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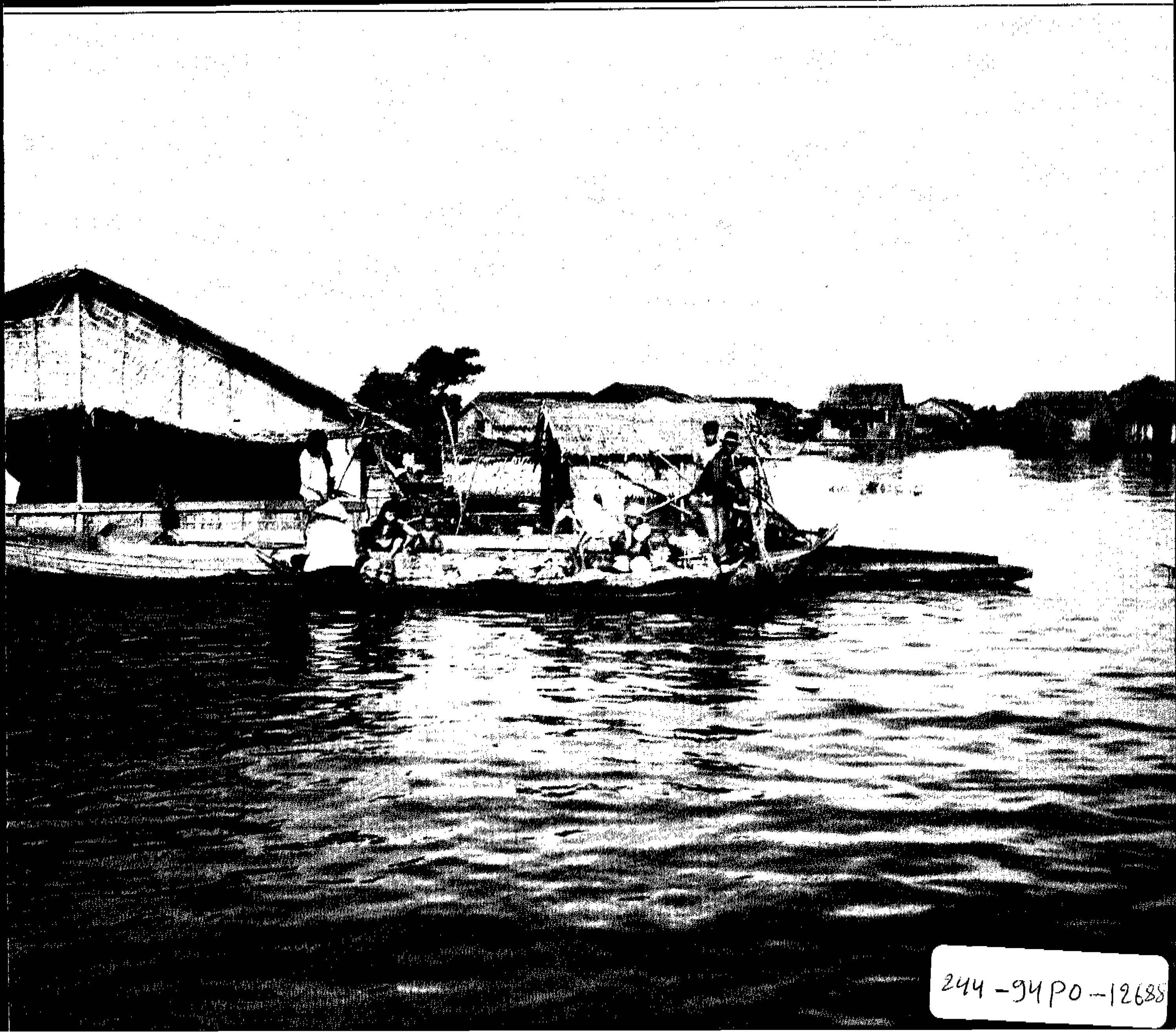

United Nations Environment Programme
The Pollution of Lakes and Reservoirs
Nairobi, UNEP, 1994
(UNEP Environment Library No 12)

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United Nations Environment Programme
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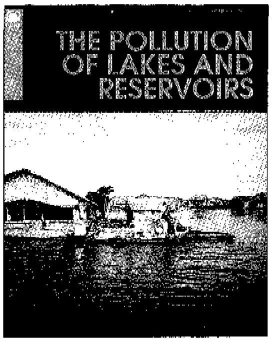
THE POLLUTION OF LAKES AND RESERVOIRS



Cover: Fishermen's village on the heavily used Lake Tonle Sap in Cambodia which is suffering from siltation and eutrophication (photo: S. Matsui)

Contents

Foreword

The Earth, seen from space, is the blue planet, the planet of water. Most of this water is of little direct use to humans. More than 97 percent of it is salt water. Of the world's fresh water, 69.6 percent is frozen, and 30.1 percent is stored underground in natural reservoirs that replenish only very slowly. The water that is most easily available to us—that found in rivers and freshwater lakes—amounts to some 0.26 percent of all the fresh water on the planet. To put it more graphically, if all our fresh water could be squeezed into a five-litre container, the contribution of rivers and lakes would fill little more than two teaspoons.

Those two teaspoons are one of the Earth's most precious resources. Most of the world's population depend on them for their supply of domestic, irrigation and industrial water. Many of the crops we produce are irrigated with water from our lakes, rivers and surface water reservoirs. Up to a quarter of the protein intake of many people in developing countries comes from freshwater fish. Lakes and reservoirs are our freshwater larder; without them, the rain that makes life possible would run straight into rivers, and then the sea, before we had time to make much use of it.

Because fresh water is so important to life, people have always chosen—when they could—to live close to it. This is the main reason why so many of our lakes and rivers are now dangerously threatened with many forms of pollution and with ecological disturbances that threaten their future as useful resources. The crisis that is threatening our lakes and reservoirs is therefore grave. It represents, as this publication points out, '... a serious ecological disaster, comparable in importance to the destruction of tropical forests and desertification.'

This publication documents the state of the world's lakes and reservoirs, and suggests ways of managing them better. It insists that good management of the world's lakes and reservoirs depends on people understanding the value of this precious freshwater resource. It is therefore important for us to publicize widely, at every level of society, the basic facts about the state of our lakes and reservoirs, and about what can be done to put them in better order. I am confident that this publication will play a significant role in this process.

Jan W. Huismans
Assistant Executive Director
Earthwatch Coordination
and Environmental Assessment

Overview

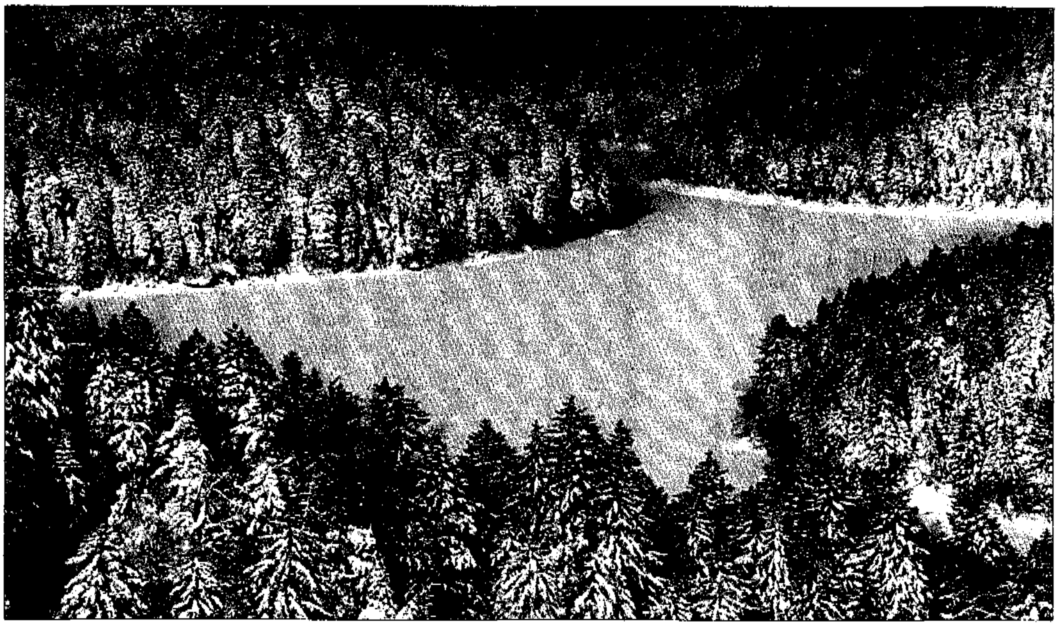
... lakes and reservoirs—and the environment of which they form a part—are in grave danger.

Photographs below and opposite show examples of good and bad lake environments. The first is of Lake Akan in Japan, the second of a lake shore in Germany. Both photographs are from the UNEP publication Your World *(Harvill, 1992).*

The world's lakes and surface water reservoirs (groundwater reservoirs are not included in this publication) are probably the planet's most important freshwater resource. They provide water for domestic use for a large part of the world's population. They are one of the major sources of the water used to irrigate the one-third of the world's crops that cannot be produced by rain-fed agriculture. They also provide an essential resource for industry and are a major source of renewable energy in the form of hydropower.

These direct uses are matched by important indirect ones. Lakes and reservoirs are a source of essential protein in the form of fish which provide 25 percent of the protein intake of many people in developing countries. They are important resources for tourism and recreation, and are home to significant elements of the world's biological diversity—one-third of all fish species live in lakes and reservoirs. They also play an important role in flood control. Finally, lakes and reservoirs are culturally and aesthetically important for people throughout the world.

Yet lakes and reservoirs—and the environment of which they form a part—are in grave danger. Since lakes attract human settlement, pollution from agricultural run-off and toxic chemicals is increasingly common. Irrigation schemes are



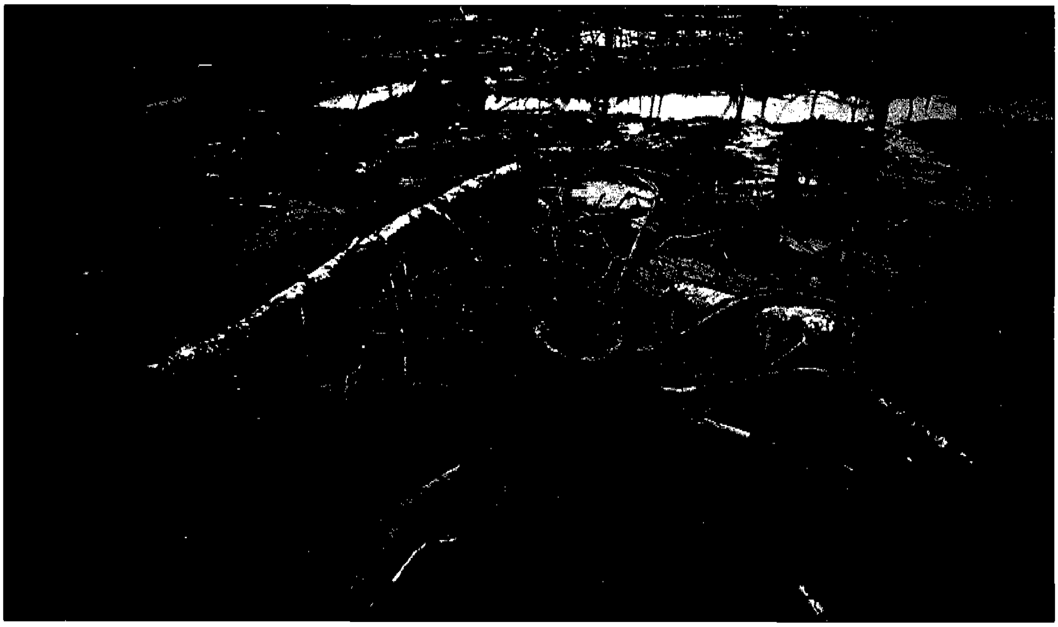
Sunada Kiyohiro/UNEP-Select

causing major fluctuations in water levels in many lakes and reservoirs, and deforestation—which encourages soil erosion—is leading to rapid siltation, thus shortening the lifespans of many major reservoirs. Acid rain has killed many forms of life in lakes in North America and north-west Europe, and the introduction of non-indigenous species of plants and animals has disrupted many lake ecosystems. Luckily, solutions exist to most, if not all, these problems.

