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Towards sustainable utilization of Lake Naivasha, Kenya

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Abstract

The current trend of utilization of the resources of Lake Naivasha poses serious threats to the fragile lake ecosystem and its biodiversity. The paper considers the dynamics of the changing lake ecosystem, imminent threats to, and the community-based approach towards the sustainable utilization of the lake. The sustainable use of the lake will not be fully realized without a sound management plan. There is a need to enact consolidated environmental legislation in Kenya, which will enable the strengthening of environmental conservation and the protection for sustainable utilization of natural resources.

Key words

Lake Naivasha ecosystem, Lake Naivasha Riparian Owners Association, sustainable utilization.

INTRODUCTION

Lake Naivasha, ~150 km^2 in total area and constantly fluctuating, is a closed basin, shallow, freshwater lake surrounded by alkaline lakes. It is situated in the Eastern Rift Valley of Kenya, ~100 km northwest of Nairobi (Fig. 1).

The lake has three distinct components: the main lake, which is the most important; Oloidien Bay, which at low water-levels is a separate lake and has a considerably higher pH; and Crescent Island Bay, which forms the deepest part of the lake, presently ~15 m deep. Due to the present low water-levels, Crescent Island Bay is almost a separate lake and is chemically distinct from the main lake. Lake Sonachi, a small crater lake, 3 km from the main lake, is also part of the Lake Naivasha system.

At present, Lake Naivasha has an average depth of 4–6 m and its level is 1886.5 m.a.s.l., a decrease from 1890 m in 1983. Total water volume is estimated at $680 \times 10^6 m^3$, but varies with water-levels. The lake receives 90% of its inflow from the perennial Malewa and Gilgil rivers. The remaining input comes from seasonal streams, direct precipitation and ground seepage. The area is semi-arid, receiving on average 620 mm of rainfall each year, while annual evaporation is approximately 1735 mm. Evaporation exceeds precipitation throughout the year except at peak rainfall. The rainfall trend is bimodal, with a major peak in April–May and a minor one in October–November. The higher rainfall in the elevated regions of the catchment (i.e. Aberdare Ranges and Kinangop plateau), partly offsets the annual deficit through the Malewa River discharge (Fig. 2).

The lake has been subject to wide fluctuations in water-levels over time and is said to have become almost dried some 150 years ago (Figs 3,4, Table 1). Natural fluctuations, coupled with human use and introduction of alien flora and fauna have made the lake ecosystem vulnerable and its fragility is a challenge to conservationists and scientists. The lake supports significant economic activities. These include fishing, irrigation, agriculture, geothermal electric power generation, domestic water supply, sewage effluent disposal and tourism. These have intensified over the past 15 years and now pose a serious threat to the lake environment and its biodiversity. The central issue now is the mechanism of achieving sustainability and a balance between utilization and conservation of the lake environment.

SOCIO-ECONOMIC VALUES OF LAKE NAIVASHA

Agriculture

Horticultural farms using lake water for irrigation surround the lake. Fruits, vegetables and flowers are grown both for local and export market. Horticulture is of national importance as a source of foreign exchange and employment to some 30 000 people. The irrigated land under production is over 10 000 ha. Farms range in size from large companies with hundreds of hectares under intensive flower production, to small farms growing vegetables for export. Dairying around the lake is well established and irrigated lucerne farms have supported the industry since the late 1950s. However,

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intensive, export-oriented horticultural production has developed only over the last 10–15 years. It is still expanding.

Geothermal power generation

A large volume of water is pumped from the lake by the Kenya Power Company (KPC) and used in drilling new steam wells and in condensing steam in the existing 45 MW geothermal power plant. The plant provides roughly 15% of national electric power requirements. KPC is in the process of erecting a second geothermal power plant which will yield an additional 64 MW. Being a relatively cheap source of energy for Kenya, power from geothermal resources is planned to increase for at least the next 20 years to about 28% of the country's demand.

Domestic water supplies

This is obtained from the lake either directly or from wells or boreholes adjacent to the lake. The town of Naivasha is supplied by three boreholes with a maximum output of 50 100 $m^3 h^{-1}$.

Commercial fishing

The lake supports a thriving commercial fishery which started in 1959. The fish species exploited are the large mouth bass (*Micropterus salmoides* Lacepede), tilapine species (*Oreochromis leucostictus* Trewavas and *Tilapia zilli* Gervais), and crayfish (*Procambarus clarkii* Girard). All are introduced species. Crayfish is exploited both for export and local consumption. The Fisheries Department manages the fishery by the issue of licences, enforcement of the number of fishing nets, and regulation of net mesh size used (Fig. 5).

Tourism and recreation

The lake offers outstanding aesthetic scenery and recreational facilities. The latter include boating, water-skiing, sportfishing, game viewing and bird watching. Some 350

