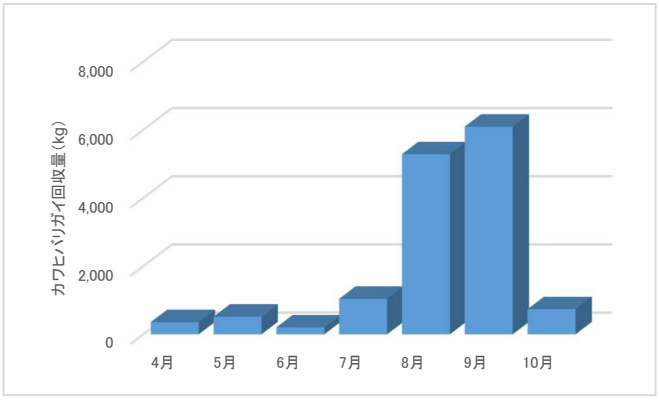

図 5 木原取水場におけるカワヒバリガイ回収量（2017 年）

5. カワヒバリガイの発生状況調査

(1) 調査箇所

霞ヶ浦浄水場木原取水場（霞ヶ浦西浦），及び鹿島浄水場爪木取水場（霞ヶ浦北浦）

(2) 調査方法

国立研究開発法人 農業環境技術研究所の技術指導を受け，霞ヶ浦を取水源とする浄水場におけるカワヒバリガイの幼生及び成体の発生数を調査した。

ア 幼生発生数

原水 100L をプランクトンネット（72 μ m メッシュ）に通水し，得られた濃縮液 160mL にエタノールを添加し，カワヒバリガイの幼生を死滅させ静置した後，上澄み液を除去し，エタノールで 50mL に定容した試料中の幼生数を実態顕微鏡で計数した。なお，カワヒバリガイは水温 15℃を超えると発生することから，水温等を考慮して 2017 年 7～11 月の間，1 回/月調査を実施した。

イ 成体発生数

浮き，ロープ，塩ビ管（内径 7.5×20cm）2 本，錘で構成したトラップ（全体長 145cm）を，木原取水場は4個，爪木取水場は3個（1個は破損のため未計測），2017 年 6～11 月の間設置し，12 月に引き上げ，トラップに付着した成体数を計数した。

(3) 調査結果

図 6 に木原取水場で採取した取水原水中のカワヒバリガイ幼生数を示す。幼生数は，図 5 のカワヒバリガイ回収量と同様，8～9 月に多く発生する傾向が見られ，最大発生数は 8 月の 28.3 個/100L であった。なお，爪木取水場（霞ヶ浦北浦）においては，全期間，幼生の発生は，見られなかった。また，成体は木原取水場においてはトラップ1個当たり 66.5 個，爪木取水場においては 0.5 個の付着が見られた。

以上のとおり西浦に比べ北浦は，幼生及び成体とも発生数が少ないことが明らかとなった。

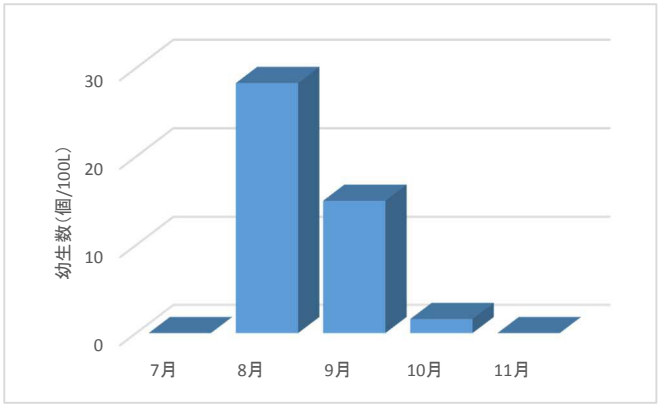

図 6 木原取水場におけるカワヒバリガイ幼生数（2017 年）

6. 結論

以上のとおり，霞ヶ浦西浦を取水源とする霞ヶ浦浄水場において，カワヒバリガイによる被害が発生しているが，取水パターンの変更や，バースクリーンの人力による清掃等によって安定的に水道用水の供給を行っている。

しかし，今後も継続してカワヒバリガイによる被害は続くものと考えられることから，機械式除塵機の導入等を行い，より効率的・安定的な浄水処理を行って行きたいと考えている。

また，霞ヶ浦浄水場は，霞ヶ浦でカワヒバリガイの存在が確認されてから約 10 年を経過した後に，被害が顕在化した。北浦を取水源とする爪木取水場においては，現在のところ被害は発生していないが，今回の調査でカワヒバリガイの成体が観測されており，今後被害が発生する恐れがあるため，引き続き霞ヶ浦におけるカワヒバリガイの発生状況を調査し，その動向の把握に努めて行きたいと考えている。

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霞ヶ浦周辺の水辺に生育する特定外来生物(植物)の現状と防除

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キーワード:霞ヶ浦, 侵入外来生物, ナガエツルノゲイトウ, ミズヒマワリ, オオフサモ

抄　録

茨城県には特定外来生物(植物)が9種定着している。その中, ミズヒマワリは2005年に霞ヶ浦の西浦で初めて確認され, その後, ナガエツルノゲイトウ, オオフサモと共に西浦に流入する新利根川などで大繁茂し, 水田の給水路などで被害が発生した。そのため, 県は2011年に新利根川などで除去を行ったが数年後には再繁茂した。これらは繁殖力が非常に強く拡散が予想されたので, 2016年6月～2017年9月に霞ヶ浦とその周辺で特定外来種の分布を調べ, 2017年12月～2018年3月に新利根川などで除去作業を行った。特定外来種は一度定着すると根絶が困難なものが多いので, すでに侵入した種については分布拡大を防ぐとともに, 新たな種の侵入をより効果的に防止する対策が必要である。

1. はじめに

特定外来生物(植物)は繁殖力が強く外来生物法でその扱いなどが規制されている。2018年時点で, 茨城県で定着が確認されている特定外来種は, アゾラ・クリスタータ, ナガエツルノゲイトウ, アレチウリ, オオバナミズキンバイ, オオフサモ, オオカワヂシャ, オオキンケイギク, オオハンゴンソウ, ミズヒマワリの9種である[1]。また, ミズヒマワリの生育は茨城県の聞き取り調査で, 2005年9月に霞ヶ浦の西浦沿いの行方市(旧麻生町) 宮田地区の護岸で確認されている。

ミズヒマワリは2008年に西浦に流入する新利根川流域に目立ち始めたので, 県及び関係する市と町がミズヒマワリ対策連絡会議を設置しミズヒマワリ定点モニタリング調査を始めた。その後, 新利根川流域地域のミズヒマワリ除去モデル構築業務を実施し, 2011年1月～2012年1月まで新利根川河口付近から上流の24 kmと, 破竹川及びその周囲の幹線排水路での除去を県が実施した。除去対象種は特定外来種のミズヒマワリ, オオフサモと作業中に確認されたナガエツルノゲイトウの3種であった。その後, ミズヒマワリ定点モニタリング調査は終了したが, ミズヒマワリとナガエツルノゲイトウは2014年頃から再び新利根川で繁茂が目立つようになった。2017年に新利根川では, 機場等の取水口付近のミズヒマワリとナガエツルノゲイトウの繁茂により, 取水障害が予想されたので, 県が新利根川の一部区間で取水口付近の除去を実施した(図1)。しかし, ナガエツルノゲイトウなどの繁茂を抑えることは出来ない状態であった。このようなことから, さらに被害が出ることが想定され, 県は霞ヶ浦の水辺に生育する特定外来植物の分布の現状把握を行った。

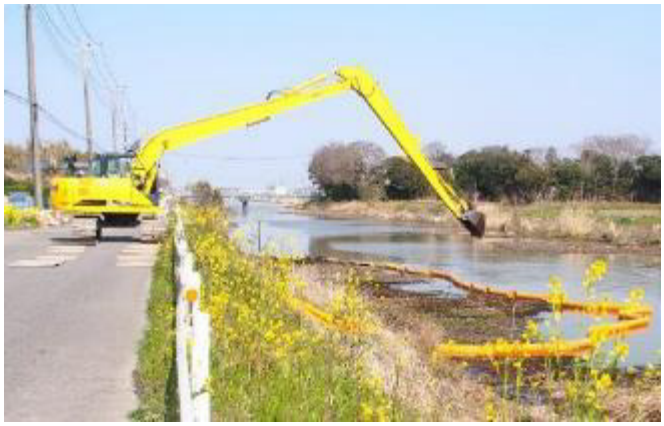

図1　外来植物の除去作業(2017年3月20日, 新利根川)

2. 調査範囲, 調査対象種と調査期間

調査範囲は, 霞ヶ浦のうち常陸利根川と横利根川を除く西浦と北浦, 外浪逆浦, 鰐川に加え, 新利根川全域および湖に流入する河川の河口から1.5 kmまで遡った水辺とその付近である。調査対象種は新利根川で被害を発生させているミズヒマワリ, ナガエツルノゲイトウ, オオフサモの3種とした。調査期間は2016年6月～2017年9月である。

3. 結果

調査範囲で確認した特定外来種はアゾラ・クリスターータ, ナガエツルノゲイトウ, アレチウリ, オオバナミズキンバイ, オオフサモ, オオカワヂシャ, ミズヒマワリの合計7種である。

調査対象種3種の生育場所は①～③に示す。

① ミズヒマワリ

西浦，外浪逆浦，鰐川，新利根川などで確認した。西浦では，消波ブロックや蛇篭付近などの波の影響が少ない場所で群生する（図2）ことが多く，一部の砂浜では波打ち際に生育する小さい個体が見られた。また，堤防のやや乾いた草地や堤内地（堤防から市街地側）の水路などでも確認された。



図２ 波の影響が少ない場所で群生するミズヒマワリ（2016年10月26日，西浦）

② ナガエツルノゲイトウ

西浦，北浦，外浪逆浦，鰐川，新利根川などで確認された。西浦と北浦では砂地の波打ち際で這うように生育していた。また，消波ブロックや蛇篭付近などの波の影響が少ない場所や，コンクリート護岸部の目地（ブロックなどのつなぎ目）の隙間に定着し，群生していた所が多い。堤内地は，水路（図3）や畦道で確認された。



図３ 流入する水路に群生するナガエツルノゲイトウ（2016年10月26日，西浦の堤内地）

③ オオフサモ

西浦，北浦，外浪逆浦，鰐川，新利根川などで確認した。西浦や北浦では，湖岸に群生する場所があった（図 4）。また，湖岸を浮遊したり，波打ち際に打ち上げられた個体も確認された。おもな生育地は河川や堤内地の水路であった。



図４ オオフサモの群落（2016年10月26日，西浦）

以上のように，湖畔に生育する特定外来種は，在来種の再生のために設置された，石積みの消波ブロックに囲まれた穏やかな開放水面に向かって伸長し群落を形成していた。その結果，在来種で生態的地位が似ている浮葉植物のササバモ，アサザ，ガガブタ（図5）などや，沈水植物のエビモ，ヒロハノエビモなどを脅かしている。

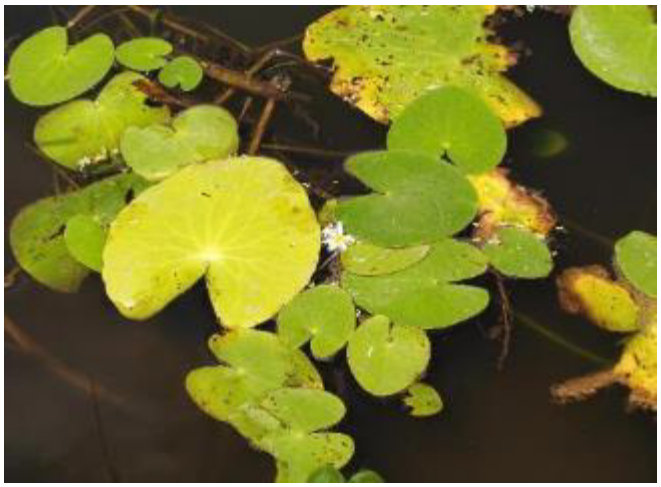

図5 浮葉植物のガガブタ（2014年8月22日，西浦）

霞ヶ浦周辺には，新利根川のように水利目的で作られた人工の河川があり，その水量は少なく水深も浅い。このような場所に繁茂した特定外来種の群落は流れの障害物となり，ゴミや泥などが堆積しやすい。また，堆積した土砂はこれらの植物の生育する基盤になっている。ナガエツルノゲイトウは岸辺に生育するミズヒマワリの群落を取り囲み，開放水面に茎を伸ばす（図６）ことで，さらに大きな群落を形成する傾向が見られた（図７）。また，オオフサモは水路幅の３分の２を覆うほどの群落があった（図８）。このような群落は，大雨で水量が増加すると基質から切り離されて浮き上がり，水の流れや風向きで移動するので，下流のみではなく上流にも分布を拡大していた。また，

堤内地のすぐ傍の水路で特定外来種の繁茂が確認されたことから，荒天時に湖畔と水路を相互に移動すると考えられる箇所があった。



図６ 開放水面に伸びるナガエツルノゲイトウ
（2015年6月5日，新利根川）



図７ 大群落を形成したナガエツルノゲイトウ
（丸枠内はミズヒマワリ 2015 年 6 月 5 日，新利根川）



図８ オオフサモの群落（2015 年 8 月 24 日，城下川）

4. 今後の課題

霞ヶ浦周辺の水辺に生育する特定外来種の調査結果に基づき，県では2017年12月～2018年3月に，新利根川におけるナガエツルノゲイトウ，ミズヒマワリ，オオフサモの除去を行った（図９）。除去対象種とした3種は栄養生殖の能力が高く，水中で茎の一部が切れても葉柄基部から根や芽を再生して新しい個体を作ることができる。また，除去しても根茎などが残ると根絶できず，放置した場合数年後には再び群落を形成する。それを抑えるための努力が必要である。



図９ 新利根川における冬季の除去作業の様子
（2018 年 2 月 14 日）

この状況を踏まえて，2018年に新利根川ミズヒマワリ対策協議会を立ち上げた。この協議会は茨城県，関係市町，土地改良区などの関係する機関が構成員となり，住民やボランティア団体と一体となった防除を目的として通年の監視と除去を予定している。協議会の活動において，除去作業の適切な時期及び間隔や除去方法についてデータを蓄積し，他の流入河川の再繁茂防止モデルとなることが望まれる。

特定外来種は既存の特定外来種への対策だけではなく，今後も新たな種が侵入することを想定し，行政機関と各研究機関および各団体との連携による情報収集と，新たな特定外来生物の侵入や被害を発生させないための，「予防」を含めた啓発活動などが重要である。

引用文献

[1] 平成29年度　第2回茨城県自然環境保全審議会資料（本県の特定外来種の状況について）

P1-41

Ecosystem-level Assessment of Living Microbial Pesticides using Aquatic Microcosm System

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Keywords: microbial pesticide, microcosm, ecosystem-level assessment, bio-diversity

ABSTRACT

Six species of microbial pesticides (*Bacillus thuringiensis* subsp. *aizawai*, *Bacillus thuringiensis* subsp. *kurstaki* and *Pseudomonas fluorescens* as bacterial pesticide, *Verticillium lecanii*, *Beauveria bassiana* and *Metarhizium anisopliae* as fungal pesticide) were assessed on ecosystem-level using gnotobiotic-type experimental aquatic microcosm system. As results, all microbial pesticides didn't increase in their population in microcosm where they were introduced, and finally be removed from the ecosystem site under biological interaction such as prey-predator interaction with indigenous microbiota. From the viewpoint of prevention of bio-diversity, it is an important problem to establish the test technique in detail for ecosystem impact risk assessment immediately, and to effectively use microbial pesticide and the DNA recombinant microorganism of which utilization expects the field of the bio-remediation as the beginning, the evaluation test technique using the microcosm system could be recognized to be one of the effective means.

1. INTRODUCTION

These days, remain and accumulation of chemical pesticide have become to be one of the most serious problems all over the world. In other hand, biological preservation such as microbial pesticide including natural enemies is look at again, and in Europe and U.S.A., microbial pesticide has already made practicable. The microbial pesticide is one of biological preservation and their main components are bacteria, fungi, virus, protozoa and nematode which is viable and/or not. These microbial pesticides are considered more safe for environment than chemical pesticide because of their origin from natural. Furthermore, not only natural microbial pesticide but also genetically engineered one are developed and more explanation is done. By the way, what effect will be given is very important problem for field release of non-indigenous lives, so the environmental impact risk assessment method for the field release of microbial pesticide including genetically engineered one is strongly needed to be proved to use generally and it has already established in Europe an U.S.A., referring to the guideline of OECD and WHO. But in Japan, no assessment method has been established, and haw the microbial pesticide behave in nature and what influence will be happen have not been made clear. So it is very important to make clear the prosperity and decay of microbial pesticide in natural ecosystem and to obtain the basal information for environmental impact risk assessment for field release of genetically engineered microorganisms (DNA recombinant microorganisims).

This study was conducted to investigate and made clear the prosperity and decay of microbial pesticide in aquatic environment using model ecosystem such as monoxenic culture, flask-size microcosm and natural lake model ecosystem. This tier test method is named step-by-step assessment method.

2. METHOD

As microbial pesticide, living cells of *Bacillus thuringiensis* subsp. *aizawai* KH, *B.t.kurstaki* and *Pseudomonas fluorescens* IID5115 as bacterial pesticide, and *Verticillium lecanii* F126-12-3M, *Beauveria bassiana* F18-4B and *Metarhizium anisopliae* M7 as fungal pesticide were supplied.

B.thurigiensis is safe for humans and is the most widely used environmentally compatible biopesticide worldwide. Furthermore, insecticidal *B.thuringiensis* genes have been incorporated into several major crops, rendering them insect resistant, and thus providing a model for genetic engineering in agriculture

P.fluorescens has shown the microbe's potential benefit in bioremediation against several strains of plant pathogens. Plant treatment with *P.fluorescens* can prevent these fungi from growing and spreading through spore production which grow on plant surfaces causing disease and death of the plant..

V.lecanii is an entomopathogenic fungus. The mycelium of this fungus produces a cyclodepsipeptide toxin called bassianolide and other insecticidal toxins such as dipicolinic acid, which infect aphids, whiteflies, rust fungi, scale insects and lead to death the host.

B.bassiana is a fungus that grows naturally in soils throughout the world and acts as a parasite on various arthropod species, causing white muscardine disease; it thus belongs to the entomopathogenic fungi. It is being used as a biological insecticide to control a number of pests such as termites, thrips, whiteflies, aphids and different beetles.

M.anisopliae is being used as a biological insecticide to control a number of pests such as Grasshoppers, Termites, Thrips, catterpillers, aphids/ etc. and its use in the control of malaria-transmitting mosquitos is under investigation.

Microcosm N-system was mainly applied to the test method for ecosystem-level assessment. Microcosm N-system is consisted of three species of microalgae as producer, that is, chlorophyceae *Chlorella* sp., *Scenedesmus quadricauda* and cyanophyceae *Tolypothrix* sp., four species of microanimals as consumer, that is, protozoan ciliate *Cyclidium glaucoma*, metazoan rotifer *Lecane* sp., *Philodina erythrophthalma* and oligochaete *Aeolosoma hemprichi*, and four species of bacteria as decomposer, that is, *Bacillus cereus*, *Pseudomonas putida*, *Acinetobacter* sp. and coryneform bacteria, and indicates high reproducibility and reflectivity of natural ecosystem.

This microcosm is cultured under condition of 25 degrees Celsius, 2,800 lux, 12/12 hrs. bright/dark cycle, and without stirring. Living cells of pre-cultured microbial pesticides were injected to microcosm at 16th day after cultivation start. Microscopic observation was conducted to detect prosperity and decay of injected microbial pesticide and indigenous microorganisms in microcosm.

3. RESULTS AND DISCUSSIONS

As results, following information was obtained. That is, in monoxenic culture test, all the microanimals such as protozoan ciliate *Cyclidium glaucoma*, *Tetrahymena pyriformis*, *Colpidium campylum*, metazoan rotifer *Philodina erythrophthalma* and oligochaete *Aeolosoma hemprichi* which can be observed generally in both natural and artificial ecosystems, were able to grow in cell suspension of bacterial pesticide, but could not in that of fungal one. In other word, *B.t.aizawai*, *B.t.kurstaki* and *P.fluoresens* were expected to decrease by predation of indigenous microanimals in natural environment similar to any other indigenous bacteria, but other fungal pesticide such as *V.lecanii*, *B.bassiana* and *M.anisopliae* were not decreased, and survived. In microcosm N-system test, *B.t.aizawai* decreased after its injection to microcosm due to microbiota, especially protozoa *Cyclidium glaucoma* was greatly affected with their interaction such as prey-predator interaction. *B.t.kurstaki* and *B.cereus* showed same behavior pattern, so, it was considered that *B.thuringiensis* would behave same as any other indigenous bacteria and fade out finally in natural environment. in natural lake model ecosystem, which includes six kinds of eutrophic and oligotrophic lake, river and sea water, *B.t.aizawai* showed same behavior pattern as in microcosm N-system, in other word, *B.t.aizawai* decreased in natural lake model ecosystem by predation effect of microanimals which persisted in natural environmental water. *B.t.kurstaki* and *B.cereus* were the same. Very high relationship between these two microcosms were observed.

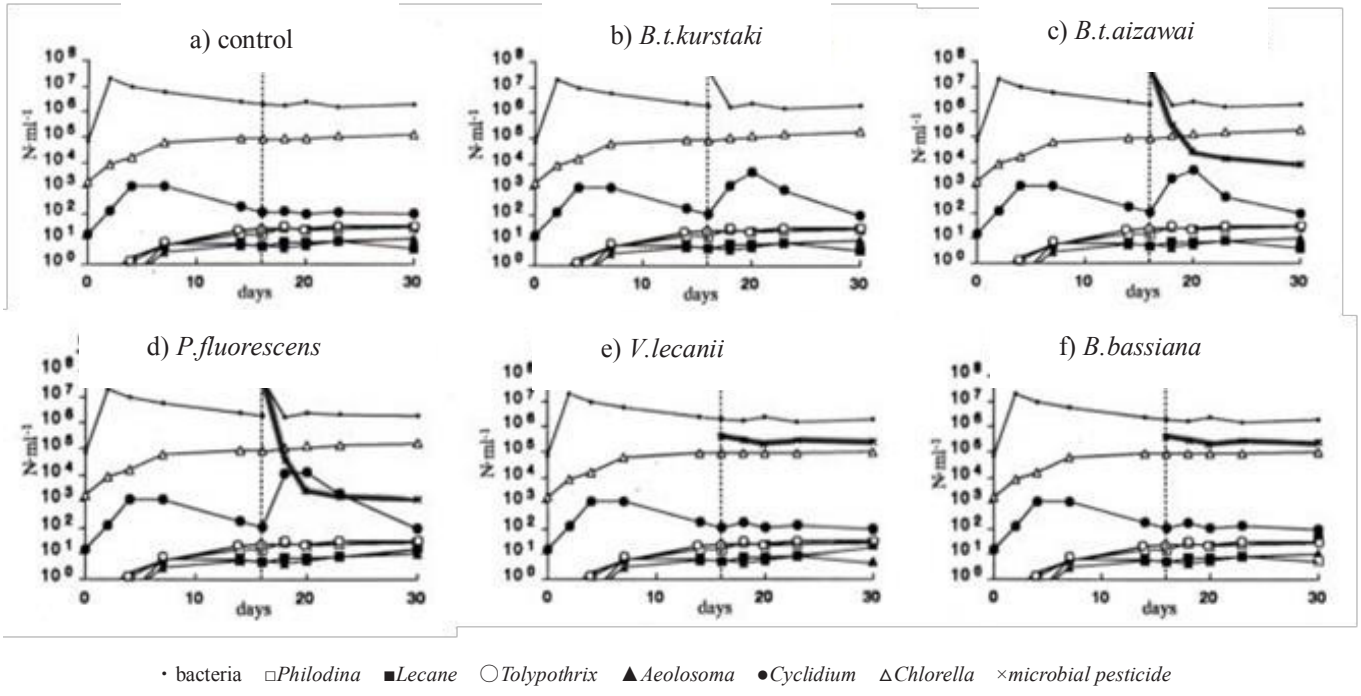

Fig.1 Prosperity and decay of microbial pesticides in the gnotobiotic microcosm N-system

From these results, it was made clear that *B.t.aizawai* and *B.t.kurstaki* as bacterial pesticide show similar behavior as *B.cereus* as control indigenous bacteria, so it is considered that even though microbial pesticide was released in to natural environment, microbial pesticide will not have great influence on indigenous ecosystem. And a new potential for environmental impact risk assessment method for field release of genetically engineered microorganisms on ecosystem level such as microbial pesticide or other bacteria which have new function, was shown here. It is considered that further comparison and analysis of results from these tests would lead the more accurate and detailed environmental impact risk assessment on ecosystem level.

4. CONCLUSIONS

The results obtained from this study can be concluded as follows:

1) Bacterial pesticide can decrease after its release to natural environment and do not affect seriously to indigenous microbiota.

2) Fungal pesticide can remain and survive after its release to natural environment because of its unsuitability to indigenous microanimals as their food source.

3) Tier test such as step-by-step testing method which shown in this study can be one of the most useful way to assess the effect of field release of non-indigenous lives on natural environment.

4) It is necessary to establish the ecosystem level environmental impact risk assessment method as soon as possible, because genetically engineered microorganisms (DNA recombinant microorganisms) is strongly expected to be one of the useful tools as to not only microbial pesticide but also bio-remediation.

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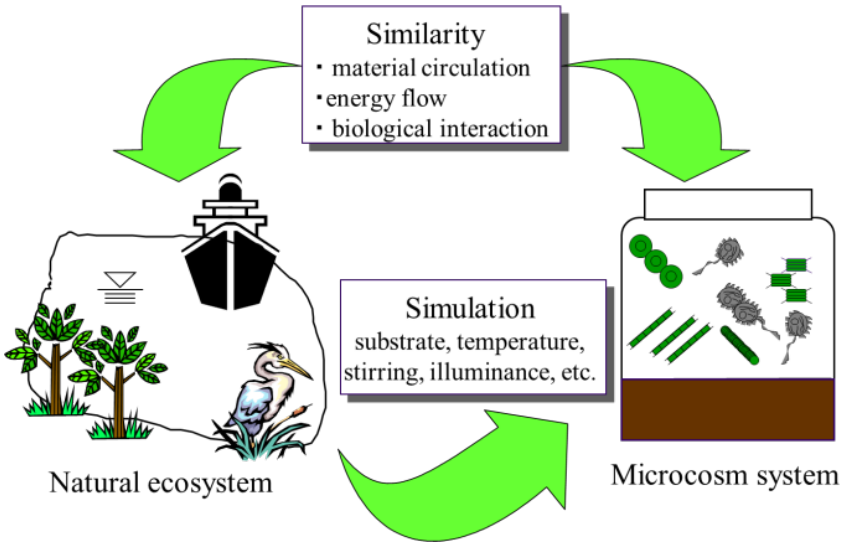

Fig.2 Relationship between natural ecosystem and microcosm system

P1-42

Use of Macroinvertebrate as the Water Quality Bio-indicator in Wang River and Creating a Learning Guide for Elementary Students

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Keywords: Macroinvertebrate, Bio-indicator, Water quality, Wang River

ABSTRACT

The study aims were to study the distribution of macroinvertebrate communities in Wang River. The macroinvetebrate samples were collect from 5 sampling sites along the Wang River from winter and summer season on January to June 2018. The macroinvertebrate diversity and abundance e were higher in the upstream to the down stream. The diversity and abundance of macroinvertebrate were decreased from winter season to summer season due to the higher of chemical concentration in the river. The chemical and physical from human activates and seasonal were an influence factors to the to the macroinvertebrate community and could be used as a tolls for monitor the water quality.

1. INTRODUCTION

In the modern world has entered an era of globalization, especially the rapid progress of science, telecommunications and information technology. As a result, countries have changed in many ways according to evolution. Including Thailand has to change dramatically in terms of economy, society, culture, science, technology and politics. Development of a country that is focused on the economy has caused problems in the distribution of income and social problems as well as environmental problems. Due to the lack of balance, the problem must be resolved quickly. Therefore, it is necessary to develop "Quality of people". The person will develop it with one important factor is education. Because education is a learning process for the growth of individuals and society. Education is a tool for developing people. It is a cornerstone of prosperity and problem solving. Because education is a process that allows people to develop themselves, which will eventually lead to social development and strategies to solve the problems and crises of the nation as the Thailand's Ministry of Education has adopted core curriculum for basic education in 2551 AD. The learning management in the course emphasizes the development of the learner in the thinking. And defined the key competencies of the learners is a key skill in the knowledge creation and knowledge to take on a life of quality. And adopting policies to encourage thinking skills into practice in a concrete classroom.

Due to various problems from the development of the country as mentioned above. Natural resources and environment are affected. Especially water resources. Because water is an important resource that impacts directly on the lives, community development and human life water is also used in consumer and consumption. In addition, water is also important in many activities such as industry, agriculture, transport, etc. The environment is simple and can be applied in teaching at various levels further. Because of the fact that the teaching and learning information is not used in this study, the idea is to create a study guide for the study of macroinvertebrates. To use in teaching and learning activities, students should be aware of the value of their local resources as well as to raise awareness about resource conservation.

For the above reasons, Researchers are interested in studying the quality of the Wang River water using macroinvertebrates as biological indicators, together with the quality of the physical and chemical composition of the water quality of the Wang River and to create an Efficiency Study Guide Learning (ESGL) tools

for the environmental education activities for school teaching and learning.

2. METHODS

The Macroinvertebrate sampling was conducted at five sampling sites along the Wang River. The sampling was carried out from Janury to July 2018. Environmental and physical and parameters included air temperature (^{0}C), water temperature (^{0}C), dissolved oxygen (mgL^{-1}), water velocity (mS^{-1}), pH, electric conductivity ($\mu S.cm^{-1}$) were measured in the field during sampling. Abiotic factors were also measure including biochemical oxygen demand (mgL^{-1}) and analyses of dissolved inorganic nutrients (ammonium, NH_4^+; nitrite, NO_2^- and soluble reactive phosphorus, PO_4^{3-} (APHA, 1992).

Three replicates of macroinvertebrates were collect at each site using the multi-habitat sampling technique described by Wang et al. (2012) which provides a more comprehensive sampling of total richness than fixed area sampler (Harrington et al., 2016, Resh and Rosenberg, 1984). Sample at each site were undertaken using a standard pond net (mesh size, 250 μm) with the total time (5 minutes per replicate). The sample were preserved in 70% ethanol. In the laboratory the samples were washed and all macroinvertebrates were sorted under a stereoscopic microscope (Tomanova et al., 2006). The taxonomical identification was conducted to the family level using taxonomic references by Merritt and Cummins (1996), and Mekong River Commissions (MRC, 2008)

3. RESULT

The diversity and distribution of macroinvertebrate from 5 samplingsites of wang River were slightly difference. The physical and chemical properties of the upstream (site 1- 2) shown a higher value and constancy than the other sampling sites. On the other hand, the distribution of macroinvertebrate was difference in term of diversity and abundance along the Wang River. The overall macroinvertebrate diversity and abundance were moderate to high compared to the previous research of Northern Thailand. Moreover, the abundance has been increasing from upstream to downstream, thus the diversity was depending on the appropriate in some sampling sites.

4. DISCUSSION

The human activities and the environmental variable were difference in each sampling of Mae Wang River. Not only environmental condition but the distributions of macroinvertebrate were also difference. The nutrients in the upstream were slightly difference in winter and summer season but the downstream were significantly difference. The Wang River riparian land use were agriculture activities so he nutrients may release and discharged to the river in the harvest season (Giorgeo, et al, 2016) . The nutrients were influence to producer as algae and other plant that might related to the distribution of macroinvertebrate through the ecosystem food chain. The water level would be reduced in a summer season and make a lower volume of water than winter season. This may have revealed a physical and chemical substance concentration in the Wang River and impact to the macroinvertebrate (Goldman and Horne, 1982) The distribution of macroinvertebrate were related to the water condition and could be used as a Monitoring tools for water quality bio-indicator. Water quality monitoring has been used to assess water quality since the 20th century (Abbasi and Abbasi , 2012). Previously, physical and chemical methods have been used for almost 85 years. Large groups of invertebrates are used to assess water quality impacts and monitor widespread water pollution. However, this old water quality test was not comprehensive and accurate. The BMWP Score system needs to be developed to match the current environment. However, the contaminated pollutants in some water sources are difficult to analyze and detect by chemical or physical so the macroinvertebrates can be used as biological indicators that indicate the presence of pollutants. Because the movement is the limit and have a long life expectancy of approximately 1 year. It can be checked all year round or every sampling period. It is therefore appropriate to use a biological index for efficient water quality monitoring.

5. CONCLUSION

The overall distributions of macroinvertebrate communities in Wang River were higher from upstream thus the diversity was depending on the site. The macroinvertebrate distributions were related to the water properties and difference season thus it could be use as tool for monitor the changing of water condition by the macroinvertebrate distribution in Wang River.

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P1-43

「里浜」～人と生き物の共生

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キーワード:自然再生, 生態系機能, 水辺空間, 生活, 地域づくり

抄録

(一社)霞ヶ浦市民協会は、1995(平成7)年開催の第6回世界湖沼会議にて採択された『霞ヶ浦宣言』の精神を理念に据え、1996(平成8)年に設立された。市民・行政・研究者・企業のパートナーシップのもと、霞ヶ浦という風土の中で培ってきた市民の英知を結集し、『泳げる霞ヶ浦』を目指して水質浄化の推進・啓発活動を続けている。『泳げる霞ヶ浦2020市民計画』は、2020年を目標に生活文化、水辺交流、環境保全、生態系保全、歴史文化、地域経済、啓発・環境学習など多岐にわたる分野での事業展開を示したもので、なかでも湖岸の整備、特に前浜再生に関わる「里浜づくり」事業を継続的に実践している。「里浜」とは、人の住む「里」と、自然の成す「浜」を合体させた造語だが、人と湖をつなぐ里浜(砂浜)をつくり維持管理しながら利活用することで、霞ヶ浦に対する人々の関心と、水質浄化への意識と行動を促すと考え、これを提案し事業として推進するものである。

1. 里浜の提案まで

1995(平成7)年に茨城県で開催された第6回世界湖沼会議は、学術会議にもかかわらず、多くの一般市民が参加したことでも記憶に残る。また、水環境保全を願う各国参加者の強い意志と決意の結晶である『霞ヶ浦宣言』がまとめられ、その宣言内容を設立理念とする社団法人(当時)霞ヶ浦市民協会が、1996(平成8)年に発足した。

2001(平成 13)年5月、当協会は 2020 年を目標に、『泳げる霞ヶ浦』の実現を目指すための『泳げる霞ヶ浦 2020 市民計画 基本構想』を、翌年には『同行動計画』を策定した。当時、20 年先の 2020 年は子どもたちが大人になり社会を担う時代であり、さらにその先へもつながる計画として、21世紀にふさわしい環境型循環社会の構築を背景にしたものである。これは、人と自然の共生を前提に、湖沼や河川の流域住民が、常に流域全体を視野に生活し、水系と関わっていることを自覚することで成り立つ、いわば『霞ヶ浦市民社会』とも言うべきネットワークの確立を目指したものでもある。

同計画の基本フレームは5つのプロジェクトから構成された。①暮らしのプロジェクト／新しい生活文化の創造…インフォメーションセンター「水の交流館」運営・夏休み教室・霞ヶ浦ジュニアレンジャー養成講座・自然観察会・環境学習・生活排水事業等 ②身近な川プロジェクト／生物多様性への模索…水質調査(地域・一斉)・新川クリーンアップ・どんぐり里子作戦・生物調査・河川清掃等 ③水辺交流プロジェクト／人と自然の回廊づくり…泳げる霞ヶ浦市民フェスティバル・水辺ふれあい事業・景観づくり等 ④地域経済プロジェクト／食に始まる霞ヶ浦ブランドづくり…土浦ビオパーク・新川浄化実験場・エコビジネス・地場産品の利活用 ⑤人とひとプロジェクト／プロジェクトの総括集結…シンポジウム・地域懇談会・世界湖沼会議・広報出版・交流会・研究など。これらの事業を市民、行政、研究者、企業、農林漁業者、学校、各種団体とともに協同・協働していく。

この5つのプロジェクトが相互に関連し合う、具体的な事業として辿り着いたのが、水辺の砂浜づくりである。昭和 40 年代初期までは霞ヶ浦沿岸に複数の遊泳場があり、人々は水に触れ、入り、泳いでいた。その泳げた時代をイメージしつつ掲げられた『泳げる霞ヶ浦』は、霞ヶ浦と流域住民の結びつきのもとで成立するものである。砂浜は、水辺の浄化機能を果たすのはもとより、親水空間としての利用価値がある。そこで、日常的に人々が集まり、水質浄化の意識行動のきっかけになる場としての砂浜を、人々の暮らす「里」と、霞ヶ浦の「浜」の結びつきを象徴する『里浜』という言葉で表した。しかし、同時

に維持管理が整わなければ砂浜は消失しかねない。

当協会は、多様な効用を持つ里浜の造成から維持のために、市民の立場で何をすべきか、何ができるかを考え、この里浜づくりを提案し、実践する。

2. 活動経過

『泳げる霞ヶ浦 2020 市民計画』策定後、里浜づくりに向けたシンポジウムやサマースクール等を開催、2006（平成 18）年3月には「第4回霞ヶ浦市民博覧会 2006」において、㈶土木研究センターなぎさ総合研究室長（当時）の宇多高明氏を講師に迎え、主に土浦市蓮河原・滝田地区の湖畔を対象に、現地視察と勉強会を行った。

宇多氏からは、養浜計画では、地形、地質、水深、汀線の角度、卓越風の方向、波の入射方向等の十分な事前調査が重要であることや、砂質、砂の安定のための方策、ヨシ浜との関係性が教示された。さらに、波のエネルギーを干さず、程よく浜に当てること、その地域にふさわしい姿にすることなどが浜づくりには重要であり、「相手は生きている湖」であることを忘れず、段階的な計画が必要であることを学んだ。

第6回世界湖沼会議後、旧建設省は、霞ヶ浦浄化の試みとして土浦市手野町石田地先に大量の砂を投入し、砂浜を造成していた。しばらくは前浜の形態を保ったものの、その後の管理が追いつかず、ヨシ等の植物繁茂、樹木の生長などで足を踏み入れる場もないほど荒れた。しかし、この湖岸は土浦の中心市街地からも近く、人々が利用する砂浜再生の場所としては適している。当協会では、この前浜をどうにか復活させ、里浜をつくろうということになった。



写真1　アシなどの草刈り

以降、年に数回、特に植物が繁茂する夏場には毎週のように、機械と人力による地道な草刈りと清掃作業を続け、各種イベントにも利用してきた。だが、整備エリアにもパワーにも限界は見えた。

2015年2月、事情を聞きつけた地元建設機械メーカーの全面協力のもと、約600㎡にわたる前浜部分のヨシを抜根した。根と砂を振るい分け、水辺近くでは浸出水に阻まれながらの大がかりな作業を終えると、地面に砂が見え始め、広々とした前浜が現れた。以降は人の手による継続的な整備作業が砂浜維持のための動力となっている。



写真2　前浜の草刈り作業

前浜の整備および利活用の一環としては、『水辺の楽校』と『砂浜の楽校』を年2回ずつ実施している。水辺の楽校は、主に子どもたちを対象に清掃活動と遊びを組み合わせたもので、自分たちできれいにした砂浜でペットボトル・ロケットを作り飛ばし、前浜にある流木でおこした焚き火で地元産サツマイモの焼き芋を作り食べるなど、水辺で遊び楽しんでもらう目的を持つ。



写真3　砂浜でのペットボトル・ロケット飛ばし

砂浜の楽校は、建設会社関係者の協力による本格的な清掃作業で、不法投棄された大量のゴミや、漂流物、流木を除去する。景観の維持はもとより、霞ヶ浦の状況を目の当たりにすることで、浄化への意識啓発につなげることも目的のひとつとなる。こちらも作業後にはレンコンやサツマイモなど地元産の食材で作った総菜や菓子で一服する。

いずれにせよ、当協会会員のみならず、地域の団体・市民、企業等の協力を得ながら続けるこの活動に終止符はなく、人力による定期的な維持管理が常に欠かせない。



写真4　前浜の整備

3.　課題と展望

砂浜は造成しただけでは維持できない。ヨシなど植物が繁茂し、ゴミが溜まることで、人は訪れずに荒れていく。しかしながら、維持のためだけに活動を続けていくのにも限界がある。望ましいのは、日常生活の中で利活用しながら維持管理していくことであり、それが里浜の理念でもある。

かつて、人々は集落をつくり、霞ヶ浦沿岸には多くの漁村があり、遊泳場があった。霞ヶ浦と日常生活は同じ線上にあり、水辺は自ずと管理されていた。すなわち、そこにこそ里浜の原型があり、地域と住民の関わりが果たす役割の大きさに気づく。とはいえ、昔のように自立的持続的な水辺との関わりを求めても不可能に近い。現状を鑑みるならば、必要なのは、新たな循環型社会、持続的な水循環の構築ということになろう。

もともと砂浜には、有機物の分解やろ過などの水質浄化機能、そして消波作用や魚類の産卵場所などの機能がある。里浜は、こうした生物の営み、生態系保全の場でもなくてはならないが、地域住民の理解と協力があってこそ、これらの環境も維持される。さらに、その理解と協力を長期的に得るためには、人々にとっても何らかのメリットが必要だろう。人々の暮らしに役立ち、生物の営みにも役立つ場としての水辺空間たる里浜が求められる。

2003（平成 15）年施行の「自然再生推進法」に基づき、当地における「霞ヶ浦田村・沖宿・戸崎地区自然再生事業」には当協会ほか多数の団体・市民が参加し、『里と湖』の接点たる湖岸帯の保全・再生、生態系の維持に向けた活動を継続、年々成果を収めている。石田地区においても、子どもたちの環境学習、レクリエーションの場としての利活用が増えてきた。



写真5　子どもたちによる砂浜づくり

この前浜を砂浜として再生し維持していくことは生態系サービスの「調整」「文化的」観点にも貢献する。茨城県が「霞ヶ浦に係る湖沼水質保全計画」の長期ビジョンに掲げる『泳げる霞ヶ浦・遊べる河川』実現のためにも、この前浜の整備、砂浜化は有効と考える。

前出の宇多氏の弁を借りれば、里浜づくりは、かつて霞ヶ浦で泳いだ世代だけが満足するものではなく、多世代の共感を呼び、理念哲学を持つことが不可欠である。「人と生き物の共生を基本とし、暮らしの中で親しみながら守り育てる浜辺」としての里浜を、『泳げる霞ヶ浦』実現のための指標と位置づけている。

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題名：コウノトリと共に生きる～豊岡の挑戦～

大逸　優人[1]

[1]豊岡市コウノトリ共生課

キーワード：自然再生，絶滅危惧種，生態系サービス，生物多様性評価

抄録

兵庫県豊岡市が取り組むコウノトリの野生復帰は、一度は野外で絶滅してしまったコウノトリを再度、人里近くに帰す取組みである。生態系の頂点に立つコウノトリの生息地を保全するため、豊岡市では様々な取組みを行っている。おいしいお米とたくさんの生きものを同時に育み、コウノトリも住める豊かな文化、地域、環境づくりを目指すための「コウノトリ育む農法」。コウノトリの生息地となる水辺環境の創出など、生息地保全の取組み。コウノトリ野生復帰を未来につなげるための子どもたちへの環境教育。今では 100 羽を超えるコウノトリが豊岡はもちろん、全国の空を飛んでいる。これからもコウノトリと共に生きていくため、豊岡の挑戦は続いていく。

1. はじめに

かつては日本中で生息していたコウノトリ。しかし、戦後の圃場整備や河川改修による湿田の消失、農薬の使用、普及により、1971 年、豊岡を最後に日本の空から姿を消した。兵庫県・豊岡市は 1965 年から人工飼育に取り組み、2005 年に初の放鳥に成功した。一度絶滅した野生動物を飼育下で繁殖させ、かつての生息地である人里に帰していくことは、世界にも例のない壮大なプロジェクトである。

コウノトリ野生復帰が目指すものは大きく3つに分類される。1つ目は「コウノトリとの“約束”を果たす」こと。コウノトリを救う最後の手段として人工飼育の道を選んだ際、いつかきっと空に帰す、と約束した。約束は果たさなければならない。

2つ目は「種の保存に関し、国際的な貢献を行う」こと。世界で 3,000 羽程度にまで減少しているコウノトリが安心して生息できる環境を保存・再生・創造することにより、日本最後のコウノトリの生息地として果たすべき国際的役割を担っている。

3つ目は「コウノトリも住める豊かな環境をつくる」こと。コウノトリは里の自然生態系の頂点に立つ肉食の鳥であり、コウノトリが野外で生きていくためには田んぼや川、水路に多様な生きものがたくさん生息する「自然環境」が必要となる。また、コウノトリを暮らしの中に受け入れる「文化環境」を再生することも必要である。コウノトリ「も」住める豊かな環境（自然と文化）は、人間にとっても持続可能で健康的に暮らせる環境と言える。

様々な分野に広がり続けるコウノトリの野生復帰の取組みについて紹介していく。[1]

2. コウノトリ野生復帰の取組み

（1）コウノトリ育む農法

水鳥であるコウノトリにとって「田んぼ」を代表とした生水辺環境は生息地として大切な場所である。コウノトリの野生復帰を支える重要な取組みの一つが、「コウノトリ育む農法」である。「コウノトリ育む農法」はおいしいお米（「コウノトリ育むお米」）を育てるとともに、多様な生きものを育み、コウノトリも住める豊かな文化、地域、環境づくりを目指した農法である。

コウノトリ育む農法で作られるお米は、無農薬・減農薬で栽培されることはもちろんであるが、その大きな特徴は、水田の水管理にある。1つ目に、田植えの1ヶ月前から田んぼに水を張る「早期湛水」。2つ目は、オタマジャクシに足がはえてカエルへと変態するのを確認できるまで約1カ月程度中干を延期する「中干し延期」。3つ目は、冬の間も田んぼに水を張る「冬期湛水」。そして、4つ目に、雑草を抑えるための「深水管理（田植え後約 40 日間8cm 程度の水位を維持）」。一般的な農法と比較すると圧倒的に湛水期間が長い。このように、年間を通じて湛水期間を長くすることによって、コウノトリのエサとなる多くの生きものを育むことが可能となる。

手間をかけ、安全・安心なお米を作るからこそ、コウノトリ育むお米の価値は高まり、慣行栽培米よりも高く販売され、生産者の所得増につながっている。コウノトリ育むお米が販売されているのは国内だけではない。コウノトリと共に生きる豊岡の取組みは、海外でも共感を呼び、安全・安心な米として評価され、香港やアメリカなどでの輸出が始まっている。コウノトリ育むお米は、市内小中学校の学校給食で使用されるなど、消費を増やすことで生産拡大を目指している。2003 年に作付面積 0.7ha

で始まったコウノトリ育む農法は、2017年は407.1haまで増加している。

（2）生息地保全

コウノトリ育む農法の作付面積が増える一方、同様に増加しているのが耕作放棄田や休耕田である。これらは放置しておくと陸地化し、草が繁茂し、コウノトリのエサ場環境としてはもちろん、景観的にも好ましくない場所となる。豊岡市では、このような休耕田を活用した水田ビオトープ事業を実施している。休耕田に水を張り、畦管理や草刈りをおこなって、水田ビオトープとして管理する。そうすることで、生きものを育む湿地の状態を維持することができ、将来、復田することも可能となる。2018年5月現在、市内には25ヵ所、約11.4haの水田ビオトープがある。コウノトリのエサ場としてはもちろん、子どもたちの環境学習の場としても機能している。

市内には水田ビオトープ以外にも様々な湿地がある。「加陽湿地」は、国土交通省の自然再生事業により創出された大規模湿地である。出石川とつながっている開放型湿地や池のような閉鎖型湿地が連なっており、川も含めてコウノトリの生息地としてだけでなく、冬鳥の越冬地としても機能している。

「ハチゴロウの戸島湿地」は、大陸から飛来したコウノトリが好んだ水田を湿地として整備した人工湿地である。水路を通じて円山川下流域とつながっているため、様々な魚介類が行き来しており、コウノトリの生息地として重要な湿地となっている。湿地内の人工巣塔では、2008年から毎年コウノトリが繁殖している。これらの湿地では、環境学習はもちろん、ボランティアや企業のCSRによる湿地保全活動が行われているが、基本的には市や国が管理している。

これらの湿地と異なるのが「田結湿地」である。豊岡市田結区の休耕田に1羽のコウノトリが飛来したのをきっかけに、田結区の住民が中心となり、土地の境界を越え共有化することで、大規模な湿地として管理している。田結湿地では研究者、NPO、企業、学生など様々な主体が関わりながら湿地の保全、活用に努めている。

市民や団体、企業や行政など様々なステークホルダーが関わりながら、消失した生態系の再生とコウノトリと共に暮らすための活動が行われており、これらの活動が世界に認められ、2012年に国際的に重要な湿地として、「円山川下流域・周辺水田」がラムサール条約に登録された。

（3）次世代育成

コウノトリ野生復帰の取組みを未来へと継続させていくのに重要なのは、取組みに共感する次世代の子どもたちである。2017年からすべての市立小中学校において「ふるさと教育」を行っている。コウノトリのことについて学ぶのはもちろん、水田ビオトープを活用した生きもの調査や、コウノトリ育む農法の体験、コウノトリ野生復帰に関わる方々に話を聞くなど、コウノトリ野生復帰の取組みを自ら体験する授業が行われている。

また、市では「コウノトリKIDSクラブ」という組織を結成している。コウノトリを軸として豊岡市の自然環境を学び、実際に湿地保全活動にも取り組んでおり、ふるさと教育の補完的な機能を有している。全国で同様の活動を行っている子どもたちと交流し、コウノトリ野生復帰の取組みや自分たちの活動について発表を行うことで、自分たちの活動をさらに誇りに思えるよう促している。

コウノトリを中心とした生きものとの共生に共感できる人が増えることは、コウノトリのエサ場（自然環境）づくりと同じく重要な生息地（文化環境）づくりにつながっている。

3. 豊岡の挑戦

2005年にコウノトリを放鳥してから10年以上が経過し、野外に生息しているコウノトリは100羽を超えた。豊岡周辺で生息できる羽数は50羽程度と言われているが、野外のすべてのコウノトリが健全に生息するためには、さらなる生息地環境を創出することが必要である。そのため、これまでに蓄積されたコウノトリの繁殖データなど、科学的データを活用して「自然再生アクションプラン」を実践する。既存の繁殖データやコウノトリ育む農法の作付面積、水田ビオトープの面積などの環境要因等を考慮して、繁殖に適した環境条件を探り、コウノトリの生息環境としてポテンシャルの高いエリアを抽出した。コウノトリの生息環境として適している場所は、豊かな生態系を育む可能性がある。豊岡市はこのような場所で効果的な自然再生活動を行うことによって、豊かな生態系を取り戻すことを目指している。今後は、地域の特性に応じた課題を明確にし、地元との協働による自然再生活動で質を高めつつ、コウノトリだけでなく、様々な生きものの生息地を創出、保全していくことを目指していく。

4. おわりに

前述で豊岡に生息できる個体数は50羽程度と述べた。残りの50羽程度はどこにいるのかというと、豊岡を飛び越え全国各地を飛び回っている。2017年には、47都道府県すべてでコウノトリの飛来が確認された。国境

を越えて韓国にまで飛来したコウノトリもいる。コウノトリ野生復帰の取組みは豊岡を飛び越え全国に展開されつつある。福井県越前市と千葉県野田市では、コウノトリを飼育するとともに、放鳥も行われている。また、2017年には徳島県鳴門市、島根県雲南市においてコウノトリが野外での繁殖に成功した。豊岡市周辺以外では初となる快挙である。今後も各地に飛来し、繁殖することが大いに見込まれるため、繁殖しているエリアはもちろん、繁殖が見込まれる飛来地と情報共有を図るとともにネットワークを築き、一丸となってコウノトリの生息地拡大を目指す必要がある。

コウノトリは人里（田んぼや川など）の生態系の頂点に立つ鳥であり、コウノトリが舞い降りる場所は必然的にエサとなる生きものがたくさんいる場所と言える。餌のある場所を求め自由に大空を舞う。コウノトリが飛来すると、その美しい姿に魅了され、様々な保全活動が展開されることがしばしばある。コウノトリは生物多様性の指標を図れるアンブレラ種であり、多くの人々を魅了し、保全活動などの関心を高めるシンボル種でもある。豊岡では、田んぼや湿地などの水辺に行くと、身近にコウノトリに出会える。しかし、今の状況はあたりまえではなく、多くの方々によるいくつもの努力があってこその景色である。美しく、雄大に空を舞い、豊かな環境のシンボルでもあるコウノトリと共に生きていくため、豊岡の挑戦は続いていく。

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P1-45

保護地域管理における“衡平性(Equity)”概念の整理と今後の論点

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キーワード:保護地域, 衡平性, 愛知目標 11

抄録

生物多様性条約第 10 回締約国会議で, 愛知目標が採択された。愛知目標 11 には保護地域に関する目標が掲げられた。その中で, ”衡平な管理”のみを評価するための指標が条約上、欠落している。しかし, 衡平な管理を評価するための指標を提案する研究が増えている。そこで、本稿は近年の研究レビューを通じて, 衡平な管理に関する指標の検討状況を概観した上で, 今後の検討のための論点を整理した。その結果, 衡平性に関する 3 つの側面はそれぞれに細分化されており, 費用や便益など, 定量的な指標が考えられるものもあれば, 意思決定や権利の有無といった定性的な指標、双方が含まれることがわかった。また, ラムサール条約において, 衡平な管理に向けた取り組みが進められていることも明らかにされた。今後の課題においては, 衡平性に係る 3 つの側面の相互作用や生物多様性条約と世界遺産条約など他の条約との協力の可能性が検討されることが期待される。

1. はじめに

地球規模での生物多様性の損失に対処するため, 生物の多様性に関する条約(Convention on Biological Diversity:以下, CBD という)が 1993 年に発効した。CBD は, 生物多様性の保全, その構成要素の持続可能な利用, 遺伝資源の利用から生じる利益の公正かつ衡平な配分の 3 つを目的としている[1]。CBD 発効後, 2002 年にオランダで開催された CBD 第 6 回締約国会議(Conference of Parties:以下, COP という)では, CBD の根本的な課題を当該条約の目的の広範さにあると指摘した上で, 生物資源の保全と持続可能な利用を国家経済, 社会, 政策立案の枠組みの中で主流化するために, 2010 年までの戦略計画を採択した[2]。しかし, 2010 年に日本で開催された CBD-COP10 で, 当該戦略計画が十分に達成されていないことを確認し, 2020 年までの戦略計画を採択した[3]。新たに採択された戦略計画は, 生物多様性の損失を止めるために効果的かつ緊急な行動を実施することを使命に, 愛知目標という 20 の目標(数値目標及び計画立案や資源動員など手続き的要素を含む)を組み込んだ。

その中でも, 保護地域の設定による生物多様性の保全は, 様々な国で実施され, その効果が認識されている取り組みの 1 つである。CBD は保護地域に関して, 締約国に対して, 1. 保護地域に関する制度を確立すること, 2. そのための選定, 設定及び管理のための指針を作成すること, 3. 保護地域の内外を問わず, 重要な生物資源の規制及び管理を実施することなどを義務付けている[4]。明確に言及されているわけではないが, 愛知目標 11 は, CBD 第 8 条の実施を促進するための目標でもあると考えられる。その保護地域に関する目標は, 以下の通りである。

“2020 年までに, 少なくとも陸域及び内陸水域の 17%, また沿岸域及び海域の 10%, 特に, 生物多様性と生態系サービスに特別に重要な地域が, 効果的, 衡平に管理され, かつ生態学的に代表的な良く連結された保護地域システムやその他の効果的な地域をベースとする手段を通じて保全され, また, より広域の陸上景観又は海洋景観に統合される。”(下線は筆者によるもの)

愛知目標は 2020 年までという時限付きの目標であり, 地球規模生物多様性概況第 4 版(Global Biodiversity Outlook4:以下, GBO4 という)によって中間評価が行われている。中間評価では, 愛知目標 11 に関して以下の評価がなされている[5]。

- □ 陸域における保護地域の割合は増加傾向にあり, その 17%という目標を達成できる。
- □ 海洋保護区の指定も加速度的に進んでいるものの, 達成に向けた軌道には乗っていない。保護区の指定も沿岸域のみで, 国家管轄権外における保護区の指定は少ない。
- □ 保護地域の管理状況は改善傾向にあると思われるものの, 効果的に管理されている保護地域は少数である。保護地域の効果的かつ衡平な管理が確実に行われるようにするためには, 更なる行動が必要。

GBO4 による評価からも明らかなように, 保護地域の

管理に関して，課題がある。特に，評価のための指標のリストを確認すると，効果的な管理を測る指標はあるものの，衡平性（Equity）のみを測る指標は確立されていない。

そういった状況の中，近年，衡平な管理を評価するための指標や要素に関する研究がなされるようになってきている。衡平性（Equity）とは，社会的正義（social justice）又は公正性（fairness）を意味する倫理的な概念である[6]。しかし，“異なる状況において，異なる人々によって，異なって解釈することができる”ため[6]，定義づけられていない[7]。

そこで，本稿ではこれまでの研究のレビューを通じて，“衡平な管理”を達成するための指標の検討状況を概観し，目標達成に向けた検討が必要な論点を整理することを目的とする。

2. 方法

本研究は，以下の手順に沿って実施された。

1. Elsevier 社の Scopus を使用して「”Protected area” ”Equitable”」という用語で検索。また，google scholar で「衡平性」という用語で検索。
2. 検索結果より，衡平な管理に関して 1. 衡平性の指標を検討した論文，2. CBD 等条約の文脈で“衡平性“が検討された論文を抽出。

この抽出された論文から，衡平な管理を達成するための指標の検討状況を整理し，今後の検討のための論点を整理した。

3. 結果

(ア) 衡平性の指標

Neil Dawson, et al. (2017) [8]は，ラオスの保護地域を事例に，衡平性には 3 つの側面（1. 認識（recognition），2. 配分（distribution），3. 手続き（procedural））があるとし，どのような実態があるのか，側面ごとに分析を行った。「認識」とは，その保護地域を有する社会的集団や異なる文化的又は社会的なアイデンティティを示し，「配分」とは，利益と費用の配分を，誰がどの程度なのかということ，最後に「手続き」とは，誰によって，どのように意思決定がされたのかということを意味する。その結果，衡平性の 3 つの側面を網羅することにより，衡平性を保全効果に結び付けられることを明らかにした。また，長期的な保全には，権利の不衡平性，定着した不公正，手続き上の失敗を乗り越えるための継続した努力，具体的にはステークホルダーダイアログが必要だと指摘した。

Zafra-Calvo, et al. (2017) [9]は，愛知目標 11 で示された衡平な管理に着目し，最低限の指標を提案した。その結果として，指標は，文化的アイデンティティ，法的及び慣習的権利，知識の多様性に関する社会的公正についての情報を対象とし，意思決定における完全な参加と透明性の確保，司法へのアクセス，意思決定に対する説明責任，保全負担の配分，および保全上の利益の共有を含むと結論付けた。ただし，これらを最低限の指標としつつも，これらに限定されるものではないと注釈を付している。

最後に，衡平性は，同じ環境分野でも気候変動の文脈で使われている。具体的には，気候変動枠組み条約における衡平性の原則である。亀山[7]は衡平性の中でも排出量の負担配分（Distribution Equity）に着目し，その基準を示している。具体的には，平等原則（1 人あたりが等しくなるような配分），各国の主張や既得益の尊重（現状を重視し，一定割合の負担），汚染者負担原則（排出量の割合に応じて，影響の被害を支払う方法），支払い能力（GDP が高い国が，より多くを負担する）等が挙げられている。

これらの研究を整理すると，衡平性に関する 3 つの側面はそれぞれに細分化されており，費用や便益など，定量的な指標が考えられるものもあれば，意思決定や権利の有無といった定性的な指標、双方が含まれることがわかる。

(イ) CBD の文脈で衡平な管理に関する検討状況

一方で，CBD の文脈において，Juffe-Bignoli D, et al. (2016) [10]は，愛知目標 11 を達成するために，何が達成される必要があるのか，包括的なレビューを行っている。具体的には，目標 11 で重要とされる要素（例えば，陸域及び内陸水域の 17%，沿岸域及び海域の 10%や効果的，衡平な管理など）別に，1. 新たな保護地域を設定する必要があるのか，それとも既存の保護地域を拡大する必要があるのかどうか，2. 保護地域の管理をどのように実施していくべきなのか，人的，技術的，金銭的な観点と手続

き的な側面から検討する必要性を指摘している。特に，衡平な管理に関しては，現状評価するための指標がないとしつつも，ラムサール条約等でその進展がみられていることを指摘している。

4. 考察

これまでの研究では，衡平性を構成する 3 つの側面の内，手続きと配分に関して，研究が進められていると考えられる。認識に関しては，手続き的な衡平性に係る誰がステークホルダーなのか，つまり，当該保護地域における管理主体や居住者，地域住民，NGO／NPO，協同組合など，立法上権限を有しているのかどうか，といった法的に重要な要素が含まれている。例えば， GBO4 による中間評価には，タイにおける国立公園の共同管理が事例として紹介されている。当該事例では，先住民コミュニティーが国立公園という保護地域の管理を巡り，どのように関与してきたのか，実態的且つ法的側面から検討を行い，住民による居住権と政府の保護地域管理権が衝突していたものの，政府と先住民コミュニティーは共同管理という協力関係を以って，衡平な管理を実現している[5]。このように，保護地域の管理体制は国ごとに異なることから，それぞれの国の文脈，法制度に沿った“認識”に関する研究が求められる。

また，ラムサール条約など，他条約による国内実施が CBD で反映することができるのかどうか，条約間の協力（条約だけでなく，国内法）のあり方の模索が必要になるものと考えられる。Juffe-Bignoli D はラムサール条約に関して提起されたが，世界遺産条約，渡り鳥二国間条約，南極条約など，他の条約も協力する条約として挙げられる。ただし，条約ごとにその目的や義務内容は異なるため，検討の際はその点に留意する必要があるものと考えられる。

5. 結論

愛知目標 11 で保護地域管理に，衡平性の要素が含まれるようになった点は、生物多様性の保全や利用の側面だけでなく，そこに関わる社会的な側面に焦点を挙げたという点で，保護地域管理のあり方を再考する 1 つのきっかけになったものだと評価することができる。

最後に本稿の結論として，今後の保護地域管理の文脈で検討することが期待される課題を提示し，締めくくる。

1. 認識，手続き，配分の衡平性の 3 つの側面が相互にどのように地域，国内，国際レベルで作用するか。
2. 各国，各地域においてステークホルダーを特定するための作業手続きのフローの作成（フローの作成にあたっては，居住権等の立法上の課題も含む）。
3. CBD だけでなく，ラムサール条約や世界遺産条約など他の国際条約における“衡平な管理”に向けた取り組みの整理と相乗効果の可能性。

以上の検討を通じて，保護地域の衡平な管理を実現が期待される。

引用文献

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P1-46

題名：コウノトリと共に生きる～豊岡の挑戦～

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キーワード：自然再生，絶滅危惧種，生態系サービス，生物多様性評価

抄録

兵庫県豊岡市が取り組むコウノトリの野生復帰は、一度は野外で絶滅してしまったコウノトリを再度、人里近くに帰す取組みである。生態系の頂点に立つコウノトリの生息地を保全するため、豊岡市では様々な取組みを行っている。おいしいお米とたくさんの生きものを同時に育み、コウノトリも住める豊かな文化、地域、環境づくりを目指すための「コウノトリ育む農法」。コウノトリの生息地となる水辺環境の創出など、生息地保全の取組み。コウノトリ野生復帰を未来につなげるための子どもたちへの環境教育。今では 100 羽を超えるコウノトリが豊岡はもちろん、全国の空を飛んでいる。これからもコウノトリと共に生きていくため、豊岡の挑戦は続いていく。

1. はじめに

かつては日本中で生息していたコウノトリ。しかし、戦後の圃場整備や河川改修による湿田の消失、農薬の使用、普及により、1971 年、豊岡を最後に日本の空から姿を消した。兵庫県・豊岡市は 1965 年から人工飼育に取り組み、2005 年に初の放鳥に成功した。一度絶滅した野生動物を飼育下で繁殖させ、かつての生息地である人里に帰していくことは、世界にも例のない壮大なプロジェクトである。

コウノトリ野生復帰が目指すものは大きく3つに分類される。1つ目は「コウノトリとの“約束”を果たす」こと。コウノトリを救う最後の手段として人工飼育の道を選んだ際、いつかきっと空に帰す、と約束した。約束は果たさなければならない。

2つ目は「種の保存に関し、国際的な貢献を行う」こと。世界で 3,000 羽程度にまで減少しているコウノトリが安心して生息できる環境を保存・再生・創造することにより、日本最後のコウノトリの生息地として果たすべき国際的役割を担っている。

3つ目は「コウノトリも住める豊かな環境をつくる」こと。コウノトリは里の自然生態系の頂点に立つ肉食の鳥であり、コウノトリが野外で生きていくためには田んぼや川、水路に多様な生きものがたくさん生息する「自然環境」が必要となる。また、コウノトリを暮らしの中に受け入れる「文化環境」を再生することも必要である。コウノトリ「も」住める豊かな環境（自然と文化）は、人間にとっても持続可能で健康的に暮らせる環境と言える。

様々な分野に広がり続けるコウノトリの野生復帰の取組みについて紹介していく。[1]

2. コウノトリ野生復帰の取組み

（1）コウノトリ育む農法

水鳥であるコウノトリにとって「田んぼ」を代表とした生水辺環境は生息地として大切な場所である。コウノトリの野生復帰を支える重要な取組みの一つが、「コウノトリ育む農法」である。「コウノトリ育む農法」はおいしいお米（「コウノトリ育むお米」）を育てるとともに、多様な生きものを育み、コウノトリも住める豊かな文化、地域、環境づくりを目指した農法である。

コウノトリ育む農法で作られるお米は、無農薬・減農薬で栽培されることはもちろんであるが、その大きな特徴は、水田の水管理にある。1つ目に、田植えの1ヶ月前から田んぼに水を張る「早期湛水」。2つ目は、オタマジャクシに足がはえてカエルへと変態するのを確認できるまで約1カ月程度中干を延期する「中干し延期」。3つ目は、冬の間も田んぼに水を張る「冬期湛水」。そして、4つ目に、雑草を抑えるための「深水管理（田植え後約 40 日間8cm 程度の水位を維持）」。一般的な農法と比較すると圧倒的に湛水期間が長い。このように、年間を通じて湛水期間を長くすることによって、コウノトリのエサとなる多くの生きものを育むことが可能となる。

手間をかけ、安全・安心なお米を作るからこそ、コウノトリ育むお米の価値は高まり、慣行栽培米よりも高く販売され、生産者の所得増につながっている。コウノトリ育むお米が販売されているのは国内だけではない。コウノトリと共に生きる豊岡の取組みは、海外でも共感を呼び、安全・安心な米として評価され、香港やアメリカなどでの輸出が始まっている。コウノトリ育むお米は、市内小中学校の学校給食で使用されるなど、消費を増やすことで生産拡大を目指している。2003 年に作付面積 0.7ha

で始まったコウノトリ育む農法は、2017年は407.1haまで増加している。

（2）生息地保全

コウノトリ育む農法の作付面積が増える一方、同様に増加しているのが耕作放棄田や休耕田である。これらは放置しておくと陸地化し、草が繁茂し、コウノトリのエサ場環境としてはもちろん、景観的にも好ましくない場所となる。豊岡市では、このような休耕田を活用した水田ビオトープ事業を実施している。休耕田に水を張り、畦管理や草刈りをおこなって、水田ビオトープとして管理する。そうすることで、生きものを育む湿地の状態を維持することができ、将来、復田することも可能となる。2018年5月現在、市内には25ヵ所、約11.4haの水田ビオトープがある。コウノトリのエサ場としてはもちろん、子どもたちの環境学習の場としても機能している。

市内には水田ビオトープ以外にも様々な湿地がある。「加陽湿地」は、国土交通省の自然再生事業により創出された大規模湿地である。出石川とつながっている開放型湿地や池のような閉鎖型湿地が連なっており、川も含めてコウノトリの生息地としてだけでなく、冬鳥の越冬地としても機能している。

「ハチゴロウの戸島湿地」は、大陸から飛来したコウノトリが好んだ水田を湿地として整備した人工湿地である。水路を通じて円山川下流域とつながっているため、様々な魚介類が行き来しており、コウノトリの生息地として重要な湿地となっている。湿地内の人工巣塔では、2008年から毎年コウノトリが繁殖している。これらの湿地では、環境学習はもちろん、ボランティアや企業のCSRによる湿地保全活動が行われているが、基本的には市や国が管理している。

これらの湿地と異なるのが「田結湿地」である。豊岡市田結区の休耕田に1羽のコウノトリが飛来したのをきっかけに、田結区の住民が中心となり、土地の境界を越え共有化することで、大規模な湿地として管理している。田結湿地では研究者、NPO、企業、学生など様々な主体が関わりながら湿地の保全、活用に努めている。

市民や団体、企業や行政など様々なステークホルダーが関わりながら、消失した生態系の再生とコウノトリと共に暮らすための活動が行われており、これらの活動が世界に認められ、2012年に国際的に重要な湿地として、「円山川下流域・周辺水田」がラムサール条約に登録された。

（3）次世代育成

コウノトリ野生復帰の取組みを未来へと継続させていくのに重要なのは、取組みに共感する次世代の子どもたちである。2017年からすべての市立小中学校において「ふるさと教育」を行っている。コウノトリのことについて学ぶのはもちろん、水田ビオトープを活用した生きもの調査や、コウノトリ育む農法の体験、コウノトリ野生復帰に関わる方々に話を聞くなど、コウノトリ野生復帰の取組みを自ら体験する授業が行われている。

また、市では「コウノトリKIDSクラブ」という組織を結成している。コウノトリを軸として豊岡市の自然環境を学び、実際に湿地保全活動にも取り組んでおり、ふるさと教育の補完的な機能を有している。全国で同様の活動を行っている子どもたちと交流し、コウノトリ野生復帰の取組みや自分たちの活動について発表を行うことで、自分たちの活動をさらに誇りに思えるよう促している。

コウノトリを中心とした生きものとの共生に共感できる人が増えることは、コウノトリのエサ場（自然環境）づくりと同じく重要な生息地（文化環境）づくりにつながっている。

3. 豊岡の挑戦

2005年にコウノトリを放鳥してから10年以上が経過し、野外に生息しているコウノトリは100羽を超えた。豊岡周辺で生息できる羽数は50羽程度と言われているが、野外のすべてのコウノトリが健全に生息するためには、さらなる生息地環境を創出することが必要である。そのため、これまでに蓄積されたコウノトリの繁殖データなど、科学的データを活用して「自然再生アクションプラン」を実践する。既存の繁殖データやコウノトリ育む農法の作付面積、水田ビオトープの面積などの環境要因等を考慮して、繁殖に適した環境条件を探り、コウノトリの生息環境としてポテンシャルの高いエリアを抽出した。コウノトリの生息環境として適している場所は、豊かな生態系を育む可能性がある。豊岡市はこのような場所で効果的な自然再生活動を行うことによって、豊かな生態系を取り戻すことを目指している。今後は、地域の特性に応じた課題を明確にし、地元との協働による自然再生活動で質を高めつつ、コウノトリだけでなく、様々な生きものの生息地を創出、保全していくことを目指していく。

4. おわりに

前述で豊岡に生息できる個体数は50羽程度と述べた。残りの50羽程度はどこにいるのかというと、豊岡を飛び越え全国各地を飛び回っている。2017年には、47都道府県すべてでコウノトリの飛来が確認された。国境

を越えて韓国にまで飛来したコウノトリもいる。コウノトリ野生復帰の取組みは豊岡を飛び越え全国に展開されつつある。福井県越前市と千葉県野田市では、コウノトリを飼育するとともに、放鳥も行われている。また、2017年には徳島県鳴門市、島根県雲南市においてコウノトリが野外での繁殖に成功した。豊岡市周辺以外では初となる快挙である。今後も各地に飛来し、繁殖することが大いに見込まれるため、繁殖しているエリアはもちろん、繁殖が見込まれる飛来地と情報共有を図るとともにネットワークを築き、一丸となってコウノトリの生息地拡大を目指す必要がある。

コウノトリは人里（田んぼや川など）の生態系の頂点に立つ鳥であり、コウノトリが舞い降りる場所は必然的にエサとなる生きものがたくさんいる場所と言える。餌のある場所を求め自由に大空を舞う。コウノトリが飛来すると、その美しい姿に魅了され、様々な保全活動が展開されることがしばしばある。コウノトリは生物多様性の指標を図れるアンブレラ種であり、多くの人々を魅了し、保全活動などの関心を高めるシンボル種でもある。豊岡では、田んぼや湿地などの水辺に行くと、身近にコウノトリに出会える。しかし、今の状況はあたりまえではなく、多くの方々によるいくつもの努力があってこその景色である。美しく、雄大に空を舞い、豊かな環境のシンボルでもあるコウノトリと共に生きていくため、豊岡の挑戦は続いていく。

引用文献

[1] 豊岡市：コウノトリと共に生きる 2017.

P2-1

気候変動による我が国の湖沼における水質・生態系の影響評価と適応策の検討に向けた将来水質予測の課題について

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キーワード:気候変動, 湖沼, 水質予測、生態系、適応策

抄録

気候変動による我が国における湖沼の水環境への影響は、政府の適応計画において重大性が特に大きいと評価されているものの、各湖沼の水質変化は地域特性によるところが大きいため、具体的な影響を把握するためには湖沼毎に詳細なシミュレーション等が必要である。そこで、環境省では気候変動影響として全循環不全や富栄養化、融雪の変化等の視点から3タイプのモデル湖沼を選定した上で、気候モデルから提供される将来気象条件を設定して、水質予測モデルを用いた将来水質予測を行い、湖沼水質の変化、生態系への影響評価を試みた。その結果、気候モデルによって水質変化の度合いには違いがあり、評価には複数ケースでの予測が必要であることや、湖沼特性に応じて適切な評価項目の設定が必要であること、水質変化の発生頻度の違いにより適応策を見極めて考える必要があること等が分かった。

1. はじめに

本報告は、環境省による「気候変動による湖沼への影響評価・適応策検討会(座長:岡田光正放送大学副学長)」(以降、本検討会)における検討の状況を報告するものである。

IPCC 第 5 次評価報告書[1)]では、気候システムの温暖化については疑う余地がないとされ、平成 27 年 11 月に閣議決定した「気候変動の影響への適応計画[2)]」では、湖沼・ダム湖の水環境への気候変動による影響は、緊急性、確信度は中程度であるが、重大性は特に大きいと評価されている。しかし、湖沼の水質変化は、地域、気象、流域等の条件によって異なるため、各湖沼でどのような影響がどの程度生じるのかを見極めることは難しい。

環境省では、平成 25 年度から本検討会において湖沼の気候変動影響検討を進めている。さらに、地方自治体等の湖沼担当者等が気候変動による将来の湖沼の水質影響を想定し、適応策を講じる契機とするための「手引き」を今後とりまとめる予定としている。

本報告では、モデル湖沼での気候変動影響のケーススタディ結果と、それを通して気候変動による湖沼の影響検討に当たっての課題を報告する。本検討会では、これらの課題解決に向けて今後検討を進める予定である。

2. 方法

(1)モデル湖沼の選定

気候変動影響予測及び評価を行うにあたり、長期的な観測データが得られた 21 湖沼(**表 1**)から、気候変動影響の検討が可能な 3 タイプの湖沼を選定した。

① 融雪による影響があり、富栄養化の問題が生じている浅い湖沼 →八郎湖
② 冬季の全循環不全やこれに起因する水質・生態系への影響が検討可能な深い成層化湖沼 →琵琶湖
③ すでに冬季の全循環が停止しており、水質等への影響がデータとして把握できる湖沼 →池田湖

表 1 モデル湖沼の選定表

地域	No.	湖沼	気候変動影響						汽水湖(海水の影響を含む)	(二次選定)モデル湖沼
			過去水温上昇		結氷短期化	アオコ・淡水赤潮発生	循環不全	融雪出水		
			夏季	冬季						
北海道	1	屈斜路湖	○	－	○					
	2	阿寒湖		－	○					
	3	洞爺湖		－	○					
東北	4	小川原湖			○	○		○	○	
	5	十和田湖	○	－	○			○		
	6	田沢湖		－	○			○		
	7	**八郎湖**	○		○	○		○		○
	8	猪苗代湖		－	○			○		
関東	9	中禅寺湖		－	○					
	10	霞ヶ浦	○	○		○				
	11	手賀沼	○			○				
	12	印旛沼	○			○				
中部	13	野尻湖	○	○	○					
	14	諏訪湖			○	○				
	15	佐鳴湖				○			○	
	16	河口湖								
近畿	17	**琵琶湖北湖**	○	○		○	△	○		○
		琵琶湖南湖	○	○		○				
中国	18	中海		○		○			○	
	19	宍道湖		○		○			○	
	20	児島湖				○				
九州	21	**池田湖**	○	○		○	○			○

※過去水温上昇は、過去30年間で水温上昇の地点があった湖沼(「－」冬季結氷のため水温測定無し)

(2)将来予測・影響評価の流れ

気候変動による将来の湖沼水質は、2100 年頃の気象条件を用いて、各モデル湖沼で構築した水質予測モデルにより解析した。気候モデルから得られる将来気象条件(気温、降水量)を入力条件として、流域からの流出、

それを入力条件として湖内の水温及び水質解析を行った。その結果を用いて、水質・生態系の影響評価を行い、影響がある事象に対して適応策の検討を行った。

(3)湖沼の水質・生態系の影響評価方法

湖沼の水質・生態系に対して、気候変動による影響である「水温の変化」、「融雪期の変化」及び「降雨の変化」に着目して、それに伴う主要な変化と水質・生態系への影響を評価するための項目を、文献調査、自治体へのヒアリング等を踏まえて、**表 2** の通り整理した。

表 2　気候変動による影響評価を行うための評価項目

気候変動影響要素	主要変化	水質・生態系への影響
水温変化	冬季全循環不全	①底層水の貧酸素化、底層利用種の酸欠
		②底泥からの窒素、りんの溶出
	水温上昇	③冷水性魚類等の生息適水温とのずれ
		④植物プランクトン量(chl. a)の変化
		⑤魚類の生息水深の変化
		⑥底泥からの窒素、りんの溶出
	藍藻類の変化・増加	⑦魚類生息影響
	湖面結氷の短期化	⑧魚類、プランクトンへの影響
融雪期の変化	融雪時期の変化による栄養塩供給時期の変化	⑨植物プランクトン量(chl. a)の変化
	河川流量変化による湖内流動・循環の変化	⑩春先の栄養塩供給量減少
		⑪湖底へ貫入する融雪水量の変化
降雨の変化	増水、渇水、ピーク流量の変化、流入栄養塩の変化	⑫浮遊物質量の増加、透明度の変化
		⑬植物プランクトン量(chl. a)の変化

(4)湖沼水質予測モデルの構築と再現性の確認

モデル湖沼での将来の水質予測にあたっては、流域モデル、湖内モデルを連成した水質予測モデルを構築した。また、河川流量や水質、および湖沼の水温・水質の実測データを用いて再現性を確認した。

(5)将来気象条件の設定

将来気象条件は気候モデルから得られる将来気象データを用いた。ここでは、なるべく高解像度(数 km)程度のメッシュサイズ(100~500m)で、かつ出水を表現するために毎時データを用いることが望ましいが、現状では、不確実性の評価のため複数の気候モデルで同じような高解像度の将来気象データを得ることは難しい。

今回の検討では「MRI-NHRCM20」RCP2.6、8.5 を用いることとした。なお、各気候モデルによる影響予測の違いを評価するため、MIROC5 及び GFDL-3CM(RCP8.5)による検討も行っているが、本報告には含めていない。

3.　将来水質予測結果

(1)将来の気象条件

1)気温

3 湖沼とも現在と比べて年平均気温で RCP2.6 では 0.5℃程度の上昇、RCP8.5 では 3～4℃程度の上昇となった(**図 1**)。

2)降水量

3湖沼とも年間降水量は多くなる傾向であった(図2)。八郎湖では増加量は小さいが、池田湖では増加が大きく、夏での増加が大きい傾向であった。

(2)将来の水質予測結果

1)八郎湖

湖水温は、通年で上昇するが、夏期の上昇が大きく、現在に比べて RCP8.5 では 3.6℃の上昇であった(**図 3** 上)。また、夏期(7～8 月)にクロロフィル a 濃度の最大値が増加する傾向が見られ、RCP8.5 では 10 ヶ年中 6 回、現在の(既往)最大値を超える年が生じた(**図 3** 下)。

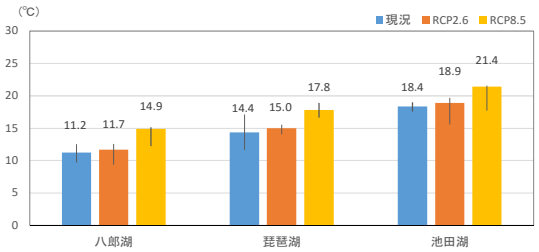


図 1　NHRCM20 での将来気温

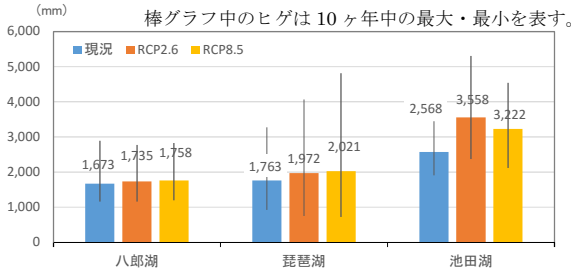


図 2　NHRCM20 での将来の年間降水量

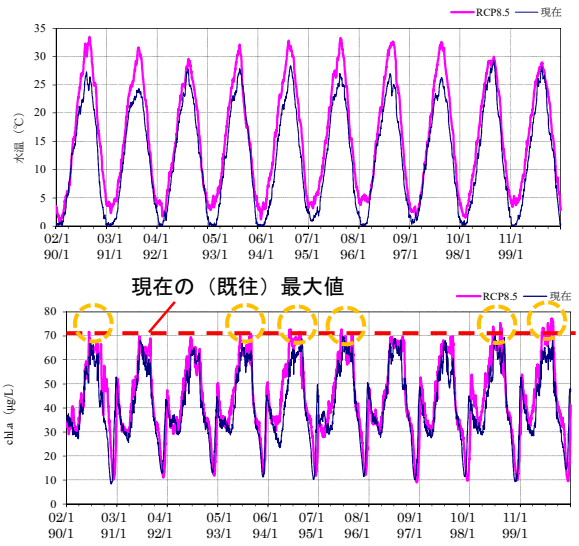


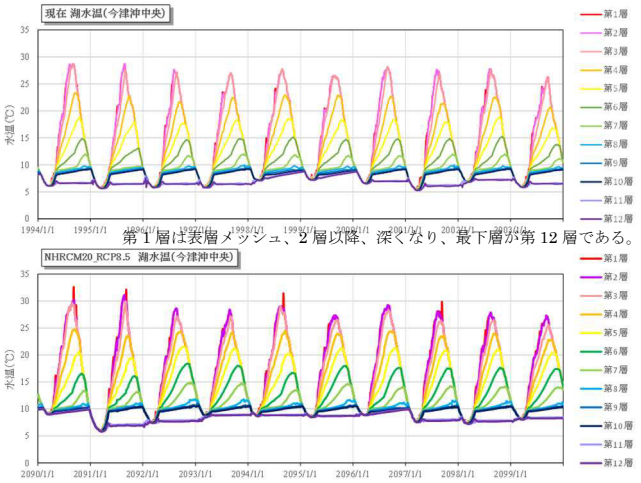
図 3　水質予測結果(八郎湖　調整池湖心)

2)琵琶湖

北湖の今津沖中央地点における、水温鉛直分布と底層溶存酸素量(底層 DO)の予測結果を併せて分析すると、底層 DO が回復していることから RCP2.6 では全循環不全は生じなかったが、RCP8.5 では 2093 年に全循環不全が生じると予測された(図 4 下)。

底層 DO の変化について、RCP2.6 では全循環不全となる年は生じず最小でも 2mg/L であった。また、RCP8.5

では全循環による底層 DO の回復が十分ではなかった 2093 年の夏にはゼロとなったが（図 5 下）、この状況は予測期間 10 年間で 1 度の発生であった。



第 1 層は表層メッシュ、2 層以降、深くなり、最下層が第 12 層である。

図 4 湖水温鉛直分布の変化（琵琶湖 今津沖中央）

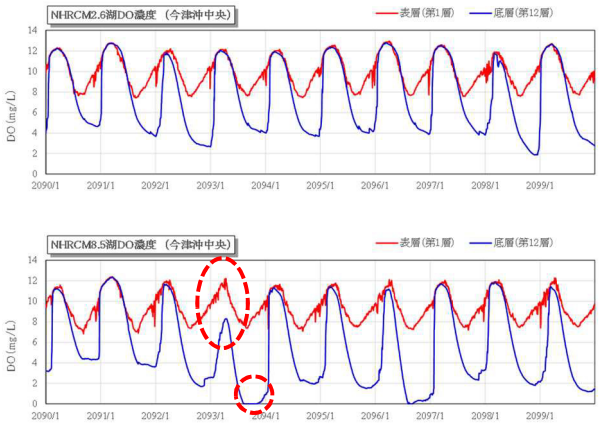


図 5 DO 鉛直分布の変化（琵琶湖 今津沖中央）

4. 気候変動による水質・生態系影響に関する考察

(1) 八郎湖における影響評価

植物プランクトンが存在すること自体は問題ではなく、異常増殖することがアオコ等の水質問題につながることから、クロロフィル a 濃度の最大値に着目した。予測結果（**図 6**）から、現在の（既往）最大値は 70μg/L であり、将来これを上回る頻度は、RCP8.5 では 6 回生じ、最大濃度は 76μg/L、約 1.1 倍になると予測された。

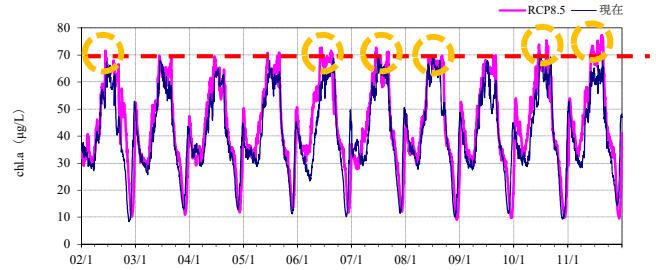


図 6 クロロフィル a 濃度の変化（八郎湖 調整池湖心）

(2) 琵琶湖における影響評価

底生魚であるイサザを対象に、底層DOの予測結果を用いて生態系の影響評価を行った。北湖において、イサザの貧酸素耐性評価値（2.5mg/L：12h-LC5 と仮定）を下回る状態となる範囲の面積を整理した（**図 7**）。この結果、10 年間で現在の最大値を超える状況が RCP2.6 では 4 回、RCP8.5 では 8 回生じると予測された。

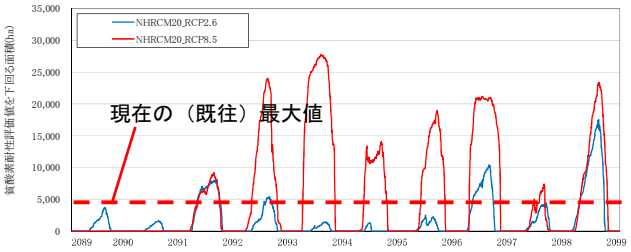


図 7 貧酸素耐性評価値を下回る面積（琵琶湖 北湖）

(3) 将来予測結果を踏まえた適応策の検討方法

まず、用いる気候モデルによって予測結果が異なることへの留意が必要である。例えば、琵琶湖では底層 DO への影響が大きい冬期の全循環不全について、気候モデルによって生じたり、生じなかったりという結果となるため、複数ケースでの検討、評価が必要と思われる。

また、発生頻度は低いが底層 DO の枯渇等、顕著な影響が生じると予測された場合、既往の対策では非現実的な実施量になる。このような場合の適応策としては、影響の規模や継続時間等を考慮し、被害の最小化、代替等の視点も含めて検討する必要があると考えられる。

一方で、比較的発生頻度が高い水質変化に対しては、既往の対策による対応も可能と考えられる。例えば、毎年のような夏期の植物プランクトン量の増加への対応としては、汚濁負荷削減対策の上積み等が考えられる。

以上より、発生頻度と影響度合いに応じて対策の方向を見極めて適応策を検討する必要があると考える。

5. 結論

本報告での現時点での結論は次の通りである。

- 将来予測で用いる気候モデルについては、水質予測モデルの時間・空間解像度に応じて適切な時空間スケールのデータを用意する必要がある。
- 気候モデルによって湖沼の水質変化は様々であり、幅がある。複数の気候モデル、排出シナリオを設定し、変化の幅等を把握した上で影響評価を行い、各湖沼の特性に応じて適応策を検討する必要がある。
- 発生頻度の違いと影響度合いに応じて対策の方向を見極めて、適応策を検討する必要がある。

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P2-2

河口域における人為起源有機物ビスフェノール A の塩分濃度に伴う動態

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キーワード:化学物質による汚染, BPA (bisphenol A), 河川水, 河口域 , 塩析効果

抄録

河口の汽水域では溶存する人為起源有機物が塩析効果によって濃縮や沈殿が起こっていることが考えられるが、実際の現場での観察例はほとんど知られていない。本研究では、相模川の河口域においてビスフェノール A (BPA)の塩分濃度の増加に伴う動態把握を、溶存態有機物(DOM)、懸濁態有機物(POM)および堆積物試料を用いて試みた。DOM と POM 中の BPA 濃度の比は、塩分濃度 5–10 ‰にて、顕著に小さくなる傾向を示した。これは BPA が塩析効果により、DOM 画分から粒子の大きい POM 画分などに移行していることを示唆している。この塩分範囲(5–10 ‰)を経験する河口域の場所は、最河口域のやや上流になる。そこにおける堆積物中 BPA 濃度は、その上流・下流行きの堆積物よりも顕著に高い値を示したことから、塩析効果によって、BPA の濃縮・蓄積が実際の現場環境でも引き起こしていることが明らかになった。

1. はじめに

これまでの河口域における堆積物中有機物の平面分布を調べたいくつかの研究結果では、汽水域(感潮域)において、上流域から輸送される有機物濃度が高くなる傾向を示していた[1, 2]。この現象の要因の一つとして、河川水と海水が混合することによって起こる塩析効果によって説明されてきた。塩析効果とは、河川水と海水が混合することで、河川水中の有機物の溶解度が低くなることで析出する現象である。実際に、この効果は、特定の有機物をつかった室内実験によっても確認されており、それは現場環境でも十分に起こりえることが指摘されている[3, 4]。しかしながら、現場の汽水域などで塩析効果と特定の化合物濃度との関係を観察した例はほとんど無い。

河川水中の人為起源の有機物は、人間活動の活発化に伴い、年々増加する傾向にあり、これらの自然環境に与える影響は無視できない[5]。これら人為起源有機物は、溶解度が比較的低い疎水的な特徴を持つ化合物が多いため、河川水中では単体で存在しているのではなく、溶存態有機物(DOM)や懸濁態有機物(POM)といった浮遊粒子に吸着していると考えられている[6]。これら有機物に塩析効果が働くとすると、DOM から POM へ、また POM から沈降物(もしくは堆積物)へと、さらに粒子の大きい画分に移行すると考えられる。したがって、汽水域における河川水中の人為起源有機物に対する塩析効果は、上流から運ばれてきたこれらの有機物を優先的に堆積物に蓄積させる“濃縮効果”のように働き、底生生物などに対する影響が懸念される。

以上のことから本研究では、人為起源有機物であるビスフェノール A(BPA)を対象として、河口の汽水域において塩濃度の変化に伴う人為起源有機物の動態を明らかにすることを目的とした。具体的には、河口の汽水域で塩濃度が大きく変化する時間帯で水試料の採取を行い、塩濃度の変化と DOM 中や POM 中の BPA 濃度の変動を追跡・解析した。

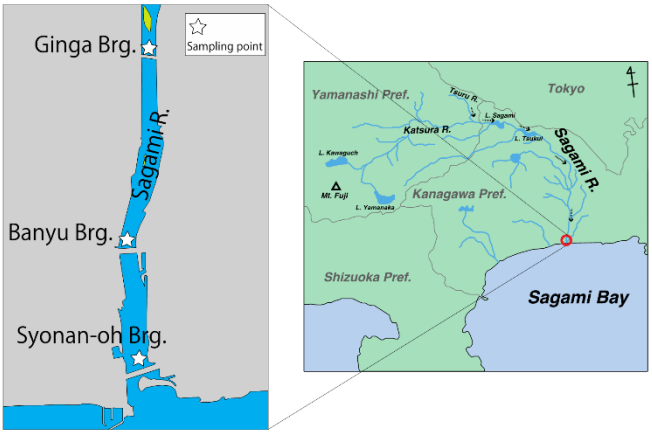

Fig. 1 試料採取地点

2. 方法

水試料の採取地点は、相模川汽水域の馬入橋と湘南大橋の 2 地点を選定した(Fig. 1)。水試料の採取は塩濃度の変化が大きいと予想される大潮の日(2016 年 6 月 4 日)、小潮の日(同年 10 月 23 日)、中潮の日(同年 11 月 23 日)を選定し、満潮時前後 2 時間、1 時間おきに 2 地

点で同時刻に採水(計 5 回ずつ)をし、塩濃度、水温、pH を測定した。堆積物試料は、2017 年 12 月 2 日に、銀河橋、馬入橋および湘南大橋にて、エクマンバージ採泥器を用いて採取した(Fig. 1)。

水試料の処理は、0.7 μm のガラスファイバーフィルター(GF/F)で濾過し、フィルター上に残ったものを懸濁態有機物(POM)として回収した。次にろ液に塩酸を加え pH 2 に調整後、DAX-8 樹脂カラムに圧力ポンプを用いて試料水を通し、有機物を吸着させた。吸着させた有機物は 100 mL のメタノールで溶離し、エバポレーターで濃縮したものを溶存態有機物(DOM)試料とした。堆積物試料は、採取後、凍結乾燥させ、すりつぶし、粉末試料とした。有機化合物の分析は Online TMAH–GC–MS 法を用いて、人為起源有機物の分析・解析を行った。

3. 結果および考察

3.1. 河川水 DOM および POM 中の BPA 濃度

Fig. 2 に相模川水中の DOM および POM 中の BPA 濃度と塩濃度の関係を示す。BPA は工業用可塑剤として広く利用されており、内分泌かく乱化学物質と考えられている有機化合物である[7]。河川水中の DOM と POM 中の BPA 濃度は、画分で大きく異なり、POM 中よりも DOM 中の BPA は、平均値で 8 倍ほど高い値を示した。したがって、BPA は、基本的に、河川水の DOM 画分に多く存在しているといえる。他の研究においても、フェノール類は DOM 画分に比較的見られることが知られており、このような傾向は、BPA の化学的特性によるものと思われる。それぞれの画分における BPA 濃度は、塩濃度が高くなるにつれて、DOM 中 BPA 濃度が低くなる傾向がみられ、POM 中 BPA 濃度は高くなる傾向が見られる。これは、DOM 中から、POM や堆積物へ、BPA の画分の移行が起きている可能性がある。さらに興味深いことに、DOM 中の BPA は、20 ‰を超える高い塩分濃度では、ほとんど検出されなかった。

3.2. 塩分濃度と BPA 濃度の関係

塩濃度と BPA 濃度の動態を見るために、DOM 中 BPA 濃度と POM 中 BPA 濃度の比(BPA_{DOM}/BPA_{POM}比)と塩濃度の関係を Fig 3 に示した。この比は、DOM から POM への移行が大きい時、その値が小さくなると解釈される。BPA_{DOM}/BPA_{POM}比は塩濃度が 5-10 ‰あたりで顕著に高い値を示し、これ以上の塩濃度では、小さい値を示した。このことは、BPA が塩濃度 5-10 ‰あたりで DOM から POM に移行し始め、それ以上の塩濃度では、

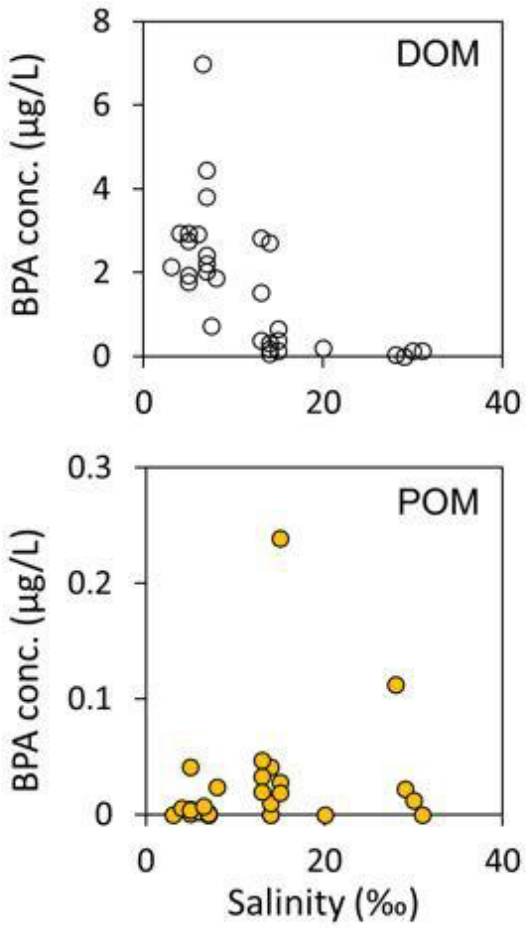

Fig. 2 相模川汽水域における DOM および POM 中のビスフェノール A(BPA)濃度と塩濃度.

塩析効果により BPA が DOM から POM へ移行したことを示唆している。この結果は、塩が添加されることで BPA の溶解度が急激に低下する室内実験の結果[4]からも支持される。したがって、現場の低塩濃度環境下で塩析効果は、有機物の動態に顕著な影響を与えると考えられる。一方で、> 10‰の POM 中の BPA 濃度を見ると、高い濃度を示してはおらず、これは、高塩分(> 10 ‰)環境下では塩析効果によって、速やかに DOM から POM に、そして堆積物に移行したためであると考えられる。

3.3. 汽水域の堆積物中 BPA 濃度の分布

水中での動態結果から、DOM 画分の BPA は、塩析効果によって、POM のみならず堆積物への移行が生じていることが考えられた。これは、塩析効果によって選択的に堆積物中に BPA が蓄積され、濃縮効果のような働きをしている可能性が高い。Fig. 4 に、相模川河口の異なった地点(銀河橋、馬入橋および湘南大橋)における堆積物試料中 BPA の濃度を示す。

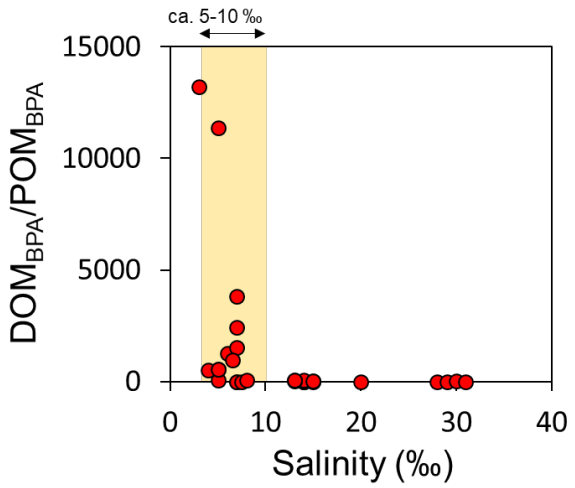

Fig. 3 河川水中の DOM 中 BPA 濃度に対する POM 中 BPA 濃度比(BPA_{DOM}/BPA_{POM} 比)と塩分濃度.

銀河橋における塩分濃度は低く、0–2 ‰ (Ave. 1‰, n=2) 程度をとる。馬入橋では、平均 8.63 ‰ (n=15) をとり、潮の満ち引きに伴い 4–15 ‰のレンジで変化した。湘南大橋では、最も海に近いため、塩分濃度は、4–31 ‰と最も高い範囲で変動した (Ave. 15.9 ‰)。

堆積物中の BPA 濃度は、馬入橋で最も高い値を示した。Fig. 3 に示した結果から塩濃度 5–10 ‰で DOM から POM への BPA の移行が見られた。この塩分濃度を潮の満ち引きで経験するのは、馬入橋付近であり、この結果は、人為起源有機物は、塩析効果によって、選択的に沈降し、堆積物中に濃縮・蓄積されることを示している。

塩濃度が常時高い場所である湘南大橋付近よりも上流の堆積物中(馬入橋)で BPA 濃度は高い値を示したことは、10 ‰程度の塩分濃度で BPA が沈殿・堆積してしまい、さらに高塩分の場ではすでに沈殿・堆積した後であると考えられる。

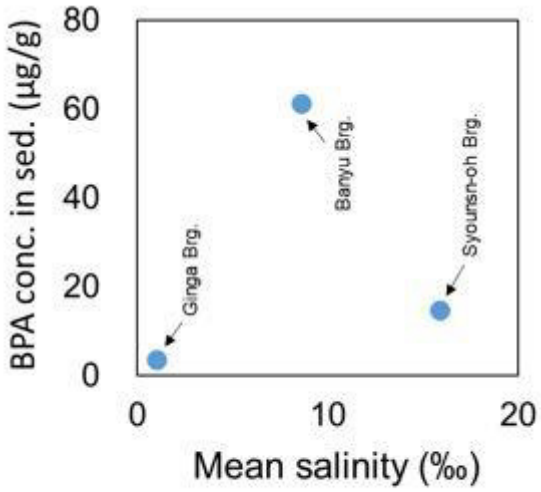

Fig. 4 相模川の各地点における堆積物中の BPA 濃度. 地点は Fig. 1 を参照.

4. 結論

DOM 中 BPA 濃度と POM 中 BPA 濃度比は塩濃度が 5–10 ‰へ増加するにつれて上昇し、10–30 ‰に増加するにつれて比の値は減少する傾向を示した。このことは、DOC と POC が共に塩濃度が 5–10 ‰あたりで塩析効果の影響を受けることを示唆した。以上のことから、現場河川水中においても塩濃度の変化に伴って人為起源有機物 (BPA) の濃度動態は変化することが明らかとなった。

堆積物においては、相模川汽水域にある 3 つの橋(銀河橋、馬入橋、湘南大橋)において、塩濃度の分布と堆積物中の有機化合物の濃度分布を比較した。結果、つねに塩濃度が高い地点よりも 5–10 ‰を経験する採泥地点において BPA は堆積しやすい傾向が示された。これは、水中の塩析効果が生じている塩分濃度範囲と一致しており、BPA は塩析効果によって、堆積物中に濃縮・蓄積していることが本研究によって示された。

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P2-3

水月湖の淡水湖から汽水湖への歴史的な変化：ステロール指標からみた貧酸素環境

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キーワード：水月湖，汽水湖，貧酸素，有機地球化学，指標

抄録

水月湖は、洪水などを防ぐための江戸時代に始まる治水工事に伴い半永続的な貧酸素水塊が形成された湖である。ステロールは、還元的環境下でバクテリアの作用によってスタノールへと変化する。したがって、スタノールに対するステロールの比（スタノール/ステロール比）は、貧酸素環境下で高くなる。本研究では、水月湖堆積物に記録されたスタノール/ステロール比を用いて、過去のから現在にかけての水月湖における貧酸素水塊が形成史復元を試みた。堆積物中のスタノール/ステロール比および緑色硫黄細菌に由来するファルネソールは、治水工事を境に、還元的環境の始まりを、確かに記録していた。一方で、それらの指標は、再表層で最も高い値を示し、最も近代に行われた治水工事（1935 年）以降に形成されたことを示した。これらの結果は、人為的な活動が、湖沼の環境を大きく変える要因として働くことを明確に示している。

1. はじめに

人間活動の湖沼環境に与える影響は、富栄養化や汚染物質の流入、生物圏の規模の縮小など、多岐にわたる。このような人為的な湖沼環境の変化は、近年的な事例のみならず、人間活動の始まった時代からすでに存在していた。その一例として、福井県の水月湖は、17 世紀は江戸時代を境として、当時行われた治水工事に伴い湖の環境が大きく変化した場所としてよく知られている。

水月湖は、若狭湾近くに位置する湖で、現代では、久々子湖および日向湖を介して、海水が流入してくる汽水湖である (Fig. 1)。この汽水環境は、水月湖に貧酸素水塊を形成し、上層が酸化的で、下層部がほぼ無酸素状態の半永続的な 2 層構造を作り上げている。さらに、貧酸素水塊には、緑色硫黄細菌などの光合成細菌が生息している[1]。

このような貧酸素水塊が形成される以前の水月湖は、淡水環境であった。1664 年（江戸時代）に、頻繁に起こる洪水対策として、湾に水を逃がすために久々子湖と水月湖の間に水道（浦見水道）が開通した。これにより、若狭湾から海水が水月湖に流れこみ、塩分躍層が形成され、淡水から汽水環境となった。その後、1800 年には、日向湖と水月湖の間に、嵯峨トンネルが建設（1835 年に再建設）され、1935 年の両水路の拡大工事が行われている。しかしながら、貧酸素水塊の形成史は、1920 年代からのモニタリング[2]を除いて、よくわかっていない。

ステロールは、真核生物のもつ特徴的な脂質成分で、湖沼や海洋の堆積物中に広く検出されている。さらに、ステロール類は、貧酸素環境下で、バクテリアの作用により、5 位のところの二重結合が還元され、スタノールへと変化する (Fig. 2)。したがって、スタノールに対するステロールの比（スタノール/ステロール比）は、貧酸素環境下で高くなる。さらに、堆積物中のスタノール/ステロール比は、昔の貧酸素環境および酸化環境の復元に利用可能であることが、先行研究によって示されている[3]。これは、水月湖の貧酸素水塊の形成史の復元にも応用できると期待される。

そこで、本研究では、水月湖の底泥を柱状（コア状）

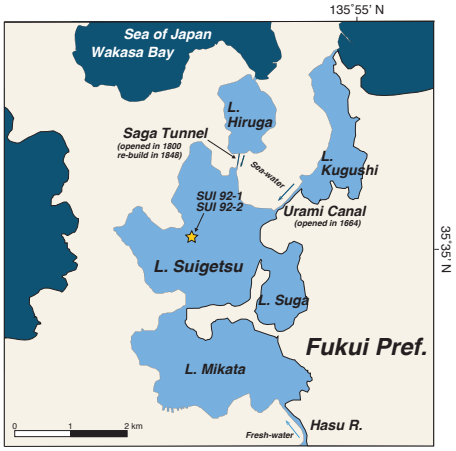

Fig. 1 福井県の水月湖[4]．若狭湾から海水が、水月湖へ、久々子湖から浦見水道を通って、嵯峨トンネルから日向湖を通って流入してくる．淡水の主な流入源は、三方湖を通って水月湖に流れ込む、はす川である．

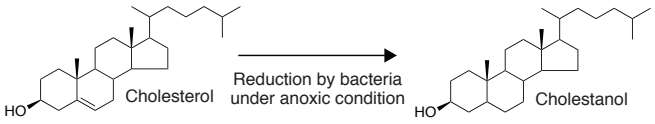

Fig. 2 貧酸素水環境下で生じるバクテリアによるステロールからスタノールへの還元反応.

に掘削し、堆積物中のスタノール/ステロール比から、過去の水月湖における貧酸素水塊形成の変遷史を追うことを目的とする。

2. 方法

水月湖の湖心（水深 34m）から 2 つのコア試料（SUI92-1 と SUI92-2）を 1992 年に採取した。コアの長さは、SUI92-1 が 80cm で、SUI92-2 が 85cm である。両コア試料は、表層から 50cm までを毎 2cm ごとに、50cm 以降を毎 5cm ごとにカットした。分けられた試料は、凍結乾燥し、粉末状にした。

堆積物試料中の有機物分析は、TMAH GC–MS 法を用いた。約 25mg の堆積物試料をアンプル管にとり、水酸化テトラメチルアンモニウム（TMAH）試薬とインターナルスタンダードとして nanodecanoic-d_{37} acid を入れ、真空下で栓をし、オーブンで 300℃30 分加熱した。加熱後、速やかに室温にまで冷却し、生成物は、酢酸エチルを用いて抽出、バイアルに回収した。回収された試料は、溶媒を乾燥後、再び 50μl の酢酸エチルに溶解し、GC–MS にて分析を行った。TMAH 法によって得られるステロール類のスペクトルパターンは、先行研究[5]を参考にされたい。

3. 結果

水月湖堆積物中からは、24-nordehydrocholesterol (24-norcholesta-5,22E-dien-3β-ol)、22-dehydrocholesterol (cholesta-5,22E-dien-3β-ol) 、brassicasterol (24-methylcholesta-5,22E-dien-3β-ol) とそれらスタノールが検出された。これらスタノール類は、40cm より浅い所から検出され始め、それ以深ではほとんど検出されなかった。スタノールが貧酸素環境下におけるバクテリアの還元によって生成されることから、40cm あたりより水月湖の還元環境が始まったことを示している。さらに、これらのステロール類より求められたスタノール/ステロール比は、いずれも類似した傾向を示し、40cm 以深では、”0”に近い値を、最表層では、最も高い値を示した（Fig. 3）。特に、最表層で最も高い値を示したことは、近代になって貧酸素水塊が広がったことを示唆している。

ステロール類とスタノール類のみならず、堆積物からはファルネソール (3,7,11-trimethyl-2,6,10-dodecatrien-1-ol) も検出された。ファルネソールは、貧酸素水塊に生息する緑色硫黄細菌に由来するバイオマーカーである[6]。ファルネソールは、40cm を境に、表層から 40cm では検出され、ファルネソールもステロール組成の結果同様、40cm から還元環境の開始を示唆した（Fig. 3）。さらに、ファルネソールは、18cm より浅い深度で、高い濃度傾向をとり、表層 5cm で最も高濃度を示した。最表層で高くなる傾向は、スタノール/ステロール比の傾向と類似していいた。加えて、このファルネソールの傾向は、他のコアより得られたファルネソールの深度分布[7]とも一致していた。

4. 考察

スタノール/ステロール比およびファルネソールの両指標は、いずれも、40cm を境に、還元的な環境の開始を示した（Fig. 3）。したがって、深度 40cm は、水月湖と久々子湖を繋ぐ浦見水道が開通した時期にあたると考えられる。実際に、他の水月湖堆積物中の珪藻種の遷移を見た先行研究[8]では、約 40cm を境として、それより深いところでは、淡水種の珪藻主が優先したのに対して、それより浅い堆積物からは海水種の珪藻主が優先して検出されたことを示しており、約 40cm が 1664 年の治水工事の時期に当たるとしている。これらのことから、本研究では、この 40cm を基に、表層から 40cm にかけての大きく堆積速度が変わらなかったとか仮定し、年代を求めることとした。

40cm が治水工事にともなう汽水環境および貧酸素水塊の形成の始まりであると考えられた一方で、いずれの指標も、1848 年の嵯峨トンネルの再建設までは、小さな値を示していた（Fig. 3）。さらに、これら指標が高くなるのは、いずれも 1935 年の浦見水道と嵯峨トンネルの両水路の拡大工事にあたる深度で、この工事が、近代のような水月湖の半永続的な貧酸素水塊の形成を最も進めたと考えられる。実際に、1926 年から 1967 年まで行われていた水月湖での貧酸素水塊のモニタリング結果では、1935 年の両水道の工事に伴い、貧酸素環境の水深が 2 倍になったとの報告をしている[2]。これは、本研究および先行研究で見られた堆積物試料中の酸化-還元記録の指標から鑑みるに、少なくとも、今回分析された堆積物深度にあたる年代では、最も大きな還元環境の形成要因であったことが伺える。

総じて、人間活動に伴う湖沼への影響は、湖沼の環境を大きく変える要因として働き、それは、近代的な大きな人間活動でなくとも、環境変化を与えるには十分であることを水月湖の堆積物記録から見ることができた。一方で、近代的なスケールの大きな人間活動（この場合は、

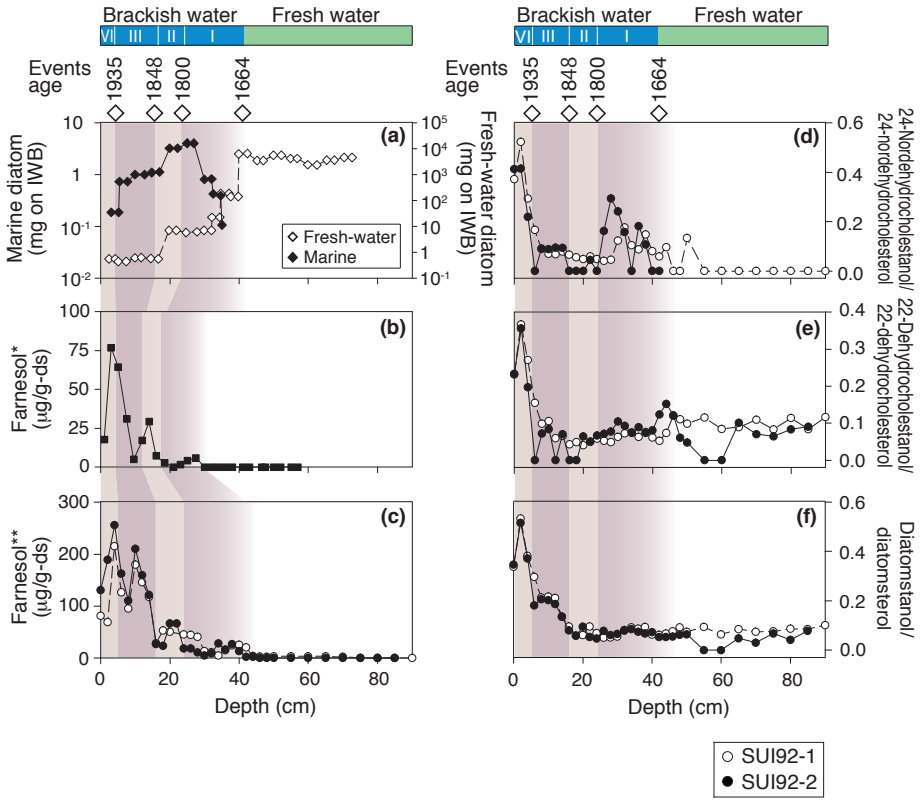

Fig. 3. 水月湖堆積物中に記録された珪藻種の遷移、ファルネソール濃度、スタノール/ステロールの深度分布.(a) 海洋に生息する珪藻種(*Coscinodiscus lacustris* [◊])および淡水種(*Stephanodiscus carconensis* [◆])の数 (mg on a weight basis after ignition [mg on IWB]) (増澤と北野, 1982[8]); (b) ファルネソール濃度 (μg/g-ds ; 上村ら (1992)[7]; (c)ファルネソール濃度 (μg/g-ds ; 本研究); (e) 24-nordehydrocholestanol/24-nordehydrocholesterol 比; (f) 22-dehydrocholestanol/22-dehydrocholesterol 比; (g) brassicastanol/brassicasterol 比. SUI92-1 と SUI92-2 は、それぞれ○と●で示されている. *Uemura et al. (1992). ** 本研究.

治水工事)は、湖沼環境をこれまでに経験し得なかった規模で、変化させることがあることあるという可能性を考える必要があると言える。

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P2-4

釧路湿原自然再生事業における土砂流入対策のモニタリング調査

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キーワード: 自然再生, 湿原, 細粒土砂, 旧川復元

抄録

釧路湿原は一級河川釧路川の下流域に広がる国内最大の湿原であり, 高度成長期に農地拡大や宅地開発などにより湿原が減少したことから自然再生事業で湿原の保全・再生が進められている. この一環で久著呂川では土砂調整地の整備, 釧路川茅沼地区では旧川復元が実施され, 湿原流入部で洪水を氾濫させ土砂を湿原の辺縁部に堆積させることにより湿原中心部への土砂流入を抑制させる取り組みが始まっている. それぞれの実施箇所での土砂の堆積効果についてモニタリング調査が実施されており, 河道の流量と浮遊砂量, 河道周辺での堆積土砂量を観測し, 久著呂川土砂調整地では洪水中の土砂量の約 10%が調整地内に堆積する結果が得られた. また釧路川茅沼地区では洪水流量の約 50%, 浮遊砂量の概ね 70−90%が旧川復元区間で氾濫している結果が得られた.

1. はじめに

釧路湿原では自然再生事業により湿原の保全・再生が進められている. 釧路湿原は一級河川釧路川の下流域に広がる面積 248.9km^2 の国内最大の湿原であり, 1960 年代の高度経済成長期に農地拡大や宅地開発などにより湿原が減少した. また釧路湿原に流入する河川では, 特に湿原流入部で農地排水の促進や洪水被害の軽減などのため河道の直線化が進められ, 農地の広がりや森林伐採などによる土砂流出の増加と河道の直線化による掃流力の増加が相まって湿原への流入土砂量が増加し, これにより湿原中心部でヨシやスゲなどの草本からハンノキ林への植生の変化が進んだ. このような背景から釧路湿原ではラムサール条約登録, 国立公園指定, 自然再生推進法制定などの流れを経て, 2003 年に釧路湿原自然再生協議会が設立され, 地域の取り組みとして自然再生が進められることとなった[1]. 自然再生事業のうち釧路川と釧路川支川久著呂川の湿原流入部で, 洪水を氾濫しやすくさせる等,洪水中の土砂を湿原辺縁部で堆積させることで, 湿原中心部に流入する細粒土砂を減らし, ハンノキ林の広がりを抑え湿原植生を回復に向かわせる取り組みが行われている. 久著呂地区では土砂調整地の整備が進められ[2], 釧路川茅沼地区では直線化された河道を蛇行した旧川に復元する事業が進められた[3]. ここではこれらの事業のモニタリング調査結果を整理することで, 各事業による土砂の流入抑制効果について現時点の結果を示す.



図 1 釧路湿原自然再生実施箇所位置図

2. 久著呂地区土砂調整地での土砂流入対策

釧路湿原への流入河川のひとつである釧路川支川久著呂川では, 当河川の下流域にあたる湿原流入部で土砂調整地の整備を進めている. これは河道から氾濫した洪水を土砂調整地内で滞留させ流水中の土砂を沈降・堆積させることにより, 湿原中心部への土砂流入量を軽



図 2 久著呂地区湿原流入部土砂調整地（2016.8 出水時の状況，2016.8.24 撮影）

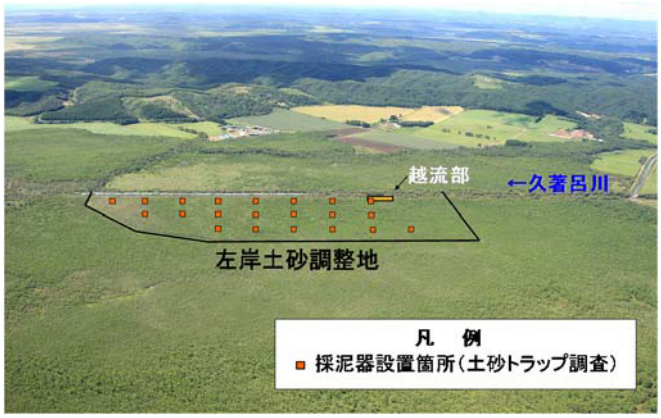



図 3 久著呂地区土砂調整地（上:左岸土砂調整地での堆積土砂調査位置，左下:人工ケルミ，右下:堆積土砂調査のための採泥器 0.22m×0.22m）

減させるものである．2016 年 8 月の北海道豪雨時では左岸調整地は長期間冠水状態となった（図 2）．土砂調整地は河道の左右岸に整備する計画で，土砂調整地の外周は木杭と木板を用いた囲い（通称「人工ケルミ」:図 3）を設置している．2012 年に左岸調整地が完成し，現在は右岸土砂調整地の整備を進めるとともに，完成した左岸土砂調整地での土砂堆積効果をモニタリング調査しているところである．モニタリング調査は，河道での浮遊砂量調査及び土砂調整地内に採泥器を複数設置し（図 3）土砂の堆積厚から土砂調整地内の堆積土砂量を推定する方法としている．

左岸調整地完成後の 2013 年から 2017 年までのモニタリング調査結果について，河道流下土砂量，左岸土砂調整地堆積土砂量とこれらによる河道流下土砂量の軽減割合を表1に示す．河道流下土砂量は土砂調整地上流側で流量観測と濁度自動計測及び採水による浮遊砂量観測をもとに算出し，堆積土砂量は採泥器での堆積厚と各採泥器の区分面積との積として算出している．河道流下土砂量軽減割合を見れば，河道流下土砂量のうち 10%程度が左岸土砂調整地に堆積していることになり，これが土砂調整地による湿原中心部への土砂流入量の軽減割合となる．ただし，土砂調整地の整備による土砂流入量の軽減効果は，モニタリング期間以外の軽減効果量も考慮した場合との比較となるため数値計算により検証することとしており，現在検証計算を進めているところである．また 2017 年は河道流下土砂量軽減割合が 1%と著しく低いが，この年の洪水が小規模であり河道水位があまり上昇しなかったために，河道から氾濫する水の量が少なかったためと考えられる．

表 1 久著呂地区土砂調整地土砂観測結果

観測年	期間	河道流下土砂量 m^3	左岸土砂調整地堆積土砂量 m^3	河道流下土砂量軽減割合
2013	7/22-10/10	1,900	240	0.13
2014	8/9-9/2	1,600	120	0.08
2016	8/3-11/18	26,000	2,400	0.09
2017	9/17-10/18	750	5	0.01

2015は欠測

3. 茅沼地区旧川復元での土砂流入対策

茅沼地区は釧路川の河口から約 30km 地点で，過去に河道が直線化された際に残されていた旧川に河道を切り替える旧川復元事業を実施した場所である．茅沼地区も久著呂地区と同様に釧路湿原の辺縁部であり，旧川接続点で流下能力を下げることで洪水がこの区間で氾濫しやすくなり，洪水とともに流水中の浮遊砂を氾濫・堆積させることで湿原中心部に流入する土砂を軽減させるものである．なお，旧川復元では土砂流入量の軽減のほか，魚類の生息環境の改善，河道周辺の地下水位の上昇による湿原植生の回復，河川景観の回復の効果を事業の目標にしている．

2016 年 8 月出水時，茅沼地区でも大規模な氾濫が生じた（図 4）．この洪水を含め 2010 年 2 月の旧川への通水後，2011 年から事業実施後のモニタリング調査を行っており，図 5 に示す五十石地点と茅沼地点で観測している河道の流量と浮遊砂量の差から，旧川復元区間での流量と浮遊砂量の軽減量がわかる．

2011 年から 2017 年の洪水時の流量・浮遊砂量の観測結果と低減割合を表 2 に示す．概ね流量の 50%，浮



図 4 茅沼地区旧川復元実施箇所(2016.8 出水時の状況, 2016.8.24 撮影)



図 5 茅沼地区流量・浮遊砂量観測地点位置図

遊砂量の 70-90%が旧川復元区間で氾濫していることがわかる. ただし, 一旦氾濫した水が茅沼地点より下流側で河道に戻ることがあり, 氾濫した浮遊砂の全てがこの区間で堆積するとは限らないが, 氾濫する水のごく一部とみなしてここでは考慮していない.2016 年 8 月出水時の流量を図 6, 流量 Q と浮遊砂量 Qs の関係を図 7 に示す. 旧川復元区間の上流側でピーク流量約 500m^3/s が旧川復元区間では約 100 m^3/s 程度に軽減している. Q-Qs の関係から旧川復元区間で洪水中の浮遊砂量濃度が高まっていることがわかる. 河道を流下する洪水のうち比較的濃度の薄い水面に近い部分が氾濫し, 浮遊砂濃度が高い河床面に近い水が下流に流下するためと推察されるが, 流量が大幅に減少するために流下する浮遊砂量は減少する.

4. 結論

釧路湿原自然再生事業で久著呂地区及び茅沼地区で進められている湿原中心部への土砂流入対策について, モニタリング調査結果から現状での効果を整理した. 湿原辺縁部で洪水を氾濫させることにより湿原中心部への土砂の流入量を軽減させていることが確認された. 長期的にはこれらの効果により釧路湿原の中心部で植生がハンノキからヨシ・スゲに回復する変化が現れることが目標であり, 引き続きモニタリング調査で追跡していく必要がある.

表 2 茅沼地区旧川復元箇所での流量・浮遊砂量の軽減割合

■流量

洪水	五十石 ΣQ(m3) A	茅沼 ΣQ(m3) B	流量低減量 ΣQ(m3) A-B	流量 軽減割合 (A-B)/A
2011 9月22日出水 (96時間)	21, 775, 331	11, 664, 555	10, 110, 775	0. 46
2012 10月1日出水 (72時間)	16, 956, 066	9, 558, 856	7, 397, 209	0. 44
2014 8月11日出水 (66時間)	38, 655, 886	19, 569, 069	19, 086, 817	0. 49
2015 8月10日出水 (51時間)	23, 625, 934	17, 893, 593	5, 732, 342	0. 24
2016 8月出水 (768時間)	500, 392, 468	250, 567, 665	249, 824, 803	0. 50

2013は欠測

■土砂

洪水	五十石 ΣQs(m3) A	茅沼 ΣQs(m3) B	浮遊砂低減量 ΣQs(m3) A-B	浮遊砂 軽減割合 (A-B)/A
2011 9月22日出水 (96時間)	1, 624	241	1, 383	0. 85
2012 10月1日出水 (72時間)	840	47	793	0. 94
2014 8月11日出水 (66時間)	9, 449	2, 118	7, 331	0. 78
2015 8月10日出水 (51時間)	4, 665	2, 664	2, 002	0. 43
2016 8月出水 (768時間)	198, 929	52, 026	146, 904	0. 74

2013は欠測

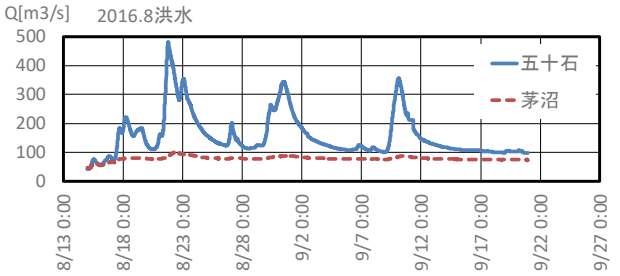

図 6 流量観測結果(2016.8 洪水)

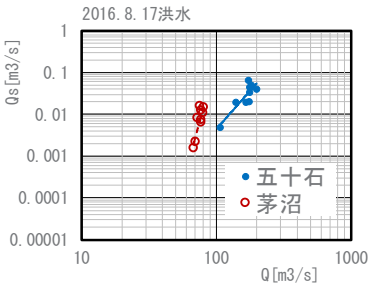

図 7 流量 Q-浮遊砂量 Qs(2016.8 洪水)

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P2-5

地下水汚染実態把握調査結果及び地下水汚染の未然防止の対策について

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キーワード:水質汚濁、モニタリング体制

抄録

環境省では、毎年度、地方自治体の協力を得て、全国の地下水汚染事例に関する調査を実施している。平成 28 年度の調査結果によると、全国の自治体で把握されている地下水汚染事例のうち、VOC 事例、重金属事例、複合汚染事例については、工場・事業場起源や自然的要因と推測される汚染が多い。工場・事業場からの地下水汚染の未然防止を図るため、平成 23 年に水質汚濁防止法が改正され、施設の構造等に関する基準の遵守と定期点検の実施等の義務付けが行われている。環境省としては、地下水汚染の実態調査等を踏まえ、引き続き、都道府県等と連携して、水質汚濁防止法の適切な施行に努めることとしている。

1. はじめに

環境省では、毎年度、47 の都道府県及び水質汚濁防止法に基づく 111 の政令市(以下、「都道府県等」という)の協力を得て、全国の地下水汚染事例に関する調査を実施し、調査結果をとりまとめ「平成 28 年度地下水質測定結果」[1]として公表している。

本報告では、調査結果の中から工場・事業場を原因とする汚染事例について報告するとともに、環境省の地下水の水質保全に係る最近の取り組みについて報告する。

2. 調査について

(1)調査対象事例

平成 28 年度末(平成 29 年 3 月 31 日)までに都道府県等が把握している、環境基準を超える値が検出されたことがある地下水汚染事例(以下、「事例」という)の全てとしている。

なお、都道府県等が実施する調査によって判明した事例のみならず、事業者による調査の報告等によって判明した事例も全て対象としている。

事例は、原則として、汚染原因を同じとする一まとまりの範囲を1事例としている。広範囲に及ぶ汚染や汚染原因が不明である汚染の範囲は、調査結果等をもとに、各事例を担当する都道府県等によって判断されている。また、以下のことに注意を要する。

・同一井戸であっても原因が異なる汚染が存在する場合は、別の事例としている。ただし、汚染項目が同じで明確に分離できない場合は除く。

・同一工場・事業場の複数種類の原材料による汚染、廃棄物による汚染、揮発性有機化合物の分解生成物が存在する汚染など、原因が同じであって複数の項目にわたる事例がある。

・1つの事例に複数の井戸が含まれる場合がある。

(2)事例の分類の定義

ア. 環境基準超過状況による分類

この調査では、各事例を環境基準超過状況に応じて表 1 に示す4つに分類している。このうち「調査不能事例」は、現在の状況を把握できないことから「3.(2)」以降の集計では集計対象外とした。

表 1 環境基準超過状況による分類

事例分類	内容
超過事例	平成 28 年度末現在、いずれかの項目で環境基準を超過している事例
一時達成事例	最新年度のデータはいずれの項目も環境基準を超過していないが、一時的な達成の可能性があり、恒久的な改善確認はできていない事例
改善事例	過去は環境基準を超過していたが、現在はいずれの項目も超過しておらず、将来的にも環境基準を超過することはないと判断できる事例
調査不能事例	井戸の廃止等により調査できなくなった事例

注:「一時達成」と「改善」の分類は、各事例を担当する都道府県等の判断による。

イ. 項目による分類

集計においては、各事例をその汚染物質によって表 2 に示す VOC 事例、重金属等事例、硝酸・亜硝酸等事例、複合汚染事例の 4 つに項目分類している。

表 2 項目による分類

項目分類名称	説明
ＶＯＣ事例	次の項目の、単独又は複数項目による事例 ジクロロメタン、四塩化炭素、塩化ビニルモノマー、1,2-ジクロロエタン、1,1-ジクロロエチレン、1,2-ジクロロエチレン、1,1,1-トリクロロエタン、1,1,2-トリクロロエタン、トリクロロエチレン、テトラクロロエチレン、1,3-ジクロロプロペン、ベンゼン、1,4-ジオキサン
重金属等事例	次の項目の、単独又は複数項目による事例 カドミウム、全シアン、鉛、六価クロム、砒素、総水銀、アルキル水銀、ＰＣＢ、チウラム、シマジン、チオベンカルブ、セレン、ふっ素、ほう素
硝酸・亜硝酸事例	次の項目の、単独による事例 硝酸性窒素及び亜硝酸性窒素（以下、「硝酸・亜硝酸」という。）
複合汚染事例	上の３分類のうち、複数分類にわたる項目による汚染事例 （例）工場・事業場のＶＯＣと重金属等の複数種類の原材料による事例や、廃棄物による事例　など

3. 結果

(1)事例件数(平成 28 年度末時点)

環境基準超過状況による 4 分類の全事例件数は 7,993 件であった。

VOC事例は2,544件で、その内訳は「超過」が947件(37%)、「一時達成」が409件(16%)、「改善」が949件(37%)、「調査不能」が239件(9%)であった。

重金属等事例は 2,153 件で、その内訳は「超過」が 1,338 件(62%)、「一時達成」が 261 件(12%)、「改善」が 338 件(16%)、「調査不能」が 216 件(10%)であった。

硝酸・亜硝酸事例は 3,148 件で、その内訳は「超過」が1,780件(57%)、「一時達成」が628件(20%)、「改善」が523件(17%)、「調査不能」が217件(7%)であった。

(2)汚染原因の把握状況

地下水汚染が判明した場合は、都道府県等によって、継続的な監視のためのモニタリング調査が行われている。その対象となる超過事例、一時達成事例、改善事例の合計 7,308 件について、汚染原因の把握状況を取りまとめた。

汚染原因が「特定又は推定」されているのは、4,353件であり、各項目分類別の主な汚染原因は、以下のとおりであった。

(VOC事例)

・「工場・事業場」(1,218 件)

注:工場・事業場における排水・廃液・原料等による汚染。

・「廃棄物」(169 件)

(重金属等事例)

・「自然的要因」(1,127 件)

・「工場・事業場」(157 件)

(硝酸・亜硝酸事例)

・「施肥」(1,530 件)

・「家畜排せつ物」(664 件)

(複合汚染)

・「工場・事業場」(87 件)

表 3 汚染原因(項目分類別)

汚染原因(複数回答有り)	件数				
	合計	VOC	重金属等	硝酸・亜硝酸	複合汚染
工場・事業場	1,462 (916)	1,218 (731)	157 (122)	0 (0)	87 (63)
廃棄物	211 (127)	169 (97)	33 (23)	3 (2)	6 (5)
家畜排せつ物	664 (596)	0 (0)	0 (0)	664 (596)	0 (0)
施肥	1,531 (1,340)	0 (0)	1 (1)	1,530 (1,339)	0 (0)
生活排水	666 (588)	0 (0)	2 (2)	664 (586)	0 (0)
自然的要因	1,149 (1,016)	0 (0)	1,127 (1,004)	20 (11)	2 (1)
その他	69 (43)	41 (23)	23 (15)	5 (5)	0 (0)
母　数	4,353 (3,412)	1,289 (764)	1,335 (1,161)	1,638 (1,421)	91 (66)

注1:括弧内の数値は、平成 28 年度末時点の「超過事例」及び「一時達成事例」の合計数。(内数)

注2:無回答があるため、各件数の和と母数は必ずしも一致しない。

(3)工場・事業場からの汚染に係る原因施設等の種別

(2)において工場・事業場が汚染原因と特定又は推定された事例 1,462 件について、その汚染に係る原因施設等の種別を表4、原因の種別を表5に示す。原因施設は有害物質使用特定施設(564件)、原因行為は汚染原因物質の不適切な取扱いによる漏洩(252 件)が最も多かった。

表 4 工場・事業場からの汚染に係る原因施設等の種別

有害物質使用特定施設	564
特定施設(有害物質使用特定施設を除く)	49
有害物質貯蔵指定施設	10
貯油施設	173
油水分離槽	5
上記以外の施設、設備等	67
上記以外の場所	4
その他	31
経緯不明	571
母　数	1,462

表 5 工場・事業場からの汚染に係る原因行為の種別

施設の破損等による汚染原因物質の漏洩事故	138
施設・設備の劣化・老朽化、破損等による漏洩	60
廃液貯留設備、保管容器の亀裂等からの漏洩	8
施設の構造上の欠陥による漏洩	3
施設更新時の漏洩	1
施設の故障等による漏洩	2
詳細不明	68
汚染原因物質の不適切な取扱いによる漏洩	252
設備等の操作ミスや汚染物質の不適切な取扱いによる漏洩	61
通常の作業工程(洗浄など)中の漏洩(滴り落ちなど)	44
溶剤や廃液等の移し替え作業時の漏洩	22
溶剤等を使用する施設の不適正な管理による漏洩	6
詳細不明	131
汚染原因物質を含む排水の地下浸透	120
廃棄物処理法施行前の廃棄物の処理	13
廃棄物処理法施行後の廃棄物の処理	21
残土の処理	2
排ガス、排気中の汚染原因物質の降下、沈着等	6
その他	22
不明	964
母　数	1,462

4. 環境省の地下水の水質保全にかかる対策について

平成元年の水質汚濁防止法の改正により有害物質の地下浸透規制等に関する規定を整備するなど、地下水質の保全を推進してきた。しかし、近年においても、工場・事業場が原因と推定される有害物質による地下水汚染事例が毎年継続的に確認されていること等から、こうした地下水汚染を未然に防止するため、「水質汚濁防止法の一部を改正する法律」(以下、「改正法」という。)が、平成 23 年6月 22 日に公布され、平成 24 年6月1日に施行された。

改正法においては、有害物質を貯蔵する施設等を届出の対象に追加するとともに、有害物質を使用、貯蔵等する設置者に対し、有害物質の地下浸透防止のための施設の構造、設備及び使用の方法に関する基準の遵守、定期点検の実施、結果の記録及び保存を義務付ける規定等が新たに設けられた。

改正法の円滑な施行を図るため、環境省では構造等に関する基準や定期点検に係る事項の解説等を盛り込んだ運用のためのマニュアルを、平成24年6月に策定した(平成 25 年6月改定)。また、平成 27 年3月には、地下水汚染未然防止のための管理要領等策定の手引きを策定するとともに、管理要領や点検記録表について、作成例を策定し、環境省ホームページにて公開している。

5. 結論

今回の地下水汚染事例に関する調査の結果より、全国の自治体で把握されている汚染事例のうち、VOC 事例、重金属事例、複合汚染事例については、自然的要因や工場・事業場が起源と推測される汚染が多いことが分かった。

環境省としては、地下水汚染の実態調査等を踏まえ、引き続き、都道府県等と連携して、水質汚濁防止法の適切な施行に努めることとしている。

引用文献

[1] 環境省: 平成 28 年度地下水質測定結果 平成 29 年 12 月.

P2-6

Regime shifts of Yangtze subtropical shallow lakes

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Keywords: regime shifts, subtropical lakes, thresholds, multiple stressors

ABSTRACT

Regime shifts between macrophyte-dominated clear-water state and phytoplankton-dominated turbid-water state have been widely reported. On the alluvial plain of the Yangtze River with a dominance of subtropical climate, there are hundreds of shallow lakes. This major geographical area with its well-developed water system and fertile soil was one of the "cradles" of Chinese civilization. However, many lakes in the basin have suffered for decades from cultural eutrophication and fishery over-exploitation, causing increased phytoplankton, deteriorated vegetation and lowered clarity. In this talk, I'd like to introduce our study on regime shifts in these subtropical shallow lakes. Based on a combination of multi-lake comparisons and long-term monitoring, we analyzed the existence of alternative states, thresholds of total phosphorus and turbidity for the regime shifts, potential effects of intensive aquaculture and high ammonia concentration, maintenance of alternative states.

Research into the underlying mechanisms and thresholds for regime shifts between contrasting states is important from theoretical and practical perspectives. The shifts in shallow lakes between a clear-water state dominated by submersed macrophytes and a turbid-water state dominated by phytoplankton, or back, are a well-known example of a regime shift. To explain regime shifts in shallow lakes, the classic research presented a graphical model on the basis of three assumptions: (1) turbidity increases with nutrient levels; (2) vegetation reduces turbidity; and (3) vegetation disappears when a critical turbidity is exceeded and recovers when turbidity drops below the threshold. Much evidence from north temperate shallow lakes has been presented to support this theory, but its validity for lakes in other climatic zones remains uncertain. Furthermore, the assumption that submersed vegetation disappears and recovers at the same critical turbidity requires direct field evidence. Published research suggests that the total phosphorus (TP) thresholds for the regime shifts between a clear-water state dominated by submersed macrophytes and a turbid-water state dominated by phytoplankton in shallow lakes vary with forms of lake basins and climates. However, such hypotheses remain untested by direct field evidence.

The subtropical Yangtze River floodplain is a mosaic of numerous shallow lakes with different nutrient levels, providing excellent opportunities for research into regime shifts. All the lakes studied (E 113°10′-121°00′, N 29°30′-32°00′) are located in the mid-lower Yangtze Basin, characterized by a dominant warm, humid subtropical monsoon climate, annual mean air temperature ranging between 14-18 °C, and precipitation between 1000-1400 mm. All the lakes in this basin are shallow floodplain lakes, isolated from the Yangtze River by embankments and sluice gates, with elevations generally lower than 50 m ASL. A dataset of 76 lake-years from 30 lakes was used for multi-lake analyses. 57 lake-years of 28 lakes were investigated by this study during 2002-2012, and 19 lake-years of 10 lakes were gathered from the literature. Long-term investigations (1987-2012) were done in two adjacent sub-areas (Shuimiao, 1.6 km^2, 2.3 m; Changlingtou, 1.5 km^2, 1.9 m) of Lake Bao'an (40.0 km^2).

TP thresholds were found to vary little at moderate depths, but to decrease notably when depth exceeds a level of probably 3-4 m, and increase sharply when depth is below a level of around 1-2 m. TP thresholds were found to be nearly equal in shallow lakes (1-2 m < mean depth < 3-4 m; ca. 0.1 km^2 < area < at least 350 km^2) from temperate to subtropical (probably to tropical) zones, being 80-120 mg m^{-3} for the forward shift from a clear-water state to a turbid-water state and 40-60 mg m^{-3} for the backward shift. The threshold of turbidity for the forward shift was found to be higher than that for the backward shift, amending the previous hypothesis of the equality of turbidity thresholds for both shifts.

Regime shift is reflected in their macroinvertebrate assemblages, which thus may serve as good indicators of long-term changes of lake ecosystems. Hence, we conducted a survey on benthic macroinvertebrates in 20 lakes located within the Yangtze floodplain but disconnected from the river channel in order to reveal invertebrate response patterns along a gradient of eutrophication. In parallel to the observed regime shift of a subgroup of those lakes due to eutrophication, macroinvertebrate assemblages changed. Most abundant groups were epiphytic invertebrates (e.g. Bithyniidae) in the macrophyte-dominated lakes but pollution-tolerant invertebrates (e.g. Tubificidae, *Tanypus*) in the phytoplankton-dominated lakes. Planktonic chlorophyll *a* concentration and wet biomass of submersed macrophytes were demonstrated as the key factors structuring macroinvertebrate assemblages. Along the eutrophication gradient, taxa richness of macroinvertebrates decreased, while their density exhibited a minimum at a moderate eutrophication level, and then increased again. However, scrapers (e.g. Bithyniidae) showed an abrupt drop of their density at the same moderate eutrophication level. In contrast, collector-gatherers (mainly Tubificidae and Chironomidae) and predators (e.g. *Tanypus*) increased continuously along the eutrophication gradient. We conclude that during the regime shift the abrupt disappearance of macrophytes means the loss of the key habitat for biota associated with aquatic plants, which then reduced to a much lower level of population density. Therefore, in ecological restoration projects, the nutrient concentration of floodplain lakes should be reduced enough to allow the re-establishment of aquatic macrophytes for a stable macrophyte-dominated equilibrium of a clear-water lake ecosystem.

The Chinese mitten crab (*Eriocheir sinensis* (H. Milne Edwards, 1854)), is a highly invasive species and poses a great threat to endemic species and infrastructure in Europe and North America. Although it is partly herbivorous and prefers to live in lakes with abundant submersed macrophytes, little is known about its effect on macrophytes. We used its native range, the mid-lower Yangtze Basin where the species has been cultured intensively for decades, as our study site to test the hypotheses that (1) high crab densities weaken the positive feedback between macrophytes and water transparency, and that (2) the effects of crabs become apparent only on decadal timescales and (3) are density dependent. We used correlative analyses based on 12 years of monitoring and multi-lake comparisons among 20 sub-areas in 4 lakes. High crab densities were found to cause negative effects on submersed macrophytes and transparency, and to weaken the positive relation between macrophytes and transparency. High densities of macrophytes showed resilience to disturbance from crabs. This resilience, however, reduced with continuous presence of high crab densities. Crab densities were strongly positively related with total phosphorus and negatively with transparency and total nitrogen. Phosphorus concentrations and transparency were not related with phytoplankton chlorophyll *a*, suggesting that crab's bioturbation strongly influences water quality. The apparent resilience of the dense macrophyte stands should however, not delay attempts to eradicate the invasive crab as this becomes more difficult once they have become established. When macrophyte abundance is already low at the time of invasion, however, immediate loss of macrophytes may occur.

Loss of submersed macrophytes and higher turbidity has been attributed to excessive loading of phosphorus (P), but recently the role of nitrogen (N) in causing the recession of macrophytes has received increasing attention. Due to the close relationship between N and P loading, it has often been difficult to disentangle the specific effects of these two nutrients and some controversy still exists as to the effects of N. We studied the effects of N on submersed macrophytes represented by *Vallisneria natans* in pots positioned at three depths (0.4 m, 0.8 m, and 1.2 m to form a gradient of

underwater light conditions) in 10 large ponds having moderate concentrations of P and five targeted concentrations of total nitrogen (TN) (0.5, 2, 10, 20, and 100 mg L^{-1}) with two ponds for each treatment. To study the potential shading effects of other primary producers, we also measured the biomass of phytoplankton (Chla_{Phyt}) and periphyton (Chla_{Peri}) expressed as chlorophyll *a*. We found that leaf length, leaf mass, and root length of macrophytes declined with increasing concentrations of TN and ammonium, while shoot number and root mass did not. All the measured growth indices of macrophytes declined significantly with Chla_{Phyt}, while none were significantly related to Chla_{Peri}. Neither Chla_{Phyt} nor Chla_{Peri} were, however, significantly negatively related to the various N concentrations. Our results indicate that shading by phytoplankton unrelated to the variation in N loading and perhaps toxic stress exerted by high nitrogen were responsible for the decline in macrophyte growth.

Based on our analyses, we present a diagrammatic model to explain the mechanisms and processes of regime shifts in Yangtze subtropical shallow lakes (Fig. 1A). The model is based on three assumptions: (1) algal turbidity (Chl *a*) increases with TP, and levels off when TP approaches a high level probably due to self-shading effects caused by excessive algae growth (Stauffer, 1991) (Fig. 1a_1); (2) submersed macrophytes reduce non-algal turbidity (Fig. 1a_2); and (3) macrophytes disappear when Turb exceeds a critical level K_f, and recover when Turb is lower than K_b (Fig. 1a_3). Combining Fig. 1a_1 and Fig. 1a_2 produces two curves as presented in Fig. 1A, showing separate TP-Turb relationships for the contrasting cases with and without vegetation; the curve is steeper for the vegetated state because non-algal turbidity decreases with the increase in macrophytes. When $TP>TP_f$ and $Turb>K_f$ (Fig. 1a_3), macrophytes disappear and the lake shifts to a turbid-water state dominated by phytoplankton (the upper equilibrium line) (Fig. 1A). When $TP<TP_b$ and $Turb<K_b$ (Fig. 1a_3), macrophytes recover and an opposite shift takes place (the lower equilibrium line) (Fig. 1A). In the shifting processes, TP varies because macrophytes reduce TP. When $TP=TP_b\sim TP_f$, two states exist: the lake tends to be in a clear-water state when $Turb<K_b$ and in a turbid-water state when $Turb>K_f$; when $Turb=K_b\sim K_f$, the lake tends to be in a clear-water state when forward shifting and in a turbid-water state when backward shifting.

Our findings suggest that, according to the subequality of TP thresholds, similar target concentrations for in-lake TP can be set in most shallow lakes world-wide to mitigate eutrophication.

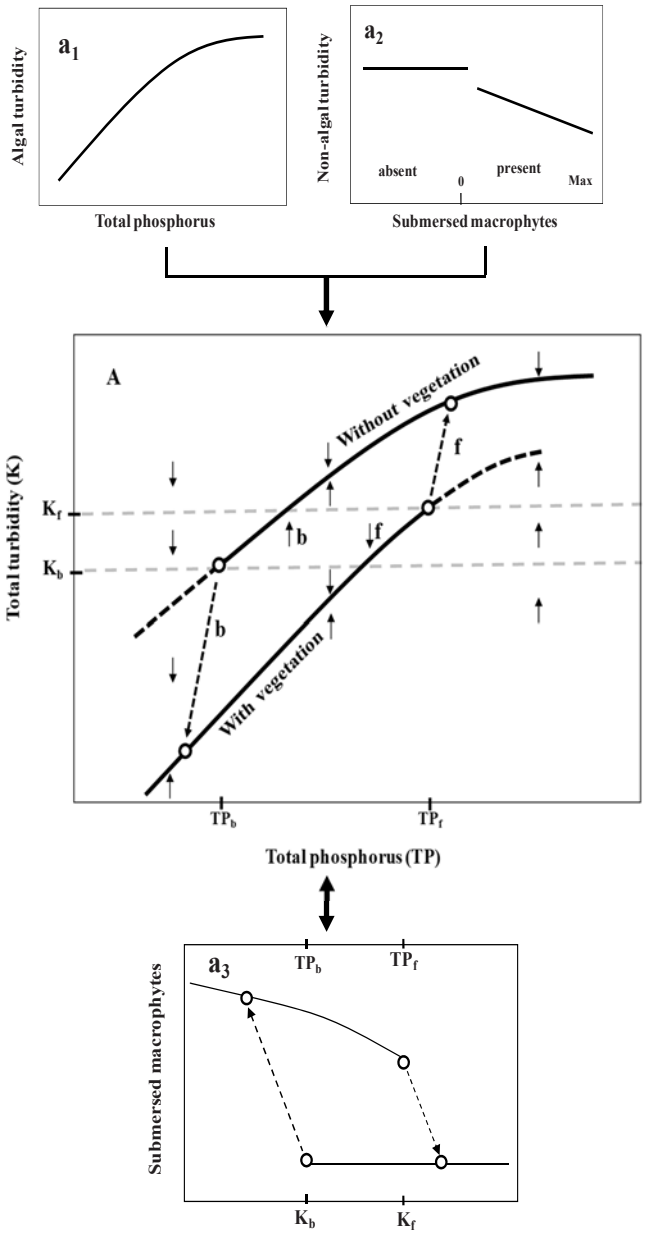

Fig. 1 Schematic diagram interpreting the triggering of regime shifts and maintenance of alternative stable states in subtropical shallow lakes. f, forward shifts from a clear-water state to a turbid-water state; b, backward shifts from turbid-water state to a clear-water state.

P2-7

Public participation in social auditing and eco-politics of water quality and ecological health of the freshwater lake Ujjani, India

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Keywords: water quality, eco-politics, safe water

ABSTRACT

Deterioration of water quality of Ujjani Lake, the tail end reservoir on Bhima river – a known World Lake Vision water body – is the result of upstream unmatched, rapid urbanization and industrial growth in last two decades. This huge water body in South Maharashtra is under pollution stress which is affecting its quality and ecology. Constant efforts for wide spread awareness from a decade have consolidated the participatory action plan by involving students of schools and colleges in the region for social auditing and biomonitoring of water quality and ecological status of the Ujjani Lake. The feedback of public participation has led to raising the issues of water quality improvement in Ujjani catchment leading to eco-politics of impact of pollution on community health. A careful assessment of socioeconomic and health issues among the population along the shoreline downstream of urban development has documented that the people have become attentive and responsive of their natural and human right of safe drinking water. People's movement for water security has outlined the political agenda in the region leading to planning and investments for urban and industrial wastewater treatment plants in upstream cities. In this paper, the outcomes of surveys have been discussed articulating the demands of villagers for sustainable, protected and pollution – free water source for agriculture, pisciculture and secured life.

Introduction

There are twenty-two dams in a series built on Bhima River of which the Ujjani Dam (an Earth-fill cum Gravity dam)1 located near Ujjani village of Madha Taluk Solapur district in Maharashtra state of India. It is the terminal dam on the river and is the largest in the valley having catchment of 14,860 km2. Construction of the dam project including the canal system on both banks was started in 1969 at an initial estimated cost of INR 400 million ($ 6.67 million at current exchange rate) and at the time of completion dam wall construction, in June 1980 it was INR 3295.85 million (about $55 million). Now it has become INR14000 million and project is still not completed.

The project was supposed to provide multipurpose benefits of irrigation, hydroelectric power, drinking and industrial water supply and fisheries development. But the pollution from upstream urban and industrial development has severely contaminated the rivers in the lake basin and has reduced the potential of lake as freshwater supply for drinking and irrigation purposes3. Now it is quoted in the media that Ujjani lake has become cesspool of pollution4. Therefore, to create mass awareness various initiatives were taken from last 12 years including organizing the meetings of ILEC functionaries. In the present paper, the initiative of public rally of 2011 and its subsequent outcomes are discussed in detail in the context of changing perceptions, upstream – downstream conflicts and co-operations with regional eco-politics.

Pollution Scenario

In a decade, water quality of 7 rivers of Pune – namely Mula, Mutha, Pawana, Indrayani, Ram, Ambil and Nagzari deteriorated over the period of time with respect to two critical parameters – Dissolved Oxygen (very important of life in water body) and Fecal Coli forms (very important for indication of human pathogens). Dissolved oxygen in the above mentioned rivers reduced to zero from last 7 years in non-monsoon period and fecal coliforms have increased ten thousand times from zero to more than millions in the river waters up to Ujjani Reservoir. Risk of water borne diseases has increased several times in the downstream of Pune city.

Organic pollution is mostly attributed to upstream urban growth where untreated sewage is thrown into the rivers before the Ujjani Lake. Industrial pollution more of toxic in nature has damaged the ecosystem severely downstream

of Pune city. Wastewater discharge (untreated or partially treated) into the rivers carrying water to Ujjani Lake has almost doubled in last 10 years. In 2000, wastewaters discharged from Pune-Pimpri-Chinchwad and industries were about 700 MLD but in 2011, it is about 1500 MLD. There is severe problem of leachate from unscientifically developed and managed solid waste dumping sites viz. Urali Devachi, Moshi etc.

Many villagers noticed that the hazardous gases (including methane, hydrogen sulphide etc) erupting from Ujjani Lake many times in the year indicating the deteriorated ecological health of the water body. It is estimated in one study that about 5000 tons of methane gas is generated annually due to accumulation of pollution in the Ujjani Lake. Villagers (of about 200 villages) along the polluted stretches of rivers in Ujjani Basin downstream of Pune city are compelled to drink tubewell water which has high concentration of hardness (a cause of kidney stone). Concentration in the tubewells / wells along ranged from 400 – 800 mg/L while the drinking water standard for hardness is 300 mg/L. It is also noticed that brittleness of bones, dental problems among the children and aged groups were prevalent.

The movement (*"Abhiyan"*)

This movement (*"Abhiyan"*) was organised and designed by Jal Pradushan Virodhi Kriti Samiti, Solapur under the guidance of Maharashtra Vikas Kendra, Pune to create awareness about the health and environmental impacts of pollution amongst the thousands of victims of Ujjani Lake water deteriorating quality during the 21st – 23rd Aug. 2011.in Solapur District. Shri Anil Patil (President of Maharashtra Vikas Kendra) has taken initiative for this *Abhiyan*. In this programme, Dr. Rajendra Singhji, President of National Jal Biradari, distinguished water scientists and activists interacted with various educated and ignorant sections of the rural society including school children, women, teachers, lawyers, doctors, senior citizens, industrialists and volunteers reaching to about 1 million population.

The major objective of this *Abhiyan* was to understand the dilapidated conditions of villagers due to severe Ujjani pollution. This pollution is an impact of insensitive upstream urban development and industries which are discharging untreated or partially treated wastewaters into the tributaries of Bhima River violating all environmental laws and natural justice

Observations during the *Abhiyan*

1. Bhima river downstream of Ujjani Lake does not have ecological flow to maintain its biodiversity and to provide sufficient water to the villages along the bank. Whatever water flows in the river, the pollution levels are very high with foul odours.

2. Bhima River at Pandharpur is laden with sewage from the city and open defecation. On 21st Aug. 2011, the river water was tested for Dissolved Oxygen (DO), Total Hardness and Nitrates using simple test kits. DO was 2 – 3 mg/L, hardness 300 mg/L and nitrates 10 mg/L. This implies that the water is not potable. Both the banks of the river were very dirty, people have thrown enormous wastes.

3. River and well-water samples were tested in Pandharpur, Sangam, Babhulgaon, Wafegaon, Malinagar, Patwardhan Kuroli, Akluj, Modnimb, and Madha. Except Madha, at every location hardness of the river water was in the range of 300 – 400 mg/L and hardness of well water and tube well water ranged between 350 – 750 mg/L. Concentration of nitrates of the river was 10 – 50 mg/L. Near Patwardhan Kuroli the concentration of nitrates was highest.

4. River was highly eutrophicated with algal blooms near Patwardhan Kuroli. People of this village complained about the miscarriages of cows, buffellows due to dirty, unclean, non drinkable and polluted water. Children were found to be anaemic. About 200 patients due to water-borne diseases visit 5 doctors' dispensary every day in a village of 4500 population.

5. At many places, villagers complained about direct discharge of spent wash in the river. At many places including Nira-Narsinhapur, the river was found to be polluted with foul odours. People have deep fear about pollution in river.

6. Fear of the river pollution is compelling the people to drink the hard well or bore well water which the cause of kidney stones. Higher nitrates in the water are leading to anaemic conditions. Algal Growth is responsible for toxic releases in the river water. Many of the villages don't have adequate water treatment facilities.

7. It can be concluded that the urban pollution from upstream metros, excessive use of fertilizers and discharges of sugar-distillery wastewaters are affecting the health and agro-economy severely. Lot peoples complained about that, There is no control by State Govt's senior officials on civic bodies, i.e. PMC, PCMC, OTHER Nagarpalika & MIDC etc those which are responsible for water pollution.

8. Incessant sand mining despite of legal bans is a major cause of accidental death of women and children who are mistakenly approach deeper stretches of river for washing

or bathing.

Impacts of the Ujjani/Bhima River Pollution

1. Deterioration of public health – unhealthy life – severe and long term impact on babies and children...

2. Deterioration of agricultural production – loss of economy, decreasing yield from agriculture sector and from cash crops also, like cane sugar....

3. Deterioration of groundwater – future loss of health and economy, problems occurred in front of livestock...

4. Ecological loss of biodiversity....

5. Everyone should understand and confirm that "River "is common property and its belongs to all peoples; State Govt has to act as his "trusty "not owner of river..Its peoples responsibility to keep it clean and continuous watch on pollution of river.

Immediate actions proposed in *Abhiyan*

1. Cleaning of ghats on Chandrabhaga (Bhima) River at Pandharpur, control on use of plastic materials and bags, provision of dust bins, permanent, dedicated staff for cleaning of river banks and maintaining the sufficient river flow round the year

2. Regular detailed monitoring and analysis of river water quality at every kilometre by involving local people

3. Protection of ancient, heritage temple of Narsimha at Nira-Narsinhapur

4. Pandharpur is to be declared as "Divisional Centre for MPCB, Maharashtra. It will help to create confidence in the people of Bhima-Sina River Basin.

Recommendations

1. Solapur Municipal Corporation and Z. P. Solapur must create a Task Group for eradication of pollution from the water used for drinking, livestock and agriculture purposes.

2. Upstream metros – Pune and Pimpri-Chinchwad must recognize the natural and constitutional right of downstream people of clean and pure water for drinking, livestock and agricultural applications.

3. Immediate actions to clean up 200 nallahs in Pune / Pimpri-Chinchwad through adoption and public participation; to convert dirty Nallah into clean water stream

4. Demonstration of Governance Environmental

Accountability and Responsibility by diverting funds to purification of rivers through taking up Nallahs to eradicate pollution

5. Adoption of downstream village (victims of pollution) by upstream Pune/Pimpri-Chinchwad cities (polluters) to cater the drinking water requirements

Impact of *Abhiyan* among the upstream and downstream population

1. Rural population started using advanced water

purifications systems with traditional systems.

2. This programme has culminated into expansion of water market for commercial water purifier systems.

3. Maharashtra Government has commenced commercial community RO systems from last two years despite of unavailability of sufficient electrical supply for the same.

4. Awareness campaign has caused rise in water expenses and wastages per capita in the rural area.

5. This campaign has reduced water borne diseases to some extent in rural literate class.

6. Upstream city corporations and authorities developed detailed project reports for the mechanised sewage treatments to be completed in next ten years.

7. Upstream awakened responsible urban citizens has taken up action plan to reduce solid waste load into rivers through action of about 0.1 million students of schools and colleges.

Conclusions

Not single action proposed or recommendation has been implemented by local and state government agencies till date. It can be concluded as common man took over actions to reduce his water problems, administrators and politicians turned blind eye to the root cause analysis and initiate the corrective actions to eliminate pollution from the water resources in the Ujjani Basin.

It seems that though government agencies and departments are reaping the benefits from water resources but the responsibility of conservation, protection and corrective actions in total is not fixed yet on any one agency. Activities like water abstraction, distribution and quality monitoring are delegated to many agencies but there is lack of integrated approach for restoration of ecological health of water resources and protection of water quality for consumptive and non-consumptive uses. The *Abhiyan* has highlighted this short-sighted plan which needs level-playing consultative platform like Integrated Lentic-Lotic Basin Management (ILLBM).

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WATER QUALITY ASSESMENT IN THE DIYAWANNA LAKE, SRI LANKA

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Keywords: algae, dissolved oxygen, electrical conductivity, pH, turbidity

ABSTRACT

Water in Diyawanna Lake, Sri Jayawardenapura, Sri Lanka indicated many water quality degradation due to human activities and interconnected stream discharge. Diyawanna Lake located in the centre of the administrative capital of Sri Lanka. Diyawanna Lake is an important water retention area which is to be completely dredged, de-silted and fully rehabilitated resent past years. In present the lake environment is become deteriorated by human and natural phenomena. The Lake catchment surrounding urban areas are influenced by various industrial zones and homestead. The study was done with the objective of determining the status and trends in water quality assessment in Diyawanna Lake. The results reveled that for the period of 2006-2010; the pH values of varied from 5.2 to 7.4. The electrical conductivity values varied from 0.07 mS/cm to 0.30 mS/cm and from 0.11mS/cm to 0.23 mS/cm respectively. The turbidity values of Location 1 and Location 2 are varied from 4.15 NTU to 33.50 NTU and from 4.00 NTU to 27.90 NTU respectively. The Dissolved Oxygen concentrations chnaged ranged from 3.02 mg/l to 6.88 mg/l and 2.17 mg/l to 6.84 mg/l respectively. The Nitrate (V)-N values of are varied from 0.01 mg/l to 0.70 mg/l and from 0.01 mg/l to 0.80 mg/l respectively.

1. INTRODUCTION

two-thirds of the Earth is covered by water. Among many water bodies, lakes are the most fertile, diversified and productive of all the ecosystems in the world. A variety of environmental goods and services are bestowed upon us by lakes which makes them vulnerable to human exploitation. The water quality of receiving water bodies such as rivers and lakes is critically important because it is one of the most essential resources for human existence and settlement. However, the rapid growth of population and increase of urban activities significantly influence the water quality of receiving water bodies [1]. water quality of urban water bodies are being changed over the time due to various reasons. Lakes are subject to various natural processes taking place in the environment, such as hydrologic cycle. With enormous developmental activities, human beings are responsible for the severe deterioration of several lakes.

The canal system which is in and around Colombo-Sri Jayewardenepura area is currently in such an environmentally deteriorated condition due to rapid development and urbanization of the area. The quality of water and habitat in most of the areas are influenced by industrial and public effluent discharge to the canal system [2]

In the recent past, water of Diyawanna Lake indicated many water quality problems such as bloom formation, fish kills etc. The maintenance of good water quality in Diyawanna Lake is fundamental to the long term future of the lake as a multi-user resource. Good water quality, with low levels of micro organisms, pesticides and other contaminants,

is vital to maintain the lake's current social and scenic value. Any future development of recreation in the lake is likewise dependent on maintaining good water quality in the lake now.

However there is no recent scientific water quality analysis conducted for the inlets of the lake to determine its' status and to identify the potential pollution sources. The lack of such scientific information is a constraint to develop proper management criteria to protect the lake and to maximize its' uses to the community. Therefore it has become a needy requirement to identify level and trends of the deterioration of the water quality of the lake by analysing the inlets' water.

The objective of this research study was to determine the status and trends in water quality changes of two inlets of Diyawanna Lake.

2. METHODOLOGY

2.1. Study Area

The study area is confined to two water inlets to the Diyawanna Lake and surroundings (Figure 1). In this study, the water samples collected at two locations namely: Kimbulawala Madiwela (Location 1) and Battaramulla South-Pelawatte (Location 2) were analyzed.

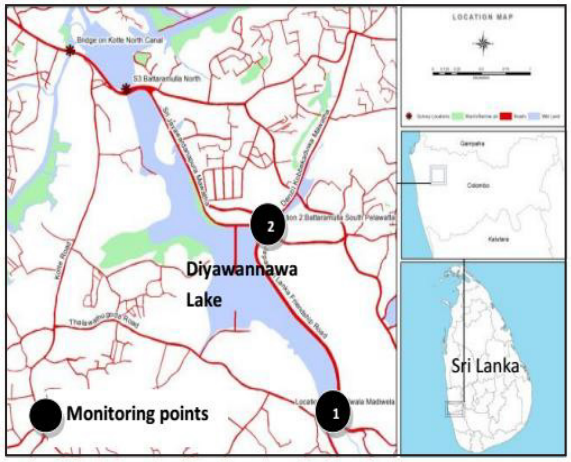

Figure 1: Study area including two water inlets to the Diyawanna Lake and surroundings

The GPS coordinates of Location 1 and Location 2 are 6°52'43.93"N; 79°55'36.58"E and 6°53'31.48"N; 79°55'17.08"E respectively.

2.2 Data Collection and Analysis

The monthly water quality data for a period of five years from 2006-2010 available at Sri Lanka Land Reclamation and Development Corporation were used for the study. The water quality parameters considered for the study are pH, Turbidity, Electrical Conductivity, Dissolved Oxygen and Nitrate (V)-N. In addition,

In addition, rainfall data, land use maps of the study area and primary data gathered through field visits were used in the study. Field visits were made along two identified canals and around the lake in order to ground verify the existing land use pattern of the area. In addition, identification of potential point and non-point pollution sources of the area, which will directly or indirectly impact on the water quality of the canals were done through transect walks.

The primary and secondary data collected through field observations and secondary sources were analyzed using MS Excel and SPSS packages.

3. RESULTS

According to the results obtained for the period of 2006-2010; the variation of the selected water quality parameters of Location 1 and Location 2 are given in Table 1 and Table 2.

Table 1: Variation of water quality parameters of Location 2 during the period of 2006-2010

Parameter	Unit	Min	Max
pH	-	5.4	7.4
Electrical Conductivity	mS/cm	0.07	0.30
Turbidity	NTU	4.15	33.50
Dissolved Oxygen	mg/l	3.02	6.88
Nitrate (V)-N	mg/l	0.01	0.70

Table 2: Variation of water quality parameters of Location 2 during the period of 2006-2010

Parameter	Unit	Min	Max
pH		5.2	7.2
Electrical Conductivity	mS/cm	0.11	0.23
Turbidity	NTU	4.00	27.90
Dissolved Oxygen	mg/l	2.17	6.84
Nitrate (V)-N	mg/l	0.01	0.80

In all the instances, except in 2006 where the mean pH is 6.7, the mean pH values of both locations are less than 6.5, which indicate the water is more acidic.

The average electrical conductivity value of Location 1 and Location 2 over the five years varies from 0.14 mS/cm to 0.17 mS/cm and 0.15 mS/cm to 0.18 mS/cm respectively. When comparing the electrical conductivity variation of 2 locations over the period of five years, the highest electrical conductivity is in year 2009 for both locations and the electrical conductivity of Location 2 is comparatively higher than the electrical conductivity of Location 1.

In Location 1, the lowest mean turbidity was recorded in 2008 (9.01 NTU) and the highest mean turbidity was recorded in 2007 (14.90 NTU). In Location 2, the highest mean turbidity was recorded in 2006 (12.21 NTU) and the lowest mean turbidity was recorded in 2010 (10.18 NTU). Except for the mean turbidity of 2009, the mean turbidity values of other four years show a decreasing trend. Except in few cases, the turbidity values of both locations are higher than the maximum permissible limits (max. 2 NTU according to SLS 614:2013; max. 5 NTU according to proposed water quality standards for Sri Lanka by CEA).

The mean Dissolved Oxygen concentration in the Location 1 over the five years is ranged from 4.69 mg/l-5.86 mg/l. The Dissolved Oxygen values over the period indicate an increasing trend. The mean Dissolved Oxygen values of Location 2 during the period of 2006-2010 are varied from 4.15mg/l to 5.29mg/l. In all five years, mean Dissolved Oxygen values in Location 1 is higher than the mean Dissolved Oxygen values in Location 2. Except in few cases, the Dissolved Oxygen levels recorded for two locations for the period of 2006-2010 are higher than 3 mg/l which indicating acceptable levels during the sampling occasions according to the proposed water quality standards for Sri Lanka by CEA for fish and aquatic life.

The mean levels of Nitrate (V)-N in Location 1 are varied from 0.14 mg/l to 0.27 mg/l where the lowest mean value is in 2006 and the highest mean value is in 2010. The mean levels of Nitrate (V)-N in Location 2 is varied from 0.12 mg/l to 0.27 mg/l whereas the variation of the mean Nitrate (V)-N value in 2010 is similar to the mean Nitrate (V)-N recorded in 2010 in Location 1. In both locations, Nitrate (V)-N levels are within the standard limits (max. 5 mg/l Nitrate (V)-N is threshold for fish and aquatic life as indicated in proposed water quality standards for Sri Lanka by CEA).

4. CONCLUSION

The study revealed that the water quality of two inlets have deteriorated over the period of 2006-2010. The quality of water in most of the areas along these two canals are influenced by both point and non-point sources. It has been severely affected on well being of the community live around these canals. Therefore it is important to conduct further studies on the current status of water quality of inlets, outlets and also the Lake and implement effective policy implications to avoid polluting the Diyawanna Lake.

Acknowledgment: Authors wish to express their sincere thanks to Sri Lanka Land Reclamation and Development Corporation.

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P3-2

Abundance and Distribution of Ciliated Protozoans in Marantao's Littoral and Pelagic Zones of Lake Lanao, Philippines

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Keywords: ciliates, protozoa, bio-indicators, Lake Lanao, freshwater

ABSTRACT

Ciliated protozoans are one-celled organisms known as bio-indicators of organic pollution in freshwater ecosystem. The study intended to determine the presence, distribution and abundance of ciliates in Lake Lanao at the littoral and pelagic zones of Marantao, Lanao del Sur during summer season of 2016. It also aimed to determine the trophic state of the waters in sampling stations. Ten (10) morphologically distinct ciliate species belonging to 6 genera, were observed in littoral zone while 11 species belonging to 7 genera in pelagic zone. In both zones the abundances of ciliates were quite low except for station 3 in the littoral zone and it was significantly different from rest of the stations in both zones. The said station was readily accessible for human activities thus probably had higher organic load during sampling which may account for its higher abundance. Although the average abundance of ciliates in the littoral zone (201.56 cells/m^3) was higher than the pelagic zone (29.19 cells/m^3), but the difference was not statistically significant. Interestingly, the ciliate abundance data when compared to a trophic state classification standard for lakes, the results implied that the water quality in both zones are still categorized as ultraoligothrophic, that is, the water was still pristine and fit for drinking. Species of *Paramecium, Vorticella, Podophrya, Tetrahymena* were commonly distributed in both zones which is reflective of their cosmopolitan distribution. *Oxytricha* sp. and *Loxodes sp.* were observed in littoral zone only while *Glaucoma* sp., *Opercularia* sp. *and Euplotes* sp. in pelagic zone only.

1. INTRODUCTION

Ciliated protozoans are one-celled animal-like organisms characterized by the presence of hair-like structures called cilia. They play a very significant link in the food chain as algal grazers and bacterial feeders. Ciliates gained popularity because they are bio-indicators of organic pollution [1,2,3] and in monitoring the health of aquatic ecosystems. They have been utilized as model organisms for microbial, cell and molecular biology studies, toxicity bioassays of pollutants, chemosensory responses, lysosomal studies and others. They have ubiquitous distribution, high reproductive rate, and they can easily be cultured in hay infusion.

Little has been known about ciliates in Lake Lanao thus this study was conducted as part of a big project on preliminary inventory of ciliated protozoan in Lake Lanao, situated in Lanao del Sur, Mindanao, Philippines. Moreover, alarming reports on lake's deterioration triggered the conduct of this study as human activities are prevailing in the lake such as throwing of garbage and sewage directly into the lake, making lake as receptacle of human wastes. Since ciliates can be tapped as bio-indicators of organic pollution, ciliate profile of the lake such as ciliate inventory, distribution and abundance is seen as important component of establishing base line data to monitor the health ecosystem of Lake Lanao. The study therefore aimed to determine the spatial variation of ciliates in terms of abundance and distribution between the littoral and pelagic zones of Lake Lanao bordered by Barangay Inudaran, Municipality of Marantao, Lanao del Sur. It also intended to determine the trophic status of the Lake by ciliate abundance. Results of the data can serve as basis for proper management, conservation, and sustainability of the lake's resources.

2. METHOD

Sampling Sites, Sample Collection and Fixation

The study was conducted in the littoral and pelagic water zones of Lake Lanao bordered by Barangay Inudaran, municipality of Marantao, Lanao del Sur. Three sampling stations (Fig 1) with 20-m intervals were established in each zone. Water temperature, pH level, and turbidity (improvised secchi disk in pelagic zone only) were also recorded. Sampling collection was conducted in April 2016, a summer season in the Philippines.

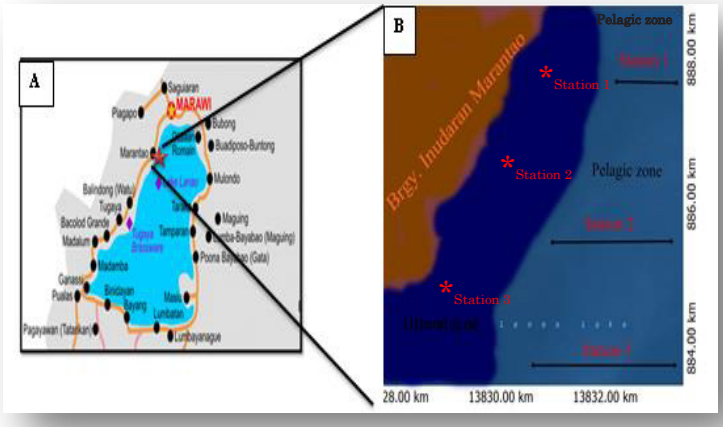

Fig 1. Map of Lake Lanao (A) showing sampling stations (B)

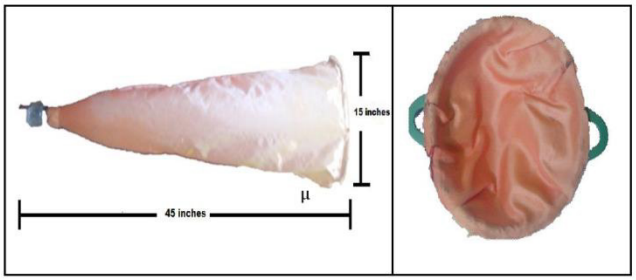

Fig 2. The improvised plankton net (left) and sieve (right)

Microscopic Observation and Documentation

Ken-A Vision and an ordinary compound microscope (at 100x and 400x magnifications) were used to observe and count ciliates. Ciliates from the fixed samples were identified primarily by the presence of a hair-like structure called cilia, ciliatures, body size, shape and nuclei [4]. The counts of each replicate were recorded for calculation of ciliate abundance as shown below.

Abundance: (cells/m^3) = (n x k) / V

Where, n= the number of counts for a particular ciliate
k= the proportion of subsample volume/ total volume sampled
V= mouth area of plankton net x distance towed diameter = 0.381m

Data Analysis

In determining whether ciliate abundance between sampling stations and between zones had significant difference, Analysis of Variance (ANOVA), Duncan's Multiple Range Test (DMRT) and Mann-Whitney U test were utilized.

3. RESULTS

Ten (10) morphological distinct ciliate species were identified in the littoral zone distributed across six (6) genera, namely: *Paramecium*, *Vorticella*, *Podophrya*, *Tetrahymena*, *Oxytricha*, and *Loxodes*; while 11 species in pelagic zones, under seven (7) genera, namely, *Glaucoma, Opercularia*, *Paramecium*, *Podophrya*, *Tetrahymena, Vorticella and Euplotes.* Selected photomicrographs of these ciliates are shown in Figs 3-7. Species of *Paramecium, Vorticella, Podophrya, Tetrahymena* were commonly distributed in both zones which is actually reflective of their cosmopolitan distribution. *Oxytricha* sp. and *Loxodes sp.* were observed in littoral zone only while *Glaucoma* sp.*, Opercularia* sp. *and Euplotes* sp. in pelagic zone only.

Fig 8 shows the abundance of ciliates in three different sampling stations from both the littoral and pelagic zones. In the deeper pelagic zone, no significant difference in the abundance of ciliates observed in three different stations by ANOVA; however in the shallower littoral zone, the mean abundance of ciliates in station 3 (536.11 cells/m^3) was far higher than the rest of the sampling stations and the difference was highly significant by ANOVA and DMRT. All stations in littoral zone were shallow at 1-1.5m depth but the water in station 3 was relatively turbid compared to other 2 stations. Moreover, stations 1 and 2 were rarely frequented by people due to the nearly inaccessible path towards that part of the Lake. Station 3, on the other hand, was readily accessible and frequently disturbed by human activities like bathing and washing clothes. The organic load of the said station could be higher during the sampling which probably accounted for higher ciliate counts.

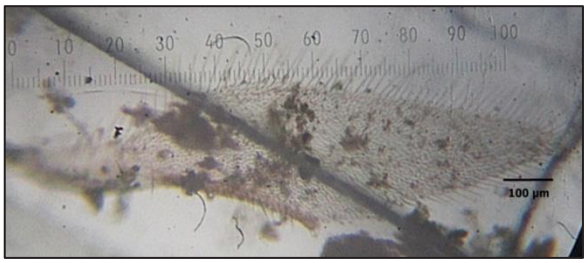

Fig 3. *Loxodes sp.*

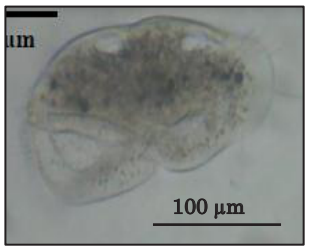

Fig 4. *Euplotes* sp.



Fig 5. *Vorticella* sp.

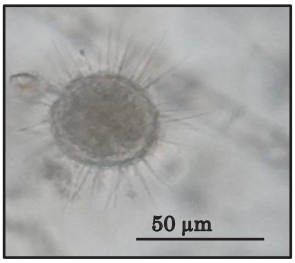

Fig 6. *Podophrya* sp.

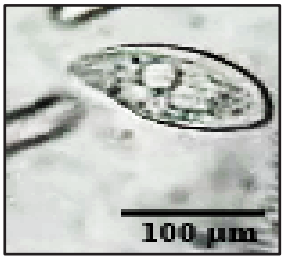

Fig 7. *Tetrahymena* sp.

The average abundance of ciliates in each zone is compared in Fig 9. The figure seemingly demonstrates that ciliate abundance in the littoral zone outweighed the pelagic zone but interestingly the difference between zones was not statistically significant when compared using Mann-Whitney U test. This could probably be due to the fact that all stations in both zones had similar lower ciliate counts except for station 3 in the littoral zone; but the abundance of the said station 3 somehow did not affect the abundance of the whole zone consequently the average abundances between zones were not statistically different when compared.

Although the sampling station 3 in the littoral zone so far

had the highest ciliate abundance but in terms of ciliate composition, but only 3 genera were observed and it was dominated by *Vorticella* species (Fig 10) comprising 92% of ciliates in the site. This is not surprising though since *Vorticella* spp. have been identified as typical indicator of pollution as early as 1952 from moderately to heavily polluted [5]. It is possible that this ciliate group indicated higher organic nurients in that particular station.

The ciliate abundance data can be utilized to determine the trophic condtion of the lake. Table 1 shows the trophic classification of the lakes set by Beaver & Crisman in 1989 [3]. Based on the gathered data on ciliate abundance, the results implied that both zones of Marantao lake waters was still under ultraoligotrophic state, that is, the lake is highly pristine, the waters are of high-drinking quality, well-oxygenated and low in nutrients [6] during sampling.

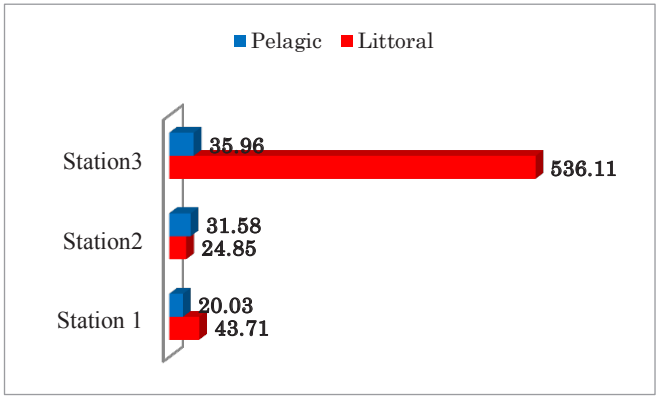

Fig 8. Mean abundance of ciliates in 3 stations (cells/m^3) of littoral and pelagic zones

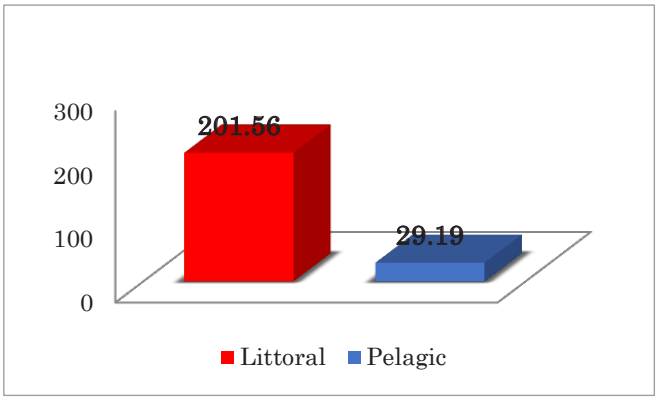

Fig 9. Average ciliate abundance (cells/m^3) in littoral and pelagic zones

4. CONCLUSION

Ciliates species under genera *Paramecium*, *Vorticella*, *Podophrya*, *Tetrahymena*, *Oxytricha*, and *Loxodes*; *Glaucoma, Opercularia*, *Paramecium*, *Podophrya*, *Tetrahymena, Vorticella, Glaucoma Opercularia* sp. *and Euplotes* were observed in the Littoral zones while *Glaucoma, Opercularia*, *Paramecium*, *Podophrya*, *Tetrahymena, Vorticella and Euplotes in pelagic zone.* Species of *Paramecium, Vorticella, Podophrya, Tetrahymena* were observed in both zones reflective of their cosmopolitan distribution. *Oxytricha* sp. and *Loxodes sp.* were observed in littoral zone only while *Glaucoma* sp., *Opercularia* sp. *and Euplotes* sp. in pelagic zone only. Littoral zone had higher ciliate abundance than pelagic and *Vorticella* spp. dominated the ciliates in littoral area possibly indicating higher organic nutrient present in the shallow waters during sampling. However, the ciliates abundance in both zones were quite low against standard, indicating the waters in sites during sampling were ultraoligotrophic, that is, the waters were still clean and safe to drink.

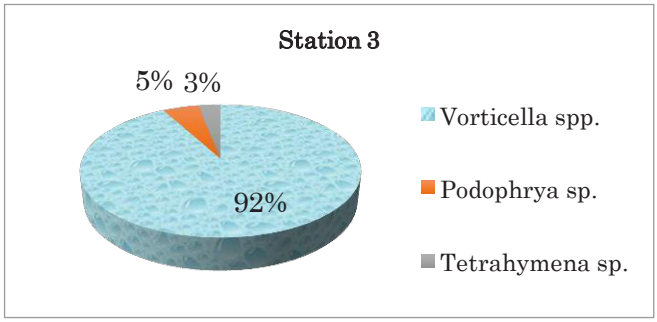

Fig 10. Percentage distribution of ciliates found in station 3, littoral zone

Table 1. Trophic state classification standard for lakes set by Beaver and Crisman (1989) utilizing planktonic ciliate abundance [3]

Trophic state	Range of observed abundances (cells/mL)
Ultraoligotrophic	2.4
Oligotrophic	2.3-10.8
Mesotrophic	18.0-70.9
Eutrophic	55.5-145.1
Hypereutrophic	90.0-215.0

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P3-3

Relative importance of physical and biological factors regulating tintinnid populations: a field study with frequent samplings in Sendai Bay, Japan

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Keywords: estuaries, microbial food web, micro-zooplankton, population dynamics, selective feeding

ABSTRACT

To examine factors regulating the summer population dynamics of tintinnid species, temporally high- frequency observations of tintinnid ciliates were performed in Hiroura Estuary in Sendai Bay. Sampling was conducted on alternate days from 5 July to 2 August 2010 at three estuary sites to examine which environmental (water temperature, salinity and tidal level change) and biological (abundances of Chl- *a*, bacteria, protozoans and zooplankton) factors are important for determining temporal changes in abundance and apparent population change rates for tintinnid species. During the study period, 20 tintinnid species were found and showed drastic population changes within a few days, resulting in different tintinnid assemblages from the first to the second half of the study period. Multivariate analysis and generalized linear mixed models showed that several environmental and biological factors were related significantly with the abundance and apparent population change rate of each tintinnid species, but no effect of potential predators such as copepods was found for the abundance and change rate. These results suggest that physicochemical and food conditions play more important roles than predation pressure in short-term temporal changes of tintinnid populations during summer in estuary environments.

1. INTRODUCTION

Estuaries are highly variable ecosystems in which the water temperature, nutrient concentration, salinity and water level exhibit short-term fluctuation related to the tidal cycle and mixing of flows from river water and offshore marine water. These harsh conditions prevailing in estuaries produce good habitats for tintinnid ciliates [1].

Monthly to weekly observations showed some physical and biological factors affect the population dynamics of tintinnid species [1–3]. Although few reports describe predation effects on tintinnid ciliates population, the study in offshore waters suggests copepod predation affects the distribution of tintinnid species [4]. Therefore, the population dynamics of tintinnid ciliates might be affected by copepods as well as several environmental factors. However, if environmental conditions change in the short-term or fluctuate along with the tide, the abundance and species composition of tintinnid ciliates might change rapidly, since generation times of tintinnids are as short as a day [5,6]. Moreover, copepods are known to prey less on ciliates when phytoplankton are abundant [7].

We hypothesized that (1) the population dynamics of tintinnid ciliates in estuaries are changing drastically in short intervals because of changes in prevailing physical and biological conditions, and (2) the predation pressure on tintinnid populations can be negligible when algal food for copepods is abundant. We performed frequent samplings of tintinnid populations along the tidal cycle in an estuary located on the Pacific Coast of Japan.

2. MATERIALS AND METHODS

This study was conducted at the Hiroura Estuary on the coast of Sendai Bay, Japan. Sampling was done at high tide slack water at three sites every two days from 5 July to 2 August 2010. The seawater level was recorded with a water level logger (U20; HOBO) placed at Site 2. The tidal trend was calculated as the difference in maximum elevation between two successive dates. This variable is positive during the transition from the neap to spring tides, and vice versa.

At each site, 30-L of integrated seawater was collected from the bottom to the surface using a 2.4-L tube sampler. An aliquot of the water sample was used to measure water temperature and salinity with a CTD sonde (556 MPS; YSI Inc.). For bacteria, heterotrophic nanoflagellates (HNF) and phytoplankton, 100-mL of the water sample was fixed with glutaraldehyde (1% final conc.) and stored at 4°C. For tintinnid ciliates, 10-L of the water sample was sieved using a 20-μm mesh net, concentrated into 100 mL, fixed with Lugol's solution (5% final conc.) and stored in the dark. For crustacean planktons, another 10-L of the water sample was concentrated to 100-mL using a 100-μm mesh net and fixed with formalin (5% final conc.). A 1-L of the water samples were separated into three size classes (<2, 2-10 and >10 μm) by filtration and analyzed Chl-*a* concentration in laboratory. Algal biomass was calculated using C:Chl-*a*=30 [8].

This study examined the population dynamics for major tintinnid species, which were defined as those found in at least 15 out of the total 45 samples (15 date × 3 sites). To examine the putative relations between environmental variables and the abundance of tintinnid populations, redundancy analysis (RDA) was done by using the vegan

package [9] of the software R [10].

To examine the effects of environmental variables on population dynamics of tintinnids, generalised linear mixed model (GLMM) with Gaussian error was done by using the R package lme4 [11]. The apparent population change rate (μ day^{-1}) for major tintinnid species was estimated as follows;

$$\mu = \ln(N_i - N_{i-1}) \times 24/(t_i - t_{i-1})$$

where N_i stands for abundance at time i; t_i denotes the elapsed time from the first sampling. Salinity, tidal range, bacteria, HNF and total copepods were selected as explanatory variables based on the result of correlation matrix. Note that the effects of salinity, bacterial abundance and HNF abundance in this analysis included water temperature or Chl-*a*. Similarly, the effects of copepod abundance included other zooplankton such as nauplii and cladocerans. All possible models were generated using R package MuMIn [12], and chose the best models according to AICc [13].

3. RESULTS

During the study period, tidal range and salinity varied from 1.4 to 1.8 m, and 3.18 to 31.0, respectively. The mean algal biomass of each size class were 15, 54, and 15 μg C L^{-1} for <2, 2-20 and >20 μm, respectively, among the study sites. Mean copepods abundance were 1.3–1.5, 0.67–2.1, and 1.8–2.9 individuals L^{-1} for *Acartia* spp., *Paracalanus* spp., and *Oithona* spp., respectively, at all sites.

In tintinnids, species composition changed drastically from 15 to 19 July (Fig. 1). For example, *Amphorellopsis acuta* was not found in the first half of the study period (5–13 July), but it was the most numerous species in the second half (15 July–2 August). *Eutintinnus* sp. and *Helicostomella* sp. were abundant in the first half of the study period, but were rare in the second half. The total tintinnids biomass was 0.21–0.43 mg C L^{-1} among the sites.

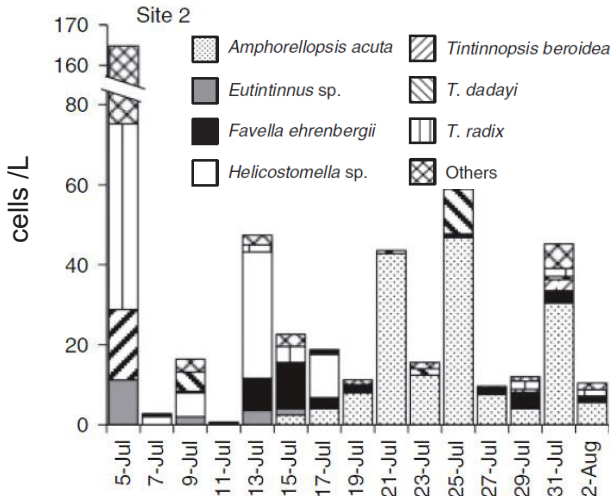

Fig. 1. Typical result of temporal changes in abundances of tintinnid species at Site 2 in Hiroura Estuary.

The relationship between tintinnid abundance and environmental variables was examined by RDA (Fig. 2).

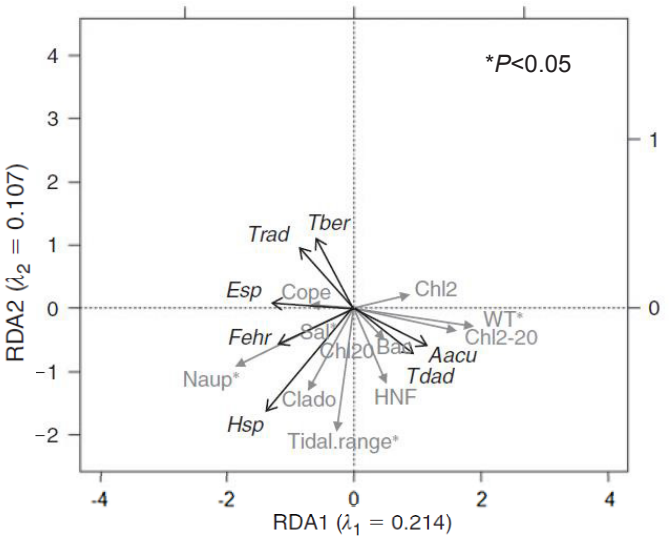

Fig. 2. Biplots of redundancy analysis (RDA) for (*a*) abundance of tintinnid species (thin black arrows) and environmental variables (bold grey arrows). The first two axes explain 32.1% of variation in abundance of tintinnid species and 76.0% of variation in environment data. WT, water temperature; Sal, salinity; Bac, bacteria; Naup, nauplius; Cope, copepods; Aacu, *Amphorellopsis acuta*; Esp, *Eutintinnus* sp.; Fehr, *Favella ehrenbergii*; Hsp, *Helicostomella* sp.; Tber, *Tintinnopsis beroidea*; Tdad, *T. dadayi*; Trad, *T. radix*.

