

Chapter 3. Human Use of Lakes

Values, Problems, and Responses

The Development and Management of a Lake

The Story of a Lake

People settled around the lakeshore many millennia ago. While the population was low, the Lake's resources were abundant, and there was little conflict between different settlements over use of these resources. The fish caught by one community did not seriously impair the ability of another community to obtain fish; the water drawn for domestic use did not noticeably lower the lake level. But, as the lake's population increased, some of these resources came under pressure. This happened first with the fish. Following some years of low rainfall, fish catches began to decline and those fish that were caught were smaller than before. The more experienced fishermen realized that this was because the wetlands were not being flooded and the fish could not breed successfully. Conflicts started to break out between different communities about access to the best fishing grounds. Fortunately, the rains returned before these conflicts became unmanageable, the breeding grounds became available, and the fish populations recovered.

Nevertheless, the incident caused the leaders of the fishing communities to agree on some rules of access to fishing grounds that would reduce tensions. Each community had the right to send only a specific number of boats to these areas. It was agreed that the wetlands were off limits during the period when they were flooded and the fish were spawning. Any transgressors would be judged by an assembly of the leaders of the lakeshore communities, with those found guilty being banned from fishing and even expelled from their community.

A more difficult problem arose many years later with the influx of a group of farming families into the catchment feeding into the lake. As they prospered and grew, these families cleared increasing areas of land. The land began to erode during the wet season and the wetlands at the entrance to the lake began to silt up. Again, fish breeding was interrupted and fish numbers began to decline. However, the farmers did not accept the claims of the fishing communities that they were causing the siltation of the wetlands. They believed that the rivers were always silty during the wet season and that the decline in fish catch had nothing to do with them. Although this caused bad blood between the farmers and fisherfolk, it did not lead to violence because other fish breeding grounds were still operating and the fisherfolk were able to compensate by moving further offshore, and building fish traps and fish ponds. Nevertheless, a distance developed between the two groups that was never bridged, and to a large extent they led separate lives.

Over time, the lakeshore communities expanded into towns. The town people, while not relying directly on fishing for their incomes, continued to identify with the lake. They were proud of its scenery, enjoyed its waters for recreation, and used it for easy transport of their goods to other destinations. They also used it to dispose of their wastes. Rubbish was dumped in creeks to be eventually flushed into the lake. To keep up with the amenity offered by other towns throughout the country, the local council installed sewage removal and primary treatment of the effluent to remove the worst of the organic matter. The resulting effluent was then disposed of in the lake at a convenient distance from the town.

A major expansion of the region occurred many years later when the national government decided to develop a large irrigated cotton growing area upstream of the lake to take advantage of increasing international demand for cotton. The development was widely welcomed by the region's business interests (they had lobbied strongly for it), and the town councils were briefed on the plan and endorsed it. Of course, the land had to be expropriated from the farmers who had settled there many generations earlier but, in compliance with national laws, the government intended to provide them with alternative agricultural land some days travel away. Many of the town people and the fisherfolk were uneasy about this development, but had no means of finding out much about it, let alone influencing it. They felt little solidarity with the farming communities and actually felt quite relieved when the irrigation area went ahead. New, wealthier farmers appeared and the old groups were moved away.

At first the new irrigation area appeared to cause no problem. The region prospered with the additional income and the towns grew rapidly to provide necessary services. A government agriculture office was opened in the major

town and many new people arrived to take advantage of the employment opportunities in the irrigation area.

After some decades, problems started to appear in the lake. Dense mats of weeds began to grow around the mouths of the town creeks and spread into the boat harbors. Waterweeds even began to appear near the fish pens. Since the region had long ceased to be dependent on the fishing industry, this was seen more as a nuisance than a major problem by many people. In fact, some entrepreneurial women harvested the weeds to use for weaving. More alarmingly to most people, the water near the towns quite quickly and unexpectedly turned dirty and had a musty smell. Many of the townspeople, particularly the older residents who remembered the beauty of the lake when they were younger, were seriously upset and complained to the town council. The fishermen were also worried, but for a different reason. They had trouble launching their boats through the weeds and they had trouble selling their fish because of the widespread perception that the fish were dirty and tasted bad.

There was a strong local opinion that the problem was caused by the upstream irrigators although the government officials in the agricultural office claimed that it had nothing to do with their industry and that the problem resulted from the expansion of the towns. Under pressure, the government promised to upgrade the sewage treatment plant for the town to remove nutrients from the sewage, since this could be completed within three years. They also promised to launch a scientific investigation into the causes of the problem.

Commentary

This story, while only a microcosm of all that can occur in lakes, illustrates many important features of lakes and their management. It shows that:

- At the broadest level, lakes provide a variety of uses or values to people and these values change over time, from initial subsistence values to later aesthetic and cultural values.
- There are potential limitations on the use of these resources as the demand for them increases-this can appear as simple overexploitation of fish, or as a more subtle overuse of the lake's capacity to absorb wastes.
- Competition for these resources intensifies and authorities-sometimes local leadership groups, sometimes more distant governments-intervene to resolve conflicts.
- Rules of behavior are discussed and agreed, and structures (councils, government departments) are established to administer and apply these rules.
- Uncertainty is central to management; unpredictable natural variations in rainfall can cause problems; some conflicts are not neatly resolved; there are different views about the causes of eutrophication.
- Knowledge, both local experience (e.g. the importance of fish breeding areas) and scientific knowledge can play a central role in making management more effective.
- Lakes are not worlds unto themselves. For some problems, as illustrated by the siltation problem, it is difficult to manage lakes without involving groups from the upstream catchments.

