

SECTION 3.2

EFFECTIVE MONITORING OF LAKE WATERS

by Asit K. Biswas

3.2.1. INTRODUCTION

Monitoring has always been an integral component of all planning and management processes, and thus, in this sense, monitoring has been as old as management itself. No sustainable water resources system can be efficiently planned, designed and managed without adequate and reliable data on the system parameters, and lakes are no exception to this rule.

With ever-increasing human and animal populations, more and more water is required for their survival and maintaining a certain quality of life. Lake waters are therefore coming under direct pressure in terms of their availability and use for domestic consumption and for agricultural, industrial and navigational purposes. In addition, lakes are often used for waste assimilation, directly through point sources for domestic and industrial waste discharges and/or indirectly through non-point sources like agricultural and urban runoff. Lakes, especially in developing countries, are also an important resource for fish production. Optimum management of any lake thus requires careful balancing of all these demands, many of which are contradictory. For example, use of lakes as waste assimilators means that water quality continues to deteriorate, which could seriously restrict the use of water for domestic, agricultural and industrial purposes and reduce fish productivity.

Signs of stresses on lake management are becoming increasingly evident in many countries, both developed and developing. Lake managers are thus faced with the complex task of devising and implementing appropriate strategies which would optimize the use of lake waters to satisfy the needs of the human population but simultaneously ensure that this could be done without endangering such resources for continuing use in the future. The art and science of properly balancing the various

possible uses of lake waters on a sustainable basis can be termed as lake management.

Lakes can only be managed efficiently if the information on which management decisions can be based is available to the decision-makers on a regular and timely basis. Unfortunately, however, for a majority of the lakes of the world, managers still have access to surprisingly limited information on which sound decisions can be based. The only way to ensure that managers have ready access to the information they need is to institute a functional monitoring system, which will regularly provide them with the data which they so badly need.

3.2.2 LAKE MONITORING

In the context of the present chapter, lakes include both natural and man-made lakes, and monitoring is defined as the continuous or periodic collection, collation and analysis of data and information for purposes of effective management of lake waters. Data includes both physical and socio-economic data which are required for proper management and optimum use of lake resources. Since the primary purpose of monitoring is to achieve efficient and effective management of lakes, it should be considered as an integral part of the management information system. Accordingly monitoring should be a regular internal activity of any institution responsible for managing lakes.

It should be clearly recognized that monitoring by itself will not be enough. Data collected must be used in a timely manner to get a clear picture of the status of any lake, both in terms of quantity and quality of its water, its availability and use, and overall effective management. Periodic evaluations need to be carried out. Evaluation in this context may be defined as a process which determines systematically and objectively to the extent possible, the impact, effectiveness and relevance of lake management in terms of their agreed objectives.

It can be persuasively argued that if the existing performance patterns of lake management in terms of achieving their objectives are to be improved significantly, it would be essential to ascertain that monitoring and evaluation become an integral component of the management process in order first to determine their achievement levels and then to identify what adjustments and corrective actions may be necessary to ensure that the future stream of benefits accrue to the appropriate users and target groups.

Some form of monitoring and evaluation is often carried out for many lakes. For example, if the water of a lake is used for human consumption, agriculture or navigation, its water level is generally monitored frequently. Often some limnological parameters are also monitored. However for a vast number of lakes, regular monitoring of essential water quality parameters is not generally carried out, or if carried out, the data are not available to planners and managers on a regular and timely basis. Reliable information on fish productivity (both total amount of fish caught annually and their types) is available only for a few select lakes. When one moves from physical factors to socio-economic factors, the status of their monitoring usually gets worse. One would indeed be hard-pressed to identify more than a handful of lakes anywhere in the world where their impacts on the lifestyles of the intended beneficiaries like farmers, fishermen and domestic water consumers have been properly evaluated at regular intervals.

