Lakes & Reservoirs: Research and Management 2006 **11**: 1–13

Lake Baringo: Addressing threatened biodiversity and livelihoods

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Abstract

Lake Baringo is a shallow, internal drainage, freshwater lake located in the Kenyan Rift Valley. The lake is an important source of water for humans and livestock, as well as a significant income source for local communities through activities such as tourism, biodiversity conservation, and fish sold in local markets. The lake has been subject to overfishing, as well as to greatly enhanced sedimentation as a result of land use changes in the drainage basin. This paper provides an overview of the conditions prevailing at Lake Baringo, and examines in detail the management response to the problems facing the lake. The roles of the many and varied institutions in the lake basin's management are discussed, and an analysis of internationally funded projects designed to ameliorate the situation is provided.

Key words

biodiversity, fishing moratorium, Global Environment Facility, Lake Baringo, lake basin management, land use change, sedimentation.

INTRODUCTION

Lake Baringo is named after the local word 'Mparingo', which means lake. It is located in the eastern Rift Valley in Kenya, being one of the seven inland drainage lakes within the Rift Valley drainage basin. The lake has a surface area of about 108 km^2 and drains a total area of 6820 km^2 (Fig. 1). It is located in the administrative district of Baringo at 1000 m a.s.l., with its basin extending to the neighbouring districts of Koibatek, Laikipia and Nakuru. Several seasonal rivers drain into the lake, including Ol Arabel, Makutan, Tangulbei, Endao and Chemeron. Perkerra and Molo are perennial rivers, although they exhibit significantly reduced water discharges during dry seasons. Lake Baringo experiences very high annual evaporation rates of 1650–2300 mm, compared to an annual rainfall of 450–900 mm. Thus, its survival depends on the inflows from rivers originating from the humid hill slopes of the drainage basin, where the annual rainfall varies between 1100 and 2700 mm.

As a freshwater body, Lake Baringo is important to the communities in its basin as a source of water for domestic use and livestock consumption. Other important uses are income generation through tourism, biodiversity conservation and fishing activities. The composition of the lake's fish species includes *Oreochromis niloticus*, *Protopterus aethiopicus*, *Clarias gariepinus*, *Barbus intermedius* and *Labeo cylindricus*. Three indigenous human communities live in the basin; namely, the Ilchamus, Pokots and Tugens. These communities earn their living through pastoralism and agro-pastoralism. As pastoralists, they maintain large numbers of cattle, which overgraze the catchment vegetation, leading to enhanced soil erosion, sedimentation in streams and the lake, and frequent flash floods. Other activities causing degradation are deforestation and conventional agricultural practices. Together with other forms of degradation, including loss of biodiversity and declines in fisheries, these activities have drawn the attention of the government, non-governmental organizations (NGOs) and other stakeholders of the need to carry out management interventions, with the aim of minimizing further degradation of the lake. Past interventions for the resource management in the lake drainage basin include:

- Baringo semi-arid project for land rehabilitation (1980–1989)
- African Land Development for grazing schemes and provision of water (1940s)

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Accepted for publication ?????? 2006.

Doi: 10.1111/j.1440-1770.2006.00309.x

L R E	3 0 9	**Operator:** Wang Jingjing	**Dispatch:** 20.10.06 / **PE:** Joyce Poh
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• Kenya Livestock Development Programme for group ranches (1960–1970)

• FAO project for fuel and fodder (1982–87)

The approaches adopted by the stakeholders for the sustainable management of the lake basin include empowering the local communities for natural resource management, diversification of agriculture, agroforestry systems, and microenterprises. Furthermore, fishing moratoria, and soil and water conservation practices, also are in place in the lake and its basin. These practices tend to reduce the degradation either by reducing pressures on certain resources, especially land, through the provision of alternative sources of income, or by effecting direct conservation measures. The institutions involved in carrying out these management activities include:

• Public institutions – Kenya Marine and Fisheries Research Institute (KMFRI); Kenya Forestry Research Institute; Baringo County Council; Ministry of Agriculture (MoA); Ministry of Water Resources and Development; Ministry of Environment and Natural Resources; Ministry of Livestock and Fisheries; and Kenya Agricultural Research Institute

• Private organizations – Block Hotels

• NGOs – World Vision; Rehabilitation of Arid Environment Trust

• Community-based organizations (CBOs) – Honey Care; Women's Groups

The past management of the lake and its basin carried out by the above-noted institutions was mainly sectoral in nature. The need for integrated management was realized from lessons learned from past projects. Thus, the involvement of UNEP and the Global Environmental Facility (GEF), through the Lake Baringo Community-Based (LBCB) Land and Water Management Project, has facilitated integrated management of the lake and its basin. In this programme, capacity-building and creation of awareness of local communities were undertaken, together with coordination and facilitation of the stakeholders, to facilitate sound management of Lake Baringo and its drainage basin.

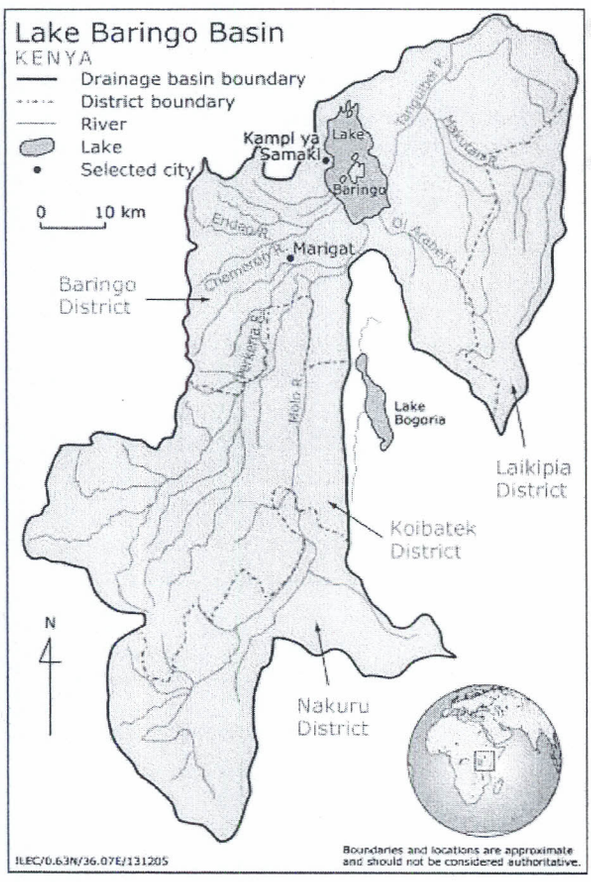

Fig. 1. The Lake Baringo drainage basin.

