THE LIMNOGEOLOGY OF THE LAKES SAGARA AND NYAMAGOMA

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ABSTRACT

The present study focuses on the limnogeological aspects of the lakes Sagara and Nyamagoma within the Malagarasi Wetland Ecosystem. Abiotic parameters from water and sediment samples were determined during the dry and wet seasons using appropriate gears and methods. The data show variation of the abiotic parameters in both lakes from the water surface to the bottom. Lake Nyamagoma is less turbid (0.7-24 NTU) than Lake Sagara (25 to 65 NTU). The water transparency was also high at Lake Nyamagoma (0.75-1.5 m) thus supporting the observed turbidity trend. The physical chemical changes may be attributed to processes such as cooling, dissociation, dissolution, decomposition, adsorption, precipitation, cation exchange and photosynthesis. However, higher nutrient concentration was observed in the wet season than dry season with the exception of SiO_2 *consequent to dilution effect by surface runoff. The mineralogical content (Kaolinite, Smectite, Illite and Quartz) of the lake sediments indicate existence of good drainage conditions at the lakes as supported by the geology of the area. It is recommended that a long-term limnogeological monitoring and evaluation be conducted so as to understand future nutrient hydrodynamics and hydrological functioning of the wetland ecosystem.*

Keywords: *Limnogeology, Malagarasi Wetland, Lake Sagara, Lake Nyamagoma*

INTRODUCTION

The Malagarasi-Moyovozi Wetland located in the northwestern Tanzania comprises Lakes Sagara (open with maximum depth of *ca* 3.5m) in the south and Nyamagoma (choked with microphytes with maximum depth *ca* 2.5m) in the north. According to reports from the local people the two lakes have existed since 1930s but have tended to shrink and expand over time depending on the rainfall regime in the area. The heavy rains of 1961 to 1965 greatly increased the size of both lakes but since then the lakes have tended to change both in depth and size.

The wetland is extremely important for large mammals, migratory and resident birds, fish and plants along with providing significant livelihood support to local communities. In the last few decades, the Malagarasi Wetland Ecosystem has undergone large chemical, biological and physical changes as a result of growing human interferences (Nkotagu and Athuman, 2004). Next to impacts from pollution, from domestic and agricultural activities leading to deterioration of water quality, shallowing of the lakes is increasing at a fast rate (Nkotagu and Ndaro, 2004).

This paper presents the abiotic parameter fluctuations and the processes causing such behaviour as observed from the two lakes within the Malagarasi Wetland Ecosystem. Some basic questions were set to shade light on the research work as follows; (i) In what ways are human induced activities affecting the limno-geologic functioning of the lakes? (iii) What are the processes influencing the chemical character of the lakes? (iii) What are the seasonality effects on the abiotic parameters in both lakes?

STUDY SITE

The study was conducted at the lakes Sagara and Nyamagoma within the Malagarasi Wetland Ecosystem during the dry and wet seasons in September 2003 and January 2004 respectively (Fig. 1.0). The wetland is located at the height of 1,069 m above sea level. The wetland's catchment area occupies about 4.5 % of the Tanzania total land mass. The lakes are located about 200 km north east of Lake Tanganyika. The Lake Nyamagoma is drained by the rivers; Igombe, Kigosi and Moyowosi along with Malagarasi River. During the dry season, the lake empties the water into the Malagarasi River direct to the Lake Tanganyika, while during the wet season Malagarasi river overflows into lake Nyamagoma. The Lake Sagara is fed by Ugalla River in the wet season and vice versa during the dry season before joining Malagarasi river. However, during very heavy rains, Lake Nyamagoma joins Lake Sagara through the Usinge point. In the present study, a total number of 18 sites were sampled for water and sediments using appropriate gears in both lakes as shown in figure 1.0.

