Lakes Baringo and Naivasha: Endorheic Freshwater Lakes of the Rift Valley (Kenya)

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Contents

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Introduction

Lakes Baringo and Naivasha are among the Great Rift Valley lakes (Fig. 1) that were formed about 25 million years ago by violent separation of two of the earth's continental plates floating on the molten magma of its core. In addition to the lakes' high biodiversity, they provide water to the local communities for domestic, irrigation, and industrial purposes. Fish in these lakes contribute to the diet of the local communities and are a source of income. Due to their unique scenery and biodiversity, the lakes are destinations for both local and international tourists. The lakes are however threatened by anthropological activities, especially water diversion and pollution. Investments around these lakes need to be balanced against the threats to biodiversity and the human population.

Lake Baringo

Lake Baringo is a freshwater lake in the eastern arm of Kenya's Great Rift Valley. Located between 0°30′–0°45′N and 36°00′–36°10′ E, the lake lies approximately 60 km north of the equator at an altitude of 975 m asl (Kâllqvist 1987) (Fig. 2). The lake has surface and catchment areas of approximately 130 km^2 and 6,820 km^2, respectively, and a mean and maximum depth of 5.9 m and approximately 10 m, respectively, at high water levels (Omondi et al. 2014). Lake Baringo waters remain fresh despite its shallow depth, a high net evaporation that characterizes the rift floor, and absence of a surface outlet. Recent hydrogeological evidence confirms that some lake water is lost by underground seepage through the fractured lake floor (Onyando et al. 2005).

The climate of the area is arid to semiarid with dry and wet seasons that are unpredictable and irregular. The dry season runs from September to February, while the rainy season is between March and August. Mean annual rainfall ranges from about 600 mm on the east and south of the lake to 1500 mm on the western escarpment of the Rift Valley. The lake is fed by perennial rivers Molo and Perkerra and seasonal rivers Ol Arabel, Makutan, Endao, and Chemeron (Fig. 2). Damming and abstraction of water from some of these rivers have reduced the amount of water reaching the lake. Lake Baringo experiences very high annual evaporation rates of 1650–2300 mm (Odada et al. 2006) and its persistence depends on the inflows from rivers originating from the hilly basin.

Geochemistry

The history of water quality measurements from Lake Baringo reveals that the geochemistry is greatly influenced by the rainfall patterns and the high evaporation rate (Omondi et al. 2014). The decreasing trend of water transparency of Lake Baringo has been attributed to suspended solids brought into the lake from the catchment and resuspension of sediments by wind action (Wahlberg et al. 2003).

