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A first limnological description of Lake Kichiritith, Kenya: a possible reference site for the freshwater lakes of the Gregory Rift Valley

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We provide a first limnological description of Lake Kichiritith, situated in the eastern Rift Valley of Kenya. Kichiritith is located in a swampy area between lakes Bogoria and Baringo; difficulties of access have meant that it is apparently undisturbed. In this, it is different from the two most important freshwater lakes of the eastern Rift Valley: Lake Baringo, situated 8 km north of Kichiritith, and Lake Naivasha. These larger bodies of water are beset by severe problems, including the introduction of alien species (Naivasha), high suspended sediment load (Baringo), and declining fisheries (both). The contrast between lakes Baringo and Kichiritith is dramatic. The latter is mildly eutrophic, similar to Lake Naivasha, with a rich and varied planktonic flora and fauna. Lake Baringo is strongly eutrophic and turbid, with an impoverished planktonic ecosystem. We suggest that Lake Kichiritith may be used as a reference site, providing background conditions for assessing the original state of Lake Baringo and, by extension, of other freshwater bodies of the eastern Rift Valley. If protected, Lake Kichiritith can be a standard against which the restoration or continuing degradation of Baringo and Naivasha can be assessed.

Introduction

We describe here a small lake named Kichiritith, situated 8 km south of Lake Baringo in the eastern (Gregory) Rift Valley of Kenya, between it and the alkaline Lake Bogoria (Fig. 1). The lake is of recent origin, appearing on the floodplain of the River Molo after the El Niño rains of 1997. It was reconnoitered in early 2000 (D. Harper, pers obs.), and the lake's shore was subsequently visited in 2001, when a first bird list for the area was established.[1] Kichiritith is located in a swampy area and difficulties of access mean that its limnology has not been investigated. It still appears to be undisturbed and pristine. In this, it is different from lakes Baringo and Naivasha, which are the two most important freshwater lakes of the eastern Rift Valley. These two bodies of water are beset by various problems, the main ones being the introduction of alien species (Naivasha) and high suspended sediment loads (Baringo); both have experienced fluctuations in water levels, abstraction of water for irrigation; deterioration of water quality with loss of transparency and decline of their fisheries.[2–5] The characteristics of the three lakes are summarized in Table 1.

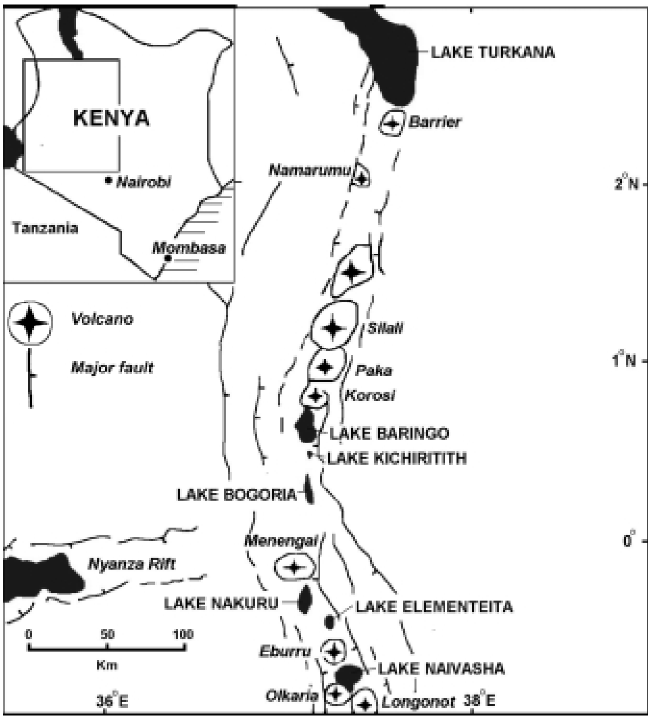

Fig. 1. Map of the Eastern Gregory Rift in Kenya, showing the locations of lakes Kichiritith, Baringo and Naivasha, other Rift Valley lakes, and evidence of tectonic activity. Modified from Clarke *et al.*[14]

Lake Kichiritith was visited during a scientific expedition to Lake Baringo sponsored by the Earthwatch Institute.[6] Lake Baringo, like Naivasha, is a RAMSAR site, famous for its high bird diversity, and hippopotamus and crocodile populations. The lake once supported a substantial fishery, and it also represents a precious source of fresh water in an otherwise dry area. However, Lake Baringo has changed fundamentally in recent

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Table 1. Summary of the physical and geographical characteristics of lakes Baringo, Naivasha and Kichiritith.

Lake:	Baringo	Naivasha	Kichiritith
Approximate size (km^2)	60	100	3
Altitude (m a.s.l.)	975	1890	>975
Rainfall (mm yr^{-1})	600	650	600
Hydrology	Surface and groundwater inflow; groundwater outflow	Surface and groundwater inflow; groundwater outflow	Surface inflow and outlow

Table 2. Summary of the analytical methods used in the water quality investigations.