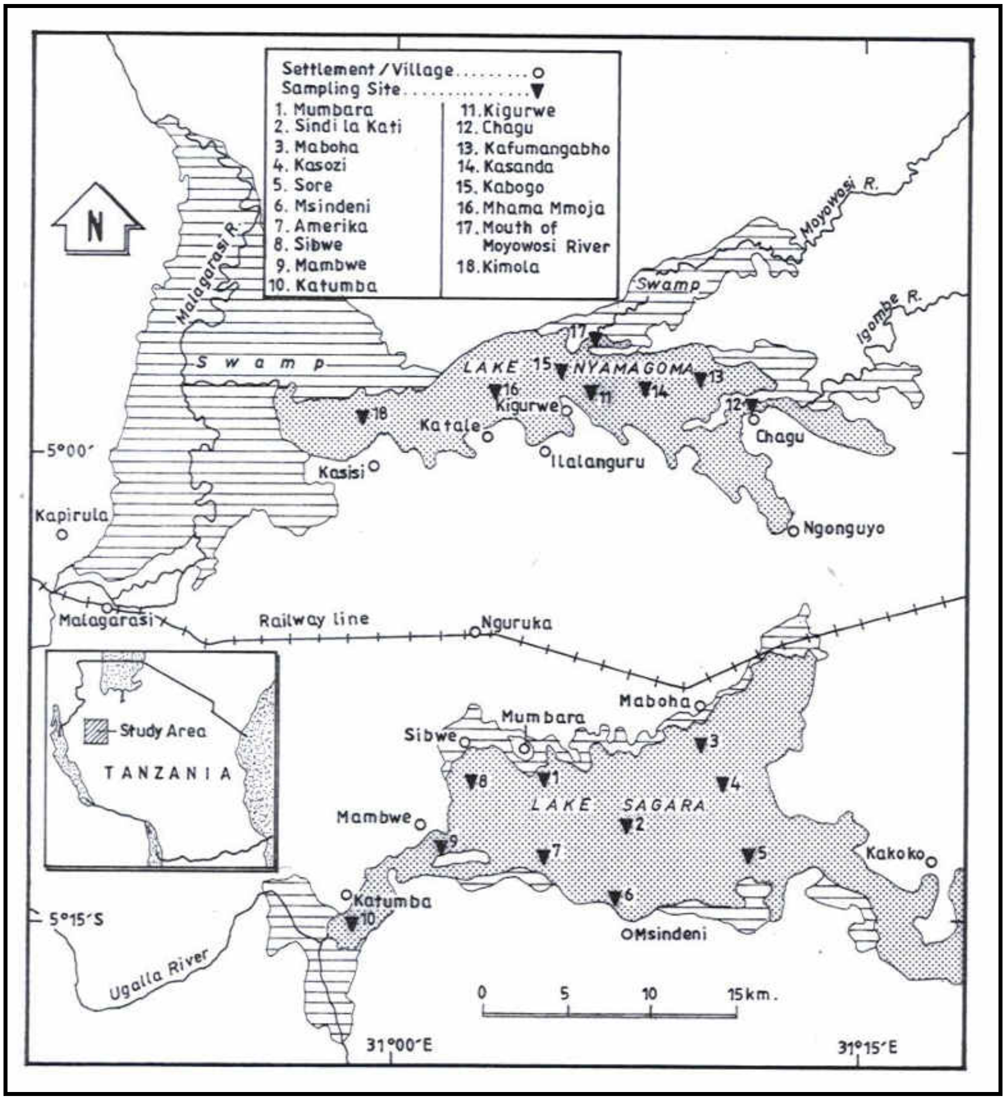

Fig. 1.0: *The Malagarasi Wetland Sampling locations*

GEOLOGY OF THE STUDY SITE

The study area is located predominantly in the mesoproterozoic and neoproterozoic sedimentary (≥800 Ma) formations formerly known as Bukoban Sandstone (Fig. 2.0). Some portions in the area are underlain by the continental and lacustrine sediments along with volcanic (*ca.*795 Ma) sedimentary formations. The lithology of the study area covers granitoid, quartzites, dolomitic limestones, migmatite, utramafic rocks and the sediments of the Kavirondian Supergroup (Pina *et al.,* 2000).