The RDA with forward selection yielded four significant environmental variables, water temperature, tidal range, salinity, and nauplii abundance. The GLMM with model selection procedures revealed that the apparent population change rates of tintinnid species were related more or less with tidal trends, and abundances of bacteria and HNF (Table 1). For no tintinnid species, however, was the abundance of total copepods incorporated in the best models.

4. DISCUSSION

Tintinnid ciliates are protozoans with a short generation time (<25 h [5,6]). Therefore, we hypothesised that the species composition and abundance of tintinnids changed during short-term intervals. Supporting this hypothesis, the abundance and species composition of tintinnids changed drastically in a few days in the Hiroura Estuary (Fig. 1). In this estuary, physical and biological environmental conditions change temporally and spatially, probably because of tidal trends and cycles. These changes cause drastic changes in the abundance and species composition of tintinnids (Fig. 2, Table 1). However, both analyses with RDA for abundance and GLMM for apparent population change rate showed no sign of

Table 1. Results of GLMM showing the best models (top 3 or ΔAICc<2) for apparent population change rate of tintinnid species with fixed effects for salinity, tidal trend, bacteria and copepods, and random effects for sites. Results of Chi-Square tests against the null model and *p*-values (*, <0.05; **, <0.01) are shown. Abbreviations are same as in Fig. 2.

	sal	tidal tr	bac	hnf	cope	k	AICc	X^2	*p*
Aacu		-	+	+		6	132.5	15.6	**
		-		+		5	133.3	11.6	**
		-	+			5	133.4	11.5	**
*E*sp.	+			+		5	123.0	7.5	*
				+		4	123.3	4.2	*
	+		+	+		6	123.5	10.2	*
Feh		+	-			5	136.3	7.5	*
		+				4	136.5	4.6	*
	+	+				5	137.6	6.3	*
*H*sp.		+	-	-		6	128.0	15.8	**
		+		-		5	128.7	11.4	**
			-	-		5	129.6	10.5	**
Tber		-	-	+		6	118.7	12.6	**
			-	+		5	119.1	8.7	**
		-		+		5	119.3	8.6	**
Tdad		-	+	+		6	141.9	15.0	**
		-	+			5	142.7	10.9	**
		-		+		5	143.7	9.9	**
Trad		+		+		5	138.7	13.2	**
		+	+	+		6	139.1	15.8	**

copepod effects on the numerical responses of major tintinnid populations, although copepods density in Hiroura estuary could be sufficient to affect the tintinnids abundance [14–16].

Some reports of experimental studies have described that copepods prey on phytoplankton such as diatoms and dinoflagellates in preference to ciliates when the latter are scarce [17,18]. Calbet and Saiz [19] demonstrated that ciliates accounted for 49% of copepod diets in ocean area with low phytoplankton biomass (<50 mg C L^{-1}), while only 22–25% of those in area with high phytoplankton biomass (50< mg C L^{-1}). In Hiroura estuary, the phytoplankton biomass was 55–99 mg C L^{-1}. Also, it was much greater than the total tintinnids biomass (~0.43 mg C L^{-1}). Consequently, because of the low biomass, tintinnids might not be affected negatively by copepod predation in this study. The vulnerability of tintinnid species to copepod predation might therefore depend on their abundance relative to those of other potential food organisms such as diatoms.

5. CONCLUSION

The abundance and species composition of tintinnids in Hiroura Estuary varied temporally and changed rapidly within a few days in relation with short term variations of environmental and biological factors and temporally ephemeral factors such as HNF and bacterial abundance. The results imply that frequent samplings are essential to understand the population dynamics of tintinnid populations in estuaries. Although tintinnids are potentially food for copepods, tintinnid abundance and species composition were unaffected by copepods, especially under high phytoplankton biomass.

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P3-4

炭素・窒素安定同位体比及び脂肪酸分析によるイシガイの藍藻同化の評価

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キーワード:富栄養化, アオコ, 二枚貝, 濾過摂食

抄録

湖沼の水質改善を目的として、二枚貝の濾過摂食機能を利用した藍藻に対するバイオマニピュレーションが検討されているが、二枚貝が藍藻を摂食した後どの程度同化するのかほとんど明らかになっていない。本研究では、夏季に藍藻ブルームが発生する八郎湖にイシガイを設置し、イシガイの藍藻同化能力を評価することを目的とした。底質直上水中の懸濁物の炭素・窒素安定同位体比は、藍藻ブルーム発生時期に大きく変動したが、イシガイ生体中の各安定同位体比はほぼ一定であり、懸濁物の同化は検出されなかった。一方、藍藻ブルーム発生時期にイシガイ中の珪藻由来脂肪酸に対する藍藻由来脂肪酸の存在比が有意に増加するとともに、イシガイの肥満度と藍藻由来脂肪酸の寄与率にも正の相関が示された($r = 0.8272$, $P < 0.01$)。本研究により、イシガイは藍藻を濾過摂食した後同化することが明らかになり、イシガイのバイオマニピュレーションツールとしての有用性が示された。

1. はじめに

富栄養化した湖沼で異常増殖した藍藻対策として、濾過摂食動物の機能を利用したバイオマニピュレーションが検討されている。しかし、藍藻は巨大コロニーを形成し摂食を免れやすいことや、摂食されたとしても水生生物の消化器官を通過し、その後、環境中に回帰して増殖する事例が報告されている[1]。そのため、バイオマニピュレーションによって藍藻の増殖を抑制するためには、コロニーを形成した藍藻を摂食してさらに同化できる生物を選定することが重要となる。

二枚貝は、濾過摂食動物の中でも高い濾水速度を有することから藍藻を含む懸濁物の効率的な除去が期待されている。著者らは無機懸濁物質を用いた室内実験において、イシガイ*Unio douglasiae*が350 μm程度の大型粒子でも濾過できることを示した[2]。しかし、イシガイが実際の環境中で藍藻を餌として同化しているかは知られていない。本研究では、夏季に藍藻ブルームが発生する秋田県八郎湖にイシガイを設置し、餌資源の利用性を評価することにより、イシガイによる藍藻の同化能力を明らかにすることを目的とした。

2. 方法

2017年7月に八郎湖南岸部の岸から10 mほど離れた水深約70 cmの地点に面積0.36 m^2のケージを設置し、その中に八郎湖で採集したイシガイの成体 50 個体を投入した。その後、2017年 11 月まで 2 週間おきに、ケージからイシガイ 3〜5 個体を採集し、殻長及び殻高、殻幅、凍結乾燥後の乾燥重量を測定した。そして、肥満度(乾燥重量÷殻長×殻高×殻幅)を求めた。さらに、足の筋肉を採取し、炭素及び窒素の安定同位体比分析及びガスクロマトグラフィーによる脂肪酸分析を行った。イシガイ採集時にピストン式採水器を用いて底質直上付近の水を採水し、顕微鏡観察により藻類を計数した。また、懸濁物質の粒径分布、炭素・窒素の安定同位体比、脂肪酸組成の分析を行った。

なお、本研究ではエイコサペンタエン酸(20:5ω3)を珪藻由来の脂肪酸、リノール酸(18:2ω6)とα-リノレン酸(18:3ω3)を藍藻由来脂肪酸とみなし、バイオマーカーとして用いた。

3. 結果

調査期間中、イシガイの肥満度は 8 月〜9 月にかけて微増し、その後 10 月以降に大幅に増加したことが確認された(図 1)。

懸濁物の顕微鏡観察から、植物プランクトンでは、主に8月〜9月に*Anabaena*属や*Microcystis*属の藍藻が

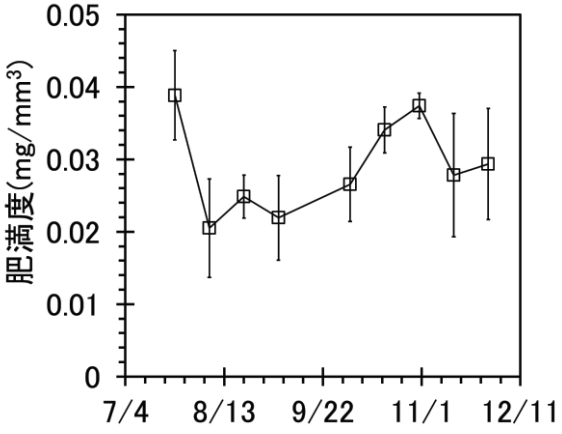

図 1 イシガイの肥満度の変動

優占し、10 月以降は、*Aulacoseira* 属や *Cyclotella* 属を主とする珪藻が優占していた。さらに、調査地点で観測された粒径分布の D_{90} 値は、調査期間を通して 100～350 μm 程度であった。すなわち、湖水中の懸濁粒子の 90%は、イシガイの可食粒径範囲内の 350 μm[2]よりも小さい粒子であることが示された。

イシガイの懸濁物の同化状況を調べるために、イシガイ生体中の炭素・窒素の安定同位体比と底質直上水中の懸濁物の各安定同位体比の経時変化を比較した。底質直上水中の懸濁物の炭素安定同位体比は、*Anabaena* 属が優占していた 8 月初旬に相対的に高い値を示し、*Microcystis* 属が優占していた 9 月初旬には低い値を示した(図 2)。窒素安定同位体比は、対照的に、8 月初旬に低い値を示し、9 月初旬には高い値を示した(図 3)。一方で、イシガイ生体中の炭素と窒素の安定同位体比は、ほとんど変動しなかった(図 2 及び 3)。

次に、バイオマーカー脂肪酸を用いて懸濁物の同化状況を調べたところ、藍藻ブルーム発生時期の 8 月～9 月にかけてイシガイ生体中の藍藻由来脂肪酸が微増するとともに、珪藻由来脂肪酸が減少していた(図 4)。藍藻ブルームが衰退し、珪藻優占状態になった 10 月以降には、珪藻由来脂肪酸の大幅な増加が観測された(図 4)。図 4 をもとに、イシガイ生体中の珪藻由来脂肪酸に対する藍藻由来脂肪酸の存在比を比較したところ、試験開始時に対して藍藻ブルーム発生時期に存在比の有意な増加が示された(図 5)。

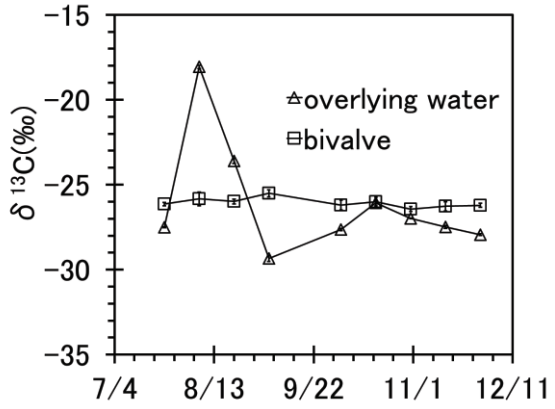

図 2 底質直上水の懸濁物質とイシガイ生体中の炭素安定同位体比の経時変化

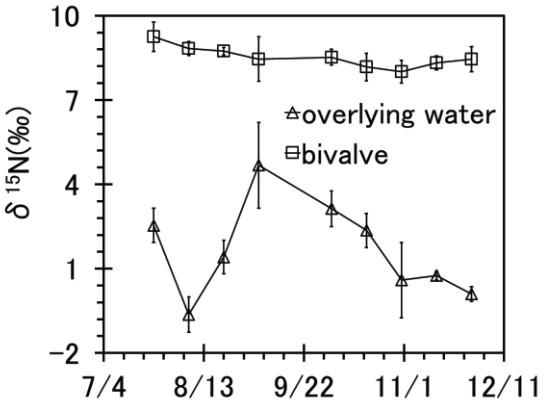

図 3 底質直上水の懸濁物質とイシガイ生体中の窒素安定同位体比の経時変化

4. 考察

肥満度の増加傾向からイシガイの餌の同化が示唆された(図 1)。藍藻ブルーム発生時期と 10 月の珪藻優占時期の肥満度の増加傾向を比較すると、10 月の珪藻優占時期の方が肥満度の増加が大きいため、珪藻優占時期に最適な餌が豊富だったと示唆された。

炭素・窒素安定同位体比分析により、イシガイの懸濁粒子の摂食傾向の評価を試みた。アオコ発生時期である 8 月～9 月に注目すると、底質直上水の懸濁物中の炭素、窒素安定同位体比は、大きく変動しているのに対し、イシガイ中の炭素・窒素安定同位体比はほとんど変化が無く(図 2,3)、イシガイ生体中の炭素・窒素安定同位体比は、懸濁物質の各安定同位体比を反映して

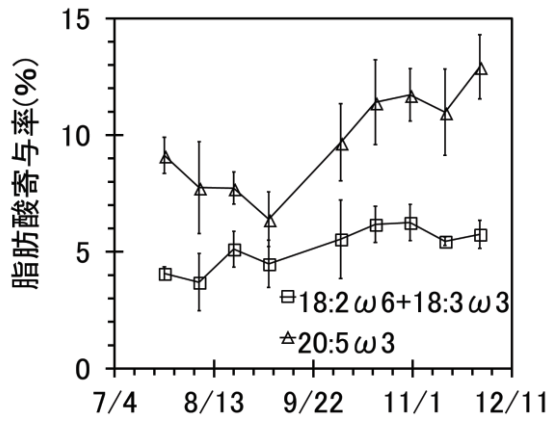

図 4 イシガイ生体中のバイオマーカー脂肪酸の経時変化

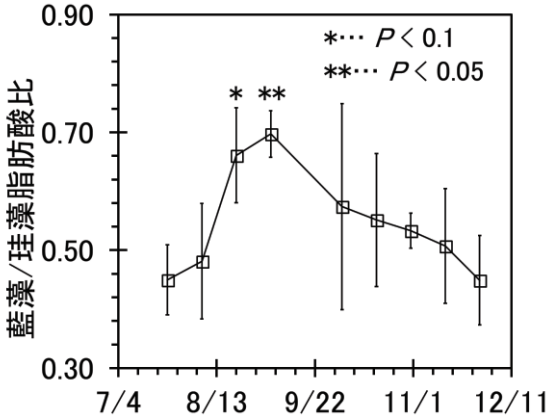

図 5 イシガイ生体中の珪藻由来脂肪酸に対する藍藻由来脂肪酸の存在比(Dunnett 法による多重比較検定, *は、$P < 0.1$, **は、$P < 0.05$ を示す)

いなかった。懸濁物を摂食、同化していてもイシガイの炭素・窒素安定同位体比に反映されるほどの量ではない可能性があるほか、イシガイが底質粒子を多く摂食し、水中の懸濁物をほとんど摂食しなかったと考えられた。

次に、バイオマーカー脂肪酸を用いて懸濁粒子の同化傾向の評価を試みた。藍藻ブルーム発生時期にイシガイ生体中の珪藻由来脂肪酸に対する藍藻由来脂肪酸の存在比が有意に増加し、イシガイの藍藻同化が示唆された。さらに、アオコ発生時期の8月～9月のイシガイの肥満度と藍藻由来脂肪酸寄与率は正の相関関係を示した（図 6, $r = 0.8272$, $P < 0.01$）。すなわち、イシガイは、藍藻ブルーム発生時期に藍藻由来脂肪酸を取り込み、肥満度を増加させたことが示唆された。脂質の回転速度が全炭素・窒素の回転速度よりも速いため、炭素・窒素安定同位体比では捉えることができなかった藍藻の摂食、同化をバイオマーカー脂肪酸によって評価できたと考えられた。

本研究結果から、イシガイの藍藻類に対する同化能が示唆されたことにより、八郎湖ではイシガイをバイオマニピュレーションツールとした藍藻除去が期待される。

5. 結論

本研究調査から以下のことが明らかになった。

1. アオコ発生時期及び珪藻優占時期の両方でイシガイの肥満度は増加傾向を示した。
2. 炭素・窒素安定同位体比分析では、イシガイの懸濁物の餌利用状況を明らかにすることはできなかったが、バイオマーカー脂肪酸分析では、イシガイの懸濁物質の摂食状況を捉えることができた。
3. アオコ発生時期の 8 月～9 月においてイシガイの肥満度と藍藻由来脂肪酸寄与率に正の相関関係が認められ、環境中でのイシガイの藍藻同化が示唆された。

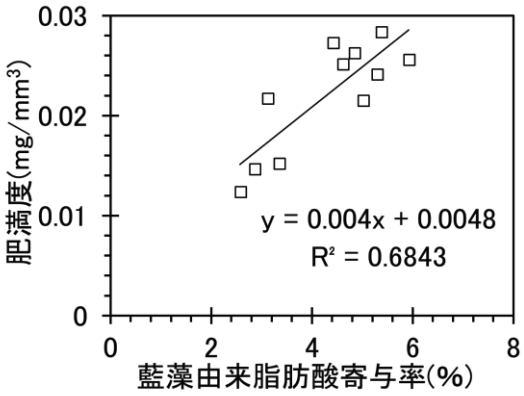

図 6 アオコ発生時期におけるイシガイの肥満度と藍藻由来脂肪酸寄与率の関係

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P3-5

八郎湖におけるアオコ形成藻類を含む細菌叢と環境因子の関係

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キーワード: 富栄養化, アオコ, 八郎湖, 次世代シーケンサー

抄録

本研究では2014年から2016年までの秋田県八郎湖の表層水における細菌叢の16S rRNAアンプリコン解析を行い, 水温, 降水量, 栄養塩濃度などの環境因子の影響を評価した。2014 年は 6 月から 8 月までの降水量が 2015 年と 2016 年の同時期の 2.5 倍と多かったが, 8 月と 10 月に短いアオコの発生があった。2015 年と 2016 年は 6 月から 10 月まで長期間アオコが観察されたが, 秋季の *Microcystis* 属によるアオコ発生は全ての年で起きていた。さらに, アオコ形成藻類を含む細菌叢は採水日前 7 日間の雨量と水温の影響を受け, 優占種が高水温かつ少降雨頻度では *Microcystis* 属, 多降雨頻度では *Anabaena* 属に変化しやすいことが示唆された。本研究のような長期間に渡った次世代シーケンサーによる細菌叢解析は例がなく, 本手法により細菌叢と環境因子の具体的な関係性を見出だせる可能性が初めて示された。

1. はじめに

富栄養化湖沼におけるアオコの発生は世界的に大きな社会問題となっている。秋田県八郎湖(八郎潟残存湖)もアオコ発生が常態化している湖沼であり, 富栄養化の進行とアオコの発生などから平成 19 年 12 月より湖沼法の指定を受けた。現在も様々な水質改善対策が進められているが, 毎年 6 月から 10 月まで長期的なアオコ発生が確認されており[1, 2], 抜本的なアオコ対策の創出が必要と言える。

そこで本研究では, 八郎湖におけるアオコ対策創出の基盤研究として, アオコ形成藻類を含む細菌叢と環境因子の関係を明らかにすることを最終目的とした。具体的には, 2014 年より 3 年間定期調査を行い, 次世代シーケンサーにより細菌叢をクロノシーケンスで解析した。また, 細菌叢の β 多様性(サンプル間での違い)と水温や各態窒素・リン濃度などの水質や平均気温, 降水量, 日照時間などの外的因子との関係を解析した。

2. 方法

2.1 調査方法及び測定項目

湖水試料は, 秋田県北西部に位置する八郎湖の距離の離れた 3 地点(図 1)で 2014 年 3 月から 2016 年 12 月まで毎月 1〜3 回表層水をヒシャクにより採取した。現地にて水温, pH, 電気伝導度(EC), 実験室にて Chl.*a*, 各態窒素・リン濃度を測定した。また, 湖水試料を酢酸抽出後, Presep®-C C18(WAKO)により粗精製・濃縮してミクロシスチン類を分析した[2]。

2.2 遺伝子解析

湖水を孔径 0.2 μm のフィルターでろ過し, ISOIL for Beads Beating(NIPPON GENE)により DNA 抽出を行った。抽出した DNA を用いて真正細菌を対象とした 16S rRNA 遺伝子アンプリコン解析を行った[2, 3]。得られた配列は Claident v.0.2(https://www.claident.org)により分子系統学的に分類した。また, 細菌叢の類似度解析は R パッケージの vegan 2.4-4 を用いて行った。

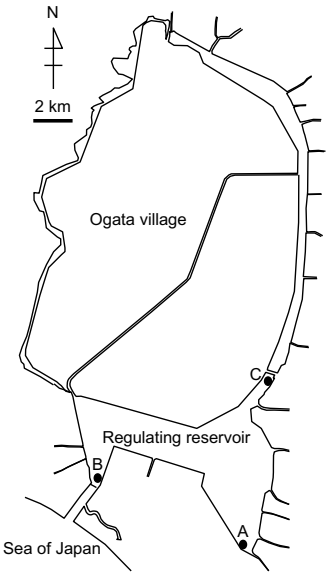

図 1　八郎湖の概要と採水地点

A: 野村港(北緯 39°42'48"500, 東経 140°02'14"470), B: 防潮水門(北緯 39°54'25"046, 東経 139°57'31"055), C: 大潟橋(39°56'58"784, 東経 140°03'22"760)

3. 結果

3.1 野村港における細菌叢変化と環境因子との関係

野村港(A)において2014年から3年間の定期調査を行った。2014 年は夏季の水温が低く，観測期間中のアオコの観察は2回だったが，10月に*Microcystis* 属主体のアオコが確認された[2]。2015 年は6月から10月まで長期間アオコが観察されたが，9 月以降は *Microcystis* 属がアオコ形成の主体となっていた[2]。また，2016 年も6月から10月まで長期間のアオコが観察されたが，9月には2015年とは異なり*Planktothrix* 属が優占した。

一方で，各年の細菌叢のβ多様性には有意な差があり($p < 0.05$)，特に2014年が明確であった。このβ多様性と水温，pH，EC，Chl.*a*，ミクロシスチン濃度，各態窒素・リン濃度に加えて，採水日前7日間の平均気温，日照時間，降水量との関係を解析した結果，採水日前 7 日間の合計雨量と水温の影響を強く受けていた。

3.1 2016年における3地点の細菌叢変化

2016 年はアオコ形成藻類として 3 地点共通して *Anabaena* 属と *Microcystis* 属，そして *Planktothrix* 属が優占した。3 地点の細菌叢の変化は概ね一致していたが，野村港でのみ *Microcystis* 属が9月下旬にも優占した。一方で，3 地点の細菌叢のβ多様性は季節的な変動はあるものの 3 地点間で有意な差は確認されなかった($p > 0.05$)。

4. 考察

2014 年から 2016 年の夏季の降水量には大きなばらつきがあり，特に2014年は6月から8月までの降水量が極めて多かった(2015 年比で約 2.7 倍)。そのため，各年でのアオコ発生状況は異なっていたが，秋季の *Microcystis* 属主体のアオコ発生には周期性が認められ，これは八郎湖特有の現象であると考えられた。

また，今回解析に用いた環境因子の中ではアオコ形成藻類を含む細菌叢は降水頻度と水温の影響を強く受けており，高水温かつ少降雨頻度では *Microcystis* 属が，多降雨頻度では *Anabaena* 属が優占した細菌叢に変化しやすいことが示唆された。

一方で，1年間のデータではあるが距離の離れた3地点での細菌叢に有意な差がなかったことから，アオコ形成藻類を含む細菌叢は湖内流動や流入水などの影響よりも季節的な変動の方が大きいことが示唆された。本研究のような長期間に渡った次世代シーケンサーによる細菌叢解析は例がなかったため，さらに継続的に調査を行うことで，アオコ形成藻類を含む細菌叢と環境因子の具体的な関係性を見出だせる可能性が初めて示された。

5. 結論

秋田県八郎湖の表層水の細菌叢を3年間に渡り解析した結果，下記のことが明らかになった。

1. 秋季の *Microcystis* 属主体のアオコ発生には周期性があり，八郎湖特有の現象であることが考えられた。
2. 細菌叢のβ多様性(サンプル間での違い)は，地点間よりも季節変動，さらに年次変動による違いが大きいことが明らかになった。
3. 細菌叢のβ多様性は，今回解析に用いた環境因子の中では特に降水頻度と水温の影響を受けており，高水温かつ少降雨頻度では *Microcystis* 属，多降雨頻度では *Anabaena* 属が優占した細菌叢になることが示唆された。

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P3-6

One individual and one cell PCR of predatory microorganisms for cyanobacteria

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Keywords: eutrophication, harmful algal bloom and toxic cyanobacteria

ABSTRACT

It is important to investigate protozoa and metazoan which can prey on toxic cyanobacteria, because the predation microorganisms affect the population of toxic cyanobacteria involving worldwide problems. Moreover we can apply such microorganisms to control or remove toxic cyanobacteria. Therefore, we developed a method without monoculture to determine the 18S rRNA gene sequences for establishing local database in molecular ecological studies. The experimental procedure using a micro glass capillary for uncultured protozoa and metazoan are shown as follows. Each swimming individual was captured by a glass capillary with the tip diameter of around 100micron meter under an inverted microscope. Then it was transferred into a drop of autoclaved water to wash the individual. This washing step was repeated 5 times at least. Then it was transferred into a PCR tube, and 70% EtOH of 100micro L was put in the tube to fix the individual. After drying completely, PCR mixture of 40 micro L (Tks-GFlex, Takara bio inc., Japan) was added to the tube. A universal primer set for metazoan Metaz 2-F and Metaz 5-R [1] (Machida, R., J. and Knowlton, N. PLOS ONE, Vol 7(9), e46180, 2012) was used for the PCR. Because DNA template concentration from one individual was very low, the optimal condition for the PCR had to be found to obtain the enough quantity of amplicons for DNA sequence. As a result, DNA sequences of several rotifer species were determined.

1. INTRODUCTION

Free-living Metazoan and Protozoa are ubiquitous in natural freshwater environments, but also proliferate in engineered water systems, including water treatment systems. These Protozoa have an important role in maintaining a good balance in biological ecosystems. Many Metazoan and Protozoan inhabits in the biological water treatment system. But almost species are uncultured microorganisms can prey toxic cyanobacteria Microcystis sp. . However, information about the presence and identity of Metazoan and Protozoa can prey the toxic cyanobacteria in water supplies in relation to the quality of treated water is scarce, which may be attributed to the limitations of microscopic techniques and cultivation methods for detection and identification of these organisms, e.g., low detection limits and selectivity for specific groups. Thus, it is important to study such Metazoan and Protozoan using molecular ecological methods without monoculture method. To analyze the 18S rRNA gene, commonly used for phylogenetic inference of eukaryotes due to its highly conserved sequence and ability to resolve relatively deep nodes. This is the first description of the general utility of environmental DNA sequencing approaches for identified character and population dynamic of Protozoa and Metazoan species.

2. METHOD

The several species of Microcystis sp. were collected fish pond water of Maejo University in the 50 ml tube, after that collect Microcytis bloom again from the surface of 50 ml tube to a 50 ml tube, we mix all Microcystis samples from several fish pond into a flask and a culture Microcystis cell in the glass tank in the filtrated influent fish pond water by GFF 55 mm. we collect Microcytis bloom again from the surface of the glass tank, treat the microcystis sample by using Ultrasonicator to separate the single cell or small colony from each colony. Adjust the Chl-a 200 ug/L dilutes by filtrated influent water. Protozoa and Metazoa were isolated from fish pond area and biofloc system (Chiang Mai Province, Thailand) and from a natural pond (Nagasaki, Japan). The isolation of Protozoa and Metazoa species was achieved using a handmade glass capillary (with 100μm tips) under the inverted microscope with x100 ~ x400 magnifications. Furthermore, the isolated Protozoa and Metazoa were transferred to 24-well micro-plates containing the filtrated water fish pond and M11 medium was sterile, containing Microcystis cell under dark condition and observation them can prey Microcystis cell or not. If can prey, we collect one cell to

the washing step and put into PCR tube. To analysis 18Sr RNA gene of the isolated Protozoa and Metazoa using the new molecular ecological method, one individual direct PCR without the culture will be developed for the identification of uncultured Protozoa and Metazoa. Then us using the Real time PCR to get the cDNA, next step we get the PCR product to do molecular cloning method for 18S rRNA will be applied to obtain the DNA sequence data. Finally, I will add each sequence in the database.

3. RESULTS AND DISCUSSION

Result of Protozoa and Metazoa species can prey mixculture Microcystis sp. were isolated 5 species from fish pond in Thailand and 3 species from natural pond in Shimabara city Nagasaki Japan. The Protozoan species were isolated include *Vorticella sp.*, *Paramecium sp.*, *Coleps hirtus.*, *Euglena sp.* The metazoan species were isolate include *Brachionus sp.*, *Colurella uncinata bicuspidate.*, *Filinia longiseta.*, *Philodina sp.*, *Lepadella sp.*, *Monostyla sp.*, as rotifer, and *Aeolosomes sp.*, was isolated as the other metazoa. The PCR purified product by the gel electrophoresis. Then cut gel and purified gel electrophoresis product. The results of 18s rRNA sequences with the previously isolated rotifer are searched by BLAST.



Figure 1 Show *Vorticella sp.*, *Stylonychia sp.* and *Philodina sp.* can prey *Microcystis sp.* were isolated from fish pond, Chiang Mai, Thailand

4. CONCLUSION

1. Protozoa and Metazoan species in such observed microorganisms possibly can remove the cyanobacteria cells by the predation and the decomposition.

2. Success to develop an isolation method using micro capillary for uncultured Metazoa and Protozoa from the biological water treatment system, reservoirs, fish ponds etc.

3. Compare efficiency the conventional method and the new method we develop to collect the Protozoa and Metazoa without the monoculture method is having a good efficiency.

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Regulation of Diatoms on Silicon Dynamics in the Xiangxi River

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Keywords: Diatom; cell density; DSi; BSi;

Abstract

In order to get insight into the impact of Three Gorges Dam operation on diatom structure and its function on silicon cycle due to diatom assimilation in the reservoir, the Xiangxi River was chosen as the delegate of the tributary in the Three Gorges Reservoir to screen the effects of diatom. Our results indicated that diatom composition and their relationship with silicon concentration were different between lacustrine site and riverine site, which represents the diatom growth with and without direct dam effects, respectively. Diatom cell density in the lacustrine zone was significantly higher than the riverine zone. Centric diatom (Melosira and Cyclotella) were the dominant genus in the lacustrine zone during the whole study period. However, there was an increasing proportion of pennate diatom in the riverine zone during the flood period. DSi has a significantly negative relationship with diatom cell density in the lacustrine site while no correlation was found in the riverine site. BSi has a significant linear relationship with diatom cell density. BSi transformation efficient is higher while the standing BSi is lower in the riverine zone than the lacustrine zone. The results imply that TGD decrease the flow velocity dramatically, contributing to a stable diatom composition, causing longer diatom growth period and progressive silicon depletion, enhancing silicon retention in the long term in the reservoir.

Introduction

In this study, Xiangxi River was selected as a delegate of the tributary in the TGR, silicon and diatom in Xiangxi River were screened in two distinct zones: the riverine zone and lacustrine zone. It is assumed that different hydrodynamic conditions in these zones may affect diatom community, consequently changed the silicon dynamics. To verify this hypothesis, monthly investigation was conducted including diatom density, silicon concentration and environmental parameters. This study will help us better understand how silicon changes with diatom growth in the TGR.

Methods

Sites and samples

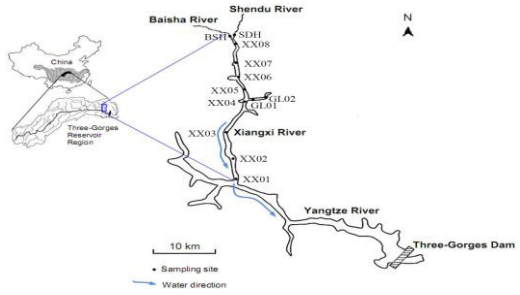

Figure 1 Sketch map of sampling stations in the Xiangxi River

Statistical analysis:Origin 9.1 and SPSS 19.0 package. CANOCO version 4.5.

Results

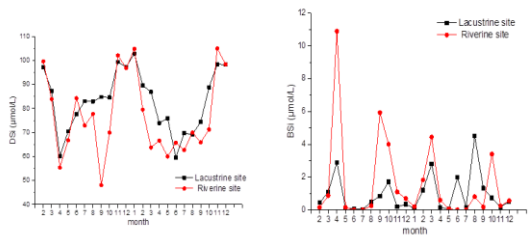

Figure 2 Monthly DSi and BSi variation from

February 2015 to December 2016

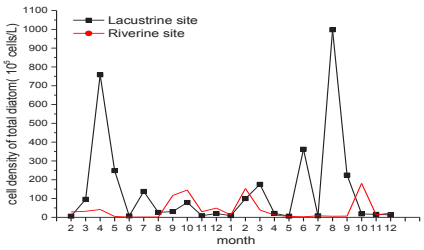

Figure 3. Seasonal cell density during the study period

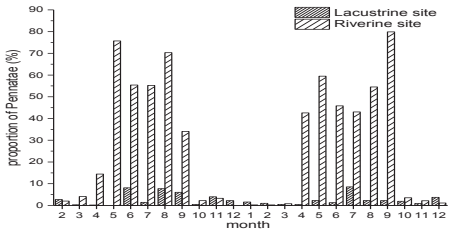

Figure 4. Seasonal variation of pennatae diatom in the lacustrine site and riverine site

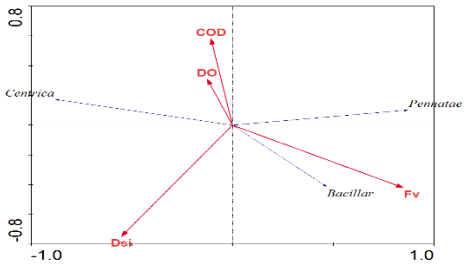

Figure 5. Biplot diagrams for RDA

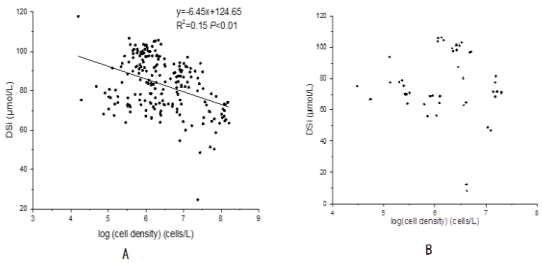

Figure 6. Relationships between diatom cell density and DSi in the lacustrine zone(A) riverine zone(B)

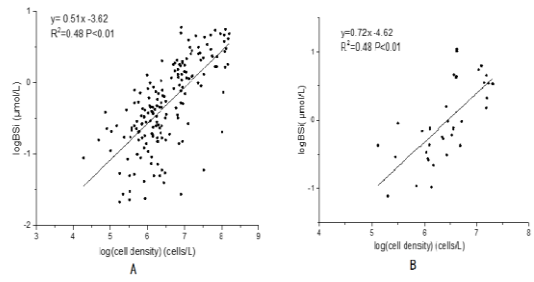

Figure 7 Relationships between diatom cell density and BSi in the lacustrine zone(A) and riverine zone(B)

Discussion

Our results showed that diatom cell density has a negative relationship with flow velocity in both riverine zone and lacustrine zone (table 1). In general, negative coefficient between diatom cell density and flow velocity was higher in the riverine zone than the lacustrine zone (table 1), indicating a stronger influence of flow velocity compared with lacustrine zone. the lacustrine zone. So diatom growth is more likely to be influenced by hydrodynamics[13]. It was found that diatom growth period in the lacustrine zone is longer than the riverine zone. Three peaks of diatom cell density were observed in the lacustrine zone. Besides spring and autumn, summer during June and August is also a favorable time for diatom growth. While in the riverine zone, there was a low diatom cell density in summer (Figure 3).

Diatom community structure is different in these two zones. Although centric diatom is the dominant species in both zones during the dry season (Figure 4). RDA analysis showed that centric diatom has a significant negative correlation with flow velocity while pennate diatom has a positive relationship with flow velocity (Figure 5). These studies demonstrated that pennate diatoms have its physiological and morphological advantage over centric diatoms in a turbulent environment.

Diatom was the main contributor to the BSi because a significant correlation was found between diatom cell density and BSi in the lacustrine zone(r=0.672) and riverine zone(r=0.878) (Table 1). This indicated that BSi originated from watershed terrestrial phytolith makes little difference to the BSi pool in the Xiangxi Rivr, which is different from some other studies. It's noticed that high diatom cell density in the lacustrine zone didn't account for higher BSi concentration in spring (from March to May) compared with the riverine zone. Cell density in the lacustrine

zone is significantly higher than the riverine zone, but BSi concentration in the lacustrine zone was lower than the fluvial zone. Linear regression model showed that cell density was positively related with BSi significantly at both zones. And diatom cell density has the same explanation coefficients for the BSi variation. But the slope in the riverine zone in significantly higher than the lacustrine zone (Figure7). It was estimated that BSi increased by 3.24μmol/L when diatom cell density increased by an order of magnitude in the lacustrine zone. However, it can be implied that BSi will increase by 5.25μmol/L when diatom cell density expands an korder of magnitude from the linear regression model. Moreover, a higher correlation coefficients between diatom cell density and BSi, Chla in the riverine zone indicated diatom contributes more to the biomass of the phytoplankton than the lacustrine zone (Table 1).

The results showed that DSi was negatively correlated with the diatom cell density in the lacustrine zone (Table 1). Despite that the regression model coefficients was low, the correlation was significant. The model indicated that diatom assimilation is the primary reason for DSi decline in the lacustrine zone (Figure6A). It can be speculated that when cell density increase by an order of magnitude , the DSi concentration will decrease by 6.45μmol/L. However, no correlation was found between DSi and diatom cell density in the fluvial zone(Figure 6B). It is suggested that diatom would dominate the phytoplankton community irrespective of season when DSi concentration exceeded the threshold of 2μmol/L.[7] This value is below the actual DSi concentration in the lacustrine zone and riverine zone even in the diatom growth period when DSi was assimilated intensively (Figure 2A). Moreover, during winter when diatom cell density is low at both zones, DSi concentration was relatively high without significant difference between these two zones. If diatom in two zones is taken into consideration together, the diatom cell density had little correlation with DSi (Figure 5.) It can be concluded that DSi concentration alone cannot be a limiting factor regulating the diatom community composition. It is more likely that flow condition was a main factor affecting diatom succession in the two zones.

Conclusion

This study verified that dam construction transform part of the river into lacustrine zone. Low flow velocity and stable environmental conditions contributed to an increase of diatom cell density. A stable diatom composition was observed in the lacustrine zone, which was dominated by centric diatom comprising Melosira and Cyclotella. Lotic diatom proportion in this zone was below 10% during the study period. Longer diatom growth period compared with the riverine zone was shown because longer residence time foster diatom growth even in summer. Diatom was strongly coupled with DSi assimilation in the lacustrine zone. Although centric diatom contributed less BSi at the same cell density compared with pennate diatom, their high cell density and longer growth period would contribute a great amount of BSi in the reservoir. And consequently cause a mass silicon trap in the reservoir in the long term.

Table 1. Spearman correlation between cell density and environmental parameters in the lacustrine zone (L-CD) and riverine zone(R-CD).

	DSi	BSi	Chla	pH	WT	DO	COD	Cond	Flowvelocity
L-CD	-0.513**	0.639**	0.722**	0.625**	0.164	0.506*	0.522*	-0.024	-0.549*
R-CD	0.017	0.830**	0.755**	0.258	-0.071	0.265	0.415*	0.497*	-0.745**

*Correlation was significant at 0.05 level **Correlation was significant at 0.01 level

P3-8

浅水富栄養化水域における溶存酸素等鉛直分布の季節変動

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キーワード:富栄養化, 植物プランクトン, 成層現象, 貧酸素, 水生生物

抄録

浄化処理水が主な水源の常時湛水型浅水調整池における水質鉛直分布の季節変動を評価した。凍結期は風雨による攪乱を受けないことから成層状態が卓越した。氷と積雪により水中に達する光は少なく, 底層はほぼ 0 lux であったことから光合成は行われず, 速度は遅いものの有機物の分解によって底層の DO 濃度は低下した。解氷と共に混合が生じ, 植物プランクトンが活発に光合成を行うことで DO と pH は上昇した。特に pH は生物の生息への影響が懸念される 11 を越えた。夏期には昼夜を通した成層が確認され, 底層の DO 濃度は低くなった。一方で, 強光阻害による植物プランクトンの活動抑制が見られた。秋季は大雨による希釈が生じたが, 底層の DO 濃度は低かった。景観形成や鳥類を中心とした生物生息空間としての機能を持つ調整池であるが, 水中環境は厳しい状況であった。水生生物の生息環境を整え, より多様な生物の拠り所とするためにも水質改善が望まれる。

1. はじめに

調査地は, 岩手県滝沢市に位置する岩手県立大学の 1998 年に竣工した常時湛水型の調整池である(図 1)。水源は, 雨水と学内の浄化槽処理水であり, その多くは浄化槽処理水が占め, 流入量は 70～150m^3/日である。面積は約 4500 ㎡, 周囲は 2m～5m の幅で水深約 30cm～50cm の浅水域があり, そこから急に水深が増して水深約 1m～1.2m の平らな池底(深水域)となる。池底は遮水シートであり, 5～10cm 程度ヘドロ状の有機物が堆積した状態であった。池の外縁はヤナギやノリウツギなどの木本のほか, 浅水域にはガマやクサヨシ, カサスゲ, さらにスイレンが生育し, スイレンの一部は深水域に進出した。木々が生育する中に湛水面があり, バンやヨシゴイなど, レッドリストに掲載される種も含め, 2008 年の記録では 38 種の野鳥の飛来が確認された。さらにその外側は緩傾斜草地に囲まれ, 自然豊かなたたずまいの池であるが, 流入する浄化槽処理水に含まれる栄養塩の影響で富栄養化が進行している。2012～2014 年の水質調査結果(表 1)では, 流入水(学内排水処理水)平均値(n=16)が T-N : 25.4mg/L, T-P : 3.53mg/L, COD : 9.27mg/L, 流出水の平均値が T-N : 10.2mg/L, T-P : 1.24mg/L, COD : 21.5mg/L であり, 典型的な富栄養化水域である。排水処理方法や在学生数, 教職員数に大きな変動は無いことから, 調査を実施した 2016～2017 年も概ねこのような水質で推移していると考えられる。

調整池には 2000 年にアブラハヤ, モツゴ, ドジョウ, メダカ, ゲンゴロウブナ, ヌカエビあるいはスジエビと思われるエビ類, タニシ類が放流された。しかし, 2012 年から複数回に渡って実施した魚類調査では, モツゴ, ギンブナ以外の魚種は捕獲されておらず, ギンブナは大型の個体のみが確認されていたことから, 再生産が滞っていると考えられた。(ギンブナの放流は確認されていないが, ゲンゴロウブナとして放流された中に含まれていた可能

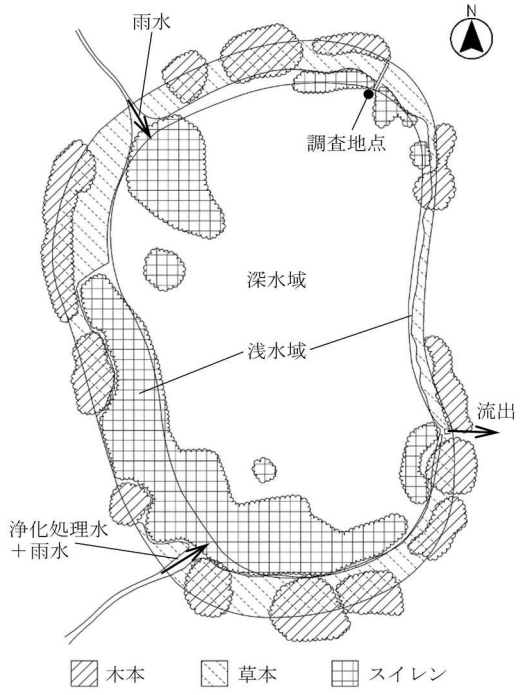

図 1 調査地の状況

表 1　調整池流入・流出水質

	流入（浄化処理水）		流出	
	値	S.D.	値	S.D.
pH	7.3	1.26	8.3	1.4
EC（mS/m）	44.1	19.4	26.4	11.6
DO（mg/L）	5.35	2.49	13.8	5.29
Chl-a（μg/L）	3.13	0.79	67.7	68.3
SS（mg/L）	8.94	8.42	26.3	22.7
BOD（mg/L）	2.26	1.42	7.62	3.62
COD（mg/L）	9.27	3.52	21.5	16.3
T-N（mg/L）	25.4	16.7	10.2	8.97
NO_3-N（mg/L）	12.1	12.6	3.8	3.88
NH_4-N（mg/L）	5.00	4.45	1.73	2.47
T-P（mg/L）	3.53	1.76	1.24	0.87
PO_4-P（mg/L）	2.38	1.63	1.07	0.87

測定は2012年11月6日～2014年2月24日（n=16）

表 2　調査日の気象データ

	日照時間	最高気温	平均風速	最大風速	雨量
	時間	℃	m/s	m/s	mm/日
3/10	3.7	3.8	2.2	5.2	0
3/30	2.7	12.8	3	6.1	5.8
4/25	4.9	19.9	3.1	7.3	0
6/30	11.1	32.3	1.7	4.4	0.1
8/29	0.0	24.2	1.7	4.9	11.8

性がある。）なお，個体数は不明であるが，モツゴの生息数は多く，再生産も順調に行われた。また，アメリカザリガニの生息も確認された。ここでは，池内の環境条件の季節変動について，生物の生息に直接的に関わる溶存酸素濃度を中心に評価する。

2.　方法

調査地点は，池の北側に作られた池の深水部の際まで至るデッキを利用した（Fig.1）。水深は約 1.05m であった。水質測定は，2016 年 9 月から 2017 年 10 月まで，月 1 回を目処に朝（9 時頃），夕（16 時頃）に携帯測定機器を用いて水温，DO，電気伝導度，pH を表層（0 cm）から底層（100 cm）まで約 20 cm毎に測定した。また，ハイロート採水器を用いて各層で採水した後，実験室にて Chl-a（蛍光法）および濁度の測定を行った。なお，採水は採水器の高さの関係で，底層は水深 80cm までの採水となった。雨量，風向，風速は，学内で測定されたデータ，日照時間は盛岡アメダスのデータに基づいた。水中照度は，2016 年 11 月から調整池の調査地点において，表層（20 cm），中層（50 cm），底層（80 cm）の 3 か所でロガーを用いて 10 分間隔で測定した。

3.　結果

ここでは，降雨の影響が少なく，季節の状況を比較的よく表していると考えられる 5 日を抽出した。各調査日の気象条件を表 2 に，水温，DO，pH，Chl-a の鉛直分布を図 2 に示した。なお，3 月 30 日，8 月 29 日共に測定後

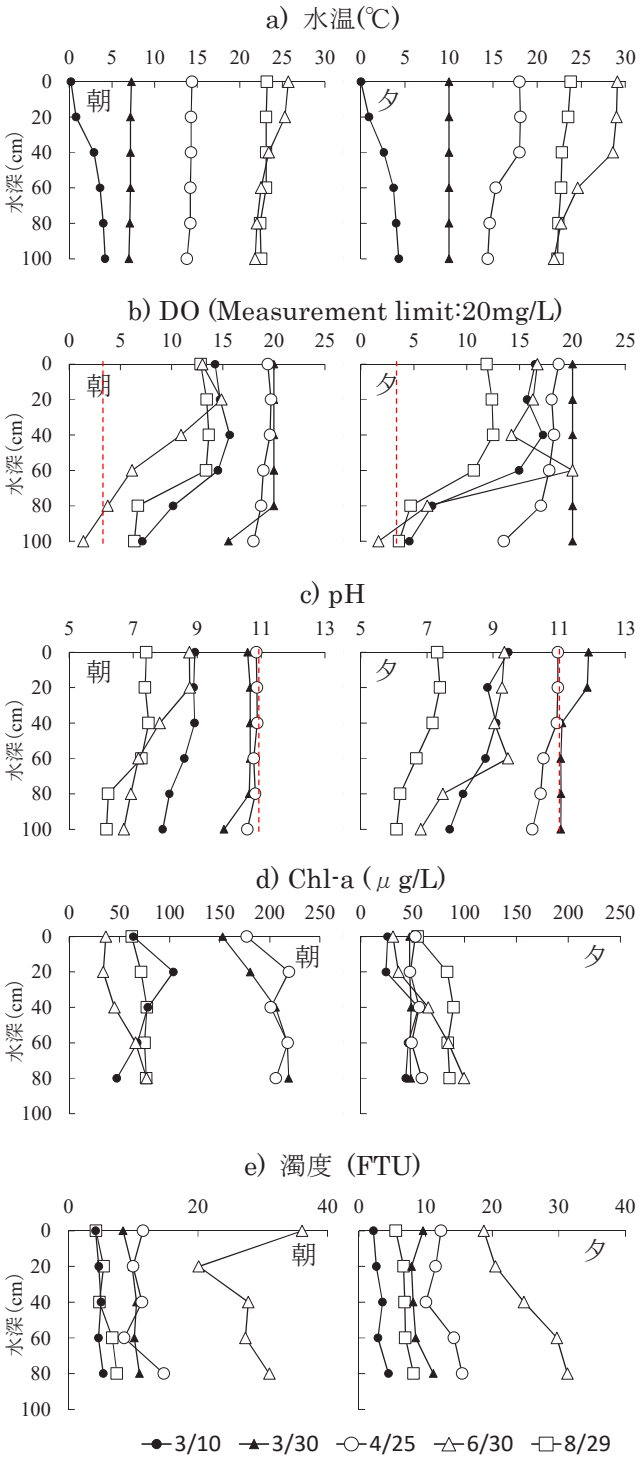

図 2　各水質項目の鉛直分布

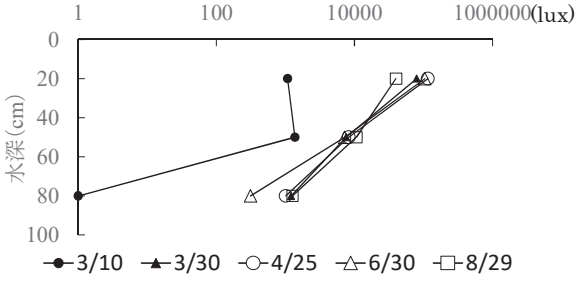

図 3　水中照度の鉛直分布

の降雨を，8 月 29 日に測定前の降雨も確認されたが，午前 4 時以前に観測したものである。調整池について測定日毎にみると，3 月 10 日は全面凍結していたため，表層は 0℃，底層は約 4℃で安定した。氷に覆われていることから水中の光は少なく，表層 20cm で比較した場合，照度は日照が強い非凍結日の 1％未満であり，底層はほぼ 0 lux であった。最表層の DO および pH が夕方に若干上昇する傾向がみられた。水温は低いものの底層の DO は消費され，低い傾向が見られた。3 月 30 日は，解氷直後である。朝夕ともに表層から底層まで水温差が見られず，かつ夕方において表層から底層まで均一に水温が上昇する傾向が見られた。また，pH は朝夕ともに 11 前後を記録し，DO も使用機器の測定上限である 20mg/L 以上の高い状態を維持すると共に，Chl-a 濃度は朝において高い傾向が見られた。4 月 25 日の pH は，朝夕ともに 11 前後を示し，高い状態を維持した。さらに，夕方において，表層の水温が上昇し，底層では DO が減少する傾向が見られた。Chl-a 濃度は朝において高い傾向が見られた。6 月 30 日は，表層で夕方に約 29℃まで水温が上昇し，朝においても表層と底層で水温差が見られた。濁度は他の時期よりも高い傾向が見られた。日照時間は長かったが，底層の照度は 310 lux と低く，底層の DO と pH も低い傾向が見られた。8 月 29 日は曇りであり，朝夕の水温の変化は小さかった。その結果，表層の DO，pH の上昇は見られず，底層の DO のみが日中に低下した。濁度が低下しているが，これは 8 月 22 日から 25 日かけて，総雨量 250mm を越える降雨があり，雨水によって希釈されたためと考えられた。

4. 考察

凍結期においては，表層が 0℃，底層が約 4℃に安定しており，成層が形成され水の動きはほとんど見られないものと推察された。植物プランクトンの光合成による酸素供給はごく表層に限られ，光が届かない底層では DO 濃度の低下が確認されたことから，水温は低いものの，緩やかに底層の有機物を微生物が分解することによって酸素が消費されたと考えられる。解氷後は，表層から底層まで均一に温度が上昇していることから，全層で活発に混合が生じていることが示唆された。植物プランクトンによる光合成によって DO は過飽和の状態であり，夕方の表層 pH 値は生物の生息に影響を与える数値[1]とされる 11 を越えた。また，気温が上昇し日射も比較的多かった 4 月 25 日の夕方において，中層付近に弱い水温躍層が見られたことから，日中には混合が生じていないことが示唆された。その結果として夕方の底層の DO が若干低下する傾向が現れ始めた。3 月 30 日，4 月 25 日共に，朝に Chl-a 濃度が高く，夕方に下がる傾向が見られた。夕方の Chl-a 値を見ると，全体的に表層よりも底層の方が高い傾向が見られたことからも，浅い水域における強光阻害[2]が生じたと考えられる。6 月 30 日は夏期晴天時のデータであるが，朝においても表層と低層の温度差が見られたことから，後田・橋本によって確認された夏期浅水域における日中の成層[3]だけではなく，昼夜を通して成層が確認された。その結果，底層の DO がバクテリアによる有機物の分解によって低下し，生物の生息に支障をきたすとされる 3mg/L[4]を下回った。一方，表層の DO，pH 共に高くなったものの，春の値よりは低かった。さらに，濁度は高かったが Chl-a 濃度は他の時期よりも低い傾向が見られ，表層付近の値が低い傾向が見られたことから，強光阻害によって植物プランクトンの活動が制限されていることが示唆された。濁度は底層の値が高い傾向が見られた。これは表層で発生した植物プランクトンが強光によるストレスで死に，底層付近に沈降して漂っているのかもしれない。8 月 29 日の結果を見ると，大雨による水の入換が生じたことから，濁度，pH 共に下がったものの，DO は表層では過飽和，底層で低下する傾向が見られた。表層と底層の温度差は見られないことから混合が生じている可能性が高いものの，底層の DO が低いことから，水温の高い条件で底層の DO が有機物分解によって迅速に消費されているものと考えられる。

5. 結論

春期の pH が 11 を超えるような条件や，多くの季節で観察された底層の貧酸素状態などは，水生生物にとって致命的となる可能性がある。本研究は，調整池内の 1 地点における評価であることから，調整池全体の環境に当てはめることはできないが，本調整池において浄化処理水による富栄養化が水生生物の生息を制限している可能性が示唆された。鳥類をはじめとする陸域の生物の生息を支える水域生態系をより豊かなものとするためにも，水質改善は不可欠である。

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P3-9

A Review on the Pelagic Ecology in Lake Lanao, Mindanao Is., Philippines

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Keywords: Lake Lanao, ancient lake, zooplankton, phytoplankton, freshwater ecology

ABSTRACT

Lake Lanao, one of the world's ancient lakes, is scarcely studied. This review focuses on the lake's hydrodynamics and planktonic system since it was first investigated in the 1960s to arrive at objective insights for an ecosystem-based management of the Lake Lanao Watershed. Sustaining the lake water is the intact forest and unstudied major rivers of the watershed. Having an atelomictic epilimnion, the warm monomictic Lake Lanao is spatio-temporally heterogeneous as seen in its dynamic hydro-meteorology and relatively diverse planktonic communities. Water quality analysis in the past indicated high sensitivity to dissolved nutrients suggesting a pelagic ecosystem that is bottom-up or resource controlled, but recent analysis indicates a eutrophic, coliform-contaminated, and invasive zooplankton species-dominated state with anthropogenic input as the possible main driver. Hence, the flux of dissolved nutrients should be a top priority of an ecosystem-based management effort that is participatory, multisectoral, multidisciplinary and science-based co-management approach. Also part of the framework is the looming climate change, which may undoubtedly lead to loss of biodiversity services of Lake Lanao.

1. INTRODUCTION

A major freshwater volcanic lake, Lake Lanao is the largest freshwater body in Mindanao Island[1]. Its watershed provides socioeconomic services that include food, goods, 727.1 megawatts of electricity, freshwater supply, and home to the *Meranaos* or people of the lake[3]. Lake Lanao is one of the 17 world's ancient lakes[3],[27], but studies are few with some published in 1969[2], 1970s[5],[6], [7],[8],[9],[10],[11],[12],[13],[14],[15], followed by others years later[16],[17],[18],[20],[19],[21], [22],[23],[24]. The aims of this review are to describe the pelagic ecology of Lake Lanao and discuss implications to a sustainable lake watershed.

2. METHOD

This review focuses on literature that deals with the hydrodynamics and planktonic ecology of Lake Lanao including other relevant studies on tropical lakes and climate change. The search for literature was conducted using online sources (e.g., Science Direct, Springer, Elsevier, Journal Storage, Wiley Online, Mendeley, ResearchGate), libraries, and high quality unpublished literature. Information was synthesized according to major themes on lake pelagic ecology.

3. RESULTS AND DISCUSSION

Geophysical Features

The lake (Figure 1) was formed about 3.6-5.5 Mya as a result of a lava dam and tectonic movements[27]. The triangular-shaped lake has a mean depth of 60.3 m[23], a surface area of 356 km^2, a pondage volume of 21.25 km^3, a discharge volume of 3.304 million km^3 annually, and a water level at 701.89 masl[2]. 60% of steep surrounding areas are susceptible to erosion[23]. In the past, 1% level of light intensity varied from 11 to 25m with Secchi disk reading of 6 m[2],[5],[6], but recent massive phytoplankton blooms decreased mean Secchi depth to 2.6 m[21].

Hydrology, Thermal Stratification and Circulation

The 1,323.8 Km^2 watershed is still dominated by forests (60%) and farmlands (40%)[23]. Four major inflowing river systems are located at the eastern portion, and water exits at the Agus River[2]. Maximum rain period occurs from June to September, and a dry period in March to April[23]. The average annual rainfall ranges from 1,329 to 5,235 mm[2]. The Lake overturns from December to early March, but stratification is re-established by late March. The mean air temperature is 23.0°C but February is the coldest (17.8°C), while May the warmest (24.5°C-28.0°C). The mean relative humidity ranges from 82%- 89%[2].

Lake Lanao is a warm monomictic lake with the water column isothermal at 24.4°C during overturn[23]. The March stratification begins with the top 30 m warming up rapidly to 26.5°C, and a sharp thermocline forms at 21-23 m that persists through April to December[2]. However, atelomixis creates secondary and tertiary thermoclines

within the epilimnion[5], namely the breeze thermocline at 5-20 m, broken down by light winds; the squall thermocline at 20-30m deep is broken by moderate winds, and the deepest storm thermocline broken by strong storm winds[5].

Chemical Profile

The oscillation of the mixed layer at the metalimnion can resupply incremental nutrients to the epilimnion, but major resupply is during the annual mixing[29],[30]. Overturn homogenizes different strata, while atelomixis homogenizes the epilimnion without disturbing the hypolimnion[5]. The 24°C temperature of the hypolimnion means high microbial nutrient regeneration rates, at a cost of oxygen at 2.6-4.3 mgC m^{-3} hr^{-1}[13], but the lake can sustain dissolved oxygen in deep waters[28]. Mean oxygen content of water column rises from its low overturn level of 4.3 ppm to a maximum stratified level of 6.4 ppm[5]. Past levels of nitrates averaged 9 ugl^{-1} in the euphotic zone, while average phosphates was 29 ugl^{-1} PO_4-P[2] with nitrogen as a limiting nutrient for autotrophs[14]. Silicate averages 2.2 mgl^{-1} which is non-limiting to diatom growth[13]. The pH at 10 m ranged from 8.2-8.9 then pH gradually declined to 7.2 at 45 m[2].

Planktonic Diversity

Recent bacterial analysis indicated positive for fecal coliform[21] as against national standards of zero total coliform per 100 ml of water[23]. A lone study on protists reported high density of 1,900 flagellate individuals ml^{-1}, which can help regulate bacterial abundance[30].

70 phytoplankton species that can show succession were recorded[7],[8],[10],[12],[13], but 70 is lower than in temperate lakes but comparable with other tropical lakes[11]. 13 species accounted for 90% of the annual mean biomass as chlorophyll *a* values of 6.9±0.6 mg l^{-1} placing the lake in a mesotrophic status[11], but its 6 m transparency makes it oligotrophic[31]. Past blooms occurred mainly during circulation[13], but recent blooms occur even before circulation[21], and confirming a eutrophic state, with dissolved nutrients registering higher maximum values (10-40 ugl^{-1} NO_3-N; 20-40 ugl^{-1} PO_4-P)[21], compared to past levels of 9 ug l^{-1} NO_3-N and 29 ug l^{-1} PO_4-P[11].

The diverse zooplankton (25 species of Cladocera, 18 Rotifera and 8 Copepoda) is important to achieving high fish yields[2],[19]. Recently, the eutrophication indicator and invasive calanoid copepod species *Arctodiaptomus dorsalis* is now abundant in the lake [24].

Primary and secondary production

Average respective primary production in the 1960s[2] and 1970s[6] were 382.33 ± 94.11 SD mgC m^{-2} day^{-1} and 2.6 gC m^{-2} day^{-1}. Photoinhibition occurred at insolations ranging from 101 to 133 kerg cm^{-2} sec[6]. The annual variation of primary production is controlled by resource (e.g., nutrient, sunlight) supply rather than temperature or biomass removal (grazing and sinking)[12].

Secondary production via grazing by zooplankton is controlled by autotrophic phytoplankton biomass[9],[14], manifesting a bottom-up control[32]. Grazing mainly occurs at the upper layers at night, but it only accounts 6.8% per day loss for autotrophs since the average replacement rate of autotroph biomass is 80% per day. The zooplanktivorous *Chaoborus* keeps prey abundance in check[9], but the impact of this species needs research as reduction in dissolved oxygen due to eutrophication and climate change may favor it with consequential reduction of zooplankton prey populations and a possible decline in fish production of up to 90%[15].

Potential Sources of Aquatic Pollution

In 1963, a 5-ha fishpond and hatchery was established stocking the lake with carp and tilapia fingerlings[20], but aquaculture is not common in the area at present. The major agriculture activities are cattle raising[1] and cultivated of cash crops, tree crops, fruit trees, corn and rice mainly at the eastern alluvial deltaic plain[23].

4. CONCLUSION

The geology of the lake is understood but the influence of hydrodynamics and chemistry on productivity is a major gap. The pelagic ecosystem is bottom-up driven, so that changes in water quality will have disastrous effects on the entire lake ecosystem. The lake now is largely eutrophic, and main drivers are anthropogenic activities.. We recommend priority research and development on climate change impact, top-down models, lotic subsystem, proper valuation of the watershed biodiversity, and the implementation of a multisectoral, participatory, and science-based co-management system.

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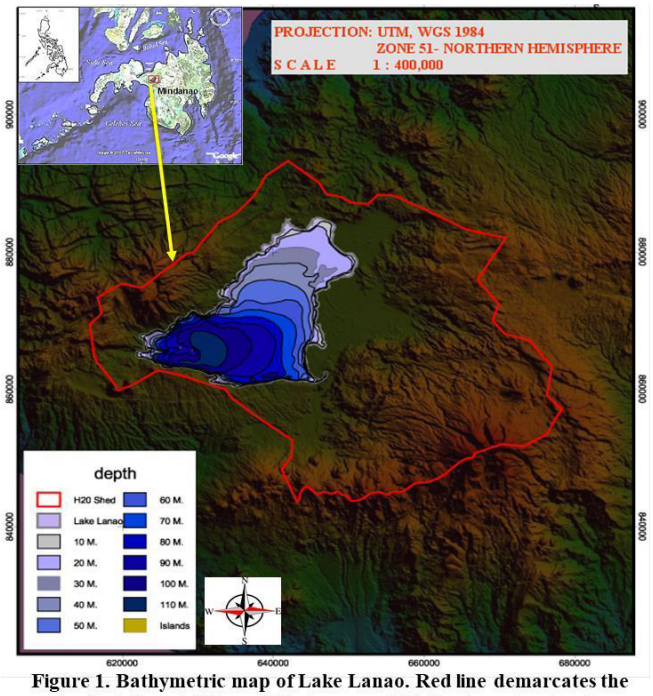

Figure 1. Bathymetric map of Lake Lanao. Red line demarcates the watershed. Insert: Map of Mindanao and Philippines showing the location of Lake Lanao. Source: DENR 2012

P3-10

霞ヶ浦湖水の白濁化と魚類生産について

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キーワード：霞ヶ浦，白濁化，植物プランクトン，ワムシ類，ワカサギ

抄録

霞ヶ浦の白濁化の発生・解消とワカサギ資源の低水準期から増加期への変化との関連性について比較検討を行い、以下のプロセスが介在していることが考えられた。FSS が減少し白濁化が解消されると，透明度が上昇し光環境が改善される。すると，植物プランクトンが増加し，それを餌とするワムシ類等の小型動物プランクトンが増加する。その結果，ワカサギ仔魚の生残率が向上し，ワカサギ資源量も増加する。以上から、白濁化が起こると、太陽光が湖水中に入射する量が不足して植物プランクトンによる光合成が阻害され，基礎生産量を低下させることになり，本来の生態系の健全な構造が歪められることが示唆された。

1. はじめに

霞ヶ浦（西浦）は，ワカサギ *Hypomesus nipponensis*，シラウオ *Salangichthys microdon*，テナガエビ *Macrobrachium nipponense* 等の水産資源に恵まれ，古くから多種多様な漁業が盛んに行われている湖である。

霞ヶ浦では，1999～2007 年頃にかけて，湖水が白く濁り，透明度が著しく低下する白濁化が発生した[1]。この現象の原因物質は，無機態の鉱物結晶であることが明らかになっている。

一方，霞ヶ浦の重要水産資源であるワカサギは，1999～2008 年の漁獲量が 200 トン以下の低水準で推移したが，2009 年以降増加に転じ 200～500 トン台を維持している。

ワカサギ資源の減少要因は，初期餌料発生量が少ないことによる孵化初期の生残率低下とされている[2]。今回の研究では，白濁化の発生・解消とワカサギ資源の低水準期から増加期への変化との関連性について比較検討を行った。

2. 方法

本研究では，国立環境研究所が公開している霞ヶ浦データベースから 1977～2013 年の霞ヶ浦湖心の懸濁物質量（SS）とクロロフィル a 量（Chl.a）のデータ[3]，及び国土交通省霞ヶ浦河川事務所が公開している水質調査データのうち 1972～2013 年の湖心の SS と Chl.a のデータ[4]を用いた。そして，SS から Chl.a 補正して求めた揮発性懸濁物質量（VSS）を SS から差し引いて，無機態懸濁物質量 (FSS)を算出した。なお，本研究では，FSS，Chl.a ともに，月別の 5 点移動平均値を用いて考察した。

植物プランクトン量は，茨城県企業局水質年報の藻類検査結果を参照した。ワカサギの初期餌料であるワムシ類の発生量は，霞ヶ浦の湖岸 7 地点で 2003～2012 年の 3 上旬～4 月下旬に週 1 回の頻度で採集し，現存量の平均値を算出した。

ワカサギ初期資源量は，霞ヶ浦 4 水域で 2003～2012 年の 6 月下旬～7 月上旬に 1 回試験操業を行い，ワカサギ仔稚魚現存量の平均値を算出した。

ワカサギ漁獲量は，農林水産統計年報を参照した。

3. 結果及び考察

（1）FSS の長期変動傾向

FSS は，国立環境研究所，霞ヶ浦河川事務所の両者とも，1977～1998 年まで，1 時期を除き 0～10 mg/L を維持していたが，1999 年以降増加し始め，2007 年まで高レベルを維持していた。ピークは 2004～2005 年であった（各々，25 mg/L，14 mg/L）。2008 年以降，FSS は減少する傾向にあった（図 1）。FSS の高レベルの時期は，湖水の白濁化の時期と一致していた。

（2）Chl.a と植物プランクトンの長期変動

Chl.a は，国立環境研究所，霞ヶ浦河川事務所の両者とも，1977～1998 年まで 30 μg/L から 80 μg/L へと徐々に増加する傾向にあったが，1999 年以降急減し，2007 年まで低レベルを維持していた。2008 年に Chl.a

は一気に 80 μg/L に達したが，その後徐々に減少していった（図 2 上）。

植物プランクトン個体数は，1996～2009 年の調査期間中，珪藻類には変動はあるものの大きなトレンド変化は認められなかった。藍藻類は 1999 年以降減少し始め，2007 年まで低レベルを維持していたが，その後増加に転じた。（図 2 下）。

Chl.a，藍藻類の低レベルの時期は，FSS の高レベルの時期，すなわち湖水の白濁化の時期と一致していた（図 1，2）。

(3)ワムシ類の発生量

ワムシ類の発生量は 2003～2007 年まで低位安定であったが，2008 年以降増加する傾向にあった。また，ワムシ類の種組成は 2008 年と 2009 年を境にして大きく変化した[5]。すなわち，2003～2008 年まではドロワムシ *Synchaeta* sp.が優占種であったが，2009 年以降はツボワムシ *Brachionus* spp.，ハネウデワムシ *Polyarthra* sp.が優占種となった。

2008 年以降のワムシ類の発生量増加は，植物プランクトンのうち藍藻類の増加に起因すると考えられた。しかし，2009 年以降のワムシ類の種組成変化の時期と白濁化解消の時期がほぼ一致している原因は明らかではない。

(4)ワカサギ初期資源量

ワカサギ初期資源量は，2009 年以降増加する傾向がみられた[6]。

ワムシ類の発生量とワカサギ初期資源量には正の相関がみられることから，ワカサギ資源量は孵化初期に摂餌量が改善されて生残率が向上したため，増加傾向に転じたと考えられる。また，2009 年以降ワムシ類の種組成が変化していることから，低次生産を含む霞ヶ浦全体の生態系が変化していると推察された。

4. 結論

ワカサギ資源量の増加には，以下のプロセスが介在していると考えられた。すなわち，FSS が減少し白濁化が解消されると，透明度が上昇し光環境が改善される。すると，植物プランクトン（Chl.a が指標）が増加し，それを餌とするワムシ類等の小型動物プランクトンが増加する。その結果，ワカサギ仔魚の生残率が向上し，ワカサギ資源量も増加する。ただし，仔魚期以降の成長期（稚魚，未成魚）では，ワムシ類以外の大型動物プランクトンやイサザアミ等が餌料として重要になるので，それらの量がワカサギ資源量に影響を及ぼすことになる。

以上から、霞ヶ浦で白濁化が起こると，太陽光が湖水中に入射する量が不足し植物プランクトンによる光合成が阻害され，基礎生産量を低下させることになり，本来の生態系の健全な構造が歪むことになる。すなわち，基礎生産に依存する動物プランクトンやそれを餌にする魚類が増えにくくなるという問題をはらんでいることが示唆された。

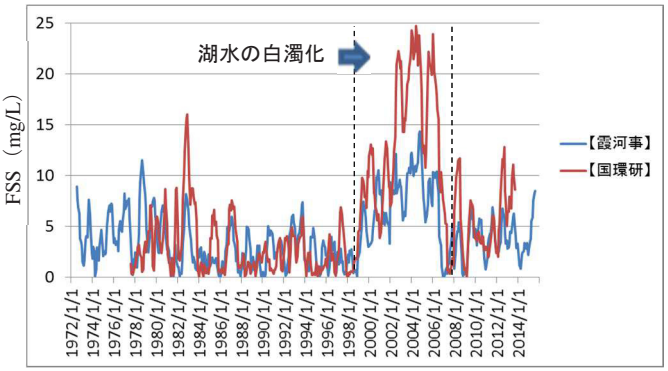

図１．霞ヶ浦(湖心)における FSS(無機態懸濁物質量)の長期変動傾向

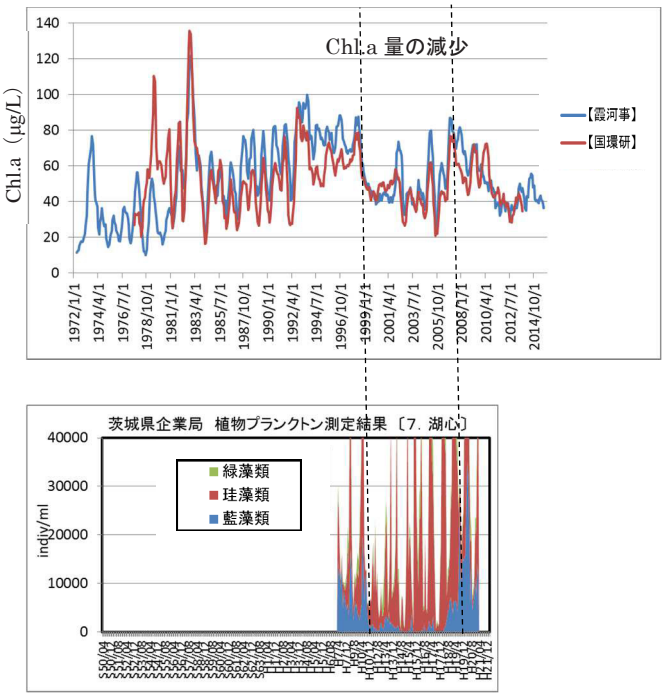

図２．霞ヶ浦（湖心）におけるクロロフィル a 量（上図）と植物プランクトン個体数（下図）の長期変動傾向とその関連性

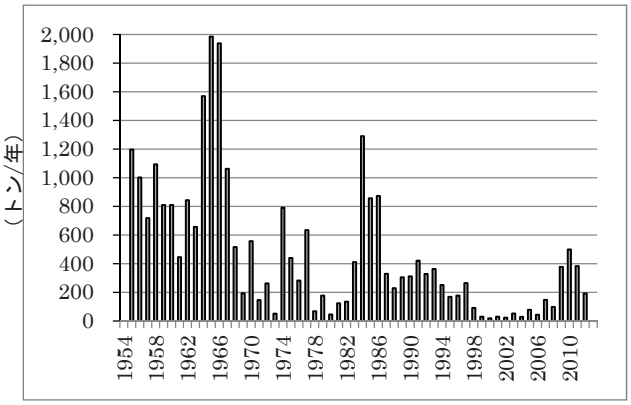

図３．霞ヶ浦におけるワカサギ漁獲量の推移
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P3-11

SENSITIVITY LEVEL OF PHYTOPLANKTON TOWARDS NUTRIENTS AND ZOOPLANKTON IN EBONY LAKE, PIK RESIDENCE, NORTH JAKARTA

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Keywords: sensitivity level, phytoplankton, zooplankton

ABSTRACT

Lake Ebony in Pantai Indah Kapuk Residence, North Jakarta received input of organic materialwhich lead a dynamic of nutrients and plankton community. This study aimed to analyze phytoplankton sensitivity level to water quality and zooplankton the lake. Water and plankton were collected from January to December 2015. There were 36 genera of phytoplankton from six classes, and seven genera of zooplankton from Three groups. Cyanophyceae and Chlorophyceae sensitive towards zooplankton; and Euglenophyceae and Dinophyceae sensitive towards orthophosphate.

1. INTRODUCTION

Ebony Lake is one of ornamental lake at coastal residence area, Pantai Indah Kapuk, North Jakarta. This small and shallow waters with about 6 ha wide and 1.2 m depth, received high content of inorganic and organic materials from residence drainage. This material input influences water quality of lake. Furthermore, this change influences any living there [1, 2, 3, 4].

Plankton, especially phytoplankton, is one of the most responsive community due to the change water quality [5, 6, 7]. Its composition, densities, and community structure have functional relationship to water condition, such as nutrients availability, light intensity, and other water quality parameters. On the other hand, phytoplankton community is also correlated to the presence of zooplankton.

The input of inorganic materials leads increasing of inorganic nutrients, which means that there is an increasing of biological available nutrients. This type of nutrients can directly utilized by phytoplankton. Furthermore, the input of organic materials is directly used by some spesies of zooplankton.

One year data series of nutrients condition, and the densities of the two community of plankton are used to study the relationship among others and the sensitivities between phytoplankton densities with water quality, nutrients, and zooplankton densities in Ebony Lake, Pantai Indah Kapuk (PIK), North Jakarta.

2. METHOD

Sampling was done at Ebony Lake that is located in Pantai Indah Kapuk (6°6,265'-6°6,594' S dan 106°44,630'-106°44,885'E), North Jakarta. Five sampling sites were set at square ring shaped of waters, the north eastern (St 1), eastern (St 2), south eastern (St 3), south western (St 4) that relatively close to the inlet, and north western (St 5) that relatively close to the outlet. The sampling was done monthly from January to December 2015.

The identifikacion of plankton followed some identification references [8, 9, 10, 11]. The density of plankton was counted using Sedgewick Rafter Counting cell (SRC) at 10x10 magnification. There were some parameters that measured or analyzed in situ, such as depth, water transparency, temperature, pH, salinity, conductivity, and dissolved oxygen/DO. Some chemical parameter that were analyzed in laboratory were ammonia (NH3-N), amonium (NH4-N), total nitrogen, nitrite (NO2-N), nitrate (NO3-N), orthophosphate (PO4-P) and total phosphate. All of those analysis methods were based on APHA 2012[12].

As statistical analysis, Pearson correlation test[13] was used to analyze relationship between phytoplankton densities with nutrients and zooplankton. Moreover, the sensitivity of phytoplankton towards nutrients and zooplankton were determined by the value of regression coefficient (βi) of each specific independent variable. The sensitivity levels of phytoplankton were derived from first differential of regression formulations as follows.

$$Y_{phyto} = \beta_0 . X^{\beta 1}{}_{NH4\text{-}N} . X^{\beta 2}{}_{NO3\text{-}N} . X^{\beta 3}{}_{PO4\text{-}P} . X^{\beta 4}{}_{NZoo}$$

$$dy/dx_{NH4\text{-}N} = \beta_0 . \beta_1 X^{\beta 1\text{-}1}{}_{NH4\text{-}N} . (X^{\beta 2}{}_{NO3\ N} . X^{\beta 3}{}_{PO4P} . X^{\beta 4}{}_{NZoo})$$

$$dy/dx_{NO3\text{-}N} = \beta_0 . \beta_2 X^{\beta 2\text{-}1}{}_{NO3\text{-}N} . (X^{\beta 1}{}_{NH4\text{-}N} . X^{\beta 3}{}_{PO4\text{-}P} . X^{\beta 4}{}_{NZoo})$$

$$dy/dx_{PO4\text{-}P} = \beta_0 . B_3 X^{\beta 3\text{-}1}{}_{PO4\text{-}P} . (X^{\beta 1}{}_{NH4\text{-}N} . X^{\beta 2}{}_{NO3\text{-}N} . X^{\beta 4}{}_{NZoo})$$

$$dy/dx_{NZoo} = \beta_0 . B_4 X^{\beta 4\text{-}1}{}_{NZoo} . (X^{\beta 1}{}_{NH4\text{-}N} . X^{\beta 2}{}_{NO3\text{-}N} . X^{\beta 3}{}_{PO4\text{-}P})$$

Hence, the values of each nutrient and zooplankton level that could change the Population of phytoplankton were calculated as follows.

$$X_{NH4\text{-}N} = \frac{\pm 1}{\beta_\cap . \beta_1 . X^{\beta 2}{}_{NO3\text{-}N} . X^{\beta 3}{}_{PO4\text{-}P} . X^{\beta 4}{}_{NZoo}} \{1/\beta_1 - 1\}$$

$$X_{NO3\text{-}N} = \frac{\pm 1}{\beta_\cap . \beta_2 . X^{\beta 1}{}_{NH4\text{-}N} . X^{\beta 3}{}_{PO4\text{-}P} . X^{\beta 4}{}_{NZoo}} \{1/\beta_1 - 1\}$$

$$X_{PO4\text{-}P} = \frac{\pm 1}{\beta_\cap . \beta_3 . X^{\beta 1}{}_{NH4\text{-}N} . X^{\beta 2}{}_{NO3\text{-}N} . X^{\beta 4}{}_{NZoo}} \{1/\beta_1 - 1\}$$

$$X_{NZoo} = \frac{\pm 1}{\beta_\cap . \beta_4 . X^{\beta 1}{}_{NH4\text{-}N} . X^{\beta 2}{}_{NO3\text{-}N} . X^{\beta 3}{}_{PO4\text{-}P}} \{1/\beta_1 - 1\}$$

3. RESULTS

There were found 36 genera of phytoplankton and seven genera of zooplankton in total. The phytoplankton community comprise six class groups. The phytoplankton were Cyanophyceae (7 genus), Bacillariophyceae (12 genus), Chlorophyceae (20 genus), Euglenophyceae (4 genus), then Dinophyceae and Cryptophyceae, each with one genera. The zooplankton were Protozoa (1 genera), Rotifera (3 genus), and Crustaceae (3 genus).

The most varied of phytoplankton was found in March, and for zooplankton were in January to April. The least varied of phytoplankton was found in November, and for zooplankton were in September to November.

The densities of phytoplankton were ranged from 106x106 to 2981x106 cell/m3; the found in March, with dominance of Cyanophyceae although in low number of genera. The zooplankton were ranged from 298 to 1852 ind/m3; that most dense in January with domination of Rotifers. Water quality and nutrients (N/P ratio) condition is shown in Figure 1. The result of correlation test between phytoplankton and nutrients and zooplankton is shown in Table 1.

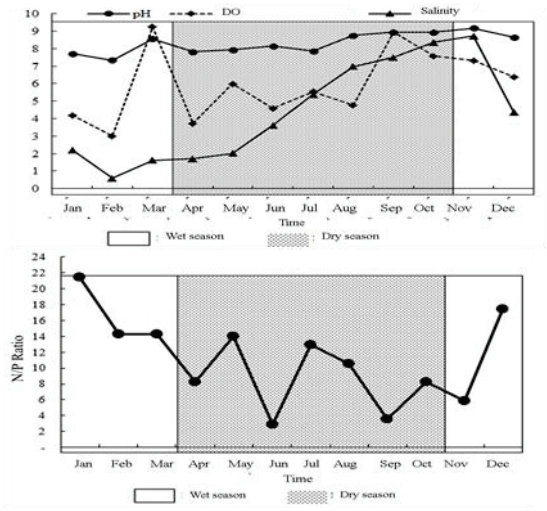

Figure 1 Water quality (A) and nutrients (N/P ration) condition (B) in Ebony Lake

Table 1 Correlation and sensitivity between phytoplankton towards nutrient and zooplankton in Ebony Lake

Group of Phytoplankton	Coefficient of regressoni (β)* and sensitivity ( ) value							Intercept (β0)	R^2	F value	F Sig.
	NH_3-N	NH_4-N	NO_3-N	NO_2-N	PO_4-P	Ro	Cr				
Cyanophyceae	-9.677	17.828		-5.464	-3.032		5.873* (0.787)	-13.585	0.962	14.696	0.003
Bacillariophyceae					-0.783	-0.917		9.927	0.648	3.256	0.086
Chlorophyceae		0.833				1.429*(0.763)		3.745	0.854	12.106	0.003
Euglenophyceae	-3.411	3.391	0.756*(0.715)		-0.457* (-0.532)			7.002	0.959	20.093	0.001
Dinophyceae					-2.080* (-0.694)			-1.578	0.694	9.307	0.012
Cryptophyceae					1.595	2.733	2.353	-11.205	0.718	2.843	0.106

4. DISCUSSION

Figure 1 and table 1 is shown that some groups of phytoplankton have a significantly correlated to nutrients and zooplankton. This was more clear in dry than in wet

season. The variation of densities and number of genera fluctuated along with N/P ratio with one month lag periode, especially in dry season. The positive correlations were shown between Euglenophyceae towards nitrate, Cyanophyceae with Crustacea, and Chlorophyceae towards Rotifers. The negative correlations were shown between Euglenophyceae and Dinophyceae towards orthophosphate.

Although there was built a relatively good model of the relationship between Cyanophyceae and most of all measured nutrients and zooplankton component, the most influence was shown significantly by Crustacea component ($p<0.05$). Furthermore, there will result an explaination as above. Furthermore, the sensitivity value of Cyanophyceae towards Crustaceae was 0.787. It means that one unit change of Crustacea will change 0.787 in proportion of Cyanophyceae. The other values are also shown the same illustration.

Some interesting things are the existence of Bacillariophyceae that dominant in the last periode of dry season and clear sensitivity of least common of phytoplankton. Usualy, nutrients are the most important component that role as limiting factors for phytoplankton Yet, the result showed that the dominance of this group was led by the increasing of salinity, not by nutrients condition. This bear a pressumption that nutrients were not only component that roles as limiting factor for the growth and development of phytoplankton in Ebony Lake. It was mentioned that sometimes other water quality parameter could role as limiting factor for phytoplankton. The high organic material that dominates the input of Ebony Lake leads the change of water quality, especially oxygen in decomposition process. Those processes and two extreme condition is occured naturally. With spesies specific charasteristics of phytoplankton, there will appear a dynamic condition of phytoplankton.

5. CONCLUSION

Cyanophyceae and Chlorophyceae sensitive towards zooplankton; and Euglenophyceae and Dinophyceae sensitive towards orthophosphate.

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P3-12

Trophic and Ecological States of Garden House Ornamental Lake, Pantai Indah Kapuk, North Jakarta

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Keywords: Plankton, nutrient, management

ABSTRACT

Garden House Ornamental Lake is one of the artificial ponds in Pantai Indah Kapuk, and it has received high input of organic matter from domestic activities. Input of organic matter may change water quality, increase trophic states, and effect the ecological conditions of the water. The purpose of this research is to analyze trophic and ecological states of Garden House Ornamental Lake. Water quality, especially nutrient was measured to support tropical state. The tropical state of lake was analyzed using Nygaard Index while the ecological state with MedPTI Index (Mediterranean Plankton Trophic Index). Concentration of orthophosphate in the lake is more than 0,1 mg/l. Nutrient parameters at Garden House Lake are high showed by high concentration. The trophic state of Garden House Lake is eutrophic, shown by 9,5-10,5 value of Nygaard index and an ecological state is poor until bad, shown by 1,46-1,85 of MedPTI index. Ornamental lake could be overwhelmed by wastewater treatment to restore lake state.

1. INTRODUCTION

Pantai Indah Kapuk, known as an estate area in Jakarta, Indonesia, has many ornamental lakes. One of the ornamental lakes is Garden house. Garden house has 11615 m^2 wide and less than 1 m depth. The function of garden house ornamental lake is for flood controlling & landscape.

The ornamental lake has received domestic waste from houses. This impact degrades lake because of organic matter caused by water quality changes [1], which can be shown from colour and smell of water. Research in 2017 also showed Garden house ornamental lake has low dissolved oxygen, high nutrient concentration, and cyanophyceae domination.

This condition leads to eutrophic condition or even may have happened eutrophic condition. Identification of trophic and ecological state of this lake is important step to define lake management, especially for landscaping necessary.

The aim of this research is to describe trophic and ecological states of Garden House Ornamental lake in Pantai Indah Kapuk, Jakarta Utara.

2. METHOD

Records of phytoplankton were applied to identify trophic states; meanwhile plankton and nutrient were applied to identify ecological status. Samples of phytoplankton and water for nutrient were taken from five stations in ornamental Lake of Garden House (Fig. 1).

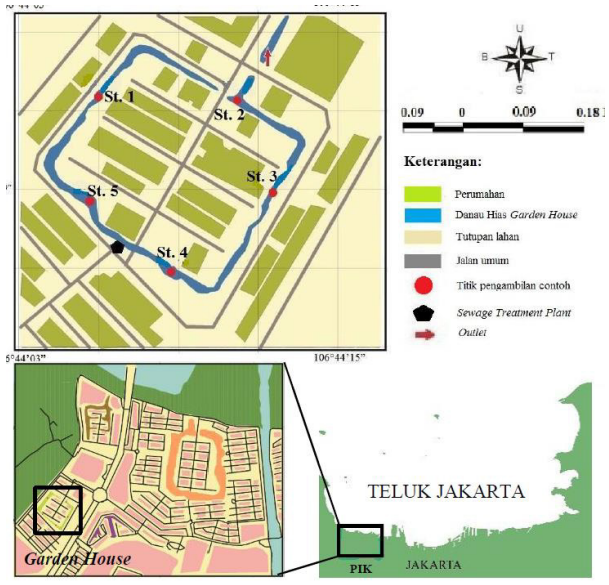

Fig. 1 Sampling site of phytoplankton in Garden House Ornamental Lake, Pantai Indah Kapuk, Jakarta

Water quality (dissolved inorganic nutrient, orthophosphate, N:P ratio) was measured in-situ & ex-situ. The degree of similarity in phytoplankton abundance between five stations was analyzed using Canberra Index[2]. Trophic state was analyzed using Nygaard Index (In), which is based on Phyoplankton species composition. Ecological status was analyzed using MedPTI index (Mediteranian Plankton Trophic Index), which involves phytoplankton biomass.

Nygard index formulation was obtained from number species of phytoplankton of Cyanophyceae (Cyano), Chlorococcales (Chloro), Diatom centrales,

Euglenophyceae (Eugleno), Desmidiacea.

$$In = \frac{N\ Cyano + N\ Chloro + N\ Diatom\ Centrales + N\ Eugleno}{N\ Desmidiaseae}$$

MedPTI index was using biovolume of phytoplankton ($B_{j,k}$), trophic value (v_k), and indicator value (i_k). The trophic value of the *k*-th taxon (*v'k*) represents the trophic preference of that taxon; it is obtained from the annual mean total phosphorus concentrations (TP) and biovolume (B) of that taxon in all the *n j*-th reservoirs of the calibration data set using the following formula [3]:

$$v'_k = \frac{\sum_{j=1}^{n} B_{j,k} \times \log(TP_j)}{\sum_{j=1}^{n} B_{+k}} \quad (1)$$

$$v = 8.5 - 3.5 \cdot v'_k \quad (2)$$

$$i_k = \frac{\sum_{j=1}^{n} B_{j,k}}{\sum_{j=1}^{n} B_{j,k} \times D_{j,k}} \quad (3)$$

$$D_{j,k} = [v_k - \log(TP_j)]^2 \quad (4)$$

$$MedPTI_i = \frac{\sum_{k=1}^{m} B_{j,k} \times v_k \times i_k}{\sum_{k=1}^{m} B_{j,k} \times i_k} \quad (5)$$

Ecological state of aquatic ecology was grouped based on MeDPTI calculation (Table 1).

Table 1. MedPTI class boundaries

Class limit	MedPTI
high – good	2.77 0.89
good – moderate	2.45 0.79
moderate – poor	2.13 0.69
poor – bad	1.81 0.59

3. RESULTS

Ornamental lake has N:P ratio less than 7,2, which means N is a limiting factor at the lake. Orthophosphate concentration in Ornamental lake garden house showed more than 0,1 mg/l. Dissolved inorganic nutrient or DIN also showed high concentration (Table 2).

Spatially, similarity of phytoplankton abundance was forming 3 groups in 70% confidence level. Group 1 consist of station 1, 2, and 4, meanwhile group 2 consist of station 3, and group 3 consist of station 5 (Fig. 2).

Table 2. Nutrient analysis in Garden House Ornamnetal Lake PIK Jakarta

Station	DIN (mg/L)	Ortofosfat (mg/L)	Ratio N:P
1	**4,964**	**1,030**	**4,82**
2	**4,642**	**0,760**	**6,11**
3	**4,742**	**0,560**	**8,47**
4	**4,364**	**0,680**	**6,42**
5	**5,964**	**1,170**	**5,10**
Average			**6,18**

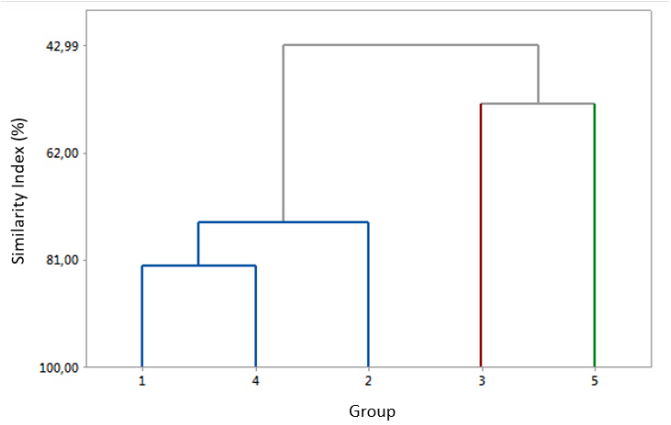

Fig. 2. Simillarity index of phytoplankton abndance in Ornamental Lake between stations.

Trophic state of Ornamental Lake Garden Housae was shown by value of Nygaard index, 9,5-10,5. Three groups of sites have eutrophic condition (Fig 3).

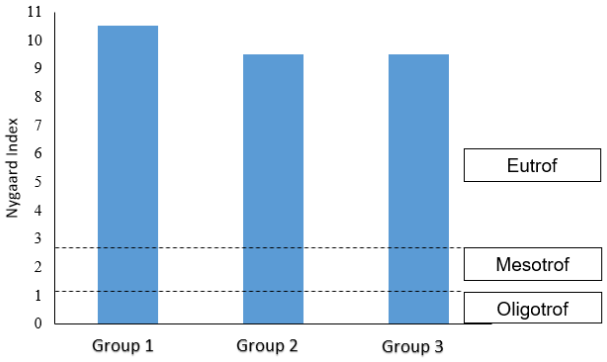

Fig 3. Trophic state of Ornamental lake Garden House based on Nygard Index

The value of ecological state of Garden House lake based on MeDPTI index was 1,46-1,85 (Fig 4). Group 1 is bad, temporarily group 2 and 3 are poor.

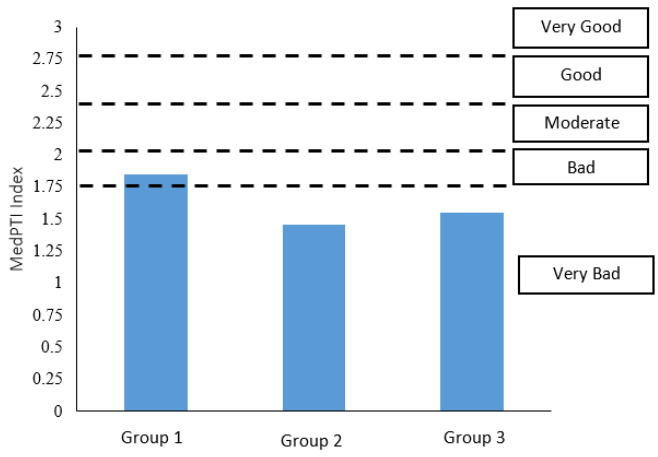

Fig 4. Ecological state of Garden House Ornamental Lake PIK Jakarta based on MeDPTI

4. DISCUSSION

Trohic state of aquatic ecosystem could develop from water quality parameters. Nutrient analysis showed low N:P ratio, which means N as limiting factor and Bacillariophyceae is predominant group in the lake. Nonetheless N:P ratio records is not adequate to describe trophic state in aquatic ecosystem. Orthophosphate concentration in ornamental lake is high and indicates hyper-eutroph state[4]. High concentration of DIN indicates eutroph state in Ornamental lake Garden House. Eutroph state was occurred in Ornamental Lake Garden House. Group 1 has the highest value of Nygard index. The eutroph condition was caused by direction of the wind and water flow to the north of lake, which is moving organic material to north site. Station 1 and 2 was located in north of lake, outlet of ornamental lake have higher organic material than other stations. Ecological state also showed bad up to poor boundaries class of ornamental lake. MedPTI is a sensitive tool, since involve orthophosphate concentration in the calculation. Nutrient in ornamental lake also showed high concentration, which is also determine eutrophic condition[5] (Goldman dan Horne 1983).

This condition was caused by nutrient input from houses. To restore this condition, waste water treatment should be managed. When water quality is in good quality, thropic and ecological state may also good.

5. CONCLUSION

Based on Nygard index, trophic state of Garden House Ornamnetal Lake is Eutroph, which is indicated by nutrient parameters. Based on MedPTI index, Ecological state of Garden House Ornamnetal Lake is bad.

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小川原湖における塩分躍層と循環水深の現状と近年の変化

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キーワード: 貧酸素, 富栄養化

抄録

青森県東部に位置する小川原湖は, 南西部から流入する淡水と, 北東部から流入する塩水により, 汽水環境が保たれている。そのため, 小川原湖では内水面漁業が盛んに行われており, 全国でもトップクラスの漁獲量を誇る。しかし, 近年の小川原湖では, 富栄養化が進行しており, 水質悪化の対策が求められている。そこで, 本研究では, 小川原湖の水質に大きく影響を及ぼす水文環境を把握するため, 塩分躍層と循環水深の現状と経時的変化を把握することを目的とし, 2006 年から 2017 年にかけてモニタリング調査を行った。春季と秋季には 15m 付近まで鉛直循環が見られたが, 夏季には 5m 付近に温度躍層が形成されていた。また, 1年を通して, 塩分躍層が 16m付近にみられた。16mの密度には経年的な変化が見られたが, その理由として, 風により 16mまで鉛直混合されたことが, ウェダーバーン数より推察された。

1. はじめに

青森県の東部に位置する小川原湖は、内水面漁業が盛んであり, ヤマトシジミ, シラウオ, ワカサギは, 全国でもトップクラスの漁獲量を誇る。また, 湖畔にはキャンプ場や公園などがあり, 地域の人々の憩いの場としても知られている。しかし近年の小川原湖では, 富栄養化が徐々に進行しアオコの発生や, 糸状藍藻類が生成する 2-MIB (2-メチルイソボルネオール) によるカビ臭等の水質悪化が問題となっており, その対策が求められている。湖水の水質には, 水文環境が大きく影響していると考えられることから, 水文環境を理解することは重要な課題である。特に, 塩分躍層や循環水深は, 小川原湖の富栄養化を考える上で欠かせない。そこで本研究では, 小川原湖の水文環境を把握するため, 2006 年から 2017 年にかけて, 小川原湖の湖心において水温, 塩分濃度, 溶存酸素の鉛直分布をモニタリングした。

2. 調査地概要

小川原湖は, 日本で 5 番目の面積を持つ汽水湖で, 面積 62.0km^3, 年間流入量 695×10^6 m^3, 最大水深 26.5 mと汽水湖の中では深い部類に入る[1]。小川原湖は, 南西部の河川から淡水が流入し, 北東部から海水が逆流することで, 汽水環境を保っている[2]。また, 小川原湖の滞留時間は約 1 年である。



図 1 調査地点

3. 方法

2006 年 4 月から 2017 年 10 月にかけて, 月に一度小川原湖の湖心(図 1)にて, 水文環境に関する水質調査を行った。多項目水質計を用いて水温, 塩分濃度, 溶存酸素濃度を表層から湖底まで 1m ずつ測定した。また, 水温と塩分濃度のデータから算出した密度と, 三沢観測所で測定した風速・風向のデータをもとにウェダーバーン数を求めた。

4. 結果および考察

2006年から2017年の塩分濃度の結果を図2に示す。表層から 10mの塩分濃度は 10 月に低くなる傾向が見られたが, 調査期間を通して 1psu から 2psu で安定していた。16m の塩分濃度は後述するように経年的に大きく変動した。18mの塩分濃度は, 2010 年 10 月に大きく低下した。20m以深の塩分濃度は, 2012 年から 2014 年に低下したが, 2015 年以降に再び上昇した。また, 2015 年 2

月と2016 年 12 月に 20m 以深の塩分濃度が上昇した。深さに伴う塩分濃度の変化量の最大値を塩分躍層とすると，小川原湖の塩分躍層の水深は，14m から 18m で推移していた（図 3）。

次に，透明度が循環水深に比べて十分に浅いため，溶存酸素量を基に循環水深を算出した。その結果，秋と春では循環水深が深く，13m から 15m まで循環していたが，夏季の循環水深は浅く，5m から 7m 付近であった。また，循環水深と塩分濃度の境界と考えられる 16m の塩分濃度が減少した原因として，その時期に循環水深が 16m 付近まで達しており，塩分濃度が減少したためと考えられる。

次に，2006 年から 2017 年の水温と塩分濃度から密度を求めた（図 4）。この図が塩分濃度の図と似ていることから，密度は水温よりも塩分濃度の影響を受けていると考えられる。16m の密度は、経年的に見てみると変動が大きくかった。特に，2006 年，2010 年，2011 年，2013 年，2017 年では大きく減少し，表層の密度と近い値を示していた。この原因を調べるため，三沢観測所の風速と密度から，ウェダーバーン数を算出し（2009 年～2017 年），風による混合の影響について考察した（図 5）。ウェダーバーン数は，W<1 の場合は風の影響により混合し，W>1 の場合は混合しにくいとされる[2]。2010 年，2011 年，2013 年と 2015 年以降に W<1 となる時期が見られた。特に 2010 年，2011 年，2013 年の 4 月から 5 月のウェダーバーン数は他の年よりも低くなっており，この時期に 16m の密度も表層に近い値をとっていた。したがって，4 月から 5 月に吹く強風により 16m が巻き上げられ塩分濃度が減少し，密度も低くなったことが示唆された。また，16m の密度が 4 月以降も低下していたことから，風の影響は長期的にわたり続くと考えられた。測定期間のその他の時期は，ウェダーバーン数が W>1 であったため，風の影響は塩分躍層まで届かないと考えられる。しかし，2016 年 8 月の台風 10 号と 2017 年 9 月の台風 18 号が上陸した際には，ウェダーバーン数が W<1 となっていたことから，極端な気象が生じると，塩分躍層まで影響が及ぶと示唆された。

5. 結論

近年の小川原湖の塩分躍層は 16m 付近に形成されており，年により 2m 程度の変動はあったものの，経年的なトレンドは見られなかった。また，小川原湖の春季と秋季には 15m 付近まで循環が起こっているが，夏季は 5-7m に温度躍層が形成されていた。16mの密度は，年により大きく変動したが，湖の変動には特に 4 月から 5 月における風の影響が大きく影響していた。また，台風といった極端な気象によっても，影響が見られた。この変化は数カ月続くことから，春の大風や台風は，小川原湖の浅層の水質に大きな影響を与える可能性が示唆された。

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小川原湖の調査に際しては，小川原湖漁協の蛯名秀樹氏，および（地独）青森県産業技術センター内水面研究所の研究員諸氏にご協力頂きました。記して謝意を表します。また，この研究は，科研費 20780233 と 15K07532 の助成を受けたものです

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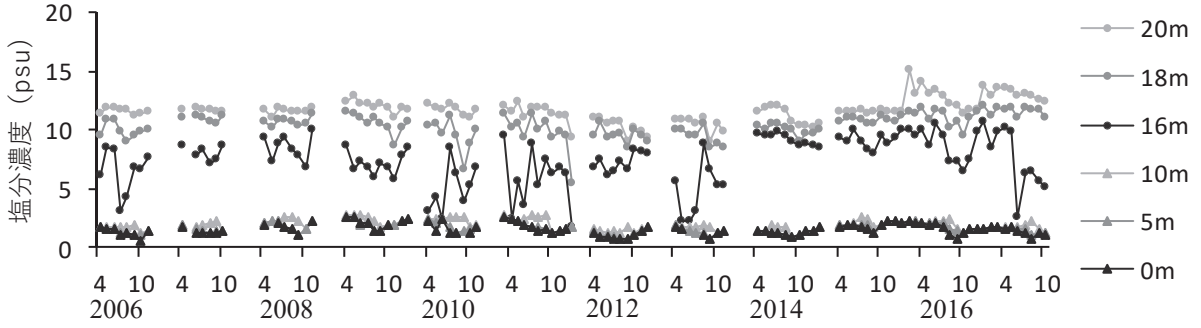

図 2 塩分濃度の経時的変化

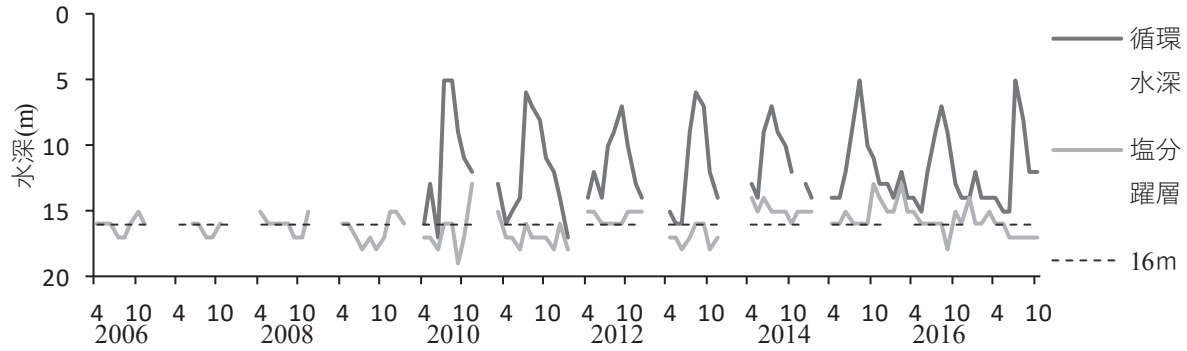

図 3 塩分濃度と循環水深の経時的変化

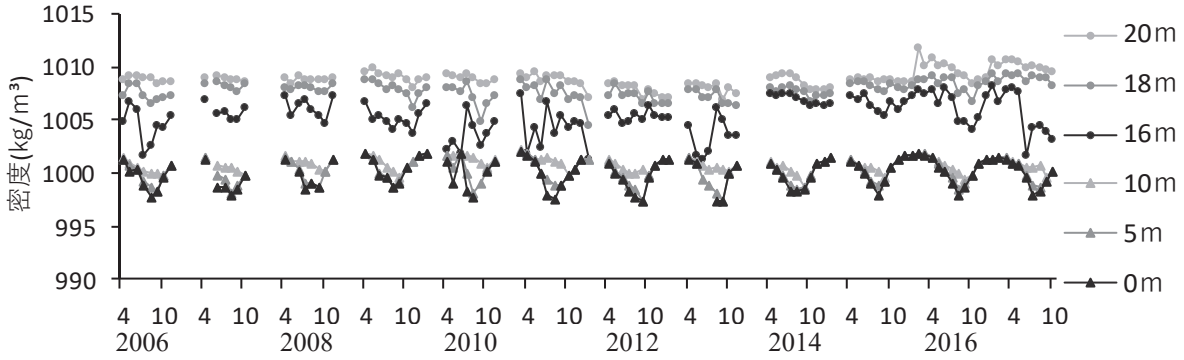

図 4 密度の経時的変化

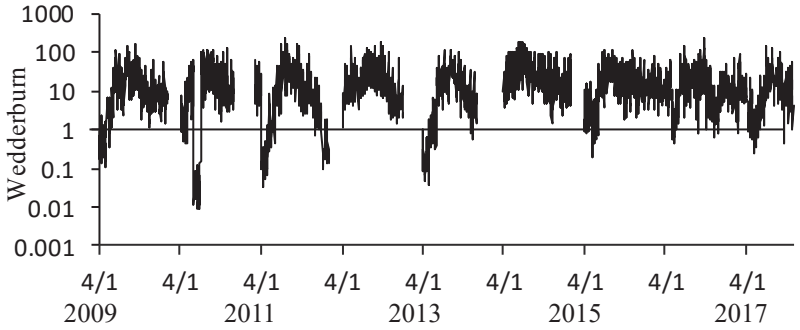

図 5 ウェダーバーン数

P3-14

浮葉植物群落を有するため池における TN／TP 比と主成分得点との関係

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キーワード: 一次生産, ため池, 水生植物, 統計解析

抄録

浮葉植物であるヒシ属が群落を形成するため池である大沢池において、その池水の水質傾向を把握するとともに池内の 1 次生産の状況を統計的に把握することを目的とした。そのために水質やヒシ葉被度などに関する現地調査を実施した。得られた毎月の水質 14 項目と浮葉植物の繁茂状態の計 15 項目について主成分分析を行い、池内の 1 次生産者である植物プランクトンと浮葉植物の繁殖と繁茂状態を主成分軸とする 2 次元に集約することができた。TN/TP 比が示す池水の栄養状態の転換時期は、統計解析で得られた主成分得点図の特徴的な位置を示した。

1. はじめに

東海地方にあるため池の代表的な浮葉植物はヒシ属やカガブタである[1]。ヒシ属の生育はカガブタと同じくPH,栄養塩類などについての適応範囲が広いとされる[2][3]ものの、近年ヒシ属の出現頻度が減少しつつあり[1]、ヒシ属の一つであるヒメビシは絶滅危惧Ⅱ類である[4]。水生植物の減少の原因には水質汚濁や池の改修埋立にともなう要因というように様々に指摘されている。カガブタに見られるように水生植物が同じ1次生産者であるアオコとの競争に負ける事例も見られる[1]。

本研究では、浮葉植物であるヒシ属が自生し群落を形成する農業防災ため池である津市大沢池において、その池水の水質傾向を把握するとともに池内の 1 次生産の状況を統計的に把握することを目的とした。

2. 方法

2.1 現地水質調査

2017 年 4 月から 12 月まで毎月 1 回調査を行った。8 月は農業用水として取水を終わる時期のため、取水終了の前後で2回実施した。灌漑期は 2017 年 4 月 16 日から 8 月 10 日であった。このうち 6 月 10 日～7 月 2 日は中干しにあたり、ため池からの取水は中断された。

大沢池（貯水量 128,000m^3、満水面積 0.06km^2）の形状は東西に細長く、西側上手に流入水路があり、東側末端に取水口が 1 箇所ある。このため、流入水路から取水口方向に池内を上流域、中流域、下流域の 3 水域に均等に分けた。池内 3 水域の表層水と流入水を採水し、水温、透視度、PH,電気伝導度 EC,溶存酸素 DO, 濁度、全窒素 TN,NO3-N,NO2-N,NH4-N,全リン TP, 化学的酸素要求量 CODcr,クロロフィル a を測定した。

当該ため池には近隣の貯水池から補給水を受ける施設が整えられているが調査年も含め過去の補給実績はない。

2.2 ヒシ葉被度と色彩の現地調査

ヒシ葉による水面の被度、およびヒシ葉の色彩を把握するために、無人航空機（UAV）を用いて撮影した。このためにコロラード（2m×2m）を池内の 3 水域に設置した。そして、水質調査日の前後で UAV を飛ばし、付属のデジカメによる撮影観察を行った。

観察方法はコロラード観察と高度水域観察とした。コロラード観察では、UAV をコロラードに近接させて撮影した。高度水域観察では、各水域全体が見渡せるような様々な高度から撮影した。 真下撮影を行っていないため、太陽光の向きを考慮してコロラードや各水域を様々な高度や方向から記録した。

コロラード観察と高度水域観察から、それぞれ得られる被度や色彩割合を平均して各水域の値とした。3 水域の被度値や色彩割合値を、さらに平均して池全体の値とした。

2.3 主成分分析

水質項目（14 項目）およびヒシ葉被度について、池平均値を用いて主成分分析を行った。水質項目は、水温、透視度、PH、EC、DO、濁度、TN、NO3-N、NO2-N、NH4-N、TP、d-COD、クロロフィル a、P-COD を選んだ。

3. 結果

3.1 ヒシ葉の被度や色彩

図 1（L）にヒシ葉被度の変化を示す。4 月下旬からヒシ葉が水面に見られ始まるが、5 月連休明けになるとまとまった被度となった。7 月末はほぼ 100%となり水面を

覆い尽くした。8月も同様であるが過密となり葉が立つ様子が見られた。8 月下旬になると徐々に被度が減少し始め 10 月下旬になると水面にはかなり少なくなった。

ヒシ葉色彩の変化について、4 月～8 月の成長期でありヒシ葉は緑色であった。8 月に入ると少しずつであるがヒシ葉に赤みを帯び始めた。9 月に入ると赤色が緑色の割合を超え、光合成をしなくなり枯死しつつあった。

3.2 流入水の水質

流入水の透視度や DO は高く、溶存態 COD の割合が高く、外見上は透明感があった。しかし窒素とくに NO3-N が高かった。これは集水域内で過去に牛豚の畜産（現在廃業）が営農されたことの影響と考えられる。さらに PH、EC が比較的高かった。

3.3 池水の水質

図 1（A～K）に池水平均の結果を示す。ヒシ葉被度が増加する 4～8 月は代掻きから始まる灌漑期に当たり池水の交換性が高まる。特に調査した 2017 年は少雨のため池水の利用が増えた。ヒシ葉被度が減少・ゼロになる 8 月～12 月は非灌漑期に相当し池水の交換性は低下した。

灌漑期は、ヒシ葉被度が増加するに伴い表層水のクロロフィル a が減少したことから、ヒシ葉による遮光効果により植物プランクトンが減少したと考えられる。連結的に PH や DO は減少した。有機成分が減ることで TN や TP は減少したと思われる。負の相関にある透視度・濁度は、この時期にそれぞれ増加・減少した。さらにヒシ葉の消波効果により有機懸濁成分は沈降することで COD は減少し溶存態の割合が高くなり、透明感のある表層水を観察することができた。

非灌漑期は、ヒシ葉被度が減少するに伴いヒシ葉の遮光や消波効果は消失していった。COD は植物体であるヒシが枯死しているにもかかわらず増加せず懸濁態の割合も低いことから、枯死ヒシは沈降懸濁態のままで池底へ堆積はすれど表層水までは大きく影響していないと考えられる。次に表層水のクロロフィル a が増加したことから植物プランクトンが増加していったと考えられる。ただし植物プランクトンは一旦 10 月に極大を示し 11 月は減少に転じた。連結的に PH や DO は増加したが極端に高くならなかった。植物プランクトンなどの浮遊性有機成分が増えることで TN や TP は増加傾向を示し、10 月は無機態 N が減少する一方で TN が増加した。11 月は植物プランクトンが減り無機態 N が増えたので過度の分解が生じた可能性がある。透視度・濁度は灌漑期から反転しそれぞれ減少・増加した。

3.4 池水のTN/TP 比（重量比）

図 2 にTN/TP 比の変化を示す。TN/TP 比は栄養塩のバランスを示す指標であり、レッドフィールド値では TN/TP 比=7.2 となる。池平均の TN/TP 比は調査期間中でほぼ 10 を超えており対象池は窒素過多の池と考えられる。しかし、8 月 10 日と 11 月に TN/TP 比が一時的に減少した。これらの時点の個別水域の TN/TP 比は 10～7.2 を下回り、リン過多を示した。この 8 月 10 日、11 月はともに植物プランクトンが減少した時期であった。

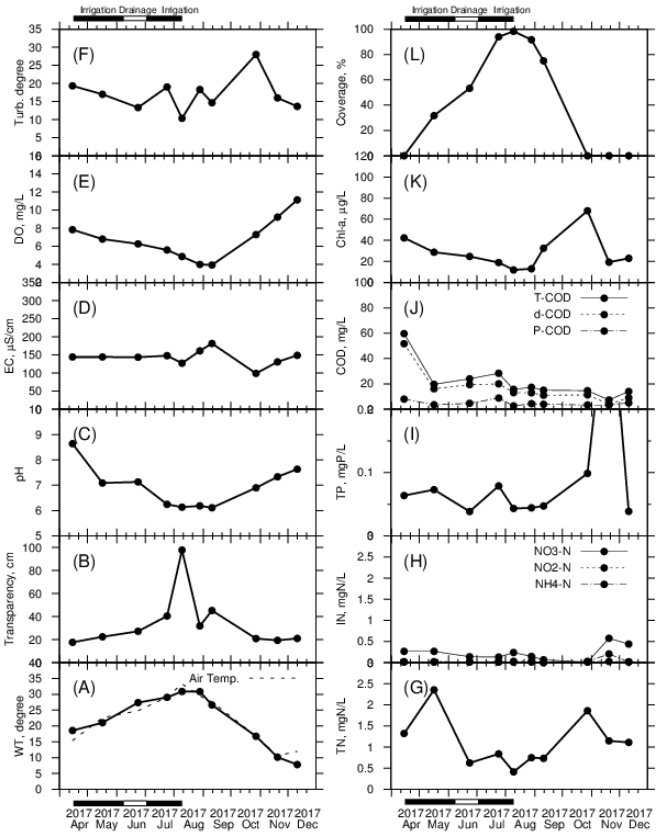

図 1 （A～K）池水の水質および（L）ヒシ葉被度の変化

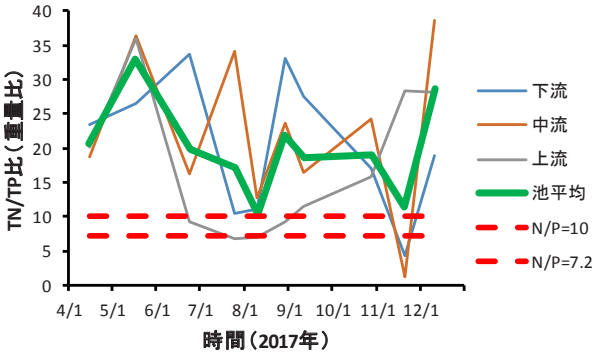

図 2 池水の TN/TP 比（重量比）の変化

4. 考察

4.1 因子負荷量と主成分得点

図 3 に因子負荷量を示す。図中で NO3-N、NO2-N、NH4-N、TP はほぼ同一方向を示したため矢印が重なっ

た。同様にクロロフィル a、濁度、P-COD も矢印が重なっている。第 1 主成分と第 2 主成分を合算した積算寄与率は 0.61 であった。

第 1、第 2 主成分軸の解釈では 15 項目の中から軸毎に成分値の大きいものに重点をおいた[5]。その結果、因子負荷量図に示される第 1 主成分軸は季節感がイメージされヒシの繁茂状態を表すとし、正方向ほど枯死の状態が大きく、負方向ほど繁茂の状態が大きいとみなした。第 2 主成分軸は逆に季節感をイメージできず、適温が異なっていつも繁殖できる植物プランクトンを表すものとして、正方向は植物プランクトンの死亡状態が大きく、負方向は植物プランクトンの繁殖が大きいと判断した。本研究ではヒシ植物体量ではなく水面を占めるヒシ葉の割合を対象にしたため枯死・分解を含む繁茂状態を表現しきれていないが、水槽での栽培実験では枯死後における水中での分解は緩慢であったため水面被度でヒシ繁茂状態を表すとした。

第1象限（右上）はヒシ繁茂が弱く、植物プランクトン繁殖も弱い状態にあたる。この象限には TN を除く無機態窒素や TP が集中していて、植物プランクトンの死亡、ヒシの枯死、それらの分解を表していると考えられる。総じて1次生産力が落ち、栄養塩が優勢となる状態と解釈した。第2象限（左上）はヒシの繁茂が優勢となるのを表すとみられる。第3象限（左下）は、ヒシが繁茂し植物プランクトンも繁殖していて、共存しながら共に優勢の状態と見て取れる。第4象限（右下）は植物プランクトン繁殖が優勢な状態を示す。中央の原点付近は、これらのヒシの繁茂・枯死や植物プランクトンの繁殖・死亡が平均的な状態を表すと解釈した。

因子負荷量図においてヒシの繁茂とは逆方向に DO のベクトルが向いている。これはヒシが繁茂すると、DO が小さくなることと読み取ることができる。これは既往の文献でたびたび指摘される現象であり、本論では統計的に示すことができた。

図 4 に主成分得点を示す。経時的に見ると、4 月は植物プランクトンが優勢な状態にあり、季節が進みヒシが繁殖し始める 5 月～6 月では平均的な状態になり、7 月～8 月 10 日にかけてヒシ繁茂が極端に優勢な状態を示す第2象限の隅に移行した。9 月から 10 月へはヒシの繁茂が衰える時期となり、10 月から 11 月には枯死・死亡が強くなり栄養塩が極端に優勢な状態である第1象限の隅へと移行した。

4.2 TN/TP 比の低下と主成分得点との関係

3.4 節で 8 月 10 日と 11 月に TN/TP 比が高い状態から TN/TP 比が 10 近くまで減少したことを指摘した。図 4 に示す主成分得点図では、これらの 8 月 10 日、11 月はそれぞれ第 2 象限と第 1 象限の隅に位置した。このように TN/TP 比が 10 近くまで低下した時点は、主成分得点図の特異的な場所に位置することが分かった。

8 月 10 日はヒシ繁茂の最盛期に相当する。ヒシ葉の遮光効果によって植物プランクトンの増殖が抑制されたために TN が減ることで TN/TP 比が減少するに至ったと考えられる。また、11 月では、ヒシは枯死していて、植物プランクトン繁殖も弱い状態にある。TN/TP 比が減少した理由は TP が極大を示したためであり、このときの NH4-N は増加が確認されたのでヒシ分解やプランクトン分解が進んだためと考えられる。

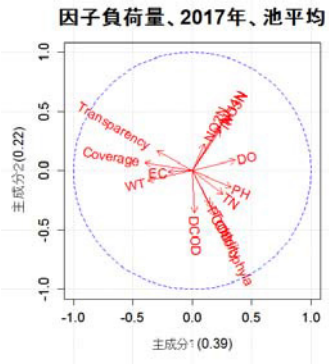

図 3 因子負荷量

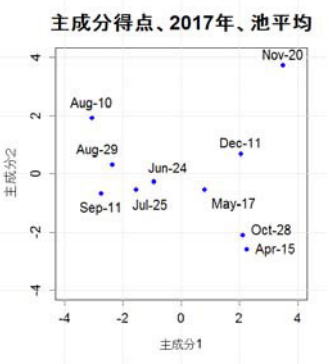

図 4 主成分得点

5. 結論

毎月の水質 14 項目と浮葉植物の繁茂状態の計 15 項目について主成分分析しため池の 1 次生産者である植物プランクトンと浮葉植物を主成分軸とする 2 次元の主成分得点図に集約させた。主成分得点図の特徴的な位置に TN/TP 比が示す栄養状態が窒素過多からリン過多へ転換する時点が配置された。

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P3-15

Potential Vegetation for Nitrogen Removal in Lake Riparian and Catchment Areas

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Keywords: eutrophication, Nitrogen, vegetation, riparian, water catchment areas

ABSTRACT

Eutrophication has worsened water quality in at least 15 priority lakes in Indonesia. Eutrophication level (oligotrophic, mesotrophic, eutrophic, and hypertrophic) is one of indicators in defining lake health status. Based on eutrophication level, only two lakes were oligotrophic, while the others were in eutrophic and hypertrophic conditions. To reduce lake degradation, vegetative rehabilitation in lake water catchment and riparian areas was proposed. Some studies provided information on vegetation for nutrient removal from water body. However, very few studies focused on measuring vegetation capability in Nitrogen (N) removal from soil. This research aims to assess N content of plant species growing in Rawapening riparian as preliminary information on plant potency for N removal. Plants and soil samples were taken in a relatively undisturbed riparian area in Bejalen village. Each plant was labeled with local name and identified using "Tumbuhan Berguna Indonesia" book to determine their scientific names. There were nine plants found: *Ampelas, Cangkring, Elo, Gempol, Dempul, Johar*, *Waru*, *Bunga Kuning* and *Mangsi*. Plant and soil N contents were analyzed in WMTC Laboratory. Riparian soil N content was 0.21%. *Ampelas, Mangsi* and *Cangkring* had the highest N content with 0.24, 0.13 and 0.12%, respectively. N content for *Bunga Kuning* was 0.7%, while for *Lo, Gempol, Dempul, Johar* were 0.5% each and for *Waru* was 0.3%. *Ampelas, Mangsi* and *Cangkring* are potential for N removal as their N contents were approaching N soil.

1. INTRODUCTION

Eutrophication is defined as the enrichment of surface waters with plant nutrients[6]. Since 18th century Vollenweider, et al. (1980) in Ongley (1996) had classified trophic status into nutrient poor (oligotrophic), mesotrophic, eutrophic and nutrient rich (hypertrophic). At that time, the major factor of eutrophication was agriculture. In 2009, besides agriculture, Selman and Greenhalgh included wastewater and burning fossil fuels as other factors in eutrophication.

In Indonesia, eutrophication has become a serious problem especially in lake management. Based on eutrophication status and other condition, the country has categorized 15 lakes as management priority[5]. They are spread throughout Sumatera (Toba, Maninjau, Singkarak, Kerinci), Sulawesi (Tondano, Limboto, Poso, Tempe, Matano), Kalimantan (Mahakam Cascade (Semayang, Melintang, Jempang), Sentarum), Papua (Sentani), Java (Rawadanau, Rawapening) and Bali (Batur). Among those priority lakes, only two were in oligotrophic status i.e. Matano and Poso lakes, while the others were eutrophic and hypertrophic.

Eutrophication sources in most priority lakes are from settlement in lake water catchment and riparian areas, agriculture, animal husbandry and aquacultures[5]. Some domestic waste management installations have been applied in some areas. Eight programs have been proposed to overcome lake degradation; they are (1) lake spatial arrangement, (2) conservation and rehabilitation of lake water ecosystem, (3) conservation and rehabilitation of lake ecosystem riparian zone, (4) conservation and rehabilitation of watershed and lake water catchment area, (5) utilization of lake water resources, (6) development of monitoring, evaluation and information system of lake ecosystem, (7) enhancement of capacities, institutionalization and coordination, and (8) improvement of community role and participation[5]. Vegetative rehabilitation both in lake water catchment and riparian

areas was a part of program (3) and (4).

Nitrogen (N) removal from wastewater using different plant species have been applied in other countries. In China, Lu and Huang (2010) tested *Nymphea tetragona* Georgi.and *Pontederia cordata* L. in N and P removal and concluded that both of them have good removal in stagnant water [4]. Li *et al*. (2014) evaluated *Lolium multiflorum* N and P removals in floating mats experiment in China and resulted in 39-49 and 47-58 % decrease [3]. Wu *et al.* (2016) investigated removal of Nitrogen by *Typa augustifolia, Phragmites australis* and *Acorus calamus* in a-30-days hydroponic experiment in China[9]. The result indicated that three of them can remove almost all N in NH_4^+ form[9]. In Indonesia, Chrismadha *et al.* (2017) examined the ability of minute duckweed *(Lemna perpusilla),* greater duckweed *(Spirodella polyrizha),* water lettuce *(Pystia stratoites)* and water hyacinth *(Eichornia crassipes)* in eliminating nutrients, N and P from polluted water[1]. The result was promising as the N and P removals were around 80 %[1].

Although research on N removal from water body by vegetation in Indonesia is still limited, none has been found in studying plant effectiveness in removing N from soil. Therefore this research was aimed to measure N content of plant species growing in Rawapening riparian as preliminary information on plant potency for N removal.

2. METHOD

Plants and soil samples were taken in a relatively undisturbed riparian area in Bejalen village, Ambarawa Sub-district, Semarang District, Central Java in April 2017. Branches, leaves, flowers and fruit of trees and including roots for smaller plants were taken destructively then cleaned from dirty and dried from water in its surface and put in aerated sample bags to prevent from quick decaying. Each plant was labeled with local name and photographed. All samples were taken to Watershed Management Technology Center Laboratory (WMTC) to be treated and analyzed for their N contents. Local names were matched to those provided in "Tumbuhan Berguna Indonesia" book [2] to determine their scientific names.

3. RESULTS

There were nine plants found consisting of seven trees: *Ampelas (Ficus ampelas* Burm.f.*), Cangkring (Erythrina fusca* Lour.*), Elo (Ficus racemosa L.* synonyms *Ficus glomerata* Roxb.*), Gempol (Nauclea orientalis* L.*), Dempul (Glochidion sp), Johar (Senna siamea* Lamk.), and *Waru (Hibiscus sp)*, a shrub (*Bunga Kuning*) and a liana, *Mangsi*.

N content for riparian soil was 0.21%. *Ampelas, Mangsi* and *Cangkring* had the highest N content with 0.24, 0.13 and 0.12%, respectively. N content for *Bunga Kuning* was 0.7%, while for *Elo, Gempol, Dempul, Johar* were 0.5% each and for *Waru* was 0.3% (Table 1).

Table 1 Total N content in riparian vegetation and soil

No	Species local names	Water Content (%)	Total Organic Carbon (%)	Total Organic Matter (%)	Total N (%)
1	*Ampelas*	51.91	4.58	7.89	0.24
2	*Mangsi*	33.65	1.27	2.18	0.13
3	*Cangkring*	54.13	2.91	5.02	0.12
4	*Bunga kuning*	58.64	3.66	6.31	0.07
5	*Elo*	43.88	2.10	3.61	0.05
6	*Gempol*	48.61	1.07	1.84	0.05
7	*Dempul*	39.90	1.82	3.14	0.05
8	*Johar*	37.46	0.99	1.70	0.05
9	*Waru*	37.50	1.06	1.83	0.03
	Riparian Soil	39.98	0.36	0.62	0.21

4. DISCUSSION

Among the top three having the highest N content, *Mangsi* is the only non-tree species, while *Ampelas* and *Cangkring* are considered as tree species. *Ampelas* (*Ficus ampelas*) found in the research site was a-4-meters sapling with 3.5 cm diameter. *Ampelas* in Indonesia is a native to Sumatera, Java, the Lesser Sunda Islands, Sulawesi, the Molluccas and New Guinea and possibly Borneo[8]. It is an evergreen tree with small to medium height up to 15 (-20) m and usually found in lowland areas[8]. The latex has been used as medicine and the fruits are edible; the leaves can substitute sandpaper[8] (*ampelas*/Indonesian is sandpaper/English).

C*angkring (Erythrina fusca)* in research site was a tree with approximate height of 12 m and diameter at breast height of 20 cm. It is an exotic species in Indonesia originated from South America that may reach height of 10-15 (max. 26) m[7]. *Cangkring* can survive in bad drained soils: swamps, stream banks and marshes[7]. It research sites, some people harvested the leaves for medicine. Another species from the same genus, *Erythrina variegata*, was known as N fixing species[7], so it is

possible that high content of N in *Cangkring* also come from N fixation from the air.

Mangsi (Javanese), in English called ink, together with *Bunga kuning* is species that have not been identified for their scientific name. *Mangsi* has dark blue/almost purple fruit and fruit content. *Bunga kuning* was found in waterlogged area and has densed rooted. It is called *Bunga kuning* for its flower color.

Elo (Ficus racemosa) is a deciduous tree (in drier area) of 20-30 m tall[7]. In April 2017, the tree was leaves-blooming after deciduous. *Elo* is commonly found in lowland area along river banks[7].

Gempol (Nauclea orientalis), is a familiar tree in research site which is still cultivated by local people for its economic and esthetic values. It is native to Indonesia, Malaysia, Thailand and Australia and can grow up to 30 m and 1 m of diameter[7]. *Gempol* are commonly found near stream and associated with *Melaleuca dealbata* and *Melaleuca leucadenron* in swampy land[7]. For its character as a pioneer species and prefer open areas[7], *Gempol* is likely suitable for replanting riparian and water catchment areas.

Johar (Senna siamea) is a legume tree usually growing in lowland area and can reach height of 18 m and 30 cm diameter[7]. The tree in research location was more than 5 m tall. *Dempul (Glochidion sp)* was still seedling with 90 cm height and *Waru (Hibiscus sp)* was an adult tree with 7 m height and already flowering.

5. CONCLUSION

Among the nine species found, *Ampelas, Mangsi* and *Cangkring* are potential for N removal as their N contents were approaching N soil and their habitat requirement matches riparian condition.

ACKNOWLEDGEMENT

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P3-16

The inconvenience of traditional fishing practice on aquatic ecosystem of Lake Nokoue in Republic of Benin (West Africa)

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Keywords: Traditional fishing practice- water pollution, Aquatic ecosystem Threat.

ABSTRACT

This case study has assessed the vulnerability of NOKOUE Lake to pollution by both "Acadja fishing practice" and domestic waste.

Situated in coastal area of Benin, where more than four millions of people are living, Nokoue Lake is the biggest lake in the West Africa due to his big surface and fishiness productivities. Unfortunately, this lake confronts a lot of challenges due to traditional system of fishing called "Acadja" and bad domestic waste management. This study highlights that "Acadja" practice and domestic waste destroy the aquatic fauna and therefore threaten and disrupt food security of the habitants by reducing fish productivity. As matter of fact, this practice of "acadja" reduces the transparency, light and increases water pollution through the proliferation of aquatic plant which reduces the amount of dissolved oxygen. The analysis was made by spectrophotometer DR/2000 Hach, multipara meter wtw 340i and atomic absorption spectrophotometry for Toxic metals (lead). The result was revealed that dissolved oxygen under 3 mg/L at the place of acadja, and the contents of nitrite 3.35 to 15.25mg/L while lead shows high values. This water quality influences dangerously fauna aquatic. It is necessary to mention that investigation made among the riverside habitants and has revealed that the weight of the fishes is reducing drastically year to year

I-INTRODUCTION

Lake Nokoue is situated and located in the southern part of Benin in West Africa (Fig1). It covers approximately 150km2 areas. The lake is connected to Porto Novo lagoon (the executive capital lagoon) at the East by Totche canal at the south by atlantic ocean through Cotonou (Economic capital of Benin) channel at the north by river sô and Ouéme stream at the west which receives the large parts of its content (Fig 2). Its connection with Atlantic Ocean originates its salinity which it's sometimes advantageous for fishes.

As it was stated above, the lake is very important for the Benin development due to1/3 of Benin population, approximately 4000000 people live behind the lake and they survive depend on the lake. Thus, behind this lake there is a big international market called "Tokpa market" situated in economic capital of Benin, Cotonou where more than 250 "tonnes" of solid waste are produced per day and rejected in the lake. Apart from this anthropogenic pressure, the lake is confronted to another phenomenon called "Acadja (Fig 3) " and water pollution due to liquid and solid-waste. .

It is useful to mention that "acadja" is invented and built by the riverside habitants, fisher men and their relatives to protect the fishing family business. Map of lake situation below

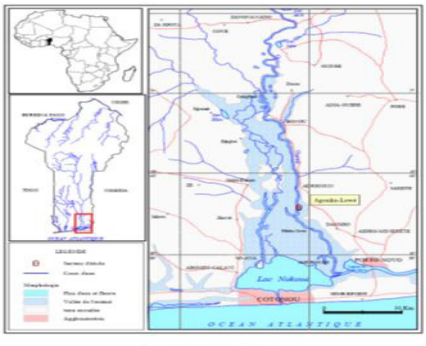

Figure 2.6 : Le delta de l'Ouémé

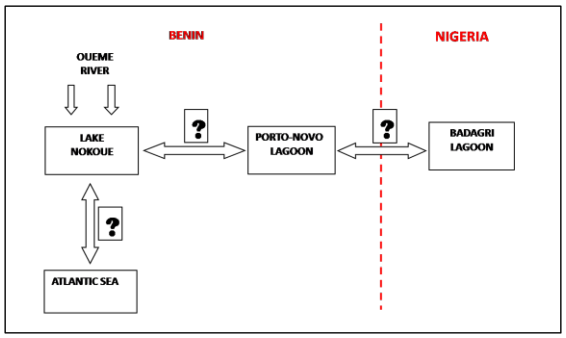

Figure:1 Lake Nokoue recharged and connection

II. METHODS

The Nokoue Lake is characterized by a subequatorial climate. It is recharged by Oueme river (the biggest river of Benin) and discharged into the Atlantic Océan . This study was carrying out during both dry and rainy season. . The parameters such as temperature, pH, dissolved oxygen, the redox potential are measured in situ. Multipara-meter/ox-meter-WTW-340i.Measurement of suspended solids (Methods 8006 with the multipara meter, colorimeter HACH DR/2000). Atomic absorption spectrophotometry has been used for Toxic metals especially lead.
Six sampling have been taken from both acadja side and non acadja side.

III. RESULTS

The results are grouped and analyzed by seasons: the intense rainy season and the intense dry season. At every sampling station,

Table 1: Data Results

Samples	1	2	3	4	5	6
pH	6,69	6,72	6,84	8,1	8,4	8,3
Température	37	36	35	29	25	27
Dissolved xygen(mg/L)	3,75	3,45	3,7	2,77	1,65	1,8
Supended solids	12,25	14,75	23,00	40,12	37,06	29,56
TURBIDITY (NTU)	07	05	10	25	40	
NO3-(mg/L)	2,75	2,5	1,5	8,5	10,5	7,25
NO_2-		3	4,25	7,15	5,83	5,90
Remark	Non	Non Acad	Non Acad	Acadja	Acadja	Acadja side

the redox potentials are negative especially in the Intense Rainy Season. The temperatures as are between 25°C and 37°C.

According to author [3], they are good condition of growth of the species fish. The pH ranges from 6.69 to 8.40. This value of pH is good at fish farming because situated between 6.5 and 9 . In case the pH values are not included in 6.5 to 9, then there are potential risks of negative chronic effects in long terms for the aquatic life protection [9].

We notice that the contents in oxygen dissolved in sampling stations vary from 1.65 to 3.75 mg/L as shown by **Figure** 2.

IV. DISCUSSION

This part will essentially based on dissolved oxygen and on suspended solids which are of important parameter of water pollution

The high dissolved oxygen contents are noticed at TCHOCHE where there aren't installations of acadjas. The dissolved oxygen is an essential ecological factor and plays an essential role in the preservation of the aquatic life. The oxygen dissolved contents in natural waters are mainly determined by the breath of the aquatic bodies, the oxidation, the degradation of pollutants, the photosynthetic activity of the flora and the exchanges with the atmosphere.. According to cerains authors , the quality of this lake is classified in the mediocre range because the content in dissolved oxygen is lower than 3 mg/L. We deduct from this that the acadjas asphyxiate the lake and therefore fauna aquatic.

The average contents of the suspended solids at TOCHE are 23.00, 40.12, 37.06 and 29.56 mg/L . The suspended solids include all the substances which are not dissolved. Their harmful effect due to formation of sediments and of a screen preventing the good penetration of the solar radiation (reduction of the photosynthesis) on the one hand, and the clogging of the fishes gills on the other hand. Their effect is also chemical by constitution of a potential reserve of pollution in sediments. The biodegradable suspended solids contribute in a significantly to the oxygen demand and cause therefore the decrease of the concentration in oxygen dissolved in the aquatic environment . The suspended solids can asphyxiate some aquatic species and even the whole aqua tic environment when they are present in excess, or to provoke momentary anoxia. There are risks of long-term

fatal chronic effects for the aquatic life protection if the value exceeds 5 mg/L.

. Furthermore, the higher the temperature and the dissolved oxygen are, the higher the micro-organisms decompose organic materials (the branches tons into the lake). This is also the reason for the high turbidity observed. The reducing power is still strongly correlated with the temperature. The high activity of microorganisms reduces dissolved oxygen content of the medium. This situation leads the aquatic environment to be reducing. This has very serious consequences on aquatic species. The results in Nokoue lake in Benin, are in accordance with those we have obtained and reveal disadvantages of acadjas practices



Figure 2. Contents in oxygen dissolved in in Nokoue Lake

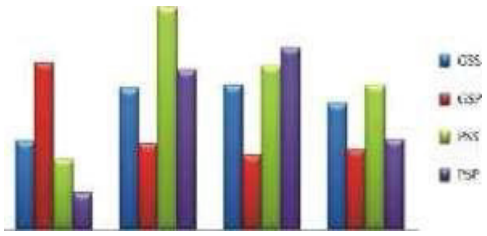

Figure 3. Variation of the suspension materials in in Nokoue Lake



Photo 1: Waste management and building house in Nokoue Lake.



Photo 2: System of Acadja on the lake

V. CONCLUSION

The practice of acadjas is a very old and wide-spread traditional fishing method observed in Benin's lakes and lagoons. It allows a good profitability of the fishing activities but it is the cause of the deforestation and erosion as well. Since several years, it is more and more forbidden by public authorities through the law n° 152/ MAEP of September 16th, 1970, concerning removal of acadjas from the Nokoué lake, the lagoons of Porto-Novo This study which we have just conducted reveals that the dissolved oxygen, which is one of the key factors of aquatic life becomes scarce because it is much more requested for the decomposition of tons of discharge woods in the Nokoue lake. And as a result, the aquatic environment becomes reducing, which allows the biochemical process of development and degrading of the original conditions of life in the aquatic medium. A program of reforestation of lagoon banks is then recommended due to its multiple advantages. IT is good to notice that the new government has decided to restorate aquatic ecosystem on this lake. Nowadays, the new government has forbiden the use of acadja

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P3-17

湖水直接浄化施設の稼働による土浦港水質浄化効果について

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キーワード:富栄養化, 栄養塩動態, 水質浄化, 生態系機能

抄録

茨城県では, 植物プランクトンの増殖に必要なりんを湖水から直接除去するために, 凝集磁気分離技術を応用した直接浄化実証施設を 2013 年 9 月に土浦港湖畔に設置, 稼働した。本研究では, この浄化施設による水質改善効果を港内の水質を調査することによって検証することを目的した。処理水量増加に伴う土浦港のりんの減少量は, 浄化施設の稼働による処理水量の増加に伴って, 土浦港のりんの減少は高くなる傾向が認められ, 稼働後は稼働前より土浦港のりんが約 23 kg 減少された。特に, 水域 a のりんの浄化効果が大きい。さらに, 浄化施設の連続稼働も霞ヶ浦のりんの削減に寄与していたと考えられる。また, 浄化施設の稼働によって, 土浦港のクロロフィル a の減少が認められたことから, 土浦港水域の植物プランクトンの減少が示唆された。本研究結果より, 浄化施設の稼働は, 植物プランクトンの発生の抑制に対して有効であると考えられる。

1. はじめに

霞ヶ浦はいまだ富栄養化の状態にあり, 特に 2011 年には, 土浦港付近でアオコが大発生し, アオコの腐敗による悪臭被害が発生するなど, 霞ヶ浦の水質改善が求められている。既往研究から, 植物プランクトンの増殖は, 湖水中の窒素, りんなどの栄養塩の過増加による湖沼の富栄養化に関連していると報告されている。

茨城県では, 植物プランクトンの増殖に必要なりんを湖水から直接除去するために, 凝集磁気分離技術を応用した直接浄化実証施設を 2013 年 9 月に土浦港湖畔に設置, 稼働した。本研究では, この浄化施設による水質改善効果を港内の水質を調査することによって検証することを目的とする。



図1 土浦港調査地点及び浄化水域

2. 方法

2017 年は, 述べ 100 万 m^3 の処理水量の目標を達成するため, 6 月 16 日から 10 月 16 日まで湖水直接浄化施設を稼働し, 浄化効果を検証した。

直接浄化施設は, 凝集疑似分離方式を用いて, 1 日あたり 10,000m^3の水処理を行うことができる。急速撹拌槽, 緩速撹拌槽, 磁気分離装置により, 約5分間程度で処理が可能。目標水質は, 全りんが 0.03mg/L, 浮遊物質量(SS)が 5mg/L とした。

表1 2017年の湖水浄化施設の稼働状況

運転期間	期間	処理水量(万m^3/day)
第1クール	6月16日～8月10日	1.0(計画) 汚泥返送(24時間)
第2クール	8月17日～10月16日 (8月11日～16日原水循環運転)	1.0(計画) 汚泥返送(24時間)

土浦港内の水質調査方法及び評価方法は, 次のとおりである。

(1)調査頻度:稼働前:2 回(平均値を取る), 第 1 クール:6 回;原水循環運転:1 回;第 2 クール:7 回;稼働後(浄化終了後):2 回

(2)水質分析項目:全りん(TP), 全窒素(TN), 化学的酸素要求量(COD), クロロフィル a 等

(3)直接浄化施設によるりん等の除去率及び除去量:

除去率(%) = (原水濃度ー 処理水濃度)/原水濃度 ×100 ･･･式 1

除去量(kg) = 原水濃度 × 処理水量× 除去率 ･･･式 2

(4) 水質変化率:

変化率(%) ＝ (稼働前水質 － 稼働後水質)/稼働前水質×100 ･･･式 3

(5) 土浦港各調査水域のりん等の減少量:

減少量(kg) ＝ 稼働前現存量 － 稼働後現存量 ･･･式 4

3. 結果

湖水直接浄化施設によるりん等の除去率及び除去量は，SS が 76%及び 9,417kg，TP が 81%及び 67kg，PO_4-P が 81%及び 27kg，TN が 21%及び 307kg，クロロフィル a が 91%及び 33kg であった(表 2，図 2)。

表 2　直接浄化施設によるりん等の除去率及び除去量

	SS	TP	PO_4-P	TN	Chlorophyll a
原水濃度(mg/L，SD)	12(3.2)	0.087(0.022)	0.037(0.021)	1.4(0.26)	0.033(0.012)
処理水濃度(mg/L，SD)	2.8(0.70)	0.017(0.0067)	0.0070(0.0072)	1.1(0.35)	0.0031(0.0018)
除去率(%，SD)	76(6.1)	81(5.4)	81(17)	21(12)	91(3.8)
除去量(kg)	9417	67	27	307	33

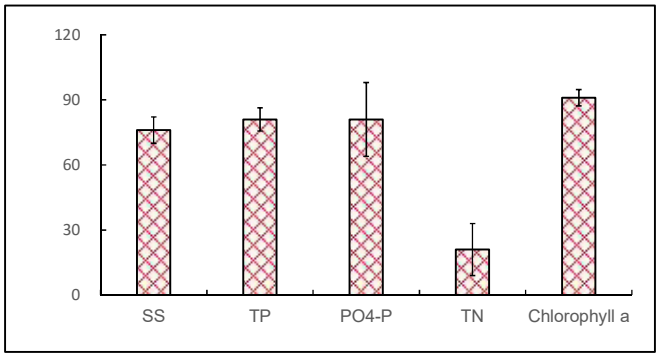

図 2　直接浄化施設の稼働によるりん等の除去率

土浦港の水質変化を以下に示す。りんの変化については，浄化施設の稼働により，土浦港の各地点のりんの低減が認められ，特に浄化対象水域のりんの減少が大きかった(図 3)。

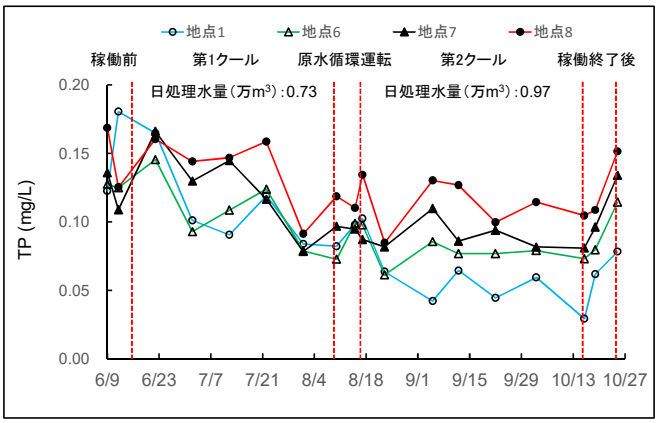

図 3　土浦港調査地点の TP（りん）の変動

植物プランクトン(クロロフィル a)の変化は，浄化施設の稼働により，植物プランクトンの現存量指標となるクロロフィル a の低減傾向が見られたことから，植物プランクトンの減少が示唆される。また，特に，浄化対象水域のクロロフィル減少が大きいことが分かった(図 4)。

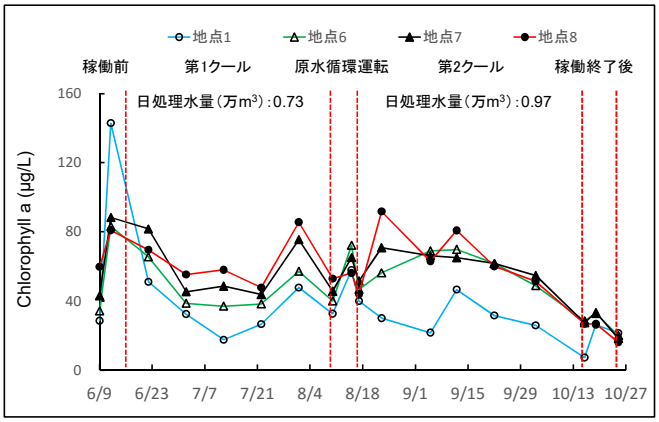

図 4　土浦港調査地点の Chlorophyll a の変動

処理水量増加に伴う土浦港のりんの減少量は，浄化施設の稼働による処理水量の増加に伴って，土浦港のりんの減少は高くなる傾向が認められ，稼働後は稼働前より土浦港のりんが約 23 kg 減少された(図 5)。特に，水域 a のりんの浄化効果が大きい。さらに，浄化施設の連続稼働も霞ヶ浦のりんの削減に寄与していたと考えられる。

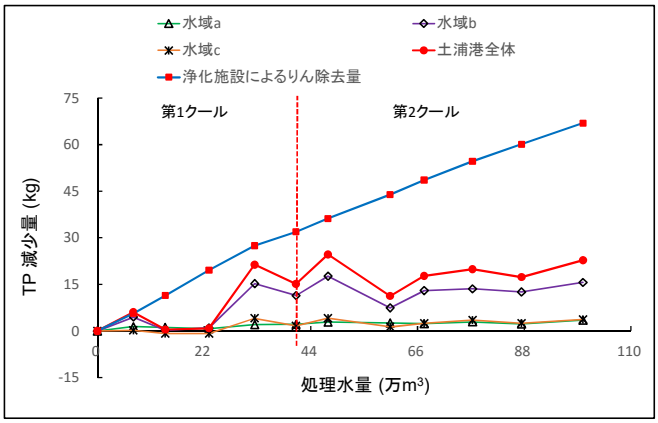

図 5　処理水量の増加に伴って，浄化施設による TP 減少量と土浦港の各水域の TP 減少量の変動

処理水量増加に伴う土浦港の植物プランクトンの減少量は，浄化施設の稼働によって，土浦港のクロロフィル a の減少が認められたことから，土浦港水域の植物プランクトンの減少が示唆された（図 6）。特に，土浦港の奥の水域 a の浄化効果が大きい。

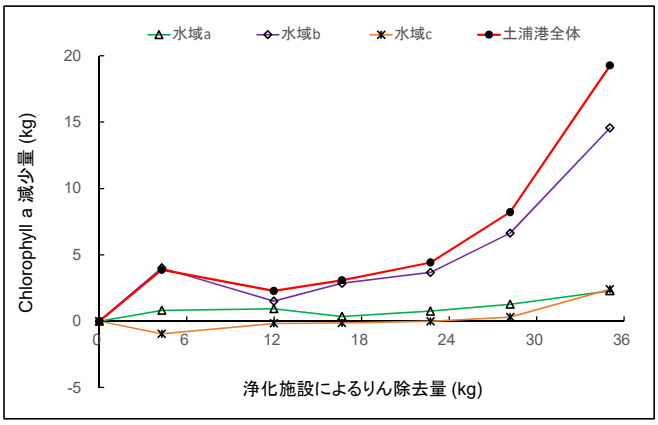

図 6　浄化施設の稼働によるりんの除去に伴って，土浦港の各水域の Chlorophyll a 減少量の変動

4.　まとめ

(1) 直接浄化施設の稼働により，土浦港の水質浄化効果が認められた。また，土浦港の奥の水域は浄化効果が高い。

(2) 処理水量の増加に伴って，土浦港のりんの減少は高くなる傾向が認められた。

(3) 浄化施設の稼働により，植物プランクトンの減少が示唆された。

(4) さらに，土浦港の底泥からのりん等の溶出の調査が必要であると考えられた。

本研究結果より，浄化施設の稼働は，植物プランクトンの発生の抑制に対して有効であると考えられた。

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P3-18

浜名湖における栄養塩類・有機物の長期変動（1995～2017 年）

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キーワード：富栄養化,窒素・リン循環,下水処理,マンケンドール検定

抄録

浜名湖は汽水湖であり，流域には農地・宅地が広がっている閉鎖性内湾である。静岡県が毎月取得している公共用水域データ（1995～2017 年）を用いて，栄養塩類・有機物濃度の長期変動解析を行った。浜名湖（12 点）においては，栄養塩類（アンモニウム塩，硝酸塩，リン酸塩）・全窒素・全リン・溶存酸素の鉛直データを，浜名湖流域河川（5 点）表層水においては，全窒素・全リン・化学的酸素要求量についての解析を行った。トレンド解析はマンケンドール検定を用いて行い、増減傾向を明らかにした。浜名湖におけるリン酸塩・全窒素・全リンはほとんどの観測点・観測深度で減少傾向であった（リン酸塩：1 定点底層水、全窒素：2 定点表層水で増減傾向無し）。流域河川における全窒素・全リン濃度も全ての観測点で減少傾向であった。そのため，浜名湖におけるリン酸塩・全窒素・全リン濃度の低下は流域での下水整備に伴う負荷量減少によると示唆された。

1. はじめに

沿岸域での人間活動により，水域への栄養塩・有機物負荷量は増加してきた。大量の栄養塩負荷は水域での植物プランクトンの大増殖を引き起こし，大量の有機物が生成・沈降する。その結果，底層での有機物分解に伴い貧酸素水塊が発生する。底層の貧酸素化により鉄は 3 価から 2 価へと還元され，吸着していたリン酸塩の一部が溶出する。そのため，貧酸素水塊が形成される水域では堆積物からの栄養塩類の溶出が富栄養化を進行させる要因になることが指摘されている [1]。そのため，水域の栄養塩収支を評価するためには，表層だけではなく鉛直的観測を行うことが必要である。

近年，著しく富栄養化した内湾である東京湾において，下水高度処理水の増加に伴い湾内での栄養塩濃度が減少，さらに貧酸素水塊が縮小し，底層のリン酸塩が減少してきていることが報告されている [2, 3]。そのため，流域下水の高度処理に伴い多くの沿岸海域でも同様の変化がみられる可能性がある。しかし，東京湾流域は下水整備率がほぼ 100%であるのに対し，本研究対象海域である浜名湖は約 80%である。さらに，流域での農業活動も盛んであるため大都市沿岸海域と同様の栄養塩動態が起こるかは不明である。そのため，本研究では浜名湖流域の下水整備が大きく進み始めた 1995 年から現在にかけての栄養塩類・有機物の増減傾向とその変動要因を明らかにすることを目的として研究を行った。

2. 方法

本研究では，静岡県が毎月行っている公共用水域調査データを用いた（1995 年 1 月～2017 年 3 月）。観測は浜名湖 12 定点，浜名湖流域河川 5 定点で行った（図 1）。浜名湖で得られた試水は栄養塩類（アンモニウム塩，硝酸塩，リン酸塩）・全窒素（TN）・全リン（TP）・溶存酸素（DO）の分析を行った。流域河川で得られた試水は TN，TP. 化学的酸素要求量（COD）の分析を行った。全ての分析は日本工業規格（JIS K0102）に従い行った。

各パラメータの増減傾向が統計的に有意であるか否かは系列誤差を補正するために改良されたマンケンドール検定を用いて検証した [4]。

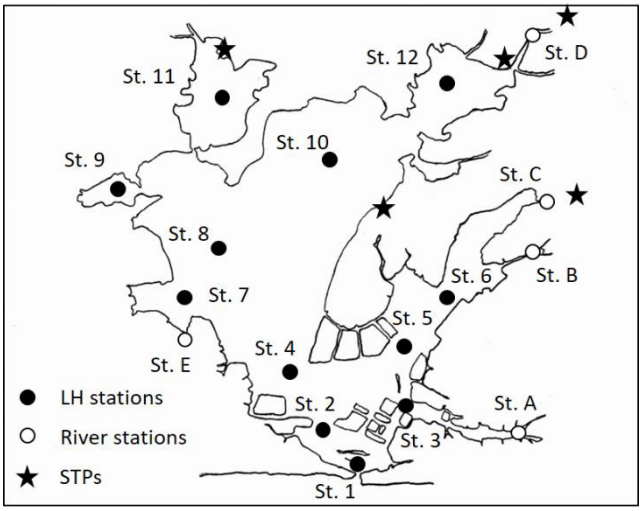

図 1 浜名湖と浜名湖流域河川の観測点

3. 結果

浜名湖表層水における，各パラメータのマンケンドール検定結果を表 1 に示した。減少傾向を示したものは“－”，増加傾向を示したものは“＋”，有意な増減傾向がみられなかったものは“±”で示した。また，*は有意水準 0.05，**は有意水準 0.005 を示している。

浜名湖では，リン酸塩は全ての観測点で減少傾向であった。鉛直観測データでも同様の結果がみられ，St. 3 の 2 m 以外全ての観測層で減少傾向であった。同様に TN，TP でも同様の傾向がみられ，ほとんどの観測点，観測深度で減少傾向がみられた。有意な増減傾向がみられなかった観測点は 2 点（St. 7，11 の表層水）あり，増加傾向がみられた観測点はなかった。アンモニウム塩は St. 1～5 で減少傾向であったものの，その他の観測点では有意な増減傾向がみられなかった。一方，硝酸塩はほとんど有意な増減傾向がみられなかったものの，一部の観測点では有意な増加傾向がみられた。

浜名湖流域河川における，各パラメータのマンケンドール検定結果を表 2 に示した。TN，TP は全ての観測点で有意な減少傾向であった。さらに、COD も St. D を除いて有意な減少傾向がみられた。

表 1 浜名湖表層水における各パラメータの検定結果

観測点	NH_4^+	NO_3^-	PO_4^{3-}	TN
St. 1	−*	±	−**	−**
St. 2	−**	±	−**	−**
St. 3	−*	+**	−*	−*
St. 4	−*	±	−**	−*
St. 5	−*	+**	−**	−*
St. 6	±	+**	−**	−*
St. 7	±	±	−**	±
St. 8	±	±	−**	−**
St. 9	±	±	−**	−**
St. 10	±	±	−**	−**
St. 11	±	+**	−**	±
St. 12	±	±	−**	−**

表 2 流域河川における各パラメータの検定結果

観測点	TN	TP	COD	DO
St. A	−**	−**	−**	−*
St. B	−**	−**	−**	±
St. C	−**	−**	−**	±
St. D	−**	−**	±	±
St. E	−**	−**	−**	+**

4. 考察

浜名湖・浜名湖流域河川共に TN，TP 濃度が減少していたことから，流域河川からの流入負荷減少が浜名湖における栄養塩濃度減少に寄与していることが示唆された。特に，下水処理水量とリン酸塩濃度には有意な負の相関がみられたことから，流域での下水整備率の増加とそれに伴う下水処理水量の増加により浜名湖の水質は改善されていると考えられた。

しかし，アンモニウム塩と TN 濃度が有意に減少しているにも関わらず，浜名湖東部では硝酸塩が増加していた。浜名湖東部は流域の土地利用の大部分が宅地で湖西部に比べ人間活動の影響を強く受けており，相対的に下水処理水の流入量が多くなっている。Azhdarpoor et al. (2016) は一部の硝化-脱窒法による処理方法では，脱窒効率の低下により硝酸塩が増加することを報告している [5]。もしくは，下水処理水と共に流出した硝化細菌により，水域で活発な硝化反応が起こっている可能性もある [6]。その結果，人為的影響をより強く受けている湖東部では TN 負荷量は減っているものの，硝酸塩が増加している可能性が考えられた。

5. 結論

静岡県公共用水域データを用いて，浜名湖の栄養塩長期変動解析を行った。その結果，水域の栄養塩濃度は流域での下水整備率・下水処理水量と相関があることが分かった。しかし，硝酸塩に関しては下水処理効率の低下，もしくは下水処理場からの硝化細菌の流入により増加傾向がみられた。そのため，水域での栄養塩増減傾向を明らかにしていくためには，下水処理水量のみならず，下水処理の各プロセスによる処理効率に着目していく必要がある。

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P3-19

Sustainable Approach to Conserve an Ancient Water Supply Scheme: Salim Ali Lake at Aurangabad, (MS), India

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KEYWORDS: Ancient water supply system, Malik Amber, Nahar- E- Ambari, Salim Ali Lake, Water Quality

ABSTRACT

Salim Ali Lake is one of the historical lake in Aurabgabad city of Maharashtra State which was a planed city in midevial period. Priorly known as, 'Khijjar Talao', later on , 'Delhi Gate Talao' and now known as, 'Salim Ali Lake'. This was an excellent example of the ancient water supply system by means of, 'Nahar- E- Ambari', founded nearabout 400 years ago. Originaly the lake area was 54 acres and now reduces to 34 acres placed and is a hub of migratory birds.

The sewage and effluent from residential and industrial areas may responsible for the contamination of surface water reservoirs. The major factors contributing to the pollution of natural reservoirs of the city are; discharge of untreated sewage and effluent, poor sanitation facilities, dumping of municipal solid waste, erosion from the catchment areas, etc. Aurangabad Municipal Corporation had consructed a 5 MLD Sewage Treatment Plant in April 2013 on a lake basin.

In present study the water quality of Lake and outlet of Sewage Treatment Plant, were analyzed. The parameters such as turbidity, Electrical Conductivity, Total Dissolved Solids, DO and Total alkalinity were not compatible with the prescribed standards .

Availability of sewage treatment plant is a crusial problem at highly populated cities. Lake ecosystem and Sewage Treatment Plant should be studied simulteneously for the sake of conservation. There is an urgent need to improve the efficiency of STP so as to conserve such ancient water supply monument. Therby only we can made harmony with the aquatic ecosystem.

1. INTRODUCTION

Aurangabad is located at the latitude of 19.53^0 north and longitude 75.23^o east. Topographically it is located in the valley region between the Chauka Hills on the north and Satara Hills on the south. The total area of the city is about 138.5 sq.km Containing about 9 lacks population as per the 2001 census. The Salim Ali Lake is consisting of rich flora and fauna. The soil along the lake is muddy and rich in algal biomass and microorganisms. This lake is ecologically important as it provide a suitable habitat for birds. Its shape is rectangular and having an area about 54 acres when it was not surrounded by residential area.[1][2]. Aurangabad corporation was constructed a 5MLD Sewage Treatment Plant in 2012 and was started from April 2013.

The domestic effluent generated from the city area accounts for 107000 CMD while that from the councils is 103000 CMD. Untreated or partially treated domestic effluent has been identified as great concern from river water quality point of view. [3]

In present study the physico-chemical parameters of Sewage Treatment Plant outlet situated near Salim Ali Lake and lake water were analyzed.

2. MATERIAL AND METHODS

The analysis of outlet of STP and lake water was carried out monthly for the duration from April 2013 to December 2013. The parameters were analyzed by standard methods [4][5][6]

3. RESULTS

Table no. 2: Physico-chemical analysis of outlet water samples at Sewage Treatment Plant near Salim Ali Lake.

Sr. no.	Parameters	April	May	June	July	Aug	Sept	Oct	Nov	Dec
1	Temp	38.8	42.5	42.5	35	32.5	27.5	26.4	24.3	23.0
2	Turbidity	**98**	**98.4**	**99**	**98.0**	**92.5**	**90.1**	**88.0**	**85.0**	**81.0**
3	TS	748	739	750	696	715	690	748	630.8	730.8
4	TDS	**724**	**716**	**724**	**674**	**693**	**670**	**723**	**615**	**710**
5	TSS	23.4	22.9	25.1	21.7	22	20	25	15.8	20.8
6	EC	**730**	**725**	**730**	**715**	**727**	**710**	**630**	**650**	**720**
7	pH	7.6	7.4	7.2	7.6	7.23	7.6	8.0	8.5	8.5
8	**DO**	**1.0**	**0.98**	**1.1**	**1.4**	**2.0**	**2.1**	**2.3**	**2.4**	**2.4**
9	BOD	12.4	12.5	12.8	12.13	13.2	14.9	20.4	22.8	22.8
10	COD	45	48	50	52	42	54	58	62	65
11	Alkalinity	215	180	182	179	190	195	210	214	215
12	Total Hardness	180	179	181	184	192	197	202	200	209
13	Nitrate	0.090	0.085	0.095	0.092	0.15	0.17	0.16	0.12	0.15
14	Phosphate	0.0070	0.006	0.0078	0.007 5	0.087	0.095	0.09 3	0.080	0.089
15	Sulphate	92.0	92.1	95.7	93.5	91.0	88.0	83.5	80.6	89.1
16	Chlorides	222	225	239	235	245	250	249	252.9	265

{Note: all parameters are in mg/l except Temp (℃), Turbidity (NTU) and EC ($\mu mhos^{-1}$).}

Table no. 2: Average physico-chemical analysis of water samples at Salim Ali Lake from January 2013 to December 2013

Sr. no.	Parameters	April	May	June	July	Aug	Sept	Oct	Nov	Dec
1.	Temp	38.7	39.7	37.5	34.6	32.3	27	26	24.7	22.3
2.	Turbidity	**58.7**	**59.1**	**59.2**	**57.1**	**54.0**	**52.1**	**51.4**	**49.6**	**45.8**
3.	TS	1464	1469	1500	1485	1656	1194	1063	982	1060
4.	TDS	**1006**	**1013**	**1017**	**1045**	**1082**	**828**	**805**	**775**	**820**
5.	TSS	**457**	**455**	**482**	**439**	**573**	**366**	**258**	**207**	**240**
6.	EC	**330**	**330**	**327**	**325**	**346**	**327**	**314**	**338**	**348**
7.	pH	8.0	7.9	7.8	7.9	7.8	7.9	8.0	8.1	8.3
8.	DO	4.2	3.9	4.1	4.3	5.2	5.6	6.2	6.2	6.5
9.	BOD	**32.95**	**30.5**	**35.4**	**34.8**	**34.3**	**34.2**	**30.9**	**27.8**	**27.4**
10.	COD	135	139	142	147	130	153	156	151	160
11.	Alkalinity	283	276	271	247	256	283	291	331	322
12.	Total Hardness	199	195	197	211	233	243	247	242	259
13.	Nitrate	3.3	3.5	3.3	3.3	3.2	3.2	3.1	3.0	3.0
14.	Phosphate	1.3	1.5	1.3	1.2	1.1	1.1	1.1	1.0	1.0
15.	Sulphate	73.5	77	66.7	157	151	146	138	135	146
16.	Chlorides	239	240	236	232	240	249	241	263	272

{Note: all parameters are in mg/l except Temp (℃), Turbidity (NTU) and EC ($\mu mhos^{-1}$

Table no.3: Water Quality Standards.

Sr. No.	Parameters	USPH Standards	ISI Standards for sewage disposal in Inland Surface water	WHO Standards	BIS Standards	MPCB Standards
1	Temp		Shall not exceed 5℃ above the Receiving water temperature			
2	pH	6.0-8.5	6.0-9.0	6.5-9.2	-	5.5-9.0
3	EC	300	-	-	-	
4	Turbidity	< 5	-	-	-	
5	TS		-			
6	TDS	500	-	500	-	2100
7	TSS		100			100
8	Alkalinity	-	200	-	-	
9	Total	-	300	-	-	

	Hardness					
10	Chloride	250	600	500	600	600
11	Sulphate	<0.3	-	200-400	1000	
12	DO	4-6	3.0	-	-	4-5
13	BOD	4.0	30	-	-	30
14	COD	4.0	250	-	-	250
15	Phosphate	-	5.0	-	-	5.0
16	Nitrate	-	10	-	-	10

{Note: all parameters are in mg/l except Temp (℃), Turbidity (NTU) and EC ($\mu mhos^{-1}$).}

4. DISCUSSION

In present study, the maximum value of Turbidity was 99 NTU of outlet water sample and 59.2 NTU of lake water sample were observed. Both the values are above the prescribed limit. Turbidity in water may be organic or inorganic origin. Maximum turbidity value was reported during rainy season due to inflow of rain water from surrounding area as well as sewage of city.[6] The maximum TDS was 724.9mg/l in STP outlet and 1082mg/l in lake water. The maximum value of Electrical Conductivity 730 $\mu mhos^{-1}$ in outlet water and 348 $\mu mhos^{-1}$ in lake water were observed. All values and above the prescribed limit. The high value indicating that water is loaded with waste water and domestic sewage from several houses showed maximum levels of conductance in the water the presence of larger amount of salts in the sewage water [7]. The dissolved oxygen value was very much less as compared to the prescribed standards [8]. Low content of DO is sign of organic pollution, is also due to inorganic reductants like ammonia, nitrates, and other such oxidisable substances. The total alkalinity of STP water sample was recorded as 215mg/l and 331 mg/l were observed. Both are above the prescribed standards.

5. CONCLUSION

The present study reveals that the parameters like Turbidity, Total Dissolved Solids and Total Alkalinity are above the standards. Outlets of sewage water containing low DO as compared to standard which is harmful for the aquatic life and is containing more Turbidity, Electrical Conductivity and Total Alkalinity.

STRATEGIES:

- There is an urgent need to increase sewage treatment capacity as well as to improve the functioning of the treatment facilities which they have provided.
- There should be some strategic action plans include identification of projects for improvement of the current situation. Even the policies regarding such issues should be reformed.
- The implementation of effective ecotechnologies such as, Bioremediation Technology, Root zone Technology, Green Bridge Technology, Green Lake Technology, and Stream Eco-System (SES) Technology to restore the quality of Salim Ali Lake.
- There should be the development of models for management of Salim Ali Lake water for sustainable utilization.

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P3-20

牛久沼における水質等調査結果について

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キーワード:富栄養化, 水質管理, 牛久沼, COD

抄録

牛久沼は茨城県南部に位置し, 古くから農業用水や漁場として利用されてきたが, 流域の開発が進行し1975年頃から水質が悪化した。そのため, 県では牛久沼水質保全計画に基づき, 湖内及び流入出河川における多地点の水質調査を行っている。その現状を把握するとともに, プランクトン調査, 気象情報収集などをも継続的に行い, 湖内の汚濁機構の解明の手がかりとした。湖心及び流入河川の水質は, 近年(第3期中:2012年～2016年)ではCODが第3期計画目標値(COD:7.2mg/L,TN:1.3mg/L,TP:0.059mg/L)を達成したものの, まだ, 最終的な目標の環境基準(湖内でCOD:5mg/L,TN:0.6mg/L,TP:0.05mg/L)に比べて高く, 引き続き, 調査を継続していく。

1. はじめに

牛久沼は茨城県南部に位置する湖面積3.4 km^2, 平均水深1 mの浅い湖沼[1]であり, 3つの肢節部を有する堰止め湖である(図1)。主に谷田川, 西谷田川, 稲荷川が牛久沼に流入し, 小貝川を経て利根川に流出する。農業用水として利用されるほか, 古くから漁場として親しまれる湖沼であるが, その水質は1975年代後半から悪化した。流域で様々な排出負荷削減対策が行われているが, COD等の項目で水質汚濁に係る環境基準を達成していない。そのため, 牛久沼における湖内及び流入出河川における水質調査を実施し, その状況を把握するとともに, プランクトン調査, 気象情報収集も行い, 汚濁機構解明のための基礎資料とする。

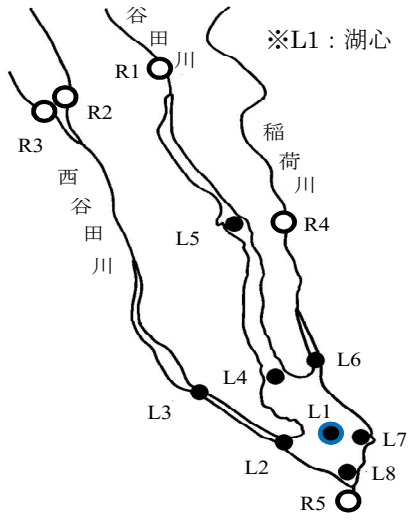

図1 牛久沼調査地点

2. 調査方法

2.1 水質調査

図1に示した地点において, 湖内に設定した8地点(L1～L8)では上層水(水面下 0.5 m)及び下層水(湖底上 0.5 m)をペリスタルティックポンプにより採水した。流入河川(R1～R4), 流出河川(R5:2007年より開始)では, 表層水をステンレス製バケツで採水した。調査期間は2002年4月から2017年3月まで, 毎月1～2回, 行った。現地では水深, 透明度, 水温, pH, 電気伝導率(EC)を測定した。

2.2 分析方法

採取した試料水は当センターに持ち帰り, 次の方法で分析した。化学的酸素要求量(COD)については過マンガン酸カリウム(100℃)による方法により分析した。全窒素量(TN, D-TN)及び全リン量(TP, D-TP)については窒素リン自動分析装置(ブランルーベ社製AUTOANALYZERⅢ)で, 各態窒素量(NO_3-N, NO_2-N, NH_4-N)及びリン酸イオン量(PO_4-P)については形態別窒素リン自動分析装置(ブランルーベ社製 AACS-Ⅱ)で分析した。クロロフィルaの測定については, 試料水を孔径1.2 μmのろ紙(Whatman, GF/C)を用いてろ別し, 得られたろ紙を凍結した後エタノールで1日間抽出し, 浮遊物質を遠心分離(3000rpm, 10分)して得られた上澄み液を分析に供した。分析には, 吸光光度計(shimadzu社製, UV-2550)を用いて吸光度を測定し, ユネスコ法の計算式を用いてクロロフィルa濃度を算出した。pH及びECは東亜DKK製多項目水質計WM-32EPを使用した。

2.3 プランクトン調査

図 1 に示した湖心調査地点（L1）において，植物及び動物プランクトン調査を行った。調査期間は，2005 年 4 月から 2017 年 3 月にかけて月に 1 回～2 回の頻度で行った。

植物プランクトンの調査方法を以下に示す。調査地点でペリスタルティックポンプを用いて上層水を 400 mL 採集し，25%グルタルアルデヒド溶液を終濃度約 4%になるように加えて試料とした。得られた試料についてプランクトン計数板を用いて種ごとの細胞数を測定し，得られた細胞数に 1 細胞当たりの体積を掛けあわせることで生体積を算出した。

動物プランクトンの調査方法を以下に示す。調査地点において小型プランクトンネット（離合社製，5513，目合い 0.1 mm）を用いて湖底直上 0.5 m から湖水面まで鉛直引きし，得られた湖水試料に 25%グルタルアルデヒド溶液を終濃度が約 4%になるように加えて試料とした。得られた試料について植物プランクトンと同様にプランクトン計数板を用いて個体数密度を測定した。

3. 結果と考察

3.1 水質の経年変化

主要な水質項目の経年変化について，図 2～図 5（湖内 8 地点（上層）平均，流入河川 4 地点平均）に示す。

主要な水質項目（COD，全窒素，全りん，クロロフィル a）をみると，過去 5 年（2013 年～2017 年）平均値について COD は湖内では 6.5mg/L～7.4mg/L の範囲，流入河川では 3.8mg/L～5.2mg/L の範囲で推移し，2017 年は上昇したものの長期的に見ると，低下傾向にあった。全窒素は，湖内では 1.5mg/L～1.8mg/L の範囲であった。長期的に見ると，変動幅が小さくなり横ばいの傾向であった。一方，流入河川では 1.9mg/L～2.5mg/L の範囲で推移し，長期的に見ると低下傾向にあった。全りんについては，湖内では 0.06mg/L～0.08mg/L の範囲,流入河川では 0.06mg/L 前後で推移し，長期的には低下傾向にあったが，2013 年以降は上昇傾向にあった。クロロフィル a については，湖内では 42μg/L～56μg/L の範囲で推移し，2007 年以降に上昇傾向が見られたが，長期的に見ると，2017 年は上昇したものの横ばいで推移した。

流入河川についても 5.6μg/L～13μg/L の範囲で推移し，長期的に見ると，2017 年は上昇したものの横ばいで推移した。

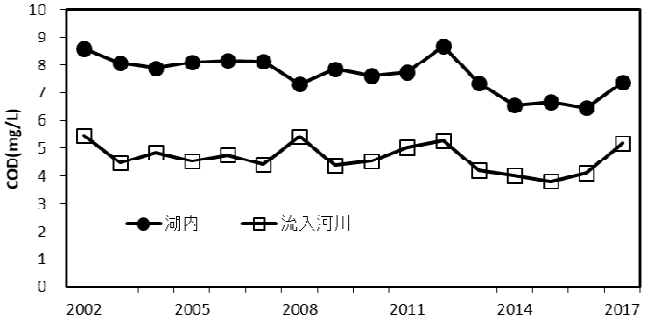

図 2　COD の変化（2002 年～2017 年）

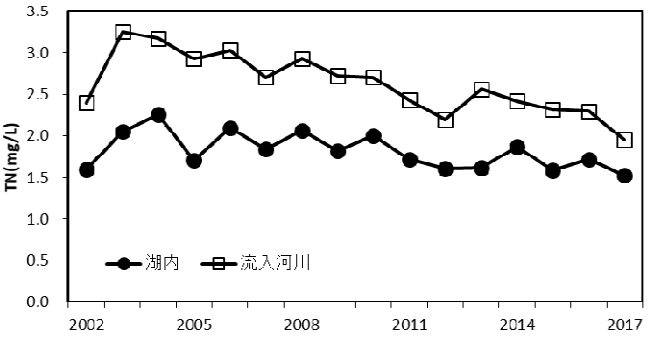

図 3 全窒素の変化（2002 年～2017 年）

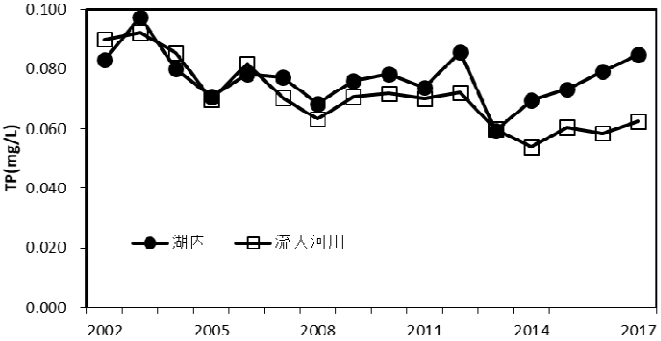

図 4 全りんの変化（2002 年～2017 年）

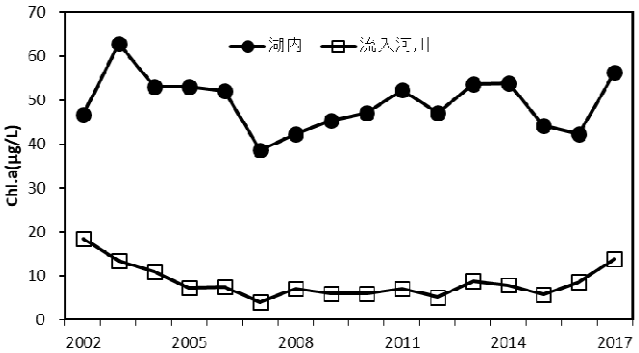

図 5 クロロフィル a の変化（2002 年～2017 年）

3.2 プランクトンの経年変化

プランクトンの経年変化について，図6～図7に示す。牛久沼に出現する植物プランクトンの多くは *Cyclotella* や *Synedra* のような珪藻類である[2]。長期的に見てもその傾向は変わらず，珪藻類（*Aulacoseira* 属）がほぼ優占し，特に春から夏までは群体を作る *Aulacoseira* 属が大きな割合を占めた（図 6）。また，アオコを発生させる *Microcystis* のような水利障害を起こすプランクトンは見られなかった。

動物プランクトンについては，個体数密度で見ると，ワムシ類（*Brachionus*属，*Asplanchna*属）が多く，その他に原生動物やミジンコ類，カイアシ類が見られた（図7）。

4. まとめ

牛久沼の湖内や流入河川の水質の経年変化についてはCODや窒素については減少傾向であるが，全りんについては上昇傾向であった。また，プランクトンについては，長期的な変動は見られず，水利用障害を起こすプランクトンも発生していない。牛久沼については，環境基準（COD:5mg/L,TN:0.6mg/L,TP:0.05mg/L）に比べて高い状態にあるため，今後とも引き続き調査を継続していく。

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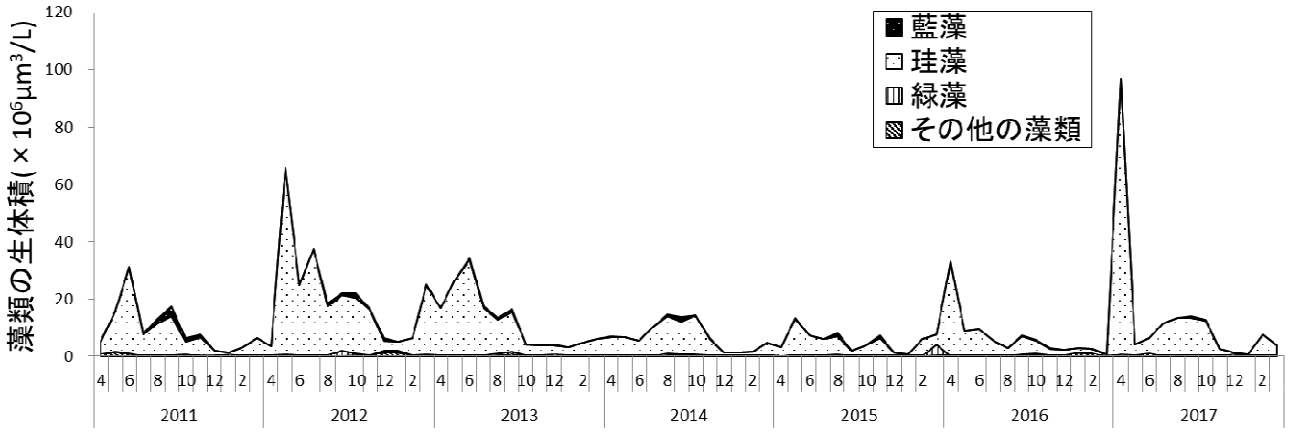

図 6　植物プランクトンの生体積の変化

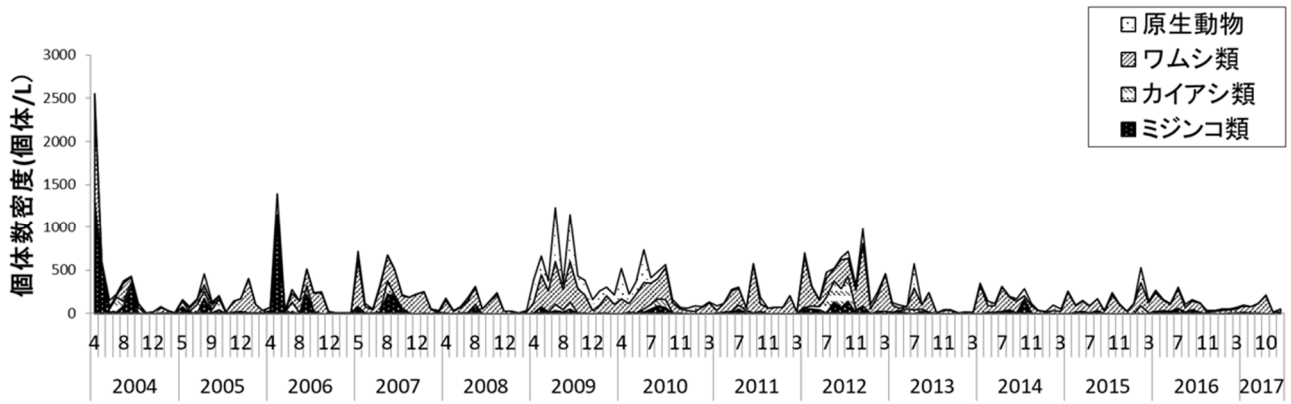

図 7　動物プランクトンの個体数密度の変化

P3-21

Ichtioindicative assessment of Water Quality in Urban Lakes (on the example of Kazan, Russia)

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Keywords: Ichtyoindicative method, Perccottus glenii , Urban Lakes

ABSTRACT

Fishes react sensitively to changes in environmental conditions, in particular the chemical composition of water, suspended matter and bottom sediments. Also, a relatively high degree of adaptation of fish to changing conditions of their life is known, but it is far from boundless.

In this work we investigated the morphometric, parasitological and biochemical features of the *Perccottus glenii* population of some urban lakes in the city of Kazan. The results of the assessment of the state of the aquatic ecosystems of urban lakes using ichthyoindication methods are presented. It was noted that in the Lake Dryanichnoye *Perccottus glenii* is characterized by the most deviating from the norm values of the liver mass index, biochemical blood indices and parameters of helminth infection.

1. INTRODUCTION

At present, a lot of ichthioindicative methods are used to assess the state of aquatic ecosystems. Fishes react sensitively to changes in environmental conditions, in particular the chemical composition of water, suspended matter and bottom sediments. One of the most interesting examples of biological invasions is the dispersal of Amur sleeper (*Perccottus glenii* Dybowski, 1877). There is a relatively high degree of adaptation of this fish to changing conditions of their life, but it is far from boundless. [1].

The aim of this work is to study the morphological, parasitological and biochemical parameters of the Amur sleeper population in urban lakes in Kazan.

2. METHOD

The material for this work was Amur sleeper's statistical samplings (n = 250) collected in 2017 in four Lakes of the city of Kazan: Marino, Maloe Glubokoe, Maloe Lebyazhye, Dryanichnoe. The collection of the ichthyological material was performed using a grid with a cell size of 1 mm. For morphometric analysis, we measured the mass, length, and height of the body. The measurements of length and height were carried out with an accuracy of ± 0.1 cm. Each fish was weighed on an EK 410i laboratory scale with an accuracy of ± 0.01 g.

The content of helminths in fish tissues was determined in the laboratory conditions. [2]. Cestod was fixed with 70% ethyl alcohol, preparations were made in glycerol-gelatin. Species identification of the parasites was carried out using stereoscopic microscopes MBS-10 and Biolar equipped with a Levenhuk C-Series 5M pixel micro-photon array. As the main characteristics of infection of fish with helminths the parasitological parameters of the extent of invasion (the percentage of infection of the host by one species of parasites), the intensity of infestation (the minimum and maximum number of parasites of one species in the host species), the abundance index (the average number of parasites of one species in the host species).

Samples of blood were collected directly when fish catching. Hematological and biochemical blood tests are performed using a biochemical analyzer "Daytona Randox". During the biochemical analysis of serum samples, the content of glucose, lactic acid, total protein and hemoglobin.

Statistical processing of the material was carried out by standard methods using the Student-coefficient and Spearman rank correlation coefficient.

3. RESULTS

According to the morphometric parameters (mass and body length), the Amur sleeper population from all lakes is not statistically significant. The exponential equation of the Amur sleeper's mass dependence on the body length is $y = 74{,}367e^{0{,}0355x}$ (R^2=0,9).

The values of the fish liver mass index from the Lake Dryanichnoye are statistically significantly different and more than 2 times higher than in other lakes.

The complex of intestinal helminths in the Amur sleeper

of reservoirs in Kazan is poorly developed. In all the lakes studied, monoinvasion of fish was detected by a specific cestode *Nippotaenia mogurndae* Yamaguti *et* Miyata, 1940. The highest values of infection rates of rotan N. mogurndae were recorded in Lake Dryanichnoe, where more than 93% of the fish in the samples are infected with a parasite, the intensity of invasion is up to 36 specimens of cestodes in the host. Statistically significant differences in the extent of invasion of rotan *N. mogurndae* were noted for lakes with the maximum and minimum contamination of cestode fish - Lake Dryanichnoe and Glubokoe,

The values of the hematological and biochemical parameters of the Amur sleeper blood in all lakes are within the norm, except the Lake Dryanichnoye. This population is characterized by the smallest concentration of erythrocytes and a low content of hemoglobin and glucose in the blood. On the contrary, there are increased values of leukocyte concentration and a high content of lactic acid in the blood.

4. DISCUSSION

Elevated values of the fish liver mass index may be evidence of high water contamination of Lake Dryanichnoe by toxicants. High values of fish contamination indicators by *N. mogurndae* indicate active feeding of Amur sleeper by the intermediate host of cestoda - a representative of copepods *Mesocyclops leukarti* (Claus, 1857), which has become widespread in many reservoirs of Russia and adjacent territories.
Deviations of biochemical and hematological parameters in the fish from Dryanichnoe lake from the populations of other lakes is an indicator of poor water quality in this reservoir.

5. CONCLUSION

It is noted that in the Lake Dryanichnoye *Perccottus glenii* is characterized by the most deviating from the normative values of the liver mass index, biochemical blood parameters and parameters of helminth infection. In this regard, we can assume that there are unfavorable environmental conditions in this lake due to unsatisfactory water quality.

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P3-22

Coniferous forests and lakes: the impact of pine pollen on water quality

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ABSTRACT

It is believed that in comparison to other types, forest catchments provide smaller quantities of allochthonous matter. Therefore, they seem to be a factor that stabilize functioning of midforest lakes. Some papers point out that forested catchment can provide to the freshwater ecosystems significant amounts of organic matter (humic acids) and trigger lakes humification. We estimated if wind dispersed pine pollen may change water quality and accelerate the increase of fertility of several lakes located in forested areas. We found that pine pollen is rich in nitrogen and phosphorus. Average phosphorus content was about 20 g P kg and nitrogen about 22 g N kg of dry mass of pollen. Based on the field experiment we estimated that during the pollen season (May – June) average pollen deposition is about 12 g d.m. per square meter of the lake. It gives every year provision more than 20 kg of P and over 25 kg of N per one hectare of the lake. According to the laboratory experiment, we provided that pollen fell on the water very quickly release nutrients, and also become a culture for bacteria and fungi. In all investigated lakes we found the increase of concentrations of nitrogen and phosphorus in the littoral zone during pollen season. Certainly these loads of nutrients may stimulate the development of primary producers and FPOM consumers, however this requires further research.

INTRODUCTION

Forested terrestrial ecosystems may strongly affect adjacent freshwater ecosystems. Despite the fact that the most significant loads of nutrients are transported to surface waters from agricultural catchments (Alexakis et al 2013), allochthonous inputs may significantly subsidize midforest lakes (Park et al. 2011). Surface runoff both from deciduous and coniferous forests supply lakes in significant amounts of nitrogen and phosphorus and thus trigger their eutrophication (Klimaszyk et al 2015). Forested catchments can be responsible for the humification of lakes resulting from high quantities of organic matter (humic compounds), transported particularly from the coniferous sites (Steinberg 2003; Klimaszyk and Rzymski 2013). Wind derived forest particles deposited on the lake's surface seems to be less important in lake matter and energy budget, however, we hypothesized that nutrient-rich pollen deposition might accelerate eutrophication of midforest lakes.

MATERIAL AND METHODS

The investigation was carried out in 2017. Six midforest lakes located in the Drawa National Park (North-West Poland) were taken under consideration. The lakes were differentiated according to the morphology (from the small - less than 1 ha to the over 70 ha) and trophic state (from humic to mesotrophic). The common feature of studied lakes was the character of catchment area – 100% overgrown by coniferous pine forest. Several Tauber's traps were installed on the lakes shore during May and June to estimate deposition of pine pollen. Traps were checked every two weeks. The deposited pollens were rinsed with ultrapure water filtered GF/C filter. Filters were inspected with a

stereoscope. After that, they were combusted and measured as ash-free dry weight. To determine the impact of pine pollen deposition on lakes chemistry and biocoenoses, samples of water for chemical analyses and samples of phytoplankton were taken. Samples were taken before (early May) in the middle and after pollen season. Electrical conductivity and pH of water were measured in the field using a YSI 556 Multiparameter Instrument. The following parameters were analysed in the laboratory: ammonium ($N\text{-}NH_4$, using the Nessler method), nitrite (NO_2^-, using the sulphonic acid method), nitrate ($N\text{-}NO_3^-$, using the sodium salicylate method), Norg (using the Kjeldahl method), TP (using the molybdate method after mineralization) and orthophosphate (TRP, using the molybdate method) (APHA 2005). Chlorophyll-a was determined after extraction in the ethanol. Samples for the phytoplankton analyses of the qualitative and quantitative composition of phytoplankton were fixed with Lugol's solution. Analyses were done using a Sedgewick-Rafter chamber with a light microscope Olympus CX 21 LED (400x magnification). Pollen was collected from ripe anthers that were harvested from lower canopies of pine trees overgrowing lakes catchments. Anthers we dried at 40ºC put in the bucket and shaken until pollen, and other debris fell into the bottom. Collected mixture was sieved 500 µm mesh size to obtain pure pine pollen. This procedure was also used to collect pine pollen from trees growing near a high trafficked road. Elemental analysis was performed using the inductively coupled plasma optical emission spectrometer Agilent 5100 ICP-OES (Agilent, USA). A total of 67 chemical elements were analyzed. To estimate the nutrients flushing rate from the pollen the experiment was designed. To each conical flask, 1 g of pollen was placed and flooded with a 300 ml of ultrapure water of known parameters. To imitate lake conditions, the flasks were placed in a thermostat (18°C) and gently shaken. Samples were taken after 1, 3, 6, 9, 12, 15 day of incubation. The pollen residues were filtered with GF/C filter. In obtained water the concentrations of nitrogen, phosphorus, pH, and electrical conductivity were measured according to above-described methods.

