THE ROLE OF TURBIDITY ON PICOPLANKTON ORGANIC CARBON SYNTHESIS AND GROWTH RATES IN LAKE BARINGO, KENYA

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A thesis submitted to the graduate school in partial fulfilment for the requirements of the Master of Science Degree in Environmental Science of Egerton University.

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DECLARATION AND RECOMMENDATION

DECLARATION

This thesis is my original work and has not been presented for a degree in this or any other university.

Signature: ..... AUGUST 4, 2008

OLILO, CASIANES OWINO Date

RECOMMENDATION

This thesis is submitted for examination with our approval as university supervisors.

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DEDICATION

To my late father Silas Olilo and my mother Masliana O. Aute, their wise and brilliant guidance was the source of my inspiration.

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All those who contributed directly or indirectly in the production of the work are gratefully appreciated.

ABSTRACT

Wind induced turbidity in Lake Baringo impacts negatively on picoplankton biomass and growth rates. This study investigated the impact of turbidity on picoplankton organic carbon synthesis and growth rates at low (northern), moderate (central) and high sediments disturbance (southern) zones in Lake Baringo. The investigation-followed simple completely randomised design and analysis of variance. Turbidity was measured in the field by a portable turbid meter. Van Dorn was used for field water sample collection. Composite samples of picoplankton from each of the sampling sites were incubated in 3 glass bottles. 100 ml of water were filtered through nuclepore filters using a suction pump to remove predators. Acrdidine orange was used to stain the nuclepore filters. Picoplankton cells were counted under epiflourescence microscope using the frequency of dividing cells technique. Results of this study have shown that picoplankton abundance was strongly and positively related to particulate organic matter ($R^2 = 0.89$; $P \leq 0.004$) and dissolved organic carbon ($R^2 = 0.88$; $P \leq 0.005$) in all the three zones. Specific picoplankton organic carbon synthesis was positively related to the turbidity at the southern ($R^2 = 0.46$; $P \leq 0.14$) and central zones ($R^2 = 0.47$; $P \leq 0.13$) but lowest positive relation was observed at the northern zone ($R^2 = 0.23$, $P \leq 0.33$). Picoplankton loss estimates showed strong association with turbidity at the southern ($R^2 = 0.503$, $P \leq 0.11$) and northern ($R^2 = 0.509$, $P \leq 0.11$) zones, but weak association in the Central zone ($R^2 = 0.38$; $P \leq 0.19$). In the Southern zone the picoplankton specific growth rates were weakly related to the lake's water turbidity ($R^2 = 0.32$, $P \leq 0.24$) while in both northern and central zones there was no link. Picoplankton specific growth rates were strongly and positively related to biological oxygen demand ($R^2 = 0.56$; $P \leq 0.04$) in all the zones. Particulate organic carbon and dissolved organic carbon were strongly and positively related ($R^2 = 0.99$; $P \leq 0.05$) in all the zones. These results reassert the phenomenon of energy storage by organic carbon in lake ecosystems. The frequency of dividing cells technique shows that picoplankton organic carbon synthesis, growth rates and the cell division phase of the cell cycle are physiological processes impacted upon and functionally dependent on turbidity. Rainfall influenced these processes with low effects during the dry season (December 2003- March 2004) and high effects during the wet seasons (June 2003-July 2003) in the central, northern and southern zones in ascending order of magnitude. This information is useful for policy appraisal and the management of Lake Baringo fisheries and other freshwater lakes ecosystems with a similar problem of sediments deposits.

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LIST OF SYMBOLS / ABBREVIATIONS / DEFINITIONS OF TERMS

⊕ - Grid reference

WRI - World Resources Institute

BOD - Biological oxygen demand

POC - Particulate organic carbon

DOC - Dissolved organic carbon

TDS - Total dissolved solids

FDC - Frequency of dividing cells

CHAPTER ONE

1.0 INTRODUCTION

1.1 Background information

The study of picoplankton organic carbon synthesis and growth rates in freshwater has drawn limnologists to search for answers to some fundamental questions about the function and role of these smaller sized plants (Callieri *et al.*, 1996). One of the recurrent themes of investigation has been the estimation of picoplankton production and the quantification of its contribution to the total primary production. However, little is researched on the effect of turbidity on the organic carbon synthesis of picoplankton.

Such study has not been done in Lake Baringo. This study measured organic carbon synthesis and growth rates of picoplankton and determined the role of turbidity on these processes. Frequency of dividing cells (FDC) technique first proposed by Hagstrom *et al.*, (1979) was used for measuring bacterial production.

Many studies on Lake Baringo, have concentrated on the species composition of diatoms and other algal species neglecting the useful picoplankton growth rates and organic carbon synthesis aspects (Beadle, 1932; Mann, 1974; Richardson & Richardson, 1972; Kiplagat, 1989; Graeme & Kiplagat, 1995, Gasse *et al.*, 1983; Hecky & Kilham, 1973; Oduor, 2000; Garner *et al.*, 2006).