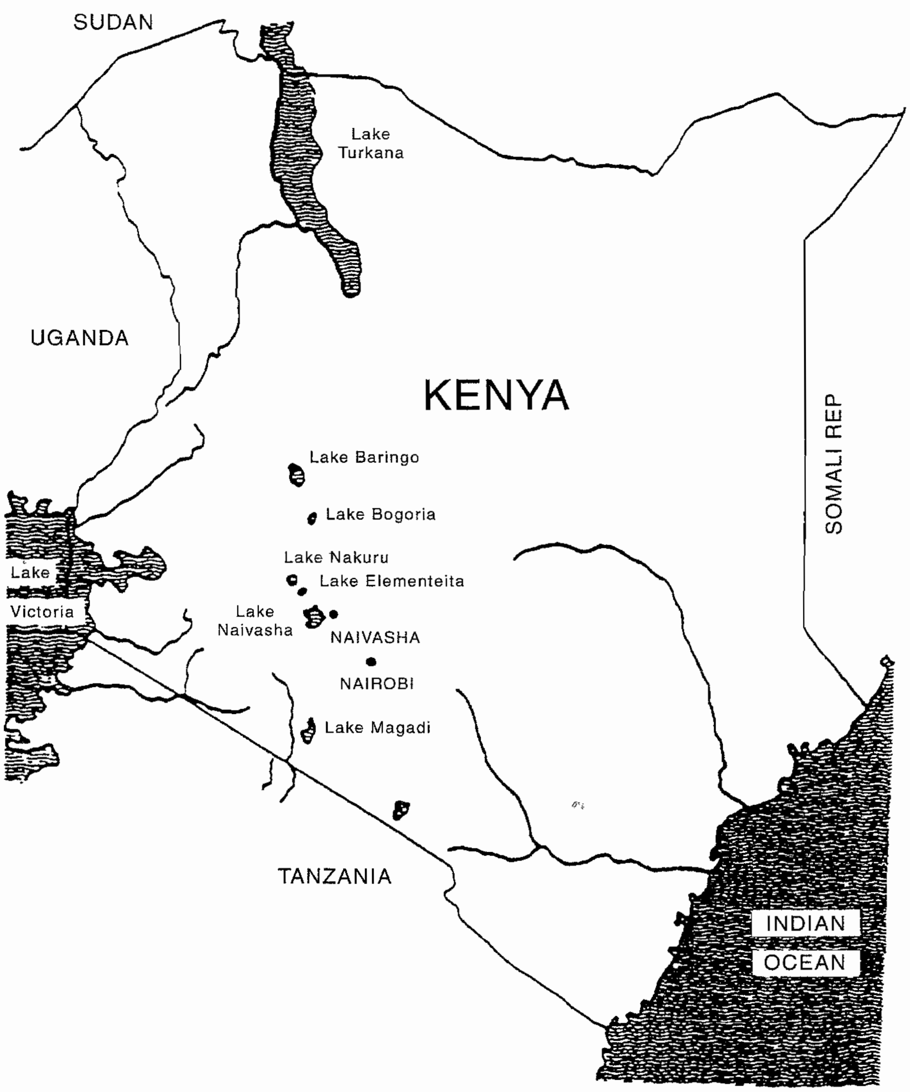

Fig. 1. The location of Lake Naivasha in the chain of lakes forming the Eastern Rift Valley which runs through Kenya.

bird species, including 75 waterfowl species have been recorded, either as resident or migratory. There are many tourist hotels, campsites, hostels and marinas for accommodation and leisure around the lake. Naivasha provides easy access to the nearby Hell's Gate and Longonot National Parks (Fig. 6). In 1994, a total of 41 000 tourists entered the two parks in the Naivasha system, representing an increase of more than 600% since 1985.

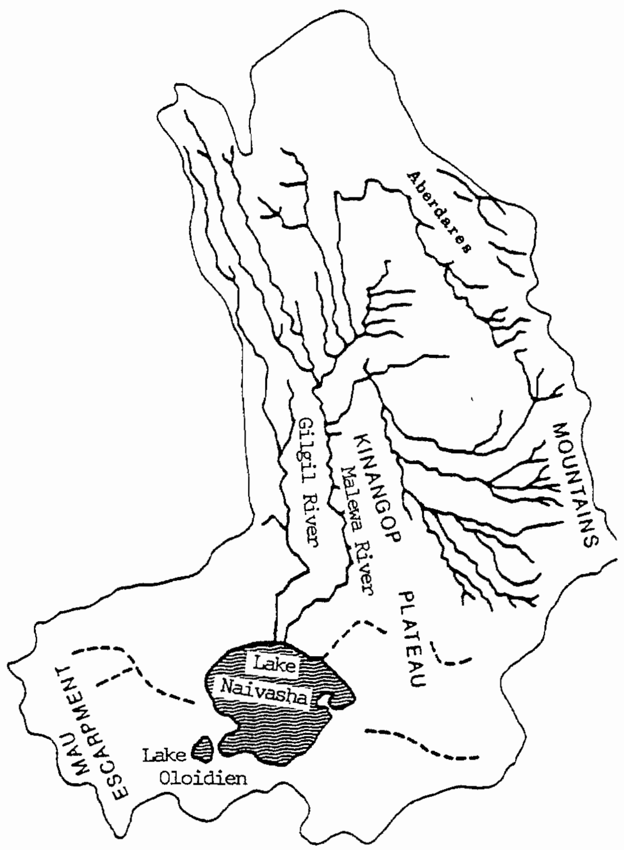

Fig. 2. The Naivasha drainage basin.

Ranching and game farming

The lake is a source of water for game such as giraffe, buffalo, zebra, antelope and waterbuck found within a number of ranches and game sanctuaries around the lake. A number of ostrich farms are also developing around the lake.

BIODIVERSITY AND FRAGILITY OF LAKE NAIVASHA'S ECOSYSTEM

Lake Naivasha, valued for its wide biodiversity of flora and fauna, provides an ecosystem which is both unstable and unpredictable. The lake's ecology is largely influenced by natural fluctuations in water-levels, a phenomenon currently aggravated by human activities. The periodic drying out of the lake is thought to have reduced the natural fish species to just one, the small-toothed carp, *Aplocheilichthyes antinorii* Vinc. This is highly unusual for a tropical freshwater lake. This carp later disappeared following the introduction of the

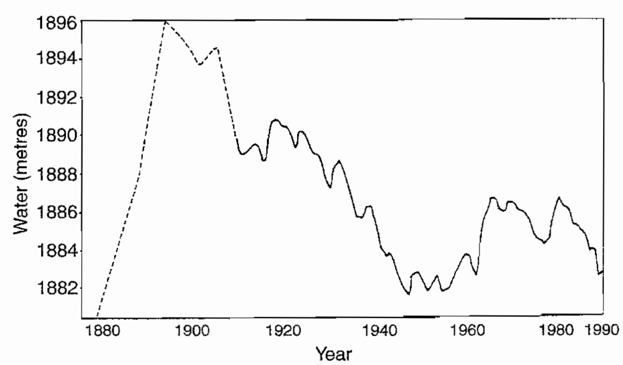

Fig. 4. Historical lake levels.