Background

Lake Baringo is a freshwater lake with importance to the population of its drainage basin as a source of water for domestic use and for watering livestock. It is also a source of food, especially fish, to the community. The current species composition of the lake is as follows: *O. niloticus* (80.4%), *P. aethiopicus* (7.95%), *C. gariepinus* (9.8%), *B. intermedius* (0.96%) and *L. cylindricus*. *Barbus* rarely appears in the fishermen's catches, while *Labeo* has almost disappeared from the lake since the damming of its inflowing rivers, which interfered with its breeding habits (Aloo 2002). The lake also is a source of vegetation products (e.g. *Aeshynomena elephroxylon*), which is used for boat construction, and water lily for making domestic bread (ugali). About 500 families live in Kampi ya Samaki, a centre that has grown mainly because of fishing activities in the lake. Half of the population in this centre is fishermen, with 300 being fish handlers. Others earn their living through such activities as boat construction. As a result of an overdependence on fishing, there has been a remarkable fluctuation in fish production (Fig. 2). The estimated economic value of the fishery for the year 2002 was based on experimental fishing, whereas that for 2001, the year of establishment of a fishing moratorium, was derived through interpolation of data.

Fish is a food source, and the sale of fish to nearby urban centres also generates income for the local people. Through fishing activities, the lake provides employment to the fisherfolk, and to the young tour operators who own boats. The boats are used by tourists for navigation in

the lake. The lake also is an important tourist attraction because of its rich biodiversity, which comprises hippos, birds and crocodiles, among others. Its shoreline also is used as a grazing ground for livestock, especially during dry seasons when the catchment is dry and grass is scarce. The local people also use the lake for navigation to link the eastern and the western parts of Baringo District.

Records indicate that between 1969 and 1972, the average depth of the lake was 8 m. In early 2003, before the onset of the long rains, the average depth was 1.7 m. The current average depth is 2.5 m, with the deepest end of the lake being 3.5 m. This increase in water depth was the result of the prolonged long rains during 2003, especially in the humid upper catchments. The surface area of the lake has exhibited a decreasing trend. Studies by Onyando (2002) revealed that the area of the lake was 219 km^2 in 1976, 136 km^2 in 1986, 114 km^2 in 1995, and 108 km^2 in 2001. Based on these trends, the author extrapolated the lake's surface area into the future, suggesting that the surface area will be reduced by 50% by 2025 if the current trend continues (Fig. 3).

The boundary of the drainage basin lies on the Tugen Hills to the west, the Eldama Ravine ranges to the south, and the Laikipia Plateau to the east. These hills rise as high as 2800 m above mean sea level (a.m.s.l.), while the lake is at ≈1000 m a.m.s.l. The geology of the area is mainly undifferentiated volcanic rocks, while the soils are of clay type. The landscape is characterized by steep slopes from the Tugen Hills and Eldama Ravine Highlands to the Perkerra River, grading in to gentle slopes, and finally to the floodplains of Marigat and Lake Baringo.

Although Lake Baringo is located in a semiarid zone, its catchment covers a range of climatic zones, from semiarid through semihumid and subhumid, to a small portion in the humid zone. The mean annual rainfalls in these zones are 450–900 mm (semiarid), 800–1400 mm (semihumid), 1000–1600 mm (subhumid), and 1100–2700 mm (humid). The mean annual potential evaporation amounts for these areas are 1650–2300 mm (semiarid), 1450–2200 mm (semihumid), 1300–2100 mm (subhumid), and 1200–2000 mm (humid). The risk of crop failure is 25–75% in the semiarid zone, 5–10% in the semihumid zone, 1–5% in the subhumid zone, and <1% in the humid zone. Similarly, the potential for plant growth in these zones can be classified as medium to low, high to medium, high, and very high, respectively. These figures indicate that the semiarid zone, in which Lake Baringo is located, is a fragile environment with low natural life-sustaining properties, thereby requiring urgent conservation attention.

The rainfall characteristic of the basin is bimodal, intense, and erratic. The long rains occur in the months of April to August, whereas the short rains fall from October to November. Daily rainfall monitoring in the basin dates back to 1903. Since that time, a total of 101 stations have been installed in the catchment by various organizations, including the Kenya Meteorological Department, research organizations and individuals. However, only 66 stations are currently operational. This translates into a density of 97 km^2 $gauge^{-1}$, which is less than the World Meteorological Organization's recommendation of 17 km^2 $gauge^{-1}$. Stream flow monitoring started as early as 1926, with a total of 26 river-gauging stations having been installed at different times since that time in various locations in the rivers flowing into Lake Baringo. Most of the above stations are not currently operational because of poor maintenance of the gauges. Thus, the available data contain many gaps, which are a significant drawback in managing the basin's water resources.

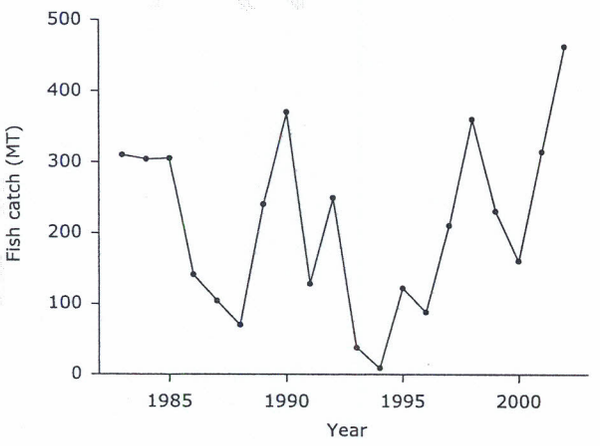

Fig. 2. Trend of fish production in Lake Baringo (comprising *Oreochromis*, *Clarias*, *Barbus*, *Protopterus* and *Labeo*)

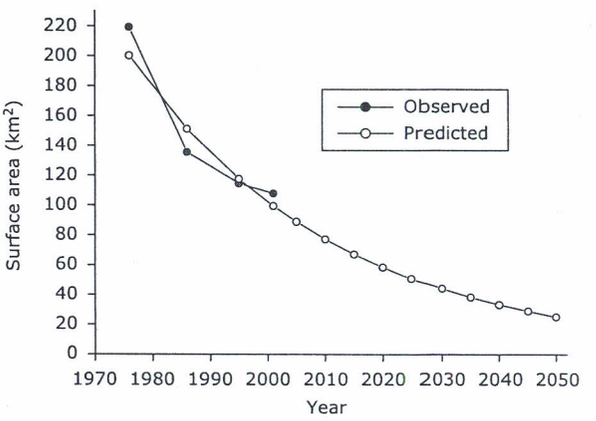

Fig. 3. Observed and predicted surface area of Lake Baringo tables.