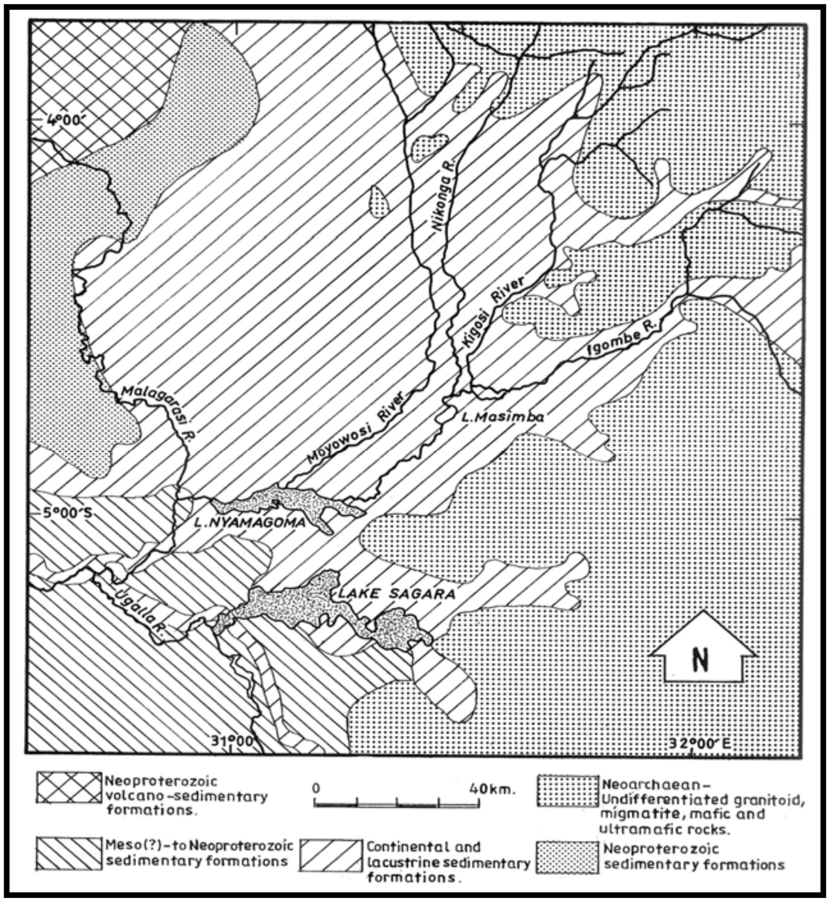

***Fig. 2.0:** Geological map of the study area*

MATERIALS AND METHODS

A SCUBA device was used to measure the depth of water in meters so as to establish the sampling sites. Water samples were collected depth wise using a 2L water sampler, filtered using 0.45 µm filter membrane and then kept into half-liter plastic bottles, cooled at 4° C and immediately taken in the laboratory for chemical analyses. Sediment samples were collected using a grab sampler for mineralogical determination. *In situ* physical parameters including temperature, pH and electrical conductivity (EC) were measured between 900 and 1300 hours using a multi 340i probe meter at different depths. Turbidity was measured by a HACH 2100P model turbidimeter. The water transparency was measured using a 20cm diameter Secchi disk.

Standard methods were used in the laboratory to analyze water samples for chemical concentration as explained by APHA, (1985). Sediment samples were collected and analyzed as reported by Nkotagu and Athuman, (2004).

RESULTS AND DISCUSSION

Temperature

For both lakes temperature decreased with depth to the lake bottom (Fig. 3.0). The temperature values fluctuated from 24.7 to 25.9° C in the dry season and 25.1 to 27.5° C during the wet season at Lake Sagara. However, at some sampling sites in Lake Sagara higher temperatures at the lake bottom than at the surface were observed. The higher bottom temperature than the surface at some sampling sites may be attributed to cooling effect at the lake surface as triggered by wind. In addition, this could be attributed to anaerobic respiration process taking place at the lake bottom resulting in the release of both CO_2 and energy under exothermic reaction.