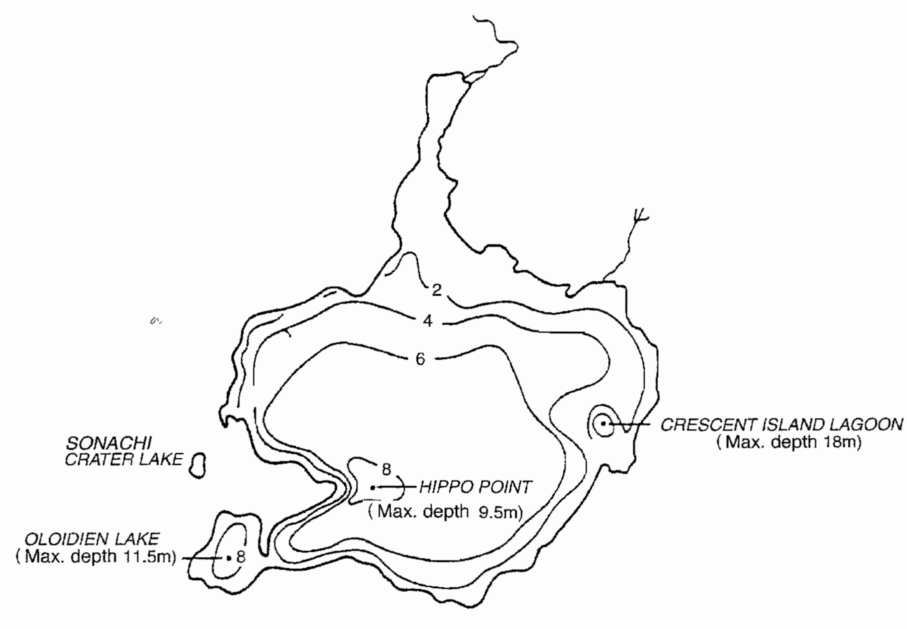

Fig. 3. Bathymetric data for Lake Naivasha (1983 levels). Source: Harper *et al.* (1990).

Tilapine species and the American large-mouth bass. The fishery of the lake is also quite unstable and a link has been established over time between fish production and water-levels (Table 2). The shallowness of the lake means that relatively small drops in level result in large changes in area and volume, that the water becomes more alkaline, and even relatively small amounts of pollution are significant. Shrinking lake margins also affect fish breeding sites.

Table 1. Hydrologic balances for Lake Naivasha and Lake Oloidien. Percentages of input and output are in parentheses for the main lake (after Gaudet and Melack, 1979)

	1973	(%)	1974	(%)	1975	(%)
Lake Naivasha ($m^3 \times 10^6$)						
Surface run-off	0.6	(0)	0.7	(0)	0.4	(0)
River discharge	90.8	(39)	204.0	(56)	240.5	(67)
Rainfall	106.1	(45)	114.2	(32)	77.1	(20)
Seepage in	37.0	(16)	42.3	(12)	50.8	(13)
Total input	234.5		361.7		388.8	
Evapotranspiration (swamps)	14.3		13.2		13.3	
Lake evaporation	309.5		276.0		278.2	
Seepage out and use for irrigation	24.6	(7)	50.6	(15)	93.3	(25)
Total output	348.4		339.8		304.8	
Change in storage						
(Cal. by balance)	−113.9		+21.4		+4.0	
Change in storage						
(Cal. from level change)	−113.9		+21.4		+4.0	
Oloidien Lake ($m^3 \times 10^6$)						
Surface run-off	0.0		0.0		0.0	
Rainfall	3.6		3.8		2.7	
Seepage in	4.1		6.0		7.0	
Total input	7.7		9.8		9.7	
Lake evaporation	11.3		10.1		10.1	
Seepage out and use for irrigation	0.0		0.6		0.0	
Total output	11.3		10.7		10.1	
Change in storage						
(Cal. by balance)	−3.6		−0.9		−0.4	
Change in storage						
(Cal. from level change)	−3.6		−0.9		−0.4	

Table 2. Summary of changes to the fish population of Lake Naivasha, Kenya, Nairobi

Species	Date and success of introduction
Aplocheilichthys antinorii (Vinc.)	Endemic. Probably extinct; last reported in 1962.
Oreochromis spirulus niger (Gunther)	Introduced in 1925. Disappeared by 1971.
Micropterus salmoides (Lacepede)	Introduced in 1929, several times during 1940s and in 1951. Present today.
Tilapia zillii (Gervais)	Introduced in 1956. Present today.
Oreochromis leucostictus (Trewevas)	Introduced unintentionally in 1956 with *T. zillii*. Present today.
O. leucostictus x *O.s. niger* hybrid	Abundant in the early 1960s but due to back crossing with *O. leucostictus* disappeared by 1972.
Oreochromis niloticus L.	Introduced in 1967. Disappeared by 1971.
Gambusia sp. and *Poecilia* sp.	Introduced
Lebistes reticulata (Peters)	Introduced; date unknown. Recorded since 1982. Present today.
Oncorhyncus mykiss (Walbaum)	Introduced into the River Malewa; dates unknown. Caught in the lake on rare occasions.
Barbus amphigramma (Blg.)	Natural invader from inflowing rivers. Recorded since 1982. Present today.

Lake vegetation was fairly stable until 1970, after which submerged and floating macrophytes began to disappear following the introduction of the coypu, *Myocastor coypus* Molina, from a farm where it was being reared for its fur, and the Louisiana red swamp crayfish from America. Coypu fed on the buds and rhizomes of water-lilies, while the