Lake Baringo is the lifeline of the communities in its basin, especially in the vicinity of the lake. These communities include the Pokots to the north, the Tugens to the east, and the Ilchamus on the south and eastern sides. The Ilchamus form about 50% of the riparian population, being mainly pastoralists. The Ilchamus and Pokots mainly practise agro-pastoralism, with emphasis on pastoralism, while the Tugens are primarily agriculturalists. These communities are politically marginalized, especially the Ilchamus and the Pokots. Thus, their poverty level is high, and they have limited access to tap water, health facilities and other services. Livestock over-grazing is a major problem in this area, because the pastoralists are not willing to reduce the number of their herds to conform with the available food biomass. Their livestock is comprised of cattle, sheep and goats. Dry seasons are critical periods for raising livestock because the grass is rare at that time and most cattle graze along the lake-shore, thereby interfering with the lake's ecosystem. The land tenure system is group ranch, with grazing being communal. This accelerates soil erosion because the cattle graze together and are driven together from place to place in search of pasture. Another area of conflict is cattle rustling, which creates friction between communities in the basin, hence limiting the collective responsibility in managing the lake and its basin.

The streams flowing into Lake Baringo originate from humid and subhumid hill slopes, where the annual rainfall is >1000 mm. Although these hill slopes are the major recharge areas, they belong to administrative districts that, while located within the basin, are not riparian to the lake (the lake is surrounded by the Baringo District). This creates restrictions in river basin management, as the administration in every district is unique. Although some low level of interaction exists between the districts, it must be further enhanced to facilitate effective management of the basin's natural resources. The hill slopes, which are located in the water recharge areas, have undergone deforestation in the recent past, through land conversion to create more land for agriculture, and through harvesting of forest products for timber, wood fuel and charcoal. The forested areas of the catchment have decreased by ≈50% since 1976. Consequently, groundwater recharge has decreased, with streams drying up more often during the dry seasons, whereas they cause flash floods during the rainy seasons. As a result of the floods, loss of property and displacement of people have been prevalent in the lower reaches of the basin.

The benefits accruing from the lake include water for domestic and livestock use, fisheries, tourism and biodiversity. Irrigated agriculture is another major benefit derived from the water resources of Lake Baringo basin, mainly through water abstraction from the Perkerra, Endao and Chemeron Rivers. The crops grown in the irrigation schemes include, among others, maize, water melons, tomatoes, onions, pawpaws and oranges.

The Lake Baringo drainage basin is endowed with rich terrestrial and aquatic biodiversity, including natural vegetation, wildlife, birds and fisheries. There are about 400–500 different bird species (Gichuki 2000), for example, most of which reside in areas with intact woodland and grassland and rehabilitated lands. Such areas also contain a variety of plant species. Reports also indicate that there are about 40–60 hippos in the lake, while about 20 crocodiles also reside there. In addition to the lake, the biodiversity offers a resource base for tourism attraction. Through tourism activities, the area has been opened to other regions, both nationally and internationally. This has promoted business enterprises and the interchange of knowledge and technologies through interactions between the locals and foreigners. By attracting foreigners, the lake and its basin have attracted markets for local agricultural and livestock products.

Biophysical environment

Water quality conditions

The water quality of Lake Baringo has deteriorated over time. The main concern is turbidity, which has increased because of high rates of sedimentation from increased soil erosion in the catchment. The turbidity values recorded in recent analysis range between 350 and 900 NTU, which are rather high values. Related to the increased turbidity is reduced water transparency, which is <0.1 m, as measured by Secchi disc. The physiochemical analyses of the lake have been carried out in the past, with the most recent and reliable analysis done between June 2001 and May 2002 (Ballot *et al.* 2003). The parameters analysed in this latter study are shown in Table 1.

As shown in Table 1, the physical conditions of Lake Baringo are characterized by high temperature and low transparency. The pH of the lake is relatively high because of the alkaline hot spring discharge from Kokwa Island, which is located in the lake. The conductivity and salinity indicate the subsalinity of the lake (Hammer 1986), whereas the high total nitrogen (TN) and total phosphorus (TP) concentrations reflect the lake's hypereutrophic condition.

Biomass production

The turbid water of Lake Baringo is characterized by a greenish colour related to the presence of the

cyanobacterium, *Microcystis aeruginosa*, which dominates the lake's phytoplankton community. As a result of the turbid nature of the lake water, primary production in the open water is very low. Thus, the phytoplankton population is limited only to the positively buoyant species, including *M. aeruginosa*, *Melosira granulata* and *Anabaena carcinalis*. The lake's high turbidity limits light penetration into the water column, resulting in low biomass production. The recent analyses revealed the concentration of phytoplankton biomass to range between 1.5 and 8.2 mg L^{-1} (Ballot *et al.* 2003). The main phytoplankton groups in Lake Baringo are shown in Table 2.

Microcystis aeruginosa dominates in Lake Baringo, compared to the other phytoplankton, mainly because it can develop gas vacuoles in its cells, allowing it to regulate its buoyancy. This ability to control vertical location enables it to locate itself in a position in the water column where it can receive relatively more light in the turbid water of Lake Baringo. Other factors contributing to the dominance of *Microcystis* are temperature and nutrient loading. The growth rates of bloom-forming cyanobacteria such as *Microcystis* are optimal at 25°C, which falls within the temperature range measured in Lake Baringo (i.e. 23.7–26.3°C). The TP and TN concentrations of 1.0 and 2.8 mg L^{-1}, respectively, indicate high nutrient loading to the lake. The production of cyanobacteria at levels between 0.2 and 5.5 mg L^{-1}, however, is not commensurate with the lake's TP and TN concentrations. Hartebeesport Reservoir in South Africa, with similar TP and TN concentrations, for example, has *Microcystis* production levels between 20 and 50 mg L^{-1} (Zohary & Robarts 1990). This latter production level is about 10 times that of Lake Baringo, thereby illustrating the degree that high turbidity can limit lake production.