In the photic zone of most lakes, autotrophic and heterotrophic microorganisms are not spatially separated (Bertoni *et al.*, 1991). In Lake Baringo this phenomenon develops through wind induced mixing of the shallow water column, which stirs the bottom sediments (Kallqvist, 1987). Wind induced mixing creates turbidity which influences picoplankton carbon synthesis and growth rates in the lake. Suspended solids comprise organic carbon and inorganic suspended solids. The sediments come from the lake's catchments area. The sediments influence picoplankton biomass and growth rates in Lake Baringo. The levels of sediments increase here due to activities such as deforestation, livestock grazing, agriculture and settlement taking place at the catchments area (Meyerhoff, 1991; de Groot *et al.*, 1992). The suspended solids increase light attenuation (Kallqvist, 1987). Suspended solids also interfere with domestic, leisure and aesthetic uses of lakes besides influencing picoplankton biomass and growth rates in Lake Baringo (Harper & Ferguson, 1995; Vollenweider, 1990).

The known methods of enumerating sea or marine picoplankton had been based on plate counts; serial dilutions or phase contrast microscopy that gave approximates of at best 10% of actual numbers (Azam *et al.*, 1983). In the recent years, Adenine Triphosphate, muramic acid and lipopolysaccharides have been used to estimate biomass as confirmed by

Azam *et al.* (1983). These techniques do, however, have the drawback of varying conversion factors between the cell component measured and bacterial biomass. The present work covered the problem of spatial and temporal effects of turbidity induced by sediments discharge into the lake's ecosystem on picoplankton in the water column, but not bacteria on detritus particles and in sediments.

Besides eutrophication, turbidity is one of the most important factors influencing the ecological functions of Lake Baringo (Peters, 1996; Orlando *et al.*, 1998). Furthermore, nutrients, pathogens, heavy metals and synthetic organic compounds and turbidity affect water quality of freshwater lakes (World Resources Institute, 1992; Smayda, 1990).

The present work augmented that one carried out by the Global Environmental Facility on the rehabilitation of Lake Baringo catchments area. Similarly, Rehabilitation of Arid Environments Trust Project situated near Lake Baringo will find the present findings useful for incorporation into their socio-economic work programme.

1.2 Problem statement

Lake Baringo basin is the lowest point surrounded by a high level ground with a catchments area of 6820 km^2. It comprises Tugen Hills to the West and Laikipia Hills to the East. The raised ground comprises unconsolidated loose topsoil. Due to an estimated human population of 872,000 and a livestock population of over 1,200,000, coupled with increased human activities in the catchments area, topsoil continues to be degraded. Human activities coupled with wind and rainfall surface run-off ensure that the eroded soil is carried into the inflowing rivers, which enter the lake. The soil entering the lake settles into sediments, which are stirred by North-easterly winds and eventually get resuspended into silt particles. These sediments impact on picoplankton biomass and growth rates in the lake that impact on the aquatic biodiversity, especially the fish. Measurement of turbidity on a seasonal and spatial basis in order to investigate how picoplankton biomass and growth rates are impacted upon in the low, moderate and high sediments disturbance zones is the core issue of the present study.

1.3 Objectives

1.3.1 Main objective

The main objective of the study was to investigate the role of turbidity on picoplankton organic carbon synthesis and growth rates at low, moderate and high sediments disturbance zones in Lake Baringo.

1.3.2 Specific objectives:

1. To determine the relationship between turbidity and picoplankton abundance in low, moderate and high sediments disturbance zones of Lake Baringo.
2. To establish the relationship between turbidity and picoplankton organic carbon synthesis in the three sediments disturbance zones of the lake.
3. To determine the relationship between turbidity and growth rates in the three sediments disturbance zones of the lake.
4. To establish the relationship between turbidity and picoplankton loss estimates in the three sediments disturbance zones of the lake.
5. To relate biological oxygen demand, particulate organic carbon, dissolved organic carbon and temperature with picoplankton biomass in the three sediments disturbance zones of the lake.

1.4 Hypotheses

HO_1: Picoplankton organic carbon synthesis is not a function of turbidity in the low, moderate and high sediments disturbance zones of Lake Baringo.

HO_2: There is no significant relationship between turbidity and picoplankton growth rates in the three sediments disturbance zones of the lake.

1.5 Justification

Turbidity caused by increased sediments discharge influences ecological functions of Lake Baringo. Although a number of studies have been carried out on the lake none so far has attempted to relate picoplankton organic carbon synthesis and growth rates to turbidity (Beadle, 1932; Worthington & Ricardo, 1936; Richardson & Richardson, 1972; Kallqvist, 1987; Kiplagat, 1989; Oduor, 2000; Schargel & Oduor, 2003; Oduor *et al* 2003; Ballot *et al.*, 2003; Graeme & Kiplagat, 1995).

This study serves as a comparative tool for future studies in Lake Baringo. These findings will add to the pool of the scientific knowledge of tropical lakes, which have received little attention in the past. Microbial loop, of which picoplankton is part in a highly turbid lake, may become a more carbon fixing cycle than the primary production cycle that depends exclusively on light energy. Picoplankton contributes a fraction of initial energy to the first trophy level, so it is of commercial significance for aquaculture and fishery of the lake (Bertoni *et al.*, 1996). The fishery managers and fishermen alike will benefit from the present findings. The study helps in bridging the gap in knowledge about picoplankton production that supports fishery production for local livelihood in the lake region.