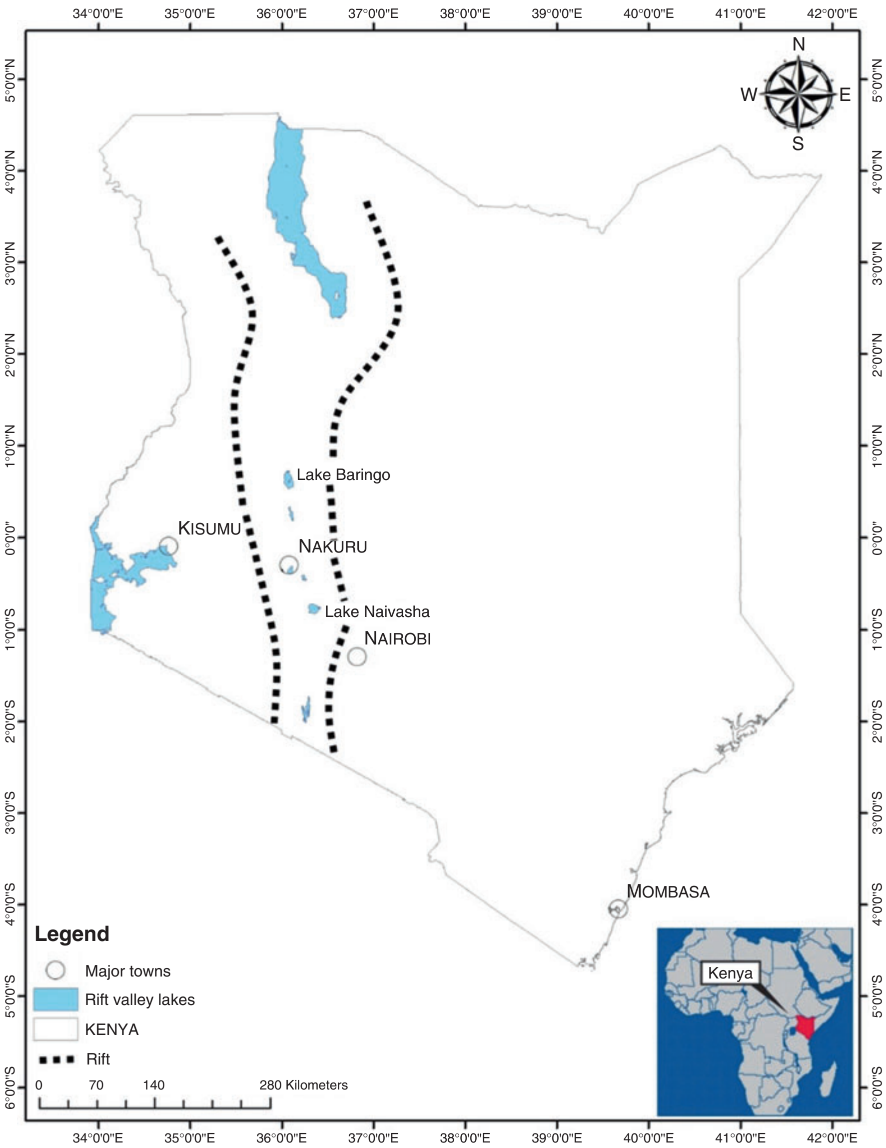

Fig. 1 Map showing the location of lakes Baringo and Naivasha, Kenya

The lowest Secchi depth of 8 cm was recorded in 1987 (Kâllqvist 1987); however, recent data showed that this had risen to 25.9 cm and this was attributed to the general rise of water levels of Rift Valley lakes (Omondi et al. 2014). The lake has a mean conductivity of 577.7 μS cm^{-1}, while total nitrogen and total phosphorus have mean concentrations of 1163.6 and 93.5 μg l^{-1}, respectively.

