LAKE BIWA AND THE WORLD'S LAKES

—WORLD VISION ON CONSERVATION OF LAKE ENVIRONMENTS—

Abstract

Fresh water is scarce. Only 3% of water on the earth is fresh, yet most is inaccessible—frozen in glaciers or buried deep underground. Of the small volume available, more than 90% is contained in lakes. Unfortunately, many of the world's lakes are polluted and their precious supplies threatened. Population growth and development have increased demands on freshwater supplies, but have in turn led to pollution that contaminates the very water needed for growth and development. The world is facing a freshwater crisis, felt largely through lakes, that demands attention.

The several million lakes and reservoirs on the earth are incredibly diverse. However, patterns of environmental degradation can be classified into six distinct categories: siltation caused by erosion; water level fluctuations caused by excessive diversions and withdrawals; toxic contamination; acidification; eutrophication hastened by excessive nutrient inflows; and the introduction of exotic species.

All of these problems can lead to the destruction of lake ecosystems, which reduces freshwater supplies and therefore constrains development. Nevertheless, we can learn much from past successes and failures in lake management, especially the case of Lake Biwa in Japan, and can make a brighter future for both the world's lakes and mankind.

Introduction

The earth is sometimes called "the planet of water". Fresh water, essential for human life, accounts for only 3% of all water on earth. Most of it is found in the polar and alpine regions, in glaciers, or deep underground. Only three-tenths of one percent of all fresh water is easily accessible for human consumption as surface water or shallow groundwater. Moreover, this

small portion of accessible fresh water is distributed unevenly around the world.

Increases in population as well as in per capita demands for water for irrigation, industry, and household use over the past few decades have claimed much of our diminishing reserve of fresh water and often degraded the quality of what we have. Our planet of water is in imminent danger of losing its precious resource values.

The earth is spotted with several million natural lakes, ranging from the enormous Lake Baikal and the Great Lakes of North America, to much smaller ones covering only one square kilometer or so. In addition, numerous man-made lakes, or reservoirs, prevent floods and provide water during dry seasons. In fact, more than 90% of all available surface freshwater is contained in lakes and reservoirs. Clearly, they are a critical component of the world's water supply.

Reservoirs have generally larger watersheds than natural lakes of similar volume, as their water is intensely utilized for different types of uses: water supply, irrigation, hydroelectricity generation, irrigation and others. This simple fact implies increased stress on the reservoirs due to the activities in the watershed. Reservoirs, along with lakes, are therefore sensitive indicators of the health of the region.

Environmental Degradation of Lakes and Reservoirs

Since prehistoric times, people have been able to use lake resources in a sustainable manner, fostering locally distinctive water-related cultures. In recent years, however, the dramatic expansion of human activity has brought about a rapid decline in sustainable water-use practices and caused a serious degradation in the quality of lake waters.

Connected only tenuously to other bodies of water, lakes serve as home to many indigenous species of biota. For example, Lake Baikal—believed to be the world's oldest lake—is home to some 6,000 species of flora and fauna. And amazingly, some 70 to 80% of these species

are indigenous. As in lakes elsewhere, however, the recent proliferation of non-native species of flora and fauna has put the biota of Lake Baikal at serious risk.

Lakes exhibit incredible diversity that results from their unique natural and socioeconomic environments. No lake is identical to another in size, shape, or flow regime. Climatic conditions also differ widely from lake to lake. In addition, the nature and intensity of watershed activities can differ completely from one lake to the next.

Water quality of reservoirs used for drinking water supply and other uses was often recorded since their construction. An analysis of some of those long series of data demonstrates that the diminution of reservoir volumes and deterioration of their water quality is reaching a dangerous degree and, moreover, the rate of deterioration is ever increasing. Especially critical is the situation in developing countries, where many different kinds of pollution occur simultaneously. Construction of new huge reservoirs is to be reconsidered, due to some negative consequences for the regions.

Despite natural diversity and the differences between lakes and reservoirs, the patterns of environmental degradation can be classified into several distinct categories:

Siltation

First, many lakes, both natural and man-made, are becoming shallower due to siltation, especially in developing countries. The most common cause of siltation is soil erosion upstream. Careless cultivation of farmland and pastures results in wash-off of topsoil, while excessive cutting of trees in catchments may increase the frequency of flooding and cause widespread erosion. The concentration of suspended solids in lake water is closely correlated with the percentage of land in the catchment basin that is devoted to agriculture. For example, Lake Dongting in China, which has been crucial in preventing floods, has been accumulating 5-6 cm of new sediment per year as a result of extensive hill-slope cultivation in the upper reaches of its inflowing river, making the lake less effective in controlling floods. Clearly, a

lake's environment and beneficial functions are intimately linked to the activities in its catchment.