1.6 Definition of terms

Allochthonous: A substance that originates from outside an area or habitat of action.

Autochthonous: A substance that originates from within an area or habitat of action.

Picoplankton: Small plants of planktonic fraction in an aquatic ecosystem measuring 0.2 – 2 μm.

Biological oxygen demand: The deoxygenating ability or oxygen demand in a water body, i.e., the level of effluents (particulate and colloidal organic matter and a host of dissolved compounds) measured by the rate at which oxygen disappears from it in a sealed bottle kept for 5 days in darkness at 20^0 C (mg O_2 1^{-1} 5 day^{-1}).

Biotope: A microhabitat of an organism (e.g., bacterioplankton) in time and space.

Eutrophication: A process by which a water body (e.g., ocean, lake, pond) becomes naturally or artificially more productive due to the accumulation of nutrients (phosphorus and nitrates) with time.

Microbial loop: The energy flow through bacterioplankton, Pico-Cynanophyceae, flagellates and ciliates in an aquatic ecosystem.

Particulate organic carbon: Organic matter derived from drainage branches, leaf litter, bud scales, flowers, pollen and spores, the faeces and carcasses of animals and finely divided soil humus which can not pass through a filter of pore size 0.5 μm.

Pollution: The process of releasing some amounts of substances (e.g. organic pesticides, herbicides, inorganic heavy metals and pathogens), which may have subtle effects on behaviour, or reproduction of organisms into land, water body or air.

Sediments: Fine silt particulates (more than 0.5 μm) of organic or inorganic nature in a water body which may be free floating or settled on the bottom, and are of autochthonous or allochthonous by origin.

Turbidity: The attenuation or abstraction of light by particles in aquatic ecosystems.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 East African Rift Valley lakes

The East African Rift Valley lakes have been formed through tectonic and volcanic forces. This feature came as a result of plate tectonics where the earth's upper mantle and crust moved persistently during geological time scale to form shapes of the continents, oceans and mountains (Beadle, 1932). The unique feature of the Rift Valley lakes is that they experience semi-arid climatic conditions characterized by alkaline and fresh water in basins of internal drainage (Hecky & Kilham, 1973). They are also characterized by high levels of evapotranspiration due to hot temperatures within the tropical climate.

These variables have been documented with varying degrees of accuracy (Beadle, 1932; Jenkin, 1932; Richardson & Richardson, 1972; Talling & Talling, 1965; Melack & Kilham, 1974; Melack, 1976, 1981; Kallqvist, 1987; Talling & Lemoalle, 1998 Schargel & Oduor, 2003; Oduor *et al*., 2003; Dunbrack *et al.*, 2006).

Lakes Victoria and Kyoga lie between the two Great Rift Valley (the Western Rift and the Eastern Rift) with the Western Rift Valley lakes extending from Lake Malawi through Lakes Tanganyika, Albert, Kivu, Edward and George. The Eastern Rift Valley extends from Lake Malawi through Tanzania, Kenya, Ethiopia, Red sea and the Jordan (Beadle, 1932). The lakes namely: Malawi, Magadi, Naivasha, Nakuru, Elementaita, Bogoria, Turkana and Baringo characterise the Eastern Rift Valley.

2.2 Lake Baringo

Lake Baringo (Fig 1) is a Ramsar site that is important for research and conservation of both aquatic flora and fauna. It is an important home to a significant number of aquatic birds that depend on picoplankton for their food. The study of these small sized plants in relation to the turbidity of the lake has caught a lot of interest among scientists. Investigations on the growth rates and organic carbon synthesis will provide information on how the lake's production is being controlled by the light and particles of sediments.

During long rainy season (April-July) the lake flooding increases the sediments discharge. Worthington (1932) reports that in the first (Kamasian) pluvial period all the Kenyan Rift Valley lakes from Lake Turkana to Lake Magadi were one big lake. This theory has since been discounted partly because Lake Baringo has only *Tilapia nilotica (Oreochromis niloticus baringoensis)* in common with Lake Turkana (Ssentongo, 1979). Lake Baringo has nine volcanic islands (Fig. 1), which are remnants of an early Pleistocene volcano (Beadle, 1932).