It should be noted that regular and reliable monitoring of lakes is not an easy task under the best of circumstances. There are methodological problems which need to be resolved in order to find a cost-effective and reliable approach that can be used for monitoring within the resources and expertise available to the institutions responsible for lake management. Ready availability of funds and trained manpower are generally critical issues for nearly all developing countries. Even when such methodological issues and resource problems can be overcome, there are other important barriers like institutional inertia, which have to be effectively overcome, before a regular monitoring and data management system can be established, which could become an integral component of the management process.

It should be noted that the various reasons for instituting proper lake monitoring are generally not mutually exclusive since they are often interrelated. Equally it is not enough to identify and monitor the various technical, social, environmental and economic parameters; it is essential to review institutional arrangements and constraints, since it is the institutions concerned which in the final analysis have to develop and implement appropriate policies for lake monitoring and then use the information obtained for sustainable lake management.

On the basis of reviews of monitoring of lakes in many countries, it is clear that very few people are satisfied with the present status. The problems appear to be many-faceted, among which are the following:

Decision-makers often claim that they have no clear idea as to the total real benefits accruing from lakes, nor do they have precise information on the anticipated beneficiaries from the resources of the lakes or even on the nature and extent of the real beneficiaries.

Planners point out that they have no objective information on how past planning of the use of lake resources has fared, and without any reliable feedback they cannot improve the existing planning process to any significant extent.

Managers state that they cannot make appropriate timely decisions since the information they receive is often somewhat general, and as such unusable and of little assistance (too little, too much, irrelevant, unreliable or too late).

People who monitor feel that their works do not receive proper attention, and what is more they are not given enough resources or time to carry out their tasks efficiently.

A realistic assessment of the current status of monitoring of lakes would indicate that virtually everyone associated feels that monitoring is essential and beneficial, but in reality the rhetoric overwhelmingly exceeds actions. Organizations, especially in developing countries, appear to embark more upon pilot exercises and training programmes on monitoring rather than carry them out properly on a long-term basis. This unsatisfactory situation must be improved.

3.2.3 MONITORING AND EVALUATION REQUIREMENTS

There are some fundamental requirements for designing any monitoring and evaluation system for an irrigated agriculture project. Among the primary requirements are the following:

- 1) timeliness;
- 2) cost-effectiveness;
- 3) maximum coverage;
- 4) minimum measurement error;
- 5) minimum sampling error;
- 6) absence of bias; and
- 7) identification of users of information.

Timeliness

Most management decisions have a time dimension, even though the timeliness of making some decisions may be more important than others. For example, if the water of a lake is of inappropriate quality for drinking or for use in agriculture, or if the fish production deteriorates for whatever reasons, it is necessary that these problems be identified as soon as they begin to surface and then necessary remedial measures are undertaken to rectify such problems. If not, the health of the people depending on lake waters would suffer, and the income foregone by the farmers due to the loss of agricultural productivity will never be recovered. Thus, it is essential that information collected from monitoring reaches the appropriate decision-makers on time, so that rational decisions can be made in time based on the data monitored. Accordingly, for a rational management system, monitored information should be channelled in a timely fashion so that it can be converted into decision and action.

It should be noted that the management success depends not only on the timeliness of the information but also on the quality, extent and the form in which the information is channelled into the decision-making process. A problem often arises because even if the required information has been collected, it could not be channelled into the decision-making process since it is either in a diffused or inappropriate form or could not be obtained and analysed within the timeframe by which decisions should be made. If information from lake monitoring does not reach its potential users in time, monitoring can at best only have a limited impact on overall lake management.

The danger is that if monitoring information does not reach the managers on time, it is likely that one or more of the following consequences, which are not mutually exclusive, may occur:

- wrong action may be taken;
- decisions taken may not be optimal on a long-term basis;
- no action may be taken when one is desirable;
- decisions taken may result in irreversible damage; or
- decisions taken may unnecessarily increase the cost and timeframe required for the resolution of a specific problem.

It is therefore essential that a lake monitoring programme be set up in such a fashion that relevant information in usable form reaches the people who need it on a continuing and timely basis.