RESULTS and DISCUSSION

We found that pine pollen is rich in nitrogen and phosphorus. Average phosphorus content was about 20±2 g kg and nitrogen about 22±3.2 g kg of the dry mass of pollen. We also found that chemical composition of pine pollen depends on environment quality and pollution. Pollen collected near the road contained twice more heavy metals than those from National Park, less polluted area. We also found that during the pollen season (May – June) average pollen deposition is about 12±5 g d.m. per square meter of the lake. It means that pollen deposition provide more than 20 kg of P and over 25 kg of N per one hectare of the lake every year. In all investigated lakes we found the increase of nitrogen and phosphorus concentrations in littoral water. In most of them, the difference of N and P concentration on the beginning and end of pollen period was statistically significant. It confirms earlier observation of Cole et al.(1990) and Graham &Vinebrook (2006), who found that pollen is an important link between coniferous terrestrial and aquatic ecosystems. However, phytoplankton analyses showed that in the most lakes the abundance of phytoplankton decreased during our studies. Total abundance of phytoplankton was the highest before pollen period (early May), and the lowest after pollen period (June). Nevertheless, Chrysophyceae and Chlorophyceae dominated through the whole time. Decreasing phytoplankton abundance may have been caused by the presence of numerous zooplankton, which is often found at the turn of May and June (Lampert et al 1986). Our laboratory experiment confirmed observations made by Lee and Both (2003), who stated rapid decomposition of pollen in water and release of nutrients. We found that maximum release of N and P takes place 3 days after pollen flooding.

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P3-23

Contribution of Nitrogen Deposition to Taihu Lake

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Keywords: nitrogen deposition, water eutrophication, driving force, human activity, Taihu watershed

ABSTRACT

Atmospheric nitrogen (N) deposition represents an important source of reactive nitrogen to ecosystems. However, excessive N inputs could cause adverse ecological effects. In present study, the Taihu basin was taken to explore the characteristics of N deposition and its contribution to water eutrophication. Results show that the annual average of total deposition (TN) and total wet deposition (TN_W) rate were 6154 and 1142 kg km^{-2}, respectively. The TN deposition concentration have a significant negative correlation with the rain intensity (*R=-0.783, P<0.01*). The main N pollutants come from domestic sewage (account for 48.88%) and agriculture (account for 28.17%). TN deposition contributed to the lake was 14400 t N a^{-1} and accounted for 12.36% of annual riverine input of TN.

1. INTRODUCTON

Nitrogen (N) deposition mainly originates from the discharge of nitrogen oxides (NO_x), nitrate nitrogen (NO_3^--N), ammonia nitrogen (NH_3) and ammonium nitrogen (NH_4^+-N) with both anthropogenic and natural sources [1, 2]. Excessive N inputs could cause soil acidification, plant biodiversity reduction, and eutrophication in the ecosystems. Many previous studies showed that the concentration of N deposition to water N loads has been increased [2, 3, 4]. Western Europe, China, and India are the three regions with the highest N deposition in the world in recent years. The primary object of this study is to characterize atmospheric N deposition and calculate the N loads from the inflowing rivers.

2. METHOD

2.1. Study area.

Lake Taihu (29°55′~32°19′ N, 118°50′~121°55′ E), one of China's five major freshwater lakes, as an important water source for water quantity regulation, industry, agriculture, and tourism. The lake water was oligotrophic in the 1950s. However, the water environment system has been destroyed quickly in the mid-1980s due to the rapid industrial, agricultural development and excessive population growth. Many policies and foundation item were initiated, for example, "Zero-point Action" and "Standard Discharge", to improve the Lake Taihu water quality. However, The Lake Taihu water quality has not improved remarkably. The natural environment of Lake Taihu has already significantly deteriorated, and water eutrophication has become serious problems.

2.2. Calculation of nitrogen inputs

This present study, we calculated the main pollutant source from agriculture (chemical fertilizer, livestock and aquaculture), domestic sewage (urban domestic sewage and rural-domestic sewage), and industrial effluents in Table 1 by the method of Technical Specification:

$$N_T = N_A * f_A + N_B * f_B + N_C * f_C + N_E * f_E \quad (1)$$

Where N_T (t N a^{-1}) is total N discharged to surface water, N_i (i = A, B, C, and E) is emission coefficient, f_i (i = A, B, C, and E) is the coefficient into water, A is industrial effluents, B is urban sewage domestic sewage, C is rural domestic sewage, E is agricultural pollution.

3. RESULTS

3.1. Spatio-temporal variation of nitrogen deposition

The main N deposition is dry deposition and accounts for 81.40%. The NH_4^+-N/NO_3^--N ratio is 1.4:1. TN and TN_D deposition rate have an apparent seasonal variation features. The high N deposition rate would promote the bloom of cyanobacteria and aggravate the water eutrophication. TN_D deposition rate has increased rapidly in spring while decreased in summer. Because amount of fertilizer and pesticide spraying may enhance the N deposition in spring.

3.2. Comparisons of atmospheric nitrogen deposition rate listed with other domestic areas

The mean annual TIN_w deposition rate in the Taihu watershed, North China plain, Pearl River Delta and Western China were 2736, 2352, 2267, 446 kg km^{-2}, respectively. The N deposition values of Taihu watershed were higher than others area obviously. However, the TN

deposition values were increased if the dry deposition rate was considered. Because the rainfall in norther China was less than in south. Obviously, the TN deposition load already exceeds the critical eutrophication load in theory which the allowable TN load was estimated to be only 491 kg km^{-2} a^{-1}.

3.3. Correlation analysis between meteorological conditions and wet nitrogen deposition

A significantly negative correlation was found between the concentration of TN deposition and rainfall ($Y=189.268X^{-0.997}$, $R=-0.999$, $P<0.01$), rainfall frequency ($R=-0.783$, $P<0.01$), and rain intensity ($R=-0.783$, $P<0.01$). This phenomenon indicate that the precipitation can clean N nutrients and the light rain clean better than heavy rain. The significant correlation between the meteorological conditions and TN deposition load indicate that high load N deposition would aggravate the water eutrophication.

4. DISCUSSION

To better understand the spatial-temporal distribution characteristics of N deposition and its estimated contributions to water eutrophication. The N deposition of simulated data in the Taihu watershed was investigated. Based on the EQ. (1), the main N pollutants come from domestic sewage (account for 48.88%) and agriculture (account for 28.17%). Compared to the previous studies from 2007 to 2015, the contribution of N deposition to the Lake Taihu has an increasing trend. Obviously, the TN deposition load already exceeds the eutrophication critical load in theory. This phenomenon may potentially accelerate the eutrophication process of the Lake Taihu.

5. CONCLUSION

1) The TN and TN_D deposition have a significant temporal and spatial distribution features.
2) The concentration of TN deposition has a significant negative correlation with meteorological conditions and significant positive correlation with N deposition rate.
3) Total amounts of TN deposition loads contributed to the Lake Taihu accounted for approximately 12.36% of total annual N input via inflow rivers.

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P3-24

Sustainable Utilization of a Crater Lake by Riparian Communities: The Quality of the waters of Lake Bosomtwe in the Ashanti Region of Ghana

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Keywords: Lake Bosomtwe, Water Quality, Seasonal Changes, Ecosystem, Water pollution

ABSTRACT

Water has vital role in all aspects of life with its significance visible in its sustenance to the environment, local economies, food security, ecosystem productivity, and health. The importance of freshwater throughout human history has been seen in its interrelationship with man. The importance of Lake Bosomtwe has been considered in relation to its quality and the services this resource provides, considering the inability of humans to survive without it. The study involved twenty-six (26) riparian communities surrounding the largest Crater Lake in Africa, the Lake Bosomtwe. Water sources such as lake, streams and boreholes used as drinking water sources were collected quarterly for a period of two years. These were analysed bacteriologically for the determination of total and faecal coliform, *E. coli, Aeromonas sp. Enterococcus sp. Salmonella sp*, *Pseudomonas sp* and total heterotrophic bacteria (THB) using Membrane filtration and pour plate. The results showed variation of bacteria counts in all the water sources. The highest *E. coli* counts of $2.9x10^3$ *cfu/100ml* was recorded in the lake and the least in the borehole $2.1x10^1$ *cfu/100ml.* The difference between the total coliform, faecal coliform and *E. coli* counts and the water sources was significant ($p<0.05$). Bacteria in the different water sources had higher bacteria counts during the dry season than the wet season which are statistically significant ($p<0.05$). Drinking these waters without any form of treatments could pose health risk to consumers because of the presence of bacteria from water pollution. These water sources can however be used for domestic purposes.

1. INTRODUCTION

Water is essential for life and the well-being of all people as well as an important natural resource useful for domestic and developmental purposes. The quality of the water sources greatly impacts on the health status of the consumers. Untreated surface and underground water are still commonly used for domestic purposes in many areas in developing countries[1]. This has a true reflection in areas such as communities surrounding the rim of lake Bosomtwe in the Ashanti Region of Ghana. This is a meteoritic impacted lake which is filled by rain and surface runoffs but has no outlet.

This study aims to determine the sustainable utilization of lake Bosomtwe in relation to the bacteriological quality of the water sources (lake, stream and boreholes) used by communities surrounding the rim of the lake as well as establishing the effect of seasonal climate changes on the quality of the water sources.

2. METHOD

This research was carried out within lake Bosomtwe and surrounding communities in the Ashanti Region of Ghana (Fig. 1). A total of 222 water samples were collected from three water sources (lake, streams and boreholes).

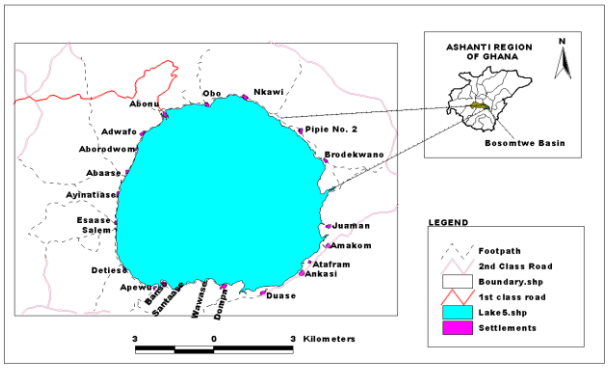

Fig. 1 Map of Study site [2]

Water samples were analysed for the presence and enumeration of total and faecal coliform, *E. coli, Aeromonas sp. Enterococcus sp. Salmonella sp*, *Pseudomonas sp* and total heterotrophic bacteria (THB). All analyses were carried out aseptically using membrane filtration and pour plate techniques. Results were expressed in colony forming unit (cfu) per 100ml and 1ml of analysed sample. The standard procedures for bacteriological analysis of water [3] were followed.

3. RESULTS

All the water sources were contaminated with bacteria in varying colony counts.

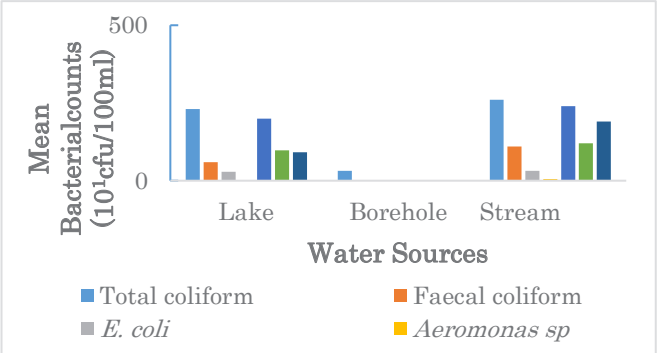

Fig. 2 Bacterial contamination in water sources

The highest mean total coliform counts was recorded in the stream samples (2.6 x 10^3 cfu/100ml) whiles the least count occurred in the borehole samples (3.2 x 10^2 cfu/100ml) Fig 2. The *E. coli* count recorded in the lake ranged from 0 - 5.4 x 10^3 cfu/100ml with a mean value of 2.9 x 10^3 cfu/100ml whiles in the borehole, it ranged from 0 – 6 x 10^1 cfu/100ml with a mean value of 2.1 x 10^1 cfu/100ml. Stream samples ranged from 2 x 10^3 - 4.2 x 10^3 cfu/100ml with a mean value of 1.1 x 10^3 cfu/100ml.

Generally, the bacteria counts recorded in the borehole source were higher during the dry season than the wet season and vice versa for the lake and streams.

4. DISCUSSION

The presence of faecal coliform bacteria and *E. coli* in water gives an indication of faecal contamination by warm-blooded animals. Their occurrence may indicate the presence of other pathogens responsible for infectious diseases such as cholera, gastroenteritis, dysentery, and typhoid fever after ingestion of contaminated water. The high bacteria counts in the lake during the wet season could be attributed to its large surface and its function as a sink, collecting pollutants and therefore exposing it to contamination through runoffs, anthropogenic activities such as swimming, washing of clothes, fishing net and cooking utensils. Also, concentration of piggeries, free range chickens and dogs close to the lake may also account for the high bacteria count in the lake. Run offs from uphill into the streams could account for the high bacteria counts during the wet season.

5. CONCLUSION

Generally, the mean bacteria count in lake, stream and borehole water samples assessed during the study period were bacteriologically unsafe to be used as a drinking water source without any treatment. Bacterial counts recorded do not conform to WHO guidelines and Ghana Standards recommended for drinking purposes. This implies that consumers of these water sources are at risk since the presence of these bacteria could pose health threats such as cholera, gastroenteritis, dysentery, and typhoid fever after ingestion of these contaminated water.

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P3-25

汽水湖中海における無機態窒素の挙動に関する研究

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キーワード:栄養塩動態, 貧酸素, 汽水湖, 亜硝酸, ヒドロキシルアミン

抄録

窒素化学種は自然環境中で微生物などに利用され、形態を変えながら循環している。これまでに私たちは、硝化や脱窒、アナモックス反応の中間体として知られている NH_2OH と N_2H_4 の新規の定量方法を開発した。本研究では、汽水湖中海における NH_2OH と N_2H_4 を含めた無機窒素化学種の挙動から窒素循環のメカニズムを解明することを目的とし、中海全域を対象とした調査を行った。中海は日本海と境水道でつながっており、潮汐の影響を受けて物質交換が起こる。また、日本海から塩分を含んだ密度の高い海水が入ってくる。流入してくる海水には溶存酸素が含まれており、底層への溶存酸素の供給がある。これによって中海の底層は微好気的環境であり、中海の南部では硝化の中間体である NO_2^- や NH_2OH が比較的高濃度で検出された。この結果から、中海では日本海からの海水の流入による酸素供給が硝化や脱窒などの窒素循環に大きな影響を与えていることが示唆された。

1. はじめに

窒素は生物にとって必須の元素であり、様々な形態をとる。有機態窒素はバクテリアによって分解され NH_4^+ となる。NH_4^+ は硝化細菌によりヒドロキシルアミン(NH_2OH)、NO_2^-を経て、NO_3^-になる。NO_3^-は湖沼の溶存酸素がほとんどなくなると、脱窒細菌の働きにより、亜酸化窒素(N_2O)を経て分子状窒素(N_2)になる。脱窒過程の中間体である N_2O は温暖化ガスの一つとしても知られている。

また、近年注目されているアナモックス反応は、NH_4^+ を NO_2^-により還元し、N_2 ガスを生成する反応である。アナモックス反応では中間体として NH_2OH とヒドラジン(N_2H_4)が生成される。そこで私たちは、既存の方法を改良することで、新規の NH_2OH と N_2H_4 の定量法[1] [2]を開発した。本研究では、この新規定量法を用いて、中海における NH_2OH, N_2O 及び N_2H_4 の挙動を把握し、汽水湖中海における窒素循環について解明することを目的とした。

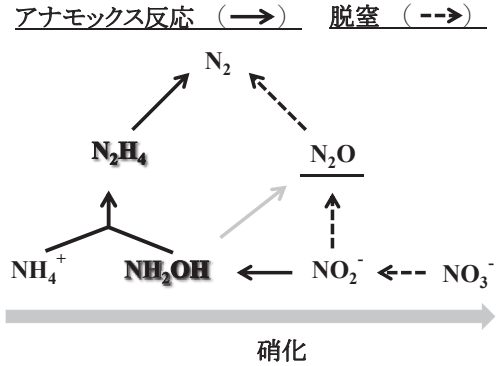

Fig. 1 アナモックス反応のプロセス

2. 調査地点及び調査方法

2017 年 9 月 13 日、島根県の東部に位置する中海の 11 地点(Fig. 2)の底層(湖底上 1 m)において調査、サンプリングを行った。

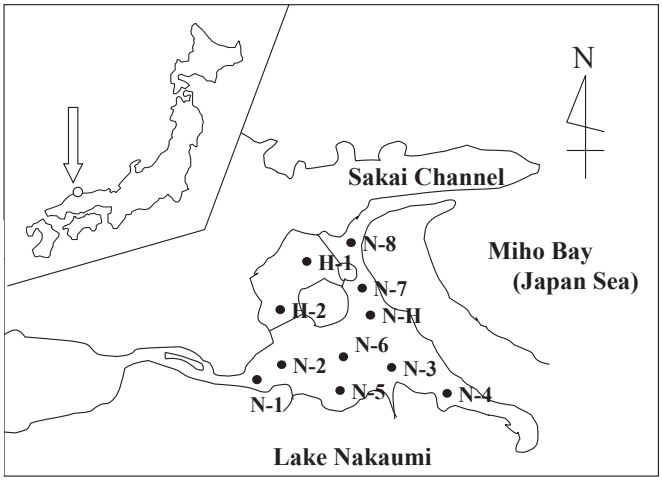

Fig. 2 調査地点

NH_2OH, N_2O は、試料をバイアル瓶に分取し、NH_2OH 測定用試料水には NaClO 溶液を、N_2O 測定用試料水にはホルマリンをそれぞれ添加後、実験室に持ち帰り、N_2 ガスを入れ、気相を ECD 付きガスクロマトグラフ(Shimazu GC－14)を用いて測定した(Fig. 3)。

N_2H_4 は、試料をろ過して発色試薬を添加後、Sep-Pak C18 カードリッジに通水・吸着させて持ち帰り、塩酸・エタノール混合溶液で溶離し、分光光度計(ShimazuUV-1800)で吸光度を測定した(Fig. 4)。

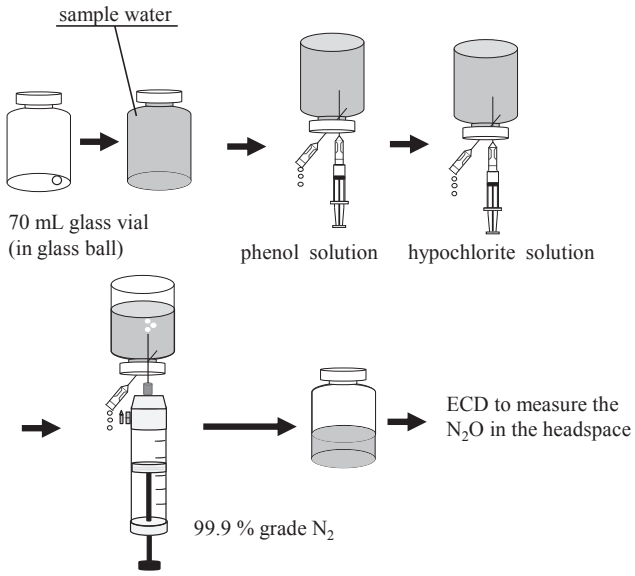

Fig. 3 NH_2OH の新規定量法

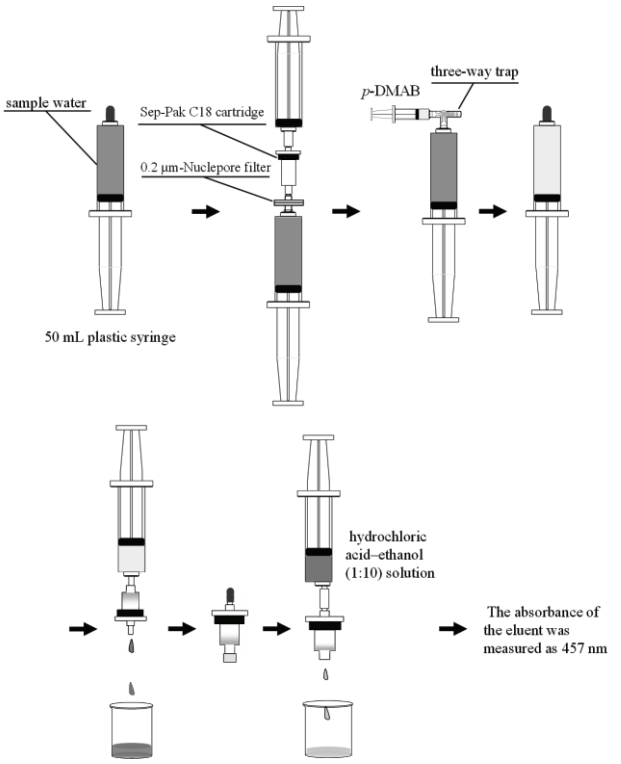

Fig. 4 N_2H_4 の新規定量法

NH_4^+、NO_2^-、NO_3^-は、採水して持ち帰った試料をろ過し、連続流れ分析装置（QuAAtro 39）で測定した。

水中の水温、塩分、溶存酸素は、現場で多項目水質計(RINKO-Profiler) を用いて測定した。

3. 結果と考察

まず、中海底層の溶存酸素の結果を Fig. 5 に示す。中海は日本海と境水道でつながっており、潮汐の影響を受けて物質交換が起こる。また、中海では日本海から塩分を含んだ密度の高い海水が入ってくる。流入してくる海水には溶存酸素が含まれており、底層の貧酸素への溶存酸素の供給がある。今回、境水道に近い N-8 や N-7 は底層でも溶存酸素は豊富に存在していたが、境水道から離れた N-3 や N-4 では貧酸素になっていた。

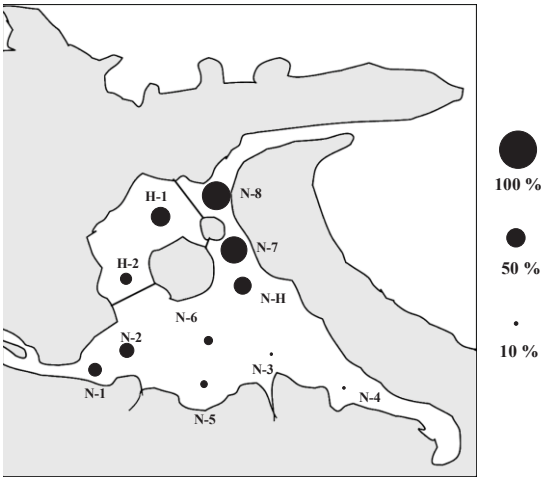

Fig. 5　中海底層（湖底上 1 m）の溶存酸素

次に、溶存無機態窒素の測定結果を Fig. 6 に示す。中海の底層では地点ごとに無機態窒素の濃度に差異があった。これまでに中海では、水深 7 m の底層は光が届くぎりぎりの深度であり、硝化のうち NO_2^-→NO_3^-のパスが光阻害され NO_2^-が蓄積されることが知られている[3]。今回、N-4 や N-H では NH_2OH が高濃度で存在していた。NH_2OHは酸素の少ない微好気的な環境で生成されることから、わずかながら酸素が供給され、硝化が生じていると考えられる。中海南東部や南西部の（N-3 や N-4）では NH_4^+が比較的高い濃度で検出された。これは、溶存酸素を含んだ海水の流入がこれらの地点まで届いていないためと考えられる。

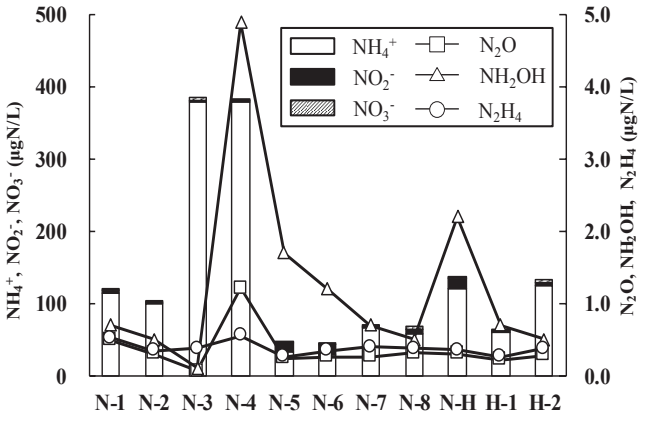

Fig. 6　中海底層（湖底上 1 m）の溶存無機態窒素

4. 結論

汽水湖中海において、新規で開発した NH_2OH と N_2H_4 の定量方法を適用することで窒素循環の解明を試みた。その結果、中海においては、この時期の日本海からの海水の流入による酸素供給が硝化や脱窒などの窒素循環に大きな影響を与えていることが示唆された。また、酸素供給が少ない中海の湖心や南部では、硝化の中間体である NO_2^- や NH_2OH が高濃度で蓄積することが分かった。

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P3-26

Nutrient Dynamics and Trophic State of Lake Tempe in South Sulawesi, Indonesia

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Keywords: nutrient, trophic state, total nitrogen, total phosphorus, floodplain lake

ABSTRACT

Lake Tempe is a floodplain lake that located in South Sulawesi province, Indonesia. Since many years ago, Lake Tempe have been providing great benefit for local people in daily activity and economically. This lake is as great fishery resources, and as nutrient deposition especially in dry season. However, in recent years, some problems occurred in this lake, such as environmental degradation and decreasing fishery production. High sedimentation rate and aquatic plants blooming have degraded environment lake. The local government plan to revitalize this lake by dredging some area of Lake Tempe. However as floodplain lake, there are some zones that have ecological function for fishery as breeding zone and feeding zone. Base on this background, the aim of study is to reveal nutrient dynamic in permanent and nonpermanent zone of the lake. That information will be used to determine the important zone for fishery or agriculture related to the nutrient rich or trophic level of this lake. The results indicated that concentration of dissolved total nitrogen (diss-TN) in nonpermanent inundation zone (zone 1, 2, 3, 4, 5) increased significantly when water level increased (July 2017). The decomposed aquatic plants and residue fertilizer are supposed contribute to increase concentration diss-TN in nonpermanent inundated zone. The concentration of diss-TN was 421 to 996 mg/m^3, it is categorized eutrophic to super trophic state. The concentration of Dissolved Total Phosphorus (diss-TP) was increasing during medium water level, the concentration was higher than 96 mg/m^3, it is categorized hypertrophic state.

1. INTRODUCTION

Lake Tempe is a floodplain lake that located in Wajo, Sidrap and Sopeng regency of South Sulawesi province, Indonesia. The floodplain inundation is very dynamics related to rainy season and dry season. There are permanent zone and nonpermanent zone (temporary zone) In rainy season the temporary inundation zone is very wide, but in dry season the inundation zone is getting smaller then remain permanent zone. When water level increase, the grass and aquatic plants will be sunken, died and decayed. After flood, dissolved inorganic nitrogen (DIN) increased [4]. Finally, this process release nitrate, nitrite, ammonia, phosphate, etc. These nutrients will be used for phytoplankton, zooplankton, aquatic plants, invertebrate organism and small fishes. After flooded, nutrient deposition in nonpermanent inundation zone (temporary zone). This area (lentic) is important site in floodplain lake as ecological function to support sustainability of fishery. High sedimentation rate and blooming aquatic plant blooming have degraded the lake environment. The government plan to revitalize this lake by dredging some area of Lake Tempe.

Base on this background, the aim of the study is to reveal the pattern of nutrient distribution in permanent and nonpermanent zone and to reveal trophic state of Lake Tempe. Trophic status could not be evaluated by examining one or two parameters [5]. In aquatic environment of waterbody, four types of trophic statues can be distinguished: oligotrophic, mesotrophic, eutrophic and dystrophic.

2. METHOD

The study was conducted in Lake Tempe, South Sulawesi Province, Indonesia. Sampling was done in March, May and July 2017. Water samples have been collected from six zones, that representative of permanent inundation zone (zone 6) and nonpermanent inundation zone (zone 1, 2, 3, 4, 5) as shown in figure 1.

Parameter TN, TP, ammonium, chlorophyll-a were analyzed according to Standard Method APHA-AWWA (Anonim, 2015), water samples for TN, TP and ammonia were filtered by membrane filter 0.45 µm. Transparency was measured by Sechi disk. *In situ* measurement was carried out for pH, temperature, DO, TDS, conductivity, ORP by Horiba U-51 Water Quality Checker. Total Suspended Solid was measured by gravimetry method.

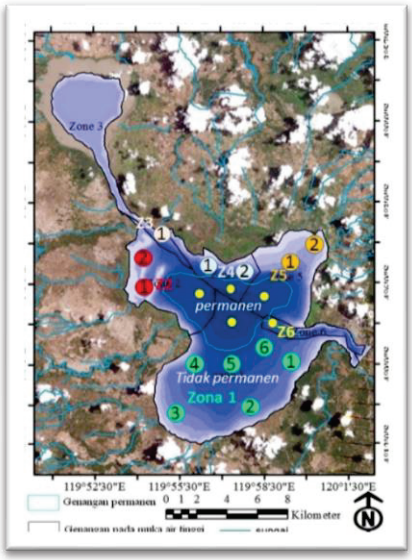

Fig. 1. Sampling sites in Lake Tempe [6]

3. RESULTS AND DISCUSSION

Many methods can be used to assess water quality of the lake. One of assessment methods is evaluating the trophic state. Some parameter such as TN, TP, ammonia, transparency (Sechi depth) and TDS can be used to determine trophic state. Generally, nitrogen and phosphor in aquatic environment origin from agriculture residue and organic materials from domestic wastes. Trophic level also can be observed through algae population or algae density. Concentration of chlorophyll-a in the water also can be used as an indicator to evaluate trophic level. In Lake Tempe, aquatic plants grow well, it is also similar with algae population, therefore by analyzing chlorophyll-a concentration in the water, we can evaluate trophic level of Lake Tempe.

Concentration of dissolved Total Nitrogen (diss-TN) in Lake Tempe was in the range 208 -2445 mg/m^3, it is categorized mesotrophic to supertrophic level [1]. In July 2017, water level was getting high, it was followed by increasing diss-TN concentration in nonpermanent zones (zone 1, 2, 3, 4, 5) as shown in figure.2. The decomposed aquatic plants and fertilizer residue are supposed contribute to increase concentration diss-TN in nonpermanent inundated zone.

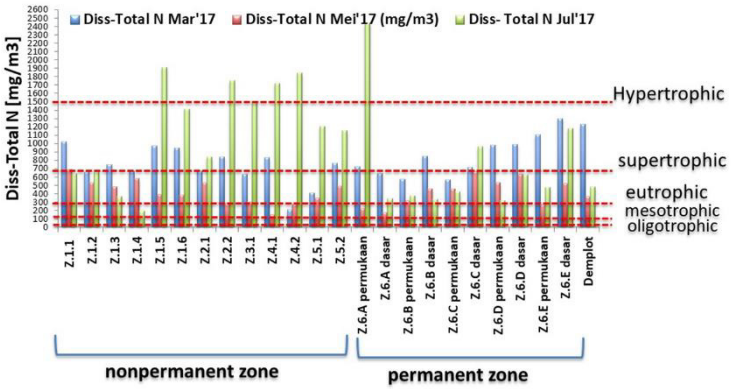

Figure. 2. Trophic state of Lake Tempe with variable Total Nitrogen (TN) concentration

Distribution of dissolved Total Phosphorus (diss-TP) is shown in figure.3. Concentration of dissolved Total Phosphorus (diss-TP) in permanent inundation zone and nonpermanent inundation zone was higher than 97 mg/m^3, it indicated Lake Tempe was in hypertrophic category. Concentration diss-TP increased when water level in medium level, especially in nonpermanent inundation zones.

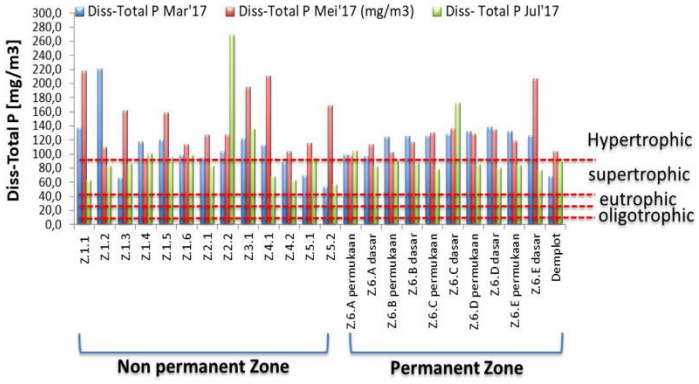

Figure 3. Trophic state of Lake Tempe with variable dissolved Total Phosphorus.

Distribution of concentration chlorophyll-a is shown in figure.4. Concentration of chlorophyll-a in permanent and nonpermanent inundation zone was in the range 1.639 – 26.109 mg/m3. According to Pavluk and Vaate [1], this value is categorized in mesotrophic to hypertrophic level. Comparing the pattern of dissolved TP and chlorophyll-a in permanent and nonpermanent inundation zone (figure 3 and 4.) showed similar pattern, it indicated source of dissolved TP originated from aquatic plants and algae in Lake Tempe.

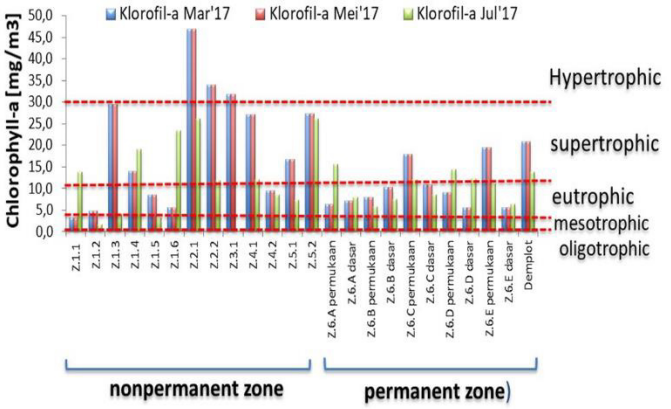

Figure. 4. Trophic state of Lake Tempe with variable Chlorophyll-a

In Lake Tempe, ammonia could be sourced from fishes excretion or aquatic plant degradation. Through mineralization process from those nitrogen sources and resuspension from sediment to the water, ammonia will be formed about 45.34 mg/mg/m^2/day and resuspension to the water about 1.29 mg/mg/m^2/day, and nitrification is about 39.72 mg/mg/m^2/day [3]. High concentration of ammonia was found in March 2017, in zone 6 (permanent inundation zone) as shown in figure. 5.

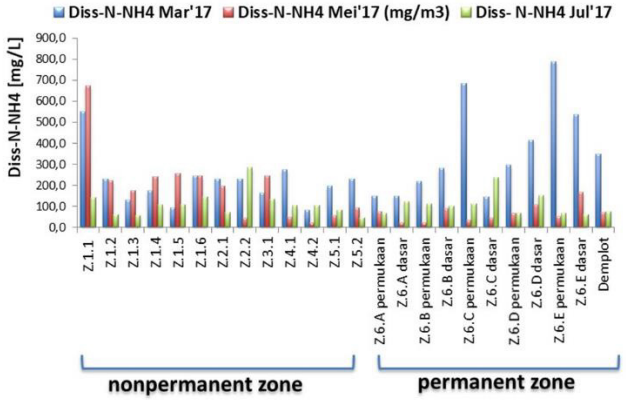

Figure. 5. Concentration of dissolved N-NH$_4$ in nonpermanent and permanent zone of Lake Tempe

Beside nutrients parameters, transparency (sechi depth) also could be an indicator for trophic state. Transparency in Lake Tempe was in the range 9 to 103 cm, it was categorized hypertrophic to supertrophic, according to Pavluk and Vaate [1]. Increasing suspended solid, aquatic plants and algae blooming could decrease transparency of water.

Based on the pattern of nutrient distribution and transparency as discussed above, Lake Tempe could be categorized in eutrophic to hypertrophic state, related to seasonally change.

4. CONCLUSION

Lake Tempe as a floodplain lake has high nutrient deposition. Lake Tempe could be categorized eutrophic to hypertrophic state. This trophic state could not be said good or poor water quality, it depends on the utilization of the water. This information can be useful for management of Lake Tempe. When Lake Tempe will be utilized for fishery and agriculture, the existing of the nonpermanent inundation zone should be maintained because here is valuable zone for fishery as breeding and feeding zone, also for agriculture as paddy field.

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P3-27

Paper title：Study on the growth of *Peridinium umbonatum var. Inaequale* and *Scenedesmus bijuga* with different organic phosphorus sources

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Key words: organic phosphorus; triethyl phosphate; *Peridinium umbonatum*; *Scenedesmus bijuga*

ABSTRACT

Phosphorus plays a vital role in algal growth, and organic phosphorus is an important part of it. It is of significance to study the growth and competition by different forms of phosphorus for better understanding of the difference. From the aspect of organic phosphorus, the PM4A plate (61 forms of P) was used as experimental P sources in this research. We use the PM4A to cultivate *Peridinium umbonatum var. Inaequale* and *Scenedesmus bijuga* and Distinguish the growth of algal and competition by different forms of organic phosphorus. In the mono-cultures, there were 12 forms and 21 forms of organic P could promote the growth of Peridinium umbonatum var. Inaequale and Scenedesmus bijuga,respectively.Besides,Pyrophosphate,Thiophosphate,Dithiophosphate,O-Phospho-D-Serine,O-Phosphoryl-Ethanolamine and Thymidine- 5'- monophosphate can promote the growth of two algae. The utilization of some organic phosphorus (Triethyl Phosphate, O-Phospho-D-Serine) by two algae were obviously higher than some inorganic phosphorus (Tripoly-phosphate, Pyrophosphate). In the co-cultures, those who could encourage the growth earlier still showed an acceleration. Compared with mono-culture, the promotion was more significant. For *Peridinium umbonatum var. Inaequale,* the promotion was further enhanced. The effective organic phosphorus promote the growth of *Scenedesmus bijuga* up to 40 forms. In a word, both of the two algae have a selectivity to utilize different organic phosphorus in the mono-culture and the co-culture. *Peridinium umbonatum var. Inaequale* has a better utilization on nucleotide phosphate and glucose phosphate. While *Scenedesmus bijuga* has a better utilization on nucleotide phosphate, amino acid phosphate and phosphoGlyceric acid. Two algae have a higher bioavailability to organic phosphorus bond C–O–P than C–P. The most significant organic phosphorus source for the promotion of *Peridinium umbonatum var. Inaequale* was triethyl phosphate.

1. INTRODUCTION

Inorganic phosphorus and organic phosphorus are the main types in aquatic ecosystems, organic phosphorus is an important component of total phosphorus which exists in the sediments. Generally, inorganic phosphorus can be directly utilized by most algae, which is the predominant bioavailable phosphorus fraction for the growth of algal[6]. Researches showed that alkaline phosphatase hydrolyze some organic phosphorus, which can be directly used by algal. Some of algae even had a better utilization than IP[7]. Those who can use OP effectively would became the dominant algae species when P is scare[8].

There were differences in phosphorus content in water areas. And the proportion of organic phosphorus is also different, then influenced the phytoplankton community succession. In order to research the growth and competitiveness of *Peridinium umbonatum var. Inaequale* and *Scenedesmus bijuga*, the PM4A plate was used as experimental P source. At the beginning, we used this biolog technology to cultivate the two kinds algae separately, and then mixed them together in laboratory. In the end, the mechanism and effect of algal growth will be identified. And the results may explain the influence by different forms of organic P. What's more, our study may provide a basis to control and predict the blooms when a dominant species in eutrophical water.

2. METHOD

2.1 Algal strains and cultivation

Peridinium umbonatum var. Inaequale and Scenedesmus bijuga were obatained from Freshwater Algae Culture Collection of the Institute of Hydrobi-ology, Chinese Academy of Sciences (FACHB). *Peridinium umbonatum var. Inaequale*（FACHB-329）and *Scenedesmus bijuga*（FACHB-76）were cultured in self-made 119 and SE medium（Appendix 1）, respectively. The algal biomass was kept at 25 ℃ with a light intensity of 2000 Lux under a 12/12 h light/dark cycle in an light incubator until reach the exponential growth phase.

2.2 Algae cultivation and experimental design

Different sources of phosphorus were purchased from PM4A plate, including 61 kinds of phosphorus sources (four kinds of DIP). In super clean bench, adding 200 uL sterile water into PM4A plate's micropores to dissolve all kinds of phosphorus resources as the mother liquor. Then pack into 0.5mL centrifuge tube, kept at low temperature after sterilization. *Peridinium umbonatum var. Inaequale* was added in the culture media, which inorganic phosphorus was not added for 2 days. Shake it well, and then equal amonts of 150 uL inoculum were added to biolog plate. After that, 50 uL of different phosphorus sources was added on each hole and cultured in the medium for 20 days. At this time, each biolog plate have 200 uL solution. The biomass density is 1.13×107 cells/L. Detectiving biomass per day by Microplate reader （ Perlong DNM-9602）.*Scenedesmus bijuga* 's inoculation and operation is similar. The initial biomass is 4.45×109 cells/L. All mediums were kept at 25 °C with a light intensity of 2000 Lux under a 12/12 h light/dark cycle for 20 days. In order to prevent the evaporation from the biolog plate, two PM4A plates were put on transparent zip-lock bag and opened in a UV sterilization stage. The competitive effects of the two species of algae were made by co-culture experiments.

The cell ratio of two kinds of algae is approximately 50:1, the well density ratio is 1:50. The cell density was determined using a light microscope, then follow the concentration ratio to inoculate *Peridinium umbonatum var. Inaequale* and *Scenedesmus bijuga.* After shaking well, we added different phosphorus sources on each hole, which concentration is same as PM4A plate. Other conditions were the same as mono-cultures. There are three groups in this study. The experimental period is 18 d and each group has a parallel sample and samples were collected each 6 days. We used 0.5mL solution and added in centrifuge tube. Algal cells were fixatived in Lugol's solution and counted by microscope.(400× magnification, Motic, BM-1000, Guangzhou).

2.3 Statistical analysis

SPSS 19.0 was used to investigate the variance and correlation analyses.

3. Results

3.1 Growth curve of algal strains under different organic phosphorus sources

The biomass density of two algal species varied greatly after 20 days with different organic P. List of phosphorus sources that promote algal growth are shown in Fig.1 indicates that the final result of proliferation. There are 22 forms P sources could promote the growth of *Peridinium umbonatum var. Inaequale* and *Scenedesmus bijuga*. At the end of experiment, *S. bijuga* has higer biomass. The maximum biomass by Cytidine-3'-monophosphate is 3.05×10^{10} cells/L.

As for *Peridinium umbonatum var. Inaequale*, there are 12 forms of P sources, which obviously stimulated the proliferation. In the mixed cultures of *P. Inaequale* and *S. bijuga* (purple parts in Fig.2), *Scenedesmus bijuga* has more forms of effective IP than *Peridinium umbonatum var. Inaequale*. Phosphorus source growth factors (GF for short) niche of two algal strains of were obtained after dealing with proliferation treatment. Gf reflects the phosphorus sources that promote the growth of algae, in which has 17 forms and 6 forms of phosphorus sources that enhance the growth of *Peridinium umbonatum var. Inaequale* and *Scenedesmus bijuga*, respectively. Besides, there are 6 forms of P sources stimulate them both.

Compared with inorganic phosphorus, organic phosphorus had a significant promotion on algal growth. And the effect of *P. Inaequale* is more remarkable. The results showed that there are 19 forms of organic P that have promotion on *Peridinium umbonatum var. Inaequale* . Including Nucleotide, Glucose, etc.. The most effective types of OP for *Peridinium umbonatum var. Inaequale* promotion are Triethyl Phosphate(gf=3.038). Although there are few organic phosphorus species promoting *Scenedesmus bijuga* growth, the growth promotion was obvious, which confirmed that *Peridinium umbonatum var. Inaequal* could boom in P-limited environments.



Figure 1. Growth dynamics of *Peridinium umbonatum var. Inaequale* and *Scenedesmus bijuga* with different phosphorus sources.

On the left side of the graph for different organic phosphorus source list, and the green background was the organic phosphorus that can significantly promote *Scenedesmus bijuga* growth, orange background represents the organic phosphorus can significantly promote the *Peridinium umbonatum var. Inaequale* growth, purple for organic phosphorus two taxa algae can effectively utilized , frame bar color depth reflect the different periods of algae cells density.

3.2 Competitive growth of two strains

In the mixed cultures, in the first 6 days of mixed cultures, *Peridinium umbonatum var. Inaequale* had utilized 23 forms of P sources to promote its growth, which is more 6 kinds than mono-cultures. There are 22 forms of P sources that boost its growth, which is more 1 kind than mono-cultures. There were 8 kinds of phosphorus sources which promoted the growth of two algae, which is 2 kinds more than mono-cultures. In mono-culture experiment, phosphorus sources have a significant promotion on *Peridinium umbonatum var. Inaequale*. And the effect is remarkable than *Scenedesmus bijuga*. Similar result was also found in co-cultures. On day 12 in the mixed cultures, for *P. Inaequale*, the cell density stared to decrease compare with the previously. The biomass density of *S. bijuga* greatly increased. The results suggested that *Scenedesmus bijuga* could grow in their available phosphorus source. In the meantime, it also showed that those Phosphorus sources stimulated *Peridinium umbonatum var. Inaequale* growth. In view of the algal growth, it is clear that IP promotion growth of *Peridinium umbonatum var. Inaequale* . On day 18 in the mixed cultures (Fig.4c), *Peridinium umbonatum var. Inaequale* had just 27 forms of effective P. But the forms of P sources to promote *P. Inaequale* growth have increased by 10 than mono-cultures. The forms of valid P for *Scenedesmus bijuga* had risen to 40. A greater cause for two algae is that the increase of P sources. For instance, there are 22 forms of P sources stimulatory effects on two kinds of algal growth, which has almost quadrupled than mono-culture. As the culture continues, significant difference was showed in algal growth between different forms of P source. For example, *Scenedesmus bijuga* had declined in Triethyl Phosphate'culture, whereas *P. Inaequale* was promoted. Meanwhile, the growth of *S. bijuga* was promoted whereas *P. Inaequale* growth was depressed in β-Glycerol Phosphate（gf=1.50）.

5. Conclusions

In this study, *Peridinium umbonatum var. Inaequale* and *Scenedesmus bijuga* were cultured alone and mixing together with different organic phosphorus, the following results are obtained:

In the mono-cultures, both P*eridinium umbonatum var. Inaequale and Scenedesmus bijuga* could utilize organic P for their growth. Moreover, they show a different P selectively on different P substrates. There are 12 forms of DIP and 21 forms organic P could promote the growth of *Peridinium umbonatum var. Inaequale and Scenedesmus bijuga,* respectively. Among them, five of which could promote the effective growth of the two algae. Our results showed that the utilization of some organic P by two species of algae was obviously higher than some inorganic P .

In the co-cultures, the promotion effect of different organic phosphorus on the two algae was more significant. For *Peridinium umbonatum var. Inaequale*, the promotion was enhanced, while increasing the effective types of organic phosphorus on *Scenedesmus bijuga*'s growth. *Peridinium umbonatum var. Inaequale* has a better utilization on nucleotide phosphate and glucose phosphate. Two forms of algae have a higher bioavailability to organic phosphorus bond C–O–P than C–P. The most significant organic phosphorus source for the promotion of *Peridinium umbonatum var. Inaequale* was Triethyl Phosphate, which indicates that *Peridinium umbonatum var. Inaequale* has a specificity of utilizing triethyl Phosphate.

P3-28

諏訪湖における藻類群集に及ぼす栄養塩組成の影響

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キーワード:栄養塩動態, 一次生産, 生態系機能

抄録

本研究では諏訪湖における栄養塩組成と植物プランクトンの関係を明らかにするため，湖水中の窒素，リン，シリカと植物プランクトン細胞数の季節変動を観察した. 諏訪湖の湖心および流入・流出河川において採水し，水中の窒素, リン, シリカ濃度を測定した. また, 湖水中のクロロフィル濃度の測定と藻類細胞数を計数した. 1979 年・2016 年・2017 年には DIN 制限が認められた．また，1979 年・2017 年には DSi 制限が認められた. 1979 年・2016 年・2017 年ともに各栄養塩制限の影響と考えられる藻類組成の変化が確認された．また，経年的な湖水中の栄養塩比の変化は下水道の整備による浄化が進んだことや, 増殖した珪藻によるシリカの取り込みによって引き起こされていると考えられ, それらによって夏期に優占する藻類の組成が変化したと考えられた.

1. はじめに

長野県中央部に位置する諏訪湖では，2007 年までは主にミクロキスティスを主とした藍藻が夏期の植物プランクトン種であった（花里・朴，2008）[1]. 現在では藍藻とともに珪藻も主要な植物プランクトン種であることが確認され，近年夏期の主要な植物プランクトン種の組成は大きく変化している. 一般に, 植物プランクトンの種組成は水温や栄養塩（窒素・リン・シリカ）濃度のほかに, 栄養塩組成の影響も受け, 富栄養化が進むと相対的に溶存態シリカが不足し，非珪藻類が優占すると言われている（原島，2005）[2].

諏訪湖では，湖水中窒素・リン濃度は 1970 年代から長期間計測されており，それらは減少傾向にあることが知られている（宮原，2013，2018）[3, 4]. 一方，湖水中シリカ濃度は 1971 年から 1972 年（倉沢，1973）[5]・1977 年から 1978 年（沖野ほか，1978）[6]以外，通年では測定されていないため，現在，諏訪湖水中の窒素・リン・シリカはどのような組成か不明である. そこで，本研究では諏訪湖における栄養塩と植物プランクトンの関係を明らかにするために，窒素・リン・シリカ濃度と植物プランクトンの季節変動について観察を行った.

2. 方法

2015 年 7 月から 2017 年 12 月において，諏訪湖湖心（36° 02’ 50” N, 138° 05’ 14” E）でカラム型採水器を用いて採水した. また，同期間において，諏訪湖の流入・流出河川の河川水も各河川の河口に近い橋の上から，ロープをつけたバケツを用いて採水した. これら試水は，いずれも孔径 0.45 ㎛のメンブレンフィルターでろ過した. また，植物プランクトンの計数のため，湖水を中性ホルマリン（1.5%）で固定した.

測定対象とした試水中の各形態の栄養塩濃度およびクロロフィル（Chl.a）濃度や藻類細胞数を図 1 に示した.

全窒素，溶存態全窒素はアルカリ性過硫酸カリ加圧分解法に基づいて分析した. 硝酸態窒素, 亜硝酸態窒素およびアンモニア態窒素はイオンクロマトグラフを用いて測定した. 溶存態無機窒素（DIN）はイオンクロマトグラフで測定した硝酸態窒素，亜硝酸態窒素およびアンモニア態窒素を合算し算出した. 生物態窒素（BN）は全窒素から溶存態全窒素を差し引いた懸濁態窒素の値とした.

全リン, 溶存態全リンは, それぞれ試水原液およびろ液を，ペルオキソ二硫酸カリウム溶液を用いてリン酸態リン（PO_4-P）に分解し，下記の PO_4-P と同様の方法で測定した. PO_4-P はモリブデンブルー法に基づいて分析した. 生物態リン（BP）は全リンから溶存態全リンを差し引いた懸濁態リンの値とした.

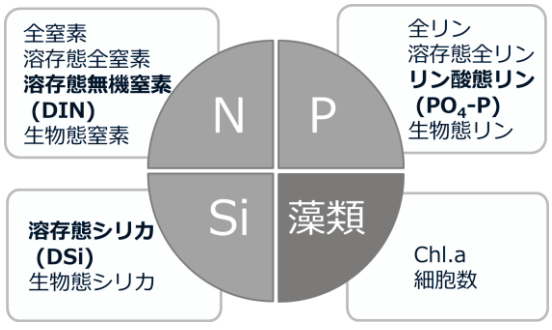

図１．測定項目

溶存態シリカ（DSi）はモリブデンイエロー法に基づいて分析した．生物態シリカはろ過に用いたメンブレンフィルターをアルカリ抽出する（中嶋さやかほか，2006）[7]ことで溶存態シリカと同様の方法で測定した．

クロロフィル（Chl.a）濃度はユネスコ法で測定した．試水を GF/C でろ過し，その GF/C をアルコール抽出した抽出液の吸光度からクロロフィル濃度を算出した．

植物プランクトンの組成は試水に含まれる藻類細胞を光学顕微鏡下で同定したのち計数することで求めた．

諏訪湖におけるシリカの収支を推定するにあたって，流入・流出河川のシリカの年間移動量は流量に濃度を乗じて算出した．湖内でのシリカの沈降量は，諏訪湖湖心にセディメントトラップを水深 5m に一昼夜設置し，得られた沈殿物を凍結乾燥し，分析に供した．底泥からのシリカの溶出量は，ポリエチレンビンの中に諏訪湖の底質と全層水ろ液を入れ，15℃，pH7-8 でコントロールしながら実験室内で 30 日間静置し，水中の溶存態シリカ濃度の変化を観測することで求めた．

3. 結果および考察

植物プランクトンにとって，最適な水中の栄養塩比は植物プランクトン自身の体組成比と考えた．そこで，諏訪湖における植物プランクトンの体組成比を調べると，窒素:リン:シリカのモル比は，18.8：1：92.6（平均）であった．この諏訪湖の植物プランクトン体組成比は，海洋の植物プランクトンを構成する栄養塩の平均組成であるレッドフィールド比（N:P:Si＝16:1:15）に比べシリカの比率が大きい．陸水におけるシリカの起源はケイ酸質岩石からの溶け出しと言われており，この結果は淡水湖沼の特徴を反映してると言える．この比と湖水中の溶存態栄養塩比を比較することで栄養塩の欠乏状況の評価を行った．

2016 年の諏訪湖の溶存態栄養塩比と植物プランクトンの体組成比を図 2 に示した．2016 年 4 月から 8 月の湖水中の DIN/PO_4-P 比や DIN/DSi 比は上記の植物プランクトンの体組成比よりも低く，この間の諏訪湖は DIN 制限にあったと考えられた（図 2）．また，2016 年 4 月から 5 月にかけて，Chl.a 濃度および植物プランクトン細胞数の減少から植物プランクトン量の減少が確認された．さらに，同年 4 月には見られなかった窒素固定型の藍藻である *Anabaena* が 8 月と 9 月に確認された．これらの藻類の量や組成の変化は DIN 制限の影響と考えられた．

一方，2017 年の諏訪湖の溶存態栄養塩比と植物プランクトンの体組成比を図 3 に示した．2017 年の栄養塩

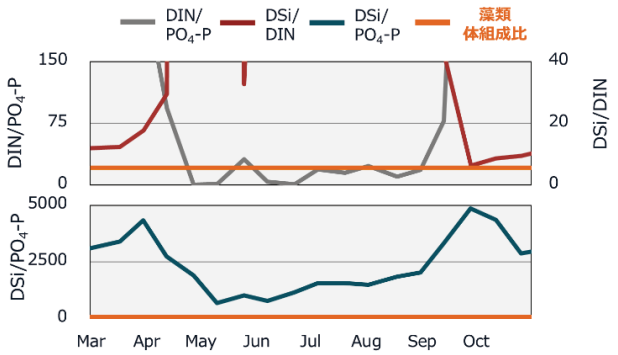

図 2 ． 諏訪湖栄養塩比（2016 年）

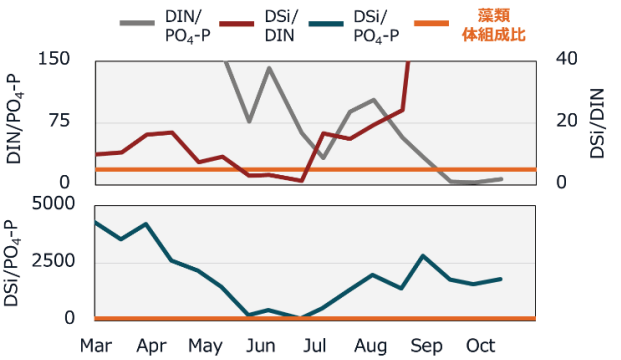

図 3 ． 諏訪湖栄養塩比（2017 年）

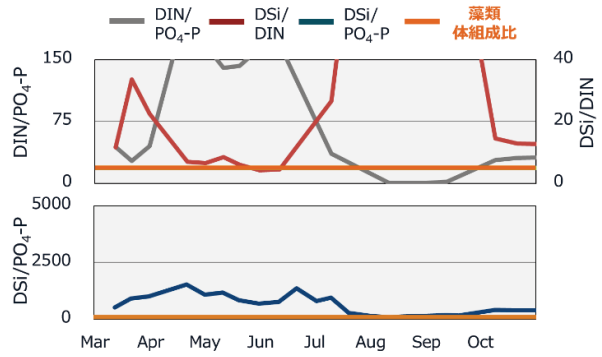

図 4 ． 諏訪湖栄養塩比
（1977 年（沖野ほか，1978 より））

濃度は 2016 年と同様の季節変動を見せたが，この湖水中の栄養塩比を植物プランクトンの体組成比と比べてみると，2017 年の 5 月から 6 月は DSi 制限，9 月から 10 月は DIN 制限にあったと考えられた．同年 5 月から 7 月にかけて，珪藻類の細胞数は減少した．この珪藻類の量の変化は DSi 制限の影響とも考えられた．

これら 2016 年，2017 年の栄養塩比から，DIN 制限は諏訪湖の特徴であり，DSi 制限は 2017 年の特徴であると言える．2017 年の DSi 制限は，DSi 濃度の減少によるものであるが，その時期の流入河川の DSi 濃度に大きな減少は認められなかった．2017 年 4 月から 6 月では，2016 年 4 月から 6 月に比べ珪藻細胞数が多かった．2017 年の DSi 制限は，2016 年に比べ何らかの理由でより増殖した珪藻による，シリカの取り込み量の増加が原因と考えられた．

現状を過去と比較するために，1977 年の栄養塩比（沖野ほか，1978）も同様の方法で評価した．1977 年の諏訪湖の溶存態栄養塩比と植物プランクトンの体組成比を図 4 に示した．1979 年は 2016 年・2017 年と同じく DIN 制限が見られたが，2016 比べ制限がかかる時期が遅く，その期間が短かった（図 4）．また，DSi 制限となる期間も見られた．そこで，1977 年から 1978 年と 2016 年の湖水全層水中の各溶存態栄養塩平均濃度を比較するとと，DIN は 35%，PO_4-P は 11%，DSi は 62%に減少していた．DSi 濃度も減少していたが，DIN・PO_4-P のほうがより大きく減少していた．これによって，1977 年よりも 2016 年の方が DIN 不足の期間は長くなり，1977 年に見られたシリカ不足は 2016 年には生じなかったと考えられた．以上から，下水道の整備による浄化が進んだことで湖水中の窒素・リン濃度が減少し，栄養塩比が変化したことによって，夏期に優占する藻類が藍藻のみであった状態から，近年では藍藻に珪藻が加わったと考えられた．

浄化対策が進んだ諏訪湖では，今後，水中の窒素・リン濃度は横ばいか微減と予想される．対してシリカ濃度は 1979 年以降通年では測定されていないため，その予測が難しい．そこで，湖水中シリカ濃度の増減を推定するため，諏訪湖における 2016 年から 2017 年のシリカの収支を推定し，図 5 に示した．

諏訪湖の湖水中シリカ濃度を増加させる要因を加算すると，23.2 × 10^3 ton SiO_2 / 年であった（内訳：21.84 + 0.995 + 0.382 ）．一方，シリカ濃度を減少させる要因を加算すると， 23.3 × 10^3 ton SiO_2 / 年であった（内訳：17.16 + 2.35 + 3.79 ）（図 5）．この差分を諏訪湖の湖水量で除すると，シリカ濃度の変化量は 0.002 mg-SiO_2 / L / 年と推定され，現在の諏訪湖のシリカの収支は，± 0 と評価された．ここから，降水量や河川水中シリカ濃度や水温などが大きく変化しなければ，諏訪湖のシリカの濃度も今後大きく変化することはないと予想される．

4. 結論

諏訪湖の植物プランクトンを構成する栄養塩の組成（窒素:リン:シリカのモル比）は 18.8:1:92.6（平均）であった．この比を湖水中の栄養塩比と比較することで栄養塩の欠乏状況の評価を行った．1979 年・2016 年・2017 年は DIN 制限が見られた．1979 年・2017 年は DSi 制限が見られた．2016 年・2017 年では各栄養塩制限の影響と考えられる藻類組成の変化が確認された．また，下水道の整備による浄化が進んだことで湖水中の窒素・リン濃度が減少し，栄養塩比の変化することによって，夏期に優占する藻類が藍藻のみであった状態から，近年では藍藻とともに珪藻も加わったと考えられた．何らかの理由で珪藻が増殖すると，そのシリカの取り込みによって，シリカ制限となることも示唆された．

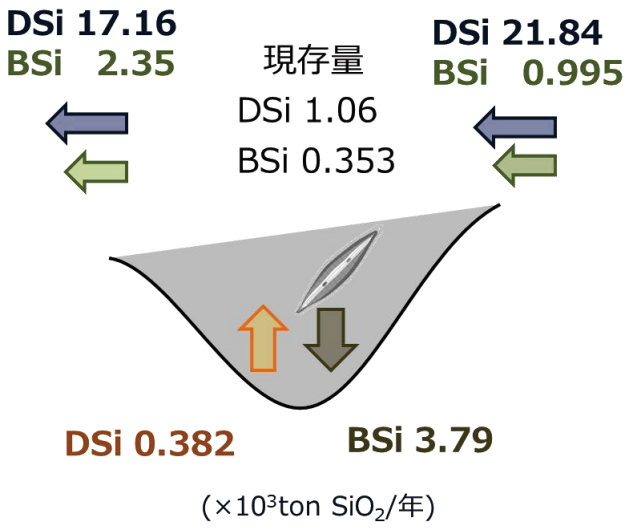

図 5 ． 諏訪湖のシリカ収支（2016 年から 2017 年）
青色が河川による溶存態シリカ移動量，緑色が河川による生物体シリカ移動量，土色が珪藻によるシリカ堆積量，橙色が底質からのシリカ溶出量を表す．

将来のシリカ濃度の推定のために，シリカの収支を算出した．シリカの収支は，±0と推定され，今後，諏訪湖のシリカ濃度および溶存態栄養塩比は大きく変化することはないと予想された．

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P3-29

Water Quality Assessment and Trophic Status Determination of Lake Lanao, Mindanao Island, Philippines

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Keywords: water quality, primary production, eutrophication

ABSTRACT

Lake Lanao is the second largest lake in the Philippines, and is of great biological, ecological, economic and social importance. Since the first studies by Frey and Lewis in early 70s , various changes have occurred. Thus, this study sought to assess the water quality and make a determination of the trophic status of Lake Lanao during the period June 2016 – February 2017. An offshore station was chosen to represent the lake. The Secchi disk depth was taken while measurements made for conductivity, dissolved oxygen, pH, and temperature. Water samples were collected, kept in a cooler, and analyzed in lab for nutrients (nitrate-N, ammonia-N, total phosphorus), alkalinity and chlorophyll-a. Dissolved oxygen value showed no lack of oxygen for use of the lake organisms. The values for the other parameters showed good water quality and were in the range for that of a healthy lake. Based on the table prepared by Brown and Simpson, and trophic status index (TSI) based on the equations formulated by Carlson gave values equivalent to an oligotrophic-mesotrophic lake. Lake Lanao is trending towards eutrophication, which is a natural process in many freshwater ecosystems as they age. However, since human-caused nutrient loading can accelerate this process, cultural eutrophication can be controlled by community and management practices in the catchment basin that will restrict the input of pollutants into the lake.

1. INTRODUCTION

Lake Lanao is the second largest lake in the Philippines and is wholly located within the province of Lanao del Sur. It has great biological, ecological, economic and social importance – as the seat of evolution of an endemic species flock of cyprinids, as a sizable contributor to the local hydrologic cycle, as the source of water supply driving the Agus hydropower plants, and as the center of life and culture of its native inhabitants - the Maranaos who call themselves the "People of the Lake." The first extensive limnological study of Lake Lanao was done by Frey[3]. This was continued by Lewis with his more in-depth field work performed in 1970-71[6]. Since these first studies, various changes have occurred such as that affecting the natural variation in the outflow of Lake Lanao due to the construction of a hydropower plant near the mouth of Agus River, its single outlet, which started operation in 1992. Some unusual phenomena, such as the occurrence of a fish kill, diagnosed as epizootic ulcerative syndrome, occurred in 1997[2] and an unusual greening occurred in September 2006[4]. These unusual occurrences point out the need for a regular periodic assessment of the water quality of the lake. Thus, this study sought to assess the current status of the usual water quality parameters and determination of the trophic status of Lake Lanao.

2. METHODOLOGY

A sampling station was selected offshore at a deeper part of the lake which alternated between three locations in order to represent the lake. See Figure 1. Field measurements and collection of water samples were done five times over the period from June 2016 through February 2017. Field measurements were done for Secchi disk depth, conductivity, dissolved oxygen, pH, and temperature[5]. At the same time, water samples were collected for laboratory analyses of nutrients (nitrate-N, ammonia-N, total phosphorus), alkalinity and chlorophyll-a.

3. RESULTS

All values are mean of measurements from the top 5 m, unless otherwise indicated.

Table 1. Secchi disk depth, temperature, and chemical factors in Lake Lanao.

Physical factor/ Chemic	27 June 2016	14 Sep 2016	15 Nov 2016	19 Dec 2016	26 Feb 2017

al factor	Tugaya Offshore	Tugaya Offshore	Taraka Offshore	Taraka Offshore	Masiu Offshore
Secchi depth, m	4.5	5.2	6.0	6.6	3.5
Temperature, ^{0}C Mean, top 5 m	28.0	27.6	27.7	26.4	25.6
Mean, 28-32 m	27.7	27.5	27.2		
Dissolved oxygen, ppm Mean, Top 5 m			7.3	7.7	6.4 (Surface only)
Mean, 28-32 m			7.6		
NO3-N, ppm	0.0257	0.0257	0.017	0.021	0.029
NH3-N, ppm	0.0673	0.0947	0.0933	0.0883	0.0883
Total P, ppm	0.0377	0.035	0.0303	0.0323	0.0197
Chl-a, mg/m^3	1.3937	0.8136	0.565	0.678	N.d.
pH	8.4	8.6	9.0	8.0	7.9 (surface)
Alkalinity, ppm CaCO3	497	500	680	623	600
EC, mS/cm	0.102	0.114	0.078	0.108	0.130

1 ppm = 1 mg/L = 1000 µg/L = 1000 mg/m^3

Table 2. Comparison of Lake Lanao values with Brown and Simpson[1] to give lake classification.

Variable	Lake Lanao values	From Brown and Simpson, Table 1
Secchi depth, m Mean Range	 5.14 3.5 – 6.6	 4.2 1.5 – 8.1; Mesotrophic
Total Nitrogen, µg/L Mean Range	(Nitrate- + Ammonia-N) 110 93 – 120.4	 660 310-11600; Oligotrophic
Total Phosphorus, µg/L Mean Range	 31 19.7 – 37.7	 27 11 – 96; Mesotrophic
Chlorophyll-a, µg/L Mean Range	 0.8626 0.565 – 1.3937	 1.7 0.3 – 4.5; Oligotrophic

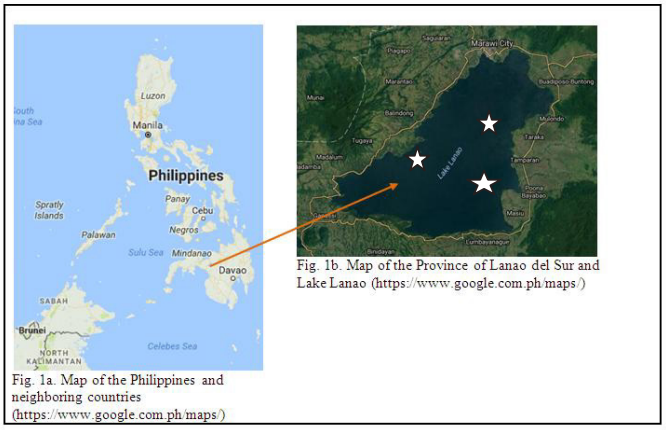

Fig. 1a. Map of the Philippines and neighboring countries (https://www.google.com.ph/maps/)

Fig. 1b. Map of the Province of Lanao del Sur and Lake Lanao (https://www.google.com.ph/maps/)

Figure 1. A map of the Philippines to show the location of Lake Lanao and a map to show the three locations of the sampling station.

4. DISCUSSION

The values of various physical and chemical parameters of Lake Lanao follow those quantities usually obtaining in most nonpolluted lakes. Secchi depth ranged from 3.5 m to 6.6 m. Dissolved oxygen at the top 5 m was nearly saturated, indicating that there was no lack of oxygen for organisms in the littoral and limnetic zone. Similar to the pH of most natural waters that is between 6.5 and 9.0, Lake Lanao pH ranged from 7.4 to 9.0. Conductivity generally ranges between 10 and 1,000 µS/cm in most rivers or lakes that have outflows, such as Lake Lanao. Alkalinity values reflect a good buffering capacity of Lake Lanao. Comparing the inorganic nitrogen and total phosphorus levels in the lake show a nitrogen limitation for algal growth. The trophic state of a lake describes its productivity, i.e., how much algal biomass it contains, and consists of three categories as the lake becomes greener or more productive: oligotrophic, mesotrophic, eutrophic. Referring to the table prepared by Brown and Simpson, Lake Lanao is oligotrophic-mesotrophic. The trophic state index based on the equations formulated by Carlson[7] further affirm the trophic status of Lake Lanao as oligotrophic-mesotrophic.

5. CONCLUSION

The values for various physical and chemical parameters of Lake Lanao showed good water quality and were in the range for that of a healthy lake. It is nevertheless trending towards eutrophication, which is a natural process in many freshwater ecosystems as they age. However, since human-caused nutrient

loading can accelerate this process, cultural eutrophication can be controlled by community and management practices in the catchment basin that will restrict the input of pollutants into the lake.

ACKNOWLEDGMENT

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P3-30

WATER QUALITY CHANGES AND EFFECTS OF POLLUTION IN KISUMU BAY WATERS OF LAKE VICTORIA

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Keywords: Transparency, phytoplankton, eutrophication, sustainable water quality monitoring, and pollution control.

ABSTRACT

The study was undertaken in Kisumu bay, Lake Victoria with objectives to determine water quality status, pollution levels and impacts on lake waters. Parameters were analyzed using APHA method. Relationship between phytoplankton counts, nutrients and physicochemical parameters was statistically determined.

River Kisat depicted poor water quality with mean DO 1.4 mg/l, Conductivity 844 μscm^{-1} and BOD 228 mg/l. Nutrients were high with mean TN ranging 0.807 ± 0.170 mg/l to 5.390 ± 0.413 mg/l, while mean TP ranged 0.088 ± 0.010 to 0.317 ± 0.039 mg/l. Mean (NO_3-N) and (PO_4-P) was 0.055 ± 0.048 mg/l and 0.054 ± 0.042 mg/l respectively. Phytoplankton taxa, Cyanophyta, Chlorophyta, Bacillariophyta and Pyrrophyta were identified, with 20 identified algae species. Chlorophyll "a" concentration was high 0.308 ± 0.085 mg/ l. Positive correlation was observed on nutrients and phytoplankton densities with significant (r = 0.918) between phytoplankton counts and TP. TN: TP > 12, indicating that P was the nutrient limiting factor. Transparency was low 0.47 ± 0.09 m. T P and TN mean values 0.188 and 2.946 mg/l were beyond upper limits given by OECD of 0.02 mg/l and 0.2 mg/l.

Therefore, as a result of pollution from River Kisat, the elevated nutrients, low transparency, increased blue green algae and water hyacinth in Kisumu bay is a sign of water quality deterioration and a water mass undergoing eutrophication. Mitigations recommended included rehabilitation of Kisumu Municipal waste treatment plant, effecting sustainable water quality monitoring programme and enforcement of existing pollution control laws.

INTRODUCTION

Eutrophication is the biological response to excess nutrients input to a lake. It refers to nutrients enrichment and is associated with increased primary productivity. The term is synonymous with increased proliferation of phytoplankton in the lake. Warm tropical lakes are more severely affected than colder water counterparts in temperate regions, because of high temperatures accelerating growth of phytoplankton (Jorgensen and Vollenweider, 1989).

According to LBDA (1997), Lake Victoria which is the second largest fresh water lake in the world with a surface area of 68,800km^2 contribute significantly towards ecological, biophysical and socio economic development along its shoreline, within its basin as well as the livelihood of communities far and beyond its catchment area. It is lifeline to the riparian for food, hydropower generation, transport, tourism, water supply for domestic, agricultural and industrial use, waste water disposal, recreation, and biodiversity conservation.

There has been momentous rise in human population and industrial development in major urban centres near the lake including Kisumu town. Rapid industrialization and urbanization with overstretched sewage system has greatly contributed to the lake pollution.

Study area :Kisumu bay which lies in longitudes - 33° 20' East and 35° 20' East, latitude - 0° 20' South and 0°50' south is within Winam Gulf of Lake Victoria. The study area is within Kisumu town with a

population of about 500,000 people. Kisumu is the biggest urban centre in western Kenya with commercial enterprises, industrial area and urban estates. River Kisat which flows into Kisumu bay receives effluents from Kisumu Municipal convectional treatment plant & industrial area and slum area at its upstream.

Overall project objective: To determine water quality status, and effects of pollution on Kisumu bay waters.

Specific Objectives

i. To determine water quality of river Kisat.
ii. Determine physical parameters and nutrients levels, their relationships with phytoplankton population and impacts on Kisumu bay waters.
iii. Compare water quality with other parts of the lake and recommend abatement measures on pollution control.

PROJECT RESEARCH METHOD.

Lake sampling stations were accessed by use of boat. A line transect was used to provide for systematic random sampling, where GPS was used to mark sampling stations. The 6 sampling stations were 1.2 km apart covering total distance of 6 km along the bay from Kisat river mouth. Samples were collected for five consecutive months – Jan, Feb, Mar, Apr, and May 2009.The hydro lab surveyor machine was used in measuring physico – chemical parameters in situ. Nutrients were analyzed in the laboratory using procedures by APHA (1992).

Data was subjected to statistical analysis for and trends and distributions were presented, in form of tables, histograms, graphs and pie charts. Regression analysis was done to determine correlations between different variables

RESULTS AND DISCUSSION

Secchi depth, PH & DO showed increased values from station A to F- while TDS, TURB, TP, TN, NO_3 - N, NO_2-N, NH_4-N and Chl "a" depicted reducing trend from station A to F. Except for PH of 7.9, most parameters in River Kisat didn't meet national standards, WHO and conditions of aquatic life. There was low D.O 1.4 mg/l and high BOD_5 of 228mg/l measured, reason being poor state of Kisumu Sewage Treatment Plant.

Mean values of physical chemical parameters in Kisat river

Parameter	Cond(µscm^{-1})	TDS(mg/l)	TUR(NTU)
Mean	844	418	23.4

Out of the 20 phytoplankton species identified, 4 taxa were established namely,Cyanophyta with 10 species, Chlorophyta 5 species, Bacillariophyta 4 species and Dinoflagellates 2 species .

All nutrients portrayed the same trend, of general decrease in concentration, from station A to F. Concentrations of chlorophyll 'a' decreased from 0.471 mg/l at station A to 0.228 mg/l at station F. The levels of NO_3-N and PO_4-P were relatively high at station A, 0.158±0-026 mg/l and 0.147±0-057 mg/l respectively. These concentrations dropped drastically at station F, 6 km away. The mean value of TN was 2.946 ± 1.769mg/l, while TP was 0.188 ± 0.085mg/l. The mean values of ammonia, ammonium and nitrite concentrations were 0.025 ± 0.019 mg/l, 0.178 ± 0.032mg/l and 0.007 ± 0.004mg/l respectively. Nitrite levels were found to be very low compared to nitrate within the study area. Regression between chlorophyll "a" and other variables was carried out and showed, PO_4-P (r = 0.948), TP (r = 0.929), TN (r = 0.912) and phytoplankton counts (r = 0.422). Chl "a" was negatively correlated with secchi depth (r = -0.838) and DO (r = -0.951).

Transparency mean value was 0.47m. Njuru &Hecky (2005) observed 0.7m in Winam Gulf and 2.3m in the open lake. Transparency is influenced by suspended matter, silt, clay & plankton. Sedimentation and reduced phytoplankton densities caused increased transparency as flow moves towards open lake. Njuguna (1985) and Lung'ayia *et al* (2000) observed declining transparency in the lake. Average DO was 5.83 mg/l. Low conc. in station A (river mouth) was due to organic matter decomposition &

biodegradation. As DO usage decline due to biodegradation, DO measurements improve. Upwelling help in oxygenation hence increased DO. at station F. DO conc. below 2 mg/l may lead to fish death (UNESCO / WHO 1992).

High PO_4-P and TP at station A was due to high phosphorous loading from river Kisat. High TP could be caused by external loading, internal loading from bottom sediments, waste water from nearby beach hotels & vehicle washing. Upwelling makes PO_4-P available at hypolimnion for use by phytoplankton (Tilzer 1990). Njuru & Hecky (2005) noted same range of PO_4-P & TP as study found. Chl "a" mean levels was 0.308 mg/l mainly caused by elevated nutrients and high illumination. Positive correlation between chl "a" and other key nutrients supports hypothesis that nutrient enrichment is synonymous with increased biota. Obtained values compares well with LVEMP (2000) findings for Mwanza bay (0.172mg/l) and Murchison bay (0.300mg/l). Chl "a" conc. and increased biomass in tropical lakes is fanned by high temp, abundant light & high photosynthesis.

TN:TP mean ratio of 13.15 was beyond Meybeck *et al* (1989) ratio of 7:1 typical of organic matters in aquatic plants thus if N:P>7, P is limiting factor while if N:P< 7, N is limiting factor. Results concur wilt Forsberg (1978), that if N:P>12 then P is the limiting factor. Reason for P being limiting factor is, naturally occurring in low quantities, readily uptake by phytoplankton, and being held by bottom sediments. TN and TP exceeded boundary values for eutrophication by OECD (1987) of 0.2mg/l and 0.02mg/l and Volleinweider (1968) of 1.5mg/l and 0.1mg/l respectively, strengthening the position that the lake is eutrophic.

The above findings mirror on previous studies which revealed elevated sediment loads, nutrients, biomass, algal blooms, and proliferation of the water hyacinth. These are indicators and manifestation of water quality deterioration and a water mass undergoing eutrophication (Talling 1966, Njuguna 1984, Mavuti 1987, Calamari *et al* 1995 and Njuru and Hecky 2005). Studies have also shown water quality changes as a contributing factor behind fisheries biodiversity and stock decline. These changes are profound in Winam Gulf which is a recipient of high loads of river, industrial and urban pollutants.

CONCLUSION & RECOMMENDATIONS

Study concluded that pollution and eutrophication are a major threat to Kisumu Bay waters. Pollution is as a result of effluent, laden with nutrients, organic and to some extent sediment pollution loads. Nutrient and algal biomass are predicted to increase with time and aggravate the situation. It is envisaged that eutrophic waters will impact negatively on the lake ecosystem, utilization potential and the livelihood of the basin communities.

Recommendations: There is need to support and effect a multi institutional water quality surveillance programme as a tool for water quality and environmental management. The Kisumu Municipal conventional waste treatment plant be rehabilitated and maintained in working conditions and regulatory authorities NEMA and WRMA ascertain that effluent released comply with stipulated discharge standards. Comprehensive studies be undertaken on nutrient budget modeling to assess and quantify nutrient inputs into the bay, investigate internal nutrient loading; estimate amounts taken up by plankton and quantities settling in bottom sediments.

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C3 および C4 植物を構成する有機物の河川への流入と変化

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キーワード:C3・C4 植物、表流水と地下水、土壌、生分解、炭素安定同位体比

抄録

有機地球化学ではリグニンフェノールや炭素安定同位体比(δ^{13}C)といった植物由来の有機物に関する指標が用いられ、古植生情報の復元などが行われている。しかし、これら有機物は、生分解や物理的、化学的分解により変化することが考えられる。したがって、有機物の変化による、指標となる値の変化を把握することは重要である。本研究では植物由来の有機物が土壌や河川へ流入する際にどのような変化を受けているのか検討した。試料は C3 植物のアシ、C4 植物のススキを選定し、これらの群生地において、植物の他、土壌、堆積物、周辺河川水（POM、DOM）を採取した。これらの有機物と炭素安定同位体比を測定した結果、植物のδ^{13}C 値は土壌や堆積物中有機物の値によく反映されているが、次第に大きい値になること、またリグニンフェノールの酸/アルデヒド比は、落葉し、土壌、堆積物、また水中へと分解が進むなかで、大きな値になっていくことがわかった。

1. はじめに

堆積物や土壌に含まれるリグニンフェノールなどの植物由来のバイオマーカーや炭素安定同位体比(δ^{13}C)は、それぞれの時代の周辺植生を反映しているとの仮定のもと、過去の植生変化が解析されている[1, 2]。植物を構成する葉や小枝は、季節・気象変化などにより脱離し、昆虫や微生物による分解を経て、土壌中有機物になり、やがて河川や大気による輸送過程を経て湖沼や海洋へ堆積していくと考えられる。植物を構成する有機物や炭素安定同位体比は、このようなプロセスを経る中でどのような変化を受けるのかを理解することは、古植生情報の復元にとって重要であるが、未だ十分な理解がなされているとは言いがたい。

これらの変化は、主に生物分解や無機的な環境、あるいは時間の経過などの影響により、生物的、物理的、化学的に起こると考えられており、この変化を初期続成変化という。この初期続成変化により構成する有機物の組成が変化し、またその際に起こる同位体分別作用により炭素安定同位体比に変化が生じる。したがって、元の生物における指標が生物的、物理的、化学的な作用により、どのような方向に変化するのかを把握しておくことは、指標を使用するうえで重要になる。

陸生植物を構成する有機物のほとんどは最終的に真菌類やバクテリアによって無機化され、わずかな残留物が土壌や腐葉土中に保存されることや、真菌類は好気性であるため嫌気的環境下では保存されやすいことが知られている[3]。また、主に木質部を構成するリグニンやセルロース、ヘミセルロースでは、水中などの嫌気条件下においてはセルロースやヘミセルロースなど炭水化物が優先的に分解されることが知られているが、十分な研究がされているわけではない。

一方、河川流域研究に関する研究において、炭素安定同位体比の値から有機物の起源の推定等が行われている。陸上高等植物には光合成経路の違いから C3 植物と C4 植物がある。C3 植物の平均的なδ^{13}C 値は -27 ‰程度であるが、C4 植物では-10～-14 ‰と大きな違いがある[4]。

本研究では、C3 植物と C4 植物が異なる炭素安定同位体比をとることに着目し、これらを構成する有機物が落葉後、土壌、また河川に至る過程でどのような変化をするのかを検討した。使用した植物は C3 植物としてアシ、また C4 植物としてススキの草本類である。

2. 方法

サンプリングを検討する際には、有機物の変化過程を追跡しやすくするためにできるだけ単純な植生の場の選択が重要と考えられたことから、C3 草本植物として神奈川県芦ノ湖の湖尻水門のアシを、また C4 草本植物として神奈川県箱根仙石原のススキを選択し(Fig.1)、それぞれの場にて植物、土壌、堆積物および河川水を

試料として採取した。

植物試料は、枝切りバサミを用いて生体から直接採取し、これらをジップロックに密閉し処理まで冷凍保存した。土壌試料は、陸土壌は表面の落ち葉や腐葉土を除去した後、表層(～5 cm) を、スコップを用いて採取しアイボーイ(Agilent Technologies 社, 広口びん 100 mL)にいれ処理まで冷凍保存した。植物および土壌は冷凍保存したのち約 24～48 時間かけて凍結乾燥した。植物試料は粉砕器にて粉末状にし、土壌試料は植物片や砂など粒径の大きいものは除去し、瑪瑙乳鉢ですりつぶした後、100 μm のふるいで分画したものを分析用試料とした。

河川水は、バケツにて表層水(～50 cm)を約 20~40 L 採水し、ポリタンクに保存した。これを静置したのち、グラスファイバーフィルター(GF/F)を用いて吸引ろ過し懸濁態有機物を分離した。それらフィルターから無機炭素を除去するため塩酸処理した後 milli-Q にて洗浄した。その後、凍結乾燥し、ろ紙上のものを回収し、乳鉢にて均一にしたものを POM (Particulate Organic Matter)試料とした。減圧濾過の際に得られたろ液については、12 M 塩酸で pH 2 に調整した後、圧力ポンプ(Pump Modules C-601, Pomp Controller C-610: 日本ビュッヒ株式会社)を用いて、流速 20 mL min-1 で DAX8-樹脂に通水して有機物を捕集した。その後、樹脂に吸着した有機物をメタノール約 100 mL で溶離し、エバポレーターにて濃縮したものを DOM(Dissolved Organic Matter)試料とした。

これらの試料において有機物分析と、炭素安定同位体比分析を行った。

有機物分析に関しては Online-TMAH-GC/MS 法にて以下の手順で行った。まず、加熱温度が 315℃のパイロホイルに試料 (DOM:約 0.1～0.5 mg, POM: 約 3.0～5.0 mg, 植物: 約 1.0 mg, 土壌: 5.0~10 mg)をとり、25% TMAH(Tetramethyl-ammonium hydroxide)試薬 20～30 mL と内部標準試料(Nonadecanoic-d37 acid)2 mL を加えて減圧乾燥させた。その後、熱分解装置(JHP3 型 Curie Point Pyrolyzer: 日本分析工業社)を連結させたガスクロマトグラフィー質量分析計(GC/MS 装置 6850 GC/5975C MS, Agilent Technologies 社)にて分析を行った。

元素組成および炭素安定同位体比は、元素分析器 FlashEA 1112 Series CHN 分析計(Thermo Scientific 社)と Delta Advantage IRMS(Thermo Scientific 社)をオンラインで繋いだ連続フロータイプの測定機器である EA/IRMS (Elemental Analyzer-Isotopic Ratio Mass Spectrometer)にて測定した。なお、試料中の全炭素量は標準物質(Acetanilide Standard: C8H9N10)を用いた検量線法で定量した。

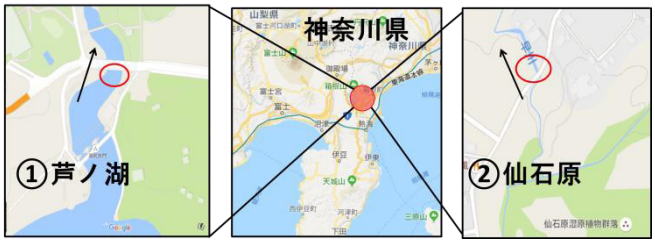

Fig.1 サンプリング地点

(矢印は河川の流れる方向を示す)

3. 結果

芦ノ湖のアシに関連した試料の炭素安定同位体比($\delta^{13}C$)の値(Fig.2)をみると、いずれの試料においても大きな違いはないが、堆積物中有機物、POM および DOM の $\delta^{13}C$ 値はアシの $\delta^{13}C$ 値よりもやや大きい(重い)値であった。

仙石原のススキに関連した試料の $\delta^{13}C$ 値にでは、ススキおよび土壌中有機物の $\delta^{13}C$ 値と河川水中の POM および DOM の $\delta^{13}C$ 値はかなり異なっていた。すなわち、土壌中有機物の $\delta^{13}C$ 値はススキの $\delta^{13}C$ よりやや小さい(軽い)値になった一方で、POM や DOM など河川水中有機物の $\delta^{13}C$ 値はかなり軽い値になった。

また、リグニンを構成するバニリルフェノールのバニリン酸/バニリン比(Ad/Al)v は、糸状菌による酸化的分解の程度を表す指標であり[5]、値が高いほど酸化的分解の程度が大きいことを示す。 Fig.3 に示した結果をみると、両地点の試料ともに、起源である植物と POM の (Ad/Al)v が近い値をとり、その一方で土壌中有機物や堆積物中有機物と DOM の(Ad/Al)v 値は起源である植物の値よりもかなり大きい値をとることを示している。

4. 考察

アシの $\delta^{13}C$ 値は、対応する堆積物中有機物、DOM および POM の $\delta^{13}C$ 値と近い値をとっていることから、アシの $\delta^{13}C$ 値は堆積物中有機物や付近の河川水中有機物(POM や DOM)にも良く反映されていることを示している。さらに詳細に検討すると、微生物分解を受けると、軽い炭素が CO_2 として放出されると考えられることから、残存する有機物の $\delta^{13}C$ 値は大きくなると予想される。その意味では、芦ノ湖のアシに関連した試料では

土壌、POM および DOM へと分解が進んでいることを示唆している。このことはリグニンの(Ad/Al)v 比の変化にも現れており、起源であるアシの(Ad/Al)v 比よりも糸状菌などによる分解作用などをうけた有機物は大きい(Ad/Al)v 比になることを示している。また、POM と DOM の(Ad/Al)v 比を比べると、DOM の値が大きいことから、有機物の分解が進んだものが DOM に分化している可能性がある。

一方、ススキに関連した試料の場合、(Ad/Al)v 比の値は、アシと同様に、土壌や POM および DOM の値はかなり大きく、分解が進んでいることを示唆しているが、ススキの $\delta^{13}C$ 値は水中の POM や DOM の $\delta^{13}C$ 値と比べて、かなり軽い値になっていることから、付近に存在する C3 植物に由来する有機物が混入している可能性がある。

5. 結論

土壌、POM、DOM のリグニンの組成変化、 $\delta^{13}C$ 値の変化、また(Ad/Al)v 比の変化は、概ね植物、土壌、POM、さらに DOM の順に 進んでいることを示唆しており、河川水中の溶存態有機物は土壌からの流入に影響を受けていることが示唆された。ただし、仙石原の試料（特に POM）にはススキ以外の有機物に由来するものが含まれている可能性がある。

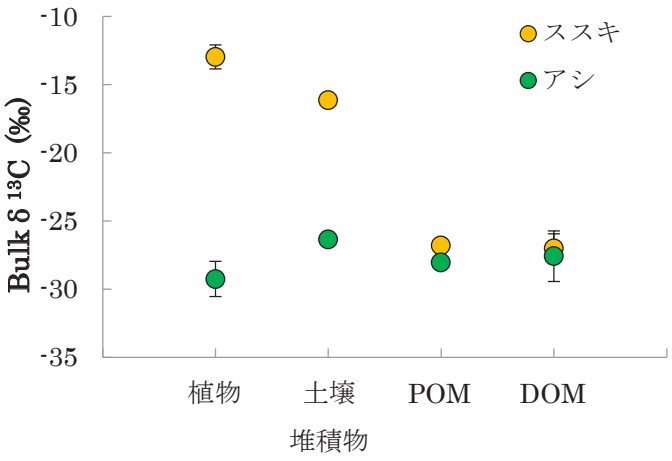

Fig.2 各試料における全炭素安定同位体比 (Bulk $\delta^{13}C$ 値)

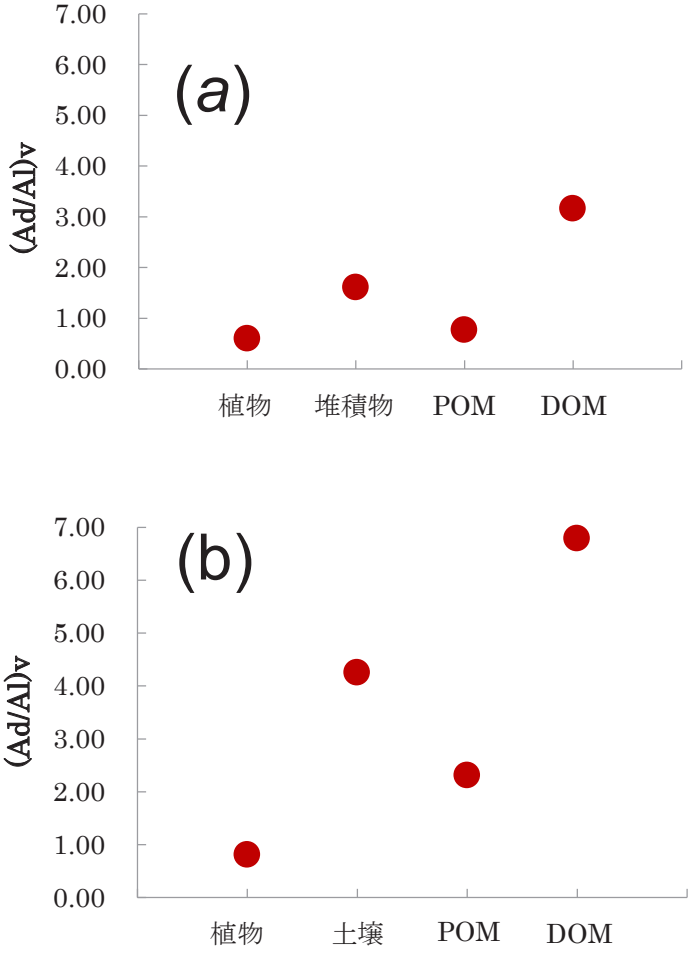

Fig.3 各地点における試料中リグニンの(Ad/Al)v 比 : (a)アシ、(b)ススキ

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Paper title：Lessons learned from Management of West Lake (Ho Tay) in Hanoi Capital of Vietnam after a haft century

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Keywords: West Lake (Ho Tay), Management, Lesson learned, Biodiversity, Water pollution

ABSTRACT

Ho Tay (West Lake), a more than 500 hectares natural lake is located in the Western of Hanoi Capital, Vietnam. The lake has played very important role in ecosystem services for the city in the past, present as well as in the future.
After over a half century, flowing with the history of Vietnam, the management of West Lake could be divided into 3 periods: 1) from 1954 – 1975: war for reunification of the country; 2) 1975 - 1986: socio-economic development after the war and; 3) 1986 – up to date (2017): "Open the door" or "Renovation" which lead to rapid urbanization of Hanoi Capital. Despite of many efforts in management have been undertaken, in comparison with the 1st period, our research analysis showed that in the 3rd period, water quality has been polluted, and biodiversity has been degraded seriously. Two hundreds of tons of fishes and aquatic animals were died suddenly in October 2016!
This paper will touch upon the experiences and lessons learned after a half century in management of West Lake toward a better conservation and management of West Lake.

1. INTRODUCTION

West Lake (Ho Tay) with a surface area of over 500ha is one of four important natural lakes in Vietnam. West Lake is located in the center of Western part of Hanoi city. The lake contributes many important ecosystem services for the city in the past, present and future (Mai & Mai, 2014).

Limnology aspects was studied in 1961. Since then, there have been many surveys on water qualities, aquatic biodiversity and management carried out regularly in the West Lake.

After a half century of management, the lake has been greatly impacted by nature as well as people. Nevertheless, lessons learned on management and conservation means for the lake, as well as the status of water qualities, biodiversity, legislation and ecosystem services (ES) of West Lake, have not been overviewed and analyzed.

2. RESEARCH METHODS

This scientific paper overviews and synthesizes related scientific papers from our and colleagues studies.

3. RESULTS

3.1. West Lake ecosystem services play different important roles in over 50 years

West Lake is located at 21°04'N and 105°05'E on an elevation of less than 10m a.s.l. The catchment has an area of 9,3km^2 (Bui, 2014). The surface area of the lake is 519.75 hectares (2014) which formed as horseshoe shape and is one of the largest natural lakes in the Red River Delta. The lake originated as a segment of the Red river but not connected with the river by any canal presently (Tay Ho DPC & WMA, Survey, assess water quality, ecosystem and propose wise used methods of West Lake, 2012) .

West Lake receives the water from precipitation (around 2000mm/year) within its catchment and waste water from surrounding human settlement (Tay Ho DPC & WMA, Survey, assess water quality, ecosystem and propose wise used methods of West Lake, 2012) . The lake is connected to the neighboring Truc Bach Lake (which is 20ha in surface water). Lake water level changes are correlated with the fluctuation of Red River but amplitudes are small.

Over a half century, flowing with the history of Vietnam, which can be divided into 3 periods:

- From 1954 to 1975: War for reunification of the country;
- From 1975 to 1986: Socio-Economic development after war; and
- From 1986 to 2017: "Open the door", "Renovation", "Socialist-oriented market economy". This period is marked as "rapid urbanization". At present, Hanoi has approximately 9 million of habitants.

The West Lake has been contributing to the development of the city through its ES. However, the ESs play different role in each periods, particularly for the 1st and the 3rd ones. In the 1st period, the provisioning and regulating and supporting services were the main contribution to Hanoi. At that time, the lake provided fishes, shrimps, water snails, clean and fresh water and regulating flood water for

Hanoi. In the 3rd period, due to the lack of management and failed utilization, the provisioning and regulating services were decreased. The quantity and quality of food productions had been significant reduced, the water was contaminated, the surrounding environment was polluted; flood control function was decreased due to the depth of sedimentation increased year by year. In the third period, the culture and supporting services of West Lake are raising due to high demand from human and nature. West Lake become the destination for many local communities and visitors from the capital city and other provinces, especially during the hot summer days as well as holidays.

3.2. Current status of water qualities, biodiversity, legislative aspects of West Lake

- *Water qualities*: The water quality is being decreased through the years (Table 1). In 1961, the Dissolved Oxygen (DO) was 5,15mg/l, but in 1995 and 2012 it decreased to 4 and 3,1 mg/l respectively. The amount of Ammonium was raising from trace to 2 mg/l during 1961 to 2012. Two other parameters like Biochemical Oxygen Demand (BOD_5) and Chemical Oxygen Demand (COD) which illustrated the contaminated of the water were increased from 21,19 to 187mg/l (BOD_5) and from 10,1 - 370 mg/l (COD).

Table 1. Water quality of West Lake in 1961, 1995, 2012

Parameter	1961	1995	2012
pH	7,4 - 8,0	6,5 - 8,5	6,9 - 9,8
DO (mg/l)	5,15	4	3,1
Cl^- (mg/l)	49,5	42 - 63	-
NH_4^+(mg/l)	trace	0,37 - 0,8	0,5 - 2
PO_4^{3-} (mg/l)	0,71	0,5 - 3,0	0,67 - 1,04
BOD_5 (mg/l)	21,19	39 - 48	16-187
COD (mg/l)	-	10,1 - 40	29 - 370
SS (mg/l)	60 - 130	75 - 225	8,6-147,3

Source: (Mai, Dang, Pham, & Dao, 1961), (Mai, 1995), (Tay Ho DPC & WMA, 2012) (Le, Mai, & Trinh, 1995). Note: - no information

- *Water depth and sediment depth*: After a half century, the West Lake's water level getting shallower. In 1961, the deepest point was 3,5 meters but in 2012 it was only 2,5 meters, the depth of sludge/ sediment was raised from 0,5 meter in 1961 to 1,5 meter in 2012. It is because of a large amount rubbishes and untreated sewage, surface run-off pouring into the lake in decades.

- *Heavy metals chemical composition of mud layer*: The heavy metals in the sludge layer and water will be accumulated into zoobenthos, mollusks, water snails, clams, fishes in the lake while many kind of fishes, clams have been harvested for food. The amount of heavy metals in table 2, shows that sediment parameters increase from 1,37 up to 30 times.

Table 2. Sediment Chemistry of West Lake in 2001 and 2014

Sediment parameter	2001	2014
As (ppm)	17	5,21 - 23,44
Cd (ppm)	0,7	1,53 - 5,72
Hg (ppm)	0,12	1 - 3,6
Cu (ppm)	6	46 - 128,8
Pb (ppm)	22	40 - 204,35
Zn (ppm)	38	100,59 - 503,33

Sources: (Wong, Le, Tran, Nguyen, & Easton, 2001), (Bui, 2014).

- *Aquatic biodiversity*: Almost aquatic plant species were removed from the lake. As to algae, the number of Bacillariophyta division is decrease, whilst Euglenophyta and Cyanobacteria are increase in number, which indicate the water become eutrophicated. Fish species was increasing in number, however, almost of them are invasive alien species (which due to intensive aquaculture practices in 2nd and 3rd period) and become dominated in the fish group of the lake presently (Table 3).

Table 3. Number of fish species in 1961 and 2017

No.	Fish family	1961	2017
		22 species	47 species
1.	Engraulidae	-	1
2.	Cyprinidae	14	26
3.	Cobitidae	1	1
4.	Bagridae	-	1
5.	Loricariidae	-	1
6.	Siluridae	-	1
7.	Clariidae	2	2
8.	Adrianichthyidae	-	1
9.	Hemiramphidae	-	1
10.	Synbranchidae	1	1
11.	Mastacembelidae	-	1
12.	Cichlidae	-	2
13.	Eleotridae	-	1
14.	Gobiidae	1	3
15.	Anabantidae	1	1
16.	Belontidae	-	1
17.	Channidae	2	2

Source: (Mai, Dang, Pham, & Dao, 1961), (Tay Ho DPC, 2017)

- *Legal management documents and activities*: the city authorities deliberated many decrees as well as activities aim to conserve biodiversity, control water quality, and protect natural environment of the lake. However as assessed, there are still many limitation and challenges. The local communities have not been involved much in

lake management and conservation activities. Street vendors, visitors are still pouring waste water, throw rubbish on the lake shore and in to the lake. Consequently, water quality is getting worse and worse, natural species was decreased in number, habitat for native and migratory species, including birds was degraded. An example for that is over 200 tons of fish was died out from October 1 - 4, 2016 due to water pollution.

3.3. Lessons learned from management of West Lake: Science -Technology and Policy – Legislation aspects

Science – Technology

- Rubbishes and untreated sewage, sediment from surface run-off caused the raising of sludge and fill up West Lake in decades.
- Development of intensive aquaculture lead negative impacts to the native aquatic biodiversity. Introduction, dominating of many invasive alien fish species increases the competition with the native species.
- Remove almost of the aquatic plant species reduced the capacity in natural purification of the lake and facilitate the development of phytoplankton.
- Overexploitation and over harvesting threaten many native commercial fish and invertebrate species (shrimps, clams, snails).
- Habitat for native and migratory bird was destroyed due to lack of appropriate management means and activities.

Policy – Legislation

- Deliberate too many legal documents, but rather weak in implementation and enforcement.
- Lack of cross-sectional responsibilities and resources.
- Community participation and involvement are still minor.
- In order to maintain the ecosystem services and wise uses of the West Lake, comprehensive and ecosystem-based approaches need to be considered and applied to avoid the above lessons in restoration and better management of the West Lake.

4. CONCLUSION

West Lake is one of the largest natural lake in Hanoi capital city, Vietnam. In ecosystem services, the lake plays important and different roles in the development and resilience of the city.

Although a number of means and activities have been applied and conducted, water quality of the lake is still polluted, biodiversity is decreased.

Though experiences and lesson learned in management and conservation during the past decades, comprehensive and ecosystem-based approaches are recommended to apply for the conservation and management of West Lake (Ho Tay).

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P3-33

気候変動が琵琶湖の水温・DOに及ぼす影響とそのメカニズム

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抄録

IPCC 第 5 次評価報告書によると，世界的な温暖化は明らかであり，温暖化は人為的な温室効果ガスの増加による可能性が非常に高いと結論づけられた．温暖化は猛暑や豪雨といった異常気象の発生頻度や強度を変化させると予測されており，湖沼生態系にも少なからず影響を及ぼすものと考えられる．そこで，本研究では琵琶湖を対象に，高解像度の GCM の気象出力データを用いた三次元流動水質シミュレーションを行い，気候変動による琵琶湖の水温・DO に及ぼす影響を解析した．その結果，琵琶湖では，将来の気温は年間を通して上昇し，豪雨の発生頻度が増加することが示された．将来は全層で水温が約 1.5℃上昇することが示された．また，底層 DO は約 2 mg/L の減少を示し，気候変動は琵琶湖底層の貧酸素化を助長させることが示唆された．その中でも，水表面での熱交換量の変化が琵琶湖の水質変化に最も支配的であることが示唆された．

1. はじめに

IPCC第5次評価報告書によると，世界的な温暖化は明らかであり，温暖化は人為的な温室効果ガスの増加による可能性が非常に高いと結論づけられた．温暖化は猛暑や豪雨といった異常気象の発生頻度や強度を変化させると予測されており，湖沼生態系にも少なからず影響を及ぼすものと考えられる．

本研究で対象とする琵琶湖は湖面積672km^{2}の日本最大の淡水湖であり，琵琶湖においても，気候変動の影響予測に関する研究が多くなされてきた．例えば, 環境省[1)]は全球気候モデルGCM（Global Climate Model）の出力を用いて2015～2039年を対象に琵琶湖水質の将来予測を行い, 表層水温が0.9～1.7℃上昇すること，全循環が弱まる時期が発生すること，それに伴い下層のDO濃度の減少やリン濃度が増加することを指摘した．しかしながら，そのメカニズムは明らかになっておらず，効果的な適応策を講じるにはメカニズムを知る必要がある．

本研究では，まず高解像GCMの気象出力データを用いて将来の琵琶湖における気候変動を明らかにする．そしてそのデータを境界条件に用いた三次元流動水質シミュレーションを行い，気候変動が湖内の水質に及ぼす影響を評価し，そのメカニズムを明らかにする．

2. GCM データの解析

(1) 手法

一般にGCM出力値にはバイアスが含まれているため，利用する際にはバイアス補正を行う必要があり，本研究では猪俣ら[2)]により開発された手法によりバイアス補正を行った．この方法では極値（全体上位0.5%）については通年で補正を行う一方，その他のデータセットについては月別に補正を行うため，極端現象を考慮することができる．本研究では1979～2003年と2075～2099年の各25年間をそれぞれ現在および将来の参照期間とした．GCM出力値には，気象庁気象研究所の大気大循環モデルGCM20によるSRESのA1Bシナリオにおける計算結果を使用した．GCM20は水平格子サイズが20kmと他のGCMと比べて空間解像度が高く, また1時間間隔の出力値が利用可能という特徴を有している．観測値にはアメダス彦根の毎時データを使用した．ただし，短波放射量は観測項目に含まれていないため，全天日射量で代替した．

(2) 解析結果

図-1に現在期間と将来期間におけるバイアス補正後の気温・短波放射量・風速の旬平均を示す．現在気候値を将来気候値と比較したところ，平均気温は年間を通して約3℃上昇するものの, 各期間の標準偏

差はともに約1.2℃であり大きな差異はみられなかった．平均短波放射量は4月から8月にかけて約1.5MJ/m^{2}の上昇を示したが，標準偏差に大きな差異はみられなかった．平均風速は1月から4月にかけて若干の増加を示したがそれらを除いた期間では減少する傾向を示した．標準偏差に大きな差異はみられなかった．表-1に1時間降水量の頻度を示す．現況と将来を比較すると10 mm以上の1時間降水量の頻度が増加しており，将来は短時間豪雨の発生回数が増加すると考えられる．

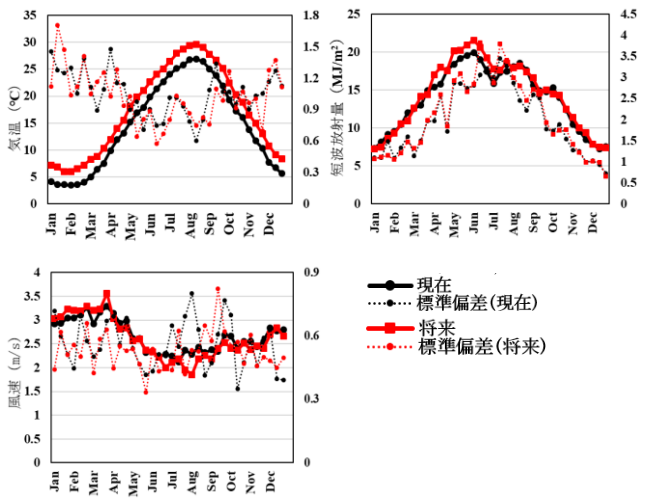

図-1　バイアス補正後の GCM 出力値

表-1　1 時間降水量の頻度

1時間降水量	現在	将来
0 mm	204055	204031
0-1 mm	3788	3102
1-10 mm	10876	11504
10-20 mm	335	403
20-30 mm	49	56
30-50 mm	16	20
50-80 mm	1	4

3. 数値シミュレーション

(1) 手法

数値モデルは準三次元バロクリニック流動水質モデル[3]を使用した．紙面の都合により，モデルの詳細については既往研究[例えば，3]に譲り，ここでは概要のみを以下に示す．デカルト座標系を採用し，計算格子にはスタッガード格子を用いている．水平方向には1km辺長の正方格子によって40×65個のグリッドに分割した．鉛直方向には50層に分割し，層厚は最表層と水深10m以深では2m，表層第2層から水深10mまでは1mとした．

(3) モデルの再現性

2013年3月1日から2年間の助走計算を行い，2015年3月1日～2016年2月28日の計算結果を基に再現性の検証を行った．モデルの再現性は，今津沖中央における水温，DOの鉛直分布の時系列について，計算結果を観測結果と比較することで評価した．気象条件には彦根における毎時観測値を与えた．ただし，風場については，湖岸5地点における地上観測値を基に，逆距離荷重法で補間して求めた空間分布を与えた．流入河川としては主要河川である姉川，安曇川，愛知川，日野川，野洲川を考慮した．これらの河川は観測データが不足しているため，西田ら[4]においても用いられている分布型流出モデルを用いて流量・水温を算定した．水質濃度は月1回の頻度で実施された平水時観測の結果[5]を基に与えた．図-2に今津沖中央における水温とDOの時系列について，観測結果と計算結果の比較を示す．観測結果に比べると下層への熱伝播がやや過大評価されているが，4月中旬から1月中旬において，水表面が過熱されることで水温成層が形成されている様子が計算結果でも再現されている．DOについてみると，成層期には底泥による酸素消費の影響を受けて底層濃度が徐々に低下し，全循環によって急激に回復する様子が再現されている．以上より，一部改善の余地は残されているものの，本モデルは琵琶湖北湖における水温・DOの季節変動特性を良好に再現しており，本モデルを用いて気候変動の影響を解析することは可能であると判断した．

(4) ケーススタディの計算条件

前述のバイアス補正を施したGCM出力値を用いて，表-2に示す5種類の計算を行った．計算期間は，それぞれ助走計算の2年間を含む3年間とした．Case-1,2は，現在および将来の計算とし，Case-3,4,5については各要素を将来のGCM出力値に置き換えた計算とした．流入河川の流量・水温については，再現計算と同様に分布型流出モデルを用いて与えた．

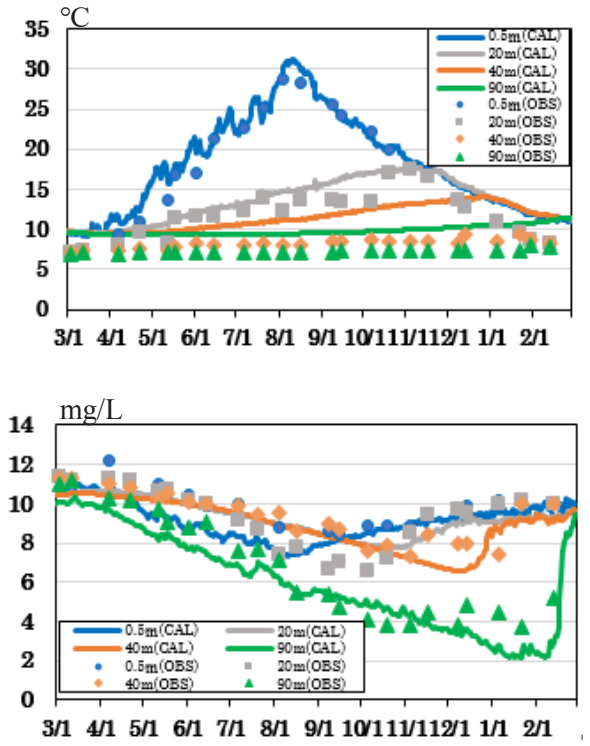

図-2　水温と DO における観測値と計算値の比較

表-2　Case 設定の内容

No.	内容
Case-1	1979 年―1982 年の計算
Case-2	2075 年―2078 年の計算
Case-3	気温･短波放射量を変化させた計算
Case-4	流入河川の流量･水温を変化させた計算
Case-5	風向･風速を変化させた計算

(5) ケーススタディの計算結果

図-3に今津沖中央における水温とDOのCase-1からの変化量の鉛直分布時系列を示す．水温については，Case-2,3の場合は年間を通して全層で約1.5 ℃程の上昇を示したが，Case-4,5の場合は大きな変化はみられなかった．DOについては，Case-4,5の場合では，大きな変化はみられなかったが，Case-2,3においては成層期の中層から底層のDOは約2 mg/L程の減少を示した．熱フラックスが変化することで琵琶湖へと供給される熱量が増加し，底層においても水温が上昇したことで底泥の酸素消費量が増加したことが底層のDOの減少の原因と考えられる．さらに，Case-1とCase-2,3,4,5を比較することで将来は貧酸素化が進行し，将来の変化要因の中でも気温・短波放射量の変化がDOに寄与する割合が大きく，熱フラックスの変化がさらなる貧酸素化を助長することが示唆された．

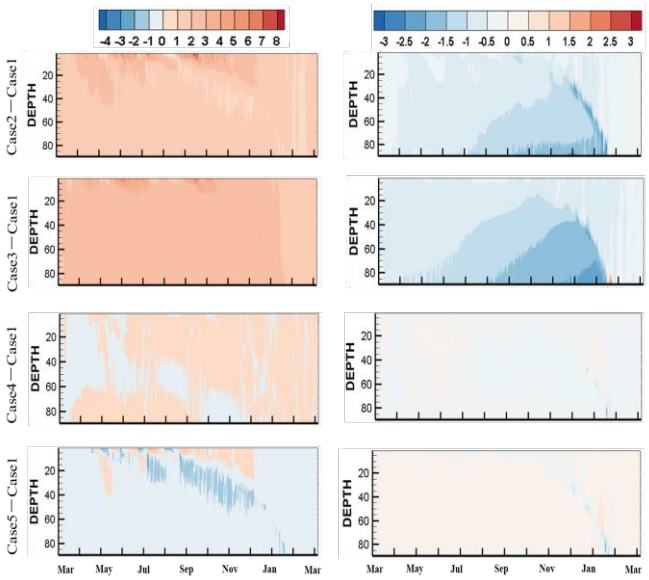

図-3　水温と DO の変化量の鉛直分布時系列

4. 結論

本研究では，気候変動が湖内の水質に及ぼす影響を評価し，そのメカニズムを明らかにした．その結果，将来は全層で水温が1.5℃程の上昇を示した．また，底層の溶存酸素濃度は約2 mg/L減少し，気候変動は琵琶湖底層の貧酸素化を助長させることが示唆された．その中でも，水表面での熱交換の変化が琵琶湖の水質変化に最も支配的であることが示唆された．

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P3-34

バイカル湖堆積物に記録された植生変動の解析

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キーワード:バイカル湖, リグニンフェノール, TMAH、植生解析

抄録

過去の気候や植生環境を知ることは、近未来に起こり得る急激な気候変動に対する対策を講じることに繋がる。本研究では、北半球高緯度域に位置するバイカル湖の堆積物試料中に含まれている陸上起源有機物を、過去の周辺の植生やそれらの流入環境を知るための指標として用い、バイカル湖周辺の古環境変動の解析を試みた。バイカル湖堆積物試料からは、リグニンや長鎖の脂肪酸、クチン酸などの陸上植物に特徴的な有機物が検出された。これら有機物は、いずれも堆積物試料の 36–50 cm で最も高い傾向を示し、この時代に、大きな植物の流入があったことを示した。さらに、リグニンを用いた植生指標は、この時に、草本植物と分解物の高い寄与があったことを示した。これらの植生の特徴は、現在のバイカル湖の西岸と類似しており、西岸から来る強い風がこれらの有機物を運び込んだと考えられた。

1. はじめに

湖沼環境は，豊かな生態系を支える場であるとともに，河川の流入，周辺の植生や土地利用など，さまざまな影響を受ける。近年，温暖化に伴う気候変動は，自然環境に大きな影響を与えると，懸念されており，これは，湖沼環境も例外ではない。その環境変化が与える影響を予測するために，さまざまな「指標」を用いて過去の環境変動の復元から将来を予測する古環境解析は，その一つの方法として有用である。

沿岸域や湖沼などの水圏堆積物中の有機物は，陸上から河川や大気を通して供給された陸起源有機物と，水中で生産された有機物で構成されている。これらの有機物の内，生分解作用を受けにくい難分解性有機物や，貧酸素環境下に置かれた有機物は、堆積物中に長期的に保存される。そのため，堆積物中の有機物は，当時の地球環境に関する情報を与えるものとして非常に重要であり、それらは過去の気候変動を知るための「指標」として用いられてきた。その中でも，植物由来の有機物は，植物種によって特徴的な有機組成を有しており，過去の周辺の植生やそれらの流入環境をとらえることができる。例えば、維管束植物の主要な有機物組成であるリグニンは、針葉樹がグアイアシルリグニンによって構成されているのに対して、広葉樹はグアイアシルリグニンとシリンギルリグニンで、草本類はそれらに加えシンナミルリグニンで構成されており、その組成は植物間で大きく異なっている。

ACIA (Arctic Climate Impact Assesment:北極圏気候影響評価)によると、地球気候変動モデルによって推定された温暖化は、北半球の高緯度域でもっともその影響が強く出ると予想している[1]。そのため、長期的な気候変動に伴う環境変化を見るには、北半球の高緯度域の研究が重要となる。北半球のシベリア地域に位置するバイカル湖（図1）は，冬は高気圧，夏は低気圧という季節によって気圧配置が大きく異なる環境下にある。そのため，気候変動に伴う長期的な気圧の変動は，過去の周辺の植生やそれらの流入環境に影響を与えたことが考えられる。

そこで、本研究では、バイカル湖堆積物中の有機物（とりわけ陸上植物の指標であるリグニンフェノールやクチン酸）の分析を行い、バイカル湖周辺の植生およびそれらの流入環境解析を行うことを目的とする。

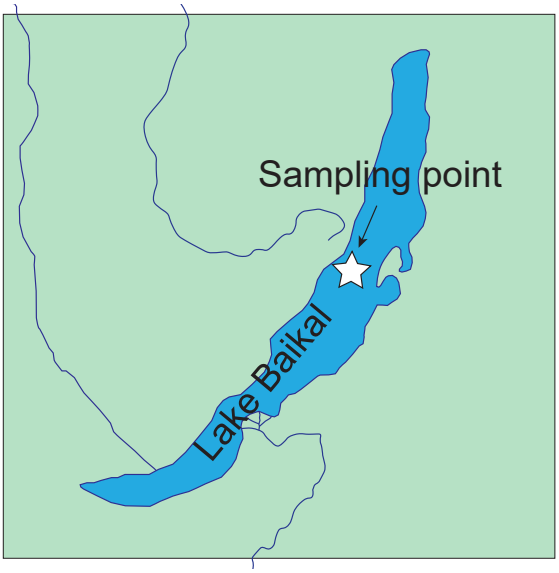

図 1. バイカル湖と堆積物試料採取地点

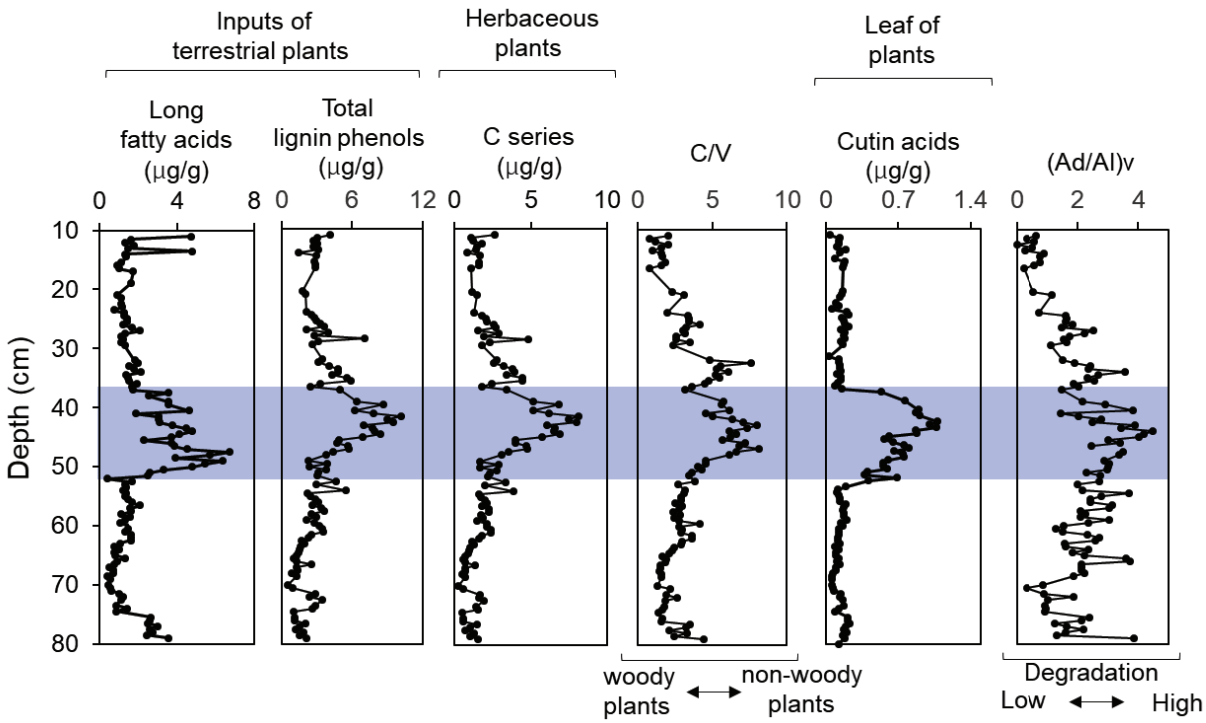

図 2. ver98-1 st.5 PA コア中の有機物指標の深度分布. 長鎖脂肪酸 (C_{24}–C_{32}) および総リグニン量は，陸上植物に由来し，これらの増加は植物の寄与が高いことを示す．リグニンの C シリーズは，草本植物に特徴的なリグニンであり，リグニンフェノールの C/V 比は，草本の寄与が高い時に高い値を示す．クチン酸は，植物の葉のクチクラ層を構成する有機物である．(Ad/Al)v 比は，リグニンフェノールのバニリル類の中でアルデヒド類 (Al) に対する酸類 (Ad) の比であり，リグニンが糸状菌などによって酸化的に分解されると，高い(Ad/Al)v 比を示す．クチン酸は 8,16-/9,16-/10,16-dihydroxyhexadecanoic acid の総和を示す．

2. 方法

本研究では、バイカル湖アカデミシャンリッジ（53° 44’33” N, 108° 24’35”E, 水深 325 m)で採取した ver.98-1 st-5 パイロットコア PA (試料長 996 mm)を用いた。

堆積物試料の有機物分析は先行研究[3-5]と同様に、Off-line TMAH GC–MS 法により行った。乾燥試料約 300 mg を 10 ml ガラスアンプル管に量り取り、25% TMAH (Tetramethylammonium hydroxide: 97%, SIGMA-ALDRCHI 社)-メタノール(特級, 和光純薬)溶液 150 μL, Nonadecanoic-d37 acid-メタノール(特級, 和光純薬)溶液(100 ng/μL)を内部標準試薬として 50 μL を添加した。その後、減圧デシケーターおよび窒素気流下の 40℃ホットプレートで乾燥させ、減圧状態にして封管した。そして電気炉にて 300℃で 30 分間熱反応を行った。反応後、300 μl の酢酸エチルで 3 回抽出を行い、減圧デシケーターで乾燥させた。その後、酢酸エチル 25 μl でメスアップを行い、2 μl を GC–MS [6890N GC 5973 MS (Agilent Technologies)]にて分析を行った。

3. 結果

ver.98-1 st-5 PA コアから検出された、長鎖脂肪酸量、総リグニン量（バニリル類 [V]+シリンギル類 [S]+シンナミル類 [C]), C リグニン，リグニンの C/V 比, (Ad/Al)v 比およびクチン酸の深度分布を図 2 に示す。長鎖脂肪酸、リグニン及びクチン酸は、陸上植物の指標として用いられている。深度約 36–50 cm にかけて高い値を示し、湖環境に陸上植物の大きな流入があったことを示している。C リグニンは、草本植物が多く持つリグニン類である。C/V 比は、リグニンのバニリル類に対するシンナミル類の比で、値が高くなるほど草本植物の寄与が高いことを示す。いずれも、植物の流入の指標と同様に、36–50 cm にかけて高い値を示しており、この時の陸上植物は、草本植物によって主に構成されていることを示している。(Ad/Al)v 比は、リグニンのアルデヒド類に対する酸類の比で、値が高くなるほど分解物の寄与が高いことを示す。この比も同様に、深度約 36–50 cm にかけて高い値を示し、この時期に分解物の寄与も高くなったことを示唆している。

4. 考察

陸上植物の指標からみた傾向から、深度約 36–50 cm にかけての陸上植物の大きな流入は、分解物を含み、

草本に富んだ植物片であることが示された。現代のバイカル湖の東西の植生環境は大きく異なっている。西岸は、草本や針葉樹、分解物を含む砂礫から、構成されているのに対して、東岸は、多様な木本植物から成る[7]。草本と分解物で構成されていた堆積物指標に記録された大きな植物の湖への流入時期(深度約 36–50 cm)は、現代の植生分布と比較すると、西岸の植生環境と一致している。

現在のバイカル湖の西岸部の森林環境は、バイカル湖周辺に吹き付ける風の影響が大きいことが知られている[7]。この風は、3000mの山脈から吹き付ける強風で、低温かつ乾燥している特徴を有する。この風が吹き付ける場では、立木をなぎ倒し、乾燥が進み草原化させる。風の向きは、北と南からと、西から東に向かって吹く。そして、この風は、特に、寒気に強くなる傾向がある。したがって、西岸からの植物片の流入の増加と考えられる深度約 36–50 cm での結果は、この風が、過去のバイカル湖気候で、現代よりも長期的な期間で強化されたために得られた記録ではないかと考えられる。実際に、現代よりも寒冷だった時代は、過去の地球史で何度も繰り返し生じてきた。残念ながら、本コアにおける正確な年代測定との比較は、まだ行っていないが、これらの結果は、確かに湖底の堆積物が周りの植生およびそれらの流入史を記録していることを示していると言える。

5. 結論

陸上植物の指標からみた傾向から、深度約 36–50 cmにかけて、分解物と草本に富んだ植物片の流入が起きたことが明らかになった。現代のバイカル湖に吹く、西から東への風は、バイカル湖西岸を乾燥化させ、草原化させている。この風は寒気に強く吹く特徴を有していることから、深度約 36–50 cm における過去のバイカル湖気候で、現代よりも長期的な期間で風が強化されたために、草原化が進み、堆積していた分解物と共に湖内へ流入したことで得られた記録ではないかと考えられた。

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P3-35

気候変動による霞ヶ浦水質への影響について

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キーワード:生態系機能, 水質汚濁, 富栄養化, 栄養塩動態, 気候変動

抄録

霞ヶ浦は茨城県県南部に位置し, 広く浅い特徴を持つ湖である。流域ではこれまでに様々な水質汚濁防止対策が講じられ, 流入河川水質は改善しているが, 湖内の COD, TN, TP の環境基準は未達成な状況が続いており, 長期的かつ詳細な要因解明はできていない。そこで, 本研究では, 霞ヶ浦の長期的水質変動について時系列・統計解析を実施するとともに, 地球温暖化等の気候変動が霞ヶ浦の水質・生態系に与える影響について検討を行った。その結果, 霞ヶ浦水質のレジームシフトを推定した結果, 西浦 COD では 1977-1978 年と 1987-1988 年と 2012-2013 年に, TN では 1991-1992 年と 2003-2004 年に, TP では 1991-1992 年と 2009-2010 年に大きく変化していることが分かった。他の地点も同様に解析を行った結果, これらの変動時期は, PDO の時系列変動と概ね一致するとともに, PDO と植物プランクトン細胞数の変動傾向が類似していることからも, 気候変動が霞ヶ浦の水質・生態系のレジームシフトに影響を及ぼしていることが示唆された。

1. はじめに

霞ヶ浦は, 茨城県南東部に位置し, 西浦・北浦・常陸利根川の3水域から成る(図 1)。湖面積 200km^2(日本で2番目の大きさ), 平均水深 4.0m, 最大水深 7.0m の広く浅い湖沼である。茨城県では, 公共用水域の水質汚濁状況を監視するため, 毎年水質測定計画を策定し, 定期的に水質測定を行っている[1]。霞ヶ浦では, 環境基準点を含む 52 地点において, 水域の重要性や汚濁状況等を勘案し, 年間 6～12 回の水質測定を行っている。

霞ヶ浦の流入河川の水質は, 1981 年の「茨城県霞ケ浦の富栄養化の防止に関する条例」の制定, 1987 年の「霞ヶ浦に係る湖沼水質保全計画(第1期)」の策定を契機に, 様々な水質汚濁防止対策が講じられ, 年々改善傾向にある(図 2)。一方で, 霞ヶ浦の湖内の水質は, COD を指標に見ると, 総合的な水質保全対策に取り組んだ結果, 1970-80 年代の 10mg/L 台よりは改善傾向であるものの, 近年では概ね 8.0mg/L と横ばいで推移している(図 3)。これまでに様々な解析が行われてきたが, 長期的かつ詳細な変動要因は解明できていない。また, 霞ヶ浦における藻類の優占種は, 1986 年までは藍藻類の *Microcystis* が, 1987 年からは同じく藍藻類の *Planktothrix* が優占したが, 2000 年からは藍藻類が減少, 珪藻類が優占する等(図 4), 数年から数十年周期でのレジームシフト様の変化があるのも特徴的である。

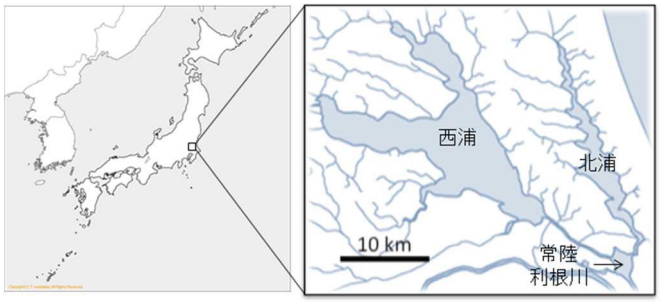

図 1 霞ヶ浦の概要

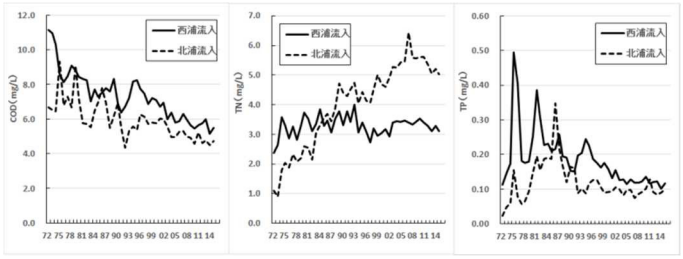

図 2 霞ヶ浦の流入河川の水質の経年変化

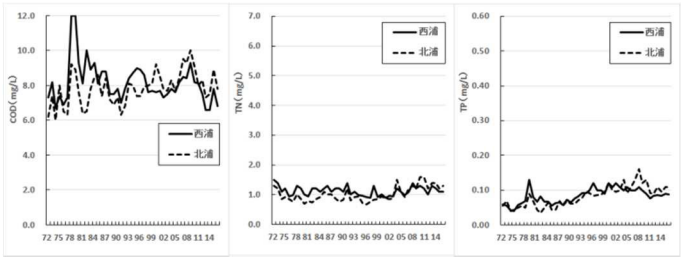

図 3 霞ヶ浦の湖内の水質の経年変化

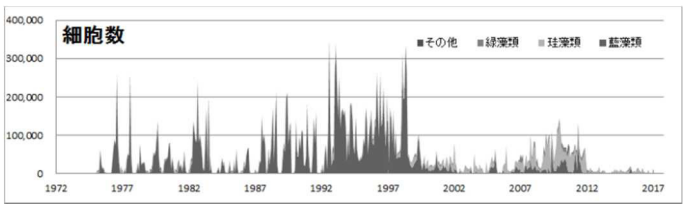

図 4 霞ヶ浦における藻類種の変遷

一方，2014 年に公表された気候変動に関する政府間パネル（IPCC）によると，ここ数十年で，全ての大陸と海洋において，気候変化が自然及び人間システムに対して影響を引き起こしていると報告された。霞ヶ浦においても，地球温暖化に伴う気温上昇や大型台風・豪雨などの異常気象により，湖内の水質や生態系に様々な影響が生じることが懸念される。

そこで，本研究では，霞ヶ浦の長期的水質変動について時系列・統計解析を実施するとともに，地球温暖化等の気候変動が霞ヶ浦の水質・生態系に与える影響について検討を行った。

2. 方法

2.1 使用データ

水質データは，霞ヶ浦（西浦及び北浦）の湖内 6 地点（西浦：湖心，掛馬沖，玉造沖，麻生沖，北浦：釜谷沖，神宮橋）の環境基準点における 1972 年から 2016 年までの約 45 年間の公共用水域水質測定結果（透明度，SS，COD，TN（全窒素），TP（全りん））を用いた（図 5）。

気象データは，気象庁の観測データ（霞ヶ浦近傍の土浦及び鉾田）を，また，気候変動を示すデータとして，十年～数十年規模の変動がある，太平洋十年規模振動（PDO：Pacific Decadal Oscillation）等を用いた。

2.2 解析手法

水質及び気象データについて，時系列・統計解析を行うとともに，The sequential t-test regime shift detection software ver.3.2 によりレジームシフトの推定を行い[2] [3]（significance level = 0.1; cut-off length = 10; Huber's weight parameter = 1），項目間の関係性を検討した。

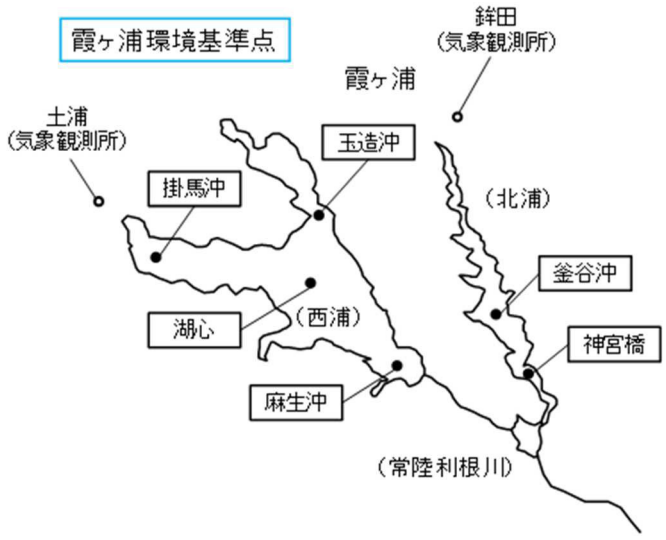

図 5 データサンプリング地点

3. 結果及び考察

3.1 地球温暖化による霞ヶ浦水温への影響

近年 40 年間の気象データを見ると，日本平均気温で 1.0℃の上昇（世界平均は 0.6℃上昇）に対し，霞ヶ浦近傍（土浦気象観測所）では 1.2℃程度気温が上昇しており，霞ヶ浦周辺では日本平均より気温の上昇幅が大きいことが分かった。

また，地球温暖化による霞ヶ浦水温への季節ごとの影響を確認するため，夏季（6月～8月）と冬季（12 月～2月）に分け，気温と水温の上昇幅を比較した。近年 35 年間の気象データを見ると，土浦気象観測所の気温の期間平均値は，夏季が 1.8℃上昇，冬季が 1.0℃上昇していた。一方，西浦湖心の水温の期間平均値は，夏季が 2.5℃上昇，冬季が 1.1℃上昇と，気温の期間平均値と比較した結果，夏季・冬季ともに，気温上昇よりも水温の上昇幅の方が大きく，地球温暖化の霞ヶ浦の水温への影響が推測された（図 6）。

3.2 気候変動による霞ヶ浦水質等への影響

気候変動を示すデータとして，十年～数十年規模の変動がある，太平洋十年規模振動（PDO：Pacific Decadal Oscillation）を用いた。PDO は，1997 年に提唱された太平洋で起こる 10 年周期での大気と海洋の連動により生じる変動であり，霞ヶ浦における藻類種（植物プランクトン）の変遷（図 4）と同様に，数年から数十年周期でのレジームシフト様の変化を示していることが分かった（図 7）。

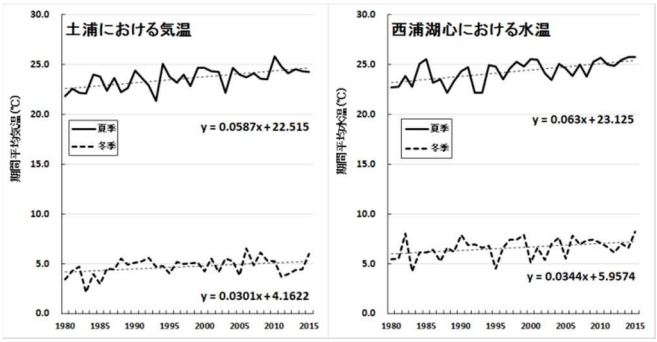

図 6 気温と水温の夏季及び冬季の期間平均値の推移

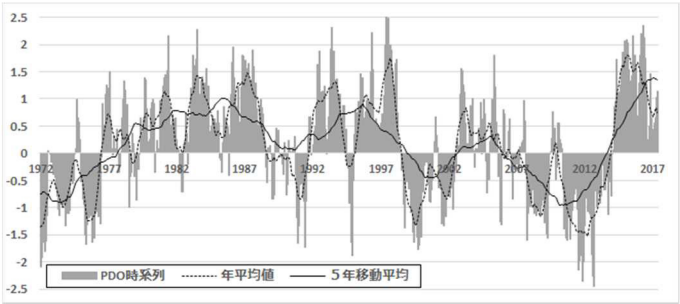

図 7 PDO の時系列変化

霞ヶ浦水質の変動時期を確認するため，各測定項目の年平均値を用いてレジームシフトの推定を行った結果，西浦 COD では 1977–1978 年と 1987–1988 年と 2012–2013 年の3回，TN では 1991–1992 年と 2003–2004 年の2回，TP では 1991–1992 年と 2009–2010 年の2回，各々大きく変動していることが分かった（図 8）。霞ヶ浦の他の水質データについても同様にレジームシフトの推定を行った結果，変動は 1980 年頃，1990 年頃，2010 年頃に顕著であることが分かった。これらは PDO の時系列変動の時期と概ね一致しており，十年から数十年規模の気候変動が，霞ヶ浦の水質のレジームシフトへ影響を与えていることが示唆された（図 9）。

また，霞ヶ浦の生態系（藻類種）についても同様にレジームシフトの推定を行った結果，1987–1988 年，1999–2000 年，2006–208 年，2012–2013 年に，大きく変動しており，PDO と植物プランクトン細胞数の変動傾向が類似していることが分かった。水質と同様に，数十年規模の気候変動が，霞ヶ浦の生態系（藻類種）のレジームシフトにも影響を及ぼしていることが示唆された（図 10）。

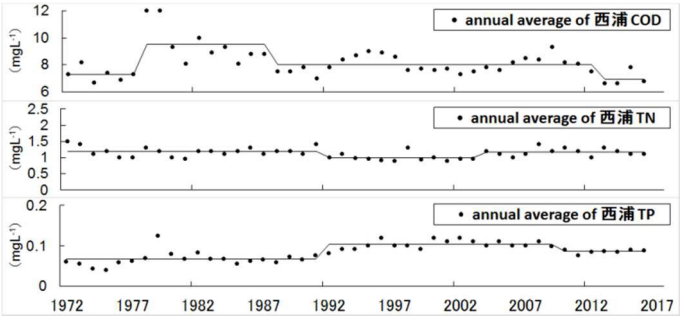

図 8 レジームシフトの推定

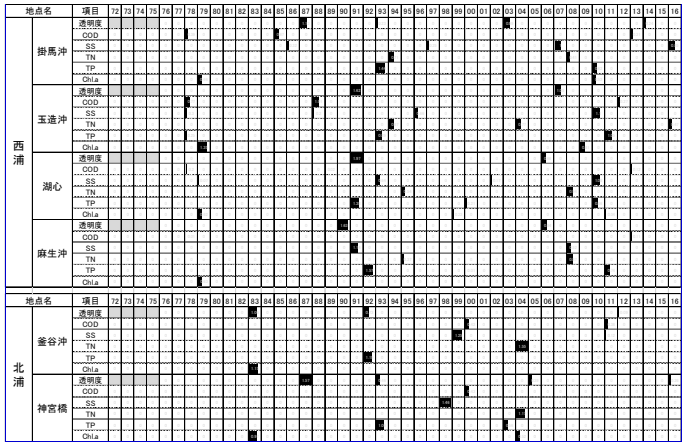

図 9 霞ヶ浦の水質のレジームシフトの推定結果

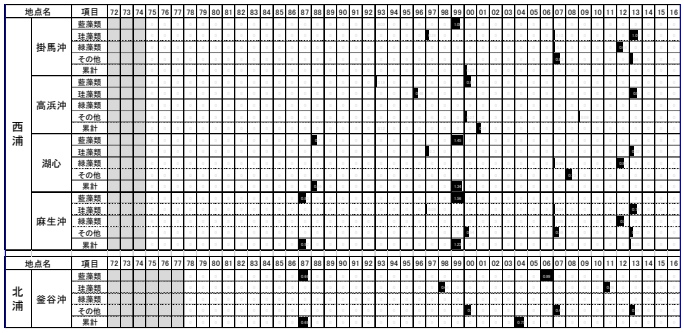

図 10 霞ヶ浦の生態系のレジームシフトの推定結果

4. まとめ

本研究の解析結果より，地球温暖化の霞ヶ浦の水温への影響が確認できたとともに，十年から数十年規模の気候変動と霞ヶ浦の水質・生態系のレジームシフト時期が概ね一致したことからも，気候変動の湖沼の水質・生態系への影響が示唆された。

今後は，これらの気候変動が，どのようなプロセスで，湖沼の水質・生態系のレジームシフトを引き起こしているのか，検討していく。

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気温と湖沼水温の関係

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キーワード:気候変動, 水質管理, 気候変動による影響

抄録

本研究では, 気温と水温に着目し, 気温と水温との関係を利根川流域に位置する霞ヶ浦, 手賀沼及び印旛沼で調べた。さらに, 印旛沼を対象に, 熱収支法を用いて, 気温を-5～5℃まで変化させた際の水温を推定し, 2 つのことを調べた。1 つは, 変化させた気温とその気温を用いて推定した水温との関係を調べた。2 つ目に, 実測値の気温から推定した水温を基準に, 気温を変化させて推定した水温との差の年平均値を気温の変動量毎に整理した。その結果, 3 つの湖沼とも気温 1℃の上昇に対し, 水温も約 1.0℃上昇し, 既往研究と同様な成果が得られた。また, 変化させた気温とその気温を用いて推定した水温との関係も気温 1℃の上昇に対し, 水温は約 0.9℃とほぼ同様な成果であった。しかし, 元の水温からの変動量では, 気温 1℃に対し, 水温は 0.5℃程度であった。これは熱収支法で気温に関連した項目の変化量と考えられ, 残りの 0.5℃は前日までの熱量の影響であると考えられる。

1. はじめに

近年, 地球温暖化に伴う気候変動は, 水環境や水資源に影響を与えると報告されている[1]。さらに, 水循環基本法や持続可能な開発のための 2030 アジェンダ, パリ協定などで, 水問題解決に関わる諸スキームがいくつも採択された。これらは水域全体の計画的な管理・運営を重視している。その水域の中で, 湖沼は利水や治水の面で多用途に使用されている。そのため, 水環境の変化は流域ないだけでなく, 流域外の多方面に影響を与える。湖沼管理・運営を行う上で, 影響頻度や程度を知ることは重要である。特に, 日本の水深が浅い湖沼は世界の浅い湖沼とは異なり, 深い湖沼と同様な機能を求められているため[2], 浅い湖沼の研究は重要である。本研究で扱う浅い湖沼とは, 田瀬らが水深と温度躍層の形成位置によって定義した分類方法[3]では『非常に浅い湖』である。この中には, 霞ヶ浦や手賀沼, 諏訪湖, 宍道湖などが分類される。

気候変動による湖沼への影響の一つとして, 水温の上昇が予測されている[4]。さらに, 既往研究では, 気温が 1.0 ℃上昇すると, 水温は約 0.75～1.0 ℃上昇するとされており[5] ~ [7], 分析方法に違いはあるものの, 統計学的解析で湖沼の大きさに関わらず, 気温と水温の上昇量はあまり変わらない。しかし, 熱量の観点からすると, 大気と水では, 比熱が大気では約 1.0 [J/(g・℃)], 水では 4.2 [J/(g・℃)]である。つまり, 水 1 g を 1℃上昇させるためには, 大気の 4 倍以上の熱量が必要である。同様に, 熱容量で考えると, 水 1 cm^3 を 1℃上昇させるためには, 大気の 3000 倍以上の熱量が必要である。そのため, 気温上昇による熱量のみで, 水温を上昇させたとは考えにくい。

そのため, 本研究では, 霞ヶ浦と手賀沼, 印旛沼で, 日平均気温と水温の関係を統計学的に調べた。さらに, 印旛沼で, 過去の実測データを用いて, 気温を変化させた際の水温を計算し, 気温と水温の関係の他, 気温変化量分のみの水温変化量を物理学的に調べた。

2. 統計学的方法

霞ヶ浦と手賀沼, 印旛沼において, 気温と水温の関係を調べる。解析で用いるデータは, 気温では湖沼から最も近い気象庁の気象観測所を用い, 霞ヶ浦では土浦観測所, 手賀沼では我孫子観測所, 印旛沼では佐倉観測所を用いた。水温データは霞ヶ浦と手賀沼では水文水質データベースの湖心表層水温を, 印旛沼は水資源機構観測している水温を用いた。対象年は霞ヶ浦では 1997 年から 2016 年, 手賀沼では 2002 年から 2016 年, 印旛沼では 2004 年から 2016 年までとし, どの湖沼も水温の時間データを日平均し, 気温と水温を比較した。

3. 物理学的方法

本研究では，熱収支法から湖沼全体の平均水温を求めた。水面における熱収支の概念図は図 1 に示す。

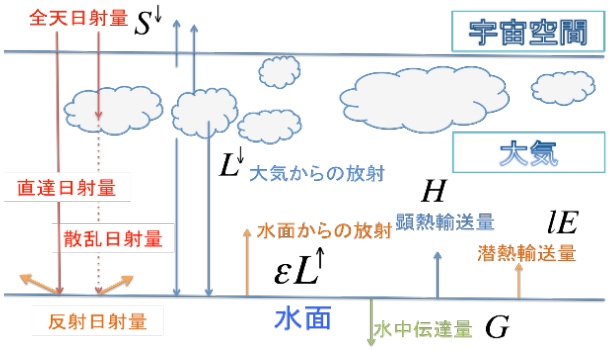

図 1　水面における熱収支式の概念図

これを式に表すと式(1)となる。また，顕熱輸送量及び潜熱輸送量の計算は 1 高度の気象データから計算が可能なバルク法を用いた（式(2)及び式(3)）。さらに，地表面が水面であるため，蒸発効率は 100 %とすると，顕熱輸送量及び潜熱輸送量のバルク係数の関係は式(4)で表される。

$$(1-ref)S^{\downarrow}+L^{\downarrow}=H+lE+G+\varepsilon L^{\uparrow} \quad (1)$$

$$H=c_p\rho C_H U(T_s-T) \quad (2)$$

$$lE=l\rho\beta C_E U\left(q_{sat}(T_s)-q(T)\right) \quad (3)$$

$$\beta C_E=C_E\approx C_H \quad (4)$$

ここに，式(1)の ref はアルベド[-]で年間通して，0.06 の一定値を与えた。$S^{\downarrow}$ は雲を考慮した日積算全天日射量[W･m^{-2}]である。$L^{\downarrow}$ は，大気中における雲を含む水蒸気等による下向きの長波放射量[W･m^{-2}]である。H は顕熱輸送量[W･m^{-2}]であり，lE は潜熱輸送量[W･m^{-2}]である。G は，水中伝達量[W･m^{-2}]である。$\varepsilon L^{\uparrow}$ は水面からの上向き長波放射量[W･m^{-2}]であり，その内の ε は射出率[-]で，1 の一定値を与えた。式(2)の c_p は空気の定圧比熱[J･(K･kg) $^{-1}$]で，1.01×103 を与えた。ρ は空気の密度[kg･m^{-3}]，C_H は顕熱のバルク係数[-]で，中立仮定のもと，1.3×10^{-3} を与えた[8]。さらに，U は風速[m･s^{-1}]，T_s は推定する水温[℃ or K]，T は気温[℃ or K]である。式(3)右辺の 1 は気化熱[J･kg^{-1}]，β は蒸発効率[-]に 1 を与えた。C_E は潜熱のバルク係数[-]，$q_{sat}(T_s)$は水温における比湿[kg･kg^{-1}]，$q(T)$は気温における比湿[kg･kg^{-1}]である。

また，式(1)の各成分の計算に関しては，$S^{\downarrow}$ 及び $L^{\downarrow}$ は近藤の式[8]，$L^{\uparrow}$ はステファン･ボルツマンの公式，G は新井らの式[9]を用いた。新井らの式を式(5)に示す。

$$G=c\rho_w d_w\frac{dT_d}{dt}=(1-ref)S^{\downarrow}+L^{\downarrow}-\varepsilon L^{\uparrow}-H-lE \quad (5)$$

ここに，c は水の比熱 [J/kg･K]，ρ_w は水の密度[kg/m^3]，d_w は水深 [m]，T_d は水体の平均水温 [K]である。式(5)は，水深が浅い場合に有効で，水面に加えられた熱量が貯水体内において垂直方向に均一に分配されるものとし，単位水柱の単位時間内の熱量変化を表している。つまり，ここで求める水温は水深平均された値である。これにより，水面だけでなく，水体全体の熱収支となる。この推定した水温を湖沼全体の代表水温として扱う。計算開始日は，1 月 1 日とし，初期値は前年の 12 月 31 日の観測値とした。計算年は印旛沼で自動観測が始まった 2003 年を除いた 2004～2016 年とした。

この熱収支式で，気温に関係する項は，下向きの長波放射量，顕熱輸送量及び潜熱輸送量である。

各年の実測気温データを基準に，-5～5℃まで 1℃ずつ気温を変化させた際の水温を求めた。

4. 結果

霞ヶ浦と手賀沼，印旛沼における日平均気温と日平均水温の関係を図 2 に示す。

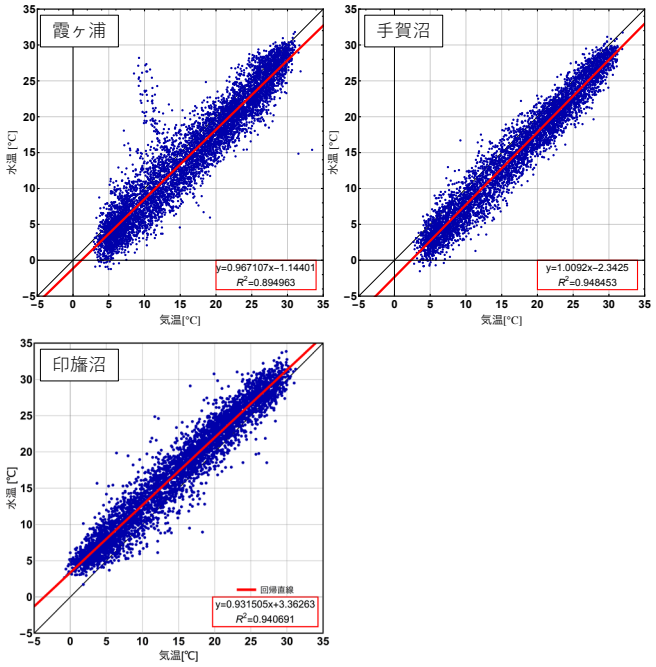

図 2　各湖沼における気温と水温の関係

図 2 によると，気温が 1℃上昇すると，水温の上昇量は，霞ヶ浦では 0.97℃，手賀沼では 1.0℃，印旛沼では 0.93℃となっている。既往研究と同様な成果が得られた。

印旛沼における気温の実測値とその気温を用いて，推定した水温との関係及び気温の実測値を変化させた気温と，その気温を用いて推定した水温との関係を図 3 に示す。

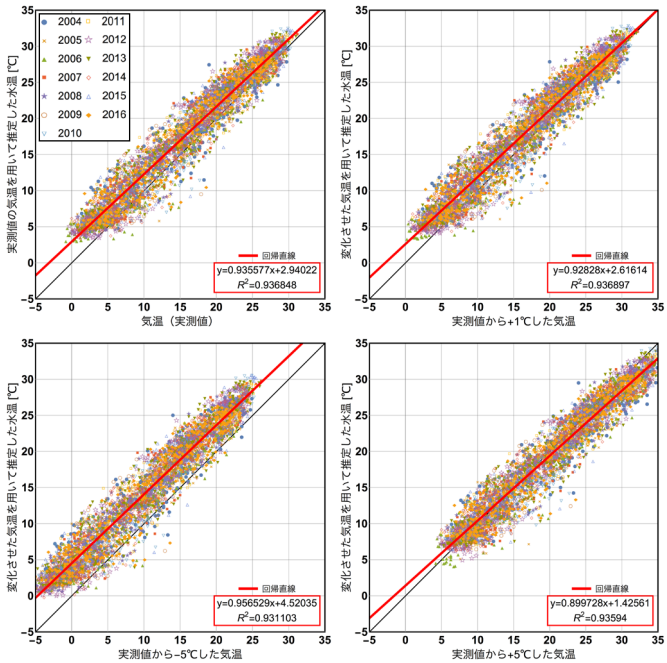

図 3　気温（実測値もしくは実測値に値を加えた）とその気温を用いて推定した水温との関係

図 2 と同様に気温と水温の関係は，気温が 1℃上昇すると，水温の上昇量は，気温の実測値からの変化量に関係なく，約 0.9℃であった。また，気温の実測値からの変化量と水温の気温 1℃に対する上昇量の関係では，気温の変化量が実測値から負の方向だと水温の上昇量は上がり，正の方向だと下がる傾向が見られた。

ここで，気温の実測値とその気温を用いて推定した水温を基準（以降，基準水温とする）に，気温を−5～5℃まで変化させ，その気温を用いて推定した水温を基準水温との差（日単位）を年平均した。（図 4 参照）

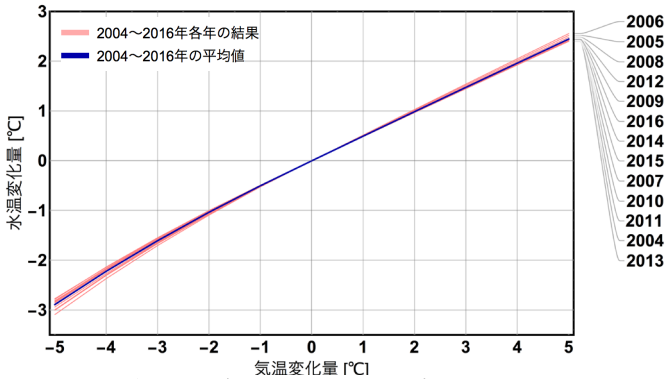

図 4　気温の変化量と水温の変化量との関係

どの年度も気温 1℃の変化量に対し，水温は 0.5℃程度の変化量である。

5.　考察

図 2 もしくは図 3 と図 4 で，気温 1℃に対する水温の変化量が異なっている理由は着眼点が違うからである。図 2 または図 3 は，気温と水温の相関関係を示しているのに対し，図 4 は気温 1℃上昇に伴う水温の移動量である。例えば，図 4 の気温変化量が+5℃のとき，その水温の変化量は，図 3 左上図のクラスターから右下図のクラスターへの移動量を表している。つまり，図 4 での気温の変化量は，熱収支式で気温の項がある長波放射量，顕熱輸送量及び潜熱輸送量の変化量と言え，これらの変化分が水温の変化量となったと考えられる。

さらに，図 2 または図 3 では約 1.0℃に対し，図 4 での水温の変化量が約 0.5℃であり，残りの 0.5℃は前日までの熱量の影響であると考えられる。

6.　結論

本研究では，霞ヶ浦，手賀沼及び印旛沼における気温と水温の関係と，印旛沼において，実測の気温を-5～5℃まで変化させた際の水温を推定し，その水温推定結果と気温との関係及び気温の変化量と水温の変化量との関係を調べた。以下に得られた知見を示す。

① 3 湖沼において，気温と水温との関係は，気温 1℃上昇に対して，水温が約 1℃上昇する。

② 印旛沼において，実測から変化させた気温とその気温を用いて推定した水温との関係も，気温 1℃の上昇に対し，水温は約 0.9℃と生データの気温と水温との関係とあまり変わらなかった。

③ 実測の気温から推定した水温を基準とし，気温を変化させ，その気温から推定した水温と基準水温との差を，気温の変化量毎にまとめると，気温 1℃変化するのに対し，水温は約 0.5℃であった。

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P3-37

Assessment of heavy metals contamination of bottom sediment in Tonle Sap Lake, Cambodia

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Keywords: heavy metals, bottom sediment, geo-accumulation index, pollution index.

ABSTRACT

Thirty-nines bottom sediments samples were collected from Tonle Sap Lake for heavy metals analysis. Concentration of selected heavy meals including Cd, Cr, Cu, Fe, Mn, Pb, and Zn were analyzed using atomic adsorption spectrophotometer (AAS-7000). The mean concentrations of heavy metals were as follow: of Cr, Cu, Fe, Mn, Pb and Zn in the sediment samples were: 0.018 µg/g for Cd, 0.83 µg/g for Cr, 1.41 µg/g for Cu, 35334.87 µg/g for Fe, 212.49 µg/g for Mn , 43.86 µg/g for Pb, and 6.61 µg/g for Zn. Sediment quality guideline was applied to assess the quality of sediment. The mean concentration of Pb was twice of the geochemical background (ASV). The mean concentration of all selected heavy metals were under the severe effect level (SEL) values, whereas Pb were exceeded toxicity reference values (TRV). The pollution load index (PLI) value indicated that all 39 sampling sites unpolluted by heavy metals. Base on geo-accumulation index Pb, Mn, Cu, Cd, Fe, Zn and Cr had I-geo values were between 0 to 1, it indicated that heavy metals contaminated in Tonle Sap Lake was in the class of non-polluted to moderately polluted.

1. INTRODUCTION

Heavy metals occurred naturally in soils, deriving from the parent material in the bedrock. When they are found in nature that mostly resulted from agricultural activities industrial waste, waste disposal, leaking landfills and mining [1]. Heavy metals discharging into a lake from both natural and anthropogenic sources were distributed between bed sediments and aqueous phases. Lake sediments were normally the final pathway of both natural and anthropogenic components produced or derived to the environment. Sediment quality was a good indicator of pollution in water column, where it tended to concentrate the heavy metals and other organic pollutants. Polluted sediments, in turn, can act as sources of heavy metals, imparting them into the water and debasing water quality [2]. Many researchers have conducted extensive surveys of heavy contamination in sediment [7,8]. Limitation surveys have been undertaken to access of heavy metal in Tonle Sap Lake sediments. The aim of this work was to access concentration of selected heavy metals and degree of contamination of Tonle Sap Lake.

2. METHOD

The study area was at Tonle Sap Lake, which is surrounded by six provinces such as Kampong Thum, Siem Reab, Banteay Mean Chey, Battambang, Pousat, and Kampong Chhnang. Tonle Sap Lake, or the Great Lake, located in the middle-western part of Cambodia is the largest freshwater lake in Asia.

Thirty-nine samples of bottom sediments were collected along Tonle Sap Lake in December 2016 **(Fig.1)**. PVC tube

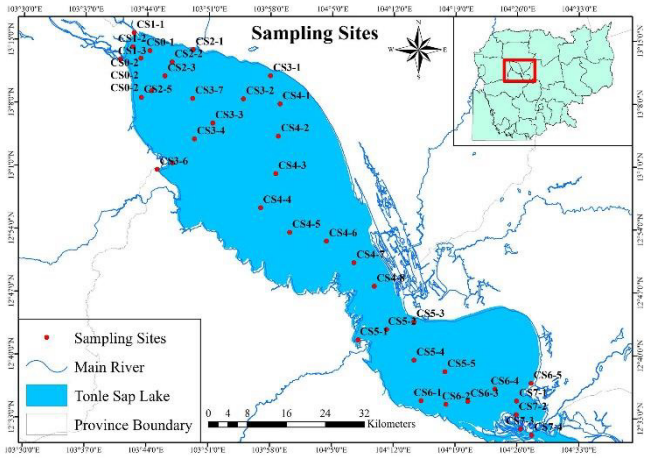

Fig. 1 Sampling locations, Tole Sap Lake, Cambodia

was used for sediment sampling. The samples were placed in polyethylene bags and transported to laboratory under frozen condition (around 4°C). The samples were air-dried for a week, then ground to a fine powder and sieved through 2mm stainless steel mesh wire. This size fraction was widely used to eliminate the effect of particle size and to obtain a more homogeneous grain distribution. Following EPA-3050b method for heavy metals extraction from the sediment, 1g of sediment was digested with 20 ml of HNO_3, 20ml of HCl and 10 ml of H_2O_2, and heated at 95°C with the hot plate [4]. The digested solution was cooled and filtered through 45µm syringe filter. The filtered sample was then diluted to 50 ml with distilled water and stored in special container. Finally, diluted samples were analyzed for selected heavy metals by

using atomic adsorption spectrophotometer instrument (AAS-7000).

Pollution Load Index (PLI) and Geo-accumulation Index (I-geo) were used to evaluate the degree of contamination in the sediments. The Pollution Load Index (PLI) was obtained as Concentration Factors (CF). This CF was the quotient obtained by dividing the concentration of each metals. The PLI of the place were calculated by obtaining the n-root from the nCFs that were obtained for all the metals. With the PLI obtained from each place. The PLI > 1 indicated polluting, whereas PLI < 1 indicated no pollution .General pollution load index (PLI) [3], which was as follows:

$$CF = C_metal / C_background\ value \quad \textbf{(Eq. 1)}$$

$$PLI = (CF_1 \times CF_2 \times CF_3 \times \cdots\cdots \times CF_n)^{1/n} \quad \textbf{(Eq. 2)}$$

Where, *CF* = contamination factor; *n* = number of metals; *C_metal* = metal concentration in polluted sediment; *C_Background value* = background value of that metal

Table 1 Geochemical background value in world surface rock average concentration [6]

Heavy metals	World surface rock average (μg/g)
Cu	32
Mn	750
Pb	16
Cr	71
Fe	35,900
Zn	127

The geo-accumulation index (I-geo) values was calculated by using **Eq. 3** [5]

$$I_{geo} = \log_2 [Cn/(1.5 \times Bn)] \quad \textbf{(Eq. 3)}$$

Where, *Cn* was the measured concentration of element n in the sediment; *Bn* was the geochemical background for the element n which is taken from the literature (average world surface rock average) [6]. Based on I-geo, sediments could be categorized into seven classes [5].

Table 2 Muller's Classification of sediments with regard to I_{geo} [5]

Class	I-geo	Pollution Level
0	< 0	Unpolluted
1	0~1	Unpolluted to moderately polluted
2	1~2	Moderately polluted
3	2~3	Moderately polluted to strongly polluted
4	3~4	Strongly polluted
5	4~5	Strongly polluted to extremely polluted
6	5~6	Extremely polluted

3. RESULTS

The concentration of heavy metas in bottom sediment samples of Tonle Sap Lack are reported in **Fig. 2.**

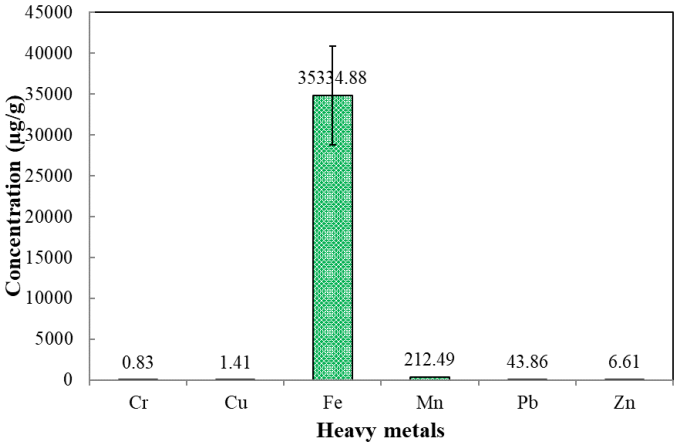

Fig. 2 Heavy metals concertation in bottom sediment of Tonle Sap Lake

The PLI provides simple but comparative means for assessing a site quality, where a value of PLI < 1 denotes perfection; PLI = 1 presents that only baseline levels of pollutants are presented and PLI > 1 would indicate deterioration of site quality [3]. The PLI values for heavy metals in Tonle Sap Lake sediments are listed in **Table 3**.

The geo-accumulation index (Igeo) was used to determine the pollution level of sediments. The calculated I-geo values, based on the world surface rock average, are presented in **Table 1** and the variations are shown in **Table 4**.

Table 3: Pollution load indices of Tonle Sap sediments

Sampling sites	PLI	Sampling sites	PLI
CS0-1	0.10	CS4-4	0.12
CS0-2	0.08	CS4-5	0.09
CS1-1	0.03	CS4-6	0.16
CS1-2	0.03	CS4-7	0.04
CS1-3	0.11	CS4-8	0.13
CS2-1	0.16	CS5-1	0.08
CS2-2	0.23	CS5-2	0.14
CS2-3	0.18	CS5-3	0.04
CS2-4	0.21	CS5-4	0.13
CS2-5	0.10	CS5-5	0.06
CS3-1	0.15	CS6-1	0.09
CS3-2	0.07	CS6-2	0.13
CS3-3	0.11	CS6-3	0.06

CS3-4	0.14	CS6-4	0.09
CS3-5	0.14	CS6-5	0.12
CS3-6	0.12	CS7-1	0.02
CS3-7	0.04	CS7-2	0.02
CS4-1	0.09	CS7-3	0.02
CS4-2	0.07	Cs7-4	0.03
CS4-3	0.12		

Table 4 Geo-accumulation indices of Tonle Sap Sediments

Sites	I-geo Cu	I-geo Fe	I-geo Cr	I-geo Zn	I-geoMn	I-geo Pb	I-geo Cd
CS0-1	-6.77	-3.70	-6.78	-4.34	-3.15	0.24	-3.28
CS0-2	-6.14	-4.10	-7.52	-4.62	-4.37	0.21	ND
CS1-1	-5.38	-4.17	ND	-5.24	-4.82	0.25	ND
CS1-2	-5.93	-4.07	ND	-4.96	-3.90	0.26	ND
CS1-3	-4.87	-3.66	-7.34	-4.42	-3.60	-0.23	ND
CS2-1	-4.81	-3.31	-6.23	-3.71	-2.90	0.29	-3.38
CS2-2	-5.09	-1.29	-6.38	-3.74	-1.29	0.40	ND
CS2-3	-4.62	-3.12	-7.26	-3.75	-1.37	0.59	ND
CS2-4	-4.26	-3.01	-5.95	-3.61	-2.17	0.51	-2.95
CS2-5	-6.12	-2.66	-9.79	-4.55	-2.22	0.68	ND
CS3-1	-5.61	-3.03	-8.40	-3.78	-1.04	0.64	ND
CS3-2	-6.83	-5.15	-7.99	-4.83	-3.43	0.62	-3.66
CS3-3	-5.93	-4.34	-7.32	-4.54	-2.63	0.50	-2.72
CS3-4	-5.47	-3.38	-6.12	-4.23	-3.14	0.49	-6.75
CS3-5	-8.72	-1.66	-6.37	-5.80	-1.49	2.41	ND
CS3-6	-4.00	-4.99	-7.78	-3.70	-4.90	2.21	ND
CS3-7	-5.33	-3.50	ND	-4.32	-1.91	0.41	ND
CS4-1	-6.33	-4.66	-7.20	-4.74	-3.21	0.02	-3.15
CS4-2	-6.58	-5.57	-7.92	-4.89	-3.75	0.34	-3.74
CS4-3	-5.30	-4.14	-7.27	-4.48	-2.62	0.47	ND
CS4-4	-5.49	-4.05	-7.48	-4.41	-2.10	0.37	ND
CS4-5	-5.96	-4.25	-8.96	-4.39	-2.18	0.47	ND
CS4-6	-5.58	-3.49	-7.02	-4.00	-1.13	0.48	ND
CS4-7	-5.77	-3.89	ND	-4.17	-1.73	0.44	ND
CS4-8	-5.45	-4.02	-7.34	-4.12	-1.69	0.33	ND
CS5-1	-6.66	-5.44	-7.74	-4.50	-2.67	0.42	-3.87
CS5-2	-5.43	-4.00	-6.08	-4.13	-2.43	0.13	-5.42
CS5-3	-6.22	-6.07	-6.86	-4.71	-8.40	-0.10	-4.67
CS5-4	-5.28	-4.29	-6.00	-4.11	-2.99	0.06	-3.50
CS5-5	-6.01	-6.85	-8.39	-5.15	-3.69	0.43	-2.54
CS6-1	-5.25	-4.75	-7.93	-3.86	-3.58	-0.39	ND
CS6-2	-5.37	-3.44	-6.45	-4.24	-3.64	0.44	-2.88
CS6-3	-5.95	-5.68	-6.72	-5.79	-4.76	0.08	-2.50
Cs6-4	-5.46	-5.50	-6.81	-4.66	-3.76	0.44	-2.86
CS6-5	-5.21	-4.38	-6.86	-4.38	-3.22	0.61	ND
CS7-1	-8.93	-4.06	ND	-5.57	-3.06	0.68	ND
CS7-2	-6.43	-5.36	ND	-5.29	-3.45	0.30	ND
CS7-3	-9.00	-5.47	ND	-5.88	-2.94	-0.28	ND
Cs7-4	-5.85	-4.90	ND	-6.46	-2.88	0.43	ND

4. DISCUSSION

The relative abundance of metals in sediment samples in the observation period that respected to the mean concentration follows the order: Fe > Mn > Pb> Zn > Cu > Cr > Cd. The concentration of Pb varied from 22.85 to 159.85 µg/g, and mean value was 43.86 µg/g. It was more than the world surface rock average as a background level. In comparison with sediment quality guideline, the mean value did not exceed the limits, and this result shows that Tonle Sap sediments are not polluted by Pb.

The pollution load index (PLI) values of sediments varied from site to site. PLI value were found to generally low (<1) at all stations.

The I-geo level varied from metal to metal and site to site. The I-geo Mn, Fe, Cr, Cd, Zn, Cu, and Pb were in the range of 0-1 meant that the classification of sediment was unpolluted to moderately polluted in all stations suggesting that the study area sediments were in background value with respect to these selected metals. The I-geo of Pb was a bit greater (positive value) if compare to other heavy metals (mostly negative value). This due to the mean concentration of Pb in sediment was higher than the geochemical background value of Pb.

5. CONCLUSION

To investigate the status of metal contamination in Tonle Sap Lake sediments, Pb, Cd, Zn, Cu, Fe, Mn and Cr concentrations were estimated in thirty-nine sampling sites. The order of the mean concentrations of tested heavy metals: Fe > Mn > Pb> Zn > Cu > Cr > Cd. According to PLI, all sites suggest perfection or no overall pollution of site quality. In general, I-geo indices for most heavy metals were negative; this implies that mean concentration of heavy metals Tonle Sap Lake sediments are lower than world surface rock average.

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P3-38

阿蘇海における貧酸素水塊発生メカニズムの評価:底質酸素消費速度とその影響因子に着目して

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キーワード:汽水湖底質, 底質酸素消費速度(SOD), 貧酸素化, 栄養塩溶出

抄録

閉鎖性汽水湖(京都府阿蘇海)底質における底質酸素消費速度(SOD)を測定し, その影響因子の分析を行った. また, SOD 試験後, 静置状態による溶出試験も行い, 栄養塩類の溶出速度の測定を行った. 阿蘇海底質の SOD (1.21~1.71 $gO/m^2/day$)は, 琵琶湖底質のそれよりも 1.5～3 倍程度大きく, 底質中の有機物に加えて, 硫化水素による酸素消費の影響を受けていると推察された. また, SOD に与える物質流動性の影響も示唆されたことから, SOD の推定にはこれらの総合的な動態を考慮する必要があると考えられた. 一方, 貧酸素化が進行した状態における静置底質からの直上水への TP 溶出試験の結果からは, 底質間隙水と直上水との水交換性(流動性)が大きく関与していることが示唆された. PO_4-P の溶出は, NH_4-N に比べて緩慢であること, 還元状態の進行と関連があること, 夏季・冬季ともに湾央最深部で最大値となることが明らかとなった.

1. はじめに

高度経済成長期に発生した水質汚濁は, 排水基準や下水道整備等により改善されてきたが, 湖沼の環境基準達成率は依然として低い現状(2016 年で COD 基準達成率は約 59%)にある[1]. 特に汽水湖に関してはその立地条件や海域からの物理化学的作用を受けて 10%以下の達成率とも言われている[1]. 多くの汽水湖では塩分による密度成層が形成されており[2], 上下混合が制限されるため底層にて貧酸素化が進行しやすい. 貧酸素化による影響は, 底泥からの栄養塩類の溶出を促進し富栄養化問題を長期化させる[3]. 青潮によって生態系に直接影響を与えている水域も少なくない[3]. 京都府北部に位置する阿蘇海(汽水湖)においても, 富栄養化による牡蠣の大量発生の問題が発生[4]している. このような中, わが国では一部の水域を対象に底層溶存酸素に関わる環境基準が制定された[5]が, 湖沼の底質環境(物質動態)を把握し, 適切な対応策を講じるためには, 溶存酸素だけでなく, 底質の酸素消費速度(SOD: Sediment Oxygen Demand)を評価することが重要である.

本研究では, 阿蘇海における貧酸素水塊発生メカニズムを解明するため, 当該海域における底質の SOD を定量し, その値に影響する因子の分析を行った. また, 貧酸素条件における, 底質から水相への栄養塩類および硫化物の溶出特性についても分析を行った.

2. 方法

阿蘇海におけるサンプリング調査は, 夏季(2017 年 9 月 19-20 日)および冬季(2018 年 3 月 24-25 日)に実施された. 底質のサンプリング地点は阿蘇海に流入する最大河川の野田川河口(地点 A), 湾央最深部(地点 B), 湾奥部(地点 C)の 3 地点に設定された(図 1). 採泥作業は調査船上から不攪乱柱状採泥器(HR 型, 離合社)を用いて行い, 採取された柱状試料 1 は不攪乱・冷蔵状態で実験室へ運搬された. その後, 速やかに SOD 試験(底質調査法[6])が行われた. また, 冬季には KK 式コアサンプラーを用いて別途柱状試料 2 を採取し, 実験室に運搬された後, 表層から 1cm ごとに層分けされ, 底質間隙水中の H_2S 濃度が測定された.

SOD 試験(図 2)は, 柱状試料 1 が入っている不攪乱状態の採泥管をそのまま利用し, 20℃恒温環境にて実施された. 柱状試料の水相部分は, 溶存酸素を飽和させた海水に置換し, その水相上端は流動パラフィンを用いて酸素供給を遮断した. その後, 柱状コアの表層が乱れない撹拌速度(70rpm)で水相中央付近を緩やかに撹拌しながら, 底質直上(水相下端)にセットされた DO 計(PS-2196, 島津理化製)にて DO の経時変化を測定した. DO の経時変化は, 通常序盤の減少が速く(化学的酸素消費が優先), その後緩やかになる(生物的酸素消費が優先)[7]が, 本研究では実験開始 10 時間までの序盤の変化量を SOD 値として定義した[8].

