CHAPTER 7

IMPACT BY MAN

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7.1 INTRODUCTION

Like rivers and wetlands, shallow lakes and lake shores are threatened by a large variety of human impacts including:

- morphometric and hydrological changes;
- eutrophication;
- pollution from toxic substances and other matter (e.g. turbid material) including acidification;
- heating or cooling;
- introduction of exotic species.

By means of paleolimnological methods many human impacts can be traced back to ancient times. There is, however, no doubt that the majority of adverse changes occurred during the last few centuries or even during the last onehundred years (e.g. loading of lakes with heavy metals and pesticides).

Only after World War II were steps for sanitation (e.g. avoidance of nutrient loading and pollution) and restoration (e.g. removal of mud, precipitation of phosphorus in situ) increasingly performed and resulted in oligotrophication and general improvement of the water quality. Lately, the restoration of littoral zones and the general management of watersheds have been increasingly recognized as important measures for the conservation of lakes.

7.2 MORPHOMETRIC AND HYDROLOGICAL CHANGES

The complete elimination of lakes occurs mainly in connection with

- the regulation of rivers (removal of levees, ox bows, lakes and other types of lake basins produced by the dynamics of running water);
- the use of the tributaries of lakes for irrigation;
- the reclamation of shallow lake basins for a variety of purposes including waste disposal.

Even in small countries like Austria several hundred lakes have been lost. In addition, the area of volume of lakes is often changed by: -

- excavation of material;
- damming for various reasons, such as power plants, water storage, etc.;
- increased sedimentation and disposal of material;
- reclamation of littoral zones;
- the use of inflows for irrigation or other purposes.

Mining of gravel, diatomite (Jonasson, 1979), calcium carbonate (Rich, 1971), peat and other material may greatly influence the shape of lake basins. If locally exploited, the resulting deep hole may facilitate chemical stratification and oxygen depletion. On the other hand, mining activities world-wide have produced a multitude of new lake basins, which - in the case of coal mining - may be extremely acidificated.

Damming of natural lakes for various reasons has a long tradition and causes eutrophication (e.g. damming of Grosser Plönersee in the 13th century, Ohle, 1978), and/or the destruction of the littoral habitat. The latter persists in lakes with frequent changes of water level caused by power plants.

The uncontrolled activities of man within watersheds, erosion and landslides result in increased sedimentation and siltation of the littoral zones. In addition, dumping of material may accelerate the rate of sedimentation in lakes. The most remarkable case of this kind in Central Europe is Traunsee (Löffler, 1983), a deep prealpine lake (z_{max} 89 m), where, since the turn of the century, the alkali works near the mouth of the inflow release daily up to 30 metric tons of largely insoluble substances. Near the releasing pipe this material has piled up to more than 40 m and at present covers a large portion of the lake bottom. With a pH between 10 and 11 it moreover prevents any colonization by benthic animals living in undisturbed parts of the lake bottom. Far more often than large lakes, small and shallow ponds are used as depositories for material including garbage.

The most common practice within lake basins is the reclamation of the littoral zones for different purposes, such as: -

- agriculture and husbandry (including the commercial harvest of macrophytes);
- traffic;
- settlements and industry;
- recreation.

The reclamation of the littoral zones of lakes is an international problem and includes all kinds of terrestrial and aquatic farming (e.g.

paddies along shore sections of Lake Biwa). Cattle breeding and other stock farming may change the littoral zone of shallow lakes considerably. Trampling and feeding on emergent macrophytes may result in a complete loss of the littoral vegetation. Sometimes, like in shallow lagoons near Lake Titicaca, even the submerged vegetation is grazed by cattle (Löffler, 196x) and the use of macrophytes by man such as *Myriophyllum* for food (Indonesia), thatching, matting, construction of rafts is well known in different parts of the world (e.g. China, South Asia, Iran, Iraq, Lake Chad, Lake Titicaca).

Very often, lake shores have been, and still are, claimed for traffic development (viz. roads, railways, airports and shipping traffic). Their construction often causes eutrophication (see 7.3), but due to large amounts of released mineral turbid material sometines also oligotrophication may occur (e.g. road construction along the shore of Mondsee, Austria, during the late 1950s).

Since lake shores have been always preferred sites for the settling of man - evidenced by the lake dwellings of Neolithic and Bronce Age farmers (5900 - 4200 b.C.) in Europe - the number of large villages and cities, often with a variety of industrial entertainments, at lakes amounts to tens of thousands at present. The large cities at the Great Lakes in North America are just one example of this kind of development. In addition to the traditional settlements near lakes, recreation (in Central Europe in the last 150 years) have increasingly caused the reclamation of lake shores for holiday houses and lately also camps. So far, only a few countries (e.g. Sweden) have set up measures against the construction of such houses close to the shoreline.