As one contribution to the solution of these problems, UNEP's Global Environment Monitoring System is expanding and improving its global network of water monitoring stations, with the aim of providing more accurate and frequent assessments of lake water quality. The UNEP International Environmental Technology Centre in Japan, inaugurated in 1992, has devoted one of its two offices to the management of freshwater lakes and reservoirs: its main aim is to speed the transfer of technologies that have been successfully used to improve lake environments to parts of the world where the lake environment is under greatest threat.

However, major and long-lasting improvements to the lake environment depend on people understanding the real value of their lakes and reservoirs, and the factors that affect these values.

In the final analysis ... major improvements to the lake environment depend on people understanding the real value of their lakes and reservoirs.



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The scientific background

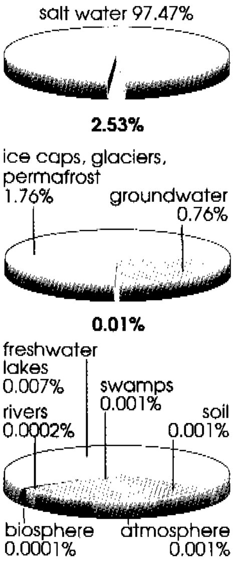


Figure 1 Distribution of the world's water. Data from I. A. Shiklomana, 'Global water resources' in Nature and resources, *Vol. 26, no. 3, 1990.*

There are nearly 14 x 10^8 cubic kilometres of water on the planet but 97.5 percent of this is saltwater. Fresh water accounts for only 2.53 percent of the total. Many people depend on freshwater lakes and rivers for their water supplies, and these sources contain respectively only 0.26 and 0.006 percent of the total volume of fresh water. More than 68 percent of all surface fresh water is locked away in continental ice. Figure 1 summarizes the world's water distribution, showing availability in terms of the percentage of total volume of fresh and salt water on the planet.

The availability of fresh water depends more on the rate at which it is recycled by the hydrological cycle than on the amount that is available for use at any moment in time. For example, while groundwater supplies are very large, they are recycled only slowly—on average, every 1400 years or so. The average retention time of water in lakes and rivers is much shorter: 1.2 years for lake water and 12 days for rivers.

In most parts of the world, the finite supply of fresh water is put to heavy use. Industrial wastes, sewage and agricultural run-off can overload rivers and lakes with chemicals, wastes and nutrients, and poison water supplies. Sediments from eroded land can silt up dams, rivers and hydroelectric schemes. Ill-conceived irrigation projects can suck dry irreplaceable ground-water reserves. Unlike the rapidly flowing water in rivers, water remains in lakes for months or years, and therefore is more easily polluted. Water quality in lakes can be quickly degraded if human activities are intensified and population increases in the drainage

Annual run-off from precipitation in selected countries

	total (km³)	*per hectare (1000 m³)*	*per capita (1000 m³)*
water-rich countries			
Iceland	170	16.96	685.48
New Zealand	397	14.78	117.53
Canada	2901	3.15	111.74
Norway	405	13.16	97.4
Brazil	5190	6.14	36.69
Australia	343	0.45	21.3
Cameroon	208	4.43	19.93
United States	2478	2.7	10.23
water-poor countries			
China	2800	3	2.58
India	1850	6.22	2.35
Peru	40	0.31	1.93
South Africa	50	0.41	1.47
Poland	49.4	1.62	1.31
Netherlands	10	2.95	0.68
Kenya	14.8	0.26	0.66
Saudi Arabia	2.2	0.01	0.18
Egypt	1	0.01	0.02

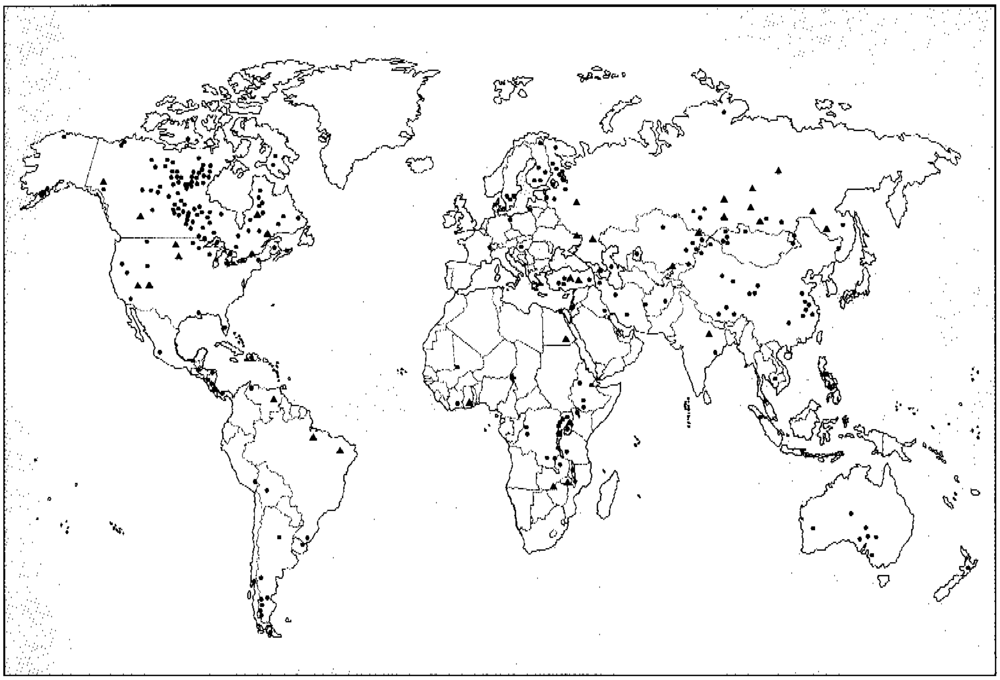


Figure 2 Distribution of world lakes (with surface areas of more than 500 km² shown as solid circles) and reservoirs (with capacities of more than 10 km³ shown as red triangles).

basin around them. Much attention must therefore be paid to maintaining lake environments in good condition and using their resources in a sustainable way. This means that not only the lake itself but also its watershed or 'catchment area' must be carefully managed.

The state of the world's fresh water is also closely linked to human health. Every day 25 000 people die as a result of poor water quality. Some 1700 million people—more than one-third of the world's population—are without safe drinking water. As a result, there are an estimated 900 million cases of diarrhoea annually, which kill more than 3 million people, mostly children, every year. Some 1200 million people lack proper sanitation facilities and at any one time more than 200 million people are suffering from schistosomiasis—a debilitating and sometimes lethal water-borne disease.

Lakes are important not only for their mass but also for their stability. Since river water flow tends to fluctuate widely, man-made lakes called surface water reservoirs are created by damming rivers, providing stable water sources for domestic use, irrigation and hydroelectric power, and reducing flooding in downstream areas. The number of reservoirs continues to increase. Japan, for example, has some 100 natural lakes with areas larger than 1 km² but nearly three times as many reservoirs in the same size range.

Natural lakes are most common in the north of the North American and Eurasian continents, surrounding the Arctic Ocean: there are several million in Siberia and Canada alone. Most, including the famous Great Lakes of North America, were

Mean residence time of selected lakes and reservoirs

	residence time (years)
natural lakes	
Titicaca (Peru/Bolivia)	1343
Tahoe (USA)	700
Baikal (Russia)	380
Superior (Canada/USA)	191
Great Bear (Canada)	124
Michigan (USA)	99.1
Vattern (Sweden)	55.9
Victoria (Uganda/Kenya/Tanzania)	23
Biwa (Japan)	5.5
Balaton (Hungary)	2
Tai-hu (China)	0.65
reservoirs	
Volta (Ghana)	4.3
Kariba (Zambia/Zimbabwe)	3
Tucurui (Brazil)	0.14

Volume of selected lakes and reservoirs

	volume (km^3)
natural lakes	
Baikal (Russia)	23 000
Tanganyika (Burundi/Zaire/ Tanzania/Zambia)	17 800
Superior (Canada/USA)	12 221
Nyasa (Tanzania/Malawi/ Mozambique)	8400
Michigan (USA)	4871
Victoria (Uganda/Kenya/Tanzania)	2750
Great Bear (Canada)	2236
Ontario (Canada/USA)	1638
Toba (Indonesia)	1258
Léman (Switzerland/France)	89
reservoirs	
Owen Falls (Uganda)	204
Bratsk (Russia)	169
Aswan High Dam (Egypt/Sudan)	162
Kariba (Zambia/Zimbabwe)	160

Surface area of selected freshwater and salt lakes

	surface area (km^2)
freshwater lakes	
Superior (Canada/USA)	82 367
Victoria (Uganda/Kenya/Tanzania)	68 800
Ontario (Canada/USA)	59 570
Michigan (USA)	58 016
Tanganyika (Burundi/Zaire/ Tanzania/Zambia)	32 000
Baikal (Russia)	31 500
Great Bear (Canada)	31 153
Erie (Canada/USA)	25 821
Léman (Switzerland/France)	584
salt lakes	
Caspian Sea (Russia/Turkmenistan/ Kazakhstan/Azerbaijan/Iran)	374 000
Aral Sea* (Kazakhstan/Uzbekistan)	64 500
Balkhash (Kazakhstan)	17 301
Maracaibo (Venezuela)	13 010
Dead Sea (Israel/Jordan)	940

* before shrinking

created by the scouring action of continental glaciers during the glacial period some 12 000–13 000 years ago. In addition, many shallow coastal and river lakes were formed along large rivers after the glacial period, particularly along the Yangtze River in China and the Atlantic coast of South America.

The largest lake in the world is the salty Caspian Sea. Lake Superior has the largest area of any freshwater lake. Lake Baikal has the largest volume and contains about 20 percent of the planet's surface fresh water. With a maximum depth of 1637 metres, Lake Baikal is also the deepest lake in the world (the Caspian has a maximum depth of 1025 metres.) Compared with these gigantic lakes and the other Great Lakes, most others are small.

However, the importance of a lake is not related solely to its size. For example, Inbanuma, situated in the metropolitan area of Tokyo, is important because it supplies domestic and industrial water to the city even though its volume is several million times smaller than that of Lake Baikal. The socio-economic importance of a lake determines the care needed in using it and managing its water quality.

As a rule, deep lakes with large volumes tend to be very transparent while small lakes often appear turbid because they are easily stirred up by the wind and overloaded by nutrients which results in excess growth of algae. It is obviously much harder to restore the quality of a large lake than a small one. Once the water quality and ecology of a large lake has been degraded, restoration is difficult because the lake water takes so long to be renewed.

