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Original Research Article

Analysis of some aspects of water quality of Lake Naivasha

James Last Keyombe[1]*, Edna Waithaka[2]
[1]Kenya Marine and Fisheries Research Institute, Turkana Research Station, P.O. Box 205 - 30500, Lodwar, Kenya
[2]Kenya Marine and Fisheries Research Institute, Naivasha Research Station, P.O. Box 837 - 20117, Naivasha, Kenya

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Abstract: In-depth analyses of physicochemical parameters and dissolved nutrients in Lake Naivasha was done during the dry (June 2014) and wet seasons (May and April 2016). A comparison of the results was made between the two seasons. Dissolved oxygen in Lake Naivasha was higher in comparison to other fresh water lakes within Kenya while relative stability was noted in the other physico-chemical parameters (pH, temperature and conductivity). Results also show that Lake Naivasha is phosphorus limited aquatic system with measurements ranging between 0.07 – 0.23 mg/l in March and 0.09 – 0.83 mg/l in April 2016. Nitrates ranged between 0.10 mg/l – 0.30 mg/l in March 2016 while in April no Nitrates were detected in the water samples. Sources of nutrient loading into the lake should be investigated and proper measure to be taken for sustainability of Lake Naivasha.

Key words: Physicochemical parameters, Phosphates, Nitrates

Introduction

Lake Naivasha ecosystem has received considerable studies relating to water quality, aquatic ecology, sedimentation and pollution (Harper *et al.,* 1990; Kitaka *et al.,* 2002; Hubble 2000; Harper *et al.,* 1995). The water quality of the lake has been considerably influenced by the high inputs of soluble materials from the human-induced activities in the surrounding and the catchment area (Kitaka *et al.,* 2002). Lake Naivasha basin's freshwater quality and quantity has been under increasing pressure due to lake water level fluctuations and increasing water demands from the fast-expanding agricultural activities around the lake (Hubble 2000). Anthropogenic activities on the lake's catchment provide both point and non-point source of nutrients to the water column. Changes in water quality characteristics have direct linkage to aquatic production. Rapid growth of human settlement around the lake and the associated urban waste disposal are potential sources of biological micro-contaminants in the lake water and could cause undesirable effects on the aquatic environment.

In natural un-disturbed environment, nutrient supply of any water body is derived from drainage of the catchment mainly through the surface runoff and storm flows, atmospheric input through direct rainfall on the water surface and internal cycling mainly from the sediment (Kalff, 1983). Dissolved phosphorus from the catchment remains in the lake water column joining the existing pool, but its resident time is very short as it's immediately incorporated into organic forms by algal and bacteria uptake (Kalff, 1983). Bacteria and algae exist in a mutually dependent steady state i.e. Bacteria have the ability to take up phosphorus faster than they can utilize it for growth, and secrete dissolved phosphate which is taken up slowly by algae (Kitaka *et al*, 2002). On the other hand, the algae secrete organic carbon which a bacterium utilizes. Phosphates can also be released by detritus during aerobic decomposition involving microbial oxidation of organic carbon sources at the bottom sediments in a lake. This process is temperature and pH dependent (Kitaka *et al*, 2002). Low dissolved oxygen levels consequently lead to an increase in the concentration of phosphates in an aquatic system (Kitaka *et al*, 2002).

Nitrogen introduction into aquatic systems can be through precipitation (Major source), nitrogen fixation both in the water and sediment and input from the surface and groundwater drainage. On the other hand, loss of nitrogen from aquatic systems occurs through effluent outflow from the basin, reduction of nitrates to nitrite to atmosphere through bacterial denitrification process and permanent sedimentation (Kitaka *et al*, 2002).

In natural aquatic systems, nitrate levels decrease with increase in depth. Depletion at the upper region is mainly by uptake by the phytoplankton (Talling and Lemoalle 1998). Availability of phytoplankton affects the oxygen concentration which in turn determines the number of nitrates available. Nitrates reduce towards bottom where there is low oxygen and eventually, conversion to nitrite and ammonium takes place (Talling and Lemoalle 1998).

Scientists from Kenya Marine and Fisheries Research Institute (KMFRI) Naivasha undertook an in-depth water quality study on Lake Naivasha on both the dry and wet seasons. Lake Naivasha ecosystem experiences

***Corresponding Author:**
James Last Keyombe,
Kenya Marine and Fisheries Research Institute,
Turkana Research Station,
P.O. Box 205 - 30500, Lodwar, Kenya.
E-mail: katalitsa@yahoo.com

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its rainy seasons and high water levels in the months of March-May and October-November. This study was done in the months of June 2014 (dry season) and March & April 2016 (Wet seasons). Data and information obtained was used to compare and update on the current status of nutrients in the lake. It will also be used to provide further management recommendations based on any recent changes that might have been observed.