また，SOD 試験後の柱状試料を，採泥管内に静置することで貧酸素状態における溶出試験が実施された．夏季試料については，試験開始直後と一定日数経過後（10, 75 日後）に底質直上の採水が行われ，TP および PO_4-P 濃度が測定された．冬季試料については，底質からの溶出量の短期的変化を捉えるために，4 日目までの毎日と 6 日目および 9 日目に底質直上の採水が行われ，pH, ORP, PO_4-P, NH_4-N および H_2S 濃度がそれぞれ測定された．また，ミズトール（DIK-8392，大起理化工業）を用いて底質間隙水の採取も行われた．

柱状試料は，溶出試験終了後に表層から 4cm ごとに層分けされ，それぞれの湿試料およびその間隙水に対して，TP, PO_4-P, AVS（酸揮発性硫化物），TC および TN がそれぞれ測定された．

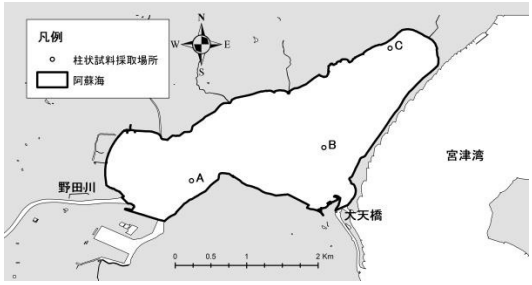

図 1　柱状試料のサンプリング地点

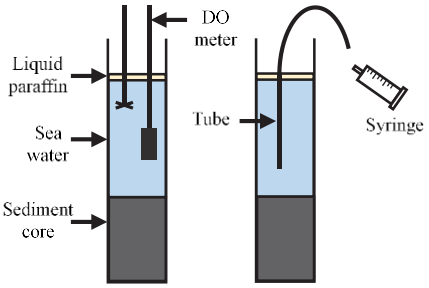

図 2　SOD 試験（左）と溶出試験（右）の方法

3. 結果および考察

3.1 SOD 試験

夏季および冬季の SOD 測定結果を表 1 に示した．季節間の SOD 比較では，冬季の方がやや低い値（平均値で 10%弱の差）となったが，大差は見られなかった．一方，地点間の SOD 比較では，冬季では大差が見られなかったが，夏季では地点間で最大 1.5 倍程度の大きな差が確認された．湾央最深部（地点 B）や湾奥（地点 C）では高い値となったが，野田川河口（地点 A）では低い値を示した．夏季調査は，台風直後に実施されたため，出水による影響（流出物の堆積）を受けたことが原因であると考えられる．

また，琵琶湖底質の SOD（0.45~1.09）[9]に比べると 1.5～3 倍程度高い傾向を示した．汽水湖では閉鎖性水域としての水理学的特徴に加えて，海水による化学的凝集効果や塩分躍層形成の影響により，底質の有機汚濁化が進行しやすい．これに加えて，汽水湖では硫化水素による酸素消費も大きいことが複合的に影響していると考えられた．

表 1　SOD 試験の結果

Sample	SOD ($gO/m^2/day$)	
	Summer	Winter
A	1.21	1.47
B	1.54	1.41
C	1.71	1.34

3.2 溶出試験

夏季底質における TP 溶出試験の結果を表 2 に示した．この結果から，地点に依らずに，直上水よりも間隙水の方が数倍～100 倍程度高い TP 濃度を示すことが確認された．一方，直上水に対する底質からの TP 溶出量（75 日目）は地点間で最大 10 倍程度異なっていた．この違いは，底質粒子あるいは間隙水に含まれる TP 濃度の違いでは説明がつかなかったが，底質含水率が高いほど TP 溶出量も大きい傾向が見られた．従って，不攪乱静置条件における底質から直上水への TP 溶出量は，底質間隙水と直上水との水交換性（流動性）が大きく関与していることが示唆された．なお，地点 A については，台風出水による底質表面の砂層が TP 溶出を抑制している可能性も考えられた．

表 2　底質リンの溶出特性とその関連指標（夏季）

Sample	TP (mg/L)				TP_{sed} (mgP/g)	AVS (mg/g-dry)	Moisture Ratio (vol %)
	Elution			Sediment pore water			
	0day	10day	75day				
A	0.05	0.02	0.11	3.74	0.85	2.71	90.4
B	0.05	0.64	1.10	2.95	0.66	9.00	93.2
C	0.05	0.52	0.70	2.34	1.08	1.08	92.7

冬季底質の PO_4-P および NH_4-N の溶出試験結果を図 3 に示した．直上水の NH_4-N 濃度は溶出試験後すぐに平衡状態に達して一定の値を示したが，PO_4-P 濃度は地点による差異があるものの，数日～10 日間以上の長期に渡って濃度上昇が続いた．10 日目の濃度で比較すると，PO_4-P および NH_4-N のいずれにおいても地点によって数倍程度の違いが見られた．地点 B は PO_4-P, NH_4-N ともに溶出量が最大値となり，夏季と同様の傾向を示した．地点 B は湾央で水深が深いため，長期に渡る強い嫌気状態の影響が示唆された．このことは間隙水中の硫化水素の分析結果（地点 B が最も高い濃度）からも裏付けられている．

表 3　底質間隙水中の硫化水素濃度（冬季）

地点	H_2S(mgS/L)			
	0-1cm	1-2cm	2-3cm	3-4cm
A	2.7	12.0	24.7	22.8
B	20.6	35.8	64.7	68.6
C	6.2	16.3	20.2	32.6

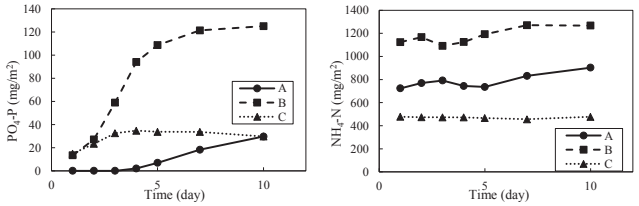

図 3　PO_4-P および NH_4-N 濃度の経日変化（直上水）

冬季底質の溶出試験に関連して，直上水中の PO_4-P 濃度と ORP との関係を図 4 に示した．両者には負の相関が示されたことから，PO_4-P 溶出は還元状態の進行とともに促進されていると考えられる．直上水中の H_2S 濃度の変化についても PO_4-P 濃度と同様の傾向が確認されたため，汽水域底質で還元状態を促進する微生物（硫酸還元菌など）影響が PO_4-P の溶出に寄与しているものと推察された．

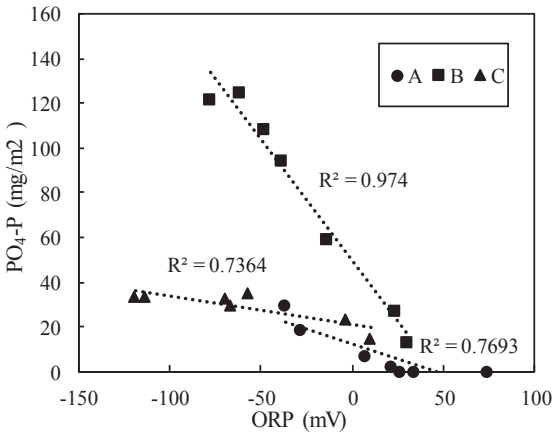

図 4　溶出試験における PO_4-P 濃度と ORP の関係

3.3　SOD への影響因子

夏季底質の SOD は地点 C で最も大きく，次いで B，A の順（表 1）となったが，底質中の TC についても地点 C が最も高い値（50.7 mg/g）であった．しかし，TC の濃度差は地点間で 1 割程度であり，その他の影響として底質間隙水と直上水との流動性の影響が予測された．この影響を考察するために，地点ごとの SOD と表層底質の含水比との関係を図 5 に示す．データ数が限られているものの，SOD と含水比との間に正相関が確認されたことから，底質の含水比（流動性）も SOD に影響を与えていることが推察された．

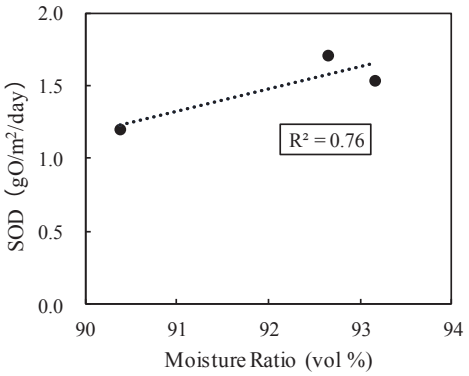

図 5　SOD と含水比の関係（夏季）

4.　結論

汽水湖底質の SOD は，淡水湖（琵琶湖）底質のそれよりも 1.5～3 倍程度大きく，底質中の有機物に加えて，硫化水素による酸素消費の影響を受けていると推察された．また，SOD に与える物質の流動性（底質あるいはその間隙水と直上水との交換性）の影響も示唆されたことから，SOD の推定にはこれらの総合的な動態を考慮する必要があると考えられた．

一方，貧酸素化が進行した状態における静置底質からの直上水への TP 溶出試験の結果からは，底質間隙水と直上水との水交換性（流動性）が大きく関与していることが示唆された．PO_4-P の溶出は，NH_4-N に比べて緩慢（数日以上）であること，還元状態の進行（ORP）と関連があること，夏季・冬季ともに湾央最深部（地点 B）で最大値となることが明らかとなった．底質間隙水中の H_2S も同様の傾向であり，長期に渡る強い嫌気状態の影響が示唆された．

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謝辞

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猪苗代湖における底層 DO の変動

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キーワード:貧酸素，水質汚濁

抄録

猪苗代湖では湖水の pH の中性化とともに COD の上昇も顕在化している。COD の上昇は湖水中の有機物濃度の上昇を示唆しており，特に成層期における底層溶存酸素（DO）濃度の低下が懸念される。そこで本研究では,データロガー内蔵 DO 計及び水温計を猪苗代湖の湖底に設置し連続観測を行った。湖心の底層 DO 濃度は，水温躍層が崩壊する前でも極度の貧酸素状態にはなっていないが，水温躍層が崩壊してから底層 DO が回復するまで1ヶ月程度要することが分かった。底層 DO 濃度を地点ごとに比較すると，水深が深い地点ほど底層 DO 濃度が低下していた。このことより，高深度には DO 濃度の低い水塊が存在していることが示唆された。

1. はじめに

近年，猪苗代湖では湖水 pH の中性化だけでなく COD の上昇も顕在化している[1]。COD の上昇は、湖水中の有機物濃度の上昇を示唆しており，特に成層期において，湖底へ沈降した有機物の微生物分解による底層溶存酸素（DO）濃度の低下が懸念される。

しかし，水深が深い湖沼における底層 DO 濃度や水温の経時変化に関する知見は少ない。

そこで本研究では，データロガー内蔵の蛍光式溶存酸素計及び水温計を湖内に設置して連続観測を行うことにより，それらの時空間的な変動を調査した。

2. 試験方法

猪苗代湖内の4地点（水深 73～93 m）で水温及び底層 DO の連続測定を行った（図 1）。データロガー類はアンカーを用いて湖内に設置した観測機器係留用ロープ上に固定した（図 2）。水温は，Onset 社の Tidbit v2 を用いて 2016 年 6 月から測定を開始し，設置間隔は表層から湖底まで約 10m 間隔とした。底層 DO は Onset 社の U26-001 を湖底から1m の範囲に入るように設置し，2016 年 10 月から測定を開始した。水温および底層 DO ともに測定間隔は 1 時間とした。また，気温は猪苗代地域気象観測所のデータを用いた[2]。

3. 結果と考察

図 3(a)に猪苗代町の気温，図 3(b)に St.2（猪苗代湖湖心，水深 92m）における水温，図 3(c)に底層 DO 濃度の経時的変化を示した。湖心の底層 DO 濃度は，水温躍層の崩壊に伴う湖水の鉛直方向の混合が底層水

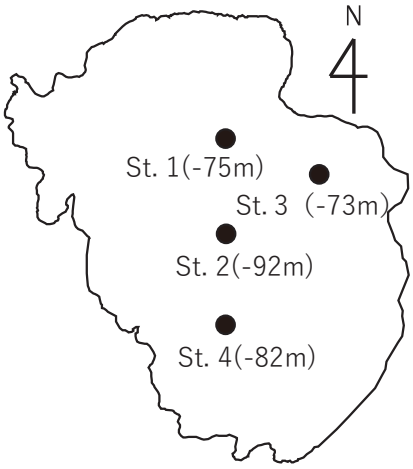

図 1　底層 DO 濃度及び水温観測地点

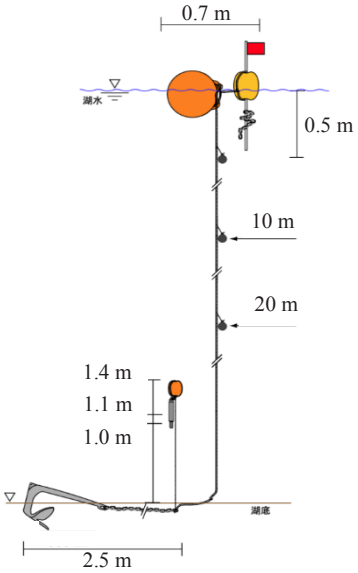

図 2　データロガー類の設置方法

へ及ぶ直前に，6 mg L^{-1} まで低下することが分かった。底層水の鉛直混合が始まった 12 月には底層 DO 濃度は 10 mg L^{-1} まで回復し，その後の水温低下に伴い徐々に 12 mg L^{-1} まで上昇した。このことから，猪苗代湖湖心の底層水では，極度の貧酸素状態にはなっていないことが分かった。また，水温躍層が崩壊してから底層 DO が回復するまで 1 ヶ月程度要することも分かった。

図 4 には St.2 における水温躍層崩壊時期の底層の水温及び底層 DO 濃度の経時的変化を示した。11 月下旬の水温躍層の崩壊により，上層水の沈み込みが起こり一時的に底層水の水温が上昇した。これは，水温と酸素濃度が高い上層の湖水と底層水が混合したことによるものであり，これに伴い底層 DO 濃度も上昇した。また，底層 DO 濃度の時間変動は，水温と同様の小刻みな増減が見られた。この変動は底層水の流動による影響と考えられた。

図 5 には地点ごとの底層 DO 濃度の経時的変化を示した。水深が 92 m となる St.2 は水温躍層が崩壊する直前に 6 mg L^{-1} 程度であり，測定地点で最も水深の浅い水深 73 m の St.3 は 9 mg L^{-1} と地点間で底層 DO 濃度に差がみられた。水深が深い地点ほど底層 DO 濃度の低下がみられることから，高深度には DO 濃度の低い水塊が存在していることが示唆された。また，St.4 のみ他の地点と逆位相で底層 DO が変動していることが確認できた。このことから，St.4 は湖心を挟んで他の地点と逆の位置にあるため，底層水が逆位相で流動していることが考えられた。

4. 結論

本研究の結果，猪苗代湖湖心の底層 DO 濃度は，水温躍層が崩壊する直前に，6 mg L^{-1} まで低下したが，極度の貧酸素状態にはなっていないことが分かった。水温躍動が崩壊すると，底層 DO 濃度は 1 ヶ月程度かけて徐々に回復することが分かった。また，水温躍層崩壊前の底層 DO 濃度に地点間での差が見られ、水深が深い地点ほど底層 DO 濃度が低下していた。このことより，高深度には DO 濃度の低い水塊が存在していることが考えられた。今後は継続して観測を続けるとともに，底層水の流動方向を調査し，底層 DO 濃度との関係について検討していく必要がある。

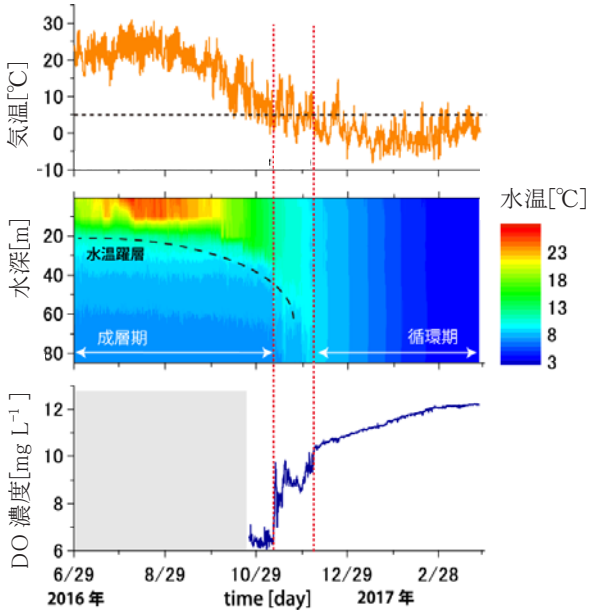

図 3 (a)猪苗代町の気温，(b)St.2 における湖水温および(c)底層 DO 濃度の経時的変化

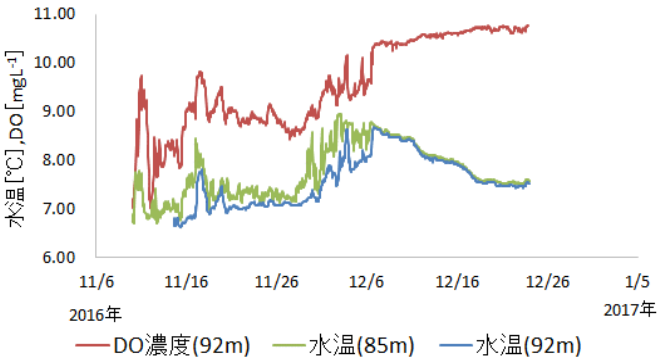

図 4 St.2 における底層 DO 濃度，水深 85m および 92m の水温の経時的変化

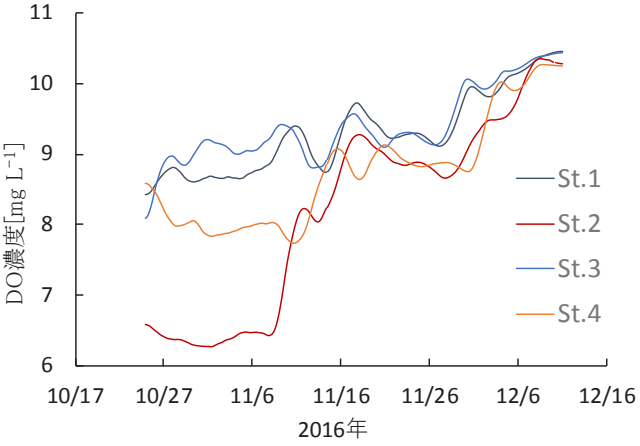

図 5 地点ごとの底層 DO 濃度の経時的変化（データを平滑化してグラフ化）

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P3-40

底層溶存酸素量、沿岸透明度に対応する水質保全対策に関する検討

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キーワード:貧酸素, 沿岸透明度, 水質管理, シミュレーション, 要因解析

抄録

日本の湖沼の水環境は、水質環境基準の達成率が横這い傾向となっていることに加え、湖底の貧酸素化や水草の繁茂、在来魚介類の減少といった課題がある。これらを受けて、2017 年に新たな環境基準等として底層溶存酸素量と沿岸透明度が追加された。環境省では、これらの新規環境基準等の設定に伴い、実際の湖沼を対象としたモデル事業の実施や水質予測計算により、効果的な水質保全対策の検討を行っている。今後これらの結果を踏まえ、新規環境基準等に対応する対策の手引きを作成し、水質環境基準の達成率の向上や望ましい湖沼水環境の実現に寄与することを目指している。本検討では、底層溶存酸素量低下の影響要因の解析と水質保全対策の有効性評価を目的としたシミュレーションモデルを構築し、成り立ちや利用状況が異なる 6 つの湖沼を対象に再現性の評価と汎用性について確認した。

1. はじめに

本報告は、環境省による「湖沼水質保全対策調査検討会(座長:福島武彦筑波大学名誉教授)」における検討の状況を報告するものである。

日本の湖沼の水環境は、徐々にではあるが改善も見られるものの、湖底の貧酸素化や水草の繁茂、在来魚介類の減少といった問題も見られ、現在の環境基準項目の達成状況だけでは水環境の現状が国民にわかりにくく、水環境保全施策の推進等につながらないとの指摘がある。

環境省では、湖沼水環境の目標や評価を国民によりわかりやすいものとするため、底層溶存酸素量(以下、「底層 DO」という。)、沿岸透明度の指標化について検討を行ってきた。この結果、2017 年 3 月に底層 DO が環境基準に追加され、沿岸透明度が地域において適切な目標(地域環境目標)として設定された。これら新規環境基準等の設定に伴い、環境省では、効果的な水質保全対策の実施に資するための検討を行っている(図 1)。

具体的な検討は、水質予測シミュレーションモデル(以下、「シミュレーションモデル」という。)を用いた底層 DO と沿岸透明度を対象とした影響要因の解析と、実際の湖沼で底層 DO 等の改善効果の検証を行う「湖沼溶存酸素量・沿岸透明度改善モデル事業」(公募で選定された地方公共団体が実施)により行なっており、今後これらの検討により得られた知見等を踏まえ、地方公共団体等の担当者に向けて「([仮称]新規基準等に対応する水質保全対策の手引き(以下、「手引き」)という。)」を作成する予定である。

本論文では、望ましい湖沼環境の実現に向けた検討(図 1)のうち、底層 DO を対象としたシミュレーションモデルによる解析の概要について紹介する。

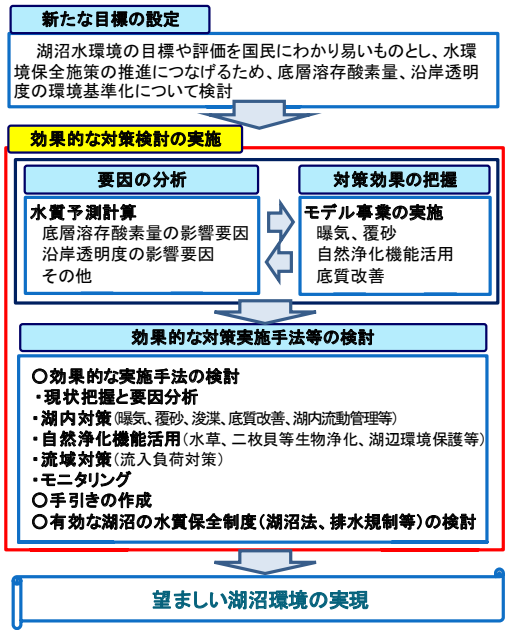

図 1 望ましい湖沼環境実現のための検討

2. シミュレーションモデルによる解析

1) シミュレーションモデル構築の目的

湖沼の環境は各湖沼の形状・地形、気象、水文・水質、生態系、流域環境、流入・流出負荷等の多様な因子により形成され、底層 DO や沿岸透明度の低下の要因はこれら複数の因子が相互に関係している。シミュレーション

モデルの構築は、全国の湖沼において影響要因の解析に活用されることを念頭に、成り立ちや利用状況等を考慮したダム湖・汽水湖を含む 6 湖沼（釜房ダム貯水池、霞ヶ浦、諏訪湖、琵琶湖、中海、宍道湖、表 1 参照）を対象に行った。

表 1 シミュレーション対象湖沼

湖沼名	成因	淡水／汽水	湖面積 (km^2)	平均水深 (m)	最大水深 (m)	総容積 (百万m^3)	平均滞留時間	流域面積 (km^2)
釜房ダム貯水池	人工湖	淡水	3.9	11.6	43.6	39.3	52日	195
霞ヶ浦	海跡湖	淡水	220	4	10	850	約200日	2157
諏訪湖	構造湖	淡水	13.3	4.7	7.2	63	39日	532
琵琶湖	構造湖	淡水	670.3	41.2	103.6	27500	5.5年	3174
中海	海跡湖	汽水	92.1	5.4	8.4	521	0.4年	595
宍道湖	海跡湖	汽水	81.8	4.5	6.4	366	0.3年	1288

2） シミュレーションモデルの概要

シミュレーションモデルは、流れ、水温（・塩分）といった湖内での物理的な側面を表現する「流動モデル」と、窒素・リンなどの栄養塩やプランクトンといった生物・化学的な側面を表現する「水質－底質結合生態系モデル[1]（図 2）」の 2 つで構成される。流動モデルは、流体力学の基礎方程式を差分化することにより解く数値モデルで、基本式は、回転系の非圧縮流体を仮定した運動方程式、連続の式および水温・塩分の保存式であり、ブシネスク近似および静水圧近似が施されている。

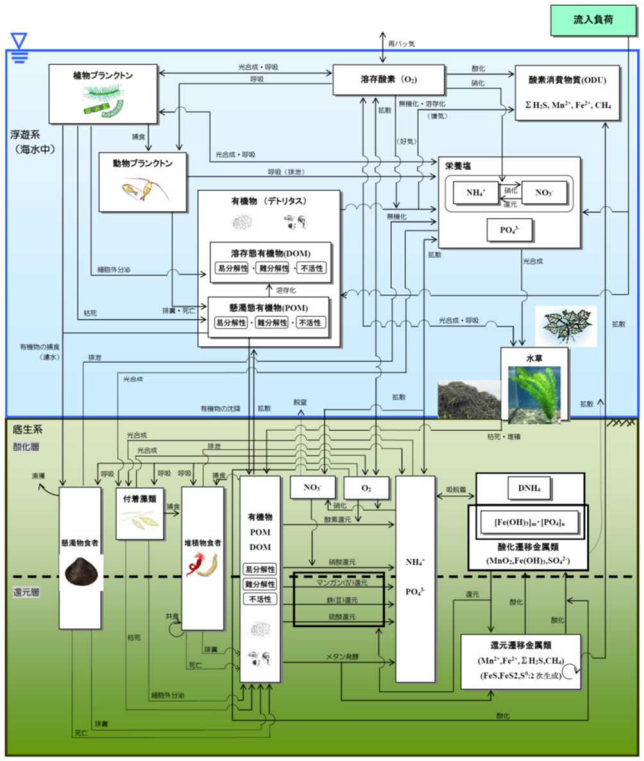

図 2 水質－底質結合生態系モデル

水質－底質結合生態系モデルは、各構成要素間の物質輸送を炭素、窒素、リン、酸素を指標元素として算定する物質循環モデルで、水質と底質の相互作用を考慮したものであり、水質サブモデル（低次生態系モデル）、底質サブモデル、底生生物サブモデルの 3 つのサブモデルから構成される。底質サブモデルでは水質サブモデルで計算される底泥への有機物の沈降量が底質を変化させ、逆に水質サブモデルは底質サブモデルで計算される栄養塩の溶出量や酸素消費量が水質を変化させる形で、3 つのモデルがそれぞれ相互に作用しあい結合している。

対象となる 6 湖沼に対し、基本的には同様の基本式からなるモデルを適用しつつ湖沼ごとの特徴を反映させている。具体的には、釜房ダム貯水池には散気曝気装置稼動による鉛直混合の促進、諏訪湖には沿岸のヒシ帯における流動阻害と懸濁物の沈降促進、琵琶湖南湖には水草の生長と枯死を、宍道湖にはヤマトシジミによる水質浄化機能をそれぞれ流動および生態系モデルに組み込んだ。

3） 底層 DO の解析の結果

底層 DO を対象とした解析結果について、諏訪湖を例に示す。諏訪湖では、陸域の負荷対策によって窒素・リン濃度の低下が見られており、底層 DO の低下要因は主に水温成層による底層への酸素の供給不足であると考えられている。また、諏訪湖の沿岸域において、近年浮葉植物のヒシの繁茂が顕著であり、底層 DO 低下の一因となっている。

湖心における底層 DO 濃度の連続観測結果と計算結果との比較（日平均値）を図 3 に示す。計算結果は、底層 DO の濃度変化の傾向を概ね再現していると言える。

次に、底層 DO 濃度の面的分布について、実測値と現況再現との比較を図 4 に示す。対象年が異なるため、単純比較はできないが、2011 年の計算結果において、湖心付近で夏季（8 月まで）に 3mg/L を下回る分布域が生じ、秋季（9 月以降）に解消する状況が示されている。

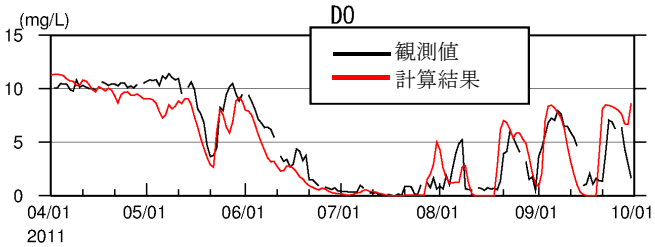

図 3 湖心での連続観測結果と計算結果の比較(底層 DO)

4） シミュレーションモデルの評価（客観的解析）

構築したシミュレーションモデルによる 6 湖沼の現況計算の妥当性を検証するため、計算値（予測値）と実測値の類似性を示す 3 種類の方法で評価を行った。

(1) 評価の方法

- 相関係数:予測値と観測値の増減のパターンが完全に一致している場合には最大値の 1 をとり、相関がまったくない場合には 0 をとる。
- 2 乗平均平方根誤差(RMSE: Root Mean Square Error):誤差の大きさを示す指標。0 に近いほど予測値が観測値に近い。単位は測定値の単位である。
- スキルスコア(Skill Score):的中率の指標。1 が完全な予測、0 がランダムな予測の的中率を示す。

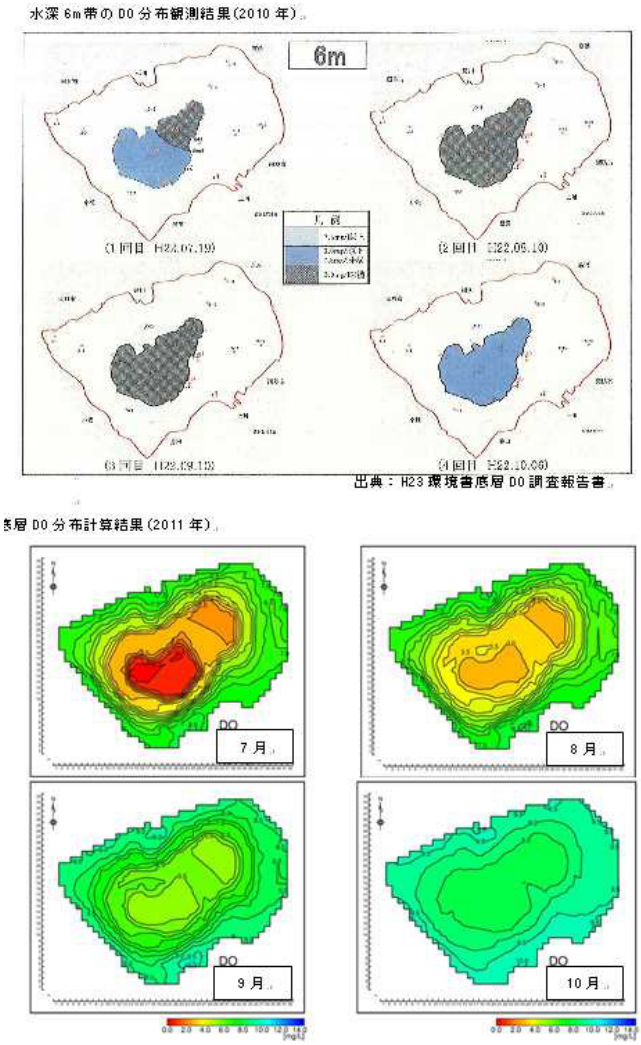

図 4 諏訪湖の 6m 帯 DO 濃度分布観測結果(上)及び底層 DO 濃度分布計算結果(下)

(2) 評価の結果

流動モデルは水温、水質モデルは底層 DO を対象に評価を行った結果を表 2、表 3 に示す。スキルスコアは解析を行う際に一定数以上のデータを必要とすることから、連続観測が行われている湖沼を対象とした。結果として水温は、いずれの湖沼も妥当性が高いと判断される。また、底層 DO は、多くの湖沼で相関係数 0.8 を上回る良好な結果であったが、一部やや低い地点も見られた。

表 2 湖沼シミュレーション結果の妥当性確認(水温)

湖沼名	相関係数	2 乗平均平方根誤差(□)	スキルスコア
釜房ﾀﾞﾑ	下層：0.954	下層：1.8	0.82
霞ヶ浦	西浦表層：0.998 北浦表層：0.997	西浦表層：0.6～0.9 北浦表層：0.7	西浦(湖心)：0.90 北浦(釜谷沖)：0.84
諏訪湖	下層：0.975	下層：1.7	0.73
琵琶湖	北湖表層：0.993 南湖表層：0.995	北湖表層：1.7 南湖表層：1.1	―
中海	下層：0.970～0.985	下層:1.5～2.4	―
宍道湖	下層：0.972～0.983	下層:1.7～2.0	―

表 3 湖沼シミュレーション結果の妥当性確認(底層 DO)

湖沼名	相関係数	2 乗平均平方根誤差(mg/l)	スキルスコア
釜房ﾀﾞﾑ	0.941	1.5	0.65
霞ヶ浦	西浦：0.727～0.873 北浦：0.867	西浦：1.6～1.9 北浦：1.8	湖心:0.00 釜谷沖：0.00
諏訪湖	0.952	1.2	0.67
琵琶湖	0.678～0.912	1.9～2.6	―
中　海	0.699～0.731	2.4～3.1	―
宍道湖	0.857～0.885	1.8～2.2	―

3. 今後の進め方

今後は、沿岸透明度を対象に、実測調査も行いつつ透明度への寄与成分が推定可能なシミュレーションモデルの構築を進めるほか、シミュレーションモデルによる影響要因の解析結果等も踏まえ、全国の地方公共団体等が底層 DO や沿岸透明度に関する対策を検討する際に役立つ手引きを作成する予定である。

手引きの作成方針として、底層 DO、沿岸透明度ともに正確な影響要因の分析や改善対策の効果把握が難しいことから、試行錯誤を繰り返しつつ、長期的な視点で適切な対策を目指すという考え方に基づいている。

また、効果的、効率的な水質保全対策の検討にあたり、シミュレーションモデル等を用いた解析が実施可能な湖沼は多くはないと考えられるため、湖沼の特性に応じて類型化し、タイプ別の典型的な水質悪化要因と対策の考え方等について例示していきたいと考えている。

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P3-41

Formation and decomposition of polymeric silicate in pore water

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Keywords: polymeric silicate, pore water, ferric hydroxide, sodium chloride, freshwater lake

ABSTRACT

Dissolved silicate is easily adsorbed onto ferric hydroxides and then is semi-permanently buried in sediment. In some lakes, the dissolved silicates seasonally increase with hydrogen sulfide, as the silicate is eluted from ferric hydroxide by its reductive dissolution. In this geochemical process, we found that polymeric silicate (PSi) was detected in freshwater lakes, but was not in brackish lakes. Accordingly, we assume that the main source of PSi in the pore water is ferric hydroxide adsorbing silicates. Another major factor controlling PSi content is NaCl concentration, as this salt is the most abundant component of brackish lake water. We examined polymerization mechanism of silicate and the effect of NaCl on PSi decomposition. After leaving a test solution (0.6 mM monomeric silicate (MSi), 0.3 mM Fe^{3+}, 0 M NaCl and pH 7) for 1 month, precipitate and filtrate 1 (F1) were obtained and then the precipitate was made to react with a Na_2S solution (pH 7). After 1 day, we collected Filtrate 2 (F2) and measured the MSi and PSi of F1 and F2. PSi was only detected in F2 and its concentration was 0.2 mM. Thus, NaCl was added to natural pore water, which was found to contain PSi. Most of the PSi was decomposed to MSi after 8 days. From these results, it can be concluded that PSi is formed only at freshwater lakes but is not at brackish lakes. Because its formation is inhibited by the presence of large amounts of NaCl.

1. INTRODUCTION

Silicon is second most abundant element in earth crust, and normally exists as silica (SiO_2) and silicate minerals. In natural water, soluble form of silica is generally formulated as monomeric silicate (H_4SiO_4). Most dissolved silicates consist of monomeric form, it is soluble and stable in aquatic solution at 25 °C for long periods of time if the concentration is less than about 1.6 mM (Iler 1979). Usually the concentration of dissolved silicate ranges from 0.1 to 0.6 mM in natural water (Gottlieb et al. 2012). Dissolved silicates inflow into a lake through the rivers, and then this used to one of essential nutrients for aquatic organism, to form skeleton of a phytoplankton such as diatom (Lacombe et al. 2007). However, dissolved silicates are easily adsorbed onto ferric hydroxides (Hallmark et al. 1982) in suspended particulate matter and sediments at the bottom of lakes (Fischer et al. 2009). Most of these particles are semi-permanently buried in the deep sediment layer. However, in some lakes where anoxic hypolimnion occurs in the summer, the dissolved silicates seasonally increase with hydrogen sulfide, as the silicates are eluted from ferric hydroxide by its reductive dissolution (Testa et al. 2013). Generally, the origin of eluted silicate was considered to be biomaterials, mainly diatomaceous debris (Van der Weijden 2007). However, in an anoxic reducing environment, it has been reported that eluted silicates are derived from inorganic oxides, such as metal oxides, rather than biogenic silica (Lehtimäki et al. 2016). The eluted silicates diffuse and supplied into the entire lake water by vertical mixing, and then the dissolved silicates are re-used as a nutrient source (Tallberg 2000) and re-precipitate in the bottom sediments. In this geochemical process, we found polymeric silicates (PSi)

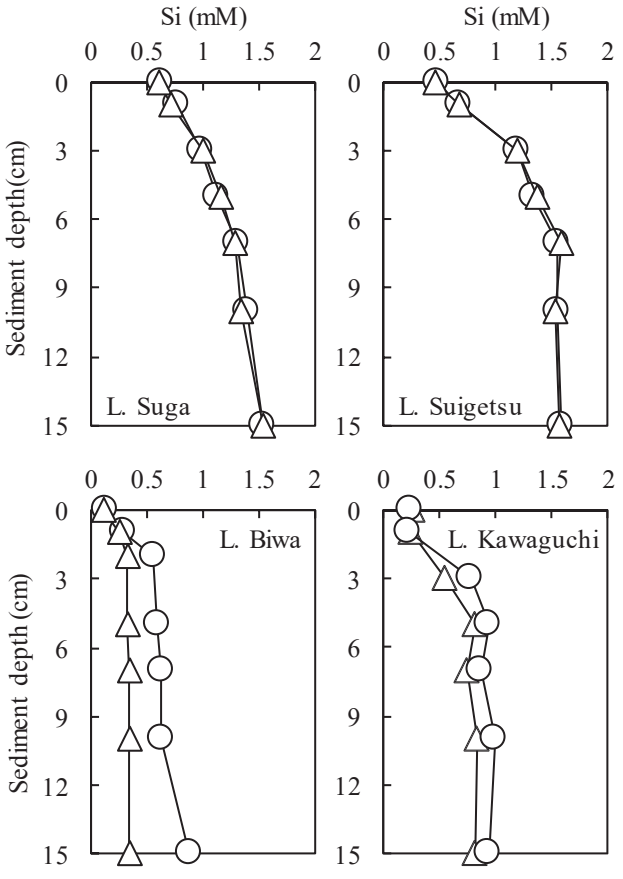

Fig. 1 MSi(△) and TSi(○) in pore water of each lake

in the pore water of some lakes. Therefore, in this study, the PSi distribution in various lakes was investigated along with the formation and decomposition mechanisms of PSi in pore water.

2. ANALYSIS

Monomeric silicate and total silicate dissolved in pore water were measured using molybdenum blue method and inductively coupled plasma atomic emission spectroscopy (ICP-AES) technique to identify silicate species. When using the molybdenum blue method, silicate can be measured from monomer to pentamer (these silicates are hereafter referred as MSi) in reaction time (O'Connor 1961), ICP-AES technique can measure total silicate (TSi; Tallberg 2000). The concentration of the dissolved PSi was calculated by determining the concentration difference between TSi and MSi. In Fig. 1, no PSi was detected in brackish lakes (Lakes Suga and Suigetsu, Japan), but both PSi and MSi were found to be dissolved in freshwater lakes (Lakes Biwa and Kawaguchi, Japan).

3. LABORATORY EXPERIMENTS

In anoxic sediments, silicates are preferably released from minerals rather than biogenic silica (BSi) sources such as diatoms (Lehtimäki et al. 2016). Therefore, we assume that the main source of PSi in the pore water of freshwater lakes is ferric hydroxide, which adsorbs silicates, and that major factor controlling PSi content is NaCl concentration, as this salt is the most abundant component of brackish lake water.

First, to examine the formation of PSi, precipitates are collected by filtration of a test solution (0.7 mM MSi, 0.1 mM Fe^{3+} and pH 7). And, the precipitate reacted with 0.02 mM of HNO_3 for 1 day. Analyses of MSi, PSi and TSi concentration were carried out for 120 days. As a result (Fig. 2), PSi began to be formed 3 days after the adsorption reaction and increased sharply until 40 days. The PSi at 120 days accounted for about 40% of TSi. Most importantly, PSi was detected only in the precipitate.

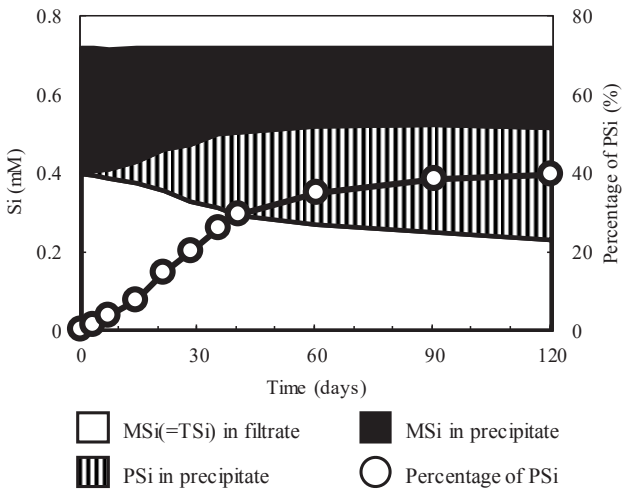

Fig. 2 Formation of PSi over time

Secondly, to confirm the stability of PSi eluted from ferric hydroxide according to oxic or anoxic conditions, the precipitate same as the first experiment was reacted with HNO_3 (under oxic (or anoxic) condition, pH 2.3) or Na_2S solution (oxic (or anoxic) condition, pH 7.2). After the reaction with the solution, $H_2S + HS^-$, MSi, PSi and TSi concentrations were measured periodically (Figs. 3 and 4). In Fig. 4, the results for DO of Na_2S under anoxic condition, DO of HNO_3 under oxic and anoxic conditions and DO of HNO_3 under anoxic condition are not shown because their results showed 0 mM of $H_2S + HS^-$ or 0 mg/L of DO throughout the experimental period. The experiment was carried out for 2 weeks. Within 2 days, dramatical decrease in PSi was observed in HNO_3 under oxic condition (Fig. 3). In HNO_3 under anoxic condition, PSi concentation gradually decreased from 0.45 mM to 0.31 mM (Fig. 3) and DO was maintained to 0 mg/L. In Na_2S solution, PSi concentration under both oxic and anoxic conditions was maintained to be constant from the beginning to the end of the experiment. Therefore, in freshwater lakes, PSi eluted from ferric hydroxide is considered to be stable for long time.

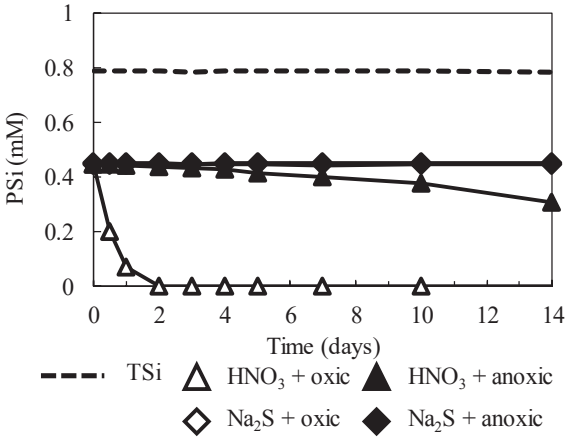

Fig. 3 PSi according to oxic and anoxic conditions

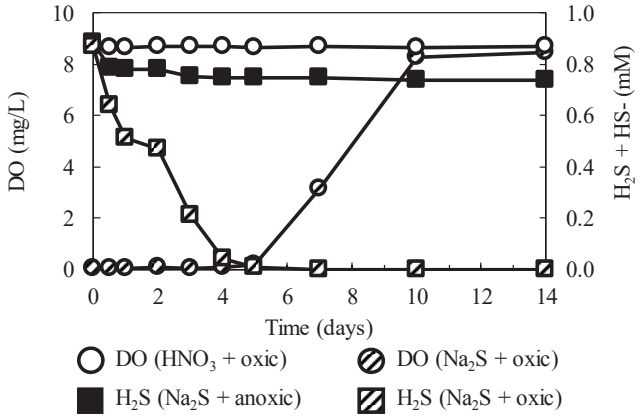

Fig. 4 Concentration changes of DO and H_2S

Thirdly, the effect of NaCl on the polymerization of silicate was examined. The NaCl concentration of a test solution (0.6 mmol/L MSi, 0 (or 0.3) mmol/L Fe^{3+} and pH 7) was adjusted to 0 or 0.6 M. After standing for 1 month, the test solution was filtered to obtain filtrate 1 (F1) and precipitates. The precipitates were made to react with a Na_2S solution (pH 7) for 1 day, and filtrate 2 (F2) was subsequently obtained by filtration. The MSi and PSi concentrations were measured in their respective filtrates. PSi was not detected in F2 from the 0.6 M NaCl solution but was found in F2 from the 0 M NaCl solution (Fig. 5).

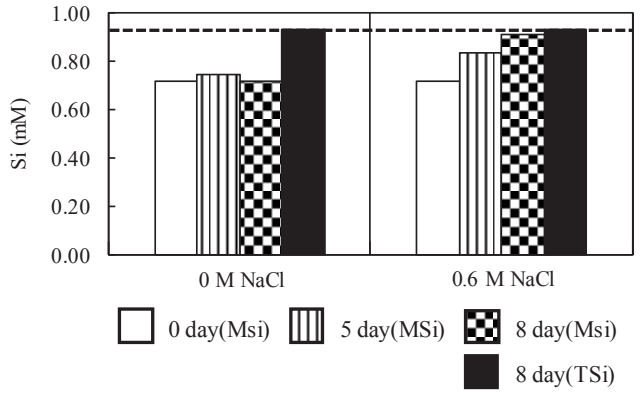

Fig. 5 Effect of NaCl on the decomposition of PSi

Finally, to investigate the effect of NaCl on the decomposition of PSi, NaCl was added to the pore water of Lake Biwa, which was found to contain PSi. Most of the PSi was decomposed to MSi after 8 days from NaCl addition (Fig. 6).

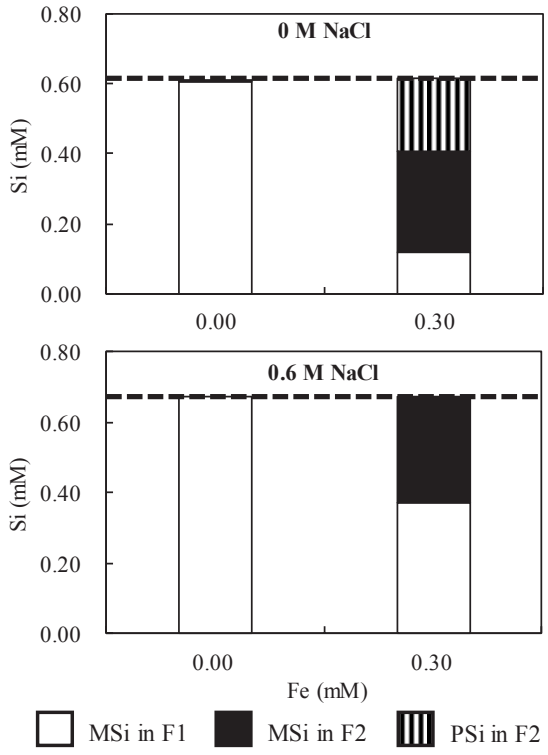

Fig. 6 Effect of NaCl on the polymerization of silicate

4. CONCLUSION

From the above experimental results, it can be concluded that polymerization of silicate occurs on the surface of ferric hydroxide after adsorption reaction, and this PSi formed is detected only in the pore water of freshwater lakes with anoxic sediment. PSi is not found in brackish lakes because its formation is inhibited by the presence of large amounts of NaCl. Therefore, if PSi is supplied to the brackish lake from rivers or other sources, it will be easily decomposed to MSi.

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P3-42

ASSESING THE HEAVY METAL CONTENT OF GOLDEN APPLE SNAIL (*Pomacea canaliculata*), WATER AND SEDIMENTS AFTER FISH KILLS INDICIDENT IN LAKE MAINIT, NORTHEASTERN MINDANAO ISLAND, PHILIPPINES

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Keywords: Degradation, Lake ecosystem function, water pollution, sediment release, water quality management

ABSTRACT

Heavy metals specifically Lead (Pb), Copper (Cu), Manganese (Mn), and Cadmium (Cd) is one of the major toxicant affecting freshwater organisms particularly the Golden Apple Snail, *P. canaliculata* which is an invasive organism. However, few studies had been conducted on the heavy metals content on the tissues of *Pomacea canaliculata* in Lake Mainit, Northern Mindanao, Philippines. This study assessed the heavy metal content of Golden Apple Snail, *P. canaliculata* (*Gastropoda:Ampullariidae)* water and sediments in surrounding areas of Lake Mainit. Collection of freshwater snail particularly the Golden Apple Snail, *P. canaliculata* was collected using Opportunistic approach and hand picking and all samples were subjected for acid digestion and Atomic Absorption Spectrophotometer (AAS) analysis. Results showed that Manganese (6.099±0.436 ppm) followed by Copper (3.325±1.884 ppm), Lead (0.995±0.332 ppm) and Cadmium (0.068±0.012 ppm) respectively is beyond the threshold level and exceeded the recommended safe limits set by the authorized agencies. Sediments in Manganese had a mean concentration 5.61±0.206 ppm which is beyond the Recommended Safe Limits set by the standard of Food and Agriculture Office (FAO) which is $\leq$100 ppm. Among the four heavy metals Manganese had the highest mean concentration 0.583±0.217 ppm in waters. Accumulation of heavy metals in aquatic organism particularly *P. canaliculata* was species dependent. Thus, strict monitoring of heavy metals particularly the Lead (Pb), Copper (Cu), Manganese (Mn), and Cadmium (Cd) by Local Government Unit (LGU) is highly encouraged to efficiently study the hazard and effect of this four heavy metals on the aquatic environs of said lake and general public welfare.

1. INTRODUCTION

In the last few decades increasing attention has been paid to the relationship between the conformation of heavy metals and their impact on aquatic organisms. Metals such as arsenic (As), mercury (Hg), cadmium (Cd), copper (Cu), chromium (Cr), lead (Pb), iron (Fe), manganese (Mn), zinc (Zn) etc. do not degrade in general; therefore, they accumulate throughout the trophic chain. Accumulation in living organisms leads to concentrations several orders of magnitude higher than those of the surrounding water (Casas et al, 2008). Last December 2015 a Fish kills incident happened in Lake Mainit due to low dissolved oxygen in the water. The incidents of fish kill in Lake Mainit have been traced to low dissolved oxygen in the country's fourth largest lake, initial findings of the Bureau of Fisheries and Aquatic Resources-(BFAR) Caraga.

Thus, aquatic molluscs used as the subject for this study as they are widely distributed in Lake Mainit, Surigao del Norte, Philippines. Results of the study will serve as baseline information for the conservation and protection of aquatic faunal biodiversity in the said freshwater ecosystem.

2. METHOD

Collection of molluscs, sediments and water. Following the methods of Su et al, (2009) with little modification, local residents caught the macroinvertebrates assessed for heavy metals during the months of August to September 2016 using a trawl net in Lake Mainit, Surigao del Norte. Local residents extensively searched for live freshwater mollusks (bivalves and univalves) using handpick in the area equivalent to a two-hour sampling efforts (de Chavez and de Lara 2011). The collection of samples using the bottom trawl fishing method started from the north end of the lake going to the south and then back to the starting point again which is the north end. Macroinvertebrates collected were immediately processed. All

macroinvertebrates were identified through the www.fishbase.org.

Digestion of mollusk tissue, water and sediments. Digestion process was adopted from the Analytical Methods for Atomic Absorption Spectroscopy (®PerkinElmer Incorporated). Samples of homogenized mollusk tissue, water and sediments were dried in the laboratory oven at 100 0C for about 3 hours. The dried mollusk tissue samples were each ground with laboratory ceramic mortar and pestle into powder form. The samples were placed in ziplocks and coded labeled with the area where it was collected with the number of replicates. A mixture of concentrated 5 ml Nitric acid (HNO3) and 5 ml Sulfuric acid (H2SO4) were added to the 1 g of homogenized dried fish samples. 10 ml of concentrated Nitric acid (HNO3) was added. After the samples become brown, it was added with 5 ml concentrated Hydrogen Peroxide (H2O2) continuously until the samples become clear or pale yellow. The resulting mollusks tissue digested samples were then filtered using Wattman filter paper No.80 and diluted to 50ml with distilled deionized water. Sample containers were pre-treated with 90% distilled- deionized water and 10% Nitric Acid.

Determination of levels of Cd, Cu Pb, and Mn in mollusks. The analysis for levels of cadmium, lead, manganese and copper was done at Chemistry Laboratory, College of Arts and Sciences, Caraga State University, Ampayon, Butuan City, Mindanao, Philippines. The analysis was done using Analytical Methods for Atomic Absorption Spectroscopy by (®PerkinElmer Incorporated) with a detection limit of 0 ppm in all the heavy metals (Cd, Pb, Ni and Hg). Sodium Borohydride (NaBH4) was used as reducing agent for samples. The Cu concentration was determined by flame atomic absorption spectrophotometry Perkin Elmer Atomic Analyst 200 with a detection limit of 0.012 ppm. The preparations of solutions of copper were as follows: About 200 – 250 mL of 1% v/v HNO3 used as a blank solutions and about 200 – 250 mL each of the three standards in 1% v/v HNO3. The suggested standards of copper are 0.5 ppm (Standard 1), 1 ppm (Standard 2), 1.5 ppm (Standard 3) and 1 ppm (Reslope) following the official methods of AOAC International. The same procedures were applied to water and sediments.

3. RESULTS

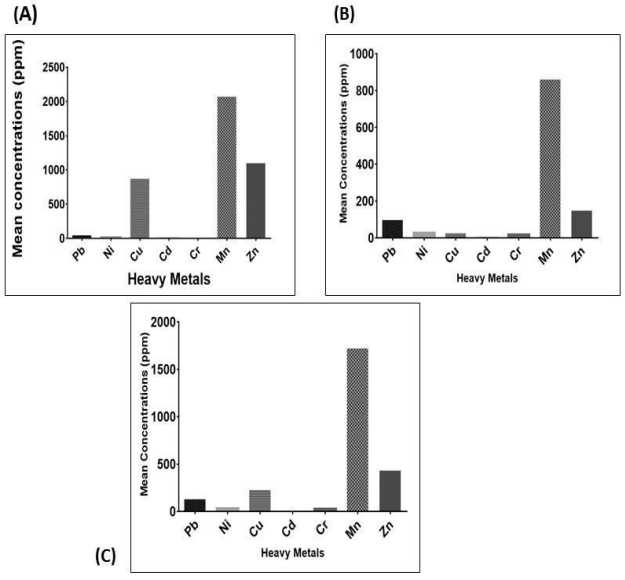

Figure 1. Graphical presentation of heavy metals concentration in the tissue of Golden Apple Snail (*Pomacea canaliculata*). (A) Station 4, (B) Station 5, and (C) Station 6

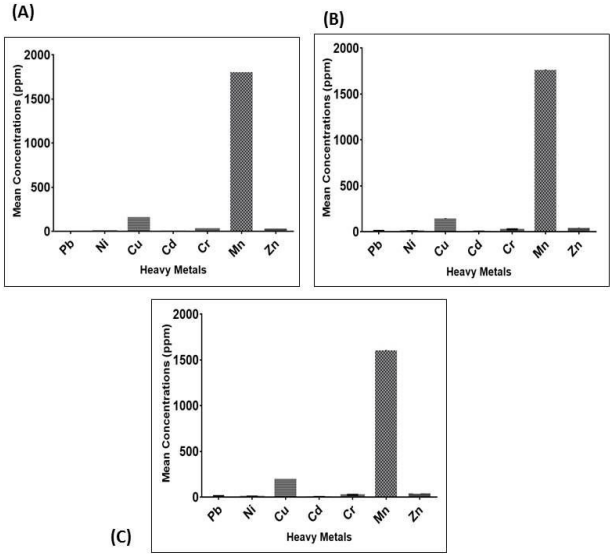

Figure 2. Graphical presentation of heavy metals concentration in the tissue of Golden Apple Snail (*Pomacea canaliculata*). (A) Station 7, (B) Station 8, and (C) Station 9.

4. DISCUSSION

Station 4 highest Manganese concentration was detected in first sampling 1549.300 mg/Kg and 1642.541 mg/Kg in second sampling followed by Zinc 560.211 mg/Kg first sampling while 44.794 mg/Kg second sampling and Copper 374.439 mg/Kg while 174.762 mg/Kg. The concentration of heavy metals along station 4, 5 and 6 within the first sampling period P-value 0.0007 is highly significant (P<0.05).

Sediments were collected in the three sampling stations of Lake Mainit, Northern Mindanao, Philippines (Table 3) and the heavy metals were Mn>Cu>Pb>Cd. Among the four heavy metals Manganese had the highest mean concentration 5.61±0.206 ppm. Sediments in Manganese had a mean concentration 5.61±0.206 ppm which is beyond the Recommended Safe Limits set by the standard of Food and Agriculture Office (FAO) which is ≤100 ppm. While, Lead mean concentration 1.572±0.482 ppm which is beyond the threshold level set by the standard of Food and Agriculture Office (FAO). Moreover, Copper mean concentration 1.496±0.256 ppm and the highest Copper concentration in sediments was in Station 6 1.953±0.141 ppm and Cadmium mean concentration 0.017±0.004 ppm respectively.

Water were collected in the three sampling stations of Lake Mainit, Northern Mindanao, Philippines (Table 4) and the heavy metals were Mn>Cu>Pb>Cd. Among the four heavy metals Manganese had the highest mean concentration 0.583±0.217 ppm.Manganese had a mean concentration of 0.583±0.217 ppm. Highest concentration of Manganese in water was detected in Station 6 0.855±0.023 ppm and beyond the threshold level set by the US Environmental Protection Agency which is ≤100. Copper mean concentration of 0.028±0.002 ppm, highest detection level was in Station 5 0.032±0.011 ppm. Further, Lead mean concentration 0.138±0.012 ppm in water and the highest Lead concentration was recorded in Station 5 0.160±0.009 ppm. Cadmium mean concentration of 0.006±0.003 ppm respectively.

5. CONCLUSION

Based from the results of the study, Lake Mainit is contaminated with Lead (Pb) , Cadmium (Cd), Manganese (Mn), and Copper (Cu) respectively. Lead (Pb), Cadmium (Cd), Manganese (Mn), and Copper (Cu) accumulated particularly in the tissues of Golden Apple Snail, *P. canaliculata.* The contamination of Lead (Pb), Cadmium (Cd), Manganese (Mn), and Copper (Cu) maybe brought by the present anthropogenic activities in the area such as presence of mining industries, forest degradation, illegal logging, urbanization and increasing population in the area. Results of this study will serve as baseline information on bio monitoring of the aquatic mollusks in the lake.

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P3-43

Analyses of microbial consortia in water and sediment samples of Tonle Sap lake

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Keywords: Tonle Sap lake, microbial consortia, pathogenic bacteria

ABSTRACT

Tonle Sap lake in Cambodia is the biggest lake in Southeast Asia. It is estimated that this lake accounts for ca. 60% of domestic protein needs and more than 1 million people stay at the floating villages on the lake. However, they use the lake water directly without sufficient treatments. Therefore, they are under threat of unsanitary water environment. In this study, we investigated the microbial consortia in the lake water and sediment by using gene analyses. Based on the results of 16S rRNA gene quantitative PCR, bacterial concentrations of the sediment were approximate 10^8 copies·mL^{-1} throughout the year. This concentration was about 10-100 times higher than that of water samples. The concentration of water sample in the dry season and rainy season were ca. 10^6-10^7 copies·mL^{-1} and 10^5-10^6 copies·mL^{-1}, respectively. According to the result of next generation sequence (NGS) analysis, it was clarified that the microbial consortia in the sediment samples were totally different from those in the water samples of every season. By statistical analyses, it was revealed that in the rainy season (August) the diversity of microbial consortia was lower than that in other seasons. Moreover, by the cultivation method using specific culture method, *Escherichia coli* and coliform were detected from the lake water samples taken from the place near the floating village, but not from the place far from it. It is thought that only the lake water near the floating village might be contaminated by human activities.

1. INTRODUCTION

Tonle Sap lake in Cambodia is the biggest lake in Southeast Asia. The area becomes 13,000 km^2 in rainy season and 2,500 km^2 in dray season (Fig.1). In this fresh-water lake, there are various kinds of fishery products and the lake accounts for ca. 60% of domestic protein need in Cambodia[1]. Moreover, many floating villages are located on this lake and it is estimated that more than 1 million residents stay there.

In Cambodia, the child mortality rate is reported to be 25 (cf. 2 in Japan) per 1000 live births reported by World Health Organization in 2015. The main reasons of this mortality seem to be caused by waterborne infectious disease or diarrhea, which can be preventable by vaccines. The people living on the Tonle Sap lake use the lake water as their dairy life water and directly dispose the waste water into the lake. A part of them uses the lake water without sufficient treatment, such as disinfection and/or removal of microbes by precipitation or filtration. Therefore, they are possibly surrounded by an unsanitary water environment, because some of them are pathogenic bacteria or produce toxic compounds. Moreover, if the antibiotic-resistant pathogens appear, it is highly possible that the residents are infected by them through the contaminated lake water. Therefore, it is very important to clarify the microbial population in the lake.

In this study, we investigated the microbial consortia in the lake water and sediment by using gene analyses based on 16S rRNA gene sequences to evaluate the water quality.

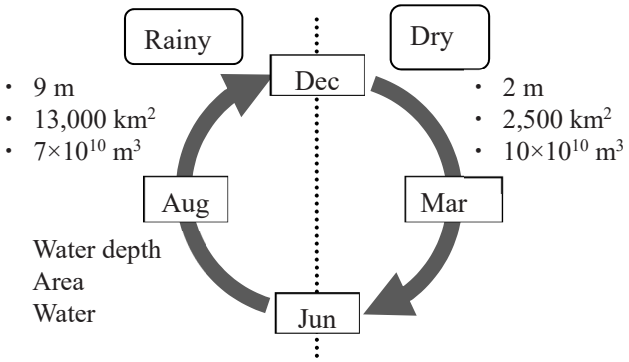

Fig.1 Seasonal change of Tonle Sap

Moreover, as a hygiene indicator of environmental water, the concentrations of *Escherichia coli*, which is an index of sanitary in the several water samples were also measured by culture method using specific media.

2. METHOD

Water and sediment samples in Tonle Sap lake

Field surveys were conducted about every three month.

The seasonal changes of characteristics in Tonle Sap Lake are shown in Fig.1. Sampling points were not only near the floating village but also in the middle of lake far from the floating village. The sampling points are depicted in Fig.2 At the sampling points, water samples from the surface (0 m), the middle (1-3 m depth from the surface) and sediments were taken. For preparation of DNA extraction, 10-30 mL of water samples were filtrated by membrane filter (pore size: 0.45 µm) after sampling. The filtrated water samples on the membrane filter or sediment samples were soaked into the ethanol solution.

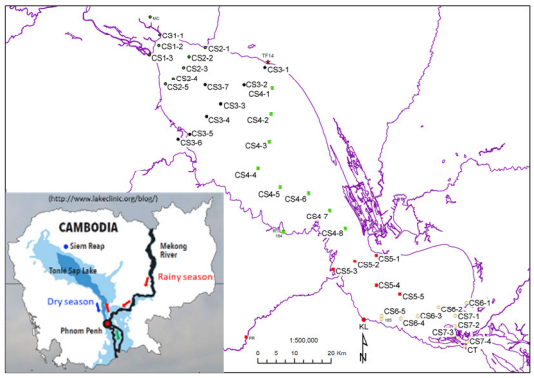

Fig.2 Sampling points of Tonle Sap lake

DNA extraction

Withdrawn samples from dialysis device were centrifuged at 6,300 g for 10 min and the pellet was resuspended in PBS. The resuspended samples were used for DNA extraction. Glass beads (0.1 mm diameter) were used to break the cells for 45 s at 6 $m \cdot s^{-1}$, twice, using a BeadBeater (FastPrep24, MP Biomedicals). The supernatant was collected after centrifugation at 1800 g for 5 min. The further DNA extraction process was previously reported[2].

Analysis of microbial community by next-generation sequencing (NGS)

The 16S rRNA gene sample was prepared by following the Illumina Miseq sequencing protocol (https://support.illumina.com/documents/documentation/chemistry_documentation/16s/16s-metagenomic-library-prep-guide-15044223-b.pdf). DNA templates were subjected to amplification by two rounds of PCR. Miseq16S_341F (5'-TCGTCGGCAGCGTCAGATGTGTATAAGAGACAGCCTACGGGNGGCWGCAG-3') and Miseq16S_805R (5'- GTCTCGTGGGCTCGGAGATGTGTATAAGAGACAGGACTACHVGGGTATCTAATCC-3') were used to amplify the V3 to V4 region of the 16S rRNA gene. The program for the first round of PCR amplification were as follows: 95°C for 5 min, 25 amplification cycles (95°C for 30 s, 55°C for 30 s, and 72°C for 60 s), and 72°C for 5 min. DNA concentration in PCR products was estimated using a Nanodrop (Thermo Fisher Scientific) after purification, and subsequently diluted to 2.5 $ng \cdot \mu L^{-1}$ using TE buffer. The index primers (Nextera XT Index Kit v2 SetD, Illumina) were used in the second round of PCR. The amplification program was as follows: 95°C for 5 min, eight amplification cycles (95°C for 30 s, 55°C for 30 s, and 72°C for 60 s), and 72°C for 5 min. PCR products were purified by QIAQuick PCR Purification Kit (Qiagen, Hilden, Germany). All samples were gathered and sent to Hokkaido System Science Co., Ltd for sequencing. The data was analyzed by QIIME ver.1.9.1 pipeline[3]. Less than 4% of the microbial community's relative abundance was classified into others.

DNA templates from influent and activated sludge were used to quantify the total number of 16S rRNA gene by real time quantitative PCR (qPCR). 341 F (5'-CCTACGGGAGGCAGCAG-3') and 534 R (5'-ATTACCGCGGCTGCTGG-3') primers were used to amplify a target DNA size of 194 bp. After primers were combined with all qPCR reagents including SYBR green, the mixture was monitored by using StepOne Real-Time PCR System (Applied Biosystems) with the template DNA standard.

***E.coli* and coliform detection by culture method**

The concentrations of *E.coli* and coliform were measured by using the Chromocult® Coliform Agar (Merck KGaA, Damstads, Germany) plates. In this plate, the colony color of *E.coli* and coliform become purple and pink, respectively.

3. RESULTS

Microbial concentration

Based on the results of 16S rRNA gene qPCR, the bacterial concentrations of sediment were ca. 10^8 $copies \cdot mL^{-1}$ throughout the year. On the other hand, those of water sample in the dry season and rainy season were ca. 10^6-10^7 $copies \cdot mL^{-1}$ and 10^5-10^6 $copies \cdot mL^{-1}$, respectively. In June, bacterial concentration of water samples in the southeast part, where is the junction of Tonle Sap lake and Tonle Sap river, the concentration was relatively lower than those of other sampling points.

Microbial consortia

According to the result of NGS analysis, it was clarified that the microbial consortia in the sediment samples were totally different from those in the water samples of every season. *Firmicutes* and *Chloroflexi* phyla were relatively high in the sediment samples, although *Proteobacteria* and *Actinobacteria* phyla were dominant in the water samples. Moreover, in the water samples on the surface (0 m), the frequency of *Cyanobacteria* phylum was higher than in the water in the middle and in the sediment. Moreover, in

August and December, the frequency of *Cyanobacteria* in the southeast part were relatively higher than other sampling places.

To evaluate the difference or similarity of microbial consortia of different sample, the principal coordinates analysis (PCoA) was carried out. From these results, it clarified that the microbial consortia in the sediment are totally different from each other every season.

***E.coli* and coliform detection**

We took several samples (2 samples: close to floating village, 3 samples: far from floating village) for culture method. The results are shown in Table 1. *E.coli* was detected only from the samples taken from near floating village (in boldface). Moreover, coliform concentration in these 2 samples were also higher than that others.

Table 1 Concentrations of *E.coli* and coliform

Sample*	*E.coli* [CFU·mL^{-1}]	Coliform [CFU·mL^{-1}]	Others [CFU·mL^{-1}]
2-1(0)	-	43	20
2-1(S)	-	732	400
KL(0)	26	446	TMTC**
7-2(0)	-	43	316
CT(0)	26	216	320

* (0): water sample at 0 m, (S):sediment,
The sample taken from near floating village is in boldface.
** TMTC: too much to count

4. DISCUSSION

Microbial concentration

Most significant difference of microbial concentration was between water samples and sediment samples. That is, microbes seem to attach the surface of solid particles in the sediment to form the biofilm. On the other hand, the bacterial concentration of water samples taken near the village and that of water samples taken far from the village was not so significantly different, although some dynamic water flow affected the microbial concentration to certain extent. It means that total bacterial concentration is not an index of contamination derived from human activities.

Microbial consortia

Based on 16S rRNA gene analysis, the microbial consortia in the sediment samples were significantly different that in the water samples. This reason is thought that the physicochemical conditions, such as dissolved oxygen (DO) concentration, light intensity, nutrient composition, various ion concentrations, and so on are different from each other. In the sediment, most of the bacteria belong to a facultative anaerobic bacteria or an obligatory anaerobic bacteria due to low DO concentration. On the other hand, in the water samples, especially at 0 m, frequency of *Cyanobacteria* phylum was higher than that in the sediment. That is, the species which can conduct photosynthesis can grow under the light irradiation. Some of *Cyanobacteria* are well known as a toxin producer. Therefore, in the further study, the water sample that contain *Cyanobacteria* should be also investigated from the view of cyanobacterial toxin production.

Moreover, to evaluate the diversity of each microbial consortia, statistical analyses were applied. According to the results, both of Chao1 and Shannon index were lowest in rainy season (August) for all samples (0 m, 1-3 m, sediment). It is thought that the reason why is the change of nutrient condition by much amount of water flowed into Tonle Sap lake from the Tonle Sap river. However, more profound investigation is necessary to clarify which factors affect significantly.

***E.coli* and coliform detection**

From the results based on cultivation on the specific culture medium, *E. coli* was not detected from the samples taken from the location far from floating village. On the other hand, in the sample taken from near the village, *E.coli* was detected. Moreover, the coliform concentrations were also higher in these samples. These results show that the water environment surrounding the floating village might be contaminated by some kinds of bacteria derived from human activities. However, their effects seem to be possibly low in the place far from the floating village, even though the bacterial concentration is not so different from that in the sample taken from near the village.

5. CONCLUSION

We analyzed microbial consortia in water and sediment samples of Tonle Sap lake to investigated the seasonal and spatial changes and detected *E.coli* and coliform. From these results, the difference and diversity of microbial consortia were clarified.

ACKNOWLEDGEMENTS

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P3-44

鳥取県湖山池における底質の平面分布と栄養塩溶出特性

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キーワード:底泥溶出, 底質, 平面分布, 汽水化

抄録

2012 年 3 月に汽水化された湖山池の底質の変化と底泥の溶出特性を把握するために, 底質の湖内全域平面分布調査と栄養塩溶出試験を実施した。底質調査は湖内全域の底質を分析し, 汽水化前の結果と比較した。その結果, 汽水化前に比べ, 深場で硫化物が顕著に増加し, 全窒素は全域で減少した。栄養塩溶出試験は直上水条件が溶出特性に与える影響を検討した。その結果, 窒素は高水温, 高塩分, 嫌気条件で溶出量が増大した。リンについては水温, 嫌気条件で溶出量が増加することが示された。このことから塩分躍層に起因する底層水の貧酸素化が溶出量の増加に大きく寄与することが示唆された。

1. はじめに

鳥取県東部に位置する湖山池では様々な水質浄化対策が行われているが, 環境基準は未達成の状況である。一方で 2012 年の汽水化以降, 夏季の貧酸素化が長期間継続するようになり, 底泥からの内部負荷が増大していることも予想される。しかし, 近年の調査結果はなく(2010 年 9 月が最後), 汽水化以降の底質状態の把握はできていない。また, 一般に栄養塩溶出は直上水の状態(水温, 溶存酸素(DO)など)で溶出特性が変化することが知られている。こうした特性を把握するとともに, 底質の現状把握を目的として, 湖内全域平面分布調査と栄養塩溶出試験を実施した。

2. 方法

(1)全域平面分布調査

2015 年 10 月 16 日に調査を実施した。調査地点は 45 地点とした(図1)。各地点においてエクマンバージ型採泥器を用いて底質を採取した。分析項目は, 乾燥減量, 強熱減量, 全窒素(TN), 全リン(TP), 全有機炭素量(TOC), 硫化物, 泥分率とした(泥分率のみ 15 地点測定(図1))。各分析項目の平面分布を視覚化するため, 各理化学分析の結果を基にコンタマップを作図した。汽水化前の底質と比較するため 2010 年の分析結果もコンタマップを作図し, 両者を比較した。

(2)栄養塩溶出試験

2017 年 5 月 26 日(春), 8 月 17 日(夏), 11 月 9 日(秋), 2018 年 2 月 9 日(冬)に 湖山池の三津地点でエクマンバージ採泥器を用いて底泥を採取した(図1)。各因子(水温・DO・塩分)の栄養塩溶出に与える影響を明らかにするため, 直上水の水温, DO, 塩分を表1のとおりに設定した。内径 5.6cm のアクリル管に底質を充填直前によく混合し15cm 程度充填した。本研究では, 繰り返し(n=3)を設け, その平均値を用いた。各条件に調製した直上水を静かに 500mL 注水した。なお, 注水した時点を 0 日目とし, 実験はすべて遮光条件で行った。0 日目と 10 日目に 10mL 採水した後, 0.45μm のフィルターで濾過した試水を栄養塩自動分析装置(SYNCA:BLTEC 社製) にてアンモニア態窒素(NH_4-N), 亜硝酸態窒素(NO_2-N), 硝酸態窒素(NO_3-N), リン酸態リン(PO_4-P)を測定した。窒素の溶出量は溶存態無機態窒素(DIN(NH_4-N, NO_2-N, NO_3-N の総和)), リンの溶出量は溶存態無機態リン(DIP(PO_4-P))の値で評価した。なお, 溶出量は1日平均の量で示している。

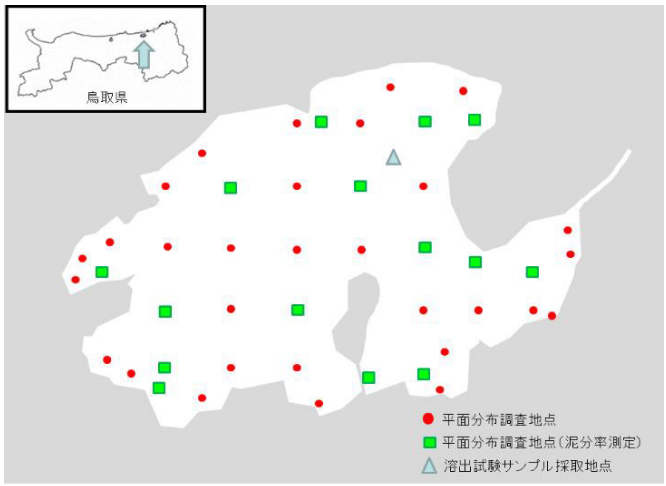

図 1　調査地点図

3. 結果

(1)全域平面分布調査

乾燥減量, 泥分率, 強熱減量, TOC, TN, TP, 硫化物は水深が浅い地点では値が低く, 水深が深い地点で

表 1　溶出試験の直上水の条件

水温(℃)	塩分(psu)	DO 条件
8	0	嫌気
8	0	好気
8	15	嫌気
8	15	好気
28	0	嫌気
28	0	好気
28	15	嫌気
28	15	好気

は値が高い傾向であった。特に硫化物は一部の地点で特異的に含有量が多かった。

この結果を汽水化前(2010 年 9 月)の結果と比較したところ，汽水化後は硫化物が深場で増加し，TN は全域で減少していた(図 2)。これに対して，乾燥減量，泥分率，有機物，TP には顕著な変化は認められなかった。

(2)栄養塩溶出特性

窒素は水温，塩分，DO で溶出量に差が見られ，水温は 28℃，塩分は 15psu，DO は嫌気条件で溶出量の増大が見られた(図 3)。ただし，好気条件では 8℃と比べ 28℃で溶出量が減少し(図 3)，塩分においても 0psu と 15psu では明瞭な差が認められなかった(図 3)。また，季節毎にサンプリングした試料間の溶出量には，明瞭な差は見られなかった(図 3)。

リンは嫌気条件でのみ，明らかな溶出量の増大が見られ，好気条件では水温・塩分にかかわらずほぼ溶出しなかった(図 3)。嫌気条件では 8℃より 28℃で溶出量が増加し，塩分では明瞭な差は認められなかった(図 3)。

4. 考察

(1)汽水化による底質の変化

汽水化後に硫化物の増加が認められた地点は夏季に塩分躍層が形成される地点(おおむね水深 3～4m 以深)と一致していた(図 2)。海水は陸水に比べ硫酸イオンを多く含み，湖内に流入した硫酸イオンは塩分躍層下層の嫌気条件下で硫酸還元菌などの影響により還元され，硫化物を生成する。このことから硫化物の増加は汽水化に伴う海水流入の増加に起因するものと考えられる。

TN は汽水化後に減少していた。汽水化前は藍藻の *Anabaena* 属が大量発生していた[2]。本属は窒素固定能を有することが知られている。汽水化前は本属が大気中の窒素を取り込んだ後に沈降することにより底質へ相当量の窒素が供給されていた可能性はあるが，明確な原因は不明である。しかし減少したものの，汽水化後でも沖合で 3～5 Nmg/g と依然として多く含有されている。

(2)栄養塩溶出特性

窒素については，28℃，15psu，嫌気状態が全組み合わせの中で最も溶出量が増大する条件だった(図 3)。水温の上昇に伴い，底質中の有機物の分解が促進され NH_4-N の溶出量が増大することが報告されている[3]。また，塩分の増加は底質中の吸着態 NH_4-N の直上水への拡散を促進させることが報告されている[4]。これらのことは，今回の結果とよく一致する。

また，好気条件では 8℃より 28℃の溶出量が減少して

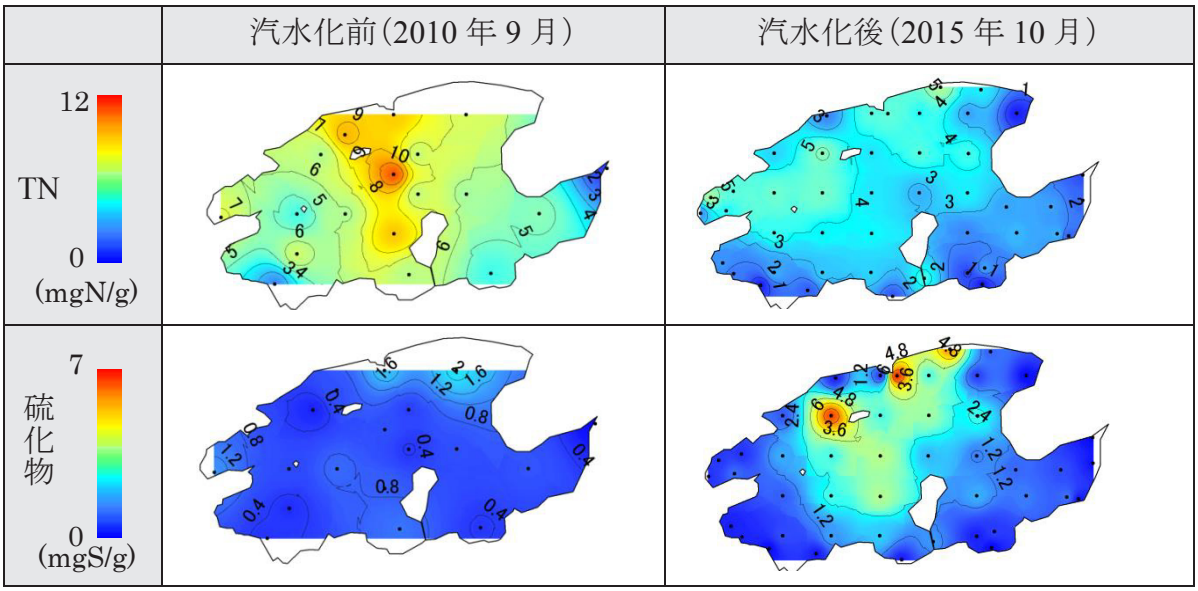

図 2　汽水化前後における底質の変化

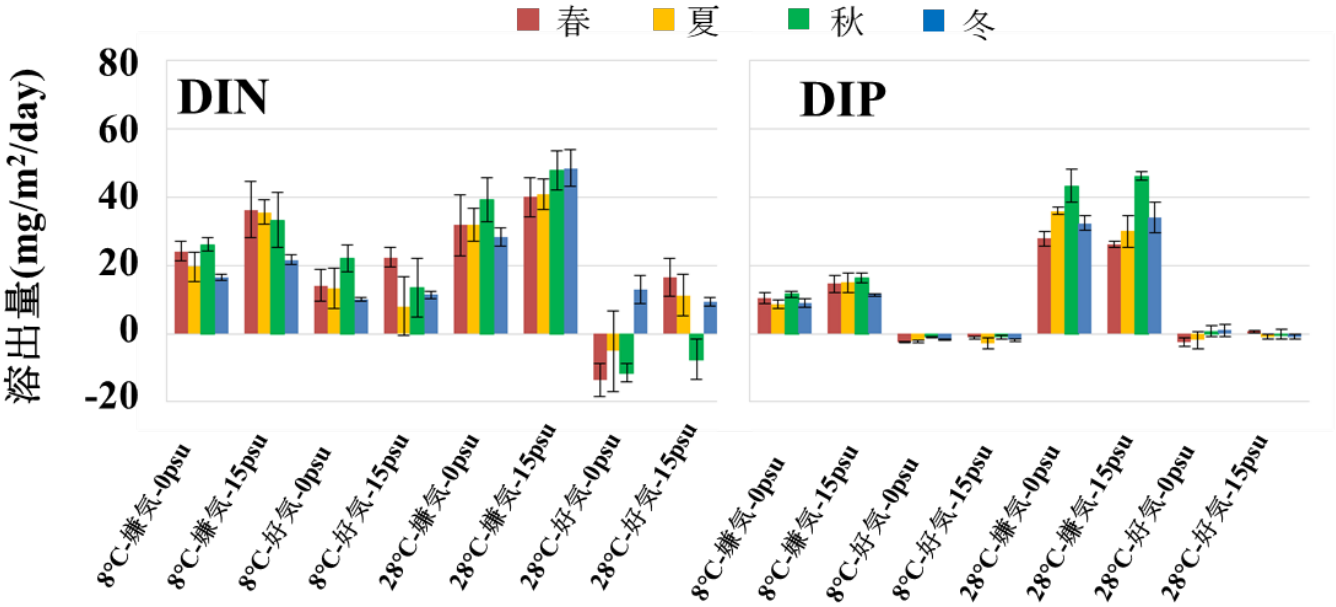

図３　各条件別の日平均溶出量

いた(図 3)。清家ら(1986)の報告[5]では，好気条件の溶出試験において NH_4-N の溶出量が 5℃より 25℃で減少すると，今回得られた結果と一致する報告をしており，この DIN の消失の原因を硝化・脱窒作用によるものと考察している。有機物に富んだ底質では，直上水の DO が豊富に存在する場合，泥表面の好気的雰囲気と泥粒子内の微細局所的な嫌気的雰囲気の影響により，硝化と脱窒の両方の作用を受けると言われている[6]。また脱窒速度は温度の影響を受け，高水温ほど脱窒活性が高くなる[7]。したがって，好気条件において 8℃の時よりも 28℃で脱窒の影響を大きく受けたため DIN が減少したと考えられる。

リンについては DO による影響が支配的であった(図 3)。リンは好気条件では水酸化鉄（Ⅲ）に吸着され，ほとんど溶出しないことが知られている[8]。また，水温についても高水温時に増大する報告があり[3]，今回の結果ともよく一致する。塩分に関しては，リンの溶出にはほとんど影響を与えないことが示された。

5. 結論

湖山池の底質は汽水化前に比べ硫化物が顕著に増加した。TN は減少したものの依然として有機物，窒素，リンに富んだ底質であった。

底質の溶出特性は，窒素については高水温，高塩分，嫌気条件で溶出量が増大した。リンについては嫌気条件でのみ溶出量の増大が認められ，高水温で溶出量が増加することが示された。

このことから塩分躍層に起因する底層水の貧酸素化が栄養塩溶出量の増加を促進させることが示唆された。

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P3-45

日吉ダムにおける複合型曝気循環装置の嫌気化抑制効果

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キーワード:ダム, 水質管理, 嫌気化, 曝気, フィールド実験

抄録

複合型曝気循環装置は、ダム湖の深層の嫌気化と浅層の藻類(アオコなど)増殖を抑制する多目的な水質保全設備であり、(独)水資源機構らが従来、深層曝気だけに使用されていた装置を 2009 年に改良して開発したものである。それ以降、日本の淀川水系の他、国内外の複数のダムで計 10 基が運用されている。本研究では、当該装置を運用した場合の深層の嫌気化抑制効果について、日吉ダム(天若湖、京都府南丹市)を対象とした調査実験を 2016 年の春(4 月末)に行った。ここでは特に、装置の運用が開始された直後3日間の水質状況に着目し、堤体近傍に設置された装置周辺における溶存酸素(DO)濃度の鉛直断面分布の時系列変化を、光学式のDO計を用いて計測した。その結果、DO 濃度の時系列変化を明らかにするとともに、本装置の深層曝気の能力として、酸素供給量に対するその移動(溶解)の効率が、春季(夏成層形成前)として当初想定した 20～10%の値となることを確認したので報告する。

1. はじめに

複合型曝気循環装置は、深層の嫌気化と浅層の藻類増殖を抑制する多目的な水質保全装置として、淀川水系他、国内外の複数のダムで運用されている。本研究では、当該装置を運用した場合の深層の嫌気化抑制効果について、日吉ダム(京都府)を対象とした調査実験を 2016 年の春に行った。ここでは特に、装置の運用が開始された直後に着目し、溶存酸素濃度の鉛直断面分布の時系列変化を計測した。その結果、装置の深層曝気の能力を確認し、夏成層形成前の当該ダムへの効果を明らかにしたので報告する。

2. 日吉ダムと複合型曝気循環装置の概要

複合型曝気循環装置が設置されている日吉ダム(天若湖、所在地:京都府南丹市日吉町、竣工年:1997 年)の水域図(堤体付近)を図1に示す。湖の北西(図の左上)に堤体があり、その近傍から(丸印で示す)2台の複合型曝気循環装置が、概ね流心に沿って 275m 離れて設置されている。湖の湛水面積は 95ha(0.95km^2)、総貯水量は 6,600 万 m^3(有効貯水量:5,800 万 m^3)、近年の回転率(湖水の入れ替わり回数)は 4.8 回／年である。

当該の曝気循環装置は、深層の嫌気化と浅層の藻類発生を抑制する多目的な水質保全設備で、湖底からアンカーとフロートで水中に鉛直支持されている。構造は図2に示すような2重管(外管直径 2m)で全長が 16m である。内管の下端から気泡を噴出し、底層の嫌気水塊を内管に取り込み、上昇しながら曝気する。曝気後の酸素濃度の高い循環水は、内管と外管との空隙を下降して再び深層に還る(深層曝気)。未溶解空気は装置上部で一時的に蓄積され、小気泡にせん断されて水中に放出する(浅層循環)、または排気管から湖面の空気中に解放される。

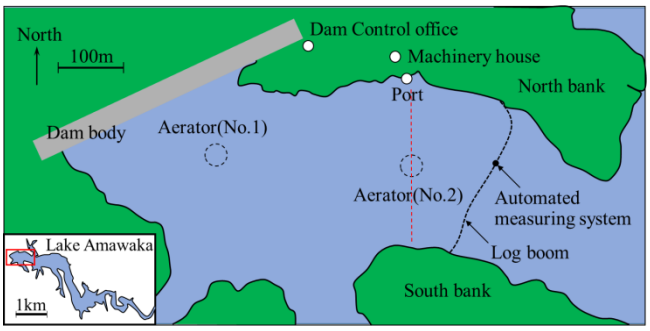

図 1 日吉ダム(天若湖)の堤体付近の水域図

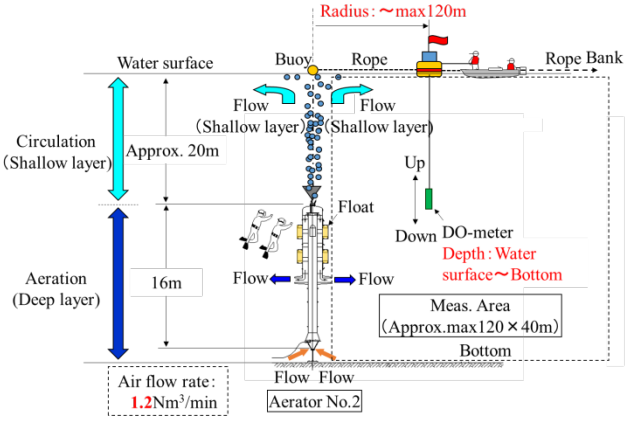

図 2 複合型曝気循環装置と DO 濃度の計測方法

3. 溶存酸素(DO)濃度の時系列計測の方法

日吉ダムでは例年、当該装置を夏成層形成期(春から秋)に運用する。ここでは、装置の曝気効果が顕著に現れる運用開始直後の3日間にわたり、湖水内の溶存

酸素（DO）分布を計測した。計測には、応答速度が比較的速い光学式の DO 計を使用した。図2に示すように、ブイに固定した昇降装置に DO 計を設置し、曝気装置（No.2）の北側（右岸）に向かって、5～10m 間隔に設定した各計測点で上下移動させた。このような計測を1日2～3回、断続的に行い、DO 濃度の時系列変化を調査した。なお、1 断面の計測は約 30～45 分で完了する。

4. 溶存酸素（DO）濃度の計測結果

計測結果の例として、装置の運転開始時刻（4/28/12:30）の直前と約 3 および 23 時間後の DO 濃度の分布または変化を図３に示す。貯水池の状態は、強い躍層が形成される前で、3 日間の流入と放流量はそれぞれ日平均で 62.5 と 72.2 万トン（総貯水量の約 1%）と、比較的安定した状態にあった。装置の曝気空気流量は 1.2*N*（ノルマル）m^3/min である。稼働から約３時間で、図３に示すように、（酸素濃度の高い）循環流の吹き出し口より深層では、DO の改善効果が見られる一方、装置真上近傍では浅層循環により深層水塊が巻き上げられ、逆に DO が低下している。ただし、約 23 時間が経過すると、図４に示すように、曝気の効果が広範囲に広がることがわかる。

5. 曝気能力に関する検討

計測断面の DO 濃度の変化の平均値を算出し、経過時間で整理した。曝気開始 3 時間までは深層水塊の引き込みにより一時的に減少するが、その後増加に転じ、増加速度は２日で約＋0.1mg/l であった。ここで、DO 濃度は装置を中心に軸対象に分布すると仮定し、湖水内の DO 増加量（総量）を積算した。さらに、それを供給酸素量で除した酸素移動（溶解）効率を求め、図４に示した。その結果、溶解した酸素量は２日で 100kg を超え、移動効率は一部のデータを除くと 20～10%の値となった。これは当該装置の取水・吐出口で得られた DO 濃度から直接求めた値[2]（取水 DO 濃度が 8.0mg/l のとき 20%）と概ね一致する。

6. 結論

本研究では、複合型曝気循環装置を運用した場合の深層の嫌気化抑制効果について、日吉ダムを対象とした調査実験を 2016 年春の３日間にわたって行い、DO 濃度の鉛直断面分布を時系列で計測した。その結果、酸素移動の時間・空間的な分布を明らかにし、酸素供給量に対する移動（溶解）の効率が春季として当初想定した 20～10%となることを確認した。

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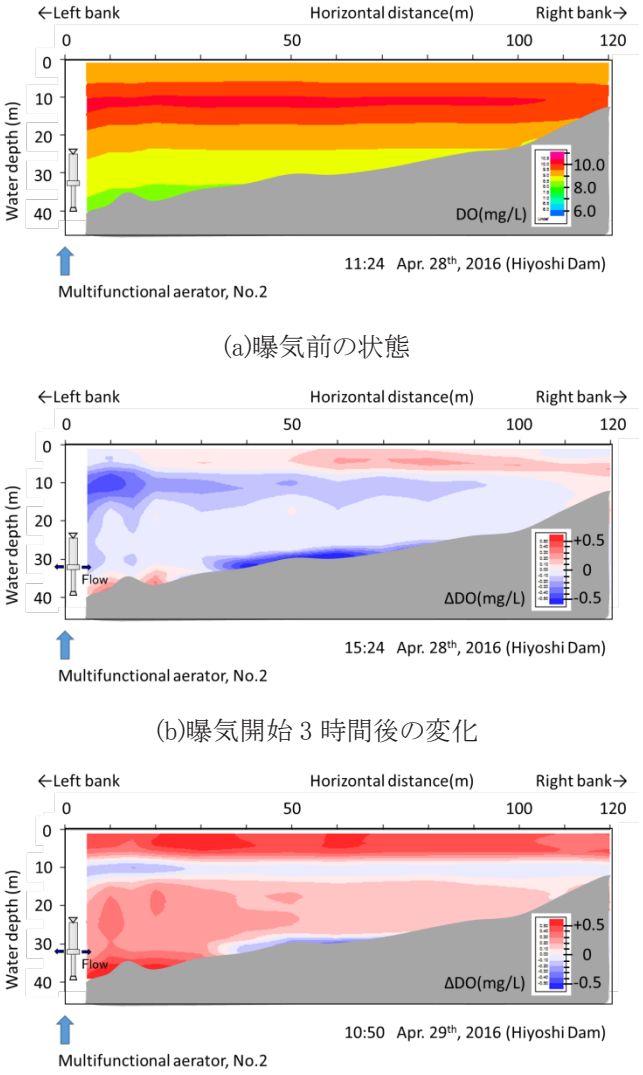

図 3 装置北側鉛直断面の DO 濃度分布の変化(No.2)

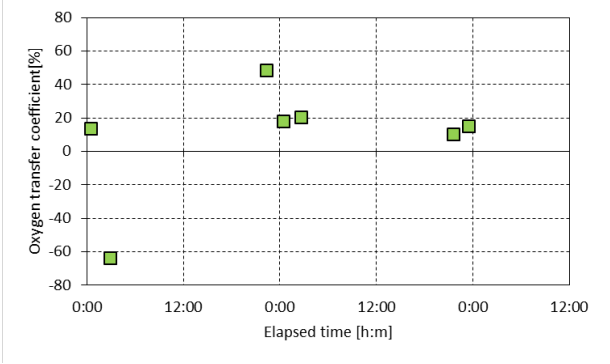

図 4 酸素移動効率（初期時刻：2016/4/28/12:30）

P3-46

琵琶湖における底泥酸素消費量の簡易測定法の検証

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キーワード:底泥酸素消費量, 湖沼, 底泥, 溶存酸素

抄録

本研究では, 湖沼における新環境基準項目となる底層溶存酸素の変動と密接に関係する底泥の酸素消費量(SOD)の簡易測定法を用いて琵琶湖北湖と南湖において SOD を測定した。本手法は, 表層構造を保った底泥の SOD 測定が可能, 既存手法に比べ小スケールで行うことが可能なため, 湖沼における多地点の SOD の測定に適応が期待される。本手法を用いて, 2017 年, 2018 年に琵琶湖北湖の SOD の季節変動を明らかにした。琵琶湖南湖においては環境基準点 2 地点の SOD の測定を行い地点間の差を明らかにした。加えて, 簡易測定法と既存 SOD 測定手法である大型底泥コア(内径 11cm 長さ 25cm 以上)を用いた SOD の値との比較を行い, 両手法で同様の変動傾向が得られたことを確認した。以上の事から, 湖沼の多地点の SOD を評価する上で本研究手法が有効な手法となる事が期待できる。

1. はじめに

底泥の溶存酸素消費量 (Sediment oxygen demand, SOD) は, 新たな環境基準として導入が決定された底層溶存酸素(DO)の低下を招く大きな要因の一つである[1], [2]。また SOD は, 底層からの嫌気的な栄養塩類の溶出にも密接に関連することから, 湖沼環境評価においても重要であることを明示している[3]。しかしながら, 後述するように, 既存の SOD 測定手法は容易とは言い難く, 湖沼で SOD に対する知見を積み重ねていく際の大きな妨げとなっている。

湖沼における SOD の測定法は, 測定用チャンバーを使用した現場法[4]や底泥コアを使用した実験室法[5]が代表的である。実験室内で底泥コアを培養して SOD を測定する場合は, 不攪乱底泥コアの使用が支持されている[6]。しかし, 不攪乱底泥コアの場合は直上水を含め直径 10cm 以上, 長さ 50cm 程度と大きく, 泥温や直上水温などの培養条件を整える際には多くの時間を要する。そのため、多地点で SOD のデータを取得するためには, SOD を容易に測定できる手法の開発が必要と考えられる。本研究では, SOD の簡易測定法を用いて, 琵琶湖における SOD の測定を実施した。

2. 実験方法

2.1 採泥

2017 年と 2018 年に, 琵琶湖北湖, 南湖の環境基準点において採泥を行った。琵琶湖北湖では 2017 年 5, 8, 10 月, 2018 年 2 月に今津沖中央(35° 23’ 41” N, 136° 07’ 57” E), 2017 年 11 月に南比良沖中央(35° 11’ 07” N, 135° 58’ 24” E)と安曇川沖中央(35° 18’ 21” N, 136° 08’ 41” E)において, 不攪乱柱状採泥器(離合社)を用いて, アクリルパイプ(内径 11cm 長さ 50cm)に底泥コア(内径 11cm 長さ 25cm 以上)を採取した。琵琶湖南湖では, 2018 年 3 月に唐崎沖中央(35° 02' 47" N, 135° 53' 46" E)と新杉江港沖(35° 04' 60" N, 135°56' 12" E)において底泥コアを採取した。琵琶湖南湖では沈水植物の繁茂の影響で不攪乱採泥器の使用が困難だったため, ダイバーによってアクリルパイプ(内径 11cm 長さ 50cm)を直接底泥に押し込み底泥コア(内径 11cm 長さ 25cm 以上)の採取を行った。

2. 2 SOD 測定

SOD の測定については, 霜鳥ら(2017)[7]の手法に準じた手法を用いた。概要は次のとおりである。底泥コアから SOD 測定用バイアル(内径 12.8mm, 長さ 125mm)に底泥コアを採取し, 孔径 0.2μm のメンブレンフィルターでろ過した底泥直上水を加え, ブチルゴム栓で密閉した(図 1)。SOD バイアルサンプルは, 現場の湖底直上水温で暗所において静置培養した (バイアル法)。DO 濃度の時間変化は, SOD 測定用バイアル内に DO センサーチップ(PreSens)を張り付け(図 1), 蛍光式酸素センサー Fibox 4 (PreSens)を用いて測定した。

バイアル法の比較対象実験として, 琵琶湖南湖の底泥を用いて環境省の底質調査法[8]に準じた SOD 測定も行った。不攪乱底泥コアと同時に得られる直上水を採水し, 粒子保持径 0.7μm ガラス繊維ろ紙でろ過した。こ

のろ液を SOD 用の試水とした。SOD 測定用底泥コアを試水で満たし，天然ゴム栓で上部に栓をした後，防水機密テープ（3M 社）で接続部を密閉した。この SOD 測定用底泥コアサンプルの直上水をマグネティックスターラーで攪拌しながらバイアル法と同様の条件で培養した(底泥コア法)。DO 濃度の経時変化はバイアル法同様，アクリルチューブ内に DO センサーチップ（PreSens）を張り付け，蛍光式酸素センサー Fibox 4 (PreSens)を用いて測定した。

培養は琵琶湖北湖では 5 日間，琵琶湖南湖では 3 日間行った。

バイアル法，底泥コア法ともに以下の式を用いて値を算出した。

SOD (g m^{-2} d^{-1}) = (Δ [DOs]/dt - Δ [DOc]/dt) × (直上水量/底泥表面積) × 24/1000

Δ [DOs]/dt：培養時間 t (h)における SOD バイアルサンプルまたは SOD 底泥コアサンプルの DO 濃度 (mg L^{-1})変化から求めた近似曲線の傾き(mg L^{-1} h^{-1})，Δ [DOc]/dt：培養時間 t (h)におけるコントロールサンプルの DO 濃度 (mg L^{-1})変化から求めた近似曲線の傾き，底泥表面積：SOD 測定用バイアル底面積または SOD 底泥コア底面積 (m^2)，直上水量：加えた直上水の体積 (L)，24/1000：単位換算係数

SOD の温度補正は，以下の式に従い琵琶湖北湖は 7℃，琵琶湖南湖は 11℃の値に補正した。

$SODT = SODr/1.047^{(r - T)}$

SODT：温度 T における SOD（補正値），SODr：現場の直上水温 r における SOD（実測値），1.047：温度補正係数[9]。

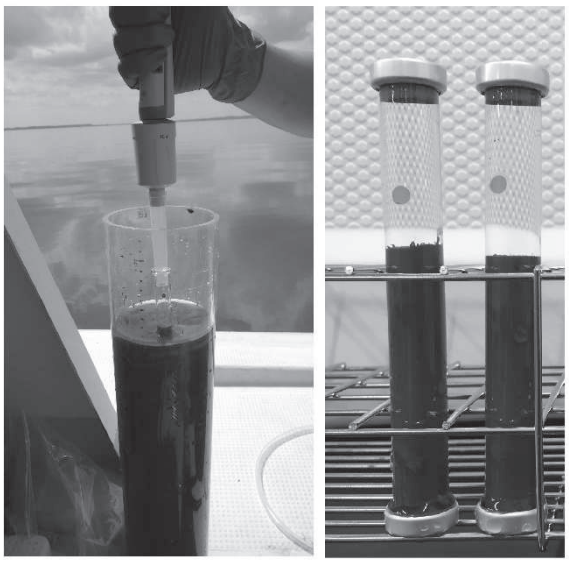

図 1 SOD バイアルへの採泥（左），バイアル法による測定サンプル（右）

3. 結果

バイアル法を用いて琵琶湖北湖 3 地点，琵琶湖南湖 2 地点で SOD を測定した。その結果を表 1 に示す。

琵琶湖北湖，今津沖中央の SOD は 0.043 g m^{-2} d^{-1} (2017 年 8 月)から 0.072 g m^{-2} d^{-1}（2018 年 2 月）であり，夏季に最小，冬季に最大となった。2017 年 11 月の南比良沖中央と安曇川沖中央の SOD は，共に 0.059 g m^{-2} d^{-1} と両者に差は見られなかった。

2018 年 3 月のバイアル法による琵琶湖南湖，唐崎沖中央と新杉江港沖の SOD は，それぞれ，0.051，0.068 g m^{-2} d^{-1} と唐崎沖中央に比べ新杉江港沖の SOD が高かった。一方，底泥コア法では，唐崎沖中央と新杉江港沖の SOD は，それぞれ 0.25，0.39 g m^{-2} d^{-1} だった。底泥コア法による SOD はバイアル法に比べ唐崎沖中央で 5.0 倍，新杉江港沖で 5.8 倍であった。

表 1 バイアル法により測定した琵琶湖各地点の SOD

Station Name	Sampling date	SOD (g m^{-2} d^{-1})	Standard deviation
今津沖中央	2017.5.29	0.050	0.006
	2017.8.28	0.043	0.005
	2017.10.25	0.064	0.009
	2018.2.14	0.072	0.007
安曇川沖中央	2017.11.27	0.059	0.008
南比良沖中央	2017.11.27	0.059	0.003
唐崎沖中央	2018.3.19	0.051	0.007
新杉江港沖	2018.3.19	0.068	0.003

4. 考察

本研究では，琵琶湖北湖，今津沖中央で SOD を測定し，同地点では夏季に SOD が低く，冬季に SOD が高くなるという季節変動が見られた。この変動傾向は，山本ら（2018）[10]が報告した，大型の不攪乱底泥コアを用いた琵琶湖北湖，今津沖中央の 2013-2015 年度の SOD の変動傾向と一致していた。この事は，本研究で用いた手法でも SOD の季節変動を捕える事が可能であることを示している。

本研究で用いた SOD の結果は，静置して培養を行うため，直上水の流速が SOD に与える影響を加味しない結果となる。琵琶湖南湖における大型コアを用いた SOD の測定値との比較から，底泥直上水の攪拌は SOD に大きく影響していることが示された。2018 年 3 月に唐崎沖中央と新杉江港沖にて採取した底泥コアを用いて直上水を攪拌しながら培養した SOD の値はそれぞれ 0.25，0.39 g m^{-2} d^{-1} だった。一方，直上水を攪拌しないバイアル法を用いて得られた同地点の SOD は 0.051，0.068 g m^{-2} d^{-1} と，両者の SOD には 5.0～5.8 倍の差が

生じた。培養時に直上水の攪拌を行った場合，SOD が増大することが指摘されている[11]。また、底泥と直上水の境界面の濃度境界層の厚さが水流流速によって変化するため，直上水の攪拌により SOD が増加する傾向にあるが，底泥構造や微生物活性によって増加の割合が異なることが明らかとなっている[12]。これらの事から，本研究で観測された差異は底泥直上水を攪拌したことによる影響が顕著に効いていると考えられる。そのため，今後は攪拌可能なバイアル法の手法を確立し，直上水の攪拌による影響評価も必要と考えられる。

バイアル法では，湖水由来の微生物や水流などの環境条件を排除した湖沼底泥の SOD の基礎データが得られていると推察される。このような一定基準で測定された湖沼間の SOD の差を把握することは，様々な環境パラメータを採取し現場環境を反映した SOD を求めていく際の重要な指針となると考えられる。

5. 結論

本研究では，不攪乱底泥コアと同様の表層構造を保った底泥を小型バイアルに入れて実施する SOD 簡易測定手法を検証した。サンプル数の増加が容易であることから，湖沼の多地点の SOD の基礎データの蓄積に大きく貢献することが期待される。本研究では，日本を代表する湖である琵琶湖において SOD を測定し，琵琶湖北湖の SOD の季節変動を明らかにした。また，琵琶湖南湖においては，バイアル法と底泥コア法で 2 地点の SOD の比較を行い，地点間の SOD の差が両測定法で同様の傾向を示すことを確認した。以上の事から本研究で用いた SOD の簡易測定手法は，湖沼の多地点の SOD を評価する上で有効な手法となることが期待される。

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Biotransformation of Arsenic Species by Phytoplankton in Freshwater

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ABSTRACT

Arsenic (As) has the detrimental effect on phytoplankton in numerous aquatic ecosystem. Extensive studies have been performed so far to understand the biotransformation and uptake mechanism of macro and micro level algal species. The influence of cellular growth stages of phytoplankton related to biotransformation of As species is insufficient. In this study, we observed the As uptake mechanism and biotransformation process by several phytoplankton species at different growth stages. It was observed that arsenic converted to inorganic arsenic and methylated forms mainly during the exponential growth stages of phytoplankton, while the methylation process became reduced at the stationary growth stage in the culture medium.

1. INTRODUCTION

Arsenic (As) is a detrimental metalloid widely distributed in aquatic environment [1]. It has four oxidation states -arsenate (As(V)), arsenite (As(III)), arsenic (As(0)), and arsine (As(−III)). Among them, As(V) is thermodynamically more stable form [2] in aerobic water whereas As(III) is prevalent in reduced redox environment. However, As(III) recognize as more toxic than As(V) in animals and marine phytoplankton but the fact is just opposite in case for freshwater phytoplankton [3]. Particularly, IAs are predominant than organoarsenicals in freshwater [1]. In the aquatic environment, prevalent IAs associated with microorganisms such as phytoplankton and in turn transformed into methylarsenicals and/or arsenosugars. In this regard, phytoplankton plays a crucial role in the freshwater aquatic ecosystem through bioaccumulation and biotransformation of IAs. The fluctuation in transformability largely depends on the several factors such as types of species, uptake/exclusion pathways, detoxification mechanism (biotic factors) as well as arsenic species, phosphate concentration, pH and time of exposure (abiotic factors) [4].

In addition, studies suggested that phytoplankton has the high ability to As bioaccumulation from enclosed water and different algal species have different uptake mechanism for IAs. As uptake also varying during different growth stages influenced by the presence of As processes in different transformation steps [5].

Most of the studies focused on the As biotransformation in the marine environment using marine species while little attention paid to the role of phytoplankton on As bio transformation in freshwater systems. It is essential to understand the As species accumulation and their bio transformation process in the freshwater ecosystem and the specific role of phytoplankton in this occasion. Further, it is also necessary to assess the relative attributes with respect to environmental risk to other organisms and humans.

This study conducted to explore the As biotransformation process by using freshwater phytoplankton in As containing media. It provides valuable information in regards of As uptake and biotransformation processes and also reveals the possible risk of As-contaminated freshwater.

2. METHOD

Six species of freshwater phytoplankton were used for the observation of biotransformation process such as *Achnanthidium minutissimum*, *Botryococcus braunii*, *Scenedesmus actus*, *Staurastrum paradoxum*, *Pediastrum duplex* and *Closterium aciculare*. For the maintenance of this phytoplankton, CSi medium (Table 1) was used as culture medium. Cultivation was carried out in an incubator at room temperature of 25°C, light intensity of 180 µmol E m^{2} s^{-1}, and light / dark cycle of 12 -12 h photoperiod. For the growth experiment, the phosphate concentrations of CSi medium were adjusted to 1.0 µmolL^{-1} or 50 µmolL^{-1}, whereas arsenic solution was adjusted to 1 µmL^{-1} (As rich) or 20 nmL^{-1} (As poor). At the initial stage, the cell concentration of phytoplankton was less than 4.6×10^{3} cells mL^{-1} in the culture

medium. During the incubation period of day three, four As species such as arsenate, arsenite, dimethylarsinate, and arsenobetaine were added and extended the incubation period for at least three weeks. A spectrophotometer (U-2000 Spectrophotometer, Hitachi) was used for the determination of freshwater phytoplankton at 540 nm.

For the determination of arsenic species infiltrate samples and cells, cold trap hydride generation atomic absorption spectroscopy (CT-HG-AAS) was used. Inorganic arsenic (V+III), monomethylarsonate (MMAA(V)), dimethyl arsinate (DMAA(V)) was analyzed by adding 5.0 mL of 0.20 $molL^{-1}$ EDTA·4Na and 5.0 $molL^{-1}$ hydrochloric acid to 40 mL of the sample solution. And for As(III), 5.0 mL of 0.20 $molL^{-1}$ EDTA·4Na and 0.5 $molL^{-1}$ potassium hydrogen phthalate was added to 40 mL of sample solution. Arsenic species was recorded as chromatogram and concentration was determined regarding the height of the peak. The total concentration of arsenic in the freshwater microalgae was determined by inductively coupled plasma mass spectrometer (ICP-MS, SPQ 9000, SEIKO). The operational condition of ICP-MS was: high-frequency output of 1.2 kW, the plasma gas flow rate of 16 $Lmin^{-1}$, the auxiliary gas flow rate of 1.0 $Lmin^{-1}$, the nebulizer gas flow rate of 1.0 $Lmin^{-1}$ and sample replacement time of 10 s.

Table 1 Composition of CSi media

Component	Concentration
$Ca(NO_3)_2·4H_2O$	635 $mmolL^{-1}$
KNO_3	989 $mmolL^{-1}$
KH_2PO_4	213 $mmolL^{-1}$
$MgSO_4·7H_2O$	162 $mmolL^{-1}$
Vitamin	1.0×10^{-6} $mg·mL^{-1}$
$MnCl_2·4H_2O$	0.546 $mmolL^{-1}$
$ZnSO_4·7H_2O$	0.23 $mmolL^{-1}$
$CoCl_2·6H_2O$	0.05 $mmolL^{-1}$
$Na_2MoO_4·2H_2O$	2.73 $mmolL^{-1}$
$FeCl_3$	1.31 $mmolL^{-1}$
$Na_2EDTA·2H_2O$	8.06 mM
$Na_2SiO_3·9H_2O$	10 mg mL^{-1}
4-(2-hydroxyethyle)-1-piperazineethanesulfonic acid	50 mg mL^{-1}

3. RESULTS

The growth of phytoplankton was observed under the high and low concentration of As and phosphate condition. As the day extended, the cell concentration of phytoplankton showed higher growth trend. However, later the growth of phytoplankton was restrained by the high concentration of As(V). In contrast, As(III) has lesser inhibition effect on the growth of phytoplankton compared to As(V). The toxic effect of As(III) reduced growth rates of C. *aciculare*, *S. paradoxum*, *B. braunii*, and A. *minutissimum* was ranged between 66% and 80% at As(III) concentrations of 10^5 $nmolL^{-1}$. The freshwater phytoplankton *B. actus* and *P. duplex* were quite resistant to As(III) toxicity even at high concentrations (Fig. 1). Organoarsenicals, DMAA(V) and arsenobetaine (AB), showed little growth inhibition effects on the freshwater phytoplankton. In general, at high $[As]_0$ treatment (1.0 $\mu molL^{-1}$), As(V) was the predominant species in the growth medium followed by As(III) at both the exponential and stationary growth stages.

4. DISCUSSION

The results indicate that As(V) and As(III) have different levels of toxic effects to different freshwater phytoplankton. It was suggesting that the growth inhibition of the phytoplankton by arsenic species depends on phytoplankton strain, which is consistent with other studies. The biotransformation of As(V) to As(III) and subsequent biomethylation to methylarsenicals (meth-As; e.g. DMAA and MMAA) and more complex organoarsenicals (org-As; e.g. AB) by phytoplankton are correlated with the growth rate of the phytoplankton and to the phosphorus nutrient status. At slow growth rates and under phosphate-depleted conditions, the phytoplankton take up greater amounts of As(V) than phosphate, reduce it to As(III) and then excrete As(III) out of their cells. Some of the As(III) is further biotransformed to meth-As and more complex org-As species, which are then excreted out of the cells. The results of the present study are also in agreement with the previous studies. Besides, arsenic uptake rate by microalgae, used in the study were varied, suggesting that the consumption or sequestration of arsenic species depend on the structural and biochemical properties of microalgae belonging to several species or class. It is likely to be related to the physiological activities of the phytoplankton such as bioaccumulation, detoxification (transformation of toxic iAs species to less toxic methyl- and organo-arsenic species), excretion of As out of the cells.

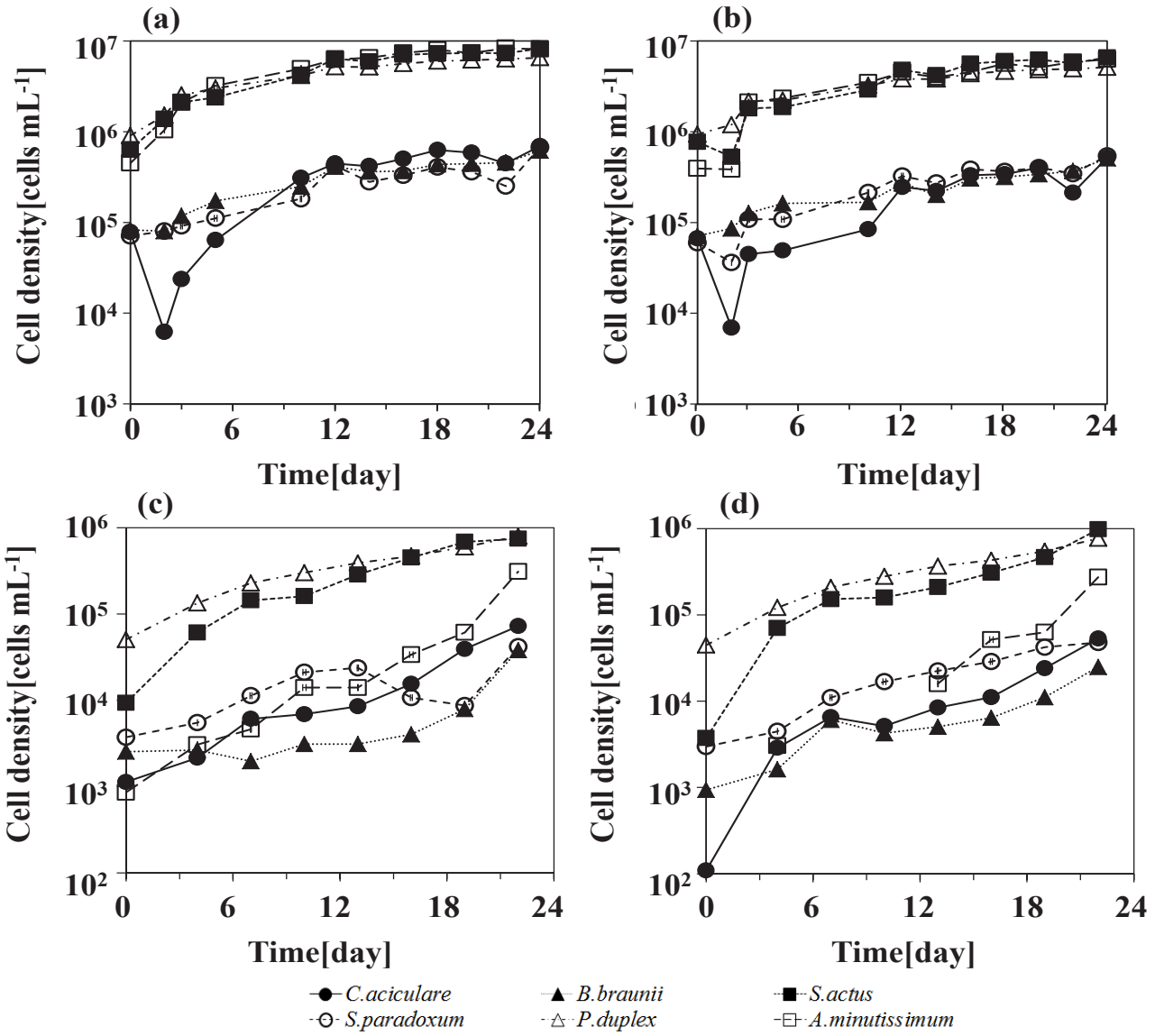

Fig. 1 Growth of freshwater phytoplankton in growth media: (a) phosphate-deficient (1.0 µmol L^{-1}), arsenate-low (20 $nmoL^{-1}$); (b) phosphate-deficient (1.0 µmol L^{-1}), arsenate-high (1.0 µmol L^{-1}); (c) phosphate-replete (50 µmol L^{-1}), arsenate-low (20 $nmoL^{-1}$); (d) phosphate-replete (50 µmol L^{-1}), arsenate-high (1.0 µmol L^{-1})

5. CONCLUSION

This study investigates the biotransformation of As species and their influence on the growth of phytoplankton exist in the freshwater environment which likely contributes to the better understanding of As biogeochemistry in such aquatic ecosystems. Inorganic arsenate was taken up by the phytoplankton, biotransformed inside their cells, and then released into the culture medium as arsenite during the exponential growth phase.

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P3-48

湖沼環境保全のためのヨード活性炭の適用可能性

－ アオコ浄化および抗鳥インフルエンザウイルス効果 －

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キーワード: アオコ、鳥インフルエンザ、消石灰、ヨード活性炭

抄録

活性炭に元素状ヨウ素（I_2）を担持させ、その化学的活性な状態が長期間保持されるヨード活性炭 IodAC®を開発した。この材料は、ヨウ素担持量が多い場合（1~10wt%）は、強い抗菌・抗ウイルス作用を示し、従来から鳥インフルエンザ発生時に消毒剤として使用されている消石灰に比べ、その消毒力の強い状態を長期間持続する。一方、ヨウ素担持量が少ない場合（0.1%以下~ppm レベル）のヨード活性炭は、水中藻類の増殖を抑制する作用を示し、閉鎖系水中においてアオコの発生・増殖を抑制する現象が起こる。この理由は不明であるが、光合成反応であるカルビンサイクルの一部抑制反応が起こるものと推測している。
湖沼の環境保全を目的として、ヨード活性炭によるアオコ対策と水辺の鳥類の感染症等の発生を抑制する方法について研究を進めている。

1. はじめに

ヨウ素を元素状(I_2)で活性炭に担持させると、その抗菌・抗ウイルス性や酸化力などの生物的・化学的特性を長期間安定的に保持できる。この特性を有する「ヨード活性炭：IodAC®」を開発した：図１。

IodAC の環境保全の適用性を判断するため、藍藻類（アオコ）の浄化効果、ならびに湖沼での鳥インフルエンザウイルス等の発生予防対策のための消毒効果や水鳥の感染症予防のための薬餌としての検討を進めている。

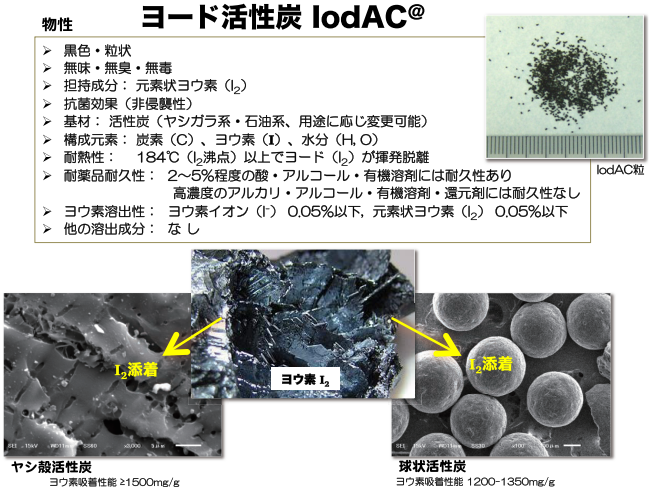

図1　ヨード活性炭

2. 実験

IodAC の湖沼環境保全への適用を目的とする実験として、藍藻類増殖に対する影響試験[実験１]、さらに鳥インフルエンザの発生予防対策として、防疫および消毒用として使用されている消石灰[1]と消毒効果の比較試験[実験２]を行った。

[実験１] 水中藍藻類の増殖抑制試験として、フィルタ付き循環型小型水槽(20L 容積) 3 台に小型魚（和金）を飼育し、フィルタ部に低ヨウ素担持 IodAC 各 25g（4/8mesh, ３つの水槽の水量に対し 0, 0.05, 0.5 mg(I_2)/L の割合）をそれぞれ設置し、水質分析および藻類の同定と増殖の状態を数ヶ月観察した。

[実験２] 細菌およびウイルスに対する消毒効果試験として、トレイ（内寸 26x38cm, 6cm 高）にキムタオルを敷き、その上に高ヨウ素担持 IodAC (AC+I_2=100+30, 32/60mesh)および市販消石灰(粉末)を、それぞれ 500g/m^2 の密度で均一に散布（それぞれ 37.5g）した。２日毎に 2mm の降雨相当の水を噴霧し、降水処理とし、その翌日にサンプルを数ｇずつ採取する降水･大気暴露試験を、22 日目まで継続した。採取したサンプルの pH を測定し、大腸菌阻止円試験および抗ウイルス試験を行った。大腸菌阻止円試験は公定法[2]に準拠し

行い、糞便系大腸菌群を標準寒天培地上で培養し、その上に採取した消石灰と IodAC サンプルをそれぞれ約 1cm 径で培地上に置き、経過時間と発育阻止円の直径の関係を求めた。一方、抗ウイルス試験は、鳥インフルエンザウイルス A/swan/Shimane/499/83(H5N3)株をウイルス液として用いた。50%発育鶏卵感染価(EID_{50})を算出し、PBS にて約 $10^{7.5}EID_{50}$/0.2mL に調整したウイルス液と採取したサンプルを混合し、10 日齢発育鶏卵尿膜腔内に 0.2mL 接種し、35℃で 2 日間培養後、尿膜腔液を採取し、0.5%鶏赤血球浮遊液と反応させ、その凝集によりウイルス増殖の有無を判定した。残存ウイルス力価は Reed and Muench 法[3]により EID_{50} を算出した。

用を保持していた。

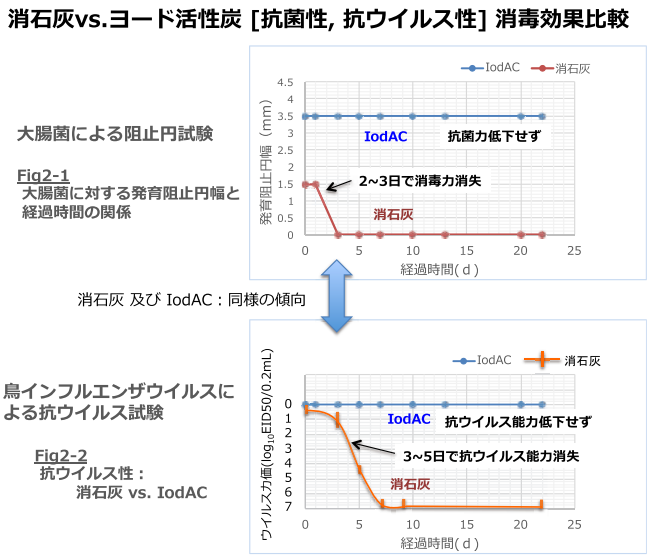

図2　消石灰とヨード活性炭の消毒効果比較試験結果

3.　結果

[実験 1] 循環型小型水槽中の水中藍藻類の増殖状況を 3 ～ 4 ヶ月間観察した結果、低ヨウ素担持 IodAC の投入量が 0 mg(I_2)/L（Ref 試験：I_2 無担持）の場合、水槽水の pH7.3~7.7、ORP(酸化還元電位) -30~-45mV であり、フィルタ部や水槽壁に藻類が著しく増殖し、水槽のガラス壁全面が藻類で覆われてしまい、見通しにくい状態となった。一方、IodAC を水量に対し 0.05 mg(I_2)/L および 0.5 mg(I_2)/L の割合で設置した場合は、水槽水の pH 7.0~7.5、ORP -15~-32 mV と Ref 試験に比べ、やや低 pH で高 ORP（酸化性雰囲気）を示し、水槽中に藻類の増殖があまり見られず、水槽ガラス壁への藻類付着・増殖は無く、水槽全体が見通せて清らかな状態を保った。

[実験 2] 消石灰および IodAC の降水・大気暴露試験サンプルの大腸菌を用いた阻止円試験と鳥インフルエンザウイルスを用いた抗ウイルス試験の結果を図 2 に示す。これらの大腸菌阻止円試験と鳥インフルエンザウイルスに対する抗ウイルス試験の経時的な結果はほぼ同様な傾向を示し、降水と大気暴露を繰り返した消石灰と IodAC において、消石灰は数日（3~5 日以内）でその抗菌・抗ウイルス作用が消失したのに対して、IodAC は 3 週間以上経過しても高い抗菌・抗ウイルス作

4.　考察

実験結果より、ヨウ素担持量が少ない場合（0.1%以下~ppm レベル）のヨード活性炭は、水中藻類の増殖を抑制する効果が長期間継続するため、閉鎖系水中におけるアオコの発生・増殖を抑制できる可能性がある。この理由は不明であるが、IodAC が触媒的に働き、光合成反応であるカルビンサイクルに対し、何らかの酸素発生阻害反応を起こしているものと推測している[4]。

ヨード活性炭 IodAC に担持されているヨウ素の形態として元素状（I_2）であるため、化学的に活性な状態を保ちながら、空気中への揮発はほとんど無く、水への溶出性も極めて低く、動物の皮膚や消化器系の内腔壁などに接触してもヨウ素は非侵襲性の特性を有する。IodAC の細孔に捕集された細菌・ウイルス類は、強い殺菌力を有する元素状ヨウ素（I_2）によって完全に死滅する：図 3。この原理を利用し、IodAC（粉末状・顆粒状）を水鳥などのエサに配合し薬餌として与えれば、腸内で除菌・除ウイルスできる可能性がある：図 4。

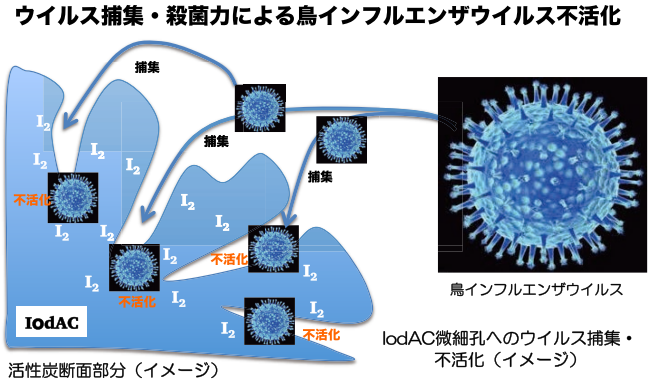

図３　ヨード活性炭の抗菌・抗ウイルス原理

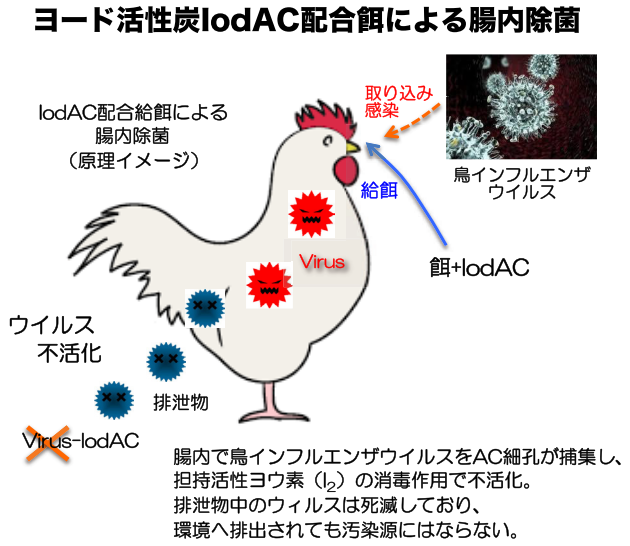

図４　ヨード活性炭：薬餌

5. 結論

ヨウ素担持量の多い IodAC は、強い殺菌力による抗菌・抗ウイルス性を有し、一方ヨウ素担持量が少ない IodAC は、魚飼育水槽の藻類の増殖を触媒的に抑制できる効果を有することが確認できた。

以上から、ヨード活性炭 IodAC®は、湖沼の藍藻類（アオコ）の浄化効果、ならびに鳥インフルエンザウイルス等の発生予防対策のための抗菌・抗ウイルス効果を有していると判断できる。

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P3-49

Establishing a Total Maximum Daily Loads (TMDL) Plan for Eutrophic Reservoir: Taking Shimen Reservoir as an Example

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Keywords: reservoir, eutrophication, Total maximum daily loads (TMDL), export coefficient of total phosphorous

ABSTRACT

Shimen Reservoir in Taoyuan, northern Taiwan, is the major water supply source for Taoyuan and partial New Taipei city area. However, its water quality has encountered eutrophication problem. In the past 20 years, 40% of observed water quality was in eutrophic state. While erosion was controlled and the sediment problem was mitigate, nutrient concentrations, especially the total phosphorous (TP), was still higher than standard concentration. The Taiwan Environmental Protection Administration (Taiwan EPA) in Taiwan has sought a complete watershed management plan to control TP from point and nonpoint pollution sources. In this watershed plan, Total maximum daily loads (TMDL) is the core concept to manage pollution sources. This study is to demonstrate the whole process of establishing the TMDL of TP for Shimen Reservoir, including onsite water quality monitoring, simulation modeling, pollution sources survey, and control cost analysis. A TMDL control boundary and the pollution reduction strategy for both point and nonpoint sources were suggested. The predict performance was also presented with verified models. In order to understand the nonpoint pollution sources concentration of agriculture, a complete storm water sampling plan was carried out in this study. The result of sampling shows that the export coefficient of total phosphorous of dragon fruit and bamboo is 18.52 mg/L and 28.84 mg/L, respectively. Moreover, the export coefficient of total nitrogen of dragon fruit and bamboo is 2.06 mg/L and 7.63 mg/L, respectively.

1. INTRODUCTION

In 2015-2017, the Taiwan Environmantal Protection Administration (Taiwan EPA) carried out the sustainable reservoir management program under the Science and Technology Master Plan 2017-2020 regarding the water environmental investigation and survey for improving the water quality of reservoirs in Taiwan. In order to achieve the goal, the tasks of this project include: (1) analyzing the data of the water quality and flow collected from the Shimen reservoir watershed, (2) intigating climate change adaptation in the water quality management and disasters mitigation strategies, (3) establishing nutrients reduction technologies and developing the action plans of nutrients reduction implementation, (4) applying decision-making model for water quality management and economic incentive for reducing nonpoint source (NPS) water pollution, and (5) holding several consultation meetings involved. Literature on NPS control practices (Best management practices, BMPS) from USA and Japan was reviewed. The water quality of the eutrophication potential reservoir, Shimen Reservoir, was investigated and evaluated based on the monitoring data in 2017, and the water quality improvement strategies of the reservoir were presented in this project. The Taiwan EPA, the local government of reservoirs, and the experts discussed the water quality improvement strategies and watershed management of the Shimen reservoir during the study. The total phosphorus TMDL and a loading reduction strategy were developed for the Shimen Reservoir.

2. METHOD

In Taiwan, pollution control and management is mature in technology and legislation. The TMDL is beyond the regular requirements and is to expose a higher standard to receiving waterbody which needs special protection, such as a eutrophic reservoir. Therefore, the selection of a TMDL candidate is important. The operation process is shown as Fig. 1. Following the process, Shimen Reservoir is listed as a TMDL candidate and needs a TMDL plan to control its TP concentration to remove from eutrophic state.

In order to confirm the pollution hot spots or area, pollution source survey, onsite water quality monitoring, and a watershed model were required. Storm Water Management Model (SWMM) was applied in this study.

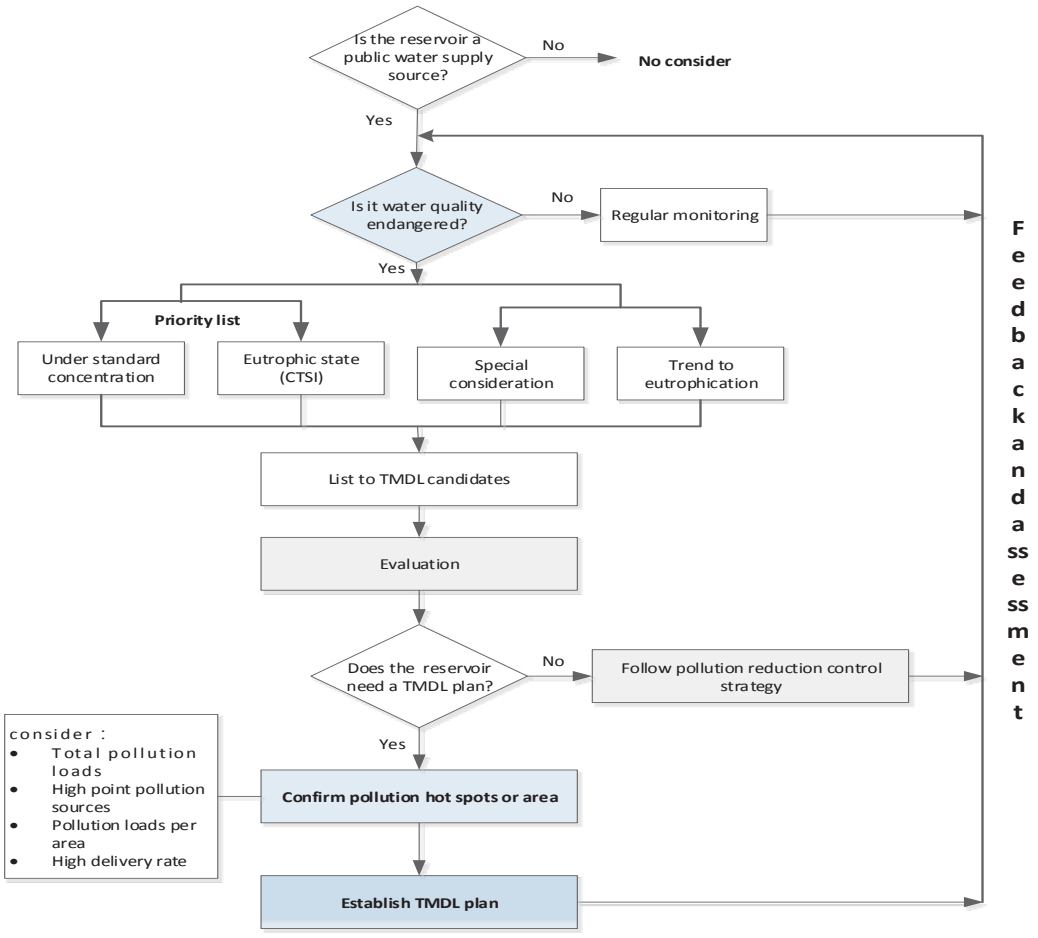

Fig. 1 The operation flow of deciding TMDL list and TMDL area.

3. RESULTS

Point pollution sources in Shimen Reservoir include domestic and tourist sewage. The TP loads from domestic sewage were calculated from the citizen numbers, water usage quantity, and the effluent TP concentration. Tourist sewage was divided to stay and non-stay (one day trip) situation. The TP emitted from domestic sewage was 4,504 kg/yr and which of tourist sewage was 487 kg/yr; therefore, the total TP from point pollution source was 4,900 kg/yr.

TP from nonpoint pollution sources was obtained from SWMM model. After model calibration and verification, the total TP from nonpoint pollution sources was 27,044 kg/yr, which was from forest and agricultural lands. In SWMM model, 25 subwatershed was delineated as Fig. 2. The subwatershed S1 has relatively high percentage of agricultural and urban lands and produced the highest nonpoint pollution loads, which is 4,089 kg/yr. This subwatershed was suggested as the priority control area because of its high TP loads and near to reservoir waterbody.

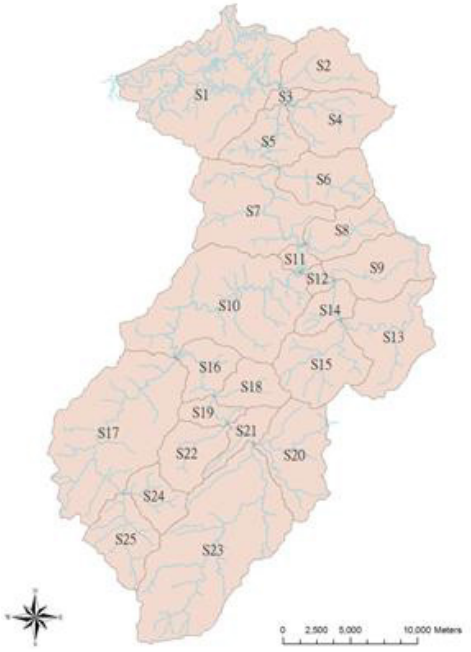

Fig. 2 The subwatershed of Shimen Reservoir.

4. DISCUSSION

There are four streams inflowing to the Shimen Reservoir, which are DaHan, SanMing, NanZiGo, and GaoLouPing. Among the four streams, SanMing and NanZiGo stream present high TP concentration, which is at least 0.05 mg/L and the standard concentration is 0.02 mg/L. The TP loads of the four streams in S1 subwatershed were calculated. They were 2245, 2183, 1069, and 571 kg/yr of DanHan, SanMing, NanZiGo, and GaoLouPing, respectively. The details of TP loads of the four streams were summarized in Table 1. SanMing and NanZiGo steams contribute high TP loads and results in high unit pollution. Therefore, the priority control area was reduced from S1 to the two streams area (Fig. 3).

Table 1 Recommended sizes of fonts

Stream	Point pollution sources (kg/yr)	Nonpoint pollution sources (kg/yr)	Total (kg/yr)	Pollution loads per area (kg/ha)
SanMing	714	1,468	2,183	1.50
NanZiGo	397	672	1,069	1.14
DanHan	813	1,431	2,245	0.63
GaoLouPing	202	369	571	0.45
others	147	273	420	0.61
Total	2,274	4,213	6,487	

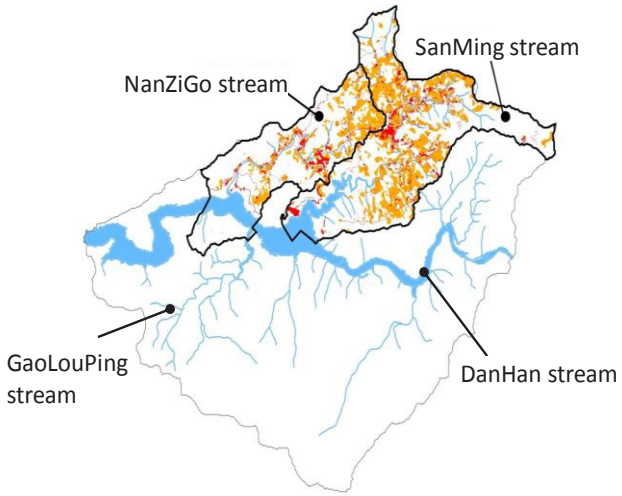

Fig. 3 The suggested TMDL area for controlling TP pollution of Shimen Reservoir.

5. CONCLUSION

This study presented the process of deciding a TP TMDL plan for Shimen Reservoir to mitigate its eutrophic state. The whole operation process, the technology of onsite monitoring, and the model application could be replicated to other cases. The TMDL plan was established in 2017 and the following implementations were started in 2018. Its performance will be checked and will feedback to actions design.

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P4-1

Rehabilitation of "flowing net with rice cake hunt" and "wide rectangle net hunt" to waterfowl.

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Keywords: Culture, Tradition, Tourism, Marin fishing industry, Policy proposal

Abstract

"Flowing net with rice cake hunt" and "wide rectangle net hunt" to waterfowl, are introduced using a case of lakes and marshes in East Kanto region, Japan. Legitimately, it was performed at Tega marsh (Chiba) and Kasumigaura (Ibaraki) until 1945. There is also cases at Sado island (Niigata, Japan sea) and Biwa lake (Shiga). The role of the public museum of Ibaraki and Niigata is big in folklore after new political system from 1945. There is preceding study from a natural history, history folklore and land water science. I also add approach with ornithology, political science, tourism economics and jurisprudence, and analyze current state and problem toward rehabilitation.

P4-2

牛久沼におけるテナガエビの産卵期と沼の恵みに関する考察

Observation of spawning season of freshwater prawn, *Macrobrachium nipponense* and a study of cultural values of Lake Ushikunuma

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抄録

茨城県南部の牛久沼は面積6.5km2の小さい沼である。湖岸には水生植物が繁茂し景観が美しい。2017年3月から1年間, ここに生息するテナガエビを観察した。その結果, 水温が20℃台になると急激に成長し始めること, 産卵期は5月中旬から8月下旬であること, 産卵期に2回産卵する個体もあること, ふ化したテナガエビは8月中旬以降に出現することが明らかとなった。また, 湖岸の植物帯はテナガエビが安定的に産卵できる環境として機能しているといえた。牛久沼には釣り人も多いことから, 憩いと余暇活動の効用もあるといえた。周辺から縄文時代中期の丸木船も出土し, 牛久沼の魚介類が人間の命や暮らしに与えた恩恵が伺えた。近現代には, 牛久沼の周辺に暮らし, 牛久沼に着想を得た多くの作品を残した画家, 小説家や詩人が現れている。牛久沼のもたらす恵みの価値を見直すことで, 今の自然環境を良好に維持していくことの意義を考えることは重要といえた。

1. はじめに

牛久沼は茨城県の南部にある面積 6.5km2 の小さな沼である。沼の成因は 3 本の流入河川と沼の流出部が繋がる小貝川の堆積作用で塞き止められるたことによる。水深は平均1m, 最大3mである[1]。湖岸は交通量の多い国道6号線が接し, 市街地から近いものの, 湖岸には広範囲にヨシやガマが繁茂し, 静かで美しい景観を保っている。湖岸ではコイやふなの釣りを楽しむ人も多く, 魚介類を採捕する漁業者もいる。牛久沼にはコイ科魚類のほかテナガエビが生息している。牛久沼が住民にもたらす恩恵には, 景観の美が与える文化的活動への触発や釣り等の余暇活動の機会, そして食糧となる魚介類を生産力がある。牛久沼の生態系サービスは, ここに暮らす人々への生活や文化への寄与といえるであろう。ここで, 約 1 年間にわたる牛久沼に生息するテナガエビの生態を観察しつつ, 牛久沼の環境が地域文化にもたらすサービスについて考察した。

2. 方法

テナガエビを捕らえる装置として, プラスチック製で粗い網目状の, 直径 10cm, 長さ 50cm の筒 3 本を一まとめとし, 一方の端部を目合 5mm のモジ網で包んだものを作成した(以後「えび筒」と称す)。これはエビ類は狭い暗がりに積極的に潜む性質に着目した例にならった[2]。えび筒は, 牛久沼の湖畔にある釣り船屋「たまやボート」の桟橋に, 錘と紐でつないで沈めた。設置箇所の水深は約1mで周囲はヨシ, ガマがかなり繁茂していた。テナガエビの観察は, 平成 29 年 3 月下旬から平成 30 年 3 月まで毎週日曜日の朝午前 8 時にえび筒を設置した桟橋で行った。水温は棒状温度計で測定した。えび筒は素早く引き上げ, 潜り込んだ魚介類をバケツにあけた。テナガエビは顎角の先から尾肢の後端までを全長としてミリ単位まで測った。テナガエビ以外の魚介類は種の同定と個体数を記録した。牛久沼に関する地域の歴史や文化について, 龍ヶ崎市歴史民族資料館や湖畔の三日月橋公民館を訪れ, 出土品や牛久沼に関する創作作品を残した芸術家の情報を収集した。

3. 結果

えび筒のモジ網で片底を包んだ側の筒の中は, 網目の重なりから比較的暗がりの様子を呈していた。採集する時は, えび筒の紐を勢いよく引き上げて, 潜り込んだ生物が端の網に引っかかるようにした。図1に水温の季節変化を示した。毎週 1 回の間隔で朝 8 時に測定した水温は, 冬は結氷もみられ, 夏は32℃まで上昇した。昼の最高水温はさらに高いといえた。採集された生物は, テナガエビのほかヌマチチブ, ウキゴリ, モツゴ, スジエビ, アメリカザリガニ, タニシであった。

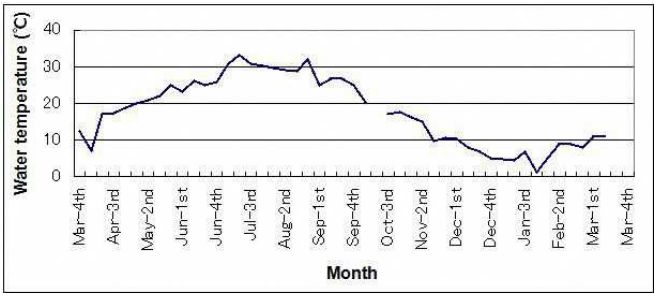

図 1 牛久沼の湖岸の水温の推移

Fig. 1 Monthly change of water temperature in Lake Ushikunuma

また 4 月と 8 月下旬には，スジエビという別種のエビも採集した。図2に，採集されたテナガエビの採集日別全長別の頻度分布の推移を，各個体の抱卵の有無や頭胸甲内にみえる卵巣の成熟の有無を区別して整理した。この結果，5 月 14 日に初めて，腹脚の間にうす緑色の卵を抱え付けたテナガエビを確認した。その後 7 月 25 日まで毎回抱卵したテナガエビが確認された。また，採集したテナガエビの大部分が抱卵していた。

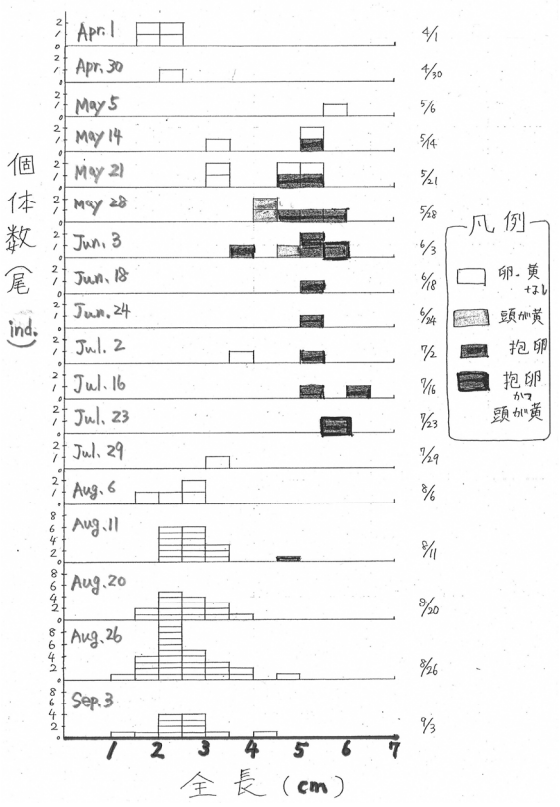

図 2 採集したテナガエビの全長別頻度分布の推移

Fig. 2 Monthly change of distribution of total length of Macrobrachium nipponense (black shows egg holding prawn)

抱卵したテナガエビは 8 月 20 日まで採集された。テナガエビの全長の推移から，4 月下旬から 5 月中旬にかけて早い成長が推察され，全長約2cm の群が約5cmの群へと大型化した。その後 7 月下旬まではほぼ5cm主体のまま推移したが，8 月 8 日に突然全長約2cmの小さいテナガエビが主体と変化した。その後全長約1～2cmの小型群が大部分を占め，採集された個体数も小型群が主体となると以前の約5倍に増加した。同時に以前の大型の個体はきわめて少なくなった。

テナガエビは通称”川えび”として一般的に食用に用いられている。しかし牛久沼のテナガエビは商業流通していない。しかし図3のとおり牛久沼漁業協同組合のテナガエビ採捕量は近年約 500kg へと増加傾向がみられるが，自家消費にとどまっているという。今回，採集したテナガエビを日本古来の伝統料理である佃煮に調理した。その結果砂糖，醤油，味醂の合いまった美しい光沢が現れた(写真1)。

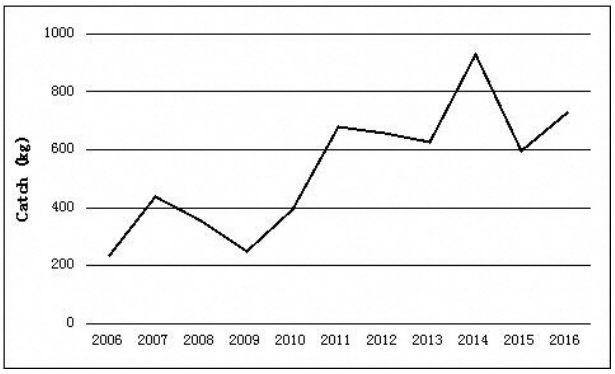

図 3 牛久沼漁業協同組合のテナガエビ採捕量の推移

Fig. 3 Change of catch of freshwater prawn by Lake Ushikunuma fishery cooperative union



写真 1 小型のテナガエビと調理した佃煮

Pic. 1 Juvenile Macrobrachium nipponense in August and traditional food “Tsukudani”

4. 考察

牛久沼におけるテナガエビの産卵期は 5 月中旬から 8 月下旬まで 7 月が最盛期といえた。6 月から 8 月には採集した個体のうち抱卵と同時に頭胸甲内の卵巣も黄

色を呈している成熟個体も確認されたことから，少なくとも産卵期に2回抱卵（ふ化）をする個体があるといえた。このテナガエビは 6 月 3 日に初めて確認したが，この個体の最初の抱卵が 5 月中旬にあったと仮定すると，抱卵からふ化までの期間は約 2 週間と考えられた。全長組成の推移でみられた急激な小型群の出現は 8 月中旬から次世代の群が現れたといえた。漁業協同組合が7月に沼に設置した定置網で採集したテナガエビには，長い腕の胸脚をもつ大型のテナガエビ（”大エビ”と称されるオスの大型個体）が多く含まれていた。一方，夏季にエビ筒のテナガエビのほぼすべてが抱卵のメスであったことから，湖岸の水生植物帯は，メスの安定的な産卵のため，外敵から隠れる等の機能を有しているといえた。調理したテナガエビの佃煮は仕上がりの美しさだけでなく，牛久沼の生物が著者の食糧となり自らの命に転換したと実感でき，自然の恵みであると感じられた。さらに 8 月にはえび筒に半透明の硬いゼリー状の大きな塊が付着していたが，外来種のオオマリコケムシであった。また牛久沼の魚類相は今も豊富で 40 種にも及ぶことが明らかである[3,4,5]。牛久沼の魚類等生物群は安定的な物質循環と産卵場環境が保持されてこそ維持され，それは人々への恵みといえた。漁業組合によれば 2017 年はテナガエビの採捕量が非常に多いとされ，テナガエビの再生産の動向は水環境の指標になり得るといえた。牛久沼の存在は食などの暮らし以外にも人間の精神的，文化的活動にも恵みをもたらしている。事実，牛久沼の流出部の地層からは，今から 4000 年前縄文時代後期と推定される丸木舟が出土しており，これは魚類採捕や水運などの生活の存在をうかがわせる[6]。芸術文化の面では，著名なる日本画家小川芋銭（1868-1938）が牛久沼を見下ろすアトリエから牛久沼や伝説の水生生物河童を描いてきた[7]。また，著名なる女流小説家の住井すえ（1902-1997）も牛久沼を見下ろす私邸で 60 年を過ごし，著名なエッセイである「牛久沼のほとり」を著し，牛久沼の周辺に生きる人々の暮らしを描いている[8]。さらにまた，牛久沼を愛した詩人として沢ゆき（1893-1972）がいる。沢は牛久沼の湖畔に生まれ，牛久沼をみつめた数多くの詩作を著した[9]。龍ヶ崎市には沢ゆきを顕彰する碑もあった。現在は西洋画の写実派の菊地義正（1948-）がおり，数多く牛久沼の自然豊かな風景を描いている(写真3)[10]。牛久沼は長い歴史の中で生物の循環と水辺の自然環境を維持してきたことにより，ここに暮らす人々に食と憩いという心身両面への恵みをもたらしてきたといえた。

5. 結論

牛久沼はテナガエビ等豊かな魚類資源をもたらしているばかりでなく，人間の精神的文化的活動へも影響も与えている。これらは湖沼環境が良好に維持されてこそ効用が発揮されるので，牛久沼の環境，景観を維持することは将来への責務ともいえる。



写真 2「紫朝靄」 菊池義正画（2012 年，油彩）

Pic. 2 ″Purple mist in the morning″ Yoshimasa Kikuchi (2012, oil painting)



写真 3 えび筒設置場所の湖岸風景の季節変化

Pic. 3 Seasonal change of lakeside scenery

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Livelihoods in the Himalayan Wetland

A Case Study in Highest Lake in the Himalaya

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Keywords: Lake, freshwater, livelihood, endangered fauna and wildlife

ABSTRACT

The splendid and picturesque Tilicho Lake is the jewel of the Nepal's Himalaya. Wedged in the Annapurna range the lake is situated at the altitude of 4919 m. Its area is about 4 km^2 (400 ha). The lake is the highest and largest high altitude wetland in the world. It is a closed glacial erosion lake. The lake remains frozen for 7 months and remains open only from June to October. Tilicho is the source of water for wildlife, pastoralists and tourists. Because of its location in the rain shadow areas, it is the only source of freshwater in the area. The Lake bears high spiritual and cultural values for Hindus, Buddhists and Lamaists (Nyngma sect) and go there for pilgrimage. Tilicho is habitats for the endangered fauna. They include snow leopard, blue sheep, musk deer, Himalayan thar, Pika, wood snipe, Bar-headed Goose, Ruddy Shelduck, common merganser and great-crested grebe. Medicinal plants, are endemic to the area. Livelihood activities include the pasture for yaks and collection of medicinal plants such as Panchaunle, Jatamashi and Kutki. Others include trade and tourism. Recently skiing and cycling on the frozen lake, deep diving to a depth of 25 meters and mountain biking. Tilicho is fragile but free from direct human influences. Even then, it is facing the problem of climate warming, inclement weather, yak-wildlife conflict, spread of moraine, avalanches, high evapo-transpiration. These problems are directly implicating the lives and livelihoods of local people.

1. Introduction

The Tilicho is the largest freshwater endorheic lake situated at the altitude of 4,919 masl in the High Himalayan Region of Nepal. It covers the total area of 400 h (4 km^2). The drainage of the watershed is oriented towards south-east. The lake is in the rain shadow area [1].

The primary objective of the study was to assess lakes and its resources and focused around the following research questions:

1. What is the general biological status?
2. What are its religious and cultural significances?
3. How vulnerable ss the lake to sudden outburst of glacial lake?
4. Is this lake linked to people's livelihoods?

2. Method

The researcher used the participatory assessment methods to collect data information. Several techniques employed in the study are: (1) direct observation, (2) community meeting, (3), key informant Interview and (4), review of secondary information. The lake is generally accessible to travelers only in the months of June to September. A 8-days trek is required to reach the lake from the motorable road. The researcher spent another 10 days in the local community for collection fo additional information

3. Results

1. The lake is an endorheic lake (receiving inflows but no outlet) and rectangular in shape.

2. The *Ramcharimanas*, a Hindu scripture, mentions a blue lake at the shoulder of the Nilachal in the Himalayas. Rhishi Kagbhusundi used to live there at

the 20th Kalpa. He was a true devotee of Bhagawan Ramchandra. During those days the lake was surrounded by four summits, each summit marked with a big tree, (1) Mango (*Mangifera indica*), (2) Pakhar/Kabro (*Ficus lacor*), (3) Pipal (*Ficus religiosa*) and (4) Bar/Bargad (*Ficus bengalensis*) [2].

Rhishi Kagbhusundi used to meditate under the papal tree; he used to offer prayers under the Pakhar tree, perform rituals under the mango tree, preach the Ramcharitmanasa to deities, Rishis, angels and birds of the world. All those who listened to him attained salvation (mokchhe) after their death. This lake was then known by the name of Kag Bhusundi Tal. It is said that during the Vedic times, people, birds, and even animals were capable to understand each others' languages and offer spiritual prayers [3].

3. Lord Shiva (creator of this universe), who was very much grieved after the tragic death of his consort, Satya Devi and was roaming around the Himalayas. At the shoulder of Mount Nilachal (Nilgiri) he saw Rishi Kagbhusundi reciting the Ramcharitmanas to birds from around the world. He immediately changed his form into that of a bird and sojourned there to listen the recital of the Ramcharimanas. The recital became a real solace to Him. Then he returned back to his spiritual capital, Kailash in the Himalayas.

4. Similarly, Garuda, the king of birds-*cum*-the mount of Lord Bishnu, was suffering from depression caused by his inability to control his craving and personal lust (*kamana* & *bashana*). He also went to to the Nilachal bathed in the lake and regularly listened to the recital of the Ramcharitmanas from Rishi. After this attendance, Garuda was cleansed from the anxiety craving and lust. Then he returned back to Baikukuntha to the attendance on Lord Bishnu.

3. In 2002 Pundit, Shankar Pd. Pandey recited the story for nine days. For this purpose there were 200 guests and 150 tents pitched out including 1 tend for the recital and 3 tents for medical purpose. A helicopter was in a stand-by position to evacuate the participants in case of emergency. Some 14 cooks were engaged to provide foods to guests and day-time visitors. The Pundit is known to have performed Nabah in the plane, ships, in desert, islands and many remote places. [6].

4. The Great Guru, Padmasavbhav was enlightened here and was successful to merge Bonpo religion and Buddhism, which is called Tantrik Buddhism (Mahayan).

5. Local people believe that rains and wind welcome a stranger to the lake. They vividly related their own experience of being in rain when they visited the place. However, the author, despite his first visit, could not receive that natural hospitality of rains and winds.

6. Important wildlife included Snow Leopard, Musk Deer, Demoiselle Crane, Himalayan griffon, Blue sheep or bharal (*Pseudois nayaur*), Nirmasi- *Parnassia nubicola*, Kutki– *Neopicrorhiza scrophulariiflora*, Jatamshi- *Nardostachys grandiflora*, Yarchagumba – *Cordyceps sinensis*, Chiraito- *Swertia* spp. (many species)and Pakhenbed- *Bergia ciliata*

7. Eight Russian professional climbers dived 25m into the Tilicho on the 23rd September 2000. Prior to diving, they checked their diving in the local lake of Manang Village and got blessing from the Lama. They planned to register the driving in the Guinnes Book of Records but in vain [4].

4. Discussion

1. Our literature survey, at least, does not document any glacial lake in the Himalaya of that size and at that altitude even in the world. So this is the largest and highest glacial lake in the world.

2. The lake is religiously important for both

Hindus and Buddhists alike. This is authenticated by cairns (collection of stones at the top of the hillock by the travelers) and monasteries In the Vedic times of Silver Age, the lake used to be known by the name of Kag Bhusundi Tal, [5].

3. The lake provides the livelihoods to local people, particularly through the collection of herbs and medicinal plants, grazing of yaks in summer and engaging in the tourism activities. Because of its strategic location, the lake can be one of the best tourist sites along the trans-Himalayan trail in the Annapurna Range [7].

3. Since the lake is endorheic in nature, there is no risk of being bursting out as the lake is in the middle of the till of almost over 1 km long between the lake and moraine.

4. A minor mistake may cost one a life. Oftentimes, rocks also come down rolling, followed by land slide and scree erosion. One has to be extra careful while trekking to this area.

5. The catchment area is full of endangered flora, fauna and herbs.

5. Conclusion

1. Upper Manang habors a large no. of medicinal plants of high trade value, many of them are endangered, so their conservation is important.

2. Threatned plants like *Dactylorhiza hatagirea*(E) *Nardostachya ghandiflora* (V) *Neopicrorhiza scrofulariflora* (V) are found. Likewise, Endemic plants like *Stelleria conjestifolia*, *Cremanthodium perpureifolium*, *Oxytropis williansii*, *Primula wigraniana* also have been recorded there.

4. Tilicho lake has great tourism potentials. Uncontrolled tourism may create threats to these plants.

5. Lamas have great role in decision making process in upper Manang. Any conservation program should seek to ensure their active and responsible participation. Even then the key role if of local communities.

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なぜ湖沼は人々の心を惹きつけるのかー湖沼と信仰に関する考察

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キーワード:湖沼再生に何が不足か、科学への過信を反省、水への素朴な信仰心の大切さ、総合的考察の重要性

抄録

湖沼の再生にとり、科学技術、流域管理、財政、政策、法令などのハード的方法論は重要であるが、一向に環境が改善しない湖沼が多い現実を見ると、それだけではなく、湖沼に対する人々の素朴な信仰心をとりもどすソフト面の対応も、車の両輪のように重要ではないか。理性によって湖沼を研究すると同時に、感性、すなわち湖沼を愛する心を涵養することが目標になるべきではないか。本論で様々な事例を紹介し、人と湖沼の関係性を心理面から重視し、湖沼観を総合的に再形成していく上での示唆を含めて、霞ヶ浦流域の地域社会における信仰について、世界の事例と比較しながら考察する。

1. はじめに

古来、静寂な湖沼を眺める人は人生の苦悩を癒され、安息の時を過ごし、人智を超えた神秘性を感じ、水の神や精霊を崇拝した。湖沼は信仰の対象であった。しかし近代合理精神によって世界の神秘性が否定され、科学が発達した。人間が湖沼を利用し、排水を河川、湖沼、海洋に捨てた。湖水は汚染され、その恵み(生態系サービス)は再生産されない。近現代の湖沼学では、湖沼は冷徹な科学的研究の対象でしかない。人と湖沼の関係の研究は科学によって本格化したが、人の心は癒されず、湖水の清澄さを取り戻すことは難しい。かつてニーチェは「神を冒涜した後、人間は自身をも冒涜する」と指摘した。一方、パスカルは、「あらゆる物体の総和も、あらゆる精神の総和も、またそれらのすべての業績も、愛の最も小さい動作にもおよばない。これは無限に高い秩序に属するものである」と示唆した。我々はパスカル的精神を尊重し、古代人の心に学び、素朴な信仰心を大事にしつつ、心理学、宗教学、哲学、民俗学などのソフト面に光を当て、湖沼学、陸水学、水処理技術、流域管理、政策などのハード的方法論を補完することで、湖沼をより大切にできるのではないか。水質、生物多様性、生態系サービスをふくめて、湖沼環境を改善できるのでないか。第 6 回世界湖沼会議で、「湖の音に耳を傾けよう」と霞ヶ浦宣言に謳われた。本論では、その先進性を継承し、湖沼と人の関係性について考察を深め、今後の湖沼環境改善へ向け、これまでの世界湖沼会議では殆どなかった視点を取り上げてみたい。

2、本論

世界中の民族は、古代から湖沼神、河川神、海神、水神、水の精霊や化身を、人智を超えた存在として信仰し、感謝しつつ畏れてきた。中国や日本では、龍、蛇、亀、河童、河伯が水神やその化身として信仰された。ヒンドゥー教ではサラスバティー神が水神であり、弁才天信仰の起源となった。ヨーロッパではヒドラやアケーロスが水神として、ポセイドンが海神として位置づけられた。絶対神を信ずるイスラム教世界においても、清浄水は貴重とされ、オアシスの緑色は国旗に使用されるシンボルカラーである。このように水を神聖とする信仰は、宗教的に洗練されたものを含めて、古代人の素朴な心に自然発生したのではないか。

弥生時代以来、稲作に精励してきた日本人は、水の神を山の神、田の神と同一視する例が多い。田植えは神と人の協働作業だった。春、山の雪解け水は落葉の成分やミネラルを含みながら流下し、山麓の水田を潤し、湖沼や沿岸海域に豊かな水産物をもたらす。山の神が水の神となって麓に降り、田神となり、稲を育て、労働を見守り、豊かな稔りをもたらす。秋、田の神、水の神は山に昇り、厳しい冬、山の神として、麓の民を慈愛深く見つめ、山、森を守る。実は山の神は農民の祖霊であり、子孫の農の営みを見守るとされた。山形県庄内平野の農民は山岳仏教に深く帰依し、雪解け水として出羽三山から祖霊が里に降りてくると信じ、春の農作業を開始した[1]。

かつて霞ヶ浦湖畔に暮らす人々は水神宮に参拝し、恵みに感謝し、時に水害をもたらす湖水を畏敬してきた

[2,3]。現在、汚濁した湖水は堤防に囲まれ、高齢の漁師以外は湖水の恩恵を実感することなく、関心が薄い。筑波山周辺には、水源が信仰の対象となる石碑が多い。筑波山麓の森林に涵養された桜川は流域の水田に農業用水を供給し、豊かな稔りをもたらし、集落の生活を支えた。中世には官衙に穀物倉庫が建てられ、南北朝期から戦国期には小田氏が桜川流域に、当時としては規模が大きい城を築くほど、生産力が豊かであった。山麓の桜川市(旧真壁町)山尾に水分(みくまり)神の石碑がある[4]。桜川の田土部堰の傍らにも水神碑がある。この堰は桜川中下流域の広い水田を潤す取水堰である。石岡市(旧八郷町)小幡では筑波山から流れだす恋瀬川支流が杉葉線香を造る水車を動かし、麓の水田を潤す。小幡にも水分神の石碑がある。

現代では湖水は巨大機場によって大量取水され、筑波山を貫くパイプラインで遠隔の農地へ送水され、水田、畑地を潤す。揚水機がなかった明治以前、周辺の水田は霞ヶ浦から水を引くことが出来ず、河川や溜池から供給を受けた。霞ヶ浦流域は年間平均降水量約 1200mm(全国平均約 1800mm)の少雨地域である。霞ヶ浦・北浦流域の笠間市(旧岩間町)愛宕山、石岡市龍神山、桜川市(旧大和村)雨引山楽法寺では雨乞い祈祷がかつて行われた。この気象条件下、霞ヶ浦周辺(特に行方地域)の谷津には溜池が約 50 箇所も築かれ、古くは常陸国風土記に谷津の水源をめぐる伝承が記録されている。かすみがうら市加茂、阿見町実穀の溜池、土浦市田村の湖畔に弁天宮がある。弁才天は仏教の守護神として日本に伝わり、各地で水の神、芸能や商売の神として素朴な信仰を集めた。霞ヶ浦の各河岸(霞ヶ浦四十八津、北浦四十四津)の水神宮は集落の人々に守られてきた。水神講を続けている集落もある。水神の祠に供える小餅は、かぴたり餅と呼ばれ、冬季に飢える河童に捧げるものであった。河童は水神の化身であり、夏に水遊びする子供達や農耕馬を水に引き込む悪戯をしないように願い、人々は河童に餅を施した[4,5]。

現代、流域の住民は湖水を揚水した水田で生産された米を主食にする。工業団地で大量に湖水を使い、製品を生産し、排水し、給与を得て家族を養う。湖水を原水とする水道水を飲用に、調理水や洗濯水に使う。生活排水は霞ヶ浦に戻る。我々はワカサギやシラウオを食べ、湖水の恵みを受け、世代交代してきた。我々は水道水を水洗トイレに使う。排泄物が湖水に戻り、物質が循環している。湖水によって、地域社会が維持され、歴史が刻まれてきた。まさに霞ヶ浦は我々自身である。しかし、そのことを感謝の念とともに常に意識している住民は多くない。

「湖沼は人間を映す鏡」(琵琶湖宣言)とすれば、現代人は、それを曇らせ、打ち割ることで自分自身と心をも破壊しかねない。流域の人間社会の矛盾を凝縮して投影するのが湖沼ではないのか。水源林の里山、平地林を破壊し、住宅団地、工場団地、ゴルフ場を造成した。住宅や工場は排水を流し、湖沼へ負荷を与える。肥料と農薬を使い、生産性を上げようとするが、窒素、リン、化学物質は湖沼に流れ込む。治水・利水目的で湖岸を人工化し、高い堤防で囲み、自然浄化力を奪った。霞ヶ浦という鏡は、堤防の枠に嵌められ、濁り、人間達の顔を映すことなく、事態はますます深刻になりつつある。

世界の湖沼等では神聖な場所が水辺にある例が少なくない。過去の世界湖沼会議で訪れたイタリアのマジョーレ湖畔の古い教会に昔の修道士のミイラが安置されていた。インドのジャイナ河畔のタージマハルは荘厳な霊廟だった。インドネシア・バリ島のブラタン湖畔のウルン・ダヌ・ブラタン寺院は水の神を祀るがゆえに湖水の清浄さが保たれていた。琉球や奄美では美しい海の彼方に祖霊の世界、ニライカナイがあるとされ、素朴な信仰を捧げる。琵琶湖では静寂な湖水を浄土とみなす信仰が息づき、日本遺産に登録される根拠となった。竹生島、沖島、浮御堂、比叡山延暦寺、石山寺などを巡る人気コースが設定され、多くの観光客が訪れ、湖を守る信仰心が地域を活性化させている好例となっている。この視点でも琵琶湖は霞ヶ浦のお手本である。

神道では礼拝前に水垢離を取る。鳥居の傍の手水場で手と口を漱ぐ。水で浄めた神聖な社を死者(先祖)と生者(子孫)の厳かな対話の場と位置づけていると解されるのではないか。仏教の般若心経では「是諸法空相、不生不滅、不垢不浄、不増不減」と唱え、浄と穢は本来区別出来ないと教えている。それに関し、霞ヶ浦周辺で栽培される蓮と蓮田の泥の関係性を考察してみよう。ヒンドゥー教と仏教では、泥から美しい花を咲かせることから、蓮花は聖俗の象徴である。泥は有機物の分解産物であり、死の姿であるが、そこから生が再生される。インドでは、

干上がった池や洪水後の泥は病を癒すとして、泥の中に身を投じ、泥を全身に塗る素朴な人々がいる。泥は湖沼生態系において、生産と分解の物質循環の中で重要な位置にある。流入河川が運搬した栄養塩類がプランクトンを増殖させ、魚類の餌料となる。生物の遺骸は湖底に沈み、あるいは波浪によって岸辺に打ち上げられ、分解され、泥となる。泥は穢れではなく、輪廻転生の姿と解される。古代インドにおいては、宗教者が長い時間をかけて自然を観察した末に、湿地や泥が意味する本質を直感的に洞察したのであろう。岸辺の泥から再生する美しい蓮花が信仰の対象となったことは当然かもしれない。一般現代人も、蓮が仏教やヒンドゥー教の象徴的な花であることに違和感がないことをみれば、湖沼や岸辺の湿地を尊重する素朴な感性に辛うじて繋がるのではないか。

湖沼の浄化を目指すとき、科学技術を捨てることはできない。霞ヶ浦宣言には「科学の英知に深い注意を払おう」とある。しかし、湖沼全体を保全するには、自然科学的認識のみでは不十分であることに、湖沼の環境保全をめざす人々は気づくべきであろう。科学と同時に、「湖沼は我々自身」という心の問題を念頭に置くことは、今後目指すべき方向性の一つではないか。湖沼問題に関わる市民が科学的理解によって課題を明確にし、思いを共有する人々と連帯・協働しながら進むことは重要だが、芸術や文化等を含めて、哲学、心理学、宗教、民俗学的な認識を深め、多様な分野に関わりながら、認識の高みをめざす努力が重要であろう。残念ながら、研究者や行政のみならず、素朴な住民が構成する地域社会において、それが不足していることは否めない。湖沼を大切にする心を価値観の上位に置くことが人々の常識になることを期待したい。

文学作品にも湖沼がメタファーになる例がある。レムの名作「ソラリス」では、惑星ソラリスの海は、探査目的で地球から派遣された研究者の記憶を可視化し、再現する。ある研究者は亡くなったはずの妻と再会したが、彼女は彼を苦しめる。ソラリスの海とは何か。人間の心を投影する神の啓示か。人類は地球上の清い流れを疎かにしながら、遥かな惑星ソラリスの海と対峙した。ソラリスの海を研究する意味はあるのか。科学とは何か。「ソラリス」はそれらを隠喩的に問う作品として解釈される[6,7]。難解な作品として知られる「ソラリス」のモチーフを、湖沼と人の関係性に投射してみると腑に落ちることが多い。湖水を汚濁させ、水産物を収奪し、農業用水、工業用水、都市用水として水資源を濫費しながら、その汚濁機序を解明し、改善方策を探るべく人間は研究する。その矛盾した姿勢に湖沼を崇敬する謙虚さを窺うことはできるのかという、根源的な疑問がこの文学作品で呈示されているのではないだろうか。

3、まとめ

石牟礼道子は「苦海浄土」で、豊穣の内海であった不知火海の恵みを否定した文明の罪を告発した[8]。ニーチェが予言したように、海の神を冒涜した人間は自身をも冒涜したのであった。素朴な人は夕暮時、茜色の空を映す鏡のような湖面を眺めて特別の思いを抱く。まさに湖沼はソラリスの海のように人生の記憶を覚醒させる。

湖沼は単に大きな貯水池ではないし、汚し、開発し、経済活動に利用し尽くす対象でもない。我々は湖沼を様々な視点から深く洞察し、謙虚な湖沼観を復活させなければならない。第 17 回世界湖沼会議の主題「人と湖沼の共生」は永遠の課題なのか。かつて古代人が美しい湖沼に惹かれ、静穏な湖面を素朴な心で眺めた時に感じたアガペー（神仏の人間に対する愛：感謝と幸福感に通じる）を現代人が取り戻すことができるのだろうか。

過去の世界湖沼会議では、日本で開催された例以外、市民参加が少ない。それは科学、技術、効率、管理、財政等を優先させる姿勢に一般市民が違和感を抱くからではないか。この会議に専門家だけでなく、素朴な心を持ち続ける人々が参加しなければ湖沼の再生は不可能だろう。「湖は私自身である」という心の声を聴き、科学の成果を尊重しつつ、理性と感性の融合をめざし、総合的で全人格的湖沼観を形成できれば、湖沼再生への希望が見えてくるのかもしれない。

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P4-5

水上飛行機を活用した地方創生プロジェクト

-軍用水上機基地が存在した霞ヶ浦美浦村を対象として-

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キーワード:水上飛行機, 建築, インフラ

抄録

水上飛行機を活用した建築群により茨城県美浦村大山の地方創生を計画するものである。水上飛行機は世界各国において利用されているインフラの 1 つである。その理由として低コストで多くの場所に離着陸水可能だからである。現在の日本においてインフラ整備は終わりつつあり、孤島や過疎地へのアクセスは不十分な所がある。そのため、水域が多く存在する日本ではこれから水上飛行機を活用する事で多くの恩恵を受けることが可能だと考える。そこで人口が少なく、水域に面していて、水上飛行機との関わりがある敷地として茨城県美浦村大山を対象とした。ここでは霞ヶ浦という豊かな自然と、戦時中に海軍航空隊が水上飛行機の訓練所として活用していた背景がある。水上飛行機ターミナルと敷地特性から導き出す建築施設群をモデルプランの一つとして提案する。

□□

1. はじめに

世界各国において水上飛行機はインフラの1つとして利用されている。これは水陸両用なことから大規模な滑走路を必要とせず低コストで多くの場所に離着水する事が可能だからである。特性上インフラ未整備地域へのアクセスが容易になるなどのメリットもある。そのため,日本でも水上飛行機が新たなインフラとして注目されている。そこで本稿では戦時中に水上飛行機が運航されていた茨城県稲敷郡美浦村大山を対象とし,メインターミナル及び周辺施設について設計提案を行う。又、これは美浦村から要求されそれに応える形での提案でもある。

2. 計画背景

2.1 社会的背景

我が国ではインフラが整備され,高度成長時代から続く高速大量輸送が主流である。しかし,インフラ整備が終わりつつも孤島や過疎地へのアクセスは充分に考慮されていない。しかし,一方で高度経済成長時代に計画され国内経済の低迷により破綻した多くの地域整備が 30 年の時を経て現在,地域おこしという形で再び展開され始めている。ここで戦前運航していた水上飛行機であれば移動速度の速さや,多様な状況・用途で使用可能であり,今後の地方創生に寄与できると考える。

2.2 (株)せとうち seaplanes

水上機を新たな海の有効活用を図る交通インフラとして位置づけ, (株)せとうち Seaplanes という会社が 2016 年 8 月に設立された。広島県尾道市ベラビスタマリーナを拠点として西日本を中心に展開している。国土交通省など関係省庁や各県が協力し, 全国に関連施設を順次整備することを計画しその拠点の1つとして霞ヶ浦に注目している。理由はピッコロ・シープレーンクラブという団体が霞ヶ浦で ULP(Ultra Light Plane)と呼ばれる水上飛行機をレジャー目的で使用しているからである。実際に 2016 年 11 月 23 日には水上飛行機の運行試運転が行われ, 東日本の運行も現実になりつつある。

2.3 水上飛行機の利便性

水上飛行機は通常の飛行機とは異なり指定の陸上滑走路の建設を必要とせず,海上に 1000m の直線距離があれば海面から離発着することができる。そのため,海辺に面している過疎地域や孤島などにアクセスすることが容易である。また,船舶と比較しても移動速度が早く,陸へも滑走路があれば離発着することが可能であるため, 多様な目的に富んでいる。

3. 計画敷地

水上飛行機を利用した地方創生プロジェクトのケーススタディとして茨城県美浦村大山 2389 にて計画を行う。霞ヶ浦を利用した水上飛行機ターミナル及びそれに付随する施設で水上飛行機普及のための拠点を提案する。(図1 対象敷地)

3.1 霞ヶ浦

霞ヶ浦は湖面積が約 220 ㎢と琵琶湖に次いで日本全国 2 位の大きさがあり湖という特性上静水域のため水上飛行機を活用するのに適していると言える。また,東京湾を中心に観光地を結ぶ水上飛行機のバックヤード基地としても優位性が高い。本稿の提案としてはバックヤード基地としての役割だけでなくローカルネットワークの中心地としても活用していきたい。

3.2 歴史

戦時中に鹿児島海軍航空隊が水上飛行機の訓練を行っていたという過去があり敷地内の霞ヶ浦大山スロープは土木遺産として補修・保存され,現在も使用されている。この様に,歴史的背景と環境から,水上飛行機運営に最適な敷地であると考える。

3.3 元鹿児島海軍航空隊司令本部

敷地内には霞ヶ浦大山スロープ以外にも鹿児島海軍航空隊司令本部時代に訓練施設として使用されていた建築物が残っている。これらは現在廃墟化し使用されていない。

3.4 ソーラーパネルエリア

敷地中央に存在するソーラーパネルエリアは美浦村が所有し,美浦村の電力を賄っている。(一部は個人の所有物である)

4. 基本計画

計画敷地の特性より霞ヶ浦大山スロープを戦時中の利用と同様に水上飛行機の発着場として有効利用しながら保存する。鹿児島海軍航空隊司令本部時代に訓練施設として利用されていた廃墟群に耐震補強を施し,内部を商業施設としてリノベーションする。ソーラーパネルエリアは美浦村にとって欠かせない施設なので日射等を考慮し,周辺を計画していく。また,マリーナ機能を設け土浦港の利用者が船を使用し立ち寄れるようにする。更に,本稿のメインテーマである水上飛行機のためのターミナルエリアと水上飛行機訓練施設を設ける。更に,霞ヶ浦の自然の豊かさを味わえる場としてグランピングエリアと農業学校も計画する。

5. 建築計画

5.1 水上飛行機ターミナル

水上飛行機ターミナルでは,ターミナル・整備所・格納庫・商業施設・レストランを計画する。水上飛行機に乗り霞ヶ浦側から施設を訪れる利用者と,陸側からアクセスしここから水上飛行機に搭乗する利用者の両方に対して開けた建築物とする。ソーラーパネルを大規模に設置している関係上 BIPV で建物を計画し,消費電力は生産する。また,整備所を敢えて見せる事によって関心を高めさせる施設配置とする。(図2 水上飛行機ターミナル内観イメージパース)

5.2 水上飛行機訓練学校

水上飛行機に乗る・見るだけでなく運転ができる様になるための訓練施設を計画する。世界各国において水上飛行機が利用されている理由の一つに国内での利用人口割合が多いことにも一因がある。そのためここに訓練施設を設けることにより,日本全国の水上飛行機ネットワークに寄与できる人材を育成する。

5.3 グランピングエリア

茨城県は観光地名度が低いかわりにとても自然が豊かな土地である。今までの観光では整備された場所に人々が集まってる傾向があったが近年の観光レジャーでは自然豊かな場所での BBQ やキャンプ,グランピングに注目が集まっている。そこで霞ヶ浦の自然を体験できるエリアとして複数箇所に分散させてグランピングエリアを計画する。湖上に軟着底式のフローティングを設け,湖上での特別な生活体験を味わえる場を創生する。(図3 湖上グランピング内観イメージパース)また,別のエリアでは緑と霞ヶ浦の水辺を体験できる場を設ける。いくつかのエリアに分散させ異なる空間を作り出す事によりリピーターを増やす狙いもある。

5.4 農業学校

茨城県は農業において毎年 4,000〜5,000 億円程の産出額を出している。北海道に次いで日本全国 2 位の農業大県である。そこで昨今の日本における農業離れを解決するため敷地内に農業学校を計画する。農業に適した土地を利用し,農業大県としてのノウハウをここで学ばせる。ここでの学習者が日本全国に散らばり農業を継承していくことによって少しでも現状の問題解決に繋がればと考える。

5.4 マリーナエリア

土浦港では個人所有しているクルザーの停泊施設があるので,そういった霞ヶ浦にて船舶を所有している人々を対象としたマリーナエリアを設ける。ここでは水上飛行機ターミナルのように水域からの利用者と陸からの利用者に対してひらけた計画とする。また,船舶を陸揚げしておく船舶停泊所と車の駐車場を広く設けることにより敷地内全体のパーキング機能を補う。



図１　対象敷地広域地図

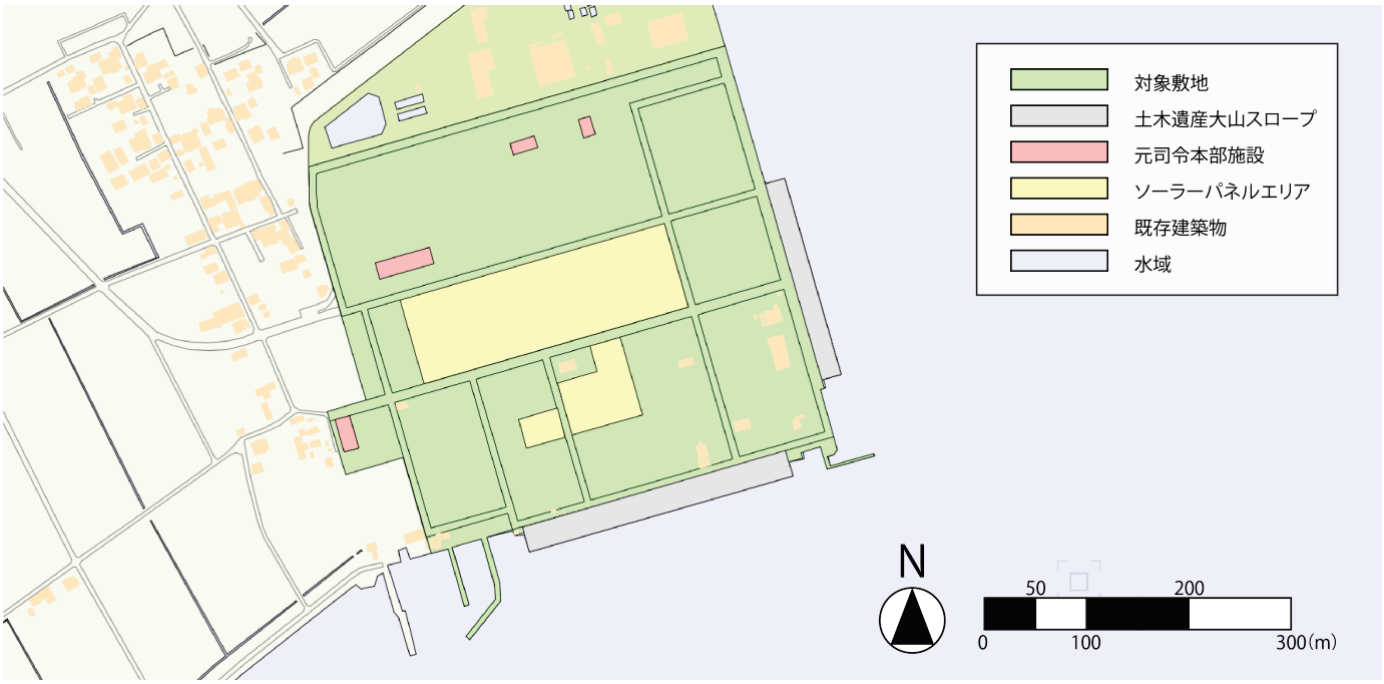

図２　対象敷地



図３　水上飛行機ターミナル内観イメージパース



図４　湖上グランピングエリア内観イメージパース

P5-1

低窒素施用水田土壌での脱窒細菌接種によるイネ生育促進効果：イネ栽培調査と根域土壌細菌叢解析

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滝本　貴弘[3], 増冨　祐司[1], 藤原　徹[4], 妹尾　啓史[4,5], 西澤　智康[1]
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キーワード：窒素循環, 食糧生産, 生育促進, イネ, 土壌細菌群集

抄録

農耕地への窒素肥料の大量投入は河川や湖沼の富栄養化を引き起こしており, 水系の窒素汚染を防ぐために施肥量の低減が求められる. 水田土壌から分離された脱窒細菌 *Azoarcus* 属 KH32C 株をイネ種子に接種すると, 室内実験系において窒素欠乏条件下でイネ初期生育を促進させた. 本研究では, KH32C 株を接種したイネを窒素無施肥水田圃場で栽培し, イネの生育およびイネ根域土壌細菌群集への影響を調査した. 土壌窒素・炭素量の異なる 2 つの無施肥水田で品種の異なるイネを栽培したところ, KH32C 株の接種により低窒素・炭素量の水田土壌で日本晴の初期生育が促進された. さらに, 日本晴の玄米中の亜鉛含有量が増加した. 一方, イネ根域土壌細菌のメタゲノミクス解析から, KH32C 株の接種は日本晴根域土壌の細菌群集構造に影響を与えたことが示された. 窒素肥料低投入の圃場において, KH32C 株の微生物資材としての利用が期待される.

1. はじめに

窒素は, 絶えず形態を変化させながら地球上を循環している. 土壌中の微生物は, 窒素固定, 硝化, 脱窒, 異化的硝酸還元などの反応を通し, 窒素循環の一部を担っている[1]. 農耕地では, 作物の生産性の向上のために窒素肥料が大量に投入されているが, 一部は作物に吸収されず流出し, 河川や湖沼の富栄養化を引き起こす. 過剰な窒素肥料の使用による環境への負荷を憂慮し, 窒素肥料の施用量の削減が求められるが, 作物の生産性の低下が問題となる.

熊本県の田畑輪換水田土壌から, N_2O を強力に還元する脱窒細菌 *Azoarcus* 属 KH32C 株が分離された[2]. KH32C 株の全ゲノム解読の解析から, 脱窒に関わる遺伝子群のほかに, 窒素固定や莢膜多糖合成に関わる遺伝子クラスターが見出され, 植物と相互作用する可能性が示された[3]. 先行研究において, KH32C 株をイネ（日本晴）種子に接種し, 窒素欠乏寒天プレート上で栽培したところ, イネの初期生育が促進された.

本研究では, 窒素無施肥水田圃場で KH32C 株を接種したイネを栽培し、イネ生育調査およびその根域土壌細菌群集に及ぼす影響を調査した.

2. 方法

2015 年および 2017 年に, 茨城大学農学部附属国際フィールド農学センター内に設置した 2 つの無施肥水田圃場でイネ栽培を実施した.

発芽したイネ種子（日本晴, タカナリ, IR64, コシヒカリ（2017 年のみ））を KH32C 株懸濁液に 10 分間浸漬し, 接種とした. KH32C 株接種（接種区）と未接種（対照区）のイネ種子は, 育苗後, 無施肥水田圃場に移植した. 生育初期, 幼穂形成期, 収穫期にイネおよびイネ根域土壌を採取した. 2017 年には, 加えて穂揃い期にイネ根域土壌を採取した.

採取した生育初期, 幼穂形成期のイネは乾燥重量を測定し, 生育速度を算出した. 収穫期に採取したイネの玄米は, 窒素・炭素量の分析およびエネルギー分散型蛍光 X 線分析装置を用いた無機元素の半定量的な分析を行った.

イネ根域土壌は, 全窒素（TN）量および全炭素（TC）量を測定した. また, 土壌 DNA を抽出し, 細菌の 16S rRNA 遺伝子を標的とした末端制限断片長多型解析（T-RFLP）を行った. 得られた T-RFs プロファイルに基づき, クラスター解析を行った. 2015 年の日本晴のサンプルでは Miseq のメタアンプリコンシーケンス解析も併せて行った. 得られた配列は, 97%の相同性で操作的分類単位（OTU）に分類し, 細菌群集の多様性解析および帰属分類群の推定を行った. また, 非計量多次元尺度構成法（NMDS）および Heatmap による細菌群の動態解析を行った. 各 OTU の代表配列は植物生育促進

細菌(PGPB)データベース[4]と比較してその相対存在量を推定した.

3. 結果

イネ根域土壌の TN 量は, 2015 年は 4.54-5.63 g/kg だったのに対し, 2017 年では 5.25-5.67 g/kg で, 2015 年が 2017 年より低かった. TC 量についても同様の傾向がみられ, 2015 年は 51.44-62.38 g/kg, 2017 年は 65.35-68.17 g/kg だった.

イネの生育速度は, 日本晴は 2015 年の生育初期と幼穂形成期でそれぞれ接種区が対照区の 1.9 倍, 1.7 倍に増加し, 2017 年では 1.3 倍, 1.0 倍であった(図 1). コシヒカリでは 2017 年の生育初期と幼穂形成期で接種区は対照区のそれぞれ 0.5 倍, 0.7 倍であった. タカナリは 2015 年の生育初期, IR64 では 2017 年の幼穂形成期において, 接種区で対照区より生育スピードが減少した. 玄米中の元素の大半で KH32C 株の接種による有意な差はみられなかった. 一部の元素は KH32C 株の接種により有意に増減したが, 2015 年と 2017 年で共通して有意に増減する元素はなかった. KH32C 株の接種によって, 玄米中の亜鉛含有量は, 2015 年では日本晴とタカナリで有意に増加(共に 30%)し, 2017 年では日本晴で 10%程度増加した. また, 日本晴の銅含有量は 2015 年および 2017 年で約 10%増加した.

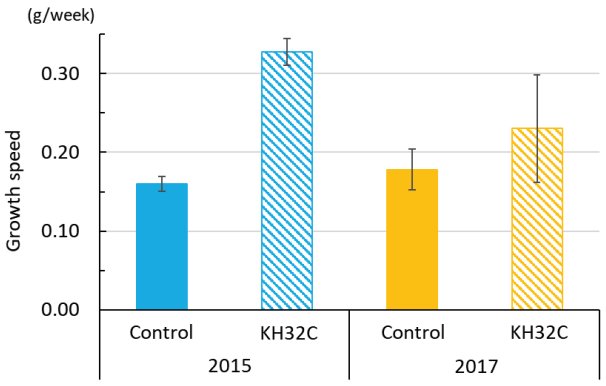

図 1. 生育初期の日本晴の生育速度

T-RFs プロファイルに基づくイネ根域土壌細菌群集のクラスター解析の結果, 2015 年の生育初期において接種区の細菌群集構造が品種間で類似した. 2017 年では, 日本晴の根域土壌細菌群集は生育期間を通して接種区で類似する傾向にあった(図 2)が, 他の品種でその傾向はみられなかった. メタアンプリコンシーケンス解析の結果, 2015 年の日本晴根域の土壌細菌群集の多様性はイネの生育段階により推移(表 1)し, 門レベルの群集構造は Proteobacteria 門と Acidobacteria 門が優占した. NMDS 解析の結果, 細菌群集構造は生育段階で類似するが, 同じ生育段階でも KH32C 株の接種の有無で異なった(図 3). Heatmap 解析の結果, *Alphaproteobacteria* 綱の細菌群集動態は接種区と対照区で異なり, 接種区では科レベルにおいて相対存在量が漸減した. 推定された PGPB の相対存在量は接種区で増加し, 特に生育初期で顕著で, インドール-3-酢酸生産細菌は 35%増加した. 推定された PGPB は *Alphaproteobacteria* 綱が優占した.

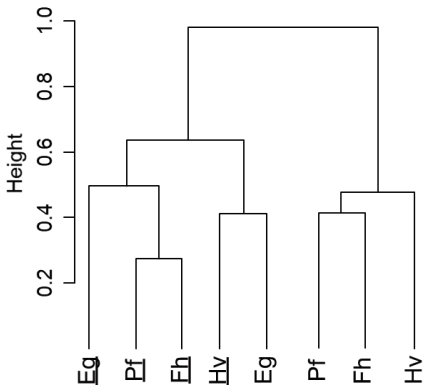

図 2. T-RFs プロファイルに基づく日本晴根域の土壌細菌群集のクラスター解析. 下線は KH32C 株接種区を示す. Eg, 生育初期; Pf, 幼穂形成期; Fh, 穂揃い期; Hv, 収穫期.

表 1. メタアンプリコンシーケンスに基づく日本晴根域土壌細菌群集の多様性解析.

	Control			KH32C-inoculation		
	Eg	Pf	Hv	Eg	Pf	Hv
Shannon index	7.48	7.32	7.67	7.42	7.36	7.62
ACE	11752	8354	13407	11503	7879	13020
Evenness	0.92	0.91	0.93	0.91	0.92	0.93

Eg, 生育初期; Pf, 幼穂形成期; Hv, 収穫期.

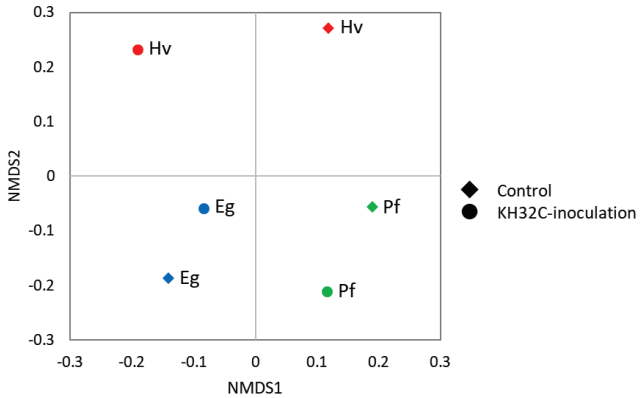

図 3. メタアンプリコンシーケンスに基づく日本晴根域土壌細菌群集の NMDS 解析. Eg, 生育初期; Pf, 幼穂形成期; Hv, 収穫期.

4. 考察

KH32C 株をイネ種子に接種し窒素無施肥水田圃場で栽培したところ，日本晴で生育促進効果がみられ，KH32C 株の接種によるイネ生育促進効果はイネの品種に特異的であることが示された．イネの窒素吸収量や窒素利用効率（収量/窒素吸収量）は，イネの品種（遺伝子型）によって異なることが知られている[5,6]．また，窒素施肥量の増加に伴いイネの窒素利用効率は減少することが報告されている[6]．土壌 TN・TC 量の低い条件において，KH32C 株の日本晴種子への接種による生育促進効果がみられた（図 1）．

大気 CO_2 濃度の上昇により，コメの亜鉛，鉄含有量が低下することが近年報告された[7]．現在，世界の 31%もの人が亜鉛欠乏症だと推定されており，亜鉛欠乏症は世界的に深刻な問題となっている[8]．玄米中の亜鉛含有量は適正量の窒素施肥により増加すると報告されている[9]．本研究結果から，KH32C 株は玄米（日本晴）の亜鉛含有量を増強させる微生物資材として利用できる可能性が示された．これまでに，遺伝子組換え技術の利用により白米の亜鉛含有量が増加したという報告もある[10]が，日本において遺伝子組換え作物の栽培は課題となっている．

土壌微生物群集は植物の生育段階や品種[11]，施肥[12,13]などにより影響を受けることが報告されている．土壌細菌群集プロファイルに基づく多変量解析から，KH32C 株のイネ種子への接種は，イネ根域土壌細菌群集構造に影響を与えることが示され（図 2，3），KH32C 株の接種が直接的もしくは間接的に根域土壌細菌群集に影響を及ぼすことが示唆された．一方，根域および根圏の微生物群が植物に影響を与えることもよく知られている．根域および根圏には，植物の生育を促進させる植物生育促進根圏細菌群（PGPR）が存在するが，植物自身が PGPR を制御しているとの報告もある[14]． KH32C 株の接種により PGPB の相対存在量が増加したと推定されたことから，KH32C 株の接種は根域土壌細菌群集にも影響を及ぼすことが示唆された．

5. 結論

本研究において，イネ種子への KH32C 株の接種がイネの初期生育およびイネ根域土壌細菌群集構造に影響を及ぼすことが示された．イネの初期生育促進はイネの品種により効果が異なり，特に日本晴では低窒素・低炭素の貧栄養な土壌において初期生育促進効果が示されたことから，KH32C 株は窒素肥料低投入の圃場において微生物資材としての利用が期待される．

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P5-2

The Analysis Between the Sedimentation Characteristics of Shallow Lake and Human Activities in the Middle Reaches of Yangtze River

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Keywords: ^{210}Pb dating, sedimentation rate, human activity, Honghu Lake

ABSTRACT

Lake sediments could record the sedimentary environment and invert environmental changes, especially in shallow lake. Environmental ^{210}Pb dating techniques were applied to determine recent sedimentation rates in a shallow lake named Honghu in the middle reaches area of Yangtze River, China. The results showed the recent sedimentation rate was 0.407~0.467g/(cm^2.a) by the ^{210}Pb intensity and CRS model. Base on the ^{210}Pb intensity and CRS model, time-depth correlation was established. It showed that four periods with sedimentation rate during more than one hundred years. (1) A lower average sedimentation rate was about Natural deposits before 1900 year. And (2) The rate was slowly increasing from 1900 to the 1949 with the increasing population slightly. (3) During the times from 1949 to the 1980, the sedimentation rate was about increasing rapidly with the people's cofferdam activities. Because the improved medical technology leads to an increase in local population after new China established whose need more foods. The higher average sedimentation rate indicated that the impact of human activities increased significantly. (4)After the1980, the variations of sedimentation rate change gently, which were in connection with natural changes, as well as the intensity of human activities on the catchment whose awareness of environmental protection have increased.

1. INTRODUCTION

Lake sediment could record the environmental change and learn the impact from human activities [1]. The paper evaluated the sediment rate using the radionuclide tracing technology and analyzed the relationship between the sediment characteristics and natural environmental changes and human activities.

2. METHOD

The sediment cores were collected from Honghu Lake in 2012 July, which is a Shallow Lake in the middle reaches of Yangtze River. Apply (1) High purity germanium gamma spectrometer to detect the radionuclide ^{210}Pb intensity[2]; (2) ^{210}Pb dating techniques to calculate the sediment rates through the CRS model.

3. RESULTS

The results of the research (experiment) will follow the method.

3.1 The distribution of ^{210}Pb activity with the depth change

The ^{210}Pb activity was rising with fluctuation from the bottom to up.

3.2 The changes of grain size in every sediment layer

The sediment composition of the lake is mainly fine silt occupied from 35.5% to 49.5% in two cores.

3.3 the sediment rate

The sedimentation rate of the sediment was 0.407~0.467g/(cm^2.a) by the ^{210}Pb intensity and CRS model, and others get the similar studying result in the middle and lower reaches in Yangtze River[3].

4. DISCUSSION

The lake sediment are affected by natural factors and

human activities in studying area. There are four stages according to the sediments characteristic.

(1) A lower average sedimentation rate was about Natural deposits before 1900 year.

(2) The rate was slowly increasing from 1900 to the 1949 with the increasing population slightly.

(3) During the times from 1949 to the 1980, the sedimentation rate was about increasing rapidly with the people's cofferdam activities.

(4)After the1980, the variations of sedimentation rate change gently.

5. CONCLUSION

With the development of society, intensity of human activities play a more important role in lake sediment deposit and lake environmental changes.

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P5-3

水稲栽培技術の環境影響評価(LCA):無代かき栽培と疎植栽培

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キーワード: 広域的大気環境の影響, 水田, 温室効果ガス, 富栄養化, ライフサイクルアセスメント

抄録

近年, 水稲作では水質保全や生態系保全などの多面的機能に配慮した技術が導入されてきている。本研究では, 秋田県八郎潟干拓地において, 慣行技術・無代かき栽培・疎植栽培技術について, LCA手法を用いた環境影響評価を行い, 地球温暖化・富栄養化の環境インパクトを評価した。無代かき栽培は田植前の代かきを省く代わりに細かく砕土する技術であり, 田植前の入水タイミングが遅いため, 湛水時のメタン発生量が減少する。疎植は栽植密度を減らす技術で, 苗作りに関するエネルギー等が軽減される。無代かき技術の導入により, 温室効果ガス排出量は慣行栽培の 69%に減少し, 富栄養化インパクトも環境改善を示す負の値に減少した。疎植栽培の温室効果ガス排出量は慣行栽培の 93%に減少した。環境への影響を減らすためには, これらの栽培方法を適切に導入していく必要がある。

1. はじめに

近年, 水田では省力化, 低コスト化といった経営面に加え, 水質保全や生態系保全といった多面的機能に配慮した技術の導入が勧められてきた。

水田は湛水下で土壌が還元状態となり, 温室効果ガス(GHG)であるメタンガスが発生する。だが, 新しい技術を導入した際の地球温暖化や富栄養化へ与える影響を, ライフサイクル過程を追って検討した事例は非常に少なく, 十分な評価がなされていない。

本研究では, 水田への普及が勧められている技術の導入が環境に与える総合的な影響を明らかにし, 慣行技術と新技術とを比較するため, LCA(ライフサイクルアセスメント)手法を用いた環境影響評価を行った。

2. 方法

2.1 調査地と栽培技術

2011～2013 年に, 秋田農試大潟農場(秋田県大潟村)の水田で水稲(あきたこまち)の栽培試験を行った。移植から7月上旬の中干しまで継続的に湛水し, その後は間断灌漑とした。肥料は鶏ふんペレットと被覆尿素を施用した(計 6kgN/10a)。メタンガスは田植から落水までの約3か月間, クローズドチャンバー法で測定した。

評価対象とした技術は, 無代かき栽培と疎植栽培である。無代かき栽培は, 代かきをせず, ロータリーで耕起した後にドライブハローで2～3回砕土する。代かき時の濁水排出がないため水質保全効果が高いほか, 水稲の根活性が高まり, 高温登熟下での品質低下が生じにくい。また, 移植前の灌水を移植直前まで遅らせると, 土壌の還元化がやや抑制されるため, メタン発生量の減少が期待される[1]。疎植は, 栽培密度を慣行より減らす栽培技術の総称で, 今回は 21 株/m^2 から 15 株/m^2 へ3割減らして行った。苗箱数が慣行より少ないため, 育苗や苗運搬の労力, 土や農薬, 苗箱などの資材費が軽減される省力低コスト技術である。慣行より登熟速度がやや遅くなるため, 高温障害を受けにくいという点からも普及が勧められている。

なお, どちらの技術も導入による収量の増減はみられず, 品質も慣行に劣らなかった。

2.2 使用ソフト

解析には, LCA ソフトウェア SimaPro ver.8.4.0 を使った。評価手法には, 地球温暖化には IPCC GWP 100a を, 富栄養化にはLIMEを用いた。解析に用いたインベントリデータの主なものを表1に示す。

表 1 インベントリデータ

収量	*10a あたり収量*
燃料	*消費量*
農業機械	*価格*, 実耐用年数, 負担率
ハウス	*面積*, 実耐用年数, 負担率
肥料	商品名, 単価, 使用量, 成分含有率
農薬	商品名, 単価, 使用量, 種類
種苗	*単価*, 使用量
資材	*商品名*, *単価*, 使用量, 種類
ガス	メタン
溶脱	窒素負荷量

斜字:秋田県水稲経営指標データ
その他:現地での実測および聞き取り調査結果等

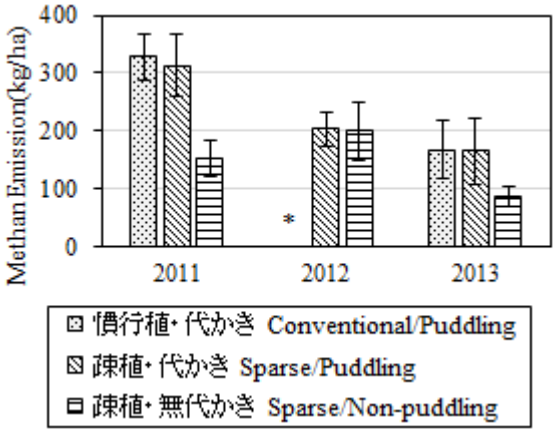
影響評価は，田面からの排出・燃料消費・機械製造・肥料製造（化学肥料・有機肥料）・農薬製造・資材等製造の 7 過程に区分して行った。

3. 結果

3.1 メタンガス発生量

田面からの発生量は年によって差が見られた。2011 年と2013 年は，無代かき区の発生量が代かき区の約半分と少なかったが，2012 年は差が小さかった（**図1**）。3 年間の総量でみると，無代かき区の発生量は代かき区の 64%であり，メタン発生が抑制されていた。

慣行植区と疎植区では発生量の差は小さく，疎植区は慣行植区の 93%であった。



* :欠測 missing
エラーバーerror bars：標準偏差 the standard deviation
耕起日 The plowing dates:
2011/5/18-26, 2012/4/19-20, 2013/5/9-10

図1 メタン発生量 Methane emissions[2]

3.2 温室効果ガス（GHG）排出量

代かき区・無代かき区での排出過程別温室効果ガス排出量を図 2(a)に示す。排出量は，二酸化炭素，メタン，一酸化二窒素の排出量を，二酸化炭素に換算して示す。

過程別にみると，田面からの排出量の割合が最も高く，代かき区では排出量全体の 86%，無代かき区では80%を占めた。田面からの排出の大部分が前節で説明したメタンであった。次に多いのが化学肥料製造過程からの排出で代かき区 4.1%，無代かき区 5.9%であった。

無代かき区のGHG 排出量は代かき区の 69%と少なくなり，無代かき栽培の導入による温室効果ガス排出量の抑制効果がみられた。疎植区の温室効果ガス排出量は慣行植区の 93%であった。

3.3 富栄養化インパクト

代かき区，無代かき区の富栄養化インパクト（特性値EPMC）を過程ごとに求めた結果を図2(b)に示した。代かき区では田面からの排出過程の寄与が大きいが，無代かき区ではその過程の値がマイナス値となっており，負の影響，つまりこの場合は周囲の水環境を浄化していることを示している。他の過程はプラス値で富栄養化を促進しているが，その値は田面からの排出による影響と比べるとわずかである。

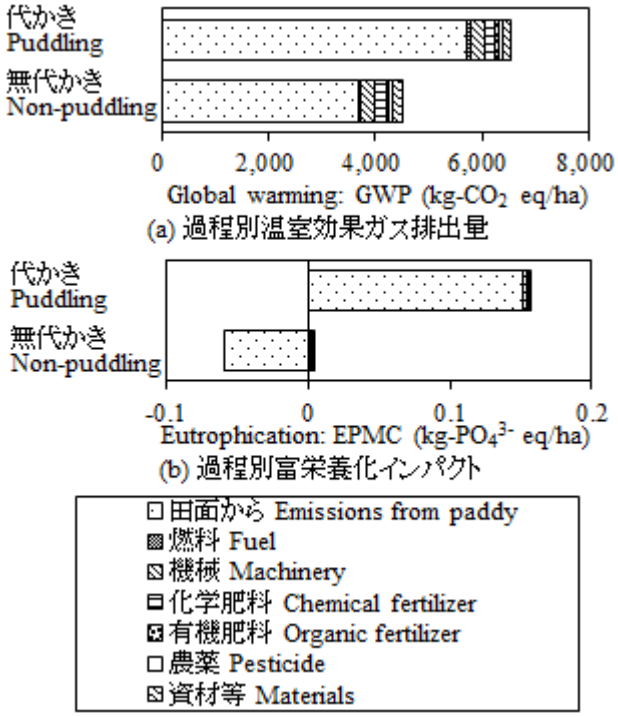


図2 代かき区・無代かき区の排出過程別の温室効果ガス排出量と富栄養化インパクト（疎植時）

4. 考察

水稲への新たな栽培技術導入による環境影響評価（地球温暖化と富栄養化）を行った。温室効果ガス排出量は，無代かき区は代かき区の 69%，疎植区は慣行植区の 93%にとどまり，地球温暖化抑制効果がみられた。富栄養化インパクトは，無代かき区では負の値を示し，水質環境の改善に貢献していることが示された。水稲作が環境へ与える影響を小さくするには，これらの栽培の導入を適切に行うことが必要である。

なお，本研究は農林水産省「農林水産業・食品産業科学技術研究推進事業」において実施したものである。

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P5-4

An *N*-alkane $\delta^{13}C$ for Assessing Sources of Terrestrial Organic Matter in Lacustrine Sediments in China

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Keywords: lake sediment, organic matter, *n*-alkane and $\delta^{13}C$

ABSTRACT

To assess sources of terrestrial organic matter in lacustrine sediments in China, three sediment cores were collected from an area of several square meters in a small catchment. Results show 126 years of sediment deposition, from year 1885 to 2011. The accumulation rates ranged from 2.69 to 8.46 mm a^{-1}. All sediment samples were dominated by odd numbered *n*-alkanes (*n*-C_{16}～*n*-C_{33}), especially *n*-C_{17}, *n*-C_{29} and *n*-C_{31} as the most abundant homologues. Aliphatic hydrocarbon fractions are mainly composed of terrestrial higher plant-derived long-chain *n*-C_{29} and *n*-C_{31} alkanes. The most abundant compounds have been described as typical constituents of trees and shrubs (C_3 plants). The indicators indicate enhanced eutrophication resulted from increased anthropogenic activities in the Taihu watershed.