- Developments outside the region can affect decisions within the region, as illustrated by the impact of international markets on development of the irrigation area.
- The choices that a decisionmaker faces are heavily constrained by other developments-the town's sewage treatment system was originally introduced for aesthetic and sanitary reasons, and subsequent actions to reduce nutrient loading to the lake had to take account of the existence of this nutrient point source.
- Finally, to maximize overall benefits, it is important to take a coordinated, planned approach.

This story is also shown in diagram form in Figure 3.1. The upper part of the figure shows the change in values supplied by the lake and its catchment over time. During the expansion phase, there is a steady increase in values as an increasing number of resources are used-such as fish, water supply, transport, aesthetic enjoyment, and recreation.

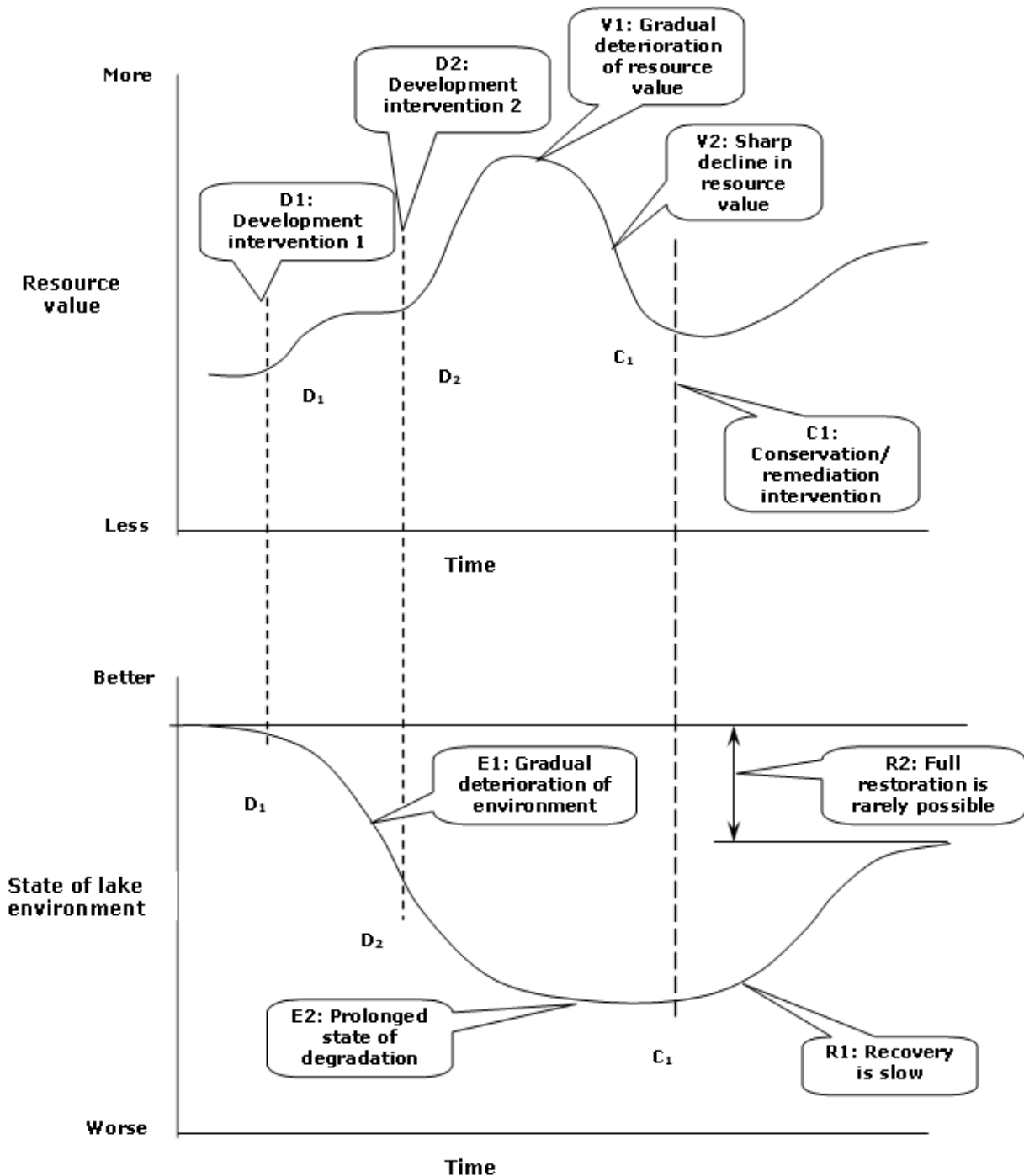
Two development interventions, the introduction of improved fishing techniques (D1) and the introduction of irrigated agriculture (D2), led to significant increases in the values extracted from the lake basin. At the same time (lower part of the figure), there was a gradual deterioration in the state of the lake from the side effects of these and other developments. At some point (V1), this deterioration in the lake's environment-increasing nutrient levels, the spread of weeds and algae, unsightly and smelly water-began to affect the value of the resources that were extracted from the lake. Overall production plateaus, and then begins to decline (V2). Remedial actions (C1)-such as upgrading of the sewage treatment plant and the ban on use of phosphate-based detergents-led to improvements in water quality and the values extracted from the lake increased again. While there are cases in which the degradation of a lake environment is small and the response to the restoration efforts is rapid, most often, the degradation may turn out to be more extensive than expected and the restoration efforts may prove to be extremely costly and