Table 1. Physiochemical conditions of Lake Baringo, June 2001–May 2002

Parameters	June 2001	November 2001	January 2002	May 2002
Water temperature (°C)	26.3	26.1	23.7	24.9
Secchi depth (m)	<0.1	<0.1	<0.1	<0.1
pH	9.0	8.8	9.1	9.1
Conductivity (mS cm^{-1})	1.66	1.39	1.51	1.67
Salinity (‰)	0.7	0.5	0.6	0.7
Total nitrogen (mg L^{-1})	8.0	1.8	1.0	0.5
Total phosphorus (mg L^{-1})	1.3	1.0	0.6	1.0

Source: Ballot *et al.* (2003).

Table 2. Mean biomass production of the main phytoplankton groups in Lake Baringo, June 2001–May 2002

Phytoplankton groups (mg L^{-1})	June 2001	November 2001	January 2002	March 2002	May 2002
Cynopyceae	5.45	1.64	0.67	0.22	2.53
Bacillariophyceae	0.26	0.19	0.04	0.46	0.03
Chlorophyceae	1.84	0.52	0.34	0.8	0.17
Euglenophyceae	0.62	0.08	0.56	0.03	0.0
Cryptophyceae	0.0	0.04	0.07	0.03	0.05
Total biomass	8.17	2.47	1.68	1.54	2.77

Source: Ballot *et al.* (2003).

Land use changes

Although industrial and urban development in the basin has gradually increased over time, agricultural development has increased rapidly, particularly in the upper reaches, where the climate is conducive for such activities. The natural forest in this region also has been exploited for timber, wood fuel and settlement. The benefits being lost as a result of deforestation include the functioning of the forest as a moisture reservoir. Forests store 100 times more water than grasslands, capture air moisture and increase the incidence of rainfall, regulate river flow and prevent flooding, reduce the sediment load in river water, and regulate rainfall patterns. In addition to these benefits, forests are a centre for biodiversity and attract tourism. The Lake Baringo drainage basin has lost >50% of its natural forest cover, decreasing from 829 km^2 in 1976 to 417 km^2 in the 2001. Thus, the same proportion of the benefits derived from the forests also has been lost.

The undergrowth in natural forest cover, and the humus-rich soil, encourages groundwater retention and recharge. This feature ensures a regulated stream flow throughout the year, compared to deforested catchments with short durations of high magnitude flows during the rainy seasons, and reduced low flows during the dry seasons. This phenomenon leads to faster drying of rivers, as observed in Lake Baringo's drainage basin. It is worth noting that the tree species also are important. Eucalyptus, for example, consumes more water and has little undergrowth, thereby leading to faster depletion of subsurface water reserves. When cut, such trees can cause water flows to increase. Other species, such as *Luceana leucocephala*, use less water and encourage undergrowth, soil water retention, and groundwater recharge in a manner similar to natural forests. When cut, such trees and forests can cause increase the incidence of low water flows.

The effects of climate change in the region are evident from the decreasing snow coverage on Mounts Kenya and Kilimanjaro. This is attributed to global warming, which increases the temperature of the air. Deforestation facilitates the accumulation of greenhouse gases, such as carbon dioxide, in the atmosphere. These gases can cause global warming and, hence, higher atmospheric temperatures. Increased air temperatures can lead to increased evaporation from the lake, causing a decreased water level in the lake. Overall, the potential effects of climate change on Lake Baringo are not yet been well understood because of a lack of reliable data.

Sedimentation

Sedimentation is considered to be the main environmental threat to the lake. It reduces both the depth and the surface area of the lake, in addition to destroying the habitats of aquatic animals. The parts of the catchment that produce the most sediment are the steep slopes with erodable soils. Such areas include the footslopes of Tugen Hills around Cheberen and Tenges. The rates of soil erosion in these areas are as large as 205.79 MT ha^{-1} $year^{-1}$. In other areas, soil erosion is low, being ≈2.21 MT ha^{-1} $year^{-1}$. The eroded soils are deposited on the flat lower reaches of the drainage basin and in the lake. The estimated sediment yield of the Lake Baringo basin, as extrapolated from erosion studies of the Perkerra catchment, is 10.38 million MT $year^{-1}$ (Onyando 2003). Other estimates made three decades ago indicated sediment yields of 13.5 million MT $year^{-1}$ (Pencol Engineering Consultants 1981).

Water abstractions and impacts on biodiversity

The reduced recharge and damming of rivers also pose a threat to the lake. The dams are meant to accumulate water for irrigation, and for rural and urban water supply. The Kirndich Dam, for example, which covers an area of 2 km^2 on the Endao River, supplies water to the town of Kabarnet. Other dams include Chemeron Dam (area of 1 km^2), which is used for irrigation. Water diversions for irrigation also have been made from the Perkerra, Molo and Ol Arabel Rivers, and also have contributed to reduced stream flows. Both the lake and its rivers have been used throughout their history to water animals at various points. Thus, the decreased water levels have significant impacts, especially on the livelihoods of the communities living downstream. This problem is likely to continue as long as the population in the upper catchment continues to increase.

The reduced water inflows to the lake resulted in a low lake depth of ≈1.7 m early in 2003. Only a limited number of aquatic animals can survive under such conditions. The fish community, for example, has been very much impacted by this situation, with overfishing also threatening their survival. The mean size of *O. niloticus* decreased to 15 cm, necessitating a fishing moratorium in 2001. Other fish species (e.g. *Barbus* and *Labeo*, which migrate upstream to spawn) are presently close to extinction in the lake.