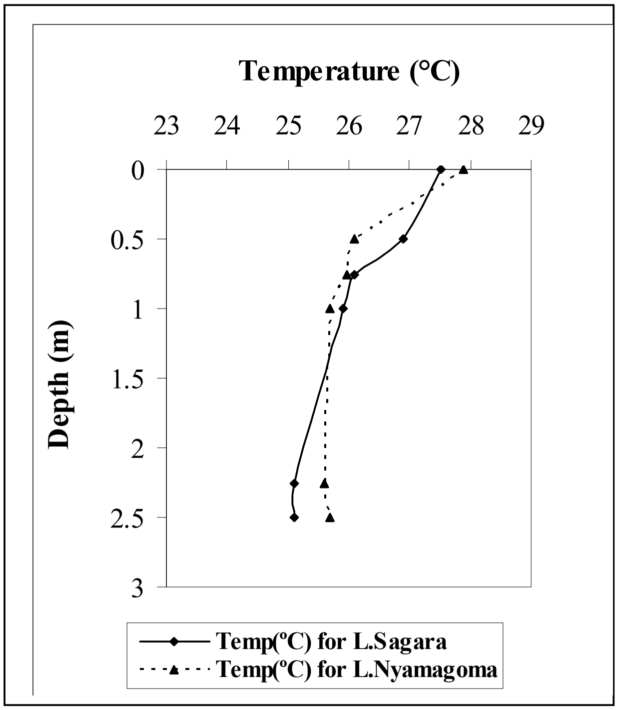

Fig. 4.0: *pH variation in both lakes*

pH

Generally, pH values showed a decreasing trend with depth in both lakes (Fig. 4.0). For Lake Nyamagoma, pH varied from 7.4 to 8.65. The pH values varied from 7.1 to 7.5 during the dry season and 7.5 to 8.8 during the wet season at Lake Sagara. The decrease in pH at the bottom in both lakes could be attributed to decomposition processes (Gaudet, 1979). The small changes of pH indicated that the water was well buffered due to high HCO_3 that ranged from 180 to 220 mg/l for Lake Nyamagoma and 150 to 260 mg/l at Lake Sagara. The low pH value at 1.0 m as shown in figure 4.0 is attributed to the dissociation process of HCO_3 during respiration and organic decomposition resulting in more carbon dioxide being added in the water. This phenomenon has also been reported by Plisnier *et al.* (1999) and (Wetzel, 2001) as per the following reaction;

$$CO_2 + H_2O \rightleftarrows H_2CO_3 \rightleftarrows H^+ + HCO_3^- \rightleftarrows 2H^+ + CO_3^{2-}$$

Turbidity

Higher turbidity values were measured at Lake Sagara (25 to 65 NTU) than Lake Nyamagoma (0.7 to 24 NTU) and increased with depth in both lakes. Turbidity values ranged also from 24 to 160 NTU at Lake Sagara during the dry season and 24.5 to 60 NTU in the wet season. The observed high turbidity is attributed to suspended inorganic and organic matter such as clay, silts, fine sand, detritus and microorganisms such as phytoplankton and colonies of bacteria (Wetzel and Likens, 1990). However, the high turbidity results recorded at Lake Sagara may be attributed to openness of the lake that favours formation of turbulent by wind action which effectively supports re-suspension of bottom lake sediments. However, the contour maps clearly show that the turbidity originates from the catchment as demonstrated at Lake Nyamagoma in both seasons (See figs 5.0 and 6.0). The sediments reach into both lakes during the wet season through the inflowing rivers and the overland flow accelerated by high deforestation within the wetland catchment.