time-consuming (R1), if not impossible (R2). Management authorities and communities often do not have the resources to invest in conservation/remediation interventions (either structural or non-structural) to the point where the lake returns to pristine conditions. Nevertheless, at the end of the story, the communities may be better off than they were at the beginning.

While the above story illustrates many important features of lakes and their management, each lake possesses unique

features, as is shown in the 28 LBMI lake briefs. Each lake has its own set of resources values, its own set of problems, and its own set of potential management actions. In the above story, the government accepted that the town sewage was the most likely cause of the algae and aquatic weeds and agreed to invest in remedial upgrade works because of the high value the townspeople placed on a clean and enjoyable lake. In other towns, it is possible that the townspeople would not have the same pride in their lake and would rather see the funds spent on further development

Figure 3.1. Changing resource value through development and conservation/remediation interventions.



investments. Such judgments depend on the values that people place on the resources of each lake, the physical characteristics of each lake that lead to biophysical manifestations of problems, and the sociopolitical characteristics of the decision processes for each lake.

The management policy, regardless of scale, reflects the management needs of the resource values of the lake and its basin. The need to manage a lake and its basin became a societal issue gradually over a period of decades, if not centuries. Different needs—such as improving the local fishery resource base, increasing irrigation outputs, resolving agriculture-fishery disputes, reducing land-based pollution of the lake, conserving biodiversity, combating floods and droughts—arise over the course of time, with the management approach gradually becoming more involved. For management to be purposeful, the management policy has to be made clear at the appropriate level of social decision-making—be it a simple, small-scale approach, as in the case of management of community fisheries in a small village, or the involved and sophisticated level in the case of management of lake water in its entirety within the context of national water policy reform. If it is management of a local fishery, then the one responsible for the village fishery has to set a policy direction. If it is management of irrigation water, then the Minister of Agriculture representing the irrigation-water-user association, in consultation with other relevant national government ministries representing the respective water use categories (such as industrial and domestic waters, as well as environmental flow) will have to set the national policy that would be consistent with the context under which the water of this particular lake needs to be managed.

Resource Value of Lakes and Lake Basins

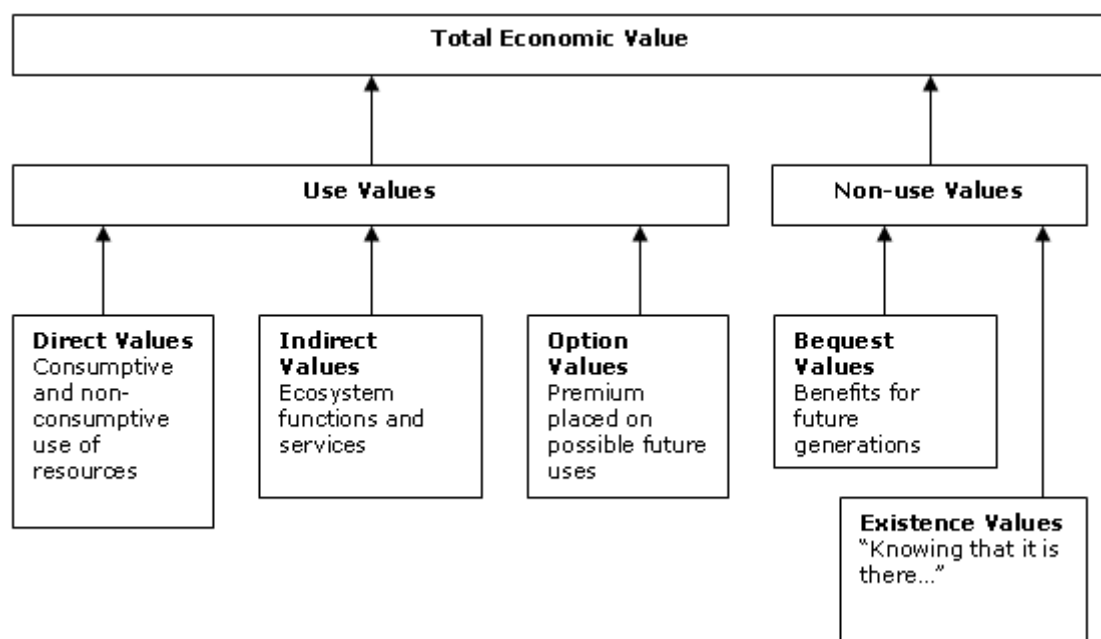
The wide range of uses of lakes and their catchments are amply shown in the 28 lake briefs. These various uses all contribute to the total value of the lake. Among the uses cited are the following:

- “...direct use of the lake for fisheries in net present value terms ... is then some PhP30.5 million” (Laguna de Bay).
- “...a potential source of water supply for Northeastern Estonia and the Estonian capital Tallinn” (Lake Peipsi).
- “...provides water supply for domestic (in the dry years), and industrial and agricultural uses” (Lake Dianchi).
- “...biodiversity offers a resource base for tourism attraction” (Lake Baringo).

Many lakes also provide valuable services to nature, such as serving as habitats for aquatic fauna and flora. These services are also part of the total value of lakes and their basins. One such service is the provision of genetic materials, which (for example) could be used to improve fish strains used in aquaculture. Another such service is as regulator of extreme hydrologic events such as floods and droughts. For additional study, [Niren](#) explores the value of ecosystem services provided by lakes.

Economists categorize the value of lake water and the resources in the lake-basin ecosystem into “use” and “non-use” values. Use values are the benefits that people receive with actual use of the goods and services provided by the lake and its environments, such as lake water, lakeshore,

Figure 3.2. Categories of Uses of Lake Resources



and biological resources. Non-use values are values that people receive but without any use-direct or indirect-of the lake or its environments. These non-use values include the benefit people receive from knowing that the lakes are there and are healthy, and the value associated with leaving an intact and healthy resource for future generations.

Use values are divided into direct use and indirect use values. Direct use values are those that come directly from using various parts of the lake ecosystem. These include both “consumptive” uses and “non-consumptive” uses. Consumptive uses are those that occur when the user actually consumes the resource, such as catching fish or waterfowl, harvesting of reeds and other plants, or diverting water for human use or irrigation. This categorization of types of values from lakes is shown in Figure 3.2. An interesting example of valuation done in India at the Bhoj Wetland can be found in [Verma](#).

Lake fishermen in the story were engaging in a consumptive, direct use of the lake’s resources. A key point about consumptive uses is that use by one person reduces the amount available for others to use, called ‘rivalry’ (see Box 3.1 for further discussion). In contrast, non-consumptive direct uses do not reduce the amount of the resource available to others. Non-consumptive uses include certain types of recreation, aesthetic and amenity values, or general ecosystem services. The later residents of the town who enjoyed the aesthetics of the lake were engaged in non-consumptive, direct use of the lake resource. Boating and sailing are also non-consumptive, direct uses. In these cases, the “users” do not actually consume the resource, or reduce the availability of the resource for other users.

Of course, in the extreme, you can have so many people using the lake in a non-consumptive, direct use manner that congestion sets in and crowding can reduce the “benefit” that each user receives. Congestion can be observed within

Box 3.1. Some “common” terms and their meaning: common-pool resources, common property, and the commons.

The “tragedy of the commons” was an idea made popular by a 1968 article in *Science* by Garrett Hardin. This article captured the spirit of the times and has gone on to trigger a massive research effort on environmental management. The problem is that the term “commons” used by Hardin was misleading because it is often assumed to refer to common property; however, Hardin’s main point was that open access to resources usually leads to overexploitation, something shown clearly in the lake briefs. To avoid confusion, we define below some terms used here.

Common-pool resources are resources for which one person’s use takes away from another’s use and for which it is hard to exclude other users. The table below compares common-pool resources against other types of resource by examining two characteristics: rivalry and excludability. Rivalry (also sometimes called subtractability) means that one person’s use of a resource subtracts from the amount available to other users; for example, someone catching fish reduces the amount someone else can catch—at least over the short term. For non-rival goods, one person’s use does not affect another’s; that is, everyone can enjoy the climate-moderating or aesthetic benefits derived from a lake. Excludability refers to the cost of controlling someone’s access to a resource. Non-excludable goods have a positive cost for restricting access.

	Excludable	Non-excludable
Rival	Private good	Common pool resource
Non-rival	Club good	Public good

Many of the resources provided by lakes are common pool; good examples are fishing, water extraction, and the use of the lake as a sink for pollutants. Some uses like flood control are public goods. For almost all uses, it is costly (but socially desirable) to exclude users.

Access to a given resource of a lake can either be open (open access) or closed (private, common, or government property). **Common property** is a type of institution that gives the rights of use of a resource to a defined group. That group usually has rules specifying how the group’s members can use the resource. Lake Naivasha is an excellent case of a riparian group (Lake Naivasha Riparian Association) using the lake as common property. Private property and government (public) property are also widespread ways that societies have developed to control access to “open access” resources.

The stand-alone term “**commons**” is often used as shorthand for either common-pool resources or for common property, often leading to confusion about what is being discussed—the nature of the resource, or the type of property regime governing its use? Some may think of the “commons” as a shared, public resource, often with no control over access.