Cost-effectiveness

Information collection, processing, analysis and scaling requires financial resources, expertise, manpower and equipment. Since the ready availability of all these resources is limited, especially in developing countries, any monitoring system designed for lakes should be cost-effective. This essentially means a sensible trade-off between the depth and context of information to be collected as well as between amount, relevance and accuracy. As a general rule, it can be said that the overall value of information collected in terms of use should exceed the cost of obtaining that information.

For most projects, from a management viewpoint at any specific time, the value of information generally increases with the increasing extent and the accuracy of information available. Value of information, however, for most decisions generally approaches a plateau at a certain stage, beyond which it increases only marginally. In contrast, the cost of obtaining information continues to increase with more coverage and higher accuracy. This is diagrammatically shown in Fig. 3.2.1.

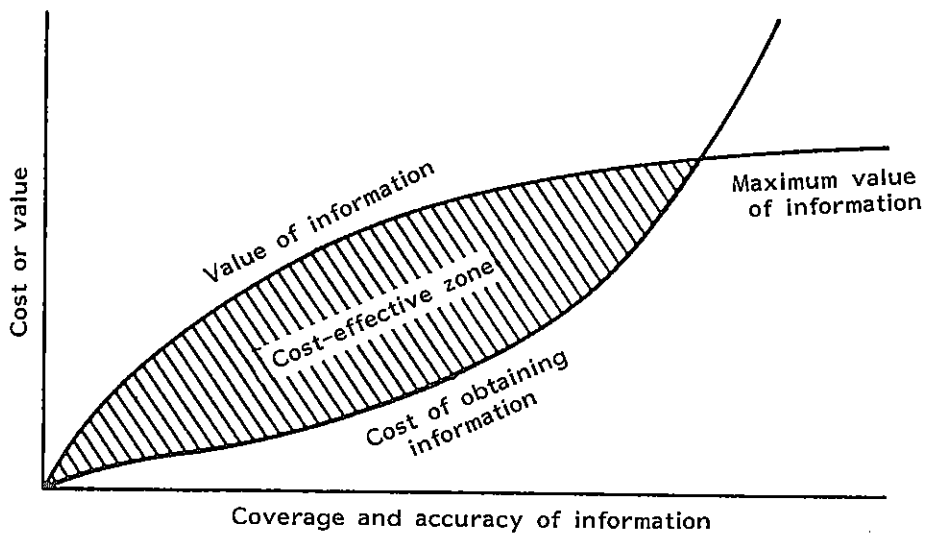


Figure 3.2.1 Cost-effectiveness of Monitoring and Evaluation of Information

The shaded area in Fig. 3.2.1 is the cost-effective zone, beyond which the cost of obtaining information will rapidly exceed its intrinsic value. Exactly where within a shaded area a decision should be made depends on a variety of factors such as type of projects, management experience and potential impact, but such trade-off considerations are often made on the basis of value judgements.

There is often a tendency to collect more data than necessary. For any monitoring and evaluation process to be efficient and cost-effective, it is essential to have a clear idea about who is going to use the data, what types of data are necessary, how the information would be used, and when and in what form they should be made available. Without such a clear focus, unnecessary and non-essential data may be collected, which is an expensive luxury all countries can do without.

While data collection processes need to be carefully integrated within the monitoring framework, consideration and desire for scientific rigour should be balanced with the need for timely information. This in reality often translates into a trade-off between accuracy and reliability with cost. In the final analysis, the value of information for the management process becomes the key factor in resolving this trade-off.

Maximum coverage

For monitoring of lakes, especially large ones, a major difficulty arises from the fact that a wide area may need to be covered, including the lake catchment area, since land use patterns and other human activities will have a major impact on water reaching a lake as well as its water quality. Thus, maximum coverage taken literally may prove to be an expensive, complex and time-consuming process.

As a general rule, sociologists and anthropologists prefer to have as much breadth of coverage as possible. However, given the high resource costs of manpower, time, transportation, and other related factors, as well as high opportunity costs, a decision may often be necessary to have limited coverage of selected variables, and then use the balance of available resources to obtain more detailed information on specific aspects and/or areas that are critical from a management viewpoint. Accordingly, maximum coverage in the present context should be interpreted to mean collection of maximum data that are necessary and will be used for management purposes, subject to resources (funds, manpower, expertise, equipment and time) availability.