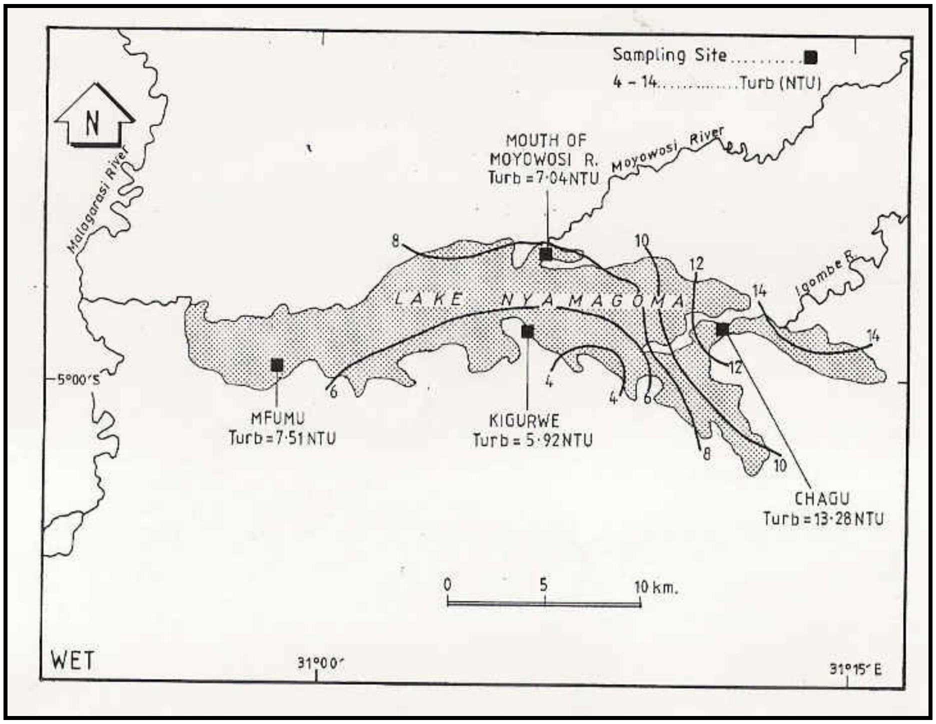

Fig. 5.0: Contour map for turbidity values at Lake Nyamagoma in the dry season

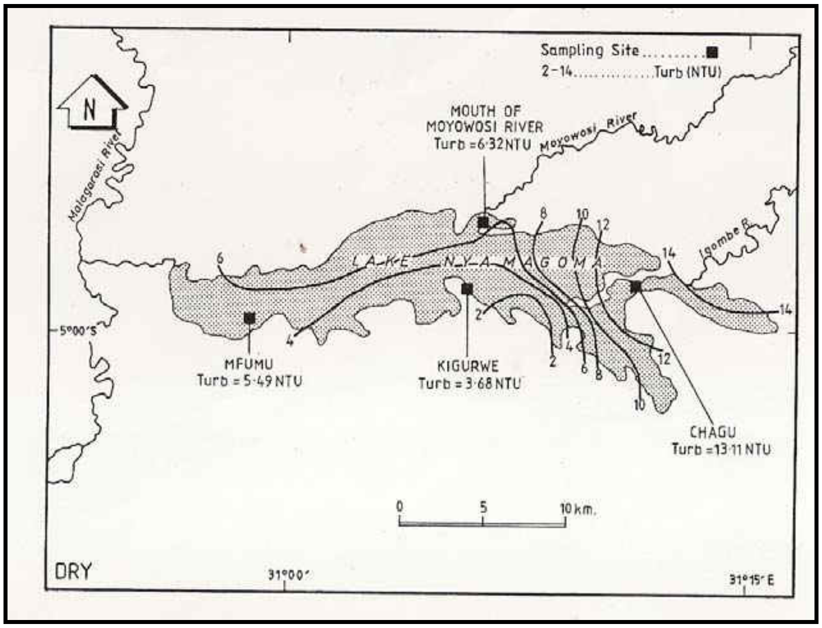

Fig. 6.0: Contour map for turbidity values at Lake Nyamagoma in the wet season

Electrical Conductivity

In general, electrical conductivity (EC) was higher at Lake Nyamagoma (380 to 640 µS/cm) than Lake Sagara (270 to 450 µS/cm) as per figure 7.0. The EC at Lake Sagara was higher in the wet season than the dry season and ranged from 250 to 430 µS/cm and 80 to 140 µS/cm respectively. However, higher values were measured after 1.0m in the wet season than that of the dry season. High EC values at Lake Nyamagoma could be explained by the contribution of salts to the lake by the Malagarasi brine springs that inflow the lake during high river stands. In addition, other brine springs at the headwaters of the lake within the lake catchments flow into the lake through the Muyovozi River during the wet season as well as salt work washouts.

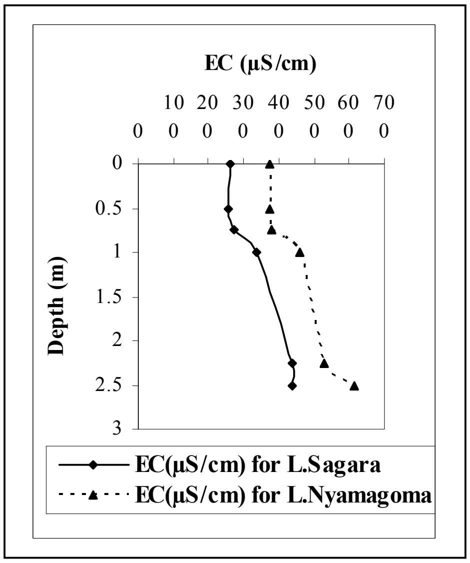

Fig. 7.0: Variation of EC with depth in both lakes

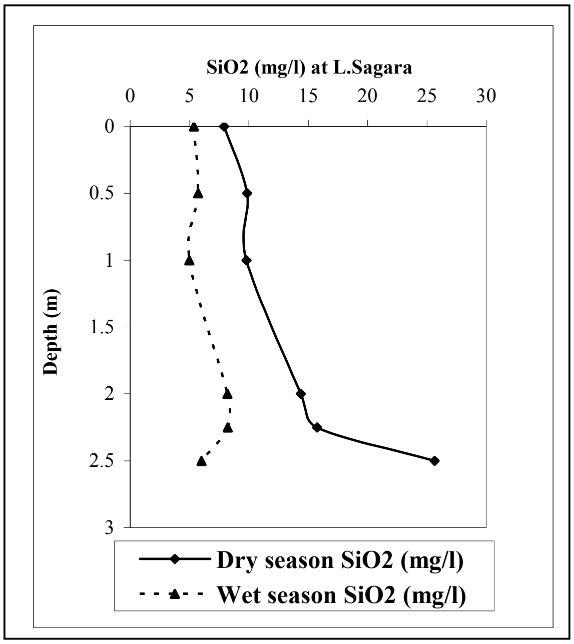

Fig. 8.0: Variation of silica with depth

Silica

The mean concentration values of silica (SiO_2) were higher at Lake Nyamagoma than at Lake Sagara as measured during the wet season. The values for the two lakes were higher at the bottom than at the surface (Fig. 8.0). The mean SiO_2 concentration was higher during the dry season (7.92 to 15.76mg/l) than the wet season (2.85 to 8.23mg/l) at Lake Sagara. The concentration trend increased with depth during the dry season and vice versa during the wet season (Fig. 9.0)