Water Level Rise/Drop

The Caspian Sea has seen its water level jump recently due to increases in precipitation in its watershed. While the Caspian's water level has historically fluctuated due to natural climate variation, some scientists speculate that the current changes may be related to anthropogenic climate change.

In contrast, many lakes are losing their water, either because of direct withdrawals or diversions from the rivers feeding into them. Such withdrawals can be particularly problematic in dry regions, where a lake's water level is maintained by balancing inflow with evaporation from the lake surface. For example, the surface of the Aral Sea in Central Asia has shrunk by two-thirds, and its water volume decreased by more than 80 percent, as a result of water diversion for irrigation. A similar situation is found in Lake Chad in Central Africa, where overgrazing of vegetation by cattle in the upland watershed may have caused change in regional climate, leading to a loss in water inflow. Adaptation can take place but is expensive and requires long-term monitoring and basin-wide planning.

While such catastrophic water level changes are rare for most lakes, the extreme water level changes induced by excessive withdrawal or impoundment of water could be quite harmful to the lakes' ecosystems. In the case of Lake Biwa, the current arrangement between the downstream water users and the watershed community is for the maximum water level drop to be kept to less than 1.5 meter from the normal level even at times of severe droughts. Such arrangements are necessary not only for fulfilling the community needs for water supply and fisheries, but also for protecting the coastal ecosystems of the lake.

Toxic Contamination

The discharge of man-made toxic chemicals can also degrade lake water quality. The toxic chemicals contained in pesticides, industrial air and water discharges, and drain waters from urban and industrial waste disposal sites, eventually find their way into lakes, damaging or destroying fish and other wildlife. Concerns over human health have also arisen because some toxins move through the food chain into our bodies. Recently, endocrine disruptors (environmental hormones) have drawn a great deal of attention in Japan because of their possible effect on reproductive systems. Decreasing sperm counts, in many species and locations, all the way from Japanese men to polar bears, are of great concern.

Ecosystems are also affected. For example, certain species of marine snails are rendered sterile by the organic tin compounds (suspected environmental hormones) in the anti-corrosion paints used for coating the bottom of water vessels. Other toxic contamination can occur in unexpected ways: it is reported that the religious activity of idol immersion into Lake Bhopal may be increasing the heavy metal content in fish ingested by the population. The well-known case of mercury poisoning in Minamata, Japan shows what terrible human costs can be associated with such pollution. Unnatural and significant increases in lake salinity can also be regarded as a form of toxic contamination. In this case, salt is the contaminant and excess quantities come from man-made changes to catchments, water diversion from lake inflows, and alterations to natural hydrological budgets. The process is referred to as salinization and it is now of special and increasing concern in many dry regions of the world. It invariably degrades water quality.

Acidification

Acidification is another serious environmental problem faced by lakes. Acid waters are observed in areas with calcium-poor but quartz-rich soil and where acid precipitation occurs. With the industrial revolution and increasing levels of air pollution, many lakes have become acidic due to receiving rain or snow with low pH values.

Many lakes in North and Central Europe and in northeastern North America have become acidic since the soils in the region have a low capacity to neutralize acidity. Approximately 8 percent of the lakes in the northeastern United States are acidified, while half of the 700,000 lakes in eastern Canada have such low alkalinity values that they are judged to be susceptible to acidification. In Sweden, which has an estimated 85,000 lakes, as many as 4,000 are classified as seriously acidified and 18,000 others are reported to be acidic during critical periods such as the spring thaw.

When a lake becomes strongly acidified, its fish and other wildlife populations may be totally lost. Acidification is different from the other problems afflicting lakes in that its causes lie outside the local watershed. Most of the acid precipitation falling on Scandinavia, for instance, can be traced to industrial emissions in northern Europe, while much of that falling on Canada originates in the United States.

Eutrophication

All lakes become eutrophic, but the process becomes harmful when it is speeded up by human activities, namely, the introduction of excessive amount of nutrients (nitrogen and phosphorus) from domestic and industrial sources. Rainwater drainage may also carry nutrients washed-off from urban and agricultural lands. These nutrients can trigger abnormal blooms of plankton, which may in turn be deposited at the lake bottom after the bloom where they cause depletion of oxygen while being degraded. Most of the world's lakes suffer from eutrophication, though to widely varying degrees. ILEC, through its survey of world lakes, found evidence of eutrophication in 54 percent of the lakes in the Asia-Pacific region, 53 percent of those in Europe, 28 percent of those in North America, and 41 percent of those in South America.