The value of lakes and reservoirs

Apart from their value as water sources, freshwater lakes have always been important to human life for other reasons. They serve as fishery grounds, recreation sites and avenues of transport. They also provide many other practical and aesthetic benefits. Salt lakes, which comprise about one-quarter of the world's large lakes, also play important roles in fishery, navigation and other areas.

Meaningful development must be sustainable development. Water resources must therefore also be managed sustainably. However, water should be considered not only as a resource but also as a major component of any ecosystem and an important carrier of matter in global biogeochemical cycles. If all the different functions of water are to be taken into account in sustainable development, it is clear that water resources must be managed on a basin-wide scale. Promotion of this concept is a major strategy of the United Nations Environment Programme.

Water uses

One of the most important roles of lakes and reservoirs is as a source of water for direct human consumption, agriculture, industrial use and hydropower. Human beings always choose to live, if they can, in places where fresh water is easily available. For example, in Japan, Lake Biwa and the river that drains it supplies drinking water to 14 million people.

Freshwater use for irrigated agriculture accounts for about 70 percent of total world use. Since 1950, the world's irrigated

Evaluating the Canadian wetlands

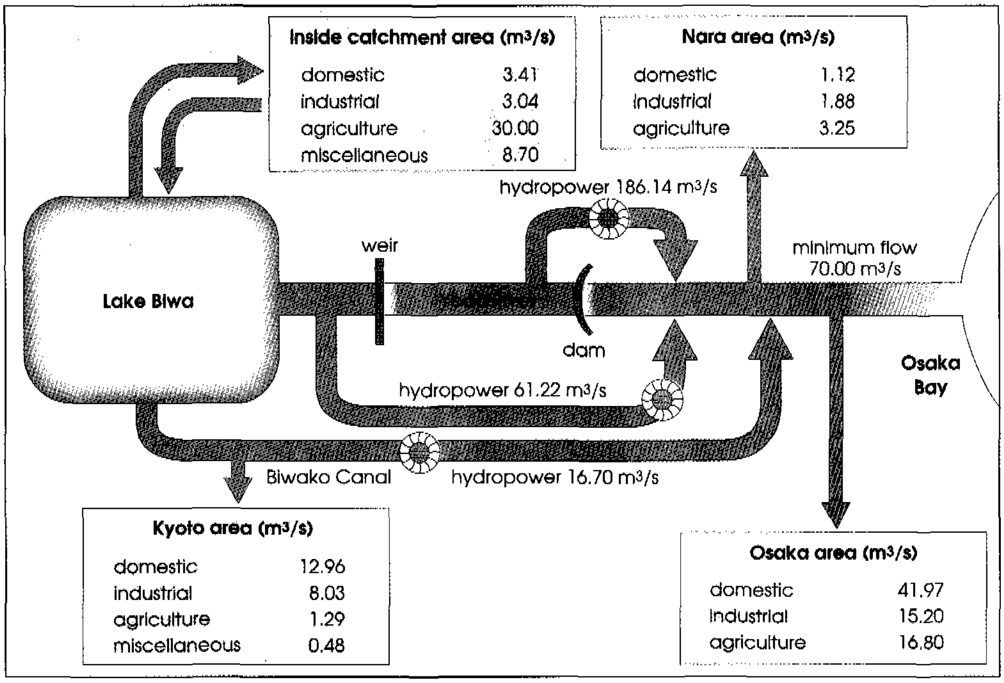
In the past, the value of Canada's wetlands has been perceived mainly as their potential for conversion to more 'productive' uses. Failure to quantify the real value of wetlands, so that they could be compared with competing or alternative land uses, has resulted in significant losses of wetland area. In fact, wetlands are one of Canada's vital economic resources, worth a significant portion of the nation's total economy. The table on the right lists some of the important functions fulfilled by wetlands and estimates their annual values.

Although knowledge of wetland functions and values has grown considerably in the past decade, there are still important gaps in our knowledge. Significant research needs to be done in analysing the social, economic and legislative factors involved in the conversion of wetlands to other uses. A second major obstacle to wetland conservation efforts results from the fact that most wetland benefits accrue to the public in general, and not exclusively to the private owner.

Wetland economic values for Canada

benefit	*estimated annual value (million Can$)*
sport fishing and hunting	1434
non-consumptive recreation	3000
trapping of fur-bearers	70
peat production	679
commercial fishing	80
water purification	1350
flood peak modification	2700
shoreline protection	no data
total	Can$9320 million

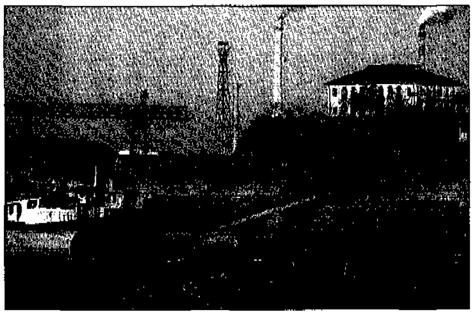
Figure 3 Water utilization (in m^3 per second) in the Lake Biwa basin.



land area has nearly tripled, to about 270 million hectares. One-third of the world's food is grown on irrigated lands, even though they comprise only 18 percent of total cropland areas.

Lake water is also a potential source of hydropower. For example, the Aswan High Dam began to produce electricity in 1967 and by 1984 it had reached 88 percent of its theoretical total electricity production (about 8000 million kilowatt-hours a year). In 1986 Aswan power provided more than one-third of the electricity used in Egypt—after reaching a peak of 53 percent in 1974, before other power stations were built—and provided the power for a new fertilizer plant with a 200 000-tonnes per year capacity and other chemical installations at Aswan.

Much water is also used by industry, particularly in the production of iron, steel, paper and chemicals.



T. Kira

Vessels unloading industrial materials for a factory on the shore of Lake Dongting in China.

Fisheries and transport

Both natural lakes and reservoirs are important sources of food for local people, especially in developing countries. In Africa, fish comprise 20 percent of the animal protein in the average diet.

In many lake areas, water transport is efficient, easy and environmentally sound. In some areas, it is the only practical means of transport. It is important not only for passengers but also for supplying goods to local markets and for moving bulk cargo, agricultural and lake products over longer distances.

Tourism and recreation

The UNEP/ILEC publication *Survey of the state of world lakes*, which covered 215 world lakes and reservoirs, showed that many world lakes and reservoirs could be developed for tourism: 80 percent of the lakes in Asia and the Pacific, 91 percent of lakes in Europe, 62 percent in Africa, 92 percent in North America and 83 percent in South America were found to have potential for tourism.

This potential is increased if a lake has rare or threatened plant and animal species, unusual ecosystems, landscapes and natural processes, a high diversity of habitats and significant altitude changes across the site. Recreation and tourism

ILEC

A small fisherman's boat on Lake Songkhla, Thailand.

contribute significantly to local, regional and national economies, both in developed countries (for example Loch Ness in the United Kingdom and the Everglades in the United States) and in developing countries (for example Lake Kariba in Zimbabwe and Zambia, Lake Toba in Indonesia, Lake Nakuru in Kenya and Dal Lake in India).

Biological diversity

Freshwater fish comprise about one-third of all fish species. The diversity of fish species in old lakes is particularly striking. In Lake Tanganyika, one of the world's oldest lakes, more than 250 fish species have been found, of which more than 80 percent are endemic. Since lakes are semi-closed systems, fish have no means of escaping from lake deterioration, and are therefore vulnerable to ecosystem disturbances.

The shore or littoral zone has the highest biological activity and productivity in a lake ecosystem, thus contributing greatly to the biological resources of the entire lake, particularly in shallow small lakes. On the other hand, human activities tend to be concentrated on lake shores, with the result that littoral ecosystems are exposed to disturbance and destruction. Moreover, because lake shores are frequently used by migratory birds, lakes can play a significant role in the ecosystems of remote areas in other regions.

Flood control

Tonle Sap, the Great Lake of Cambodia, is fed in the rainy season by water and sediment from the Mekong River draining

Impact of the Aswan High Dam on fish production

In Egypt, combined fish production from the Mediterranean and the Aswan High Dam Lake is significantly larger than that from the Mediterranean alone before the Aswan Dam was built. Thus the overall impact of the Aswan Dam on fish production in Egypt has been overwhelmingly positive, and not negative as some environmental literature suggests.

The Lake Authority, charged with developing the lake and its environment, is encouraging former residents to return to the area and help develop fishing and farming industries. There are already about 7000 fishermen on the lake.

Fish species in old lakes

	lake age (million years)	number of fish species	ratio of endemic species
Tanganyika (Africa)	5–20	>250	>80%
Victoria (Africa)	0.75	>240	>80%
Malawi (Africa)	2	>260	>80%
Baikal (Asia)	20–30	40*	50%*
Biwa (Asia)	2	60*	20%*

* approximate value

the mountainous areas of Thailand, Laos and the Chinese border. Thus the lake, by retaining flood flows, maintains a constant flow regime downstream into Vietnam, preserves water quality there and enhances biological productivity for both the aquatic life of the river and for the human communities of the region.

In South America, activities in the Brazilian catchment of the Parana River, in particular deforestation, water diversion and mining, are causing concern for the future of the Pantanal, the world's most extensive wetland, which straddles the frontiers of Brazil, Paraguay and Bolivia. Furthermore, changes in land use within the Pantanal itself, including reduction in forest cover and expansion of cropland, have altered the flooding regime of the Parana further downstream along much of its course in central Paraguay and Argentina.