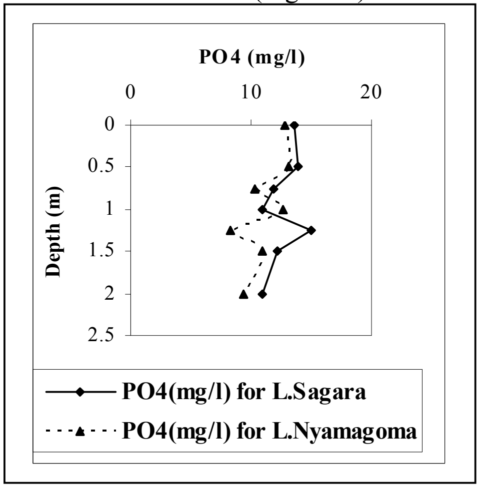

Fig. 9.0: Seasonal variation of silica in both lakes

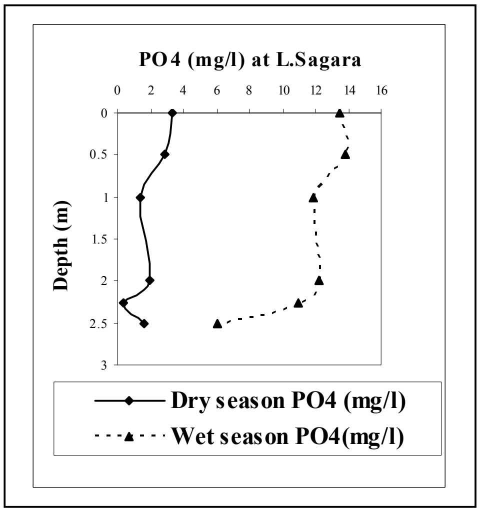

Fig. 10: Seasonal variation of phosphate with depth at Lake Sagara

According to Wetzel (2001), low SiO_2 concentration at the surface water may be attributed to utilization by diatoms that occur during the photosynthesis process. Increased pH and temperature also lead to decreased SiO_2. However, the increase of SiO_2 noted at the bottom in both lakes is consequent to the dissolution favoured by decreasing pH and temperature. The decrease of SiO_2 in the wet season in Lake Sagara may be attributed to dilution effect triggered by increased overland flow consequence to the ever increasing deforested lake's catchment resulting from poor agricultural practises and bush fires along with overstocking within the entire area.

Phosphate

The mean phosphate (PO_4) values ranged from 7.0 to 13 mg/l at the Lake Nyamagoma and showed an opposite trend to that of Lake Sagara. Higher values were measured at the surface than at the bottom in both lakes. However, higher values were observed at Lake Sagara than at Lake Nyamagoma (Fig. 10.0). At 1.0 m PO_4 levels increased at Lake Sagara but decreased at Lake Nyamagoma. PO_4 concentration ranged from 6.0 to 15 mg/l during the wet season and from 0 to 3.2 mg/l in the dry season at the Lake Sagara (Fig. 11.0). High values were measured at the surface and decreased depth wise in both seasons.

PO_4 is readily adsorbed on silt particles (Golterman, 1973) thus, the observed decrease in both lakes with depth could be attributed to sediment trap through adsorption process on to ferric hydroxide $Fe(OH)_2$ particles as inorganic phosphate (Mortimer, 1971). The high concentration of phosphate in the wet season at Lake Sagara could be due to inputs from the surface runoff during wet season as washed from the lake's catchment.

Iron

During the wet season iron (Fe^{2+}) concentration increased with depth up to 0.75 m and then decreased significantly up to 1.0 m in both lakes, with Lake Nyamagoma having zero values. After 1.0 m the values increased with depth in both lakes up to the lake bottom, with Lake Sagara having higher values than Lake Nyamagoma (Fig. 12.0). Similar trends in Fe^{2+} values for Lake Sagara are observed in both seasons. The increase of Fe^{2+} at 1.25 m in both lakes indicates the presence of reducing conditions. However, iron values decrease with depth up to 1.0 m may be a consequence of adsorption process on the sediments that trap iron under oxidizing conditions. Iron fixing bacteria can also explain the observed decreasing concentration trend with dep