Parameter	Method
Secchi depth	25-cm-diameter Secchi disc
pH and conductivity	Hach (Ames, Iowa), calibrated hand-held instruments
Suspended solids	Hach DR 2000 spectrophotometer, method 8006, extinction at 810 nm
Chlorophyll *a*	90% hot ethanol extraction on filtrate from Whatman GFC 0.45-μm paper measured on Hach DR 2000 spectrometer at 665 nm against 750 nm
Alkalinity	Titration using Hach Method 8203 with digital titrator to end points with phenolphthalein (phenolphthalein alkalinity) and bromocresol green–methyl red (total alkalinity) indicators
Orthophosphate	Molybdate blue reaction using Hach 'Phos Ver 3' with ascorbic acid, method 8048, absorbance at 890 nm on samples filtered through 0.45-μm Whatman GFC paper
Dissolved metals and metalloids in water (Baringo and Kichiritith only)	Sample first passed through a 0.45-μm filter and then acidified to pH 2, thereafter analysed by a combination of ICP-AES and ICP-MS at the Analytica laboratory, Luleå, Sweden

years; its ecosystem has become degraded and the fishery has collapsed. The deterioration is thought to be related to irrigation agriculture that reduces water inflow, and to excessive grazing by cattle and goats in the lake catchment, which has led to increased erosion of soils.[5] Baringo's water is now extremely turbid and the lake has become ever shallower in recent years.

In contrast to Baringo, Lake Kichiritith is protected on all sides by dense swamp vegetation (*Cyperus papyrus* and *Typha angustifolia*) and, as yet, only a few artisanal fishermen are using the lake. We believe, therefore, that Kichiritith provides contemporary evidence supporting the pre-1970s literature (e.g. ref. 7) of the near-pristine state of Rift Valley freshwater ecosystems, such as Baringo and Naivasha, before their present state of enrichment and overfishing. Here we compare the physico-chemical and biological conditions of Kichiritith, Baringo and Naivasha, in order to assess whether the first may provide a useful control against which the changes that have occurred in the others may be compared and assessed.

Materials and methods

Investigations were conducted in Lake Baringo between 5 and 16 October 2002, in Lake Kichiritith on 17 and 18 October 2002, and at Lake Naivasha in December 2001 and 2002. Water samples were collected from the open water of the lakes, at up to 90 sites in Lake Baringo, at three sites in Lake Kichiritith and five at Naivasha. Plankton was collected from the lake centres, concentrated through a 35-μm phytoplankton net, and identified under a microscope to taxonomic level. The analysis methods used are summarized in Table 2

Results and discussion

Water quality

The Rift Valley of Kenya has not experienced above-normal rain for the first two years of the 21st century. As a consequence, the three lakes have reached near-steady states under mean precipitation regimes, with little variation in water quality properties (Table 3). Highest pH and conductivity were shown in Baringo, which was also very turbid and with high phosphate levels, indicative of a severely eutrophic lake. The contrast with Lake Kichiritith was marked and limnological conditions there indicated only a mildly eutrophic lake. In the latter, the mean transparency in the open water was 26 cm, but in fringing lagoons, the lake bottom was clearly visible (indicating a transparency of more than 100 cm). This contrast in transparency between open water and lagoons represents conditions similar to those of Lake Naivasha a decade ago.[8,9]

The concentrations of dissolved metals and metalloids were similar in both lakes measured. The levels are in line with worldwide background levels, below existing quality standards for the protection of aquatic fauna (*cf.* refs 10, 11).

Table 3. Summary of the physico-chemical parameters (mean ± s.d.) measured in the three lakes.

Lake: Parameter	Baringo (*n*)	Naivasha (*n*)	Kichiritith (*n*)
Secchi depth (cm)	2.2 ± 0.34 (30)	31 ± 2.5 (20)	26 ± 1.7 (3)
pH	8.9 ± 0.21 (46)	8.7 ± 0.8 (20)	7.4 ± 0.19 (3)
Conductivity (μS cm^{-1})	1760 ± 140 (90)	378 ± 4 (20)	330 ± 26 (6)
Suspended solids (mg l^{-1})	760 ± 220 (34)	–	52 ± 0.0 (3)
Alkalinity (mg l^{-1} $CaCO_3$)	670 ± 91 (45)	162 ± 61 (10)	140 ± 4.0 (4)
Orthophosphate (μg l^{-1} P)	1200 ± 240 (29)	250 ± 50 (10)	240 ± 20 (3)
Dissolved metals/metalloids (*n* = 1 in both lakes)			
Al (μg l^{-1})	6.7	–	14
As (μg l^{-1})	1.1	–	0.33
Cd (μg l^{-1})	<0.002	–	0.019
Cu (μg l^{-1})	1.2	–	0.75
Fe (mg l^{-1})	0.016	–	0.027
Hg (μg l^{-1})	0.0052	–	0.012
Mg (mg l^{-1})	12	–	3.2
Mn (μg l^{-1})	150	–	14
Pb (μg l^{-1})	0.71	–	0.51
Zn (μg l^{-1})	1.5	–	5.1

*Over the years 1997–99.[15]

Table 4. Chlorophyll *a* concentration (mean± s.d.), and major plankton taxa of the three lakes.