Overall, it is important to clearly distinguish between the characteristics of a resource and the characteristics of the management regime governing use of the resource. A lake may provide various resources, each with different characteristics, but many sharing a common-pool or public good nature. Therefore, it is misleading to speak of a lake, as a whole, as a common-pool resource: it is clearer to specify which use of the lake is being referred to.

a particular use sector or among sectors. An example of the former would be when lake-based recreation becomes so crowded that all the recreators experience decreased enjoyment. An example of the latter would be when expansion of the water intake structures to service the town's water supply started to interfere with the fish cages. In general, direct uses of the resources in the lakes and their basin are both easier to identify and easier to measure, both qualitatively and quantitatively, than other parts of lake values.

Indirect use values are also often important and include most services provided by healthy ecosystems, such as maintaining water quantity or quality, moderating flooding, and providing a sink for effluents. Indirect use merely means that the beneficiary is located somewhere else (usually downstream) and receives a benefit from the lake ecosystem. For example, downstream populations will benefit from these ecosystem services provided by the lake, and will enjoy them as direct use values (again, they may be either consumptive or non-consumptive). In Japan, for example, one important benefit from Lake Biwa being maintained as a sound ecosystem with good water quality is the indirect use value accruing to the people living downstream of the lake in Osaka and Kyoto. Similarly, in Lake Toba, an indirect beneficiary of the lake water includes various industrial facilities, including an aluminum smelting plant that was dependent on cheap hydropower produced by the Asahan River hydroelectric plant. Indirect use values are often harder to measure and value than the more easily observed direct use values.

Obviously, the line between direct and indirect use values gets blurred in many cases-lakeshore communities that extract lake water as a source of drinking or municipal water should probably be labeled as "direct" users of the lake and its resources, even if the consumers receive their water in a pipe and do not know where it comes from.

The two types of non-use value referred to above-that the lakes are there and are healthy, and that the lake environments ought to be kept intact and healthy for future generations-are respectively called "existence values" and "bequest values."

An additional category of value is referred to as option value-the benefit that people receive from knowing that the resource will be there in case they want to use it in the future. This is a hybrid between use and non-use values and is usually listed under use values as a form of "deferred use." Use values are often reflected to a greater or lesser extent in prices-such as payment for water supply or in fish prices. However, the two types of non-use values (bequest values and existence values), as well as option value, are rarely reflected in market prices simply because they are not traded in markets. The consequence is that they are commonly overlooked by decisionmakers. However, they may be very important to the people concerned, and are therefore valid components of the total value of the lake.

It is also important to note that, in general, lake values are often overlooked by decisionmakers for two major reasons: lack of information and institutional weaknesses. Because of the pervasive nature of externalities (see Box 3.2), many benefits from improved lake management affect someone else, often at some distance. Actions in the upper basin affect both the quantity and quality of water that drains into the lake, and actions along the lakeshore and in the lake affect the water that leaves the lake, and the ecology of the lake. For smaller lakes, it may be easier to actually see the links (as in Lakes Dianchi or Toba, for example), while for very large or international lakes it is harder to understand all of the actions that affect the lake resource (and are in turn affected by the lake's water quality).

The second constraint to recognizing lake benefits is an institutional one-government ministries and agencies are held responsible for and are rewarded for the actions that they take that affect their differing resources. The Fisheries Department is accountable to the fishermen and fish catch, even if fishing activities ultimately affect the welfare of downstream water consumers and agriculture users. Since these groups fall "outside" the area of responsibility of the Fisheries Department, benefits and costs that occur elsewhere are largely ignored. A similar case exists with agricultural authorities in the upper watershed. Lake basin management authorities are designed to overcome these two problems but, even if they have a broader knowledge of the resource, they usually lack any effective management authority at the sectoral level. Therefore the institutional management challenges remain (and are discussed in Chapter 4).

Typical Problems Facing the World's Lakes

Problems can be defined as the impediments to obtaining desired values from lake resources. Ironically, problems often arise from the side effects of the use of lake resources. The proximate causes of these problems can arise from both the direct exploitation of lake resources as well as from human activities taking place within and outside of the lake basins that have little to do with the direct use of the lake resources. Thus, the farmers who settled in the catchment above the lake caused problems for the fishermen, even though they (the farmers) were not using lake resources directly. This type of problem would be classified as an externality since the farmers received the benefits from soil cultivation and the downstream fishermen bore the costs. Externalities are particularly important for lakes and are expanded on later in this chapter. Downstream users also can cause problems for users of lake resources. For example, downstream irrigation schemes can place demands on water from the lake that restrict developments around the lake. Root causes of these problems include increased population and the increased capacity of people to affect the world they live in, through, for example, industrialization.

The lake briefs show that lakes around the world experience diverse problems. From a biophysical perspective, these can be categorized as water quantity, water quality, and ecological problems. Water quantity problems arise when there is either too much or not enough water to meet human uses. Examples include flooding caused by increased runoff of cleared catchments and lake drawdown caused by excessive water withdrawals. There are numerous water quality problems ranging from sedimentation, to the presence of toxic substances, to excess quantities of nutrients. Ecological problems arise because lakes, among their other functions, provide habitats that support various biological organisms and communities, which are the basis of many of the ecological services that people depend on lakes for. Note that under the above definition a change in water quantity, quality, or ecology is not a problem unless it represents a loss of value to someone.