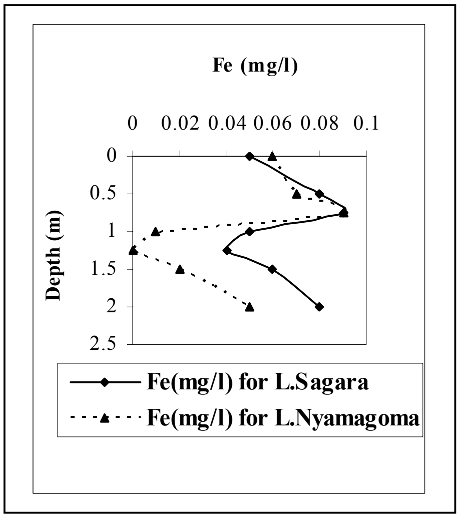

Fig. 12.0: *Variation of iron with depth in both lakes*

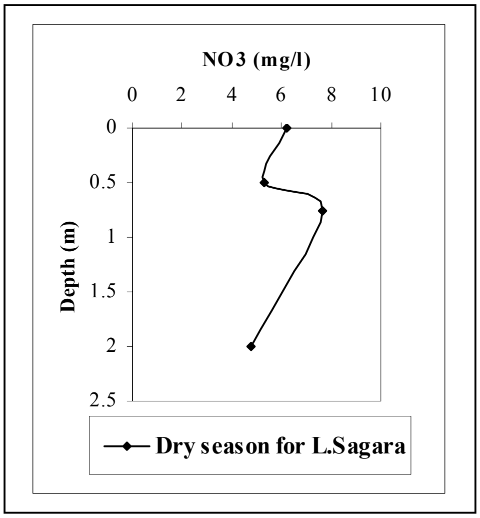

Fig. 13.0: *Variation of nitrate concentration*

Nitrate

The nitrate (NO_3) concentration ranged from 4.5 to 7.8mg/l at Lake Sagara during the dry season and decreased with depth. The NO_3 trend showed a peak at 0.75m and then decreased significantly with depth (Fig. 13.0). However, measurements were not done for Lake Nyamagoma due to lack of reagents.

Sediment Mineralogy

The lake bottom sediments in both lakes are composed dominantly of Kaolinite and Smectite with occasional Illite and Quartz minerals (Nkotagu and Athuman, 2004). The geology of the study site also supports the dominance of the sediment mineralogy. However, this implies also good drainage conditions at the lakes

The decrease of NO_3 at the bottom in Lake Sagara could be attributed to the denitrification process, which is favoured by reducing conditions generated through organic matter decomposition and or by nitrate fixing bacteria. The abundance of blue green algae at the lake sediments (Pol *et al.,* 2004) indicates according to Wetzel (2001) and Cohen (2003), that nitrogen fixation is taking place and consequently reducing nitrate concentrations.

Specific Ion Ratio

The sodium/calcium ratio from Lake Nyamagoma waters show significant values in both seasons (Figs 14.0 and 15.0). Similar ion ratios were also observed from Lake Sagara waters. This observation may be attributed to precipitation of calcium rich mineral and or cation exchange in the lakes waters.