Materials and Methods

Study area

Lake Naivasha is a shallow equatorial fresh water lake situated in the eastern rift valley of Kenya (0^o 46'S, and 36^o 20'E) at an altitude of about 1890 m above sea level (Mavuti and Harper, 2005). It covers a surface area varying between 120 Km^2 and 160 Km^2 depending on the dry and wet seasons, respectively with a mean depth varying between 4 m and 6 m (Hickley *et al.*, 2008). The lake is surrounded by a papyrus fringe and was adopted as a Ramsar site in 1995 (Harper *et al.*, 2011). There are three smaller lakes adjacent to the main lake which are; Oloidien, Sonachi and Crescent Crater. The main Lake Naivasha is a fresh water lake despite lacking any visible outlet and is therefore assumed to have an underground outflow (Gaudet & Melack, 1981). The lake is the major source of fresh water for the horticultural industry in the area. Apart from transient streams, the lake is fed by the perennial Malewa and Gilgil rivers with the former being the main one (Kitaka *et al.*, 2002). The mean temperature around Lake Naivasha is 25^{0}C with the maximum temperature being 30^{0}C. December to March are the hottest months and July the coldest with mean temperature of 23^0 C (Keriko *et al.*, 2003). The mean annual rainfall in the area is 650 mm (Ndungu *et al.*, 2013).

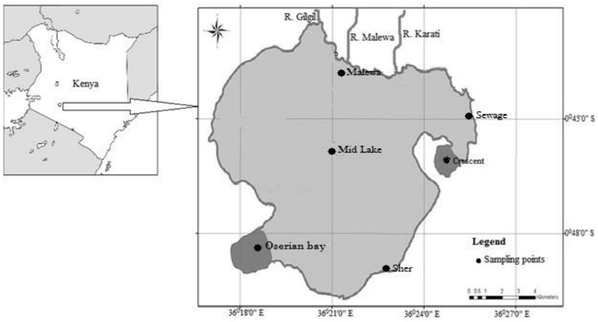

Figure 1: Map of sampling stations in Lake Naivasha

Sample collection and analyses

Six stations in Lake Naivasha were sampled as shown in figure 1. *In situ* measurements were done for total depth, temperature, conductivity and pH using a HANA multi-parameter probe. Water, for various analyses, was collected using sampling bottles. Nutrient analysis in June 2014 was carried out using methods outlined in Wetzel and Likens (1991). Nitrate was measured following the cadmium reduction method while phosphate was measured following the ascorbic acid method. Analysis for nutrients in March and April 2016 was done using the powder pillows and spectrophotometer.

Results

The values of physico-chemical parameters (depth, dissolved oxygen, temperature, pH, conductivity, nitrate and phosphate) for the three months are presented in Tables 1, 2 and 3 below. Crescent lake and Mid lake sampling stations had the deepest waters throughout the sampling period while Sewage was the shallowest.

Table 1: Dissolved nutrients in Lake Naivasha in June 2014

Sampling stations	Depth (m)	Dissolved Oxygen (mg/l)	Temperature (°C)	pH	Conductivity (ms/cm)	Nitrate (mg/L)	Phosphate (mg/L)
Crescent	9.00	6.95	21.60	8.46	0.26	0.055	0.021
Sewage	2.20	7.06	21.90	8.68	0.26	0.055	0.021
Malewa	3.50	8.60	21.40	8.97	0.26	0.055	0.021
Mid Lake	7.40	7.55	23.10	8.81	0.26	0.058	0.021
Sher	4.10	6.58	23.05	8.50	0.26	0.054	0.021
Oserian	7.00	7.66	22.70	8.74	0.26	0.054	0.021

Table 2: Dissolved nutrients in Lake Naivasha in March 2016

Sampling stations	Depth (m)	Dissolved Oxygen (mg/l)	Temperature (°C)	pH	Conductivity (ms/cm)	Nitrate (mg/L)	Phosphate (mg/L)
Crescent	13.3	7.30	25.30	7.71	0.24	0.30	0.09
Sewage	1.45	17.12	25.80	7.94	0.25	0.10	0.14
Malewa	1.67	7.21	25.00	7.41	0.23	0.00	0.08
Mid Lake	6.76	7.13	24.50	7.84	0.24	0.30	0.23
Sher	3.45	17.37	23.40	8.10	0.24	0.20	0.07
Oserian	5.24	7.96	23.60	8.20	0.23	0.20	0.07