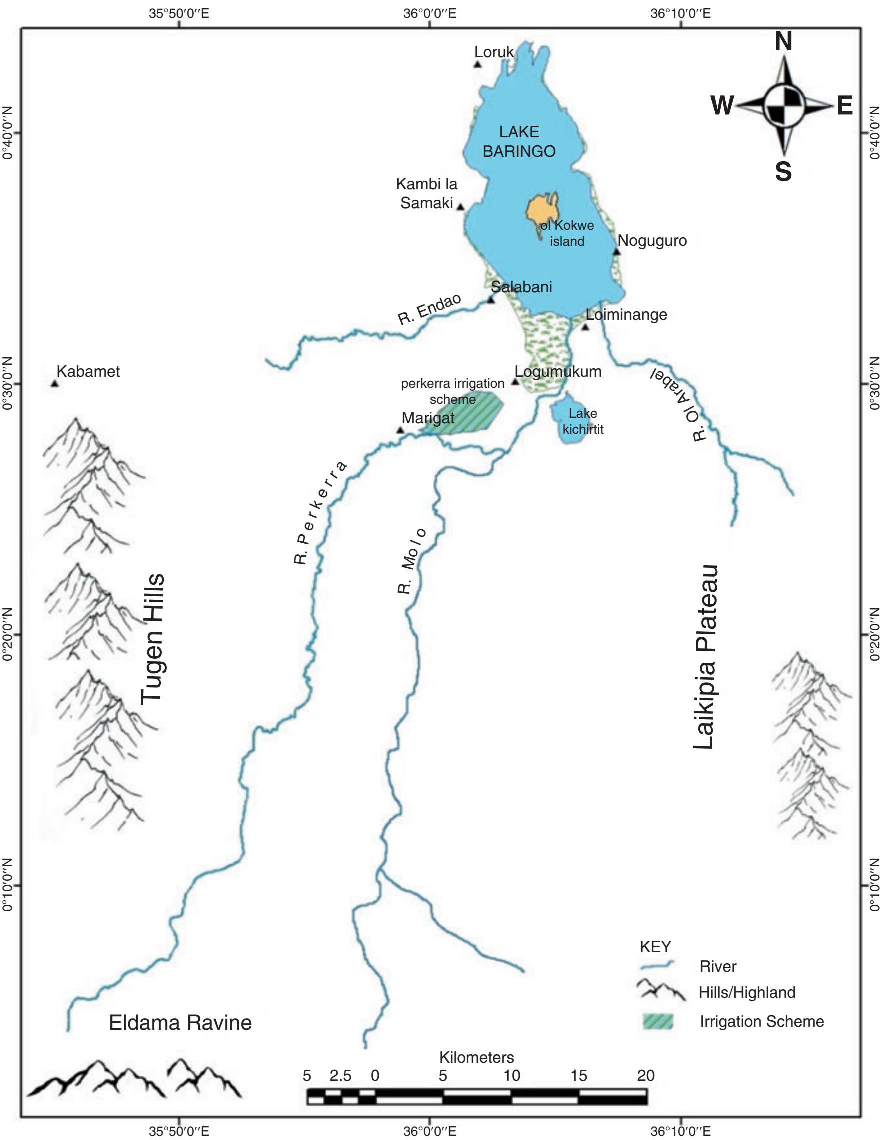

Fig. 2 Map of Lake Baringo catchment

Wetland Ecosystems and Biodiversity

Lake Baringo was designated as a Wetland of International Importance under the Ramsar Convention on Wetlands on 10 January 2002. The lake is shallow and is virtually a wetland in its entirety, with submerged *Ceratophyllum demersum*

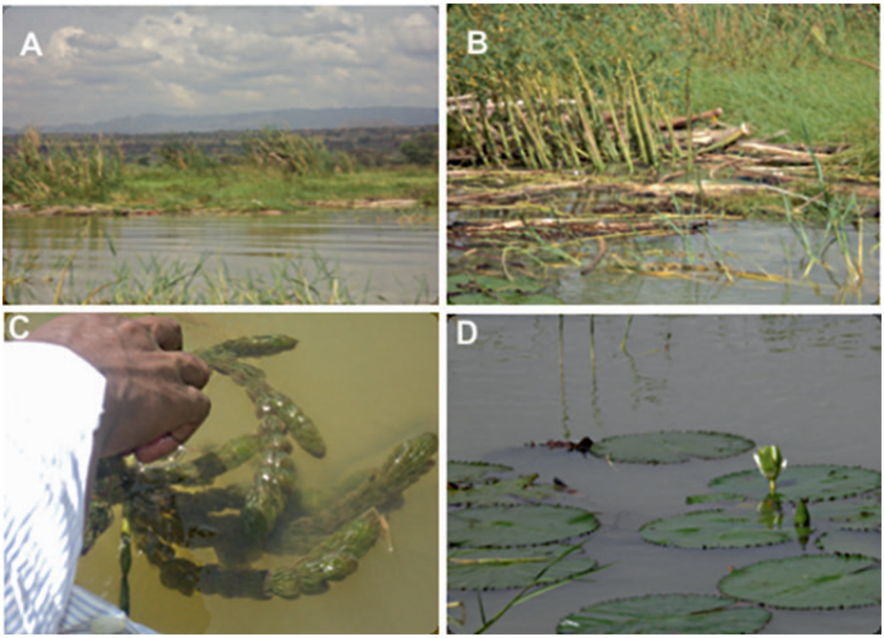

Fig. 3 Some common macrophytes in Lake Baringo. (**a**) *Paspalidium geminatum* and *Typha domingensis*, (**b**) *Aeschynomene pfundii*, (**c**) *Ceratophyllum demersum*, and (**d**) *Nymphaea lotus* (Photo credit: R. Omondi © Rights remain with the author)

occurring in the deepest portions of the lake. However, larger marshes are found at the river mouths to the south and east. The southern marsh, which is the most expansive, is dominated by a member of the Poaceae, *Paspalidium geminatum*, while the southeastern marsh is dominated by *Typha domingensis*. The northeastern marsh is dominated by *Aeschynomene pfundii*, while there is a low population of *P. geminatum* in the eastern bay. Other macrophytes in the lake include the free-floating *Azolla pinnata*, *Azolla nilotica*, and *Pistia stratiotes*, submerged *Ceratophyllum demersum* and *Najas horrida*, floating-leaved *Nymphaea lotus*, and emergent *Aeschynomene pfundii* (Fig. 3). During high water levels, a large swamp forms at the northeastern area within dry *Acacia tortilis* trees.