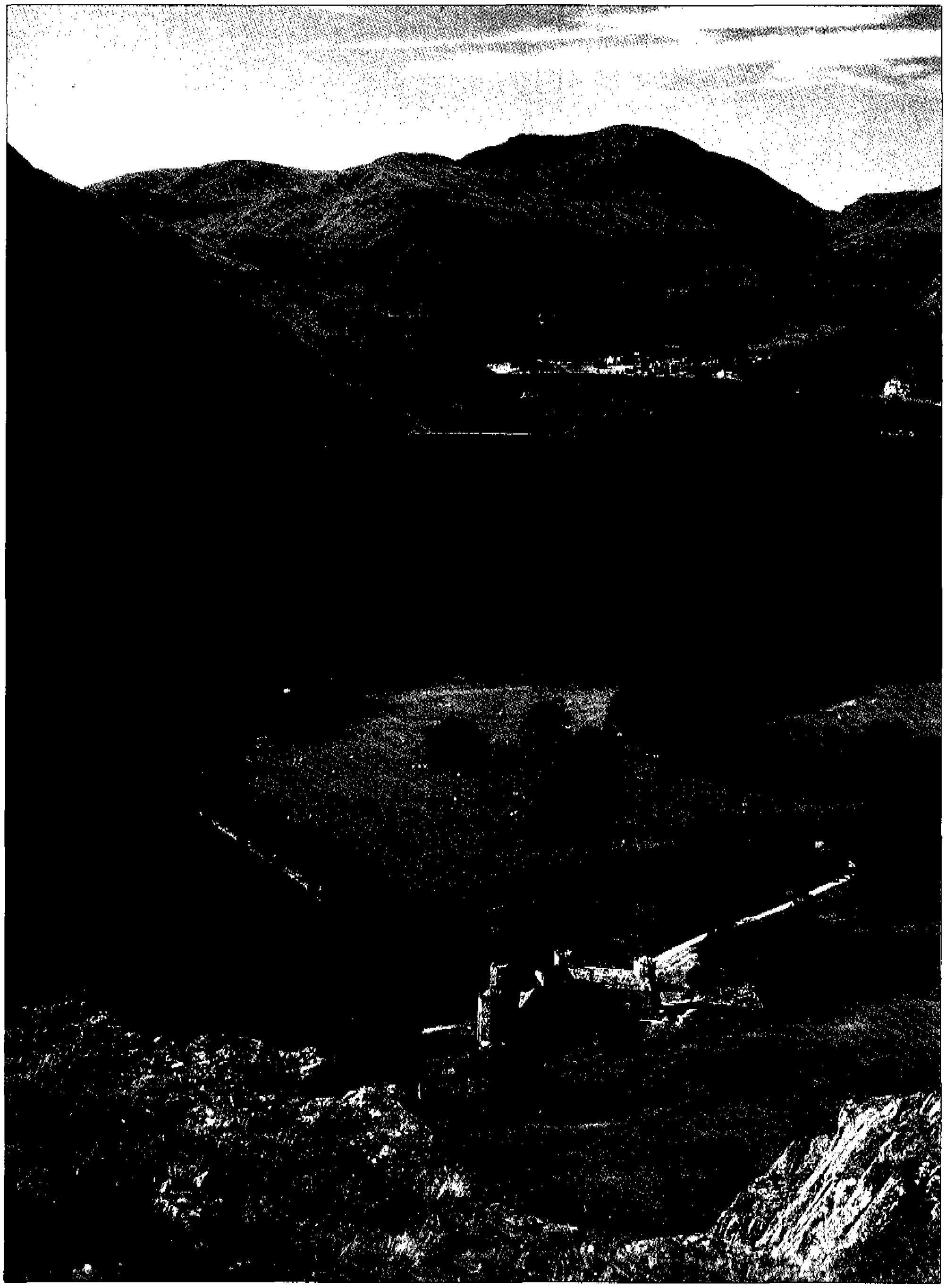
Lake Titicaca

Despite its altitude (3810 m), people have lived around Lake Titicaca since pre-Incan times. Before the arrival of Europeans, the lake supported a healthy economy based on raising alpacas and llamas, fishing and commerce. Today the large lake-side population still relies heavily on the wetland environment. The domestic herds are now composed of vicunas and cattle, and trout have been introduced. Submerged aquatic vegetation, 'Yacco', is collected as cattle feed and Totora reed is used for making boats and floating crop beds, in handicrafts and as food. Some 5000–6000 tonnes of fish are harvested annually.

Cultural heritage and aesthetic significance

Lakes are often key components in the landscape of the region that surrounds them, providing diversity and a focal point for viewing the landscape. Landscape and its associated aesthetic values are difficult to recreate once destroyed.

Many lakes, large and small, have for centuries played a central role in the economies of their respective regions. Lakeside communities follow the natural cycle of the lakes closely, adjusting to the seasonal movements of fish, to vegetation growth and to changing water levels. In almost all lake systems, the local population uses a diversity of resources, including fish for consumption or sale, vegetation for livestock and construction,



Colin Raw/Tony Stone Worldwide

'A lake is the landscape's most beautiful and expressive feature. It is the earth's eye; looking into which the beholder measures the depth of his own nature.'

Walden
by Henry David Thoreau

Lake Burley-Griffin in Canberra, an artificial lake that was created for scenic purposes.

A. Kurata

and the moist shoreland on which to grow vegetables and other crops.

Many communities use distinct sites for religious and spiritual activities, or value a site for some religious or spiritual occurrence that they believe took place there. This devotion to a site may be so integrated into the way of life of a community that it is not immediately apparent to outside observers. Lakes often serve as such sites.

In addition, local inhabitants may have a strong spiritual attachment to a site because their family or community has used the site for many generations, or because it is associated with aspects of their culture. In many cases it is impossible to compensate for the loss of such sites which are, by definition, unique.

Upgrading the tourism value of Xi-hu Lake

With its picturesque hills, Xi-hu (West Lake), a shallow lake close to Hangzhou City in China, has been famous for its scenic beauty since the Tang Dynasty (618–907 AD). Efforts have been made to maintain the beautiful lake shore, and the lake has attracted many tourists. In 1983, an overall development plan was adopted which defined tourism as an important function of the lake.

Measures were taken by local environment agencies to reduce eutrophication and to protect the landscape of the lake. These included the construction of waste water treatment plants, diversion of nearby clean river water into the lake, the removal or closing down of industrial pollutant sources, dredging the bottom sediment, building block stone banks to prevent the inflow of silt and nutrients from storm run-off, replacement of diesel engine pleasure boats by electric ones, reducing nitrogen and phosphorous levels through a ban on baiting for fish, and controlling the pollution caused by the large number of tourists. The interception of waste water and the diversion of clean water made a fundamental difference to the balance of nitrogen and phosphorous in the lake, and their loads were reduced by 71 and 74 percent respectively.

The deterioration of lakes and reservoirs

The report of the UNEP/ILEC joint project *Survey of the State of World Lakes* identifies six major problems that are confronting the world's lakes and reservoirs (see Figure 4). In view of the growing importance of lakes and reservoirs as sources of fresh water, these problems represent a serious ecological disaster, comparable in importance to the destruction of tropical forests and desertification.

The resultant deterioration of water quality and aquatic ecosystems as well as the decreasing amount of available fresh water is a global environmental problem in the sense that it is taking place simultaneously over much of the world.

Eutrophication

Eutrophication—a process of water quality degradation caused by excessive nutrients—is depriving lakeside residents of good quality water in many densely populated areas of the world. The development of treatment plants for sewerage and waste water have reduced eutrophication in many lakes in the industrialized countries. The recovery of water quality is not yet complete, however, because of the difficulty of controlling diffuse sources of nutrients such as run-off water from agricultural land and urban areas.

In developing countries, most cities have no or limited sewerage systems. Enormous investments of money and time are needed to construct these systems. Some lakes in developing countries are now so eutrophic that many of the native plants and animals they once supported have now died.

The percentage of lakes and reservoirs with eutrophication problems in the 215 lakes and reservoirs covered by the UNEP/ILEC surveys was as follows: Asia

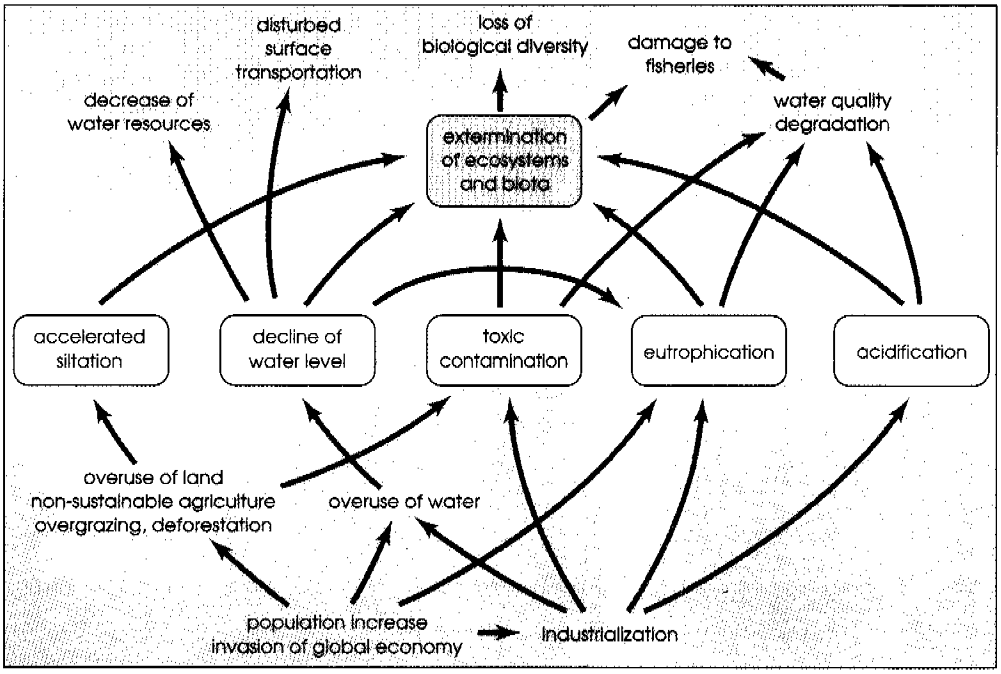
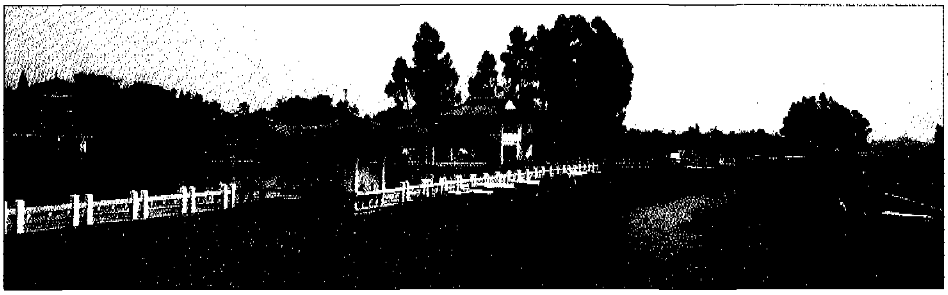


Figure 4 The six major environmental problems in world lakes and reservoirs. The figure shows the ways in which they are related to one another.

Eutrophication in Lake Dianchi

In Dianchi Lake near Kunming City, the capital of Yunnan Province of China, heavy blooms of the blue-green algae, *Microcystis*, cover the lake surface almost all the year round, killing 90 percent of native waterweed, fish and molluscs, and destroying the fish culture industry because of the oxygen deficiency in lake water. Water supplies for the 1.2 million residents of Kunming are running short, and the city began to use this hypertrophic lake water as a source of tap water in 1992. The first sewage treatment plant also started working in summer 1993, but it can treat only 10 percent of the city's sewage.



H. Kawaguchi

and the Pacific, 54 percent; Europe, 53 percent; Africa, 28 percent; North America, 48 percent; and South America, 41 percent.

Water level fluctuations

Taking too much water from a lake or its tributary rivers results in a decrease in lake area and volume, temporary eutrophication symptoms and concentration of minerals in the water. This can damage industries that depend on lake resources and even destroy the lake ecosystem. The case of the Aral Sea, which has lost one-third of its area, two-thirds of its water and almost all its native organisms during the past 30 years, is a well-known example. Similar symptoms are said to be common in other arid zone lakes such as Balkhash (Kazakhstan), Chinghai (China) and Mono (United States). Increased use of water for hydroelectric power generation and irrigation led to a drop in water level of 18 metres and dramatic eutrophication in Armenia's Lake Sevan between 1935 and 1976. There are indications that even a drop in water level of a few metres can cause water quality degradation (as in Erhai Lake in Yunnan, China). Further studies, however, are needed. Two further examples of water level fluctuations are described below.

The Caspian Sea

Although not far from the Aral Sea, the water level of the Caspian Sea has been rising quickly in recent years. There is evidence that the water level of this gigantic closed lake has oscillated over historical times. A drastic drop in level occurred between 1932 and 1945. The area of the lake decreased by 37 000 km^2, mainly at the expense of the shallow northern part of the Sea. All ports had to be rebuilt to adjust to the lower water level. The fish spawning grounds reduced in area, resulting in a loss in fish production. Salty deserts appeared to rise from the lake itself.

At the end of the 1970s, the water level started to rise quickly, exceeding the lowest level by about 1.5 metres. The main reason was increased precipitation in the lake's basin. The lake economy now has to adjust to the rising water level. Cities, other settlements, railways and roads will all have to be protected from the rising water, and continued exploitation of the area's oil fields is becoming a problem. The case of the Caspian Sea shows the need for long-term monitoring and basin-wide planning.