The southern basin of Lake Biwa is on the list. The water from this part of the lake has been known to impart foul taste and odor in summer and fall due to algal blooms. When eutrophication progresses to hypertrophy, lake water becomes nearly totally devoid of oxygen

and no longer able to sustain any form of life, apart from a few microorganisms.

Introduction of Exotic Species

The invasion by non-native species of fish and other aquatic life is a different kind of threat. A lake is a closed ecosystem, yet when foreign species are introduced, it suddenly becomes an open system, where the original species cannot compete as well. In Lake Victoria, for example, the Nile perch was intentionally introduced in the 1950s to increase the commercial value of the fishery industry. The perch consumed the smaller native fishes, and are believed to have caused the extinction of at least 200 species of local fish.

Growing international commerce and exchange have contributed to acceleration of species invasion. One example is the zebra mussel, which somehow reached the Great Lakes from Europe in late 1980s. This creature is found today not only in other U.S. ponds and lakes, but in many lakes all around the world. It is known to cause clogging of water intake pipes, to consume massive amount of plankton and eventually to transform a lake ecosystem to an entirely different and unstable system.

The introduction of exotic species of aquatic vegetation and animals has also been a serious concern for Lake Biwa. For example, water-weed called *Elodea nuttallii*, a species originally found only on the North American Continent, has spread extensively, pushing out the native species. Particularly problematic, however, was the introduction of alien fish species such as bluegill (*Lepomis macrochirus*) and largemouth bass (*Micropterus salmoides*), preditors to many of the indigenous species including endemic *Carassius carrassius grandoculis* and *Chaenogobius isaza*. No extinction has been reported due to this introduction, but these economically and culturally important fish have suffered dramatic population declines.

Summary---Destruction of Lake Ecosystems

All of the above problems will eventually lead to serious disintegration of the entire lake ecosystem, unless timely actions are taken. Once ecosystem balance is lost, it becomes extremely difficult and expensive to restore it (hysteresis). As the world has seen time and

time again, it is much easier to prevent such problems in the first place or to intervene at an early stage of their development, than it is to deal with the consequences.

Toward a World Lake Vision

Of course, there are ways to deal with these problems, such as injection of air or oxygen to the lake bottom, dredging of sludge from the lake bottom, mechanical removal of algae from the water surface, or lime spraying to neutralize acidity. These measures, however, have only temporary effects. They will be effective only if the sources of pollution are properly managed and the pollution load reduced or eliminated. Since the lake environment reflects the state of the catchment area, the two components must be considered as an inseparable unit when environmental improvement measures are planned.

There are several success stories in lake restoration. Lake Washington near Seattle, U.S.A. achieved a dramatic recovery from eutrophication when sewage effluents were diverted from the lake. Dredging of bottom sediments may work well in small lakes, like Lake Trumen in Switzerland. Citizens groups were instrumental in the enactment of an ordinance to ban the use of phosphorus-containing detergents in the Lake Biwa watershed. Successful neutralization of acidic lake water by liming is reported for Lake Orta in Italy. Even endangered ecosystems have been restored, as in Mono Lake in California, U.S.A. The water level of Mono lake, whose headwaters were diverted and used as a major water source for the City of Los Angeles, is gradually recovering after the water diversion was discontinued, thanks to a court ruling in favor of restoration of the lake ecosystem. These are examples of successful measures that required much time and money to achieve. No after-the-fact measure, however, can ever be as effective as prevention.

Furthermore, these problems do not exist independently of each other. Often, the factors involved are intertwined and compounded. For example, a drop in the water level of a lake in summer may promote eutrophication in semi-enclosed local areas such as bays and harbors. The algae grown in such areas may be rapidly spread to the whole lake by density currents or

winds. Some of the algae may also produce toxins hazardous to animals and humans upon contact or consumption. Remedial measures may be quite complex and difficult under these circumstances.

Lake managers in many parts of the world are poorly informed about good approaches to lake management. They have limited access to information on the fundamentals of lake management, and in any case are flying blind, as essential scientific data on their own lakes are often non-existent. Further, they may have no access to information on successes and failures of lake management experienced in other parts of the world.

Environmental problems today are more often created by humans acting on nature than by nature acting on its own. If people, especially local residents, reduce the burden they put on nature, their chance of resolving problems would increase. A key to success, especially in the long term, is providing proper information to the public to raise awareness, especially through environmental education of the young.