Lake:	Baringo	Naivasha	Kichiritith
Chlorophyll *a* (mg m^{-3}) (*n*)	74 ± 7 (78)	82 ± 12 (6)	71 ± 48 (2)
Plankton community			
Phytoplankton	*Microcystis* sp. (dominant)	*Scenedesmus* sp. (common) *Cosmarium* sp. (common) *Botryococcus* sp. (common) *Aulacosira* sp. (common) *Synedra* sp. (common) *Aphanocapsa* sp. (common) *Microcystis* sp. (common)	*Aulacosira* sp. (dominant) *Trachelomonas* sp. (abundant) *Euglena* sp. (common) *Phacus* sp. (common) *Stauratrum* sp. (common) *Microcystis* sp. (rare) *Pediastrum* sp. (rare) *Scenedesmus* sp. (rare)
Zooplankton	*Keratella* sp. (rare) Cladocera (rare) Copepoda (rare)	*Brachionus calciflorus* *Keratella cochlearis* (dominant) Diaphansoma *Daphnia* (common) Copepoda (common)	*Brachionus* (common) *Keratella* (common) Cladocera (rare) Copepoda (rare)

Key: dominant: >50 % of all individuals; abundant: 10–50%; common: 5–10%; rare: <5%.

Plankton

Algal chlorophyll *a* levels indicated similar biomass in all lakes (Table 4). The chlorophyll concentrations in Lake Baringo were as high as in the two other lakes, which is surprising, considering that Baringo was strongly turbid. Even in Kichiritith, the orthophosphate levels were well in excess of algal demand, suggesting that light is limiting algal abundance in all three systems. In Naivasha and Kichiritith, the light limitation may be due to self-shading by algal cells, whereas in Baringo the high sediment-driven turbidity further limited light transparency and allowed only buoyant colonies of *Microcystis* species to thrive. In contrast, phytoplankton species indicated a greater similarity between Kichiritith and Naivasha.

Baringo also supported limited zooplankton species, probably because of the restricted food, as both cyanobacteria and inorganic suspended solids offer little that is palatable. The contrast between the small lake and neighbouring Baringo confirmed that the latter's ecosystem is experiencing considerable stress.

The lagoons of Kichiritith supported a dense mat of aquatic plants, dominated by the blue water lily, *Nymphaea nouchallii* var. *caerulea,* and floating *Pistia stratiodes* with submerged macrophytes underneath. Such vegetation is rare in Lake Baringo, partly because of its highly turbid water and partly because of its higher conductivity. Lake Olodien, adjacent to Lake Naivasha and contiguous with it twenty years ago, has progressively become more saline; it now has a conductivity double that of Baringo and no submerged macrophytes. At the time its conductivity was similar to Baringo's today, it had an underwater flora limited to *Potamogeton pectinatus* (D. Harper, pers. obs.). Lake Naivasha formerly had an extensive aquatic plant community dominated on the water surface by *N. nouchallii* var. *caerulea* and underwater by *P. schweinfurthii* and *Naias horrida*;[12] since the late 1970s the entire community has been sporadic in its appearance, largely due to the grazing effect of the exotic omnivorous Louisiana crayfish, *Procambarus clarkii.*[13]

Conclusions

The contrast between the closely adjacent lakes Baringo and Kichiritith is very marked. The smaller has the characteristics of a mildly eutrophic lake, similar to that of Lake Naivasha. Lake Baringo, in contrast, is now a strongly eutrophic and turbid body of water with an impoverished planktonic flora and fauna, indicating an ecosystem which is experiencing severe environmental stress. The preliminary data reported here suggest that Lake Kichiritith may be used as a reference site, providing background conditions for assessing the original state of Lake Baringo and possibly, by extrapolation, of other freshwater bodies of the eastern Rift Valley. However, the data collected from Lake Kichiritith are relatively limited and further work is needed to document and understand the lake. Preliminary observations suggest that ecosystem parameters that need to be studied include the small lake's fish population, and its apparent rich bird life. Considering the dramatic, and often unwanted, changes that have occurred in other freshwater lakes of the Rift Valley, the future protection of Lake Kichiritith assumes considerable importance, and it may serve as a standard against which restoration or continuing degradation of Baringo can be assessed.

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