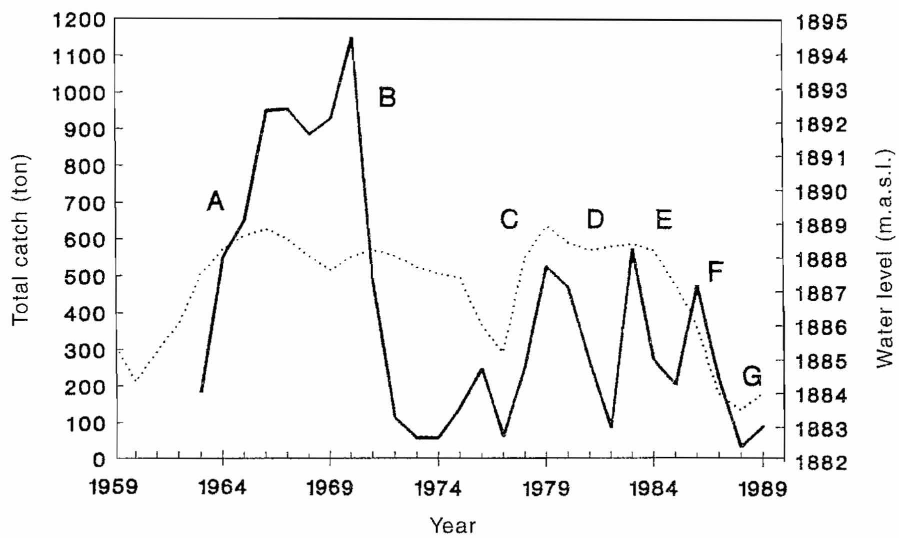

Fig. 5. Total catches (—) from the gill net fishery and water-level changes (……) for Lake Naivasha during the period 1963–88 inclusive. Commercial fishing began in 1959 and records were kept from 1963. A, Period of development of the new fishery; B, period of receding lake level. Also, pressure to supply fish for processing factory led to the use of small-meshed nets. C, low levels of fishing (6–17 canoes) coupled with a rise in water-level allowed the fishery to recover. D, period of high water but with loss of submerged plants; E, sudden decline in lake level combined with high levels of fishing (104 canoes); F, recovery of aquatic plants but sustained high effort (49–75 canoes) and further decline in water-level; G, low levels of fishing (30 canoes). Lake level starting to rise, flooding terrestrial vegetation and providing good nursery areas.

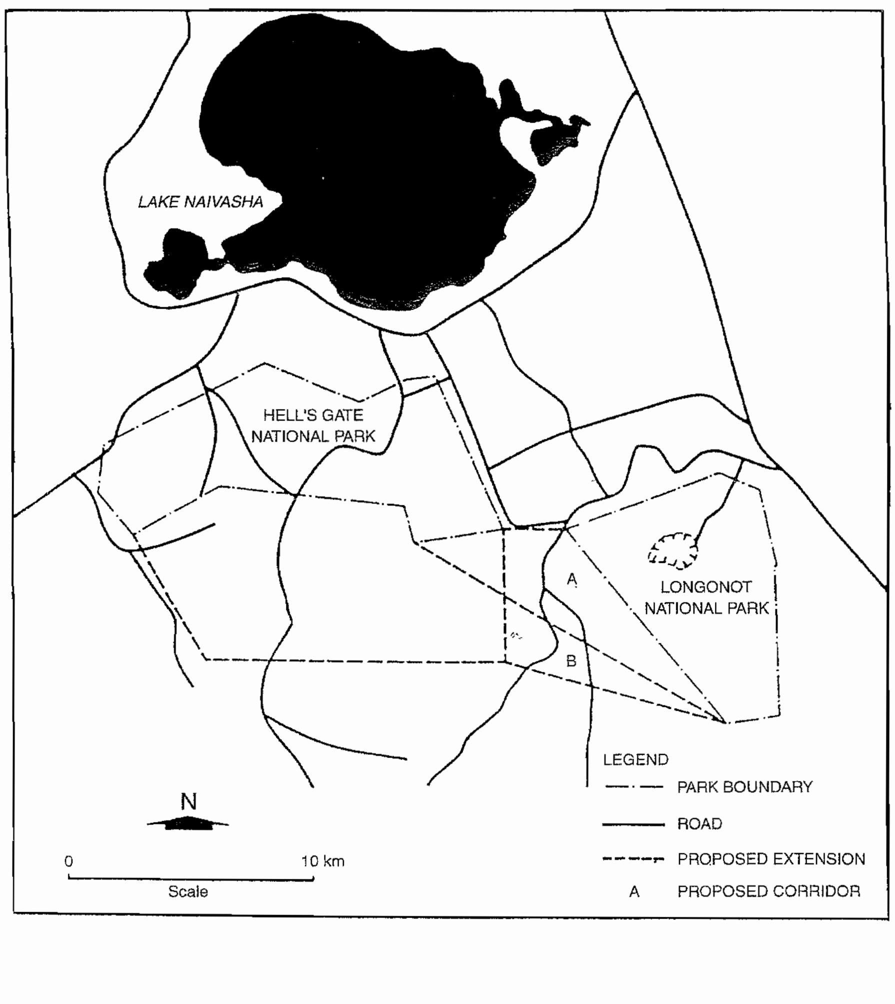

Fig. 6. Hell's Gate/Longonot national parks and proposed corridors.

crayfish grazed generally on the lake bottom vegetation and young lily plants. Water-lilies have now virtually disappeared from the lake. However, following the disppearance of the coypu and the decline in crayfish populations, there was a resurgence of submerged macrophyte beds from 1984–87. The reduction of fringing papyrus swamps has given rise to higher nutrient levels which has created the present state of high phytoplankton biomass in the open water together with extensive littoral submerged macrophyte beds, comprising mainly of *Potamogeton* species, *Ceratophyllum* species and traces of *Najas pectinata*. The zooplankton is largely under-utilized, and comprises the following genera: *Diaphonosoma*, *Simocephalus*, *Mesocyclops*, *Thermocyclops* and *Branchionus*. Phytoplankton is dominated by blue-greens, chlorophytes and diatoms. It includes *Microcystis*, *Lyngba*, *Oscillatoria* and *Melosira*. Invertebrates are dominated by chorionomids and oligochaetes.