Apart from the destruction of large shore sections by these building activities, eutrophication (see 7.3), pollution (see 7.4) and thermal impacts (see 7.5) are the consequences and at present successful sanitation or restoration of such afflicted lakes or sections of their shore often seems unfeasible.

The use of inflows to lakes for irrigation, energy or drinking water supply results in major changes of the water budget and in closed lakes morphometric alterations and increasing salinity or(and) alkalinity. Mono Lake in California, one of the oldest lakes in North America (about 500,000 years old), represents one example of this. Since 1941, the saline lake's level has dropped 11 m as a result of water diversion for the city of Los Angeles. Eventually, increased salinity would lead to destruction of brine shrimp and brine fly population and deprive hundreds of thousands of birds - among these those feeding on the shore - of their food. Another, even more dramatic case of this kind is the Aral Sea in USSR, part of the former Paratethys during the Miocene. More recently, water of its major influents Amu Darya and Syr Darya has been diverted for irrigation and therefore the water budget and salinity of this large closed (63,800 km^2) and saline lake have been seriously affected.

7.3 EUTROPHICATION

The influence of eutrophication (see chapter xx, guideline book no xx) on the littoral zone of lakes may very greatly. In alpine lakes with rock shores the well developed zonation of sessile (epilithic) algae (Kann, 19xx) in the upper littoral (supralittoral, eulittoral, infralittoral) of oligotrophic lakes is often replaced by a monotonous algal mat of *Gladophora sp.* and likewise the diversity of benthic animals decreases. In the same way, the emergent macrophytic vegetation, with its attached epiphytic algae, tends to increase but at the same time becomes more uniform and finally the helophytic vegetation may even vanish. The decrease of phragmite stands in Lake Constance is thought to be connected with eutrophication and the resulting development of sapropelic soil. The physiology of this destruction, however, is not yet fully understood and may include allelopathic elements. With increasing nutrient supply submersed macrophytes often become more important to the total primary productivity of lakes until the fertility of the whole system is subjected to severe light attenuation due to intense phytoplankton productivity (Wetzel, 1983) and(or) a dominance assumed by pleustonic plants. The bloom of *Salvinia molesta* short after the establishment of the Kariba Dam may be mentioned as an example, which, after the exhaustion of nutrients (released from the flooded terrestric vegetation), quickly became reduced to its present minor extent.

If dystrophic-oligotrophic lakes turn into an eutrophic-alkaline condition, a major change of the littoral vegetation and fauna will most likely take place (see below). Eutrophication and hence increased food sources in the open water causes some littoral animals to show a tendency to move into the littoral zone. This is known from several *Cladocera* species (e.g. *Chydorus spaericus*) and a few fish species, such as *Perca fluviatilis.*

Excessive loading of lakes with nutrients, mainly phosphorus and nitrogen, caused by man started in connection with slash and burn practices and deforestation in general. Erosion and therefore increased runoff of nutrients within watersheds are the common consequences of any forest clearing (Limens et al., 1970), especially if clear cutting is applied. Erosion with all its consequences may also cause profound changes in the chemical conditions of lakes other than just increasing nutrient contents. Forest clearance followed by field cultivation has changed Lake Lovojärvi in Finland from oligotrophic- dystrophic into alkaline-eutrophic (Huttonen & Tolonen, 1975). Obviously, this change must also have greatly influenced the littoral vegetation.

Likewise, erosion from mining and engineering activities in the watershed has occured extensively in the past. The impact of the construction of Via Cassia (171 b.C.) on Largo Monterosi, a small closed basin of volcanic origin north of Rome has caused eutrophication for a few centuries (Hutchinson, 1970). Damming of the shallow Grosser Plöner See in northern Germany (see 7.2, Ohle, 1978) about 700 years ago has on the other hand introduced an eutrophication period which still persists.

The development of agriculture within forested watersheds or watersheds with dense vegetation of some kind contributed greatly to erosion, eutrophication of soils and non-point source nutrient loading of inland waters. Erosion is increasingly enhanced if sparse plantations like vineyards and corn fields dominate. Very often, reclamation of littoral zones for agriculture resulted not only in the destruction of the shore vegetation but also in eutrophication.

The impact of urban systems and recreation facilities along lake shores may have limited effects on the littoral zone if a proper sewer system takes care of all the possible sources of nutrient (and pollution, see 7.4) loading. One of the main contributions to nutrient loading has been, and in many countries still is, the use of P-containing detergents. They have caused eutrophication in many inland waters and only recently have such agents been banned.

Finally, a large variety of industries may contribute to eutrophication if the resulting sewage is released untreated. Among these food producing and fertilizer industries, breweries, etc. take a prominant position. In many industrial countries, sewage plants with three or even four steps do take care of the waste water. Air pollution with nutrients, however, remain a problem still to be solved.