Socioeconomic factors

Socioeconomic factors also have had both direct and indirect impacts on the lake. These include:

1. Increased demands for developing and using lake resources such as fish, water and tourist facilities.
2. Limited public awareness and understanding of human impacts on the lake including low literacy levels, cultural beliefs and stratification within communities.
3. Insufficient governance and accountability systems that involve inadequate consultation, a lack of expertise and insufficient mobilization of institutions to address problems.
4. High poverty levels, which compound disasters caused by droughts and floods, low crop yields and low livestock returns.
5. Poor land management with cultivation of river banks and cultivation of steep slopes without conservation measures.

Other problems

Other environmental and sustainability problems associated with the lake include invasive species, especially *Prosopis juliflora*, a fast-spreading shrub with hairy evergreen leaves. Introduced in 1982, it has spread to cover much of the grazing land in Baringo District, especially around the lake. The shrub forms an extensive and impenetrable thicket that gradually chokes out other plants, including the acacia tree and grass, leaving much of the soil bare and prone to erosion. It has deep roots, and is likely to be linked to the lowering of the water table in the areas it colonizes. It has aroused concern among the pastoralists, especially the Ilchamus, as it chokes out all the grass on which their cattle depend.

Management environment

Institutional roles

The goal of management of the lake and its basin is its sustainability and that of its biotic communities, at the same time benefiting the populace through wise use of its resources. For effective management of Lake Baringo's resources, a management plan is necessary, but has not yet been developed. The management efforts in the past

have been sectoral. The involved institutions and their roles in managing the lake and its basin are outlined below.

Kenya Marine and Fisheries Research Institute. This is a public research institution with the responsibility of carrying out research on fish production and the quality of the lake water as related to fish production. It provides statistics on fish trends and lake productivity, with its operation enshrined in the Fisheries Act.

Kenya Forestry Research Institute. This also is a public research institution mandated to carry out research on agroforestry systems, preservation of indigenous tree species, and development of environmentally friendly tree species. The trees are planted in the catchment and used for various purposes, depending on the species. Some of their uses include conservation of soil and water, as wind breaks, and as sources of fodder, wood fuel and timber.

Ministry of Livestock and Fisheries. This ministry was created recently as part of government reforms to further streamline the fisheries and livestock departments. The Fisheries Department in this ministry operates under the Fisheries Act. The department's role is to prevent illegal fishing and the use of illegal gear sizes. It also recommends provision of licenses to fishermen and transporters. The Livestock Department provides extension services on livestock management. It also is involved in re-seeding of degraded rangelands, livestock improvement and marketing. The ministry also has affiliated research institutions, both national and international, which are involved in livestock research.

Kenya Agricultural Research Institute. This is a public research institution under the MoA. It is responsible for agriculture-based research, including developing drought-resistant crops, fast maturing crops, and disseminating research findings.

Ministry of Water Resources Development. This ministry is responsible for water resources management and development within the lake basin. It operates under the Water Act and provides guidelines on water abstraction and borehole development, among other topics.

Ministry of Environment and Natural Resources. This ministry is responsible for environmental conservation in the catchment, including its rivers and the lake. It advises the Government on the use of natural resources in such a way as to minimize environmental degradation. It also promotes environmentally friendly management interventions. Its activities are enshrined in the Environmental Act.

Ministry of Agriculture. This is a public institution responsible for improving food production, while at the same time conserving the resources to ensure a sustainable supply of food needs. Its activities involve carrying out extension services on modern farming techniques, creating awareness on the sustainable use of resources, and educating farmers, among other tasks.

Kenya Wildlife Services. This is a public institution responsible for wildlife management. It controls, as necessary, the population of predators to minimize human–wildlife conflict.

Baringo County Council. This council is composed of elected leaders from the district. It owns the trust land where the lake is located, and collects taxes from revenue generated from the lake. The taxes are ploughed back, through facilitation of its personnel, who oversee the general management of the lake.

Rehabilitation of Arid Environment Trust. This is an NGO, which undertakes planting and regeneration of indigenous trees and grasses in badly eroded lands within the basin.

World Vision. World Vision is an NGO that provides famine relief to families affected by extended droughts and which have lost crops and other resources. Assistance also is given to those who have lost property to floods. The objective is to enable them to recover from their losses, and resume their livelihood activities, as rapidly as possible.

Honey Care. This is a CBO responsible for promoting honey production and sale. Honey is an important resource in the Baringo District, providing an alternative income source to the local people.

Women's Groups. These comprise CBOs composed of women, with the common goal of improving livelihoods. They operate microenterprises as alternative sources of income. Such enterprises relieve consumption pressures on the lake and its resources, thereby contributing to improved resource management.

Block Hotels. This is a private organization operating the three-star hotel, Lake Baringo Club, near the lake. The lake and its rich biodiversity attract tourists, from which the hotel generates income. In turn, the Block Hotels, as a direct beneficiary, participates in lake management, thereby also contributing to the sustainability of the lake. This activity also helps sustain its business.

Legislation

The lake management programme operates on the basis of government legislation and policies. It is linked to other programmes, such as the National Action Plan on Desertification, National Biodiversity Action Plan, Poverty Reduction Strategy Paper, and National Wetland Management. All these have the common objective of sustainable use of natural resources to meet livelihood needs. The legislative framework to enforce management

initiatives operates under various acts of the Kenya Government, including the Fisheries Act, Water Act, Agriculture Act, Forest Act, Land Control Act, and Land Planning Act.

The enforcement laws are contained in the acts which, in the past, have been implemented sectorally. The Environmental Management and Coordination Act was enacted in 1999, however, to harmonize all the environmental management laws scattered throughout the various existing acts. The implementation of this Act is overseen by the National Environment Management Authority. At the local level, district environmental committees and village environmental committees have been established to ensure that environmental management initiatives are implemented. These committees operate by encouraging the local communities to participate in environmental management activities.

In cases where serious degradation is taking place, or where it is anticipated as a result of human activities, gazettment can be done by the concerned minister, as a measure to stop the degradation. This has been done in forest areas following extensive felling of trees for timber, and recommendations have been made to the central Government for timber to be imported.

In other cases in which there is a deliberate illegal use of resources, law enforcers are encouraged to keep vigilance and arrest the involved parties. In cases of illegal fishing, scouts carry out surveillance in the lake and arrest poachers. The scouts are armed in order to eradicate forceful poaching. Apart from scouts, local chiefs, the administrators in the localities, have the mandate from the provincial administration to enforce legislation. Cases of arrests have been recorded in the Lake Baringo area, with illegal gear sizes of <4 inches being burned in public.