The aquatic weed *Salvinia molesta* infested the lake in the early 1960s and came to cover nearly 25% of the lake in the 1980s. It has been substantially reduced following the introduction of the biological control agent *Cyrtobagus salviniae* in March 1991. Similar attempts are being made to control *Eichhornia crassipes* using the water-beetle *Neochetina eichhorniae*. This was introduced in May 1995. The lake is an important flyway for Palaearctic and Afro-tropical waterfowl and regularly hosts more than 20 000 waterbirds, including some very rare species such as the Maccoa duck. For this reason, the lake has qualified for listing as a wetland for international importance under the Ramsar Convention and was designated as a Ramsar site in April 1995. The African fish eagle *Haliaeetus vocifer*, at the top of the lake's foodchain, is considered an important indicator in the monitoring of the ecological status of the lake. In 1995, counts revealed 75 bird species, a decrease from 92 found in 1993, an indication of ecosystem degradation (Table 3, Figs 8–10). Marginal vegetation dominated by papyrus reeds *Cyperus papyrus* is home

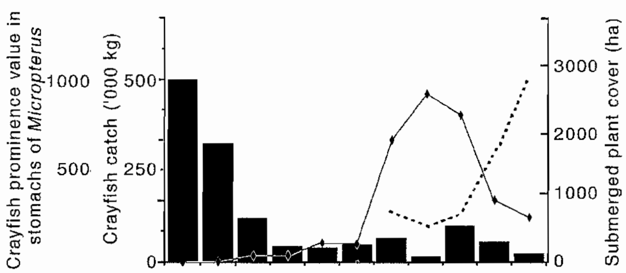

Fig. 7. Relationship of (■) crayfish catch to submerged vegetation cover and as feed for Black Bass. (—◆—) plant cover; (– – –) prominence value.

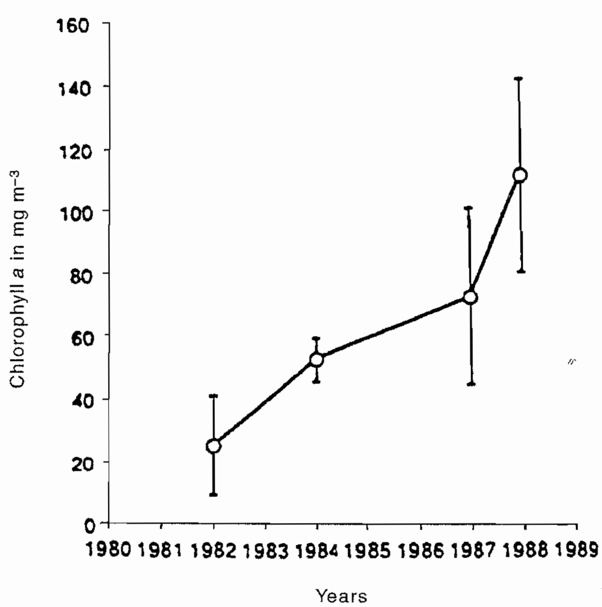

Fig. 8. Phytoplankton standing crop biomass measured as chlorophyll *a* in the main lake open water, between 1982 and 1988.

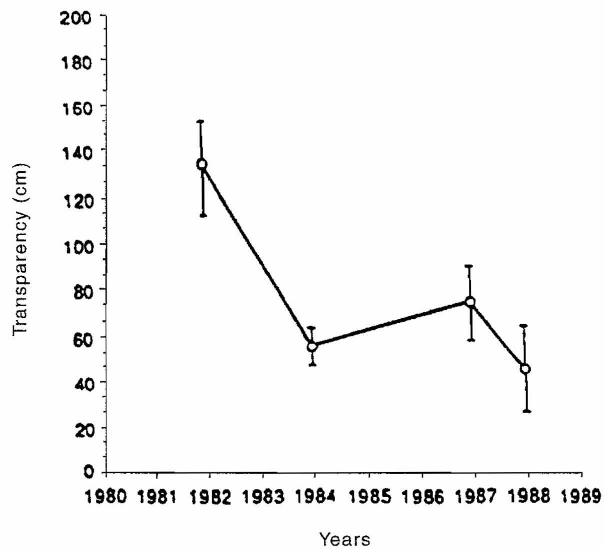

Fig. 9. Secchi disc transparency measured in Naivasha main lake open water between 1982 and 1988.

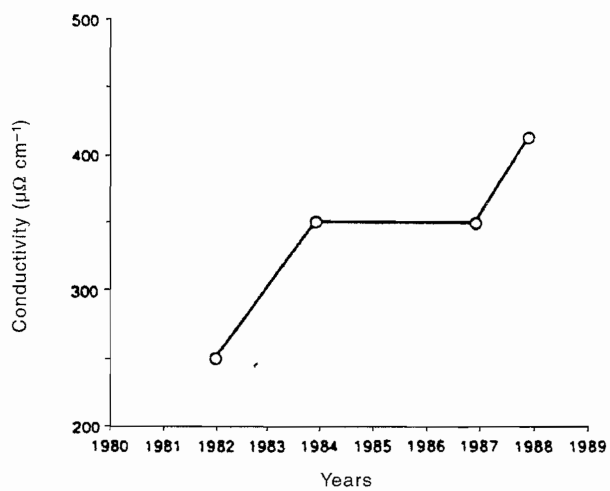

Fig. 10. Conductivity measured in Naivasha main lake open water between 1982 and 1988.

Table 3. January 1995 Lake Naivasha system waterbird counts

Family and species	Oloidien	Naivasha
Grebes		
Black-necked Grebe		2
Little Grebe	79	242
White Pelican	9	147
Pink-backed Pelican	10	6
Cormorants and darters		
Long-tailed Cormorant	3	371
Great Cormorant	452	416
Herons		
Grey Heron	10	64
Goliath Heron		25
Black-headed Heron	5	2
Purple Heron		20
Squacco Heron		70
Cattle Egret		355
Great White Egret		28
Black Heron		2
Little Egret		84
Yellow-billed Egret		135
Storks		
Saddle-billed Stork		2
Marabou		6
Yellow-billed Stork	1	7
Ibises and Spoonbills		
Hadada	16	45
Glossy Ibis		58
Sacred Ibis		169
African Spoonbill	16	39
Flamingos		
Lesser Flamingo	15	
Greater Flamingo	2	250
Ducks and Geese		
White-faced Whistling Duck	8	
Egyptian Goose	454	87
African Pygmy Goose		1
Pintail	27	91
Shoveler	4	143
Red-billed Teal	9	11
Hottentot Teal	247	96
Garganey		77
Yellow-billed Duck	38	82
Southern Pochard		317
Maccoa Duck	14	16
Spur-winged Goose	42	13
Knob-billed Duck	20	
Birds of prey		
Eurasian Marsh Harrier		3
Marsh Harrier spp	1	16
African Fish Eagle	11	75
Osprey		2
Cranes		
Grey Crowned Crane		5
Gallinules and coots		
Common Moorhen		12
Black Crake		22
Purple Gallinule		2
Red-knobbed Coot	114	5110
African Jacana		157
Plovers and sandpipers		
Little Ringed Plover		1
Ringed Plover	183	21
Kittliz's Sandplover	18	
Three-banded Plover	57	2
Blacksmith Plover	59	70
Long-toed Plover		114
Spur-winged Plover		58
Common Sandpiper	88	107
Spotted Redshank		15
Wood Sandpiper	30	50
Greenshank	9	15
Green Sandpiper		75
Marsh Sandpiper	70	51
Common Snipe		3
Snipe sp.		2
Curlew Sandpiper	68	17
Little Stint	443	149
Black-tailed Godwit	15	26
Unidentified godwit		3
Ruff	91	749
Unidentified Sandpiper		3
Black-winged Stilt	10	98
Gulls and terns		
Grey-headed Gull	99	438
Lesser Black-backed gull		27
Black-headed Gull	130	224
Unidentified gulls		3
Whiskered Tern	8	120
White-winged Black Tern		6
Gull-billed Tern	32	109
Unidentified terns		12
African Skimmer		2
Kingfishers		
Pied Kingfisher	7	60
Malachite Kingfisher		35
Woodland Kingfisher		1
Total	3024	11 549