7.4 OTHER KINDS OF POLLUTION

Pollution, other than by nutrients, has increased exponentially during the industrial age. It comprises a huge variety of inorganic and organic compounds many of which affect the littoral zone. Mineral oil and its derivates, though much more of concern to the sea and large rivers where oil transportation takes place, is the most obvious example. The hazard of oil pollution in lakes is caused by pipelines along lake shores (e.g. Lake Constance), by shipping, by oil transportation and in rare cases also by oil production and by uncontrolled waste disposal close to lakes and ponds (e.g. oil barrels). The disastrous outcome of oil spilling for water quality and aquatic organisms is well known.

Another major impact on mainly soft water lakes and their littoral zones is the complex influence from airborne acidification - acid rain - and direct acidification by industry (e.g. pulp industry). As mentioned in 7.3, events of this kind, often resulting in annual pH decreases of as much as 0.2 units, may give way to a complete change of the lake ecosystem which frequently causes the extinction of fish and therefore is of considerable economic importance. Moreover, acidification of the watershed results in increased release of heavy metals from soil and thus contributes to fish kill particularly if aluminium is involved.

The littoral plays a significant role in the transfer of heavy metals from terrestrial non-point sources. It contributes greatly to the transformation of elementary metals or their inorganic compounds into biological relevant organic substances. In addition, like terrestrial plants, aquatic vegetation exhibits specific capacities for the uptake and enrichment of heavy metals and may significantly contribute to their cycling in the whole lake.

Among other pollutants pesticides may play an important role in the littoral zone. Herbicides, often used against massive growth of macrophytes in channels and running waters, were sometimes also put into action in lakes (e.g. Bayersoiner See, Kucklentz & Hamm, 1988). Case studies show an increase of nutrients due to the decaying plants. At present, the use of herbicides against undesirable weeds is prohibited in several countries. Apart from chemical weed control, campaigns against vectors of deseases such as malaria (DDT), schistosomiasis (molluscicides), etc. not only affect the littoral communities but also imply considerable health risks. In addition, a variety of other pesticides used in agriculture such as aldrine, etc. exert adverse influence on lake ecosystems. Their role in the littoral communities, however, is not yet understood. Among other organic substances, 3.4 benzopyrene and other polycyclic aromatic hydrocarbons stemming from asphalted and tarred roads have been reported from lakes (e.g. Lake Constance, Elster et al., 1963). At least 3.4 benzopyrene has been proved cancerogenic. Again, their influence on the littoral community is unclear.

7.5 HEATING AND COOLING

From several studies available, so far only from the northern temperate zones, it emerges that any heating of lakes - mainly by power plants - results in a general increase of the biomass and that individual lakes show peculiar shifts in planktonic species and sometimes also the immigration of exotic species. If the lake looses its cool hypolimnion, a dramatic change of the profundal fauna can be observed. Very little information exists, however, about the impact of heating on the littoral zone. In one Canadian lake an increase of *Elodea canadensis* was observed (Allen & Gorham, 1973) resulting in the replacement of macrophyte species which were dominant before. Increase of biomass and decrease of diversity often seem to be more general features than response of the littoral community to heating.

The construction of electric power plants sometimes implies the cooling of a lake, if it is used as a basin for the release of water which is the source of energy and which is sufficiently cold. Thus, the diversion of water from the River Tagliamento in northern Italy for such a power plant and its release to Largo di Cavazzo has resulted in a considerable drop of the epilimnic summer temperature. Since then carp have been replaced by trout and swimming is no longer part of the ongoing recreation. No information exists on subsequent changes in the littoral zone.

7.6 INTRODUCTION OF EXOTIC SPECIES

Among the most infamous cases of the introduction of exotic species by man is the stocking of Lake Titicaca with rainbow trout and of Lake Victoria with nile perch. The catastrophic effects on the endemic fish fauna of these lakes are a clear demonstration of thoughtless activities. Likewise, the introduction of chinese grass carp has often led to the complete destruction of submersed macrophytes in shallow lakes and littoral zones. On the other hand, the stocking with eel has profound effects on the littoral animals (amphibians, certain invertebrates) and spawn of fish. Stocking with fish where it was not present before results frequently in the extinction of certain invertebrates such as fairy shrimps (*Anostraca*), large species of *Cladocera* or *Copopoda*, etc.

Stocking of European lakes with fish species from North America during the late last century contributed to the introduction of pests like *Elodea canadensis* which has become the dominant macrophyte species in many European lakes, especially in the Alpine region. Similarly, many other species have been spread often on a worldwide scale. More recently, motor boating and sailing have also contributed to the dispersal of many species such as the mussel *Dreissena polymorpha*.

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