Phytoplankton in Lake Baringo is dominated by blue-green algae (Oduor 2000), zooplankton by copepods (Omondi et al. 2011), and macroinvertebrates by Mollusca (Owili et al. 2008). Lake Baringo has large populations of crocodiles (*Crocodylus niloticus)*, hippopotamus (*Hippopotamus amphibious*), lizards (*Varanus* spp.), and some species of frogs (*Rana* spp.).

The lake is an Important Bird Area (IBA) with over 470 species of birds including globally important species such as lesser kestrel (*Falco naumanni*), lesser flamingo (*Phoeniconaias minor*), Madagascar squacco heron (*Ardeola ralloides*), and pallid harrier (*Circus macrourus*). A number of regionally threatened species, great crested grebe (*Podiceps cristatus*), African darter (*Anhinga rufa*), great egret (*Ardea alba*), saddle-billed stork (*Ephippiorhynchus senegalensis*), white-backed duck (*Thalassornis leuconotus*), white-headed vulture (*Trigonoceps occipitalis*), martial eagle (*Polemaetus bellicosus*), Baillon's crake (*Porzana pusilla*), and African skimmer (*Rynchops flavirostris*), are also found in the lake. These are classified as least concern to near threatened species. In addition, the lake hosts over 20,000 water birds throughout the year including Palearctic migrants. Ol Kokwe Island is an important breeding site for Goliath herons (*Ardea goliath*).

The fish community of Lake Baringo comprises seven species (Odada et al. 2006). These include *Aplocheliches* sp., *Barbus intermedius australis*, *B. lineomaculatus*, *Clarias gariepinus*, *Labeo cylindricus*, *Oreochromis niloticus baringoensis*, and *Protopterus aethiopicus* (Britton et al. 2006). Of these, four species, namely, *B. i. australis*, *C. gariepinus*, *O. n. baringoensis*, and *P. aethiopicus*, are economically exploited. The fishery of the lake was once dominated by the endemic *O. n. baringoensis* but is presently dominated by *P. aethiopicus* introduced in 1975.

Ecosystem Services

The human communities around the lake include Pokot to the north, Ilchamus to the south, and Tugen to the east. The area is essentially a rangeland and apart from the scattered isolated pockets of dry subsistence agriculture and small irrigation farming around Marigat; the major socioeconomic activities undertaken by the communities include mostly livestock husbandry and beekeeping. Lake Baringo is an important water body nationally and internationally. The lake is of great benefit to the communities living in the basin for domestic use and for watering livestock. Fish from the lake provides food and a source income for the local communities. Lake water is used for irrigation agriculture, around Marigat, and for production of food crops like watermelon, onions, tomatoes, and maize among others. Lake Baringo is known to attract both local and international tourists for its biodiversity and boat riding. Tourism-related activities such as the expansion in hotel industry and related services provide employment and income to the local community.

Lake Naivasha

Lake Naivasha is situated between 0°40′–0° 50′and 36°15′–36°25′ E at an altitude of 1890 m above sea level (Sikes 1936). The lake has a surface area of approximately 130 km^2, a catchment area of 3200 km^2, and a mean depth of 4.1 m (Mugo 2010) (Fig. 4). The lake's surface inflows come via rivers Gilgil and Malewa which are perennial and Karati which is seasonal. River Malewa contributes 90 % of the water discharged into the lake. The waters of Lake Naivasha remain fresh despite the lack of a surface outlet, shallow depth, and high net evaporation that characterizes other lakes on the rift floor. Some waters from the lakes are lost by underground seepage through the fractured lake floor (Clark et al. 1990).