Summary of January 1995 waterfowl count

Family and species	Oloidien	Naivasha
Total		
Number of species	#REF1	#REF1
Flamingos	17	250
Difference	3007	11 299
Grebes	79	244
Pelicans	19	153
Cormorants	455	787
Herons	15	785
Storks	1	15
Ibises and spoonbills	32	311
Afrotropical duck	832	623
Palaearctic duck	31	311
Afrotropical waders	134	244
Palaearctic waders	997	1279
Stilts and avocets	10	98
Gulls	229	692
Terns	40	247
Charadriidae	317	266
Calidridinae	617	944
Tringinae	197	313
#Tringinae + Charadriidae + Calidr.	1131	1523

to various bird species (Tables 4, 5). Some 250 hippopotamuses also reside in the lake.

THREATS TO LAKE NAIVASHA'S ECOSYSTEM

The lake environment and its natural resources face a number of threats as a result of socio-economic activities within the lake and in its catchment. Land-use has evolved from pastoralism to sedentary farming and ranching. A rise in human population density has resulted in intensive irrigated farming, land subdivision, intensive use of agro-chemicals, deforestation and the growth of the Naivasha township. Consequently, more run-off, silt and nutrients have been discharged into the lake via inflow rivers.

The increasing rate of utilization of lake water also raises concern. Large amounts of water are pumped from the lake each year, well beyond the $32.7 \times 10^6\,m^3y^{-1}$ permitted by the Water Apportionment Board. Current water abstraction is estimated at $45–80 \times 10^6\,m^3y^{-1}$, the bulk of which goes to irrigated horticulture and geothermal power production. Seepage out, assumed to be equivalent to seepage in, is estimated at $50 \times 10^6\,m^3y^{-1}$, and direct precipitation at $70 \times 10^6\,m^3y^{-1}$. Evaporation accounts for some $170 \times 10^6\,m^3y^{-1}$ water loss. This clearly shows that current water abstraction direct from the lake has significantly influenced the lake's water balance and is often more serious during dry conditions. Further indirect abstraction involves pumping from wells and boreholes around the lake.

Catchment rivers have not been spared. A total of $36.7 \times 10^6\,m^3y^{-1}$ is abstracted from the Turasha River, a key tributary stream to the Malewa River. In addition, a dam has been built on the Turasha River to produce 18 000 m^3 per day to supply water to the nearby Nakuru and Gilgil townships. These further damage the lake. A proposal to dam the Malewa River to supply an additional 113 600 m^3 per day has been shelved following protests by the Lake Naivasha Riparian Owners Association (LNROA). This proposal would pose the greatest threat to the lake.

Concern has been expressed about the possible effects of the intensive horticultural activity around the lake on water quality, and the possible effects of pollution of the lake by fertilizers and chemicals. Of chemicals applied to crops 30–90% terminate in the soil, some of which drain to the lake during heavy rainfall (Table 6). Some farmers are suspected of using unacceptable chemicals. Organo-chloride pesticides, through biomagnification, could affect bird species at the top

Table 5. Nutrient concentration at Naivasha, 1984 and 1988 (median values in $\mu g\,L^{-1}$)

Year	1984	1988
Soluble-N	45	125
Soluble-P	5	12
Total N	600	475
Total P	89	73

Table 4. Area (in km^2), annual net production (in kg C 10^6) and percentage of net production in the vegetation zones of the different phases of change at Lake Naivasha, Kenya

	Papyrus			Phytoplankton			Submerged			*Salvinia*		
Phase	Area	Production	Percentage	Area	Production	Percentage	Area	Production	Percentage	Area	Production	Percentage
1a. Low lake level, minimum agriculture, 1940s–1950s	50	160	95	120	7	4	3	2	1	0	0	0
1b. High lake level, initial development of agriculture 1960s–1970s	20	66	82	150	12	15	3	2	3	0	0	0
2. High lake level, reduced plant communities, early 1980s	25	82	86	150	10	11	0	0	0	10	3	3
3. Low lake level, extension of agricultural clearance, late 1980s	5	16	33	120	20	42	14	11	23	2	1	2

of the food chain. However, the level of pesticides detected in the water is presently too low to cause concern. Even so, pesticide residues exist and the potential pollution threat is real (Table 7). The lake is also under threat from nutrient enrichment from urban and agricultural growth in the catchment and surrounding areas.

Untreated sewage from the Naivasha township also finds its way into the lake, enhancing the levels of nitrates and phosphates and giving rise to eutrophication with resultant loss in transparency and to reduced oxygen levels.

Anthropogenic pressure presents a considerable threat to the lake environment. The Naivasha township, situated on the north-eastern shore of the lake, is a rapidly growing agricultural, tourist and commercial centre, with a population of 50 000. Elsewhere around the lake, there has been a high influx of people due to increased job opportunities; this has resulted in an additional population of some 200 000, often living in inadequate housing and unsanitary conditions. The Naivasha municipal sewage treatment works is in urgent need of repair and expansion. Septic tanks pollute the lake through the shallow aquifer, and MPN coliforms measuring over 2400/100 mL have been recorded from some parts of the lake.