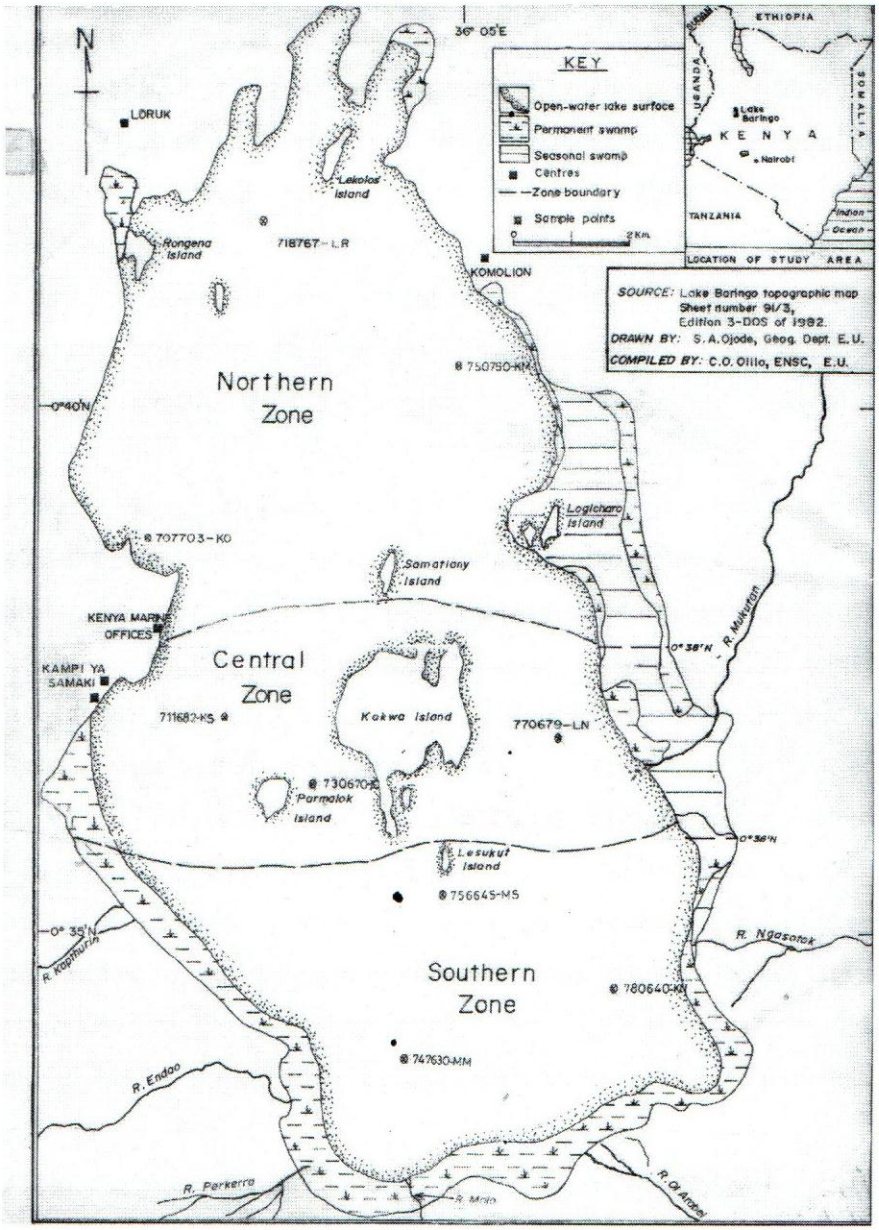


Figure 1: Lake Baringo, sampling sites and drainage.

Key to the map of Lake Baringo:

IC - Island camp; KM – Komolion ; KN - Kiserian ; KS - Kampi Ya Samaki ;

LN - Longicharo;LR - Loruk ; MS - Mlima sitan; MM - Molo mouth;

; KO - Kenya Marine & Fisheries Research Institute Offices

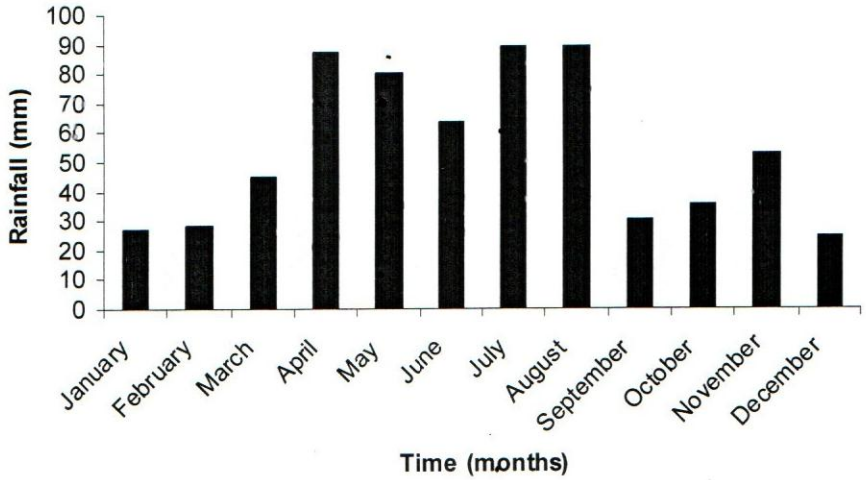
The annual natural cycle of lake flooding has been reduced considerably due to the impoundment of the inflow streams for domestic and agricultural use (Odhiambo & Gichuki, 2000). Endao River for example, which originates from Tugen Hills, was dammed in the year 2000 at Kituro village next to Kabarnet municipality. The purpose was to provide water for domestic use as well as the municipality. The Kirandich Dam is a multimillion project, which not only created a barrier but also reduced the volume of water entering Lake Baringo. This dam was constructed between the years 1996-2000. Koriema River was dammed in 1998, at Koriema village (Kimau Dam) for domestic and livestock use. Chemeron River was dammed in 1989 at the Njemps Plain–Tugen Hill border (Chemeron Dam). It is used for both domestic and agricultural irrigation on the lower parts of Njemps Plain of Salabani area in Baringo District.