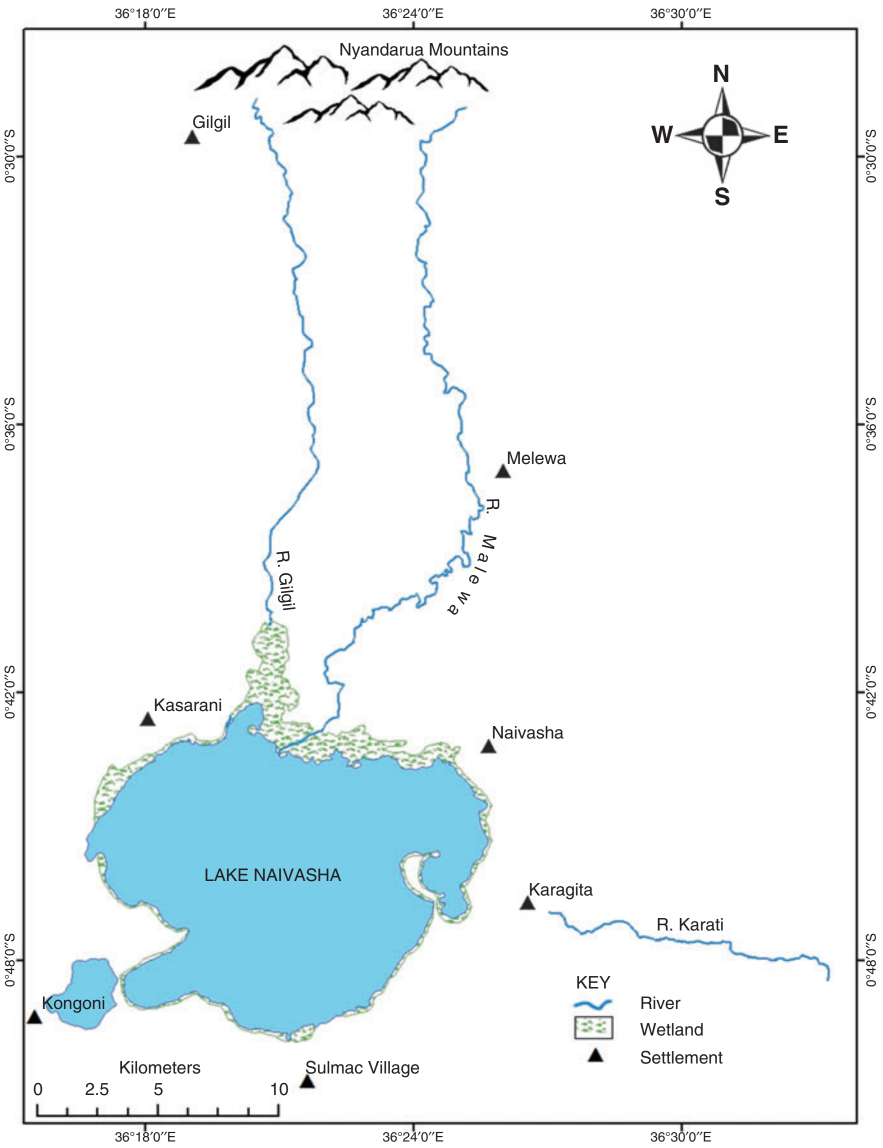

Fig. 4 Map of Lake Naivasha catchment

Mean air temperatures are moderate with monthly means varying from 15.9 °C to 18.5 °C. The combination of low temperatures, low relative humidity, and low rainfall makes January and February the months with the highest evaporation rates (Gaudet and Melack 1981). Rainfall is bimodal occurring in April–July and October–November for the long and short rains, respectively. Direct precipitation on the lake is minimal although occasional torrential rains are witnessed. Irregularity of the rainfall pattern is also quite common. Rainfall on the surrounding highlands quickly percolates into the ground and from there rapidly seeps through into the lake (Gaudet and Melack 1981). Rainfall in the basin is highest in the Nyandarua Mountains (1400–1600 mm/year^{-1}), while the lake which is located in the rain shadow receives between 500 and 700 mm/year^{-1} (Richardson and Richardson 1972).