Problems with lakes have been documented in a number of earlier reports, including the *Survey of the State of the World's Lakes*, which was compiled in the late 1980s and early 1990s by ILEC and UNEP. Based on this work, former Tatuo

Kira (former chairman of the ILEC Scientific Committee) concluded that lakes face a number of widespread and continuing problems, including eutrophication, acidification, toxic contamination, water level changes, salinization, siltation, and the introduction of exotic species. These and other problems continue to be identified in the lake briefs commissioned for the LBMI project (Table 3.1). A full list of problems for each lake can be found in Appendix A. The table identifies the primary causes and their effects on lake uses and values, and identifies lakes in this project exhibiting these problems.

These problems are not unique to lakes—they occur in most waterbodies. However, the special characteristics of lakes, described in the previous chapter, influence the way in which the problems are manifest in lakes.

The relatively long retention time of lakes means that many problems can take a long time to become apparent. This is particularly true where the problem arises because of long-term change to some component of the lake that is not visible. For example, toxic contaminants can build up

Table 3.1. Some typical problems facing the world's lakes

Problem	Cause	Impacts on lake values	Example from this study
<i>Biodiversity loss</i>	Many kinds of human impacts, including most on this list	Loss of ecosystem function; loss of option value for future use	Lake Victoria
<i>Climate variability</i>	Natural and anthropogenic causes	Changes in hydrological balances of lakes	Lake Chad
<i>Eutrophication</i>	Excessive nutrient input	Algal blooms, excessive macrophyte growths, loss of water transparency, taste and odor compounds, algal toxins	Lake Dianchi; Mendiando
<i>Exotic species</i>	Natural, intentional, or unintentional introduction	Food web changes, loss of biodiversity	Laurentian Great Lakes (zebra mussel)
<i>Overfishing</i>	Unsustainable exploitation of fish for sustenance and commercial purposes	Decreased fish catches, loss of biodiversity	Lake Malawi
<i>Pathogens</i>	Fecal contamination from domestic and livestock sources	Waterborne diseases	Lake Ohrid
<i>Salinization</i>	Diversion of inflow, discharge of saline waters from irrigated lands, runoff of salts from deforested land	Ecosystem degradation, loss of freshwater supply	Aral Sea
<i>Siltation</i>	Soil erosion from cultivation and deforestation	Decrease in lake volume and flood control capacity, destruction of aquatic habitats	Lake Baringo
<i>Structural impacts</i>	Lakeshore development (e.g., embankments, weirs, roads)	Destruction of littoral communities in lake	Lake Biwa
<i>Toxic contamination</i>	Industrial effluents agricultural and urban runoff, atmospheric deposition	Toxicity to fish and disruption of endocrine system, bioaccumulation in fish increases risk to humans and other predators	Laurentian Great Lakes (DDT and PCB contamination)
<i>Water level decline</i>	Diversion of inflow, over-withdrawal of water	Secondary salinization, ecosystem degradation	Lake Naivasha

in the sediments over many years before they cause a problem by entering the food chain. Similarly, alterations to the lower levels of the lake's food chain (caused by sediments in the water, which change the light regime) may not be immediately apparent to the users of the lake. By the same token, these problems can take a long time to correct in lakes, a point discussed in the next section on management responses.

The complexity of lake dynamics also influences the way in which problems become apparent. This is readily seen in the case of eutrophication, where a steady buildup of nutrients can apparently cause little problem in lakes until a critical point is reached. At that critical point, the lake can abruptly switch into a different state with reduced use and non-use values. In the case of Lake Victoria, nutrients had been building up in the lake water and sediments for decades without apparent effects until the early 1990s when, quite suddenly, the basis of the lake's ecosystem shifted. Cyanobacteria dominated the base of the food chain, much of the lake became turbid, and blooms of potentially toxic cyanobacteria became common in the nearshore areas of the lake. It is known, from experience in other lakes, that it is very difficult (if not impossible) to shift such a lake back to its previous state (see Figure 2.1 on hysteresis in Chapter 2).

The integrating nature of lakes simply means that problems can seldom be localized with lakes. The fluidity and mixing of the water ensures that physical, chemical, and ecological problems become apparent, to some degree, throughout

the whole lake and downstream waters. Floods affect all of the lake's shoreline; pollution spreads beyond its source to affect much of the lake; and biological problems, such as introduced species, can spread throughout the lake. However, there are often limits on the extent to which problems can spread throughout the lake. Deep lakes are often stratified and the bottom waters do not readily mix with the top waters, and large lakes are not completely uniform across their surfaces.

Response to the Problems: Management Interventions

The story at the beginning of this chapter illustrates that there are two types of management interventions in lake management, one for development of lake resource values and the other for conservation/remediation of the same. As shown in Figure 3.1, the cumulative impacts of development interventions often necessitate introduction of conservation/remediation interventions. Intervention measures in either case can be structural, such as construction of a water intake structure or sewerage system, or non-structural, such as the introduction of new fishing technology or a new regulatory provision for the control of effluent discharge. For now, we confine ourselves to management interventions for conservation/remediation (C/R interventions) of resource values.