Perkerra River has been in use for agricultural irrigation since 1954. Prisoners constructed the dam during colonial uprising according to the local narratives. The River passes next to Marigat Town and its water is used for the irrigation of horticultural crops of onions, tomatoes, oranges, watermelon, and paw paw, chillies as well as cereals crops such as maize in the lower eastern region of the Town. Molo River, whose origin is Mau escarpment (Mau Forest) was diverted in 1985, at Loboi to provide water to be used for irrigating horticultural crops. Ol Arabel River was diverted in1988 for irrigation of horticultural crops as well as domestic piped water in the Mochongoi Hills, bordering Laikipia Hills and Marmanet forest. The river water barriers, diversions, underground seepage and high rates of evapotranspiration in the semi-arid environment; contribute to the increased levels of the lake's water turbidity. The foregoing factors, coupled with the unconsolidated topsoil carried in the rainfall surface run-off and river channels contribute to the high levels of turbidity in the Lake (Bryan, 1994).

Johansson and Svensson (2002) as well as Onyando and Chemelil (2002), have both attributed the drying up of Lake Baringo to the aspects of sediments discharge and hydrological changes which result from agricultural practices and livestock grazing in the catchments area of the lake. The increased livestock keeping has resulted into overgrazing in the lake basin and its catchments area. This has led to eventual land cover change coupled with soil erosion and eventual sediments discharge into the lake. This phenomenon causes diversity loss due to energy flow interference in the microbial loop of the lake's ecosystem. This leads to the low production and eventual low turnover for fish food in the water body.

The local climate is hot and semi-arid (Republic of Kenya, 1997). Total rainfall ranges from 500 mm in the lake basin to 1500 mm per annum in the highlands (Fig. 2). Based

on the definition of a dry month receiving precipitations of less than 50 mm, Lake Baringo station is dry in most months of the year (Mpawenayo, 1996).



(1996

Figure 2: Mean monthly rainfall (mm) pattern for Lake Baringo area (1982-2004)

However, there are variations and shifts in rainfall pattern each year (Fig. 3), but the rainy season lasts for three months followed by nine months of dry spell (Republic of Kenya, 1997). Air temperature in the lake basin ranges from a minimum of 22^0 C (July) to a maximum of 39^0 C (March). The highlands' air temperatures range from a minimum of 10^0 C to a maximum of 33^0 C. Evaporation measures 1500 mm per annum. The area is classified as climatic zone 5 with humidity index ranging from 42 to 51. The lake is also characterised by daily Northeasterly winds with afternoon storms. These afternoon winds cause mixing and resuspension of sediments in the lake. Eroded soil, which ends as suspended solids in the lake through inflow, is also triggered by these winds.

2.3 Effects of suspended solids on picoplankton biomass and growth rates

The importance of suspended solids as variables for determining the trophic status of swamps and lakes has been recognised since the beginning of the 20^{th} Century (de Bernardi, 1991). These substances may cause alterations to natural substrate composition (Jeffries & Mills, 1990). Sediments induce emigration and shifts in the community structure in Lake Baringo (Kallqvist, 1987), and such observations have been made in Lakes Tanganyika, Victoria and Naivasha (Cohen *et al.*, 1993; Alin *et al.*, 1999).