Geochemistry

Lake Naivasha's water level has experienced great fluctuations sometimes as much as 7 m over many years attributed to large-scale climatic influence (Vincent et al. 1979; Becht and Harper 2002). These fluctuations have been correlated with wide variation in the geochemistry of the water. Earlier studies reported on the mean ranges for various parameters: total nitrogen values (300–675 μg l^{-1}), total phosphorus (50–200 μg l^{-1}), conductivity (250–400 μS cm^{-1}), and Secchi depth (50–250 cm) (Litterick et al. 1979; Gaudet 1981; Njuguna 1982; Kitaka 1991). Recent investigations, however, report mean water and Secchi depths of 4.1 m and 48 cm, respectively, a mean conductivity of 259.2 μS cm^{-1}, and mean concentrations of total nitrogen and total phosphorous of 304 and 42.7 μg l^{-1}, respectively (Mugo 2010).

Wetland Ecosystem and Biodiversity

Lake Naivasha was designated in April 1995 as Kenya's second Wetland of International Importance under the Ramsar Convention on Wetlands (LNRA 1999). The wetland consists of the main lake covered by a fringing vegetation of *Cyperus papyrus* and other macrophytes. Macrophytes in the lake are diverse and include emergents dominated by *Cyperus papyrus*, free-floating species dominated by nonnative *Salvinia molesta* and *Eichhornia crassipes*, floating-leaved *Nymphaea caerulea*, and submerged angiosperms consisting of three species of *Potamogeton* – *P. pectinatus*, *P. schweinfurthii*, and *P. octandrus*, together with *Najas pectinata* (Harper et al. 1995). Mats of floating papyrus (*Cyperus papyrus*), water hyacinth (*Eichhornia crassipes*), and *Salvinia molesta* are currently the most notable features in the lake.

The phytoplankton community in Lake Naivasha is diverse with 143 described taxa but dominated by Cyanophyta (blue-green) and Bacillariophyta (diatoms) (Kalff and Watson 1986). The main zooplankton groups include Copepoda, Cladocera, and Rotifera. Copepods include the genera *Thermocyclops* and *Mesocyclops*; cladocerans reported from the lake are *Diaphanosoma*, *Simocephalus*, *Daphnia*, and *Moina*, while rotifers are *Brachionus*, *Hexarthra*, *Keratella*, *Filinia*, and *Lecane* (Uku and Mavuti 1994).

Terrestrial trees within the vicinity of Lake Naivasha consist predominantly of *Acacia xanthophloea*, which is gradually being cleared and the area converted to riparian cultivation, grasslands for intensive livestock management, and irrigated production of horticultural crops (Watson and Parker 1969).

The avifauna of Lake Naivasha is diverse, with approximately 80 resident and migratory water bird species, with large populations of the African fish eagle *Haliaeetus vocifer* and red-knobbed coot. The great crested grebe, maccoa duck, African darter, great egret, saddle-billed stork, white-backed duck, Baillon's crake, and African skimmer are all found in the Lake Naivasha region.

Lake Naivasha has historically had multiple introductions and reintroductions of various fish species (Britton et al. 2006; Ojuok et al. 2007). Introductions were purportedly desired to provide food sources and sport fishes and for mosquito control. Introduced fish species which are still being landed on the shores of Lake Naivasha include the largemouth bass (*Micropterus salmoides*), redbelly tilapia (*Tilapia zillii*), blue spotted tilapia (*Oreochromis leucostictus*), Nile tilapia (*O. niloticus*), and common carp (*Cyprinus carpio*). Other species which have been recorded but not of commercial importance include rainbow trout (*Oncorhynchus mykiss*), mosquito fish (*Gambusia* sp.), guppy (*Poecilia reticulata*), and *Barbus amphigramma*. A crustacean, Louisiana red swamp crayfish (*Procambarus clarkii*), was introduced in 1970 as food for *Micropterus salmoides*.