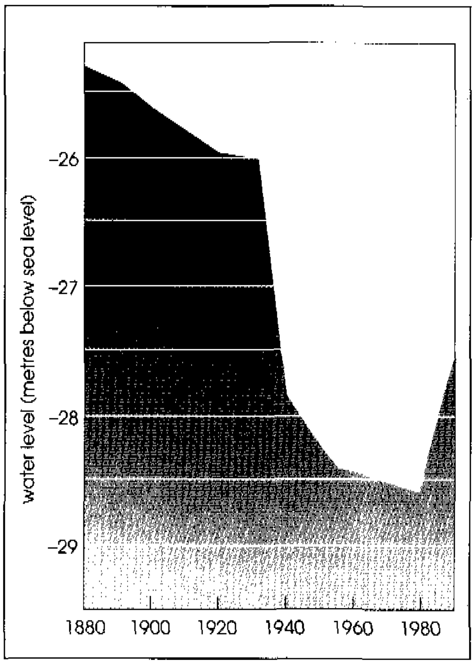


Figure 5 Water level fluctuations (the figures are in metres below sea level) of the Caspian Sea.

M. Ando

The Iranian town of Anzali inundated as a result of water level rise in the Caspian Sea.

The Aral Sea disaster

The Aral Sea, once the world's fourth largest lake, now ranks only sixth. Since 1960 the Amu and Syr rivers which flow into the lake have had so much of their water diverted for agriculture that not enough remains to counteract evaporation from the lake surface. As a result, water levels have fallen and salinity increased. At present rates of inflow, the Aral will continue to shrink and by the year 2000 will be reduced to two-thirds of even its present size.

Half of the investment in agriculture in the Aral Sea basin over the past 30 years went into irrigation. However, the irrigation canals are mostly unlined, and much water is lost. The Sea has been shrinking since the beginning of the 1960s, while the salt concentration of the lake water has been increasing. Part of the former lake bottom is now a salty desert, whence salts are spread by the wind. This environmental degradation has led to unacceptable drinking water quality, a high salt content in the air and, high levels of pesticide residues; all this has had a direct impact on human health in the Aral Sea basin.

In the lower reaches of the Syr River, morbidity rates have increased 20 times over the past 20 years. Infant mortality in some districts exceeds 110 per 1000—three times the average for the former Soviet Union and comparable to figures for the least developed countries. Infant mortality in the autonomous Republic of Kara-kalpakskya is seven times the all-Union level. More than 90 percent of the population there suffers from anaemia. Some 46 percent of women have genetic disorders of different kinds and in the capital Nukus the breast milk of all the 35 mothers sampled was unsuitable for feeding. Clearly, the area close to the lake is in a state of environmental catastrophe, and the whole of the Aral Sea basin is not in much better shape.

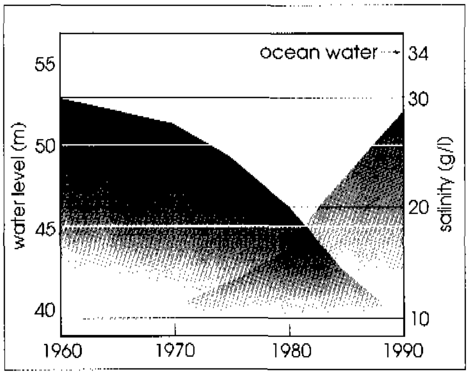


Figure 6 Water level and salinity changes in the Aral Sea.

M. Nakayama

An abandoned boat resting on the dried-up floor of the Aral Sea.

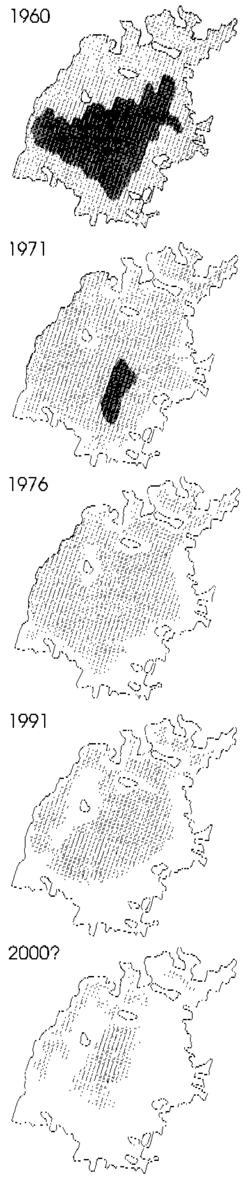


Figure 7 Chronology of the Aral Sea changes.

Lake Chad

This shallow and closed Sahelian freshwater lake is suffering from a lowering of water level due to climatic variability. Sand dunes in the lake show that it has also expanded and shrunk over time. The lake was five times its present size several thousand years ago, while the drought years of the 1970s turned the northern half of the lake completely dry; the southern basin became a densely vegetated area with scattered swamps and open pools. By the end of the 1970s, the lake, which until the 1960s occupied an area of up to 25 000 km^2, was reduced to about one-tenth of its former size.

Siltation

Many lakes in developing countries, both natural and man-made, are suffering from siltation caused by accelerated soil erosion from the overuse or misuse of arable, grazing and forest lands within their catchment basins. This occurs mainly because traditional forms of sustainable land use are rapidly disappearing with increasing numbers of people and the invasion of the cash economy, even in remote rural areas. In fact, the concentration of suspended solids in lake water is often closely correlated with the percentage of land in the catchment basin that is devoted to agriculture.

The percentage of lakes and reservoirs that had serious siltation problems in the 215 lakes and reservoirs covered by the UNEP/ILEC surveys was as follows: Asia and the Pacific, 14 percent; Europe, 5 percent; Africa, 19 percent; North America, 13 percent; and South America, 16 percent.

Lakes and reservoirs can diminish the destructive onslaught of flood crests

The shrinking of Lake Dongting

Lake Dongting in Central China, which receives flood water from the Chiang-Jiang (Yangtze River) every summer, was much bigger (6200 km^2) 150 years ago than it is now (2740 km^2). The rapid advance of sedimentation and land reclamation works have resulted in the formation of three more or less separate lakes—the West, South and East Dongting. In the summer flooding season, however, the three lakes unite into a single water body of about 3900 km^2. The lake is now accumulating new sediments at a rate of 5–6 cm per year as the result of extensive hill-slope cultivation in the upper reaches of the river. This means that the lake, with an average depth of 6.7 m, may be filled up within some 100 years. The problem is essentially a socio-economic one which is especially difficult to solve by technical measures alone.

T. Kira

Soil erosion in the upper reaches of Chiang-Jiang (tobacco field in Yunnan Province, China).

Copper sulphate in Lake Mendota

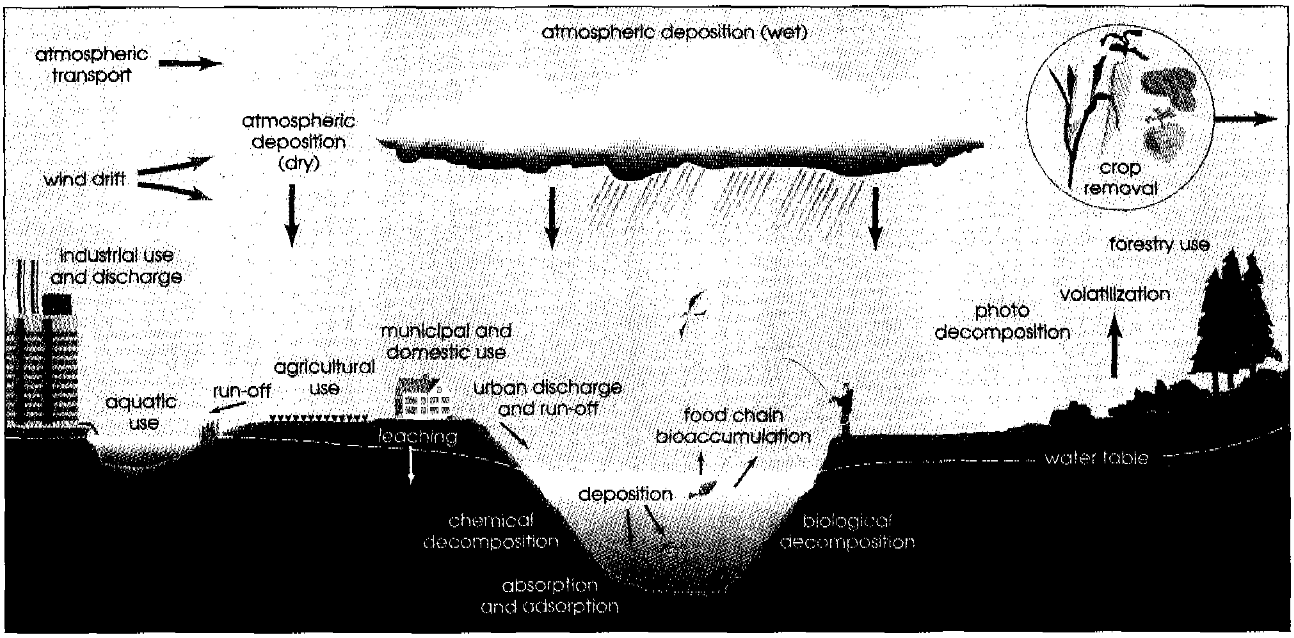
One of the treatments to reduce blue-green algal blooms is the application of copper sulphate to surface waters. Copper in ionic (Cu^{++}) form is a general biological poison; however, judicious application in relatively low concentrations can kill algae without harming fish or aquatic invertebrates. This was the method used between 1912 and 1958 to reduce the incidence of blue-green algal blooms in the chain of lakes at Madison, Wisconsin, United States. There, Lake Mendota, Lake Monoma, Lake Waubesa and Lake Kegonsa are linked by the Yahara River. Thousands of tonnes of copper sulphate were used over the 46-year period to create clear-water conditions in the lakes. Between 1926 and 1936, 27–45 tonnes of copper sulphate were applied annually to reduce algal growth. These additions now lie buried in copper-rich layers of sediment—a useful reminder to future scientists of the futility of trying to solve man-made eutrophication problems without cutting off the supply of nutrient-rich wastes.

downstream by storing precipitation and releasing run-off evenly. For example, Poyang Lake, China's largest freshwater lake, is surrounded by extensive wetlands and can store one-third of the annual flood waters from Jiangxi Province. It reduced the peak of the June 1954 flood by one-half. Dongting Lake and its wetlands provided a similar reduction for Hunan Province. Siltation of these lakes now prevents them from controlling floods so effectively.

Toxic chemicals

The contamination of lake water, sediments and organisms with toxic chemicals is one of the problems that have not yet been overcome in industrialized countries, where the problem first arose. It persists,

Figure 8 Pollution pathways.



for example, in the North American Great Lakes, where eating fish is still controlled in some areas because of contamination with chlorinated hydrocarbons such as PCBs, pesticides and heavy metals. Similar contamination has now spread to many parts of the developing world but specific data are still scarce. More work is needed to fill the information gap through a global monitoring network.