1. INTRODUCTION

The sedimentary organic matter (OM) is a heterogeneous and a complex mixture of organic compounds with different chemical characteristics, originating from autochthonous primary production and allochthonous terrestrial materials (Wang et al., 2015 and references therein). However, autochthonous and allochthonous contributions in the complex environments of the watershed with excursions to larger carbon stable isotopes ($\delta^{13}C$) values make it difficult to determine accurately the OM sources by *n*-alkanes distribution. The principal aims of this study were: to identify sedimentary OM sources and assess quantitatively the C_3 plants contribution to sedimentary OM.

2. METHOD

In present study, three sediment cores were collected from an area of several square meters in a small catchment. The core was sectioned at 1 cm intervals. The sub-samples were crushed to a fine powder (particle size ≤ 0.15 mm). The activities of ^{226}Ra and ^{210}Pb were determined using a high-resolution HPGe γ-spectrometry system with 62% relative detection efficiency (GWL-120-15, USA). A constant CRS model was applied to date the sediment core. The alkane compositions were analyzed by gas chromatograph (GC, HP 6890 II, Agilent, USA) with a split/splitless injector and a flame ionization detector (FID).

3. RESULTS

The $^{210}Pb_{ex}$ activities in the sub-samples ranged from 16 to 102 Bq kg^{-1}. A constant CRS model gave 126 years of sediment deposition, from year 1885 to 2011. The accumulation rates ranged from 2.69 to 8.46 mm a^{-1}.

All sediment samples were dominated by odd numbered *n*-alkanes (*n*-C_{16}～*n*-C_{33}), especially *n*-C_{17}, *n*-C_{29} and *n*-C_{31} as the most abundant homologues. In this study, aliphatic hydrocarbon fractions are mainly composed of terrestrial higher plant-derived long-chain *n*-C_{29} and *n*-C_{31} alkanes. The values of bulk $\delta^{13}C$ for organic matter ($\delta^{13}C_{SOC}$) (by IRMS, USA) varied from -24‰ to -21‰. The values of carbon isotopic compositions of long-chain *n*-alkanes ($\delta^{13}C_{27}$, $\delta^{13}C_{29}$ and $\delta^{13}C_{31}$) exhibited a range of -33‰ to -25‰, -35‰ to -28‰ and -31‰ to -26‰, respectively.

4. DISCUSSION

The *n*-alkanes distribution observed in this study agrees with earlier observations in the Shuanglong catchment of the Dianchi watershed (Wang et al., 2015). The terrestrial higher plants may be the main sedimentary OM origin. The most abundant compounds have been described as typical constituents of trees and shrubs (C_3 plants).

5. CONCLUSION

1) The contribution of terrestrial C_3 plants ranged from 41% to 95%.
2) The sedimentary OM was mainly derived from terrestrial higher plants with C_3 metabolism.
3) Increased human activities enhanced the OM inputs and deposition in the watershed, resulting in much worse ecosystem in the past decades.

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P5-5

題名：基盤整備後ハス田地帯からの流出量調査について

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キーワード：ハス田, 農業, 流出負荷量, 基盤整備

抄録

全国第 2 位の湖面積を有する霞ヶ浦の流域はレンコン栽培が非常に盛んな地域である。茨城県のレンコン出荷量は全国 1 位であり，全国のレンコン収穫量・出荷量の半分近くを占めている。茨城県土浦市手野地区はレンコン専作地帯で, 1995 年から 2015 年にかけて日本で初めてハス田での基盤整備を実施し, コンクリート畦畔整備や用排分離等を行った。本研究では基盤整備された手野地区において流出負荷量調査を行い, 基盤整備による流出負荷量の影響を調査した。その結果, 過去の手野地区における研究に比べ, 差引排出負荷量が大きい値を示した。これらは用排分離を行った結果, 田越灌漑の沈殿効果の消失した影響であることが考えられた。しかし，土浦市内の他の地区における差引排出負荷量と比較した場合, 本研究の値はそれらと大きな差はないことから, 一般的なハス田群からの流出する負荷量と同程度であることが示唆された。

1. はじめに

霞ヶ浦は茨城県, 栃木県及び千葉県の一部を流域とする日本第 2 位の湖沼面積を有する湖沼である。しかし, 湖沼面積が広く, 水深が浅いなどの特徴や湖水の交換日数に約 200 日かかることから, 元来水質汚濁が生じやすい湖沼でもある

茨城県のレンコン作付面積は 1,610ha であり, その収穫量・出荷量は全国の半分近くを占めている[1]。レンコンの収穫方法は水掘りと手掘りがあり, 茨城県では水掘りにて収穫している。この水掘りは地下水をくみ上げ, ポンプの水圧で泥を飛ばしレンコンを収穫するため, 作業効率は良いが濁水が生じやすい[2]。

手野地区は, 茨城県土浦市東北部の霞ヶ浦湖岸に位置するレンコン専作地帯である。手野地区のハス田は, もともと区画が小型不整形で道路は狭く屈曲し, 用排水施設も未整備であった。このため, 1995 年から 2015 年にかけて日本で初めてハス田での基盤整備を実施し, コンクリート畦畔整備や用排分離等を行った。これまでに, 手野地区では基盤整備完了前に流出負荷量調査が行われていたが, 基盤整備完了後に調査は行われていない[3,4]。

そこで, 本研究では基盤整備された手野地区において流出負荷量調査を行い, 基盤整備による流出負荷量の影響を調査したので報告する。

2. 方法

2. 1. 調査地の概要

調査地は茨城県土浦市手野地区のハス田群 148ha を対象にした（図 1）。地区内に数戸の住宅が見られるが, 土地利用のほとんどはハス田である。

手野地区の排水は石田揚排水樋門へ集まり, 霞ヶ浦に自然排水している。ただし, 大雨等の場合のみ石田排水機場からポンプを用いて強制排水を行っている。用水は石田揚排水樋門へ流れてくる排水を手野第一用水機場にて地区東側に揚水しており, 地区西側を流れる境川の水を手野第二用水機場にて地区西側に揚水している。手野第一用水機場については石田揚排水樋門から自然排水しているため, 用水ポンプを稼働すると霞ヶ浦から一部流入が認められる。また, 一部ハス田は境川上流から分岐する用水路から取水している（図 1）。

2. 2. 調査方法

手野地区において，2016 年 9 月から 1 年間調査を実施した。採水は末端の用排水機場では自動採水器を用いて 24 時間間隔，用水機場と用水路では毎週手動採水を行った。排水量は堤脚水路に設置した

自記水位計と電磁流速計の結果から算出した。取水量はポンプ稼働時間と流入水量から算出した。ハス田の調査はハス田に設置した自動採水器を用いて朝夕採水した。排水量は直角三角せきを用いて算出した。水質分析はJIS法（K 0102）に準拠して行った。

3. 結果と考察

手野地区はもともと田越灌漑でレンコン栽培を行っていたが，基盤整備に伴い畦畔のコンクリート化と用排分離を行った。

本研究で手野地区における流入水と排水を調査した結果，過去の手野地区における研究に比べ，差引排出負荷量が大きい値を示した [3,4]。ハス田で田越灌漑を行うと，下流のハス田を通過する最中に負荷量が削減することが知られている [5]。このことから，基盤整備により田越灌漑の負荷量削減作用が消失した結果，過去の研究に比べ差引排出負荷量が大きくなったことが示唆された。しかし，土浦市内の他の地区における差引排出負荷量と比較した場合，本研究の値はそれらと大きな差はないことから，一般的なハス田群からの流出する負荷量と同程度であることが示唆された [4]。

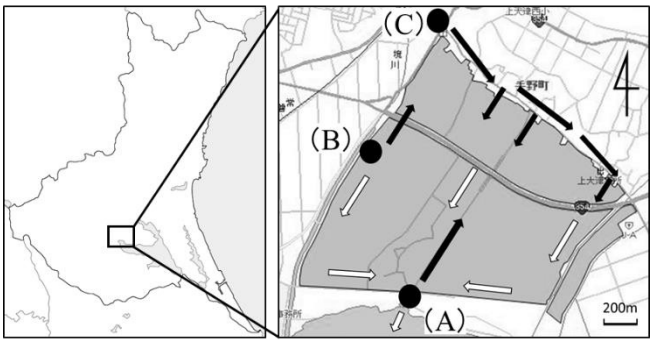

図 1　調査地点地図

手野地区は地区南側の（A）石田揚排水樋門から霞ヶ浦に排水している。また，地区北側の境川から分岐する（C）用水路と，西側の（B）境川にある手野第二用水機場から取水している。（A）手野第一用水機場では排水を揚水している。

➡ :用水方向，　⇨ :排水方向

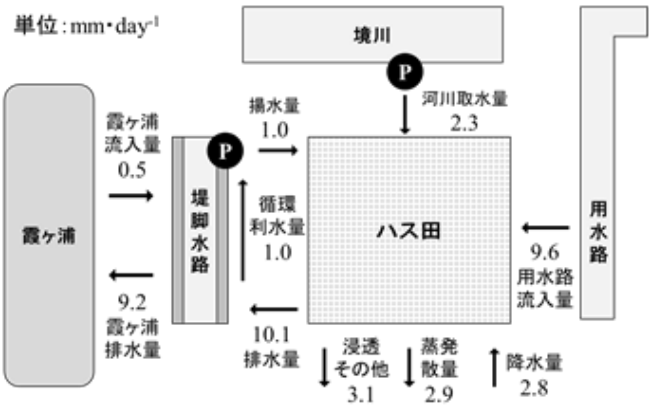

図 2　手野地区日平均水収支フローダイヤグラム

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P5-6

Recent changes in the vertical distribution of Nitrogen and Phosphorous in a brackish lake Ogawarako of northeastern Japan.

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Keywords: Brackish lake, Nutrient Dynamics, Eutrophication, Long-term monitoring, Nitrogen, Phosphorous

ABSTRACT

Lake Ogawarako is a brackish lake located in a rural area of the east part of Aomori Prefecture, the northernmost part of the main island of Japan. There, eutrophication, which leads to the dominance of cyanobacteria, has become a big problem as is the case with other brackish lakes. To cope with this problem, we surveyed recent changes in the total amounts of total nitrogen (TN) and total phosphorous (TP) in the whole lake water (hereafter refer to ΣTN and ΣTP, respectively) and its vertical distribution from Oct. 2010 to Aug. 2017. ΣTN and ΣTP were 1092±179 t and 109±29 t, respectively. About 22-63% of ΣTN and 38-79% of ΣTP were distributed in the high-salinity layer of 15-21m, which composed only 13% of the lake water volume. TN and TP amounts in this layer largely varied temporally, suggesting that they were contributing significantly to the TN and TP amounts in the low-salinity layer. ΣTN decreased from 2015, and at the same time, halocline also deepened from ca. 15 m to 17 m. Therefore, it is considered that TN in the high-salinity layer were advected and diffused into the low-salinity layer, and outflowed from the lake. ΣTP tended to increase during the survey period. However, after typhoon events in Aug-Sep 2016, it dropped sharply, probably due to the flush out of massive amounts of water from the watershed and possibly due to adsorption of phosphate onto Andisol transported from the watershed.

1. INTRODUCTION

Lake Ogawarako is a brackish lake with the fifth largest surface area in Japan, where catches are among the highest for inland fishery in Japan. Recently, it has become increasingly eutrophic, and water quality degraded as is seen by the blooming of cyanobacteria and production of unusual odor. To cope with these problems, it is necessary to unveil the dynamics of nitrogen and phosphorous in the lake water. Therefore, we investigated the vertical distribution of total nitrogen (TN) and total phosphorous (TP) in the lake water from Oct. 2010 to Aug. 2017, and discussed the influential factors including typhoon.

2. STUDY AREA

Lake Ogawarako is a brackish lake located in the northeastern part of the main island of Japan. The area is a temperate rainy climate (Cfa), with annual average temperature of 12.4˚C (max 25.1˚C; min -0.5˚C) and annual precipitation of 861 mm. It is a rural area and the main landuse of the watershed is forest and arable land. Surface area and max and average depths of the lake are 62 km^2, 26m (deepest among brackish lakes in Japan), and 11 m, respectively. Residence time of the lake water is about 1 year. Most of river water flows into the lake from the southwest and flow out to the north. Sea water sometimes runs back from Pacific Ocean, especially in summer and winter. In recent years, high-salinity water with no oxygen is stagnated, forming halocline at around 16-18m.



Fig. 1 Map of Lake Ogawarako[2]

3. METHODS

Vertical water samples were collected using a Van Dorn water sampler every 2 m at the center of the lake every month from Apr. 2015 to Aug. 2017. Analysis of total nitrogen (TN) and total phosphorus (TP) was conducted by continuous flow analysis with an auto-analyzer (SWAAT, BL-TEC). TN and TP data from Oct. 2010 to Mar. 2015 was cited from long term monitoring data collected by Ministry of Land, Infrastructure, Transport, and Tourism, and is publicly available in Water Information System (http://www1.river.go.jp/). The volume of the lake water was calculated based on a digital bathymetric map of Geospatial Information Authority of Japan (http://www.gsi.go.jp/kankyochiri/lakedatalist.html) by using SAGA GIS (ver. 2.3.2). TN and TP amounts were calculated by multiplying TN or TP concentrations and water volume of each depth section.

4. RESULTS

4.1. Total nitrogen

Total amount of TN in the whole lake water body (ΣTN) ranged from 642 t to 1554 t, with an average of 1092 t from Oct. 2010 to Aug. 2017. It increased during Jan. to Apr., showing by 9% higher values than other months (Fig. 2). ΣTN increased from 800-1100 t in 2011 to 1100-1500 t in 2014, then turned to decrease and was 800-1000 t in 2017. When looking at vertical distribution, 43% on ave (min 22%, max 63%; Fig.3) of ΣTN was distributed in 15-21 m depth section. When looking at intra-annual variation, the TN amount remarkably increased in the <10m section from Jan. to Apr. For interannual variation, TN amount tended to decrease at < 10 m from 2015, and the TN amount in 15-21 m section decreased sharply from Aug. 2016, after unusual disturbance by typhoons.

4.2. Total phosphorous

Total amount of TP in whole lake water body (ΣTP) ranged from 61 t to 192 t with an average of 109 t from Oct 2010 to Aug. 2017 (Fig. 2). While no appreciable seasonal trend was observed, it increased from 60-130 t in 2011 to 100-190 t in 2014, and kept the value until Aug. 2016. The ΣTP showed a sharp decrease to 70-120 t from Sep. 2016, after extensive disturbance caused by a series of typhoons.

A large amount of TP was distributed between 15-21 m section, which composed of ave 66% (min 38%, max 79%) of ΣTP (Fig.3). The amount remarkably increased from Jan. to Apr. as was the case with TN. TP in 15-21m section sharply decreased while TP <10 m increased in Feb. and Aug. 2016.

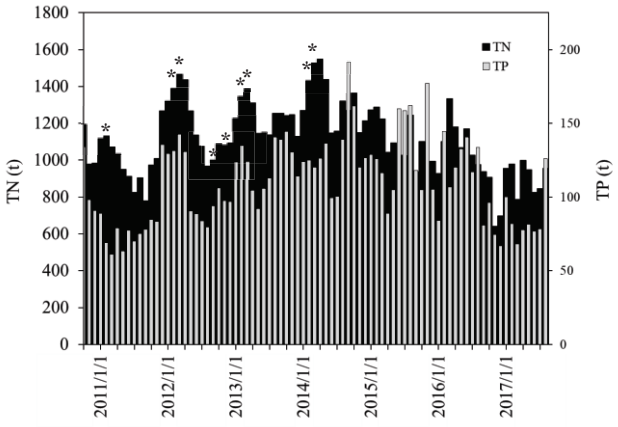

Fig. 2 Total amount of TN and TP in the whole water body of Lake Ogawarako from Oct. 2010 to Aug. 2017. Bars with * were obtained mathematically by spline interpolation.

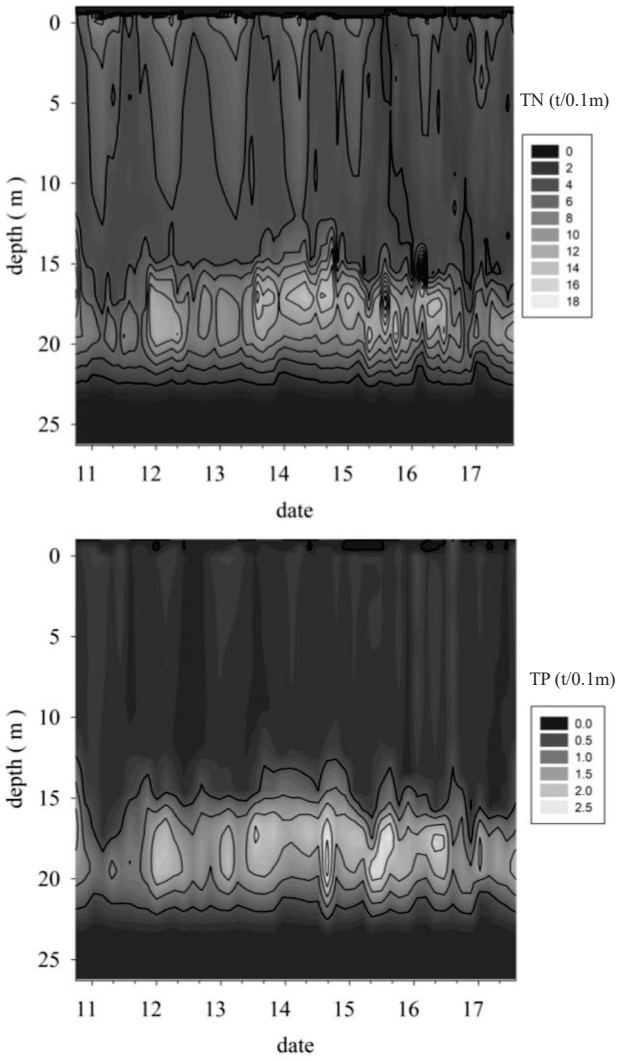

Fig. 3 Vertical distribution of the amount of TN and TP in Lake Ogawarako from Oct. 2010 to Aug. 2017.

5. DISCUSSION

Lake Ogawarako has halocline at around 15-18 m all through the year. Since the mixing of lake water beyond halocline is restricted, and in addition, TP and TN are loaded from the bottom sediment under anoxic condition, TN and TP concentrations in high-salinity water were ave 10 and 37 times higher than surface water, respectively. Reflecting these, 22%-63% of ΣTN and 38%-79% of ΣTP were distributed in 15-21 m section, where only 13% of total water volume existed. Interestingly, the total amount of TN and TP in 15-21 m zones changed significantly over time. Therefore, TN and TP in this section is considered to be the important source of those in the upper section.

We found that TN and TP concentrations below halocline zone changed dramatically when sea water inflowed from Pacific Ocean. Since the density of back-flow sea water was much heavier than that of lake high-salinity water, it went under the lake water, lifting it up. This probably caused advection diffusion of high salinity water and followed diffusion into the low-salinity layer with vertical mixing. This phenomenon was usually observed from Oct. to Apr. unless the surface got frozen.

The ΣTN tended to be larger by 9% from Jan.-Apr. than other months. This is probably because the relative contribution of internal loading became larger during this period with the decrease in the river water inflow, leading to the prolonged retention time of the lake water. ΣTN (1092 t) and ΣTP (192 t) corresponded to 1.0 and 4.5 times of their annual loading from the watershed[1] (TN: 1059 t, TP: 24 t), respectively. This suggested that the amount of N in the lake was more prone to be influenced by inflowing water.

ΣTN turned to decrease after 2015, which change was in accordance with when the depth of halocline layer dropped from ca. 15m to 17m. As such, changes in the volume of high-salinity layer, which accumulates a large amount of TN, probably causes changes in ΣTN in the lake. ΣTP turned to decrease after Sep 2016, and one month before that, TP amount from low-salinity water section increased sharply. As such, the changes can be attributed to three typhoons landed/passed by in series. Especially, typhoon No. 10 (aka. Lionrock) landed Tohoku district on Aug. 30, 2016 for the first time after 1951 mixed the lake water severely, made P in the high-salinity layer move up to low-salinity layer. Followed with that, a portion of TP in low-salinity layer was flushed out from the lake with massive amount of inflowing water from watershed. It is notable that the decrease was only observed for TP. This could be due to the difference in the degree of contribution of internal loading and could also due to the adsorption of phosphate onto Andisol, which was transported from the watershed into the lake as suspended solid.

6. CONCLUSION

We investigated the actual status of N and P in the water body of Lake Ogawara, a brackish lake in temperate region, and their recent changes. Further, we discussed the possible influential factors. Total amounts of N and P in the whole water body of the lake is estimated to be 1092±179 t and 109±29 t, respectively. On average, 43% of TN and 66% of TP were distributed in 15-21 m section, where only 13% of total water volume existed. The amount of N and P in this section significantly changed intra-annually and inter-annually, and serving as the important nutrient source of the upper section. Total amount of N tended to decrease since 2015 in association with the deepening of halocline. Thus, changes in the vertical circulation is considered to influence largely on the water quality in the surface water. Total amount of P tended to increase since 2011, but it decreased sharply after typhoon events in Aug-Sep. 2016. This result suggested that P dynamics in the lake water is influenced strongly by extreme weather events. Concluding this research, water quality in Lake Ogawarako was shown to be strongly affected by hydrology characteristics of the lake. Further long-term monitoring and experimental verification are necessary to reveal the mechanisms of the changes in nutrient cycling caused by global warming, which changes lake/watershed hydrology and increases the number and extent of extreme weather events.

ACKNOWLEDGEMENTS

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P5-7

Evaluation of Available Water Resources and Nitrogen Runoff in Northeast Thailand

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Keywords: TOPMODEL, Water balance, Nitrogen dynamics, Spatial distribution

ABSTRACT

In Northeast Thailand, the ratio of irrigated agricultural land is only 8% and others are rain-fed so that climate change makes agricultural production more unstable and also makes crucial damage to the societies and economics in local area. To mitigate these issues, it is desirable to develop and disseminate enhanced adaptation systems. In this study, water and nitrogen-load estimation model was developed and applied to Northeast Thailand. Both calculated river discharge and nitrogen load were good agreement with observed data. By using the proposed model, spatial distribution of available water and annual nitrogen load were estimated, and histograms of nitrogen load from each land use was evaluated.

1. INTRODUCTION

Meteorological Uncertainty caused by Global Climate Change would have significant impact on agricultural sector, because agricultural systems are strongly related with local climate condition. Especially in Northeast Thailand(Fig.1), the ratio of irrigated agricultural land is only 8% and others are rain-fed so that climate change makes agricultural production more unstable and also makes crucial damage to the societies and economics in local area. To mitigate these issues, it is desirable to develop and disseminate enhanced adaptation systems. In this study, water and nitrogen-load estimation model was developed to assess the spatial distribution of available water resources and nitrogen runoff, and applied to Northeast Thailand.

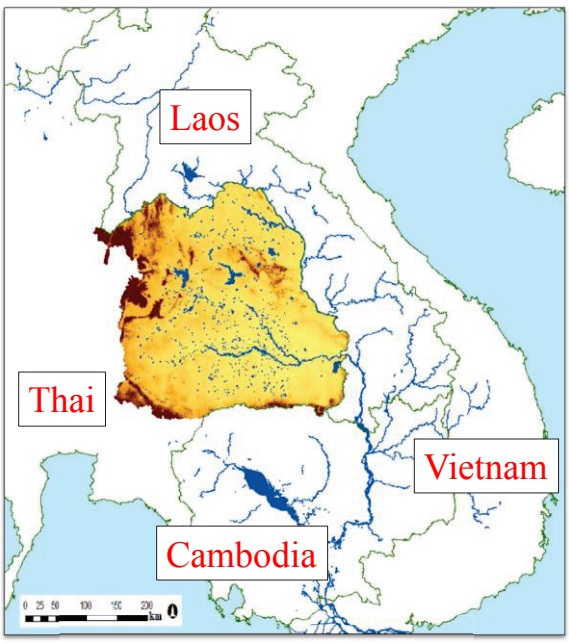

Fig. 1 Study Area

2. METHOD

2.1 TOPMODEL

To evaluate nitrogen transportation according to the river water flow, a distributed water-cycling model was developed and applied to analyze the water balance in the basin [6]. TOPMODEL was employed for the rainfall-runoff analysis. This distributed model can include the spatial distributions of topography, land use, and soil characteristics. Therefore, TOPMODEL is used widely for hydrological characteristic analysis, water management, water quality analysis, and future forecasting. Firstly, TOPMODEL was proposed by Beven and Kirkby (1979) based on the contributing area concept in hillslope hydrology.

Because TOPMODEL requires only three parameters (i.e., m, To, and Srz_{max}), the model is easy to link with GIS data[1]. In addition, a dam operation model was combined with TOPMODEL to calculate water storage in the reservoirs [3].

2.2 Nitrogen balance model

For a nitrogen dynamics analysis in soil, Suga (2005) mentioned that three type of nitrogen such as organic, ammonium, nitrate should be considered. In this study, a conceptual nitrogen balance model was developed by considering three pools in soil, organic N, ammonium N, and nitrate N, as shown in Fig. 2. In this study, organic N here is assumed as nitrogen contained in relatively firstly decomposed organic matter which can be obtained by autoclave-extractable nitrogen test. The soil N, present mainly in organic form, is almost unavailable for plants. The vegetation uses mostly inorganic forms of N, which are made available by decomposition of organic matter. Soil microorganisms convert the N contained in the

organic matter through the process of mineralization. Nitrates dissolve quickly in pore solution, which is taken up by plants. On the other hand, this means that nitrate is easily leached to groundwater. Ammonium N is less mobile because it is strongly adsorbed on clay minerals because of its positive charge.

3. RESULTS AND DISCUSSION

By using the proposed model, water and nitrogen balances in Northeast Thailand were calculated at a resolution of 1 km × 1 km. The calculated river discharge was in good agreement with the amounts observed at Yasothon station from 1987 to 2003 (Fig. 3). The first 5 years of data were used for parameter calibration, and the latter 12 years of data were used for validation. At the Yasothon station, Nash-Sutcliff efficiency (NSE) were 081 in the calibration and validation periods. Model performance can be evaluated as "good", if NSE > 0.75 [4].

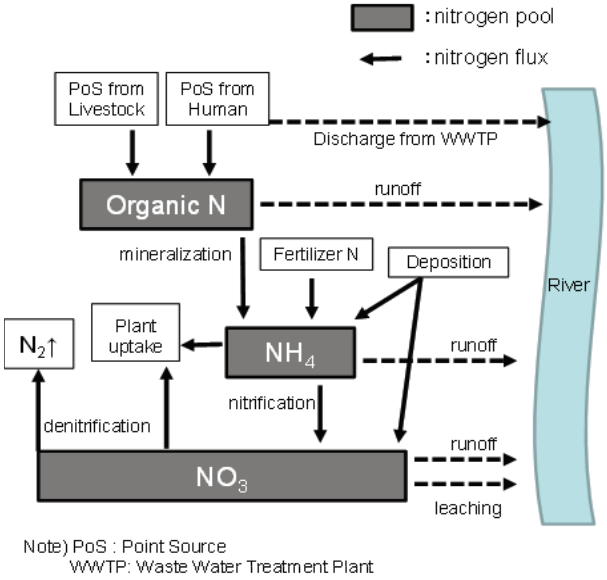

Fig. 2 Nitrogen Balance Model

The observed and calculated daily nitrogen load at the Yasothon station is shown in Fig. 4. Estimated correlation coefficients R were 0.69. The data of total nitrogen concentration in the Mun-Chi River Basin were measured only once per month; therefore, there is a possibility that peak nitrogen load might not be observed in such data. The current monitoring system of water quality data is manual, so if the frequency of monitoring were to be improved by using an automatic monitoring system, the model parameters also could be calibrated through better fitting.

To make clear the characteristics of nitrogen load from different land use, the histograms of nitrogen load from each land use were evaluated (shown in Fig. 5). In urban grid cell, nitrogen load ranged very widely compare to other land use, however average nitrogen load was 15.6 kg/ha/year, and it was larger than other land use. On the other hand, nitrogen load in forest was relatively small (0.84 kg/ha/year).

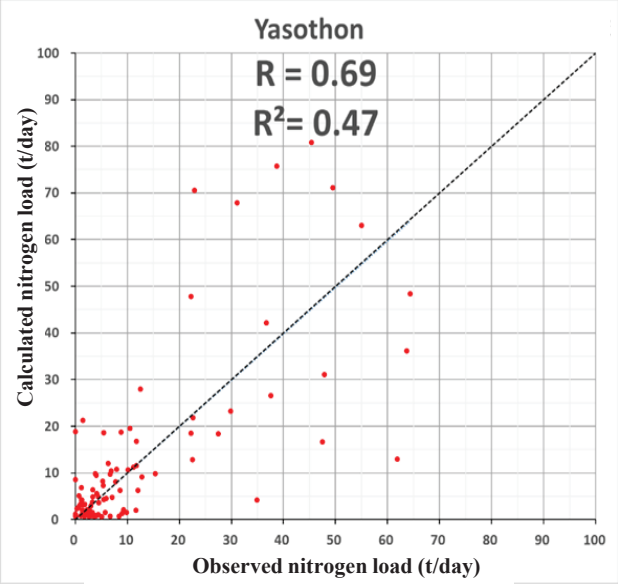

Fig. 4 Obs and Cal nitrogen load at Yasothon station

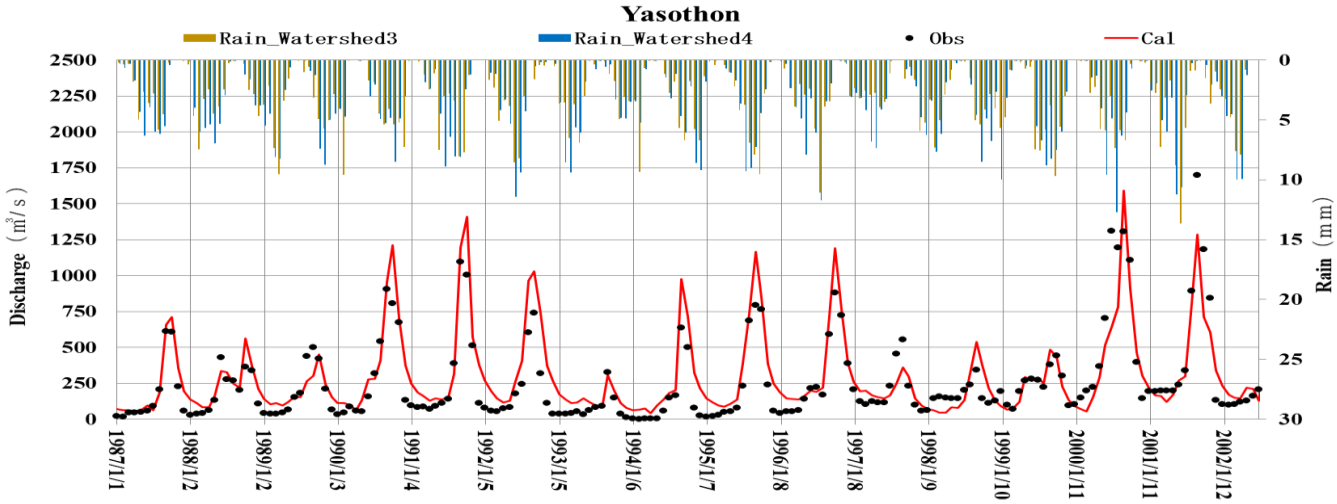

Fig. 3 Observed and calculated river discharge at Yasothon station

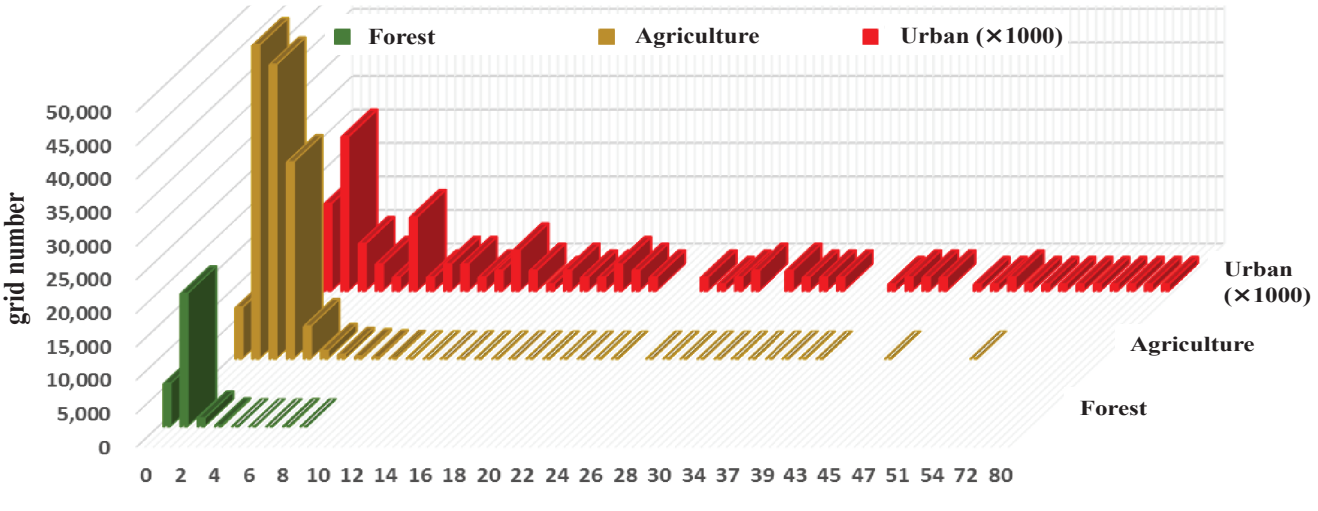

Fig. 5 Histograms of estimated nitrogen load from each grid cell

4. CONCLUSION

In this study, conceptual nitrogen balance model combined with TOPMODEL was developed and applied to Northeast Thailand as the quantitative evaluation tool of the spatial distribution of nitrogen loading from different land use. Nash-Sutcliffe efficiency of river discharge at observed station were more than 0.75 which model performance can be evaluated as "good". The correlation coefficients of estimated average annual nitrogen-load at Yasothon station were 0.69. By using the proposed model, spatial distribution of annual nitrogen load was estimated and histograms of nitrogen load from each land use was evaluated. As a result, nitrogen load from large cities was large.

To improve the model accuracy, further research is needed both in field observation and model development. In Northeast Thailand, long-term observed water quality data is not available after 2004, however even in short-term observation, basin wide monitoring data in tributary level may be helpful for more accurate parameter calibration. In this study, we employed many assumptions to simplify the nitrogen balance model. For example, we neglected N uptake in forest, assuming that most of forest are mature with no net accumulation of biomass. This would be changed for well-managed, semi-natural or disturbed natural forest where uptake of N occurs. Because of sparsity of data, we ignored the spatial and temporal heterogeneity in fertilizer management within the basin (e.g. difference of N application rate and timing of application). These problems may cause errors in the calculation of N transformation processes. Despite all the uncertainties, our results provide a first insight in the magnitude and spatial distribution of nitrogen loading in Northeast Thailand, and this kind of model can be used in the impact assessment of different management strategies for sanitation systems or farming practices.

In the future, climate change will accelerate the water cycle and severe droughts often occur in Northeast Thailand. Especially in dry season, nutrient concentration in large cities will increase due to the shortage of available water resource which dilute the nutrient concentration in drainage canal. And water environment in city will be degraded. Therefore, suitable sanitation system should be introduced to the city which have relatively large population density.

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P5-8

印旛沼流域における出水時の栄養塩類濃度と藻類増殖ポテンシャルの関係

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キーワード:藻類増殖ポテンシャル・栄養塩・降雨時流出・印旛沼流域・点源及び面源汚染

抄録

閉鎖性水域での藻類増殖は水質汚濁の主要要因の 1 つで、この水質汚濁低減のためには、藻類増殖因子となる栄養塩類負荷量を低減する必要がある。出水時の栄養塩負荷量は明らかになりつつあるが、藻類増殖との関係は不明である。出水が藻類増殖に寄与するかどうかを明らかにするため、印旛沼流入河川において、土地利用の異なる 4 地点で出水時に数時間間隔で河川水を採水し、窒素、リン、金属濃度と藻類増殖ポテンシャル(Algal Growth Potential:AGP)を測定し、採水地点毎の栄養塩類と AGP 流出特性の把握、AGP と土地利用および金属濃度の関係について統計解析を行った。その結果、AGP 負荷量は、畑の割合が多い流域では出水時に増大し、市街地の割合が多い流域では、出水時に減少することがわかった。また、Mg^{2+}、溶存態ホウ素、Ca^{2+}は、藻類増殖と正の相関が確認された。

1. はじめに

閉鎖性水域での藻類増殖は水質汚濁の主要要因の 1 つで、この水質汚濁を効率的に低減するためには、負荷源別に藻類増殖因子となる栄養塩類負荷量を明らかにし、優先順位をつけた負荷削減対策が必要である。陸域からの全栄養塩負荷量に占める畑など面源負荷の割合は高く、出水時の汚濁負荷量も無視できないと考えられる [1)]。しかし、出水時の負荷量は、調査の困難さから定量的な把握は不十分で、出水が直ちに藻類増殖に寄与するかについても不明である。そこで、出水時の栄養塩類負荷量、出水の藻類増殖への寄与、藻類増殖と金属の関係評価を目的として、印旛沼流入河川において、土地利用の異なる4地点で出水時に数時間間隔で河川水を採水し、窒素、リン、金属濃度と藻類増殖ポテンシャル(Algal Growth Potential:AGP)を測定した。採水地点毎の栄養塩類と AGP の流出特性の把握、AGP と土地利用および金属濃度の関係について統計解析を行った。

2. 方法

印旛沼は千葉県北西部に位置し、北印旛沼(6.26km²)と西印旛沼(5.29km²)から構成され、富栄養化状態にある。調査河川は、土地利用が異なる採水地点を選択できる西印旛沼流入河川である高崎川とし、流出水に影響する土地利用や養豚の状況に着目し、特徴的な 4 地点を選定した。図-1 に高崎川流

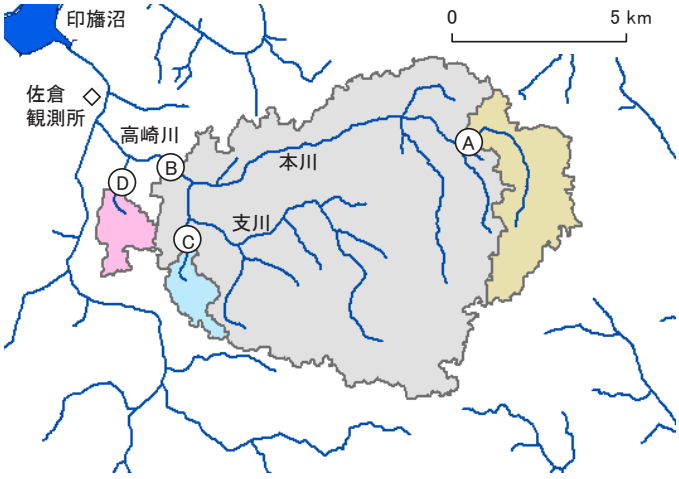


図-1 印旛沼の高崎川流域と採水地点

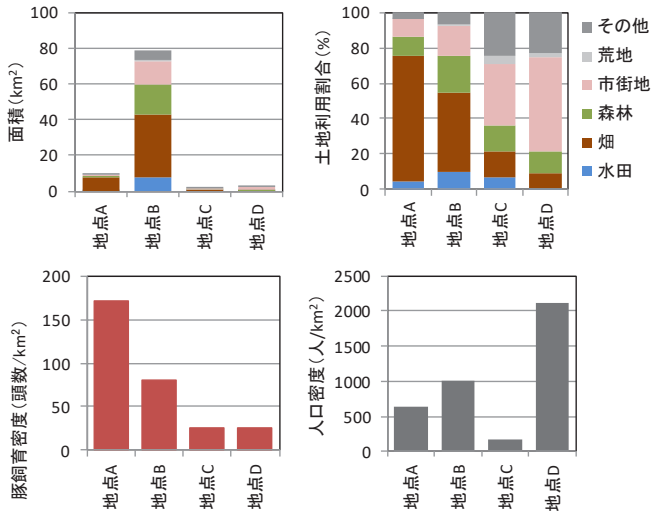
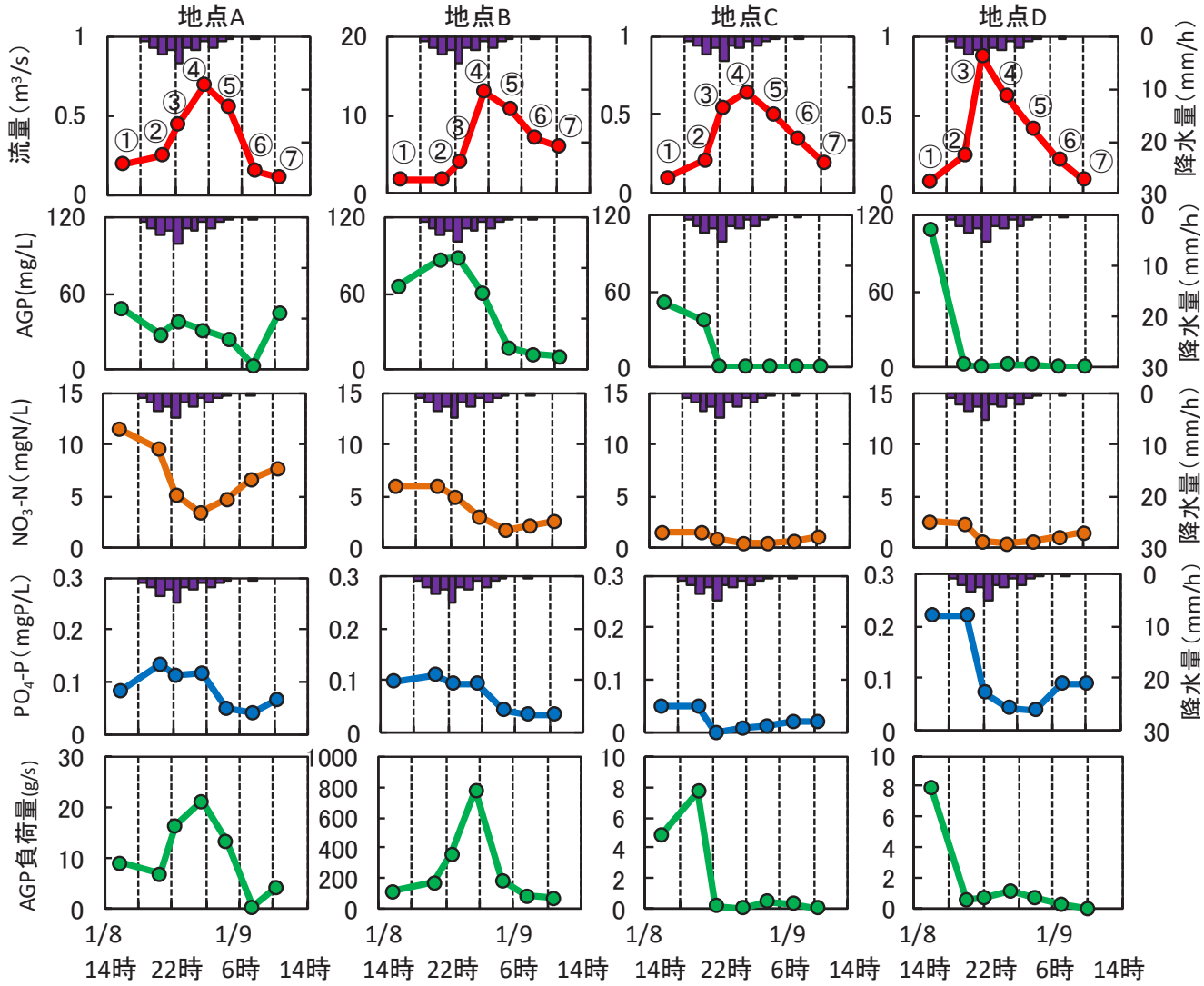


図-2 採水地点上流域の土地利用、豚飼育、人口密度



※ヒストグラムは時間降水量、流量の図中の①~⑦は 1/8~1/9 間の採水通し番号

図-3 出水時の降水量、河川流量、AGP、NO_3-N、PO_4-P 濃度および AGP 負荷量

域の採水地点を示した。図-2 には各採水地点より上流域の土地利用等の割合を示した。採水地点 A は、高崎川上流域で畑が 70%を占め、豚飼育密度が高い。地点 B は地点 A、C の下流で流域面積が大きく、畑と森林で 65%を占める。地点 C は市街地の割合が 35%であるが、工場用地の割合が高く人口密度は低い。地点 D は都市水路で市街地の割合が 53%を占め、人口密度が高い。地点 C、D の豚飼育密度は低い。

採水日は H26 年 1 月 8～9 日の降雨時で、佐倉観測所の雨量観測データでは、累積降雨量は 24.5mm、降雨のピークは 1 月 8 日 23 時頃であった。出水時の河川水は降雨開始時を含め 2～5 時間間隔で 7 回採水した。

河川水の水質分析項目は、SS、VSS、T-N、T-P、NH_4-N、NO_2-N、NO_3-N、PO_4-P、DOC、Na^+、K^+、Mg^{2+}、Ca^{2+}、Cl^-、SO_4^{2-}、Fe、Al、Mn、Zn、Cu、B、Mo、Ni、Co、

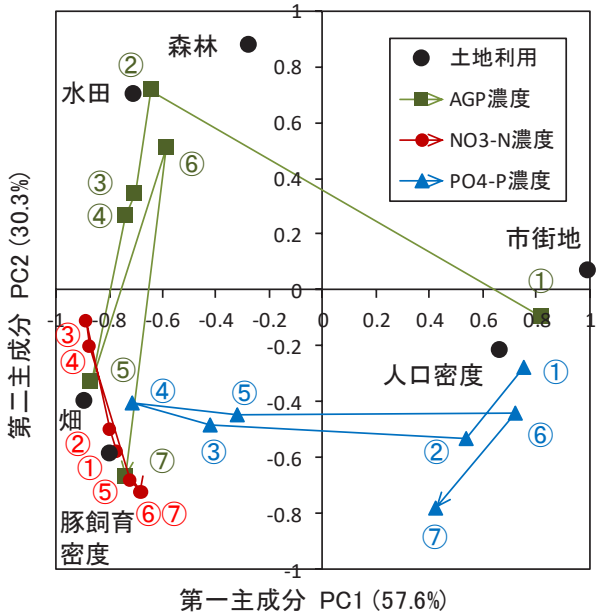
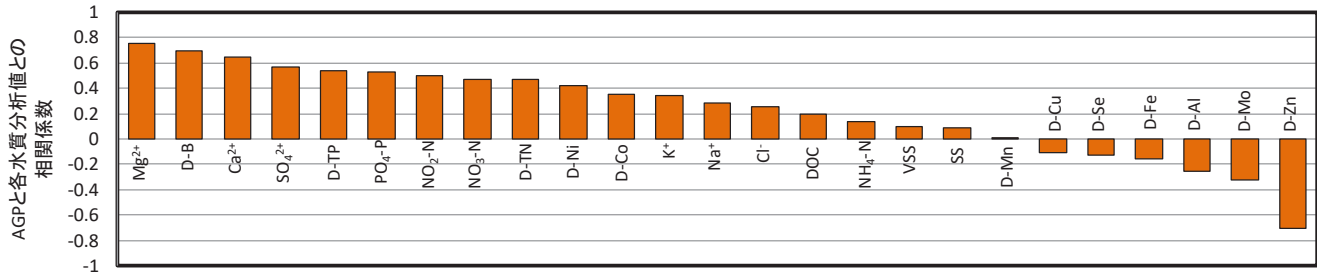


図-4 土地利用と AGP と主成分分析の結果



※図中の D-：溶存態の略

図-5　AGP と各水質項目との相関係数

Se であり、金属は藻類増殖の必須元素を中心に選定した。

AGP 試験[2]は次のとおり行った。4 カ所の地点で数時間間隔で採水した全ての試料を測定対象とし、孔径 0.45 μ m のメンブレンフィルターでろ過し、ろ過試料を 300ml 容三角フラスコに 100mL 取り、緑藻であるムレミカヅキモを植種して 16 日間培養し、藻類増殖量を乾燥重量（mg/L）として求めた。

3. 結果

3.1 出水時の AGP と栄養塩濃度の変化

図-3 に佐倉観測所での降水量、各採水地点の河川流量、AGP、NO_3-N、PO_4-P および AGP 負荷量（濃度×流量）を示した。AGP は、地点 A では出水期間中に大きく増加することはなかった。下流の地点 B では、流量ピーク前に増加し、流量ピーク以降に減少した。地点 C、D は、出水前に高く、出水時は低くなっていた。NO_3-N 濃度は、地点 A で出水前が最も高く、出水時は希釈された。他の地点でも同様の傾向を示した。PO_4-P 濃度は、地点 D で出水前が高く、出水時は低下する傾向となった。出水時の AGP の変化は土地利用によって異なることが確認された。AGP 負荷量は、A、B 地点では出水時に増大し、C、D 地点では出水時に減少していた。

3.2 主成分分析による土地利用と AGP の関係

土地利用と出水時の AGP の変化について全体像を把握するため、主成分分析を行った。図-4 に、第一、第二主成分について各土地利用項目の主成分負荷量プロットを示す。第一主成分（PC1）は、市街地、人口密度が＋方向に、森林、畑の割合がー方向に分布したことから、集水域の都市化に関連する成分、第二主成分は、森林、水田が＋方向に、畑の割合および豚飼育密度がー方向に分布したことから、畑の割合と豚飼育密度に関連する成分であると考えられる。次に、第一、第二主成分について、AGP、NO_3-N、PO_4-P の主成分負荷量を採水時間毎に算出し、図-4 に重ねてプロットした。AGP は、出水前は、市街地や人口密度に近い位置にプロットされ、出水時は森林や畑の方向にプロットが移動した。この解析からも AGP は、出水前は市街地、出水時は畑や森林の影響を受けることがわかった。

NO_3-N は、出水期間中、畑、豚飼育密度と近い位置にプロットされ、PO_4-P 出水前は市街地に、出水時は畑の近くにプロットされた。

3.3 藻類増殖因子の解析結果

図-5 は、全測定試料を用いて AGP と溶存態の各水質測定項目を単相関解析したときの相関係数である。窒素、リンが藻類増殖因子であることは知られているが、この他にも AGP と正の相関を示すものがあった。AGP と高い正の相関（r=0.6 以上）を示した項目は、Mg^{2+}、溶存態-B（ホウ素）、Ca^{2+}であり、こうした金属類も藻類増殖に寄与している可能性があった。

4. 結論

出水時の栄養塩類負荷量、出水の藻類増殖への寄与、藻類増殖と金属の関係評価を目的として、印旛沼流域において出水時の栄養塩類と AGP の流出特性の調査を行った。AGP と土地利用および金属濃度の関係については主成分分析、単相関解析から評価した。

本研究で得られた主な知見を以下に示す

(1) 出水時の AGP 負荷量解析の結果、AGP 負荷量は、畑の割合が多い流域では出水時に増大し、市街地の割合が多い流域では出水時に減少することがわかった。

(2) 主成分分析から AGP と土地利用の関係を解析した結果、AGP は、出水前は市街地、出水時は畑や森林の寄与を受けることがわった。

(3) AGP と各水質項目の単相関解析から、藻類増殖には、窒素、リンの他に Mg^{2+}、溶存態-B、Ca^{2+}が寄与している可能性があった。

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P5-9

Biochemical Potential of Freshwater, Brackish, and Sea Sediments for Removing Antimony from Water Environment

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Keywords: antimony, bacteria, Lake Biwa, brackish lake

ABSTRACT

Biochemical potential of sediment samples for removing antimony from water phase was evaluated. The sediment samples collected from Lake Biwa North and South Basins, Asoumi Sea (a brackish inland sea), and Wakasa Bay were suspended in 20 mL solution containing 100 mg-Sb/L as $K[Sb(OH)_6]$ under anaerobic condition at 28ºC for 3 weeks. The sediment samples of Lake Biwa showed biochemical potentials for removing Sb from water phase by formation of orange precipitation (Sb_2S_3) although the Sb removal was low (10-30%). The sediment samples of Asoumi Sea and Wakasa Bay showed high biochemical potentials of Sb removal (80-90%) by formation of white precipitation ($Sb_2(OH)_3$). Bacterial colonies with antimonate-reducing and Sb_2S_3-accumulating abilities were obtained from the sediment samples of Lake Biwa and Asoumi Sea. Bacteria with the biochemical potential for soluble Sb removal would be ubiquitously distributed in lakes and seas in Japan.

1. INTRODUCTION

Various natural, agricultural, and industrial processes can cause antimony contamination of surface waters. In Japan, the effluent standard for antimony has not been established yet in the Water Pollution Control Law, but antimony has been selected as a monitoring-required water quality parameter of Environmental Quality Standards for Water Pollution. Actually, there have been reported that the Sb concentration in river downstream of some factories exceeds the guideline value (>= 0.02 mg/L).

However, removal processes for antimony from water phase have not been fully established. An alternative for cost effective antimony removal might be biological treatment using antimonate-reducing bacteria. Figure 1 shows a hypothetical mechanism of the Sb removal from water phase. Bacterial reduction of antimonate into antimonite, resulting in formation of diantimony trioxide (Sb_2O_3) and stibnite (Sb_2S_3), is known to play an important role in detoxification of soluble antimony in the natural environment[1-3]. Sb_2O_3 ($Sb_2(OH)_3$) and Sb_2S_3 are easily removed from the aqueous phase because of its insoluble characteristics.

However, little is known about antimony-removing bacteria in water environment in Japan. In this study, the biochemical potential of lake and sea sediments for removing antimony was evaluated.

2. METHODS

2.1 Sediment samples

Characteristics of sediment samples used in this study are shown in Table 1. The sediment samples were collected from Lake Biwa North Basin near Chikubushima island, South Basin off the coast of Ogoto, Asoumi Sea which is a brackish inland sea, and Wakasa Bay in 2017.

2.2 The antimony removing test

A basal salt medium containing 100 mg-Sb/L $K[Sb(OH)_6]$, 2mM lactate as the sole carbon source, 20mM HEPES, 0.1 g/L KH_2PO_4, 0.1g/L K_2HPO_4, 0.48g/L NH_4Cl, 0.2g/L NaCl, 1.2mg/L H_3BO_3, 0.34mg/L $CoCl_2 \cdot 6H_2O$, 0.18mg/L $CuCl_2 \cdot 2H_2O$, 0.2mg/L $MnCl_2 \cdot 4H_2O$, 0.44mg/L $ZnCl_2$, 0.4g/L $CaCl_2$, and 0.48 g/L (HS-BSM) or 0.048 g/L $MgSO_4 \cdot 7H_2O$ (LS-BSM) was used for the antimony removing test (pH 7.2). For brackish and sea sediment, 26 g/L NaCl was added to the media (pH 7.6).

Portions of the sediment sample (4mg wet weight) were inoculated into 20 mL of HS-BSM or LS-BSM in 50-mL serum bottles. Headspace of the bottles were replaced with N_2 gas for creating anaerobic condition. The bottles were sealed with rubber stoppers and capped with aluminum crimp seals and incubated on a rotary shaker (100rpm) at 28°C. After 4weeks 1 mL of each culture was transferred to the fresh medium.

2.3 Analytical procedures

Water samples (1 mL) were periodically collected from the bottles and centrifuged (21,900×*g*, 10 min) for removing the cells and precipitates. The Sb concentration in the water samples was determined by inductively coupled plasma optical emission spectrometry (ICP-OES Agilent 700 Series, Agilent Technologies, Inc.).

Bacteria were enumerated by the poured plate method with the LS-BSM and the HS-BSM with 15 g/L agar. The

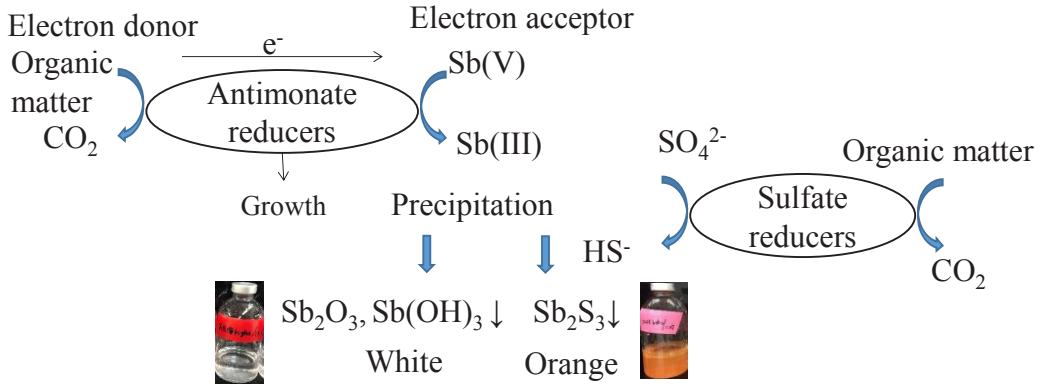

Fig.1 A hypothetical mechanism of biochemical removal of antimony from water phase.

Table 1. Sediment samples used in the antimony removing test

Sampling		Air /Water temp.	Depth	Note
place	date			
Lake Biwa North Basin (near Chikubu island, Shiga Pref.)	2017/10/1	19℃/8℃	70m	ORP -270mV, grey, silty
Lake Biwa South Basin (off the coast of Ogoto, Otsu, Shiga Pref.)	2017/10/1	19℃/24℃	4m	ORP -156mV, dark green, silty, sandy, rotten-egg smell
Asoumi Sea (Miyazu, Kyoto Pref.)	2017/9/19	20℃/22℃	10.5m	ORP -420mV, black, rotten-egg smell
Wakasa Bay (Matsubara beach, Fukui Pref.)	2017/9/7	25℃/25℃	0.5m	Sandy, aerobic

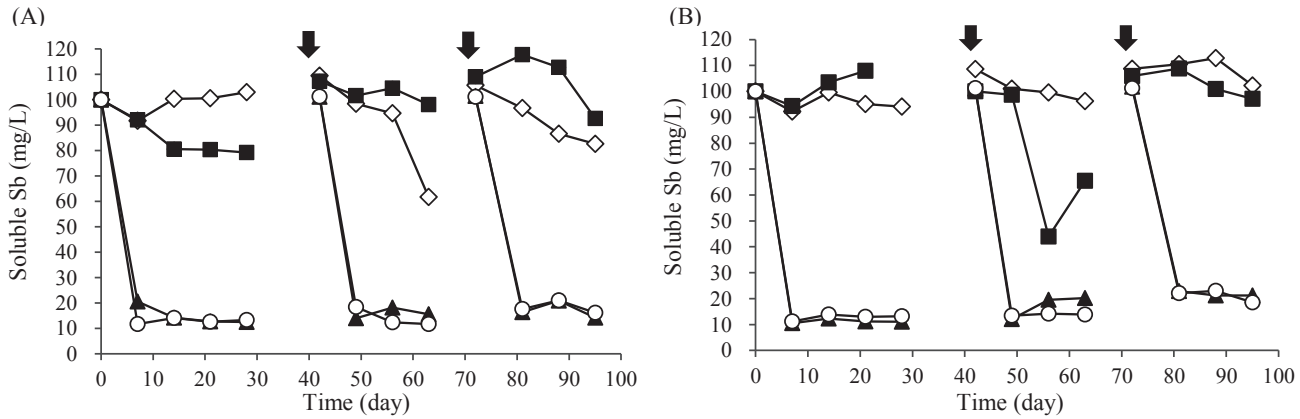

Fig.2 Time courses of soluble antimony concentrations in the microbial cultures derived from sediment samples. Cultures were enriched HS-BSM (A) and LS-BSM(B). Sediment samples were collected from Lake Biwa North Basin (open diamonds), South Basin (closed squares), Asoumi Sea (closed triangles), and Wakasa Bay (open circles). Arrows indicate the transfer of the culture into new medium.

plates were incubated in an anaerobic box (anaeropack kenki, Sugiyama-gen, Co. Ltd.) at 25ºC for 2weeks.

3. RESULTS AND DISCUSSION

3.1 Biochemical removal of Sb by sediment samples

Time courses of removal of soluble antimony by the sediment samples are shown in Fig. 2. The sediment sample of Lake Biwa South Basin removed 20% antimony from the HS-BSM within 1 week in the first test. Although the Sb removal was low, the sediment samples of Lake Biwa North Basin in the HS-BSM and of South Basin in the LS-BSM and the HS-BSM formed specific orange precipitation, indicating Sb_2S_3, as shown in Fig. 1. Although the Sb removal did not increased, similar results were obtained in the second and third tests.

Table 2. Summary of the biochemical potential of the sediment samples for antimony removal

Sediment sample Medium	Lake Biwa North Basin HS-BSM	Lake Biwa South Basin HS-BSM	Asoumi Sea HS-BSM	Asoumi Sea LS-BSM	Wakasa Bay HS-BSM
Precipitates' color	Orange	Orange	White	Orange	White
Sb removal	1st: 0% 2nd: 50% 3rd: 30%	1st: 20% 2nd: 10% 3rd: 30%	1st: 90% 2nd: 85% 3rd: 85%	1st: 90% 2nd: 80% 3rd: 80%	1st: 90% 2nd: 90% 3rd: 85%
Viable counts after the 3rd removal test	1.1×10^4 CFU/mL	1.1×10^3 CFU/mL	1.8×10^3 CFU/mL	3.7×10^3 CFU/mL	$<1.0\times10^1$ CFU/mL
Colonies on the agar plates	Yellowish orange colonies	Yellow colonies	White colonies	Yellow on whole agar	-

3.2 Bacteria in the cultures derived from sediment samples

The sediment samples of Asoumi Sea and Wakasa Bay showed high antimony removals of 80-90% from the LS-BSM and the HS-BSM in the tests. The sediment samples of Asoumi Sea formed orange precipitation in the LS-BSM. However, the other sea sediment samples showed white precipitation, indicating $Sb_2(OH)_3$, as shown in Fig. 1. The sediment sample of Wakasa Bay in the HS-BSM formed orange precipitate in the second test and white precipitation in the third test, suggesting co-existence of Sb_2S_3 forming bacteria and $Sb_2(OH)_3$ forming bacteria.

3.3 Bacteria related to Sb removal

Figures 3 shows colonies obtained from the bacterial cultures. Yellowish-orange colonies of 10^3-10^4 CFU/mL were formed on the HS-BSM from the bacterial cultures derived from the sediment samples of Lake Biwa. Yellowish-orange colonies and white colonies were respectively formed on the LS-BSM and the HS-BSM from the bacterial culture derived from the sediment sample of Asoumi Sea. Those bacterial colonies did not show yellowish-orange under aerobic condition or on the BSM excluding Sb under anaerobic condition. These results suggests that bacteria forming yellowish-orange colonies have antimonate-reducing and Sb_2S_3-accumulating abilities.

4. CONCLUSION

The biochemical potential of the sediment samples for antimony is summarized in Table 2. The freshwater sediments of Lake Biwa showed biochemical potentials for removing soluble antimony by formation of orange precipitation (Sb_2S_3). The brackish sediment sample of Asoumi Sea and the sea sediment sample of Wakasa Bay showed high biochemical potentials for removing soluble antimony by formation of white precipitation ($Sb_2(OH)_3$). Bacteria with the biochemical potential for the Sb removal would be widely distributed in lakes and seas in Japan.

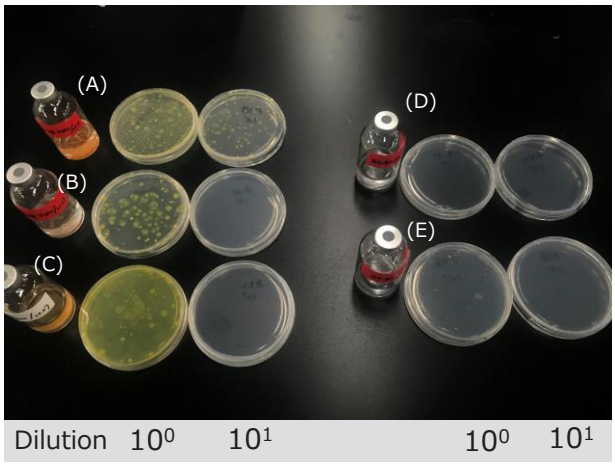

Fig.3 Colonies in the microbial cultures derived from sediment samples. Cultures were enriched from Lake Biwa North Basin in HS-BSM (A), Lake Biwa South Basin in HS-BSM (B), Asoumi Sea in LS-BSM (C), Asoumi Sea in HS-BSM (D), and Wakasa Bay in HS-BSM (E).

ACKNOWLEDGEMENT

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P5-10

平成 27 年 9 月関東・東北豪雨の影響を受けた土壌の無機元素組成および細菌群集構造解析

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キーワード:河川氾濫, 細菌群集構造, 重金属汚染, 常総市, 流域管理

抄録

平成 27 年 9 月関東・東北豪雨により, 常総市では鬼怒川で破堤・溢水が発生し, 大量の土砂水が周辺地域の土壌生態系に流れ込んだ。豪雨災害によって引き起こされる被害は, 住居や産業施設, 農業資産などに留まらず, 土壌生態系にも大きな影響をおよぼす。本研究では, 関東・東北豪雨による浸水の影響を受けた土壌生態系に関する環境情報を収集・提供すること目的として, 常総市における浸水地域土壌の化学性分析および土壌細菌群集構造の解析を行った。洪水堆積物の影響を受けた土壌の無機元素組成や希釈平板法による生細菌数の調査および土壌細菌群集構造の T-RFLP 解析を行った結果, 氾濫により砂が堆積することで生じる土壌の理化学性の変化と同時に, 土壌微生物性へも影響がおよんでいることが示唆された。土壌生態系に関わる総合的な情報を蓄積していくことで, 浸水被害を受けた農耕地の機能回復に資する付加情報となることが期待される。

1. はじめに

2015 年 9 月 7 日に発生した台風 18 号は, 関東地方関東北部から東北地方南部を中心に豪雨をもたらし, 9 月 7 日から 11 日までの総雨量は関東地方で 600mm, 東北地方で 500mm を超えた。このうち, 9 月 9 日から 11 日にかけて発生した豪雨は各地で河川氾濫を発生させ, 気象庁により「平成 27 年 9 月関東・東北豪雨」と命名された[1]。この豪雨により常総市では, 鬼怒川で破堤・溢水が発生し, 大量の土砂水が周辺地域の土壌生態系に流れ込んだ。これを受け, 茨城大学では常総市における大規模な水害に際し, 支援協働研究を行う「茨城大学平成 27 年関東・東北豪雨調査団」を結成し, これまでに調査を行ってきた。

豪雨災害によって引き起こされる被害は, 住居や産業施設, 農業資産などに留まらず, 土壌生態系にも大きな影響をおよぼす。本研究では, 関東・東北豪雨による浸水の影響を受けた土壌生態系に関する環境情報を収集・提供すること目的として, 常総市における浸水地域土壌の化学性分析および土壌細菌群集構造の解析を行った。

2. 方法

2016 年 11 月に市南部の介護施設内の家庭菜園土壌(浸水した D1, D2 および浸水しなかった微高地の d1)および浸水区域外の雑木林(d2)から表層土壌(0～5cm)を採取した。また, 2017 年 9 月に市北部の溢水箇所付近から市中部にかけて, 自然堤防(u1)および浸水した水田や家庭菜園の土壌(U1～U5)を採取した(図 1)。採取した土壌は pH(H_2O), 含水率および全炭素・全窒素含量を測定した。また, 加圧整形ディスクを作成し, エネルギー分散型蛍光 X 線元素分析装置により元素組成の半定量分析を行った。

微生物分析については, 細菌群集構造を把握するため, 希釈平板法による生細菌数の調査および土壌細菌群集構造の T-RFLP 解析[2]を行った。



図 1 土壌採取地点および浸水被害範囲

3. 結果および考察

溢水箇所付近で採取した土壌（U1，U2，u1）は含水率，全炭素量および全窒素量が低く，既往研究[3]と同様に，粘土や有機物の含有量が非常に少なく，砂質の土壌が分布していた。

生細菌数は土壌中の水分量と比例関係にあるとされている[4]。生細菌数と含水率のグラフからは含水率が低いとき，生細菌数が減少する傾向見られた。細菌は団粒内部，すなわち，より小さい孔隙内に豊富に存在していると考えられる。土壌 pH が中性を示した U1，U2，および u1 は，新規に堆積した砂質土壌で構成されているため，生細菌数が低かったと推察される。

T-RFLP プロファイルに基づくクラスター解析（図 2）から，浸水土壌（U4，D1，D2，D3）と非浸水土壌（d1，d2）の間で類似性が高かったが，土壌 U1，U2，U3，U5，u1 とは類似性は低かった。細菌群集プロファイルに基づく多変量解析法の CCA 解析（図 3）では，細菌群集の差異は，主に含水率および pH による影響によるものであることが示され，また，含水率および土壌 pH が生菌数に影響を及ぼしており，河川の氾濫により堆積した砂は土壌細菌群集構造にも影響を及ぼすことが示唆された。

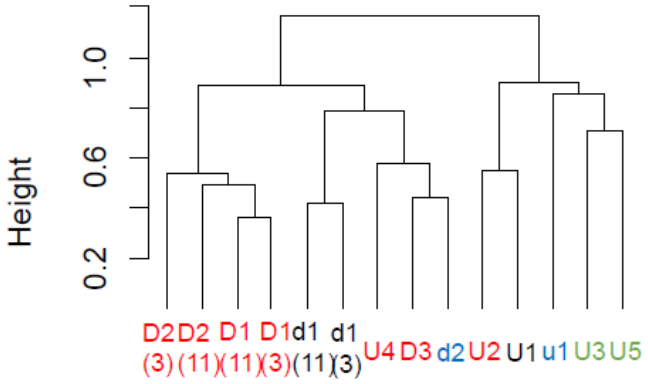

図 2 T-RFLP プロファイリングに基づく階層クラスター解析

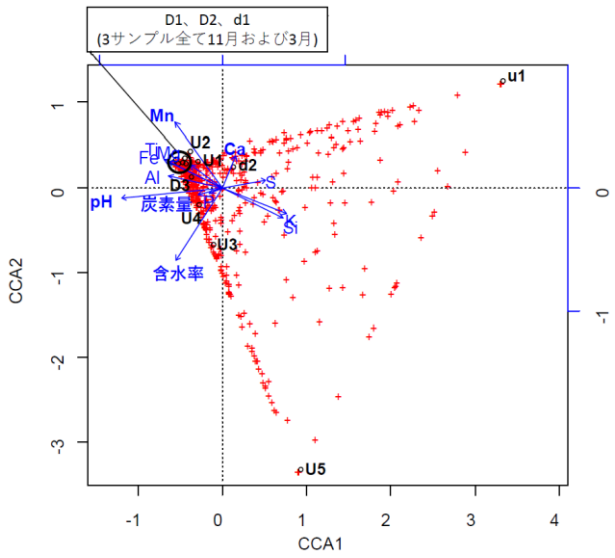

図 3 T-RFLP プロファイリングに基づく正準対応分析

4. 結論

2015 年 9 月の豪雨により常総市では鬼怒川の堤防の一部が破堤・溢水し，大量の土砂水が周辺地域の土壌生態系に流れ込んだ。浸水の影響を受けた土壌生態系の化学性および生物性に関する環境情報を収集した結果，氾濫により砂が堆積することで生じる土壌の理化学性の変化と同時に，土壌微生物性へも影響がおよんでいることが示唆された。土壌生態系に関わる総合的な情報を蓄積していくことで，浸水被害を受けた農耕地の機能回復に資する付加情報となることが期待される。

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P5-12

駒止湿原開墾跡地におけるブナ生育に関わる共生菌類の探索と植樹試験への利用

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キーワード:耕作放棄地, 湿原管理, 植生回復, 土壌再生, ブナ林

抄録

駒止湿原では, 2000 年よりブナ稚樹の植樹が試みられてきたが, 一部地域では生育が不良で植生回復に至っていない。本研究では, ブナ二次林および開墾跡地に生育するブナの共生菌類を調査し, 生育促進に関わる外生菌根菌あるいは内生菌類を選抜し, ブナ稚樹への接種および植樹試験をおこなった。ブナ林から開墾跡地に掛けて調査区を設置して土壌コアおよびブナ実生を採取し, 菌根形態型を調査したところ, 菌根チップ総数および出現形態型数は, ブナ林区から開墾跡地にかけて減少する傾向にあった。次に, ブナ実生根部より根部内生菌を調査して選抜した 2 菌株を用いて, ブナ稚樹に接種して植樹試験をおこなった。今後, 本研究で選抜した菌類による影響の調査を継続するとともに, 同菌種を用いた実験室内での接種試験も行い, 菌根菌−内生菌−宿主植物の相互関係を明らかにしていく。

1. はじめに

駒止湿原は福島県南会津町および昭和村の境界付近に位置しており, 戦後の農地開墾により失われたブナ林を回復させるため, 2000 年よりブナ稚樹の植樹が試みられてきた[1]。植樹されたブナは, 一部地域では良好な生育を見せているものの, 生育が不良で植生回復に至っていない場所も認められる。本研究では, ブナの生育において重要な役割を担う外生菌根菌に着目してブナ二次林および開墾跡地に生育するブナの共生菌類を調査し, ブナの生存・生育の促進に関わる外生菌根菌あるいは内生菌類を選抜し, ブナ稚樹への接種および植樹試験をおこなった。

2. 方法

2016 年 8 月にブナ林から開墾跡地に掛けて幅 10 m, 長さ 30 m の調査区を設置した(図 1)。優占する植物種を考慮し, それぞれ 10 m×10 m のブナ林区、境界区および開墾跡地として区分した。

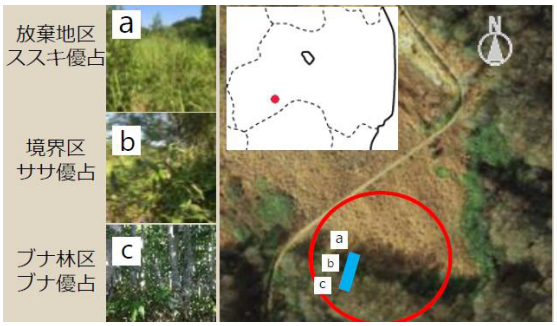

図 1 駒止湿原周辺に設置した調査区

調査区内外の放棄地区, 境界区およびブナ林区から土壌コアおよびブナ実生を採集した。土壌コアについては, コア内に含まれる菌根チップ数を計数し, 含まれる形態型の割合を求めた. ブナ実生については, グリッドシート法により菌根形成率を求めた。形態型別に形成率を算出し, 形態型に基づく外生菌根菌群集構造の類似性を比較した。その後, Cetyltrimethylammonium bromide(CTAB)法により菌根チップから DNA を抽出し, 菌根形成菌種の同定を行った。

次に, ブナ実生根部において形成頻度が高いまたは低い形態型を基準に選抜した菌根片および非菌根(計 156 片)を用いて, 洗浄法および表面殺菌を行い, 根部内生菌の分離を行った。得られた分離菌株の培養菌糸から DNA を抽出し, 菌種を同定した。以上の結果から, 調査地域においてブナと密接な関係にあると推察される菌類 2 種を選抜して液体培養をおこない, 樹高 30〜50 cm 程度のブナ稚樹の根部に接種し, 開墾跡地において植樹試験をおこなった。試験は共生菌 2 種と対照の 3 区を設け, 1 反復あたり 12 本, それぞれ 3 反復(計 108 本)で植樹区を設定した。

3. 結果および考察

土壌コアおよびブナ実生より, これまでに 66 種類の菌根形態型が確認された。調査区内における土壌コア内の菌根チップ総数および出現形態型数は, ブナ林区から開墾跡地にかけて減少する傾向にあった。ブナ実生の菌根形成率も同様の傾向を示した。調査地における

外生菌根菌群集の特徴は，ブナ林区・境界区におけるブナ実生のグループと開墾跡地におけるブナ実生のグループに分かれており開墾跡地ではブナ林内とは異なる菌類相であることがブナの生育の妨げになっていることが考えられた。

菌根チップから抽出した DNA により菌根形成菌種の同定を行った結果，外生菌根菌のみではなく，根部内生菌を含む系統群である *Helotiales* 目菌類が認められたことから，ブナ実生の生育には，共生菌類として外生菌根菌だけではなく根部内生菌も関与していることが考えられた。そこで，ブナ実生根部より根部内生菌 97 菌株を分離し，うち 83 菌株を分子同定した。分離した 65 菌株中，33 菌株が *Helotiales* 目菌類であり，その中で 21 菌株が *Leptodontidium* 属菌であった。これらの菌類は主にブナ林区および境界区に認められ，菌根の形態型には依存せずに分離された（図 2）。放棄地区でも同属の *L. orchidicola* が分離されたことから，調査区において，*Leptodontidium* 属菌はブナの生育と密接に関係していることが推察された。また，外生菌根菌として報告のある *Cenococcum geophilum* を菌根部から 2 菌株分離された。以上より，現地における開墾跡地への植樹試験に用いる接種菌株として，根部内生菌 *Leptodontidium* sp.および外生菌根菌 *C. geophilum* を選抜した。

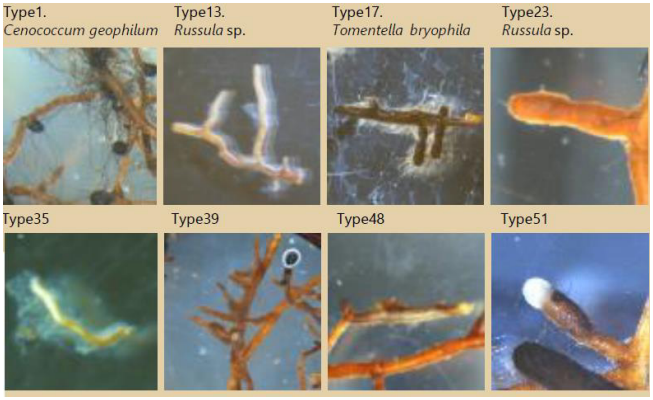

図 2 *Leptodontidium* 属菌が分離された菌根形態型

選抜菌株は，1.5% Malt Extract 液体培地で培養し，菌糸懸濁液（1.0×10^X 菌糸片/mL）を作成した。現地において 4 m×5 m の植樹区を 9 つ（対象区，*Leptodontidium* sp.区および *C. geophilum* 区を 3 反復）設置し，それぞれの区に 12 本のブナ稚樹を，1m 以上の間隔を空けて植樹した（図 3）。*Leptodontidium* sp.区および *C. geophilum* 区については，菌糸懸濁液を現地で希釈し，大型のビニール袋内でブナ稚樹の根部と接触させることで接種した後，速やかに植樹をおこなった。これらの稚樹については，主幹長や葉の葉緑素含量によって生育評価を行っていく。



図 3 現地植樹試験の様子

4. 結論

樹木の生育には共生菌類の関与が必要不可欠であり，駒止湿原におけるこれまでの植樹活動でも，山引苗を利用するなど，従来の森林環境に学んだ取り組みが多数実施されている[2]。今後，本研究で選抜した菌類による影響の調査を継続するとともに，同菌種を用いた実験室内での接種試験も行い，菌根菌-内生菌-宿主植物の相互関係を明らかにしていく。

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P6-1

MONITORING AND EVALUATION OF THE WATER QUALITY OF TAAL LAKE, TALISAY, BATANGAS, PHILIPPINES

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Key words: Cool dry season, hot dry season, rainy season, Taal lake, water quality.

ABSTRACT

Abstract

The study is an update on the physico-chemical properties of Taal Lake for local and government officials and non-government organizations. A total of nine (9) water quality parameters were monitored and analyzed. The study shows that Taal Lake's surface temperature, pH, total dissolved solids, total suspended solids, color, and dissolved oxygen content conform to the standards set by the DENR while phosphate, chlorine, and 5-Day 20°C BOD are below the standard. T-test result shows that there is no significant difference in the overall average of the two sites at Taal Lake ($P > 0.05$). Based on the data, the lake is safe for primary contact recreation such as bathing, swimming, and skin diving and can be used for aqua culture purposes.

1. INTRODUCTION

The health condition of every human being depends on the environment where they live. With the unabated urbanization of localities due to increasing population, human and industrial activities and more so the extreme climatic condition, the supply of substantially healthy and fresh food in the market is affected. Sources of fish like lakes, seas, and rivers have been abused by man in exchange to industrial and domestic consumption. Non-conformance of businessmen particularly those who rely on the supply of natural food such as fish pen and cage operators from water sources to government imposed regulations make our body of waters more vulnerable to pollution.

The Philippines has a typical humid tropical climate. Average rainfall is approximately 2,026 millimeters per annum, which falls during rainy season, from June to October. Its surface area covers about 234 square kilometers with an average depth of about 63 meters. The normal range of annual water level fluctuation of the lake is 2 meters (Lakenet 2003).

Despite governments' declaration as protected area, illegal fish cages continue to increase rapidly in the lake. Approximately, there are 12,000 fish cages that contribute to its degradation. Some native fishes disappeared and the scenic view of the lake is blocked and its nature reserve put at risk.

Before, the fish cages in Taal Lake were regulated by the Department of Environment and Natural Resources (DENR) under secretary Lito Atienza in coordination with Batangas Governor, Vilma Santos Recto. The two government servants tried to limit the number of fish cages. However, problems arose during the phase one of program implementation. This is because thousands of people benefit from this business and provide aquatic food products for CALABARZON and Metro Manila

2. METHOD

Water Sampling Method

Water sampling was done in *situ* to determine the quality of water of Taal Lake at Talisay, Batangas. Samples were collected at two sampling sites according to depth namely; Site 1 (with fish cages) and Site 2 (without fish cages) in Talisay, Batangas. Each site was divided into two layers, the surface layer (layer 1) and the layer where the light is no longer visible (layer 2, 10.5 feet). Depth level of layer 2 was measured using Secchi disk. Collection of sample was conducted quarterly for one year. Sampling was done in two sampling intervals namely early morning and late afternoon

to determine if there are differences in the results done in different times of the day.

In chemical and physical analysis, approximately 1000 mL of water sample per sampling site were collected. The samples collected were placed in ice cooler and transported promptly to the laboratory for analysis.

Physico-chemical Analysis

Water temperature was measured *in situ*, using handheld thermometer. Other factor like chloride and phosphate were tested at JEFCOR laboratory.

In biochemical oxygen demand (BOD) test, a standard 300-mL glass BOD bottles was used. Two DO measurements were involve in the 5-day, 20°C BOD of the water samples, an initial measurement when the test begins at t = 0 and a second measurement when t = 5. It was done after the sample has been incubated in the dark for five days at 20°C. The BOD is the difference among the two measurements. To determine the BOD of the water sample Dilution Technique was used.

To determine the dissolved oxygen (DO) concentration a membrane electrode meter was used after careful water sampling. The electrode probe senses small electric currents that are relative to the dissolved oxygen in the water.

Gravimetric method was used to determine the total suspended solids (TSS). A 100mL water sample was evaporated into dryness using pre – weighed 100mL beaker. The beakers were placed in desiccators before weighing after evaporation.

set by DENR-EMB.

Total dissolved solids (TDS) were also determined using Gravimetric method. The water sample was filtered and 100 mL of the filtrate was evaporated in a pre-weighed evaporating dish on a stove. The residue left after evaporation was dried to constant weight in an oven. The increase in mass over that of the empty evaporating dish represents the TDS in mg/L.

Analysis of Data

The gathered data were clustered according to layer, site, and into three seasonal variations namely; rainy (June to November), cool dry (December to February), and hot dry season (March to May) after determining the physical and chemical characteristics of water samples. T – test was used to test if there is a significant difference in the characteristics of water of Taal Lake based on the selected sampling sites. The average mean for the whole year were calculated since there is no significant difference in the values per site, layer, and season. It was compared with the standard set by Department of Environment and Natural Resources – Environmental Management Bureau (DENR-EMB).

3. RESULTS

Physical and chemical characteristics of Taal Lake were monitored and analyzed for twelve months. The results were compared with the standard set by DENR-EMB. Table 1 shows the total mean of physical and chemical characteristics of Taal Lake for the whole year as compared to the standards

Table 1. Results of physical and chemical characteristics of Taal Lake at Talisay, Batangas for the whole year. Values shown are total mean and standard limits set by DENR-EMB for surface waters

Parameters	Unit	Total Mean/Observation	Standard Set by DENR-EMB	Interpretation
Water temperature	°C rise	26.14	3*	Within the standard
Color		No abnormal discoloration from	No abnormal discoloration	Within the standard
pH		8.31	6.5 – 8.5	Within the standard
Total Dissolved Solids (TDS)	mg/L	912.96	1000 mg/L	Within the standard
Total Suspended Solids (TSS)	mg/L	5.17	Not more than	Within the standard
Chloride as Cl	mg/L	576.36	250 mg/L	Exceed the standard
Phosphate as Phosphorus	mg/L	0.21	0.2	Exceed the standard
5-Day 20°C BOD	mg/L	3.25	5 (minimum)	Below the standard
Dissolved Oxygen (DO)	mg/L	7.79	5(minimum)	Within the standard

* The allowable temperature increase over the ambient temperature is 3°C

4. DISCUSSION

Stable water temperature was observed at Taal Lake during the 12-month period of monitoring with an average of 26.2°C. The increase during hot dry season is very minimal and conforms to the standard set by DENR-EMB. Increase of water temperature results to greater natural activity while its decrease results to increase of dissolved oxygen (Johnson, 2000). If the water gets warm, water and nutrients mixed uniformly right through the water and oxygen is restored. This oxygen is being used by microorganisms in Taal Lake that results to the reduction of the amount of dissolved oxygen. In general, the increase of temperature of Taal Lake for the whole year did not affect its situation since no irregularities have been monitored like degrading of environment and decline of photosynthetic movement. The study of Heejun Chang in Han River also shows no considerable increase in temperature for the entire period of the research while Odemis and Evrendilek study of National Watersheds in Turkey shows increasing trend in river water temperature, at a mean annual rate of about 0.2°C.

Average pH level is extremely significant to the health of marine life. Low pH level may cause death to many fishes in rivers and lakes because some aquatic organisms are susceptible to changes in pH and a few of them may not be able to endure the changes. Low pH can also raise the quantity of heavy metals such as aluminum and mercury (Lusch, 1997). For example, a pH of 4 or less of water cannot be tolerated by a fish in the river. In Taal Lake, a negligible change in pH was monitored with an average value of 8.31 pH units. This value conforms to the standard set by DENR-EMB.

The lake has a total mean of 912.96 mg/L and 5.17 mg/L of total dissolved solids (TDS) and total suspended solids respectively for the whole year. The value of TDS is very close to the standard set by DENR-EMB which is 1000mg/L but still conforms to the standard. TSS also conforms to the standard set because more than 30% of this amount was not monitored. The amounts of these parameters are possibly because of the accumulated lava from the volcano or maybe from the feeds given to fishes and other activities such as bathing and fishing. The rising water temperature is directly correlated to total dissolved or suspended solids (TSS and TDS). An increase of amount of TDS and TSS can increase the temperature of water since floating materials absorbs heat from sunlight. These two parameters can also reduce the color of the water and can influence photosynthesis. (IWR-MSU 1997).

An average of 576.36 mg/L Chloride was monitored during the entire period of the study. This value did not conform to the standard set by DENR-EMB which is 250mg/L. High amount of chloride is perhaps because of the thirty-seven (37) tributaries that drain into the lake for years. This is quite alarming because high chlorine content can cause poisoning of aquatic organisms. This could be one of the possible reason why fish kills happened at Taal Lake for many times (ADB 2003). Chloride is also damaging and killing some parts of the body each time one bathes, or swims in the river (Bordin, 2007). This result is the same with the findings of Moskovchenko, Babushkin and Artamonova in their study of Vatinsky Egan River catchment in West Siberia which shows wide and high concentration range of chloride.

Phosphorus has an average value of 0.21 mg/L. Based on the data, the study shows that Taal Lake has a little bit higher phosphate content as compared to the DENR-EMB standard of 0.2 mg/L. This condition is anticipated since heavy rainfall increases the downpour of top soils carrying naturally occurring phosphorus from the neighboring highlands (Helmer and Hespanhal, 1997).

Higher phosphate content in the lake can be dangerous to marine organisms. It can cause tremendous development of plants that may lessen the quantity of light in the water and decrease the amount of dissolved oxygen. It can also cause algae growth, thus fish will be deprived of sufficient oxygen (Bodzin, 2004).

Biochemical oxygen demand (BOD) is a measure of how a huge quantity of oxygen is used by marine life in the aerobic oxidation, or subsides of natural substances in the lake. BOD presence in the lake can be attributed to the increase of discharges into the lakes such as polluted topsoils and other household wastes from the nearby resident transported by heavy precipitation. In the case of Taal Lake, below the minimum standards set by DENR-EMB were monitored with a value of 3.25 mg/L.

Dissolved Oxygen (DO) in Taal Lake has a value of 7.79 mg/L for the whole year. This value conforms to the standard set by DENR-EMB. DO is necessary for the survival of most marine organisms. Low DO readings show high oxygen requirement from microorganisms, and can result to severe pollution.

Color was also monitored but no abnormal discoloration (changes color of water to light brown or more intense light brown) from unnatural causes was observed meaning it conforms to the standard set by DENR-EMB.

T – test was used to test if there is a significant difference in the characteristics of water of Taal Lake based on the selected sampling sites. The result shows that there is no significant difference in the overall average of the two sites at Taal Lake since the t-value of 0.006 has a p-value (0.996) greater than 0.05.

To preserve the quality of water in Taal Lake, safety, security and environmental management plan should be implemented by concerned local government units (LGU), so that the present best beneficial use of the lake is likely to last. Information campaign on the protection and preservation of the lake has to be advocated in nearby residents and mountaineers to atone the quantity of contaminants in the vicinity.

CONCLUSION

Based on the overall results of the study, Taal Lake water can still be classified as Class B (DENR-EMB 2005), Recreational Water Class I. The classification is the same with Pagsanjan river of Laguna, the Bolbok river of Batangas, and Palicpican and Mamba River at Mts Palaypalay. In general, the lake can be beneficially used for primary contact recreation such as bathing, swimming, and skin diving. Taal Lake is still suitable for aqua culture purposes, for fish propagation and growth.

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P6-2

網走川大曲堰における塩分収支の推定

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キーワード: 可動堰, ADCP, 塩水楔, 塩分収支, 湖沼・河川モニタリング技術

抄録

網走湖は, 下層が塩水層, 上層が淡水層の 2 層構造の汽水湖である。昭和 50 年代後半以降, アオコ・青潮の発生が確認され, これらの原因は湖内塩水層の上昇によるものと結論づけられた。海水流入による湖内塩水層の上昇を抑制するため, 網走湖下流に可動堰(大曲堰)が設置された。大曲堰の適切な運用には, 塩分収支を正確に把握する必要がある。そこで, 自記塩分計を鉛直に複数台設置し, 塩分の遡上・流下特性を調査した。また, ADCP による鉛直層別流量と自記塩分計から層毎に算出した塩分量の総和の収支と, 各層の塩分計を鉛直代表として算出した塩分収支を比較検証した。その結果, 前者では, 塩分は逆流から順流への切り替わり時に塩水楔となる現象を確認し, 後者では, 底層の塩分計で算出した塩分収支ほど流出を過大に評価することを明らかとした。また, 各層の塩分収支の誤差率から今後の塩分収支の正確な把握に向けた塩分計の設置標高について提案した。

1. はじめに

北海道オホーツク地方に位置する網走湖は, 面積 32.3km^2, 水量約 2 億 3 千万 m^3 を有する。網走湖は潮汐によって, オホーツク海の海水が流入する下層が塩水層, 上層が淡水層の 2 層構造の汽水湖であり, ヤマトシジミ, ワカサギ等の水産資源も豊富である。湖の水量の半分近くを占める塩水層は重く, 高濃度の栄養塩を含んでいる。塩水層は淡水層からの酸素供給が少ないこと, 水生生物・プランクトンの死骸の分解時に酸素を消費することから無酸素状態となっている。

網走湖の塩水層は, 昭和 50 年代後半以降, 徐々に上昇し, アオコや青潮の発生が確認されるようになった。これらの対策のため, 国・流域市町村では, 様々な技術的な検討や対策事業が行われてきた。網走湖水環境改善事業では, 平成 16 年度～平成 29 年度にかけて, 青潮・アオコの発生抑制, 流域を含めた汚濁負荷削減等の対策事業が集中的に実施されてきた。

網走湖における青潮発生は, 強風に伴う塩水層の上昇が条件となっている。また, アオコの発生は, 塩水層からの栄養塩供給が主要因の 1 つとされる。したがって, 青潮・アオコの発生抑制には, 湖内塩水層を降下・安定化させる必要があり, その目標として塩水層の上層の淡水層厚を 6～7m に管理することとしている。上記を背景に, 海水流入による湖内塩水層の上昇を抑制するため, 平成 25 年, 網走湖下流に可動堰(以下, 大曲堰)が設置され, 平成 26 年 1 月より運用が開始された。

大曲堰の運用には, 塩分収支を正確に把握する必要があり, 塩分の遡上・流下特性を把握することが重要である。特に大曲堰周辺では, 逆流から順流への切り替わり時に塩水楔のような現象が確認されることから, この現象を踏まえた塩分収支の把握が重要である。

そこで, 本研究では, 大曲堰周辺に自記塩分計を鉛直に設置すると共に河床に ADCP(以下, V-ADCP)を設置し, 層別の流量推定と層別の塩分濃度から塩分収支の精密観測を行った。また, これらの結果を基に今後の自記塩分計の設置標高について考察を行った。

2. 大曲堰について

大曲堰は, 網走川河口から約 7.0km 上流の川幅約 45m に設置された幅 20.7m×2 門の鋼製起伏ゲートであり, 逆流時のみ起立する。堰倒伏時は EL-1.5m の河床にあるが, 堰起立時には EL0.0m まで上昇し, 逆流時越流方式の堰としている。大曲堰は冬期間の海水流入を防止する施設であるため, その運用期間は概ね 1～3 月の 3ヶ月間である。堰周辺には, 自記水位計, 自記塩分計, 自記 DO 計および自記水温計が設置され, 10 分間隔でモニタリングが行われている。

3. 方法

(1) 遡上・流下時の塩分鉛直分布

大曲堰の上下流の KP6.9 および KP7.1 に自記塩分計を設置した(図 1)。自記塩分計は河床から 0.3m 毎に 7 層設置し, 10 分間隔で計測した(図 2)。設置期間は, 2018 年 1 月 10 日～2018 年 2 月 8 日の約 1 ヶ月間とした。堰通過塩分濃度は, KP6.9 と KP7.1 の各層の平均とした。

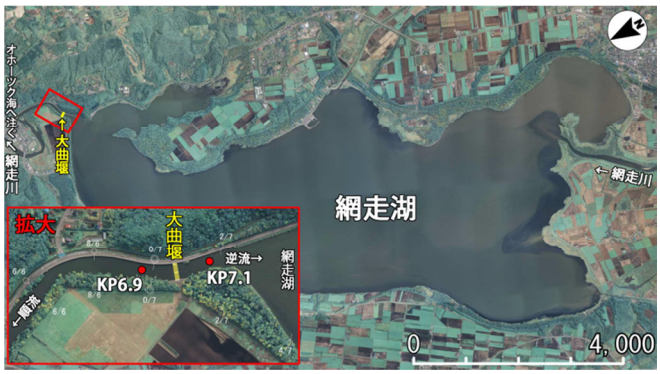

図 1 自記塩分計および V-ADCP 設置位置

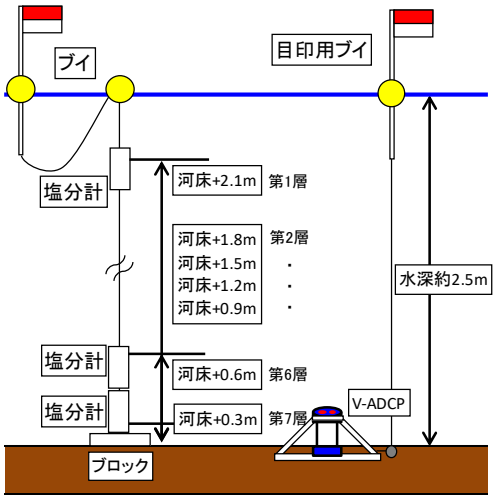

図 2 自記塩分計および V-ADCP の設置模式図

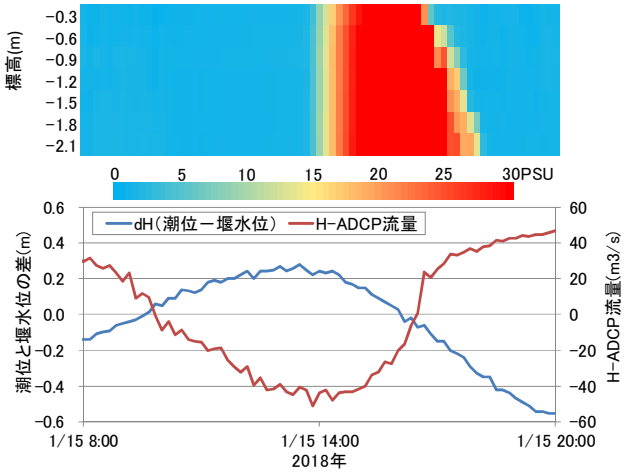

図 3 大曲堰周辺における遡上・流下時の塩分鉛直分布
流量はマイナスが逆流，プラスが順流を示す

(2) 層別流量の推定と大曲堰塩分収支

網走川 KP7.1 の流心部河床に V-ADCP（Teledyne RD Instruments 社製 Workhorse 1200kHz）を設置し，0.05m 間隔の鉛直流速分布を 10 分間隔で計測した。

V-ADCP からは流心の鉛直流速分布のみ得られることから，各層の流量に換算する必要がある。そこで，各層の流量算出にあたっては，アメリカ地質調査所

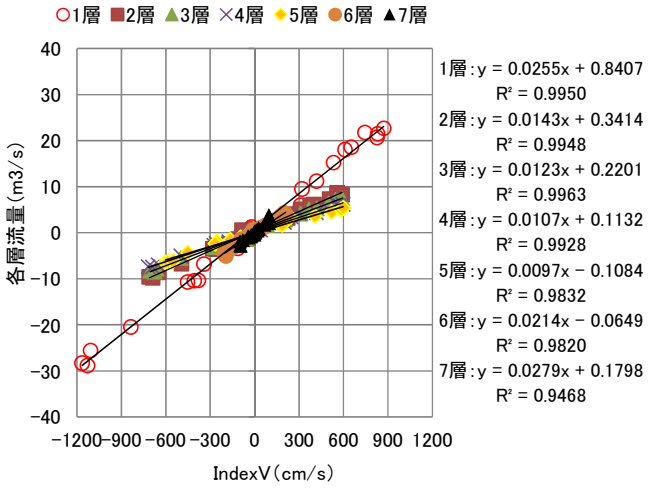

図 4 各層流量と IndexV との関係

(USGS) の Index Velocity 法 (IndexV) を適用した[1], [2]。

まず，ADCP (Teledyne RD Instruments 社製 Workhorse1200kHz) 曳航観測から，各層の流量を算出した。次いで，V-ADCP の各層に該当する流速の総和 (IndexV) を算出し，IndexV-Q 相関式により各層流量に換算した。

大曲堰塩分収支は，各層の流量とそれに該当する層の自記塩分計値を乗じた塩分量の総和とした。なお，各層の流量および塩分量は表層から第 1 層～第 7 層と称す。

ADCP 曳航観測は，2018 年 1 月下旬，2 月上旬の大潮時に各 1 回，満潮ピーク付近から干潮ピーク付近までの概ね 12 時間を対象に 1 時間に 1 往復の観測を基本とした。V-ADCP の観測期間は，自記塩分計の設置期間と同様とした。

4. 結果および考察

(1) 遡上・流下時の塩分鉛直分布

大曲堰周辺における遡上・流下時の鉛直塩分濃度について図 3 に示した。大曲堰地点においても既往の知見同様，遡上時の鉛直塩分濃度はほぼ一様であり，強混合で逆流してくることが示された[3]。一方，流下時には，上層ほど，塩分濃度が低い傾向が見られる。これは，順流に転じた際には，より潮位との標高差の生じやすい上層から網走湖表層の淡水と入れ替わるためと考えられる。

(2) 層別流量の推定

層別流量の推定ための ADCP 曳航観測による各層流量と V-ADCP 流速の総和（IndexV）との関係を図 4 に示した。いずれの層の流量においても IndexV との相

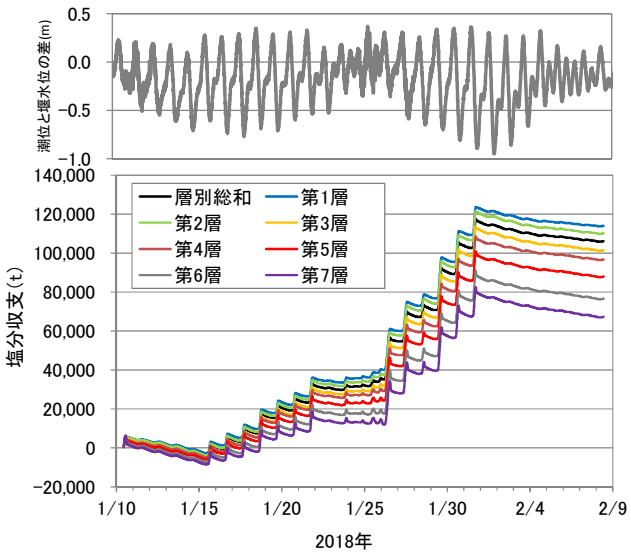

図 5　各層塩分収支の比較と算出期間の潮位・堰水位差

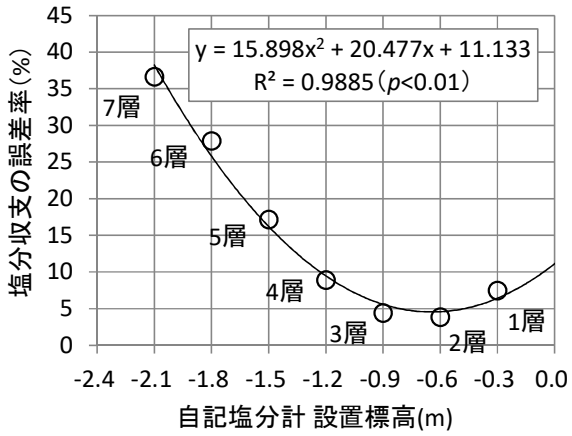

図 6　各層自記計の塩分収支の誤差率

関が高く，V-ADCP 流速分布から十分な精度で層別流量およびその総和である断面流量を推定できることが示された。

(3) 大曲堰塩分収支の推定

各層流量と各層自記塩分計から算出した塩分収支の総和を真値とし，断面流量と各層の自記塩分計値から算出した塩分収支との差を図 5，同誤差率を図 6 に示した。2018 年 1 月 10 日～2018 年 2 月 8 日の約 1 ヶ月間での塩分収支は，約 10 万 6 千 t となった。

一方，各層自記塩分計での塩分収支では，第 2 層（設置標高-0.6m）の塩分計から算出した塩分収支が最も真値と近い値を示し，底層の塩分計で算出した塩分収支ほど，真値より小さい値を示した。これは，強混合で遡上した塩分が順流に切り替わった後も底層部に残存することを反映した結果と考えられる。

誤差率は，2 次曲線式で近似され（p<0.01），得られた 2 次曲線式からも実測の誤差率と同様，設置標高 -0.6m で最小値を示した。

5.　今後の大曲堰塩分収支の把握に向けて

大曲堰に設置された自記塩分計は，当初，EL-2.0m（第 6 層～第 7 層のほぼ中間に相当）の河床付近に設置されていた。本研究より，逆流から順流への切り替わり時には上層から徐々に淡水に切り替わるため，底層に近い EL-2.0m の自記塩分計で塩分収支を評価した場合，流出を過大に評価していたことが示された。大曲堰には，自記計が左右岸に各 1 台設置されているため，今回観測したように鉛直に複数台の自記塩分計を設置し，塩分収支を把握することが困難と考えられるが，現状の機器を誤差の最も小さい標高へ調整することで大曲堰塩分収支の精度向上が図られると考える。

一方，今回の観測期間（1 月上旬～2 月上旬）では，第 2 層塩分計による塩分収支と真値との差は 4 千 t 程度であった。網走湖の冬季の塩水層の平均標高に換算すると凡そ 0.01m に相当する。本研究で得られた自記塩分計標高に調整することで適切な大曲堰の運用が可能であると考える。

6.　結論

網走湖下流に設置された大曲堰の塩分収支の正確な把握のため，塩分の遡上・流下特性の調査およびそれを踏まえた層別の流量・塩分収支の把握を行った。

その結果，塩分の遡上・流下特性では，遡上時には強混合であるが，流下時には塩水楔のように高濃度の塩分が底層に一定時間残存する現象を確認した。層別自記計による塩分収支では，底層ほど，塩分収支の真値との差異が大きいことを確認し，1 台の塩分計で塩分収支を把握する場合には，EL-0.6m（第 2 層）に設置することで精度の高い塩分収支を把握できることを明らかにした。

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P6-3

網走川大曲堰における H-ADCP による通過流量の推定

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キーワード:H-ADCP, 可動堰, 感潮域, 逆流時越流方式, 湖沼・河川モニタリング技術

抄録

網走湖は塩水層と淡水層の 2 層構造を呈し, 塩水層は高濃度の栄養塩を含む無酸素層となっている。網走湖ではアオコ, 青潮の発生がみられ, 塩水層の上昇が要因とされている。海水流入による塩水層の上昇を抑制するため, 逆流時越流方式の可動堰(大曲堰)が網走湖下流に設置された。大曲堰の適切な運用には, 塩分収支を正確に把握するための流量把握が重要であるため, 堰倒伏時・堰起立時の流量推定を H-ADCP で行うと共に H-ADCP 推定流量の経年的な精度管理についても検討した。その結果, 堰起立時も含めて, 同じ定数の春日屋の式から精度の高い H-ADCP 推定流量が得られることを明らかにした。また, 網走湖下流河川のような河床変動が余り大きくない環境での経年的な精度管理には, 実測による定数の変更の検討よりも H-ADCP 設置断面の河床変化によるノイズデータの発生状況を踏まえた有効計測幅の検証が重要であることを示した。

1. はじめに

北海道オホーツク地方に位置する網走湖は, 面積 32.3km^2, 最大水深約 16m の汽水湖である。網走湖は塩水層と淡水層の 2 層構造を呈し, 塩水層は高濃度の栄養塩を含む無酸素層となっている。昭和 50 年代以降, アオコ, 青潮の発生が確認され, これらを改善するため, 国・流域市町村で様々な技術的な検討や対策事業が行われてきた。網走湖水環境改善事業では, 平成 16 年度～平成 29 年度にかけて, 青潮およびアオコの発生抑制, 流域を含めた汚濁負荷削減等の対策事業が集中的に実施されてきた。

網走湖における青潮発生は, 強風に伴う塩水層の上昇が条件となっている。したがって, 青潮発生抑制には, 湖内塩水層の降下・安定化が必要であり, 海水の流入による湖内塩水層の上昇を抑制するため, 平成 25 年, 網走湖下流に可動堰(以下, 大曲堰)が設置され, 平成 26 年 1 月に運用が開始された。

一方, 網走湖内における塩水層の降下・安定化に資する大曲堰の運用には, 堰の塩分収支を正確に把握する必要があるが, 塩分収支の把握には, 第一に堰通過流量の正確な把握が不可欠である。しかし, 感潮域かつ堰稼働時の流量推定の事例は無く, 流量推定手法の確立が課題であった。そのため, 大曲堰上流 100m に H-ADCP(Teledyne RD Instruments 社製 Workhorse 600kHz)を設置した。H-ADCP による流量推定は, 堰のない感潮域での事例はあるが[1], 堰稼働条件での観測事例はこれまで報告されていない。

そこで, 本研究では, ADCP による経年的な現地観測から感潮域かつ堰稼働時における H-ADCP による流量推定について検証した。さらに, H-ADCP 流量の経年的な精度管理についての知見についても報告する。

2. 大曲堰ついて

大曲堰は, 網走川河口から約 7.0km 上流の川幅約 45m に設置された幅 20.7m×2 門の鋼製起伏ゲートであり, 逆流時のみ起立する。堰倒伏時は EL-1.5m の河床と同等の高さにあるが, 堰起立時は EL0.0m まで上昇する逆流時越流方式の堰である (図 1)。

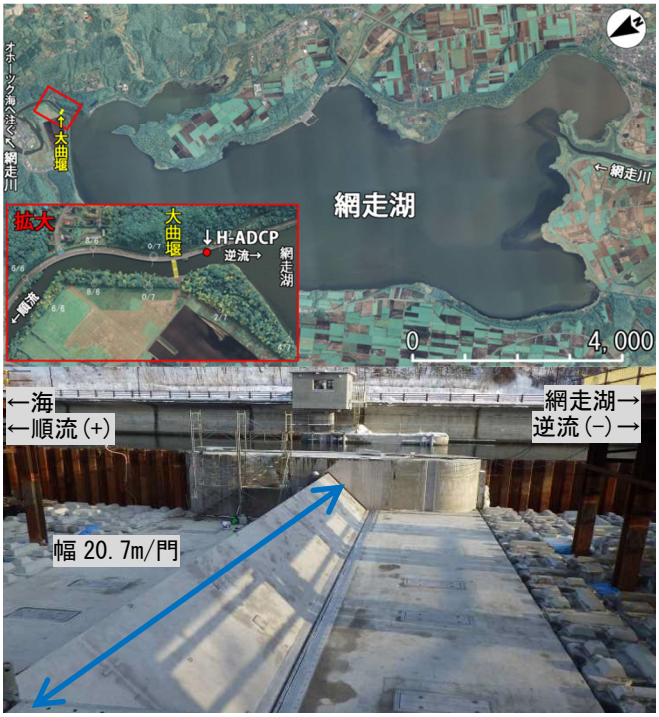

図 1　網走川大曲堰位置および堰外観

3. 方法

(1)H-ADCP による連続観測

H-ADCP は，大曲堰上流約 100m の EL-0.2m の右岸河岸壁面に設置し，水平層厚 1m 間隔での流向・流速分布を 10 分間隔で測定した。観測は河岸垂直線より上下流 25 度の 2 ビームを使用し，1 秒間隔で 150 サンプル測定した。観測は，同機が設置された平成 26 年 3 月以降，連続観測が継続されている。

(2)H-ADCP を用いた流量推定

①H-ADCP 流量推定の基本式

H-ADCP から得られるデータは，水平方向の流速分布である。流量を算出するためには，断面流速分布を得る必要がある。そこでADCP（TeledyneRD Instruments 社製 Workhorse 1200kHz)曳航観測による流速鉛直分布と H-ADCP による水平流速分布との関係から断面流速分布を推定した。断面流流速分布の推定には，既往の感潮域での事例[1]から春日屋の二次曲線形流速分布[2]を採用した。

$$v(z)=\frac{V_m}{p}\left\{pk+2a\left(\frac{z}{h}\right)-\left(\frac{z}{h}\right)^2\right\},$$

$$p=\frac{1-3a}{3(k-1)},\quad k=\frac{V_s}{V_m},$$

$$V_m=b*V_{H-ADCP},\quad V_s=c*V_{H-ADCP}$$

ここで，$v(z)$は流下流速の鉛直分布，z は水面からの深さ，V_m は鉛直平均流速，a は流速ピーク位置の相対水深，h は水深，V_s は表面流速を示している。V_m，V_s は H-ADCP の測定値 $V_{H\text{-}ADCP}$ に比例すると仮定し，b，c は定数である。

②H-ADCP 流量推定の手順

流量推定の手順としては，まず，大曲堰倒伏時に ADCP による曳航観測を行い，ADCP による流速分布と上記の春日屋の式から推定した流速分布との誤差が最小になる a，b，c を求めた。次に大曲堰起立・逆流時に ADCP による曳航観測を実施し，同様に a，b，c を求めた。最後に経年的なADCPによる曳航観測によって，春日屋の式の精度検証を行った。精度検証の際には，定数の変更および H-ADCP 流速の有効計測幅等についても合わせて検討した。

大曲堰倒伏時の観測は，平成 26 年 10 月下旬，平成 27 年 12 月中旬，平成 29 年 1 月中旬及び平成 29 年 12 月上旬に実施した。大曲堰起立・逆流時の観測は，平成 27 年 1 月下旬，平成 28 年 1 月中旬，平成 28 年 2 月下旬，平成 29 年 1 月下旬及び平成 30 年 2 月上旬に実施した。いずれの観測も 1 時間に 1 往復の ADCP 曳航観測を行うことを基本としたが，逆流から順流へと流向が変わる時間帯では 10 分間隔で密に観測を実施した。

4. 結果

(1)堰倒伏時の H-ADCP 推定流量

堰倒伏時における ADCP 曳航観測データより，H-ADCP 流速全層で，順流時，逆流時ともに a =0.15，b =0.85，c =1.00 で誤差が最小となった。この定数を用いて推定した H-ADCP 流量と ADCP 曳航観測流量の比較結果を図 2 に示した。大曲堰倒伏時においては，逆流から順流全ての観測において，H-ADCP 推定流量は ADCP 曳航観測流量とほぼ一致した。

(2)堰起立時の H-ADCP 推定流量

次いで，堰起立時における ADCP 曳航観測データより定数を求めた結果，堰倒伏時と同じ定数で誤差が最小となることを確認した。H-ADCP 推定流量と ADCP 曳航観測流量の比較結果を図 3 に示した。堰起立時においても H-ADCP 推定流量は堰倒伏時と同じ定数で ADCP 曳航観測流量とほぼ一致した。

(3)H-ADCP 流速の有効計測幅

H-ADCP 流速計測の超音波が河床と干渉した場合や，2 ビームの流速の差が大きい場合にノイズデータが現れる。H-ADCP による流速観測データを図 4 に示した。図中の黒または白くかすれたものがノイズデータである。平成 27 年以降は全観測を通じ H-ADCP より 12～29m の範囲でノイズデータの発生が少なく，安定した観測ができていることを確認した。よって，これを経年的に共通する H-ADCP 流速の有効計測幅と判断した。以降，H-ADCP 流量算出にはこの有効計測幅の流速を使用することとした。

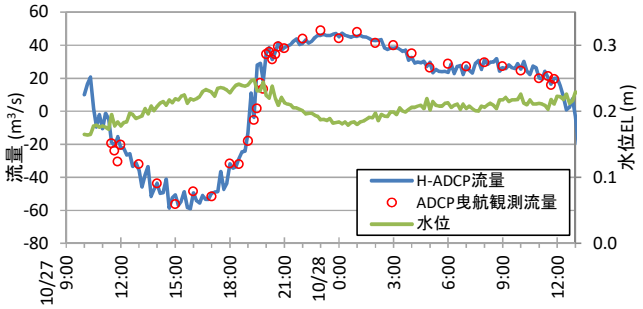

図 2 堰倒伏時の H-ADCP 流量と ADCP 曳航観測流量
流量のマイナスは逆流，プラスは順流を示す。

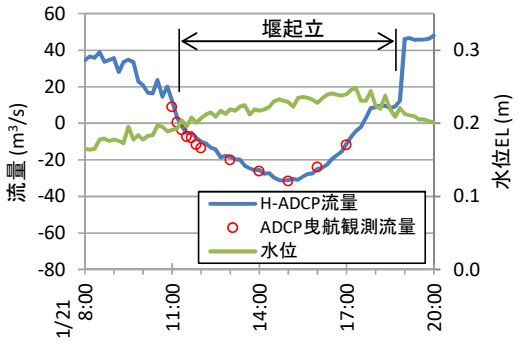

図 3　堰起立時の H-ADCP 流量と ADCP 曳航観測流量

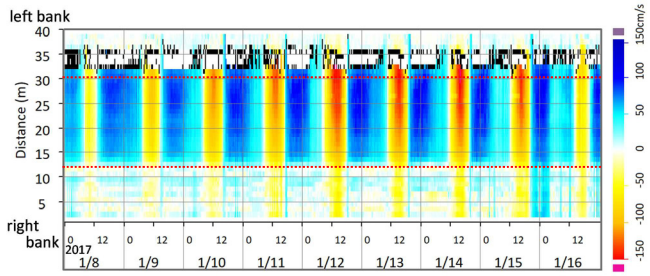

図 4　H-ADCP 流速のノイズデータの発生状況

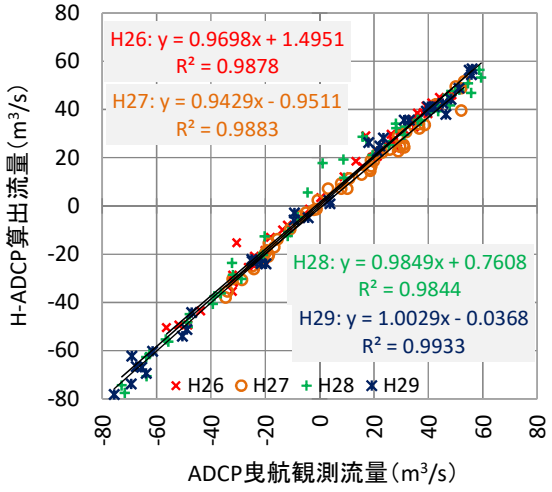

図 5　H-ADCP 推定流量精度の経年変化

(4) H-ADCP 推定流量の経年変化

H-ADCP 設置後の平成 26 年以降の H-ADCP 推定流量精度の経年変化について図 5 に示した。H-ADCP 推定流量は，堰倒伏時・倒伏時ともに平成 26 年度に設定した春日屋の式の定数で，有効計測幅を 12～29m とすることで経年的にも精度が保たれていることが示された。

5.　考察

感潮域かつ可動堰のある環境において H-ADCP による流量推定を行い，経年的な精度について確認した。その結果，堰倒伏時・堰起立時のいずれにおいても同じ定数の式（春日屋の式）で精度の高い流量推定が可能であることを明らかにした。これは，堰起立時の鉛直流速分布も堰倒伏時と大きく変わらなかったことを意味する結果と考えられるが，越流状況によっては，鉛直流速分布が異なることも想定されることから，形状や稼働方式の異なる他の堰への適用については，今後さらなる知見の蓄積が望まれる。

一方，推定流量精度を経年的に確認した結果，ADCP 曳航観測による春日屋の式の定数変更の必要性は低く，有効計測幅にのみ留意すれば，経年的にも，精度の高い流量が得られることが示された。これは，大曲堰が網走湖下流に設置され，河床変動がそれ程大きくない環境であることが要因と考える。有効計測幅については，横断測線上の何割程度を把握できれば，精度の高い推定流量が得られるか等を今後，検討する必要があると考える。

また，塩水遡上を伴う逆流から順流に流向が変わるタイミングで一時的に表層が順流，下層が逆流の塩水くさび状の流速分布が現れており，本報告で用いた二次曲線形流速分布ではくさびを表現することができない。そのため，流速分布の推定の精度向上に向けては更に知見を深化させる必要がある。

6.　結論

本研究では，網走湖下流の感潮河川域においては，堰倒伏時・堰起立時のいずれも同じ定数の春日屋の式から H-ADCP によって精度の高い流量推定が可能であることが示された。また，経年的な精度管理には，H-ADCP のノイズデータに着目した有効計測幅に留意することが重要であることが示された。

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P6-4

Analysis of Statistical Methods for Water-level Forecasts of Niger Inner Delta in Mali

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Keywords: Niger Inner Delta, water-level, wetland, simulation model

ABSTRACT

Niger Inner Delta (NID) is a wetland that was selected as International Important Wetland under the Ramsar Convention (on February 1st, 2004) still can be considered as a hotspot of biodiversity in the Sahel. The Niger River as main source of water for the NID is also used for urban life and irrigation. Therefore, the sustainable use of water to ensure the environmental flow in the NID is under discussion. In this paper, we evaluate the performance of our model established with Water Balance Method (WBM) and make a comparison with different others approaches for the NID water-level forecasting. The result show that our WBM model present a good result very close to the Levenberg Marquardt Artificial Neural Network which is the best and much better than Multilinear Regression and Gaussian Process Regression models.

1. INTRODUCTION

For many decades, water shortage has been a dire problem for millions of people living along the southern fringe of the Sahara Desert [1]

The Niger river take its source on the Fouta Djallon Mountains in the South of Guinea (West Africa), it flows Northeast through the Upper Niger basin and enters the Niger Inland Delta (NID) in Mali with a large floodplain ranging from 30,000 to 40,000 km2 along the Niger River in Mali [2] (See Fig 1).The annual flooding of large alluvial plains is a vital resource for many ecosystem services, including agriculture, livestock, groundwater recharge, and biodiversity(see Fig 2). The rapid expansion of irrigation upstream, by the diversion dams on Niger river and its subsidiary (Bani), have a significant impact on the Water-Level (WL) in the DIN downstream [3].

The main objective of this study is to develop stochastic and deterministic statistical models for the Niger Inner Delta Water Level forecasting and make a comparison between these different Models. The evaluation and forecasting of Water-Level Fluctuation (WLF) is increasingly important for the NID owing to its close relation to human living & production, and socio-economic & environmental sustainable development.

2. STUDY AREA AND DATA SOURCE

Beyond the town of Ségou, the Niger River forms a vast inland delta (41,800 km²); it joins with its main tributary, the Bani, at Mopti and then forms several lakes. The watershed area of this Inner Delta covers 130,000 km² [15]. The NID is extremely flat and contains many lakes and streams of varying morphology. The altitude of the river bed decreases only by approximately 10 m over the 350 km between the entry and exit of the delta [5]. For the purpose of this study the data are from different sources: The Niger river flow at Mopti and the Water Level at Akk are from the Malian Government Hydraulic Service, the meteorological data are from Mali-Meteo & Atmospheric Science Data Center (NASA)

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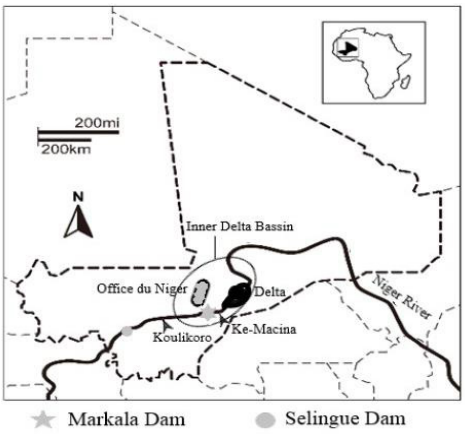

Figure 1: The Niger Inner Delta in Mali



Figure 2: NID during dry season(Source Google)

3. METHODS

The most common methods for river flow and WL forecasting is the application of physical, conceptual and/or statistical rainfall-rainoff methods [4], [5], [6]. In recent years the Artificial Intelligence (AI) as a modern approach for data series analysis have received a great attention for hydrology modeling like Artificial Neural Network (ANN), Adaptive Neuro-Fuzzy Inference System (ANFIS) [4], [7], [8], [9], [10], [11], [12], [13],.

3.1. Water Balance Model (WBM)

The water depth in the NID may be obtained as follow:

$$\boldsymbol{H_{i+1} = Max(H_i + (Q_{i+1} - Q_{out})\frac{D}{A_1} + \left(R_{i+1} - ET_{0_{i+1}} D\right)\frac{(A_1+A_2)}{A_1}, \gamma)} \quad (3.1)$$

The outflow Q_{out} is $\boldsymbol{Q_{out} = \beta Max(H_i, 0)^{\alpha}}$ **(3.2)**

The wet soil area is given as $\boldsymbol{A_2 = \delta\sqrt{A_1}}$ **(3.3)**

Time, monthly maximum inflow from Mopti station upstream (Q_i), monthly rainfall (R) the daily potential Evapotranspiration (ET_0), the number of month day (D), pond water surface (A_1) data was fed into the spreadsheet. To estimate the maximum Water Level (H_i) at various time steps using the equation 3.1 based on the parameters α, β, γ and δ.

3.2. Multiple Linear Regression (MLR)

As opposed to simple linear regression models, which describe the linear functional relationship between a single explanatory variable X (inflow, Rainfall, ET_0) and the response variable Y (NID Water-Level), multiple linear regression models comprise the use of a collection of explanatory variables for describing the behavior of Y [15]. In formal terms $\boldsymbol{y = \beta_0 + \sum_{j=1}^{k} \beta_j x_{ij}}$ (3.4)

Parameter estimation in multiple linear regression is based on the least squares methods.

3.3. Artificial Neural Network (ANN)

An artificial neural network (ANN) is a non-linear black box statistical approach [11], its main objective is to find the optimum architecture of an ANN that can model the relationship between input and output variables. The most commonly used ANN structure is the feed-forward multilayer perceptron (MLP). It is a network formed by simple neurons called perceptron. The perceptron computes a single output from multiple real-valued inputs by forming combinations of linear relationships according to input weights and even nonlinear transfer functions [4].

Mathematically, the MLP can be express as:

$$\boldsymbol{y = f(\sum_{i=1}^{n} w_i p_i + b)} \quad (3.5)$$

The previous studies indicated that the Lavenberg-Marquardt algorithm produces reasonable results for most ANN application [17], [4]. For the present study we considered the three algorithms available in Matlab: Lavenberg-Marquardt (LM), Bayesian Regularization (BR) and Scaled Conjugate Gradient (SCG) algorithms.

3.4. Gaussian Process Regression (GPR) Model with Matlab Regression Learner

Gaussian process regression (GPR) models are kermel-based probabilistic models [16].

A linear regression model is of the form:

$$\boldsymbol{y = x^T \beta + \varepsilon} \quad (3.6)$$

Where $\varepsilon \sim N(0, \sigma^2)$. The error variance σ^2 and the coefficient β are estimated from the data. A GPR model explains the response by introducing latent variable, $f(x_i),\ i = 1,2,\ldots n$, from a Gaussian Process (GP), and explicit basis functions, h

4. RESULTS

The results of the different models develop in this study. use the data from 1960 to 2010 (the inflows from the NID inlet station at Mopti, the Water-Level of NID in the middle station located at Akka and the meteorological data from Mopti station (Fig.3). To evaluate the models, Correlation Coefficient (CC), squared R (R2) and Root mean squared Error (RMSE) were used (Table 2). The monthly data from 2011 to 2015 were used to evaluate each of the models; the result is shown in table3. The plot of the monthly maximum WL (Hmax) variation for different models is shown in figure 2.

Appendix: *About discussion conclusion and reference, we would like to show them at the presentation place.*

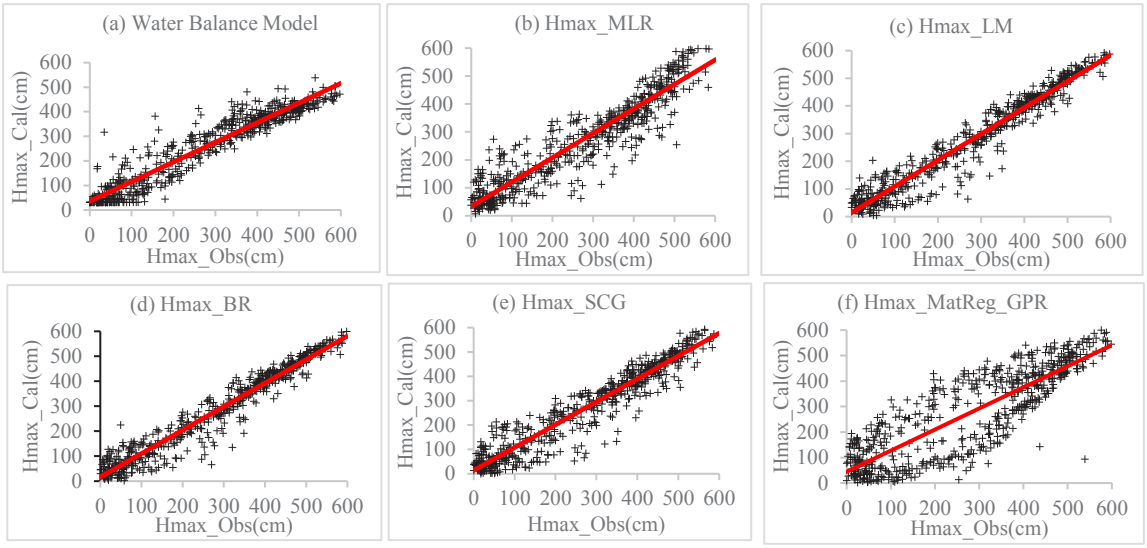

Figure 3: Scatter plots of observed versus modelled Water Level. (a) Water Balance Model (WBM), (b) Multilinear Regression model. Stochastic models: (c) Levenberd Marquardt ANN, (d) Bayesian Regularization ANN (e) Scaled Conjugated ANN, , (f) Gaussian Process Regression,

Table 1: Models validation statistics (1960-2010)

N	*Model*	*CC*	R^2	*RMSE(cm)*
a	Hmax_WBM	0.95	91%	60.00
b	Hmax_MLR(exce	0.93	87%	65.02
c	Hmax_LM	0.97	94%	41.47
d	Hmax_BR	0.97	89%	59.00
e	Hmax_SCG	0.96	92%	52.05
f	Hmax_Mat_GPR	0.85	93%	46.88

Table 2: Models test statistics (2011-2015)

Model	*CC*	R^2	*RMSE(cm)*
Hmax_WBM	0.96	93%	39.88
Hmax_MLR(exce	0.96	92%	46.68
Hmax_LM	0.97	95%	38.36
Hmax_BR	0.97	95%	38.20
Hmax_SCG	0.96	92%	46.99
Hmax_Mat_GPR	0.87	75%	83.76

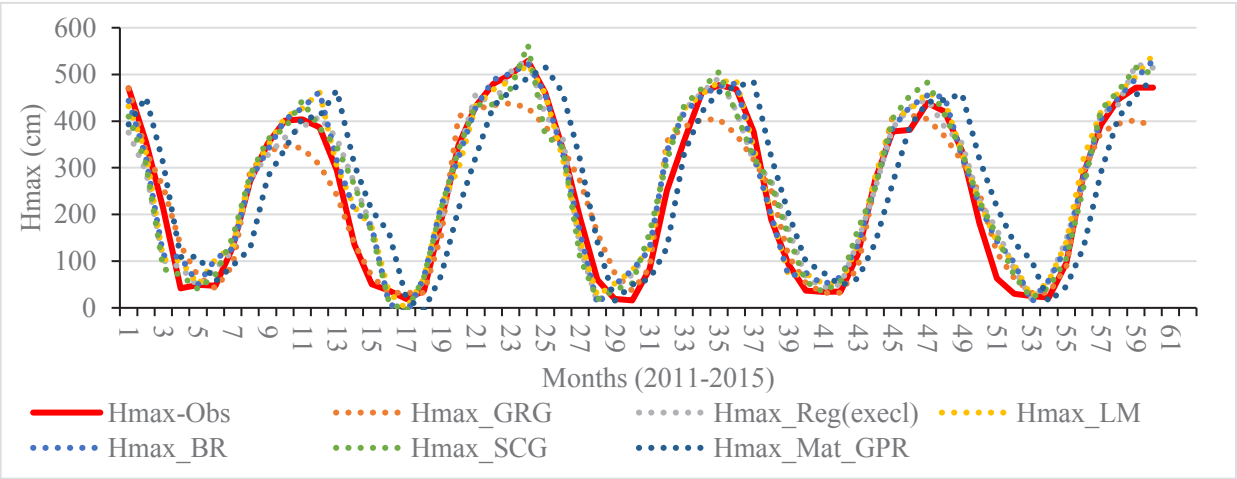

Figure 4: Monthly Maximum Water Level Fluctuation for different models

P6-5

効率的・効果的な湖沼管理に向けた河床変動メカニズムの分析・調査

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キーワード：土砂移動調査，湖沼環境管理

抄録

小川原湖は，ヤマトシジミやシラウオ，ワカサギ等水産資源が豊富な汽水湖であり，青森県経済を第 1 次産業から支える重要な湖であるが，その汽水環境は高瀬川および湖口マウンドを通じた塩水遡上，湖に流入する支川流域からの流入量，洪水による湖内撹乱・塩水希釈・排出等がからみ合う複雑なバランスの上に形成されている．

本調査は，効率的・効果的な湖沼管理に向けて，高瀬川河床変動のメカニズムを分析し，予防保全的な河道・湖沼管理方策を検討していくための基礎資料として，着色砂を用いたトレーサー調査を行ったものである．その結果，下流部（1.4k）に投入した着色砂が満潮時の逆流の流れ等により約 2 週間で中流部まで移動し，さらに冬期間を経て湖口マウンドまで達していることが確認された．

1.　はじめに

小川原湖は，ヤマトシジミやシラウオ，ワカサギ等水産資源が豊富な汽水湖であり，青森県経済を第一次産業から支えている重要な湖であり，その汽水環境は，海域からの塩水遡上，湖に流入する支川流域からの流入量，洪水による湖内撹乱・塩水希釈・排出等がからみ合う複雑なバランスの上に形成されている．

小川原湖と海域は，高瀬川と湖口マウンドと呼ばれる浅水域で結ばれており，洪水の排水を担うとともに，入退潮による湖内への塩水侵入量をコントロールしている．そのため，効率的・効果的な湖沼管理には，高瀬川の河床変動メカニズムを把握することが重要である．

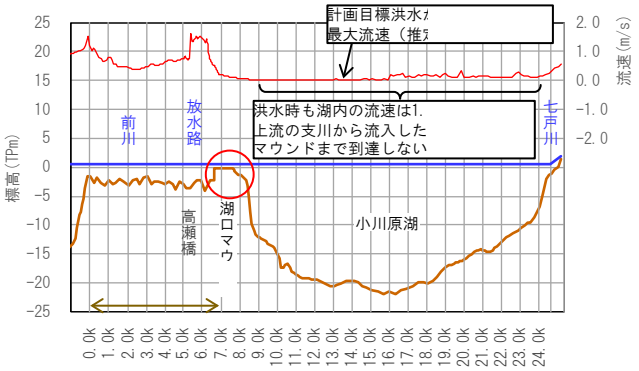

図 1　洪水時流速と高瀬川・小川原湖の河道縦断図

小川原湖は流入支川に対して広大な容積を有しているため洪水時も流速は小さくなる．数値シミュレーションにより，河川整備基本方針目標流量が発生した場合の洪水時流速を推定すると，湖中央部での最大流速は 0.1m/s を下回り，高瀬川や湖口マウンドへの上流からの土砂供給は望めないと考えられる．

横断測量成果を用いて高瀬川河床の経年変化を確認すると，平成 10 年～平成 20 年にかけて高瀬川の河床は急激に低下していることがわかる．この河床低下は潮位が高い期間と連動しており、逆に出水規模と明確な関連性は薄い．

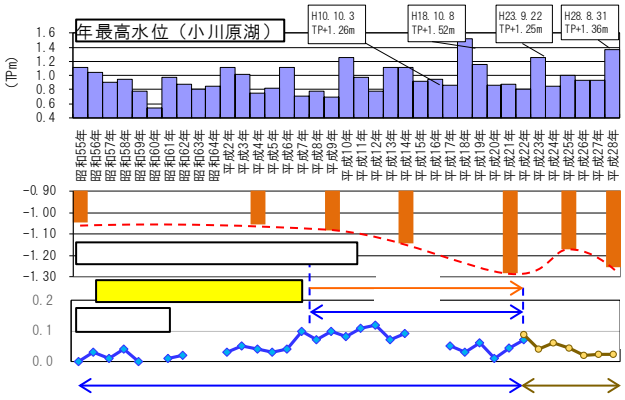

図 2　高瀬川の河床および想定外力の経年変化

高瀬川の河床粒径は 0.3mm 程度（60%粒径）と小さく，日常的な入退潮により発生する流速で容易に移動する河床となっている．

本調査は，海域より高瀬川河口に運ばれた土砂が，冬期の波浪等により高瀬川を通じて湖口マウンドまで運ばれ，湖口マウンドの形状が維持されているものと仮定し，着色砂を用いたトレーサー調査により，土砂移動の実態を把握したものである．

2.　調査地点・期間および調査手法

調査は平成 28 年～平成 29 年にかけて実施した．

着色砂の投入地点は，下流部，中流部，上流部の 3 地点とし，採取地点は投入地点上流を中心に設定した．

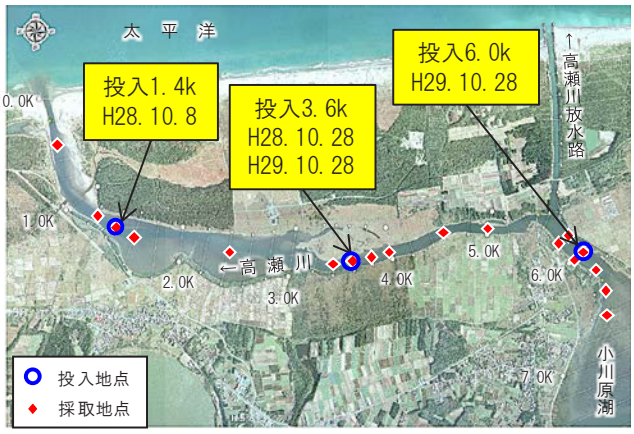

図 3 トレーサー調査地点

平成 28 年調査は，大潮 1 回での移動状況を把握するため，調査期間を 2 週間とした．平成 29 年調査は，前年度調査結果を踏まえ，調査期間を 4 週間に設定した．また，冬期波浪による移動状況を確認するため，春期に前年度に投入した着色砂の採取を行った．

着色砂は作業船より最深河床部に投入し，採取は採泥器を用いて，作業船上から行った．採取位置は，定期横断側線上の最深河床位置とし，平成 28 年度調査は概ね 1.0k 間隔で高瀬川全川（0.0k～6.6k）を調査対象区間とした．平成 29 年度調査は，平成 28 年度調査結果を踏まえ，高瀬川中流の 3.6k より上流区間（～6.6k）を調査対象区間とした．

3. 調査結果

本調査で，高瀬川を通じて湖口マウンドまで，土砂供給がなされていることが確認出来た．

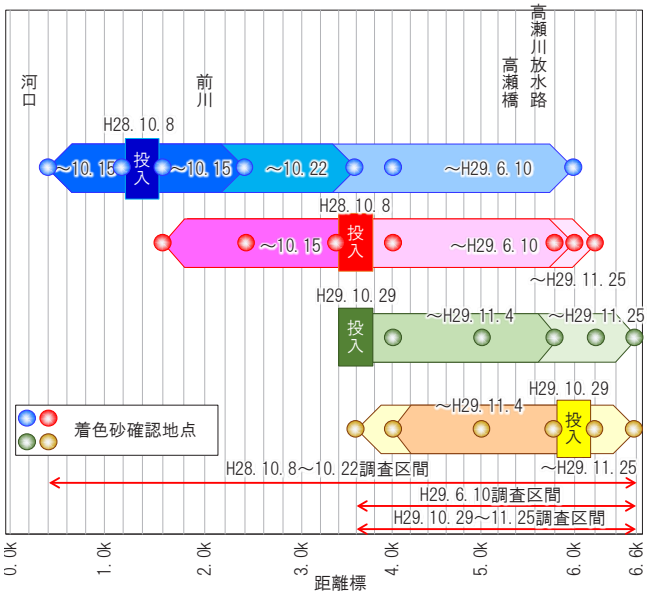

図 4 河床材料移動追跡調査結果

平成 28 年 10 月に投入した着色砂を投入後 2 週間で採取したところ，下流部（1.4k）に投入した着色砂は，上下流方向ともに移動が確認され，上流方向には 3.6k 地点までの移動が確認された．しかしながら，中流部（3.6k）に投入した着色砂は下流方向への移動しか確認出来なかった．平成 29 年 6 月に採取を行ったところ，平成 28 年 10 月に投入した着色砂は，下流部投入砂，中流部投入砂ともに，上流方向 6.0k まで移動していることが確認出来た．

平成 29 年 10 月に投入した着色砂については，3.6k 地点より上流区間のみを採取地点として，移動状況を確認した．その結果，調査地点の上流端である湖口マウンド（6.6k）まで着色砂が移動していることが確認された．

4. 考察

高瀬川河口部の河床材料（漂砂）の構成は 0.1mm～2.0mm であり，高瀬川 1.0k～6.0k 地点および湖口マウンド 7.4k 地点の河床材料構成と概ね一致している．

限界掃流力（岩垣の式）で評価すると，入退潮の掃流力により概ね 0.7mm 以下の粒径が上流に移動し、これも概ね河床の主要な構成材料粒径と一致している。

高瀬川は近年潮位が平均的に高くなったことで，入退潮の流れが大きくなり，河道が広くなった可能性がある．また，海岸施設等の構造物により，高瀬川河口付近に到達する沿岸漂砂が減少していることも考えられる．

入退潮による漂砂の移動・供給により高瀬川の河道が維持されていると考えられることから，今後も潮位や海域からの土砂供給の変化に注視していかなければならない．

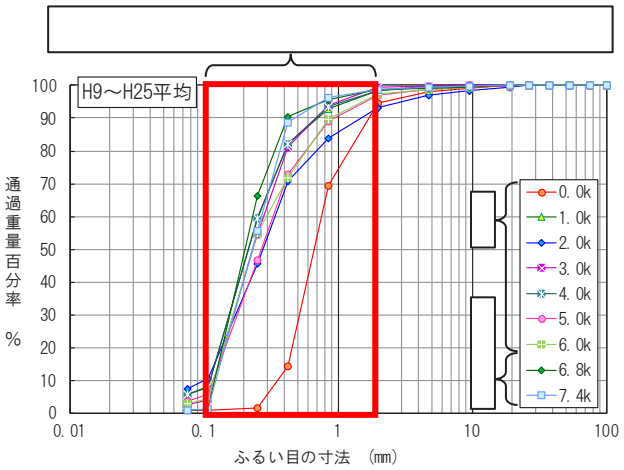

図 5 高瀬川河床の粒度分布

5. 結論

本調査で，高瀬川の河道変化のメカニムの一端が推定された．今後，海域からの土砂供給の実態や河道変化による湖内環境への影響を分析し，予防保全的な河道・湖沼管理に向けた対策を検討していく。

P6-6

農業用排水路の魚巣・魚溜に堆積する土砂の粒度分布

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キーワード: 魚巣, 魚溜, 流砂, データ解析とモデリング

抄録

霞ヶ浦流域内の農業用排水路の魚溜区間を対象として, 魚巣・魚溜内に堆積している土砂と, コンクリート排水路から降雨時に採水した試料中に含まれる土砂の粒度分析を行った. 魚巣内には採水試料中に含まれている比較的小さな粒径の土砂も堆積していた. また魚溜内の堆砂の中央粒径は魚巣のそれより大きく, 細砂から礫までの分布が見られた. 魚巣・魚溜は単調な排水路において多様な堆砂環境を創出していると考えられる.

1. はじめに

我が国の多くの農業用排水路はコンクリート 3 面張りの区間を有しており, 土砂の輸送や堆積が頻繁に起こる自然護岸の水路とは環境が大きく異なっている. コンクリート 3 面張りのような特殊な環境では, そこに適応することの出来る生物種のみが卓越する単純な環境となることが指摘されている[1]. 近年では上記のような状況を鑑み, 農業用排水路においては, 魚巣や魚溜といった環境配慮工が配置されてきた. これらの環境配慮工について, 魚類の利用状況の調査[2]や乱流特性を考慮した流況の調査[3]などはなされているものの, 堆砂に着目した研究はほとんどなされていない. また鵜木ら(2015)[4]は農林地流域での掃流砂, 浮遊砂を観測しているが, 環境配慮工は対象としていない. 本研究では魚巣および魚溜内で採取した土砂と魚溜区間に上流から流入してくる土砂の粒度分析を行い, 環境配慮工における堆砂の粒度分布の特徴を明らかにする.

2. 方法

2.1 調査地概要 対象地は霞ヶ浦流域内の農業用排水路で, 魚巣と魚溜が設置されている. 対象区間は全長約 15m, 魚溜区間が 11m, 魚溜区間内の片岸に 3 つずつ両岸で 6 つの魚巣が配置されている. 魚巣は開口部が縦 1m, 横 1.2m, 奥行き 0.9m である. 魚溜よりも約 100m 上流に水位計, 濁度計, 自動採水器を設置している.

2.2 粒度分析 水路床に堆積した土砂と, 降水時に自動採水器によって採取した土砂を粒度分析した. 粒度分析には島津製作所の SALD-2300 を使用した. 堆積土砂は 2017 年 11 月 16 日に魚巣・魚溜内で採取した試料を, 採水試料は 2017 年 10 月 29 日の降雨時に採水器によって採取した試料をそれぞれ用いた. また, 2017 年 11 月 16 日に対象区間で横断測量を行い, iRIC[5]を用いて路床標高分布を推定した. Fig.2-1 に堆積土砂の採取地点を示す. 堆積土砂の採取は魚巣内 2 地点(N1, N2)と魚溜内 3 地点(P1, P2, P3)の計 5 地点で行い粒度分析をした. また Fig.2-2 に 2017 年 10 月 29 日の流量の変化を示し, 採水のタイミングを○で示す. 採水時の流量は S1 が 2.2m^3/s, S2 が 2.3m^3/s であった. これら 2 つの試料(S1, S2)についても粒度分析を行った.

3. 結果

Fig.2-1 のように, 魚巣の奥には土砂が堆積し, 魚溜の右岸側の魚巣前部では洗掘が見られた. 魚溜上流部(Fig.2-1 赤枠で囲った地点)には直径 5~10cm 程度の礫が堆積していた. 粒度分析の結果, 魚巣内 N1, N2 の中央粒径はそれぞれ 0.438mm, 0.248mm, 魚溜内 P1, P2, P3 の中央粒径はそれぞれ 0.953mm, 0.646mm, 0.643mm だった. また採水試料中の土砂 S1, S2 の中央粒径はそれぞれ 0.00917mm, 0.00300mm だった. Fig.3-1 に各採取試料の粒径の頻度分布を示す. Fig.3-1 から魚巣内には魚溜内と比べ小さな土砂が堆積し, 採水試料中に含まれるような小さな土砂も含まれていた. 魚溜内には比較的大きな土砂が堆積し, 採水試料中に含まれているような小さな土砂は堆積していない. また魚溜内では, 一般的な河川同様, 流下するに従い堆積土砂の粒径が小さくなっていることも確認出来る.

4. 考察

粒度分析の結果から，魚巣内には採水試料中に含まれる土砂が堆積していることが分かった．対象排水路に設置された魚巣は流速を減少させ，滞留時間を長くし，小粒径の土砂を堆積させる能力を有していると言える．また魚溜内には 0.3mm の細砂から 100mm の礫まで様々な粒径の土砂が堆積していた．魚巣内と合わせると実に様々な粒径の土砂が存在しており，コンクリート 3 面張りの排水路において，魚巣や魚溜は多様な堆砂環境の創出に役立っているものと考えられる．

5. おわりに

本研究では魚巣・魚溜を有する農業用排水路を対象として，堆積した土砂と流入土砂の粒度分布を調べた．その結果，魚巣・魚溜のような環境配慮工が路床内に多様な堆砂環境を生み出していることがわかった．

粒度分析にあたって茨城大学広域水圏環境科学教育センターの山口直文先生にご指導賜りました．また一部の図の作成に iRIC ソフトウェアを使用しました．記して感謝の意を表します．

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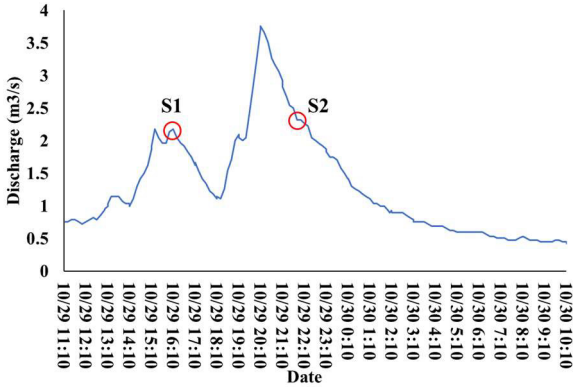

Fig.2-2 10/29~10/30 の流量の変化と採水時点

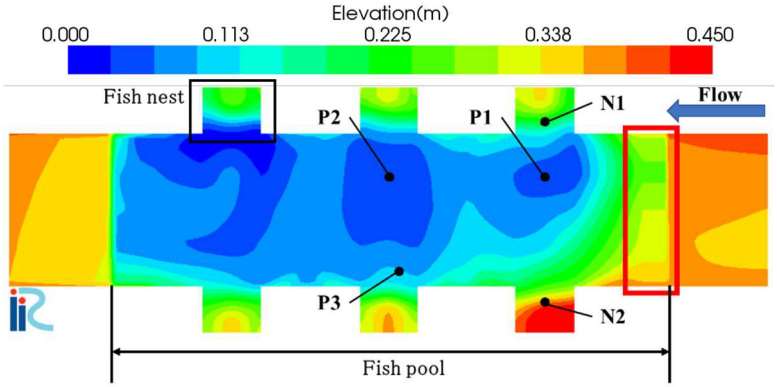

Fig.2-1 対象区間の路床標高と採土地点

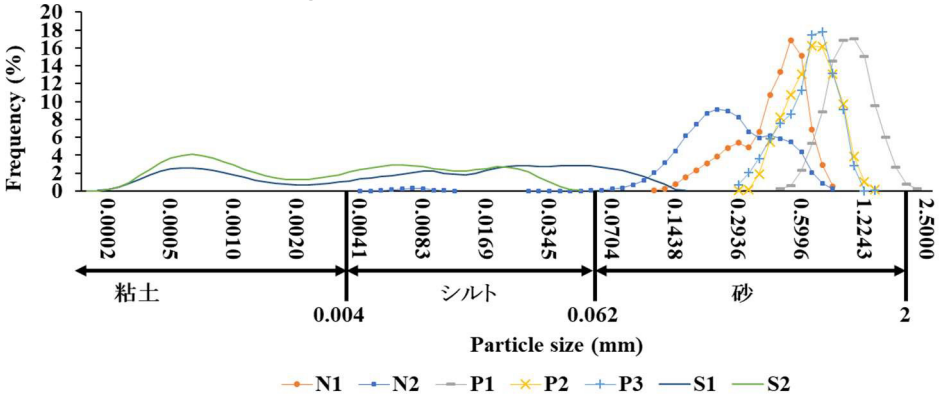

Fig.3-1 各採土試料の粒径頻度分布

P6-7

Assessment of Harmful Cyanobacteria Growth Potential based on Hydrodynamic Modelling

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Keywords: harmful cyanobacteria, growth potential, EFDC, streambed sediment, hydrodynamic modelling

ABSTRACT

This study was conducted to assess harmful cyanobacteria growth potential based on hydrodynamic modelling with EFDC (Environmental Fluid Dynamics Code) in Bukhan river (Korea) through culture experiments using streambed sediment. Akinetes of cyanobacteria have settled down on the streambed sediment in areas of low water velocity. We monitored the five sites where particles are likely to deposit due to slow flow rate from result driven by hydrodynamic analysis. Akinetes or resting cells are estimated to be germinated or recruited from streambed sediment in April/May when environmental conditions such as flow rate and residence time are appropriate, and it is considered that they are deposited into streambed sediments after September when water temperature decrease.

1. INTRODUCTION

Cyanobacteria have ecological characteristics such as forming resting cell or akinete when they are not in favorable environmental conditions, which sink to the lake bottom[1]. Sedimentation of particles is related to hydraulic characteristics such as flow rate of water body, and is likely to be deposited at a slower flow rate. The Ministry of Environment has operated the harmful algae alert system by designating the cyanobacteria belonging to four genera of *Anabaena, Microcystis, Aphanizomenon,* and *Oscillatoria* as harmful cyanobacteria and makes a lot of efforts to prevent the algal blooms. The main objective of this study is the assessment of potential harmful cyanobacterial blooms in Bukhan river (South Korea), based on hydrodynamic modelling through culture experiments designed using riverbed sediment.

2. METHOD

2.1 EFDC-based hydrodynamic modelling

Numerical model constructed in the study conducted by the National Institute of Environmental Research in 2016 was used to analyze the hydrodynamics of the Lake Paldang[2]. The numerical model was developed based on the EFDC(Environmental Fluid Dynamics Code) model, which was originally developed at the Virginia Institute of Marine Science and is continuously managed and developed under the support of US EPA and Tetra Tech. Inc. EFDC is applicable to various water systems including the river, lake, wetlands, estuaries and reservoirs[3].

A hydrodynamics was analyzed for about 23 km from Cheongpyeong Dam to the Lake Paldang. Analytical lines and points are selected as shown in Fig. 1 considering the followings.

- the water level gauge or water quality monitoring station is located.
- hydraulic dead zone is expected caused by wetlands, hydraulic structure and etc.
- mainstream impacts(discharge, velocity, water quality and so on) from tributary inflows are expected.

From numerical simulations of 2014 and 2015, hourly hydraulic data of selected analytical lines was extracted.

2.2 Harmful cyanobacteria growth potential

From April to November of 2017, riverbed sediments were sampled once a month using core sampler, and 30L of the surface waters of the site were filtered with a phytoplankton net(mesh size 20μm). Species identification was carried out using an optical microscope with a Lugol's iodine preservative solution.

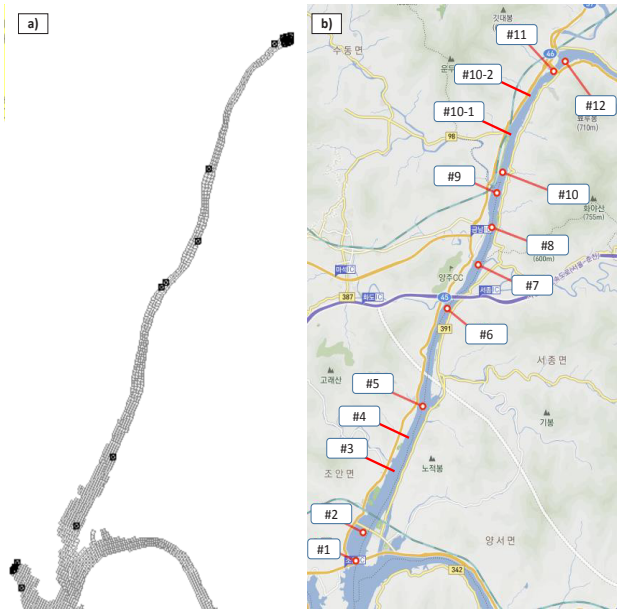

Fig. 1 a) EFDC grid, b) Location of each section

The sediment was cut into top to 5 cm, and after mixing equally, 75 g of sediment was mixed with 150 mL of BG11 cyanobacterial medium, and the mixture was treated with ultrasonic grinder for 30 seconds twice and then cultured for 7 days at a temperature 25 ℃, a luminous intensity of 40 μmol/m^2·S and light period 16(L):8(D) as shown Fig. 2.

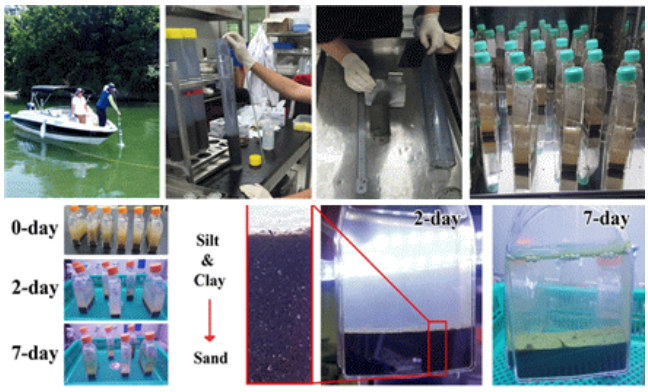

Fig. 2 Harmful cyanobacteria growth potential test for sediment

3. RESULTS

3.1 EFDC-based hydrodynamic modelling

In line #12 and line #11, the average annual flow rate of about 10~27 cm/s appears due to discharge of the Cheongpyeong Dam. The influence of discharge of the Cheongpyeong Dam gradually decreased as shown in Fig. 3, average annual flow rates from line #10-2 to line 1 below about 5 cm/s were calculated. The deviation of the velocity between left bank and right bank occurred significantly in four sections (line #12, line #7, line #2, line #1) except for the other sections. The average monthly flow rate was about 5 cm/s except during flood season, June to August.

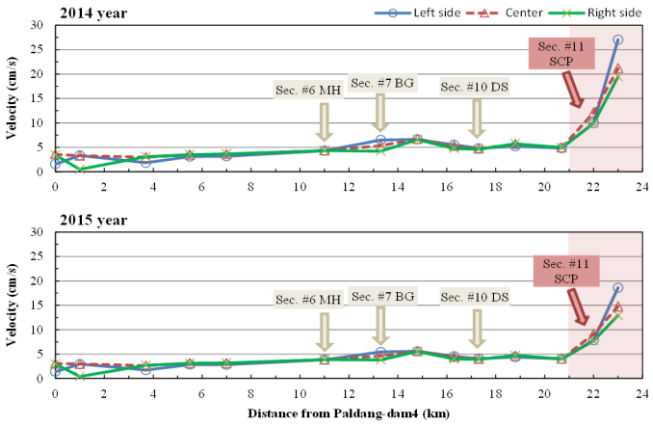

Fig. 3 Sectional mean velocity for each point

Based on the results of the hydraulic analysis described above, five sites after confluence of Mukhyun stream were selected as the monitoring sites with high possibility of harmful cyanobacterial blooms as shown in Fig. 4. The monitoring sites are MS(confluence of Mukhyun stream), SB(Sambong), SS(confluence of Sambong stream), SC(Songchon sewage treatment plant discharge point), and P4(Lake Paldang confluence area).



Fig. 4 Monitoring sites of sediment and phytoplankton

3.2 Harmful cyanobacteria growth potential

Experiment of potential growth of harmful cyanobacteria by riverbed sediment cultivation showed that 8 species of harmful cyanobacteria such as *Anabaena, Microcystis, Aphanizomenon* and *Oscillatoria* were geminated. The abundance of harmful cyanobacteria that occurred from sediment cultivation at each site ranged from 106 to 3,913 cells/mL in April, the highest in P4, and in May from 37 to 547 cells/mL. The average abundance in May at all monitoring sites decreased to 12.9 % from April. From June to August, abundance of harmful cyanobacteria was low at around 200 cells/mL at all sites, and was significantly increased at SC and P4 sites from September, reaching 21,024 cells/mL at SC in November (Fig 5). The pelagic harmful cyanobacteria rarely appeared below 10 cells/mL at all sites in April, started to increase from May and was highest abundance at MS. The potential for growth of harmful cyanobacteria in riverbed sediment was highest at SC.

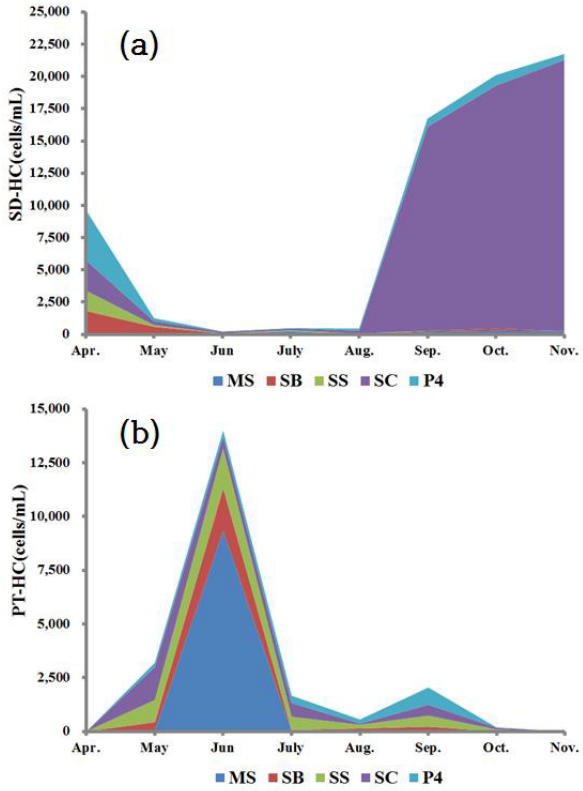

Fig. 5 Standing crop of harmful cyanobacteria in Lake Paldang (SD-HC: Sediment Harmful Cyanobacteria; PT-HC: Planktonic Harmful Cyanobacteria)

4. DISCUSSION

The harmful cyanobacteria are estimated to be germinated from streambed sediment in April/May when environmental conditions such as flow rate and residence time are appropriate, and it is considered that they are deposited into streambed sediments after September when water temperature decrease.

5. CONCLUSION

From this study, it is possible to predict the site where the possibility of blooming of cyanobacteria is high and to manage preliminary harmful cyanobacteria through riverbed sediment management.

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P6-8

Simple and reliable Biological Monitoring of Lakes for Sustainable Services

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Key words: Biological Monitoring, Multiple Water Uses, ecological succession and ILEC format.

ABSTRACT

Continuous monitoring of water bodies for multiple use such as drinking, fisheries, Horticulture, Agriculture, wildlife and Recreational activities are essential for the sustained quality of life.. Changing land use pattern in both urban and rural settlements in India are at the cost of water bodies and open spaces. Biological monitoring of water bodies using desmids, chlorococcales, diatoms and euglenoids are established methodologies which are cost effective, reliable and indicates ecological succession of water bodies. In this paper Chikkarasinakere in Maddur Taluk, Mandya district of Karnataka state, India has been monitored for four months in 2015 using phytoplanktons along with physicochemical parameters. The water quality has been assessed using Pearson's correlation matrix for physicochemical parameters and CCME WQI for biological monitoring of the water quality. Seasonal variations in the physicochemical and plankton diversity were observed. The abundance of diatom *Navicula cryptocephala* indicates organic pollution while *Synedra ulna* and *S. acus* are indicators of anthropogenic pollution. The water quality of the lake has been classified as poor for overall purpose such as drinking, aquatic and recreation and marginal for irrigation and livestock use. It is suggested that ecological succession of water bodies can be rapidly assessed by using micro biological parameters.

1. INTRODUCTION

Changing land use pattern in both urban and rural settlements in India are at the cost of water bodies and open space. Continuous monitoring of water bodies for multiple use such as drinking, fisheries, Horticulture, Agriculture, wildlife and Recreational activities are essential for the sustained quality of life to meet its functional needs. Phytoplanktons have long been used as indicators of water quality. Because of their short life span and quick responses to changing environmental changes their species composition indicate the quality of water in which they are found. Clean water supports a great diversity of organisms whereas very few organisms survive in polluted water with one or two dominant forms. As species composition of phytoplankton communities change in response to environmental variations, long term studies of plankton component in relation to fluctuations of water quality parameters are useful in developing and evaluating significant water resources for multiple uses. (Roy and Chattopadhyay, 2007)

Biological monitoring of water bodies using desmids, chlorococcales, diatoms and euglenoids are established methodologies which are cost effective, reliable and indicates ecological succession of water bodies. In this paper Chikkarasinakere in Maddur Taluk, Mandya district of Karnataka state, India has been monitored for four months in 2015 using phytoplanktons along with physio--chemical parameters. The lake has a catchment area of 105 hectares with maximum depth of 10 meters when full. The Cauvery river feeds the lake through a channel. The lake water is used for irrigation and villagers use it for domestic purpose and cattle rearing.

2. METHOD

. The water quality has been monitored for physio-

chemical parameters for four months in 2015 following the method of APHA (1985). Correlation of various paramenters were done using Pearson's correlation matrix. To analyze the phytoplanktons water samples were collected form surface water at various places and preserved by the method described by Welch (1948) .The water quality Index of the lake has been done using CCME WQI

3. RESULTS

Seasonal variations in the physic-chemical and plankton diversity were observed. During the month of February, color positively correlates with sulphate, while in March Color positively correlates with fluoride and negatively correlates with DO and fluoride negatively correlates with sulphate. In April, sulphate positively correlates with DO. During May, pH positively correlates with color and temperature while iron shows negative correlation. Similarly colour negatively correlated with iron, phosphate and alkalinity negatively correlates with COD. .Among the phytoplanktons, the diatoms were the most predominant forms in all the four months. The abundance of diatom *Navicula cryptocephala* indicates organic pollution while *Synedra ulna* and *S. acus* are indicators of anthropogenic pollution. The water quality of the lake has been classified as poor for overall purpose such as drinking, aquatic and recreation and marginal for irrigation and livestock use.

4. DISCUSSION

There are eight core parameters such, as Temperature, pH and eighteen general parameters such as chemical species in physio-chemical analysis of lake water. It is inferred that biological monitoring using indicator species gives a definite indication on the health status of the water body. Further, a policy frame work for continuous monitoring of water bodies using biological parameters is found essential.

P6-9

Ecological Health Assessment of Loei River and Tributaries by using aquatic insects under river continuum concept

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Keywords: river continuum concept, aquatic insects, Ecological health assessment and Loei River

ABSTRACT

The study is aimed to investigate the environmental factors that influenced the living organisms based on functional feeding groups from the upstream to downstream in Loei River. The study sites were selected to 10 sites based on the impact of human activities along the river. The sampling were collected from February to June 2017 to represent all three seasons. A total of 27,702 individuals, belonging to 112 Families in 9 orders of macroinvertebrates were found. The most number of individual was mayfly in order Ephemeroptera, family Baetidae. The River Continuum Concept analysis of Functional Feeding Groups (Collector, Grazer, Predator and Shredder) based on principle of The River Continuum Concept indicated that the proportion of Functional Feeding Groups from separation the study sites including 1 to 3 (Upstream), 4 to 8 (Midstream) and 9 to 10 (Downstream). Therefore, the Ecological Health of Loei River is moderate to good level. In addition, there are also correlations in the statistical analysis based on changes in biological, physical and chemical in each month.

1. INTRODUCTION

At present this has rising of the population and economic in the world. Accordingly, the passion to demand the water resource has increased all sectors. As a result, there is the risk to the crisis be highly probable of the water resource in the world. In addition, global warming and climate change. The average temperature of the earth's surface that increases and the global average sea level that rising [1]. These the cause above has an effect on the freshwater resource in the world to decrease.

Loei River at Loei province, Thailand. This is main the tributaries of Khong River. Consequently, Loei province has many human activity such as industries, agricultures, communities and usable area. As Loei River had interested to research about the water quality measurement by The River Continuum Concepts or RCC.

The River Continuum Concept or RCC is a conceptual model that predicts biological community responses to physical changes along the lengths of rivers. [2] As a river changes from headstream to the downstream, there will be a change in the relationship between the production and consumption. This one organism that interested in the river is benthic macroinvertebrates by functional feeding groups (FFGs). [3] Benthic macroinvertebrates are often utilized in studying the biological responses of the system because they clearly reflect changes in food resource availability in relation to stream size. [2]

In this study, we describe longitudinal variation in benthic macroinvertebrates community structure of Loei River. Because there has length river is 231 km [4] that this is appropriate for study along river. And Loei riverside areas has many human activity as a results to this has effect to change the community of benthic macroinvertebrates or not? The results it is the benefit for populations to development the RCC to base data for water quality measurement or knowledge for youth. These things will make to cause awareness them water resource and environmental for used in the future not endless.

2. METHOD

a. study areas

Benthic macroinvertebrates, chemical parameters and Physical parameters was collected at 10 study sites (Figure 1) along Loei River between 231 km by divided the river into 3 parts (1-3 study sites was Upstream, 4-8 study sites was Midstream, 9-10 study sites was Downstream) [2].

b. sampling

Sampling took place on March May and July 2017. Macroinvertebrates were collected by D-frame net (weight 30 cm cross size, 500 μm mesh size), Surber sampler and Sampler. Sampling duration was 1 min/point. D-frame net and Surber sampler was repeated the collect to 3 times/bank (left and right) by Kick-sampling (the D-frame was

used on high water level and this area had cover by the water plant around riverside. Surber sampler was used on low water level until saw the substrate). Current pH, velocity, total dissolve solid, conductivity, dissolve oxygen, temperatures (water and air) were measured in field. In addition, water sample were collected to measure biochemical oxygen demand, nitrate-nitrogen, ammonia-nitrogen, orthophosphate, identified macroinvertebrates in laboratory.

c. statics

Analyzed of River Continuum Concept: RCC [2] by Functional Feeding Groups: FFG [5] on upstream (site 1-3), midstream (site 4-8) and downstream (site 9-10) from amount of benthic macroinvertebrates samples. According, Pearson's correlation was calculated between chemical-physical parameters with parts of stream and benthic macro-invertebrates. The significant of this relationship between chemical-physical parameters with each month of sampling the samples.

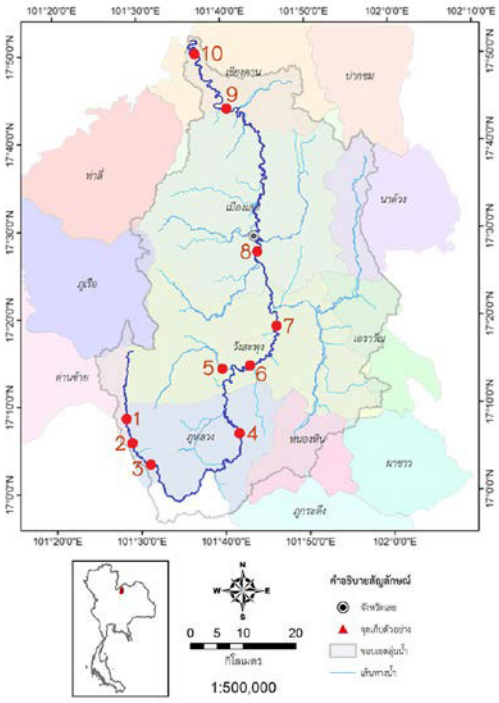

Figure 1: The coordinates of 10 study sites

3. RESULTS

In March was used represent to be dry season and May, July this both months represent to be wet seasons because those it was heavy flooding and flash flood between the sampling samples. As a result to important point this was used changing the value about chemical-physical parameters together with the macroinvertebrates community.

The individuals results of benthic macroinvertebrates part. The highest of the number is 21,939 (Family Chironomidae). This had 4,929 individuals. On May the highest of the number is 842 individuals (Family Tubificidae). And July the highest of the number is 489 individuals (Family Baetidae). Diversity of each month on March at upstream this had the highest, downstream and downstream respectively. Whole along river this was the highest of percentile is 61% in collector, grazer 22% , predator 14% and shredder 3% respectively. The upstream in March, May and July. The result of Functional Feeding Groups (FFGs) this was the highest is collector 48%, grazer 36%, predator 11% and shredder 5%. Range of midstream was found collector 60%, grazer 20%, predator 18% and shredder 2%. Downstream was found collector 79% , predator14%, grazer 6% and shredder 1% respectively.

The relationship between months of sampling (March, May, and July 2017) with ranges of stream (upstream 1-3, midstream 4-8 and downstream 9-10) was calculated by Pearson's correlation. That months was used on intensity, BOD, NH_3-N and orthophosphate parameters as not have relationship. According, another parameters are water temperature, velocity, conductivity, TDS and Turbidity was separated as 2 groups are May, July (1) and March (2). The relationship result between macro-invertebrates with parameters as not relationship. Results of ANOVAs of environmental factors (intensity, water temperature, velocity, conductivity, TDS and turbidity) of different ranges river (May, July (1) and March (2)) are significant difference ($p < 0.5$).

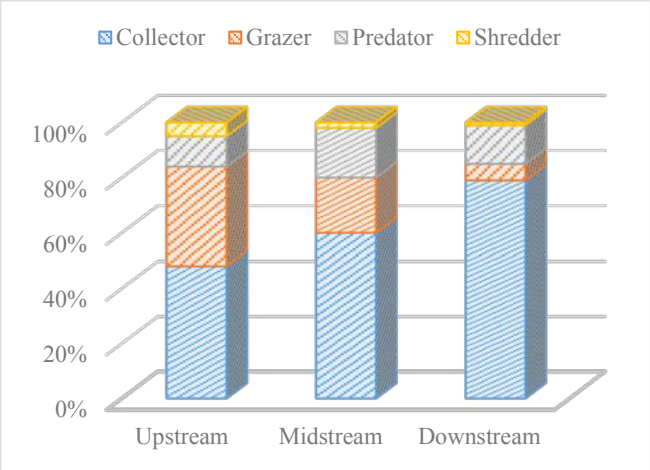

Figure 2: The proportion of FFGs

4. DISCUSSION

Shredders are an important ecological guild in headwater streams, playing a vital role in the process of leaf litter decomposition [6]. Che Salmah et al. (2013) documented a higher proportion of shredders (18.22% of total macroinvertebrates) in Malaysian forest headwater streams [7]. Shade conditions and substrate are important factors for shredder habitat. Our results were found the

proportion of shredder and grazer to decreasing from upstream to downstream. This conform to the study of Lan Fu et al. (2016) that Shredders decreased and collector-filterers increased significantly, as predicted by the RCC [8]. According to the RCC, relative collector abundances should stay around 50% in the sampled portions of Quebrada Máquina [2].

Many collector-gatherers are tolerant to disturbance and organic pollution, such as Tubifex spp., Limnodrilus spp., Branchiura sp., and Chironomidae and abundant in polluted rivers [8]. However, predator populations only depend on the relative abundances of the other functional groups. Therefore, no matter how the grazers, shredders and collectors respond to resource availability, the relative predator population should stay the same [2]. So the results of this study show on midstream to downstream where have human activity to increase followed by land use. The number of Family Chironomidae this increased that according to above reasons and FPOM that have increase decomposition from upstream.

However, May and July this both months was flooding from heavy rain during sampling the samples. This factor is effect to changing chemical-physical parameters and drift the macroinvertebrates. So the result this shown to clearly separate into 2 groups are represent for dry season and wet season. But those factors did not relationship community of macroinvertebrates for Ecological Health Assessment of Loei River and Tributaries.

5. CONCLUSION

The river continuum concept (RCC) at Loei River and Tributaries accord with our results by increasing of the benthic-macroinvertebrates proportion. So this show to The Assess the Ecological Health of the Loei River under the River Continuum Concept (RCC) on March 2017. This the valuation to abundance river condition. The flooding is the most importance factors for inconstant to chemical, physical and biological determinants on May and July 2017.

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P6-10

Spatio-Temporal Evaluation of Flood Impacts on Wetland Vegetation using Remote Sensing

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Keywords: wetland, remote sensing, spatial assessment, spectral indices

ABSTRACT

Increase in sediment yield and nutrient-rich water in Kushiro Mire has intensified the vegetation in the area. Because of this, the wetland is becoming arid. It is therefore necessary to understand the preservation of wetland. As flood is relevant on the wetness condition of the wetland, preliminary investigation using satellite remote sensing data was conducted to spatially investigate the response of surface conditions to flood. Landsat 8 OLI TIRS and MODIS data utilized bands to acquire information on its conditions using the reflection and absorption to sunlight on the surface. This study aims to evaluate the response before and after extreme flood event. The variation of the surface condition response was quantified using spectral indices. The results show that there is a significant difference of response of the vegetation between non-flood and flood periods spatially. The results can provide helpful preliminary assessment for planning the restoration of Kushiro wetland.

1. INTRODUCTION

Wetlands play a significant role in the hydrological cycle, influencing groundwater, evaporation, water retention and flood control and protection. [1] Wetland ecosystem has been habitat for an enormous diversity of plants and animal species. In Kushiro wetland, it has been the home to the red-crowned crane, a special natural monument, and, the Japanese huchen, which is Japan's largest freshwater fish, and other rare organisms.

The Kushiro Mire is the largest wetland area in Japan with 18,290 ha in area. [2] It was discussed at the Ramsar Convention the importance of preserving the biodiversity of the Kushiro Mire wetlands. [3] The wetland mostly consists of fen covered with reeds and sedge grasses, and portions of the wetland are areas with sphagnum moss. It is covered with alder woodlands in the northern part of the wetland. [4]

The increase in sediment yield and nutrient-rich water in the wetland from the upper reach is due to development in the surrounding land, riverbed degradation and deforestation. With this, the number and density of alder trees have increased because the sedimentation and accumulation of soil favor its growth. [5]

Present issues raise in the wetland becoming arid, thus it is important to understand the preservation of the wetness of the wetland.

In August 21, 2016, flood event happened that inundated the Kushiro wetland. This flood event contributed relevantly on the wet condition of the wetland. As vegetation has largely influence in determining the wetland increase of land area, it is important to investigate also on how vegetation responded to flood events and determine the impact on the restoration of the wetland.

In-situ observations of the surface conditions is very relevant for wetland assessment, however, it is tedious to have field evaluation to assess a large area with various land cover types. Thus, wetland assessment using remote sensing data have been used for rapid evaluation.

Several case studies proposed application of remote sensing data in spatial assessment and classification of the alder tree and other vegetation in Kushiro Mire. [5,6,7] These studies have proposed different methods of vegetation classification on the wetland. It was determined in these studies that there is a dramatically increased in vegetation over time. However, there has been no studies on the spatial evaluation of the surface conditions and flood impacts on the vegetation of Kushiro wetland using remote sensing.

Thus, this study aims to evaluate the response of the wetland vegetation before and after flood events which is significant for planning of restoration of the wetland.

2. DATA AND METHODOLOGY

Remotely sensed data was utilized to have preliminary assessment of the land surface condition of the wetland. This study applied two remote sensing data. Landsat 8 data at 30-meter spatial resolution consist of sensors, the Operational Land Imager (OLI) and the Thermal Infrared Sensor (TIRS) which collect nine spectral bands and two thermal bands and Moderate Resolution Imaging

Spectroradiometer (MODIS) provides bands 1 (620–670 nm), 2 (841–876 nm) at 250-meter resolution in an 8-day gridded level-3 product in the sinusoidal projection.

Remote sensing provides information in the reflection and absorption to sunlight on the surface which also acquires information on its conditions.

Table 1 Equations used for evaluating surface conditions

Index	Equation	Definition
Normalized Difference Vegetation Index (NDVI)	$NDVI = \frac{NIR - Red}{NIR + Red}$	NDVI quantifies vegetation.
Normalized Difference Soil Index (NDSI)	$NDSI = \frac{SWIR - NIR}{SWIR + NIR}$	NDSI examines the soil conditions
Normalized Difference Water Index (NDWI)	$NDWI = \frac{Green - NIR}{Green + NIR}$	NDWI maximizes the reflectance properties of water.

These indexes provide information to determine the change of surface conditions of the wetland before and after flood.

3. RESULTS AND DISCUSSION

The impact of flood inundation on vegetation was determined on the peak date of the significant flood of Kushiro river as basis for the selection of remotely sensed images. On September 16, 2013 with peak discharge of 318.19 m3/s and August 21, 2016 with peak discharge of 469.10 m3/s were selected.

It is an important information to know wetland surface condition, to know the area of the concentration of the wetness condition of the wetland.

Fig. 1 shows the spatial distribution of the moisture of the ground after and before flood event based on NDSI. Dark brown relates with greater soil reflectance. Furthermore, in Fig. 2 shows the spatial distribution of water content in the surface of the wetland based on NDWI. Cooler color represents higher water content. It is shown in this visual information that in the central wetland shows the concentration of changes in soil and water conditions.

In the flood event, it is expected that flood inundation would bring significant influence on the growth of the vegetation. The variation of the vegetation response was quantified using NDVI. In order to investigate the impact of flood inundation on vegetation, non-flood period and flood period was compared.

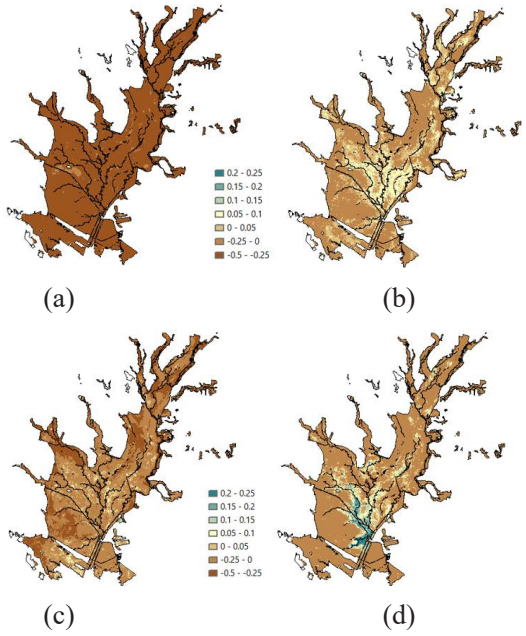

Fig. 1 NDSI spatial distribution (a) before 2013 flood (08/02/2013) (b) after 2013 flood (10/12/2013) (c) before 2016 flood (06/07/2016) (d) after 2016 flood (10/02/2016)

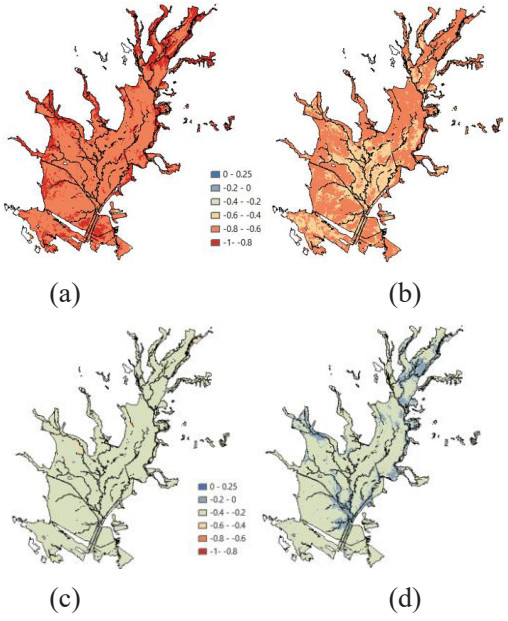

Fig. 2 NDWI spatial distribution (a) before 2013 flood (08/02/2013) (b) after 2013 flood (10/12/2013) (c) before 2016 flood (06/07/2016) (d) after 2016 flood (10/02/2016)

Based on the flow data, the non-flood period is selected. NDVI during non-flood period shows a variating trend on the vegetation as shown Fig 3. However, the NDVI index values are maintained in the positive values between 0.3 to 1, much it implies the dense vegetation canopy during non-flood period.

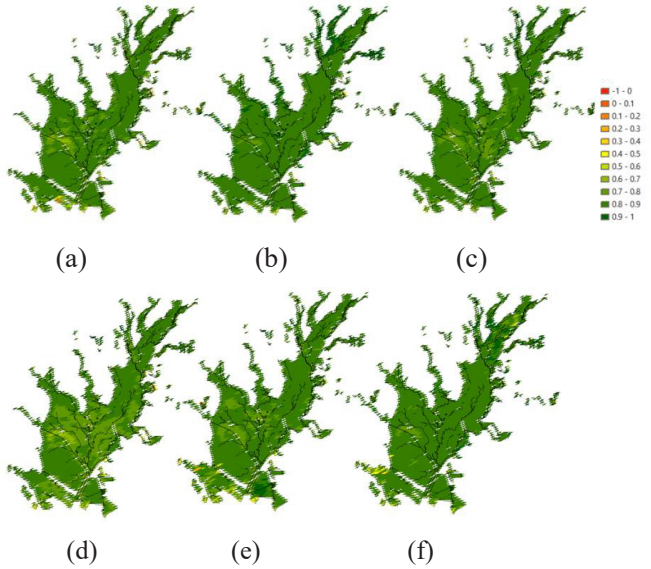

Fig. 3 NDVI spatial distribution on non-flood period for 2013 (a) 06/26/2013 (b) 07/04/2013 (c) 07/28/2013 and for 2016 (d) 06/25/2016 (e) 07/03/2016 (f) 08/04/2016

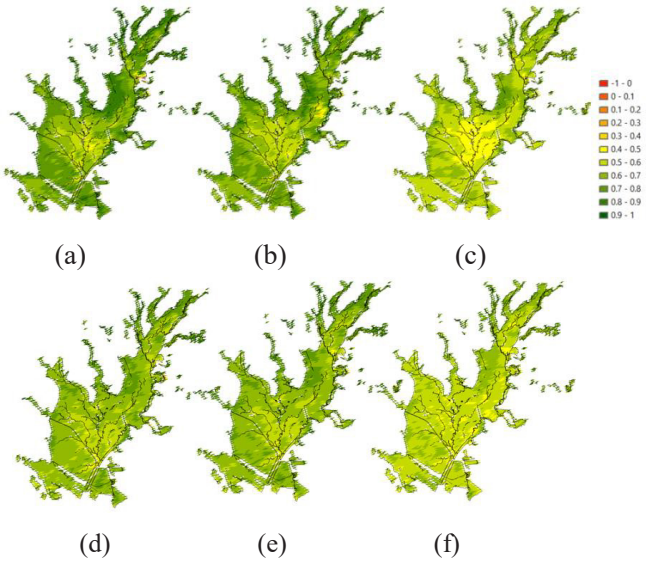

Fig. 4 NDVI spatial distribution after flood event for 2013 (a) 09/14/2013 (b) 09/22/2013 (c) 10/08/2013 and for 2016 (d) 09/21/2016 (e) 09/29/2016 (f) 10/07/2016

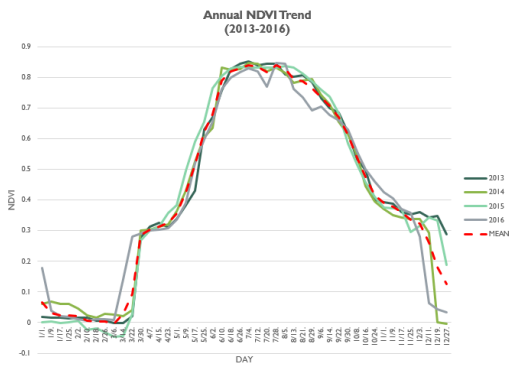

Fig. 5 Annual NDVI Trend from 2013 - 2016

Analyzing the effects of flood inundation on vegetation, NDVI after 8-day and 16-day interval was calculated as shown in Fig. 4. The results show decrease trend on vegetation based on NDVI both in 2013 and 2016 flood event unlike on the NDVI values of the non-flood period.

It is shown also in Fig 5 the annual NDVI trend of the vegetation in the wetland. It can be seen that from 2013 to 2015, the changes in the NDVI from the mean state follows almost the same trend, whereas in 2016, there is a drastic change in the trend around August 2016 where the flood event occurred.

The results show that there is a significant difference of response of the vegetation between non-flood and flood periods. The spatio-temporal evaluation on the wetland can provide preliminary information for planning in the wetland.

4. CONCLUSION

This study spatially evaluated the impacts of flood on the vegetation of the Kushiro wetland utilizing remote sensing data. The land surface conditions on the influence of flood was preliminary investigated using remote sensing. Further investigation is necessary. However, the spatio-temporal evaluation on the wetland can provide preliminary investigation that can be utilized for initial assessment on the wetland.

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P6-11

Release of the Satellite-based Lake and Reservoir Temperature Database in Japan (SatLARTD-J) Version 3

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Keywords: monitoring technologies for lakes and/or rivers, lake basin databases and knowledgebases

ABSTRACT

The Satellite-based Lake and Reservoir Temperature Database in Japan (SatLARTD-J), released in July 2012, provides water surface temperatures around 10:30 am (JST) measured by thermal infrared bands of the Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER) onboard NASA's Terra satellite, for 1,005 inland water bodies such as lakes and reservoirs in Japan (http://tonolab.cis.ibaraki.ac.jp/SatLARTD/). Because the mean frequency of successful measurements by ASTER for each water body is two or three times per year at most, SatLARTD-J also provides water surface temperatures regressively estimated with ground air temperatures from the Automated Meteorological Data Acquisition System (AMeDAS) in a five-day interval, using a regression equation obtained for each water body between the ASTER's water surface temperature and the AMeDAS ground air temperature corrected in spatial, temporal, and elevational. The version 2 of SatLARTD-J, released in July 2014, provided water surface temperatures only for a limited period from March 2000 to December 2013, but the latest version 3, released in January 2018, has a new function of near real-time updating, and the recent water surface temperatures for each water body are automatically added to the database. Water temperature is a key environmental factor for ecosystems in an inland water body, and the SatLARTD-J is expected to give some contributions to various fields including biodiversity conservation. As a next step, we are currently developing the world version of SatLARTD for future release.

1. INTRODUCTION

Many inland water bodies such as lakes, marshes and reservoirs are inhabited by many lives. For these lives, water temperature is an important environmental factor, because water temperature influences and regulates many chemical, physical and biological processes[1]. In addition, water temperature is also important in the aspect of global warming monitoring[2] . Thus, water temperature measurements of inland water bodies are important, but in Japan, they are insufficient except for some large lakes. Also, temperature measurements with contact-type thermometers are not realistic for monitoring many water bodies, because such water bodies are scatteredly located, and managed or owned by various people or organizations. Therefore, thermal infrared (TIR) remote sensing which can simultaneously observe surface temperature in a wide area is useful for these purposes. Under such background, our group developed the Satellite-based Lake and Reservoir Temperature Database in Japan (SatLARTD-J) using TIR images (90 m resolution) observed by the Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER) onboard NASA's Terra satellite, and released it in July 2012[3] [4] [5] . The version 2 of SatLARTD-J, released in July 2014, provided water temperatures only for a limited period from March 2000 to December 2013, but the version 3, released in January 2018, has a new function of near real-time updating, and the recent water surface temperatures for each water body are automatically added to the database. In the present paper, the overview of the SatLARTD-J version 3 is introduced.

2. SatLARTD-J VERSION 3

In the SatLARTD-J version 3, 1,005 inland water bodies such as natural lakes and reservoirs are registered (see Fig. 1). Since water surface temperatures are estimated using ASTER/TIR images with a spatial resolution of 90 m, most of water bodies have an area of 270 m square or larger for getting one or more pure pixels.

In the version 2, ASTER Data β products[6] provided by the National Institute of Advanced Industrial Science and Technology (AIST) were used for estimating water surface temperatures. But it is difficult to implement the function of near real-time updating using these products, because they are not regularly produced. Thus in the version 3, ASTER-VA products provided from the METI AIST Data Archive System (MADAS)[7] have been used in water temperature estimation for observation dates after January

2014. The updating module of SatLARTD-J checks and downloads a new ASTER image on MADAS automatically every day, and then estimates water surface temperatures for water bodies included in that image.

Water temperature estimation with ASTER/TIR images is performed by recalibration[8] , straylight correction[9] , atmospheric correction by the water vapor scaling (WVS) method[10] [11] , ASTER standard temperature and emissivity separation (TES)[12] , and screening. The details can be found in [3] [4] [5] . On the other hand, the mean frequency of ASTER observations is once per 48 days, and that of successful observations available for water temperature estimation is two or three times per year. Therefore, SatLARTD-J also provides water surface temperatures regressively estimated with ground air temperature from the Automated Meteorological Data Acquisition System (AMeDAS)[13] in a five-day interval, using a regression equation obtained for each water body between the ASTER's water surface temperature and the AMeDAS ground air temperature corrected in spatial, temporal, and elevational.