Research and science

Research and science are prerequisites for effective resource management. Through research and scientific studies, inferences from analysis of statistics of natural phenomena and biodiversity can be made and incorporated in management plans. As an example, the provision of data on bird life, allowing the numbers of various birds of different species to be determined, is essential for establishing bird sanctuaries.

Research linkages have been made with both local and international universities. Examples include Egerton and Kenyatta Universities in Kenya and the University of Uppsala in Sweden. The research findings have been disseminated to rural communities through participatory rural appraisal (PRA). Such research findings provide a basis for recommendations for sustainable resource management, based on available resources and capacity. The fish ban, for example, was a recommendation based on research findings, resulting in improved quality and quantity of the fish catch. The improved catches made the practice readily acceptable to fishermen.

Management strategies

Mitigation measures undertaken to control degradation in the basin include control of soil erosion through terracing, contour farming and gully control, among other actions. Stone walls and desert plants (e.g. cactus) also are used to trap sediments in the floodplains. Construction of check dams and semicircular bands to reduce overland flow rate also was undertaken. Afforestation and control of tree cutting are other control measures done to minimize degradation. These techniques, however, are long-term interventions requiring time, up to a decade or more in some cases, to counteract the lake's degradation.

Other management measures include re-seeding with high-yielding pasture, conservation of wetlands around the lake, and agroforestry practices in the lake's catchment using fodder trees. In addition to these measures, water harvesting and groundwater supplies are undertaken to provide alternative sources of water. Diversification of alternative livelihood opportunities is encouraged to reduce exploitation pressures on lake resources, one possible way of doing this is through the facilitation of microenterprises.

A fishing moratorium involving the local communities was implemented to improve fish stocks in the lake. The moratorium was instituted after recognition of dwindling fish stocks, based on monitoring efforts by the KMFRI and the Fisheries Department. The fisherfolk were experiencing income losses due to dwindling fish stocks. It was not difficult for them therefore to accept the moratorium in anticipation of better yields in the future. When a monitoring report was presented by the KMFRI and the Fisheries Department, they readily agreed to impose the moratorium, which involved instituting a fishing ban until the fish stock improved. The moratorium was enforced by the Fishermen Cooperative and the Fisheries Department. It involved regular surveillance to control illegal fishing, as well as ensuring the use of recommended gear ratios when the ban was lifted. Although fishing is a major income-generating activity for the communities around the lake, they are not entirely dependent on it, but also engage in agropastoralism and microenterprises. During the fishing ban therefore they concentrated on these other livelihood opportunities. However, regulated subsistence fishing, using hooks, was allowed to continue among the communities living on the

island. Some opposition to the moratorium was noted from a few individuals, who continued to poach. This situation, however, diminished with time, following community participation in surveillance and education facilitated by the LBCB's land and water management project.

The progress in increasing fish production during the moratorium was monitored by the Fisheries Department and the KMFRI. The outcome of the exercise was disseminated to stakeholders through quarterly reports and stakeholder forums. Recent spot checks showed that the ban, instituted about 2 years ago, has allowed tilapia (*O. niloticus*) to grow to an average size of 29 cm, from the previous average of 15 cm. To prevent future moratoria, overfishing should be minimized by requiring the use of the correct-sized fishing gear, regulating the number of licensed fishermen, and ensuring regular surveillance to prevent illegal fishing. In contrast to the fish moratorium, erosion control in grazing lands has had little success. This is because, when compared to the lake, a common resource, the cattle that cause overgrazing are individually owned by pastoralists, who are reluctant to control herd numbers to conform with the land's carrying capacity.

Wildlife conservation and community-based water projects also are being undertaken to further reduce degradation of the lake and its resources. Some of the biodiversity conservation activities are fish and bird counts, protecting endangered species, prohibition of illegal poaching, and establishment of a Ramsar site for Lake Baringo.

The current management initiatives in the Lake Baringo drainage basin are mainly sectoral. Activities currently receiving the most attention include fishing, soil conservation and agroforestry, tourism development and biodiversity, microenterprises and water resources management. Through its designation as a Ramsar site in 2001, Lake Baringo is now recognized as a wetland of international importance, therefore open to funding opportunities to conserve its resources, support livelihood opportunities and reduce land degradation. The management plan under development is aimed at integrating all the sectoral plans, and is in accordance with the Ramsar Convention. Lake Baringo itself is in trust land, with its management under the jurisdiction of the Baringo County Council. The Council focuses on income-generating activities (e.g. tourism, fishing), however, with little attention given to catchment conservation. Thus, with the development and implementation of an integrated management plan, it is anticipated that the management of the lake and its basin will be diversified, and include both income and non–income-generating activities, as well as incorporating all stakeholders.

Conflicts and constraints

The institutions responsible for managing Lake Baringo are not devoid of constraints, thereby hindering sound management of the lake. One constraint is the lack of resources, such as boats for surveillance. The Fisheries Department, for example, has been incapacitated and could not carry out regular surveillance for an extended period of time, because of the lack of motorized boats. This has resulted in cases of illegal fishing during the period of the ban. Coordination of stakeholder activities is another constraint in managing the lake, mainly because every stakeholder has a programme of activities that might not conform to others, in regard to a common goal of sustainable management of natural resources. Conflict of interest is another drawback in lake management. This is particularly so with the local communities, who exploit the resources of the lake and its basin to meet their livelihood needs. The fishing ban could conflict with the interest of the fishermen to meet their livelihood needs through fishing activities.

Cattle grazing along the lakeshore, especially during dry seasons, is another area that generates controversy. The pastoralists keep large herds of cattle, which cannot be sustained by the available biomass, especially during dry seasons. Thus, they enter the lakeshore areas, where their cattle graze and destroy the habitats of other plants and animal species. Control of the number of the herds as a management strategy is an unacceptable practice to the pastoralists. As an alternative, a participatory range management plan that regulates access to grazing lands and movement of herds could be developed and implemented. The plan could be derived from traditional systems, with involvement of pastoralists and enforcement by elders. Through CBOs, rotational grazing can be introduced, in which herds are rotated to allow re-vegetation. This is likely to increase the carrying capacity of the rangelands, and will readily be accepted by the pastoralists. Lack of support, ineffective legislation, lack of transparent decision-making systems, lack of qualified personnel in environmental management and lack of sufficiently trained personnel are additional drawbacks affecting the institutions.