Minimum Measurement Error

The level of accuracy and reliability of any data that will be collected is an important consideration for any monitoring process. Generally engineers and physical scientists are more concerned with the accuracy of measurements and data collected than sociologists and anthropologists. For example, if the presence of certain toxic chemicals in lake waters is to be considered, often these are to be measured in terms of parts per billion. Under these circumstances "minor" errors could have significant implications.

Minimum sampling error

Since it is neither necessary nor desirable to monitor all possible developments in the project area, sample surveys are essential. Lake management covers numerous issues and diverse disciplines, and accordingly there is no straightforward or uniform solution as to what may constitute suitable sample size. For example, for analyses of rainfall, one rain gauge per square kilometer will be considered to be a very dense network, and thus totally unnecessary unless very exceptional circumstances warrant it. In contrast, the identical sample size would be totally unacceptable to sociologists. In the final analysis, determination of sample size will depend upon the type of information to be collected, and the use that will be made of it.

Absence of Bias

Monitoring of lakes often suffers from biases of people performing the task. This happens because monitors, often due to their disciplinary orientation, expertise and past experiences, may have the tendency to concentrate on specific issues at the cost of other issues which may be of similar importance. For example, a common bias often is to concentrate on limnological factors and not other issues.

It should be noted that in a real world, an issue is an issue. It is often labelled limnological, engineering, economic, social or legal depending upon an individual's discipline, experience, and ways and means of approaching it. Thus, ideally, monitoring should be carried out by multidisciplinary people, who may specialize in one discipline but are knowledgeable in other disciplines. They should be flexible, observant, sensitive, eclectic and constructive. They should be capable of intermixing freely and questioning sympathetically and inventively. Since, in reality, such qualified and experienced individuals are very difficult to find, one may have to depend on who is available. To a certain extent, the problem can be resolved by carefully choosing a multidisciplinary team, which may offset biases of individual members by the juxtaposition of the insights of various disciplines. However, it should be noted that

past experiences indicate that use of multidisciplinary teams for monitoring of lakes, where team members are not familiar or do not have established working relationships with each other, generally do not produce an integrated multidisciplinary approach.

Identification of Users of Information

If the results of any monitoring are to be actually used, it is necessary to identify who are going to be the users of the information and their information requirements before designing a monitoring system. At the different levels of management, the hierarchy of information needs is different. For example, at a certain level of management, detailed information on a specific aspect of an irrigated agriculture project may be necessary, whereas at other levels (generally higher), aggregated information may be required. It is necessary that the right type of information is provided to the appropriate levels.

For any utilization-focused monitoring, after identification of relevant information users, it is desirable to: 1) actively involve the users in ways that would increase their commitment to the utilization of evaluation finds; 2) train users to increase their understanding of evaluation and make it possible for them to play a useful role in the evaluation process; and 3) provide genuinely useful information to the users so as to reinforce their future commitments to evaluation.

Trade-off between the Requirements

The principal requirements discussed above should not be considered individually in isolation since some may reinforce each other and thus are mutually supportive but others may be in conflict. The quality of any monitoring system is determined by not any one of the requirements but rather how effectively all these factors are integrated in one system. For example, there is always a trade-off between maximum coverage, minimum sampling error and cost, and these trade-off decisions are generally case specific. There is no one single universal clear-cut solution.

3.2.4 FRAMEWORK FOR LAKE MONITORING

Monitoring of lakes is a complex process since a large number of regular and specific tasks have to be performed, both concurrently and sequentially, in a coordinated manner, by a variety of professions, within available expertise, time and

resources. Thus, designing an efficient lake monitoring system, and making it work properly on a continuing basis is a complex task under the best of circumstances.