3. USAGE

Fig. 2 displays the top page of the SatLARTD-J version 3. In the left half, the locations of the registered water bodies are shown as markers on the Google map. The upper part of the left half has a function for searching a water body with its name and prefecture.

Fig. 3 shows an example of viewing plots and values of water temperatures for Lake Kasumigaura (lake center) in Ibaraki Prefecture (two points in one lake are selectable for only Lake Kasumigaura). The pop-up window on the left map gives the name, the latitude and longitude, and the elevation of the selected water body. The upper part of the right half shows the plots of water temperatures, where red points indicate ASTER estimates, and a blue polygonal line indicates regression estimates. The plot part of interest can be enlarged by clicking and dragging, as shown in Fig. 4. Enlarged plots can be returned to the original plots by double clicking.

The lower part of the right half displays all ASTER estimates and their corresponding regression estimates as values. The frequency of ASTER successful observations at Lake Kasumigaura is about 7 or 8 times per year which is higher than other water bodies, because the surrounding area of Lake Kasumigaura has been focused in ASTER scheduling.

4. CONCLUSION

The SatLARTD-J which provides water surface temperatures for 1,005 inland water bodies in Japan has been updated to the version 3 with the function of near real-time updating. Water temperature is a key environmental factor for ecosystems in an inland water body, and the SatLARTD-J is expected to give some contributions to various fields including biodiversity conservation. As a next step, we are currently developing the world version of SatLARTD for future release.

ACKNOWLEDGEMENT

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Fig. 1 Locations of 1,005 inland water bodies registered in the SatLARTD-J version 3.



Fig. 2 Top page of the SatLARTD-J version 3 (http://tonolab.cis.ibaraki.ac.jp/SatLARTD/).

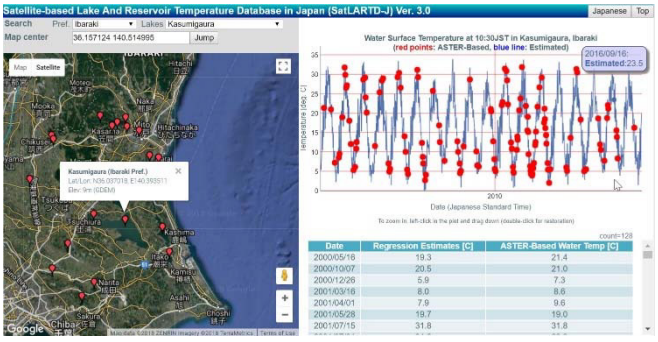

Fig. 3 Example of viewing plots and values of water surface temperature for Lake Kasumigaura (lake center), Ibaraki Prefecture.

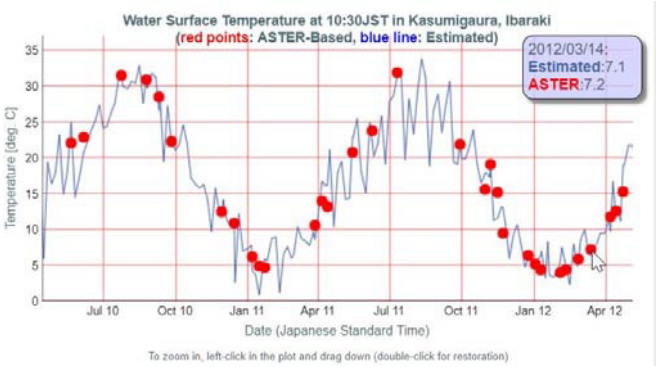

Fig. 4 Enlarged plots of water surface temperature for Lake Kasumigaura (red points: ASTER estimates, blue line: regression estimates).

P6-12

Improvement of hydrological and hydraulic model by applying satellite-based precipitation in the Tonle Sap Lake

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Keywords: Satellite precipitation, Hydrological and hydraulic model, The Tonle Sap Lake, Monitoring technology

ABSTRACT

The Tonle Sap Lake in Cambodia is the largest fresh water lake in Southeast Asia. The diverse ecosystems of the Lake provides huge amount of fresh water and foods to humanbeing, animal and plants. However, hydrological and hydraulic conditions of the lake are changing by climate change and hydropower production in the upstream of the Mekong River. Hydrological and hydraulic models are powerful tools to understand these situations. Due to poor measuring density of gauge-based precipitation in Cambodia, the satellite-based precipitation GPCP is used in this paper with an objective to improve the reproduction accuracy of hydrological and hydraulic model of The Tonle Sap Lake basin in Cambodia. Since original GPCP tend to be larger value than gauge-based precipitation, bias adustment was carried out and then inputted to hydrological and hydraulic model. Nash-Sutcliffe efficiency (NSE) was used for the accuracy evaluation. Evaluation factors are precipitation, runoff discharge from each watershed to the lake and water level at Kg.Luong, which is a representative water level station of the lake. The findings are as follows. 1) NSE of GPCP before and after adustment against gauge based rainfall was improved from 0.043 to 0.748. 2) By replacing gauge-based pricipitation to adjusted GPCP, the NSE value of runoff discharge from the Chinit River watershed was improved from 0.694 to 0.817. 3) NSE of water level at Kg. Luong was improved from 0.971 to 0.986 by replacing gauge-based precipitation to adjusted GPCP.

1 Introduction

The Tonle Sap Lake basin in Cambodia is one of the major catchment of the Mekong River (**Figure 1**). It is the largest fresh water lake in Southeast Asia. The Lake has unique hydrological characteristics, where water area and storage volume changes greatly between wet and dry season every year. This is because water flows into the Lake from the Mekong via Tonle Sap River when water level of the Mekong is higher than that of the Lake in rainy season. The Lake plays important roles of rich biodiversity of aquatic ecosystems, in addition, it supplies highly productive aquatic animals with humankind [1]. Since it is driven by unique flood pulse, maintenance and understanding of hydrological and hydraulic conditions are necessary to sustain current ecological environment.

Recently, impact of climate change and development in Mekong is being assessed [2]. Current hydrological and hydraulic conditions of the Lake is predicted to change in the future.

Hydrological and hydraulic models support to grasp these current and future conditions. They need a lot of current meteorological data. However, in Cambodia, it is difficult to obtain enough number of gage-based meteorological data such as precipitation and evaporation. Without precipitation data, it is difficult to evaluate and assess the current hydrological situation by hydrological and hydraulic model.

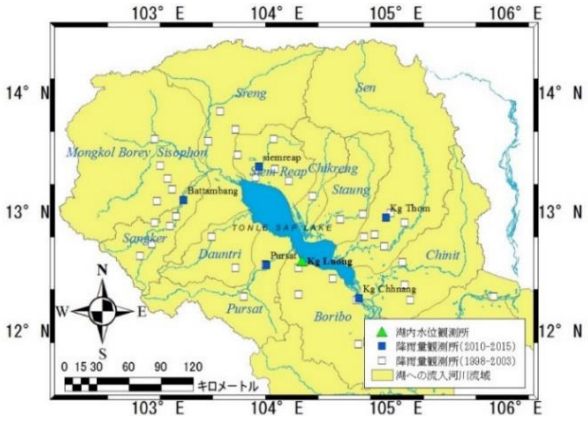

Figure 1 Map of the Tonle Sap Lake basin

On the other hand, satellite-based precipitation data estimated by satellite have been developed in recent years. Applying satellite-based precipitation data is an advantage in an area where gauge-based observations are poor such as Cambodia [3].

The objective of this study is to improve reproduction accuracy of hydrological and hydraulic model by replacing gauge-based precipitation to satellite-based precipitation (GPCP).

2 Study area and period

Study area of the Tonle Sap Lake basin is shown in **Figure 1**. The minimum lake area is about 2,500km^2 in dry season, and it expands about six times larger to about

16,000km^2 in rainy season. The Lake has inflow from 12 tributaries and total catchment area is about 83,000km^2 (**Table 1**).

Study period for calibration is 1998-2002 and validation period is 2010-2015.

Table.1 Catchment area of 12 tributaries

Name	Area[km²]	Name	Area[km²]
1,Chinit	8,240	7,Sisophone	4,310
2,Sen	16,360	8,M.K.Borey	10,570
3,Staung	4,360	9,Sangker	6,050
4,Chikreng	2,710	10,Dauntri	3,700
5,Siem Reap	3,620	11,Pursat	5,970
6,Sreng	9,990	12,Baribo	7,150
		Total	83,010

3 Methods

3.1 Hydrological and hydraulic model

In this study MIKE11 and MIKE-NAM, developed by DHI – Water & Environment, Denmark, are used as an 1-dimensional hydraulic and hydrological model [4].

3.2 GPCP

GPCP (Global Precipitation Climatology Project) one-degree daily [5] is selected as a satellite precipitation. It is based on satellite observation and its spatial and temporal resolutions are 1°×1° latitude/longitude and daily, respectively.

Since provided GPCP compared with gauge based precipitation tend to be larger than gauge based precipitation, it is adjusted and inputted to the hydrological and hydraulic model.

3.3 GPCP adjustment

Method of GPCP adjustment is as following equations.

$$C_{ij}=\frac{\frac{1}{n}\sum_{t=1}^{n} Robs_{ij}}{\frac{1}{5}\sum_{t=1}^{5} RGPCP_{ij}} \quad (1)$$

$$AGPCP_{ij}=C_{ij}*OGPCP_{ij} \quad (2)$$

Where i: cell number of longitudinal direction, j: cell number of latitudinal direction, C: adjustment factor, t: number of analyzed years, n: number of data existing years, Robs: accumulative gauge based precipitation in rainy season interpolated by Kriging method, RGPCP: accumulative original GPCP in rainy season, AGPCP: adjusted daily GPCP, OGPCP: original daily GPCP.

3.4 Evaluation function

Nash-Sutcliffe efficiency (NSE) [6] is applied as evaluation function. It is defined by the following equation.

$$NSE=1-\frac{\Sigma(X_{obs}-X_{cal})^2}{\Sigma(X_{obs}-\bar{X}_{0bs})^2}, \quad -\infty<NSE\leq 1 \quad (3)$$

Where X_{obs}: observed value, $\bar{X}_{obs}$: mean of all values, X_{cal}: calculated value.

3.5 Evaluation factor

Evaluation factors are as follows: 1. Precipitation at five stations (Kg.Thom, Siem Reap, Kg.Chhnang, Pursat, Battambang), 2.Runoff discharge from six watersheds (Chinit, Sen, Staung, Chikreng, Pursat, Boribo) to the lake, six watersheds which doesn't have enough gauge based water level are excluded, and 3.Water level at Kg.Luong, which is a representative water level station of the lake.

4 Result and Discussion

4.1 Precipitation

Monthly precipitation of Original GPCP and adjusted GPCP are compared against gauge-based precipitation at Kg.Thom in calibration period (**Figure 2**). NSEs of original and adjusted GPCP were 0.043 and 0.748 respectively. Mean NSE of GPCP at five stations are shown in **Table 2**. The NSEs of adjusted GPCP were better than those of original GPCP at almost stations.

Table 2 Mean NSE of GPCP at five stations.

	Calibration	Validation
Original GPCP	0.296	0.337
Adjusted GPCP	0.717	0.675

4.2 Runoff discharge

Table 3 shows the meaning of term Obs, Cal-A and Cal-B. NSEs were calculated between Obs and Cal-A, and also between Obs and Cal-B. **Figure 3** shows comparison of runoff discharge in Chinit River basin in calibration period. NSEs of Cal-A and Cal-B were 0.694 and 0.817, respectively. **Table 4** shows mean NSE of runoff discharge in six watersheds. Mean NSE of Cal-B is better than that of Cal-A. In other words, hydrological model using

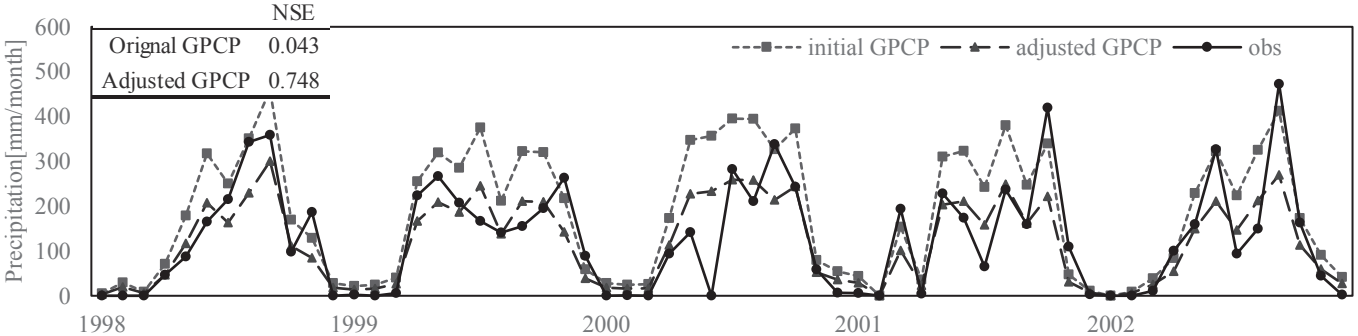

Figure 2 Comparison of three kind of monthly precipitation at Kg.Thom in calibration period

adjusted GPCP was improved the reproduction accuracy. This is because GPCP is able to supplement the precipitation in the upper part of the basin where has no gauge-based observation data. Runoff of Cal-B shows better NSE (mean NSE was 0.472 in both calibration and validation) than Cal-A, even though it doesn't show satisfactory accuracy. This may be due to the limitation of lumped model in large catchment areas.

Table 4 Mean NSEs of runoff from six basins and NSEs of water level at Kg. Luong.

	Calibration		Validation	
	Runoff	Water level	Runoff	Water Level
Cal-A	0.420	0.971		
Cal-B	0.472	0.986	0.472	0.976

* Cal-A calculate only calibration period.

4.3 Water level in the lake

Table 4 also shows NSEs of water level at Kg. Luong. The NSE of Cal-A and Cal-B were 0.971 and 0.986 respectively in calibration periods. **Figure 4** shows the comparison of water level among observed, Cal-A and Cal-B at Kg.Luong in calibration period. The result of hydrological and hydraulic model using adjusted GPCP also has shown good accuracy both in calibration and validation. Cal-B was slightly better than Cal-A.

5 Conclusion

In this study through replacing gauge-based rainfall to adjusted GPCP, the reproduction accuracy of the hydrologic and hydraulic models were improved both runoff discharge from watershed and water level at Kg. Luong.

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Table 3 Meaning of term Obs, Cal-A and Cal-B.

Name	Explanation
Obs	Runoff : Runoff discharge from rating curve[7]. Water level : gauge based water level at Kg Luong.
Cal-A	Calculated value by hydrological and hydraulic model using gauge based precipitation.
Cal-B	Calculated value by hydrological and hydraulic model using adjusted GPCP.

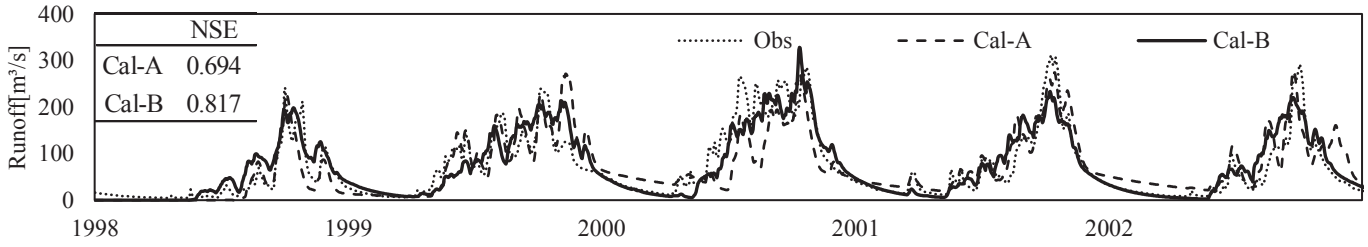

Figure 3 Comparison of runoff discharge in the Chinit river basin in calibration period.

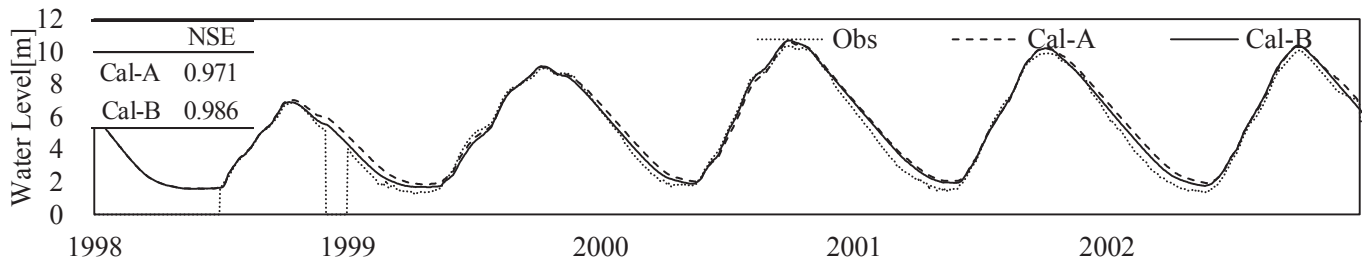

Figure 4 Comparison among observed, Cal-A and Cal-B of water level at Kg.Luong in calibration period.

P6-13

Spatiotemporal Variability of Chlorophyll-a Concentration in Lake Malawi using MERIS Data

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Keywords: Chlorophyll-a, Remote Sensing, MERIS, Lake Malawi

ABSTRACT

Lake Malawi is one of the most important lakes in Africa, due to its biodiversity and usefulness to the adjacent populations. However, some anthropogenic activities can threaten its water quality and ecosystem services. Lack of a systematic regular monitoring of chlorophyll-a (Chl-a) concentration, and understanding of its spatial and temporal variation are some of the drawbacks. In this study we propose the use of MERIS Level 1B data to monitor the lake's Chl-a concentration, and its spatial and temporal distribution. Using the NASA's standard OC4E_v6 algorithm for clear water, Chl-a concentration was retrieved, during the 2003-2011 period. The highest mean concentration (> 1 mg m^{-3}) for the entire lake was found in 2003. Since then the values dropped to a mean value below 1 mg m^{-3}. Nevertheless, the results showed a slight increase along the years although in small concentration. The Western and Southern part of the lake proved to be the most affected, having a mean Chl-a concentration around 5 mg m^{-3} , probably influenced by the anthropogenic activities in these areas, as the population pressure is high. The seasonal effects have also shown to have an influence in the Chl-a concentration, the highest concentrations were found in the first two seasons (November to April; May to August). It was also found that Chl-a concentration may differ depending on the location and season.

1. INTRODUCTION

Freshwater accounts for around 2.5% of total global water from which surface fresh water is about 1.2% and lakes 20.9% of the surface freshwater[1]. As the numbers above show, lake water is part of a very small percentage of fresh water available for direct use on earth. Lake Malawi is one of the most important lakes in Africa along with Tanganyika and Victoria. It is the source of fresh water, fishery products, and a variety of benefits to the bordering countries of the lake basin. It is located between (09° 30' -14° 40' S, 33° 50' - 33° 36' E, 472 m amsl) and also known as Niassa in Mozambique and Nyasa in Tanzania, but internationally and scientifically known as Lake Malawi. This lake is the 3rd largest lake in Africa after Victoria and Tanganyika and the 9th largest in the world[2]. Due to its location, Lake Malawi experiences three different seasonal variations in temperature, wind, and precipitation, here after from November to April Season one (S1), Season two (S2) May to August, and Season three (S3) from September to October. Chlorophyll-a (Chl-a) is tested in lakes to determine how much algae is in the lake, and algae is important in lakes because it adds oxygen to the water as a by-product of photosynthesis. On the other hand, if there is too much algae in a lake it can produce a foul odor which can be harmful to the people[3]. Therefore, understanding Chl-a concentration, its spatial and temporal variation in Lake Malawi is of paramount importance.

2. METHOD

We propose the use of MERIS Level 1B data downloaded from [4] to monitor Lake Malawi's Chl-a concentration, and its spatiotemporal distribution. The outputs from the atmospheric correction Neural Network (NN) of Case 2 Regional (C2R) processor, water-leaving reflectance were used as input for the calculation of Chl-a concentration. The C2R processor underwent a validation process for atmospherically corrected water-leaving reflectance[5]. Due to the known characteristics of Lake Malawi (clear water), NASA's standard MERIS OC4E_version_6 [6] was found to be the ideal model to retrieve Chl-a. This is a blue and green band ratio algorithm aimed at clear waters. The algorithm is expressed as follows:

$$\mathrm{Chla}_{\mathrm{OC4Ev6}} = 10^{(0.3255 - 2.7677b + 2.4409b^2 - 1.1288b^3 - 0.4990b^4)}$$

where b is the $\log_{10}$ of the maximum band ratio of the three bands at the Rrs443, Rrs490, Rrs510 to Rrs560 and the coefficients were derived using version 2 of the NASA bio-Optical Marine Algorithm Data set (NOMAD) [6].

3. RESULTS

In this study, periods of peak of Chl-a were detected as well as their seasonal variability, which was complemented with the long-term change variation. Chl-a mean value-based maps were produced for yearly data.

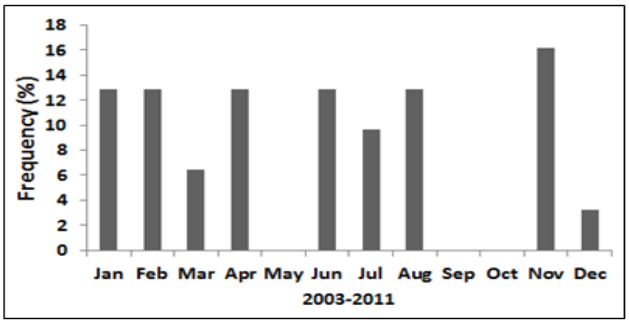

Fig 1. Monthly mean distribution of chla peaks for the period from 2003 to 2011.

As shown in Fig 1, no peaks were found in May, September, and October for the entire study period. However, March and December showed peak availability less than 10%. Contrary to previous months, November shows the highest peak frequency more than 14% followed by January, February, April, June, and August. These results go along with [7] regarding the peak found in April 2012 in their study and shows other peak seasons that were not detected by *in situ* measurements. The fraction of peak distribution throughout the months shows that S1 is the most active in terms photosynthesis in Lake Malawi. Fig 2 illustrates the Chl-a concentration range based on the annual mean value.

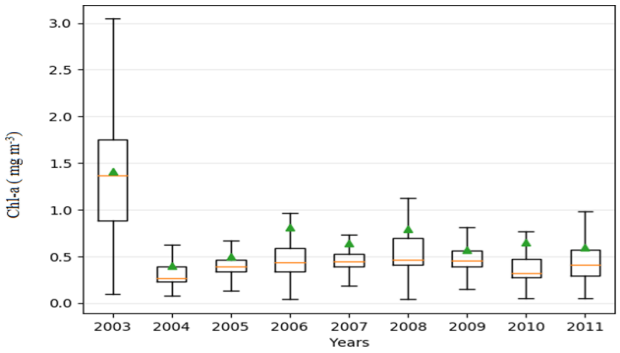

Fig 2. Temporal Variability of Chl-a.

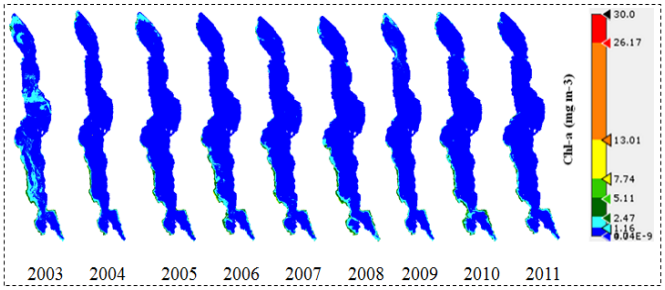

Fig 3. Spatial Variability of Chl-a

Figure 3, shows Chl-a spatial distribution during the 9 years of study. The first year of the study revealed to be the most spatially dynamic compared to other years. Generally, the mean Chl-a value in fig. 2 are (< 1 mg m^{-3}), represented by the green triangle.

4. DISCUSSION

After the abnormality in Chl-a spatial distribution in 2003, the yearly variation stabilized to a smooth but noticeable increase from 2004 to 2008 and an oscillation between 2009 and 2011. Throughout the 9 years of study, it was found that the highest values of Chl-a are found in the northern region of Lake Malawi, and in the central region with distinct attention to the West coast of the central and southern part of the lake. This is particularly true and goes along with formerly published papers [7,8] indicating the influence of anthropogenic activities. Chl-a detected in this corresponding area varies from 1.16 to 7.74 (mg m^{-3}).

5. CONCLUSION

During the 9 years of study using remote sensing data, S1 showed to be the most influential. The seasonal effects have also shown to have an influence in the Chl-a concentration, the highest concentrations were found in the first two seasons (November to April; May to August). It was also found that Chl-a concentration may differ depending on the location and season. Although 2003 presented high Chl-a values the rest of the years show low Chl-a concentration values, therefore the lake can still be considered as clear (oligotrophic). However, this trend tends to change, suggesting an increase in Chl-a concentration in the Lake.

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P6-14

Unmanned vehicle on water quality monitoring in reservoir

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Keywords: Water quality; Real-time monitoring; Unmanned vehicle; Internet of things (IOT)

ABSTRACT

Baoshan Reservoir supplies water to the Hsinchu Science Park in Taiwan, because the high-tech wafer process requires a lot of pure water. Therefore, how to ensure the water quality and stability of Baoshan Resevoir is particularly important. Due to that Baoshan Resevoir is an off channel reservoir, it can select the water source from Shig-Ping Weir to avoid Inferior quality water flows into Baoshan reservoir. There are many pollution sources because of prevalence of agriculture and a lot of residential buildings around Baoshan Reservoir. Monitoring the water quality of Baoshan Reservoir by unmanned vehicles, and establish the pollution hotspots to provide a scientific evidence to the reservoir management, and further set up appropriate pollution reduction facilities. At present, specific sites monitoring or manual sampling detection are the most common method in Taiwan. However, manual sampling is time-consuming and can not be monitored over a long period of time. Specific sites monitoring can not be adjusted according to the level of water level monitoring points. As the specific sites monitoring can not represent the whole area of water quality, and there may be aquatic organisms and plant attached, the cost of setting up number of specific sites monitoring point will be too high. It can be effectively lower the cost by using unmanned vehicles equipped with direct reading instrumentation MAX-RS485 multiparameter water quality detector, the data can through the Internet of things (IOT) back to the server, then remote control and give instruction to confirm the reservoir water quality changes and the source of nutrients.

1. INTRODUCTION

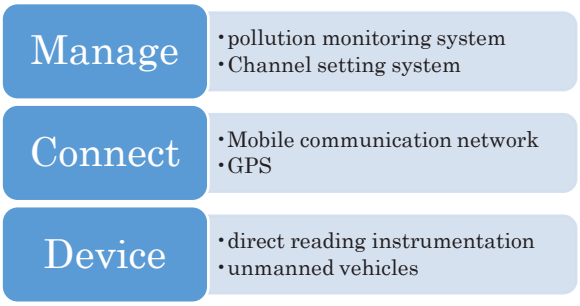
Unmanned vehicle on water quality monitoring is mainly divided into two parts: water quality testing and unmanned the body of boat. This unmanned monitor utilize a commercial water quality detector to monitor the water quality on the route through the preset task route. By measuring the water quality data every 15 seconds via the underwater direct reading perceptron, the coordinates and data are transmitted to the database for analysis by the mobile communication network after the return to the surface buoy. Through the hull of t built-in GPS , unmanned vehicle can fix a double motor output power and adjustt direction back to set the task route, once the offset Angle is above 40 degrees electricity And while the battery is low, it will automatically go back to the setting point to charge it. In this study, seven main monitoring points were established after understand the geographical information of baoshan reservoir and further site investigation through GIS. These 7 main monitoring points are respectively: 1. the more domain the water outlet 2. drawbridge 3. densely populated residential areas 4. tourist restaurant 5. farmland 6. camp site 7. orchard. The 7 points are covered in the whole baoshan reservoir, and the data was collected through the unmanned water quality monitoring vehicle, which can be analyzed the contaminated hot zone of the whole area.

2. METHOD

MAX-RS485 multiparameter water quality detector is a circular cylindrical monitor that can be fitted with a variety of water quality parameter monitors, including pressure(SMR01), pH(SMR04), conductivity(SMR07), dissolved oxygen(SMR09), turbidity(SMR10), chlorophyll A(SMR35), potassium ion(SMR39).

The concept of this unmanned vehicles applies the internet of things, can be divided into three classes: Device, Connect, and Manage. In the Device section, there are six sensors and hulls, the sensed water quality data, GPS and hull walking routes and related hull data, will use the mobile network to transfer to the manager’s server for calculation through the Connect section. In the Manage section, there are water quality monitoring management system and hull management system, water quality monitoring and management system will have been calculated in the server information, and presented in the monitoring program with immediate coordinates, pH, conductivity, dissolved oxygen, turbidity, chlorophyll A and potassium ions. Hull management system can plan the walking routes in advance, and get the direction of travel,

location and speed data immediately. When the hull management system found that the hull is in the direction of deviation, it will send a modified order to the hull, to amend the direction of the direction.



This study used the interpolation method of Topo To Raster embedded in ARCGIS, The data was measured by the unmanned vehicles equipped with direct reading instrumentation, after calculating by interpolation, analysis the depth and pollution distribution of the Reservoir, then display by 2D plane space, so that the value of the parameters of the reservoir is very clear.

3. RESULTS AND DISCUSSION

At present, we utilize MAX-RS485 techniche to conduct the water quality monitoring, the monitored parameters includes pH, conductivity, DO, turbidity, chlorophyll-a, and potassium ion. The related results are shown as follows.

(1) pH

The PH value measured by MAX RS485 is between 9.1 and 9.7. In Fig. 1, The water quality in the reservoir is alkaline and a case of eutrophication as a result of intense photosynthesis. And the pH valua is increasing suddenly at 5, 6 and 7 point, bacause the water flow rate is not high and the distance is far from the inlet and outlet.

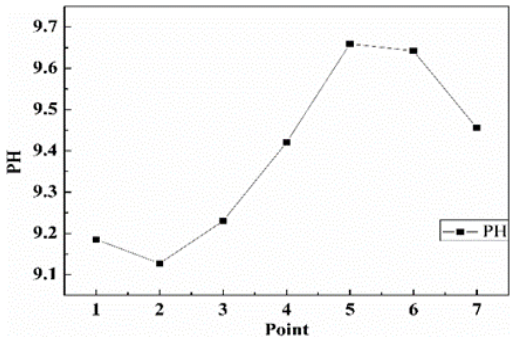


Fig.1 pH concentration distribution

(2) Conductivity

The conductivity measured by MAX RS485 is 190~205 μs/cm. As shown in Fig.2, the conductivity is much higher at 1, 2 and 3 point, because these points are located at the inlet and outlet path and have high concentration of pollutants. The 3 point is close to the residential areas, leading to a highest conductivity.

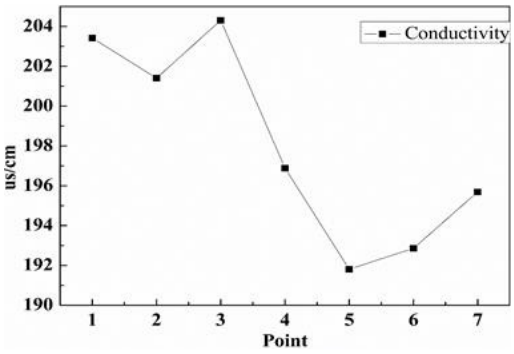


Fig.2 Conductivity concentration distribution

(3) DO

The DO value measured by MAX RS485 is 9~12 mg/L. In Fig.3, DO value is increasing orderly. Due to the slow flow and huge ammount of algae, direct solar radiation can cause the supersaturated state on water quality, it would be accompanied by high PH and the phenomenon of algal blooms. Turbidity

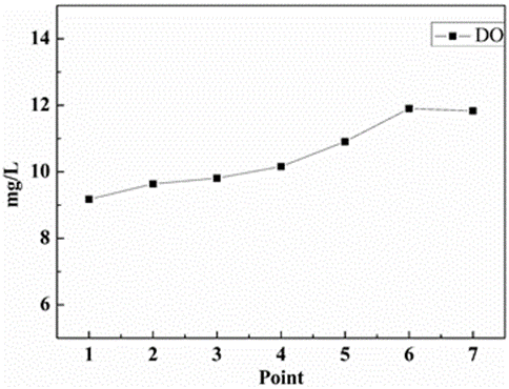


Fig.3 DO concentration distribution

(4) Turbidity

The turbidity measured by MAX RS485 is 5~7 NTU. In Fig.4, the overall turbidity value keep a good condition due to the sunny day and slow water flow.

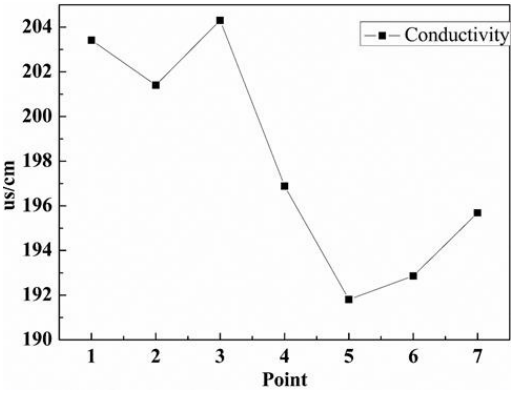


Fig.4 Turbidity concentration distribution

(5) Chlorophyll-a

The chlorophyll-a measured by MAX RS485 is 0~3 ppb. As shown in Fig.5 and Fig.6, If the status of the water quality status is only determined by Chlorophyll-a, the degree of the eutrophication is the ordinary level.

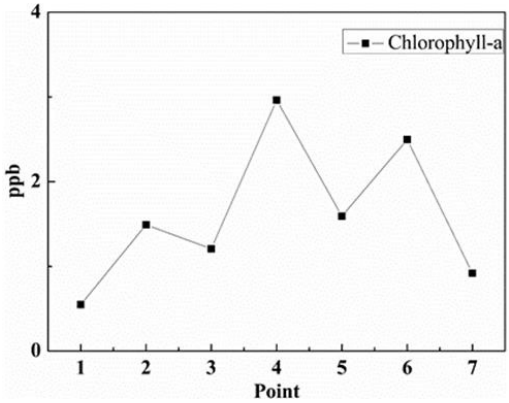


Fig.5 Chlorophyll-a concentration distribution

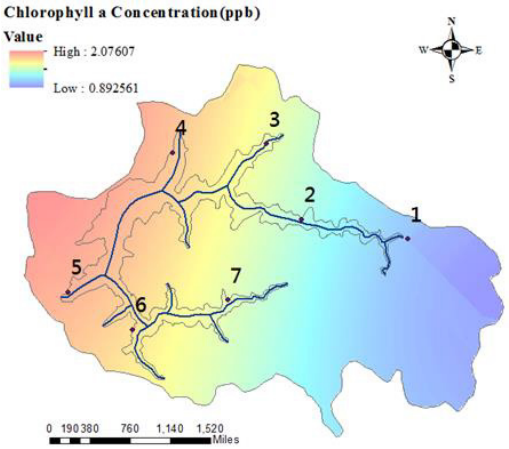


Fig.6 Chlorophyll-a concentration distribution by GIS

4. CONCLUSION

The tested resulted show that the temperature of water, pH, dissolved oxygen no obvious fluctuation. Conductivity is up to 204.31μs/cm at densely populated residential areas; Turbidity in orchard is up to the highest at 6.46NTU; Potassium ions at the more domain the water outlet were the highest at 0.29 ppm. Due to utilizing the public information supplied by government, we know that Baoshan Reservoir is at the edge of the eutrophication. Unmanned water quality vehicle can further help us research the source of pollution, analyze the proportion of pollution sources, real-time monitor of water quality for a long time monitoring.

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P6-15

イラン国アンザリ湿原におけるドローンを活用した違法狩猟管理の試行

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キーワード:ドローン、保護区管理、違法狩猟管理、ラムサール条約、モニタリング

抄録

One of the project activities supported by Japan International Cooperation Agency(JICA) under the Anzali Wetland Ecological Management Project - Phase II in Gilan Province, Iran, is to strengthen management capability for conservation of the wetland. Since many waterfowls such as wild geese and ducks come flying into the Anzali Wetland in winter, citizens are permitted to hunt them for food and recreation as an ecological service of the wetland. The hunting is permitted outside the protected areas of the wetland under limited license which is issued by Department of Environment of Iran. However, in practice, due to the large 193 km^2 area of the wetland and lack of human resource, capability, equipment, and budget for the rangers, illegal hunting activities are occurring both outside and inside of the protected areas. We will report on utilization of drones as conservation management tools for detection and monitoring of the illegal hunting and hunting nets hidden in the reeds.

1. はじめに

(1) アンザリ湿原の概要

アンザリ湿原は、1975 年にラムサール条約湿地に登録されたイラン北部カスピ海南岸に位置する約 193 km^2 の湿地である。カスピ海と連動する広大な湿地は、渡り鳥や魚類等にとって国際的に極めて重要な生息地である一方で、過剰な狩猟、カスピ海の水位変動、土砂堆積、水質汚濁、外来水生植物の繁茂等の環境劣化を理由に、1993 年に優先的な保全措置が必要な湿地リスト(モントルーレコード)に加えられた。

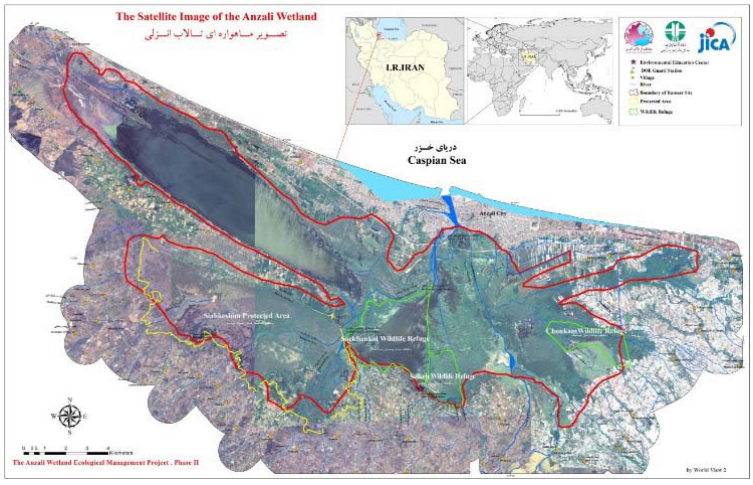

図 1 アンザリ湿原マップ(赤線はラムサール条約指定湿地の境界)

(2) プロジェクトの背景

以上の状況を踏まえ、イラン国政府からの要請に応じ、JICA はこれまで「アンザリ湿原生態系保全総合管理計画調査」[1]および「アンザリ湿原環境管理プロジェクト・フェーズ I」[2]を実施支援してきた。今般、さらなるイラン国政府の要請に応じて、JICA は「アンザリ湿原環境管理プロジェクト・フェーズ II」(以下、本プロジェクト)を 2014 年から開始し、総合的な湿原管理の本格的な仕組み作りと保全施策の実施支援に取り組んでいる。なお、日本工営は JICA の委託を受けて当初より全般の業務を行っている。

(3) プロジェクトの目的

本プロジェクトでは、アンザリ湿原の美しい水流、豊かな生態系の保全及び地域住民が関係機関との関係強化のもとワイズユースが実現できる事を目指すとともに、アンザリ湿原で確立される総合的な湿原管理システムがイラン国内に普及され、さらに近隣諸国においてもモデルとして認知されることを目指している。

プロジェクト目標は、「アンザリ湿原に関わる全関係機関の効果的な関与による湿原の総合的管理の確立」とし、以下の成果の達成に向けた活動を実施している。

・アンザリ湿原管理委員会の能力の強化
・日イ共同のパイロット活動(試行)の特定・実施
・プロジェクトで得られた知見と経験のイ国内および海外への共有

(4) プロジェクト期間

2014 年 3 月～2019 年 5 月(約 5 年間)

(5) プロジェクト内容

第 1 年次には、2005 年に JICA の支援で策定したマ

スタープラン（アンザリ湿原保全の総合管理計画）とその後のイラン側の取り組みを見直す形でプロジェクト期間中に実施すべき各分野（①湿原生態系保全（保全再生施策、モニタリング、ゾーニング及び土地利用管理）、②流域管理、③汚水管理、④廃棄物管理、⑤エコツーリズム、⑥環境教育）の施策のアクションプラン（実施計画）を策定した。その後、アクションプランの中から優先施策を共同パイロット活動として選定し、イラン国環境庁やギラン州政府などイラン側関係機関と共に実施することにより、「イラン国が独自に施策の継続実施を行っていくための技術移転」及び「プロジェクトサイクル（PDCA)の定着」を図ることを目的として現在実施中である。また、これらの結果を踏まえた上で、プロジェクト終了後のイラン国における継続的な施策実施のためのミッドタームプランの策定を今後行う予定である。

（6） 共同パイロット活動（ﾚﾝｼﾞｬｰの管理能力の強化）

プロジェクトで行っている各分野の共同パイロット活動は数多くあり、そのうちの一つが、湿原生態系保全の分野で行っている保護区におけるレンジャーの管理能力の強化である。

2. 方法

（1）違法狩猟の背景

当湿地では、冬季にガンカモ類をはじめとする多くの水鳥が越冬のために渡来し、生態系サービスとして食料やレクリエーションのために市民は狩猟を行っている。市民は、保護区の外側でイラン国環境庁のライセンスを取得することで限定的な狩猟が許されている。しかし実際のところは、湿地の面積が 193 km^2 と広大であり、湿原内に 5 箇所あるﾚﾝｼﾞｬｰｽﾃｰｼｮﾝでは 30 名がシフト勤務しているものの、レンジャーの人数、能力、機材及び予算の不足により、保護区の内外において、違法狩猟が十分には管理できていない状況である。レンジャーは、水域は主にモーターボートでパトロールしているが、水深が浅いためアクセスできなかったり、また予算不足で燃料が制限されたりして違法狩猟者を十分取り締まれていない状況にある。特に、水路から目の届かないヨシ原の中では、大規模なかすみ網の網場が設置されて、カモ類の違法な狩猟が行われていても発見するのが難しい。散弾銃やライフルによる狩猟と比較して、大規模なかすみ網は一度に数百羽を捕獲できることもあり、これらの管理が課題となっている。特に 2017～18 年は、鳥インフルエンザの蔓延から、イラン国環境庁により全ての狩猟ライセンスの発行が停止されており、あらゆる狩猟が禁止されているにもかかわらず、地元レストラン等に野生カモ類等の料理が普通に出回っている等、違法狩猟の管理が十分でなかった。世界中の水鳥のデータを解析した研究[3]でも、カモ類が最も減少しているのはイランを含む中央アジアとされており、その原因として保護区の違法狩猟の管理が十分でないことが挙げられている。これらの状況を踏まえると、10 万羽以上の水鳥が越冬するアンザリ湿原の違法狩猟の適切な取締りは国際的にも重要な課題であると言える。



図 2　当湿原周辺でかすみ網により大量捕獲されたコガモ

（2）ドローンによるパトロールの試験

イラン国環境庁のレンジャーと合同で、昨冬 2 月及び 3 月に計 4 度、市販のドローン（DJI Phantom 4 Pro）で湿原の保護区をパトロールし、発見後に取締り（網場や作業場の撤去）を行った。

具体的には保護区周辺から離陸させ、半径 2 キロ程度以内のヨシ原上空や岸沿いを低空（約 20 m程度）で飛翔し、標準搭載ビデオで録画を行った。当該湿地は広大であるため、離陸地点を移動し、なるべく広範囲をスキャンできるように録画した。録画映像は、事務所にて、大型モニター（Full HD 42 インチモニター）にて再生し、かすみ網を発見に努めた。



図 3　イラン国環境庁レンジャーとの合同パトロール

3. 結果

パトロールの結果、6 箇所での網場を発見した。発見後、ドローンの GPS ログデータや映像の地形的特徴から、網の位置を地図に記録し、レンジャーに連絡した。レンジャーは地図をもとに、速やかに現場に急行し、かすみ網や作業場を撤去した。ハンターが不在だったため、現行犯逮捕とはならなかったが全施設の撤去に成功した。



図 4 レンジャー事務所から 900 m 先で確認された網場



図 5 狩猟者の作業小屋（上空からでも発見しにくい）



図 6 レンジャーにより撤去中のかすみ網

4. 考察

ドローンからはリアルタイムで映像が転送されるものの、明るい屋外の現場では、タブレットのモニターは暗く小画面であるためかすみ網は見えづらく発見は難しかった。そのため、事務所での大型高精細（Full HD）モニターで再生確認作業が必要となった。かすみ網は Full HD モニターでは、確認することができた。

本手法は、GPS の飛行ログを使っての位置の特定も容易であり、十分実用レベルと考えられる。

なお、当該ドローンは 4K で録画可能であり、モニターも 4K 対応にすることで、Full HD のモニターと比較して 4 倍の画素数となることから、さらに精度を高めた確認作業が可能となる。

5. 結論及び今後の課題

レンジャーによる従来手法（徒歩やボートによるパトロール）では発見しにくい、ヨシ原内の網場の発見やモニタリングにはドローンが効果的である事が確認された。イランにおいては、このようなドローンを使った狩猟管理は初めての試みである。

今後は、レンジャーによる日常的なパトロールに組み込むために、操縦及び機材保守のトレーニングや映像データのハンドリング方法のトレーニングにより技術移転を図っていく必要がある。ただし、ドローンによるパトロールが日常化すれば、違法狩猟者の銃撃等の妨害行為が予想され、被害を防ぐための飛行高度や操縦方法の最適化や、ドローンを喪失した場合のバックアップ体制等も検討していく必要があると思われる。これらの経験を活用して、イラン全域の保護区管理にドローンを活用していけば、国内における違法狩猟数の減少ひいては国際的な渡り鳥の保全に寄与できる可能性がある

また、ドローンは違法狩猟だけでなく、その他一般的な保護区管理ツールとして有効であり、本プロジェクトでは違法な土地利用の発見、植生モニタリング、広報素材の撮影などにも活用している。

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P6-16

LC-MS/MS DETERMINATION OF ANTIBIOTICS AND HORMONES AND ITS APPLICATION IN LAKE WATER MONITORING

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Keywords: water quality, water pollution, monitoring technologies for lakes, water quality instruments

ABSTRACT

Many water contaminants are relatively stable and are not completely removed during wastewater treatment and post-discharge processes. In this study, a fast and sensitive LC-MS/MS method was optimized for the direct analysis of trace antibiotics and hormones in water. Water samples taken from Laguna Lake (Philippines) were filtered and analyzed without enrichment. The chromatographic separation was done using a C18 column and gradient elution of water-methanol with 0.10 % formic acid or 0.10 % ammonium hydroxide. Detection and quantitation were done using multiple reaction monitoring. The detection limits were 0.01-0.42 ug/L for the antibiotics and 0.01-0.07 ug/L for the hormones. Correlation of determination was >0.98 for each analyte in 0 to 100 ug/L concentration range. This method is suitable for routine monitoring of water contamination considering detection capability, sensitivity and specificity. Preliminary analysis of lake water samples from nine sampling sites in Laguna Lake shows that these antibiotics and hormones are not detected. Determination of the occurrence of these emerging contaminants is important particularly in the use of the lake for aquaculture and potable water production. Monitoring potentially harmful water contaminants in lakes is important especially in areas where the implementation of environmental policies is still a challenge.

1. INTRODUCTION

Many lakes especially in Asia are a source of livelihood for the surrounding communities. Human activities, however, may cause deterioration of the quality of water in these lakes. Lakes can be threatened with contamination due to anthropogenic chemicals including the emerging environmental contaminants. Such impact may compromise the productivity of lakes and the benefits that lake systems provide. Among the emerging contaminants now being studied in the environment are antibiotics and hormones. These contaminants may affect the health of the lake ecosystem as well as human health. Antibiotic resistance, for example, is now a major global concern. Pharmaceuticals such as antibiotics, natural hormones and estrogen-based contraceptives are now seen as environmental contaminants contributing to the pool of endocrine disrupting compounds in water systems [1,2].

Laguna Lake is the largest and one of the economically important lakes in the Philippines. It has many uses such as in fish cultivation, source of water for industrial and agricultural purposes, raw water source for water treatment plants, in transport and recreation, floodwater reservoir and as a final sink for effluents from the domestic, industrial and agricultural activities around the lake. Similar to other lakes in the world, Laguna Lake is also affected by continuous urban development and population growth. The west part of the lake is polluted mainly by effluents from industries and the urban sprawl, while the east part which is less populated takes in mostly agricultural discharges [3]. Together with the local government units, this lake is managed by the government through the Laguna Lake Development Authority. The conditions of the lake water are monitored by this government authority. The water quality parameters that are currently monitored do not include yet other potentially harmful emerging contaminants such as antibiotics and hormones.

In our project on "Endocrine Disruptors, Antibiotics and Heavy Metals in Laguna Lake Water: Impacts on Food and Water Security" funded by the Philippine Department of Science and Technology, we aim to optimize and validate analytical methods to be able to determine the occurrence and concentrations of emerging water contaminants. In this study, we explored the use of an optimized LC-MS/MS method without pre-concentration to determine the possible occurrence of antibiotics and hormones in

Laguna Lake water.

2. METHOD

Surface water samples were taken in January 2018 from the nine sampling sites in Laguna Lake that are regularly monitored by the Laguna Lake Development Authority (Figure 1). The water samples were stored in amber glass bottles and transported to the laboratory in ice chests. The samples were filtered and 1.5 mL of each sample was transferred into an autosample vial where the internal standards (ciprofloxacin-d8 and ß-estradiol-d2) were added. The samples were directly analyzed using a LC-TSQ triple quadrupole mass spectrometer (ThermoFisher Scientific). Calibration solutions were prepared in concentrations of 0-100 ug/L for the antibiotics (amoxicillin, cephalexin, cloxacillin, ciprofloxacin, penicillin G) and hormones (ethynylestradiol, ß-estradiol, estrone, progesterone, testosterone) in 10% methanol in water. Twenty microliters of each of the samples and the calibration solutions were injected into the column. The analytical separation was done on a BetaSil phenylhexyl column (50 mm x 2.1 mm x 3 um) using gradient elution of 10 to 90% methanol-water containing 0.1 % formic acid for antibiotics analysis and 0.1 % ammonium hydroxide for the hormones analysis. The total run time is 8 min. The ionization was ESI-positive and ESI-negative for antibiotics and hormones, respectively. Using the optimum instrumental parameters, the analytes were determined by multiple reaction monitoring.

3. RESULTS

Table 1 summarizes the MRM transitions used in the mass spectrometric determination of the antibiotics and hormones in water. Using a specific quantitation mass for each analyte, the detection limits were 0.01-0.42 ug/L for the antibiotics and 0.01-0.07 ug/L for the hormones. Correlation coefficients for the analytes were >0.98 in the 0.1 to 100 ug/L range. The analytical measurements were reproducible in the 5-100 ug/L concentration range with % RSD of <10.5% except for ciprofloxacin. The recoveries of 50 ug/L of the antibiotics or hormones spiked in lake water, tap water and bottled water are also summarized in Table 1. Analysis of the lake water samples from the nine sampling sites did not result in the detection of any of the antibiotics or hormones studied.

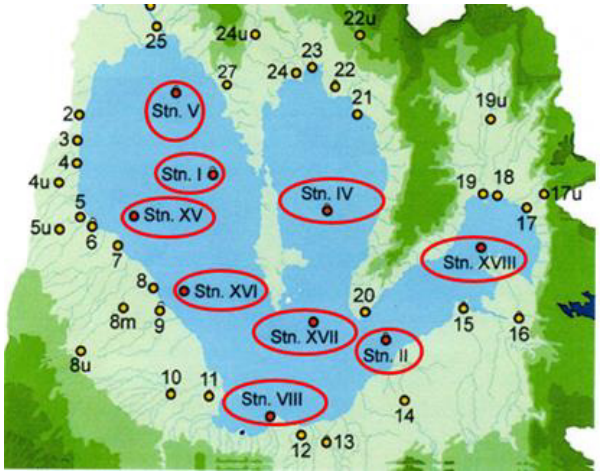

Fig. 1 Sampling sites (encircled) in Laguna Lake

Table 1 Analytical determination of antibiotics and hormones in water

Compounds	MRM Transitions Precursor>Product[c]	Percent Recoveries[d]
Hormones[a]:		
Ethynylestradiol	295.2>*145.4*, 266.9	107-115
β-Estradiol	270.9>*183.0*, 147.2	107-108
Estrone	269>*145*, 143	98-117
Progesterone	315.1>*108.9*, 97	87-88
Testosterone	289>*109*, 106.9	88-92
Antibiotics[b]:		
Amoxicillin	366.2>*160.41*, 114.11, 208	-
Cefalexin	348.3>*158.5*, 174.3	141-149
Cloxacillin	436.9>*277.7*, 160.1	79-109
Penicillin G	335.1>*160.1*, 176.1	82-88
Ciprofloxacin	332>*314*, 231, 288	-

[a]Recoveries calculated using internal calibration; [b]Recoveries calculated using external calibration; [c]Quantitation mass in *italics*; [d]50 ug/L spiked in lake, tap and bottled waters

4. 4. DISCUSSION

5. The analytical method presented for the determination of antibiotics and hormones in water without pre-concentration and using LC-MS/MS can be used in assessing contamination in lake water in terms of antibiotics and hormones. Since there is no pre-concentration involved, the method detection limits allow only for the measurements of the compounds above 0.01 ug/L or 10 ng/L. Below this concentration, the antibiotics and hormones cannot be quantified. Results of

this initial study suggest that the surface water in Laguna Lake does not contain the antibiotics and hormones in concentrations <10 ng/L. There is limited information on lake water contamination due to these compounds. For similar antibiotics, these compounds have been found in a lake in Turkey and in a lake China in concentrations below 4 ng/L (e.g., amoxicillin) and 2 ng/L (e.g., penicillin G), respectively[4,5]. For the hormones, a study in a lake in China showed concentrations between 0.03 and 0.28 ng/L for ethynylestradiol, ß-estradiol, estrone, progesterone, and testosterone[6]. The studies on these lakes show that antibiotics and hormones are found in low ng/L concentrations in the lake water. In the study on a lake in Turkey [4], the hormones were detected in between below detection limits and 11 ng/L. To date, these antibiotics and hormones are not yet detected above 10 ng/L in surface water samples from Laguna Lake. Extraction and pre-concentration using solid-phase extraction, for example, should be done to be able to determine the possible occurrence of these compounds in Laguna Lake water in concentrations below 10 ng/L. While antibiotics and hormones are not yet included in the regular monitoring of water contaminants in Laguna Lake, the method presented in this study can be used to quickly assess potential water contamination in the lake especially from water coming from the tributary rivers that run along urban, industrial and agricultural areas surrounding the lake.

5. CONCLUSION

Currently, emerging contaminants such as antibiotics (amoxicillin, cephalexin, cloxacillin, ciprofloxacin, penicillin G) and hormones (ethynylestradiol, ß-estradiol, estrone, progesterone, testosterone) are not yet detected above 10 ng/L in the surface waters of Laguna Lake.

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P7-1

Effects of organic pollutant from anaerobic digestate on solubility of poly-brominated diphenylether in aquatic environment

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Keywords: polybrominated diphenyl ethers, dissolved organic carbon, partition coefficient, anaerobic, aquatic environment

ABSTRACT

In this research, two kinds of typical polybrominated diphenyl ethers (PBDEs) were selected as the target pollutant and their aqueous solubility in the presence of two dissolved organic carbons (DOCs) from two different anaerobic digesters (35℃ and 55℃) were measured. In the solubility experiment, a wide range of DOC strengths based on the chemical oxygen demand (COD) concentration was used. From the linear relationships between PBDE and DOC concentrations through 48 hours equilibrium experiment, furthermore, the partition coefficients (K_{DOC}) of the two PBDEs between water and individual DOC were determined. The results revealed that K_{DOC} at the thermophilic condition (K_{DOC} =0.0114) was 10 times higher than that at the mesophilic condition (K_{DOC} =0.0011), suggesting that the solubility of PBDE was affected by the DOC sources in the environment.

1. INTRODUCTION

Because of its excellent fire resistance ability, some PBDEs as the famous retardant were widely applied in textile, plastics, and electronic circuitry industry worldwide [1]. On the one hand, it is known that such PBDEs are toxic to the endocrine system and the nervous system and also has enrichment in vivo, and has a huge threat to the humanity [2]. Currently the PBDEs are diffused everywhere in the environment, and they are easily detected especially in the water environment. Hence, they are listed as persistent organic pollutants (POPs) under the Stockholm Convention. Although these POP- PBDEs are hydrophobic, their aqueous solubility tends toincrease according to the organic concentration in water. This feature is the key for POP-PBDEs to diffuse into the environment. Therefore, in order to understand the behavior of POP-PBDEs in aquatic environment, it is important to grasp dissolution characteristics for various organic pollutants in water environment.

PBDE partition coefficients (K_{DOC}) between water and DOC components in water environments such as rivers and lakes have been measured in previous studies so far [3]. The K_{DOC} is calculated by the following equations (1-2):

$$\frac{S_{DOC}}{S_{Water}} = K_{DOC} * C_{DOC} \quad (1)$$

$$\frac{S_{Total}}{S_{Water}} = K_{DOC} * C_{DOC} + 1 \quad (2)$$

where S_{Total}, S_{DOC}, and S_{Water} is the PBDE concentration in total solution, DOC phase, and water phase, respectively, and C_{DOC} is the DOC concentration in the solution. Because K_{DOC} is constant regardless of DOC concentration, the higher the DOC concentration, the higher the risk of contamination expansion by PBDE [3].

In this study, we focused on digested methane fermentation solution containing very high DOC as a sample of water system. Methane fermentation is operated under various conditions. Typical conditions are classified to two temperature conditions: medium (35 ℃ - mesophilic) and high (55℃ - thermophilic) temperatures. The objective of this study is to clarify the influences of DOC extracted from two different digested liquids of methane fermentation (35 ℃ and 55 ℃) on aqueous solubility of two POP-PBDEs resulting in determining their K_{DOC} values for two different DOCs.

2. METHODS

Solution Preparation: The sludge was centrifuged and filtered with a 0.22 μm filter, then the supernatant was used as DOC stock solution. The DOC solution was adjusted to 0, 10, 50, 100, 250, and 500 mg/L (as COD measuring [3]), respectively. We selected BDE-47 and BDE-99 (AccuStandard Co., USA) as target POP-PBDEs. 5 mg of each PBDE was dissolved into 500 mL of hexane respectively. The solution was used as the standard solution in the following experiment.

Equilibrium Experiment: First, the standard PBDE hexane solution was added into a 15-mL test tube. Second,

the test tube was heated at 90℃ to evaporate hexane. The amount of solidified PBDE in the tube exceeded the mass of PBDE required for preparing its solubility in 15 mL of water. Then 12 mL of prepared DOC solution was added into the tube and shaken at 35 ℃ for 48 hours in an incubator. Three parallel experiments for each sample were carried out at the same time.

Sample Extraction: After the equilibrium experiment was settled down, the supernatant of the solution was filtered to remove the superfluous solid PBDE with a 0.22 μm filter paper, getting 10 mL of each sample. And dichloromethane was used to extract PBDE in the solution for 3 times, then dichloromethane in the extract was replaced with 10 mL of n-hexane. All samples were stored in brown bottle at 4℃ .

Sample Analysis: The PBDE content in hexane was determined by a gas chromatography/electron ionization-quadrupole mass spectrometry (GC-EI-QMS) system (5975C GC/MSD system; Agilent Technologies Inc., Santa Clara, CA, USA) equipped with a DB-5MS capillary column (15 m × 0.25 mm, 0.1 μm film thickness; Agilent Technologies Inc., Santa Clara, CA, USA), according to a previous study [4].

3. RESULTS and DISCUSSION

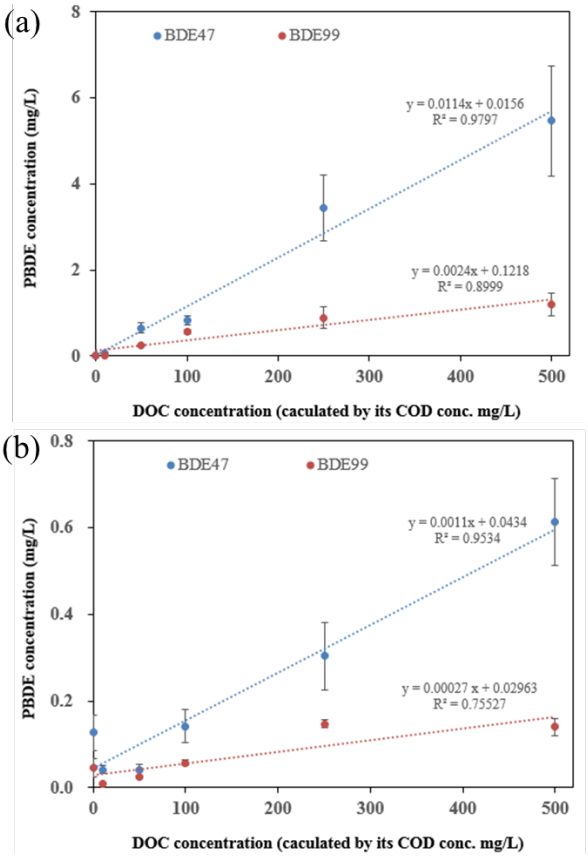

Fig. 1 KDOC of thermophilic and mesophilic DOC solution for the BDE-47 and BDE-99

Fig. 1 illustrates a linear relationship between the DOC concentration and the two PBDE contents. The correlation coefficients for BDE-47 are both higher than 95%.The K_{DOC} values for the thermophilic solution of BDE-47 and BDE-99 were 0.0114 and 0.0024, respectively, while the mesophilic K_{DOC} values for the two PBDEs were 0.0011 and 0.00027 by order.

Under both 35 and 55 ℃ conditions, the K_{DOC} of BDE47 was higher than that of BDE-99. This is because the increase in the number of Br in PBDE molecule decreases the solubility. [3]. In addition, the difference in K_{DOC} between mesophilic and thermophilic conditions may be due to the number of adsorption sites and types of functional groups in DOC molecule.

4. CONCLUSIONS

Aqueous solubility of BDE-47 and BDE-99 in the presence of DOC derived from medium temperature and high temperature anaerobic sludge were investigated. The K_{DOC} was determined from the solubility data and DOC concentration data. The results obtained in this research indicated that K_{DOC} of PBDE with DOC of thermophilic digested sludge was clearly higher than that with DOC of mesophilic sludge. It suggested that the solubility of PBDE was affected by the DOC sources in the environment. Further study is necessary to clarify the mechanisms of the factors caused high solubility of PBDE.

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P7-2

ディスポーザー排水嫌気性処理における流入濃度の影響

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キーワード：バイオマス，メタン発酵，無動力撹拌槽，嫌気性ろ床

抄録

河川や湖沼流域の水質を保全するために，ディスポーザー排水を適切な処理することが重要である。本研究では，無動力撹拌槽と嫌気性ろ床槽を組み合わせたシステムに用いた都市生ごみディスポーザー排水のメタン発酵実験を行い，生ごみの流入濃度が処理性能に与える影響を検討した。流入 TS 濃度が 6.8 から 15.5 g/L に増加に伴い，システムに流入する COD が 14.4 から 35.5 g-COD/L/d に増加した。システムのメタンガス生成速度も 0.46 から 0.92 L-CH_4/L/d に増加した。一方，流入 TS 濃度が 23.8 g/L にさらに増加すると，無動力槽にスカムが大量に発生した。COD の転換率を算出した結果，いずれの希釈条件においても流出水に残存した COD が 2%前後であったが，流入濃度の増加とともに，システム槽内に残存した COD が大幅に増加した。安定したメタン発酵を維持するために，15.5 g/L 以下の TS 濃度で供給することが重要であることが分かった。

1. はじめに

都心部の商業ビルやショッピングセンター，ホテルなどではまとまった量の生ごみが一般廃棄物として排出され，また一定規模以上のビルには厨房除害設備を設置する必要性から余剰汚泥が排出されているところもある。これらの処分には高い場外処分費がかかり，その貯蔵，運搬には臭気が出るなど衛生面の問題も大きかった[1]。一方で，エネルギー回収と減量化の 2 つのメリットを有するメタン発酵技術は，生ごみのようなバイオマスの利活用拡大に資する技術として期待されている。生ごみをディスポーザーで破砕，水道水で希釈した後の排水がサイフォン式無動力メタン発酵槽を用いた研究が報告されているが[2, 3]，このディスポーザー排水の流入濃度が処理性能に与える影響に関する先行研究はまだ少ない。また，この排水処理がうまくいかないと河川や湖沼流域に汚濁負荷源になる恐れもある。

本研究では，メタン発酵の処理性能を向上することを目指し，サイフォン式無動力撹拌槽と嫌気ろ床槽の組み合わせた高効率なシステムの確立に向けた検討を行った。生ごみをディスポーザーで破砕処理した後，組み合わせた処理システムによってエネルギー回収することを想定し，処理性能に対する生ごみの流入 TS 濃度の影響を究明することを目的とした。

2. 方法

茨城県つくば市にある和食店の生ゴミを破砕機によって破砕し，微細化した後，表 1 に示した各希釈倍率の水道水で希釈し，基質タンクに保存した。

表 1　実験条件まとめ

実験段階	1	2	3
日数(d)	0~63	64~133	134~145
希釈倍数	18	9	6
システムの HRT(d)	10	10	10
システムの OLR (g-COD/L/d)	1.44	3.65	6.36

図 1 に示したようにメタン発酵システムはサイフォン式無動力撹拌槽（有効容量 10 L）と嫌気ろ床槽（有効容積 10 L）の組み合わせであった。ろ床槽の金属箱に小円筒状ろ材で充填し，2 室で合計 73%の充填率とした。無動力撹拌槽と嫌気ろ槽側面

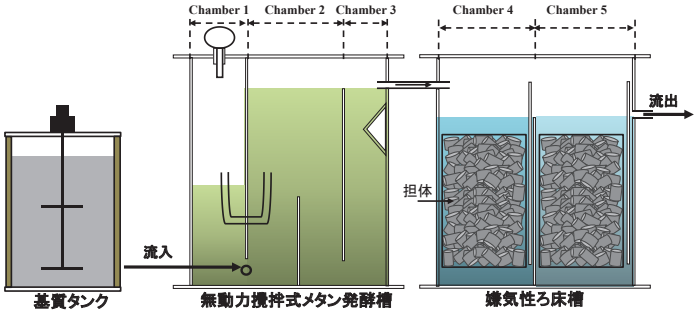

図 1 メタン発酵システム概略図

のウォータージャケットに温水循環装置から温水を供給することで常時 35 ℃ に保持した。タイマー制御式ローラーポンプを用いてメタン発酵システムに投入し，連続運転を行った。消化液は，オーバーフローで排出した。システムのバイオガス生成量は湿式ガスメータにより測定した。本研究では流入および流出水を週 2 回程度サンプリングし水質分析を行った。

3. 結果

図 2 に処理システムのメタンガス生成速度，TS および COD の経日変化の結果を示す。生ごみの流入 TS 濃度が 6.8 から 15.5 g/L に増加するとともに，基質（無動力槽流入水）の COD が 14.4 から 35.5 g-COD/L/d に増加した。これに伴い，システムのメタンガス生成速度が 0.46 から 0.92 L-CH_4/L/d に増加した。これらの条件で，システムの COD 除去率が 96%以上であり，安定した処理性能を維持できた。一方，流入濃度が 23.8 g/L にさらに増加すると（実験開始 134 日目から），メタンガス生成速度が一時的に増加したが，実験開始 143 日目に無動力槽にスカムが大量に発生し，嫌気ろ床槽に流入した。その結果，システムのガス生成量が測定できなかった。

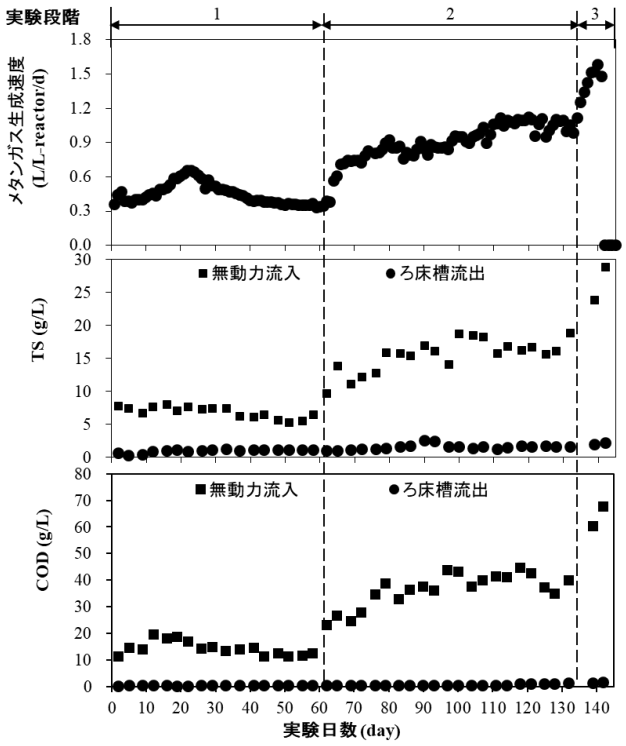

図 2 ガス生成、TS および COD の経日変化

4. 考察

図 3 に各希釈倍率における流入 COD の転換率を示した。流入濃度が 6.8 から 15.5 g/L に増加するとともに，流入 COD がメタンガスへの転換率が 90.6%から 64.8%に減少した。一方，システム槽内に残存した COD が 7.1%から 32.7%に増加した。いずれの条件においても，流出水に残存した COD が 2%前後であった。

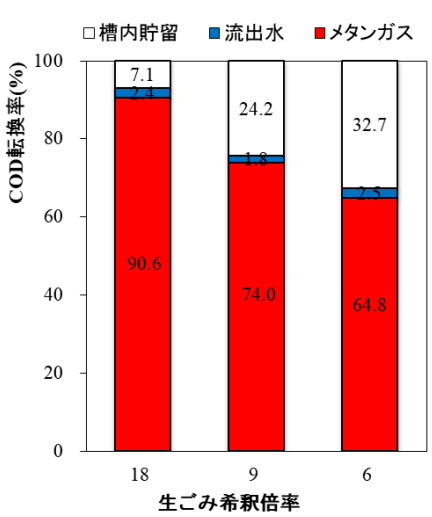

図 3 各希釈倍率における流入 COD の転換率

5. 結論

無動力撹拌槽と嫌気ろ床槽の組み合わせたシステムを 145 日間連続運転し，生ごみの濃度が処理性能に大きく影響することがわかった。流入 TS 濃度が 23.8 g/L の場合，メタン生成に悪影響を与えた。一定した水準以下の TS 濃度（15.5 g/L）で供給することが良好な嫌気性処理の鍵となる。この研究の結果から，ディスポーザー排水の適切処理によって，流域への負荷削減に寄与することが示唆された。

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P7-3

Verification on AOSD Control System as Electric Power Reduction Saving Energy /Advanced Wastewater Treatment Technology in VIETNAM and Spread for Environmental Restoration in Asian Areas

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Keywords: Bio-engineering system, Advanced wastewater treatment, Electric power reduction N/P, Automatic Oxygen Supply Device (AOSD) system

ABSTRACT

The AOSD (Automatic Oxygen Supply Device) system is the latest environment renovation system which supplies only the necessary quantity of oxygen of the microorganism in the advanced sewage treatment under the electric power reduction. It also contributes to COP21 including a basin of lakes and marshes. In the sewage treatment process, optimal oxygen amounts required for organic matter removal, nitrogen nitrification-denitrification etc. are predicted by using some parameters such as water temperature and dissolved oxygen (DO), and efficiency of blowers and stirrers can be operated automatically. As the model project of Asia Water Environment Improvement by Ministry of the Environment of Japan, "Vietnam's sophistication of wastewater treatment and cost saving response control system dissemination project" is carrying out. By this project advanced BOD, nitrogen and phosphorus removal have been accomplished and verified with more than 50% electric power reduction in combination with AOSD system, simultaneously. We need to start the spread in Asian areas such as Lake KASUMIGAURA basins.

1. INTRODUCTION

For the restoration and preservation of lake areas, N/P removal and saving energy waste water treatment is very important.

The energy for aeration in the aeration tank usually occupies large part of total energy consumption in wastewater treatment plants. An oxic-aeration blower usually needs its operation of 24hours. AOSD system is one of the best ways for energy-saving equipment for improving advanced treated water quality. The application of this equipment will serve to improve water quality, reduce electricity cost by constantly sending to CPU-PLC information signals regarding temperature and dissolved oxygen to work out the nitrification-denitrification velocity and the proper aeration hours and the system off-aeration time. The time length for aeration depends on the load of inflowing organic substances. Automatic controls of aeration enable advanced sewage disposal, by maintaining pH for proper bio-treatment, depending on pH decrease by nitrification or pH increase by denitrification. Moreover, the Innovate AOSD system could confirm the stability of water treatment power reduction performance and best biota under on/off aeration, automatically.

In the last fiscal year, we created relationships with related government and companies in the verification, determined the candidate sites for demonstration with AOSD (Automatic Oxygen Supply Device)system which can improve performance of wastewater treatment and save cost for aeration and investigated the conditions such as treatment method and water qualities. As a result, 4 sites were selected for the demonstration in this fiscal year as follows;1） Binh Hung Wastewater Treatment Plant at Ho Chi Minh City managed by Steering Center of the Urban Flood Control Program, 2） Thu Dau Mot Wastewater Treatment Plant at Binh Duong Province managed by Binh Duong Water Supply – Sewerage – Environment Co., Ltd. (BIWASE), 3） Wastewater Treatment facility at industrial park at Binh Duong Province managed by Investment and Industrial Development Corporation (BECAMEX),4） Wastewater Treatment facility for food processing factory at Mekong Delta area managed by private company.

2. METHOD

AOSD system have been introduced as a main target for Asian water environmental improvement, restoration and preservation.

The effect value on the introduction of AOSD system have been evaluated by the road map building of the spread development for environment protection revival plan in Asia. The thing with a high possibility of the business expansion estimated AOSD introduction of the system business application properties as its effect, and was inspected. These results can be contributed to the restoration and preservation of Lake KASUMIGAURA basins.

3. RESULTS

It succeeds at amount 140,000 m^3/ day,17,000 m^3/ day sewage-treatment plants, 1,000m^3/ day industrial park processing institutions and 500m^3/ day fish processing effluent treatment facilities.

AOSD system introduction at a sewage-treatment plant, about more than 30-60 % of electric power reduction below T-N and the BOD10mg/L were achieved by the base of the most suitable DO control. And it was found out that a phosphorus outflow load can be reduced nearly about 50 % compared with an existence system.

In the case of introduce AOSD system for HRT about 2.8 hours of 141,000 m^3/ day and change the former 2 hours for 1 cycle in 1 hour, nearly 60 % of power reduction effectiveness , and T-N and the BOD concentration less than 10mg/L was obtained. Continuous aeration for 24 hours have been caused and occurred dispersion of activated sludge in low loading in the time when that inflow large rain fall, reduction of inflow raw water volume and system trouble appears.

But, aeration time have been reduced less than nearly 10 minutes for 1 cycle under the AOSD introduction system in comparison with conventional 60 minutes. And advantage of an artificial intelligence (AI) system was inspected. For example, as the case of Thu Dau Mot Wastewater Treatment Plant, the results on AOSD system is shown in Fig.1, Table1, 2, Fig.2 and 3.

4. DISCUSSION

4.1 Binh Hung Wastewater Treatment Plant

It succeeded that the performance of AOSD control was reproduced by the open and close of the air-flow valve on site without any influences to existing blower. And furthermore reducing the amount of air for aeration was able to make the gently mixing under the anoxic condition. As a result, AOSD could create nitrification and denitrification and removed nitrogen with higher

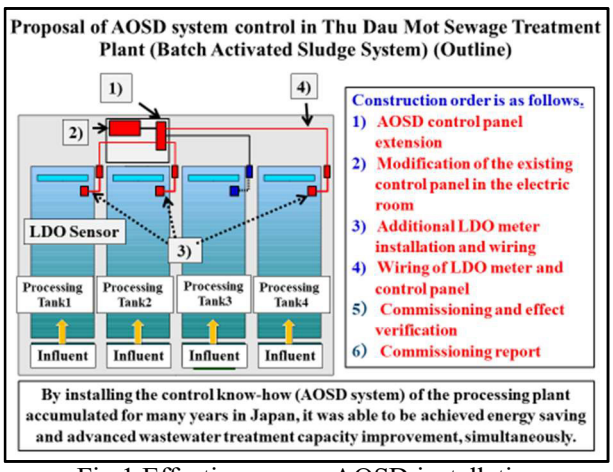


Fig.1 Effectiveness on AOSD installation

Table1 Operation time for each process of Thu Dau Mot in current operation method

Operation	Time
Aeration	5cycles(24min * 5times = 120min)
Stirring	2cycles(24min * 2times = 48min)
Settle（Precipitation）	60min
Supernatant discharge	60min
Per 1 cycle	288min (4.8hr)
Pre 1 day	288min * 5 cycle= 1,440min (24hr)

Table 2 Operation time for each process of Thu Dau Mot after AOSD installation

Operation	Time
Aeration	3cycles(28min, 14min, 14min; Sub-total 56min)
Stirring	3cycles(28min, 42min, 42min; Sub-total 112min)
Settl（Precipitation）	60min
Supernatant discharge	60min
Per 1 cycle	288min (4.8hr)
Per 1 day	288min * 5 cycle= 1,440min (24hr)

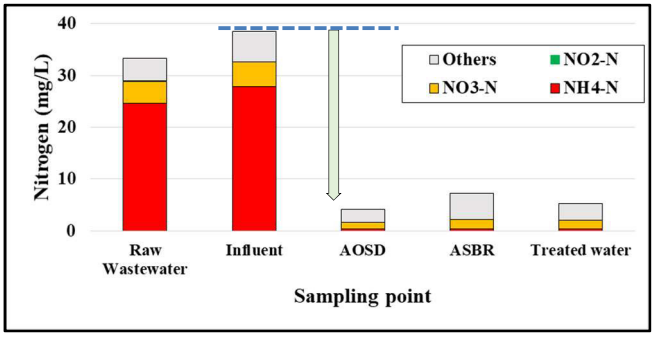


Fig.2 Average integrated value of each nitrogen form

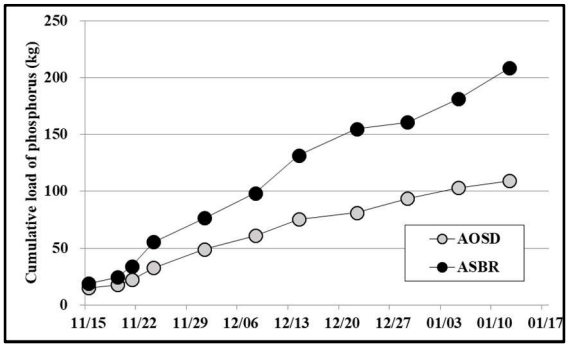


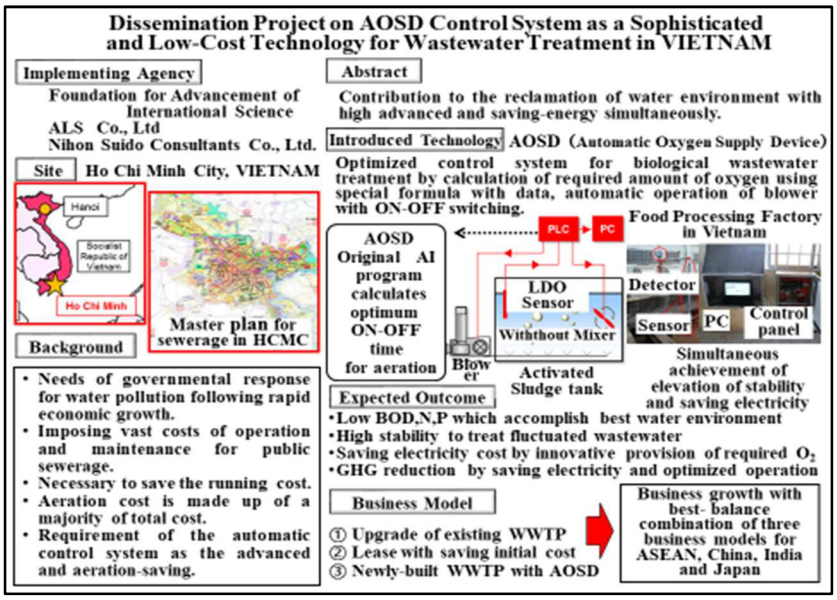
Fig.3 Reduction of effect by AOSD on phosphorus load

Percentage than existing system. Therefore, AOSD system reduced 13% (5,587 kg) of the load of nitrogen discharged to the natural environment compared with existing system during the demonstration. The reduction ratio of electricity consumption calculated by the opening time and closing time of air-flow valve was 42 ~ 61% with high performance, although it fluctuated in consequence of seasonal change.

4.2 Thu Dau Mot Wastewater Treatment Plant

AOSD system carried out the improvement of wastewater treatment and saving electric consumption at the same time with higher performances even though the existing system

was already installed PID control program to save electricity with DO sensor. In particular, 35.2 minutes of aeration time can be reduced and reduction ratio of electricity consumption was 15.5% compared with existing system. High performances to treat organic pollutants such as BOD and COD and SS were maintained and treatment of nitrogen was improved. It is particularly worth noting that phosphorus removal was improved dramatically compared with existing system. Therefore, AOSD system reduced 47.1% of the load of phosphorus discharged to natural environment compared with existing system during the demonstration (for 65 days). Additionally, as a consequence of whole day research, we found that the performance of wastewater treatment by AOSD was highly stable even though there has fluctuation of concentration of wastewater.



Fig,4 The outline of this project and effects of the AOSD system introduction by Ministry of the Environment of Japan.

4.3 BECAMEX wastewater Treatment facility

Because of the raw water acceptance discharged from another wastewater treatment facility managed by BECAMEX, the facility subjected to have installed AOSD system needed to receive the wastewater and the amount became more than usual. Under the quantitative and qualitative fluctuation of wastewater, AOSD system maintained the performance of wastewater treatment. At the same time, 74.3% of aeration time saved and estimated reduction ratio of electricity consumption was 53.0% compared with existing system. The saving electricity arises from the suitable control of amount of air required for removal of organic pollutant.

4.4 Mekong Delta wastewater Treatment facility

The quality of wastewater in Mekong Delta facility included high nitrogen and much fluctuation of raw water that is typical of industrial wastewater. Under the control of AOSD system, microbial reaction such as BOD oxidation and nitrification-denitrification maintained good condition and quality of treated water was stable highly. As a result, removal for BOD, COD were almost perfect. Regarding the treatment of nitrogen, nitrification ratio was 95.8% and removal ratio of nitrogen was 90.5%. Both high performance of wastewater treatment and reduction ratio of electricity consumption was 61.1% as average in demonstration period and 83.7% in lunar New Year holidays. We found that AOSD carried out the electricity saving not only daily operation but also big event such as long vacation.

4. 5 Cost evaluation

Based on the results of demonstration related to reduction of electricity, the cost evaluation was studied. Applied methods were B/C method as one of Present Value method, EIRR method as one of Internal Rate of Return method and Payback Period method. As a result, for example in case of Binh Hung Wastewater Treatment Plant, investment efficiency on introduction of AOSD system was high in all applied methods and it expects these results served as a great incentive to install the system.

Fig.4 show the outline of this project and effects of the AOSD system introduction.

5. CONCLUSION

The new challenges emerged from the demonstration in this fiscal year will be revealed through verification test with high accuracy. Based on the obtainable data, the project effect including the cost evaluation will be estimated and studied, and the business plan made from feasibility study in the last fiscal year will be readjusted for commercialization. Depending on the result of summary, we have to put forward a suggestion to government that changes enforcement of policy. In parallel to the establishment on business model, the enlargement of sales activities such as the installation of AOSD system to planned projects of sewerage system in Vietnam and the spread to Japanese private companies have to promote strongly. Based on these win-win advanced treatment and electric power reduction results, we need to pursue the preparation to start the spread in Asian areas such as Lake KASUMIGAURA basins. From fiscal year 2018, in the bottom of cooperation and support of Rtec co.LTD, using AOSD system can be contributed for the restoration of accelerated pollution environment and global warming.

P7-4

Nutrient removal performance in a constructed wetland using modified biochar as a bed filter

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Keywords: biochar, constructed wetland, nitrogen, tidal flow

ABSTRACT

Nutrient removal performance in a constructed wetland using modified biochar, which has a high monovalent anion exchange capacity, was studied. Moreover, the performances of two influent feeding modes—tidal flow and horizontal subsurface flow—were compared. *Zizania latifolia* dominated in constructed wetlands with modified biochar and grew better in the horizontal subsurface-flow constructed wetland, which had a constant water level. Modified biochar effectively removed NO_3-N, whereas removal of NH_4-N was assumed to be due to plant absorption. Nitrification progressed better in the tidal-flow constructed wetland than in the horizontal subsurface-flow constructed wetland.

1. INTRODUCTION

In rural areas where sewerage systems are not constructed, either domestic wastewater is treated by household wastewater treatment facilities that combine primary and secondary treatment processes, or excrement and urine are treated and miscellaneous drainage is discharged without treatment. Therefore, in many cases, wastewater in those areas is not purified as efficiently as that processed by sewage treatment facilities. In particular, nitrogen and phosphorus are not removed sufficiently. Constructed wetlands have been studied as an advanced treatment method for such domestic wastewater.

In recent years, modified biochar, which has a high monovalent anion exchange capacity, has been commercially available. We studied the possibility of using the biochar as a bed filter in compact constructed wetlands to enhance the nitrogen purification of the effluent from a combined treatment tank. We also compared the efficacies of two different influent feeding methods, namely tidal flow and horizontal subsurface flow.

2. METHODS

Each model constructed wetland (0.6 m long × 0.41 m wide × 0.2 m deep) was filled with 6.67 kg (dry weight) of modified biochar (particle diameter 1–3 mm; Nisshoku Corp.), and vegetation (*Zizania latifolia* L., *Vinca major* L., *Trachelospermum asiaticum* 'Hatsuyukikazura', *Salvia microphylla* Kunth) was then transplanted into the wetland. Two constructed wetlands with different feeding modes of artificial wastewater were prepared. One was a tidal-flow constructed wetland (TF) with a water depth that was varied from 5 to 14 cm each day by using a siphon, and the other was a horizontal subsurface-flow constructed wetland (HSF) with a constant water depth of 14 cm (Fig. 1). Artificial wastewater (18.5 mg/L NH_4-N, 17.0 mg/L NO_3-N, 5.6 mg/L PO_4-P) representing effluent from a combined treatment tank was supplied to the constructed wetlands. The wastewater loading rate was 4 L/day (~160 mm/day). Volumes of influent and effluent, and water quality parameters, were measured weekly for 22 months. Plants in the constructed wetland were harvested several times during the experiment to measure dry weight and nitrogen and phosphorus concentrations. At the end of the experiment, the nitrogen and phosphorus concentrations of the modified biochar were measured. The amount of NO_3-N adsorbed to the modified biochar was also measured by KCl extraction.

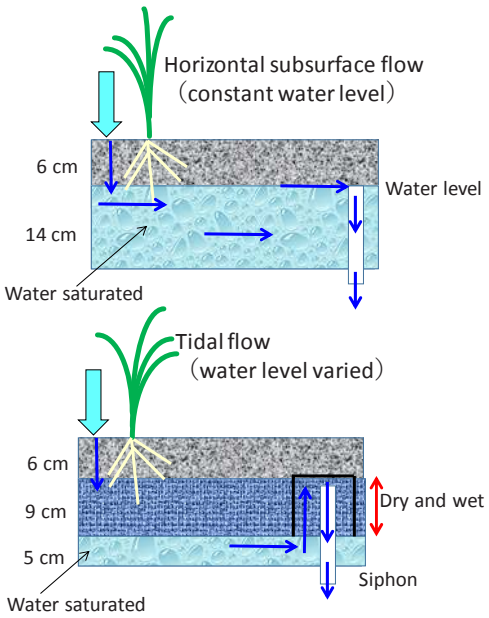

Fig. 1 Constructed wetlands (wetland area: 0.25m^2)

3. RESULTS AND DISCUSSION

Zizania latifolia dominated the vegetation; the other plant species died or showed inferior growth. This outcome was likely due to the low pH of the modified biochar. The dry weight of the aboveground plant parts in HSF was about 1.5 times greater than that in TF. Thus, *Z. latifolia*, which is an emergent macrophyte, appeared to prefer the constant water level of HSF.

The concentration of NO_3-N in effluent was less than 1 mg/L for about 6 months after the start of the experiment in June 2015, but it then shifted to 2–4 mg/L (Fig. 2). The NO_3-N concentration in the effluent from TF started to rise sharply at about 18 months after the start of the experiment, suggesting that the adsorption sites of modified biochar became saturated more rapidly in TF than in HSF. On the other hand, the concentration of NH_4-N showed a seasonal fluctuation that declined during summer with vigorous vegetation growth and increased during winter (Fig. 2). The PO_4-P concentration of effluent remained low for about the first 4 months, but then increased and showed seasonal fluctuation (Fig. 3). The PO_4-P concentration in effluent from HSF tended to be lower than that from TF.

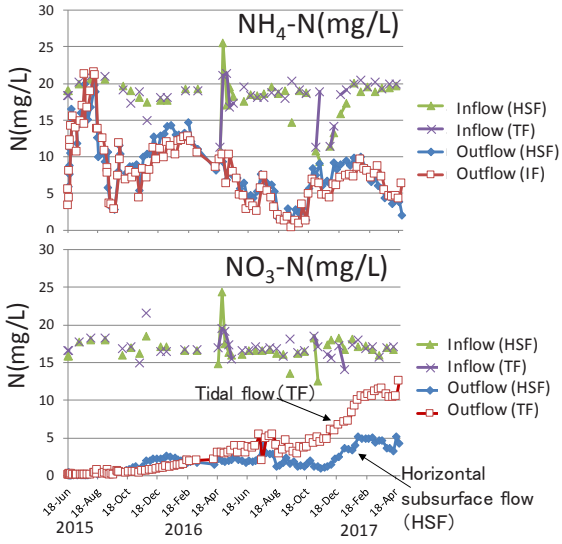

Fig. 2 NH_4-N and NO_3-N concentrations in influent and effluent of constructed wetlands

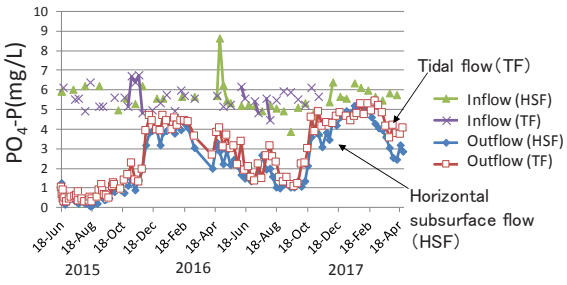

Fig. 3 PO_4-P concentrations in influent and effluent of constructed wetlands

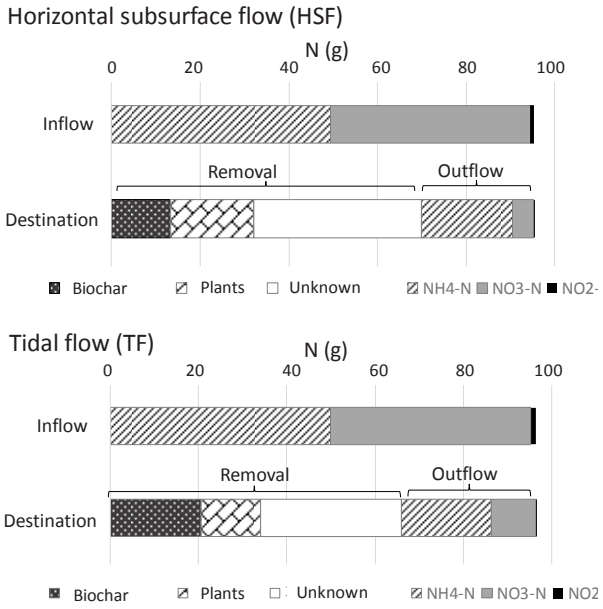

Fig. 4 Nitrogen balances in constructed wetlands

In a batch adsorption test using artificial sewage, modified biochar adsorbed NO_3-N at a maximum of 7 mg/g (dry weight; data not shown). A KCl extraction test indicated that the NO_3-N adsorbed on the modified biochar in TF reached 34% (3.44 mg/g) of removed N, whereas that in HSF, where the vegetation grew better, reached only 11% (1.27 mg/g). Based on the N balance illustrated in Fig. 4, we assumed that NH_4-N was removed mainly via absorption by *Z. latifolia*, because this species absorbs NH_4-N preferentially over NO_3-N [1]. Nitrification N (NH_4-N decreased – N absorbed) was estimated as 21% of influent NH_4-N in HSF and as 32% in TF. Thus, TF seemed to be advantageous in terms of oxygen supply to the bed filter. Most unknown parts in the N balance are assumed to have been due to denitrification. In HSF, denitrification seems to have progressed well because of the abundant supply of organic matter from the roots due to the vigorous plant growth.

4. CONCLUSION

Zizania latifolia dominated in the constructed wetlands with modified biochar and grew better in the HSF system , which had a constant water level. Modified biochar effectively removed NO_3-N, whereas the removal of NH_4-N was considered to be due to plant absorption. Nitrification progressed better in TF than in HSF.

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P7-5

Characteristics of Nitrogen and Phosphorus Removal Type Onsite Wastewater Treatment System and Applicability to Foreign Countries

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[1]Fuji Clean Co., Ltd.

Keywords: domestic wastewater control, nitrogen removal, phosphorus removal, iron electrolysis

ABSTRACT

Small-scale onsite wastewater treatment plants are widely used as decentralized wastewater treatment systems in sparsely populated areas of Japan. The Fuji Clean CRXⅡ model has been developed in Japan as an enhanced nitrogen and phosphorus removal system using an iron electrolytic process. The structure, function and mechanics of the CRXⅡ model is introduced along with performance data from grab samples taken from 27 actual sites. The result showed high treatment performance, suggesting that the CRXⅡ model is an effective option to protect water resources worldwide.

1. INTRODUCTION

Small-scale onsite wastewater treatment plants referred to as *Jokaso* are widely used to treat domestic wastewater in sparsely populated areas of Japan. *Jokaso* means "purification tank" in Japanese. The current number of operating *Jokasos* in Japan as of March 2017 is 7,589,176[1]. Recent developments in *Jokaso* technology provide for reduction in nitrogen and phosphorus compounds as well as BOD and SS. These nutrient reduction systems are increasingly popular to prevent eutrophication in the environmentally sensitive areas near compromised water bodies.

Fuji Clean Co., Ltd developed the CRX model as the first phosphorus removal type *Jokaso* in 2002 and has installed about 4,000 units in Japan. The CRX model uses iron electrolysis to remove phosphorus. Because of its easy installation and maintenance properties, this model was well received in the industry. More recently, the updated CRXⅡ model was released in November 2016[2] featuring reduced energy consumption as well and even easier installation and maintenance. In this paper, structure and function of the CRXⅡ model, and actual field testing results are described. Then challenges for exporting Japanese *Jokaso* technology to the other countries are discussed.

2. STRUCTURE AND FUNCTION OF CRXⅡ

The CRXⅡ model was tested and accredited by the Building Center of Japan with a treatment performance of biochemical oxygen demand (BOD)≦10 mg/L, total nitrogen (TN)≦10 mg/L, total phosphorus (TP)≦1 mg/L, suspended solids (SS)≦10 mg/L and chemical oxygen demand by $KMnO_4$ (COD_{Mn})≦15 mg/L. The tank is made of fiber-reinforced plastic and contains five functional treatment chambers (Fig.1 and Table 1). The first chamber is a sedimentation chamber and the second chamber is an anaerobic filtration chamber which contains cylindrical skeleton filter media. These two

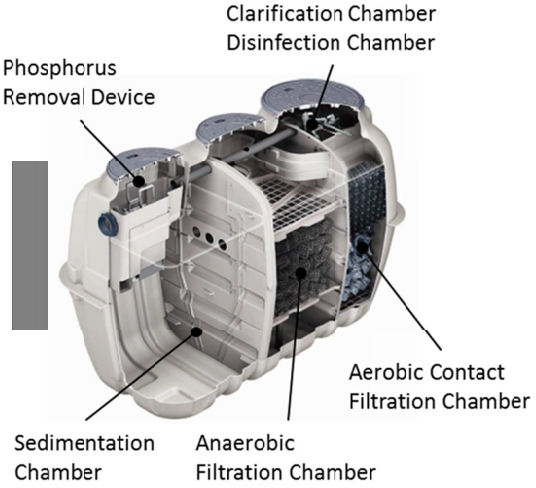

Fig. 1 Structure of CRXⅡ model

Table 1 Design specification of CRXⅡ model

Model	CRXⅡ-5	CRXⅡ-7	CRXⅡ-10
Person Equivalent (PE)	5	7	10
Hydraulic Loading (m^3/d)	1.0	1.4	2.0
Total Volume (m^3):			
Sedimentation	1.048	1.502	2.113
Anaerobic Filtration	1.052	1.498	2.106
Aerobic Contact Filtration	0.482	0.687	0.939
Clarification	0.237	0.339	0.470
Disinfection	0.015	0.021	0.044
Total	2.834	4.047	5.672
Blower Flow Rate (L/min)	60	90	110
Power Consumption (W):			
Blower	45	58	80
Phosphorus Removal Device	3.8	7.4	10.7
Total	48.8	65.4	90.7

chambers provide primary treatment functions such as sludge separation, sludge accumulation and anaerobic decomposition. The third chamber is an aerobic contact filtration chamber which is filled with two different types of media; board contact media in the upper section and cylindrical net contact/filter media in the lower section. In aerobic chamber, organics are biologically decomposed and ammonia is nitrified to nitrite or nitrate. The fourth chamber is a clarification chamber followed by a disinfection chamber. A recirculation air-lift pump is equipped to constantly return treated water from the bottom of the clarification chamber back to the sedimentation chamber through a phosphorus removal device installed in the sedimentation chamber. Recirculation volume is 4-6 times Q (4-6 Q) with 1Q equivalent to total daily flow. Sludge accumulated at the bottom of the clarification chamber is transferred to the sedimentation chamber by this recirculation process. Nitrified process water is also recirculated to the sedimentation chamber as nitrite and nitrate solutions, which are converted to inert nitrogen gas in the anaerobic filtration chamber and vented to the ambient air.

The phosphorus removal device is composed of two or three pairs of iron electrodes (quantity depends on system size) connected to direct current power source. Fig.2 shows the process of phosphorus removal by iron electrolysis. Iron released from the anode is oxidized to ferric ions. These ferric ions combine with phosphate ions to form phosphorus compounds which precipitate and settle in the sedimentation chamber. Eventually, phosphorus compounds are removed by the occasional sludge pump out procedure. The amount of iron released from electrodes can be controlled via a control panel by adjusting electric current flow. The recommended molar ratio (Fe:P) is 1.7. The polarity is inverted every 24 hours to prevent forming an oxide layer, which doesn't conduct electricity.

3. METHOD

Twenty seven sites at five prefectures (regions) in Japan were investigated from October to December, 2017; 9 in Kanagawa, 8 in Ibaraki, 5 in Fukushima, 4 in Miyagi and 2 in Gifu -prefectures. The investigated number of models CRXⅡ-5, CRXⅡ-7 and CRXⅡ-10 were 20, 4 and 3, respectively. In Japan, a CRXⅡ-5-person equivalent (PE) tank is typically installed for a house with a total floor space equal to or less than 130m^2, a CRXⅡ-7 PE is for houses larger than 130m^2 and a CRXⅡ-10 PE is for a two-family house (duplex). The average water temperature in the aerobic contact filtration chamber was 19.7℃ with a range of 12.6 to 25.8℃.

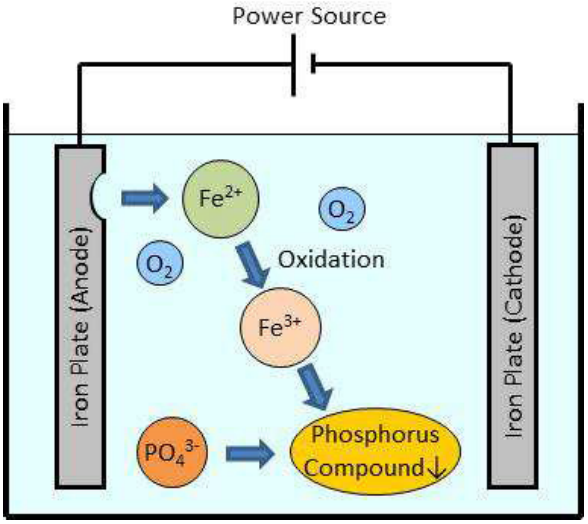

Fig. 2 Process of phosphorus removal

Grab samples were taken from the clarification chamber at each site. BOD, CBOD, SS, TN, NH_4-N, NO_2-N, NO_3-N, and TP were measured.

4. RESULTS AND DISCUSSION

All effluent data are summarized in Table 2. The average concentrations of BOD, CBOD, SS, TN and TP expressed in mg/L are 8.0, 3.2, 4.3, 10.0 and 0.5, respectively, showing good treatment performance.

However, the maximum values were much higher than the average and median values. These were mainly caused by sites with a high number of occupants and improper operation, such as an improper recirculation rate setting. At the site of CRXⅡ-5 where 7 people are living (two more than standard for this model), BOD, SS, TN and TP were 13.3 mg/L, 13 mg/L, 25.2 mg/L and 2.3 mg/L, respectively. At the site with no recirculation, BOD, SS, TN and TP were 55.1 mg/L, 8.0 mg/L, 23.2 mg/L and 1.4 mg/L, respectively. At the site whose recirculation rate was as much as 19 Q (too high), BOD, SS, TN and TP were 28.7 mg/L, 24 mg/L, 7.4 mg/L and 1.0 mg/L, respectively. These data indicate that adjusting recirculation properly is one of the most important maintenance procedures and essential to good treatment performance.

Fig.3 shows accumulated distribution data for BOD, CBOD, SS, TN and TP. More than 90% of the data points are less than 20 mg/L of BOD, CBOD, SS and TN, and 85% are less than 1.0 mg/L of TP.

Overall, the result shows good treatment performance for every analytical parameter. Furthermore, effluent quality could be further improved by proper maintenance including adjustment of recirculation and electric current.

Upsizing to a larger blower is also one proven technique to improve treatment quality on sites with high inflow loading.

5. APPLICABILITY TO FOREIGN COUNTRIES

Table 3 shows national testing condition in Japan[3] compared to those in the United States of America[4], EU[5] and Australia[6]. There is a significant difference between Japanese standard and the other countries. The range and maximum are typically wider and higher for other countries. As shown in Table 3, phosphorus concentrations in the other countries are much higher than that of Japan. It means that more electric current, larger iron electrodes and more tank volume for sludge accumulation derived from phosphorus removal may be necessary in order to treat this high concentration wastewater properly.

The data of BOD and CBOD in Table 2 and Fig. 3 show that more than half of the BOD was derived from nitrification. This is because the effluent sample is usually taken from the clarification chamber before disinfection in Japan. On the other hand, CBOD is measured in the USA and Germany. In Australia, effluent is taken from the disinfection chamber after chlorination and BOD is measured after de-chlorination. In this case, the BOD value becomes similar to CBOD because nitrifying bacteria is sterilized by chlorination procedure.

It is important to understand such differences in standards as described above, and to incorporate these differences in model design and selection when the Japanese *Jokaso* system is exported to the other countries.

Table 2 Summary of effluent data from 27 sites in Japan

	BOD mg/L	CBOD mg/L	SS mg/L	TN mg/L	NH_4-N mg/L	NOx-N mg/L	TP mg/L
Avg.	8.0	3.2	4.3	10.0	2.3	6.2	0.5
S.D.	11.1	3.1	5.3	6.3	4.9	5.2	0.5
Med.	3.8	2.0	2.0	7.4	0.5	4.4	0.3
Max.	55.1	11.5	24.0	25.2	22.7	21.7	2.3

NOx-N is sum of NO_2-N and NO_3-N

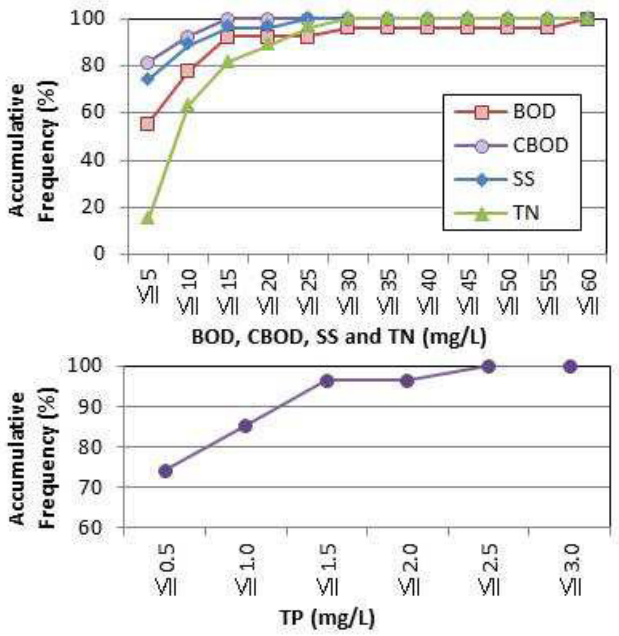

Fig. 3 Effluent quality

Table 3 Comparison of influent concentrations

	Japan	USA	EU	Australia
BOD (mg/L)	180-220	100-300	150-500	150-750
CODcr (mg/L)	-	-	300-1000	-
SS (mg/L)	145-175	100-350	200-700	150-750
TN (mg/L)	40-50	-	-	20-150
TKN (mg/L)	-	35-70	25-100	-
NH_4-N (mg/L)	-	-	22-80	-
TP (mg/L)	4-6	-	5-20	6-25

6. CONCLUSION

About 120,000 onsite aerobic wastewater treatment units for residential use are sold annually in Japan. Fuji Clean CRX Ⅱ model is a high-performance model which can reduce nitrogen and phosphorus as well as BOD and SS. This study demonstrated that treatment performance is very high showing an average effluent quality of 8.0 mg/L for BOD, 4.3 mg/L for SS, 10.0 mg/L for TN and 0.5 mg/L for TP. It is anticipated that this *Jokaso* technology will work for other countries as well, if it is properly operated and maintained and model selection considers wastewater characteristics within each country.

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P7-6

Nutrient Removal from Domestic Wastewater by *Johkasou* in Watershed of Lakes

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Keywords: domestic wastewater, nutrient removal, *Johkasou*

ABSTRACT

The removal performance of nutrient (nitrogen and phosphorus) by actual *Johkasou*, on-site household domestic wastewater treatment facility was investigated in the watershed of Lake *Inba-numa*. The nitrogen removal type *Johkasou* showed better performance for BOD and nitrogen removal than the conventional *Johkasou*. The high performance of nitrogen removal type *Johkasou* was attributed to a mixed liquor (after aerated) circulating system for denitrification. However, phosphorus in the effluent from nitrogen removal type *Johkasou* was not different from that of conventional *Johkasou*. Therefore, in order to reduce phosphorus from *Johkasou*, the phosphorus removal pellets which recently developed were put into various types *Johkasous*. When 400 g of phosphorus removal pellets were placed in the *Johkasou* in one week, total phosphorus (T-P) and orthophosphate (PO_4-P) in the effluent from various types *Johkasous* decreased. By using these systems the *Johkasou* is able to remove nutrient from domestic wastewater in areas not provided with a public sewerage system in watershed of lakes.

1. INTRODUCTION

Lake *Tega-numa* and Lake *Inba-numa* are polluted lakes in Japan (Fig. 1), and their chemical oxygen demand (CODMn) are about 10 mg / L. One of the causes of pollution of these lakes is eutrophication. Chiba Prefectural Government and other organizations implemented various measures such as sewerage system construction for the reduction of nutrient mainly nitrogen and phosphorus in lake water. In these watersheds of lakes there are also areas without sewerage, and in these area most of the domestic wastewater is treated with various on-site treatment systems. The on-site treatment systems are called *Johkasou* which plays an important role to reduce pollutants caused by domestic wastewater in Japan. As shown in Fig. 2, domestic wastewater accounts for a large proportion among the nutrient loads of the watershed of Lake *Tega-numa* and Lake *Inba-numa*. Most of the load of these domestic wastewaters is discharged from the house using various *Johkasous*. As shown in Fig. 3, *Johkasou* for domestic wastewater is classified into *Tandoku-shori Johkasou*, conventional *Johkasou*, and nitrogen removal type *Johkasou*, and the like. (In Japan *Tandoku-shori Johkasou* is not allowed to be newly installed now.) It is important to reduce nutrient from the *Johkasou*. Therefore, in this paper, we studied a method of removing nutrients from the effluent from *Johkasou*.

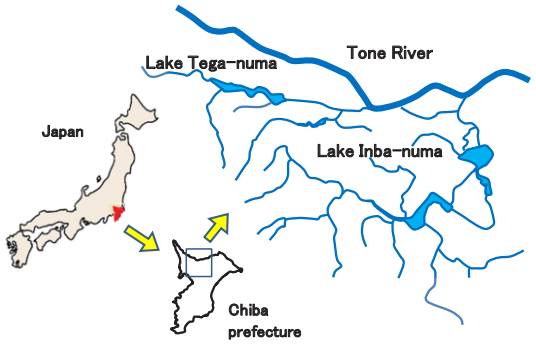


Fig.1 Lake *Tega-numa* and Lake *Inba-numa*

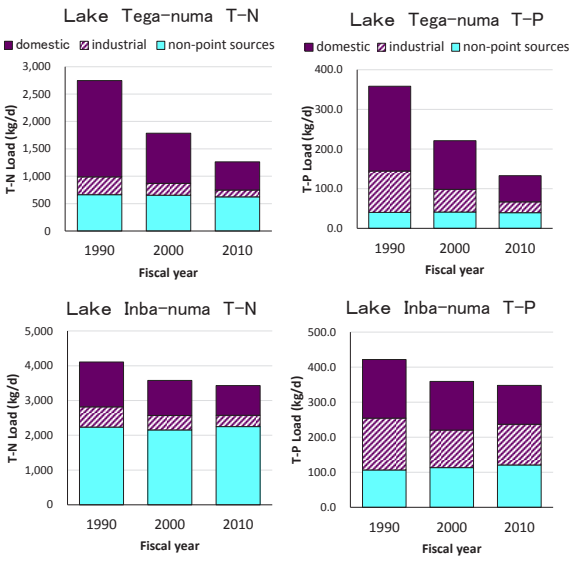


Fig.2 The Load of T-N and T-P in Watershed of Lake *Tega-numa* and Lake *Inba-numa*

* Present address : The Committee for the Lake *Inba-numa* Watershed Management

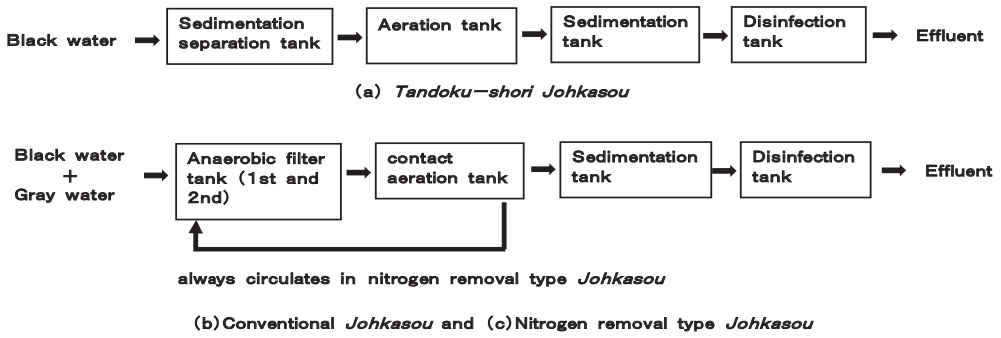


Fig. 3 Typical process of (a) *Tandoku-shori Johkaso,* (b) Conventional *Johkasou* and (c) Nitrogen removal type *Johkasou*

2. NITROGEN REMOVAL TYPE *JOHKASOU*

Conventional *Johkasou* generally treats black water (night soil) and gray water (domestic wastewater) and the biochemical oxygen demand (BOD) of the effluent after treatments of these systems is expected to be less than 20 mg/L in most of the cases [1]. Nitrogen removal type *Johkasou* is widely used in Japan recently. The nitrogen removal type *Johkasou* is equipped with a device constantly circulating treated water in a conventional general system and having an anaerobic tank and a contact aeration tank (Fig 4). In this paper, we report the results of the survey of the effluent water of the actual 34 nitrogen removal type *Johkaosu*. Those nitrogen removal type *Johkasous* smaller than 10 population equivalents (p.e.) in watershed of Lake *Inba-numa* (Chiba Prefecture) were surveyed from 1998 to 2004. The results of survey approximately 80% of BOD and T-N data for the final effluent water exhibit below 15 mg/L [2]. The data ranges for the effluent water qualities and their average values are shown in Table 1. The results were represented for nitrogen removal type *Johkasou* compared with conventional type without recycling [2]. It was clear that the values of BOD and T-N for the nitrogen removal type *Johkasou* were lower than those of conventional *Johkasou*. The significant decrease in T-N suggested that the denitrification of NO_3-N could take place in the anaerobic filter tanks by recycling liquor containing NO_3-N [2]. Whereas the T-P concentration for nitrogen removal type *Johkasou* was not remarkably different from the conventional *Johkaosu* (Table 1), because the nitrogen removal type *Johkasou* does not have any function to remove phosphorus. In watershed of lakes it is desirable to use a *Johkasou* with phosphorus removal function in addition to nitrogen removal function.

3. PHOSPHORUS REMOVAL PELLET

Phosphorus removal pellets for the reduction of phosphorus were tested in existing *Johkasou*. The pellet was developed by Sugawara et al. [3] and was produced by

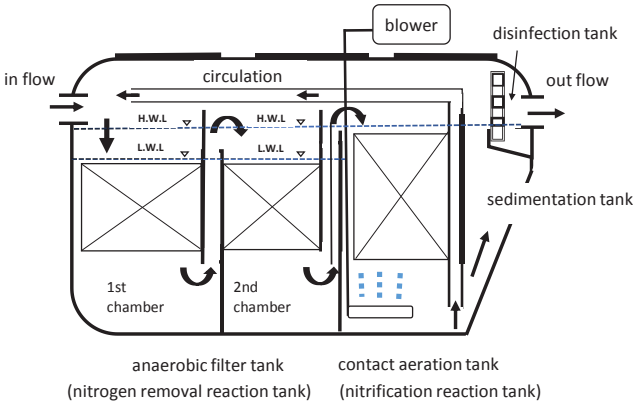


Fig. 4 Typical scheme of small-scale nitrogen removal type *Johkasou* ; individual household type.

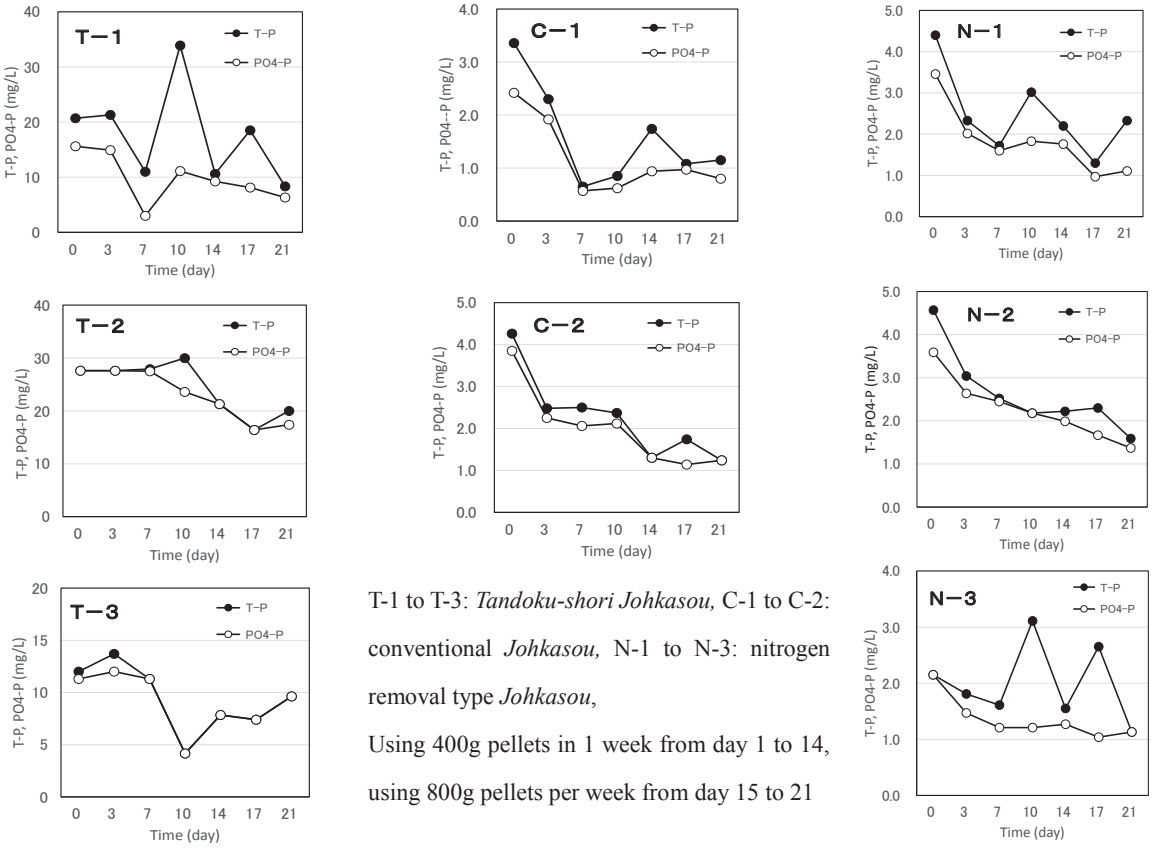
Table 1 Effluent water qualities in the nitrogen removal type *Johkasou* and conventional *Johkasou*

mg/L

	Nitrogen removal type *Johkasou* n = 75		Conventional *Johkasou* without treated water recycle n = 68	
	min-max	average	min-max	average
BOD	0.9 - 55	10	2.3 - 127	19
CODMn	6.0 - 38	14	7.1 - 47	17
SS	1 - 59	8.4	0.5 - 63	13
T-N	4.0 - 33	12	7.1 - 74	25
T-P	0.7 - 8.5	2.9	0.31 - 7.6	3.1

Table 2 Types of *Johkaosu* investigated for phosphorus removal

Type of *Johkasou*	Equipment No.	Number of users for design	Actual number of users
Tandoku-shori Johkasou	T-1	5	3
	T-2	7	5
	T-3	10	3
Conventional *Johkasou*	C-1	7	3
	C-2	5	3
Nitrogen removal type *Johkasou*	N-1	5	4
	N-2	10	7
	N-3	7	3
	N-4	7	4



T-1 to T-3: *Tandoku-shori Johkasou,* C-1 to C-2: conventional *Johkasou,* N-1 to N-3: nitrogen removal type *Johkasou*,

Using 400g pellets in 1 week from day 1 to 14, using 800g pellets per week from day 15 to 21

Fig. 5 Changes of T-P and PO_4-P in effluent water from various *Johkasous*

Nikka Maintenance Co., Ltd, Japan. Main component of the pellet is potassium aluminum sulfate ($AlK(SO_4)_2 \cdot 12H_2O$) and the pellet was formed with adding a small amount of auxiliary materials. Potassium aluminum sulfate has been used as a coagulant, the pellet became safer to human body and easier to handling by molding into tablets.

Various *Johkasous* shown in Table 2 were investigated in cooperation with *Johkasou* users in watershed of Lake *Inba-numa*（Sakura City） in 2010.

Fig. 5 shows the phosphorus concentration in the effluent water from *Johkasou* when the pellet was added into the raw water tank of various *Johkasous* (sedimentation separation tank or anaerobic filter tank, Fig. 3). There was no input of pellets on day 0 and 400 g of pellets were put in one week from day 1 to 14. Then pellets of 800 g were put in one week from day 15 to day 21. As shown in Fig. 5, when the pellet was put in the raw water tank, the phosphor concentration of effluent water in various *Johkasous* was reduced, and the effect of pellet on the reduction of the phosphorus was clarified.

4. NUTRIENT REDUCTION BY *JOHKASOU*

Johkasou has been used mainly for the purpose of reducing organic matter of domestic wastewater. However, in the area without sewerages in the watershed of lakes, reduction of nutrient in effluent from *Johkasou* is required. Nitrogen can be reduced by the *Johkasou* circulating treated water, and phosphorus can be reduced by using phosphorus removal pellets. The reduction of nutrient in domestic wastewater is expected in the future by various methods.

5. ACKNOWLEDGEMENT

We would like to thank Dr. Inamori, Dr. Sugawara and Mr.Kondo for helpful advice for the study on phosphorus removal pellets. We also thank Chiba Prefecture Water Quality Conservation Division and Sakura City Living Environment Section for their cooperation on this research. In addition, we would like to express our gratitude for the fact that this research was carried out in the project of the Committee for Lake *Inba-numa* Watershed Management.

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P7-7

環境技術実証事業の概要と有機性排水処理技術の性能評価

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キーワード:浄水・排水処理技術, 技術実証, 性能評価

抄録

環境技術実証事業では, 環境技術の普及を支援する目的で, 第三者機関が技術の環境保全効果を実証している。実証対象技術分野の一つである有機性排水処理技術分野では, 装置における流入水と流出水の汚濁負荷量を比較することで, 装置の性能(除去効率)を評価している。しかしながら, 小規模の飲食店や食品工場等からの排水は, 流量や汚濁物質濃度の変動が激しいため, 一般的な採水及び分析に基づく手法では, 汚濁負荷量を正確に把握することが難しい。本稿では, この課題を解決するために採用した, コンポジット採水手法や原単位を用いた性能評価手法について紹介した。

1. 環境技術実証事業の概要

環境保全に有用であると考えられる環境技術の中には, その性能が客観的に評価されていないために, ユーザーからの信頼が得られず, 普及が進んでいないものがある。環境省の事業の一つである「環境技術実証事業(ETV 事業)」では, そのような技術の普及を支援する目的で, 技術開発者でもユーザーでもない「実証機関」と称する第三者機関が, 環境保全効果等を実証している。実証結果は, 環境省のウェブサイトに公開され, ユーザー等が自由に閲覧することができる。また, 実証済みの技術には, 図1に示すとおり, 技術毎に個別のロゴマークが交付され, 技術紹介・広告等のために使用することができる[1]。



図1 交付される個別ロゴマークの1例
(有機性排水処理技術分野の場合)

環境技術実証事業では, 現在(2018 年度), 次の 8 つの分野で実証が行われている。このうち, 有機性排水処理技術分野では, 当協会が実証機関として選定され, 技術の処理性能等を試験している(実証試験)。本技術分野が環境技術実証事業で取り上げられた理由は, 下水道普及率の向上に伴い, 下水道未普及地域での排水規制対象外の小規模施設からの排水が, 水環境保全上の大きな課題となっていることから, 適切な排水処理技術を普及させ, 環境保全に資すること等であったと報告されている[2]。

表 1 に, 近年実証された技術の概要を示す。ノルマルヘキサン抽出物質のみを処理対象とした, 排水からの油分除去・回収技術は, レストランや小規模の食品工場等のユーザーからの関心が高く, 近年はこれらの技術の性能が実証されることが多くなっている。

【実証対象技術分野(2018 年度)】

① 中小水力発電技術分野
② 自然地域トイレし尿処理技術分野
③ 有機性排水処理技術分野
④ 閉鎖性海域における水環境改善技術分野
⑤ 湖沼等水質浄化技術分野
⑥ ヒートアイランド対策技術分野(建築物外皮による空調負荷低減等技術)
⑦ ヒートアイランド対策技術分野(地中熱・下水等を利用したヒートポンプ空調システム)
⑧ テーマ自由枠(特定の対象技術を定めない, 上記技術分野以外の環境技術が対象)

表１ 環境技術実証事業「有機性排水処理技術分野」で近年実証した技術の概要

実証年度	実証技術名	申請者	浄化原理の概要
2017	油脂分離回収装置 「環吉君 Jr.」	株式会社 ティービーエム	既存のグリース阻集器に後付で設置し，水と油の比重差を利用して阻集器内の浮上油分を回収する。
2016	厨房及び食品工場排水 油水分離回収・SS 回収装置 グリス ECO SS+2	株式会社 大都技研	厨房排水等の油分を油水分離器により回収するとともに，スクリュー式の加圧ろ過装置で浮遊物質を除去する。
2015	BS-400 バイオ固形剤による 阻集器内油分除去方法	セキュリオン ・24 株式会社	配合菌が分泌する酵素の油脂分解能を利用して油水分離槽の機能を補完し，油分含有排水を処理する。
2014	遠心分離方式搾油機 「レノバティ」	有限会社 ウインダム	揚げ物調理で発生する揚げカスから油分を遠心分離により回収し，洗浄排水への油分混入を低減する。
	酵素工場システム	株式会社 メイカム	担体流動方式による生物処理に消化酵素を加え，油分が多い排水を処理する。

2. 有機性排水処理技術の評価における採水手法の課題

有機性排水処理技術分野では，実証対象となる処理装置における流入水と流出水の汚濁負荷量を測定することで，装置の性能（除去効率）を評価している。このため，流入汚濁負荷量を正確に把握することは重要である。しかしながら，小規模事業場の排水は，流量や汚濁物質濃度の変動が激しいため，一般的な採水方法では，代表的な水質の排水を採取することが困難であり，汚濁負荷量を把握することが難しい。

図 2 には，A 事業場において排水を高頻度で採水した際の濃度変化（油分：n-Hex）を示しているが，このような排水濃度変動の激しい事業場では，採水のタイミングによって水質濃度が大きく変化するため，採水間隔を適切に設定しないと，汚濁負荷量が過大または過小評価されるおそれがある。採水間隔を短くすれば短くするほど，より正確に汚濁負荷量を把握することが可能となるが，採水や分析に係る作業量が増加し，試験費用が増大するという問題が発生する。また，敷地面積の限られる飲食店等では，排水処理装置が厨房フロア（床）に埋設されているケースもあり，高頻度の採水作業は，営業の妨げになることもある。

3. コンポジット採水手法

上記の採水手法の課題を解決するため，筆者らは，コンポジット採水手法を検討した[3]。本手法では，図 3 に示すような小型の採水ポンプを用いて，排水を少量ずつ自動で採取して混合することで，対象期間中の平均的な水質の排水を採取することが可能である。混合されたコンポジット試料を分析するため，分析試料数も少なくすることができる。また，自動で採水が行われるため，採水作業に伴う営業の妨げも防止することが可能である。

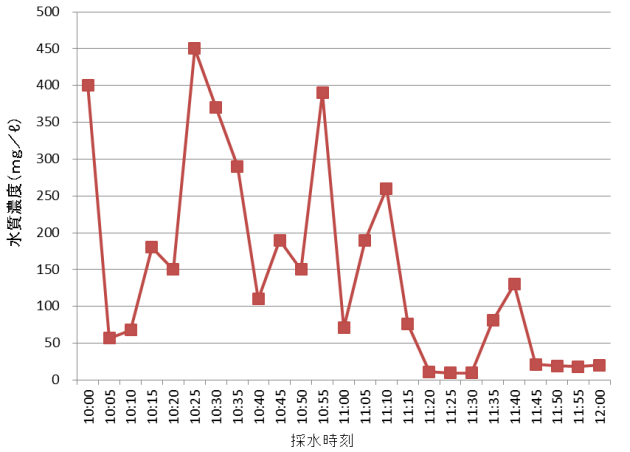

図２ 小規模事業場排水における濃度変動の1例（文献[3]を一部改編）



図３ コンポジット採水機器の1例

一方，水質のみでなく流量変動も激しい事業場の場合は，本手法を用いても評価が困難となる。正確な汚濁負荷量を把握するためには，流量に比例させて採水速度を変化させる必要があるが，小規模事業場において，流量変動をリアルタイムで把握し，それに合わせて採水速度を自動的に制御することは困難である。実際に過去の試験において，短期間に高濃度の排水が大量に発生した際に，本手法で採取した排水は僅かな水質濃度の上昇に留まり，汚濁負荷量が過小評価されたことがある[4]。この際は，この高濃度の排水の汚濁負荷量を個別に調査することで，全体の汚濁負荷量の補正を行った。

油分が除去対象の場合は，水中に均一に分散していないため，採水チューブの吸引口の位置によって採取される排水の濃度が大きく変化するおそれもある。さらに，懸濁物質が多い等，排水性状によっては，採水チューブの閉塞が生じるため，本手法を採用することが困難となる。

4. 原単位を用いた有機性排水処理技術の性能評価

採水および水質分析に基づく従来の評価手法に代わる手法として，筆者らは原単位を用いた評価手法を検討した[5]。本手法は，小規模事業場の主要な汚濁排出工程における汚濁負荷量を把握する際に利用することができる。たとえば，ラーメン店においては，下式に示すとおり，ラーメン1杯あたりの平均的な残汁の水量および濃度を測定することで，1食あたりの汚濁負荷量（原単位）を把握し，さらに店舗から提供された食数を掛け合わせることで，主要な汚濁源である残汁由来の汚濁負荷量を算出することが可能である。

{汚濁原単位（g/食）} ＝
{残汁量（L/食）} × {残汁濃度（g/L）}

{汚濁負荷量（g/日）} ＝
{汚濁原単位（g/食）} × {食数（食/日）}

表2に，事業場 B（ラーメン店）における，原単位を用いた残汁排水の汚濁負荷量の算出例を示す。上記の方法でメニュー毎の汚濁原単位を調査した結果，4.6～29.9g/食であった。それぞれの原単位の値に，店舗から提供された食数の値を掛け合わせることで，汚濁負荷量を算出した。その合計は約 4,470g であった。別に求めた流出汚濁負荷量（約 110g）から，処理装置の除去効率を約 98%と算出した。一方，通常の定時採水及び分析に基づいて流入汚濁負荷量を評価した場合は 934g であり，原単位調査と比べ，低い値であった。一時的に発生する高濃度の排水を，定時採水では採取することができず，結果として汚濁負荷量が過小評価されたと考えられた。

原単位を活用した評価手法では，排水の濃度・流量変動の影響を受けずに流入汚濁負荷量を把握することが可能であり，小規模事業場からの排水に対しては，有用な手法であると考えられる。一方，排水工程やメニューの種類が多い場合には，調査試料が多くなり，調査が煩雑化し，費用も増大するおそれがある。また，食数データの入手のために，事業場の協力が不可欠である。

5. 結論

有機性排水処理技術の性能をより正確に評価するために，コンポジット採水手法や原単位を用いた評価手法を検討し，一部の実証試験において採用した。一方，これらの手法にも課題が存在することから，調査対象事業場の排水の流出特性に合わせて，適切な手法を選択するとともに，複数の採水・評価手法を組み合わせる等の工夫が必要である。

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表２ 原単位を用いた汚濁負荷量の評価事例

メニュー	原単位（g/食）	食数（食/日）	汚濁負荷量（g/日）
A	29.9	122	3,642
B	13.5	51	690
C	6.4	19	121
D	6.4	2	13
合計			4,466

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鉛直流式人工湿地による直鎖アルキルベンゼンスルホン酸の除去

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キーワード:生活排水対策, 浄水・排水処理技術, 人工湿地, 直鎖アルキルベンゼンスルホン酸

抄録

直鎖アルキルベンゼンスルホン酸(LAS)は, 陰イオン界面活性剤の一種であり, 家庭用洗剤として汎用されている。生活排水に含まれる主な汚濁物質の一つであり, 水生生物に対する毒性を有することから, 日本では, 水生生物の保全に関わる水質環境基準項目の一つになっている。本研究では, 環境適合性と経済性に優れた排水処理技術として多様な有機・無機化合物の除去に適用されている人工湿地による LAS の除去について検討を行った。ヨシ植栽／非植栽のラボスケール鉛直流式人工湿地システムを用いてモデル下水二次処理水及びモデル河川水中の LAS の除去を試みた結果, 植栽の有無によらず LAS の除去が可能であった。また, 詳細な検討の結果, LAS の除去は主に吸着により生じており, 非植栽系では吸着飽和によって除去率が時間とともに低下したが, 植栽系では長期にわたり高い除去率が維持され, 植物の存在による除去能の向上が示唆された。

1. はじめに

直鎖アルキルベンゼンスルホン酸(LAS)は, 陰イオン界面活性剤の一種であり, 家庭用洗剤として利用されているほか, 各種工業においても幅広く利用されている。特に家庭用洗剤としての使用により, LAS は生活排水中の主な汚濁物質の一つになっており[1], 世界中で下排水処理に汎用されている活性汚泥法等による処理後にも一部が残存し, 水環境中に排出されている[2]。LAS は比較的生分解されやすい物質ではあるものの, 魚類や藻類などの水生生物に対して毒性を示す可能性があることから, 日本では 2013 年に水生生物の保全に関わる水質環境基準項目に追加され, 適切な汚濁防止対策が求められている。

人工湿地は, 湿地の植物, 土壌(基材), 微生物など自然生態系の自浄作用を活用して排水処理方法である。処理に広い面積を要し, 処理性能が天候に左右されるという問題点を有するものの, 環境適合性や経済性に優れ, また, 運転や維持管理が容易であることから, 発展途上国にも適用可能な排水処理技術として注目されている。人工湿地では, 植物によって吸収される栄養塩類(窒素, リン)や金属類に加え, 基材への吸着や微生物による分解により有機化合物の除去も可能である。既往研究では, 医薬品類[3]や多環芳香族化合物[4]などの有害化学物質の除去について検討され, 多様な有機化合物を除去し得ることが示されている。我々のグループにおいても, 鉛直流式人工湿地システムを用いて, 廃棄物最終処分場の浸出水中に含まれる重金属類[5]及びフェノール性の難分解性有機化合物[6]の除去が可能であることを示してきた。

そこで本研究では, 生活排水由来の汚濁物質の除去, ならびに水域保全に対する鉛直流式人工湿地システムの有効性を検討するため, 家庭排水由来の主要汚濁物質である LAS の除去について一連の検討を行った。

2. 方法

2.1. 鉛直流式人工湿地システム

大学構内にある温室にラボスケールの人工湿地リアクターを設置し, 実験を行った(図 1)。温室内では, ガラス面を透過する太陽光に加え, 地表面における照度が約 2000 lux の照明を午前 6 時から午後 6 時まで点灯した。高さ 63 cm, 直径 18 cm の透明な塩化ビニル製容器に粒径約 15 mm の砂利を基材として約 50 cm 敷き詰めたものを人工湿地として 4 基作製した。その内, 2 基にはヨシを植え付けて植栽系とし, 残り 2 基はヨシの植え付けを行わず, 非植栽系とした。

2.2. 人工湿地による LAS 除去実験

下水二次処理水及び環境水中に含まれる LAS の除去を想定して, それぞれ合成下水を活性汚泥で 1 日処理し, ろ過して 2 倍希釈した水(モデル下水二次処理水)及び合成河川水(モデル河川水)を用意し, 直鎖アルキルベンゼンスルホン酸ナトリウム(炭素数 12)を LAS として添加して, 実験に用いる流入水とした。人工湿地の上部から各流入水を 5 L 流入し, 1 日間ポンプで人工湿地内を循環させた後, 人工湿地内の水(処理水)をすべて排出し、新たな流入水を上部から流入することを 5 回繰り返し, 流入水及び処理水中の LAS 濃度を測定した。

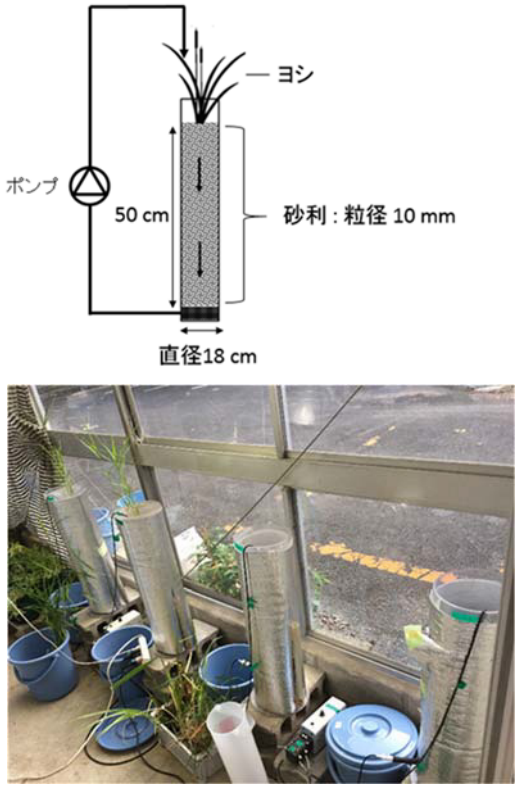

図 1 人工湿地システム（上）及び温室内に設置した人工湿地の外観（下）

2.3. LAS 除去メカニズムの検討

人工湿地システムで確認された LAS 除去のメカニズムを詳細に理解するため，小型の実験系を用いた検討を行った。まず，オートクレーブ滅菌した砂利を 500 mL 容トールビーカー6 つに敷き詰め，その内 3 つにヨシを植え付けて植栽系とし，残りの 3 つを非植栽系とした。また，滅菌した 1 L 容褐色瓶を 3 つ用意し，500 mL になるように滅菌した砂利を入れ，滅菌系とした。LAS を添加した合成河川水を流入水とし，流入水 250 mL をこれらの小型実験系に加え，2 日間温室で静置させた後に排出し（処理水），新たに流入水を加えることを 7 回繰り返し，流入水と処理水の LAS 濃度を測定した。

2.4. 分析方法

流入水及び処理水中の LAS は，InterSep SlimJ C18-ENV カートリッジを用いて抽出した後，高速液体クロマトグラフィーにより定量分析した。

3. 結果及び考察

3.1. 鉛直流式人工湿地によるモデル下水二次処理水及びモデル河川水中の LAS の除去

モデル下水二次処理水及びモデル河川水を用いた鉛直流式人工湿地システムによる LAS 除去実験において，水温はそれぞれ約 25℃及び約 29℃であった。各実験における LAS 除去の結果を図 2 に示す。流入水においては，モデル河川水を用いた実験の一部で測定ミスによるデータの欠損があったが，LAS 濃度は実験期間を通じて 7 mg/L 弱であった。処理水中の LAS 濃度は，植栽系，非植栽系ともに，モデル下水二次処理水を用いた実験では 1 mg/L 以下，モデル河川水を用いた実験では 2 日目を除いて 1.5 mg/L 以下となり，ヨシの有無によらず，LAS が除去可能であることが示された。既往研究では，水平流式の人工湿地システムを用いた LAS の除去がわずかに報告されているが[4,7]，本研究により，鉛直流式人工湿地システムでも LAS を除去することが可能であることが示された。また，モデル下水二次処理水を用いた実験では 2 日目以降，モデル河川水を用いた実験では 3 日目以降に除去率が向上したことから，サイクルを重ねることで LAS 除去に寄与するメカニズムがより効果的に作用したものと考えられた。

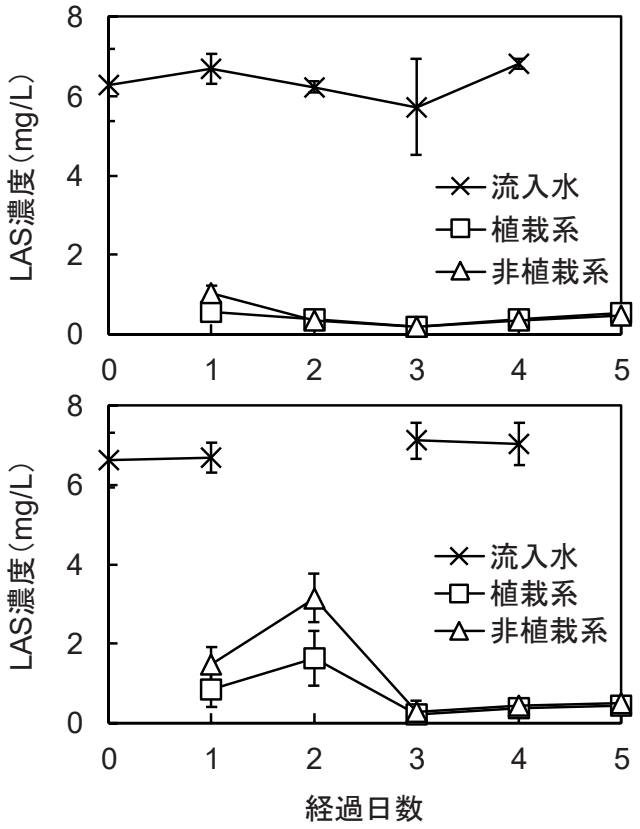

図 2 人工湿地システムによるモデル下水二次処理水（上）及びモデル河川水（下）中の LAS の除去（n=2）

3.2. LAS の除去メカニズム

小型の実験系（植栽系，非植栽系，滅菌系）を用いた LAS 除去実験の結果を図 3 に示す。流入水中に約 10

mg/L 含まれるLASは，いずれの実験系においても除去された。しかし，その除去率は植栽系＞非植栽系＞滅菌系であった。さらに，植栽系においては実験期間を通じて同等の除去率が維持されたが，非植栽系及び滅菌系では時間の経過とともに除去率が低下し，特に滅菌系では 12 日目には殆ど除去されなくなった。これらの結果から，LAS の除去は主に砂利（基材）への吸着によって生じていることが示唆され，非植栽系及び滅菌系においては閉塞の進行によって除去率が低下し，滅菌系では実験終盤に吸着飽和に達したものと考えられた。一方，植栽系においては，砂利への吸着だけでなく，ヨシによる吸収や根圏微生物による分解の活性化が同時に生じることにより，非植栽系及び滅菌系に比べて長い期間優れた LAS 除去能が維持されたものと示唆された。

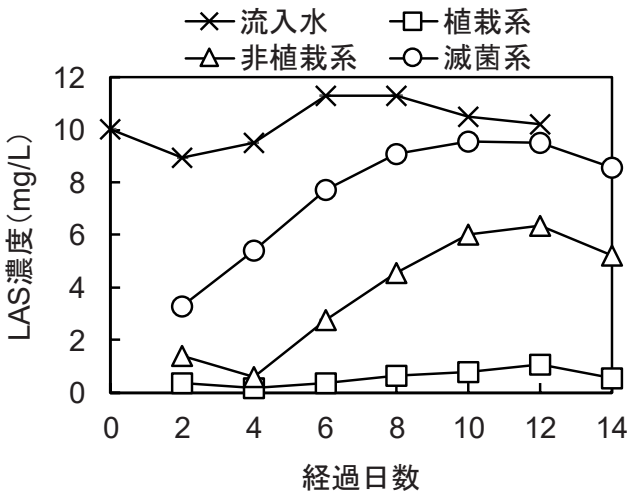

図 3 小型実験系を用いた LAS 除去実験の結果（n=3）

4. 結論

本研究の結果より，LAS が鉛直流式人工湿地システムにより除去可能であることが明らかとなった。また，LAS は主に吸着によって除去され，非植栽系では時間経過とともに除去能が低下するが，ヨシを植栽した場合には吸着以外の除去メカニズムが働き，優れた除去能が長期間維持されることが示唆された。

謝辞

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P7-9

グレイウォーターフットプリントによる油水分離装置導入効果の解明

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キーワード:グレイウォーターフットプリント, 油水分離装置, 環境影響評価, 環境容量に基づく管理

抄録

排水中の油分は, 下水道管の閉塞や生物処理槽へ悪影響を及ぼすだけでなく, 充分に処理されないまま公共用水域に排出されると, 有機物汚濁を引き起こし, 水生生物への悪影響や悪臭の原因となる。そのため, 排水中の油分を処理対象とする環境技術は数多く開発されている。そのため, 環境技術を導入するユーザーは, 性能・効果を見分ける必要があり, 環境技術を客観的に評価する手法が求められている。そこで, 飲食店で油水分離装置が導入された場合における環境影響評価手法の確立を目的として, 店舗外に排出される排水による環境への影響を評価するために直接的な WF_{grey} による解析を行った。グレイウォーターフットプリント解析により, 油水分離装置導入によってn-Hex 抽出物質による環境影響は 88.8%削減されるとともに, 除去率 54.5%以上の油水分離装置を導入することで, 販売食数の増加に伴い, 排水量が増加しても水環境の負荷低減が可能なことが明らかとなった。

1. はじめに

日排水量が少なく, 油を多量に使用する飲食店や食品加工場などの小規模事業所からは, 油分濃度の高い排水が排出される。排水中の油分は, 下水道管の閉塞や生物処理槽へ悪影響を及ぼすだけでなく, 充分に処理されないまま公共用水域に排出されると, 有機物汚濁を引き起こし, 水生生物への悪影響や悪臭の原因となる。そのため, 油分の流出を防ぐために油脂分離槽であるグリストラップ(以下「GT」)などの油分除害設備を, 厨房にできるだけ近い排水管の途中に設ける必要がある。しかし, 一般的に設置されているGTは, GTの滞留時間が 1 分以内の場合もあり, GTの油分除去効果は十分でないことが報告されている[1]。また, GTの油分除去効果を上げるために, 微生物資材を利用したバイオ技術など, 様々な環境技術が開発されている。しかし, 微生物資材には, 品質管理の法的な制度や基準がなく, その効果は十分に確認されていないものも多い。そのため, GTからの油分流出により, 東京湾へオイルボールとして漂着するといった環境問題が報告されている。

排水を含む水環境への影響評価は LCA などの手法では困難とされているため, 水利用に関する潜在的な環境影響を評価する手法としてウォーターフットプリントの活用が期待されている。Water Footprint Network が提唱するウォーターフットプリント[2]は, 表流水や地下水のうち消費された量を Blue water footprint, 雨水のうち作物に取り込まれた量及び, 土壌中に水分として蓄えられた量をGreen water footprint, システム境界外に排出される環境負荷物質を環境基準まで希釈するのに必要な水量として算出することができる Grey water footprint(以下「WF_{grey}」)を用いて, ある製品を生産する際の水環境への影響を, 直接的ならびに間接的に消費される水量として示すことができる評価手法である。しかしながら, 国内において, 排水処理にウォーターフットプリントを用いた評価事例は少ない。

そこで, 筆者らは, 飲食店で油水分離装置が導入された場合における環境影響評価手法の確立を目的として, 店舗外に排出される排水による環境への影響を評価するために直接的な WF_{grey} による解析を行った[3]。本稿では, その一部を示す。

2. 方法

2. 1 調査対象施設

本研究では, 宮城県仙台市にあるラーメン店(以下「S店」)を調査対象とした。S 店では, 自社工場で一括生産されたラーメンスープや麺などを調理し提供している。S 店では, ラーメン残汁中の油分により店舗敷地内の下水道管の閉塞が年に数回起きていたため, 2009 年 10 月に食器洗浄プロセスに油水分離装置を導入した。

2. 2 WF_{grey} による水環境への影響評価

WF_{grey} は，排出される環境負荷物質の負荷量を環境負荷物質の環境基準値から排出先（受水域）を自然値とした水質濃度を引いた値で除して算出される[4]。排出される環境負荷物質の負荷量を L [mg]，環境基準値を S [mg/L]，受水域の水質濃度 N [mg/L]を用いて

$$WF_{grey} = \frac{L}{S - N} \quad (1)$$

とした。

環境負荷物質は、排水中の油分濃度を示す n-Hex 抽出物質 [mg/L]，有機物による汚濁の指標となる BOD [mg/L]の2種を用いた。環境基準値は下水排除基準[5]を，受水域は排出先である流域下水道の直近下流の接続点の水質データ [6]を用いた。それぞれの水質濃度を表1に示す。

表1 下水排除基準と仙台 1 号の水質濃度

項目	下水排除基準	受水域の水質濃度
BOD [mg/L]	600	190
n-Hex 抽出物質 [mg/L]	30	15

システム境界外に排出される環境負荷物質の負荷量 L [mg]は，厨房排水水質を C [mg/L]，GTからの排水量を V [L]，油水分離装置による除去率を R [%]，GTによる除去率 G [%]を用いて

$$L = C \times V \times \left(1 - \frac{R}{100}\right) \times \left(1 - \frac{G}{100}\right) \quad (2)$$

とした。

なお，油水分離装置導入前後の水質ならびに，油水分離装置による油分除去率ならびに BOD 除去率は，平成 21 年度環境省実証事業報告書[7]より用いた。GTの油分除去率は SHASE 規格の 90%[8]を，BOD 除去率は千葉県環境研究センター年報[9]より算出した。油水分離装置導入前後における各項目の水質濃度を表2に示し，油水分離装置とGTの除去率を表3に示す。

表2 油水分離装置導入前後における各項目の水質濃度

項目	水質濃度 [mg/L]	
	油水分離装置導入前	油水分離装置導入後
BOD	3,500	3,909
n-Hex 抽出物質	4,000	330

表3 油水分離装置とGTの除去率

項目	除去率*[%]	
	油水分離装置	GT
BOD	46.1	20.6**
n-Hex 抽出物質	94.9	90

＊油水分離装置の除去率は，実地試験の結果から算出した除去率であり，GTの除去率は，性能評価基準として示されている除去率である。

＊＊GTによる BOD 除去率は，小島らによる飲食店（ラーメン・中華）の排水等に関する調査結果[9]の流入水平均濃度 2,455 mg/L，処理水平均濃度 1,948 mg/L から算出した。

3. 結果

3. 1 WF_{grey} による水環境への影響評価結果

油水分離装置導入前後におけるひと月あたりの WF_{grey} 算出結果を図1に示す。

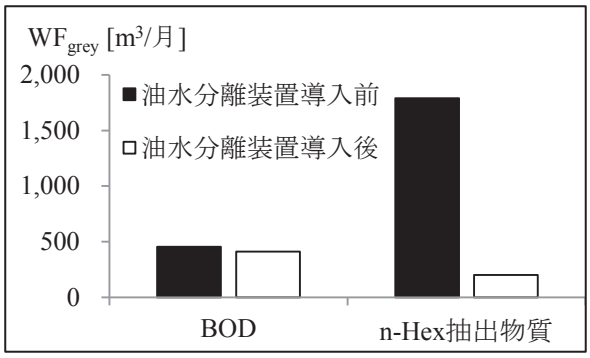

図1 油水分離装置導入前後のひと月あたりの WF_{grey}

油水分離装置導入前の排水では，BOD の WF_{grey} は 454 m^3/月であり，n-Hex 抽出物質の WF_{grey} は 1790 m^3/月であった。そのため，油水分離装置導入前の排水においてBODによる水環境への影響よりも，n-Hex抽出物質による水環境への影響の方が，およそ 4 倍あり，油水分離の必要性が示された。

また，油水分離装置導入前後の WF_{grey} 削減率を比較すると，BOD において 9.25%であり，n-Hex 抽出物質では 88.8%であった。これにより，調査対象施設に導入した油水分離装置は，n-Hex 抽出物質を除去するのに特化した装置であることが示された。

油水分離装置導入後の n-Hex 抽出物質による WF_{grey} と，下水排除基準である n-Hex 抽出物質濃度 30 mg/L の排水が，油水分離装置導入後のGTからの排水量で，店舗から排出したと仮定した場合の WF_{grey} を比較した。店舗外に排出される n-Hex 抽出物質による環境負荷量

は，下水排除基準の n-Hex 抽出物質濃度に，油水分離装置導入後のGTからの排水量を乗じて算出した。その結果を図2に示す。

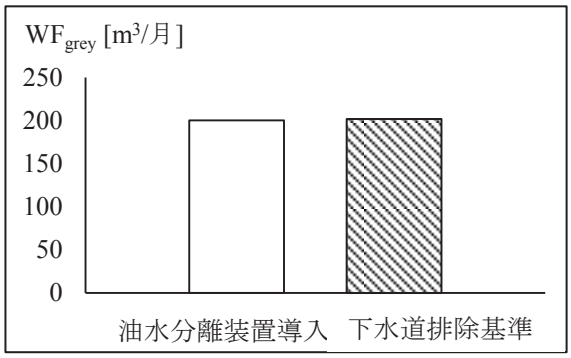

図2 導入後と下水排除基準の n-Hex 抽出物質における WF_{grey} の比較

下水排除基準の n-Hex 抽出物質による WF_{grey} は 202 m^3/月であり，油水分離装置導入後の n-Hex 抽出物質による WF_{grey} 200 m^3/月と同程度であった。よって，下水排除基準の WF_{grey} と油水分離装置導入後の WF_{grey} の差から，油水分離装置導入後の n-Hex 抽出物質濃度において，ひと月あたり 680 L の排水量が増加した場合に，下水排除基準の WF_{grey} に達することが示された。

油水分離装置の性能を評価するために，油水分離装置による除去率を変化させ，油水分離装置導入前の WF_{grey} と比較した。その結果を図3に示す。本研究の事例において，除去率 54.5%以上の油水分離装置を導入する事で，販売食数の増加に伴い，排水量が増加しても水環境への負荷低減に繋がることが示された。また，平成 21 年度環境技術実証事業で示された油水分離装置の流入水と処理水から算出した油分除去率は，94.9%であるため，導入された油水分離装置は，本調査対象施設に適した装置とみなすことができる。

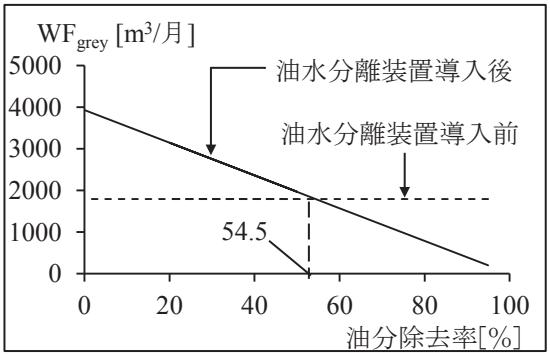

図3 油分除去率が WFgrey に与える影響と導入前後の比較

4. 結論

本研究で示した WF_{grey} を用いた環境影響評価手法は，環境負荷物質の濃度と排水量を考慮するため，調査対象とした飲食店や油水分離装置のみならず，一般的な飲食店において，油水分離装置を導入した場合の環境への影響評価に応用可能である。また，油水分離装置の性能評価結果から，導入予定の環境技術に対して，環境負荷を低減するのに必要な性能を導入以前に推定できると考えられる。よって，飲食店における油水分離装置導入に対する有効な環境影響評価手法を確立することができた。

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P7-10

Efficient and Sustainable Removal of Phenolic Endocrine-Disrupting Chemicals by Common Reed and Degrading Bacterial Association

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Keywords: endocrine-disrupting chemicals, common reed, degrading bacteria

ABSTRACT

The efficacy of rhizobacterium (*Sphingobium fuliginis* TIK1) of common reed (*Phragmites australis*) for the sustainable treatment of phenolic endocrine-disrupting chemicals (EDCs) contaminated wastewater was investigated. Strain TIK1 had been isolated from common reed rhizosphere. Strain TIK1 degraded various 4-alkylphenols (4-*tert*-butylphenol, 4-*tert*-octylphenol and 4-nonylphenol) and bisphenols (bisphenol A, bisphenol F and bisphenol S). Thus, strain TIK1 has a wide degradation spectra for phenolic EDCs. The strain TIK1 utilized common reed root compounds as a sole carbon source and sustainably colonized common reed roots, where the strain degraded phenolic EDCs. In sequencing batch reactor experiments using common reed-strain TIK1 association (strain TIK inoculated common reed) completely and sustainably removed phenolic EDCs (bisphenol A, bisphenol S, 4-*tert*-butylphenol, 4-*tert*-octylphenol and 4-nonylphenol) from polluted wastewater. The results suggest that hydroponic systems using common reed-strain TIKI association will be useful for sustainable treatment of polluted waters containing various phenolic EDCs.

1. INTRODUCTION

4-Alkylphenols including 4-nonylphenol (4-NP), 4-*tert*-octylphenol (4-*tert*-OP) and 4-*tert*-butylphenol (4-*tert*-BP) and bisphenols including bisphenol A (BPA), bisphenol F(BPF) and bisphenol S (BPS) are persistent and toxic compounds classified as endocrine-disrupting chemicals (EDCs) capable of interfering with the hormonal systems of numerous organisms. The widespread and extensive use of these phenolic EDCs has led to their release into aquatic environments. Phenolic EDCs are often found in effluents of sewage and wastewater treatment plants and in surface waters and sediments. It is therefore necessary to establish technologies to decontaminate waters polluted with phenolic EDCs.

Rhizoremediation, the degradation and removal of pollutants by microbial activity in the rhizosphere of plants, is a cost-effective and environmentally friendly remediation technology [1]. Recently, an emergent aquatic plant, common reed (*Phragmites australis*) have been shown to accelerate the biodegradation of BPA and 4-NP in the rhizosphere [2, 3]. In the rhizosphere, oxygen and organic compounds released from plant roots are known to support bacterial growth and accelerate biodegradation [1]. However, rhizoremediation processes are often limited by the presence of persistent and toxic pollutants. The introduction of specific pollutant-degrading bacteria to the rhizosphere, that is bioaugmentation into rhizosphere, will enhance the efficacy of rhizoremediation.

The aim of this study was to treat waters polluted with phenolic EDCs by using common reed in association with its rhizobacteria. Recently, *Sphingobium fuliginis* TIK1 was isolated from the common reed rhizosphere [4]. First, the biodegradation activity of strain TIK1 for alkylphenols and bisphenols were assessed. Second, the survival and biodegradation activities of strain TIK1 on the root surfaces of common reed were examined. Third, common reed-strain TIK1 association (strain TIK inoculated common reed) hydroponic reactor was prepared. The performance of this reactor to remove EDCs removal from wastewater was examined.

2. METHODS

Sphingobium fuliginis strain TIK1 was used in this study.

To assess the ability of strain TIK1 to degrade various phenolic EDCs, cells of TIK1 were incubated in liquid medium with each phenolic EDC (0.5 mM) as sole carbon source. Concentration of phenolic EDC was monitored during 24-h experimental period.

To assess the ability of strain TIK1 to utilize common reed root compounds for the cell growth, strain TIK1 was inoculated into liquid medium with common reed root compounds as sole carbon source. Cell density was monitored during 36-h experimental period. In addition, cells of TIK1 were inoculated on the root surface of sterilized common reed. Colonized TIK1 cells on the root surface were monitored.

To prepare common reed-strain TIK1 association, strain TIK1 was inoculated on the root surface of common reed.

The common reed-strain TIK1 was cultured in 1000 mL bottle. The culture was defined as common reed-strain TIK1 hydroponic reactor. The common reed-strain TIK1 and non-inoculated common reed reactors treated EDCs (5 mg/L BPA, 5 mg/L BPS, 5 mg/L 4-*tert*-BP, 2.5 mg/L 4-*tert*-OP and 2.5 mg/L 4-NP)-polluted wastewater. The reactors were operated in a fill-and-drain sequencing batch mode (12 h reaction time/cycle). In every 12-h cycle, the reactors were filled with 500 mL of EDCs-polluted wastewater for 12 h. After 12h, the wastewater was drained from the reactor. The fill-and-drain sequencing batch was repeated for 10 cycles. During the sequencing batch experiments, concentrations of the EDCs were monitored.

3. RESULTS AND DISCUSSION

Strain TIK1 degraded various 4-alkylphenols (4-*tert*-BP, 4-*tert*-OP and 4-NP) and bisphenols (BPA, BPF and BPS). Therefore, strain TIK1 has a wide degradation spectra for phenolic EDCs and is potentially useful for the treatment of various phenolic EDCs-polluted wasters.

Strain TIK1 grew using the root compound of common reed as carbon source. The yield coefficients of the cell mass was 0.74 mg dry-weight (mg carbon of root compound)$^{-1}$. After inoculation of the strain to root surface of common reed, strain TIK1 colonized the roots at a density of 9.1 ± 2.3 × 10^{10} CFU (g dry root)$^{-1}$ and maintained high cell density for long-term (Fig. 1). In addition, the colonized strain TIK1 effectively degraded phenolic EDCs on the root surface. The results suggest that common reed root provide growth space for strain TIK1 and support its growth and phenolic EDCs-degradation for long-term.

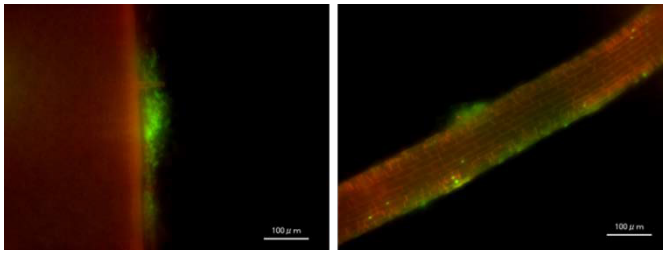

Fig. 1 Observation of colonizing TIK1 strain on the root surface of sterilized common reed. The high intensity of green fluorescent indicates strain TIK1.

Sequencing batch reactor experiments were conducted to evaluate the potential for using common reed–TIK1 association to treat EDCs-polluted wastewater. Non-inoculated common reed reactor removed small amounts of EDCs (BPA, BPS, 4-*tert*-BP, 4-*tert*-OP and 4-NP) from wastewater (Fig. 2). In contrast, common reed–strain TIK1 association reactor completely and sustainably removal of all phenolic EDCs from wastewater throughout all 10 cycles. The results suggest that strain TIK1 can thoroughly colonize on the surface of common reed roots. Common reed–strain TIK1 association hydroponic reactor will be used for long-term simultaneous removal of phenolic EDCs from polluted wastewater.

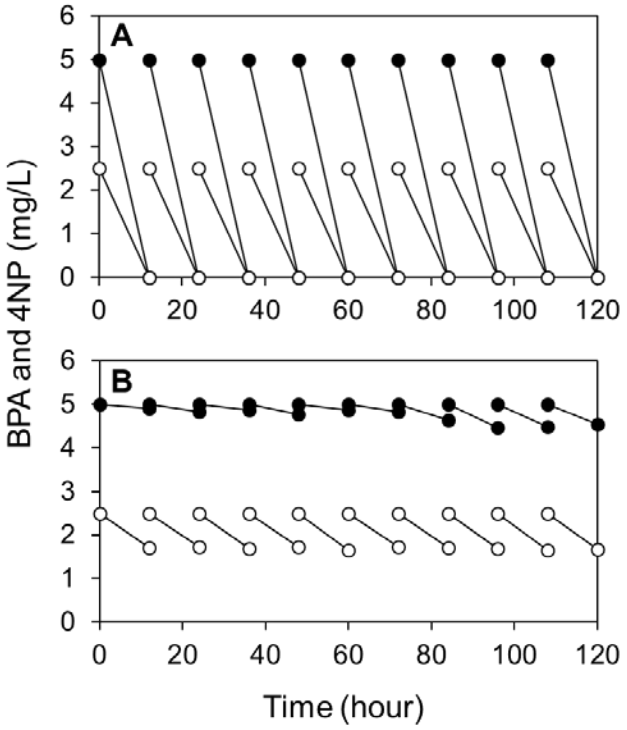

Fig. 2. Changes in concentration of BPA and 4-NP of EDCs-polluted wastewater in the common reed‐strain TIK1 association hydroponic reactor (A) and non-inoculated common reed reactor (B).

4. CONCLUSION

This study showed that *Sphingobium fuliginis* strain TIK1, which have been isolated from common reed rhizosphere, can degrade various 4-alkylphenols and bisphenols. Strain TIK1 was shown to have a wide degradation spectra for phenolic EDCs. The strain sustainably colonized the roots of common reed, with the support of organic compounds exuded from the roots, and inoculated common reed was able to simultaneously and sustainably remove various phenolic EDCs from polluted water. We conclude that the use of hydroponic system using common reed–strain TIK1 association will be an effective strategy for the sustainable treatment of various phenolic EDCs-polluted waters.

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Pollution of Water Bodies and Mitigation in Sri Lanka

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Keywords: industrial waste, water bodies, water pollution, run off, land use practices

ABSTRACT

Kelani River is one of the main rivers in Sri Lanka. Although not the largest in the country, this river is considered very important for the water requirements of Colombo, the capital city of Sri Lanka and its suburbs. The water needs include domestic, industrial, institutional, environmental and other needs. The water requirement from the Kelani River is increasing continuously due to rapid urbanization. Deterioration of water quality in the river creates adverse impacts on human health and to the socio economic development of the country. Due to the rapid development, most of these water bodies are being continuously polluted at an alarmingly increasing rate. These pollution sources mainly include point sources such as industrial discharges and uncontrolled sewage discharges and non-point sources of pollution which primarily include the storm water runoff from residential, industrial, commercial and agricultural lands. The analysis of the quality of river water revealed that it requires extensive purification before it is rendered suitable for drinking. Therefore, the people living along the coasts of Kelani River should be made aware about the chemical contaminations within the river basin resulting from anthropological activities, land use practices and industrial discharges. Harnessing the potential of the local community to play a more proactive role in preserving their own environment, as well as to communicate the overall message of preventing pollution in the Kelani River to other communities living in the vicinity, is a critical step forward.

1. INTRODUCTION

Majority of the population in Colombo and Gampaha districts receive pipe borne water abstracted from Kelani river by the National Water Supply and Drainage Board (NWSDB). There are several major water intakes located along the Kelani river viz., at Avissawella, Kosgama, Kelani Right bank, Chico, Pugoda and Ambathale. There are the other intakes on the tributaries of Kelani river such as Seethawaka Ganga (Penrithwatta) and Wakkoya. Further, there are two impounding reservoirs located at Labugama and Kalatuwawa in which two water intakes are located.

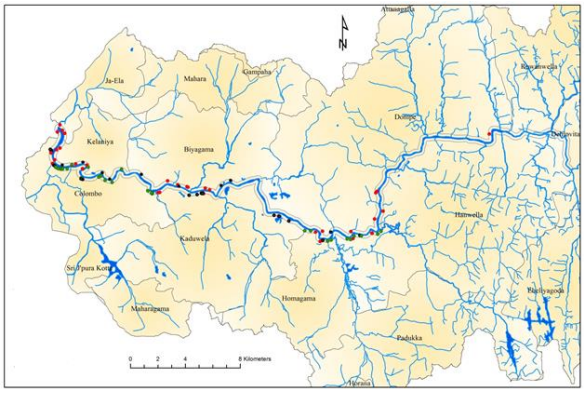

Fig. 1 Industries along the Kelani River

2. METHODOLOGY/APPROACH

The methodology of this research has been designed to accomplish the aim of the present research which is to explore the factors that cause water pollution, with the primary focus on Kelani River.
The main purpose of this study is twofold. First, to understand the impact of industrial water discharge on Kelani River and to study the contaminants in the industrial waste which may pose substantial health risk. Second is to propose a strategy for minimizing the impact of industrial pollution on human health.

For achieving these objectives, two methods of data collection were adopted (primary and secondary) along with questionnaires. Semi structured interviews were also conducted at some of the sample collection sites. The study revealed the direct relationship between turbidity, E.coli, Electrical Conductivity, Cl- and BOD.

The flow of the river changes during the monsoon period and the dry season. For instance, during monsoon the river flow is 800-1500 m^3/s and during the dry season it is some 20-25 m^3/s. The water quality data for the selected sites were collected from the NWSDB, Sri Lanka. All the samples collected were then tested for a range of physical, chemical and biological water quality parameters according to the specified Standard Methods for Examination of Water and Wastewater.

3. ANALYSIS AND RESULTS

A total of 11 water quality parameters were measured to identify the water pollution trend in the study area. The data thus obtained were compiled and subjected to statistical analysis. Descriptive statistics for every water quality parameter were worked out. Mean values of samples were analyzed using descriptive statistics for all selected water quality parameters. It was observed that pollution levels vary depending on the type and quantity of waste generated and disposed; also by the type of the industry and the type of raw material they use. Eg. Textile, Rubber, Leather production, paint or fertilizers. Industrial effluents mainly consist of heavy metals, chemicals, enzymes, antibiotics, phthalates, etc.

The study also lead to the conclusion that highest value of conductivity, TDS, hardness, heavy metals, COD, BOD, nitrates and low level of DO values were detected from the latter part (meandering part) of the river basin and most of the parameters exceed the World Health Organization guideline values. The middle part of the river basin showed low pH values and recorded as acidic and the head part of the river contaminated with total and fecal coliform bacteria as well.

4. DISCUSSION

The main sources of water pollution are the release of industrial waste, dumping of solid waste, sewage, human waste including fecal matter and sediment run off due to soil erosion. As a result, concentration of dissolved carbons, heavy metals, biohazards such as bacteria and virus and other nutrients in water sources have increased.

These wastes disposed to the environment, with partial or without treatment, pollute the surface and ground water bodies, directly or indirectly. Since the cost of industrial waste treatment is high, in order to optimize operational cost and to make a large profit margin, industries tend to discharge wastes without even partial treatment.
Although these issues have been continuously raised by environmentalists and civil society activists, so far the authorities have not been able to provide a permanent solution.

5. CONCLUSION AND RECOMMENDATION

Regulatory authorities have already paid increasing attention to safeguard the water quality mainly by implementing various mitigation actions such as structural and non-structural best management practices and water quality monitoring programs.

With the intention of controlling future disasters and damages to the Kelani river water quality, real time monitoring of water quality will be carried out, to enable the concerned authorities to prevent damages likely to be caused by industries as well as from other sources to the Kelani River.

To strengthen water quality monitoring, development of knowledge products to facilitate environment management and conservation will be done and key stakeholder groups will be identified at minor-watershed level to initiate implementation of best practices.

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題名：マグネシウム系材料による底質改善とその応用

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キーワード：アオコ, 富栄養化, 底泥溶出, 湖内浄化対策

抄録

海水中のマグネシウムイオンを抽出し精製して得られるマグネシウム系材料は，1995 年頃から国内の養殖場の底質改善に使用されており生体に対して安全であることも確認されている。当社はマグネシウム系材料の底質改善効果を実証するため H27 年度環境省環境技術実証（ETV）事業を申請，閉鎖性海域における水環境改善技術分野において「酸化マグネシウムの散布による底質改善技術」を実証した。酸化マグネシウムの散布の有無による効果を確認するため試験区（散布区）と対照区（無散布区）を設定し実証試験を行った。期間中の底質の pH，硫化物（AVS），間隙水中の硫化水素，底生生物調査を行ったところ散布後 2 週間程度底質中の pH を 8.5 以上まで上昇させる効果がみられ，底質の硫化物，硫化水素ともに対照区と比較し試験区では低い値を維持する傾向が見られた。また硫化物（AVS）の上昇を抑制した期間中，試験区において対照区と比較して，底生生物の減少が緩和された。

1. はじめに

河川や湖沼と同じく多くの内湾では栄養塩負荷による富栄養化状態が続いている。富栄養化は底質の貧酸素化をもたらし，環境悪化の要因となる硫酸塩還元菌の活動によって有毒な硫化水素が発生する。複雑な入り江や湾奥では養殖の残餌による負荷も問題になっており，貧酸素化により底泥から硫化水素が発生することで養殖生産活動にも影響している。

このような底質環境悪化への対応として，従来から堆積有機物の分解促進のために生菌製剤や，有機酸の生成による底質の酸性化対策のための貝化石や生石灰散布などと共に，海水中のマグネシウムイオンをアルカリ源と反応させて得られるマグネシウム系材料が使用されてきた。このマグネシウム系材料は1995年頃から国内の養殖場の底質改善に使用されており，生体に対して安全であることも確認されているが，材料の効果メカニズムをより明確にするため，公的な第三者機関での実証として H27 年度環境省環境技術実証（ETV）事業に申請し，閉鎖性海域における水環境改善技術分野「酸化マグネシウムの散布による底質改善技術」を実証した（実証番号：090-1402）ので，ここで報告する。

2. 方法

試験は，大村湾の湾奥部に位置する長崎県時津町浦郷の地先で実施した。試験区，対照区はそれぞれ 3m×3m の区画で 3mずつ離して設定した。試験区には当社製の酸化マグネシウムを400g/m^{2}散布した。比較のため水酸化マグネシウムでも並行して区画を設けて同様の試験を行った。各マグネシウム系材料の特性を表 1 に示す。

散布作業は 6/23 に行い，継続効果確認のため 2 回散布区画を別途設定し 8/7 に 2 回目の散布を行った。均等に散布するため，潜水士により目視の上で手作業にて散布した。散布後の調査は約 2 週間ごとに潜水士により採泥し実施した。調査項目および分析方法を表 2 に示す。

表 1 マグネシウム系材料の性状

		MgO	$Mg(OH)_2$
化学組成 (%)	MgO	99.2	
	$Mg(OH)_2$		97.7
	CaO	0.58	0.62
	SiO_2	0.12	0.09
	Fe_2O_3	0.04	0.03
形状		0.15mm 以下の微粒品	2mm の粒状品

表 2 調査項目および分析方法

項目		分析方法
底質調査	pH	ガラス電極法
	硫化物（AVS）	水質汚濁調査指針 5.11.12（検知管法）
	強熱減量	底質調査方法 (H24.8) Ⅱ-4.2
	酸化還元電位（ORP）	白金電極法
	粒度	JIS A 1204（2009）
	含水比	底質調査方法 (H24.8) Ⅱ-4.1
	クロロフィル a	海洋観測指針 6.3 蛍光光度法に準拠
	硫化水素（間隙水中）	S47.環告 9 号 別表第 2，第 3 に準拠
底生生物調査	個体数	顕微鏡観察
	湿重量	
	種類数	
水質調査	水温	白金電極法
	塩分	電磁誘導法
	溶存酸素濃度	ガルバニ電極法

3. 結果

底質の pH は，酸化マグネシウムの散布による鉛直効果範囲を測定するため柱状に採泥し，底泥表面下 1cm，3cm，6cm，9cm を測定した（図 1）。対照区の底質の pH は試験開始の 6 月から 12 月まで海水の pH より若干低く pH7.3～7.7 の間を推移したのに対し，試験区は底面下 6cm の所まで pH の上昇効果が見られ，表層 1cm においては約 1.5 ヶ月間 pH8 以上を維持した。

底質表層の硫化物（AVS）は，対照区において上昇している一方，試験区では上昇が抑制された（図 2）。

底質表層の間隙水中の硫化水素（H_2S）は，1 回目散布の試験区では 2 週間後の 7/7 において，対照区と比較して有意に低い値を示した（図 3）。7/7 以降は対照区の硫化水素が減少したため試験区においてもの硫化水素の明確な抑制は確認できなかった。しかしながら，硫化水素の発生に起因する硫化物（AVS）の上昇が試験区において抑制されており，当該期間中の硫化水素の発生を抑制していたと推測される。

底生生物調査は，底質表層のサンプルを，1mm の篩にかけ篩上に残った試料の底生生物の種類，個体数，湿重量を顕微鏡観察にて測定した（図 4）。9 月以降，試験区，対照区それぞれ環境の変化に伴って種類，個体数，湿重量の減少が確認されたが，対照区と比較して試験区の方が減少の度合いが緩やかであり，その後も高い値を維持した。底泥から 20cm の水深の溶存酸素を連続測定したところ，9 月上旬および下旬に底層水の貧酸素化が見られたが，試験区では対照区と比較して 7～8 月にかけて硫化水素の影響が少なかったため底生生物の減少が緩和されたと考えられる。

なお， ETV の実証報告書に記載されている酸化マグネシウムと並行して水酸化マグネシウムでも確認試験を行い，同様の効果が得られることを確認した。

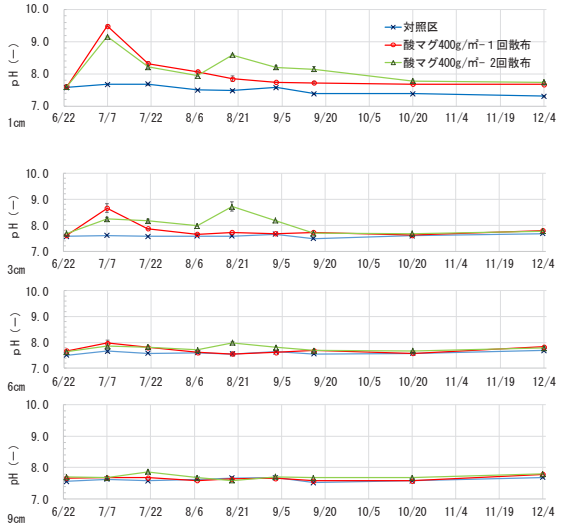

図 1 底質の pH の経時変化

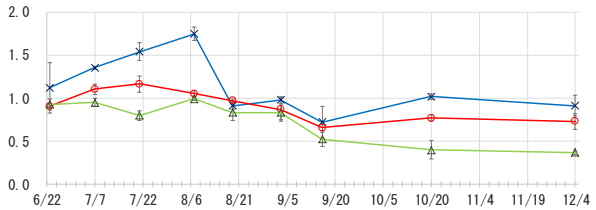

図 2 底質の硫化物（AVS）の経時変化

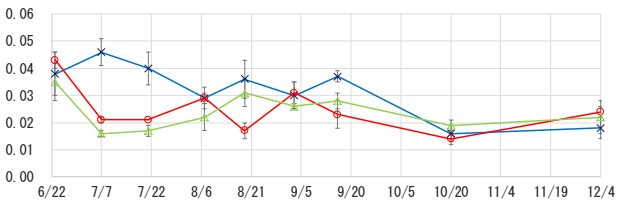

図 3 底質の硫化水素（H_2S）の経時変化

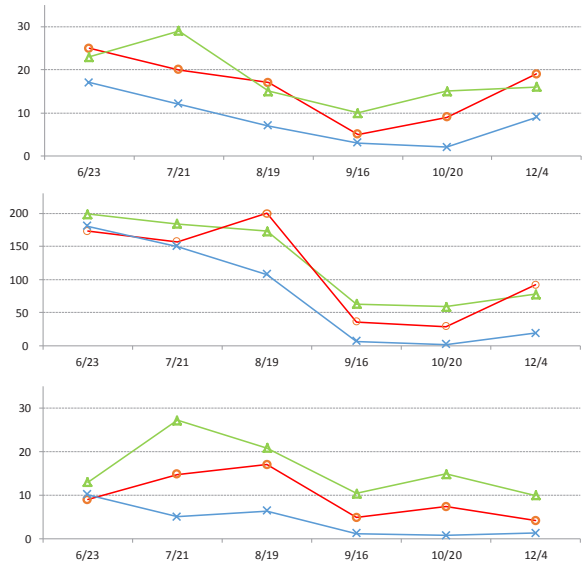

図 4 底生生物の経時変化

4. 考察

本試験により，マグネシウム系材料を散布することにより底質表層を pH8.0 に維持でき，硫酸塩還元菌の活動を抑制することで環境改善の効果が確認された。秋口に逆転層が起こって海底に酸素が供給されるまでの間，可能な限り多くの底生生物が存在する環境を作ることが，底質の自浄作用のスピードアップの鍵となる。酸化マグネシウム系材料を散布することで底生生物の減少が緩和され，底質の自浄作用の促進が可能となる。また，底泥が貧酸素化する前に散布し，硫酸塩還元菌が活動しにくい環境を整えておくことが，本技術の効果的な適用方法であると言える。

5. 結論

本試験により，マグネシウム系材料の有効性が確認され，現在は更に陸水系に向けた展開として，都市部の人工的な池の環境改善，湖沼のアオコ対策やビルの地下ピットからの硫化水素を原因とする悪臭の対策など，新しい環境分野への応用を進めている。今後も無機材料の供給メーカーとしての責任を果たし，多くの分野に貢献できるよう，より良い製品の開発に努めていきたい。

P7-13

養豚廃水処理施設に存在するアナモックス菌バイオフィルムの探索

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キーワード:養豚廃水, 活性汚泥, アナモックス, 窒素除去

抄録

アナモックス反応は, 亜硝酸とアンモニアのカップリングにより, 窒素ガスを発生させる反応である。養豚廃水への応用が期待されているが, 増殖速度が遅いため, 十分な菌体量を得るのに時間と労力を要していた。本研究では, 養豚廃水の活性汚泥処理施設を調査し, アナモックス菌を高濃度に含むバイオフィルムが存在する施設を 4 カ所見いだした。バイオフィルムのアナモックス菌 DNA 濃度および活性はそれぞれ, $2.8x10^{8}$-$1.4x10^{12}$ copy/g-IL および 0.06-560 μmol-N_2/g-IL/hr であり, 最も高いものは, 合成培地で集積されたアナモックス汚泥と同レベルであった。同一施設において, バイオフィルム中にアナモックス菌は安定して高濃度に存在する施設と, 採取時期によってその濃度が大きく変動した施設があった。バイオフィルムが存在する施設に共通する施設条件は見いだされなかったが, 曝気槽中の溶存酸素濃度は低い傾向にあった。

1. はじめに

養豚廃水には高濃度の窒素が含まれており, 放流する際は窒素の除去が必要である。窒素除去は, 通常微生物反応により, アンモニアを亜硝酸, もしくは硝酸まで硝化させた後, 脱窒反応により窒素ガスに還元を行うが, 養豚廃水は有機物／窒素比 (BOD/N 比) が低いため, 通常の手段では十分な窒素除去が行われない。近年報告されているアナモックス反応は, 亜硝酸とアンモニアのカップリングにより, 窒素ガスを発生させ, 窒素除去に有機炭素を必要としないため(図1), BOD/N 比が低い養豚廃水への応用が期待されている。

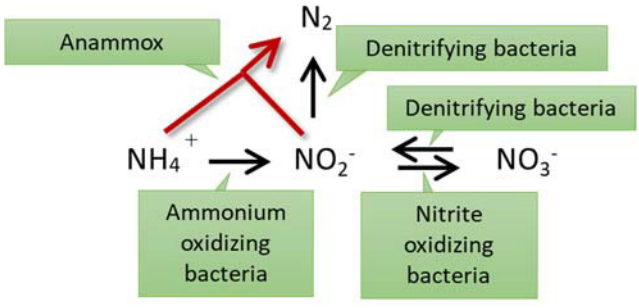

Fig. 1 Change of inorganic nitrogen compounds by microbes

アナモックス菌は増殖速度が遅いため, 十分な菌体量を得るのに時間と労力を要していたが, 近年, 一部の養豚廃水処理施設に, アナモックス菌を高濃度の含むバイオフィルムが存在することが示されている[1]。このバイオフィルムを利用することにより, アナモックス処理装置の短期間での立ち上げや, 活性汚泥処理施設の運転性能改善への利用が期待されるが, バイオフィルムの存在条件の詳細は明らかとなっていない。本研究では, 当該施設の調査を継続するとともに, 新たな施設を探索した結果を報告する。

2. 方法

茨城県, 静岡県, 埼玉県内で養豚廃水を活性汚泥処理している養豚農家を対象に 2014 年から 2017 年にかけて調査を行った。アナモックス菌バイオフィルムが見いだされた一部の農家については, バイオフィルムについて複数回調査を行った。一般水質項目の測定を行うとともに, アナモックス菌の濃度と活性について測定を行った。アナモックス菌濃度の測定は施設内曝気槽から活性汚泥が混合した汚水もしくは曝気槽・沈殿槽壁面から得たバイオフィルムを採取し, DNA を抽出した後, アナモックス菌に特異的なプライマー amx368F/820R を用いて, リアルタイム PCR 法により DNA 量を測定した。アナモックス活性は, ^{15}N 標識亜硝酸塩と非標識アンモニウム塩を含む無機塩培地で無酸素培養を行い, 培養によりアナモックス反応で発生した $^{29}N_2$ を四重極 MS を用いて経時的に測定することにより求めた[2]。

3. 結果

調査を実施した浄化処理施設 11 施設(A-K, Table 1)中 4 施設(農家名 H, I, J, K)において, 目視でアナモッ

クス菌に特徴的である赤色のバイオフィルムを確認した。調査した施設における浮遊汚泥のアナモック菌濃度は $8.0x10^6$-$5.2x10^9$ copy/g-VSS であった。一方，バイオフィルムについては $2.8x10^8$-$1.4x10^{12}$ copy/g-IL であり，一例を除いて浮遊汚泥より高い値が得られ，最も高い濃度は，既往研究の集積汚泥と同等レベル($6.23x10^{12}$ copies/g-VSS)[3]と同等であった。アナモックス活性については，浮遊汚泥において，0.03-3μmol-N2/g-VSS/hr の値が示され，バイオフィルムにおいては 0.06-560 μmol-N_2/g-IL/hr の値が得られ，アナモックス菌濃度と活性の正の相関が見られた(Fig. 2)。ただし，農家 I において，アンモニア濃度が非常に高濃度になった時期に採取された赤色でないバイオフィルムは活性が検出されなかった。農家 H においては 2014 年から 2017 の間の3度の測定において，240-550 μmol-N2/g-IL/hr の安定した高いアナモックス活性が得られた。一方，農家 I と J においては，採取場所と採取時期により活性に大きな変動があり，I においては，2017 年に高濃度のアンモニアが蓄積した際に，菌濃度が激減したと考えられた。アナモックス菌バイオフィルムが得られた浄化槽の方式は様々であり，共通する条件は見いだされなかったものの，曝気槽の溶存酸素濃度は多くの場合において，0.5mg/L 以下であり，一般的な畜産廃水の活性汚泥の曝気槽より低い条件であった。アナモックス菌は無酸素条件を好むため，曝気槽中の低溶存酸素条件が生育に適していたと考えられた。

4. 結論

アナモックス菌を高濃度に含むバイオフィルムが存在する養豚廃水の活性汚泥処理施設を 4 カ所見いだした。同一施設において，継続して高濃度に存在する場合と，採取時期によって濃度が大きく変動した施設があった。

バイオフィルムが存在する施設に共通する施設の条件は見いだされなかったが，曝気槽中の溶存酸素濃度は低い傾向にあった。

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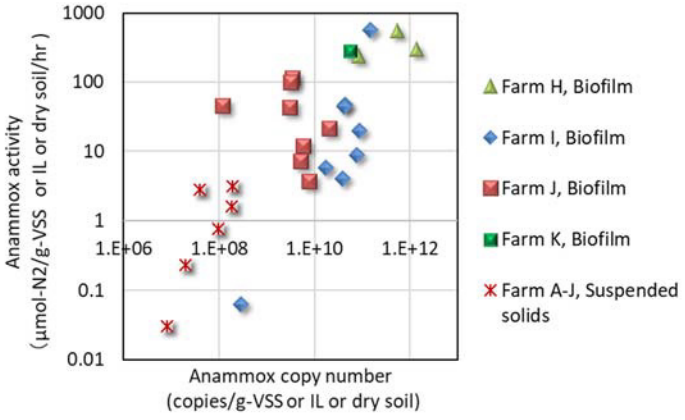

Fig. 2 Relationship between anammox activity and anammox DNA copy number

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Table 1. Waste water treatment facility conditions

Farm name	Location	Pretreatment method for solid-liquid separation	Treatment method	Aeration condition
A	Ibaraki pref.	Mechanical separation with flocculation agent	Continuous reactor and settler	Continuous
B	Ibaraki pref.	Gravity sedimentation	Sequencing batch reactor	Continuous
C	Ibaraki pref.	Mechanical separation with flocculation agent	Continuous reactor and settler	Continuous
D	Ibaraki pref.	Gravity sedimentation	Continuous reactor and settler	Continuous
E	Ibaraki pref.	Gravity sedimentation	Sequencing batch reactor	Intermittent
F	Ibaraki pref.	Mechanical separation with flocculation agent	Continuous reactor and settler	Continuous
G	Ibaraki pref.	Gravity sedimentation	Continuous reactor and settler	Continuous
H	Ibaraki pref.	Gravity sedimentation	Sequencing batch reactor	Intermittent
I	Ibaraki pref.	Mechanical separation with flocculation agent	Three-stage continuous reactor and settler	Continuous
J	Shizuoka pref.	Screen for solid-liquid separation	Two-stage continuous reactor and settler (Activated sludge and Contact aeration)	Continuous
K	Saitama pref.	Mechanical separation with flocculation agent	Three-stage continuous membrane reactor	Intermittent（the 1st tank), Continuous（the 2nd, and 3rd tanks）

P7-14

Paper title： Enhancement in Energy Conservation by Using Liquid-Film-Forming Apparatus in Shrimp Cultivation Pond

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Keywords: liquid film, volumetric mass transfer coefficient, oxygen transfer power efficiency, shrimp cultivation, appropriate technologies for developing regions

ABSTRACT

The aeration process is widely applied to provide dissolved oxygen (DO) into the water for aquaculture to survive. Generally, the mechanical aeration on the water surface is commonly used in large-scale pond due to providing sufficient oxygen and mixing, however, it requires high energy. Liquid-Film-Forming Apparatus (LFFA) is a simple device which does not consume any additional energy besides the air pump for the diffused aerator. The large-scale experiment was conducted with the variety of installations to compare the oxygen transfer performance. It was found that the volumetric mass transfer coefficient provided from the paddle equipment was higher than that from the LFFA due to the strong turbulence for favorable mixing condition. However, in terms of power efficiency, the paddle equipment showed the lower of oxygen transfer power efficiency compared with the LFFA. This can prove that the LFFA system has an ability for energy-saving. Regarding the usage application in shrimp cultivation, even though the yield of shrimps in the LFFA pond was lower than that in the paddle pond, the power required for aeration was lower while obtaining the same amount of yield, indicating that the energy saving by using LFFA in the large pond was confirmed.

1. INTRODUCTION

Generally, the conventional aeration introduces oxygen into liquid by either diffused or mechanical aerators. The oxygen in gas can be dissolved into liquid by two primary processes. The first process is bubble transfer which gas containing oxygen is introduced into the liquid and forms as bubbles dispersing inside the liquid. The second process is surface transfer which allows oxygen in the atmosphere to be dissolved due to the turbulence of water surface. The dissolved oxygen (DO) is the important factor for aquatic cultivation which farmers have to ensure that the DO in the cultivation pond is sufficient for organism respiration for their survival.

The common method to supply oxygen in the large-scale aquatic cultivation pond is mechanical surface agitation using paddle equipment to create turbulence on water surface. It is reasonable that the more oxygen can be dissolved, the larger yield of product can be obtained. However, it is recognized that this method is not efficient in terms of energy usage since the obtained yield can be offset by the cost from power consumption. Thus, it comes to another aspect to improve oxygen transfer by increasing contact area between gas phase and liquid phase from diffused aerator.

This study aimed to improve the oxygen transfer by promoting the surface transfer while maintaining the benefit from bubble transfer. There is evidence indicating that about one-third of the total volumetric mass transfer coefficient comes from surface transfer [1-2]. The Liquid-Film-Forming Apparatus (LFFA) was developed to enhance surface transfer. It has simple design and can be directly installed on water surface above the existing gas diffusers without sophisticated modification [3-4]. Thin liquid films generated by this device can increase contact areas between gas and liquid phases and promote oxygen dissolution from the atmosphere by retaining on the water surface in a long period of time. The experiments in laboratory scale have confirmed that the LFFA could improve the aeration performance [3-4]. However, there is no substantial research devoting in large scale. In this study, the aeration methods by using LFFA and paddle equipment were compared. Then, the application of LFFA was carried out in shrimp culturing, aiming for the yield, and survival rate of shrimps, and power consumption rate.

2. METHOD

2.1 Liquid-Film-Forming Apparatus (LFFA)

Schematic drawing of the LFFA is illustrated in Fig.1. The LFFA consists of a cone-shaped part and an effluent part. The cone-shaped part functions as bubbles collector from gas diffuser to the effluent part where liquid foams are released onto the water surface (Fig.2). The device was placed on the water surface above the air diffuser. When

the air is diffused into water in the form of bubbles, the bubbles will pass through the device and emerge onto the surface of the water. These bubbles will accumulate and form as liquid foams on the top of the effluent part. Thin liquid films of these foams allow oxygen to dissolve into the water from the inner interface (between air bubble and liquid film) and the outer interface (between atmosphere and liquid film) of the film, increasing the available interfacial area between oxygen and water, in turn, promoting the oxygen transfer efficiency.

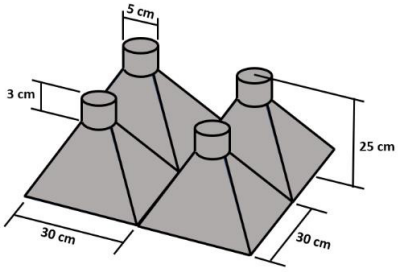

Fig.1 Liquid-film-forming apparatus.