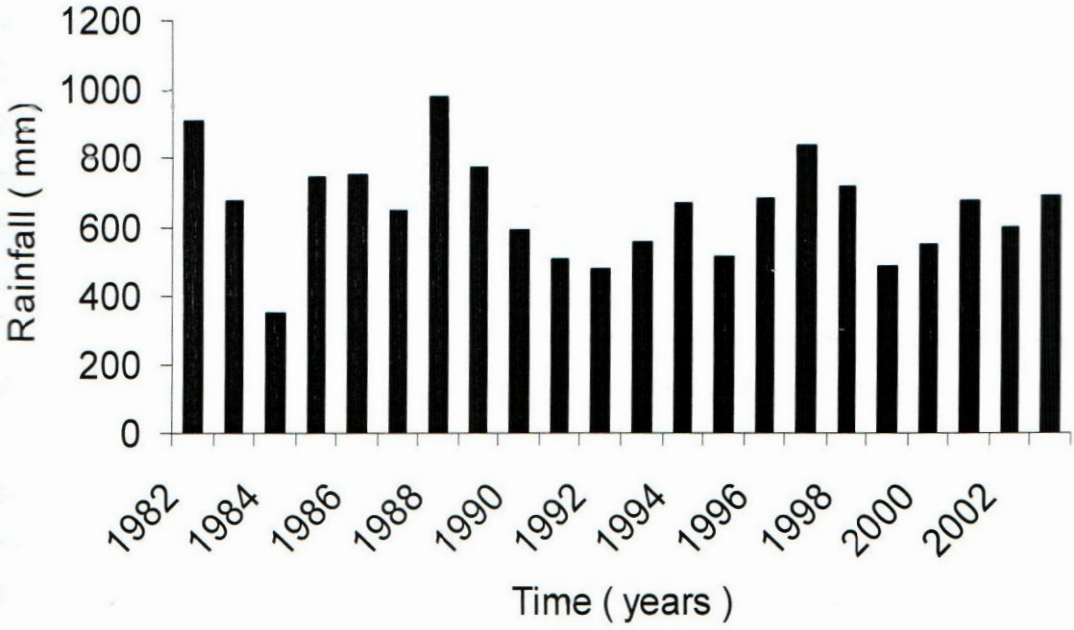


Figure 3: Mean annual rainfall (mm) pattern for Lake Baringo area (1982-2003)

Suspended sediments increase turbidity, which induces inhibition of picoplankton organic carbon synthesis hence growth rates. It has been reported that Lake Baringo has a higher rate of sediments deposition as compared to Lakes Naivasha and Victoria (Kallqvist, 1987). As a consequence, light penetration is limited in this lake.

Lake Baringo faces the problem of increased inorganic suspended solids reaching it from the catchments area through the inflowing rivers and surface run-off (Beadle, 1932; Richardson & Richardson, 1972; Kallqvist, 1989; Graeme & Kiplagat, 1995). None of these studies has related turbidity to organic carbon synthesis and growth rates of Pico-Cyanophyceae in the lake.

2.4 Effects of nutrients on picoplankton biomass and growth rates

The role of nutrients on organic carbon synthesis and growth rates of picoplankton has not been determined for most of the tropical lakes unlike their temperate counterparts (Strickland & Persons, 1968; Bertoni, 1978; Wetzel & Likens, 1991; Likens, 1972; Bertoni & Callieri, 1993).

Studies on tropical ponds show that suspended sediments carry nutrients into these aquatic ecosystems (Orlando et al., 1998). These nutrients must be contributing to the increases of organic carbon synthesis and growth rates by picoplankton cells though no study links the two processes of nutrients enrichment and organic carbon synthesis in Lake Baringo. Previous studies on nutrients

in the lake have concentrated on determining nutrients levels, but have not indicated how these nutrients are related to the physiological processes of organic carbon synthesis and growth rates of picoplankton cells (Talling & Talling, 1965; Talling, 1966; Kiplagat, 1989; Barton *et al.*, Oduor, 2000). Nutrient enrichment increases the lakes' eutrophication (Bertoni & Callieri, 1993; Peters, 1996; Kohler & Gelbrecht, 1998; Kallqvist, 1987; Barber & Harworth, 1981; Patterson & Kiplagat, 1995). It also affects photosynthetic rates, assimilation efficiencies, rates of nutrient utilisation and grazing rates in the microbial loop in marine and fresh water ecosystems (Wetzel & Likens, 1991; Shivoga, 1991).

2.5 Effects of particulate organic carbon (POC) dissolved organic carbon (DOC) and biological oxygen demand (BOD) on picoplankton biomass and growth rates.

The variation in the measured levels of picoplankton organic carbon synthesis rates on a spatial and temporal basis reveals the extent to which turbidity affects this physiological process in an autotrophy (Bertoni & Callieri, 1993). De Bernadi (1991) reported that POC and DOC are likely to be the energy and mass stock or reserve inducing delays in ecosystem recovery. Despite their recognized importance, POC and DOC were neglected in long term studies of aquatic ecosystems though receiving due theoretical and empirical attention in modelling energy and matter cycling in lakes (Wetzel, 1972; Riemann & Sondergaad, 1986). Studies in Lake Zurichsee showed that dissolved organic carbon concentration increased as phytoplankton algal cells of the lake progressed (Hasler, 1947). The qualitative and quantitative approaches based on biological indices have generally neglected POC and DOC as determinants of the picoplankton cells fluctuation (Warren, 1971; Hagstrom *et al.*, 1979; Munawar & Fahnenstiel, 1982; Krienitz *et al.*, 1998; Bertoni & Callieri, 1993; Callieri *et al.*, 1996, Zaret, 1982).

The most likely reason for this is the professional preparation of the scientists involved who favoured morphological rather than chemical aspects (Bertoni & Callieri, 1993). It is only recently that the collection of long-term data series of parameters falling in POC and DOC analytical region has been undertaken though hardly for Lake Baringo (Bertoni *et al.*, 1991; Bertoni & Callieri, 1993; Callieri *et al.*, 1996).

Since shallow lakes such as Lake Baringo receive high amounts of organic matter inputs from terrestrial inflows, they are dominated by benthos decomposition (Wetzel, 1972). It has been reported further that the consumption of oxygen associated with bacterial decomposition of sediments organic matter is greater than the consumption by higher plants and animals in a lake ecosystem (Wetzel, 1972). This is termed as the BOD required by the bacteria for their decomposition role in lakes. High BOD due to the bacterial decomposition

of POC to a more usable DOC by bacteria is explained by increased oxygen demand (Bertoni *et al.*, 1996). High picoplankton biomass results from organic carbon synthesis and faster growth rates. This occurs when autotrophic production and bacterial utilisation of organic carbon proceeds. Measurement of BOD in Lake Baringo is lacking. No study so far has shown the relationship between rates of picoplankton organic carbon synthesis and BOD levels in this lake.