The tendency by some Riparian farmers to reclaim more land for cultivation as the lake recedes results in the destruction of fringing marshland and papyrus zones; this subsequently increases siltation and reduces the buffering effects of agrochemical and nutrients on surface run-off.

Table 6. Estimates of crop areas around the lake

	Farm land			Fodder crops				Horticulture crops								
Compass direction	Hoding area	Cultivated area	Irrigated area	Non-irrigated	Lucerne	Pasture	Maize	Aspara carrots	French beans	Cabbages	Grapes	Oranges	Straw-berries	Apples	Flower bulbs	Cut flowers
Eastern	3 123	1303	1018	285	66	185	111	142	212	121	65	32	43	16	12	13
Western	22 074	1265	1257	8	120	230	475	110	39	3		10	50			220
Southern	11 258	1289	1289			87		20							4	1178
Northern	8 764	3574	3344	230	685	863	721	339	282	215	1	19		15	1	203
	45 219	7431	6908	523	871	1365	1307	611	533	339	66	61	93	31	17	1614

Source: LNROA (1993)

Table 7. Results of pesticide residues in Lake Naivasha water samples

Farm	Commodity	Location	Pesticide	Conc.
Sulmac	Water	At intake direct from the lake, field 90s	Aldrin (organo-chloride-OC)	0.79 ppb
	Water	At intake direct from the lake, field 90s	Dieldrin (OC)	0.33 ppb
	Water	At intake direct from the lake, field 90s	O'P'DDT (OC)	0.08 ppb
	Water	Puddles of standing water, field 50s	Aldrin (OC)	0.87 ppb
	Water	Puddles of standing water, field 90s	Aldrin (OC)	0.87 ppb
			P'P'DDE (OC)	0.30 ppb
Flamingo	Water	In sump	Permethrin (pyrethroid – P)	0.95 ppm
	Water	~70 m from sump	P'P'DDT (OC)	0.21 ppm
	Water	~70 m from sump	Permethrin (P)	0.44 ppm
	Surface soil	~200 m from sump	P'P'DDT (OC)	0.15 ppm
	Surface soil	~200 m from sump	Fenvalerate (P)	0.15 ppm
	Surface soil	~200 m from sump	Cypermethrin (P)	0.39 ppm
	Soils 2–4" deep	~200 m from sump	Fenvalerate (P)	0.09 ppm
		~200 m from sump	Cypermethrin (P)	0.79 ppm

Organo-chlorines (OC) in water would be taken up by aquatic animals and deposited in the adipose tissues. Potential danger: Biomagnification. The species of animals at the top of the food chain may be adversely affected (e.g. bird eggshell thinning etc). Crop uptake of soil residues of organochlorines is extremely low.

Pyrethroids (P). These pesticides are biodegradable in the environment. The level of the pesticides detected in water and soil is too low to cause any concern.

The work on soil and water sampling in and around Lake Naivasha is still going on.

Reclamation of swamps for irrigated agriculture enhances utilization of lake waters. Additionally, the trend by illegal fishermen to burn fringing papyrus from fear of hiding hippos and buffaloes results in the re-release of bioaccumulated toxins into the lake in the form of ash.

Finally, the rapid expansion of the tourist industry around Naivasha may outstrip the provisions of infrastructural facilities such as sewage disposal and also cause disturbance to natural breeding places and the fragile lake ecosystem itself.

EFFORTS TO MANAGE LAKE NAIVASHA'S SUSTAINABILITY

Lake Naivasha provides a good example of community involvement in the management of a tropical African lake under pressure from a variety of interests, some conflicting. This has been reflected in the significant efforts of the LNROA over many years towards the sustainable utilization of the lake.

The LNROA draws its membership from all those who own land contiguous to the lake. It began in 1929, and in 1931 signed an undertaking with the government in which it was agreed that all land that was formerly part of the bed of Lake Naivasha (all of the land below the 1906 lake level of 1893.3 m above sea-level) was to be used by the Riparian land owners as they saw fit, providing that no permanent structure was erected and no claims made against the government should the water rise above land developments. The Association was also given the authority to settle Riparian land disputes. Its activities over recent years have centred on the preservation of a clean, pollution-free body of water, and in supporting attempts to improve the aesthetic quality of the lake and to conserve the ecosystem and its biodiversity in the face of the various socio-economic activities both around and within the lake.

In its endeavour to protect the lake environment, through its members the Association adopted a voluntary code of practice, this includes support for drip irrigation as opposed to overhead irrigation, the banning of attempts to reclaim extra land from the lake for cultivation, the leaving of at least a 50 m buffer zone of natural vegetation between the open lake and cultivated land, and the protection of fringing papyrus.

The Association has developed a three phase environmental impact study of recent developments round Lake Naivasha. Phase I is designed to collect all available research information on the lake; phase II is the preparation of a management plan for the lake ecosystem and its catchment area; and phase III is the implementation of the management plan and consolidation of the monitoring unit.

Phases I and II have been successfully accomplished by the LNROA, and phase III was due to take effect from July 1995. However, this was deferred indefinitely, following criticisms and contoversies from other parties. The LNROA, on the other hand, believed that the management plan, if implemented, would ensure that the quantity and quality of lake water would be maintained for as long as possible for future generations, while guaranteeing currently sustainable socio-economic development around the lake. In effect, the management plan provides a framework for moderating human activities in the lake's ecosystem through the voluntary adoption of sustainable wise-use principles to ensure conservation. This is premised on the fact that the lake's capacity is not infinite and needs to be exploited rationally. There is a feeling the lake cannot sustain further development on the scale witnessed over the past 10–15 years. The management plan would therefore allow for sustainable development of the Naivasha township, the horticultural industry and geothermal power.

THE MANAGEMENT PLAN

Utilization of lake water on a sustainable basis

Conservation measures include control of expansion of water abstraction though the licensing process, instituting metering for water abstraction, reviewing water permits and establishing current level and efficiency of water usage.