Contamination by oil is a particularly insidious form of pollution which fortunately occurs on a large scale only in those relatively few lakes where oil is transported in bulk or whence it is extracted. Both activities occur on Lake Maracaibo, a large brackish lake in Venezuela, where there are more than 5000 oil wells. The lake has repeatedly suffered from oil spills during drilling, extraction and transportation, and from the oil-related industries on the shore. These spills have affected the Lake Maracaibo ecosystem. The lack of data from the period before oil exploitation began makes it difficult to evaluate the effects of these oil spills on the ecosystem. Official solutions to the problem have so far been ineffective. Six decades have passed without effective measures being taken to protect the lake basin.

Acidification

Acidification and the death of fish and other animals which it causes are so far confined to the lakes of north-western Europe and the north-east of the United States and adjacent parts of Canada. These symptoms are not yet apparent in other parts of the world which receive rainwater of similar acidity. The reason for this is probably related to the nature of the soil in the regions concerned, which has a high buffering capacity and is able to neutralize

Pesticide contamination of the Great Lakes

Large amounts of organic pesticides are used in the United States, in Europe west of the Urals and in the Far East. In North America, a major database tracks information on the concentrations and the eventual fate of pesticides in aquatic ecosystems in the Great Lakes. In these lakes, in spite of their size, organic pesticides are found in high concentrations in lake sediments, in predator fish and in other living organisms. The concentrations of some contaminants are so high that human consumption of some fish species has to be carefully controlled.

The concentrations of most organic pesticides have declined, often dramatically, over the past 25 years. Nevertheless, for some organochlorine compounds, these declines have now levelled off. Part of the reason is that the atmosphere has now become a major source of some organochlorine compounds.

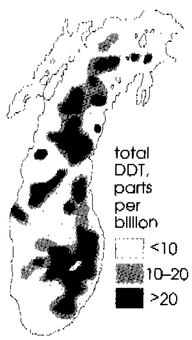


Figure 9 Distribution of total DDT in the top 3 cm of Lake Michigan's bottom sediment.

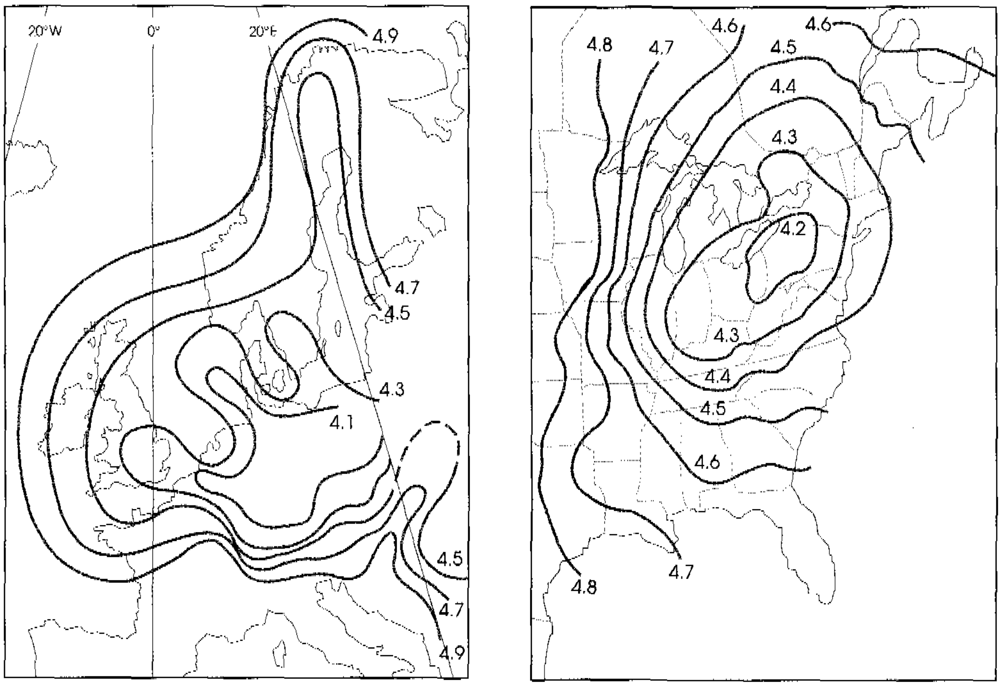


Figure 10 Acidity levels in precipitation in Europe and Eastern North America. Rain water with an acidity of less than pH 5.6 is classified as acid rain.

the acidity of rainwater before it reaches streams and lakes. However, the buffering action of soil may not last forever in such regions; eventually, the materials in the soil that buffer acidity may be exhausted if acid precipitation continues. Scientists are now trying to predict when this can take place in different types of soil.

Swedish and Norwegian lakes and rivers were the first habitats to suffer visibly from extensive acid rain damage. More than one-fifth of Sweden's 85 000 medium and large lakes are now acidified, 4000 of them seriously. In Norway, fish populations had disappeared from an area covering 13 000 km^2 by 1980 and been depleted in a further area of 20 000 km^2.

Acidification of Lago d'Orta, Italy

The pollution of Lago d'Orta in Italy began at the end of 1926 when a factory producing artificial silk (rayon) using the cupro-ammoniacal method was established at the southern (upstream) end of the lake. Within a few years the chemistry of the lake water was showing clear signs of becoming uninhabitable for most of the organisms present. In 1958 a recovery plant was set up, and the copper load from the factory was significantly reduced. However, the factory continued to dump loads of untreated ammonium sulphate in the lake. It was not until the beginning of the 1980s that a treatment plant was set up and a plan made to treat the lake by spreading natural limestone powder on the lake. This liming is bringing about positive changes in the lake chemistry and is also contributing to the re-establishment of a structurally more complex biological community. It will be essential to continue the operation until the permanent recovery of the lake can be guaranteed.

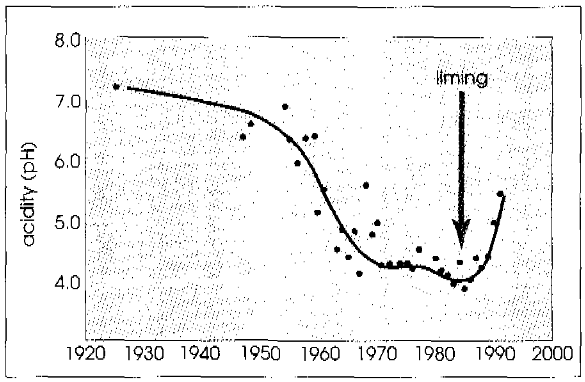


Figure 11 Evolution of average acidity in Lago d'Orta.

The disruption of lake ecosystems

Lake ecosystems, and the fauna and flora they contain, normally evolve slowly over time. The sudden introduction of new species, however, can quickly upset an ecosystem that has been stable for centuries or even millennia. Equally disrupting effects can occur when lake conditions are changed—for example, as a result of excess nitrogen in agricultural run-off—causing a sudden eruption in the population of one or more species that were previously in balance with other members of the ecosystem.

Impact of the zebra mussel on the Great Lakes ecosystem

The zebra mussel, a tiny bivalve species of European origin that sticks to any surface and forms dense colonies, was first found in North America in St Clair Lake in June 1988. During 1989 and 1990, the mussel was reported in all five of the Great Lakes. By 1991 it had spread down the St Lawrence River into New York's Hudson and Mohawk rivers via the Erie Canal and into the Illinois River via the Chicago Sanitary Canal. In heavily infested areas, dense colonies have clogged water intakes (see photo above) and delivery systems for municipal and industrial water supplies and electric power stations. They have fouled boat hulls and the water intakes of boat motors, and converted sandy beaches into piles of shells. In addition, the mussels can colonize and disable sensitive recording instruments such as pH and DO probes, causing serious problems for in-lake environmental sensing. The US Fish and Wildlife Service estimates that zebra mussels may cause $5000 million worth of damage to factories, ships, power plants, fisheries and water supplies in the United States and Canada over the next decade.

F. M. D'Itri

Colonies of zebra mussels clogging up a water intake pipe.

Abnormal weed growth in lakes

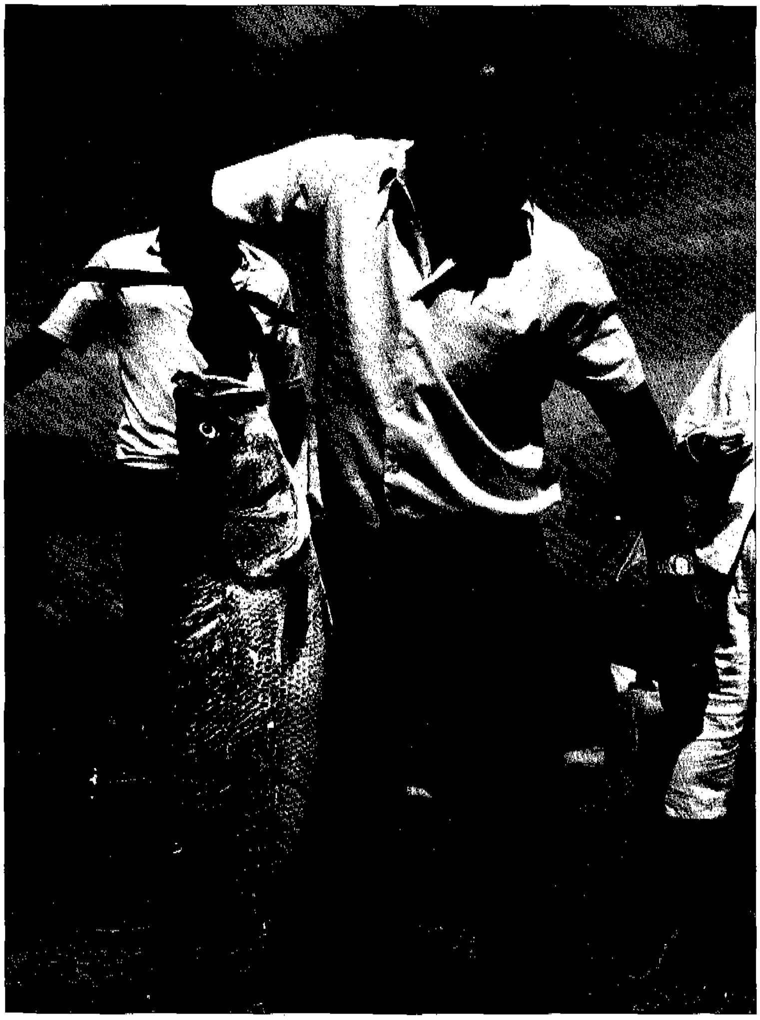
Water-weeds can cause serious problems for shipping during the growing season and, when they drift ashore, the foul-smelling decomposing plants lead to a deterioration of water quality on lake shores. In Lake Rotorua in New Zealand, the weed beds of *Lagarosiphon major*

T. Kira

*Abnormal growth of exotic water weed in Lake Biwa (*Elodea nuttallii*, North American origin).*

reached a peak in the mid-1960s. At present, *L. major* and *Elodea canadensis* grow in some sheltered areas and near stream outlets. Some danger exists that *L. major* and *E. canadensis* might be replaced by *Egeria densa,* which can thrive at lower light levels. Alternatively, reduction of phytoplankton populations because of reduced nutrient inputs may lead to a resurgence of growth by *L. major* and *E. canadensis.* The very recent arrival of *Ceratophyllum demersum* at Lake Rotorua is likely to complicate matters further. It is possible that the spread of these weeds has occurred coincidentally with enrichment and pollution in New Zealand lakes, rather than because of it.

Nile perch at Lake Victoria.



T. Kira

Exotic species in Lake Victoria

Following the introduction of the large Tilapia fish and the carnivorous Nile perch to Lake Victoria, serious damage has occurred to the native fish community. The situation has become so severe that native fish have hardly been caught at all for 10 years, and all endemic Haplochromine fishes are facing extinction. Official fisheries statistics, however, show that the present fishery yield is several times greater than it was.