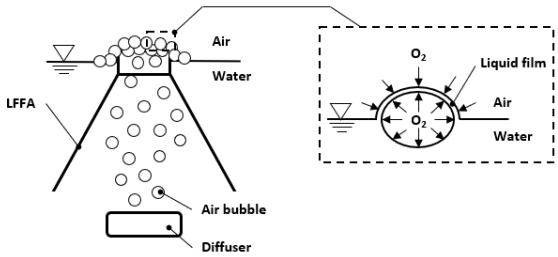

Fig.2 The mechanism of LFFA and liquid film

2.2 Oxygen Transfer Performance Determination

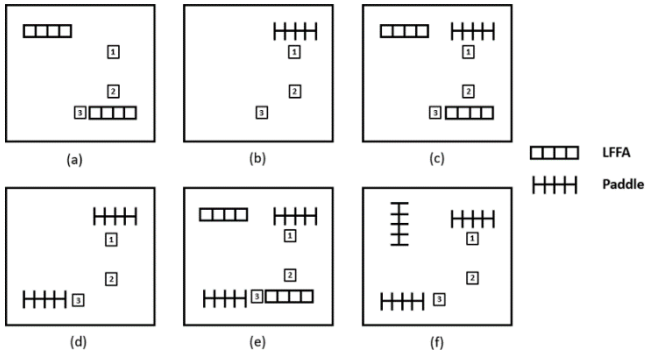

Fig.3 The setup and measuring point for DO
(a) 2 LFFAs (b) 1 Paddle (c) 1 Paddle and 2 LFFAs
(d) 2 Paddles (e) 2 Paddles and 2 LFFAs (f) 3 Paddles

The experiments were conducted in the pond (23m width, 25m length, and 1m depth) in Chanthaburi, Thailand. The brackish water with 0.7% salinity was used to represent the condition that is suitable for *Litopenaeus vannamei* shrimp cultivation. The installations of the pond are shown in Fig.3. One LFFA configuration consisted of four sets. Each set included four LFFA units and one air diffuser connected to an air pump (100 L/min). During the aeration process, DO concentration was measured using DO meters (HOBIRA, OM-51). The probes were located at three positions as shown in Fig.3 with two levels near bottom and the surface for each position. The average value was calculated to represent the average DO concentration for the whole volume in the pond.

The oxygen transfer was determined in terms of the volumetric mass transfer coefficient by the standard method of ASCE (1993) [5]. Sodium sulfite was added in the appropriate amount to reduce the DO concentration of the water to approximately 0 to 4 mg/L. The change of DO concentration was measured during the aeration. Then, the volumetric mass transfer coefficient at the actual water temperature T °C, $k_L a_T$ [hr^{-1}] was evaluated graphically from the slopes of graphs of $\ln(C^* - C_t)$ versus time t.

$$\ln(C^* - C_t) = -k_L a_{(T)} t + ln(C^* - C_0) \quad (1)$$

where C^* and C_t are the saturated concentration of DO in water [mg/L] and the concentration of DO measured at time t [mg/L], respectively. The obtained $k_L a_{(T)}$ was then calibrated to the standard temperature of 20 °C, $k_L a_{(20)}$ [hr^{-1}].

$$k_L a_{(20)} = k_L a_{(T)} \times 1.024^{(20-T)} \quad (2)$$

Another criterion to evaluate oxygen transfer performance can be assessed in terms of energy efficiency [4].

$$E_p = \frac{k_L a_{(20)} \times C_{s(20)} \times V}{P} \times 100 \quad (3)$$

where E_p is oxygen transfer power efficiency [%], $C_{s(20)}$ is saturated oxygen concentration in water at 20 °C [mg/L], V is water volume [m^3], P is power required [kW]. The power requirement is approximately 2.2 kW per unit for paddle aerator and 0.4 to 0.8 kW for the LFFA system.

2.3 Application in Shrimp Cultivation

The two-paddle-and-two-LFFA pond (in this section referred to as the LFFA pond) and the three-paddle pond (in this section referred to as the paddle pond) were used for shrimp cultivation. The pond size was 20m length, 40m width, and 1.5m depth. In each pond, 50 thousand of 15-day-old shrimps were discharged and cultured for 85 days. The measurement parameters were the average weight, and survival rate of shrimps, and power consumption of each pond. To determine the average values, 50 samples of shrimps were harvested to measure their weight and subsequently returned to the ponds.

3. RESULTS AND DISCUSSION

3.1 Oxygen Transfer Performance

The oxygen transfer performance is shown in Fig.4. The pond which had only two LFFAs had the lowest volumetric mass transfer coefficient, whereas the pond with three paddles had the highest value, which was about 5 times higher. It was noticeable that the more paddles were used, the higher value could be obtained. This is because the

paddle caused strong turbulence contributing to the mixing ability which allowed the oxygen to be dissolved into water at a great rate. However, regarding the addition of LFFA in the ponds with paddles, the LFFA could effectively increase the mass transfer coefficient as well.

Regarding the oxygen transfer power efficiency. The LFFA-only pond provided the highest power efficiency, about 1.7 times higher than the paddle pond, even though it provided low mass transfer coefficient. The main reason is that the LFFA system requires less power than the paddle. Therefore, it indicated that the LFFA system has an ability for energy-saving.

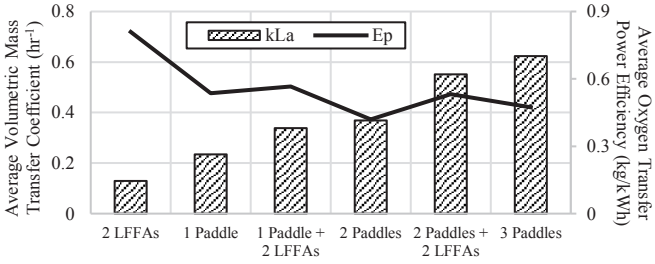

Fig.4 The oxygen transfer performance

3.2 Cultivation of shrimp in LFFA pond and paddle pond

Regarding the growth of shrimps, the shrimps in the LFFA pond could grow larger those in the paddle pond (Fig.5). This might be because the water flow in the LFFA was relatively gentle and less stress. Therefore, it is conceivable that this condition was suitable for aquatic creatures to grow healthily, not only for the shrimps but also phytoplankton which are also the nutritious food sources for shrimps.

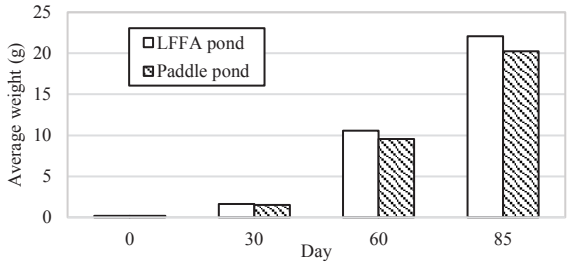

Fig.5 The average weight of shrimps

In Table 1, the survival rate of the shrimps was superior in the paddle pond, accounting for 96%, whereas the shrimps in the LFFA pond could survive only 70%. As the previous section has mentioned that the LFFA pond could provide oxygen dissolution lower than the paddle pond, the shrimps in the LFFA pond might encounter suffocation due to temporary oxygen shortage in some periods of the day, especially in the early morning as the result of the phytoplankton respiration during night-time.

The paddle pond could provide more yield than the LFFA pond (Table 1). This might be due to the temporary shortage of oxygen as explained earlier. However, regarding power consumption, the LFFA pond could save the power required up to 36% from that the paddle pond needed. Furthermore, the power consumption per kilogram of yield of the LFFA pond was lower, indicating that the LFFA pond could save the energy while obtaining the same amount of yield.

Table 1 The results from shrimp cultivation

	LFFA pond	Paddle pond
No. of shrimps on Day 85	35,000	48,000
Survival rate [%]	70	96
Yield obtained [kg]	772.5	996.7
Overall power required [kWh]	3,030	4,740
Power consumption rate [kWh/kg]	3.9	4.9

4. CONCLUSION

The LFFA can improve the oxygen transfer power efficiency. However, it should be noted that it was difficult to supply oxygen to the large-scale pond with the LFFA system alone. It was found that the supplementary mechanical aeration was required to collaborate with the LFFA system to ensure the sufficient mixing condition. Therefore, it should be taken into consideration to keep the balance between maintaining the mixing condition and utilizing the energy. Regarding the usage application, although the yield in the LFFA pond was lower, the power requirement for aeration was lower while obtaining the same amount of yield, indicating that the energy saving by using LFFA in the large-scale pond was confirmed.

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湖沼底層の貧酸素化が底質中の藻類細胞の再増殖に及ぼす影響

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キーワード:貧酸素化, アオコ, 植物プランクトン, 底質有機化, 湖沼沿岸帯

抄録

湖沼沿岸帯の底質は, 植物プランクトン(藻類)の供給源として機能し, そこから回帰した藻類が水質形成へ大きく影響する。近年問題となっている湖沼底層水の貧酸素化は, 底質中の保存藻類へ作用し, 水質保全やプランクトン生態系へ悪影響を及ぼす可能性がある。本研究では, 埼玉県の富栄養湖沼山ノ神沼の底泥を用いて, 保存時の溶存酸素量(DO)および暴露時間をパラメータとした藻類回帰実験を行った。その結果, 貧酸素(DO 0mg/L)または好気(DO >6mg/L)の DO が異なる条件で 100 日間保存した底質からは, 貧酸素条件では藍藻が, 好気条件では緑藻, 珪藻および藍藻が水中へ回帰した。微好気(DO 2～3mg/L)条件で保存した底質からは, 珪藻が優占して観察された。これらの結果は, 湖沼底層の貧酸素状態が出現藻類に対する藍藻の優占化をもたらすことを示唆しており, 貧酸素状態が解消され, 少なくとも微好気の状態が維持されることが望ましいと考えられる。

1. はじめに

日本における湖沼の COD による環境基準達成率は依然として低く, 2016 年は 56.7%である[1]。富栄養化は, 水質のみならず底質の有機化を進行させ, 底層での酸素消費が増加し, 貧酸素化を引き起こす。そして, 水生生物保全の観点から, 2016 年には, 底層溶存酸素量が湖沼の環境基準へ新たに追加された[2]。一方, 一般に湖沼における植物プランクトン(藻類)の優占種は, 周期的な季節変動を示す。その際, 底質は沈降した藻類の細胞を保存し, 再び水中へ回帰させる供給源として, 重要な機能(シードバンク)を有していると考えられる。底層の貧酸素化に伴い, シードバンク機能にもダメージが与えられ, 劣化している可能性があるものの, 明らかになっていない。本研究では, 将来的な沿岸帯管理のあり方に関する基礎的情報収集を目的として, 底質の藻類シードバンク機能に着目し, 富栄養湖沼山ノ神沼(埼玉県蓮田市)(**図 1**)をモデルとして, 溶存酸素量および時間をパラメータとした藻類回帰実験を行った。

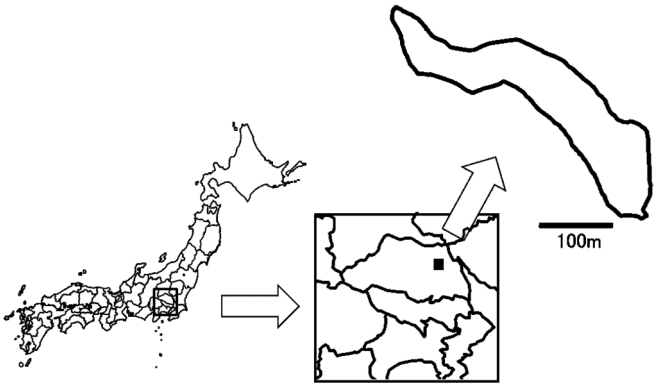
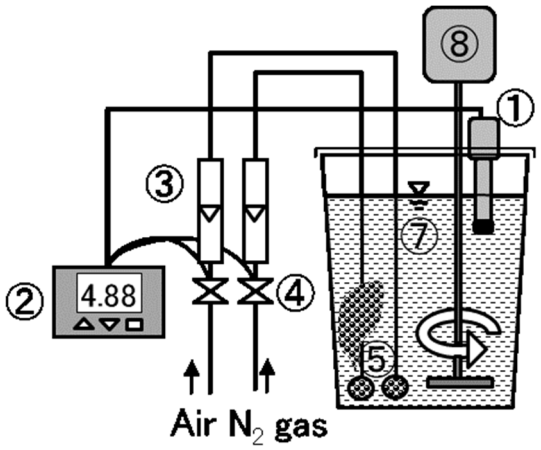


図 1 山ノ神沼位置図(埼玉県蓮田市)

2. 方法

山ノ神沼は, 面積約 3ha, 平均水深 1m 程度の浅い天然湖沼で, 現在は富栄養化が進行し, 毎年夏期にはアオコが発生するが, かつては水深も深く, 沈水植物が繁茂し, 底まで見えるほど透明度が高かった。山ノ神沼は灌漑用水源として重要な役割を担ってきたが, 現在は散策や魚つりなど主にレクレーション目的で利用されている。実験に用いた底質は, エクマンバージ採泥器で採取した山ノ神沼底質ケーキの表層1cm までの部分を削り取ってよく混ぜたものをビニール袋に密閉し, 4℃暗所で実験開始まで保存した。山ノ神沼底質の性状の季節平均は, 全炭素 68g/kg･dry, 全窒素 7.6g/kg･dry, 全リン 1.7g/kg･dry である。その底質を室温(空調設定温度 21℃)において, DO 濃度を 0, 2～3, >6mg/L の 3 段階に設定して 100 日以上保存した底質を用いてシードバンク機能への影響を評価した。DO 0mg/L の状態は, 密閉容器に脱酸素剤エージレス(三菱ガス化学製)とともに保存することで作り出した。DO 2～3mg/L での保存は, 山形東亜 DKK 製溶存酸素計(YPMS-48DO)を用いて, 溶存酸素濃度をモニタリングし, DO2～3mg/L の範囲を逸脱すると電磁弁が開き, 窒素ガス(N_2 ガス)または空気が吹き込まれるリアルタイム制御システムを構築して行った(**図 2**)。DO >6mg/L の保存は, 常時空気を吹き込み, 最低 DO を 6mg/L として実施した。底質からの回帰藻類の評価方法は, 底質を採泥した地点の湖沼水 800ml(0.45 μm のメンブレンフィルターでろ過)を 1L トールビーカーに満たし, 試料の底質 80mL を加え, 水とよく撹拌してから一時間以上静置して砂などの易沈降性の懸濁物質を沈降させた後, 実験を開始した。光条件は, タイマー運転した蛍光灯照明

(2,500lux[約 47 μ mol/m²/s]) 下の 12hr/12hr 周期明暗条件(以下, 明暗条件)またはアルミホイルを用いて完全遮光した連続暗条件(以下, 暗条件)で行った。温度条件は室温 23℃とし, 各ビーカー内の水温, pH および DO は, 多項目水質計(ハイドロラボ社製 MS5)を用いて 20 分間隔で連続記録した。水中に回帰した植物プランクトンは, 生物顕微鏡により観察した。



①DO 電極 ②DO コントローラー ③流量計 ④電磁弁 ⑤エアストーン ⑥遮光容器 ⑦底質 ⑧攪拌機

図 2 本研究で用いた溶存酸素量制御システム

3. 結果

保存時の DO 条件を 2～3mg/L および>6mg/L に設定し, 室温遮光状態で 100 日保存した山ノ神沼底質を用いた実験中の水質は, 保存時の DO が 2～3mg/L, >6mg/L のどちらも連続暗条件では, DO は一次反応的に減少後, 6 日目以降はほぼ 0mg/L で推移した。一方, 12h/12h 周期明暗条件では, 実験開始直後の DO は連続暗条件と同様に減少したが, その後異なる変化を示し, 明期中は DO と連動して pH が一時的に上昇する特徴が見られた。この現象は, 設定 DO が 2～3mg/L では 2 日目から, >6mg/L では 3 日目から上昇傾向を示し, 10 日目には約 8mg/L まで上昇した。pH は, 設定 DO が 2～3mg/L よりも>6mg/L の方が低い値を示した。水中の藻類を光学顕微鏡で観察した結果, 出現した種類数は極わずかで, 藍藻は *Synechococcus* sp.や *Merismopedium tenuissimum*, 緑藻は *Scenedesmus* spp., そして珪藻は *Nitzschia* spp.であった。

4. 考察

藻類回帰実験中に観察された DO および pH の変化は, 底質から回帰・増殖した藻類の光合成による酸素供給が DO を, 炭酸同化作用が pH をそれぞれ上昇させたと考察された。本実験において, 保存時の DO 条件が低かった実験区ほど, 藍藻は緑藻や珪藻よりも高い細胞密度で観察されたことから, 底層の貧酸素化は, 藍藻にとって再増殖可能な活性が維持された状態で細胞が保存されていたと考えられるため, 有利な環境条件である可能性が示唆された。なお, 珪藻類は保存条件が DO 2～3mg/L において最も保存されていた結果となった(**図 3**)。本研究から貧酸素(DO 0mg/L)状態で保存した底質からは藍藻が優占して観察された。一方, 好気(同 >6mg/L)状態で保存した底質からは, 緑藻, 珪藻, 藍藻がバランスよく観察できた。また, 微好気(同 2～3mg/L)状態で保存した底質から珪藻が最も多く観察された。これらのことから, 藻類のシードバンク機能を維持するために必要な DO 量を評価すると, 貧酸素状態は藍藻の優占化を引き起こす恐れがあるため, 微好気の状態が最低限維持されることが望ましいと考察された。なお, 山ノ神沼の藻類調査の結果では, 夏季には *Microcystis* 属を主とするアオコ(藍藻)が発生する。一方, 冬期の藻類相は *Nitzschia acicularis* を始めとする珪藻が優占する。山ノ神沼底層は, 高有機物含有底質のため, すでに潜在的貧酸素状態になっているものの, 水深の浅いことが幸いし, 底層の貧酸素化が解消されやすい環境であると考察された[3]。

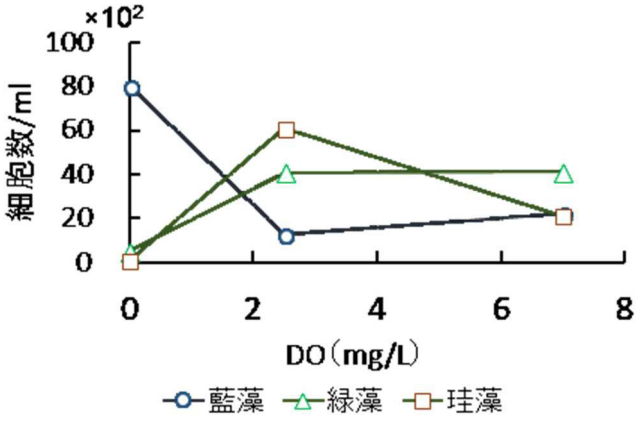


図 3 底質保存時の DO 条件(0, 2～3, >6mg/L)の各条件と底質から再増殖した藻類細胞数の関係

5. 結論

富栄養湖沼山ノ神沼で採取した泥質の底質を用いて藻類回帰実験を行った結果, 貧酸素状態は回帰・再増殖が可能な状態の藻類シード(細胞)が保存される上で, 緑藻や珪藻よりも藍藻にとって有利な状況を作り出すと考えられる。したがって, 緑藻・珪藻を含む藻類のシードバンク機能が持続するためには, 底層の貧酸素状態は解消される必要がある。そのためには, 湖沼の沿岸帯整備の際には, なだらかな形状を復活させることにより, 水の滞留域の解消による泥質化の抑制および藻類の光合成を可能とする光環境の改善が有効である

ことが推察された。

謝辞

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Economics of Non-point Source Pollution Control: An Overview and A Proposal for A Relative Evaluation Approach

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Keywords: Closed water area pollution, nonpoint source pollution, incentive-based control policies, relative evaluation

ABSTRACT

Many of the wetlands are in closed water areas or semi-closed water areas where water circulation is less working and are suffered from Non-point source (NPS) pollution. It is well known that the traditional environmental policies could not be applied to the NPS pollution and therefore wetlands pollution has not been well improved for a long time. So far, a variety of NPS pollution control policies have been discussed in the environmental economic theory studies, though applications are still few. There still exists a major gap between environmental theory studies and the ongoing environmental programs for the NPS pollution control. In this article, we firstly overview the NPS pollution control policy studies and examine which NPS pollution control policies are relatively more realistic and show the better improvement for each type of wetlands under the different practical or physical constraints. After that, we also propose a tournament tax policy as the possible efficient NPS pollution control policy. By numerical calculations with the specified model for two polluters, we show the proposed policy satisfies the major properties such as 1) efficiency, 2) truth-telling, 3) budget-balancing, 4) collusion proofness.

1. INTRODUCTION

In the environmental economic theory studies, it has been long considered that two difficulties make pollution control in closed water areas difficult. One is its difficulty to observe the individual pollution emissions and the other is its difficulty to estimate the emissions amount due to stochastic natural factors. Because the traditional environmental policies (e.g. Pigovian tax) could not be applied to such pollution, various alternative environmental policies have been discussed.

Firstly, input taxes and output taxes have been considered mainly in the agricultural economics studies. Input taxes could attain the first-best outcome, though the calculation of the optimal tax rates is complex. Outcome taxes could not even attain the first-best outcome. So, uniform tax rates among different economic agents, different inputs and outputs have been adopted as a second-best policy. After that, nonlinear taxes or damage based taxes were proposed by Hansen (1998) and Horan et al. (1998). This type of tax is simple and efficient, but it must put too heavy burden on the economic agents. Another representative policy, self-reported emissions based policy, proposed by Hansen and Romstad (2007) improved the problems of the former mechanisms, but requires a large number of economic agents to efficiently work. Thus, in the present circumstances, applying different policies to the small and large scale NPS pollution could be the relatively more realistic policy implementation.

In the following sections, we therefore would like to introduce a tournament tax policy which has the potential to attain the first-best outcome independent of the scale of NPS pollution and could be advantageous to any existing NPS pollution control policies.

2. METHOD

We consider a closed water area polluted by the two economic agents, $i = 1,2$. Let the profit function of the agent i be $B_i(z_i)$, which is C^2 class concave function and increasing in pollution emissions z_i. And let the environmental damage function be $D(z_1 + z_2, \varepsilon)$, which is C^2 class convex function, increasing in overall pollution emissions $z_1 + z_2$ and increasing in stochastic variable ε reflecting the natural factors. Then, social optimal level of pollution emissions is determined by solving

$$\max_{z_1, z_2}(B_1(z_1) + B_2(z_2) - E[D(z_1 + z_2, \varepsilon)]) \qquad (1)$$

and let the solutions of this problem be z_1^* and z_2^*. In numerical calculations, we specify the profit function by the logarithmic function and specify the damage function by the quadratic function assuming that the expected value of the stochastic variable is zero.

Next, we would like to introduce the relative evaluation method we call “a tournament tax policy”. Under the mechanism, the policy maker requires agents to

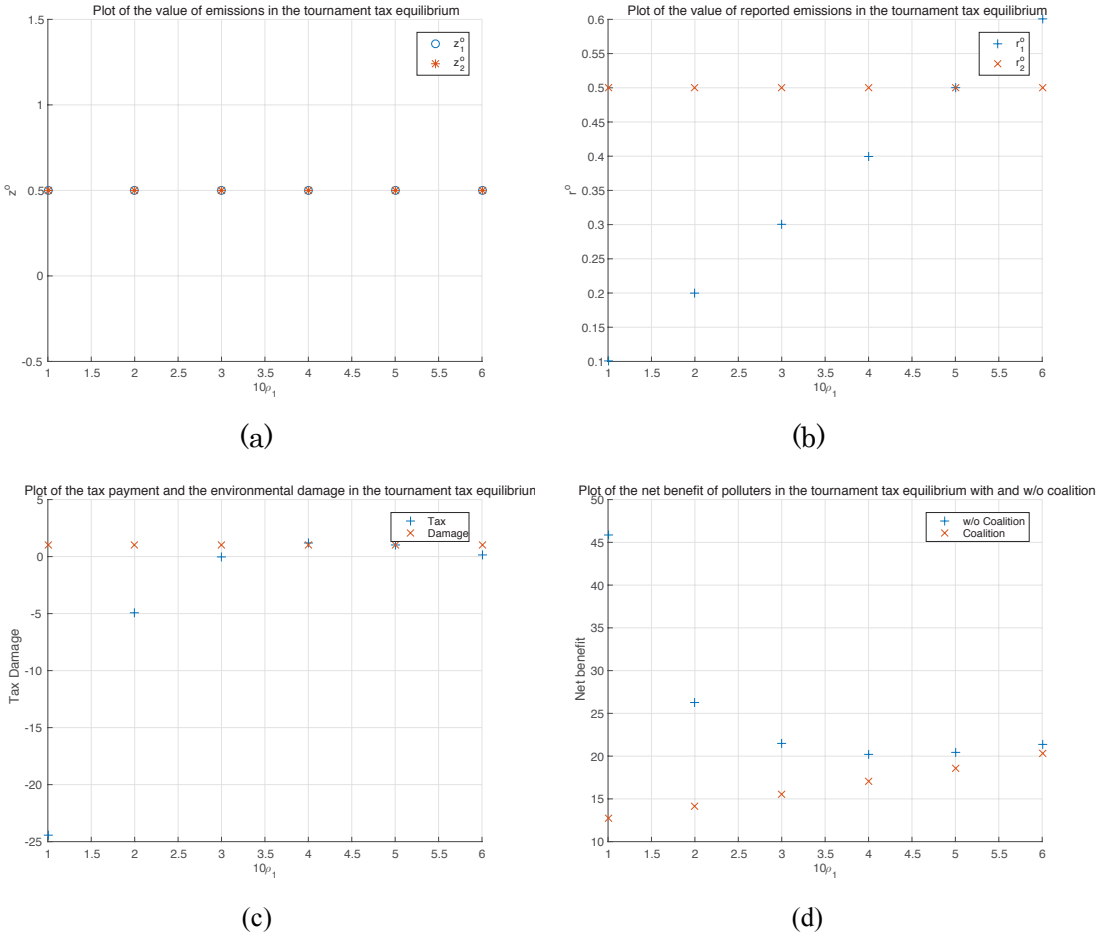

Fig.1 Calculation results for (a) efficiency, (b) the policy target control, (c) budget-balancing, (d) collusion proofness.

inform their emissions amount. Let the reported emissions by agent 1 and agent 2 be r_1 and r_2, respectively. These r_1 and r_2 are not necessarily equal to z_1 and z_2 .Then, the amount of tax payment for agent i is expressed by

$$T_i(z_i, r_i; z_j, r_j) = t_i r_i + (\bar{T} - s_i T_i), \tag{2}$$

where t_i is the tax rate on the reported emissions, $\bar{T}$ is the lump-sum tax and $s_i T_i$ is the tax refund composed by the two factors, the refund rate s_i and the refund base T_i. This amount of tax payment takes the different forms according to the magnitude relationship between self-report based damage and the realized damage which is stochastically determined due to the natural factors. Thus, policy maker informs economic agents of the probability where the self-report based damage becomes lower than the realized damage given pollution emissions and reported emissions:

$$\Pr\{D(r_1 + r_2) < D(z_1 + z_2, \varepsilon)\} = \frac{p \cdot (z_1 + z_2)}{p \cdot (z_1 + z_2) + r_1 + r_2}, \tag{3}$$

where p is the positive parameter reflecting the characteristics of the natural factors. Then, the refund rate could be characterized by

$$s_i = \begin{cases} \alpha_i \text{ if } D(r_1 + r_2) \geq D(z_1 + z_2, \varepsilon) \\ \beta_i \text{ if } D(r_1 + r_2) < D(z_1 + z_2, \varepsilon) \text{ for } \mathrm{Q_i} \\ \gamma_i \text{ if } D(r_1 + r_2) < D(z_1 + z_2, \varepsilon) \text{ for } 1 - \mathrm{Q_i} \end{cases}, \tag{4}$$

where, $\alpha_i \geq \beta_i > \gamma_i$, $\mathrm{Q_i}$ is the probability where the refund rate for agent i becomes β_i and $1 - \mathrm{Q_i}$ is the probability where the refund rate for agent i becomes γ_i. This probability for two agents is expressed by

$$\mathrm{Q}_1 = \frac{\sigma_1}{\sigma_1 + \sigma_2}, \tag{5}$$

$$\mathrm{Q}_2 = \frac{\sigma_2}{\sigma_1 + \sigma_2}, \tag{6}$$

where σ_1 and σ_2 are the target levels of reported emissions explained later. There probabilities are also informed to economic agents in advance.

To sum up the mechanism, if the observed damage is less than or equal to the self-report based damage, then the tax refund could take the maximum value. And if the observed damage level is greater than the reported damage, then the tax refund rate would become lower and stochastically determined by the probability informed by the policy maker.

Finally, private optimal level of pollution emissions and reported emissions for agent i is determined by solving

$$\max_{z_i, r_i} \left(B_i(z_i) - E\left[T_i\left(z_i, r_i; z_j, r_j\right) \right] \right) \text{ for } i = 1,2 \qquad (7)$$

and let the solutions of this problems be $z_1^o, r_1^o, z_1^o, r_1^o$.

Based on the above understanding, we calculate the solutions and examine whether the proposal policy satisfy the four economically important properties, efficiency, truth-telling, budget-balancing and collusion proofness.

3. RESULTS

Fig.1 (a) shows the private optimal level of pollution emissions under the tournament tax policy for $p = 1$, $\rho_1 = 0.1,0.2,0.3,0.4,0.5,0.6$ and $\rho_2 = 0.5$. Optimal pollution emissions are $z_1^* = z_2^* = 0.5$ in the calculations. Therefore, the tournament tax policy could attain the efficiency independent of the selection of the policy targets. On the other hand, Fig.1 (b) shows the private optimal level of the reported emissions for $p = 1$, $\rho_1 = 0.1,0.2,0.3,0.4,0.5,0.6$ and $\rho_2 = 0.5$. In the figure, the reported emissions and the target level always take the same value and that is the reason why we call σ_1 and σ_2 target levels target level. Thus, truth-telling properties could be satisfied by setting the target level at the social optimal pollution emissions (in this case, $\rho_1 = 0.5$).

Fig.1 (c) shows the amount of tax payment and the level of environmental damage in the private optimal equilibrium. The amount of tax payment includes the lump-sum part $\bar{T}$. In the calculation, we preset $\bar{T} = 9.5$ so that it satisfies the budget-balancing property if economic agents efficiently emit pollutions and honestly report their pollution emissions. In the figure, we could find that the both values become equivalent when $\rho_1 = 0.5$. Thus, if efficiency and truth-telling are satisfied, then budget-balancing is also satisfied.

Fig.1 (d) shows the net profit of economic agents in the private optimal equilibrium with and w/o collusion. When they collude, economic agents choose the pollution emissions and reported emissions which maximize the sum of their net profit shown in (7). In the figure, the profit of economic agents w/o collusion is always greater than that with collusion. Therefore, as far as our setup in the numerical calculations, economic agents do not have the incentive to collude and deviate from the efficient pollution emissions in the private optimal equilibrium.

4. DISCUSSION

In this article, although we limit our analysis to the two economic agents, the proposed policy for paired up economic agents could be easily expanded to the N economic agents. If there exists an even number of economic agents, we could directly apply the policy to the $N/2$ number of paired up agents. And if there exists an odd number of economic agents, we could attain the first-best outcome by applying the policy to $(N-1)/2$ number of paired up economic agents while applying the traditional emissions tax to the rest of one economic agent.

A truth-telling property and a budget-balancing property are also easily examined by directly applying the procedure for two economic agents. However, collusion-proof property would become somewhat more complex, because a wide variety of combination of the collusion would become possible. Especially, we must carefully examine the collusion which would newly appear between one of the paired up economic agents and the non-paired up single economic agent.

5. CONCLUSION

In this article, we show that the application of a tournament tax policy to NPS pollution control could attain the first-best outcome while satisfying truth-telling, budget-balancing and collusion proofness by the numerical calculations for the two economic agents. As we discussed here, environmental policies could effectively incentivize the economic agents whose pollution emissions are hardly observed. We expect the increasing discussions about the implementation of the environmental policies in the NPS pollution improvement programs.

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鉄イオン溶出法による富栄養河川等のリン削減に関する実用装置の開発

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キーワード:河川のリン削減, 鉄イオン溶出, 植物プランクトン, 実用装置

抄録

湖や池の富栄養化による植物プランクトンの発生を抑制することが長年の課題となっている。霞ヶ浦においても同様であり, 茨城県は 2013 年度より 4 年間にわたり公募型新たな水質浄化空間創出事業において, 霞ヶ浦流入河川等におけるリン削減として民間提案の鉄イオン溶出法による実証試験を適用した。2013・2014 年度は 3m^3 の中型実証試験によって処理流量 43m^3/日に対して PO_4-P の年平均削減率 24.8%を得た。2015 年度は装置を改良し, 10 m^3 の処理槽(2 槽)と 5m^3 の反応槽による大型実証試験装置によって処理水量 100～300m^3/日に対して PO_4-P を計画の 30%を上回る結果を得た。2016 年度は反応槽を 10m^3 と大きくし, 土浦市の既設浄化施設の沈澱槽 50m^3 と曝気等を加える改良によって 400～550 m^3/日に対して PO_4-P のみならず TP の削減率 30%を達成し, 実用型装置の稼動につなげた。

1. はじめに

湖や池などの富栄養化による植物プランクトン(アオコ)の発生が長年の問題となっている。筆者らは, 鉄イオン溶出体(以下 D 材と称す。)[1]を用いて, 植物プランクトンの栄養源となる溶解性のリン(PO_4-P)を低減させる技術に取り組んでいる[2]。茨城県は 2013 年度より 4 年間にわたり公募型新たな水質浄化空間創出事業として霞ヶ浦流入河川等におけるリン等を削減する実証試験を実施し, この事業に鉄イオン溶出による方法が一手法として適用されることとなった。

室内実験による PO_4-P 削減効果の確認を踏まえ, 2013・2014 年度は 3m^3 の中型実証試験(単管および二重管カートリッジ, D 材 48kg)によって処理流量 43m^3/日に対して PO_4-P の年平均削減率 24.8%を得た[3]。2015 年度からは回転ドラム式カートリッジ(以下ドラムと称す)の装置に改良し, 処理槽の規模を 25m^3(2015 年度)および 30m^3(2016 年度)とし, 処理流量を 100～550m^3/日と実用レベルを目指す大型実証試験を実施した。

本論文は, メカニズムに関する室内実験とともに, 大型実証試験の結果について報告するものである。

2. 方法

2.1 鉄イオン溶出と PO_4-P 削減の原理

本実証試験では, 金属鉄と炭素材を固着させた D 材を用いた。一般に, 鉄を水中に置くだけではイオン化させることは困難であり, 溶出しても極微量である。これに対して共著者である杉本は**図 1** に示すように電気陰性度の異なる金属鉄と炭素材とを固着させた D 材を水など電解液に浸潤させることにより両材料間で局部電池が生じ, 金属鉄(0 価)が二価鉄イオン(以下, Fe^{2+})として高濃度で溶出させる技術を開発した。

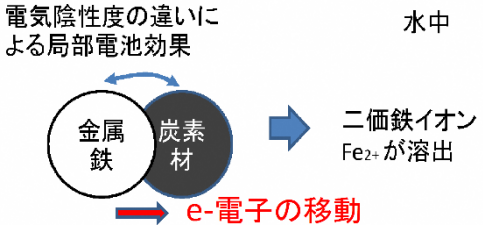

図 1 鉄イオン Fe^{2+}溶出のメカニズム

溶出した Fe^{2+}は水酸化第二鉄 $Fe(OH)_3$ となり, 富栄養な水域に存在する PO_4-P と式(1)のように化学的に吸着し, 懸濁態(TP)となる。

$$Fe^{2+} \rightarrow Fe(OH)_3 \rightarrow Fe(OH)_3 \equiv PO_4^{3-} \quad (1)$$

このメカニズムによって水域の PO_4-P の濃度の減少が図れることから, これを栄養源とするアオコや水生植物の繁茂を抑制に寄与することができる。ダム湖水 10L を水槽に入れ D 材を 100g 投入することによって溶解性リン D-TP が 1 週間で初期濃度の 10%まで削減されることを確認している[4]。

2.2 流水条件における PO_4-P 削減のカラム実験

流水条件において Fe^{2+}を溶出させた場合の PO_4-P の削減効果を把握するために, 写真 **1** に示すカラム(長さ

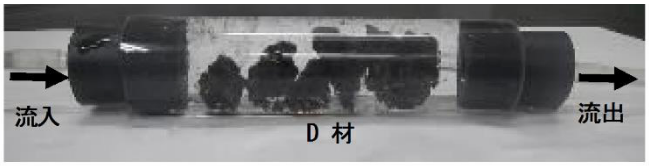

写真 1 D 材を封入したカラムテスト

10cm, 内径 19mm)内に直径約 10mm の D 材 17.9g を封入し, 流量を変化させて水道水および 1.0mg/L に調整した PO_4-P 溶液を通水させる実験を行った。**図 2** の水道水実験では流量が 0.033 から 0.385mL/s と多くなると, 溶解性鉄(D-Fe)濃度は 1.83 から 0.74mg/L と希釈されて低くなる傾向が確認された。**図 3** は同じカラム条件で 1.0 mg/L に調整した PO_4-P 溶液を通水した実験結果であり, 流量を 0.385 から 0.033mL/s と少なくすると, D-Fe は PO_4-P と反応して 0.03 から 0.59mg/L に増加し, 一方, PO_4-P は D-Fe と反応し 0.91 から 0.64mg/L と減少している。流水条件下において両者が即時的に化学的吸着を生じていることが分かる。

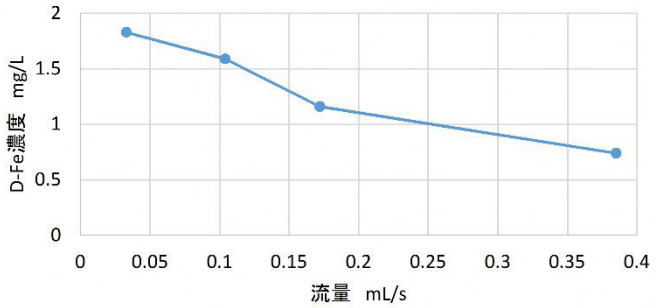

図 2 水道水の流量と溶出した D-Fe 濃度との関係

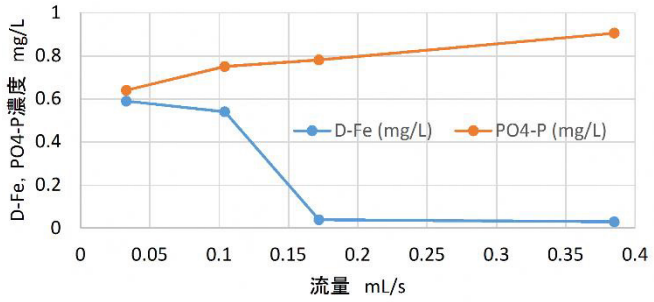

図 3 1mg/L 調整 PO_4-P 溶液の流量と濃度との関係

2.3 大型実証試験

本実証試験は, 霞ヶ浦に流入する新川上流部(虫掛生活排水路, 茨城県土浦市)で実施した。実施場所には BOD 削減を目的とした既設浄化施設があり, この施設で処理する前の河川水を実証試験の原水とした。

D 材 0.0179kg(=0.0179kg, M_{cd})を用いたカラムテスト(**図 2**)をもとに, PO_4-P の濃度が 0.7mg/L すなわち初期濃度 1.0mg/L に対する削減率 30%に相当する流量が 0.1mL/s(=0.00864m^3/日, Q_{c30})となる結果をもとに, 実証試験の処理流量を 200m^3/日程度として D 材必要量を試算 390kg(M_d)とした。鉄イオン溶出装置 4 ユニット(1 ユニット 8 ドラム)の装置を製作した。実証試験の処理流量を 2015 年度は 100～300m^3/日とし, 2016 年度は 400～550m^3/日に上昇させ, リンの低削減効果を把握するとともに, 削減率 30%を達成させるために装置を改良した。各クールで流量を 100m^3/日ごと増加させ, **表 1** に示す試験条件を適用した。

図 4 および**写真 2** は 2016 年度の装置仕様である。既設浄化施設の沈砂槽から原水を取水し, 鉄イオン溶出槽と PO_4-P との反応をさせ, その後同施設の処理槽の一つ(50m^3)を使用して懸濁態となった TP を沈澱させる仕様としている。

表 1 実証試験各クールの条件

クール	流量(換算) Q m^3/日	工程	データ数	ドラム秒/回転	曝気	ユニット数
第1	100	2ヶ月	5	30	無し	4
第2	200	2ヶ月	4	30	無し	4
第3	300	2ヶ月	4	30	無し	4
第4	400	1･2週	2	45	無し	4
		3･4週	2	30	無し	4
		5･6週	2	15	無し	4
		7･8週	2	30	3槽2台	4
第5	500	1･2週	2	30	3槽2台	4
	(667)	3･4週	2			3
	(1000)	5･6週	2			2
	500	7･8週	2		1槽2台	4
第6	550	1~4週	4	30	1･2槽各1 (3槽充填材)	4
		5~8週	4			4

1槽:第1鉄イオン発生槽, 2槽:第2鉄イオン発生槽, 3槽:反応槽

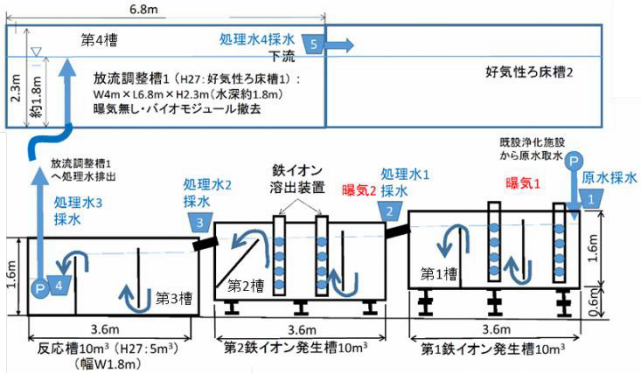

図 4 実証試験装置の配置模式図および採水位置



写真 2 装置の運転状況

3. 結果

3.1 処理流量 100～300m^3/日の PO_4-P 削減効果

図 5 に各クールの原水および各処理段階の処理水の PO_4-P の平均値の変化を示した。PO_4-P の削減率[(原水－処理水)/原水]は, 処理水 1 (鉄イオン発生槽 1) では鉄イオン発生装置は 2 ユニットのため削減率は低かった。処理水 2 以降は同 4 ユニットとなっている。処理水 3 において第 1 クール 44.1%, 第 2 クール 31.4%, 第 3 クール 41.2%であり目標 30%を上回った。また, 複合処理水は既設浄化施設における 5 つの水槽を経過したものであり, それぞれ 33.9%, 47.1%, 58.6%と第 1 クールを除いて削減率がより増

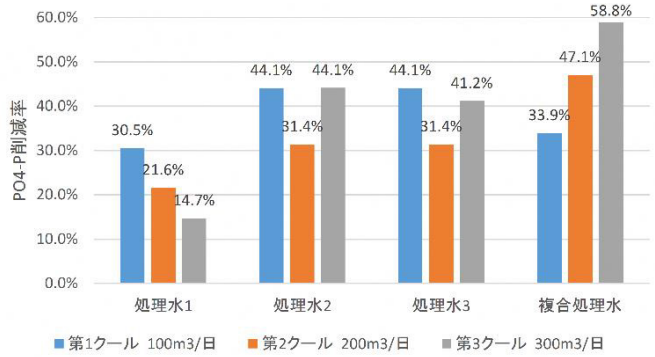

図 5 処理流量と各処理段階における PO_4-P の削減効果

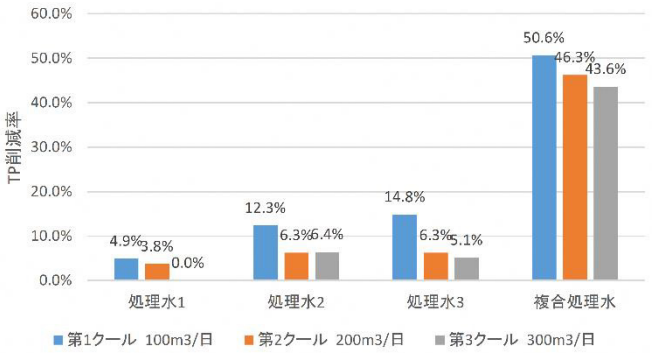

図 6 処理流量と各処理段階における TP の削減効果

加した。**図 6** は TP の削減効果を同様に整理したものであるが，処理水 3 において 14.8%から 5.1%と小さい値となった。一方，複合処理水では TP の沈澱効果が発揮され 50.6%から 43.6%と高い値となった。

3.2 処理流量 400m³/日以上における TP 削減効果

PO_4-P と $Fe(OH)_3$ の吸着は還元条件において分離され PO_4-P は溶存態にもどる。したがって，この実証試験では懸濁態となった TP を確実に沈澱させ，濃度低減された処理水を放流することとし，TP を 30%削減するための装置条件について検討することとした。

図 7 は 400m³/日の処理流量における各処理段階における TP の削減率(比)を比較したものである。第 4-1～4-3 クールまでは TP が増加するケースもあったが，第 4-4 クールでは反応槽に曝気を行ったことから TP が安定的に削減でき，しかも削減率の増加が確認された。

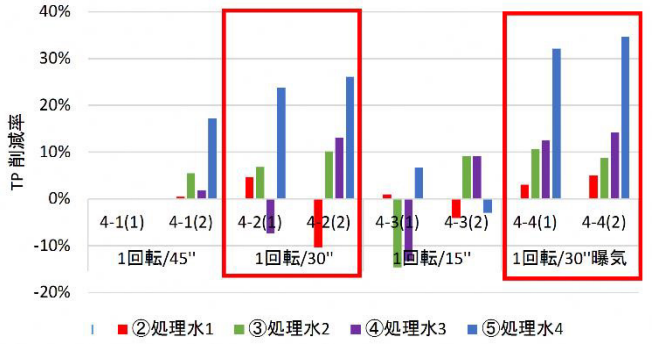

図 7 反応槽の曝気による TP 削減効果の向上

図 8 は処理流量 550m³/日の条件において TP の削減効果を比較した結果である。第 6-1 クール～第 6-2 クールにおいて TP 削減率は処理水 3 で最大 7.2%，処理水 4 で最大 18.8%と計画の 30%に対して低い値を示した。したがって，反応槽に充填材（中空のプラスチック製，比表面積 500m²/m³，2m³,）を処理水の流れの抵抗体として設置し，TP の削減効果を試行的に確認した。その結果，処理水 3 で最大 19.3%，処理水 4 で最大 36.1%の TP 削減効果が発揮された。

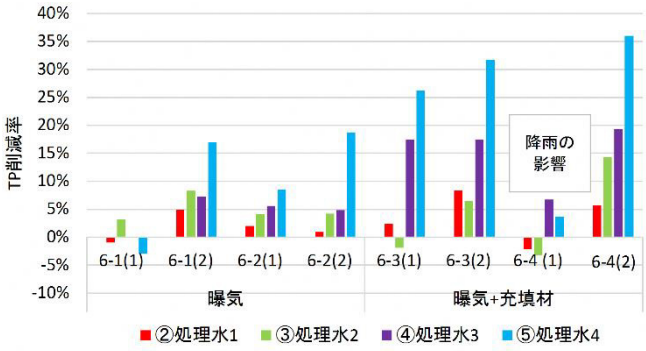

図 8 充填材設置による TP 削減効果（550m³/日，曝気有り）

4. 結論

室内カラム試験によって，D 材の量と流量の関係をもとに，処理水量を 100~550m³/日とした際の河川水の PO_4-P を 30%削減するための大型実証試験を実施した。回転ドラム方式装置によって処理流量が 300m³/日程度までであれば鉄イオン発生槽および反応槽までの規模で PO_4-P の 30%削減が達成できた。一方，400m³/日以上では TP を確実に沈澱させることとし 50m³ の沈澱槽の追加，曝気や反応槽の充填材設置の改良によって 550 m³/日において TP 削減率 30%を達成した。この実証試験によって，実用レベルの装置として有効性を確認できた。

謝辞 本実証試験は茨城県の「公募型新たな水質浄化空間創出事業に係る実証試験業務（土浦市虫掛地内）」に基づき，茨城県から復建調査設計㈱への委託により行われたものである。また，水質分析に関しては茨城県環境科学センター，土地等の利用に関しては土浦市市民生活部環境保全課にご協力をいただいた。記して謝意を表します。

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P7-18

Contamination of River Ecosystems with Harmful Organic Chemicals Released from Recycling of Electronic-Waste in Northern Vietnam

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Keywords: river ecosystems, chemical contamination, electronic-waste recycling, Vietnam

ABSTRACT

Waste from end-of-life electrical and electronic equipment, known as e-waste, is a rapidly growing environmental problem worldwide. There is considerable interest in recovery of valuable and reusable materials from e-wastes for environmental and economic reasons. However, concerns were raised about environmental and human health risks posed by harmful organic chemicals, such as polybrominated diphenyl ethers (PBDEs) and their alternative flame retardants, associated with primitive recycling of e-wastes in developing world. We investigated contamination of river ecosystems with PBDEs and their alternative flame retardants released from processing of e-wastes in a village in northern Vietnam. On the basis of the obtained results, we determined concentrations of PBDEs and their alternatives in river fish and sediment samples and identified potential processes for contamination formation. Our findings suggested that open-storage of e-wastes should be prohibited and that wastewater treatment should be implemented at each workshop to reduce contamination of river ecosystems with harmful organic chemicals from recycling of e-wastes in developing world.

1. INTRODUCTION

Waste from end-of-life electrical and electronic equipment, known as e-waste, is a rapidly growing environmental problem worldwide. According to a press release by the United Nations University, the world generated 44.7 million metric tonnes of e-wastes by 2016 [1]. There is considerable interest in recovery of valuable and reusable materials from e-wastes for environmental and economic reasons. However, concerns were raised about environmental and human health risks posed by hazardous components, such as heavy metals, plastic flame retardants, and dioxins. Primitive processing of e-wastes in developing world have been recognized as causing localized environmental contamination and human exposure, as well as widespread contamination due to subsequent hazardous component emissions into indoor and outdoor environments.

A broad array of plastic flame retardants has been used for several decades to reduce flammability of polymeric materials in electronic products in order to pass fire safety regulations. Polybrominated diphenyl ethers (PBDEs) were extremely common flame retardants before 2004 [2]. In the last decade, commercial PBDE mixtures have been globally banned as persistent organic pollutants under the Stockholm Convention, because of their persistence, bioaccumulation, and potentially toxic effects [3,4]. The strict bans have been imposed on the worldwide use of PBDEs during the past decade. Emerging halogenated and organophosphorus flame retardants were introduced as alternatives for PBDEs [5].

Our earlier studies [6–8] reported that primitive processing to recover valuable and reusable materials of e-wastes in an informal e-waste-processing area in northern Vietnam resulted in causing contamination of river sediments with PBDEs and their alternatives. The occurrence of PBDEs and their alternatives in river sediments suggested that ecological exposure to PBDEs and their alternatives may be caused from the processing of e-wastes.

To provide data on contamination of river ecosystems with harmful organic chemicals released from recycling of e-wastes in developing world, this study measured PBDEs and their alternatives in fish samples collected from a farming pond and the river that flows through the e-waste-processing area in northern Vietnam.

2. METHOD

Fish samples were collected from an e-waste-processing area in Bui Dau (Cam Xa, Hung Yen province), northern Vietnam. Five samples of fish in a farming pond and fifteen samples of fish in the river that flows through the e-waste processing area were collected in December 2014. The samples of fish muscles were stored in amber glass bottles at −20 °C until chemical analysis.

Thirteen PBDE congeners (BDE-28, 47, 49, 99, 100, 153, 154, 183, 196, 197, 206, 207, and 209), five alternative halogenated flame retardants (AHFRs), and eleven organophosphorus flame retardants (PFRs) were selected for the target analysis of PBDEs and their alternatives based on results of environmental occurrence in our earlier studies [6–8], current understanding of potential replacements for PBDEs [5], health concerns [5], and analytical capability. Following homogenization and freeze-drying, approximately 5 g of each sample was extracted using a rapid solvent extractor (SE-100; Mitsubishi Chemical Analytech) with acetone:*n*-hexane (1:1, v/v) mixture and toluene. The extract after the purification was subjected to measurement using GC-MS (Agilent Technologies) and LC-MSMS (Waters).

Table 1. Concentrations of PBDEs, AHFRs, and PFRs in pond fish, river fish, and river sediment samples collected in Bui Dau in 2014. The data of river sediment samples were adopted from Matsukami et al. (2017) [9].

	Pond fish (n = 5)			River fish (n = 15)			River sediment (n = 8)		
	Min.	Median	Max.	Min.	Median	Max.	Min.	Median	Max.
	ng/g lipid weight			ng/g lipid weight			ng/g dry weight		
Polybrominated diphenyl ethers (PBDEs)									
BDE-28	0.25	0.64	4.8	0.68	13	59	0	0	0.56
BDE-47	2.2	3.8	18	7.9	71	370	0	0.14	2.2
BDE-49	0.95	1.2	4.6	1.3	17	77	0	0.14	3.3
BDE-99	<0.3	<0.3	0.52	0.52	5.4	79	0	0	0.44
BDE-100	<0.2	0.42	1.7	1.2	8.4	41	0.069	0.61	9.8
BDE-153	<0.3	<0.3	<0.3	2.6	15	110	0	0.09	1.8
BDE-154	1.0	1.9	7.3	7.8	54	410	0.56	3.4	55
BDE-183	<0.7	<0.7	<0.7	<0.7	2.0	75	0.36	1.4	25
BDE-196	<2	<2	<2	<2	<2	7.9	0.43	2	31
BDE-197	<2	<2	<2	<2	<2	18	0.077	0.2	2.4
BDE-206	<4	<4	<4	<4	<4	56	2.4	11	180
BDE-207	<4	<4	<4	<4	<4	25	1.4	7.1	81
BDE-209	<7	<7	<7	8.4	73	1400	46	170	1700
Alternative halogenated flame retardants (AHFRs)									
TBBPA	<15	<15	310	<15	19	190	41	110	710
HBB	<2	2.2	4.1	<2	2.2	5.3	0.25	0.59	12
BTBPE	<8	<8	<8	<8	<8	<8	0	0	4.6
DBDPE	<40	<40	<40	<40	<40	2600	9	23	680
DP	<0.2	0.67	24	4.6	270	880	0	2.02	24
Σ5AHFRs	<40	24	320	4.6	390	3700	50	140	1400
Organophosphorus flame retardants (PFRs)									
TCEP	29	54	85	<20	46	160	0	0	0
TCIPP	68	170	290	63	130	300	0	5	140
TDCIPP	<10	21	40	12	27	79	0	0	6.7
TPHP	9.2	28	94	43	92	230	0	36	200
MPDPP	6.1	12	31	11	24	68	0	1	14
EHDPP	<5	<5	12	<5	<5	11	0	0	6.8
TMPP	<5	12	61	11	37	94	0	0	20
TDMPP	<5	<5	<5	<5	<5	7.9	0	0	14
PBDPP	<5	8.0	9.5	<5	6.1	8.2	2.3	42	330
BPA-BDPP	<5	<5	5.3	<5	<5	10	5.7	48	400
PBDMPP	<5	<5	<5	<5	<5	9.3	0	9.5	51
Σ11PFRs	140	310	580	180	410	730	9.7	180	1200
Σ13PBDEs	<7	7.8	36	43	250	2300	51	220	2100
Σ16PBDE alternatives	160	310	790	210	790	4200	25	340	6800

3. RESULTS AND DISCUSSION

All 29 target compounds measured in this study were detected in fish samples collected from a farming pond and river in Bui Dau (Table 1). The concentrations of PBDEs in pond and river fish samples ranged from <7−36 and 43−2300 ng/g lipid weight (lw), whereas those of PBDE alternatives ranged from 160−790 and 210−4200, respectively. The levels of PBDE alternatives in fish samples were higher than those of PBDEs. Of the detected flame retardants, PBDEs, tetrabromobisphenol A (TBBPA), decabromodiphenyl ethane (DBDPE), dechlorane plus (DP), tris(2-chloro ethyl) phosphate (TCEP), tris(2-chloroisopropyl) phosphate (TCIPP), and triphenyl phosphate (TPHP) were dominant in fish samples.

Commercial PBDE mixtures have been incorporated into polymeric materials of Cathode Ray Tube monitors and TVs, and household appliances for high temperature

applications. TBBPA is used mainly as a reactive agent in PCBs and the housings of electronic products. TBBPA is a high-production volume unregulated flame retardant with applications similar to those of PBDEs. DBDPE, which was introduced in the mid-1980s, is used as a replacement for PBDEs. DP is used as an additive for polymeric materials, such as electrical wire and cable coatings, and computer connectors. TCEP, TCIPP, and TPHP have been used as replacements for PBDEs in polyurethane foam. These applications suggest that open storage of large amounts of polymeric materials in e-wastes along the riverside and e-waste-processing associated wastewater might contribute to elevated concentrations of these flame retardants in fish samples.

According to our earlier studies [6−8], the concentrations of PBDEs and their alternatives in river sediments in 2014 ranged from 51–2100 and 25–6800 ng/g dry weight, respectively (Table 1). The contamination of river environments with PBDEs and their alternatives resulted in accumulation of PBDEs and their alternatives in the river ecosystems. These concentrations in fish samples varied by more than about 2−3 orders of magnitude between the farming pond and river. The difference among sampling sites suggests that the concentrations of PBDEs and their alternatives in fish samples might reflect the contamination of their living environments.

It is noteworthy that concentrations of PBDPP and BPA-BDPP in fish samples were 1−3 order of magnitude lower than those of other flame retardants (Table 1), even though the concentrations of PBDPP and BPA-BDPP in river sediments were high side for those of target compounds measured in this study. The results of this study indicate lower bioaccumulation potential of PBDPP and BPA-BDPP compared with other flame retardants.

4. CONCLUSION

Results of this study provided information on the contamination of river ecosystems with harmful organic chemicals released from the primitive recycling of e-wastes in the developing world. On the basis of the obtained results, open-storage of e-wastes should be prohibited and that wastewater treatment should be implemented at each workshop in order to reduce the contamination by harmful organic chemicals in the river ecosystems. This information would be useful for planning appropriate measures for the environmentally sound management of e-wastes in the developing world. This is also expected to help address the Sustainable Development Goals (SDGs) related to environmental protection (Goals 6, 11, 12, and 14) and health (Goal 3).

Our data suggests that the potential bioaccumulations of PBDPP and BPA-BDPP in fish muscle tissues might be lower than those of other flame retardants. This information on their bioaccumulations obtained from this study might give a hint to consider a design of flame retardants with low bioaccumulative potential.

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下水処理水有効利用のための下水再生処理システムの実証研究

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キーワード: 下水, ウイルス, 紫外線, 水資源の利用・開発, 浄水・排水処理技術

抄録

都市における水資源として、下水処理水の有効利用が求められているが、下水処理水中に残存するウイルスや、クリプトスポリジウムのような病原性微生物に関する安全性を確保する必要がある。紫外線消毒は塩素消毒に比べて、設置面積の節約と有害な副生成物の懸念の少ないことが特徴であり、安全性確保の手法として有望視されている。紫外線の消毒効果は紫外線照射量で示され、その測定は生物線量計に依っているが、生物線量測定は装置規模が大きくなると実施が困難なことが課題であった。下水再生処理システムの実証研究では、下水二次処理水中のウイルスのうち F-RNA ファージに着目し、その指標性を検討して、本システムの安全性、経済的有効性について実証した。本報告では実証研究の中で検証したウイルス不活化の評価方法について報告する。なお、本実証研究は平成 27 年～28 年にかけて国土技術政策総合研究所からの委託研究として実施したものである。

1. はじめに

近年、病原性微生物の検出技術の進歩により、下水処理水中に残存するノロウイルス(NV)[1]のような病原性微生物への関心も高まっており、下水試験方法でも、水質汚濁防止法排水基準の規制対象であるこれまでの大腸菌群数に加え、規制対象にない NV に関する記述も掲載された。従来の塩素消毒によるウイルス除去には、ヒトが直接触れても安全なレベルとされる 5Log 以上(99.999%以上)の除去率と同等とするに必要な CT 値は 450 とされ、且つ接触時間は 90 分以上となっている[2]。従来の塩素消毒では残留塩素および消毒副生成物の懸念があるため、高い CT 値を要求されるウイルスの低減には、残留性や副生成物のない紫外線(UV)消毒による不活化が効果的であると考えられる。

筆者らは、国土交通省が実施している下水道革新的技術実証事業（B-DASH プロジェクト）において、限外ろ過膜（UF）と UV 消毒の組み合わせによる下水処理水の再生処理システム（本システム）に関する実証研究を行い、直接灌漑の用途にも用いることのできる安全な下水再生処理システムを実証した[3]。下水二次処理水中に存在するウイルスに対して、UV による不活化効果を直接評価した例は少ないが、本研究において京都大学の田中宏明教授らのグループの協力を得て、下水二次処理水中に存在するウイルスの中から UV 消毒効果を測定できるウイルス（NV は現状これに該当しない）を特定し、UF と UV によって高い安全レベルとされる 5.2Log 以上のウイルス除去率を直接評価した[4]。

2. 方法

2-1 実証施設

1,000m^3/日の処理能力の下水再生処理実証施設（本施設）を沖縄県糸満市浄化センターに設置し、平成 27 年から 28 年の 2 ヵ年に亘り B-DASH プロジェクトとして実証研究を行った。

本施設のフローを図 1 に示す。本施設では糸満市浄化センターの下水二次処理水を原水とし、その UF ろ過水を UV 消毒することによって安全な再生水に処理した。本施設の UV 消毒槽は迂回形開水路で 3 つのモジュールを直列に配置し、2 モジュールを常用として 1 モジュールを予備とした。

本施設で製造された再生水は農地に運搬し、栽培試験や収穫物の実証販売によるアンケート調査などを行って、再生水の利用促進に取組んだ。

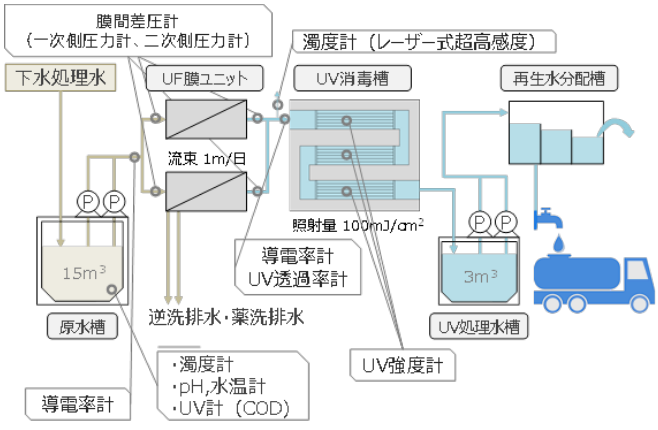

図 1 再生水実証施設のフロー

また、モデルウイルス(MS2)の添加実験は本施設の規模ではウイルス量確保の観点から実験が困難であっ

たため、同センター内の 10m^3/日の処理能力のパイロットプラントで実施した。パイロットプラントの処理フローを図 2 に示す。パイロットプラントの UV 消毒装置は密閉式の直列 4 基で構成され、UV1 本目の処理水から 4 本目の処理水まで各途中段階の処理水の採水が可能な構造である。

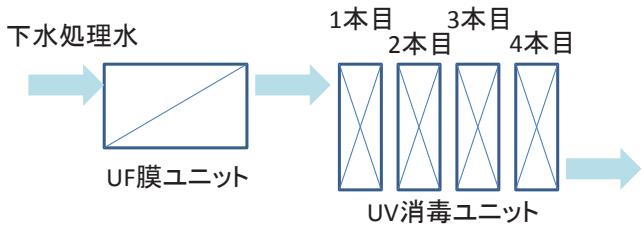

図 2 パイロットプラントの処理フロー

2-2 ウイルス分析

ICC-PCR 法(Integrated Cell Culture - Polymerase Chain Reaction 法)は、培養法と PCR 法を組み合わせることによりウイルスの増殖能力の有無を測り、不活化評価が可能な方法である。UV 消毒は生物の DNA や RNA を損傷させ、細胞の増殖能力を失わせるが、消毒効果の確認のためには、ウイルスを細菌などのホストに感染させる必要がある。本実証研究では、大腸菌(WG49)を含む液体培地で F-RNA ファージを増殖させ、その後 PCR を行うことで、対象とする遺伝子型の感染力の有無を判断した。この方法では、定性的な結果しか得られないが、同時に最確数法(MPN 法)を適用することにより定量性の有るデータを収得することができる。

3. 結果

3-1 ウイルス不活化の実証結果

糸満市浄化センターの下水二次処理水中(原水)に残存する F-RNA ファージの存在濃度を ICC-PCR により測定した。結果を図 3 に示す。原水の F-RNA ファージは GIと GIIタイプが他のタイプと比べて高濃度で検出され、GIVタイプはほとんど検出されなかった。

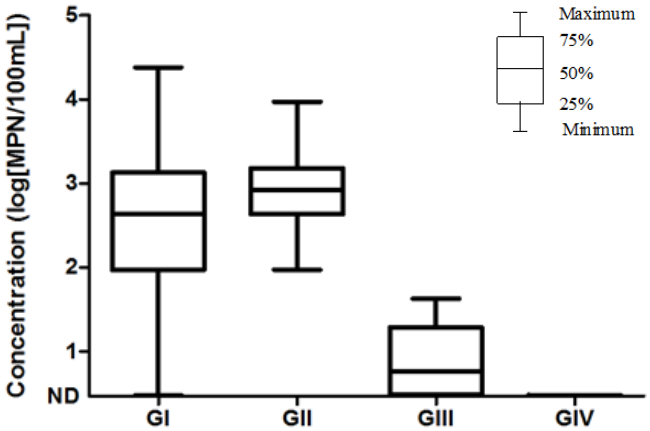

図 3 原水の F-RNA ファージ測定結果(ICC-PCR)

原水中に比較的高濃度に存在する GIタイプと GIIタイプによって、人為的にウイルスを添加せずに本システムのウイルス除去率を直接評価できると考え、ICC-PCR による再生水のファージ分析を行なった。UF と UV によるファージ除去性能を図 4 に示す。実証施設のファージ除去率は 6Log 程度を上限として、それ以下の場合も ICC-PCR の定量下限値未満の存在濃度までファージを不活化する結果となり、本システムで 5.2Log 以上の除去率であることを直接実証した。また、パイロットプラントでは人為的に培養した MS2 の添加実験による評価も併せて行ない、MS2 で本システムが 5.2Log 以上の除去率であることを確認すると共に、GIタイプで定量下限値以下の 5Log を超える除去率が得られた。

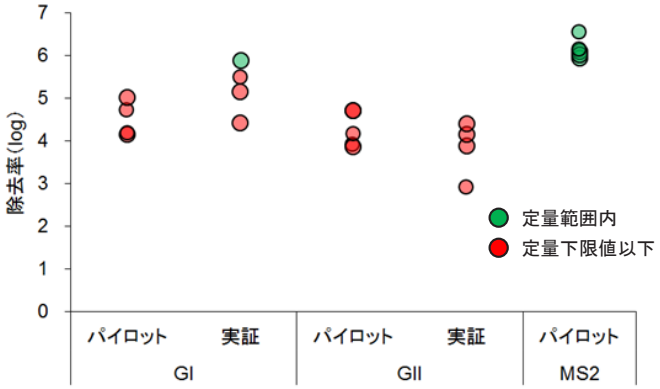

図 4 UF+UV のファージ除去性能

3-2 原水の F-RNA ファージの指標性

原水中の F-RNA ファージが MS2 と同様に UV 照射量の指標になり得るかを検討するため、同一の運転条件でパイロットプラントの MS2 と原水の F-RNA ファージの除去率を求め、それぞれの UV 感受性を比較した。結果を図 5 に示す。

図 5 では UF 処理水および、直列 4 基の UV 消毒装置の 1 基目流出水から 4 基目流出水までそれぞれの地点で採水した結果を示しており、UV1 本目の照射量に対し、4 本目では 4 倍の照射量になる。

各ファージは UF 膜で 1.5～2Log 程度除去され、UF 膜から合計して UV1 本目で GIIタイプは 4Log 程度、MS2 と GIタイプは 3Log 程度の除去率を示した。UV2 本目では GIIタイプは 5Log 程度、MS2 は 4Log 程度で GIタイプは 4Log を若干下回る程度の除去率を示した。UV3 本目で GIIタイプは検出されなくなり、MS2 は 5Log 程度、GIタイプは 4.4Log 程度の除去率を示した。UV4 本目では GIタイプも検出されなくなったが、本試験の原水に存在する GIタイプの濃度が少なかったためと考えられる。前述の図 3 の結果にもみられるように、原水中に残存する F-RNA ファージの存在濃度には変動があり、

それによって確認できる除去率はICC-PCRの定量下限値により制限がある。一方 MS2 は高濃度で添加しているため、UV4 本目でも検出がみられ、求められたファージ除去率は 6Log 程度であった。

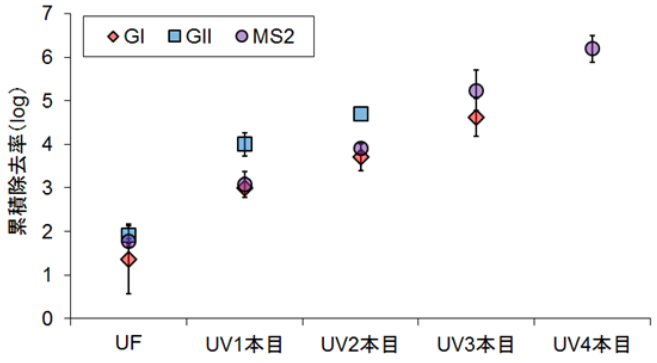

図 5　MS2 と F-RNA ファージの UV 感受性の比較

パイロットプラントの紫外線照射量(生物線量)を文献値[5]から式 1 により MS2 の除去率ごとに算出した。GIタイプとGIIタイプの F-RNA ファージ除去率と MS2 による生物線量との関係を図 6 に示す。

平均不活化率(Log Inactivation)＝-0.0001×照射量 ^{2} ＋0.0607×照射量－0.0017　(式 1)

F-RNA ファージの GI、GIIタイプは MS2 を用いた測定による 60mJ/cm^2 未満の UV 照射量では、MS2 より除去率がやや高いが、GIタイプは全体的に UV 感受性が MS2 とほぼ同等でやや安全側の指標となることが予想される。すなわち、本システムで確保する 5.2Log のウイルス除去率のうち、図 5 の結果のように UF で 1Log 程度、UV で 4.2Log 程度の除去率を確保するには 85 mJ/cm^2 程度の UV 照射量が必要であるが、実験結果より、GIタイプは 85mJ/cm^2 程度の UV 照射量においてMS2 よりも UV 感受性が低い可能性が示唆された。

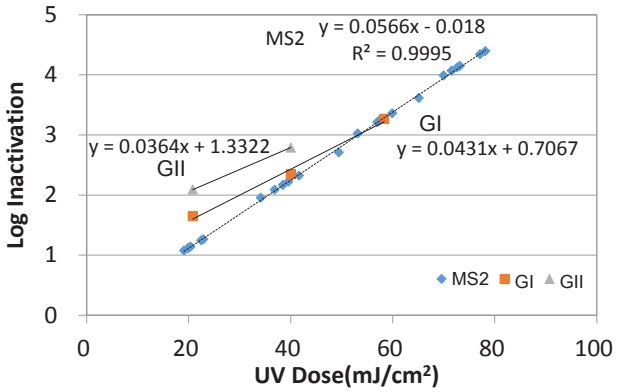

図 6 F-RNA ファージ除去率と MS2 生物線量の関係

4.　考察

本システムの目標値である 5.2Log のウイルス除去率のうち、4.2Log 程度を UV 消毒で確保することを検証するうえで、下水二次処理水中に存在する F-RNA ファージは、従来指標として用いられてきた MS2 と同等かやや安全側の指標として UV 消毒装置の生物線量計に用いることができると考えられる。MS2 による評価では人為的に添加する必要があることが課題であったが、F-RNA ファージは自然に存在しているため、施設規模による制約は無いと考えられる。一方で、F-RNA ファージの存在濃度は一定ではないため、例えば必要なウイルス除去率を 5Log とした場合、原水の存在濃度が満たなければ ICC-PCR 法の定量下限値未満となって、必要なウイルス除去率を評価できない可能性がある。

また、例えば F-RNA ファージ GIタイプは、MS2 のような単一種を指すものではないため、MS2 との UV 感受性の比較について、さらに知見を収集するべきであると考えられる。

5.　結論

UF と UV の組み合わせによる下水再生処理システムのウイルス除去性能が実証された。また、下水処理における UV 消毒効果の検証において、従来課題であった規模の大きな施設での生物線量試験の実施に、従来の指標である MS2 と同等かやや安全側の指標として F-RNA ファージ GIタイプを用いられる可能性が示唆された。ICC-PCR 法によって従来よりも低濃度のサンプルでも定量性のあるウイルス評価が行なえるため、下水二次処理水中に存在している F-RNA ファージを用いた評価では、MS2 のような人為的な添加の必要がない。

F-RNA ファージの存在濃度は地域や季節で異なる可能性が懸念されるものの、実際に存在するウイルスに対して、UV 処理能力を設計値に適用し、さらに試運転などで検証できる可能性が示されたことは、再生水をはじめとする様々な水処理分野でさらに UV が普及拡大し、残留性や有害副生成物のない安全な消毒技術として、水環境の保全や新たな水循環システム構築に役立てるのではないかと期待する。

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下水処理場における化学物質の除去－1,4-ジオキサンの場合－

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キーワード: 下水道, 化学物質, 1,4-ジオキサン, 排水処理技術

抄録

深芝処理場の流入水には石油化学工業を主とする工場から排出される多様な化学物質が含まれる。しかし, 放流水の有機物量の指標は, 流入水に比べ十分低く, 化学物質が処理場内で除去されていることが推測される。そこで, 処理場の流入水に含まれる化学物質の中から, 発がん性が疑われ, 生物分解性が低いとされる 1,4-ジオキサンを調査対象物質に選定し, 処理場内における物質収支及び生物分解性試験を実施した。その結果, 深芝処理場では, 1,4-ジオキサンは, 標準活性汚泥法を採用する反応槽の流入水に比べ流出水で濃度が低くなっており, 微生物により除去されていることが示唆された。また, 処理場における 1,4-ジオキサンの除去率は, 最低でも 30%以上で, 最高では 90%を超えた。一方, 都市下水処理場の活性汚泥には, 1,4-ジオキサン除去能は認められなかった。本研究では深芝処理場の活性汚泥が特有の化学物質除去能を有することを示した。

1. はじめに

化学物質は, 全世界で 2,600 万種を超える物質[1]が知られている。しかし, 多種多様な化学物質のなかには, 環境残留性や発がん性を有する有害物質も存在する。そのような化学物質の一つに,14-ジオキサン[2]がある。

1,4-ジオキサンは国際がん研究機関（IARC）の発がん性分類で, ヒトに対して発がん性を示す可能性があるグループ 2B に分類[3]される化学物質で, 化学的安定性が高く, 水や有機溶媒と任意の割合で混和することなどから化学反応の溶媒として使用されている。また, 界面活性剤の基材であるエチレングリコールを製造する際に副生し, 末端の消費者が使用する洗剤やシャンプーに含まれることもある化学物質である。1,4-ジオキサンは化学的安定性が高いために, 物理化学的分解を受けにくく, 処理法が確立されていない[4]。つまり, 1,4-ジオキサンが環境中に放出されると, 長期に渡り環境を汚染することとなる。

しかし, 近年, 1,4-ジオキサンを分解する微生物が, 河川や底泥等の水環境あるいは活性汚泥中から発見[5]され, 浄化装置への応用が研究されているが, 研究開発段階にある[6]と考えられる。

茨城県の深芝処理場は, 1970 年の開所以来, 石油化学工業から排出される多種多様な化学物質を含む廃水を処理しており, 処理場の流入水には 1,4-ジオキサンも含まれていることから, 処理場の活性汚泥は 1,4-ジオキサンの除去能を有することが期待される。

そこで, 処理場内における 1,4-ジオキサンの物質収支調査及び活性汚泥を用いた生物分解性試験を実施し, 活性汚泥の 1,4-ジオキサン除去能を評価した。

2. 方法

2.1 深芝処理場について

深芝処理場は, 茨城県の東南部に所在する鹿島臨海工業地帯の一角に位置し, 石油化学工業を中心とする工場・事業場から排出される廃水を標準活性汚泥法により処理し, 処理水は太平洋へ放流している。

処理工程は, 沈砂池, 曝気油脂分離槽, 調整槽, 最初沈殿池（初沈）, 反応槽, 最終沈殿池（終沈）, 塩素混和池の順に配置され, 初沈から終沈までは A 系と B 系の 2 系列がある。一日当りの処理能力は, A 系が 125,000 m^3, B 系が 40,000 m^3 で合計 165,000 m^3 である。

流入水量は, 工場・事業場が一斉に点検や修理を行う 5 月から 6 月に減少し, 年間を通じた流入水量は日量 100,000～130,000 m^3 の間で変動がみられ, 日平均約 120,000 m^3 であり, このうち約 90%を工場・事業場廃水が占めている。流入水は調整槽を経た後, B 系に一日当り約 30,000 m^3 を, 残りを A 系に分配している。

流入水及び放流水の主な水質を表 1 に示す。放流水

表 1 深芝処理場の流入水及び放流水の水質

	流入水	放流水
COD[mg/L]	86	20
BOD[mg/L]	86	4
TOC[mg/L]	53	15
Ca [mg/L]	2,000	2,000
Cl [mg/L]	5,200	5,200

2012～2016年度の平均

の化学的酸素要求量(COD)，生物化学的酸素要求量(BOD)及び全有機炭素濃度(TOC)等の有機物を表す指標は流入水に比べ，十分低くなっており，流入水に含まれる化学物質が除去されていることが推察される。また，その他の特徴として，海水の組成に対し，カルシウム(Ca)が約 5 倍，塩素(Cl)が約 4 分の 1 の濃度で含まれていることが挙げられる。

2.2 物質収支に係る調査方法

物質収支調査は，平成 28 年 12 月から平成 29 年 7 月の間に計 8 回，実施した。

水試料として，流入水，A 系及び B 系の初沈越流水，A 系及び B 系の終沈越流水，放流水，返流水の 7 ヶ所，大気試料として，曝気油脂分離槽及び調整槽からの排気用の送気管，A 系反応槽水面の直上大気，B 系反応槽からの排気用の送気管の 3 ヶ所，汚泥試料として A 系及び B 系の初沈引抜汚泥，A 系及び B 系の終沈引抜汚泥(返送汚泥)の 4 ヶ所，で採取した。

なお，大気試料の採取は，ダイヤフラムポンプにより 1 L/分の流速で 100 L の大気を捕集ビンに吸引通気し，1,4-ジオキサンを捕集ビン中の精製水に捕集した。この捕集液を 1,4-ジオキサン濃度測定に供した。

また，反応槽の水面直上大気は，1,4-ジオキサンの散逸を防ぐため，縁にポリエチレンシートを備えた箱で反応槽の水面を覆い，箱の底部中央に貫通させたステンレス管から大気試料と同様の装置で採取した。

移動量は，各試料の濃度に，調査日の各処理施設の水量(m^3)，送風量(Nm^3)又は汚泥量(m^3)を各々掛け合わせ算出した。

2.3 生物分解性試験

生物分解性試験[7]は，返送汚泥と初沈越流水に 1,4-ジオキサン溶液を添加し，1,4-ジオキサン濃度 約 1 mg/L，MLSS 約 1,500 mg/L に調整した混合液 500 mL を入れた三角フラスコを振とう培養器に入れ，所定の水温，振とう速度 70 rpm で 12 時間培養した。比較のため主に都市下水を処理している利根浄化センター及び潮来浄化センターの汚泥についても調べた。

2.4 1,4-ジオキサンの測定方法

1,4-ジオキサンの測定は，ヘッドスペースガスクロマトグラフ質量分析計を用い，日本工業規格 K0125 5.2 に規定された方法に基づいて実施した。また，試料における定量下限は，水及び汚泥試料が 0.001 mg/L，大気試料が 0.0001 mg/Nm^3 である。

3. 結果

3.1 処理場内の 1,4-ジオキサンの物質収支

図1に示すように，各試料における 1,4-ジオキサンの 1 日当たりの移動量は，流入水では平均 12.1 kg，初沈越流水では 10.6 kg，終沈越流水では 5.0 kg，と反応槽の前後で移動量は半減した。環境への 1,4-ジオキサンの排出量は，大気への放出量が 0.01 kg 未満で，放流水が 4.2 kg となっており，主に水系へ排出されていた。

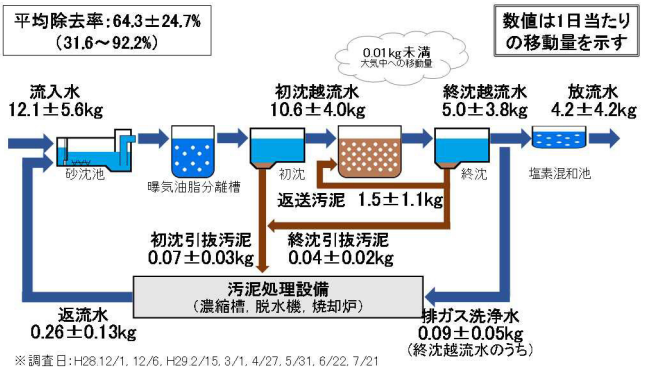

図 1 処理場内における 1,4-ジオキサンの物質収支

また，処理工程内での移動量をみると，返送汚泥として 1.5 kg が反応槽と終沈を循環し，初沈引抜汚泥，終沈引抜汚泥及び排ガス洗浄水の合計量 0.20 kg は，汚泥処理設備で処理された後の絞り水と排ガス洗浄水が合流した返流水に含まれる量 0.26 kg と同等であることから，汚泥への吸着や汚泥処理系での除去は無視できると考えられた。

3.2 生物分解性試験での除去率

図 2 に示すように，1,4-ジオキサンの除去率は，いずれの処理場の活性汚泥でも時間の経過とともに上昇した。12 時間後では，深芝処理場の活性汚泥は，24℃～34℃の範囲の水温で，88%～97%と良好な値を示し，都市下水を処理している利根浄化センターと潮来浄化センターの活性汚泥では，高くても 40%に留まった。

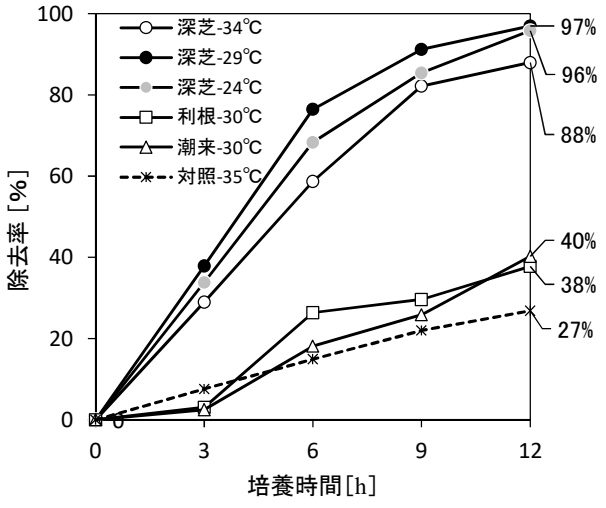

図 2 各処理場の活性汚泥を用いた生物分解性試験における 1,4-ジオキサンの除去率と水温の関係

ただ，これらの値は，活性汚泥を加えず精製水に 1,4-ジオキサンのみを添加した対照の除去率 27%を差し引いて評価する必要があるが，深芝処理場の活性汚泥は利根浄化センターや潮来浄化センターの活性汚泥に比べ，高い 1,4-ジオキサン分解能を有すると考えられる。

4. 考察

4.1 物質収支に基づく 1,4-ジオキサンの除去率

深芝処理場における除去率は最低で 31.6 %で，最高では 92.2%と，既報[8]の 8.5 %に比べれば約 4～11 倍の除去率であるが，変動が大きい。変動を大きくしている要因は，除去率が 30%台の調査が 2 回あるためである。除去率が低くなった 2 回の調査日は，5 月 31 日と 6 月 22 日で，工場・事業場が一斉に点検や修理を行っていた時期に相当し，通常時の流入水に含まれ 1,4-ジオキサンの分解を支援する物質[9]の欠如や微生物の活性を阻害する物質[10]の混入等，流入水の変質が 1,4-ジオキサンの除去に影響した可能性が考えられる。1,4-ジオキサン分解菌として分離同定されている微生物の中には，1,4-ブタンジオールで前培養すると 1,4-ジオキサンの分解速度が高まる種が知られている[11]。良好な 1,4-ジオキサンの除去を維持するためには，流入水に含まれる化学物質の詳細な調査が必要と考える。

4.2 1,4-ジオキサン分解に関与する微生物

1,4-ジオキサン分解菌として分離同定された微生物は環状エーテルを酸化する酵素をコードする *thmC* 遺伝子[9]を有するとされる。そこで，深芝処理場と利根浄化センター及び潮来浄化センターの活性汚泥中の *thmC* 遺伝子濃度を調べた。図 3 に示すように *thmC* 遺伝子濃度は，深芝処理場の活性汚泥には常時，10^{10} copies/g-MLSS オーダー以上の濃度で存在するが，都市下水処理場である利根浄化センターと潮来浄化センターの活性汚泥からは定量下限未満の濃度であった。

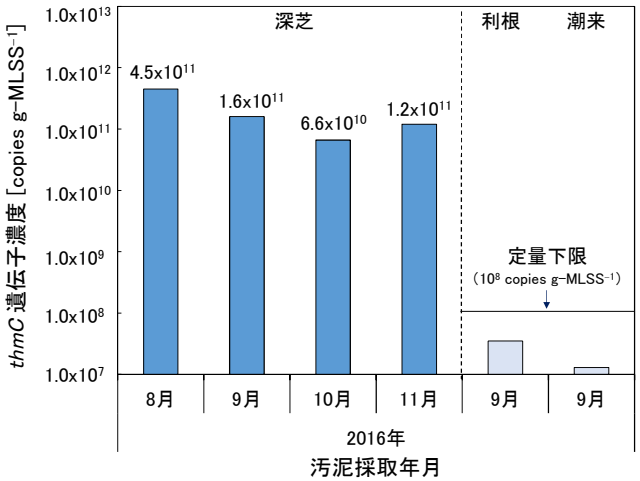

図 3 活性汚泥中の *thmC* 遺伝子濃度

このことは，深芝処理場の活性汚泥には 1,4-ジオキサン分解菌が常在し，他の処理場の活性汚泥には分解菌が存在しないことを示しており，生物分解性試験による 1,4-ジオキサンの除去率に違いがみられた原因と考えられる。

深芝処理場の流入水には多種多様な化学物質が含まれており，それらを利用して増殖できるように細菌叢が形成されたものと推察され，化学物質に対する高い除去能は深芝処理場に特有と考えられる。

5. 結論

深芝処理場に排出される化学物質の中から発がん性が疑われ，生物分解性が低いとされる 1,4-ジオキサンを調査対象として，処理場内の物質収支を調査したところ，深芝処理場における除去率は，最低でも 30%以上で，最高では 90%を超過することが判明した。また，1,4-ジオキサンの除去には活性汚泥中の微生物が関与していることが示唆され，特有の化学物質除去能を有していることが推察された。

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Evaluation of partitioning potential and bioaccumulation of seven SCCPs in lake ecosystem

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Keywords: Short chain chlorinated paraffins, Phase partitioning, Bioaccumulation

ABSTRACT

Short chain chlorinated paraffins (SCCPs) have been listed in Stockholm convention as persistent organic pollutants (POPs). SCCPs are of great concern due to recently increasing detection in the environment, including lakes. Since the aquatic bioaccumulation is crucial in the food chain, there is potential risk of SCCPs to human health. In this paper, we evaluated the potential influence of seven SCCPs in lake ecosystem, based on phase partitioning estimation between air, water and sediment, as well as the bioaccumulation calculation. The results indicated that the water is the main compartment for SCCPs with proportion of 51-71%. Multi-chlorinated SCCPs are favorable in sediment as well. The bioaccumulation factor (BAF) results indicated that the potential risk is higher in multi-chlorinated SCCPs. The variety of molecular structures of SCCPs would lead to different influence in lake ecosystem.

1. INTRODUCTION

Short chain chlorinated paraffins (SCCPs) are highly complex technical mixtures with general formula of $C_nH_{2n+x-m}Cl_m$, where the value of n is between 10-13. SCCPs are of great concern due to their high persistence, bioaccumulation potential and toxicity. Currently, SCCPs have been listed as persistent organic pollutants (POPs) for global regulation under Stockholm Convention. The environmental existence at various matrices (air, water, soil and sediment) have been widely reported [1].

Lake, the typical aquatic ecosystem, could also encounter the environmental challenge along with the intervention of SCCPs, i.g. by effluent from sewage treatment plants [2]. It is still under great challenge for quantifying SCCPs in environmental samples [3], resulting in relatively weak environmental management of SCCPs releasing. Recently, the bioaccumulation of SCCPs in lake ecosystem has been increasing investigated [4,5]. The potential risk of SCCPs has received great attention.

In this study, the potential influence of seven typical SCCPs in lake ecosystem was evaluated by estimating their environmental partitioning between air, water and sediment, and assessing the potential of bioaccumulation. The distinction between different SCCPs was also discussed.

2. METHODS

Seven typical SCCPs with chain length of 10 and chlorine number from 1 to 4, including 1-Chlordecan, 1,10-Dichlordecan, 1,1,1-Trichlorodecane, 1,1,1,3-Tetrachlorodecane, 1,1,10,10-Tetrachlorodecane, 5,5,6,6-Tetrachlorodecane, and 1,5,6,10-Tetrachlorodecane, are assumed as the target pollutants for phase partitioning and bioaccumulation calculation (See Table 1).

Table 1 Seven SCCPs used as the model compounds

CAS No.	Name
1002-69-3	1-Chlordecan
2162-98-3	1,10-Dichlordecan
64554-71-8	1,1,1-Trichlorodecane
51755-60-3	1,1,1,3-Tetrachlorodecane
33025-70-6	1,1,10,10-Tetrachlorodecane
91087-09-1	5,5,6,6-Tetrachlorodecane
102880-00-2	1,5,6,10-Tetrachlorodecane

The modified fugacity model was applied to evaluate the partitioning of SCCPs in the main compartments including air, water and sediment [6].

The partitioning parameters were generally calculated using fragment contribution method. Briefly, the values of octanol-water partitioning coefficient K_{ow}, Henry's law constant H, were obtained by multiple regression of reliably measure data from a universal database with correlation.

The conceptional equation is as follows.

$$\log K_{ow} = \sum(p_i)n_i + a \quad (1)$$

$$H = \sum(h_i)m_i + b \quad (2)$$

Where p_i, h_i denote the contribution factor of certain fragment; n_i, m_i denote the number of fragment in the chemical; and a,b represent the correction constant.

The octanol-air partitioning coefficient K_{oa} is then calculated as follows.

$$\log K_{oa} = \log K_{ow} - \log(H/RT) \quad (3)$$

where R and T represent ideal gas constant and absolute temperature, respectively.

The sediment adsorption coefficient K_{oc} is estimated by the following equation according to quantitative structure–activity relationship model.

$$\log K_{oc} = 0.5213 \times \mathrm{c} + 0.60 \quad (4)$$

where c is the molecular connectivity index.

Subcooled liquid vapor pressure, S, is estimated using the modified equation.

$$\mathrm{S} = 888 \exp((-(4.4 + \ln T_b)[1.803(T_b/\mathrm{T} - 1) - 0.803 \ln(T_b/\mathrm{T})] - 5.8(T_m/\mathrm{T} - 1)) \quad (5)$$

where T_b and T_m denote the boiling point and the melting point, and T is the desired temperature.

Arnot-Gobas predication model is used to evaluate the bioaccumulation factor (BAF) at general tropic levels and representative environmental condition with input K_{ow} of chemical normalized fish whole-body metabolic biotransformation rate constantK_M [7].

3. RESULTS

The simulated partitioning results are shown in Fig. 1.

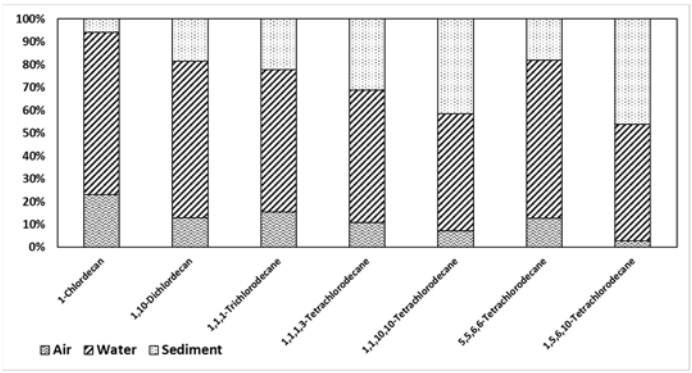

Fig. 1 Partitioning of different SCCPs in air, water and sediment

The calculated values of $\log BAF$ are shown in Fig. 2.

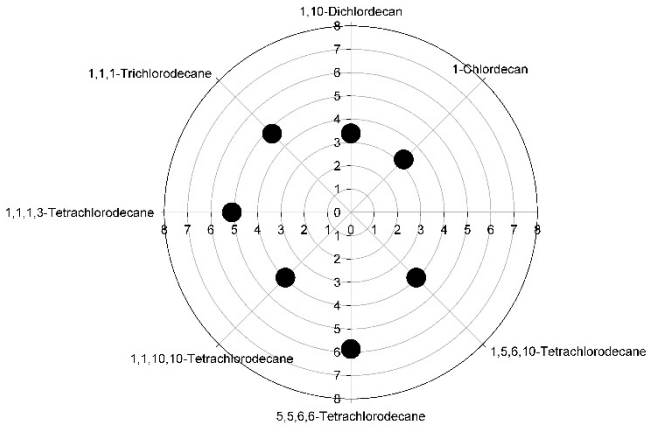

Fig. 2 $\log BAF$ values of different SCCPs

4. DISCUSSION

The results (Fig. 1) indicated that in lake ecosystem, water is the main compartment for the seven selected SCCPs, with proportion ranging from 51% to 71%. The SCCPs transporting phenomenon including emission to air and absorption to sediment should be also taken serious consideration since there are still rational distributions in the air and sediment compartments. The results also revealed the distinction for different SCCPs, implying the chemical structure with more chlorines would be more favorable in the compartment of sediment, which should be ascribed to the strong absorption of SCCPs to sediment.

The calculated values of $\log BAF$ for the seven SCCPs were ranging from 3.204 and 5.864, with maximal risk potential for 5,5,6,6-Tetrachlorodecane and minimal risk potential for 1-Chlordecan, respectively. For the chemical structure with 4 chlorines, it is observed that SCCP with chlorinated position in middle of the chain would be more easily bioaccumulated than that with chlorinated position in one end or both ends of the chain.

5. CONCLUSIONS

The potential influence of SCCPs in lake ecosystem was evaluated in this study. The methodology by estimating the partitioning and bioaccumulation behavior of SCCPs was adopted. The variety for molecular structures of SCCPs would lead to different influence in lake ecosystem.

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P7-22

Lake Chad: Need for Restoration for Peace

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Keywords: LAKE CHAD, WATERPOLLUTION, ARMED CONFLICTS, WATER LEVEL DECLINE, WILD LIFE LOSSES

ABSTRACT

Lake Chad faces wars and terrorism, extreme poverty, loss of cultural heritage and other human-centric problems. These problems have led to serious water pollution resulting in massive fish kills, extensive habitat loss of wildlife including one for hippopotamus and large-scale riparian land degradation. Combined, the resultant situation is severe deterioration of quantity and quality of water, of crop land and forest land, and of most other riparian and upland ecosystems. This paper give a picturesque message on the state of Lake Chad, while calling for a global initiative for its restoration that would contribute to bringing peace and stability in the region.

the objective is to presented lake Chad and this conference for every person work for to reduce poverty and in long the run to enhance the condition of living of the population living in the region of the lake Chad.

1. INTRODUCTION

Lake Chad water surface area occupies less than 1 percent of its draining basin, but remains the fourth biggest Africa lake after Lake Victoria, Tanganyika and Nyassa. It extends over the territories of four countries: Chad, Niger, Nigeria and Cameroon. The main inflowing river are Chari and Logone traversing the Central African Republic, Cameroun and Chad. These two rivers account for 95 percent of the total inflow, though extremely seasonal. Apparently no river flows out from the lake, though some water is said to percolate along the dry bed of the Gazal River to feed the oases of the Bodele, It is very shallow even in normal years, averaging 1.5 m in depth. Traditionally, local inhabitants use the stems of papyrus as material for canoe making. There are many small islands formed by the invasion of moving sand dunes near the northeastern coast; some of them are inhabited and utilized as bases for fishing. Besides the products of agriculture, livestock grazing and fishery, the drainage basin is known for its yield of natural soda, an activity that contributes to keeping the lake water fresh [1]. However, the seize of the open water part shrank from 25000 km2 in 1973 to less 2.500 km2 in 1990, believed to have been cause in part to the climate change, over drafting of river waters and the subsidence of groundwater level for some unknown reasons. At the same time, the regional political and military conflicts surrounding the region have seriously exasperated the ecosystem deterioration and the living condition of the residents in the region.

2. METHOD

Being a Lake Chad education expert, the method adopted for this investigative reporting is one based on making field observations and on assembling and interpreting the visual materials on the problematic aspects of Lake Chad. Attempts have been also to present some potentially useful ways to address the problems that should be supportable by the international community.

3. OBSERVATIONS

During the last decades, terrorism became the gravest misfortune for Lake Chad that creates all the ills (Photos 1, 2 and 3).



Photo 1

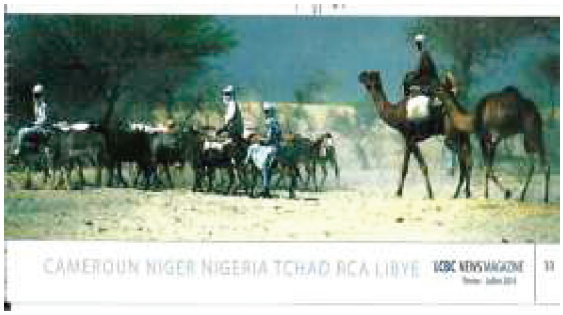

Photo 2



Photo 3

Also dramatic is the fact that the seize of the open water part of the lake has shrank from 25000 km^2 in 1973 to less 2.500 km^2 in 1990. The meager fish catch is causing affecting the livelihood of local fishermen (Photo. 4). Actually, the climates of basin region have dramatically changed from hot to desiccating (Photo 5-6), causing fish kills and diseases to Kouri cattle of Lake Chad (Photo. 7).



Photo 4



Photo 5



Photo 6



Photo 7

Nonetheless, there are ongoing restoration effort made by the local community to restore lake's biodiversity resources. Even in the wake of terrorism attack, efforts to restoration and enhance lake water quality and quantity continues, for example, by planting greenery from the pirogue boats (Photo 8). Restoration of the shoreline biodiversity will help the spinning gear fishery to support the meager family livelihood (Photo 9).



Photo 8



Photo 9

Without such efforts, reinforcement of the socio-economic base of the region, enhancement of the agro pastoral and fishing production, and sustainable management of the natural resources and preservation of the ecosystem of Lake Chad won't be possible. Without ecosystem preservation of lake and its catchment area, promotion of integration and preservation of peace and security in the Lake Chad area won't be achievable. Such ecosystem restoration research together with restitution of sustainable management efforts for Lake Chad, together with halting of terrorism attacks around Lake Chad will lead to restoration of its fisheries and wildlife habitat.

4. DISCUSSION

Through this international conference, I would like to address the need for development of a plan toward 2015 for the restoration of Lake Chad by the years 2025. This vision underpins all the development activities to be implemented with the cooperation of every partners. The framework of such a strategic action plan be for 2018-2025. Development of such a vision will be the priority. By then, the lake's common heritage and the wetland resources need to be brought under preservavtion plan for sustainable development. The economic security of the fresh water ecosystem and sustained biodiversity and aquatic resources of the basin should be equitablly pursued to meet the need of the Lake Chad population.

5. CONCLUSION

The theme of this visual resource presentation is about Lake Chad's yesterday, today and tomorrow. Everyone attending this conference should accept the responsibilities for conservation of freshwater ecosystem and its biodiversity, together with judicious implementation of integrated river and lake basin management. It applies to Lake Chad as well. Achievement of sustainable development of Lake Chad won't possible without such attitude. Without saving Lake Chad and without having adequate water resources, meeting the needs of people and exercising the rights for accessing the fresh water resources won't be possible.

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P7-23

An Attempt for Improvement of Water Quality and Cultivation of Plankton by Conducting Polymers

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Keywords: paramecium, conducting polymers, polyaniline

ABSTRACT

We conduct cultivation of paramecium in the presence of polyaniline as an electroactive-conducting polymer. The polyaniline employed in this study is in a form of half-doped state. The half-doped state partly has acid as a dopant in the main-chain. Paramecium discharges ammonia because no Ornithine cycle exists in their organs, resulting the discharged ammonia pollutes water environment. The half-doped state of polyaniline absorbs ammonia as a neutral agent. This function of electroactive polymer can be useful for purification of water. Furthermore, the conducting polymers have capturing function of heavy metals. These characters of the conducting polymer can be expected to improve the water quality for biological system. Cultivation of paramecium in the presence of the polyaniline depress the increase of pH with time. However, film form of the polyaniline could not improve the increase of pH in the cultivation system. Oxidation-reduction potential (ORP) value of the cultivation water in the presence of polyaniline is also monitored.

1. INTRODUCTION

Plankton in the water system does not possess Ornithine cycle, resulting discharge of ammonia as a poison chemical. In the case of mass generation of plankton occasionally, discharge of ammonia from the plankton deteriorates the environment. We have studied on conducting polymers for cultivation of microbes in the water [1,2]. Half-doped state of the conducting polymers as a characteristic electronic state can neutralize ammonia without any negative effect against biological system in the laboratory. In this research, we cultivate a microorganism and measure change in pH and ORP. We discuss possibilities for improvement of water environment system using this unique advantage of conducting polymers.

2. MATERIALS AND METHOD

Polyaniline as a conducting polymer was prepared with oxidative polymerization with ammonium persulfate (APS). As prepared polyaniline was treated with ammonia/water to remove excess amount of acid dopant. The as prepared polyaniline (full doped state, emeraldine salt) cannot be employed for cultivation of paramecium due to strong acid. Polyaniline thus obtained is half-doped state (reduced) as emeraldine base (PANI-EB) form, remaining small parts of acid fractions in the main-chain (Scheme 1). Polyaniline cast film was prepared from polyaniline/*N*-methylpyrrolidone (NMP) solution. Fig. 1 shows an example of the polyaniline film. Paramecium was provided by Fujishima lab. (Yamaguchi Univ., Japan). Fig. 2 shows optical microscopy and polarized microscopy images of the paramecium with transmission and reflection light.

3. RESULTS

Cultivation of paramecium in the presence of polyaniline was carried out. Fig. 3 shows change in pH of the cultivation water in the presence of polyaniline (powder form, normal PANI), camphor sulfonic acid (CSA), polyaniline film (PANI film), or control (no polyaniline).



Figure 1. A polyaniline film.

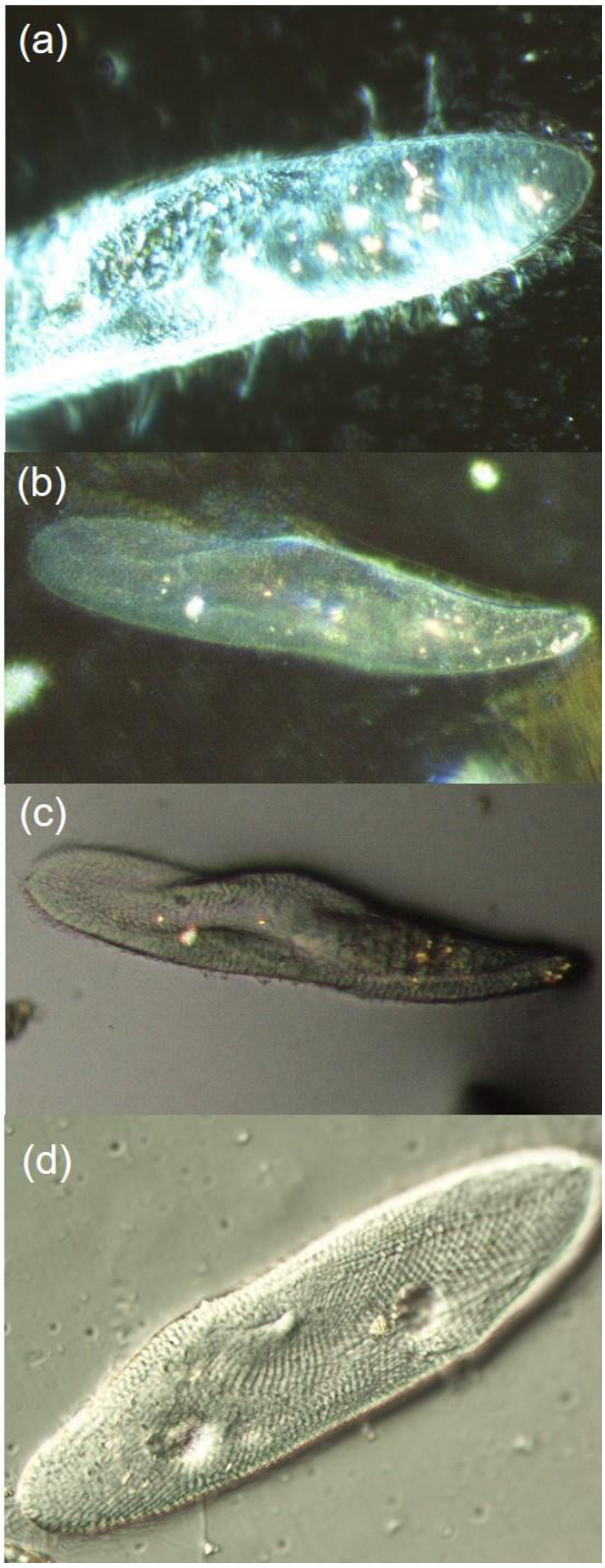
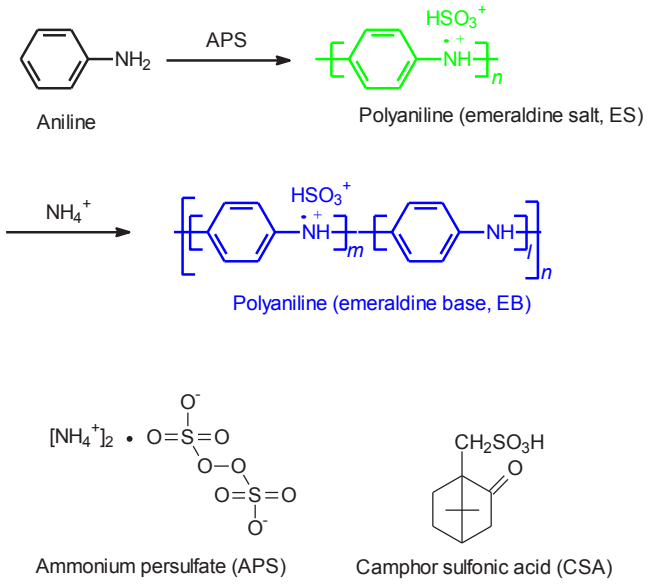


Figure 2. Optical microscopy images of a paramecium. (a) Optical microscopy images of paramecium with reflection light. (b) Optical microscopy image of moving paramecium with transmission light. (c) Optical microscopy image of moving paramecium with reflection light. (d) An entire figure of paramecium with transmission light.



Scheme 1. Synthetic route of polyaniline emeraldine base (PANI-EB) and molecular structure of camphor sulfonic acid (CSA). APS = ammonium persulfate.

The pH value increased with time because the paramecium in the water discharged ammonia. The polyaniline bulk (normal polyaniline, powder form) can suppress increase of pH value. Small amount of acid parts in the main-chain of the polyaniline (emeraldine base) neutralizes ammonia in the water. This function can provide a favor environment for cultivation of paramecium in the water. While, the polyaniline film could not effectively function for neutralization of the water.

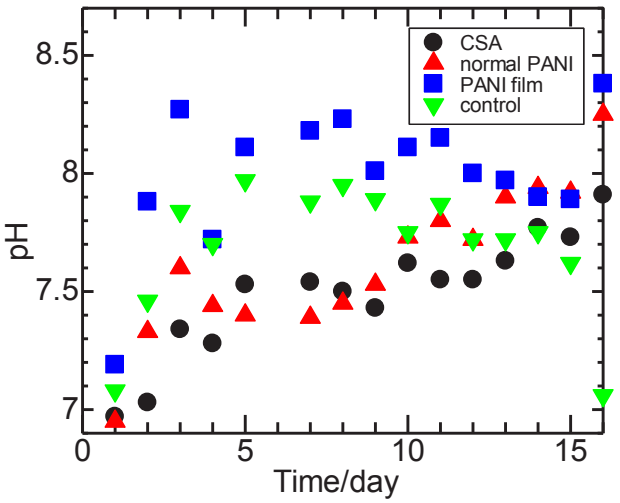


Figure 3. Change in pH value vs. time (day) of the water in the presence of paramecium, and polyaniline (powder form, normal PANI), camphor sulfonic acid (CSA), polyaniline film (PANI film), or control.

Fig. 4 shows oxidation-reduction potential (ORP) value of the cultivation water in the presence of paramecium as a function of time (days). Higher ORP value of the water was observed in the presence of CSA and normal polyaniline (powder form).

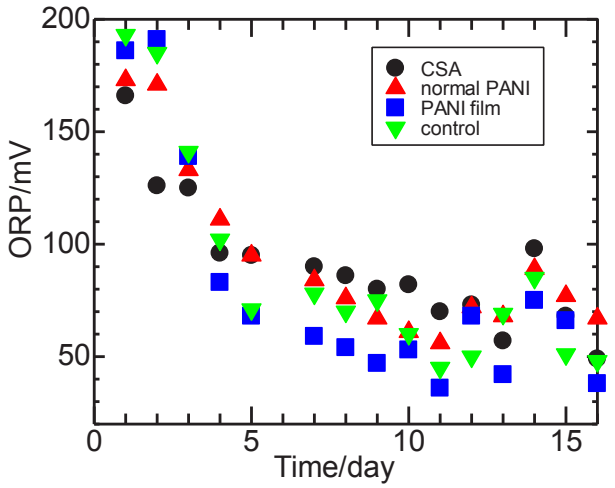


Figure 4. Change in oxidation-reduction potential (ORP) value vs. time (day) of the water in the presence of paramecium, and polyaniline (powder form, normal PANI), camphor sulfonic acid (CSA), polyaniline film (PANI film), or control.

4. DISCUSSION

Polyaniline emeraldine base functions as a neutralizer for the water in the presence of paramecium. The ammonium element discharged from paramecium becomes biological poison in the water environment. Polyaniline as a conducting polymer can absorb ammonia or other discharged materials from microbes in the water.

It may purify the water suitable for living organism in the lake and improve the water environment. This research is a new attempt for the water purification using conducting polymers.

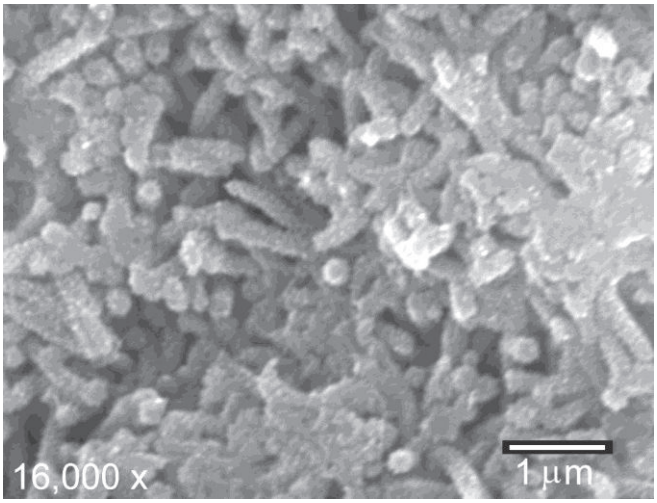


Figure 5. Scanning electron microscopy image of polyaniline prepared with camphor sulfonic acid (CSA).

5. FUTRUE ASPECT

Polyaniline forms several characteristic nano-structures. For example, polyaniline prepared with camphor sulfonic acid forms a nano-fiber structure（in this case small amount of a platinum complex [$Ph(CN)_2PtCl_2$] was added in the polymerization reaction. Ph = phenyl）[3], Fig. 5. Polymerization of aniline in the presence of polyvinylalcohol (PVA) can produce polyaniline microsphere [4]. Large surface area derived from the nano-structure can provide good contact with water to exhibit the water purification function. Materials with unique micro- or nano-structures have possibilities to show fine performance in environmental science. Conducting polymers are one of the candidates as organic functional material for it.

ACKNOWLEDGMENTS

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P7-24

養豚廃水の活性汚泥処理における低溶存酸素条件での窒素除去
−パイロットプラント運転結果−

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キーワード:浄水・排水処理技術, 排水規制

抄録

高濃度の窒素を含む養豚廃水の処理において, 簡易な窒素除去技術の開発が求められている。本試験では養豚農家に広く普及している連続曝気式活性汚泥処理において, 曝気槽の溶存酸素濃度を低く保つことで窒素除去率が改善する効果を確認するため, パイロットプラントの運転を行った。固液分離後の養豚廃水を用いて, 80L 規模の 2 台のプラントを用い, 異なる溶存酸素濃度(低溶存酸素区:平均 0.48 mg／L, 対照区:2.86 mg／L)で運転し比較した。

流入水の BOD 及び全窒素(TN)濃度は各平均 1,703 mg／L, 726 mg／L であった。処理水の BOD 濃度および除去率は低溶存酸素区と対照区で各平均 188 mg／L, 92 mg／L, 86%, 93%であり, 対照区の方が除去率は有意に高かった。処理水の TN 濃度, 除去率は各平均 226mg/L, 358 mg/L, 53%, 35%であり, 除去率は低溶存酸素区が有意に高かった。活性汚泥処理において, 曝気槽中の溶存酸素濃度を低濃度に制御することにより, 窒素除去能が改善することが示された。

1. はじめに

養豚廃水には高濃度の窒素が含まれており, 処理水を放流する際は水質汚濁防止法におけるアンモニア, アンモニウム化合物, 亜硝酸化合物及び硝酸化合物(硝酸性窒素等; NH_4^+-N × 0.4 + NO_2^--N + NO_3^--N)の排水基準を満たす必要がある。この排水基準について, 畜産農業では現在, 暫定基準である 600 mg/L が適用されているが, 一般排水基準は, 100 mg/L である。暫定基準は, 今後さらに厳しくなることが予想されるため, 一般排水基準にも対応できる簡易で低コストな窒素除去技術が求められている。

連続曝気式活性汚泥処理において, 曝気槽の溶存酸素濃度を低溶存酸素条件に制御することにより, 窒素を除去できることが, ラボスケールの装置および活性汚泥モデルを用いた解析により示されている[1)]。当該反応による窒素除去の再現性をスケールアップした条件において確認するため, パイロットプラントを異なる溶存酸素濃度で運転し比較を行った。

2. 方法

本県畜産センター養豚研究所に 80L 規模の連続曝気式活性汚泥処理パイロットプラントを２台設置し, 固液分離後の養豚廃水を水理学的滞留時間 2.7 日, BOD 容積負荷 0.5kg/m^3/day で処理した（図)。パイロットプラントの曝気槽の溶存酸素濃度は, 低溶存酸素条件のリアクタ（低溶存酸素区；①）を 0.05−0.2mg/L, 通常好気条件のリアクタ（対照区；②）を 2−2.5 mg/L とし, 曝気量制御システムで調整した。流入水, 曝気槽水, 処理水について, 毎週サンプリングを行い, pH, 溶存酸素, BOD, 無機態窒素（アンモニア, 亜硝酸, 硝酸), 全窒素等を測定した。水温は 20 度以上になるよう加温をし, 1 年 4 ヵ月間運転を行い, 運転条件の安定した 2.5 か月以降のデータを用いた。

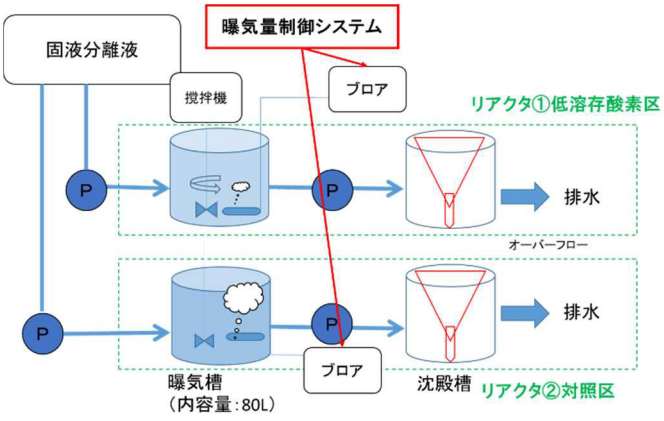

図　パイロットプラント概要図

3. 結果

サンプリング時の曝気槽の平均溶存酸素濃度は，流入水の負荷変動により設定値と異なる場合が生じたため，リアクタ①，②において，それぞれ，0.48±0.83，2.86±1.68 mg/L であった。pH は流入水において 8.1±0.2，リアクタ①，②の処理水中においてそれぞれ，7.8±0.7，7.1±0.9 であった。BOD 濃度は流入水において 1,703±2,322 mg/L であったものが，リアクタ①②の処理水においてそれぞれ，188±258, 92±73 mg/L となり，対照区が有意に低かった。

全窒素濃度は流入水において 726±423mg/L であったものが，リアクタ①②の処理水においてそれぞれ，226±107, 358±104 mg/L まで低下した。全窒素除去率はそれぞれ 52.9±23.9（%），34.9±24.4（%）であり，リアクタ①の方が有意に高かった。無機態窒素濃度は流入水において 544±234mg/L であったものが，リアクタ①，②の処理水においてそれぞれ，255±132, 338±107 mg/L まで低下し，無機態窒素除去率はそれぞれ 46.7±27.5%，26.5±26.5%であった。処理水窒素組成は，リアクタ①については，アンモニア平均 76%，亜硝酸平均 19%，硝酸平均 4%であったが，リアクタ②についてはアンモニア平均 52%，亜硝酸平均 7%，硝酸平均 41%であり，リアクタ①の処理水はアンモニアと亜硝酸の混合体で排出された。硝酸性窒素等濃度はリアクタ①，②の処理水においてそれぞれ，138±70, 231±67 mg/L であり，リアクタ①においては，一般排水基準の 100 mg/L まであとわずかの結果となった。

流入水の BOD/N 比が 2.1 であり，窒素除去においては不利な条件であったが，曝気槽の溶存酸素濃度を低く保つことにより，窒素除去能が改善されることが示された。また，リアクタ①の処理水は，その組成がアンモニアと亜硝酸の混合体であったことから，活性汚泥処理の後段において，窒素除去の高度処理を行う場合，アンモニアと亜硝酸のカップリングにより窒素ガスを生成する，アナモックス反応の利用に適していると考えられた。

4. 結論

80L 規模の連続曝気式活性汚泥処理パイロットプラントにおいても，曝気槽を低溶存酸素濃度にすることで窒素除去率を改善できることが確認でき，ラボスケール装置および活性汚泥モデルを用いた解析結果の傾向を再現することができた。

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謝辞
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P7-25

滋賀県の下水道が琵琶湖の水質保全に果たしてきた役割と今後の課題について

松本　寛[1], 一色　一平[1]

[1]滋賀県琵琶湖環境部下水道課

キーワード:水質汚濁、富栄養化

抄録

滋賀県では琵琶湖の富栄養化防止に貢献するため、供用開始当初からいずれの処理場とも高度処理を導入し、通常の有機物除去を中心とした処理に加えて窒素、りんの除去を行っている。

湖南中部処理区供用開始から 36 年が経過した現在の滋賀県の下水道を紹介する。

1. はじめに

日本最大の湖である琵琶湖。古代より滋賀県は琵琶湖の与える恵みにより栄えてきた。しかし1960年代後半から高度成長に伴い、工場や生活排水の増加による琵琶湖の水質汚濁が問題となり始めた。そこで滋賀県では琵琶湖をはじめとする公共用水域の水質を保全し、県民の快適な居住環境を実現するための有効な手段として下水道を位置づけ、4処理区からなる琵琶湖流域下水道および流域関連公共下水道と、大津市では単独公共下水道を主体とした下水道整備を進めてきた。

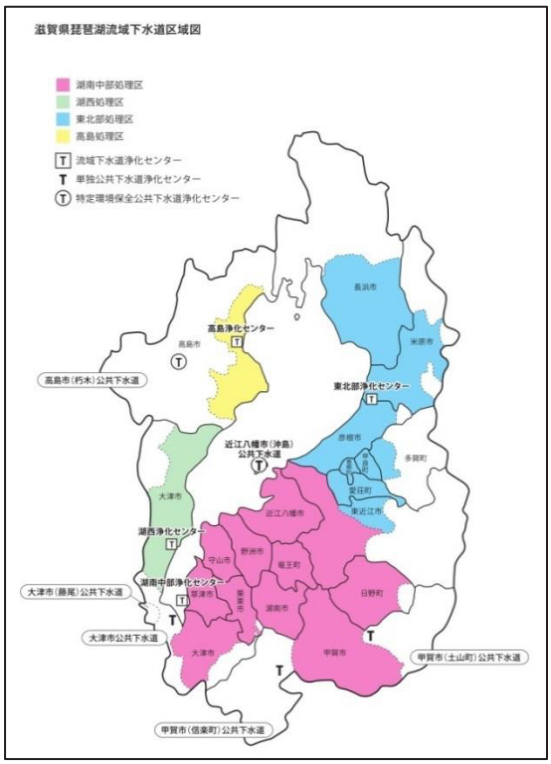

図 1 琵琶湖流域下水道区域図[1]

2. 経緯

琵琶湖流域下水道が着手し管渠工事や浄化センターの工事が行われていた最中の 1970 年代後半、琵琶湖に淡水赤潮が大発生した。その原因の一つが合成洗剤に含まれていたリンであることが判明すると、合成洗剤の使用をやめて粉石けんを使おうという県民運動、いわゆる「石けん運動」が巻き起こった。

県民からの強い要望を受け 1979 年に滋賀県琵琶湖の富栄養化の防止に関する条例（富栄養化防止条例）が制定され、窒素リンの規制が始まると、ただちに琵琶湖流域下水道に高度処理を導入することが決定した。

これらの琵琶湖の水質保全に関する県民意識の高まりの中、琵琶湖総合開発特別措置法のもとにおいて急ピッチに県および市町による下水道の整備が行われた結果、昭和57年度に5%程度であった下水道普及率は、平成 28 年度末には 89.3%と全国第 7 位と飛躍的に上昇した。ちなみに高度処理の人口普及率は 88.2%と全国第1位となっている。

下水道の普及とともに琵琶湖の水質は改善傾向が見られる。ただし北湖では貯水量が南湖の 100 倍以上と膨大であるため、顕著な変化は見られない。また近年はプランクトンの大発生等により全リンの上昇が見られている。

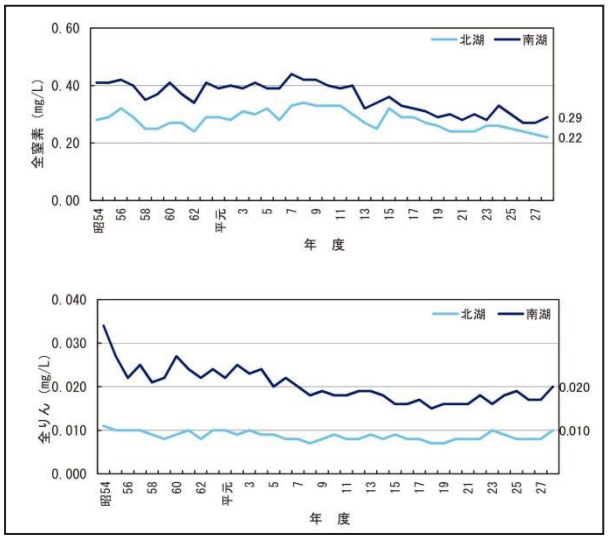

図 2 琵琶湖水質の経年変化（T-N、T-P）[2]

3. 現在

水処理においては4処理区とも供用開始当初より、窒素除去を目的とした循環式硝化脱窒法による高度処理を実施してきた。近年では増設・改築の際にはステップ流入式多段硝化脱窒法を採用し、より高い窒素除去率を実現している。なお、リン除去については当初から現在に至るまで PAC 添加による同時凝集法により実施している。

汚泥の最終処理においては、従来より高島以外の3浄化センターで焼却溶融炉によるスラグ化を実施してきたが、溶融炉は高温で処理を行うため耐火物の交換など点検整備に多大な経費を要し、また燃料費等ユーティリティも嵩むため、東北部浄化センター以外では溶融を停止した。

このうち湖西浄化センターでは汚泥の有効利用を推進すべく、平成 28 年1月より DBO による汚泥燃料化事業を実施している。これは湖西浄化センターおよび大津市水再生センターで発生した汚泥を炭化し、燃料化物として石炭代替燃料として販売まで行う事業であり、低炭素化に寄与するものである。

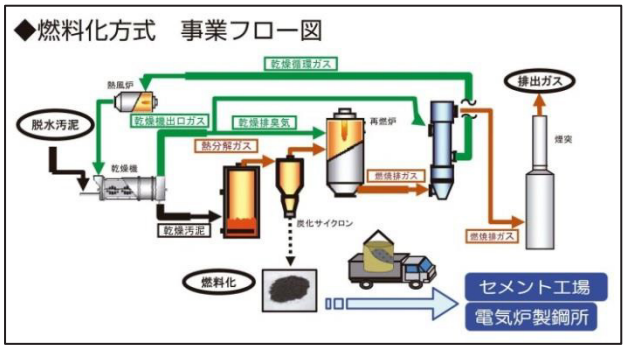

図 3 湖西浄化センター燃料化施設フロー図[2]

4. 今後の課題

下水道の整備により琵琶湖への生活系・産業系の汚濁負荷は年々低減されている。今後は下水道以外の面源負荷の対策が必要となる。

また、分流式下水道にも関わらず大雨時に処理能力を超えて流入する不明水への対策が喫緊の課題となっている。

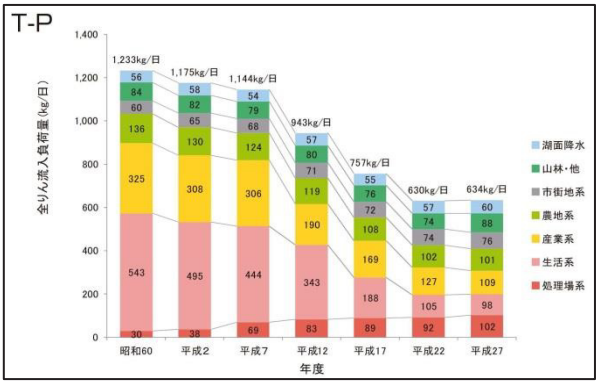

図 4 琵琶湖に流入する発生源別全リンの経年変化[2]

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P7-26

Verification Experiment for the Improvement of an Anoxic Brackish Lake

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Key words: water quality improvement, anoxic, water environmental conservation

ABSTRACT

Lake Abashiri is a brackish lake in which there is a boundary between the underlying salt water layer and the overlying fresh water layer. Vertical water circulation in the bottom salt water layer tends to be suppressed, the anoxic condition of the bottom layer has become persistent, and hydrogen sulfide and nutrient salts have accumulated in high concentrations. When strong winds disturb the salt water layer, the substances in that layer are carried into the fresh water layer and cause the condition of the fresh water layer to deteriorate by causing water quality problems such as the abnormal propagation of algae and the occurrence of blue tides. Fishery is thriving at Lake Abashiri. Local fishermen have been suffering losses from the frequent water quality problems. To improve the water's anoxic condition and detoxify the toxicants, an oxygen supply experiment was done using an experimental plant constructed onsite with a Water Environment Preservation (WEP) system. The experiment verified that it is possible to increase the dissolved oxygen concentration to 40 mg/L and to oxygenate the hydrogen sulfide so that it becomes sulfur by supplying dissolved oxygen to the salt water. It was further verified that the orthophosphoric acid in the water decreased when water whose hydrogen sulfide had been completely oxidized was placed in contact with the bottom sediment. It was found that supplying oxygen does not affect the ammonium nitrogen.

1. INTRODUCTION

When the bottom water layer of a stagnant water body such as a dam reservoir, lake, pond, or sea area becomes anoxic, many problems arise with respect to fishing industry and water quality. Researchers [1] have not gained sufficient knowledge on how oxygen supply changes substances in the water and the range of dissolved oxygen (DO) recovery from oxygen supply in a brackish lake. For brackish lakes, which have a boundary between the salt water layer and the fresh water layer, a different approach is required, because it is estimated that conventional oxygen supply promotes the vertical mixing of water, the salinization of the freshwater layer, and eutrophication. Aiming at improving the anoxic condition of the bottom salt water layer, this study used an underwater gas-liquid dissolving apparatus (a WEP system) to verify the chemical changes that occurred during oxygen supply. We constructed an experimental plant onsite and used it to conduct a demonstration experiment for oxygen supply. The results are summarized in this paper.

2. SUBJECT WATER AREA

Lake Abashiri, the subject of this study, is in northeastern Hokkaido (Fig. 1). This lagoon lake with an area of 32.3 km^2 has a maximum depth of 16.1 m, an average depth of 6.1 m, and a pondage of about 230,000,000 m^3. The major rivers that flow in are the Abashiri River and the Memanbetsu River. The average water level is 0.39 m above sea level. The lowest reaches of the Abashiri River connect the downstream-most area of the lake to the Sea of Okhotsk. In Lake Abashiri, a

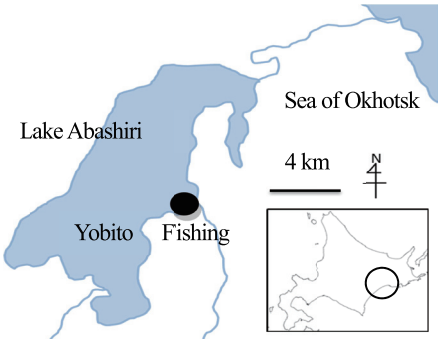

Fig. 1 Field of Observation

two-layer structure—a fresh water layer overlying an anoxic salt water layer—continuously exists, with a boundary at about EL.-6 m. Lake Abashiri requires the improvement of the anoxic condition of the salt water layer without involving the upper fresh water layer. Yajima and Masuki[2] demonstrated that a water mass with a high concentration of oxygen from the WEP system moves horizontally. This horizontal movement from the WEP system is thought to be advantageous in improving the oxygen condition of only the salt water layer in a brackish lake.

3. ONSITE EXPERIMENT

(1) Oxygen supply experiment

Fig. 2 shows the locations of the onsite experiment, the water sampling locations, the location of the A-B cross-section, and the vertical distribution of water quality. Water sampling was done at EL.-8m of Point A(river bottom EL. of -9m). We circulated 90 L of experiment water in an open water tank to dissolve oxygen gas (99.5 %) under 1 atm. The changes in DO, turbidity, and ORP in the tank were monitored by a water quality meter. Hydrogen sulfide was quantified in zinc acetate fixation by using the method of Sugawara et al.[3] The water quality items analyzed were total organic carbon (TOC), total phosphorus (TP), orthophosphate (PO_4-P), total nitrogen (TN), ammonium nitrogen (NH_4-N), nitrite nitrogen (NO_2-N), and nitrate nitrogen (NO_3-N).

(2) Experiment results

Fig. 3 shows the results of the oxygen supply experiment on the experiment water by using the WEP system. By 10 minutes after the start of oxygen supply, DO increased to 40 mg/L, then decreased once and became constant at 41 mg/L in 50 minutes. The temperature of the experiment water was 17 degrees Celsius. It was verified that the WEP system can saturate the experiment water in about 50 minutes, because the DO becomes about 42.9 mg/L at the maximum when gas intake is done at a partial pressure of oxygen of about 100 %.

The turbidity monotonically increased for 50 minutes and became constant after that. The experiment water, which was initially dark and transparent, started to change color immediately after the start of oxygen supply and became completely turbid whitish in 120 minutes. Particulate matter was found in the turbid whitish experiment water. The ORP, which was nearly constant at -290 mV from 5 minutes to 50 minutes after the start of oxygen supply, showed an increasing trend after 50 minutes, and became -10 mV at 140 minutes.

Table 1 shows the results of quality analysis for the raw

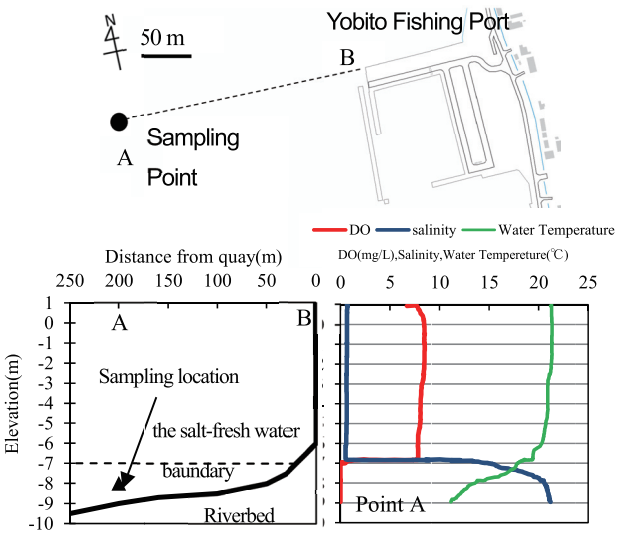

Fig. 2 The experiment location and the surveyed water quality (bottom left: cross-section of A-B; bottom right: vertical distribution of water quality at Point A)

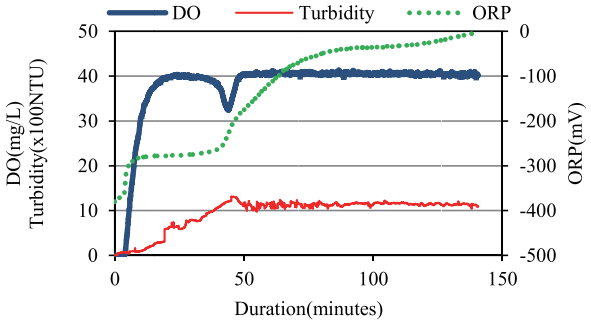

Fig. 3 Results of circulating oxygen supply in the tank

Table 1 Water quality analysis results

(mg/L)	Raw water (fresh water)	Raw water (salt water)	After oxygen supply (salt water)	After 3-day contact with bottom sediment (salt water)
TOC	9.7	10	10	8.8
TP	0.12	4.3	4.3	1.3
PO_4-P	0.086	4	3.8	1.1
TN	1.3	22	22	25
NH_4-N	0.1	21	20	23
NO_2-N	0.06	ND	ND	ND
NO_3-N	0.91	ND	ND	ND

water (fresh water and salt water) and the experiment water at 120 minutes after the start of oxygen supply. "ND" in the table indicates non-detection. First, the comparison of the qualities of fresh water and salt water for the current Lake Abashiri shows that the TOCs are similar between the two; however, the concentrations of phosphorus and nitrogen differ greatly. In light of the above, it is understood that the organic matter distributes uniformly irrespective of salt concentration and that the nutrient salts accumulate in high concentration in the salt water layer. The values after oxygen supply were examined, and PO_4-P and NH_4-N were found to have slightly decreased. The other items showed no changes. Next, the sampled bottom

mud was placed in an acrylic tube and the experiment water after oxygen supply experiment was gently filled over the mud such as to avoid disturbing the mud. The tube was left in a dark place at a temperature of 5 degrees Celsius for 3 days. The analysis of the experiment water after 3 days showed that the TOC decreased, the TP and PO_4-P markedly decreased, and TN and the NH_4-N increased. The above analysis verifies that, in the case of the experiment water only, the organic matter, phosphorus and nitrogen showed no notable changes even after oxygen supply but that the other matter reacted with the supplied oxygen. When the oxygen-saturated experiment water was placed in contact with the bottom mud, the phosphorus in the water rapidly decreased. It is estimated that the PO_4-P was absorbed through the oxidation of the surface of the bottom mud.

The time series changes of hydrogen sulfide is shown in Fig. 4. The concentration of hydrogen sulfide in the initial experiment water was 130 mg /L-S, which linearly decreased after the start of oxygen supply to become 0 mg/L at 50 minutes. It can be estimated from Fig. 4 that the supplied oxygen was consumed in the oxidation of hydrogen sulfide during the first 50 minutes, and that the next stage of reaction started after the disappearance of the hydrogen sulfide.

(3) Changes during oxygen supply

The above experiments clarified that the initial reaction that occurred during the first several minutes to several days of oxygen supply was the oxidation of hydrogen sulfide in which the precipitation of solid sulfur prevailed. It was found that, during this time, hydrogen sulfide completely oxidized and that organic matter and nutrient salts showed no clear changes. Nitrification was found to have no influence, from which it is suggested that the oxidation of NH_4-N is not a chemical process, but a reaction of micro-organism. The reaction that occurs in anoxic salt water when oxygen is supplied is ultimately estimated to be described by Equation (1), where the intermediate products are ignored.

$$2H_2S + O_2 \leftrightarrow 2S\downarrow + 2H_2O \qquad (1)$$

From Equation (1), it is understood that making the right-hand side of the equation heavy is advantageous with respect to the detoxification of hydrogen sulfide. It is thought that oxygen supply and the removal of sulfur are effective in improving the water quality.

5. Conclusion

At Lake Abashiri, where the fishing industry is thriving, serious losses have occurred from hazardous substances such as hydrogen sulfide and ammonia in the anoxic water mass. This study suggested that by using the WEP system, which is a high-concentration oxygen supply apparatus, it is possible to selectively improve the anoxic condition of the water and to detoxify the hydrogen sulfide.

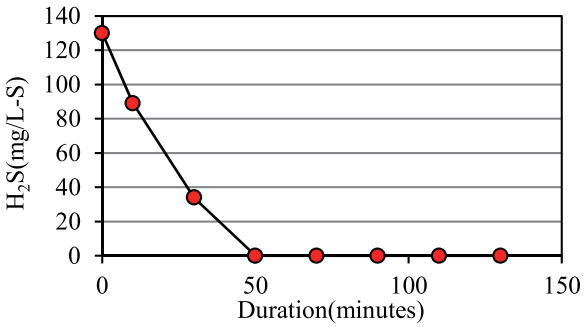

Fig. 5 Changes in the concentration of hydrogen sulfide during oxygen supply

An oxygen supply experiment on anoxic salt water in Lake Abashiri was conducted using a WEP system. The hydrogen sulfide in the water mass was oxidized and precipitated as solid sulfur. During the initial period of oxygen supply, the hydrogen sulfide reacted preferentially, with phosphorus, nitrogen, and organic carbon showing no notable changes.

It was found that, as long as the dissolved oxygen is saturated, the precipitated sulfur can be removed by settling. In contrast, it was observed that when the water became anoxic after sulfur precipitation, the sulfur re-dissolved as hydrogen sulfide.

When the water mass in which dissolved oxygen was saturated was placed in contact with the bottom mud, the concentration of PO_4-P in the water mass decreased, but the ammonium nitrogen showed no changes. In light of the results of the onsite oxygen supply experiment, it is expected that the water quality would be improved by the oxidation of the hydrogen sulfide in the water mass, the oxidation of the bottom surface mud, and the absorption of phosphorus by the bottom surface mud.

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P7-27

投げ込み式放電リアクタによる難分解性物質の分解と細菌数の変動

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キーワード:難分解性物質, 排水処理, 個別処理, 促進酸化法, 高電圧パルス放電

抄録

環境対策が求められる排水中の難分解性有害物質への対応として, 高電圧放電を利用した促進酸化法と, これによる細菌数の変動について検討している. 難分解性のメチレンブルー色素および河川水を含む 3.2 L の試水を対象として, 回転電極を用いた平均電力 90 W, 30 分間までのパルス沿面放電処理を行った. 細菌数が大幅に減少する前に大部分の色素が分解され, 生分解しやすい物質にまで酸化分解された.

1. はじめに

人口減少時代の下水処理インフラでは, 個別処理である浄化槽の活用が重要となる. 浄化槽はコンパクト化と高度化が進められており, さらに放流水中の難分解性物質への対応が課題になる. 難分解性物質の処理では, 水中の高電圧放電を利用してオゾン・OH ラジカルといった化学活性種を発生させ, これを促進酸化法に適用することが考えられる. ここで, 水中に微生物が存在すれば, 高電圧から直接的・間接的な影響を受ける. 高電圧の効果として, 殺菌や制菌といった, いわば微生物にとっての負の作用が知られている[1].

本研究では促進酸化法[2][3]と生物処理の組み合わせをコンパクトな一つの処理槽で行うことを目標として, 放電による微生物への影響を調べている. 微生物としては環境中の細菌群を対象としている. 作用機序は次の二段階を想定している. すなわち, ① 水と空気の境界で沿面放電させることで複数の化学活性種および紫外線が同時に発生すると, 水中の難分解性有機物の一部が生分解可能な物質へと酸化分解される. ② これを好気性の微生物が酸素を呼吸しながら栄養源として取り込んで微生物が増殖するというものである. 本研究ではコンパクトな投げ込み式の回転電極を用い実験した.

2. 実験方法

投げ込み式放電リアクタ　回転電極による投げ込み式の小型放電リアクタを製作した(図 1). リアクタの材質はテフロン(絶縁部)およびフッ素ゴム(O リング)であり, 接地電極と高電圧電極はステンレス製である. 駆動パイプは表面が絶縁されたステンレス製であり, 放電のための電力供給路と空気の供給路を兼用している. モータにより水中のリアクタを約 10,000 rpm で高速回転させると駆動パイプからエアギャップに空気が引き込まれるので, これに接した高電圧電極で気液境界の沿面放電を起こした. また, 水の旋回流の成長を防ぐと共に, 水中の夾雑物の巻き込みを防ぐために, リアクタの回転方向は約 1 秒毎に反転させた. 高電圧は SiC トランジスタ 16 個で発生させた繰り返し周波数 1 kHz, 半値幅 230 ns, 10 kV または 15 kV の負極性の高電圧パルス(瞬時電力約 600 kW, 平均電力 90 W)である.

難分解性物質および微生物を含む試水として, 久慈川榊橋地点(茨城県日立市)で 72 時間以内に採取した

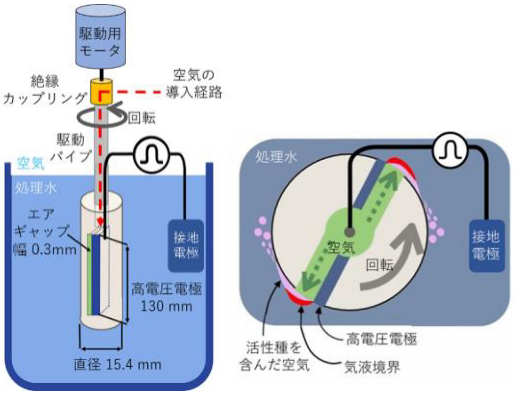

図 1 回転電極による投げ込み式リアクタ

高電圧電極はリアクタ外周上の2カ所で処理水と接し, その部分に設けたエアギャップから空気が放出され気液境界が形成される.

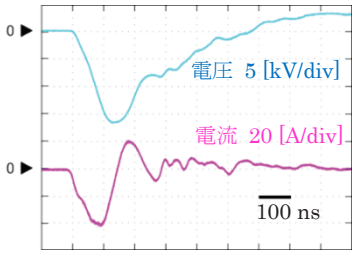

図2 リアクタへ投入したパルス電圧および電流波形

ピーク電圧 15 kV, ピーク電流 40 A, 瞬時電力 600 kW, 半値幅 230 ns, 1 パルス当たりのエネルギー 90 mJ : 濃度 10 ppm, 導電率 2.2 mS/m, pH 6.9 のメチレンブルー溶液に対する放電処理時の波形

河川水 460 mL に，精製水（活性炭とイオン交換樹脂による，非滅菌）を加えて 3.2 L とした上で，難分解性のメチレンブルー色素を 10 ppm となるように加えたものを用いた．この時点で試水は濃い青色を呈する．

放電によるメチレンブルー酸化分解の確認 放電処理によりメチレンブルー色素は徐々に酸化分解されるため，試水は次第に脱色される．放電処理の開始から 5 分，10 分，20 分，30 分が経過した時点での試水のサンプルを，あらかじめ 1.5 mL マイクロチューブにて調製しておいた濃度 0.5～10 ppm の水溶液と比色することで試水のメチレンブルー濃度を測定した．

酸化分解による生分解性向上の確認 酸化分解により試水の生分解性が向上し，微生物が増加すると考えられる．これを確認するため BOD（Biochemical oxygen demand）測定を行った．放電処理を開始してから 5 分間経過した時点の試水のサンプルを採り，未反応の酸化性物質の反応を終了させ，かつ溶存酸素量を飽和させるためにマグネチックスターラーで 15 分間撹拌した．これをフラン瓶 (102 mL) の半量とり，残りの半量を，微生物の生存に必須の無機塩類と緩衝液（JIS K 0102 －工場排水試験方法に定める A～D 液）を含む希釈水でフラン瓶を満たしたのち，20℃の暗所で 5 日間の酸素消費量を測定した．希釈水の BOD は 1.0 mg/L であった．放電処理では，高電圧パルス（ピーク電圧 15 kV または 10 kV）を加えた場合と，対照として無電圧の場合についても実験した．

放電中の生菌数への影響の確認 放電処理前と処理中 10 分，20 分，30 分時点での試水に含まれる従属栄養細菌の生菌数（CFU/mL）を計数するために，オートクレーブ処理された R2A 寒天培地（低栄養培地）による平板表面塗抹法を用いた．サンプルは，オートクレーブにより滅菌された精製水により 10 倍段階希釈を行い，6 分画した寒天培地に各希釈倍率とも 20 μL ずつマイクロピペットで滴下し，20℃で 5 日間培養後にコロニーを計数した．さらに，BOD 測定を行ったフラン瓶中の 5 日後の生菌数を調べた．

3. 実験結果と考察

パルス電圧 10 kV と 15 kV，放電処理時間 30 分の実験で得られたメチレンブルー濃度変化を図 3 に示す．

放電処理 10 分間までのメチレンブルーの分解量と，それに要した投入電力量からメチレンブルーの分解効率 (g/kWh) を計算した（表 1）．リアクタ部のみへの投入電力量についても付記した．

パルス電圧 10 kV では 20 分，15 kV では 10 分で試水中のメチレンブルーの 90 % を分解できることが分かった．また，パルス電圧が低い方が投入電力当たりのメチレンブルー分解効率が高くなっている．これは，パルス発生に用いている SiC トランジスタが，15 kV 出力時にはドレイン定格電流の 80 % を超えて運転しているため出力抵抗が増加したことによると考えられる．

他グループによるメチレンブルー分解実験では，水上放電による分解効率が 0.073 ~ 1.8 g/kWh [4]，水中放電による処理では 5 g/kWh [5] と報告されており，本研究での分解効率はこれらと同程度であった．気液境界での液相の撹拌が活性種の溶け込みと分解処理に与える影響については報告例[6]がある。

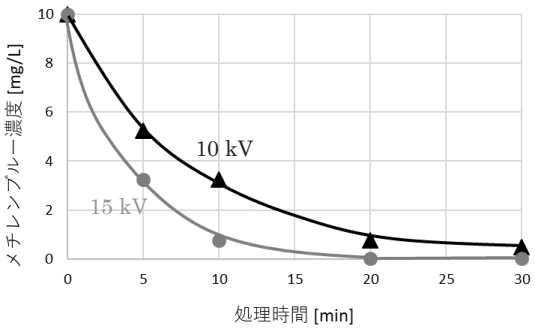

図 3 放電によるメチレンブルー濃度の変化

植種の採水日：処理前のメチレンブルー濃度，導電率，pH

2018/4/5 : 10 ppm, 2.2 mS/m, pH 6.9

表1 投入電力量当たりのメチレンブルー分解効率

電圧	10 kV		15 kV	
分解量［mg］	22		30	
投入電力量［Wh］	全体	リアクタ部	全体	リアクタ部
	5.5	4.7	20	15
分解効率［g/kWh］	4.0	4.7	1.5	2.0

2017/12/22 から 2018/4/6 までに 4 回行った放電処理水の BOD 測定結果を図 4 に示す．図では河川水の採水日（日によって BOD が異なる）をパラメータとしてパルス電圧の違いによる放電処理後の BOD を比較している．このうち，2017/12/22 のメチレンブルー濃度 5 ppm のデータについては曝気した水道水を原水とし，BOD 測定の初日に微生物の植種を行った．

図 4 より，全ての実験でパルス電圧を加えたことによる BOD 値の増加がみられる．メチレンブルー濃度 10 ppm の実験について，処理直後と処理 5 日後のフラン瓶中の従属栄養細菌数の比較を表 2 に示す．

この表から，5 日間で生菌数が 2 桁以上増加している

ことが分かる. このことからBOD値の測定に用いた5日間の酸素消費は微生物によるものであると確認した. 以上のことから, 放電によりメチレンブルーが微生物によって BOD として測定可能な生分解されやすい物質に酸化分解され, 試験環境中の細菌が増殖したものと考えられる. 細菌の大部分は河川水に由来するが, 未滅菌の精製水(活性炭およびイオン交換樹脂による処理)およびBOD希釈水に添加するA液, B液由来[7]の細菌も含む. 河川水以外は低栄養状態であるため, 河川水以外に由来する細菌については芽胞を作る菌種が主になっていることが疑われた.

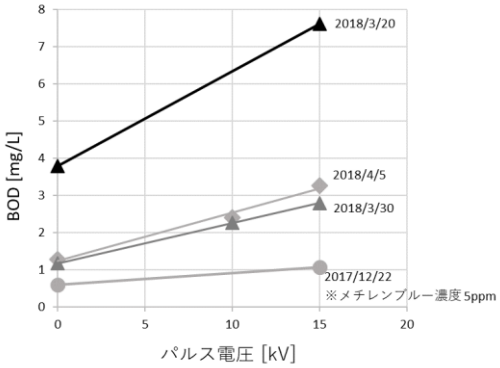

図4 各パルス電圧の BOD

採水日:処理前のメチレンブルー濃度, 導電率, pH
2017/12/22 : 5 ppm, 13 mS/m, pH 8.0
2018/3/20 : 10 ppm, 2.1 mS/m, pH 7.3
2018/3/30 : 10 ppm, 2.9 mS/m, pH 7.5
2018/4/5 : 10 ppm, 2.2 mS/m, pH 6.9

表 2 フラン瓶中の生菌数の増加

10kV については上から 2018/4/5 , 2018/3/30 の実験, 15kV については上から 2018/4/5 , 2018/3/30 , 2018/4/5 の実験である.

電圧 [kV]	処理直後の生菌数 [CFU/mL]	処理 5 日後の生菌数 [CFU/mL]
10	5.0×10^3	3.4×10^5
	7.5×10^3	6.0×10^5
15	1.0×10^3	1.2×10^6
	8.2×10^3	1.1×10^6
	5.0×10^2	3.0×10^5

30 分の放電処理中に採取したサンプルの従属栄養細菌数(R2A 培地による 20℃, 5 日間培養)を図 5 に示す. パルス電圧 10 kV 30 分の処理では生菌数に変化は見られず, パルス電圧 15 kV では 30 分経過時点で生菌数が減少した. どちらの電圧でも, この時点までにメチレンブルーの脱色が進んでいることから, この処理では高電圧放電による殺菌効果が顕著となるまでの処理時間に酸化分解を進めることが可能であった.

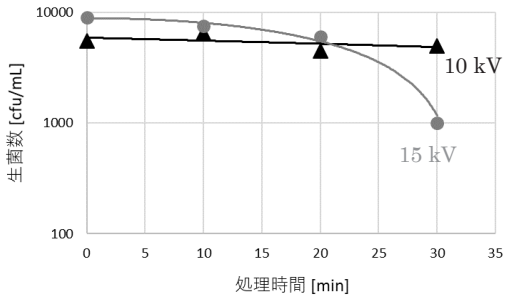

図 5 放電による生菌数の変化

植種の採水日:処理前のメチレンブルー濃度, 導電率, pH
2018/4/5 : 10 ppm, 2.2 mS/m, pH 6.9

4. まとめ

投げ込み式の放電リアクタを用いて水中の難分解性有機物を促進酸化処理する際の細菌数の変化を調べている. 実験では生菌数が大幅に減少する前にメチレンブルーは生分解されやすい物質にまで酸化分解され, BOD 測定中に生菌数が増加することを確認した.

今後は処理水中の細菌が放電により死滅しないリアクタの運転パターンにより, コンパクトかつ電力消費の少ない排水処理法を構成したい.

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P8-1

水環境問題に取り組む市民運動--水郷水都全国会議の 34 年--

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キーワード: 市民運動, 水郷水都全国会議, 水環境問題

抄録

第 1 回世界湖沼会議は, 富栄養化が進み琵琶湖総合開発に批判が向けられるなど, 琵琶湖の環境や水資源開発への社会的関心を背景として, 行政・研究者・市民の協働により実施された。会議後, 多様な主体が関わり合う活動を継続しようと作られたネットワークが水郷水都全国会議である。湖沼会議の翌年, 宍道湖で最初の全国会議が開かれ, その後 34 年にわたり活動が続いている。論点は, 当初の公害や公共事業による環境破壊を糾弾するものから, 生物多様性の保全, 循環型社会の構築, 環境に配慮した地域づくり, 環境教育などに広がった。一方, 市民運動に対する社会の見方も変わり, 日本では 90 年代中頃以降, 市民団体を一律に反体制的な集団と見る傾向が薄れ, ボランティアや市民参加が高評価され, 市民団体の社会的地位は向上している。長年の活動を経て, 水郷水都全国会議はさまざまな課題を抱えるようになり, 市民団体の緩やかな連合体の存在意義が問われている。

1. はじめに

第 1 回世界湖沼環境会議は 1984 年に滋賀県大津市で開催された。そこで採択された琵琶湖宣言には, 世界の湖沼が直面する自然的・文化的環境の危機に際し, それを健全な状態に保つために, 全世界の住民と研究者と行政関係者がそれぞれ具体的な行動をとることがうたわれた。そして, 住民には, 環境に対する価値観を高めること, より多くの人が参加できるように情報の伝達に努めること, 個人や地域社会による行動を促すために自発的な組織づくりを進めることが求められた[1]。この会議に参加した各地の住民団体や行政関係者, 研究者らが, 「このまま解散するのはもったいない」と話し合って, 日本国内の水環境に取り組む住民運動の連絡組織を作ることになった [2]。そこで生まれたのが水郷水都全国会議で, 湖沼会議の翌年, 1985 年に宍道湖・中海で最初の全国会議が開催された。

水郷水都全国会議 20 年を記念したシンポジウムにおいて, 世界湖沼環境会議の開催や水郷水都全国会議の立ち上げに関わった木原啓吉は, 20 年の活動を振り返り, 各地に現れていた住民運動の横の連絡協力組織を作ったことに歴史的意義があったと述べ, 親水権の思想, 霞ケ浦アオコ河童の提言, 柳川掘割物語, 樹を植えて魚を増やす, 森は海の恋人, 雨水活用の水循環, アメニティとセキュリティなど, いろいろな言葉や思想を取り上げ, 世に広めてきたと強調している [2]。また, 水郷水都全国会議を支えた地域の活動は, 中海干拓事業の中止, 吉野川第十堰の建設中止, 柳川の掘割再生などの実績を上げており, 全国会議もそれらを支援してきた。

水郷水都全国会議は設立から 34 年目を迎え, そのあり方が見直されるべき時期を迎えている。本報告では, 水郷水都全国会議のこれまでを振り返るとともに, 現状を把握し, 直面している問題・課題を明らかにする。その上で設立当時とは大きく社会経済状況が変わってきた中で, 当時「開催地の運動を学び激励する柔らかな集まり」[2]として作られた全国連絡組織の現代的な意義と課題を考察する。

2. 方法

本報告に関わる情報は, まず報告者がこれまでに参加してきた水郷水都全国会議や, 研究対象にしてきた霞ヶ浦や宍道湖・中海の市民活動に関わる中で得てきた知見による。それらは, 聞き取り調査や, 活動団体がまとめた記録, 活動への参与観察等により得てきた。また, それらとは別に, あらためて全国会議の立ち上げ期からのメンバーへの聞き取り(2016 年 9 月 27 日松江, 2017 年 5 月 21 日土浦)を行ったほか, 全国会議の毎回の資料集・報告書から情報を抜き出し, 考察の材料とした。この部分では, 広島大学総合科学研究科の留学生であった程誠がまとめた修士論文を参照した。

3. 主な論点(開催地とテーマ)

水郷水都全国会議は, それ自体が環境を守る運動を率先して行う団体ではなく, 「開催地の運動を学び激励する柔らかな集まり」[2]として組織されている。あくまで実際の活動を行っているのは各開催地にある市民団体である。そのため, 会議の開催地には, 全国から人をよぶだけの事情があることが多く, 開催場所とそのテーマをみると, この 30 年ほどの間にどこでどのような問題が起き

たのかをたどることができる。

第 1 回全国会議は，中海干拓事業で揺れていた松江市で開催された。そのテーマは「水と暮らしー人と湖の共存を求めて」であった。会議の 3 年後に湖の淡水化は無期延期となり，さらにその後，干拓事業は中止になった。もっとも，干拓事業の中止は，両湖沿岸の市民団体が継続的に行ってきた運動が結実したものであり，各地の団体と連携したことの効果は定かでない。ただし，反対運動の当事者（保母武彦）は，開催の成果として，それが淡水化事業凍結の一要因となったこと，全国との連携がローカルな課題であった淡水化事業の全国化に資したこと，地元の運動が各地の実践からの学びで強化されたことをあげている[3]。

次いで，深刻な富栄養化に直面していた霞ヶ浦に面する土浦市で「水文化の再生をめざしてーアオコ河童からの提言」をテーマとする第 2 回全国会議が開かれた。霞ヶ浦に限らず，毎回の会議では開催地が抱える問題に焦点を当て，全国的な観点から見解が表明される。それに加えて，会議に参加する各地の問題についても，情報や問題意識の共有を図り，全国団体としての訴えがなされる。第 2 回会議では，湖の水質悪化に注目しつつ，その背後にある水資源開発や沿岸開発などの公共事業に焦点が当てられた。

以後は，「水と人間の共生ー富士の山椒魚は考える」（富士市），「水環境と地域の再生ー四万十川・人と自然を考える」（中村市），「水循環の回復と地域の活性化ー柳川堀割から水を考える」（柳川市），「水と森林」（小山市），「水と共に生きる都市」（高槻市），「水ー流れが交わり，文化が生まれる」（新潟市），「いま，河口のあり方を問う」（桑名市），「序章・自由水権運動」（八王子市），「水環境のワイズユース」（釧路市），「都市河川新時代」（横浜市），「川と日本」（徳島市），「水と人との共生」（米子市），「森は海の恋人」（気仙沼市），「水はめぐるー天，地，海，生命」（宮古島），「創ろう活かそう！私たちの川とまち」（墨田区），「流れる水は生きているー21 世紀の公共事業のあり方を問う」（高野町），「川は川らしく，湖は湖らしくー市民権力と役割」（大町市），「おいしい水を守るには」（鶴岡市），「未来へ残そう，美しい水環境」（浜松市），「公共事業“新”時代」（久留米市），「水とともに生きる都市ー15 年目の検証」（大阪市），「あらためて，人と水の共存を求めて」（松江市），「水郷水都運動の新しい段階を作ろう」（東京都），「水と人と公共事業」（桑名市），「水辺と人の関係づくり」（栗東市），「諫早湾干拓潮受堤防ー開門をどのように進めるのか」（諫早市），「雪と湧水の“縄文の里”で水環境を考える」（津南町），「水文化の再生をめざしてーカッパは 3.11 を乗り越えられるか」（土浦市），「みんながかかわる里山・里海」（東広島市），「海は誰のもの」（名護市），「“水”が生きるまちをめざして」（大野市），「九州北部豪雨に学ぶ減災と復興」（久留米市）と続けられてきた[4]。

初めの頃は，公共事業による環境破壊を訴え，人と自然の関わり方を見直そうという意識が強く，それを単に公共事業批判にとどめず，親水権や住民自治といった権利の問題や，水文化の再構築のような文化の問題としてとらえた。2000 年頃から，政策批判的なものに加え，市民運動や市民参加のあり方を問う内省的な課題が前景化されるようになる。また，当初は水質悪化や水資源開発，水循環を対象にするものが多かったが，生態系や自然再生，都市の水辺環境再生，環境教育など，対象が広がってきたことも指摘できる。加えて最近は，原発問題，米軍基地問題，土砂災害などもテーマになっている。

4. 参加者数の推移と報告テーマ

以上のとおり，活動は継続して行われているが，参加者数や会議での報告団体数は大きく変化している（図 1）。開催地により参加人数が変動するのは当然としても，組織が作られてから 10 数年は参加人数が 400～1,200 人の幅で推移し，報告団体数も 1992 年まで毎回増えていった。しかし，1998 年からは，松江や諫早湾などでの大会には多くの参加者が集まったものの，その他の大会では参加者が 400 人に満たなくなり，2008 年に東京で「水郷水都運動の新しい段階を作ろう」と運動のあり方をテーマにして以降は，参加者は 200 人前後で推移している。あわせて報告団体数も 20 件に満たなくなっている。この東京での大会が，そもそも運動を取りまく状況の変化を感じ取って開催されたものである。

また，全国会議での報告内容に関して，その推移をみていると[5]，時間とともにその内容が，大会のメインテーマの変化と同様に変化してきていることがよみとれる。

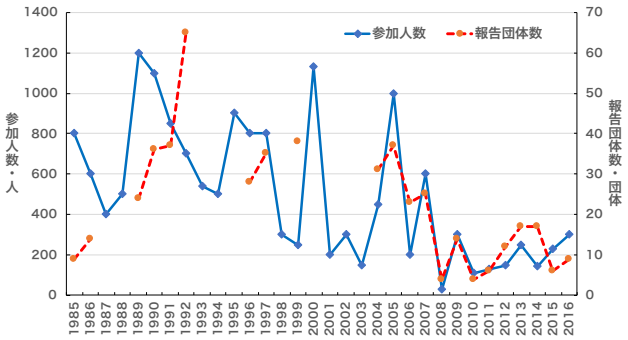

図 1 水郷水都全国会議への参加人数・報告団体数

表 1 全国会議時の報告テーマの推移

	1回	2回	5回	6回	7回	8回	臨時	12回	13回	15回	20回	21回	22回	23回	25回	26回	27回	28回	29回	30回	31回	32回
開発に関わる問題	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●
環境保護・自然再生	●	●	●	●	●	●		●	●	●	●	●	●	●		●			●	●	●	●
地域づくり			●	●	●	●			●	●	●	●								●		
水質に関わる問題	●	●	●	●	●	●		●	●		●	●		●	●				●			
市民・住民運動		●	●	●	●	●		●	●	●	●	●	●	●	●	●	●	●	●	●	●	●
都市の水循環（上下水道等）		●	●	●	●	●		●	●	●		●	●									
地下水問題		●	●	●	●	●				●			●									●
生物保護に関する問題			●	●	●	●		●	●	●	●	●				●		●	●	●		●
行政・政策・権利			●		●	●	●	●	●	●	●	●				●				●	●	●
森林と水				●	●	●			●		●							●				
環境と教育					●	●			●	●	●	●								●		
酸性雨問題						●																
農漁業と水						●				●	●	●		●					●		●	
土壌に関する問題						●							●									
海洋・海岸に関する問題						●				●	●		●	●								
棚田								●														
干潟								●	●	●									●	●		
持続可能社会・循環型社会											●			●								●
水の商品化													●									
原子力・放射能汚染																		●	●	●		●
自然災害																			●	●		
地域の歴史・文化				●	●	●		●			●	●	●	●	●		●	●	●		●	

出典：程誠（2017）日本における水環境問題の変遷と環境活動の関わり. 広島大学総合科学研究科修士論文.

一貫して取り上げられているのは，開発に関わる問題と市民・住民運動である。自然保護や自然再生に関わる話題もほぼ毎回取り上げられている。また，生物保護に関する報告や，地域の歴史・文化に関する報告，行政・政策に関わる報告も期間を通じて多い。一方，水質問題や都市の水循環（上下水道問題）は期間の前半に多く，後半には報告されなくなっている。逆に，期間の後半で取り上げられているのは，循環型社会，原子力・放射能汚染，自然災害である。

全国会議が作られた頃は，各地で水質問題が注目され，干拓事業や水資源開発などの公共事業の是非が問われており，それらに関心をもつ市民団体が中心になって全国会議を作りあげてきた。それらの問題の一部は決着し，湖沼河川の水質も高度経済成長期のような劣悪な状況は脱している。そのため，1990 年代半ば以降，報告テーマが変化・多様化する中で，報告団体数が減り，会議への参加人数も減ってきたと考えられる。

5. 社会運動の変化と全国連絡組織の存在意義

市民運動をとりまく社会環境は変化し，かつて偏見をもってみられることもあった環境団体の地位は高まり，さまざまな活動が行われるようになっている。しかし，上述のように，関心の対象が変化する中で，当初に運動を牽引した層が高齢化する一方，新しい環境問題に対応する市民団体が全国会議に広く加わってこない。

また，情報化の進展により，各地の市民活動の情報はインターネットを通じて容易に入手することができ，連絡もとりやすくなっている。年に 1 回，各地の団体が一堂に会して情報交換する意義は薄れてきた。また，関わる環境団体や地域づくりの団体が増え，活動を担う個人のレベルでは掛け持ちになることも多く，水郷水都全国会議の活動が，ますます One of them の活動になってしまうことを否めない。SNS の普及に対し，運動団体内（間）のジェネレーションギャップも生まれ，中高年齢層の担う組織と若者が担う運動との間に，組織論や戦術面でのつながりをつけにくくもなっている。

このような状況において，従来型の全国的な市民団体の連絡組織，ネットワークのあり方の見直しは急務である。運動の対象や論点の変化に応じて，これまでにつながりのない団体との連携が必要になるかもしれないし，これまでのような「全国」の連携にとどまらず「世界」レベルでの連携が必要になるかもしれない。

かつて琵琶湖宣言で言及され，木原や保母が説いた住民運動の横の連絡協力組織をつくることの意義は，現在でも失われてはいない。しかし，そのことの確認を含めて，水環境問題に関わる市民団体の全国連絡組織の意義は何か，役割は何かを再検討すべきである。その上で，今後求められる活動を創り出すことが求められる。

最後に，世界湖沼会議と市民活動について，先の霞ヶ浦での湖沼会議でも，琵琶湖での里帰り湖沼会議の際でも，研究者・行政・住民が一体となるという当初の精神がしっかり生かされているのかが問い直されている。1995 年の霞ヶ浦では，「霞ヶ浦宣言」とは別に「NGO 霞ヶ浦宣言」が別日別会場で採択され，2002 年の琵琶湖でも「琵琶湖宣言 2001」とは別に「NGO 水世紀宣言」がなされている。研究者・行政・住民の連携には乗り越えるべき幾多の課題がある。水郷水都全国会議のあり方を問い直すことは，ただそれだけにとどまるものではなく，環境問題の解決に向けて市民がどう関わっていくのかを問い直すものでなければならない。

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[4] 浜松大会分までは，水郷水都全国会議編『水郷水都全国会議 20 年記念資料集ふるさとづくり提言の時代』により，その後は水郷水都全国会議のウェブサイト（http://www.sui-sui.sakura.ne.jp/activities/activities.htm）による。

[5] 程誠：日本における水環境問題の変遷と環境活動の関わり，広島大学総合科学研究科修士論文，2017.

P8-2

題名：霞ヶ浦の清掃活動と今後の展望

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キーワード：協働・自然保護・市民参加・水辺ふれあい・意識啓発

抄録

我々、水辺基盤協会が主催する水辺の清掃活動によって、これまでにここ霞ヶ浦から少なく見積もっても 157 トン以上のゴミを回収してきました。その多くが、流域住民による不法に投棄された生活ゴミです。霞ヶ浦で大好きな釣りを思い切り楽しみたいと思っても、目につく多くのゴミがそれを興ざめさせてしまいます。綺麗な環境で釣りがしたいという動機で続けている清掃活動ですが、今では行政機関や民間団体との協働によって成り立っています。しかし、我々はいつも活動維持のための資金難に苦しんでいます。ゴミを拾うのも、その処理を行うにも費用が発生します。長く活動を継続してゆくための問題も山積しており、ボランティアという参加者の誠意だけでは厳しい局面に直面しています。本稿ではゴミ拾いを始めた経緯から、どの様に活動をしているのかという紹介、活動における問題点や今後の課題について述べてゆきます。

1.　はじめに

釣り人による水辺の清掃活動を始めたのは、1995 年の 2 月 25 日でした。私たちは、ブラックバスという外来種を対象にした釣りを霞ヶ浦で楽しんでいますが、あまりのゴミの多さに辟易していました。清掃活動のきっかけは、自分たちの釣り場は自分たちで守るというところから始まっています。それから 22 年が経過し、春と秋の年二回の霞ヶ浦クリーン大作戦「53Pick Up!」を展開してきました。毎回 250～300 名ほどの参加者が集まり、霞ヶ浦全体を対象にゴミを回収し、今年の 11 月で 45 回目の開催となります。また、2003 年からは、少人数で狭い範囲の清掃活動をする「防塵挺身隊」を立ち上げました。こちらは年六回のペースで行われ、今年の活動すべてを終了すると、全 84 回の開催になります。

2005 年の 4 月に茨城県より特定非営利活動法人を承認され現在に至ります。

2.　清掃活動の方法

年二回開催の「53Pick Up!」ですが、先述したように清掃対象は霞ヶ浦の全域です。参加者は、徒歩で近辺のゴミ回収をする方や、自身の車を駆って思い思いの場所へ赴き、ゴミを満載にして集合場所へ戻ってくる方など人それぞれです。回収したゴミは、産業廃棄物処理業者に処理を依頼します。当初は、霞ヶ浦のゴミ拾いなのだから、国土交通省霞ヶ浦河川事務所が処理をしてくれるだろうと思い相談しに行きましたが、行政区分によって管轄が異なるため、陸域のゴミは当該市町村、河川のゴミは県、霞ヶ浦のゴミは国土交通省で・・・という返答でした。回収してきた大量のゴミを行政管轄ごとに仕分け・分別するのは現実的ではありません。産業廃棄物処理業者への依頼は必然の結果でした。しかし、業者への処理依頼は、同時に費用が掛かるということになります。当初のゴミ処理費用は。2 ㎥で 30,000 円もかかりました。その費用の捻出を参加者から参加費として徴収し賄うことにしたのです。一人 1,000 円をあずかり、ゴミ処理費用と保険料、余りを参加者に食事を提供しました。手弁当とはまさにこのことです。

参加者が実費を払ってゴミを拾う清掃活動は、他に類を見ないのではないでしょうか？行政に依存することなく、釣り人による水辺の清掃活動をする意義が、そこにあるようにも思います。

もう一方の「防塵挺身隊」ですが、53Pick Up!では手を付けられない範囲をカバーする、更に踏み込んだ清掃活動になります。53Pick Up!において、運営側である我々が、自ら思いきりゴミを拾うために立ち上げた活動です。参加人数も 20～40 名で、清掃範囲は目星をつけておいた特にゴミが集中して溜まっている 200～500m、長くても 1,000m 程度の範囲に限られます。とにかく徹底的にゴミを拾うので、そのくらいの範囲の活動に限られてしまうのです。場所によっては水際まで行けない場所もあります。船を用いて湖側から陸地側のゴミを回収したり、チェストハイウェーダーという、胸まである防水長靴とライフジャケットを着用して水中にあるゴミの撤去も行います。湖岸線の殆どの場所に繁殖している野薔薇はゴミ回収の行く手を遮る厄介な相手です。レインウェア等の衣服を、いとも簡単に切り裂く棘に十分注意しながらの作業となるため、回収の効率が著しく低下してし

まいます。手袋も通常用いるゴム製ではなく、皮手袋以外は役に立ちません。刈払い機で事前に野薔薇を刈り除く準備も時には必要になります。野薔薇だけでなく、枯れた葦などから目を防御するためのサングラスやフェイスガードも必要な備品です。防塵挺身隊においては、ビニール袋片手にトングでゴミを拾う・・・といったイメージは皆無です。

回収したゴミの処理ですが、範囲が狭いので、市町村をまたぐことがありません。そのため、開催するところの市町村でゴミの処理を引き受けていただいています。53Pick Up!とは違い、防塵挺身隊の参加費は 500 円です。保険料とゴミの処理費に充てるのが本来の意図ですが、現在では粗大ゴミやリサイクル家電、危険物などは霞ヶ浦河川事務所で処理していただけています。行政に処理をお願いするにあたっては、ゴミの分別が必要になります。私たちのゴミ拾いは分別しながらではなく、とにかく拾いまくります。これが最も効率の良い方法です。回収したゴミは一か所に集められ、可燃・不燃・その他粗大ゴミ等に分別していきます。

ゴミ拾いの実施時期についてですが、53Pick Up!は春の陣と称した前期が 5 月、秋の陣と称した後期が 11 月です。防塵挺身隊は 1 月から 4 月までの毎月と、暫く期間を開けて 10 月、12 月の開催です。一年間でみると、10 月の秋から 5 月の春までになっています。植物が生い茂る春以降、秋までの期間は、伸びた植物に埋もれたごみの回収が困難であることに加えて、毛虫や蜂、蛇などの危険生物との遭遇機会が増えてしまうからです。更に草いきれなどムッとする高湿度の状況での活動は、熱中症のリスクがあり危険を伴いますので、あえて避けているのです。

3. 結果

冒頭で述べたように、回収するゴミの大半は、流域住民の投棄による生活ゴミです。これは本当に悪意の塊です。弁当の容器や飲料のペットボトル、栄養ドリンクの瓶、発泡スチロールが目立ちます。このほかにも農業の肥料袋やマルチビニル、漁業者の投棄した漁具に加え建築資材や廃材、注射針・薬瓶など、回収に注意が必要な危険を伴う事業系産業廃棄物の不法投棄ゴミまで多岐に渡ります。そして、悲しいことですが、釣り人の捨てた釣り糸や餌のパッケージなども含まれます。それらを撤去する防塵挺身隊の活動を同じ場所で続けていると、翌年の植生の成長が他所に比べ激変します。成長の勢いが良いのです。特に人工的なゴミが堆積した個所を丹念に掘り返し除去したエリアは顕著です。ゴミによって空気が遮断された状況が改善され、植生に適した状態に戻るからだと思われます。

水生植物は、水質浄化を促進させるために重要な働きをすることは周知の事実です。また、水生動物・昆虫にとっても欠かすことのできない存在です。そこから無機物であるゴミを取り除くことは簡単な道理ですが、実は倒木などの大きな有機物のゴミも植生に深刻なダメージを与えることがあります。強風に伴う大波によって運ばれた倒木は、その勢いで葦を始めとした水生植物を広範囲に渡ってなぎ倒してしまいます。場合によってはこういった有機物も回収の対象になるのです。

4. 考察

清掃活動の継続は、霞ヶ浦からゴミを減らす唯一無二の方法です。ゴミが湖岸線に不法に投棄されると、ゴミがゴミを呼ぶという、負の連鎖が生じます。ゴミを捨てる人たちにとって、捨てやすいイメージを持つのかどうかは定かではありませんが、それを撤去しなければ必ず同じ場所にゴミが増えてゆきます。

海洋生物に与えるマイクロプラスチックの影響が問題となっていますが、それを増幅させない意味においても、海に流出する前の淡水域でのゴミの防除は極めて有意義です。波風等の影響で細かく粉砕される前に撤去することが肝要です。とはいえ、霞ヶ浦でも、発泡スチロールが砕けて一粒ずつ独立した状態になってしまっています。葦原に層になって堆積したそれを見ると問題の深刻さが理解できます。

ゴミの問題はまた、行政の政策にも深く関係があります。一般家庭から出されるゴミの排出量を抑制しようとする目的で、処理費用の増額や、有料ゴミ袋の値上げが行われますが、現状の便利な生活レベルを下げてまでゴミを出さない質素な生活を、一体どの程度の市民が実行するでしょうか。過去の家電リサイクル法施行以降の家電ゴミの不法投棄を見てきた我々からすれば、ゴミが増加するのは火を見るよりも明らかでした。そしてそれを拾い自分たちの出したお金で処理する。なんともやるせない思いです。

問題は、ゴミの状況にとどまらず、我々の活動においても山積しています。

まずは資金難であること。これまで述べてきたようにゴミの処理には費用がかかります。そこは参加者からの参加費によって賄われるので何とかなります。ゴミ拾いに至る準備段階で購入するゴミ袋や軍手などの資材費など何かと入用です。資金が潤沢にあれば、トラックや重機も手配でき、ゴミの回収労力や効率も飛躍的に向上

できることに加えて身の危険も軽減させられます。もう一方の大きな問題は、活動賛同者が増えない状況です。決まったメンバーや、協力団体の一部の方々による活動に留まってしまうこと、若い世代の新規参入者が居ないことです。もっと大きなムーブメントとまではいかなくても、釣り人による清掃活動という点では、まだまだ無関心な人たちや釣り具メーカーが多く、他人事で片づけられているように感じます。自分事として捉えてもらえるような啓発にも力を入れていかねばならないと痛感しています。

5. 結論

我々の活動に対していただくご意見に、「ゴミを拾う努力よりも、ゴミを捨てさせない努力をすべきだ」というものがあります。ゴミを捨てる人たちが減らなければ、ただの鼬ごっこだというのです。それには声を大にして反論したい。拾えばゴミは確実に減ります。決して無駄な行為ではありません。ゴミを捨てさせない努力については並行して進めるべきですが、そちらはそういう意見をおっしゃる方や、行政にお任せしたいと思います。

フィールドに実際に立ち、現況を目視さえすれば、目の前のゴミを拾わずして他人の意識を変えようなどという考えは、おこがましいとさえ思えてしまいます。我々にできることは釣りや水辺のゴミ拾いを通じて、釣り場を守ろう、魚がいる環境を大切にしようという考えを持ってもらえるきっかけ作りです。結果としてゴミを捨てない啓発に繋がると信じています。その具現が「53Pick Up!」であり、その次のステップとしての「防塵挺身隊」なのです。

霞ヶ浦で朝焼けや夕焼けをご覧になったことはありますか？穏やかな湖面に映る色彩、波が作り出す水音、鳥や蛙、昆虫などの野生生物が出す鳴き声しか聞こえない水辺に立って見る景色の素晴らしさ。

類まれなるこの湖を、もっと綺麗にしたい。その中で釣りを心ゆくまで楽しみ、釣りという文化を後世に残すためにこのフィールドを守りたい。

我々はそのための努力を惜しみません。問題は多く、先行きも安定している訳では決してありませんが、前を向いて活動を継続してゆきます。

P8-3

地域社会協働による都市池の保全と再生

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キーワード :協働、都市池, 保全と再生、水草, 絶滅危惧種

抄録

典型的な都市池である千葉県市川市「じゅん菜池」の保全と再生に地域社会で協働して取り組んでいる。流域の都市化に伴う湧水の枯渇により、地下水により維持されている「じゅん菜池」では、絶滅危惧種 20 種以上が確認されている。しかし、近年の水質悪化により、かつて池に自生したジュンサイとイノカシラフラスコモ（絶滅危惧Ⅰ類）は消滅した。2017 年より消滅した水草の再生、および周辺住民へのより良い水辺の提供を目的とした池の再生活動を地域の市民、行政と教育機関が協働して開始した。現在、池の水環境悪化の原因とその機構が明らかとなり、実行可能な回復・再生方法を検討している。地域社会で協働することにより、池の維持・管理、科学的調査、教育・啓発と多義にわたる活動を効率よく行うことが可能となった。一方、水草の再生活動には外部専門家の助言が不可欠であり、外部専門家との連携、活動と教育の連携、資金の獲得が今後の課題である。

１．はじめに

日本の重要湿地 500 選の 1 つである「じゅん菜池」は，千葉県市川市北西部の住宅地内に位置する長さ約 600m,最大幅約 30m の細長い形状をした沼沢群である。谷津に湧出する湧水により形成されたと考えられるが,流域の都市化に伴う湧水量の大幅な減少により，戦後、池は一旦消滅した。その後、1979 年に市川市により掘削された井戸からの地下水供給により再生され,現在にいたる。

湧水により維持されていたかつての「じゅん菜池」には水草であるジュンサイ（*Brasenia schreberi*）やイノカシラフラスコモ（*Nitella mirabilis var. inokasiraensis*）（絶滅危惧Ⅰ類）が自生していた。しかし,近年では夏に藻類が繁茂し,水質が悪化して池内ではジュンサイもイノカシラフラスコモも消滅している。このような池の自然環境再生のために，2017 年より，地域の行政，市民，教育機関が協働しておこなう水環境再生活動を開始した。過去に池内に自生していたイノカシラフラスコモやジュンサイなどを復活させることが第１の目的である。また，将来に向けての自然環境保全には自然環境にふれあい、その大切さを知り・守る行動を育む環境教育が重要である。地域の中・高・大学及び住民により良い水辺を提供し、池の自然環境改善過程を含め、環境教育の場なる池とすることを第２の目的とした。

２．調査・活動項目および調査方法

池の維持・管理は主に市川市と市民が担当し、大学は主に科学的な基礎調査をおこなった。また環境教育・啓発活動は市民と中・高等学校が担当した。

池では①水源水の水質と水量調査,②池水の水質とその変化の要因調査,③池の水環境改善策効果の検討,④水鳥調査をおこなった。　また,池周辺において中学生を対象とした環境教育も行った。

池外では⑤気候変動･都市化の影響調査,⑥専門家の池への招聘と交流をおこなった。一般市民・大学生を対象とした写真展も池外で開催した。

これらの調査・活動とその進捗状況は 2 か月に一度開催される関係者会議において報告し、その都度計画の見直しを行いながら活動を進めた。

湖水面積･流域面積･周辺地形･土地利用は Google Earth と現地踏査により調査した。気象は,気象庁 HP

*1より，市川市に近い「船橋」の過去39年間(1978-2016)のデータを用いた。また,2017年4月～2018年1月の間約2週間に1回,計20回,現地において採水および生物観察をおこなった。水質はｐH(pHメータHI98107N Hanna Inst.)，EC（ECメータHI98303N Hanna Inst.)，DO（デジタル溶存酸素計DO-5501,マザーツール）は現地で測定した。NO_3^-（デジタルパックテスト,共立理化学研究所）PO_4^{3-}（デジタルパックテスト,共立理化学研究所)は試水を実験室に持ち帰り,24時間以内に分析をおこなった。水鳥観察は目視による計測のほか自動撮影カメラを設置し,定点観測をおこなった。

３．じゅん菜池の水環境

①水源水の水質と水量調査

池に流入する主な水は降水,深井戸水,浅井戸水および湧水の4種類である。イノカシラフラスコモおよびジュンサイ（以降,水草）は弱酸性,貧栄養または腐植栄養の湖水を好むことが知られている。水質調査より，池の給水に利用している地下水の水質は取水深度により異なり，浅井戸水は低いpH，高い硝酸性窒素濃度を有し,深井戸は高いpH，高いリン酸イオン濃度を示した。高い栄養塩濃度により,地下水は浅井戸も深井戸も水草の育成には適さないことが明らかとなった。一方,降水は弱酸性,低栄養塩濃度を呈し,水草の育成に適するが,現在,池に流入する量では池水の維持には不足であることがわかった。湧水はその存在が確認できなかった。したがって現時点では池の水源は地下水に依存せざるをえない。池の環境を悪化させる藍藻類・緑藻類の繁茂を抑制し，水草の育成に適した水環境創生のためには供給水である地下水のpHと栄養塩濃度を制御する仕組みの構築が必要である。

②池水の水質とその変化の要因

池水のｐHと栄養塩濃度は流入水の水質に大きく影響され,浅井戸水の供給口近辺では低いｐHと高い硝酸イオン濃度を呈し,深井戸水の供給口の近辺では高いpHと比較的高いリン酸イオン濃度を示した。池内においては，夏季にはアオミドロ,アオコが繁茂し,それらの光合成が原因と推定されるpHの著しい上昇が認められた。一方,抽水植物の根付近では,池中央に比べ,低い硝酸性窒素濃度と低いｐHが確認された。抽水植物による栄養吸収と日陰の影響と推定された。

③池の水環境改善策効果の検討,

夏季の間,緑藻類および藍藻類の繁茂抑制を目的として,池の一部でばっ気をおこなった。ばっ気をおこなった池では、おこなわなかった池に比べ、アオコおよびアオミドロの繁茂抑制効果が認められた。一方,ばっ気をおこなった池の池底付近ではDOとリン酸イオン濃度の増加が観測された。DO増加はばっ気の直接的影響,リン酸イオン増加はばっ気による池の底泥の攪乱が原因と推定された。

11月から2月にかけて池の一部でかいぼりおよび底泥への山砂の投入をおこなった。天日干しの後、底泥のｐHは弱酸性を呈し,水草育成に好条件となったことが確認された。また,かいぼりをした池底へはサギ類の飛来がほぼ毎日確認され,水草育成の障害となっているアメリカザリガニを捕食していると推定された。

④水鳥調査

じゅん菜池は比較的小規模な池であるにもかかわらず多くの水鳥が飛来する。特に11月以降はカモ類が飛来し,その総数は1月には連日300羽近を超す。水鳥は水中の有機物を捕食し,池の水質改善に寄与する一方,その糞はリンを含み富栄養化の原因となりうる。正確な水鳥の池水質への影響を明らかにするために自動撮影カメラによる観察をおこなっている。

⑤気候変動・都市化の影響調査,

市川市に隣接する船橋の過去39年間の降水量は経年的に増加傾向を示すとともに,30㎜以上豪雨の回数も増加傾向にあることがわかった。すなわち,流域内の降水量･浸透水量ともに自然増加している。*2，3。これらの気候変動は今後、湧水の自然回復に寄与する可能性がある。現在、流域内住宅の屋根に

降った降水は集水されたのち、流域外へ排水されている。水草育成に適するこれらの水を周囲の流域から集め,直接的･間接的に池内に導くことも環境改善策の一つとして検討に値することがわかった。

⑥専門家の招聘と交流

池の再生活動をしている我々の中に,水環境再生や水草の専門家はいない。従って,再生活動を進めるためには専門家との交流・アドバイスが不可欠である。千葉県中央博物館からは水草に適する水環境とジュンサイの栽培方法についてアドバイスを受けた。また、じゅん菜池に遺伝子的に正しい千葉県産のジュンサイを再生することが重要であるとの指摘を受け、千葉県中央博物館より千葉県印旛沼産のジュンサイを譲り受けた。市川市自然博物館からはイノカシラフラスコモの栽培指導をうけている。そのほか,水環境研究所/千葉工業大学からは池の水環境改善策についてアドバイスを受けた。

現時点では,池の水環境はジュンサイ等の育成に適しないため,ジュンサイとイノカシラフラスコモは池脇に設置した水鉢において育成中である。池への移植の事前準備として,これら水草の増殖と池水環境を弱酸性,貧栄養とすること,また,ザリガニの駆除が必要である。

そのほか,関連する学術大会で本活動の報告発表をおこない,同様の活動をおこなっている団体,専門家から情報を収集した。本池における活動についてはこれらのアドバイス,情報を活かした再生計画を立案・実施している。

⑦環境教育と啓発活動

地域内の大学においては一般市民と大学生を対象とした写真展を開催したほか,大学1年生を対象とした講義をおこなった。また,中学を対象とした野外学習および出前講座をおこなった。

４．まとめと今後の課題

典型的な都市池であるじゅん菜池においてかつて池内に自生した水草（ジュンサイとイノカシラフラスコモ）の再生、および周辺住民と教育機関による池の活用を目的とした活動を、地域の市民、行政と教育機関が協働して2017年より開始した。 現在、池の水環境悪化の原因とその機構が明らかとなり、実行可能なできるだけ自然を利用した水環境再生方法を検討する段階となった。

市民、市、教育機関が協働することにより、池の維持・管理、科学的調査、教育・啓発と多義にわたる活動を効率よく行い、多くの情報発信が可能になった。一方、再生活動には外部専門家の具体的なアドバイスが不可欠である。外部専門家との連携、池の再生と教育活動の連携、資金の獲得が今後の課題である。

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P8-4

Birds sightseeing as a strategy for raising awareness of Lake Chapala ecological importance

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Key words: sightseeing, conservation, basin

ABSTRACT

Lake Chapala, the largest natural body of water in Mexico (1,140 km²) was visited and described by the famous German naturalist Alexander von Humboldt on his trip in 1803. Although it maintains great scenic values, the lake faces conditions of degradation and disappearance of native species due to lack of knowledge of its operation and the scarce engagement of the population on its conservation. A component of great relevance for the area of birds, in which there are registered 307 species (30% of the total for Mexico).

To promote interest in caring for the environment and encourage nature tourism, an Environmental Interpretation Trail was installed, which includes 7 observation points, where school groups and the public are attended. Specialized signage and a map for visitors with photographs and descriptions of the most common birds in the area are available, consistently pointing their importance and current situation; there is also a group of local guides trained to take care of the visitors. In a complementary way, environmental education workshops are held with primary and secondary students from the municipality of Chapala, and a media and social media outreach campaign, with a minimum impact on 20,000 people. Participants' interest in the conservation of birds and their habitats is fostered to maintain environmental services, such as pest control, seed dispersal and pollination, and water quality. The project is the result of a careful planning process and was carried out within the framework of the Germany-Mexico Dual Year, promoted by the Goethe Institute.

1. INTRODUCTION

The diversity and abundance of birds were one of the criteria to obtain the Declaration of Ramsar Site of Lake Chapala in 2009. Several studies show the value of birds in the region internationally, however, there is a gradual process of habitat loss as well as lack of knowledge of the population about its importance and current situation. As a way to inform and involve the local and visiting public, in 2010 the Lake Chapala Bird Festival was held as a way to promote the conservation of the ecosystems in which these animals live. The festival lasts two weeks and is held annually, resulting in the need of having a permanent educational space, in which people can observe birds freely and learn about them and the actions necessary for their conservation. From there the Interpretation Trail project was integrated, which was installed in the San Antonio Tlayacapan waterfront of the municipality of Chapala.

Goals:

• Establish a path of environmental interpretation as a space for observation and learning about the birds of Lake Chapala.

• Increase the knowledge of residents and visitors about the importance of birds and the environmental benefits they generate.

• Spread the cultural and scientific importance of Lake Chapala through the figure and work of the naturalist Alexander von Humboldt.

2. METHOD

First Phase: Public presentation of the project.

Second Phase: Content design, graphic design and printing of education and divulgation materials.

Third Phase: Design and implementation of the web platform.

Fourth Phase: Installation of signaling on the trail.

Fifth Phase: Training guides to operate the trail.

Sixth phase: Environmental education workshops in schools.

Seventh phase: Visit of the trail to schools and public.

Eighth phase: Elaboration of the final report and spread of results.

3. RESULTS

First phase

The public presentation of the project was made on August 20, 2016, where authorities of the municipality, as well as the municipal president of Chapala and some foreign members of the Chapala Lake Birders organization, attended.

The formal inauguration of the trail took place on September 28 where 107 people attended, among which the representatives of the Mexican Association of German teachers (representing the Goethe Institute Mexiko), state institutions, municipalities and different media.



Second phase

Visits were made to the site, to identify characteristics and themes of the trail and to analyze the characteristics of the village. A report on poly-sensorial criteria and an inventory of the attractions was drawn up, using the longitude of the work area as a reference for the definition of contents, the type of audience to which the theme is addressed, the ecological characteristics of the site (climate, habitats, altimetric behavior of the lake, seasonality and the habits of the birds of the area) and the access facilities that the space provides.

Seven themes were defined, one for each station (signaling). The contents for each one was integrated into both Spanish and English versions, considering the high frequency of foreigners.

Later, the trail regulations were designed.

Graphic design and printing of signage plates.

Third phase

Design and implementation of the web platform:

In the implementation of the project's web platform

nine posters were included on the organization's page in the form of a presentation, in a user-friendly format.

Fourth phase

The bases where the signage plates are installed were realized.

Fifth phase

Several people belonging to this institution and some residents of the Municipality of Chapala were trained to carry out the guided tours on the trail and the workshops in Chapala schools, as well as tours of weekends aimed at the public.