CHAPTER THREE

3.0 MATERIALS AND METHODS

3.1 Study area

Lake Baringo is situated between latitudes $0^0$36'N and $0^0$45'N and longitudes 36^0 04' E and 36^0 10' E at an altitude of 975 m above sea level in an endorheic basin (Kallqvist, 1987; Ssentongo, 1979). It has a catchments area of 6820 km^2 in the Eastern Rift Valley of East Africa, Kenya (Moss, 1988; Meyerhoff, 1991; Pencol, 1981). The lake is 22 km long and 12 km wide. The average depth of the Lake is 4.5 m with a maximum of 5.5 m and a surface area of 132 km^2 (Meyerhoff, 1991).

Research work in Lake Baringo may be traced back to the 1929-1931 Cambridge Expedition to the East African lakes (Worthington & Ricardo, 1936). Gregory (1921) gave the first detailed description of the general feature of the geology of Lake Baringo area. The main soil types include nitisols and ferrasols on summit ridges, lithosols on steep slopes, luvisols and solonchacks in the Njemps Plain (Rowntree, 1986). These features of the soil make the catchments area a fragile environment liable to soil erosion. The geology and soil types in the Njemps Plain consist of unconsolidated sediments, which result from the erosion of the uplifted Tugen Hills.

This lake comprises the rocky Northern zone and a swampy Southern zone as well as a Central zone with influence from Kampi Ya Samaki Town. The location and dimensions of the lake depict a characteristic Rift Valley endorheic lake of Pleistocene era. The lake is shallow and closed. The Rivers draining into the lake include: Kapthurin, Endao, Perkerra, Molo, Ol Arabel, Ngasotok and Mukutan (Fig.1). The lake has an underground seepage in the Northern zone (Kiplagat, 1989). These rivers are important to the lake due to the increased suspended solid loads that they bring into the lake coupled with nutrients and other minerals, which enrich the lake environment. The lake water is yellow–brown due to iron-silt complex, which circulates during the daily afternoon mixing of the lake waters. Water level fluctuates between 1.50 m to 1.70 m seasonally and annually (Kallqvist 1987; Moss, 1988).

Diel variation in water temperature had a mean of 23.3 ± 0.2 (S.E) ^{0}C. A difference of 4^0 C was recorded on the surface and benthic water temperature. Both the water and air temperatures are influenced by the radiant solar energy (Oduor, 2000).

The aquatic fauna in the lake include: Notonectidae, Copepoda, Chironomidae, *Crocodilus niloticus*, Hippopotamus sp., *Anas capensis* and diverse fish species such as *Barbus gregorii, Clarias gariepinus, Labeo cylindricus, Oreochromis niloticus baringoensis, Barbus lineomaculatus, Aplocheilichthys* sp. and *Protopterus aethiopicus* (Mlewa & Green,

2004; Mlewa &Green, 2006; Mlewa, et al, 2005; Worthington and Ricardo 1936; Ssentongo, 1979). Some fish species such as *O. niloticus baringoensis* feed mostly on algae. Some dominant algal species reported include blue green algae (Cyanophyceae e.g. *Microcystis* sp.), green algae (Chlorophyceae e.g. *Stigeoclonium* sp) and diatoms (Bacillariophyce e.g. *Flagilaria* sp) (Kallqvist, 1987).

The swampy areas around the lake comprise the following aquatic macrophytes: *Aeschynomene cristata, Azolla nilotica, Cyperus laevigatus, Cyperus papyrus, Pistia stratiotes, Vossia cuspidate, Phragmites mauritianus, Ludwigia stolonifera, Polygonum senegalense, Typha domingensis, Sesbania kinesis, pennisetum* sp., *Lemna* sp., *Ceratophylum demersum* and *Najas pectinata.* The aquatic macrophytes form a barrier to the transport of sediments into the lake and an important source of organic matter entering the lake. They are useful fish protection sites and habitats for their reproduction. The local population uses *Aeschynomene cristata* (locally known as Ambach) in building rafts and fishing floats while *Cyperus papyrus, Phragmites mauritianus* and *Typha domingensis* are used in house roofing

The land vegetation surrounding the Lake includes: *Acacia tortilis, Acacia Seyal, Acacia nubica, Prosopis brazilensis, Balanites aegyptica* (Meyerhoff, 1991). On the Tugen Hills there are shrubs such as: *Juniperus procera, Rhus natalensis, Trichcladus ellipticus, Grewia* sp., *Acacia reficiens, Acacia nilotica, Croton dichoganius, Salvadora persica* and *Adansonia digitata.* Most of these plants are economically important for the local people who use them as medicinal plants, edible fruits, gum, craft industry, beehive shelters and house building (Beentje, 1994).