There has been controversy over the introduction of the new breeds, in spite of increased yields. It is argued that formerly the small native fish could be easily caught by local people but that the Tilapia and Nile perch are too big for the average fisherman to catch and are too expensive for local consumption.

Prevention and restoration

Monitoring

The Global Water Quality Monitoring programme (GEMS/WATER), a joint UNEP, WHO, WMO and UNESCO programme begun in 1977, was the first of its kind to address global issues of water quality through a network of monitoring stations in rivers, lakes, reservoirs and groundwater on all continents. Technical cooperation with developing countries was the main focus of the programme's first phase, and this resulted in the establishment and expansion of national water quality monitoring systems in many countries.

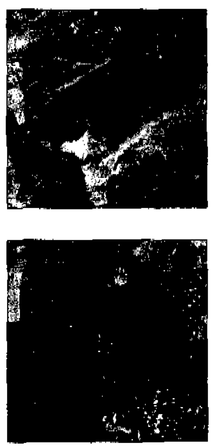
Phase Two of the programme will concentrate, during the period 1990–2000, on data interpretation, assessment of global and regional water quality issues, and water quality management options. The number of monitoring stations will be increased and categorized as: Baseline Stations (located in headwater lakes or undisturbed upstream river stretches to establish background conditions); Trend Stations (located in major river basins, lakes and aquifers to follow long-term changes in water quality in relation to industrial, agricultural and municipal pollution and various land-uses); and Global River Flux Stations (located at the mouth of major rivers to determine annual fluxes of critical pollutants and nutrients from river basins to the ocean).

The long-term objectives of Phase Two include providing governments, the scientific community and the public with water quality assessments and information relating to the health of human populations, aquatic ecosystems and the global environment; and to strengthen national water quality monitoring networks in developing countries, including the improvement of their analytical capabilities and the quality of the data they produce.

Monitoring by satellite

The world's first Earth observation satellite LANDSAT-1 was launched by the United States in 1972, more than 20 years ago. Since then, the technology of remote sensing has been greatly developed. Today this technology can provide much-needed information—for example, on some aspects of water quality or vegetation cover—for lakes and wetlands where access is difficult or where a large area needs to be surveyed and the cost of a ground survey would be too high.

Relatively inexpensive personal computers can now be used for image processing. Although problems remain—for example, the availability of cloud-free images is the major obstacle in humid tropical countries—satellite imaging can be used as a monitoring tool for basin management in developing countries. However, some further developments are necessary and proper training must be given to those interested.



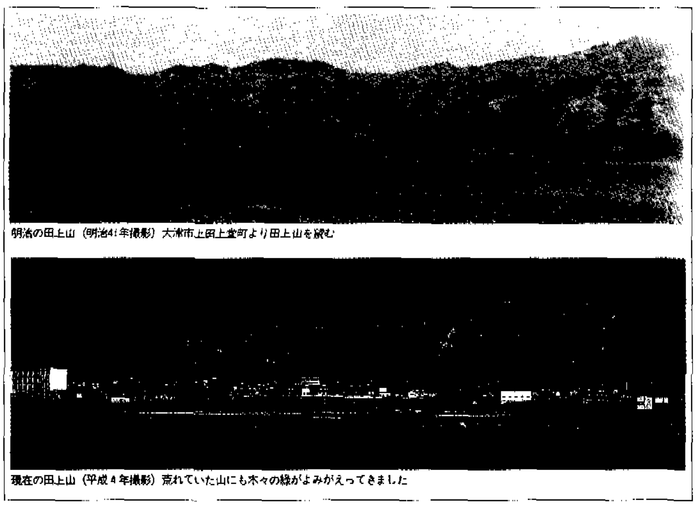
M. Nakayama

Satellite remote sensing scenes showing encroaching plantations around Tasek Bera, a wetland lake in Peninsular Malaysia, between 1979 and 1988.

Forest management in the Lake Biwa basin

In the southern part of the Lake Biwa basin in Japan, population pressure led farmers to over-harvest their forest lands, turning some previously forested areas into bare slopes almost devoid of vegetation. Deforestation was particularly bad in the Tanakami mountains to the southeast of Lake Biwa. The government undertook to restore this area by introducing, and adapting, erosion control technology from Western Europe as long ago as the 1870s. Though still practised today, this work was largely successful, and it allowed pine forests to recover steadily.

In the northern part of the basin, by contrast, deciduous forests had been used to supply people with firewood and charcoal. The forest was cut once every 20–30 years for charcoal production, and left to regenerate naturally. Repeated cuttings over the centuries led to the survival of only those tree species that sprouted vigorously. Regeneration took place so rapidly that soil erosion and degradation remained negligible, even on steep slopes. This was therefore an ideal form of sustainable energy forest use.



Japanese Ministry of Construction

Contrasting views of the Tanakami mountains in Lake Biwa Basin in 1908 and 1992, showing badly eroded slopes and the subsequent recovery of pine stands.

Sustainable management

Basin-wide land-use management is needed for the sustainable management and development of river basins, including the control of non-point source pollution. Strategies used to control water quantity and quality should be combined. Basin-wide management requires improvements in soil management (to reduce erosion and salinization, for example) which, in turn, require sound land-use planning for the basin as a whole.

This cannot be done without proper regard for the natural features of the basin, including an analysis of the processes that lead to environmental problems. Nor can it be done without considering the objectives and goals of socio-economic development in the basin. In 1986, UNEP launched a programme to deal with these issues on a regional basis: EMINWA, the Environmentally Sound Management of Inland Waters.

The programme is intended to introduce a comprehensive approach to planning and management of freshwater resources on a basin-wide scale, thus promoting sustainable development of the whole inland water system. The programme aims to help governments develop suitable management programmes, to train experts and establish training networks in developing countries, and to prepare manuals of principles and guidelines.

The first priority of EMINWA is to help countries sharing common water basins to develop their water resources in a sustainable manner and to use them without conflict. The first project addressed the Zambezi River, of which Lake Kariba is among the major components. The second involved the preparation of a Master Plan for the

Development and Environmentally Sound Management of the Natural Resources of the Conventional Lake Chad Basin Area. This Plan was finalized in August 1991. The Aral Sea basin is also among the target areas of EMINWA and other freshwater basins will be future targets.

Environmental impact assessment
Environmental impact assessment (EIA) is an essential policy instrument for incorporating environmental considerations into development projects. EIA involves a scientific and inter-disciplinary assessment of the possible environmental impacts that investments and development projects may have before they are undertaken. EIA is an important tool in making rational policy decisions.

EIAs should be used whenever projects are likely to affect the lake environment. For example, an increase in endemic diseases may accompany the creation of large reservoirs. EIAs need, therefore, to include studies on vector ecology and to investigate the possible impact of the development on the incidence of endemic diseases. Similarly, the desalinization of brackish lakes to make their water suitable for agricultural irrigation will affect fish production. The Japanese experience in Kasumiga-ura and Naka-umi Lakes are typical examples of the anticipated impacts; simulation studies showed that a decrease in the salinity of the irrigation water would probably have adverse effects on existing fisheries.

The following issues, among others, have to be considered in EIAs on the lake

The use of wetlands for waste water treatment

The water quality of Lake Balaton in Hungary has deteriorated over the past decades as a result of eutrophication. To reduce nutrient loading, a reservoir (wetland) was constructed on the Zala River in 1985, which has a surface area of 18 km^2, a mean depth of 1.14 m and a water retention time of 44 days. The reservoir has reduced levels of NO_3-N by 57–69 percent and of PO_4-P by 57–90 percent. A second reservoir is now being constructed further downstream.

Lake Kinneret (the Sea of Galilee) in Israel used to be fed mainly by a river passing through the papyrus swamps of the Hula valley which trapped sediments and stripped nutrients from the water. Since the swamps were reclaimed for agriculture, a delta of sediment has developed in the lake and turbidity has increased. With the loss of the filtering capacity of the swamp, concentrations of nitrates are also rising.


T. Kira

A wetland created as a nutrient trap at Lake Balaton.

In Uganda, the National Sewerage and Water Corporation is supporting the conservation of papyrus swamps and other wetlands in the Kampala area because of the role that they play in nutrient trapping.

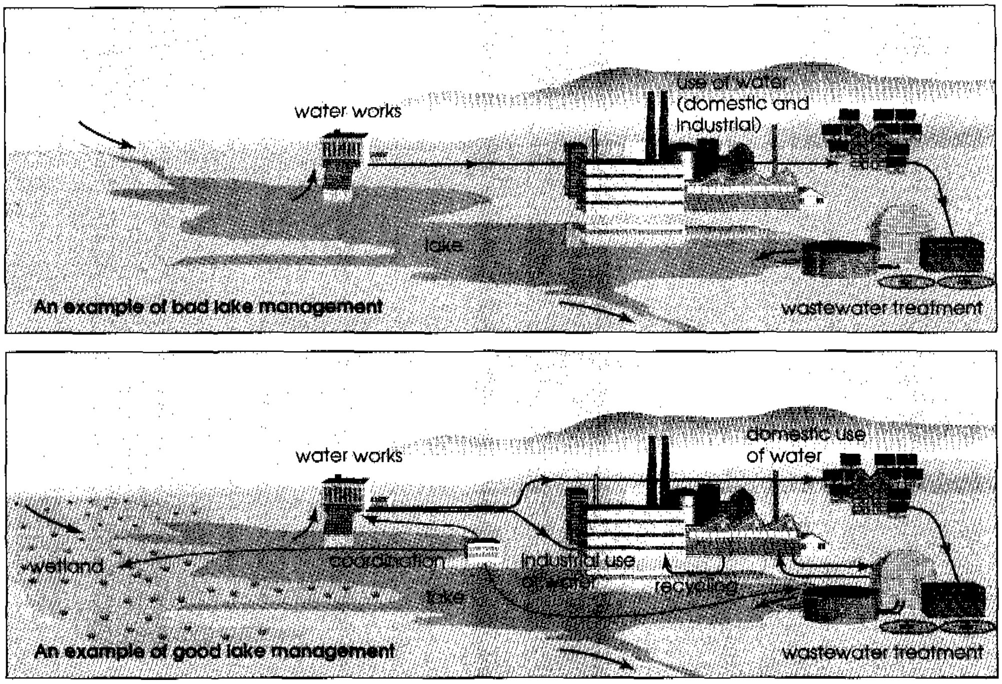


Figure 12 Examples of good and bad lake management.

environment: water quality and quantity, water input and output changes, changes in water level fluctuations, physical shoreline changes, vegetation, soil degradation, siltation, wildlife habitats, irreversible changes to cultural and historic sites, changes in water and land use, and population resettlement. As a guiding principle, it is important to remember that prevention is cheaper than treatment.

While EIAs have been made compulsory in many countries, their use in developing countries is still limited. This is partly because EIA methodology is difficult to apply in areas where there is limited expertise, resources, data and time. The OECD Specialist Project Group on Environment Assessment and Development Aids has estimated that 0.01 to 1.1 percent of project costs are spent in preparing EIAs in developing countries.

Good and bad lake management

Good management strategies require that individual problems are analysed in terms of the entire lake and its environment. The lake's water supply authorities, for example, may wish to use the lake to produce high quality drinking water, and the waste water authorities must try to reduce the effects of waste water on the water quality of the lake. All too often, however, there is no coordination between the two authorities.