Lake Naivasha provides natural habitat to several resident populations of large mammals such as zebras *Equus quagga*, impalas *Aepyceros melampus*, wildebeests *Connochaetes taurinus*, and giraffes *Giraffa camelopardalis*. The lake has the largest metapopulation (approximately 600–700) of *Hippopotamus amphibious* in the Kenyan Rift Valley. The littoral zones provide crucial habitat for fish breeding and foraging by wildlife, which include hippo, waterbuck, and buffalo.

Ecosystem Services

The area surrounding the lake has a cosmopolitan population made up of various ethnic groups in Kenya. This population has continued to increase rapidly since the 1990s associated with the increase of the acreage under horticulture and floriculture products which has provided ready employment for the people. The majority of the local population is made up of Kikuyu on the lake's eastern and northeastern side who are mostly involved in farming. The pastoralist and agropastoralist Maasai community has settled toward the southern side. The majority of the workforce in the flower farms and fish and hotel industry includes the Luo, Luhya, and Kikuyu communities.

Lake Naivasha ecosystem is very rich in biodiversity and provides habitat for a wide range of terrestrial flora and fauna and aquatic organisms. Together these play an important role in sustaining ecosystem services and supporting anthropogenic activities. The beautiful sceneries of the lake and the abundant hippo and birds are popular with nature-loving tourists.

The fringing vegetation acts as a filter to organic and inorganic nutrients/material before they enter the lake. The lake which has a large surface area is an important storage facility for water. This water is utilized by various stakeholders in farming, industrial, and domestic use. (Harper et al. 1990, 1995).

Threats and Future Challenge for Lakes Baringo and Naivasha

Lakes Baringo and Naivasha are faced with numerous threats and challenges including an increasing human population, deforestation and erosion, pollution, impacts associated with tourism, human–wildlife conflict, impact of invasive species, and climate change. Although the current population of communities immediately adjacent to the lakes is 150,000, the population in the catchment areas is 900,000 people and has a 6.5 %/year^{-1} population growth rate which is higher than the national rate of 3.5 %/year^{-1} (Kenya Republic, 2010). The high human population growth rate in these riparian zones has resulted in an increasing demand for land dedicated to human settlement and agricultural. These trends related to socioeconomic demands in an area well known for its wildlife population continue to cause human–wildlife conflicts resulting in the loss of human lives and property. Poaching is an illegal activity and court battles are to be expected; alternatively human–wildlife conflicts can result in misunderstandings between land owners/users and resource managers. The increasing human populations have also led to the unregulated extraction of forest resources for medicinal purposes, fuelwood, charcoal burning, and timber and the destruction of riparian forest, coupled with foraging by livestock; these activities are severely damaging to the catchment area and ultimately lead to soil erosion and sedimentation in the lakes' riparian areas.

Other agricultural-related activities (e.g., floral industries) and urban centers are major sources of chemicals (e.g., fertilizers, pesticides, herbicides) and general wastes that pollute these freshwater resources. Periodic algal blooms and fish kills in Lake Naivasha have been attributed to these pollutants.

Recent attempts to increase aquaculture production in Kenya may result in the unintentional introduction of invasive species. Due to a lack of adequate local supply of fingerlings, there has been uncontrolled transportation of fingerlings from different regions for stocking fish in the two lake basins. Introduction of new species to these water bodies may lead to disruption of food webs. Such transfers may also result in the introduction of aquatic macrophytes, especially water hyacinth, which to date has not been reported in Lake Baringo. In addition to macrophytes, there is also the danger of increased spread of the invasive shrub *Prosopis juliflora*, from its current locations around Lake Baringo. Although there are economic gains from tourism, the industry poses some threats to the communities around lakes Baringo and Naivasha. Tourism encourages clothing styles and other practices which are inconsistent with the cultural norms of the local communities. Lakes Naivasha and Baringo are situated in semiarid areas, which put them at risk of climate change phenomenon. The increased variability on local temperature, rainfall, and wind patterns, among other climate change factors, could negatively impact lakes' morphology, hydrology, biodiversity, and socioeconomic aspects. Recent rise in the lake levels in the two lakes resulted in the destruction of infrastructures and economic losses in the riparian zones.

Cross-References

► Lake Turkana, the World's Largest Permanent Desert Lake
► Soda Lakes of the Rift Valley, Kenya
► Tana River Delta Wetlands, Kenya

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