The lack of a management plan for the lake and its drainage basin is another constraint to its management. As the current management initiatives are sectoral in nature, the negative impacts that could occur from an activity also are likely to influence other sectors. Such sectors might have difficulty in formulating solutions to problems whose origin they might not know. The construction of dams upstream for domestic water supply, for example, resulted in reduced flows downstream and into the lake.

Consequently, the downstream population suffered from inadequate water supplies, which they need both for domestic use and for irrigation. Fish production also decreased partly because of reduced inflows into the lake. Siltation of Chemeron Dam is another side-effect that has reduced the capacity of the dam and, hence, the reliability of the downstream water discharge to meet irrigation needs. As there is interconnection between the activities of various sectors, however, involvement of all stakeholders is inevitable, which requires a management plan and a clear government policy, especially on lake management, which is unfortunately still lacking.

Other constraints to the management of Lake Baringo and its drainage basin include the following:

- Lack of local expertise, lack of coordination, retrenchment of staff, especially in government institutions, and low incentives, which demoralize personnel responsible for effective management of resources
- Inadequate understanding by the public and decision-makers on the effects of human activities on the lake and its drainage basin
- Lack of data and information about the problems facing the lake and it drainage basin
- Inaccessibility to information on past studies and research on the lake and its drainage basin
- Lack of understanding by many lake basin inhabitants, especially among those who live on the hill slopes at a considerable distance from the lake, about their individual roles in causing lake problems
- Lack of knowledge by most of the indigenous communities of what actions to take to help solve lake problems
- Lack of feedback of information to government officials
- Frequent droughts and floods
- Inadequate accessibility to safe water
- Livestock diseases
- High land preparation costs
- Limited market opportunities
- Lack of public awareness
- Land tenure system and cultural values

Some constraints can be minimized through environmental educational programmes. The conflicts, however, are resolved from two possible approaches. One way is through the provincial administration, whereby the district security teams from different districts organize roundtable discussions to find amicable solutions to the conflicts, or to enforce law and order among the conflicting groups. The other approach is through village elders from the conflicting groups. The elders usually can easily identify the root causes of the problem and help find solutions acceptable to the conflicting groups.

Capacity building and public participation

Capacity-building efforts undertaken to manage the lake and its drainage basin include training of farmers to create awareness, so that they become receptive to resource management initiatives. These activities include involvement of local communities in the tree-planting process, participation in programmes such as the Kenya–Finland Livestock Development Programme Bull Scheme, which also entails empowering women's groups in land rehabilitation. Other activities include on-farm demonstrations by extension workers, village environmental committees to oversee the day-to-day implementation of the on-farm management practices, and training extension staff regarding new technologies. Strengthening institutions through facilitating support of microenterprises on income diversification and educational visits to demonstration sites are additional capacity-building initiatives.

As part of capacity-building activities, an excursion to Lake Bogoria resulted in passing resolutions that were to be used as guidelines to ensure good management of the lake, as follows:

- Formation of beach committees
- Joint patrol and surveillance with the Fisheries Department
- Supporting research to determine the rate of recovery of the lake's fishery
- Participation in tree planting
- Involvement of women groups in fodder farming and zero grazing

One of the experiences of stakeholder involvement is that they tend to participate in activities in which they will get direct benefits, or if the activities are linked to their livelihood needs. Creation of awareness among stakeholders on the importance and value of the lake, and the need to conserve it, has been made possible through training, sensitization and mobilization using PRA methods. Such methods include field days, workshops, seminars and demonstrations in which the stakeholders learn through participation.

Financial investment

Financial investments made to help solve the problems associated with the sustainable use of the lake and its resources include:

- Ministry of Livestock and Fisheries – $US30 000 between 1998 and 1999
- Local Afforestation Scheme – $US52 000 for 1.8 million seedlings for planting during 1999 and 2000
- UNICEF, various NGOs – $US107 000 in 1999–2001 to undertake community-based water projects
- Kenya–Finland Livestock Development Programme Bull Scheme for cow rotation – ≈$US74 000

• UNEP/GEF, through the LBCB project – ≈$US750 000 during 2001–2003 for capacity building and rehabilitation of degraded Lake Baringo basin areas

UNEP/GEF LBCB project

Environmental degradation was identified as a major constraint to the development of the Lake Baringo basin. The increase in both human and animal population beyond the land carrying capacity, and unsuitable land use activities in the drainage basin, resulted in a decrease in the natural resource base that supports livelihoods and biodiversity. The environmental status of Lake Baringo has been the concern of the Government of Kenya (GOK), NGOs and local communities for a long time. In 2000, the GOK forwarded a proposal to UNEP to fund the LBCB project, with the main objective of building the capacity of the local communities and institutions to respond positively in addressing the impacts of land degradation, through the demonstration of best land use practices. The project was formulated with line ministries, in consultation with the local communities and other stakeholders. The entry point to the communities was through PRA and socioeconomic surveys, with the main problems focusing on land degradation, biodiversity conservation, and aquatic resources.

The approach adopted was to facilitate institutions to build their capacity for sustainable environmental management. The advantages of this approach include involvement of stakeholders in a participatory manner, strengthening of institutional partnerships/synergies, resource mobilization and ownership.

The disadvantages of this approach include weak partners, little budgetary harmonization, ownership of credit concerns, lack of transparency and high stakeholder expectations.

The entry point of the UNEP/GEF project was to build capacity for managing natural resources, and improving income through facilitation of various stakeholders. One such activity to which UNEP/GEF funds were committed is microenterprise, which was introduced to assist organized community groups to engage in environmentally friendly income-generating activities, in order to relieve land use pressures and, at the same time, raise people's livelihood standards. Other activities include environmental education and conservation programmes, facilitation of stakeholder forums, and policies and facilitation of research.

Lessons learned

Stakeholder involvement

Lake management programmes should involve all relevant stakeholders and all other parties interested in the sustainable use of a lake and its resources. This practice will not only minimize the duplication of activities, but also ensure wise and efficient resource use. Through the sharing of information, knowledge will be generated and appraised. The interests of the community, preferences and values also will be taken into account in the management plan, thereby minimizing conflicts of interest. This approach also makes the community more receptive to lake management efforts. To ensure that their interests are adequately considered, care should be taken to involve members of the community from all strata in the management efforts.