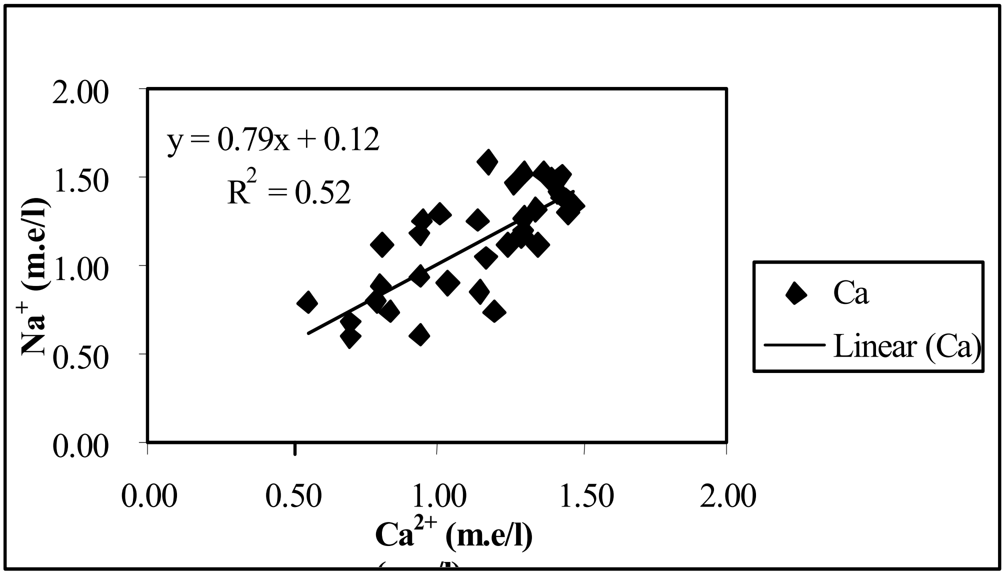

Fig. 14.0: *Variation of Na^+ and Ca^{2+} at Lake Nyamagoma in the dry season*

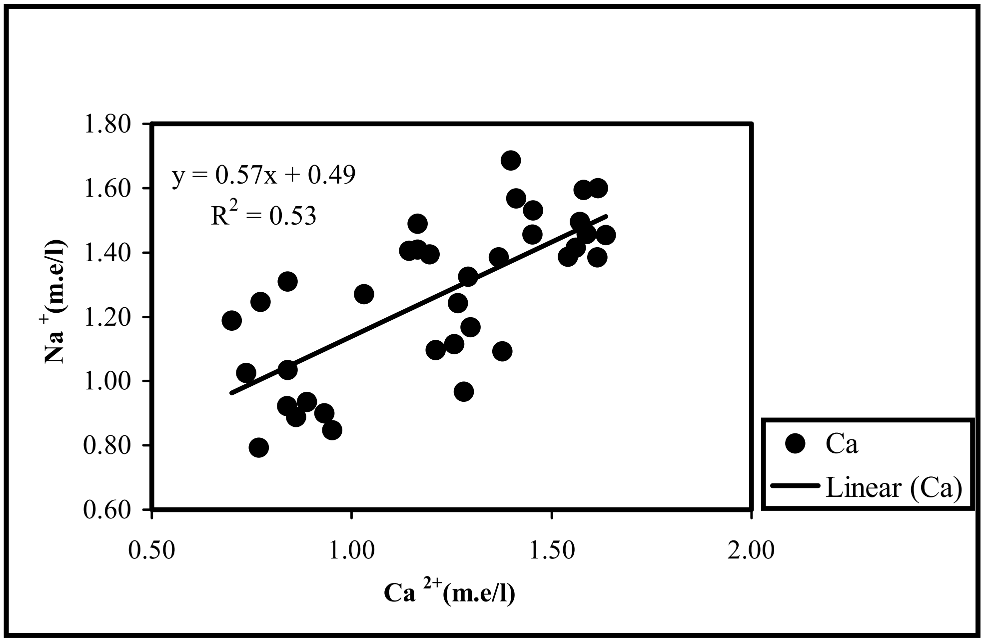

Fig. 15.0: *Variation of Na^+ and Ca^{2+} at Lake Nyamagoma in the wet season*

Heavy Metals

The concentrations of heavy metals at the lakes are higher in the sediments than in the overlying water and the filtrate as demonstrated at Lake Sagara (Tab. 1.0). This observation indicates that sediments are sinks of the heavy metals and hence depleting them from the water column thus reducing their toxicity potential to aquatic organisms (Nkotagu and Athuman, 2004).

Table 1.0: Mean concentration of heavy metals from the water column, filtrate and sediments at Lake Sagara.

Metal	Overlying Water	Filtrate	Sediments
Hg (µg/l)	0.64	9.85	43.75
As (µg/l)	1.07	3.84	403.11
Mn (mg/l)	0.03	0.10	150.16
Cd (mg/l)	0.04	0.001	0.37
Cu (mg/l)	0.01	0.01	25.35
Ag (mg/l)	0.01	0.01	0.04
Pb (mg/l)	0.01	0.01	14.42
Cr (mg/l)	0.01	0.01	44.91
Co (mg/l)	0.01	0.01	5.78
Ni (mg/l)	0.01	0.02	11.56
Zn (mg/l)	0.01	0.03	47.67

CONCLUSIONS AND RECOMMENDATIONS

The study reveals that the concentration of most abiotic parameters in both lakes varies depth wise consequent to processes including cooling, dissociation, dissolution, decomposition, adsorption, precipitation, cation exchange and photosynthesis. Higher abiotic concentrations are observed in the wet season than the dry season with the exception of SiO_2. This could be attributed to dilution effect by increased surface runoff resulting from catchment deforestation. However, good drainage conditions do exist at the lakes as supported by the mineralogy of the lakes bottom sediments. It is recommended that a long-term limnogeological work be conducted so as to understand the long-term nutrient hydrodynamics and hydrological functioning of the wetland ecosystem.

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NOMENCLATURE

TAFIRI = Tanzania Fisheries Research Institute

NTU = Nephelometric Turbidity Units

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