The story told here-how conservation/remediation interventions are carried out-is the story of how lake uses are governed by society. "Governing" is defined as "controlling, influencing, regulating, or determining...the course or

Box 3.2. Externalities and the Integrating Nature of Lakes

The integrating nature of lakes means that externalities are a particularly important source of problems in lake management. Externalities occur when the action of one individual (or group) affects the welfare of another individual (or group) and the latter group is not effectively consulted (or compensated) during decisionmaking. In the case of lakes, the flow of water from the catchment to the lake readily transmits problems from upstream to downstream (as in the example of the farmers and the fishermen); the integrating nature of the lake means that many people around the lake can be affected by the actions of a few.

Externalities are commonplace in the lake briefs. Upstream forest clearance results in increased sedimentation in Lake Baringo. The introduction of water hyacinth in Lake Victoria hinders lake transportation and fishing. Tonle Sap water levels are affected by changes in the Mekong River annual flows, and some of these changes have their origin in China or Laos. These externalities are all transmitted by the fluidity of water: many are local, but some are international.

Externalities are usually thought of as negative and so cause problems. However, they can also be positive. For example, reforestation in the upper watershed around Lake Sevan has improved water quantity and quality in the lake over time. In all cases where externalities exist, however, there is a "break" between the person taking the action and the people where the impact is felt. And since there is no link, normal market signals (that is, prices) do not reflect these links and their impact.

Problems caused by externalities can be overcome by "internalizing the externalities"-that is, by including benefits and costs, wherever they occur (this speaks to correctly defining the boundary of the analysis) and whomever they affect (a social welfare perspective). This is easier said than done. With sufficient foresight and recognition of the issues, however, it is possible to do such an analysis and thereby make better decisions about management alternatives. In addition, even if some of these impacts cannot be formally valued in economic terms, just recognizing them and including them qualitatively in the analysis is an important first step.

The basic concepts of environmental economics are further described by [Kondo](#).

issue of events.” The sort of governing acts common in the 28 lake briefs include:

- Forming organizations that provide continuity of lake management, including development of plans, representation of the goals of different groups, implementation and management of structural investments, and enforcement of decisions (Chapter 4)
- Developing rules, including regulatory powers as well as financial incentives, about sharing the lake basin’s resources and limiting externalities for other users (Chapter 5)
- Changing people’s values, so that the net benefits gained from the use of a lake basin’s resources are maximized (Chapter 6)
- Engaging people in management through devolution of responsibilities (Chapter 6)
- Introducing technological measures to reduce or ameliorate adverse impacts (Chapter 7).

Just as the characteristics of lakes have an effect on the way in which problems occur, they also have an influence on how to manage those problems. The long retention time of lakes-particularly for larger and deeper lakes-necessitates that their management be anticipatory, committed, and well-planned over the long term. For lake management to be successful, there must be (a) a good understanding of the lake’s physical, chemical, and biological processes; (b) long-term goals supported from the highest political level to the local communities; and (c) carefully developed long-term plans. The instruments of management-institutions,

people, laws, rules and regulations, finances for operations, investments in infrastructure, knowledge for efficient interventions-all need to be established and supported for the long term. At the same time, they must be flexible enough to adapt to changing values and new knowledge. In fact, the long timescales involved in lake management argue for the existence of institutions in order to give permanence to management beyond the shorter timescales of individuals. One other implication is the need for secure financing to make sure that structural and non-structural interventions are effective over the long term.

The complex dynamics of lakes also argues for drawing on the best available scientific knowledge and, if necessary, mounting research programs to obtain additional knowledge that is critical to management. However, it is important to have a proper conceptual model of these dynamics worked out in advance in order to make sure that the research is truly focused on the critical needs for management.

Finally, the integrating nature of lakes-and the consequent difficulty of excluding users from accessing many of the lake’s resources-has many management implications. Common-pool resources (see Box 3.1), such as the fish in the lake, can be overexploited since there is no incentive for individual users to limit their use of these resources. Rules are usually introduced, once the resource shows signs of overharvesting, to ensure that these common pool resources are shared equitably. Rules may also need to be introduced to protect public goods, the other category of non-excludable lake uses. Examples of such public goods include the visual amenity of the lake and flood protection from levy banks. Unlike common-pool resources, these rules are not needed to allocate the goods among competing

Box 3.3. Equity

Equity considerations-that is, who benefits and who loses (and how much) from any action-are important in managing a lake ecosystem. The distribution of costs and benefits is important for ethical reasons, as well as being an important factor in designing effective policies and management plans. There are two dimensions to equity-distributional concerns (the people dimension) and effective policy design. Formal government institutions are more likely to address the concerns of those people who are both “mainstream” and more powerful economically. Consequently, decisionmakers need to be particularly aware of the needs and role of the poorer and more politically marginal groups. These same groups may also belong to minority populations. Fishermen, who are often politically weak and marginalized, illustrate the second dimension. A sustainable fishing industry can promote an ecologically sustainable lake for the benefit of other groups.