Improvement of livelihood security

Local people will tend to support interventions they perceive to favour their aspirations, especially those that improve their livelihood security. Most farmers in the lake basin, for example, were not willing to construct terraces and other water conservation structures until they saw the successful harvest obtained by those who did so. Similarly, they do not see direct gains in natural resource conservation and management. This is exacerbated by the lack of critical mass with interest in resource conservation, communal land ownership and high poverty levels. Thus, it is important to develop environmental awareness packages with incentives, in order to build a conservation constituency at a grassroots level.

Diversification of income

Income diversification offers more alternatives for meeting livelihood needs. It reduces overdependence on one resource, which often can lead to environmental degradation. The Pokots and the Ilchamus, for example, are mainly pastoralists and keep large herds of cattle that do not match the carrying capacity of the grazing land. This causes problems of overgrazing, with increased soil erosion and the siltation of rivers and lakes. In addition to land degradation, their animals die during drought periods, thereby reducing their livestock products. Other income-generating activities (e.g. bee keeping, microenterprises) are necessary because they reduce pressure on land and minimize risks.

Biodiversity – a source of income and food

From the perspective of the local people, biodiversity in arid and semiarid areas involves a pastoral risk management strategy. From their perspective, biodiversity is a source of food and income. During severe droughts, pastoralists hunt wildlife to supplement their protein supplies. Similarly, they burn acacia and other trees to produce charcoal for sale to compensate for livestock losses. Biodiversity conservation is acceptable to the local people if it can generate socioeconomic benefits higher

than the subsistence utilization, a mentality caused by a lack of awareness. It is worth noting that improved rangeland can attract more biodiversity with more gains. As an example, four animal species have returned to a piece of land rehabilitated for a period of 12 months. Similarly, birds have built nests on trees in demonstration plots set up by a local NGO, whereas there are no nests on trees in nearby degraded areas. Thus, it is important to have sufficient information on biodiversity in the lake basin, including the social dimension of its conservation.

Conservation to focus on the means of achieving the end result

Conservation projects should focus not only on producing physical end products, such as the total area and species conserved, but also on the means of achieving the end result. This is especially critical when multiple stakeholders are involved. As a means of enhancing the conservation of natural resources in the Lake Baringo drainage basin, the LBCB project applied the participatory approach and formation of partnerships among key stakeholders to create synergy and increased sense of ownership. While it is prudent to take an integrated approach involving various development partners and stakeholders, it also is important to critically examine some of the underlying assumptions. Most development agencies share the same vision of livelihood improvement, but have their own preconceived ideas about community approach and implementation strategy. They also operate on different budgets and time scales. If the operations of these partners are not regulated and harmonized, it can create confusion for the local communities, and scrambling for recognition at the expense of conservation. The UNEP/GEF project played a pivotal role in the synchronization of activities among the stakeholders through a participatory approach.

Awareness creation, capacity building and sustainable resource use

Creation of stakeholder awareness and education on various management scenarios are the major aspects of building capacity for implementing and addressing the principles of sustainable lake management. The local communities that are the direct beneficiaries, and who exploit the resources to meet their livelihood demands, should be made aware of the risks involved in such exploitation. In the majority of cases, they only consider the short-term benefits, at the expense of the long-term ones. In addition to the excessive exploitation of fish, the forest reserves also have been exploited not only in the hill slopes of the Lake Baringo drainage basin, but in all forest areas of Kenya. The forest area of Kenya is currently <2%, much less than the 9% forest coverage characterizing Africa and 20% forest coverage of the world. The GOK targets a forest coverage of 10%. As the Government plans to achieve this goal, the education of the masses to live in harmony with the natural resources is essential.

Inclusion of the entire drainage basin in the lake management plan

Management of Lake Baringo should not concentrate only on the waterbody itself, but should also extend to the whole basin that drains into the lake. In most cases, the administrative boundaries do not coincide with the river basin boundaries, as is the case for the Lake Baringo drainage basin, which is located in four districts of Baringo, Koibatek, Nakuru and Laikipia. The LBCB project, however, was only designed only for the Baringo District. This made it difficult to involve other districts in resource management efforts, even though activities in parts of these latter districts in the catchment directly affected management of the lake. Thus, management programmes should be designed to include the entire drainage basin.

Financial investment in lake basin projects

Financial constraints made the UNEP/GEF-funded LBCB project focus mainly on the Baringo District. The project was a medium-sized project (MSP), for which the upper funding limit at the time was $US750 000. One lesson learned in this effort is that financial investments larger than that available through the MSPs are needed for formulating effective integrated lake basin management programmes. Furthermore, time frames longer than 3 years, the average duration of an MSP, are needed to bring about changes in the management of an entire lake drainage basin.

Water conservation for domestic and livestock use

Alternative water resources, such as rainwater harvesting through roof catchment, should be explored to supplement river water for domestic use. This will reduce water abstractions through damming, thereby also allowing more water to flow downstream and into the lake. This should be practised not only in the semiarid downstream area, but also in the humid upstream area as well. This is because the people located upstream use more water, whereas those located downstream, as well as the lake, are most affected by water shortages. Thus, the upstream population should rely more on rainwater for domestic use, so that most of the river water can flow downstream and into the lake.

Documentation and extension

The information and data gained from lake management programmes and experiences can be disseminated to national and local governments, lake management practitioners, NGOs and other stakeholders through reports, seminars, workshops and the Internet. All should be available in libraries as well, where they can be easily accessed. Field days through PRA also are an avenue for disseminating the information, particularly to local communities.

ACKNOWLEDGEMENTS

The authors would like to thank J. Richard Davis, Stephen Lintner, Victor Muhandiki and the participants at the Lake Basin Management Initiative (LBMI) African Regional Workshop for comments on an earlier draft. Preparation of this paper was supported by the Global Environment Facility as part of the World Bank-implemented, International Lake Environment Committee-executed project titled, 'Towards a Lake Basin Management Initiative'. The views expressed here are those of the authors, and do not necessarily represent those of their organizations or of the sponsors of the LBMI project.

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