Table 3: Dissolved nutrients in Lake Naivasha in April 2016

Sampling stations	Depth (m)	Dissolved Oxygen (mg/l)	Temperature (°C)	pH	Conductivity (ms/cm)	Nitrate (mg/L)	Phosphate (mg/L)
Crescent	8.00	7.02	23.00	8.20	0.23	0.00	0.25
Sewage	1.47	8.30	22.80	8.28	0.23	0.00	0.83
Malewa	2.00	7.43	23.10	7.70	0.23	0.00	0.34
Mid Lake	6.72	7.85	22.80	7.89	0.23	0.00	0.25
Sher	3.86	7.64	22.30	7.83	0.23	0.00	0.24
Oserian	5.00	7.59	24.10	7.12	0.23	0.10	0.09

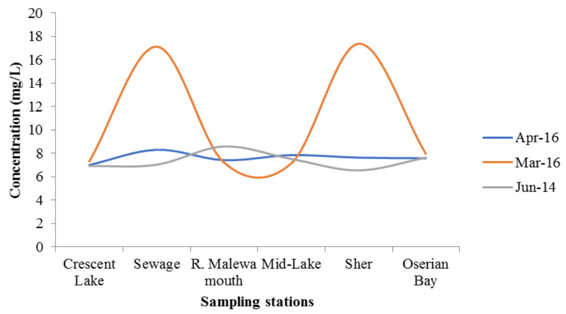

Figure 2: Dissolved oxygen levels in Lake Naivasha

This study reveals that during the month of March 2016, the waters at Sewage and Sher sampling stations had supersaturated oxygen concentrations with values of 17.12 (mg/l) and 17.37 (mg/l) respectively (Figure 2). The lowest dissolved oxygen levels were also recorded during the month of June 2014 at Crescent and Sher sampling stations with values of 6.95 (mg/l) and 6.58 (mg/l) respectively. There was no major variation in dissolved oxygen levels at different sampling stations in June 2014 and April 2016 compared to March 2016

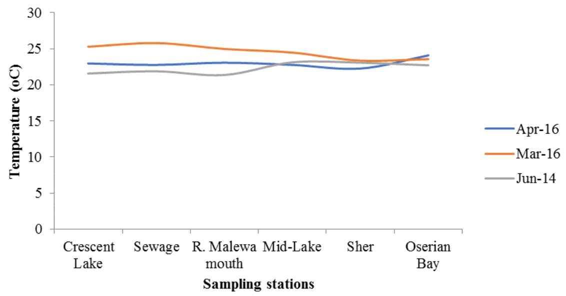

Figure 3: Water temperature levels in Lake Naivasha

This study noted no major differences in the water surface temperatures of Lake Naivasha in all the sampling stations throughout the sampling period (Figure 3). During the sampling period, the highest water temperature was recorded in March 2016. Crescent lake had the highest temperature variation in the sampling period compared to the other sampling stations.

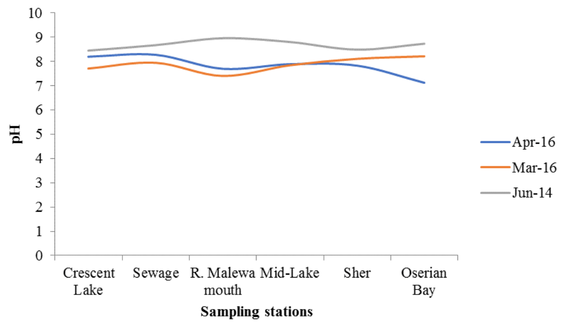

Figure 4: pH levels in Lake Naivasha

This study observed no major differences in the pH levels in all sampling stations during the study period (Figure 4). The lowest pH level recorded was 7.12 in April 2016 at Oserian Bay sampling station followed by River Malewa mouth sampling station in March 2016.