The ideas of “internalizing externalities” and “maximizing social welfare” carry the implicit assumption that economic transfers are actually made and that those who are disadvantaged by some action are compensated. Obviously this is not always the case. Therefore, even when the “socially preferred” management option is identified and implemented, it is important to make sure that the required transfers and compensation actually take place. Equity concerns are among the most difficult issues any natural resource decisionmaker has to address, and lakes are no exception!

Equity is not the same as equality. Equality implies that ALL stakeholders are equal with respect to income or resources. This is almost never the case anywhere in the world. Equity, on the other hand, is a measure of “fairness” and implicitly implies that those who are poorer/worse off are not disproportionately affected by any change. The Lake Kariba brief describes the way in which the Tonga people were displaced and made worse off by the construction of a large reservoir, while the benefits were reaped by powerful sections of a colonial society. In fact, an equity objective for lake management may mean that management actions disproportionately benefit the poorest members of society (even if there is a “cost” in terms of conventional economic measures of benefits and costs).

users (by definition the use by one person does not affect another person's use). Instead, the rules may be needed to protect the quality of the good. For example, prohibitions may need to be introduced on dumping rubbish to protect the visual amenity of the lake, or rules may be needed to ensure that all beneficiaries from flood protection contribute toward the costs.

The integrating nature of water also means that, for many problems, the lowest effective level of management (the principle of subsidiary) is the lake and its catchment. Managing the water resource at this level can help internalize the externalities that arise from the integrating nature. Of course, having a management structure that is responsible for the whole of a lake basin is no guarantee that these externalities will be managed—that will depend on factors such as the sense of community and financial transfers. This does not necessarily imply that a monolithic lake basin management authority is the best institution for management. Rather, it argues for management coordination across the area of the basin and, often, coordination across the different sectors that use the basin's resources. Sometimes this can be most efficiently carried out by a single basin management authority, sometimes not.

From the preceding discussion, it is apparent that there are a number of aspects to managing a lake's resources to ensure that they are accessed equitably and efficiently, given the inherent characteristics of lakes and their basins. These aspects, or components, can be categorized as:

- Institutions
- Incentives and Regulations
- People (Values and Participation)
- Technology
- Information
- Finance

Institutions carry forward the mandate for managing the lake and its catchment for the benefit of all lake resource users. They are sanctioned by society to give them the necessary authority and longevity to operate effectively. They can operate at the local level (such as local councils), at the regional level (such as a lake basin authority), at the national level (such as sectoral government departments), or at the international level (such as international commissions for transboundary lakes).

Rules governing peoples' use of lake resources and impacts on lakes can be encoded in formal laws, statutes, and regulations and implemented by formal institutions. They can also be informal, often being developed and accepted among traditional groups of lake people. Rules are used to both ensure equitable allocation of lake resources and to ensure that these resources are not wasted.

The involvement of people is central to lake management. They decide the values to be obtained from the lake's

resources; they provide knowledge and experience; they form informal organizations for management; they provide support for enforcing rules; and they can be a source of the finance needed to operationalize management. Institutions don't operate in a vacuum; they require leadership from committed and visionary individuals, as shown in some of the case studies.

Technology is not always essential for management; non-technological solutions can sometimes be sufficient. However, technical responses can dramatically increase access to a lake's resources and contribute to the resolution of some types of problems. For example, embankments can significantly add to a lake's ability to buffer floods (an indirect use value), while sewage treatment plants can be very effective at removing wastes and contaminants from concentrated sources of pollution.

Information, both traditional knowledge and scientifically acquired knowledge, promotes efficient management. That is, the more that reliable and demonstrable knowledge is used in management, the more likely it is that the goals of those groups using a lake's resources will be met at minimal cost. These materials place considerable emphasis on scientific knowledge, primarily because it is obtained via a process that is open to scrutiny and leads to incremental improvements in understanding. This emphasis does not deny the value of traditional knowledge—in the introductory lake story, the experienced fishermen were well aware of the role that the intermittently flooded wetlands played in fish breeding.

Finance is the Achilles' heel of lake management in many developing countries. Policies can be well thought-out, institutions properly designed and established, rules embedded in laws, and people can be involved. But if there is no provision for long-term funding of both structural and non-structural interventions, then management is a hollow concept. In practice, this is the component that is most difficult to successfully establish.

These six components of lake management are discussed in detail the remainder of these training materials as part of the governance of lake basins. These discussions draw lessons from the case studies and other experience about the application of these components in practice.

Further Reading

1. [Kondo](#) presents some of the fundamental concepts of environmental economics that are related to lake basin management.
2. [Niren](#) examines the valuation of the “ecosystem services” provided by lakes and how these values are taken into account in the management process.
3. [Verma](#) shows how valuation was done in the case of Bhoj Wetland, India and presents lessons on how to more effectively bring valuation into the decision making process.
4. [Mendiando](#) provides a global review of lake and reservoir eutrophication and associated management challenges.