Habitat management and conservation of biodiversity

Proposed actions include restoration and permission of the papyrus fringe to grow naturally around the lake (because of its water purifying effect and as a habitat for wildlife), thus creating a buffer zone of at least 50 m from the land edge of the papyrus fringe. Further actions include the use of natural vegetation, monitoring growth, spread and control of floating weeds, promoting measures to prevent damage to papyrus and buffer zones, ensuring conservation of catchment area and rivers, protecting sensitive areas of the habitat (especially the breeding, feeding and resting sites of fish and birds), conducting regular waterfowl census, monitoring and collecting accurate data on commercial fish catches and maximum sustainable yield, carrying out environmental impact assessments on any proposed new species introductions, and monitoring of the the compositions and abundance of submerged vegetation in the lake.

Tourism and recreation

The plan seeks to oversee monitoring of the impacts on the lake and its environment of tourists and sportfishing, the improvement of tourist infrastructures and the promotion of awareness among tourists of the plan.

Pollution control

The plan advocates monitoring the use of agrochemicals, and studies of their life span, storage, use and appropriateness, the monitoring of water quality in the lake, inflow rivers and surrounding boreholes, the promotion of wastewater management strategies (e.g. storage ponds, constructed wetlands), the regulation of the use and sites of septic tanks around the lake, and the monitoring of the disposal of industrial effluents and municipal sewage.

Research needs and prioritization

Research programmes should be prioritized according to their relevance to the sustainable utilization of the lake. In this way, the results of such programmes will help close information gaps and in so doing strengthen the management plan. Priority areas include research on lake water balance, food chains, fishery resources, and the impact of socio-economic activities on biological resources, both within the catchment and the lake.

Awareness creation and information

This would be aimed at promoting an understanding of the management plan and its objectives by all concerned. It would be achieved by establishing a data information centre, mounting awareness campaigns in schools and for local and central government, promulgating the management plan, and inviting input and promoting awareness and a sense of participation in the catchment community.

Lake monitoring and evaluation programme

This will cover physico-chemical and socio-economic parameters. Consequently it will provide information that will establish trends and allow forecasting and aid in understanding the lake ecosystem and water budget and how these are affected by environmental factors and human activities.

Lake management committee

The LNROA proposes to form a community-based management committee. This will implement and interpret policy guidelines. Its membership will consist of a majority of elected LNROA members, at least one of whom will be a member of the National Wetlands Standing Committee of the government and will include representatives from agriculture/horticulture interests, the Naivasha Municipal Council, the District Officer, the District Environment Officer, the Kenya Wildlife Service and IUCN/Ramsar.

DISCUSSION

The central question that is yet to be satisfactorily answered is just how much water can be safely extracted without seriously upsetting the water balance? This is a key issue in the sustainable utilization of the lake's water. The determination of an accurate water balance is made difficult partly by a lack of adequate routine water monitoring data. River discharge into the lake has been estimated using water discharge data from four river gauging stations: two on the Malewa River and one each on the Turasha and Gilgil rivers. However, none of these stations provides uninterrupted records. This is a matter that should be addressed seriously. Current knowledge suggests that water extraction has exceeded replenishment in drier years and available evidence suggests that the lake could be heading towards yet another major dry phase. This emphasizes the need for a management plan and the need for other comprehensive efforts to be put in place as soon as possible to enable the valuable lake resources to survive as long as possible.

The Kenya Wildlife Service (KWS), as the custodian of the Ramsar Convention in Kenya, has a key role to play, particularly in the formulation of the Lake Naivasha management plan together with LNROA and IUCN/Ramsar. Other bodies with interests in the lake include local government agencies at provincial, district and municipal council levels, national bodies (e.g. the Presidential Commission on Soil Conservation and Afforestation [PCSCA], the National Environment Secretariat [NES]). Each of these is expected to play its proper role in the conservation of the lake and its catchment areas.

The eco-technological approach is also now being seriously considered as one way of conserving lake water quality, by using existing wetland vegetation to purify urban effluents and by re-creating continuous buffer zones around the lake margins. In this context, the use of constructed *Eichhornia* and papyrus ponds to purify further effluents from the Naivasha township sewage is contemplated. Note the need to establish a programme of education on environmental and water conservation needs and their scientific basis for administrators, farmers, schools and the general public. Environmental education is expected to provide the recipients with the necessary knowledge, values, attitudes and commitment to participate both individually and collectively to help solve the environmental problems of the lake.

The current lack of consolidated environmental legislation in Kenya renders the coordination and management of environmental conservation and protection for sustainable utilization of natural resources weak. Different institutions generally work in isolation and often create conflicting policies and programmes. Existing legislation which touches on environmental issues pertaining to conservation of natural resources and pollution control is embodied in different Acts of Parliament, such as the Water Act Cap 372, Agriculture Act Cap 318, Forest Act Cap 385, Land Planning Act Cap 303 and Public Health Act Cap 242.

Fortunately, efforts continue on the Environmental Management and Co-ordination Bill, 1995. Once enacted, this will provide for the establishment of an appropriate legal and institutional framework for the management of the environment and natural resources. The need for improved legal and administrative co-ordination of diverse sectoral initiatives is recognized as a prerequisite to improve the national capacity for the management of the environment and natural resources.

The Bill proposes the establishment of a National Environment Management Authority, headed by a Director General to be responsible for the administration of the Act. There is a provision for the protection of rivers, lakes and wetlands, and even the declaration of a lake shore, wetland, coastal zone or river bank as a protected area, at the discretion of the Director General after considering certain inherent factors. This provides hope for the future of Lake Naivasha.

Conflicts that have arisen over the implementation of the LNROA-base Lake Naivasha management plan are partly a result of over-riding socio-economic interests opposed to conservation. The Horticultural Crop Development Authority (HCDA) claims that the plan will slow down development, affect food production, and scare investors. Consequently, there will be a loss of jobs. This demonstrates that the sustainable use of the lake requires a clear scientific understanding of its resource base and its fragility. This understanding will enable support for the management plan which should be implemented by consent among potentially conflicting users. Despite difficulties, the LNROA has an opportunity to lead the rest of Africa with the sustainable management and utilization of a tropical lake, Lake Naivasha, Kenya.

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