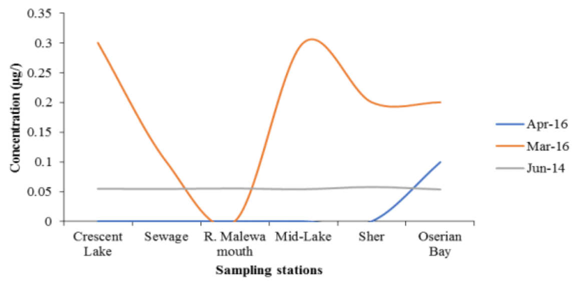

Figure 5: Nitrate concentration levels in Lake Naivasha

Lowest levels of dissolved nitrates in Lake Naivasha were recorded in April 2015 at all sampling stations except Oserian Bay which recorded 0.1 mg/l (Figure 5). Crescent Lake and Mid Lake sampling stations had the highest values of dissolved nitrates both recording concentrations of 0.30 mg/l. Within the same month, fluctuations in nitrate were observed at different sampling stations.

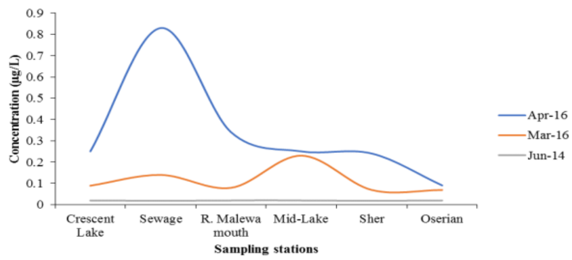

Figure 6: Phosphate concentration levels in Lake Naivasha

Highest concentrations of phosphate was recorded in April 2016 with sewage sampling station having a value of 0.83 mg/l. June 2014 had a constant value of 0.21 mg/l in all sampling stations. In March 2016, Mid Lake sampling station recorded the highest concentration of phosphates at 0.23 mg/l.

Discussion

This study reveals high levels of dissolved oxygen in comparison to other fresh water lakes within Kenya. Harper *et al.*, (2003) attributed this scenario to lakes in high altitude. The lakes high altitude above sea level coupled with atmospheric pressure may have promoted the dissolution of oxygen in the waters of Lake Naivasha. High levels of dissolved oxygen can be an indicator of the high presence of high levels of ammonia in the sediments and lower water stratum cause by a point source of pollution (Kitaka *et al.*, 2002). This study noted relative stability in the other physico-chemical parameters (pH, temperature and conductivity). The moderate and stable pH values recorded in all sampling stations in this study is an indication of high buffering capacity of Lake Naivasha. However, an earlier study in Lake Naivasha by Kaoga *et al.,* (2013), found out the pH ranges were between 6.71 – 8.9 compared to our findings of between 7.12 and 8.97. This could be a threat to the lake if the trend continues with the similar pattern since slight changes in pH could alter the functioning of the whole aquatic ecosystem. The conductivity levels in Lake Naivasha are within the range of earlier studies by Harper *et al.,* (2011) who reported a range of between 0.23 and 0.48 mS/cm in the study of the lake. Water temperature was highest in March 2016, a transition period between the dry and rainy seasons, when environmental temperatures are usually very high.

Results from this study indicate that Lake Naivasha is a phosphorus limited aquatic system. However, sewage sampling station was observed to have significantly high concentrations of phosphate in March 2016 indicating a point source of pollution of phosphate based chemicals from the nearby Naivasha Town sewage treatment plant. High values of phosphates in an aquatic system can lead to cases of eutrophication resulting in algal blooms. From studies undertaken within the tropics; Talling & Talling (1965) and Talling (1966) observed low levels of nitrogen compared to phosphorus in many East African freshwaters, e.g. Lake Victoria. Viner (1975) showed a permanent shortage of nitrogen and phosphorus in Lake George, Uganda. Moss (1979) found out that nitrate, phosphate and sulphate were limiting algal growth in Lake Malawi. Also, evidence of phosphorus limitation in some lakes in East Africa was documented, although according to Talling and Lemoalle (1998) these lakes are cool by virtue of their altitude of around 1800M above sea level. A good example of this is Lake Sonachi studied by Melack *et al.,* (1982) using in situ enclosures and later supported by Kallf (1983) using 32P uptake bioassays. Other phosphorus limited lakes are Oloidien and Elementaita.

Conclusion

This study noted relative stability in all water physico-chemical parameters. However, the pH values were higher compared to those observed in previous studies. An increase in pH values could be a threat to the lake if the trend continues with the similar pattern. Sources of nutrient loading into the lake should be investigated and proper measure to be taken for sustainability of Lake Naivasha. More attention should be paid to nitrogen and phosphorus since they are the limiting nutrients in fresh water aquatic ecosystems.

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