One important issue is worth pointing out here. This pertains to the physical boundary within which monitoring should be carried out. While lake boundaries may be comparatively easy to define, they may not be the boundaries within which all monitoring efforts should be confined for sound lake management. This is because what happens outside the lake boundaries may have direct impacts on the quantity and quality of water available and lake productivity. For example, if land use patterns around a lake change, and increasing emphasis is given to agricultural activities, part of the runoff which normally used to reach the lake, may have to be diverted for irrigating crops. Equally, water from the lake may have to be used for irrigation. This could mean that the water balance of the lake would change radically. In addition, increasing agricultural activities around a lake would mean accelerating use of fertilizers and pesticides, a significant part of which may leach to the lake water. This could increase the eutrophication problem, and water use for domestic consumption may have to be curtailed. This type of information, which is from outside the lake boundary, is necessary for sustainable lake management. Thus, it is not an easy task to define the boundary within which lake monitoring should be confined.

In terms of rational lake monitoring, no one single system can be proposed that would be valid for all lakes anywhere in the world. It is thus essential that an effective monitoring system be designed for each specific lake based on the requirements discussed earlier. Overall, however, four interrelated levels of a monitoring framework can be proposed, which naturally would have to be somewhat general. Within this conceptual framework, managers of each lake should develop their own specific monitoring system in terms of identification of the parameters that need to be monitored, and frequencies and locations of monitoring each parameter.

Within this overall context, the following four levels of lake monitoring should be considered:

- 1) water quantity monitoring;
- 2) water quality monitoring;
- 3) biological monitoring; and
- 4) environmental monitoring.

Three important aspects should be noted. First, the four levels of monitoring are not sequential: they are generally simultaneous. Second, these levels are interrelated. For example, quantity of water has a direct bearing on water quality, and water quality

parameters are likely to have direct impact on biological and environmental factors, and vice versa. Third, for many parameters, there could be seasonal, or in some cases even diurnal variations. It is thus essential that the monitoring system designed should be able to specifically consider such variations.

Water quantity monitoring

For both natural and man-made lakes, monitoring of appropriate variables like inflows to a lake, outflows, water withdrawals and losses from the lake, and water levels need to be monitored. A clear knowledge and understanding of the lake water balance is essential for its sustainable management.

Of all the four levels, water quantity monitoring is generally the most simple and straightforward. The number of variables involved is not only easily identifiable but is also limited. The monitoring techniques are fairly simple, which means that they can be carried out with limited expertise. Expensive equipment and a fully-equipped laboratory are not necessary. For these reasons, some form of water quantity monitoring for the most part is generally carried out for many lakes.

Water quality monitoring

Water quality monitoring is significantly more complex than water quantity monitoring for many reasons. First and foremost is the fact that the potential number of water quality parameters that could be monitored are numerous. Literally it is not possible to put an upper limit to the number of water quality parameters that could be monitored. This is because the number of man-made chemicals and other products is increasing exponentially. For example, if only pesticides are considered, prior to 1939, only a few natural products like derris, pyrethrum and nicotine were used along with largely inorganic compounds such as lead arsenate, sodium arsenite, copper in various forms, sulphur and mercury. In 1950, the British Ministry of Agriculture, Fisheries and Food had in its Approvals List of pesticides fifteen chemicals, used in nearly 300 formulations. By 1975, the number of chemicals used had increased to 200, and the number of formulations to just over 600. At present there are over 600 chemicals and more than 1800 formulations. Since pesticides would leach into any lake around which modern agriculture is practised, the number of pesticide parameters alone that could be monitored could theoretically run into hundreds. Monitoring such a large number of pesticides would undoubtedly be a very expensive and time-consuming task. Furthermore, such indiscriminate monitoring will not be a cost-effective process. Hence, considerable thought must be given to which pesticides should be monitored and how often. Some criteria have to be developed

on the basis of which such rational decisions could be taken. For example, one criterion could be the identification of major pesticides which are used extensively around a lake. Thus, in contrast to water quantity monitoring, where the choice of parameters to be monitored are almost automatic, water quality parameters that should be monitored have to be carefully selected.