Good management often means first that there is coordination between the production of drinking water and the treatment of waste water. Furthermore, the possibility of recycling some of the water should be considered. Some industries may be able to recycle their water or else use partly-treated waste water. This decreases the cost of drinking water and of treating waste water; it may also reduce the impact of these industries on the ecosystem.

The emission of nutrients from agriculture must also be considered if eutrophication is to be reduced and expensive waste water treatment plants are to be avoided. Good lake management involves maintaining wetlands along the shores of tributaries to function as traps for the nutrients coming from non-point sources.

Technology transfer

The conditions under which lake conservation is pursued in one country are rarely the same as in another. Nevertheless, the substantial experience and technical skills developed in managing lakes and reservoirs in one nation can, if used appropriately,

Physical and legislative restoration measures for lakes and reservoirs

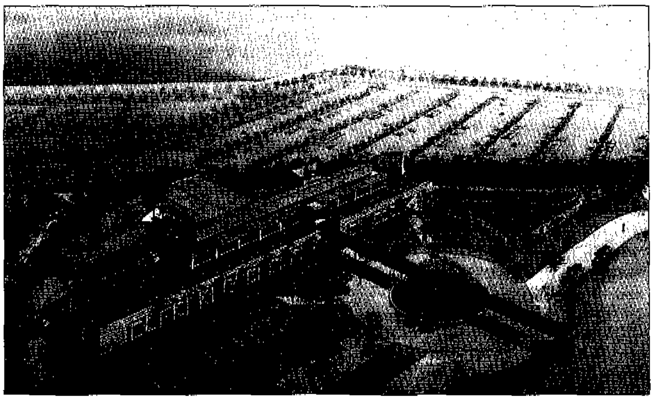
External control measures	example
protection of catchment area	
control of hydrological cycle and soil erosion	
afforestation in upstream areas	Dian-chi (China)
hillside work	Biwa (Japan)
installation of buffer-zone between agricultural land and lake shore	Broa Reservoir (Brazil)
contour cropping	Barra Bonita Reservoir (Brazil)
land-use regulation	
stringent regulation of land use	Tahoe (USA)
moving of pollutant sources from the basin	Feitsui Reservoir (Taiwan)
ban on reclamation	Constance (Germany, Austria, Switzerland)
control of pollutant-emitting factories	Baikal (Russia)
sewage treatment	
construction of large-scale treatment plant	Maggiore (Switzerland, Italy)
construction of oxidation pond	Ya-er (China)
small-scale waste water treatment plant	Naka-umi (Japan)
use of septic tanks	Biwa (Japan)
diversion of sewage outlets	McIlwaine (Zimbabwe)
livestock waste treatment facilities	Furen (Japan)
methane fermentation of domestic waste water	Chao-hu (China)
regulation of the use of agrochemicals	Kinneret (Israel)
ban on toxic substance discharge	Orta (Italy)
nutrient control in inflowing river waters	
use of wetlands for waste water treatment	Balaton (Hungary)
establishment of coordination units for international river/lake basins	Rhine River basin countries
ban on phosphate-containing detergent	Michigan (USA)
control of waste discharge from enterprises	Mjosa (Norway)
embankment for prevention of polluted water inflow	Rotorua (New Zealand)
effective use of agricultural fertilizers	Tota (Colombia)
recycling of treated water to afforested areas	San Roque Reservoir (Argentina)
night soil treatment facilities	Biwa (Japan)

Internal control measures	example
physical measures	
mixing and thermal destratification	
improvement of lake water turnover	Bled (Slovenia)
introduction of clean water to lakes	Ijsell (Netherlands)
aeration, hypolimnetic oxygen inflation	
lake bottom aeration	Baldeggar (Switzerland)
forced vertical mixing of reservoir water	Sagami (Japan)
release prevention from sediments	
sediment removal by dredging	Trummen (Sweden)
sediment sealing with sand layer	Biwa (Japan)
biological measures	
mechanical and chemical removal	
harvesting water weeds	Léman (Switzerland, France)
harvesting blue-green algae	Kasumiga-ura (Japan)
killing algae	Mendota (USA)
killing water hyacinth	Kariba (Zambia/Zimbabwe)
biomanipulation and protection	
manipulation of food chain	small ponds
release of grazing fish for water-weed control	Dong-hu (China)
use of grasshoppers for water hyacinth control	Kariba (Zambia/Zimbabwe)
water-level control for vegetation protection	Chao-hu (China)
lake shore vegetation protection	Neusiedler (Austria)
restriction of navigation to protect lakeshore vegetation	Taupo (New Zealand)
chemical measures	
liming	Orta (Italy)

The International Environmental Technology Centre

The IETC, which was inaugurated in 1992 as an integral part of UNEP, is dedicated to the transfer of technologies relevant to conservation of the environment. IETC has two offices in Japan; the one in Shiga focuses on management of freshwater lakes and reservoirs, and their basins; the one in Osaka focuses on environmental issues related to big cities. Technology transfer at IETC will initially involve:

- provision of information and data, consisting of the development and supply of databases, development of a database for project findings, and promotion of library services;
- training courses for promoting capabilities in lake and reservoir monitoring, assessment and management;
- research and consulting services, consisting of the promotion of use of GIS and remote sensing technologies for lake and reservoir basin monitoring and management; and
- the promotion of public awareness through the production of printed materials, and assistance with project identification and NGO activities.



The Shiga office of the UNEP International Environmental Technology Centre dedicated to technology transfer for freshwater management.

contribute important lessons for lake and reservoir conservation in others. Assessment and monitoring, reserve selection and management, training methodologies, and cooperative management of international freshwater resources are but a few of the specific areas where transfer of experience and technology should be explored.

The UNEP International Environmental Technology Centre (see box) exists specifically to facilitate this kind of technology transfer.

Ecotechnology

The pollution of lakes is a complex problem and can rarely be solved by the use of a single method. Ecotechnology—also named ecological engineering—has emerged as an alternative technological

Appropriate technologies from Japan and China

In Japan, a unique system of separate collection, treatment and recycling of night soil (human excrement) has been in operation for centuries. It is highly effective and much cheaper than expensive sewerage systems. However, cultural differences may prevent this simple technology from being adopted in other countries.

In China, the Tai-hu Lake, the third largest freshwater lake in China, is faced with two serious and difficult requirements: to increase both aquatic productivity and water quality to meet the needs of the growing population of the basin. A new form of aquatic agriculture has been developed to optimize use of the lake's food chain. This involves integrating fish and plant cultures. Selected submerged plants are grown in the area surrounding fish pens, and are used as food for the fish. The areas for plant and fish culture can be changed from year to year for water quality conservation, and because nutrient-rich sediments under the fish pen serve as fertilizers for aquatic plants. Aquatic plants also help wave action, improve water quality by absorbing nutrients and increase dissolved oxygen in the water. The annual fish productivity of 22–30 tonnes/hectare is economically viable.

approach during the past decade, due to the failure of conventional environmental technology. Ecotechnology exploits the self-purification capabilities of lakes and their immediate environment—for example, wetlands can be used to purify polluted water and forests to stabilize erosion and an erratic water regime. Ecotechnology offers a wide spectrum of possibilities, but it must be used hand-in-hand with environmental technology to achieve the best possible result. This approach can be used to deal with non-point sources of pollution or to return degraded lakes to their natural balance.

Appropriate technologies

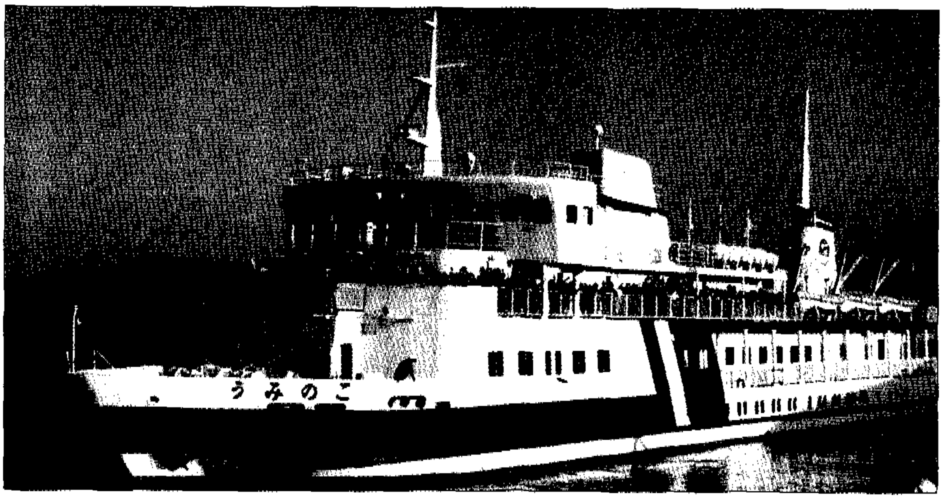
While technology transfer is generally thought of as having a North-South focus, much more needs to be done to improve international communication between all scientists and managers in both the northern and southern sectors. The opportunities to apply this knowledge more widely also need to be enhanced. For example, lake management experiences in China may be applicable to other developing countries. The Hungarian experience of using wetlands for nutrient retention in place of costly treatment plants may benefit countries with large areas of cheap land. However, some measures that are effective for one lake may not be applicable to others. Technologies should be selected carefully according to the economic, technical and cultural conditions of the area concerned.

Publicizing the benefits of lakes

While many people benefit from lakes and reservoirs, few appreciate their real value. Unless this is changed, and people are made aware of the actions needed to maintain these benefits, preventive and remedial measures may not be taken. As no two lakes share the same natural and socio-economic circumstances, the prescriptions for sustainable lake use also differ for each lake. The exchange of information about successes and failures in lake management are therefore of great importance. Information transfer needs to be promoted at all levels of society: among young people, their teachers, the general public, users of local lake resources and decision makers. Publications, training courses, conferences and improved education in schools are all greatly needed if the world's lakes are to be better managed and, hence, better used.

The floating school on Lake Biwa

Since 1983 the Shiga Prefectural Government in Japan has been offering an overnight school for 5th grade elementary school pupils at Lake Biwa on a study boat called *Uminoko*. The programme provides pupils with an experience that can rarely be obtained in the classroom. The course includes microscopic observation of plankton, measurement of lake water transparency, lakeshore clean-up activities and rowing practice on one of *Uminoko*'s boats. It fosters social adaptability and appreciation of the home province, and provides the excitement of spending a night on a boat with school classmates. *Uminoko* offers 100 cruises a year and, by 1993, 185 000 children had participated in the programme.



Shiga Prefectural Educational Board

The floating school study boat Uminoko.

Teacher training in natural laboratories

In 1986 the University of São Paulo in Brazil started to train school teachers to reinforce their understanding of sustainable watershed management and to exploit the possibilities of using local watersheds as a natural laboratory. During a 10-day field and laboratory course, groups of 20–25 school teachers were trained in recognizing sub-systems (watershed rivers, reservoirs, wetlands, gallery forests, impacts from activities such as mining and deforestation) and human uses of the watershed. The teachers were taught to develop their own observations on the state of their local watersheds. A second project started in 1991. It trains school teachers to measure water quality and to relate this to watershed uses. A specially designed 'water quality kit' for making the appropriate measurements was distributed to schools in 20 towns of São Paulo State. The continuous observation and experimentation that will result from use of these kits will be useful in analysing the evolution of water quality in the watershed.

J. G. Tundisi

Training of Brazilian school teachers in a natural wetland laboratory.

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