To maintain sufficient, safe water for the development of future generations, mankind has to change many attitudes. Water needs to be conserved at all levels; pollution prevention has to dominate over much more expensive water purification; engineers need not confine themselves with the use of expensive technical approaches when cheaper ecotechnological methods are applicable and feasible for keeping water clean.

Finally, because lakes are highly sensitive and vulnerable to ecosystem disturbances, they serve as good indicators of the earth's vulnerability to growing environmental threats. Thus, if we have any hope of saving "our planet of water", we must succeed in restoring our lakes. We must work together to save our lakes, beginning now.

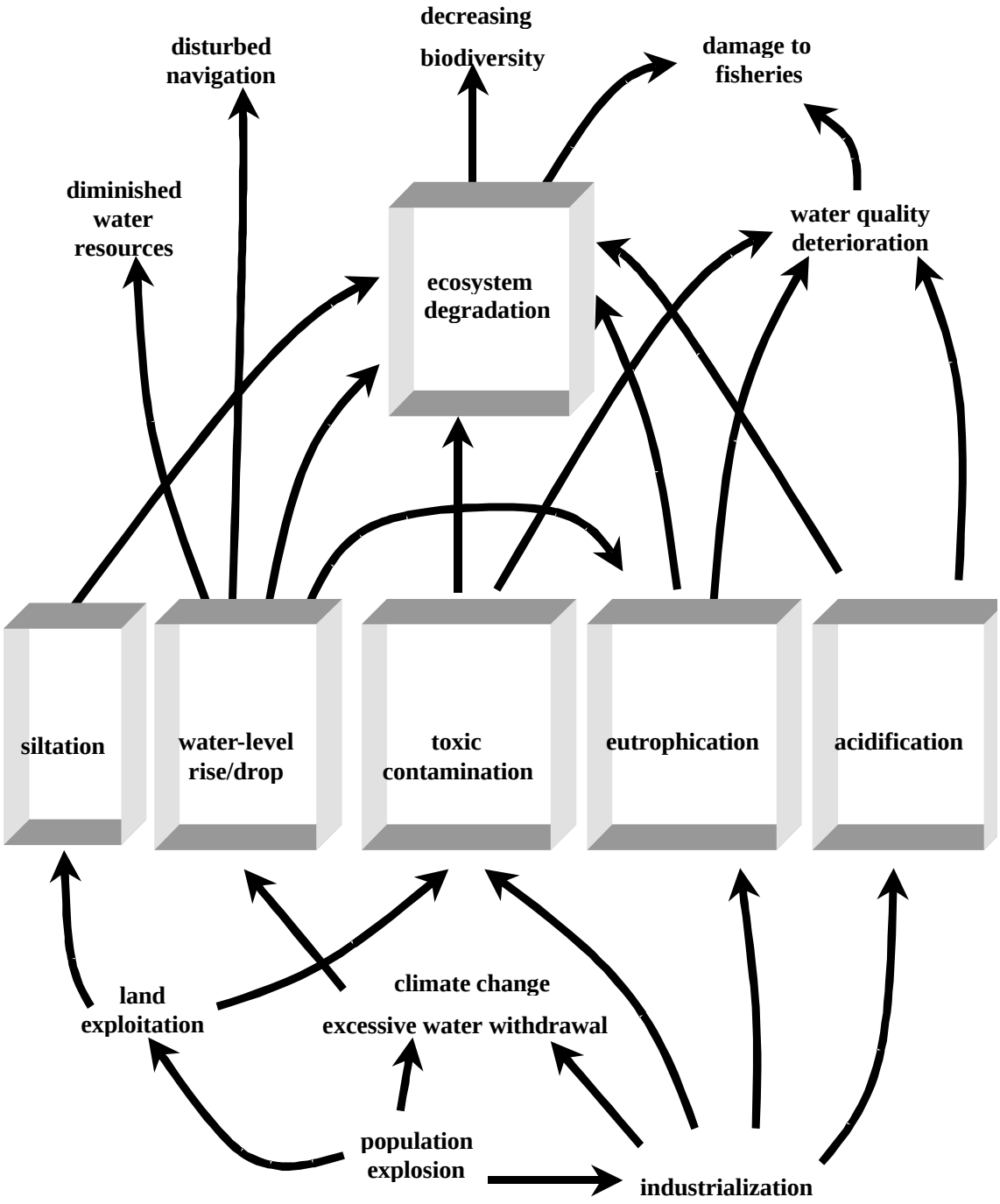

Figure 1. The six major environmental problems in world lakes and reservoirs