Secondly, there is a time dimension to the parameters that needs to be monitored. Because of the changing patterns of use of chemicals and other compounds, and since type of industry and effluents produced in an area generally vary with time, the list of water quality parameters that need to be monitored should be reviewed periodically. Often some new parameters have to be added to the list, and equally some old ones may have to be deleted. Thus, the water quality monitoring process is not as simple or automatic as water quantity monitoring: it requires significantly more thinking and deliberation.

Thirdly, collection and analysis of water quality data requires considerable expertise, resources and time. Expensive equipment in a functional laboratory is an indispensable requirement. This often becomes a serious problem in most developing countries, where availability of trained manpower, adequate resources and sophisticated equipment are serious constraints. Equally maintenance of complex analytical equipment due to lack of spare parts, foreign exchange and trained repairers is generally a serious problem, which often disrupts the continuity of the monitoring process.

There are certain water quality parameters which need to be monitored for nearly all lakes that need to be managed. Among these are dissolved oxygen (DO), biochemical oxygen demand (BOD), chemical oxygen demand (COD), pH, temperature, coliform, P and N.

Biological monitoring

Biological monitoring can provide information on the overall status of the aquatic ecosystem of a lake as a whole since aquatic organisms can integrate the various factors affecting their surrounding environment. Accordingly, biological monitoring, if carefully designed and carried out, could be an important component of any lake management information system.

There are, however, a wide range of organisms and communities which could be included in biological monitoring of lakes. For example, information on planktons could be important to assess the quality of lentic systems. Benthic macro-invertebrates are preferred for lotic systems since they have limited mobility and thus are comparatively easy to sample. Equally they cover large number of species which

are differentially sensitive to water quality.

Monitoring of fish populations should be an integral part of any effective lake management for two important reasons. First, both natural and man-made lakes are important sources of food in terms of fish catch, especially in developing countries where protein consumption is generally low. Thus, managing a lake efficiently often requires maximizing fish catch on a sustainable basis. Second, fish act as bio-accumulators of many undesirable contaminants, and thus could be used as a proxy for the overall problem.

In order to integrate various biological parameters, some indices like a diversity index have been proposed by some scientists. However, none of the indices proposed satisfactorily provide a summary of the biological parameters that are monitored in a lake. Accordingly, use of any index is of very limited value to lake management.

Environmental monitoring

Many environmental parameters may have to be monitored for a lake. The decision as to which parameters should be monitored can be taken in the context of only a specific lake. This would require identification of environmental parameters that are important for the management of the lake concerned.

For example, if the lake is in a geographical region where vectors of water-borne diseases like schistosomiasis, malaria, filariasis or onchocerciasis could be present, it would be essential to institute a monitoring system which will provide appropriate information to managers in order that disease incidents could be under control. Equally, if a specific health issue is not a concern in an area, there is not much point to using scarce resources for wasteful monitoring. For example, for any lake in India, it is totally unnecessary to have a monitoring system that considers schistosomiasis, since it does not occur in the country. However, if a monitoring system is to be designed for a lake in Kenya, Brazil or in southern Africa, where schistosomiasis is prevalent, it must be monitored.

3.2.5 CONCLUDING REMARKS

Monitoring is an integral component for management of any lake. However, this does not mean that if monitoring is carried out, efficiency of lake management will be

automatically improved. In fact, on the basis of a review of lake monitoring carried out in many parts of the world, it can be said that the general situation appears to be that monitoring is having far less impact on lake management processes than expected or even possible.

There are many reasons for this unfortunate state of affairs. One of the main reasons for this is that often parameters that are monitored may not be the most important ones on which managers would like information. Scientists often monitor what they wish to monitor in terms of their need for scientific research, and not what the managers would like to see monitored. Equally, the managers may not receive the monitored information in a form that would facilitate decision-making, or may not receive required information in a timely and regular manner.

If a cost-effective monitoring system can be designed for lakes that specifically addresses the interests of managers, then unquestionably the present status of lake management can be improved substantially.