Sixth phase

Educational workshops in schools have been carried out with a focus on local birds, a total of

55 workshops, in 8 schools, to 1,806 students. They were chosen schools located in San Antonio Tlayacapan, Chapala and Ajijic.



Seventh phase

Visit of schools and the public to the trail

The tours began on August 20.

Tours were given with 47 different groups, totaling 1,902 people.



Eighth phase

The divulgation of the project has been done through different means of communication including the Laguna Weekly, Guadalajara Reporter, XCJB Radio (interview), Periódico de la Ribera. In addition to the publications of the municipal government and the president of Chapala.

The total impact of the publications on the Facebook of the “Corazon de la Tierra” Institution on the Path have been more than 27,300.

4. DISCUSSION

This project aims to involve people keen on birds to protect their environment. In this way a new environmental consciousness arises among people who are attracted by the birds, pushing them to protect and be aware of their natural habitats. Particularly, due to the wide range of birds present in this area, visitors could identify themselves in the type of birds they prefer, resulting in a greater concern towards the Lake’s conservation.

This will lead to a good way of spreading awareness on the Lake Chapala lake, its fauna, and most importantly its natural environment.

5. CONCLUSION

The Alexander von Humboldt Trail is of great importance in the region since, in addition to dealing with issues related to bird conservation and spreading its ecological and tourist value, encourages the population to be aware of the environmental problems encountered in the Lake Chapala basin and its surroundings. Currently, guided tours and environmental education workshops continue, not only with visitors from Chapala but also with groups of the neighboring municipalities.

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水害常襲地における復興まちづくりの事例からみる地域社会の持続性に影響を与える要素の検討

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キーワード：まちづくり、地域活性化、協働、水辺空間、文化

抄録

まちづくり計画の構想に見られる地域社会の持続性の視点を検証することを目的として、茨城県筑西市の南部に位置する、母子島遊水地の建設事業を事例として調査をおこなった。遊水地として指定された区域内には建設当時109戸が所在していたが、遊水地の区域内に集団で移転し、新たな街「旭ヶ丘」が造られている。しかし、事業が完了してから30年を経て旭ヶ丘の住民が感じているのは、持続性への「体感としての不安」であり、復興まちづくりは、この不安をもたらした産業の変化を想定できなかった、という否定的な評価であった。これは、復興まちづくりの中で生み出されるはずの「地域の位置づけ」が不透明になっており、これが場所の個性を形成するに至らなかったと説明でき、現在進められている「地域の位置づけ」に向き合う活動は、移転から1世代を経てようやく本来の「復興まちづくり」が始まったことを示唆している。

1. はじめに

自然災害は、地域社会における被災前のトレンドを加速させることが指摘されている[1]。被災をきっかけとして、地域の「衰退」が加速する可能性があるのである。この傾向は、人口が減少しつつある日本においては、地域社会の持続可能性に直結することとなる。災害を受けてすすめられる復興まちづくりでは、「持続性」への配慮が欠かせない。しかし、現在進められている復興まちづくりにおいては、逆に地域を喪失させる、「復興破壊」ともいえる政策が進行しているとの声もある[2]。

では、持続性を維持するために復興まちづくりではどのような観点が必要なのであろうか。この点を検証するためには、現在進められている計画ではなく、被災から相当年数を経過した地域社会において、被災後の社会的な変化を横目にしながらの分析が必要となる。

よって、復興まちづくりの構想に見られる持続性・継続性の視点を検証することを目的として、過去にすすめられた復興まちづくり」が縮小時代に突入した現在という地点からみて振り返った時に、どのような課題を抱えていたのか実証的に明らかにすることを試みた。

2. 方法

茨城県下館市（現：筑西市。以下、本稿で言及する自治体名はいずれも当時）で実施された母子島遊水地建設事業ならびに附随する各種活動を事例として、地元自治会ならびに行政機関へのヒアリング内容を中心とした質的分析をおこなった。

遊水地建設事業のメインとなるのは、区域内の5集落による集団移転計画である。この移転では、遊水地内に土盛をしてそこに集団移転をするという、「日本初」の試みがなされている。

2.1. 事例地について

事例地は、小貝川と大谷川という2つの河川の合流部に所在している。事例地の下流域一帯は江戸時代に大規模な干拓事業が進められ、同時に河道の改修などがおこなよりせき止められていた事例地

には水が流入するようになり、近世以降は幾度となく水害に見舞われる「水害常襲地」となっていた。戦後、一部において堤防の整備が進められたものの、河川の合流部付近などには無堤部も残されたことから浸水被害は解消されなかった。無堤部が残されたことについては、建設省の担当者も大雨による出水は織り込み済みとの認識が示されており、住民側も、下流域の水害を事例地が「引き受ける」構図を認識していた。

このような中で発生した 1986 年 8 月の水害は、これまで「引き受けて」いたような出水の範囲を超え、これまでに経験したことのない規模であった。

2.2. 水害について

1986 年 7 月 29 日にグアム沖で発生した熱帯低気圧は、8 月 1 日に台風 10 号となり、8 月 4 日には御前崎の南南西の海上で温帯低気圧となるも、そのまま関東・東北地方へ至った。温帯低気圧となってからは速度が低下し、結果として太平洋沿岸に長期間強い雨を降らせることとなり、16 都県に被害をもたらしている。

小貝川では 4 日 24 時に警戒水位を超過、5 日 14 時に計画高水位を超えて過去最高の 6.86m を記録した。事例地周辺地域においては越流による堤防の流失、洗堀などの被害が多発したほか、5 日 13 時 30 分頃に下流部の明野町赤浜地先において決壊、6 日 9 時 58 分頃には石下町本豊田地先において決壊した。浸水範囲は約 4,300ha、被災家屋は 4,479 戸の大水害となった。 被害の大きさを勘案し、建設省は 5 ヶ年の激甚災害対策特別緊急事業（以下、劇特事業）を採択。小貝川においては、浸水範囲のうち下館市の養蚕橋から明野町の小貝橋までの区間が対象となった。この激特事業の中心的な計画が、事例地における遊水地建設である。

2.3. 母子島遊水地について

治水計画の見直しによって、増加した計画高水量をまかなうための流量調節が必要となった。小貝川は平地流域であったために、ダム建設適地が少なく、また、工期の問題で河道整備も難しかったことから、遊水地群の建設が採用されることとなった。

遊水地として整備されたのが、事例地であった。遊水地に指定された区域内の 5 集落は、当初は遊水地の外に移転する方針であったが、集団で移転するという希望が多かったことと、農家が多いことから 5 集落のひとつである小釜地区のあたりを集団移転地とする代替地方式を採用している。

2.4. 復興まちづくりについて

遊水地内の土地は、一部は国が買い上げたが、多くの農地に関しては取得価格の 25%の地役権を設定して対応した。

移転にあたっては、事業期間の制約が大きな影響をもたらした。先に、地域の意向を反映して代替地方式を採用したとしたが、建設省の担当者による回想では、用地買収などの時間的な問題も影響していたことが示唆されている。住民側も、こうした流れに呼応し、「推進委員会」を作って事業の完遂に協力した。結果として、1992 年までに無事移転が完了し、集団移転地は公募により「旭ヶ丘」と命名された。なお、移転時の方針としては「移築」が基本とされたものの、当時の住民は持ち出しも厭わず、新築で大きな住宅を建設したという。

集団移転の完了後、下館市は河川区域となった遊水地内の土地の有効利用を目指して、総額 33 億 6,000 万円の整備計画を発表した。しかし、同時期に発生した経済不況の余波を受けて、事実上この計画は未着手となっている。

3. 結果

ヒアリングによって住民意識の把握を進めた結果、水害から 30 年を経て、地域社会の構造が質的に変化していることが明らかになった。先に述べた移転後の大きな住宅は、農業が身近であった社会において、家が当然に継承されるという思惑においてなされていた。しかし現状は、若年・壮年世代が定着せず、結果としてまちの管理にも手が回らない状態になりつつあった。 ただ、この状況は、住民にとって集団移転の評価に結びつくものではなかった。集団移転によってもたらされた生活環境の変化は、おおむね好意的なものであった。それは、移転時に反対

であった住民も納得させ得るほどの効果を持っていた。現状の衰退は、こうした利点をもたらした集団移転によるものではなく、あくまでも「想定外」の社会的な変化によってもたらされたものという認識が支配的であった。

人口流出をもたらした要因は、直接的には産業構造の変化によるものであった。農地の近くに移転したものの、農業の比重が低くなり、その結果として現在地に移転した意味を失いつつあるという構造である。しかし、ヒアリングからは、生活の主体が農業以外に移転前から移りつつあったことが語られている。この潮流は移転後に顕著な動きをみせ、事例地周辺の農業は大規模農家に集約されつつある。

以上のように、住民の認識の上では持続性に不安を抱える旭ヶ丘であるが、これに対抗する活動もまた住民側から起こされている。自治会では、自治体との交流を深め、「官民協働」を基調としたまちづくりを推進している。この一環として、これまで曖昧な形で進められていた周囲の環境整備に関して、2013 年以後相次いで協定が新たに結ばれることとなった。停滞していた周辺整備も、筑西市が「かわまちづくり」支援制度を利用するなどして、徐々に進められることとなった。結果として、近年では景勝地としての注目も集めるようになっている。

自治会で活動をしているのは定年を迎えた世代が中心であるが、それより下の世代においても、まちの維持に尽力したいという理念のもと、2009 年に別の組織が作られている。

4. 考察

持続性が求められている復興まちづくりであるが、旭ヶ丘においては持続性そのものが課題となっていた。これは、社会的なトレンドに復興まちづくりが対抗できなかったということを示している。そして、このトレンドは移転前から予期できていた。しかし、この点への考慮がなされなかった要因として、「事業の完遂」を優先する論理により、移転後の生活を考える余裕が無かったことが指摘できる。ここで考慮されなければならなかったのは、持続的な社会を実現するための視点であった。ここでは「持続的な社会」のモデルとして、環境史の分野で提唱されていた概念を援用して「都市圏生態系（Regional Ecosystem）」という社会システムを想定した。「都市圏生態系」において持続性の要素とされるのは、生産活動に関わる視点、と生活に関わる視点の 2 つである。前者は、当該の地域社会が所属する都市圏において、どのような役割を担っているのかという視点であり、後者は、生活の場として積極的な理由となる「場所の個性」をどのように生み出すか、という視点である。これらを合わせて本研究では「地域の位置づけ」と表現した。そして、旭ヶ丘ではまさに「地域の位置づけ」への観点が不足しており、生活の更新がなされた集団移転をもってしても持続性に寄与しなかったといえる。

一方で、被災後の状態から回復するという観点においては、激特事業そのものは成功のうちに終わったと評価できる。しかし、災害は、これまでの社会を客観的に捉えなおす「再創造」の場でもある[3]。旭ヶ丘の集団移転は、過去の生活との訣別も内包されている。しかし、移転後の生活を新たに位置づける機会は提供されず、移転前の意識を残したまま、焦点の定まらない「再創造」となってしまったといえよう。

以上をまとめると、水害を引き受ける場所であった事例地は、この役割を遊水地に分割し、生活の意識の外に置いた。しかし、新たな生活は位置づけられないまま、一連の「まちづくり」は完結してしまったと評価できる。近年の「官民協働」は、こうした状況に対して「再創造」を求める動きであり、この意味で、復興まちづくりは 1 世代を経てまさに始まろうとしているともいえるのである。

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霞ケ浦環境科学センターにおける環境学習実施後の環境保全意識の変容

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キーワード:環境保全意識, 環境学習, 環境学習プログラム, 茨城県霞ケ浦環境科学センター

抄録

茨城県が実施する霞ヶ浦湖上体験スクールに参加した児童を対象に, 環境保全意識に関するアンケートを行った。霞ケ浦環境科学センターが行う「野外観察」,「プランクトンの観察」,「水質調査」の３つのプログラムを体験した児童が回答したアンケート調査結果をそれぞれ分析すると,「野外観察」では「責任意識」「知識」,「プランクトンの観察」では「責任意識」,「水質調査」では「責任意識」「知識」「環境配慮行動」について効果が見られた。

1. はじめに

茨城県では, 平成 17 年に県内の自然環境を積極的に活用し, 水質浄化に対する取組を行う総合的な拠点施設として, 霞ケ浦環境科学センター（以下, センターと記す）を設置した。その機能の一つとして自然体験学習を伴った「環境学習」がある。その中でも霞ヶ浦湖上体験スクール（以下, 湖上スクールと記す）は, 霞ヶ浦における船上での体験後, センターに来館し,「野外観察」,「プランクトンの観察」,「水質調査」の３つのプログラムから利用者が選択し, 一日を通して霞ヶ浦に関する学習を行うことができる環境学習である。主な参加者は児童である。また, 児童らの環境保全の意識を涵養することが湖上スクールの目的となっている。センターでは, 湖上スクールの実施前後にアンケートを実施している。これまで, 環境学習に対する環境保全の意識の変容に関しては, 分析はしてきた[1]ものの, ３つのプログラム各々の環境保全の意識変容とその検討は行われていない。

２．研究の目的

そこで, 本研究では, 茨城県で実施している湖上スクールにおいて, センターを利用した児童が体験した各々の３つのプログラムによる環境保全の意識変容を探ることを目的とする。

３．研究の方法

環境保全の意識変容を探るために各プログラム実施後に, 表１に示したように３つの環境学習プログラム共通のアンケート調査を行った。なお, 調査対象は, 平成 29 年度湖上スクールに参加し, センターでの環境学習を行った小学３～６年生（無作為に抽出）であり, 回答は, ４件法による選択（そう思う・どちらかというとそう思う・どちらかというとそう思わない・思わない）及び自由記述である。なお, 環境保全意識を構成する「親しみ」,「責任意識」,「保全意識」,「価値意識」,「関心」,「知識」,「環境配慮行動」の７つの観点から分析する。

表１　アンケートの実施内容

内容：①霞ヶ浦に親しみを（身近に）感じるか。【親しみ】
②自分も霞ヶ浦や身近な川を汚していると思うか。【責任意識】
③霞ヶ浦や川の水をきれいにしたいと思うか。【保全意識】
④霞ヶ浦は人や生きものにとって大切な湖だと思うか。【価値意識】
⑤霞ヶ浦や川についてもっと知りたいか。【関心】
⑥霞ヶ浦や川を汚さないようにするための方法が分かるか。【知識】
⑦霞ヶ浦や川を汚さないようにするための行動をしているか。【環境配慮行動】

４．環境学習プログラム

湖上スクールにおいて, 霞ヶ浦での船上における学習後, センター来訪児童が行う環境学習プログラムの内容は以下の３つである。

１）野外観察

センターの庭を「霞ヶ浦」に見立て, 多様な自然を体験させるため, ７分ごとに①魚の観察, ②室内での植物プランクトンの観察, ③野外での動物プランクトンの観察, ④霞ヶ浦の景観の観察, ⑤野鳥の観察, ⑥霞ヶ浦の植物の観察, 以上の６カ所を巡る環境学

習を行う。例えば，①魚の観察では，池や水槽の観察を通して，多くの生き物が暮らす水辺，魚と動物プランクトンの関係について説明する。また，生物を観察する際に，生き物どうしの繋がりや生活排水とアオコの関連について説明している。

２）プランクトンの観察

一人一台顕微鏡を使用し，動物及び植物プランクトンの観察を行い，種類や特徴を知る。霞ヶ浦に生息する本物のプランクトンを自分で見つけ，それをスタッフが撮影して一人一人に写真を配付する。観察したプランクトンと他の生物とのつながりやアオコの原因となるミクロキスティスについて環境学習の過程で説明している。

３）水質調査

身近な水の代表例として，霞ヶ浦の水，流入河川の水，そして生活排水として一万倍に薄めたしょう油（以下，薄いしょう油と記す）を使用し，色や臭い，透視度，パックテストによるCOD測定など，基本的な水質調査を行う。結果として，薄いしょうゆ油は，色はほぼ無く，においは無いと判断する児童が多い。一方，霞ヶ浦や川の水は，濁っており色やにおいを感じる。透視度についても，薄いしょうゆ油は 100cm 以上である。この時点で児童は，最も良好な水は薄いしょうゆ油で，良好でない水は霞ヶ浦と判断する。しかし，COD値は，霞ヶ浦や川の水が１～５mg/Lであるのに対し，薄いしょう油は８mg/L以上となり，予想と逆転する結果となる。

以上の３つの学習プログラムの特質は，観察・実験後に，環境学習の終末で水質汚染の原因，人が環境に与える影響，湖の恩恵，環境保全のための取組について推論させ，話し合ったり発表したりする時間を確保していることである。

５．結果と考察

１）調査期間及び調査人数

アンケートは，平成29年５月から12月に実施した。事前アンケートは学習前１週間までに実施し，事後アンケートは学習後１ヶ月以内に行った。

事前アンケートの回答は，野外観察 187 名，プランクトンの観察 204 名，水質調査 273 名，合計 664 名から得ることができた。事後アンケートの回答は，野外観察 184 名，プランクトンの観察 199 名，水質調査 266 名，合計 649 名から得ることができた。

２）３つの環境学習プログラム実施後の環境保全意識の変容

表２は，野外観察を実施した児童の環境保全意識の変容人数（割合）と直接確率計算（母比率不等）の結果である。「責任意識」，「知識」について１％水準の有意差が確認できた。「責任意識」について１％の有意差が確認できたのは，②植物プランクトンの観察の際に，アオコに関することやその原因となるミクロキスティスを実際に観察し，環境学習の終末で水質汚染の原因について推論させたことによる。「知識」について，１％の有意差が確認できたのは，①魚の観察や⑥植物の観察において，生物の生態系での役割や絶滅危惧種について説明を受けたことや，②植物プラクトンの観察において，ミクロキスティスを実際に見て，アオコと家庭排水との関連に気付き，日常生活で環境のためにできることを環境学習の終末において，推論し，発表したことによる。

表３は，プランクトンの観察を行った児童の環境保全意識の変容人数（割合）と直接確率計算（母比率不等）の結果である。「責任意識」について１％水準の有意差が確認できた。「責任意識」について１％の有意差が確認できたのは，ミジンコなどの動物プランクトンとミクロキスティスなどの植物プランクトンを観察し，生物のつながり，アオコという現象について知り，自分たちの生活と関連付けて水の浄化の方策を推論させたことによる。

表４は，水質調査を行った児童の環境保全意識の変容人数（割合）と直接確率計算（母比率不等）の結果である。「責任意識」，「知識」，「環境配慮行動」について１％水準の有意差が確認できた。「責任意識」について１％の有意差が確認できたのは，しょう油一滴が自然環境へ与える影響について実験を通して認識できたことによる。これは，実験において色やにおい，透視度の結果から最も良好な水は，薄いしょう油であると判断した後に，COD値を測定すると，予想と逆転する結果が印象的であり，この経験も効果の要因として考えられる。「知識」について１％の有意差が確認できたのは，生活排水を減らすための対

表２　湖上体験スクールで野外観察を実施した児童の環境意識の変容（肯定的な回答の割合）

	肯定的		否定的	
	実施前	実施後	実施前	実施後
親しみ	141 (80.9)	171 (93.0)	46 (19.1)	13 (7.0)
責任意識**	74 (42.7)	141 (76.6)	113 (57.3)	43 (23.4)
保全意識	163 (93.9)	174 (94.6)	24 (6.1)	10 (5.4)
価値意識	167 (96.1)	177 (96.2)	20 (3.9)	7 (3.8)
関心	139 (79.8)	156 (84.7)	48 (20.2)	28 (15.3)
知識**	101 (57.8)	144 (78.2)	86 (42.2)	40 (21.8)
環境配慮	64 (36.5)	91 (49.5)	123 (63.5)	93 (50.5)

**P<0.01，　(　　)は割合[%]を示す

表３　湖上体験スクールでプランクトンの観察を実施した児童の環境意識の変化（肯定的な回答の割合）

	肯定的		否定的	
	実施前	実施後	実施前	実施後
親しみ	162 (79.4)	187 (93.9)	42 (20.6)	12 (6.1)
責任意識**	64 (31.3)	139 (69.8)	140 (68.7)	60 (30.2)
保全意識	193 (94.6)	192 (96.5)	11 (5.4)	7 (3.5)
価値意識	198 (97.0)	195 (97.9)	6 (3.0)	4 (2.1)
関心	176 (86.3)	180 (90.5)	28 (13.7)	19 (9.5)
知識	129 (63.3)	155 (77.9)	75 (36.7)	44 (22.1)
環境配慮	85 (41.6)	107 (53.7)	119 (58.4)	92 (46.3)

**P<0.01，　(　　)は割合[%]を示す

表４　湖上体験スクールで水質調査を実施した児童の環境意識の変化（肯定的な回答の割合）

	肯定的		否定的	
	実施前	実施後	実施前	実施後
親しみ	241 (88.3)	256 (96.2)	32 (11.7)	10 (3.8)
責任意識**	86 (31.5)	192 (72.2)	187 (68.5)	74 (27.8)
保全意識	263 (96.3)	259 (97.3)	10 (3.7)	7 (2.7)
価値意識	259 (94.9)	260 (97.7)	14 (5.1)	6 (2.3)
関心	243 (89.0)	242 (90.9)	30 (11.0)	24 (9.1)
知識**	150 (54.9)	224 (84.3)	123 (45.1)	42 (15.7)
環境配慮**	83 (30.4)	129 (48.5)	190 (69.6)	137 (51.5)

**P<0.01，　(　　)は割合[%]を示す

応策を終末に学んだことによる。「環境配慮行動」について１％の有意差が確認できたのは，水質実験を通して湖や川の汚染を防ぐための方策を思案し，自分たちにできることを推論させたことによる。

各プログラムにおいて，有意差が確認できなかった項目に関しては，実施前から肯定的な割合が高いことから，これまでの学校教育や家庭教育の中で既に身に付いている環境保全意識であると考えられる。

以上のことから，センターでの体験的な環境学習は，プログラムの内容及び調査項目により異なるが，環境保全に関する意識の向上に一定の効果があると言える。

一方，児童の環境保全に関する意識の向上は，自由記述にも多く表れた。例えば，「責任意識」に関するものとしては，「気づかないところで自分も霞ヶ浦を汚していることが分かった。これから生活排水を減らすようにしたい」，「家や学校から出る水が汚れの原因であるので減らします」，また，「環境配慮行動」に関するものとしては，「油をふき取ってから食器を洗う」，「給食をなるべく残さないように食べる」，「親しみ」に関しては，「霞ヶ浦が好きになりました。大切に，そして大事にしていきたいです」という環境保全に対する意識の変容を伴う代表的な記述があった。

６．おわりに

本研究では，センターにおいて，湖上スクールを体験した児童の環境保全意識の変容について，アンケート調査から分析した。環境学習プログラム実施前後で比較すると，特に「責任意識」の変容が顕著であった。また，「環境配慮行動」については，水質調査の実施前後で有意差は確認できたものの，５割程度しか肯定的な回答が得られなかった。したがって，環境保全に関する具体的な行動，学校や家庭で既に行われている取組を紹介するなど，行動に結びつく内容を構成しなければならない。他方，児童にインタビューなどを行い，変容の具体的な要因について探らなければならないことも課題である。

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Human Race Is Preparing Its Own End! Is It Possible to Slow Down?

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ABSTRACT

The human race trapped by the technology is not aware of the catastrophe that it has created because integration of it's life with environment and nature has been destroyed. Every day, environmental conditions are getting worse as a result of the activities of human race and it is trying to find ways to tackle with challenges that climate change and pollution has caused. Is human race going to be successful in this fight? This is a hard question to answer. But there is a great truth which we should not forget that we borrowed this world from our children and our grandsons and we should leave a liveable world to them. By keeping in mind this truth, human race has to do its best to slow down negative changes in the environment.

Starting from this point, DSİ, as being the major Turkish institution responsible for water resources development, has initiated the Water Ambassadors Project. The Project is aimed at awareness raising about effective utilization and conservation of water resources for the sake of future generations. The Project, developed by DSİ, is being conducted by DSİ together with Turkish Ministry of National Education and Turkish Radio and Television Corporation. Part of the project was realized via financial support of EU in 2017. A wide range of activities have been undertaken including cartoon series production, curriculum overview, orienteering competitions, stage performances, documentary production and establishment of a web TV.

If humans do not touch nature, nature continues to live for millions of years.

1. INTRODUCTION

Although ¾ of it's surface is covered with water, the amount of fresh water available on the earth is only about %0,3 of this amount and it is unfortunately not possible for all people to reach all of this little amount.

Also; according to UN data, the world population, now at 7.6 billion, is expected to increase rapidly, reaching 8.6 billion in 2030 and 9.8 billion in 2050. Unfortunately, due to uncontrolled changes in consumer habits of this population, their needs are also rapidly increasing. When the adverse effects of climate change are added to the ever-increasing environmental pollution resulting from meeting these increasing needs and the human activities, there is a complete chaos about the accessibility and usability of already scarce freshwater resources. If we do not intervene in this chaotic environment now, we will pass the irreversible point and unfortunately massive deaths will begin to appear in the world.

The existence of this chaos environment has made it necessary to take urgent and lasting steps in order to protect the water resources and to use them efficiently and efficiently. This has revealed the reasons of the Water Ambassadors Project and the Water Ambassadors Project has been started because of this reality.

2. METHOD AND RESULTS

Water Ambassadors Project is a project developed by the General Directorate State Hydraulic Works (DSI) which is a primary governmental agency responsible for the development of Turkey's water resources. The main goal of the Project is to raise awareness on water resources conservation and efficient use of water resources to ensure that sufficient and clean water resources are available for future generations, thereby increasing global citizens' awareness of water and making them more sensitive individuals.

In the Water Ambassadors Project developed by DSI, which is world-wide known institution by it's experience on water structures and educating it's staff at academic level, Turkey Radio and Television Corporation (TRT) regarding communication, and Turkish the Ministry of Education (MEB) regarding education are the other project partners. Although the main target group of the Project is our children and young people, and activities are being carried out for the entire public within the scope of the project.

Some parts of the project were realized by the financial support from the European Union and in this EU Project, in addition to the above-mentioned three institutions, General Directorate of Meteorology, General Directorate of Nature Conservation and National Parks, General Directorate of Water Management and Turkey Water Institute (SUEN) of the Ministry of Forestry and Water Affairs, Ministry of Environment and Urbanism, and Ankara University took part as other stakeholders.

Within the scope of the EU project, in such a short term of 10 months, studies were carried out under the following project components:

- Training of Trainers
- Curriculum Development
- National Young Water Embassies Assembly
- Promotional Activities

The objective of the Trainers' Training Component is to train Trainers who will disseminate training activities on water resources and protection of the environment. Within the scope of this component, 85 people chosen from the staff of the stakeholder institutions' headquarters and their representations in the 3 pilot water basins of the project, were given trainings on pedagogy, communication and training techniques as well as technical trainings on water resources and climate change etc. In addition, the Training Manual was prepared and distributed to the Trainers. These Trainers then informed about 120 thousand people in the pilot basins during the project.

Within the context of the Curriculum Development component of the project,

- MEB's current curriculum has been scanned for the protection of the water resources and environment and suggestions have been developed to address the issues that need to be improved.
- Box games and computer games for children are prepared.
- Water Ambassadors Clubs have begun to be established in the schools.
- Poster preparation, story writing and painting competitions have been realized in the schools all around Turkey and all of the first 3 winners in each of 9 categories have been awarded.

Within the scope of the project, National Young Water Ambassadors Assembly (named as GencSEM in short) was established with the participation of 26 female and 26 male university students selected from all around Turkey. GencSEM, whose first meeting was held in Ankara between 20-24 March 2017, chose its own management team in this meeting. Also included within this component are;

- The members of GencSEM have established separate commissions in different topics and after being informed by the experts of the subject of each commission, the members have studied about the activities they can do under these headings.
- Returning to the basins, GencSEM members continue to work on activities they can do.
- The website www.sumeclisi.org is established for GencSEM activities and is still active.
- GencSEM members travelled to Belgium and France to find out about water and environmental management and awareness raising studies and similar youth organizations' work in these countries.
- The second meeting of GencSEM was held in Ankara on 23-29 October 2017.

Within the scope of the Promotion component, which constitutes one of the most important parts of the project, activities were carried out for all sections of the society, including primarily children. These are as follows;

- Web addresses named "www.suelcileri.org" and "www.waterambassadors.org" have been opened for the project and all developments about the project are published here.
- Animated series of Water Ambassadors consisting of 39 episodes, each 7 minutes-long and each having different subjects about water resources and environmental protection, was prepared and broadcasting of the series on TRTÇocuk TV channel started in April 2018.
- For the monthly TRT Children's Magazine, 10 Water Embassies Special Issue was prepared with special supplements and 250.000 copies were published and distributed in the MEB schools.3 Public Spots were prepared, passed through the necessary approvals and started to be shown on TV channels.
- Three documentaries, each 30 minutes in length, have been prepared and will soon started broadcasting on the TRTDocumentary TV channel.
- Stage Performances with famous Turkish artist Kadir ÇÖPDEMİR were performed in Muğla, Konya, Trabzon and Ankara.
- Orienteering competitions were organized in Koycegiz Lake, Beysehir Lake and Uzungöl Lake,

which are important water resources in the Project pilot basins, and in Ankara, and the best national team of the world, Swedish National Orienteering Team, participated in the orienteering competition in Ankara.

- Social media accounts opened on Facebook and Twitter before the EU project have been kept active throughout the EU project and about 40 thousand people are still active in these accounts.

The EU funded part of the project was carried out between 25 January and 15 December 2017. From the end of the EU Project to the present day, education activities are carried out in primary and secondary schools throughout the country. Within the scope of these training activities, approximately 11 thousand students and 500 teachers were informed about the importance of the water, the necessities for the protection of the water resources and the environment and the Water Ambassadors project.

3. DISCUSSION AND CONCLUSION

We borrowed this world from our grandsons and our most important duty is to leave them with a livable world and, of course, available water resources in the future. The Water Ambassadors Project has also taken action to explain this consciousness to the people of the world.

Of course, it is not right to expect that the work undertaken under the Project will yield very fast results in a world where selfish consumer habits have developed. The priority of the Water Ambassadors Project is to place the consciousness of protection of water resources and environment to the very deep parts of our children's subconscious, as today's children will work in different occupations, sectors and positions all over the world, and to be a manager, user and polluter of water in the future. This awareness will be internalized by our children with activities to be carried out in the Water Ambassadors Clubs established in the schools, computer games, informative activities carried out in the schools and animated series.

And of course the project will not stop at this point. Currently, negotiations with many countries are continuing to ensure that the project is spread worldwide in the near future. We are looking forward to the support of all governments to make Water Ambassadors an organization that is structured all around the world under the umbrella of the United Nations.

Water is not a problem of just a nation, but it is the problem of the whole world. So it is our duty to make sure that children and young people all over the world are aware of the different events and problems that are happening in different parts of the world in relation to water resources and the environment, and that they develop the habit of solving these problems together in the future.

We, as Turkey, continue to do our duty about conservation of water resources in the best way and we are always willing to cooperate with the countries of the world on such issues.

In order to ensure the sustainability of the Water Embassy Project, many collaborations with many of our country's institutions have already been developed by our experts. Some of them are as follows;

- Together with the General Directorate of State Theaters, theater plays for SU-based adults and children are being prepared.
- Animation studies with water feature are continuing with the General Directorate of Cinema.
- Joint training with Gendarmerie General Command is planned.
- In addition to this, activities to disseminate the work done in the EU Project continue at full speed.

We, all nations, travel together on this ship called Earth. We have no choice but to protect water resources together.

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ペットボトルロケットを使った湖沼環境サンプリング教材の開発状況

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キーワード：カリキュラム開発，人材育成，レクリエーション

抄録

湖沼の環境学習において岸から離れた湖沼内地点の環境データを取得する手段と機会は船舶などを利用する以外にはほとんどなく，そのため湖沼環境の時空間変異を調査できる簡易なサンプリング手法の開発が期待されている。中でも，観測者が陸上にいながらセンサー等を岸から離れた湖沼内地点に輸送する手段はそういったサンプリング手法の中でも特に要となる技術である。そこで本研究では青少年の宇宙教材として国内外で広く利用実績のあるペットボトルロケットをベースに，岸から離れた湖沼内地点へセンサー等を輸送するための分離機構を考案し製作した。これにより，湖沼環境サンプリング教材を構成する基盤技術の導入を図ることが可能となった。

1. はじめに

全国有数の面積サイズを要する霞ヶ浦は児童・生徒・一般市民が参加する環境教育の対象となっており，様々な団体がそれに関連して水質調査や野外観察などバラエティーに富むプログラムを展開している[1]。専門機関による水質など環境パラメータの定点モニタリングも行われており[2]，湖沼に関する環境研究も活発に行われてきた。また，霞ヶ浦の水質改善への取り組みも積極的に行われており，かつて遊泳できた湖の姿を取り戻そうという機運が近年高まっている[3]。

大きな面積サイズを有する湖沼では水質の空間分布を明らかにするために多地点での調査が必要である。船舶等を用いることでその解決を図ることが可能であるが，その所有や運用は専門機関に頼らざるを得ない。したがって，湖沼環境の時空間的変異に関するデータ取得，とくに湖岸から隔てられた地点での環境データを容易に取得できるサンプリング手法が期待されている。とりわけ，一般市民や生徒・児童らが自らの手により湖岸から離れた地点の水の取得と調査が可能となれば，環境教育の幅を広げることができるばかりでなく湖沼環境の時空間変異に関するデータの蓄積に寄与することができる。

2. 方法

船舶を利用せず湖岸から離れた地点の環境データをサンプリングするためには，その地点にセンサー等を輸送しなければならない。そこで宇宙教育用の教材としてポピュラーなペットボトルロケットを活用することにした。ペットボトルロケットは水と圧縮空気を利用して飛行のための推進力を獲得するシンプルな仕組みになっており，物体の運動の原理を分かりやすく学習できる科学教材としても広く活用されている。ペットボトルロケットは基本的に遠くに飛ばすことを目的とした構造になっているため，湖岸から離れた地点の水をサンプリングする手段として用いるにはいくつかの機構を追加する必要がある。代表的なものとしては，1.ロケット内部に搭載したセンサー等を分離するための機構(分離機構)，2.落下地点の環境データを採取する機構(サンプリング機構)，3.ペットボトルロケットとセンサー等を回収する機構(回収機構)，が挙げられる。

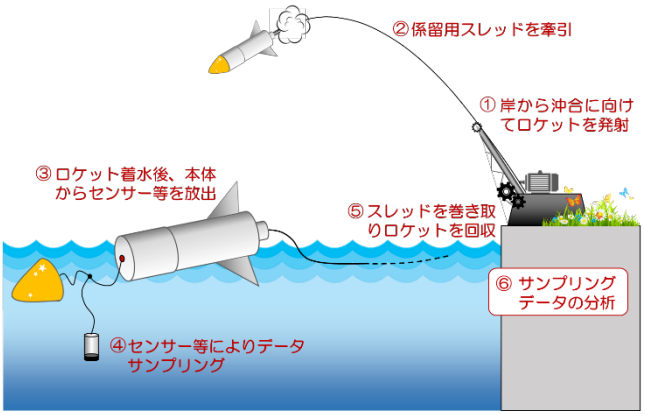

図 1 サンプリングシステム概要

図 1 に現在開発中のペットボトルロケットを使った湖沼環境サンプリングシステムの全体像を示す。①ペットボトルロケットにスレッドを取り付け沖に向けて発射する，②ロケットがスレッドを牽引しながら飛行する，③ロケット本体が二つに分離する，④ロケット内部に搭載されたセ

ンサー等が放出され，データを収集する，⑤スレッドを巻き取り，ロケットを回収する。今回はこの湖沼環境サンプリングシステムを構成する要素技術のうち，おもに分離機構と回収機構を製作した。

3. 結果



図 2 ペットボトルロケット発射装置

図 2 に今回製作したペットボトルロケットおよびその発射台を示す。ロケット発射台はマニュアル操作により発射角度の調整できる機能を有しており，ロケットを発射台のレール上にスライドさせることでロケット発射時の方向性をチューニングできる。ロケットの全体構造は水と圧縮空気を入れるタンク部分(1 段目)とその上にノーズコーン部分(2 段目)を載せた 2 段式となっている。1 段目と 2 段目の接続部分は両者の接触部分をなるべく小さくすることで分離を容易にできるようにした。

1 段目と 2 段目の具体的な分離プロセスは，①ロケットの 1 段目最後部に一定長のスレッド(ここでは釣り糸)を結び付け，もう片方のスレッド端を発射地点に固定する，②ロケット発射後，飛行距離がスレッド長に達したとき 1 段目が急停止し，2 段目は慣性により 1 段目から分離する，というシンプルな方式を採用した。ロケットの燃料は水と圧縮空気で，自転車用の空気入れを用いてタンク内の空気圧を上げる方法は一般的なペットボトルロケットと同様である。

4. 考察

ペットボトルロケットは青少年の宇宙教育の教材として国内外で広く活用されている[4]。したがって，本システムの基本構造もそれに沿ったものであり，科学教育の発展性を図る設計を心がけた。分離機構も尖った技術を用いず，力学の簡単な応用であり，工夫と創意で製作可能なレベルとしている。また，本ロケットの 2 段目に内部スペースを確保したことで，センサー等のペイロード搭載が可能な構造としていること，また，素材がペットボトルであるので 2 段目のサイズ調整の加工は容易であり，これらの特徴により様々な利用シーンの増加が見込まれる。

5. 結論

ペットボトルロケットを利用した湖沼環境サンプリングシステムの開発を目指し，その要素技術であるロケットの分離機構を製作した。これにより湖沼環境サンプリング教材を構成する基盤的技術の導入を果たしたと思われる。今後，陸上でのロケット発射試験により分離機構の性能を調べるとともに，分離機構を制御するスレッド長ならびにスレッド強度について検討する。とくにペイロード搭載時のロケット飛行特性や分離機構のパフォーマンスに関する分析は重要である。同時に，サンプリングシステムを構成する他の要素技術の製作を順次進めていく予定である。

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池干しによる茨城県自然博物館の「とんぼの池」の再生

－絶滅危惧種の生息域外保全と自然保護の普及活動の場として－

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キーワード：池干し, 生態系復元, 外来生物駆除, 博物館野外施設の利用

抄録

茨城県自然博物館の野外施設「とんぼの池」は，自然水系から独立しており，人間の捕獲圧や外来種混入の危険にも晒されないため，絶滅危惧種の生息域外保全に極めて適した条件を有している。しかし，「とんぼの池」を生息域外保全の池として利用するには，外来種の存在，貧弱な植物相，水質の悪化など，多くの問題がある。そこで，「とんぼの池」を絶滅危惧種の保全と環境保護の普及啓発活動の場として再生させるため，生物相のリセットと水質の改善を目的とした池干しを行った。池干し後の「とんぼの池」では，植物の休眠種子の発芽はじめ，いつくかの生物の自然復元が観察された。2017 年 9 月には，生息域外保全の第一段として，霞ヶ浦産のゼニタナゴの導入を試みた。また，池干しの際に池内の生物を捕獲するボランティアを一般募集したり，博物館内で池干しについての特別展示や講座を開催したりするなど，本活動を通じた自然保護のための普及活動も行った。

1. はじめに

茨城県自然博物館には，15ha の野外自然観察施設があり，その中に面積 0.7ha の人工池「とんぼの池」と付随するビオトープ群が存在する。これらの水系は，限りなく自然に近い環境を有しながらも他の自然水系から完全に独立しており，環境収容力の点においても十分な面積を有している。他水系から生物が流入せず，外来種の混入など人間による影響を排除した大規模な自然環境は極めて貴重であり，茨城県において，絶滅危惧種の保全にこれほど理想的な環境を他に見いだすことは難しい。しかしながら，博物館ではこれまで「とんぼの池」ついて自然保護に則した管理規定や自然観察以外の運用目的を定めてこなかった。そのため，外来魚の放流や無計画な水生植物の刈り取りなど，野放図な管理が行われ，その結果として，「とんぼの池」は外来種を主とする単純な動物相と劣悪な水質の池となってしまった。そこで，「とんぼの池」を絶滅危惧種の保全と環境保護の普及活動の場として再生させるため，生物相のリセットと水質の改善を目的とした池干しを行った。「とんぼの池」の問題は，日本の多くのため池が抱える問題と同じものであり，年間 40 万人を超える利用者がある茨城県博物館の「とんぼの池」の再生は，自然保護および生物多様性保全の実践例として非常に強い影響力を持つと考える。また，絶滅危惧種が自然に近い状態で繁殖し，その生態を観察できる環境が実現すれば，絶滅危惧種の保全という観点だけでなく，生物多様性の観点においても，教育・研究の観点においても，その価値は非常に大きいと考える。

2. 方法

事前調査　池干し実施するにあたり，事前に池に生息する生物を調査し，検討を重ね，生態系の回復に悪影響を及ぼすと考えられる種を駆除対象種として選定した。特に飼育型のコイについては，富栄養化の原因となり，多様な生物に対する捕食圧などを通じて在来生態系に悪影響を与える[1,2]。このため，今回の池干しでは，コイついても駆除対象種とした。また，池干し前後の土壌や水質の変化を比較するため，池内の 5 地点において底質（含水率，強熱残留物，強熱減量）と水質（濁度，pH，DO，COD，SS，窒素，リンなど）の調査も行った。

池水の排水　池水は 2016 年 11 月 1 日から 2 週間かけて徐々に排水した。外来生物の流出を防止するため，排水口には φ4mm のナイロン製の網を設置した。池水は完全には排水できず，池の両端となる東側と西側にそれぞれ面積約 400m^2 と約 1000m^2 の残水域ができた。排水できずに残った水は水中ポンプを使って排水した。

生物の捕獲作業　2016 年 11 月 19 日に東側の残水域（約 400m^2）において，一般参加のボランティア 50 名と手製の追い込み網を使って生物の捕獲作業を実施した。

西側の残水域は約 1000m^2 と範囲が広く，過去に浚渫された影響で 1m 以上の泥が堆積している場所も確認さ

れた。そのため，博物館のスタッフやボランティアだけでは捕獲作業は難しいと判断し，排水を造園業者に，魚類の捕獲を地元漁協にそれぞれ委託して，2018 年 2 月 28 日に捕獲作業を行った。

捕獲した駆除対象種については，捕獲時に全個体の標準体長および重量を測定した。また，駆除対象種以外の生物については，博物館内の水族館施設に保護し，池干し後に「とんぼの池」に再導入した。

消石灰の散布　鈴木ら[4]を参考に，捕獲作業では捕りきれなかった外来魚類を駆除するため，消石灰の散布を行った。

東側の残水域においては，2017 年 1 月 26 日に水中ポンプで水をすべて排出した後，池底に粉末状の消石灰を 200kg 散布した。翌日（1 月 27 日）には湧き水により残水域が再び現れた。この残水域の pH 値は 12.5 であった。pH 値が 11.5 以上では数時間以内に魚は死亡する[5]。このため，東側残水域の魚類は駆除できたと判断した。西側の残水域においても，2 月 28 日の捕獲作業終了後に同様に消石灰 360kg を散布した。翌日（3 月 1 日）には再び水が増えたが，pH 値は 12.4 であり，死魚が多数確認できた。

消石灰散布後の水は強いアルカリ性になるが，貯水により薄まるため，貯水後は生物への影響はなくなる[4]。西側の残水域の例では，湧き水によって残水域が広がるにしたがって pH 値は減少し，散布した日から 3 日後には 9.4，7 日後には 8.2 まで pH 値が減少した。

3. 結果と考察

池干しで捕獲された生物　池干しにより捕獲された生物は，魚類 17 種類，カエル類 1 種，カメ類 1 種，エビ類 2 種，貝類 1 種である（表 1）。捕獲された魚類には，全長 1m を超えるハクレンやアオウオなど，導入経緯が不明の魚種もあった。コイ，フナ類（ギンブナ，ゲンゴロウブナ），カムルチーの体長組成を調べたところ，サイズが均一で，特に小型の未成魚はまったく捕獲されなかった（図 1）。これは産卵基質となる水生植物が消失したことにより，再生産が行われなくなっていたためと推測される。 また，2007 年の博物館の調査記録では，ブルーギルとオオクチバスが確認されていた。しかし，今回の池干しでは，ブルーギルの捕獲数は池全体で 11 個体だけであり，オオクチバスにいたっては捕獲されなかった。泥の堆積により産卵場所となる砂礫底が消失したことやコイなどによる産卵床の攪乱などが衰退の原因と考えられる。反対にモツゴやタイリクバラタナゴなど繁殖が植生に依存しない種については，数多く捕獲された。また，池底からは冬眠中のミシシッピアカミミガメが大量に捕獲された。

表 1　池干しで捕獲された生物の種類と捕獲数

科名	和名（属名）	学名	捕獲数
コイ科	コイ	*Cyprinus carpio*	72
	フナ属（ギンブナ・ゲンゴロウブナ）	*Carassius* sp.（*C. auratus langsdorfii*・*C. cuvieri*）	471
	ハクレン	*Hypophthalmichthys molitrix*	5
	アオウオ	*Mylopharyngodon piceus*	1
	ニゴイ	*Hemibarbus labeo*	1
	モツゴ	*Pseudorasbora parva*	134
	タイリクバラタナゴ	*Rhodeus ocellatus ocellatus*	172
	ツチフキ	*Abbottina rivularis*	25
	タモロコ	*Gnathopogon elongatus*	7
タイワンドジョウ科	カムルチー	*Channa argus*	64
ナマズ科	ナマズ	*Silurus asotus*	1
ウナギ科	ニホンウナギ	*Anguilla japonica*	1
メダカ科	ミナミメダカ	*Oryzias latipes*	11
サンフィッシュ科	ブルーギル	*Lepomis macrochirus*	11
ハゼ科	ウキゴリ属	*Gymnogobius* sp.	2
	クロダハゼ属	*Rhinogobius* sp.	11
（魚類以外）			
アカガエル科	ウシガエル	*Rana catesbeiana*	4
ヌマガメ科	ミシシッピアカミミガメ	*Trachemys scripta elegans*	74
テナガエビ科	テナガエビ	*Macrobrachium nipponense*	13
	スジエビ	*Palaemon paucidens*	90
イシガイ科	ヌマガイ	*Sinanodonta lauta*	54

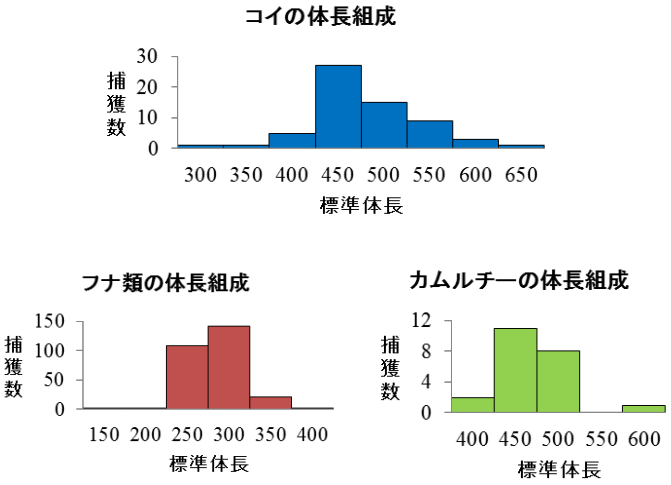

図 1　捕獲された魚類の体長組成

池干し後の「とんぼの池」の変化　2017 年 3 月 4 日から貯水を開始し，3 月中旬には満水となった。その後，3 月下旬に水族館施設で維持していた生物を再導入した。

池底を乾燥させることで，栄養塩類の溶出抑制や有機物の好気的分解作用などにより，土壌や水質の改善が期待できる。しかし，「とんぼの池」では，湧水が池の各所に湧き出しており，池底が湿潤な状態のままで十分に乾燥することができなかった。このため，池干しの前後で水質の変化や底泥の栄養塩や有機物の有意な減少

は確認されなかった。ところが，例年は植物プランクトンによって濁ったままの状態である池水が，2017 年は 6 月まで濁ることがなく，池底が見える状態を保っていた。原因は不明だが，排水による洗い流しや消石灰の散布，冬季の低温による殺藻作用などが影響したと考えている。水の濁りが消えたことで土壌シードバンクによる沈水植物の復活を期待したが，残念ながら沈水植物は確認できなかった。試験的にエビモを池の 4 地点に導入してみたが，翌日にはアメリカザリガニにすべて食害されてしまった。このため沈水植物の回復がアメリカザリガニによって阻害されている可能性が考えられる。

その他の変化として，2007 年以来消失していたヒシ群落の自然回復が確認された。また，チョウトンボの飛来も 5 年ぶりに確認された。池干し以前には記録のない現象としては，アズマヒキガエルの幼生が大発生し，5 月上旬には無数の幼体の上陸が観察された。6 月中旬には，水面が緑色のアオコのようなもので覆われたが，顕微鏡による観察でミドリムシの 1 種の異常発生であることがわかり，10 日間ほどの短い期間で消失した。また，水底に太陽光線が届くようになったことにより，糸状緑藻の大発生が起き，7 月以降は底から剥がれた糸状緑藻群落の一部が水面に大量に浮ぶ状態となった。

「とんぼの池」における生息域外保全の試み　池干し後の調査で産卵母貝となるヌマガイの個体群が残っており，競合するタイリクバラタナゴが確認されなかったことから，「とんぼの池」における生息域外保全の第一段として，茨城県霞ヶ浦産のゼニタナゴの導入を試みた。ゼニタナゴは環境省のレッドリストで絶滅危惧 IA 類に分類されており，霞ヶ浦においては 2001 年以降記録がなく，野生絶滅の可能性が高いとされる[3]。霞ヶ浦産ゼニタナゴの継代保全を行っている市民団体「土浦の自然を守る会」よりゼニタナゴ 39 個体（雌雄の内訳は不明）を譲り受け，2017 年 9 月に「とんぼの池」に導入した。

普及活動　2017 年 11 月 19 日の魚類の捕獲作業では，「とんぼのいけの池干し大作戦」というイベント名でボランティアを募集した。残念ながら当日は悪天候のため，子供の参加を中止したが，100 名の定員に対して 130 名の応募があり，興味と関心の高さが伺えた。また，このときの作業の様子を撮影・編集した普及用の映像を作製し，2017 年 4 月より常設展において特別展示を行っている。本映像は，2018 年 5 月現在で延べ 50 万人以上の来館者が視聴した。

また，博物館で開催された第 67 回企画展「外から運ばれて来た生き物たち－You はどうして日本へ？－」（2016 年 10 月 8 日～2017 年 1 月 29 日）おいて，毎週日曜日に 2 回，来館者に対して外来生物の問題や本活動の目的について解説する講座を開催した。

4. まとめ

本活動における外来魚類駆除の成功により，「とんぼの池」での稀少魚類の生息域外保全が可能となった。今後は，茨城県内において生息数が著しく減少しているアカヒレタビラの導入や霞ヶ浦産ゼニタナゴの追加導入を計画している。「とんぼの池」の水質の改善には水生植物の再生が必要不可欠であるが，そのためにはアメリカザリガニの生息個体数を低密度に抑制しなければならない。他にも糸状藻類の大発生やアカミミガメの大量に繁殖しているなどの問題もあり，植生回復と水質改善については，今後も試行錯誤を重ねていく必要がある。

偶然ではあるが，2017 年に外来生物が生息する町中や公園などの池の水を抜いて調査するテレビ番組が人気を博し，本活動に対しても注目が集まった。展示映像を熱心に見ている来館者や活動に対する問い合わせも増え，自然保護や生物多様性保全の意義についての普及啓発に予想以上の効果があったと感じている。

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Ecotourism Facility Assessment and Conservation Perspectives of Boga Lake by Indigenous Community

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Keywords: Ecotourism, Boga Lake, Bandarban, Indigenous Community

ABSTRACT

Boga Lake, the highest mesmerizing natural beauty of Bangladesh; 2700 feet above the sea level. It is about 2000 years old hill enclosed natural Lake covering total 15 acres of land. The Lake is about 65 km away from the Bandarban town & 15 km away from Ruma Sadar Upazilla. The Lake is average 38 meters deep. Bagachara is the deepest part with 153 meters. There are small tribal communities: the Bawm, Tripura and Khumi located around the Lake. Along with the original inhabitants, Marma and Murong indigenous communities are also noticed on the way or in the surrounding areas of the Lake. The only way to the Lake by Chander Gari or a private vehicle, followed by boat riding and walk through the zigzag hilly way. Tourist can hire local tour guide from Ruma or Bandarban. On the way tourist have to register their details in the respective security camp of Army. Only 20 cottages with TK. 100.00 per person is the only way to stay in the Lake side area. Foods are also arranged by the cottages, mostly traditional Bengali or community special menu. The area is rich in biodiversity especially plant diversity. But due to the acidity of the Lake, there is no immediate vegetation on its banks and no fish was recorded in its waters either. Mostly the Lake is a unique beauty, pristine and heritage only because of the conservation practices of community people with belief and sustainable resources use which promotes conservation education values.

1. INTRODUCTION

Boga Lake is called the highest natural Lake of Bangladesh. It is about 2700 feet above the sea level. Boga Lake is about 2000 years old hill enclosed natural Lake covering total 15 acres of land. The origin of the name Boga come from the local word “BAGA” means fire of Dragon. Boga Lake is familiar through different local names among the local habitats. Suppose Bagakain Lake, Bagakyne Lake or Baga Lake along with Boga Lake.

The location of the Boga Lake is some kind of different than other common Lakes and water reserves of Bangladesh. Boga Lake is bounded by deep bamboo bushes from its three sides and high hill in rest side. One of the peaks of the mountain range Politai, in Naitong mauza, situated in the renowned upazila Ruma of Bandarban , Chittagong is considered the politically recognized location of Boga Lake in Bangladesh. It takes about 29 km way from the eastern bank of the famous river Shankha of Bandarban to reach to Boga Lake. Boga Lake is about 65 km away from the Bandarban town. Boga Lake is registered to be 1500fts above sea level & 15km away from Ruma Sadar Upazilla of Bandarban. Boga Lake has covered total 15 acre areas to attract the tourists and common people indeed. The Boga Lake is average 38 meters deep. Bagachara is the deepest part of Boga and it is 153 meters deep. There is a small village just beside the Lake. The Boga Lake is either rectangular or funnel shape.

Some Geologist argue that the Boga Lake have origin from a devastated earthquake. Some geologists believe that the origin of Boga Lake from a dead volcano and the collection of rain water in the cave area resulting the creation of Boga Lake. The nature of the water and the soil of the Boga Lake also support their opinion. Due to high

acidity in water, Boga Lake is not appropriate for living any kind of common flora and fauna. But it is interesting that no travelers miss the chance to take a hot bath in the beautiful Lake to refresh their soul.

At present, Boga Lake has placed as a heavenly place of beauty and great pleasure for those travelers who love adventure and to face challenging travel. That is why a number of tourists from home and abroad make their destination to the paradise of nature every year. Boga Lake is as a heaven where nature has opened up all its beauty and charms without any hesitation for the tourists. The bamboo and wild bushes around the Lake, the grass and the known and unknown amazing wild flowers and other plants contribute as like verse of a great poem of beauty and charms. Boga Lake is such a magnetizing place which must astonish the tourists with amazing landscape, zigzagging thin path-way and all other wild elements around the Boga Lake.

2. METHOD

The assessment and data collection was conducted in the month of November and December 2017. Two field visits was conducted in both months with the duration of 6 days in each. Eco-tourism facilities assessment was done based on feasibility study of some basic aspects for instance, communication, accommodation, food, tour guide, community involvement etc. Consultation meeting with local community in person and small group was conducted to get data about the role of the Lake and conservation approaches by the indigenous groups.

3. RESULTS

There are small indigenous communities like the Bawm, Tripura and Khumi located around the Lake. Along with the original inhabitants of Boga Lake, there are some other diverse indigenous communities are noticed on the way or in the surrounding areas of Boga Lake. There is also a church for the local people. Most of them are Christian.

Boga Lake is 15 kilometer away from Ruma Sadar Upozilla of Bandarban District. The only way to make a trip from Bandarban to Ruma Upozilla by Chander Gari (public jeep) or a private vehicle. Then by public bus or again Chander Gari to go Koikhong Jhiri. It takes 1-1.50 hours to reach koikhong Jhiri. Later on a hired boat will take approx one hour journey to Koikhong Jhiri. And finally walk through the zigzag hilly way to Boga Lake. In the rainy season, it is quite difficult to stroll beside the Lake. Still no tour operators are in action. But tourist can hire local tour guide from Ruma or in Boga Lake and the guides will take the payment with happily whatsoever tourist pay. On the way they have to register their name, contact address and other details in the respective security camp of Army. It is mentioned that tourists are not allowed to leave Ruma for Boga Lake after 4 pm.

There are around 20 cottages located in the BogaLake surrounding. The most popular cottage is Siam Didi's cottage along with Laram's cottage and Robert cottage. Accommodation cost is per head basis TK. 100.00 only. Foods are also arranged by the cottages.

The area is rich in biodiversity especially plant diversity. But due to the acidity of the Lake, there is no immediate vegetation on its banks and no fish was recorded in its waters either.

4. DISCUSSION

In the northern side of the Boga Lake their lives the Marma indigenous community which is renowned as the largest indigenous community of our country indeed. Again, there are also seen Murong communities in the Bog Lake area. And all these diverse communities form an act as a common community which is well known as Boga Lake para. Among the inhabitants of Bog Lake para the Bawm and the Murong indigenous people are famous for their friendly attitude to welcome the tourists and trekkers warmly. Foods are fresh and hygienic. Food menu

includes plain rice, potato vorta, pulse, egg fry and vegetables pricing TK. 100.00 only. There is no need to advance reservation. Before entering BogaLake, tourists need to take permission from army camp situated there. Since there are limited cottages in Boga Lake, the tourists or travelers manage their foods, drinks and other stuffs from local indigenous communities.

The astonishing beauty of Boga Lake is undoubtedly its first attraction for the travelers and trekkers to make a real adventurous journey with a smiling face. But it is also cannot be denied that the way of treating of the local inhabitants also add a breathe of satisfaction to them in the Boga Lake area. In that unknown unfriendly area from food to every single thing the new comers have to rely on the indigenous communities. And to their utter surprise they just not only manage all the stuffs with a happy smiling and a helping hand but they also enjoy it.

Apart from a very few exceptions the common tribes really follow the traditional Bengali culture. They lead basically very simple life. Most of them prefer or have to prefer cultivation as their profession. There is a common tradition of zum cultivation which is a renowned one in the Bog alto. They form usually large families and They are pretty much well behaved to their guests of Boga Lake and try to make them satisfied to their hearts content. They feel free to share their lifestyle in the Boga Lake.

5. CONCLUSION

Nature lovers always feel a thirst inside for beauty, thrill and enchantment. And the holy nature has bestowed Bangladesh with an overwhelming and unparallel creature which is publicly known as Boga Lake. Boga Lake is considered as a source of wonder, unlimited beauty and adventure for the nature`s lovers and travelers. Boga Lake is waiting with its unique beauty for those adventurous travelers who just not only want to satisfy their eyes with artificial and tedious natural beauties but also want to fill their heart with eternal joy and thrill to innovate their restless mind. And it has also conservation education values as it has been managing by the indigenous community with their belief and sustainable resources use.

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富士五湖湖沼群の特性を用いた環境教育プログラムの開発

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キーワード:富士五湖, 環境教育, プログラム, 湖沼生態系

抄録

富士五湖湖沼群は, 富士山北麓に位置し, 富士山を中心とする世界文化遺産の構成要素でもある。東から山中湖, 河口湖, 西湖, 精進湖, 本栖湖の 5 湖からなり, 湖の最大水深, 面積, 平均透明度, 栄養塩濃度等がそれぞれ異なっている。このように特徴が異なる湖沼を, 自動車を利用すれば 1 時間以内で観察できる湖沼群は日本国内では珍しく, 湖沼学や湖の生態系を学ぶ上では貴重な学習資源と考えられる。

本研究では, 本湖沼群の特性を生かして, 主に小学生を対象とした環境教育プログラムを開発することを目標として, カリキュラム構成や疑似体験ゲーム等の学習方法を検討するとともに試行を行った。その結果, 近傍にありながら透明度や水色が異なるという富士五湖の特性は学習の導入に有効であると考えられた。その一方で, 湖沼生態系についての理解を深めるためには, 疑似体験学習方法の利用が有効であると考えられた。

1. はじめに

地球規模の環境問題が顕在化している今日, 持続可能な開発社会を構築するための教育の重要性が増している。こうした状況の中, 2008 年に告示された文部科学省の学習指導要領[1]では, 環境教育の視点が強化され, 環境の保全に貢献し, 未来を拓く主体性のある日本人を育成することを目的として, 各教科において具体的な目標が提示された。中でも小学校 6 年生の理科においては,「生物間の食う食われるという関係などの生物と環境とのかかわり」が新設された。

その一方で, アメリカの陸水学者であるフォーブスが「小宇宙としての湖」と表現しているように, 湖はそれ自身が一つの生態系を形成していると考えられており, 生物と環境との関わりを理解する上で効果的なフィールドと考えられる。

湖を対象とした環境教育は, 琵琶湖[2],[3], 霞ヶ浦[4],[5]で事例が見られ, 北海道内でも大沼[6], 洞爺湖[7]等での実施報告も見られるが, 富士五湖湖沼群をフィールドとした報告は見られない。

山中湖, 河口湖, 西湖, 精進湖, 本栖湖からなる富士五湖湖沼群は, 世界文化遺産に登録された富士山の北麓に位置し, その構成要素にもなっている。表 1 に示したとおり 5 つの湖は面積, 容積, 水深, 透明度等において多様性に富んだ湖沼群であり, この特性を用いることで湖の環境教育が効果的に実施できると考えられた。

本研究では富士五湖を題材に, 小学生を対象とした学習プログラムの開発を試みたので報告する。

2. 方法

本研究での教育プログラムの作成は以下の条件で行い, 導入(質問), 湖の生物の生態系, 疑似体験(シミュレーションゲーム), 湖での体験及び観察, 討議の 5 ステージの構成とした。なおこのプログラムを実施するための事前学習として, 光学顕微鏡の使用方法の説明を小学校において行っていただいた。

表 1 富士五湖湖沼群の概要

Lake	Altitude	Surface	Volume	Max Depth	Ave. Depth	Ave. Tr.	Ave. Color
Motosu	900 (m)	4.70 (㎢)	319.1 (X$10^6$$m^3$)	121.6 (m)	67.9 (m)	15.1 (m)	3.5
Sai	900	2.12	80.9	71.7	38.5	7.5	7.3
Kawaguchi	830	5.70	53.0	14.6	9.3	4.8	10.0
Yamanaka	980	6.78	63.9	13.3	9.4	4.1	11.4
Shoji	900	0.5	3.5	15.2	7.0	3.2	12.6

対象及び人数:小学校 6 年生 25 名

実施場所:山中湖または河口湖

実施時期:7 月下旬

実施時間:4 時間(13:00～17:00)

3. 結果と考察

1) 作成プログラム

試行したプログラムの例を表 2 に示した。導入部分はパワーポイントファイルを用いて説明を行った。最初の導入部では富士五湖湖沼群の特徴についての説明を中心に行い，湖により透明度や水の色(水色)等が異なることを視覚的に捉えることに留意した。湖による違いを理解するためには，実際に複数の湖へ行くことが理想的であり，プログラム実施時間が許すのであれば，事前体験学習(たとえば午前中に)として，透明度が高く，水色がほぼ青色の本栖湖と，別の湖を遊覧船などで体験しておくことが有効であると考えられた。その点で富士五湖湖沼群は近傍に位置することから，他の湖沼(群)にはない利点を有しているものと考えられた。

特に湖の水色の差は視覚的に捉えやすいため，違いはなぜ生ずるのかという問いかけは，その後の発展には有効なものとなった。

2) 学習の目標設定

本研究での環境教育の目標として，次の 3 項目を設定した。

① 湖の中の生態系(食物網)を理解する

② 湖の中の生物の役割を考えられる

③ 湖の生物のバランスを保つ方法を考えられる

表 2 に示したプログラム例では③を目標としたが，どの目標に設定するかは，プログラムの実施時間と，対象とする生徒の予備知識の状況により選択する必要がある。本研究では③を設定した事例が最も生徒の討議が活発であり，様々な方法が考え出された。さらに③の目標を設定した場合，次に述べるシミュレーションを班別討議の後に行うことで，生徒自身が考えた方法を検証することができ，より効果が高まると考えられた。

3) 疑似体験(シミュレーション)

湖のなかの生物について整理をする中で，生態系，特に食物網の考えを説明し，生物と湖の水色との関係を班別に考えて仮説を立てた後に，シミュレーションを行うことで仮説の検証を行うことができる。

表 2 環境教育プログラムの例

所要時間	ねらい	内　容	生徒の活動内容
15(分)	導　入	・湖にはそれぞれ違いがあることを理解し、その理由を考える ・湖の色をとおして、湖を構成するものは何か気づかせる	・水の色はなぜ違うのか、判別に考えてみる
30	発　展	・湖の構成要素のひとつである生き物にポイントをしぼり、生き物のかかわりを体感する	・ゲームを行い、湖の色がどのようになったか見比べる
10	小まとめ	・なぜ構成する生物の数により違う結果が得られたのか考えよう	・N, P カードやミジンコカードが多い場合の差を確認し、その原因を考える
5	体験学習導入	・実際に湖に行って水や生物を観察してみよう ・具体的な作業の提示 透明度の計り方 パックテストの使用方法 プランクトンの採取方法	・説明を聞く
45	体験・観察	・実際の湖を観察してみよう ・各種測定 ・その他気がついたことを記録する	・観察を行なう ・採水を行う
45	室内観察	・顕微鏡で観察する ・パックテスト	・プランクトンの観察 ・水質の測定
30	班別討議	・実地観察で気がついたこと、疑問に感じたことを共有する	・班別で討議する テーマ例： 「湖の色を青くするにはどうすればよいか」
15	全体振返り	・各班から出された気づきや考えを全体で共有する	・発表をする ・発表を聞く

シミュレーションの方法として，

① 生物追いかけっこゲーム

② 生物カードゲーム

③ 食物連鎖シミュレーションソフトウェア

の 3 つの方法を用いた。①のゲームは生徒が魚類，動物プランクトン，植物プランクトンなどの役になり追いかけっこを行うことで，食物網を再現するものである。この方法は遊びの要素が強いため，生徒が喜んで活動する反面，広い場所を必要とすることと，衝突事故等が発生する可能性があるという点で配慮が必要である。

②のカードゲームは湖の生物を描いたカードを用い，食物網の上位者カードを出すことで手持ちのカードを増やし，ポイントを競うと言うもので，①と同様に遊びの要素が含まれているので，熱心に取り組む姿勢が見られた。しかしカードで生態系を再現しようと試みることにより，ルールが複雑化するので，実施にいたるまでの事前説明に時間を要する短所があった。

③のシミュレーションソフトとして，ウェブ上で公開されている食物連鎖シミュレーション“rensa2”を用いた[8]。食物網の上位者等の条件を変更することで，生物バランスの変化をシミュレートできるアプリケーションであり，視覚的には最も分かりやすいが，陸上生物を対象とした設定であることと，適切な条件設定が難しい点で問題があった。この他に湖の生態系を扱うソフトウェアーとして”ダーウィンの箱庭”が公開されているが，短時間での実施は難しく，本研究では用いなかった。

いずれの方法においても，シミュレーションは湖の生態系の理解を高めるために有効な手段と思われた。

4. 今後の課題

本研究では小学生を対象としたため，湖の透明度や水色の違いという，比較的分かりやすい視点を導入とした。さらに，透明度や水色の季節変化に言及するなど，さらに内容を深めることにより，教育の対象を中学生，高校生へと広げることが可能と思われる。今後はより効果的なシミュレーション手法の確立とともに，学習対象の幅を広げることに取り組む予定である。

5. 結論

本研究では，富士五湖湖沼群の特性を生かして，主に小学生を対象とした環境教育プログラムを開発し，カリキュラム構成や疑似体験ゲーム等の学習方法を検討するとともに試行を行った。その結果，近傍にありながら透明度や水色が異なるという富士五湖の特性は学習の導入に有効であると考えられた。その一方で，湖沼生態系についての理解を深めるためには，疑似体験学習方法の利用が有効であると考えられた。

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P8-12

Water Quality Research and Water Environmental Soundness Index Estimation of Lake Inba (FY2012-FY2017)

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Key words: Lake Inba, Water quality, Water Environmental Soundness Index, Environmental education, Circle activity

ABSTRACT

Lake Inba is a freshwater lodging swamp located in northern part of Chiba prefecture. Since the 1960s, the quality of the swamp deteriorated with the increase in the catchment population. It has been ranked in the worst five times in the swamp water quality nationwide. In this report, as part of the activities of the Institute of Environmental Science, Chiba Institute of Technology, we investigated the water quality situation of Lake Inba. By understanding thewater quality characteristics of Lake Inba from the data for the six years from 2012 to 2017 and by conducting a survey based on the "Water Environmental Soundness Index", how people perceive and feel to Lake Inba changes It was aimed at grasping what to do. According to the survey results for 6 years, the Mizukusaen tends to be more alkaline than the Furusatohiroba. COD fluctuates in summer and winter, but it has remained almost flat for 6 years. In addition, Lake Inba is a nitrogen-rich lake, so it is necessary to reduce nitrogen fertilizer flowing out from basin area. According to the Water Environmental Soundn ess Index, the score in comfortable waterfront parameters was slightly lower. But overall, viewpoint and way of thinking about Lake Inba have not changed significantly in these 6 years.

1. INTRODUCTION

Lake Inba is a freshwater lodging lake located in northern part of Chiba Prefecture. Lake Inba is a designated lake in the Law Concerning Special Measures Concerning the Conservation of Lake Water Quality, spanning the western part of Chiba Prefecture, Yachiyo City, Sakura City, Narita City, Inzai City, Inba-gun Shisui Town, Sakae Town. It is a source of water for daily life in Chiba City, Funabashi City, Narashino City. Since the 1960s, the quality of the swamp deteriorated with the increase in the catchment population. It has been ranked in the worst five times in the swamp water quality nationwide. In this report, as part of the activities of the Institute of Environmental Science, Chiba Institute of Technology, we investigated the water quality situation of Lake Inba. By understanding the water quality characteristics of Lake Inba from the data for the six years from 2012 to 2017 and by conducting a survey based on the "Water Environmental Soundness Index", how people perceive and feel to Lake Inba changes It was aimed at grasping what to do.

2. CHIBA INSTITUTE OF TECHNOLOGY ENVIRONMENTAL SCIENCE RESEARCH GROUP

The Chiba Institute of Technology Environmental Science Study Group belongs to the Cultural Association Circle, and the number of members is 16 (as of 2017). We also exhibits in Echomeesse in Chiba (September). As a motive for each member to enter, there are many "interested in water quality". Therefore, many students who are interested in environmental problems are active.

3. MATERIALS AND METHODS

3.1. Research point



Fig. 1 Lake Inba and research point

This survey was carried out at two places of the western Furusatohiroba (Fig.1①) and Mizukusaen (Fig.1②).

3.2. Survey method

In the water quality survey, environmental water was collected in a water sampling bucket and water quality parameters was analysed. The measurement parametars were water temperature, transparency, pH, DO, COD, NO_3-N, NO_2-N, NH_4-N, and PO_4-P. Water temperature was measured with alcohol thermometer. The transparency was measured with Clean measure. COD, NO_3-N, NO_2-N, NH_4-N and PO_4-P were analyzed by pack test. The pH and DO were measured by equipment. The Water Environment Soundness Index was evaluated on the appearance of the waterside according to the Ministry of the Environment's " Water Environmental Soundness Index (Mizushirube)".

4. RESULT AND DISCUSSION

The results obtained from the survey carried out from May 2012 until November 2017 were shown in Figs. 2 to 9.

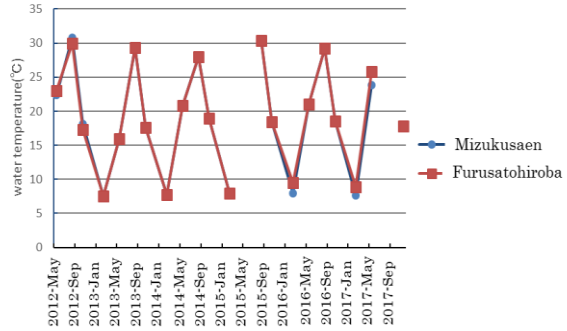

Fig. 2 Time course of water temperature

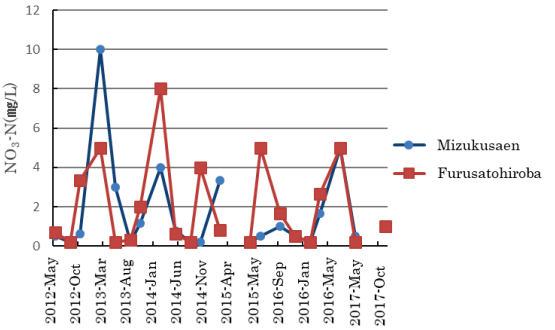

Fig. 3 Time course of transparency

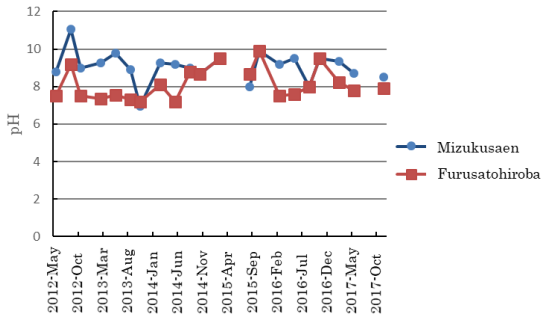

Fig. 4 Time course of pH

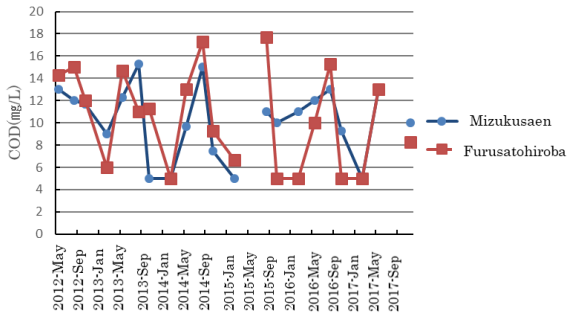

Fig. 5 Time course of COD

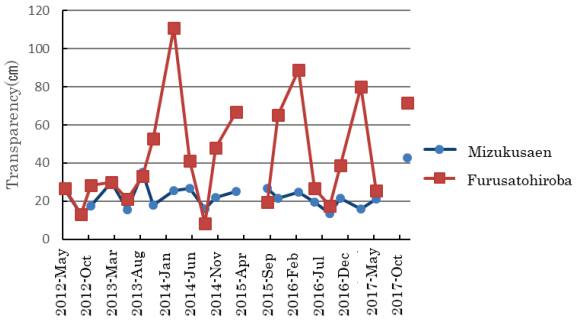

Fig. 6 Time course of NO_3-N

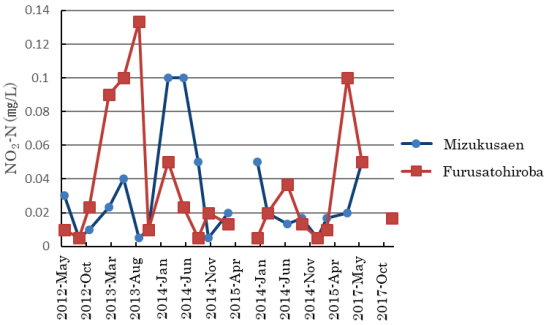

Fig.7 Time course of NO_2-N

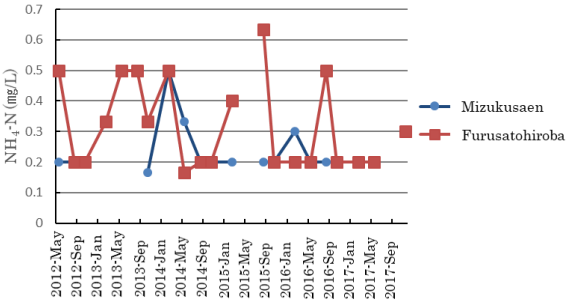

Fig.8 Time course of NH_4-N

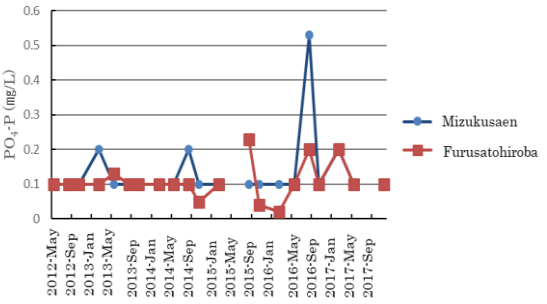

Fig.9 Time course of PO_4-P

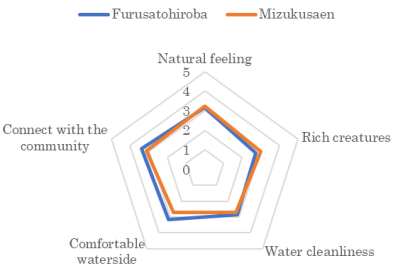

Fig.10 Mizushirube radar chart (2012)

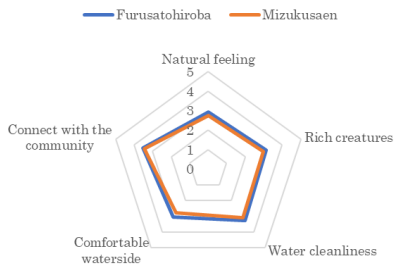

Fig.11 Mizushirube radar chart (2017)

In addition, Fig.10 and Fig.11 show the results of the Water Environment Soundness Index (Mizushirube) in 2012 and 2017.

Transparency tends to be high in winter and low in summer. On the whole, the transparency of furusatohiroba is higher than that of water garden and it can be said that the water is clear. Mizukusaen is more alkalinity higher than Furusatohiroba in pH. It is thought that phytoplankton is likely to propagate because nutrient salt tends to stagnate in closed Mizukusaen. Therefore, it is considered that the pH is high because photosynthesis by aquatic plants and phytoplankton absorbs CO_2 in the water and the amount of carbonate ion decreases.

COD tends to increase in summer when the water temperature rises. But almost flat in 2012 ~ 2017. It was thought that COD is lower than the Mizukusaen in which the flowing Furusatohiroba is not more fluid. But both spots had been around 8 to 16 mg/L. Furusato plaza is the estuary part with the Kashima River which is the largest inflow river to Lake Inba. The river basin of Kashima River is in Chiba city in urban area and in Yatimata city (less than 30% penetration rate of sewerage as of end of March 2009) etc, and it is considered to be the point where domestic wastewater enters a lot. Also, The environmental standard value of COD is 3 mg /L or less in the case of Lake Inba, and it is still a difficult situation to achieve. But if sewage maintenance progresses, it is thought that it will improve in the future.

NO_3-N, NO_2-N, and NH_4-N tend to increase in winter and decrease in summer. This means that in the process of actively propagating phytoplankton in the summer season, it ingests nitrogen as nutrition, and it is thought that in the winter, the sedimented plankton is decomposed and returns to the water again.

Overall, PO_4-P is around 0.1 mg/L. But since the minimum value of PO_4-P in the pack test is 0.1 mg /L, it may actually be less than 0.1 mg/L. Therefore, in the future, it is necessary to investigate more detailed values by using pack test for low concentration.

The N/P ratio was calculated by dividing the sum of the values of NO_3-N, NO_2-N and NH_4-N by the value of PO_4-P, and is shown in Fig. 12. Generally, It is appropriate when N/P is 10 , when it is 10 or more it is said to be excessive nitrogen, and it is said to be excessive phosphorus when it is 10 or less. In the case of Lake Inba, it tends to return more than 10 in the winter season and to return properly in summer. According to Fig. 10, since the value of PO_4-P exceeds the environmental reference value, it is found that the nitrogen

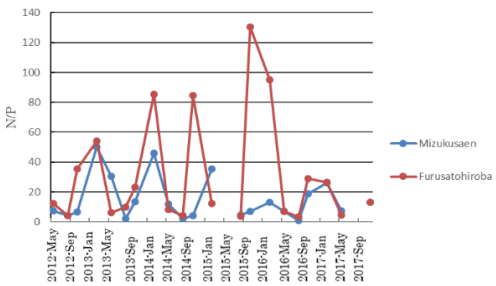

Fig. 12 Time course of N/P ratio

component is a very large value with respect to the phosphorus component, and Lake Inba is a nitrogen-rich lake.

The amount of pollutant of nitrogen and estimated as phosphorus discharged to Lake Inba is decreasing due to popularization of sewer systems, etc. But Surface source drainage discharged from fields, urban areas, etc. tend to increase rather. Approximately 40% of the land in the Lake Inba is a farm and a paddy field. For exanple, reduction of nitrogen fertilizer is the solution. The use of fertilizer of a type with a small amount of nitrate ion flux and cultivation method such as multi cultivation are effective for reducing the runoff amount.

According to the Water Environmental Soundness Index, parameters in "comfortable waterside" have been decreasing in Furusatohiroba in 2017 compared to 2012. In Furusatohiroba, garbage is noticeable along the coast. It is thought that the score dropped with a question such as "Was you seeing the garbage?" or "Is the river and surroundings beautiful?" However, according to a comparison between the two graphs, it is considered that people's viewpoint and way of thinking about Lake Inba have not changed so much in 6 years.

5. CONCLUSIONS

1) According to the survey results for 6 years, the Mizukusaen tends to be more alkaline than the Furusatohiroba.
2) COD fluctuates in summer and winter, but it has remained almost flat for 6 years.
3) Lake Inba is a nitrogen-rich lake, so it is necessary to reduce nitrogen fertilizer flowing out from basin area.
4) According to the Water Environmental Soundn ess Index, the score in comfortable waterfront parameters was slightly lower. But overall, viewpoint and way of thinking about Lake Inba have not changed significantly in these 6 years

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P8-13

題名：霞ケ浦と諏訪湖における下水道普及率と汚濁物の関係

宮内正行
一般社団法人霞ケ浦市民協会

キーワード：霞ヶ浦、諏訪湖、下水道普及率、汚濁物濃度、ヒステリシス

抄録

「霞ヶ浦の水質汚濁改善は、30 年以上の間、多くの人の努力にも拘らず改善の目処が立たない。」ことが認識されている。諏訪湖では約 30 年間にわたる水質浄化の努力の結果、一定の成果を得ている。そこで、霞ヶ浦と諏訪湖との比較を試みた。 両湖ともに、下水道・浄化槽整備を水質浄化策の中心に据えており、両湖の DATA を WEB 上で入手できる下水道普及率（以下普及率）に着目し、普及率と汚濁物濃度(COD,T-N,T-P)との相関性を検討した。その結果、諏訪湖（現在、普及率 98%以上）の 3 種の汚濁物濃度は普及率 60%程度までは変動を伴いながら低下し、COD は普及率 80%以上では顕著に低下することが認められた。他方、霞ケ浦では普及率 65%程度まで上昇してきたが、3種の汚濁物濃度に低下傾向は認められない。諏訪湖での経験を考えると、霞ケ浦でも普及率 80%以上に達すると汚濁物濃度低下が始まると期待できる。

1. はじめに

「霞ヶ浦の水質汚濁改善は、30 年以上の間、多くの人の努力にも拘らず改善の目処が立たない。」ことが認識されている。他方、諏訪湖は同時期の 1980 年代後半に水質保全計画を策定し、水質浄化に一定の成果を上げてきた。[1]　この諏訪湖での経験を学ぶために、両湖の比較を試みた。

2. 方法

霞ヶ浦の流域人口は約 100 万人で、諏訪湖では約 20 万人、貯留量はそれぞれ 8.4 億トン、0.6 億トンである。土地利用状況（表1）は山林の占める割合が大きく異なり、霞ヶ浦では約 44%、諏訪湖 74%で、諏訪湖は単純系の湖と言える。両湖ともに、30 年以上にわたって水質浄化に務めてきており、それらの主な対応策は下水道・浄化槽整備で、下水道・浄化槽整備の進捗は下水道普及率にて表現され、その成果は汚濁物濃度(COD,T-N,T-P)低下として把握されている。

表2に整理したが、この間で COD 全体の負荷量は削減されており、その多くは生活系負荷量が占めているので、下水道普及率に着目してCOD汚濁負荷量・濃度を議論することは可能であろう。

そこで、この約 30 年間の下水道普及率と汚濁物濃度の関係を両湖間で比較し、COD 汚濁負荷量と COD 濃度の関係も比較した。 なお、WEB 上で入手できる両湖の「湖沼水質保全計画」および「関連文書」のDATAを用いた。[1] [2]

表1　土地利用状況（%）

	水田	畑	市街地	山林	計
霞ケ浦	22	16	18	44	100
諏訪湖	6	4.6	15.3	74.1	100

表 2　COD 負荷量比較結果

		COD 負荷量(T/日)		COD
		全体	生活系	(mg/L)
霞ケ浦	1985	31.7	13.6	8.2
	2015	24.6	5.4	8.2
	削減量	7.1	8.3	
諏訪湖	1991	5.4	1.5	6.5
	2016	3.4	0.1	4.4
	削減量	1.9	1.4	

3. 結果

全国的に湖沼の水質汚濁が進む中、霞ケ浦と諏訪湖いずれも 1960 年代に過度の富栄養化現象によるアオコ発生が相次ぎ、1970 年代から流域下水道建設が始まり、水質浄化事業が始まった。全国的に湖沼の水質改善が進まない中、1984 年に「湖沼水質保全特別措置法」（湖沼法）が制定された。 霞ヶ浦は 1985 年に、諏訪湖は 1986 年に指定湖沼になった。「第 1 期湖沼水質保全計画」は霞が浦で 1986 年に、諏訪湖では 1987 年にスタートした。 以後 5 年ごとに改定されて、現在はそれぞれ、第 7 期期間中です。両湖の 1970 年代からの下水道普及率推移を図1に整理した。[1] [2]

諏訪湖で下水道普及率は 1990 年代後半には 80%台に、現在は 98%台に到達している。霞ヶ浦では現在 65%以上に上昇してきた。この間の、下水道普及率と汚濁物濃度の関係を図2～図4に示す。

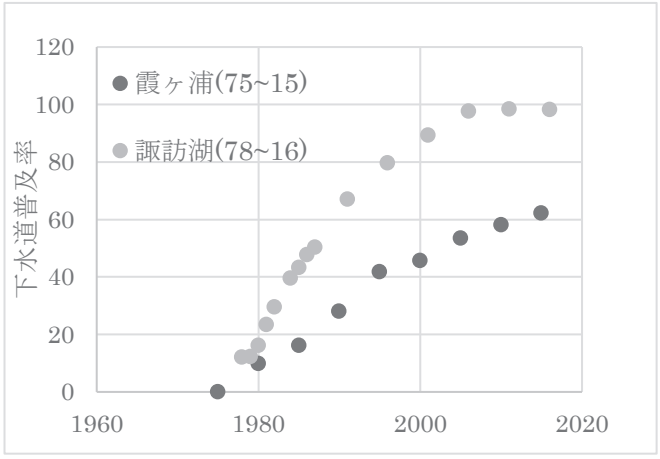

図 1 下水道普及率推移（霞ヶ浦、諏訪湖）

諏訪湖の 3 種の汚濁物濃度は普及率 60%程度までは変動を伴いながら低下する。 COD は普及率 80%以上では顕著に低下し、2016 年には 4.4(mg/L)まで低下した。T-N と T-P では、下水道普及率 60%以上になると単調に低下し、2011 年には、それぞれ 0.77(mg/L), 0.43 (mg/L)まで低下した。従い、下水道普及が諏訪湖水質改善に主たる要因と考えられる。他方、霞ケ浦では普及率 65%程度まで上昇してきたが、3 種の汚濁物濃度に低下傾向は認められず、諏訪湖での経験と異なる。

次に、COD 汚濁負荷量と COD 濃度の関係を図5～図 6 に示す。諏訪湖では、COD 負荷量と COD 濃度の相関が認められ,合理的である。しかし、霞ケ浦では、

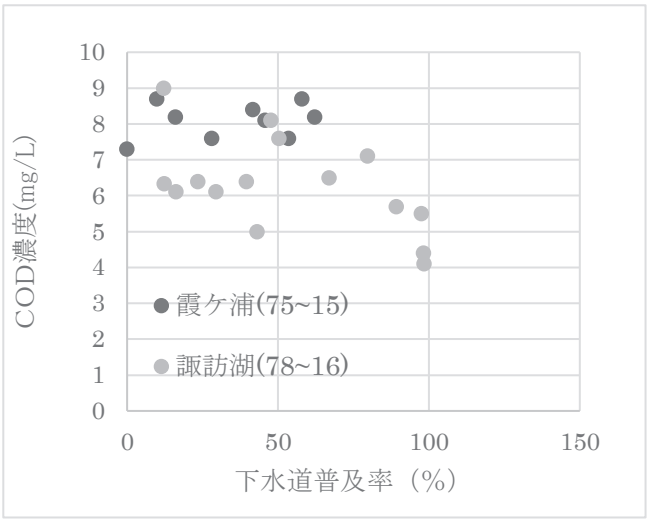

図2 下水道普及率 vs COD濃度

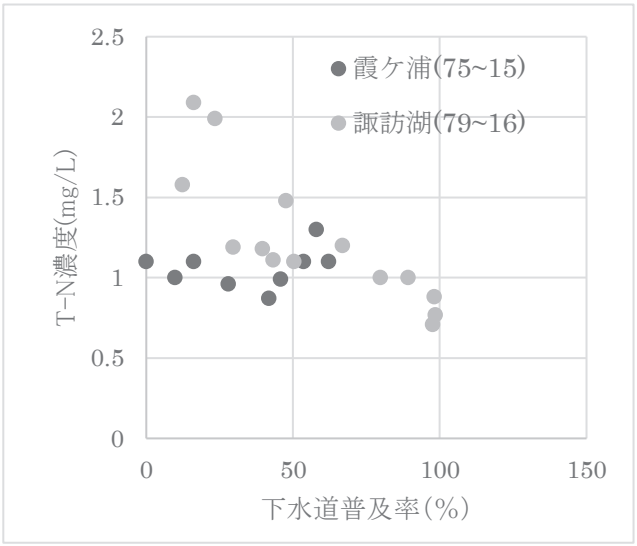

図3 下水道普及率 vs T－N濃度

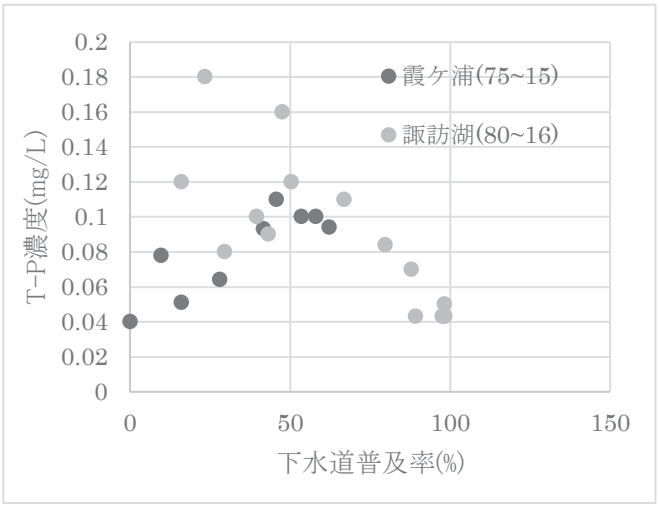

図4下水道普及率 vs T－P濃度

その相関が認められない。両湖で流域人口・土地利用の状況・湖の容量・汚濁負荷源の割合等異なるが、両湖

で、この相関の有無に差のある理由は判然としない。

すでに述べたように単純系の諏訪湖では、「下水道普及に連れ、湖沼へ流入する汚濁負荷量は削減され、結果として汚濁物濃度が低下した。」と言える。しかし、現時点では複雑系の霞が浦では異なるようだ。

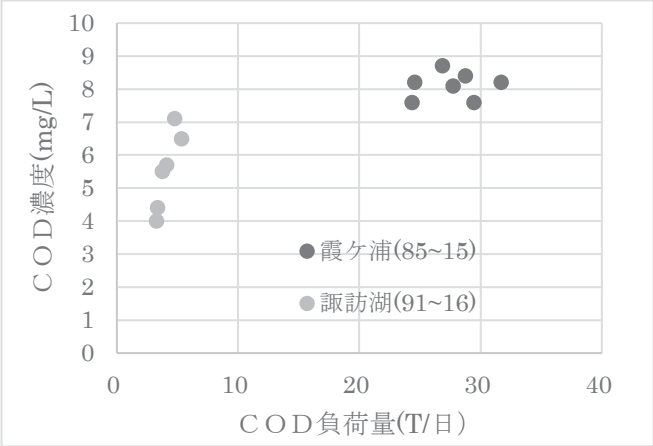

図5 COD負荷量 vs COD濃度（霞ヶ浦と諏訪湖）

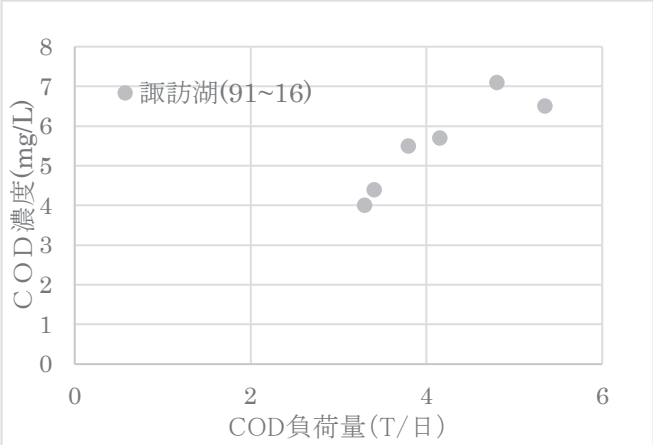

図6 COD負荷量 vsCOD濃度（諏訪湖）

4. 考察

汚濁物が湖沼へ流入、水面へは降水・落下し、そして湖内を経て、流出していく汚濁物経路を考えると、両湖の相違は湖内での汚濁物の挙動にあると考えられる。山林からの流入水の多い、つまり単純系の諏訪湖では、流域人口が多く、農業・畜産の盛んな、複雑系の霞ヶ浦とはだいぶ異なるのだろう。 複雑系で、極限まで汚濁しきった霞ヶ浦では、湖内での汚濁物挙動が重要で、これを考慮に入れたモデルが必要であろう。

汚濁しきった霞ヶ浦での水質回復過程を考える時、中村太士教授（北大）のヒステリシスモデルが参考になる。[3] （図7） それは、「環境汚濁過程では、環境負荷の増加に伴い環境が悪化していく。そして、ついに環境が極限まで悪化しきった後に、環境回復させる過程では、環境負荷が多少低減しても環境指標に直ちには反映されず、かなりの程度まで環境負荷が削減された時始めて環境指標が改善され始める。」と理解しました。このモデルで今後の霞ヶ浦の水質回復を考えると、「泳げる霞ヶ浦」実現が期待できそうだ。

諏訪湖では下水道普及率 80%以上で、COD が顕著に低下しているので、霞ヶ浦でも下水道普及率が 80%以上のレベルに達してはじめて、CODが低下始めると期待できる。

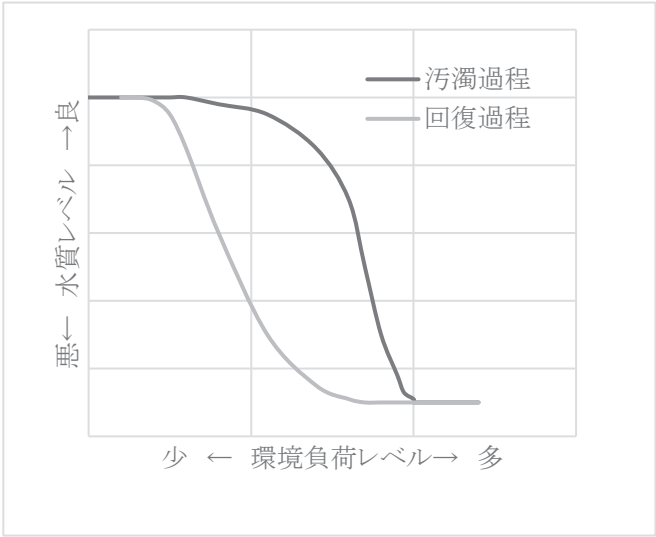

図7 環境汚濁・回復過程モデル図

5. 結論

かつてアオコが発生していた諏訪湖は下水道・浄化槽整備を進め、現在では下水道普及率 98%以上に達して成果を得てきた。 諏訪湖に習うと、霞ヶ浦でも下水道・浄化槽整備を徹底し、下水道普及率を現在の 60%台後半から大幅に引き上げることが必要で、例えば 80%以上になると水質回復し始め、その先に、かつての「泳げる霞ヶ浦」実現を期待できるものと考える。

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牛久沼における水質浄化の取組

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キーワード：牛久沼，環境基準，水質保全計画

抄録

牛久沼は茨城県南部に位置する浅く小さな湖沼であり，農業用水や漁場としての利用など茨城県民の貴重な財産となっている。しかし，1980 年頃から富栄養化による水質汚濁が進行し，茨城県は湖沼の環境基準をあてはめ，3 期 15 年にわたり湖沼水質保全計画を策定し，水質改善の取組を進めてきた。一方，牛久沼流域の自治体及び関係する土地改良区，漁業協同組合で構成される牛久沼流域水質浄化対策協議会は，水質浄化にかかる実践活動を展開してきた。牛久沼流域の人口は，大規模開発により大幅に増加しているものの，排出負荷量は下水道の整備により減少してきている。牛久沼流域は，今後も人口増加が見込まれ，流入する汚濁負荷量の増加を防ぎ，牛久沼の水質を改善するためには，関係機関や地域住民が協力し，水質保全活動に取り組んでいくことが重要である。

1.　はじめに

牛久沼は茨城県南部に位置し，谷田川及び西谷田川が小貝川の堆積作用により堰き止められて形づくられた，平均水深1m（最大水深3m），湖面積 6.5km2 ，湖容積 650 万㎥の浅く小さな湖沼である。その流域は，龍ケ崎市，牛久市，つくば市，つくばみらい市の4市に及び，農業用水や漁場としての利用はもとより，釣りなどのレクリエーションや憩いの場，自然観察の場として，霞ヶ浦や涸沼と並び茨城県民の貴重な財産となっている。

牛久沼では，1980 年頃からアオコの発生が見られるなど，湖沼特有の富栄養化による水質汚濁が進行したことから，茨城県は環境基準のあてはめを河川から湖沼に改定するとともに，湖沼水質保全計画を策定し，水質改善の取組を進めてきた。

一方で，牛久沼及び流入河川の水質浄化に関する事業を推進し，住民福祉の向上を図ることを目的として，1985 年 8 月 9 日，牛久沼流域の自治体及び関係する土地改良区，漁業協同組合のそれぞれの長をもって牛久沼流域水質浄化対策協議会が組織された。

本報では，茨城県の水質保全計画策定と協議会の活動から，牛久沼の水質浄化に向けた取組について報告する。

2.　茨城県の取組

(1)環境基準の変更と水質保全計画の策定

牛久沼の環境基準は，1975 年 4 月 10 日，小貝川水域谷田川(1)として，牛久沼水門より上流の範囲に河川B類型（BOD3mg/L 以下）があてはめられたのが最初となる。その後，1980 年頃からアオコの発生が見られるなど，湖沼特有の富栄養化による水質汚濁が進行したことから，茨城県公害技術センターによる調査結果を踏まえ，1999 年 2 月 15 日，牛久沼全域を湖沼B類型（COD5mg/L 以下）に改定し，環境基準の達成期間については，段階的に暫定目標を達成しつつ，環境基準の可及的速やかな達成に努めることとなった。これで牛久沼は，環境基準において湖沼として扱われることとなった。

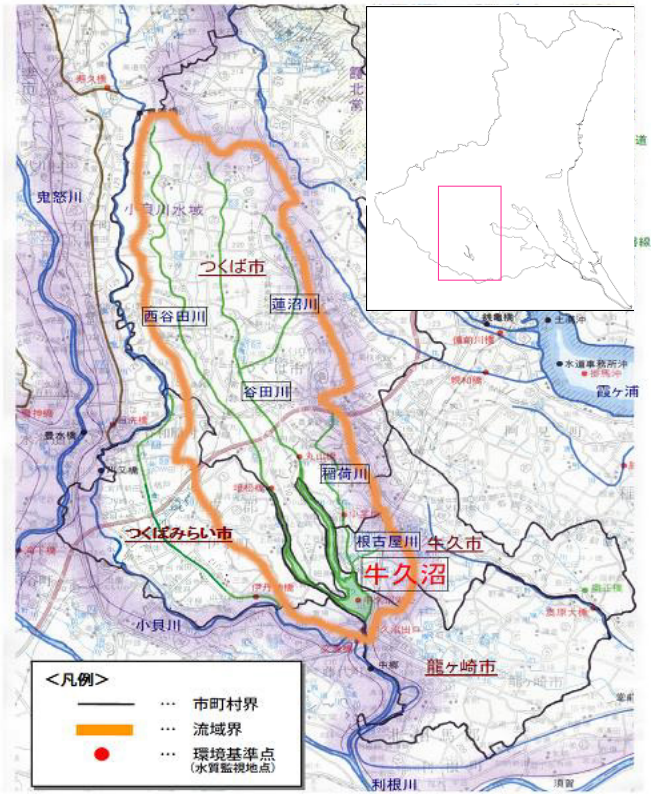

図1　牛久沼流域図

さらに，富栄養化の原因物質である窒素とりんについても，りんについては 1999 年 2 月 15 日，窒素については 2008 年 3 月 21 日，それぞれ環境基準Ⅳ類型（全窒素 0.6mg/L 以下，全りん 0.05mg/L 以下)をあてはめた。達成期間については，COD 等の基準と同じく，段階的に暫定目標を達成しつつ，環境基準の可及的速やかな達成に努めることとなった。

(2)湖沼水質保全計画の策定

環境基準の達成期間が「段階的に暫定目標を達成しつつ，環境基準の可及的速やかな達成に努める」こととなったため，茨城県は，2001 年度を目標年度とする暫定目標を設定した。さらに暫定目標とその達成に必要な施策を取りまとめた第 1 期の「牛久沼水質保全計画」を 2003 年 2 月策定し，より積極的に牛久沼の水質改善を図ることとなった。

第 1 期の牛久沼水質保全計画は，計画期間を 5 年間とし，水質目標は 2001 年度を目標年度として設定した暫定目標を引き継ぐこととした。汚濁負荷削減対策としては，下水道や農業集落排水施設の整備や浄化槽の設置促進など生活排水対策をはじめ，工場・事業場対策，畜産対策，面源負荷対策，その他の対策が定められた。また，水質浄化への住民の協力・参加の促進として，環境学習・環境教育の充実や牛久沼流域水質浄化対策協議会の活動への支援，流域の住民や事業者，団体等の協力・参加によるアクションプランの策定，さらに調査研究等の推進について記述された。

水質保全計画は，その後も 5 年ごとに策定が続けられ，これまで 3 期 15 年にわたり牛久沼水質保全計画に基づく各種対策を実施してきた。現在は，2018 年 3 月に策定した第4期の牛久沼水質保全計画に基づき，2021 年度を目標に，引き続き総合的な水質保全対策を推進している。

3. 牛久沼流域水質浄化対策協議会の取組

(1)組織の概要

牛久沼流域水質浄化対策協議会は，牛久沼及び流入河川の水質浄化に関する事業を推進し，住民福祉の向上を図ることを目的として，1985 年 8 月 9 日，牛久沼流域の自治体及び関係する土地改良区，漁業協同組合のそれぞれの長をもって組織された。

その後策定された第 1 期から第 4 期までの牛久沼水質保全計画では，牛久沼流域水質浄化対策協議会が実施する水環境保全活動への支援が規定されており，牛久沼の水質保全活動に重要な役割を果たしている組織である。

表 1 暫定目標（計画目標）の変遷

計画期	第 1 期	第 2 期	第 3 期	第 4 期
目標年度	2006	2011	2016	2021
ＣＯＤ（年平均値）	―	7.5	7.2	6.7
ＣＯＤ（75％値）	8.6	8.5	7.8	7.5
全窒素（年平均値）	―	1.4	1.3	1.4
全りん（年平均値）	0.06	0.06	0.059	0.062

（単位：mg/L)

※暫定目標は，COD（75％値），全窒素（年平均値），全りん（年平均値）が該当する。

表 2 牛久沼流域水質浄化対策協議会の構成員

龍ケ崎市長，牛久市長，つくば市長，つくばみらい市長，牛久沼土地改良区理事長，稲荷川土地改良区理事長，土浦市外十五ヶ町村土地改良区理事長，茎崎村外五ヶ町村土地改良区理事長，牛久沼漁業協同組合代表理事組合長

(2)水質浄化実践活動

牛久沼流域水質浄化対策協議会の活動は水質浄化実践活動と住民意識啓発活動がある。水質浄化実践活動としては，それぞれの構成市が実施する牛久沼流域清掃大作戦清掃事業，構成市に設置された家庭排水対策協議会の運営，食用廃油の回収事業を行っている。また，住民意識啓発活動としては，構成市内の小中学校児童生徒を対象とした水質浄化ポスター募集事業や，牛久沼水質浄化パンフレットの配布，街頭での水質浄化キャンペーンの実施，牛久沼水質浄化ポスターの入選作品の展示の活動を行っている。

また，2013 年度には牛久沼の水質改善を目指し水質浄化に関連する情報の共有や意見交換を行うため，「牛久沼水質浄化研究会」を発足させた。

4. 流域人口と排出負荷量の推移

(1)流域人口の推移

牛久沼の流域は 1963 年の閣議了解により，研究・学園都市の建設が決まり，1970 年には「筑波研究学園都市建設法」が制定され，開発が進められてきた。また，1989 年には「大都市地域における宅地開発及び鉄道整備の一体的推進に関する特別措置法」が制定され，2005 年 8 月 24 日に開業したつくばエクスプレスと一体的な宅地開発が行われ，牛久沼流域では，研究学園葛城（葛城地区），田園都市島名（上河原崎・中西地区）（島名・福田坪地区），つくばみどりの里（萱丸地区）において大規模な宅地開発が行われ，現在も開発が続いている。

そのため，1999 年には 9 万 2 千人だった牛久沼の流域人口は，2016 年には 13 万 1 千人と 17 年で約 1.4 倍に増加しており，第 4 期水質保全計画の目標年度である 2021 年には，さらに 14 万 2 千人まで増加することが予想されている。

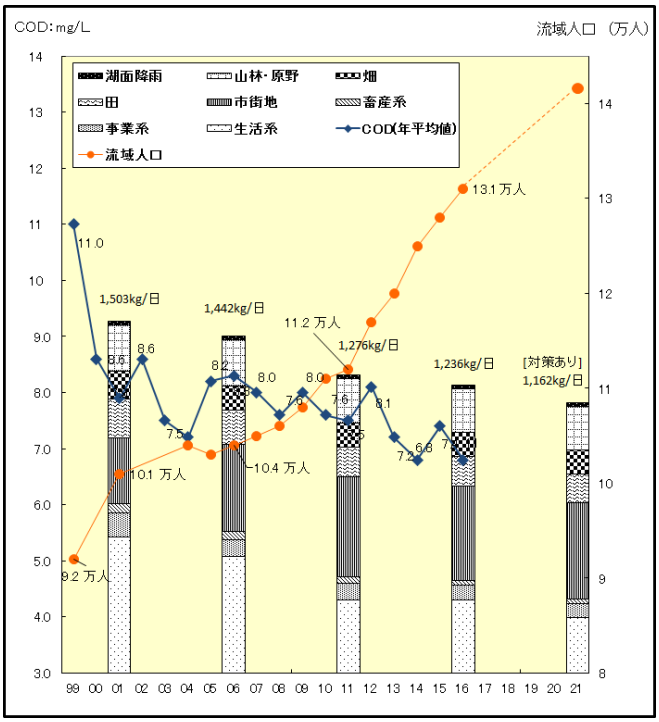

図 2　排出負荷量と水質・流域人口の推移

(2)排出負荷量の推移

流域人口は急激に増加しているものの，牛久沼に流入する排出負荷量（COD)は，2001 年 1,503kg/日から，2006 年 1,442kg/日，2011 年 1,276kg/日，2016 年 1,236kg/日と減少している。

特に減少しているのは生活系の排出負荷であり，2001 年の 574kg/日が 2016 年には 307kg/日となっている。牛久沼流域に整備されている下水道は霞ケ浦常南流域下水道であり，利根川沿岸の利根町にある終末処理場で汚水を処理し，処理水は利根川に放流している。そのため，汚水を下水道に接続していれば，その排出源からの汚濁負荷は牛久沼に影響しない。大規模に宅地開発された地区には下水道が整備されているので，大幅に人口が増加したにもかかわらず，生活系の排出負荷を減少させることができている。なお，牛久沼流域の下水道普及率は 80.9%であり，接続率も 95.3%となっている。（2021 年度）

第 4 期水質保全計画の目標年度である 2021 年の排出負荷量は 1,162kg/日と予想されており，これを達成するため，下水道の普及率を 85.9%まで整備する計画としている。

5.　今後にむけて

牛久沼流域は，今後もつくばエクスプレス沿線の開発等により人口増加が見込まれる。流入する汚濁負荷量の増加を防ぎ，牛久沼の水質を改善するためには，生活排水対策の推進のみならず，関係機関や地域住民が協力し，水質保全活動に取り組んでいくことが重要である。

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Evolution of a Hybrid Framework for Adaptive Watershed Governance in a Micro-watershed Scale Laguna de Bay Basin, Philippines

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Keywords: watershed governance, collaboration, participatory planning, community involvement, micro-planning, women empowerment

ABSTRACT

There have been numerous watershed governance models developed for planning and managing natural resource projects. However, these models are generally applied in a macro scale discounting some vital social and environmental concerns that are peculiar in a local setting.

This paper will discuss the importance of focusing environmental conservation initiatives on a smaller scale, adopting and modifying applicable existing watershed governance framework and approaches. As a take-off point, Barangay Carmen in the town of Silang was selected in view of the existence of the Malindig Spring situated within the Malindig Micro-watershed. The said spring is important in the social-cultural and economic activities of the community. However, sustaining its ecological integrity is a challenge which necessitates multisectoral involvement coupled with the government's efforts in spearheading actions for community support. The need to identify a group of champions in environmental management is a key success factor in environmental management, thus, the women in Barangay Carmen became the target sector to take the lead in view of their interest and respected roles in the community.

The results of engagement with communities in a micro-watershed scale revealed the need to refocus the strategies in managing natural resources from a macro-scope to a micro-level scale. This will ensure a more efficient assessment of the socio-cultural-economic-environmental and political situation leading to more effective strategies in managing natural resources.

INTRODUCTION

The continuing economic as well as environmental pressures on the watershed is outpacing the capacity of the government to effectively and efficiently plan and implement the strategies vital for proper management of resources. Management of resources is an integral component within a complex dynamic social-environmental system that requires addressing uncertainties in the process coupled with interaction to a variety of stakeholders with different needs and interests.

It is in this light, that an adaptive watershed governance model for planning and managing natural resource projects has been developed and implemented taking into consideration various concepts such as non-linearity,

trans-disciplinary science, self-organization and community participation.

The watershed can be regarded as a complex system that function in a continuously changing environment. Rapid economic growth and land use change have transformed former rice and sugar cane plantations into prosperous urban centers. The land use change in the watershed will soon impact the hydrology of the watershed and threatens freshwater resources from which the quality of life of communities depend. Similar to a bigger watershed, a typical micro-watershed is also exposed to the same pressures but of a lesser degree depending on the geophysical and social conditions.

The Malindig Micro-watershed is situated within the Macabling Sub-Watershed under the Sta Rosa Watershed. It spans within the Barangays of Carmen, Tibig and Hukay in Silang, Cavite and discharges towards Laguna de Bay via Macabling River. Macabling Subwatershed is administratively located in the Cities of Biñan and Sta. Rosa, Laguna and Silang, Cavite with an area of 3435.56 has. Silang's geographic situation, being located at the upstream portion of the basin, has significant amount of groundwater recharge and serves as the headwater of seven river basins in the Santa-Rosa Watershed.

Malindig River is a significant natural resource in the watershed because of its socio-cultural value that has been preserved through time. However, sustaining its ecological integrity and services is a challenge that requires the involvement of all sectors within the micro-watershed. Of special interest in this micro-watershed is Barangay Carmen which is situated at the downstream portion of the river with 2,506 (PSA 2015) household population. About 90% of the agricultural area is privately owned and the community has been threatened for eviction due to the absence of land entitlement. Two unnamed shallow streams are situated within Brgy. Carmen and flow towards the Malindig River. These streams were found degraded due to domestic and agricultural pollution.

The challenge of mobilizing the community to initiate strategies to conserve the Malindig River is a gargantuan task exacerbated by social - political pressures.

STUDY FOCUS: BARANGAY CARMEN, SILANG, CAVITE

Brgy. Carmen is a rural barangay with a total area of 265.11 ha. of mixed residential and agricultural land. The community derives daily sustenance mostly from agricultural farming supported by other sources of income such as employment in nearby industries, construction works and driving of public transport.

Governance is led by a Brgy. Council composed of a Barangay Chairman, seven (7) Sangguniang Barangay Members, one (1) Barangay Secretary and one (1) Barangay Treasurer. While a Women's Desk is created to handle minor conflicts within the Barangay.

Brgy Carmen has its own waterworks system. Water is abstracted from the ground and supplied to the respective households by gravity owing to the physical configuration of the area. However, scarcity of water is experienced during summer months and weekends due to the higher volume required by the consumers on said period.

Within the interior of the Barangay are interconnected canals serving as storm drainage and catchment of household wastes. Liquid wastes are discharged directly to the canal which eventually flows downward to the stream and manmade channel in the farm.

Situated in this Brgy. are the Malindig River and Malindig Spring which are of high importance to the socio, cultural and economic life of the community. The spring has been considered as a source of potable water and a source of special "power" for believers and faith healers as well as eco-tourism destination during summer months. However, the community has inadequate initiatives to sustain the ecological integrity of the river. This is manifested by the absence of environmental related activities/projects coupled with the lack of policies and guidelines on the use of the river and other environmental concerns.

4. ASSESSMENT APPROACH

This paper narrates a process-based action research which applied a simple planning tool which is the Project Cycle Management (PCM) introduced by the Japan International Cooperation Agency (JICA). However, there were modifications on the application of approaches in view of the level of understanding, age consideration and depth of appreciation of the participating community members.

The community was guided in assessing local situation and planning for strategies to address issues taking into consideration the following planning elements: Situational Analysis, Stakeholders Analysis, Problem Tree Analysis,

Objective Analysis, Alternatives Analysis, Project Design Matrix and Plan of Operation. These were discussed in a series of workshops participated by representatives of various sectors in the community using simple and creative exercises to come up with the desired results.

Working with the community in assessing local situation has encouraged critical thinking, built awareness and strengthened existing organizations for a unified action. In the course of the application of existing planning tools, variations of approaches are developed to suit with the local situation. Focusing efforts in a micro-scale and partnering with the smallest political unit and active sectoral groups are key success factors in resource management.

5. DISCUSSION

This study strongly believes in the pivotal role of community in the planning process and sustainable implementation of action plan. Involving the community is an effective mechanism which enables them to define their own values as stewards of the environment as it promotes sense of ownership and self-worth. The planning process undertaken did not only become an avenue for learning but also promoted mindfulness of the current condition and recognition of one's accountability. Recognizing the positive receptivity and active role of women in the community undertakings, they were engaged to perform tasks essential to the study. Their participation enabled appreciation of their vital role in the management and conservation of the environment particularly of the Malindig River and Spring.

The PCM process was used in the diagnostic assessment of the current environmental situation in Brgy. Carmen focusing on the conservation of the Malindig River and Spring.

Based on the processed result, dumping of waste on streams and waterways was the major issue in the Barangay. However, through analysis of the current situation and environmental issues in the community, lack of consciousness on the sustainable management and protection of the river was agreed as the core problem and that dumping of waste in canals and tributaries was only a consequence. This analysis was associated to the premise that the community only values the river as a source of income during summer months and that efforts to sustain it through programs and policies are lacking.

6. CONCLUSION

Focusing action in a micro-watershed scope provides a more specific information on the existing social, environmental and economic situation as well as the political climate in the area. A dialogue platform such as workshops and regular visits foster participation and engagement of communities towards planning of strategies that can be implemented within the bounds of their capacity and understanding.

Mobilizing people for action cannot be done instantly and at determined period. It requires substantial time, effort and resources to be able to win their respect and trust.

Experience with the communities in managing natural resources led us to conclude that the microwatershed has its own peculiarities in terms of the social-environmental situation and issues as well as the political climate.

The endeavor is a learning process in which the goal is to enhance capacities of the community in order to identify their own issues and correspondingly, develop strategies to address identified problems. A shared understanding of the local issues is necessary in crafting the community's common vision for the environment.

The hybrid model of this action research refers to the enhancement of existing planning and intervention processes and simplification of biophysical processes through learning tools in microwatershed. Without this model, it would have been difficult to communicate the value of the resources as a kick-off agenda in gathering the community and collectively mapping-out actions for environmental conservation and sustainability. The understanding of biodiversity principles and watershed management planning that the community gained through this endeavor had motivated them to jointly work and thus increase their adaptive management capacity.

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題名:オオハクチョウ最南端越冬地『古徳沼自然を守る会』活動

目黒　嵩 [1], 飯田士朗 [1], 赤川　博 [1], 萩野谷儀一 [1], 岡村光雄 [1], 山田俊夫 [1], 寺門真喜男 [1]
[1] 茨城県那珂市瓜連地区まちづくり委員会、

キーワード:水資保全, 里山, 溜池, オオハクチョウ

抄録

わが国は稲作農業を中心とした水田(314 万 ha、国土面積の約 6%)の水源として、農業用溜池が数多く築造されてきた。溜池の約 70%は江戸時代以前に築造された。わが町の宝物である“古徳沼”も谷津田の地形を活用し江戸時代(元禄 14 年・1701 年)の豪農、永田八郎衛門の設計指導によって改修の拡張工事が行われ、最近まで農業用水として重要な溜池であった。現在、那珂市瓜連の観光資源として、1966 年からオオハクチョウの最南端の越冬地“古徳沼”として広く知られ、地域の憩いのスポットになっている。しかしながら、掻い掘りによる溜池の水質維持が難しくなってきたと同時に、溜池周辺の里山や谷津田の環境も著しく損なわれてきた。この現状は、国内の溜池の大きな課題になっている。 瓜連地区まちづくり委員会は 2010 年頃から古徳沼周辺の里山を中心に、古徳沼環境整備活動を進めており、今回、「古徳沼自然を守る会」の住民活動の成果および課題について報告する。

1. はじめに

古徳沼は、南北朝時代(1300 年代) の古徳城の防衛沼地として活用され、江戸時代(1701 年)の豪農、 永田八郎衛門の設計指導によって改修の拡張工事が行われ、最近まで唯一の重要な溜池であった。 また、茨城県中央に位置し、国内最小面積の旧瓜連町(14.66Km^2)に位置した周囲1.5Kmの小さな溜池であり、瓜連の宝物・観光資源として、住民の憩いの場所になっている。2005 年の瓜連町/那珂町合併後、那珂市瓜連地区まちづくり委員会活動の一環として、2010 年頃から古徳沼周辺の里山を中心に環境整備活動が進められてきたので、「古徳沼自然を守る会」のボランティア活動について報告する。

古徳城址　谷津田　古徳沼　富士神社

2.背景・現状

1966 年にオオハクチョウが飛来するようになり、最南端の越冬地として、今年も 150 羽に上る飛来(1990 年 238 羽のピーク)が確認できた。また、約 100 種類の渡り鳥の大切な要所になっている。

この古徳沼(図 2)は、農業用水に使用され、また、渡り鳥の要所、歴史的、さらに、地域住民の憩いの場所であり、古徳自治会(187 戸)が中心になり大切に守れてきた。

古徳沼

しかしながら、溜池本来の農業用水需要は激減し、管理運営が厳しくなるとともに、水質の悪化及び沼周辺の立ち枯れが進み、自然環境が悪化している。

現状での古徳沼の水質は透明度 10cm、化学的酸素要求量(COD)8mg/L であり、未だ満足できる状態ではない。しかし、数年に渡る古徳沼上流部の 1km余りに広がる谷津田と「静・古徳道を巡る散策路」の環境整備活動の成果(図 1)によって、回復できる環境が整いつつある。また、周辺の水源として、豊富な湧水(図 3)が古徳沼に注ぎ込まれている。

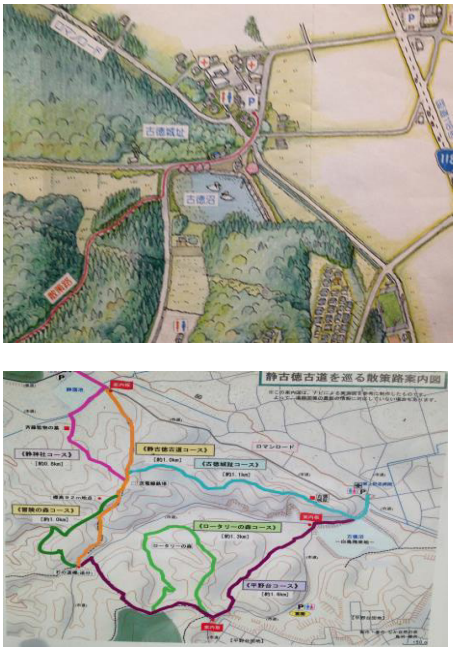

図 1.「古徳城址」・「富士神社」・「谷津田」に囲まれた宝物“古徳沼”

上:古徳沼周辺の地図

下:静・古徳道を巡る散策路

一方、保護鳥である川鵜が那珂川と久慈川の豊富な餌場の中間位置に古徳沼が辺り、最高のねぐらになっており、川鵜の生息(巣)と糞の被害で沼周辺の大木が根腐れを起こして、倒木被害及び水質悪化を受けている。



図 2.　古徳沼の全景

数多くの冬の渡り鳥の飛来地として、1966 年初めてのオオハクチョウの最南端の飛来地以来、現在では、この古徳沼を基地として、周辺沼地を広く飛来している。





図 3.　豊富な湧水と湿地

小高い雑木林（広葉樹）に囲まれ、水源として、恵まれた環境にある。





図 4.　川鵜の巣・糞による倒木被害

川鵜に生息（巣）と糞の被害により、沼周辺の大木が根腐れを起こして倒木被害を受けている。

3.活動目標

瓜連地区まちづくり委員会として、約 10 年間続けてきた防犯・防災・環境部会活動を充実し、会員による住民参加型のボランティア活動により、古徳沼の水質浄化、周辺道及び里山保全・整備を目標として、瓜連の宝物“古徳沼”を子供から高齢者まで、愛しく、楽しめる憩いに場にする。

4.活動方法

従前活動の継続とともに、平成 30 年～平成 32 年を重点活動期間とし、以下の活動を実施する。

＜具体的作業＞

① 古徳沼周辺の草刈り・清掃活動年(年 3 回)
② 古徳沼の水質改善活動(年 3 回)
③ 渡り鳥の観察と古徳沼周辺の看板整備
④ 古徳沼周辺の老木等伐採整備(年 2 回)
⑤ 桜の植樹活動・休耕田の利用による白鳥の好物であるマコモ栽培活動

＜事業継続＞

① “古徳沼自然を守る会”による地域ボランティア活動と会員の会費等で事業継続
② 那珂市第2次総合計画基本計画を受けての事業及び茨城県及び民間等の助成による事業継続
③ 地域環境関連団体及び教育団体との連携　構築により事業継続

5．　考察

農業用水として、歴史と実績のある瓜連の宝物“古徳沼“を地域住民のボランティア活動によって環境整備活動が培われてきた。しかしながら、未だ、満足できる環境に達していない現状を広報するとともに、今後の課題解決するために、最大限の住民パワーによる持続的な活動が求められる。

6．　結論

100 歳高齢化社会に向けて、子供から高齢者まで楽しめる憩い場“古徳沼”が、冬は白鳥、春は桜、夏は沼辺の蛍、秋は紅葉と四季を楽しめる将来が見えてきました。

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Development and Thinking of the Integrated Treatment System of Basin Water Environment

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Keywords: basin water environment, integrated management system, Shaping River

ABSTRACT

The current water environment issue has become an important factor constraining China's socio-economic development. With the introduction of a series of major governance initiatives at the national level, the water-environment-treatment market is expanding. This paper based on the analysis of the challenges faced by China's eco-environmental policy environment and water environment governance, elaborates the importance of enterprises' participation in water environment integrated treatment and the development and future direction of water environment integrated treatment technology system. In addition, this paper analyzes the application of water environment integrated treatment technology system taking the project of integrated treatment of Shaping River water environment in Heshan City as an example.

1. BACKGROUD

With the rapid development of urbanization and industry, surface water in most cities has become into black and odorous due to increasingly serious pollution. Thus, water environmental problems have become an important factor that restricts China's social and economic development currently. Since 2010, the country has successively issued action plans such as "Action Plan for Protection and Control of Water pollution", "Sponge city construction", and "treatment of black and odorous water bodies". It is proposed that by 2020, black and odor water bodies in built-up areas at or above the prefecture level shall be controlled within 10%; by 2030, black and odor water bodies in the urban built-up areas will be eliminated as a whole [1]. With the introduction of a series of major governance initiatives at the national level, the market for water environmental treatment is accelerating its release.

2. WATER ENVIRONMENT TREATMENT CHALLENGES

(1) Unclear Right and Responsibility:

Watershed integrated water environment treatment involves a number of government departments, and the management and responsibilities between the various departments are crossed. On the other hand, due to the unclear boundary of the water environment project, the division of responsibilities between government and enterprises is not clear. The unclear responsibilities among various government departments and between government vs enterprises ultimately lead to the absence of the main responsibility body for treatment effect.

(2) Lack of systematics:

Horizontally, integrated water environment treatment involves various specialties such as municipal engineering, water conservancy, environment engineering, landscape, and so on. Vertically, the whole life cycle processes of integrated treatment projects are divided into four stages: decision-making, design, construction and operation. However, most projects lake of the whole lifecycle management and control: project plan and design entity was not coordinated with construction and operation entity, which lead to the project object and responsibility are not matching during the marketization process of water environment projects.

The lack of horizontal and vertical systemic management of the water-environment-treatment project caused individual projects that are quick to gain instant benefits and short-term results implemented, while overlook the long-term treatment effects and lead to waste investment and resources.

(3) Contradictions with socio-economic development:

The huge funding needs of the comprehensive water treatment project will bring financial pressure to the government. At the same time, the improvement of the quality of the city through the improvement of water environment will drive the surrounding industries and bring about huge social and economic benefits. How to promote the development of peripheral industries in the process of water environmental treatment is huge challenge.

3. IMPORTANCE OF ENTERPRISES IN THE INTEGRATED TREATMENT OF WATER ENVIRIONMENT PROJECTS

In the past, water-environment-treatment projects were carried out by the way of government itself. Currently it gradually transformed into government procurement service way, which select the competent companies to carry out the tasks of water environment treatment. The treatment responsibility of water environment project was transferred from government itself to the enterprises. The government supervises the water environment governance project by establishing a sound performance appraisal mechanism. Enterprises must provide professional services such as investment and technology from the perspective of long-term compliance, so as to benefit society, enterprises and the public. Enterprises can provide their tremendous strength and vitality, realize spend less money, do more affairs and good things, and create greater value for the society. In addition, enterprises cooperate with the government to continuously deepen reforms in the field of environmental protection, and promote the institutional innovation of water environment projects.

4. INTEGRATED WATER ENVIRONMENT TREATMENT SYSTEM DEVELOPMENT

Based on oriented by demand, driven by technological innovation, improving the supply capability, the enterprises constantly develop an integrated technology system for water environment treatment.

(1) Treatment methodology should be transformed from end-point treatment to integrated regional/watershed treatment, including: wastewater treatment plant, pipe network and river integration; water supply and drainage integration, urban and rural areas integration, water management and water environment integration, smart water management, and normalization of environmental education.

(2) The technical system involved from a single technology to a comprehensive integration of multiple technologies, including technologies for intercepting pollution sources, ecological restoration, water resources allocation, and waterfront landscapes.

(3) The assessment system changes from water quality indicators to comprehensive performance assessment indicators, such as operation and maintenance, and water quality goals.

5. CASE STUDY: INTEGRATED TREATMENT OF WATER ENVIRONMENT IN SHAPING RIVER BASIN, HESHAN, GUANGDONG

Heshan City is located on the right bank of the lower reaches of the Xijiang River in the Pearl River Delta. The inner Shaping River is a first-level tributary of the Xijiang River. The Shaping River Basin is the most developed socio-economic region in Heshan City. The basin area is 328km^2, and the population in the basin is concentrated at about 300,000, accounting for 2/3 of the city's population, and the total economic output accounts for more than 80% of the city's total.

With the rapid development of the industry in Heshan City, the urban population is increasing, and a large amount of untreated industrial wastewater and domestic sewage are discharged into the Shaping River, causing serious pollution of the water body. According to the results of water quality monitoring from 2011 to 2016, the water quality from the Yuqiao (the main stream of the Shaping Rive) to Shaping Sluice was in a poor grade V for a long period of time. During the dry season, the body of water becomes fouled with black and odor, causing serious pollution.

The main construction engineering of “Integrated Treatment of Water Environment in Shaping River Basin, Heshan City” includes urban flood control projects, landscape projects, and sewage interception projects. The project adopted the public-private partnership (PPP) model. In accordance with the principles of "overall planning and step-by-step implementation", the project implement in two phases. The first phase of the project included bridge projects, flood control projects, and landscapes, which was begun in April 2016. The second phase of the project includes sewage collection and treatment, rural sewage treatment, and ecological rehabilitation of water bodies, which is scheduled to start this year. After the completion of the project, the ecological environment, human settlement environment and investment environment in Shaping and Heshan City will be comprehensively upgraded. At present, the Integrated Management and Control Platform for the River Chief System have been highly recognized by the local government and residents.



Figure 1 the Integrated Management and Control Platform for the River Chief System

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霞ヶ浦の水環境に対する市民の意識向上に向けて

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キーワード:生態系サービスと流域政策

抄録

霞ヶ浦では 2016 年 2 月に河川整備計画が策定され、今後 20～30 年をかけて、計画に基づく霞ヶ浦の水環境事業に取り組んでいる。1995 年第 6 回の世界湖沼会議を契機に市民活動が活発になり、さまざまな関わりをもって市民が活動してきた。2018 年 10 月に第 17 回世界湖沼会議を迎えるにあたり、市民の関心も薄れてきているとの意見もあり、流域内の機運醸成及び連携推進が肝要と考え、霞ヶ浦水環境に対する流域市民の意識を把握するため、幅広い層の市民を対象に 4 種類のアンケートを行った。その結果、霞ヶ浦に興味を持ち、霞ヶ浦に訪れ触れあうなど、霞ヶ浦と関わりが多い市民ほど霞ヶ浦の水環境を高く評価していることが明らかとなった。今後は、霞ヶ浦における流域内連携をより一層推進するための広報や霞ヶ浦と直接触れあう事業を展開し、流域市民の意識向上を図ることが重要である。

1. はじめに

本報告は、霞ヶ浦流域の市民が霞ヶ浦に対する水環境に関して求めるもの及び既往の事業に関して感じていることを把握するために実施したアンケート調査であり、結果は今後の流域全体の取り組みに役立てていきたい。

2. 方法

(1)調査手法

幅広い層の市民の意見にアプローチするため、従来多く行われる住民基本台帳抽出によるアンケート（以下、『住基』）に加え、親子アンケート（同、『親子』）、現地アンケート（同、『現地』）、Web アンケート（同、『Web』）の 4 つの調査手法により、2015 年 11～12 月に実施した【表-１】。

表-1 調査手法

調査手法	調査のねらい	調査方法	分析対象数
『住基』	従来多く行われている方法	流域市町村に在住する20歳以上の男女	369
『親子』	子育てや仕事で忙しく回答を得ることが難しい世代の意見を得る	沿岸市町村の11小学校（5年生児童とその保護者）	423
『現地』	霞ヶ浦及びその周辺に実際に訪れる人の意見を得る	霞ヶ浦近傍の5施設の来訪者（20歳以上の男女）	195
『Web』	情報提供や意見聴取の手段として活用されているWeb利用者層の意見を得る	流域市町村に在住するインターネットアンケートモニター（20歳以上の男女）	400
合計			1,387

(2)設問構成

アンケートは「利用・関心」「認識・評価」「属性」の大きく 3 区分の設問構成とし、霞ヶ浦の利用度・水環境への関心度や、生態系サービス、水環境イメージ、将来像の認識・評価を中心に問うものとした【表-２】。

なお、アンケート作成にあたっては、回答者属性及び霞ヶ浦の利用度や関心度合いの高さと、霞ヶ浦の認識と評価などを関連づけて分析が出来るように配慮した。

表-2 アンケートの設問構成

大区分	小区分	設問番号	設問	回答方法
利用・関心	霞ヶ浦の利用度	問1 問2 問3 問4	・霞ヶ浦の利用有無 ・霞ヶ浦の利用頻度 ・霞ヶ浦の利用目的 ・子どもの頃の遊んだ経験	SA SA MA SA
	霞ヶ浦水環境への関心	問5 問6 問7	・新聞や雑誌の記事を読む頻度 ・事務所ホームページを閲覧する頻度 ・水環境行政に対する意見機会	SA SA SA
認識・評価	霞ヶ浦の生態系サービス	問8	・①提供サービス／②調整サービス／③生物多様性／④文化的サービス	MA
	霞ヶ浦の水環境イメージ	問9	・①ゴミ／②透明感／③アオコ／④臭い／⑤眺め／⑥アクセス性／⑦自然の豊かさ／⑧生き物の豊かさ⑨身近さ／⑩過去の水質との比較／⑪水環境の良さ	SD
	霞ヶ浦水環境の将来像	問10 問11	・①水質／②自然／③親水性／④水の安定供給 ・実現するまでの機関	AHP SA
	霞ヶ浦水環境保全対策	問12 問13	・水環境保全対策の認識 ・今後の対策の進め方	SA SD
	自由回答	－	・記述式自由回答	FA
回答者属性	－	問10	・性別／年齢／職業／住所／居住年数	SA

【回答方法】
SA:単一回答 MA:複数回答 SD:段階評価 AHP:一対比較 FA:自由記入

3. 結果

(1)霞ヶ浦の水環境に対するイメージの評価

霞ヶ浦の水環境に対するイメージについて、良いーやや良いーどちらでもないーやや悪いー悪いの５段階評価で回答を得た。

全回答者(n=1,205)による霞ヶ浦の水環境に対するイメージは、悪い(やや悪いを含む)が約５割で、良い(やや良いを含む)の約２割を上回っており、評価が低い【図-１】。

霞ヶ浦の水環境に対するイメージの評価の違いをみるため、調査手法別や、『親子』調査における 5 年生児童とその保護者、居住年数別に評価した。

調査手法別の評価は、『住基』と『現地』、『住基』と『親子(保護者)』では有意差があり($p<0.01$)、『住基』と『Web』では有意差がなく、『現地』＞『住基』≒『Web』＞『親子(保護者)』の順に評価が高い【図-２】。

『親子』の結果では、児童と保護者の評価に有意差があり($p<0.01$)、児童の評価が保護者よりも高い【図-３】。

また、居住年数別にみると、霞ヶ浦流域に 30 年以上居住している市民は、30 年未満の市民よりも評価が高い($p<0.05$)【図-４】。

現地で実際に霞ヶ浦を目にしている市民や霞ヶ浦流域に長く居住している市民、環境学習等で霞ヶ浦に触れあう機会が多い児童は、霞ヶ浦の水環境のイメージを高く評価していると推察された。

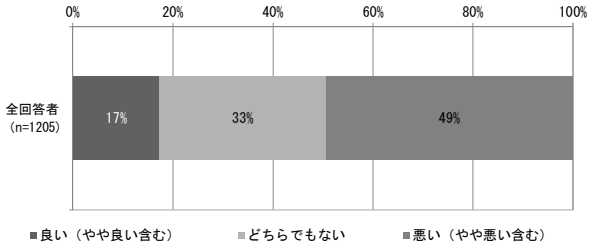


図-1 霞ヶ浦の水環境のイメージ評価（全回答者）

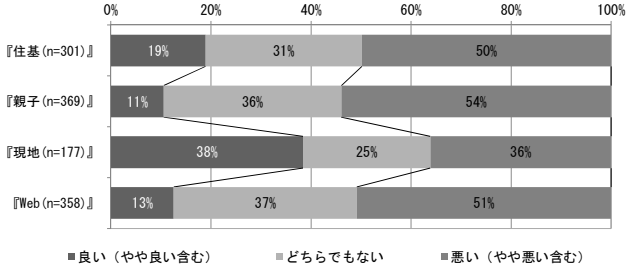


図-2 霞ヶ浦の水環境のイメージ評価（調査手法別）

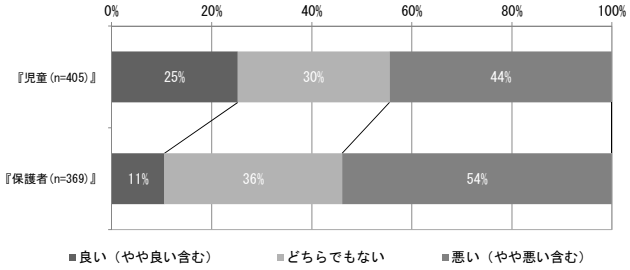


図-3 霞ヶ浦の水環境のイメージ評価
(『親子』: 児童と保護者)

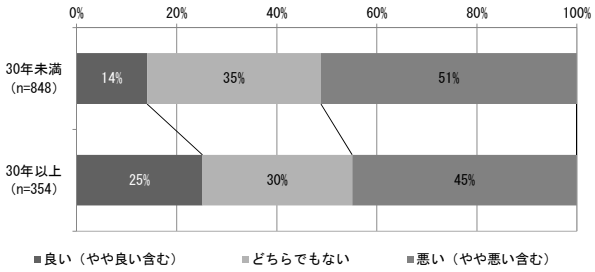


図-4 霞ヶ浦の水環境のイメージ評価（居住年数別）
※図-1～図-4 はいずれも「わからない」・「未回答」を除く集計結果

(2)霞ヶ浦の水環境に対するイメージ評価を規定する項目

霞ヶ浦の水環境に対するイメージと関連する要素 10 項目のイメージの評価をもとに、全ての２変数間の相関係数を求めて関係の強さをみた。霞ヶ浦水環境のイメージ評価は、「身近に感じる」「眺めが良い」「自然が豊さ」よりも「水に透明感がある」「臭いがしない」「アオコがない」「ゴミが少ない」の項目と相関が強く、人間の五感によって評価されていると推察された【表-３】。

表-3 水環境のイメージと要素項目イメージの相関 (n=1,387)

項目	相関係数
水に透明感がある	0.559
不快な臭いがしない	0.554
10年前より水質がきれいになった	0.550
アオコがない	0.525
ゴミが少ない	0.524
生き物が多い	0.406
自然が豊か	0.387
湖に近づきやすい	0.338
湖岸からの眺めがよい	0.317
身近に感じる	0.211

(3)生態系サービスの評価

人間の暮らしは、食料や水の供給、気候の調節、レクリエーションの場や機会など、生物多様性を基盤とする生態系からの恵みにより支えられており、それらの恵みは生態系サービスと呼ばれている。霞ヶ浦からどのような恵みを受けているかの設問では、流域市民は、飲み水や農水・工水等の「供給サービス」や「生物多様性」を他のサービスよりも認識していた。また、新聞や雑誌等のメディアに触れる市民は、供給サービスや生物多様性の恩恵を強く認識していることが明らかとなった($p<0.01$)【図-５】。

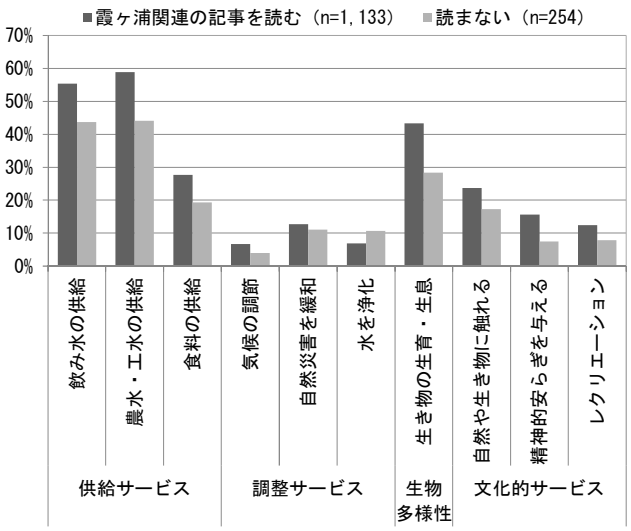
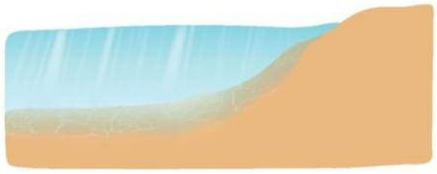
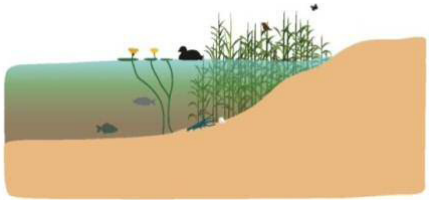
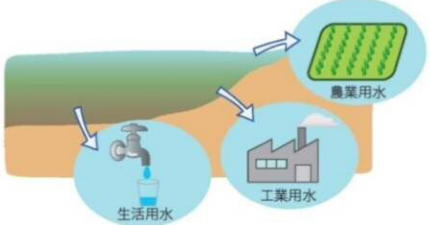


図-5 生態系サービスの評価（3 つまで回答）

(4)霞ヶ浦の水環境の将来像

霞ヶ浦の水環境の将来像を４つ挙げ、全ての将来像を一対比較し、どちらがどの程度重要かを９段階で回答を得た。その結果から将来像の優先順位と優先度を重み付けした。優先順位は「水質」＞「自然や生き物」＞親しみやすさ」＞「豊富な水量」であるが、優先度に大きな相違は認められず、流域市民は全ての将来像が重要であると考えている【表-４】。

表-4 霞ヶ浦の水環境の４つの将来像の優先順位

霞ヶ浦水環境の将来像	優先順位（重み）
水質のきれいな湖 	1 位 (0.305)
自然や生き物が豊かな湖 	2 位 (0.274)
水辺に親しみやすい湖 	3 位 (0.240)
流域が水不足にならない湖 	4 位 (0.181)

4. 考案

霞ヶ浦の水環境に対するイメージの評価は、現地で実際に霞ヶ浦を目にしている市民や霞ヶ浦流域に長く居住している市民、環境学習等で霞ヶ浦に触れあう機会が多い児童が高く評価している。また、その評価は「水の透明感」「臭い」「アオコ」「ゴミ」など、人間の五感によるものである。現在の霞ヶ浦には「供給サービス」や「生物多様性」の恩恵を、メディアに触れる市民ほど強く認識している。霞ヶ浦の水環境に対する将来ニーズは、水質だけでなく、生物や親水性など多岐にわたっている。

5. 結論

アンケートの結果、霞ヶ浦に興味を持ち、霞ヶ浦を訪れ触れあう市民、すなわち、霞ヶ浦との関わりが多い市民ほど、霞ヶ浦の水環境を高く評価していることが明らかとなった。この結果を踏まえ、今後は、「霞ヶ浦に足を運んでもらう」「子供たちと一緒に霞ヶ浦に触れあう」「流域全体で霞ヶ浦の魅力をPR しあう」等、霞ヶ浦における流域内連携をより一層推進するための事業を展開し、流域市民の意識向上を図ることが重要である。

P9-3

国土交通省の管理ダムにおける水質マネジメント

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キーワード:湖沼・湿地・貯水池などの静水系を含む河川流域管理(ILLBM), 水質管理

抄録

ダム貯水池の水質を改善するため、国土交通省では、様々な機関が密接に連携し、体系的に検討・対策を行っている。本稿は、国土交通省が管理するダム貯水池の水質マネジメントの概要及び、今般公表予定の「ダム水貯水池水質改善の手引き」について述べたものである。

1. はじめに

ダム貯水池では、時に水質が問題となることがあり、例えば、富栄養化現象、濁水長期化現象、冷温水現象、底層嫌気化現象が知られている。このような水質問題に的確に対策するには、様々な機関が密接に連携し、体系的に検討・対策を行うことが重要である。

2. ダム貯水池の水質マネジメント

国土交通省の管理するダムにおける水質マネジメントの概念図を図1に示す。各ダムの水質監視や水質対策については、ダム管理所等が行っている。その際、一部の調査や検討については専門とする民間コンサルタント等に委託を行い、新技術を含めた民間の技術の積極的な導入に努めている。また、ダム管理等フォローアップ委員会や個別に設置する委員会に諮ることで、学識経験者等からの評価や指導助言を積極的に取り入れている。国土技術政策総合研究所・土木研究所では、水質問題が発生したダム管理所等に技術指導を行うとともに、ダム水質に関する知見の集積や研究・技術開発を行っている。国土交通省水管理・国土保全局では、全体をコーディネートするほか、国土技術政策総合研究所・土木研究所と連携し、蓄積された知見をもとに技術の一般化・普及・継承等に努めている。また、流域の地方公共団体等と積極的に相互協力し、流域対策の促進を含めた流域一体となった対策を進めている。

3. 「ダム水貯水池水質改善の手引き」の公表

今般、国土交通省水管理・国土保全局河川環境課では「ダム貯水池水質改善の手引き」の公表を予定している。この手引きの体系図を次頁の図 2 に示す。これは、ダム毎に水理・水文・流入負荷特性、流域の社会環境特性、求められる水質改善レベル、水質問題への対応の緊急性等が異なる中で、ダム貯水池の水質改善対策の共通する検討プロセスを抽出・体系化し、その基本となる考え方をとりまとめたものである。取りまとめに際しては、学識者等や地方整備局職員等からなる有識者委員会に諮り、国土技術政策総合研究所及び土木研究所の監修のもと整理した。

この手引きでは、水質変化現象の発生後、「発生・要因の推定」、「対策の検討・実施」、「効果確認」、「運用・調査・対策施設の効率化検討」の一連の流れを整理している。ただし、所定の効果の発揮が確認されない場合は、立ち戻って検討を行うPDCA サイクルとしている。また、各過程で、流域関係者との連携や学識者からの指導・助言といった「連携・助言の活用」、「ダム管理フォローアップ委員会からの意見聴取」、水質問題が発生した場合の迅速な情報提供や日頃からの PR を含めた「情報提供」を明記している。今後、この手引きに基づき、ダム貯水池の水質対策を進めて行く予定である。

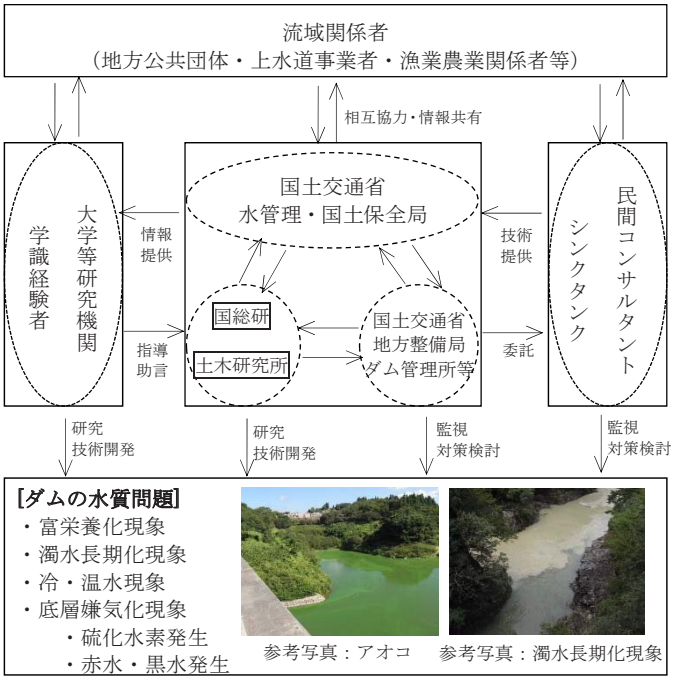

図 1 国土交通省管理ダムの水質マネジメントの概念図

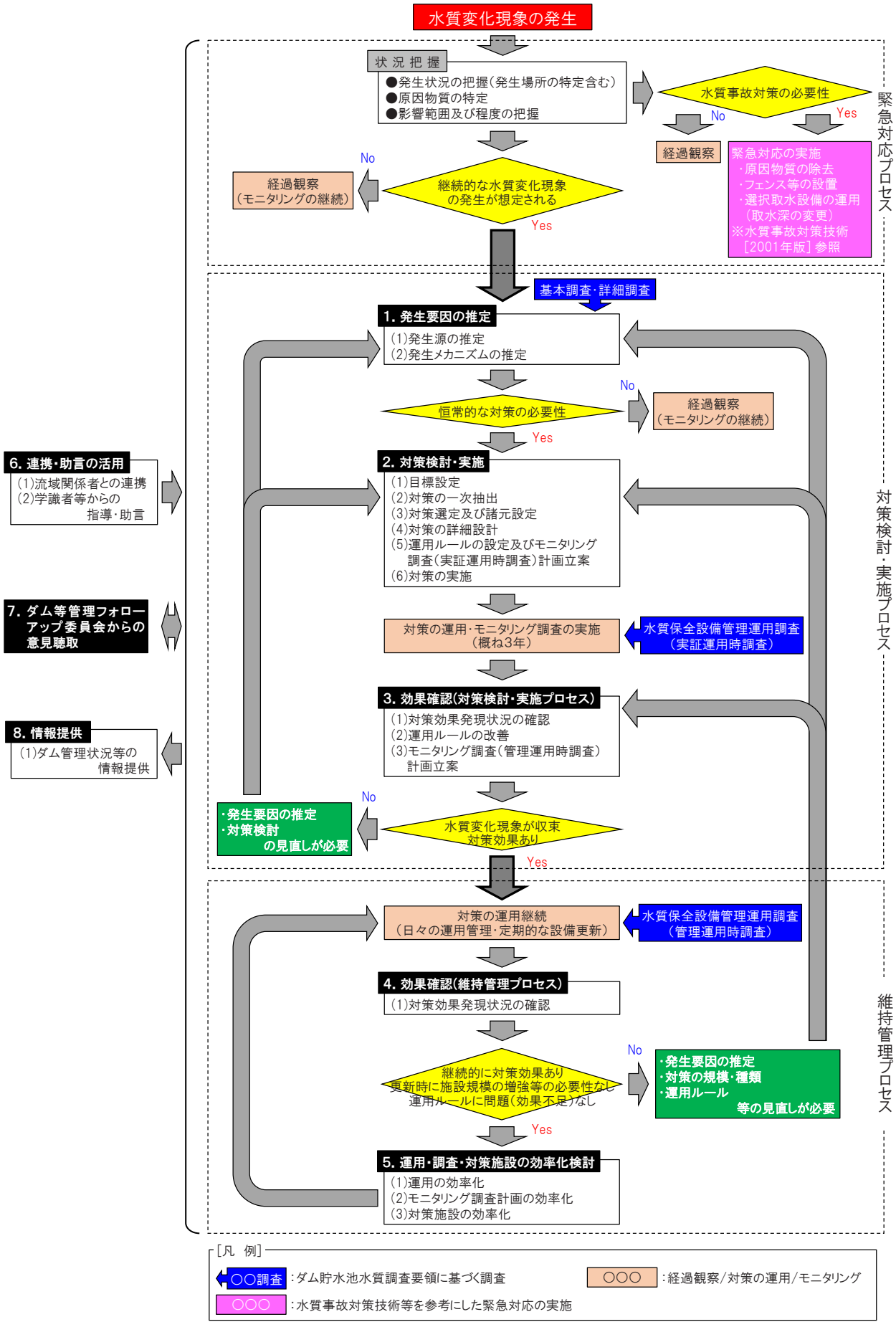

図 2「ダム貯水池水質改善の手引き」の体系図

P9-4

霞ヶ浦の湖沼浄化地域活動

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茨城県　つくば市環境マイスター

キーワード ： 霞ヶ浦と河川流域住民が進める水質浄化活動

抄録

つくばエンバイロオフィスは、生物多様性地域戦略・自然との共生・都市と農村の生態系保全・内水面漁業振興対策等、国の自然環境再生事業に呼応した、県市民の進める地域自然環境活動を支援する。

1. はじめに

世界は、持続可能な社会をどう築くかで動きはじめている。日本の国土は 67%が森林だが、生態系で健全なところは 7%しかないといわれている。筆者の所属している茨城県では、2002 年～持続可能な社会構築を目途に、循環型社会を目指すつくばフォーラムの活動を継続している。その活動の中で、2014 年つくば市に於いて、気候対応及び環境保全の動向とこれからの研究開発要素についてフォーラムを開催し、参加者と意見交換をおこなった。テーマは、水戸気象台より、地球温暖化と予測、東海村より、生物多様性地域戦略の策定と自然の恵をまちづくりに活かす活動の報告、茨城町より、涸沼ラムサール条約の登録により、動植物の適性利用を促進する活動等の報告と意見交換が行われた。1987 年開催の世界環境会議では、すべての人が環境リテラシーを身に着けることの重要性が示されている。環境問題に対して、個別の事象だけ切り離してみるのではなく、全体として環境負荷を下げることを目指そうとする考え方を身に着けることが求められる。今後、環境リテラシーと環境保全や自然再生活動などを進めるため、フォーラムなどの開催を通じて一般住民の意見と活動を加えた、河川及び湖沼の浄化活動を普及推進していく。[1]

2. 方法

環境リスクを管理するため、科学的知見の解明が重要となる。リスクに関する情報が適切に共有できれば、関係者は自らの判断で環境リスクをなるべく回避するような行動をとることが可能となる。関係者をリスク管理の過程に関与させることにより、リスク管理の計画などが関係者に受け入れやすく、計画の実行が容易となり、総合的に見れば意思決定にかかる時間と費用の節約につながる。即ち、① 問題を洗い出し、その原因と影響を調査する ② 問題に関するリスクを分析する ③ 地域の環境リスク削減方策の検討 ④ 地域の環境リスク削減の実施 ⑤ 地域の環境リスク管理の評価。

以上の PDCA サイクル活動の他、関係者への普及啓発・関係者からの問い合わせへの対応・関係者間の対話の促進・事故等のコミュニケーションの促進などがある。これまでの方法では、関係者間の信頼関係が築きにくく、関係者全員が意思決定に関与する参加型で行う。参加型のリスクコミュニケーションでは、情報の発信側も受信側も対等な立場で意見を出し合い意思決定を行う。環境コミュニケーションに関する O14063/JIS14063「環境マネジメント・環境コミュニケーション・指針および事例」では、これらの形態として整理されている。[2]

3. 結果

市民参加型環境活動を進めるため、つくば市環境マイスターの会及び、つくばエンバイロオフィスに所属し、各種展示会及び、環境フォーラム活動を推進している。情報の発信側として、特に留意した点は、国の自然再生事業関連事業として、2012 年～行政及び、地域活動者区分が公表され、市民環境活動に支援が行われることを骨子とした。また、2015 年～自然資源の持続的な利用手法分類や管理手法が示され、環境改善を行う市民活動のガイドラインとして取組ができるよう情報提供した。市民の自律的環境活動を開始するため、現状で紹介されている活動モデルを公開し、多くの方々と情報交換を継続して行うことで、環境に対する興味と活動を喚起することに期待をしている。[3]

4. 考察

霞ヶ浦及び、河川流域に居住する一般住民が、自律的に推進できる活動として、国が示している水質浄化活動で、農業振興地域に該当する事業がある。この活動

に関して、農業従事者外の地域住民が協力できる活動として、地域共同で行う農地、水路等の資源の日常管理と水質保全、生態系保全などの農村環境の向上に資する活動があり、共同で水質浄化等活動を推進・協力することが考えられる。以下[4]

水産庁の内水面漁業振興対策のうち、健全な内水面生態系復元等推進事業がある。内水面魚種の棲み場所として必要な、河川環境の調査や、再生産に寄与する放流種苗の育成方法の開発等を実施するとともに、漁業関係が行う外来魚の取組みを、漁業関係者以外の一般市民も参加し協力作業ができると考察される。同じく水産庁の、水産多面的機能発揮対策事業がある。漁業者等が行う、水産業・漁村の多面的機能的機能の発揮に資する活動に対して、支援が定められている。これは、多面的機能の一つである、地球環境の保全機能の内、藻場・干潟の有する公益的機能の維持を図るために行う保全活動に対しても、一般市民が参画し活動支援に協力すべきと考える。

環境省所管では、自然環境の保全・自然と共生に資する活動に対する支援がある。持続可能な社会構築のための、環境保全に資することを目的とした研究課題は、湖沼会議開催後の課題として、新たに取り組む浄化対策活動等にも該当することが考察される。

地域にある生態系サービスから生じる、地域の財産を再発見し、持続的に活用する暮らしと自然の未来像を描くため、住民が参加した地域づくりの保全活動の実践と提案が期待できる方策が考えられる。以下[5]

伝統的な農林漁業などの、自然利用の方法や自然との関わりながら成り立ってきた暮らし方、自然を守る活動などを明らかにし、持続可能な地域づくりに活用する。地域の暮らしと自然の未来像をテーマに講演会、シンポジウム、意見交換会、ワークショップなどを開催し、少人数から始めることも大事。分かり易い言葉や絵・地図などで未来像を共有する。地域の個性・財産を市民とともに発見し、未来像が見えてきたら、思いやイメージを市民が共感できる言葉やイラストでまとめ共有する。行政・市民や企業、研究機関や団体のなすべきことを示す。

地域の現状を整理する。遺したい対象について現状に関する情報を把握し、対象についての課題を整理する。森の消失・分断農地の変化など、土地利用変化が明らかになってくる。課題の特定とそれが引き起こされる因果関係を把握する。課題がなぜ発生しているか、問題の構造と根本原因を分析する。

問題解決のために、だれがどんなアクションをするのか行動計画をつくる。課題が生じている原因への対処が大事。優先順位で目標設定する。行動計画の評価・見直し方法を決める。実行できなかったときに、その原因を解決できる行動計画に見直す。計画の実施体制を確保する。地域戦略を推進するための人材や資金の調達も戦略の一部とする。行政の役割:ボランティア組織化と支援・市民:生きもの多様性保全・再生に取組の推進。

5. 結論

市民とともに、暮らしと自然の未来像をつくる。そのために、解決すべき課題を特定し、行動計画とその実行・見直し体制等を構築推進していく。また、湖沼と流入河川の、生物多様性地域戦略等の普及と実践のための体制を構築していく。

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P9-5

Functioning of the karstic system of influence in the Bacalar lagoon, applied to the Territorial Ecological Regulation

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Keywords: karstic system, hydrology, interactoral and intersectoral linkages, public policy, water sensitive city.

ABSTRACT

The Yucatan Peninsula in Mexico presents a highly permeable biogenic karst topography, resulting in a vertical underground water system, horizontally connected with surface expression as sinkholes, lagoons and wetland but without rivers or perennial streams. Numerous scientific studies of the last decade, examined the peculiarity of this type of biophysical system and concluded that it has a high vulnerability to ecological deterioration associated with pollution and fragmentation of structural and functional connectivity of the water flow. Given the need for land use, legislative elements are implemented whose aim is the maintenance of ecological balance -the relationship between natural elements that enable life. Territorial environmental regulations (OET, for its Spanish initials) are binding public policy instruments regarding land use, and should be built in consideration of the natural vocation and intersectoral participation mechanisms. The government of Quintana Roo has operated the development of the program "Local Ecological Ordinance of the municipality of Bacalar" (POEL, for its Spanish acronym), showing in 2017 a version that ignores the high permeability of the municipal area, which leads us to ask why progress in the design of aforementioned program does not recognize the characteristics of the karstic system. This research will be of qualitative character during 2018, combined with mixed-method work: semi-structured interviews, field journaling map of actors, participant observation, documentary analysis, conceptual model generation as a basis for the determination of the natural vocation, matrices of the environmental compliance, which is expected to identify opportunities to improvement in the intersectoral linkage given in this process.

1. INTRODUCTION

The Yucatan Peninsula, Mexico, shows a landscape of biogenic karst relief created in the last 200 million years (Beddows et al.) Despite the abundant rainfall (CONAGUA) perennial rivers lacks surface (CONABIO) Given the high permeability of karst, between 80 and 90% of rainwater infiltrates or is evapotranspired (Cervantes Martínez 2007). This system is vulnerable because of the multiple connections generated due to karstic dissolution forming channels and expressions of aquifer connected together (Torrescano-Valle N., Islebe GA 2007;Perry et al. 2009;Gondwe et al. 2010) as well as to the Caribbean Sea(Hernández-Arana et al. 2015).

The Mayan culture inhabited this area until 1531 B.C. (Morales-Rosas 2006), which was adapted to the karstic system (Zapata Peraza 1989). Along with colonization both sacred bond, such as adaptation to soil they were disjointed.

Quintana Roo was created in 1974 (Xacur Maiza Rosas Morales-1998 and 2006) and the municipality Bacalar in 2011 (DOF 2012) With 39.111 inhabitants, 66 ejidos, this municipality fully contains the karst landscape, it has the country's second largest freshwater lagoon: Bacalar lagoon that protects exceptional natural elements: mangle freshwater (Hernández-Arana et al. 2015) and stromatolites (Centeno et al. 2012). As these resources attract visitors, the municipality is also focusing on tourism, increasing its hotel infrastructure seven times in four years (Government Quintana Roo 2013).

In Mexico, a new political delimitation will continue its regulatory planning, as is the case of land management based on the vocation of ecosystems (DOF 2017) so the government began in 2012 to design the Local Ecological Zoning Program of Bacalar (POEL) (SEMA 2017). However, in the version presented at the VI meeting of the committee in 2017 it is clearly not responding to the karstic system (EMS 2017B, p. 84-92 and SEMA 2017 p 103-185).

By ignoring the plethora of available scientific information, it should question the quality of the link between the social and governmental sector, academia and although

participation is provided for the legislation, it is possible that they are not giving communication mechanisms that enable an active, proactive and open participation (López Cerezo 2005).

Given the broad spectrum of players and multisectoral confluence in generating public policies congruent with ecosystems and society, it should analyze the processes linking (Arrojo Agudo et-al. 2012), Understood as the relationships that exist, or should exist-between actors and sectors and public policies, especially (but not limited) with academia (Campos and Sanchez Rios Daza 2005), the overall objective of this research is as follows:

To identify from legal regulations and intersectoral and interactoral linkage, the reasons for the separation of the POEL Bacalar with elemental intrinsic characteristics of the karstic system in southern Quintana Roo. The hypothesis is that linking mechanisms and sectoral participation in public policy, they is a window of opportunity for consideration of hydrological connectivity in the karstic system in the Bacalar POEL.Please list the number of the references in the quoted part[1].

2. METHOD

Study zone. Bacalar is located in the south of Quintana Roo, Mexico, 45 kilometers of Chetumal, bordered on the west with the state of Campeche, south with the municipality of Othón P. Blanco and east with the longitudinal half of the water mirror Lagoon Bacalar. In the scope of influence this qualitative research developed during 2018, with mixed-method work combined: semi-structured interviews Journaling field, participant observation, document analysis, generation of a conceptual model as the basis for determining the vocation ecosystem, building a criteria matrix of the ecological regulation applied to POEL linked to the ecological balance and natural vocation of the karstic system (developed with the participation of researchers from the Colegio de la Frontera Sur, Universidad de Guadalajara and the Center for Scientific Research Yucatan, for defining natural vocation and consistent emission to the structural and functional connectivity criteria, which will be presented to the government sector by the means provided for in the law.

3. PRELIMINARY RESULTS

Research is in progress, the main result is the creation of the model on karstic system influence on Bacalar and its presentation in order to generate criteria of ecological regulations related to the natural vocation of the system, results are in process.

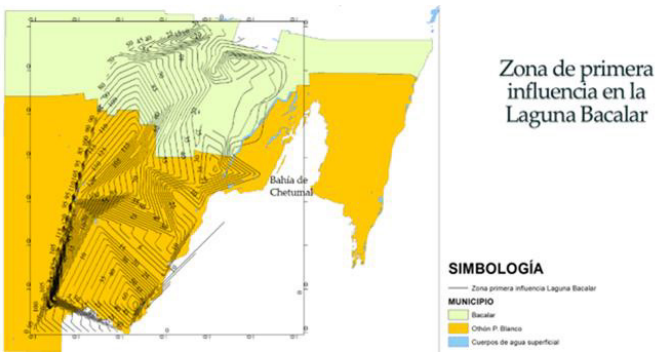

Illustration 1.- Local Area influence on the Bacalar lagoon. Source: Prepared with information piezometric 2008-2014 study by government agencies

4. DISCUSSION

The discussion will be developed after obtaining results

5. CONCLUSION

There are still not conclusions

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P9-6

フィリピン・ラグナ湖周辺を対象とした洪水氾濫解析のための土地利用モデルの構築

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キーワード:ラグナ湖, 洪水氾濫解析, 人口・世帯動態, 土地利用モデル

抄録

昨今, 気候変動に伴い世界各地で洪水が頻発している。特に, フィリピンのような発展途上の国において大規模な洪水が発生した場合, 人命に関わる被害と同時に, 経済的な損失が懸念される。そのため, 洪水発生が想定されている地域, とりわけフィリピンではいかにこのような状況に適応していくのかといったことが課題となる。また, 将来, 人口が増加し, 経済成長することも予測されており, 都市とその周辺部において開発が進めば土地利用が大きく改変される。これがまたさらに河川流出に影響を与え, 洪水発生のリスクが増すことになる。本研究では, フィリピン・ラグナ湖周辺を対象に, 土地利用改変を考慮した洪水氾濫解析を分析するため, まずは取得できたデータを用いて土地利用モデルを構築することで 2100 年までの土地利用を示す。この際, 将来の人口・世帯動態によって土地利用も大きく異なることから, これらをシナリオとして設定した。

1. はじめに

近年, 気候変動の進行に伴い, 世界各地で大規模な洪水が頻発し, 多大な被害が生じている。フィリピン・ラグナ湖周辺も例外ではなく, 2006 年 9 月には Milenyo 台風によって, 湖西に位置するシラン・サンタロサ川流域において深刻な洪水被害が発生した[1]。こうした洪水を助長する原因として, 気候変動による異常気象の影響が挙げられるが, それ以外にも人為的な要因, すなわち人口増加や経済成長に伴う大幅な土地利用の改変が挙げられる。特に, 雨水処理施設や堤防, またダム機能等といったインフラが未整備の発展途上国の場合, 受ける被害は甚大となる。本研究では, ラグナ湖周辺の流域を対象に, 洪水氾濫解析を行うことを最終的な狙いとしている。ここでは, その前段階として, 2100 年までを対象に, 人口・世帯動態をもとにした土地利用モデルを構築する。

2. 推計方法

本研究ではまず, 将来の人口動態を把握するため, 3 つのシナリオをもとに, コーホート要因法によって推計する。そして, 得られた人口推計の結果から, 世帯数を割り出し, 最終的に将来の土地利用を詳細な空間単位で把握する。以降において, その推計の詳細を記す。

人口は, 2010 年から 2100 年までの 5 年間隔において, コーホート要因法によりバランガイごとに推計した。コーホート要因法とは, 各集団すなわちコーホートごとに, 「自然増減(出生と死亡)」及び「純移動(転出と転入)」という 2 つの「人口変動要因」を考慮し, それぞれの将来動向を考慮しながら人口を推計する手法である[2]。

本研究では, 2010 年と 2015 年のバランガイの人口データを入手した。しかし, バランガイごとの男女 5 歳階級別の人口データが存在しないため, 次の方法で代用した。2010 年の人口データは, PHILIPPINE STATISTICS AUTHORITY[3]が公開している 2010 年のバランガイの総人口のデータを PHILIPPINE STATISTICS AUTHORITY[3]が公開している 2010 年の州ごとの病院などで居住している人を除いた「Household Population」の男女 5 歳階級の人口割合で割り振った。2015 年の人口データは, PHILIPPINE STATISTICS AUTHORITY[3]が公開している市ごとの男女 5 歳階級別人口をもとに, 2015 年のそれら市に属するバランガイの総人口を用いて割り振った。コーホート要因法は, 合計特殊出生率, 死亡率(1-生存率), 出生比, 純移動率のデータが必要である。

本研究では, 将来の様々な人口変化を想定するため, BAU(Business As Usual), Scenario High, Scenario Low の 3 つのシナリオを設定している。3 つのシナリオは, 合

計特殊出生率のみ値を変更した。BAU の合計特殊出生率は，国連人口推計[4]によるフィリピンのシナリオの中位と低位の中間値を用いた。Scenario High の合計特殊出生率は，国連人口推計[4]によるフィリピンのシナリオの中位の値を用いた。Scenario Low の合計特殊出生率は，国連人口推計[4]によるフィリピンのシナリオの低位の値を用いた。これら 3 つのシナリオの生存率については，国連人口推計[4]によるフィリピンにおける生存率シナリオの中位の値を用いた。死亡率は 1 から国連人口推計[4]による生存率シナリオの中位の値を減じた値を用い，出生比は PHILIPPINE STATISTICS AUTHORITY[3] が公開している 2015 年の出生比を 2100 年まで持続させる形で用いた。純移動率は，まず 2010 年の男女 5 歳階級別の人口に国連人口推計[4]が公開しているフィリピンにおける 2010 年の男女 5 歳階級別の生存率を乗じることで封鎖人口を求めた。そして，2015 年の人口データから 2010 年の封鎖人口を差し引くことで純移動数を算出した。次に，算出した純移動数を 2015 年の人口データで除すことで 5 歳階級別の純移動率を求めた。しかし，算出した純移動率に大きなばらつきがあったため修正した。さらに，対象地の純移動率は 2100 年において現在の日本の純移動率と同等になると仮定し，上記によって算出した純移動率から国立社会保障・人口問題研究所[5]が公開している 2010 年における神奈川県の純移動率に線形的に変化させた。

表 1 土地利用

自然的土地利用	
単年生作物農地	養魚地
多年生作物農地	マングローブ
雑木林・低木	空き地・荒野
疎林	閉鎖林
牧草地	ー
自然的土地利用（開発対象外）	
陸水	湿地
都市的土地利用	
都市	

シナリオごとに算出された男女 5 歳階級別の人口に世帯主率を乗じて，バランガイごとの世帯数を算出した。市ごとの年齢層世帯主率は，PHILIPPINE STATISTICS AUTHORITY[3]が公開している市ごとの年齢層別世帯主数を 2015 年の人口データで除すことで求めた。

人口や世帯数推計の結果を用いて，対象地域の将来の土地利用を推計した。土地利用の元データは，National Mapping and Resource Information Authority[6]が提供している 2015 年のものを使用した。このデータは表 1 のように土地利用が分類されており，これをもとに自然的土地利用と都市的土地利用の 2 つに区分した。ここで陸水，湿地は開発の対象外とする。そして，人口や世帯の動態に伴い将来の都市的土地利用面積がどのように変化するか次の方法で推計した。まず，2015 年の都市的土地利用面積をバランガイごとに割り出し，2015 年の各バランガイの世帯数で除すことで一世帯当たりの面積を算出した。次に，このバランガイごとの一世帯当たりの都市的土地利用面積を，世帯数の推計によって得られた各年の結果に乗じることで 2100 年までの都市的土地利用面積を 5 年ごとに求めた。そして，2015 年の土地利用データを 450m 格子ごとにまとめることで，各メッシュの土地利用面積割合を算出した。各土地利用面積は，次の方法で算出した。都市的土地利用面積が増加した場合，同じメッシュ内の自然的土地利用面積を減ずる。ただし，都市的土地利用面積が格子面積を超過した場合には，その超過量を同じ州に属している他の格子の自然的土地利用面積から減じた。具体的には，超過量を州のメッシュごとの自然的土地利用面積比率で割り振り，各格子の自然的土地利用面積から減じた。この際，都市的土地利用が含まれている格子を優先し自然的土地利用面積を減じている。

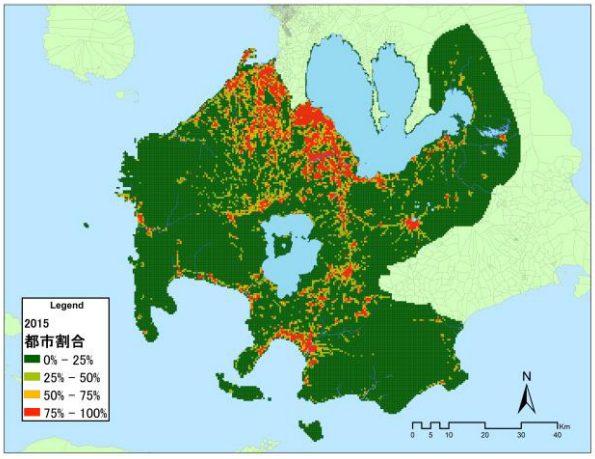

図 1 都市的土地利用の面積割合（現状）

3. 結果

図 1 は，現状の世帯数をもとに都市的土地利用面積割合を示したものである。現状では，ラグナ湖南西部に都市が集中していることが分かる。図 2 に，2100 年のシナリオ別の都市的土地利用面積割合を示す。また図 3 に，時系列的なシナリオ別の都市的土地利用面積割合の変化を示す。この結果，現状では約 15%を占める都市的土地利用は，2100 年の BAU と Scenario Low において，各々約 41%と 33%に増加した。Scenario High では，2100 年に約 48%が都市的土地利用となり，約 19 万

ha の自然的土地利用が開発されることになる。とりわけ，湖西に位置するカビテ州では，都市的土地利用への変化が顕著であり，どのシナリオにおいても都市が拡大している。また，ラグナ湖の沿岸部の大部分では，都市的土地利用に変化することが分かる。これらの土地利用変化は，都市周辺に広がっていた単年生作物用地や多年生作物用地が都市に開発されたことが起因しているものと考えられる。しかし，これは構築した土地利用モデルの設定に依存しているため，今後，検証が必要である。

4. 結論

本研究では，フィリピン・ラグナ湖周辺を対象に人口・世帯の動態を推計することで土地利用の変化を把握した。地域によって多少異なるものの，本推計では将来，土地利用が大きく改変されることが分かった。土地利用変化は，自然的土地利用を開発し都市的土地利用に転用することで行われることが多い。これは，ラグナ湖周辺の多くの地域で起こっていることから，今後，洪水の危険性が高まることが懸念される。また，一度開発されると，その土地を元に戻すことは難しい。そのため，気候変動に対する適応を十分に考えながら，都市開発等を行っていくことが望まれる。本研究では，入手できた限られたデータを用いて将来の土地利用を推計している。そのため，ここで得られた結果は，あくまでも暫定的な結果であることに留意されたい。

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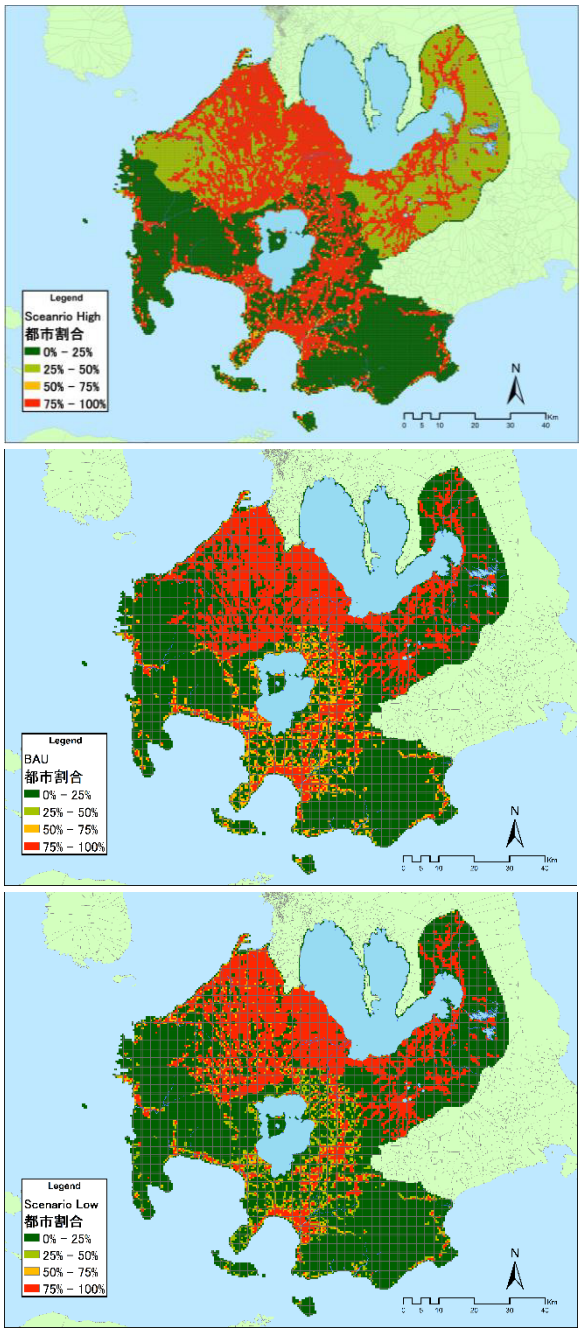

図 2 都市的土地利用の面積割合（将来：上から Scenario High, BAU, Scenario Low の順）

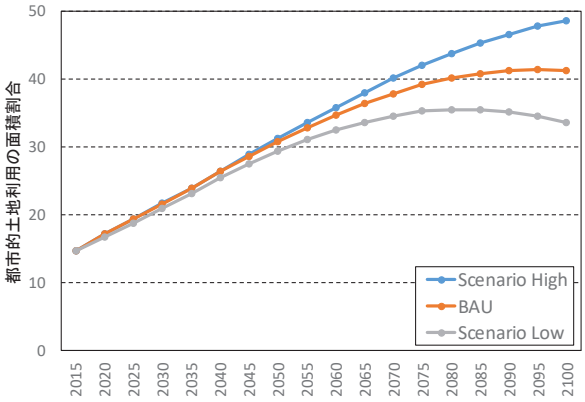

図 3 時系列的な都市的土地利用の面積割合の変化

P9-7

Climate Resilient Water Security for Urban Settlements:

Role of Lakes a case of Bengaluru, India

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Key Words: Lake basin governance, ILBM, Ecosystem services, Multiple uses of Lake

ABSTRACT

The enormous life loss, economical damages and ecological implications due to climate changes of extreme dry and flood conditions have been causing concern. The international initiatives in the form of ILEC Foundation has the necessary heritage of standard formats to document and develop sustainable conservation and management of lakes.(ILEC/UNEP, 1989). Studies using survey maps and satellite imagery have indicated that the urban growth is galloping at the cost of water bodies and lakes at Bengaluru (NNRMS, 1985). In this presentation the Landuse of Bengaluru (BDA, 2031) and the causes for degradation of water bodies in the urban region is reviewed. The efforts to manage water bodies through statutory and policy directives and their effectiveness are discussed. Community centered water bodies management an offshoot of citizen response since 1990s are documented. Necessity prevail for definite policy guidelines with socio-technical aspects of Lakes management using ILEC SENCLE model.. Best practices in lakes management and environmentally Sound Technologies (IETC, 1999) are focused.

1. INTRODUCTION

Climate resilient water security planning for urban settlements with definite role of Lakes is a global need. Over 307 cities all over the world have definite climate resilient plans of action on environmental management (IIED, 2017), Irreparable economical and environmental impacts due to quadrupled disasters over 100 years have been forcing the stakeholders to embark upon sustainable plans (UNEP, 1989) . Over 40000 lakes in the state of Karnataka alone have shown degradation and are disappearing (GoK, 1986).

Studies on Bengaluru using survey maps and satellite imagery during 1900 to 1985 revealed that lowered priority on water bodies and unsustainable strategies are causing irreparable losses (NNRMS, 1985). Recent Comprehensive Development Plan for Bengaluru for 2031 (BDA, 2017) reveal inadequate plans for climate resilient management and a complete diagnosis for conservation and management of lakes.

2. METHOD

Quantification of pollution loads to lakes based on WHO rapid assessment techniques are documented. Using the conventional and advanced techniques quality parameters are analyzed to establish the real ecological succession of the lakes. Later by using SENCLE Model conservation and management action plan suggested for a selected lake.

Legal sampling results listed by the statutory body Karnataka State Pollution Control Board are analyzed and benefits and constraints for suitability of lake for multiple uses.

Restoration Plan and interventions were based on field studies and their analysis. Ecological succession status for each lake has to be considered for its restoration. In the proposed restoration plan, established basis for solving the problems facing endangered lakes namely Socio-Economic Natural Complex- Lake Ecosystems (SENCLEs) was used as guidelines. Further, the State of Art Techniques elucidated in the IETC/UNEP guideline document is followed.

In the SENCLEs approach the core is human beings, including the organization, technology, and culture, comprising laws, strategies, customs and traditions for management and utilization of lakes. This is the

controlling part of SENCLEs, and may be called the Eco-core. The second layer is the direct environment of human activities within a SENCLE, including the geographic, biological and artificial environment, which is the fundamental medium activities and is called the Eco base. The third layer is the external environment of SENCLEs, including source, store, and sink, which is the external supporting system of SENCLEs and called the Eco-pool. These three layers are interacting upon one other.

3. RESULTS

The field studies and analysis on urban lakes at Bengaluru reveal mixed results. There are lakes which have been partially restored by intervention by preventing further degradation for reasons of lake multiple use options. Majority of lakes have not been diagnosed for causes of degradation and action plan not complete to its best uses. There are issues of conflicting Landuse priorities and other reasons inspite of a very strong public outcry and participation. A strategy coupled with policy is suggested. Environmentally Sound Technologies are found to be cost effective and can provide water resources for multiple urban needs.

4. DISCUSSION

Study of Bangalore using maps and satellite imagery during 1900 to 1985 (G. Behera, et al., 1985) revealed that ecological security remained a lowered priority and a casualty. Rapid growth of Bangalore urban in the last three decades has witnessed both a further ecological degradation and efforts to make best use of available water resources. Estimates indicate that at Bangalore over 3600 apartments with over 50 flats where about 300 MLD water could be recycled. An estimated 3000 Ha M natural recharge per year with 830 mm annual rainfall over 800 Sq km area is reported. In the scenario of a demand of 1920 MLD the actual water supply to Bangalore is about 1228 MLD. Interestingly, the rain water potential is five times the water pumped from 120m Kms Cauvery Water source against a vertical lifting of water for over 1.5 Km with 1000 INR of electric charges. At Bengaluru Urban 142 Percent Ground water overdraft has taken place with over 368 percent in excess over annual recharge of about 3000 ha. There has been tradition of recycling of waste water In domestic and industrial sectors at Bangalore since 1980s. SENCLE Model for lakes is suggested for conservation and management, However, the actual role of urban water bodies for total dry and flood conditions due to Climatic changes are not analyzed or considered in the proposed development plan 2031 for Bengaluru.. Selected case studies are analyzed from the 307 climate resilient cities and best practices are taken up for evolving location specific strategies and policies. At one urban lake after ESTs it is proposed to make available water for different uses in a cost effective manner,

5. CONCLUSION

The role of lakes in climate resilient water security for urban settlements is challenging and need policy guideline and definite strategies and action plan. The current trend of crises management needs to shifted to Ecological Planning in Urban Development. Hybrid approaches of treating all wastes and further impounding them in the water bodies and later polishing for multiple water uses by ensuring quality requirements is suggested. Environmentally Sound Technology (IETC, 1997) have been available for validating scales of operation in pollution prevention and management of lakes.

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P9-8

Integral Control of Water hyacinth in the lagoon of Yuriria, Guanajuato Mexico

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Keywords: Yuriria lagoon, aquatic lily, integral control

ABSTRACT

Yuriria lagoon is a freshwater body located in the city of Yuriria, Guanajuato, Mexico, cataloged as Natural Protected Area (NPA) and RAMSAR site. For decades in the lagoon has spread the growth of the aquatic plant *Eichhornia crassipes* (commonly known as water hyacinth), causing environmental, social and economic issues in the region. To continue using the hydric and biological resources of the system, integral efforts to reduce the impact area to the aquatic weed in the lagoon were made. Mechanic, manual and chemical actions were applied. The impacted area was monitored through satellite images. The impacted area with water hyacinth in June 2017 was near to 22% of the lagoon. In April 2018 the impacted area was 10 %. Efforts should continue to reduce water hyacinth present in Yuriria lagoon to acceptable levels.

1. INTRODUCTION

Yuriria lagoon is a freshwater body located in the city of Yuriria, Guanajuato, Mexico. The lagoon meets the criteria to be cataloged as RAMSAR site [1], and Natural Protected Area, for that reason it is considerate one of the most important lagoons in Mexico. For decades in the lagoon has spread the growth of the aquatic plant Eichhornia crassipes (commonly known as water hyacinth), covers a big part of the lagoon surface [2]. Water hyacinth is a perennial plant that have two reproduction ways: sexual and vegetative [3]. The uncontrolled growth of the aquatic weeds has generated environmental, economic and social issues. These include the loss of water due to evapotranspiration, deterioration of water quality, loss of biodiversity in the water body by displacement of native species, restriction on fishing activities, restriction to tourist use and recreational activities and the reduction of useful life due to increased sediments [4]. Therefore, it is required to reduce to an acceptable level the number and vigor of biomass per unit of area of the water hyacinth present in the lagoon [5]. To perform this action efforts have been made to decrease the amount of aquatic weed, the activities carried out are based on an integral control of the water hyacinth. The integral control is the use of two or more techniques that are used together to reduce the weeds in the body of water. The present work shown the advances obtained in the mitigation of water hyacinth present in Yuriria lagoon by the application of an integral control.

2. METHOD

Study site

The study site is located on the coordinates 20°14'44.39" North latitude and 101°07'39.31" West longitude, at 1818 masl. The lagoon is in the city of Yuriria, Guanajuato, Mexico and occupies an area of approximately 5.777 hectares with an average depth of 2.6 m and a capacity of 325 million of m3 (Figure 1).

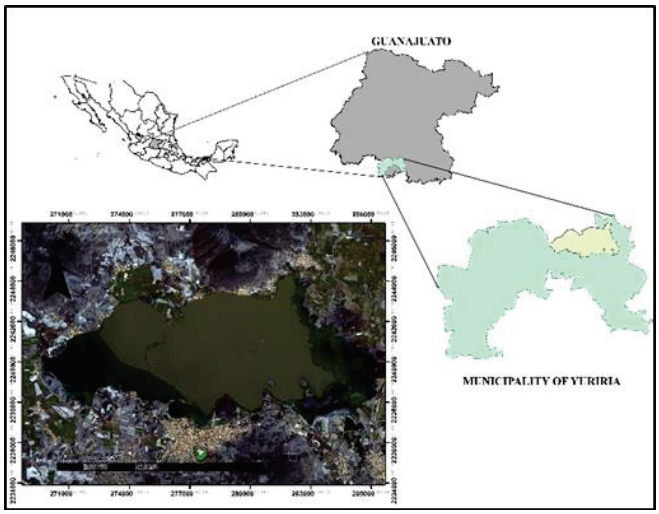

Fig. 1 Location of the study site.

Integral Control

1) Mechanical control. To remove the water hyacinth from the lagoon 3 types of machines were used. A harvesting machine, a machine with collection bands and a crushing machine.

2) Manual control. It is a simple procedure of manual extraction of the water hyacinth that is done with workers who remove the weeds that accumulate on the shores of the lagoon.

3) Chemical control. Was carried out with the application of the herbicide glyphosate [N-(phosphonomethyl) glycine], The sprinkling was carried out with two drones mark DJI Agras during the months of January-March of 2018.

Mechanical and manual control were used since June 2017 to the actuality. Chemical control was used since January to April 2018.

Water Hyacinth Monitoring

For the monitoring of the advance of the integral control of the aquatic weeds the estimates of the affected areas of water hyacinth was obtained by images of the satellite Sentinel 2 of each month from June 2017 to April 2018.

The water hyacinth is a floating plant, so the weeds are not static in a specific area of the lagoon. Depending on the direction of the winds can be moved, adopting different patches or it can disperse throughout the lagoon. The estimation of the surface of the water hyacinth was carried out under these conditions, where it was considered the pixel size that is represented in the reality in an area of 100 m^2. Therefore, the calculation or estimation of the area was performed by assigning a percentage of the presence of water hyacinth in the levels of the vegetation index of normalized difference (NDVI) obtained from the satellite image.

It was determined that the values of NDVI in the range of 0.6 to 1 correspond to compact water hyacinth, from 0.55-0.6 to the presence of water hyacinth in a 60% in a 10 x10 m pixel, from 0.55-0.5 to 35% of the pixel and finally from 0.5-0.35 corresponds to 12% of the pixel.

The negative values belong to the spectral response of the water of the lagoon and low values of NDVI ranging from 0-0.35 were classified as the spectral response of the combination of water and the delimitation of the stain of water hyacinth in the lagoon and were not assigned a percentage water hyacinth presence.

3. RESULTS

The integral control of the water hyacinth has been working successfully in the lagoon of Yuriria, Guanajuato, in addition to that it has been monitoring the surface of the lagoon infested by the weeds by images of the Sentinel satellite 2 in an interval of 11 months. The table with the percentages of water hyacinth found from June 2017 to April 2018 is shown below [table 1]. We observed an average of the water hyacinth of a 22 to 29% in the months corresponding to the year 2017 when only mechanical and manual control were used. In January 2018 chemical control was used addition to the others. The average of the water hyacinth was reduced to 10.26% for the month of April 2018.

Table 1. Percentage of water hyacinth

Year	Month	Percentage of aquatic Lily
2017	09 June	22.60
	19 July	22.56
	08 August	25.58
	17 September	21.67
	07 October	22.66
	16 November	25.09
	01 December	29.12
2018	15 January	30.75
	26 March	20.84
	05 April	17.28
	15 April	21.80
	20 April	10.26

The activities carried out on the site are fishing, agricultural irrigation and tourism. The greatest human impact presented on the water quality of the lagoon, which receives input from the sewers of several villages, as well as agrochemicals. Both are the main causes of the proliferation of the weeds, due to the contribution of nutrients. The affected area by the water hyacinth was between 22-25% of the lagoon in 2017.

We obtained maps of the estimates of the surface of water hyacinth from June last year to April 2018. Where there is a historical set of how the integral control carried out in the lagoon of Yuriria has been advancing. Below is the map of April 20, 2018, where you can see in green the water hyacinth present on this date (Figure 2).

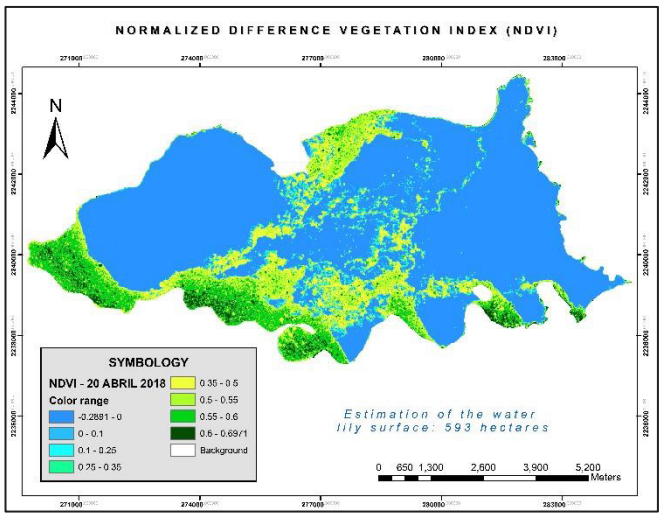

Fig. 2 Estimation of the surface of water hyacinth in the lagoon of Yuriria, Guanajuato.

4. DISCUSSION

The results obtained so far show that progress has been made in reducing the infested surface of water hyacinth in the lagoon of Yuriria with integral control applied, with respect to the estimation of the water hyacinth made monthly.

The quantification of the water hyacinth is an approximation that could be improved with the use of other sensors that allow to have better spatial resolution of the images used.

5. CONCLUSION

The integral control used has shown that it is efficient for the reduction of the surface of water hyacinth in the lagoon. But efforts must continue to be made in reducing this weed, because the water hyacinth has the ability to proliferate in a short period of time, being able to increase their population if mitigation actions are not carried out.

Therefore, it should also be considered the origin of the problem, the reduction of the contributions of nutrients such as phosphorus and nitrogen that are carried out in the lagoon of Yuriria. It should also be assessed whether the methods of control used, caused negative consequences in the wild life in the lagoon.

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