3.2 Socio – economic aspects

Lake Baringo is currently silted with low primary production, which has resulted from a complex interaction of social and ecological forces over the years (Kallqvist, 1987; de Groot *et al.*, 1992). The social aspects are attributed to the presence of three different ethnic groups inhabiting the area and practising different agro pastoral activities (women and men herders) (Meyerhoff, 1991). These groups include the Tugen, the Pokot and the Ilchamus or Njemps (Meyerhoff, 1991; de Groot *et al.*, 1992).

The Kikuyu, Kipsigis and Ogiek ethnic groups also live and practise farming (women and men) and logging (men) in Nakuru District which is the catchments area of the Molo River. These activities have impacts on the lake's sediments input. The Tugen live to the West of the lake in the Tugen Hills and on the Tugen Plateau. They are primarily agriculturalists but also keep herds of cattle, sheep and goats. The Pokot occupy the flatter region to the North. They are semi-nomadic pastoralists, herding large herds of cattle, sheep,

goats and camels. The Ilchamus living to the South of the lake are related to the Maasai (Meyerhoff, 1991). They are mostly sedentary agro-pastoralists, although the Illchamus practise some agriculture; they are heavily dependent on their livestock of primarily cattle, sheep and goats. They are fishermen who depend on fishing activities for their livelihood. The once vibrant fish factory at Kampi Ya Samaki town collapsed in the early 1990s due to the diminishing fish catches. Such a study will shade light on the possibility of using the knowledge obtained in cultivating picoplankton for the increased fish food in the lake.

3.3 Sampling sites

The study area has been described in section 3.1. Within the study area, there were Southern zone comprising three sites namely: Molo River mouth (MM), Mlima Sitan (MS) and Kiserian (KN). The Central zone comprised the following sites: Kampi Ya Samaki (KS), Island Camp (IC) and Longicharo (LN). The Northern zone comprised of the following sampling sites: KMFRI offices (KO), Loruk (LR) and Komolion (KN). The zones were chosen based on the level of turbidity that resulted from sediments and suspended solid matter. Those disturbances were dependent on the activities taking place in the catchments area (Okorie, 1975). Wind induced suspension of sediments was caused by afternoon Northeasterly winds. Those disturbances often occurred during afternoon.

Human disturbance on the other hand are induced by livestock grazing on the swampy habitats where fish breed. Human population also cleared the swampy areas during fishing or farming activities.

3.3.1 High sediments disturbance zone

Southern zone: inflows from Rivers Kapthurin, Endao, Perkerra, Molo, Ol Arabel and Ngasotok. It is a silt muddy benthic area of depth 2-3.5 m. A swampy area bordering the lake with aquatic vegetation made up of aquatic macrophytes described in section 3.1.4. Fishing and livestock grazing activities are discernible in the zone. This zone has more anthropogenic disturbance than wind disturbance.

3.3.2 Moderate sediments disturbance zone

Central zone: inflows from River Mukutan, with a sandy gravel and silt benthos area of depth 2-3.5 m. This zone receives the wastewater from Kampi Ya Samaki town and Island Camp hotel that are important sources of phosphate and nitrates for the lake.

Human activities include: Washing, water collection, livestock grazing (goats, sheep, cattle, and camels), watering points, fishing and landing beaches for boats with outboard engines. The zone is bordered by aquatic macrophytes. Hot springs from Kokwa Island drain into the lake in this zone.

Northeasterly winds occur in this zone. Due to the winds, the bottom sediments are stirred and resuspended in this zone each afternoon.

3.3.3 *Low sediments disturbance zone*

Northern zone: A rocky cliff with a maximum depth of 5.5 m. The benthos area has sand mixed with mud. Human activities include fishing (men), fish trading (women) and livestock grazing (men and women). The zone is sparsely surrounded by aquatic macrophytes. A Northeasterly wind dominates in this zone and is the most wind disturbed zone of all the three zones.

3.4 *Field sampling procedure*

Sampling was done at three sampling sites within each of the three zones (Fig. 1) once every month for twelve consecutive months beginning at 6.00 a.m. from June 2003 to May 2004. Sampling followed a three stage nested experimental design whereby each of the nine sampling sites was nested within the sampling zones.

Water samples were collected once at each sampling site. Sampling was carried out using a pre-cleaned Van Dorn water sampler (Plate1) at depths of 0 m, 0.75 m and 3.0 m respectively. Water samples for inorganic suspended solids were kept in 1-litre glass bottles. Water samples for BOD analysis were transferred to scrubbed darkened glass bottles.

Water samples for total phosphorus and total nitrogen content analysis were transferred to 1-litre glass bottles prior to treatment with mercuric chloride (to stop bacterial nutrient uptake). All the samples collected were stored at 4°C in a cool box for analysis in the laboratory. Analysis was carried out within 48 hours.

Transparency and turbidity were determined *in situ* using a 20 cm secchi disk and a turbidimeter, respectively. Temperature, pH and conductivity were measured *in situ* using battery operated thermometer, pH meter and conductivity meter respectively. Dissolved oxygen and percentage oxygen saturation were measured using an oxygen meter. Total alkalinity was determined using acidification method as described in Wetzel and Likens (1991).

Picoplankton from depths of 0 m, 0.75 m and 3 m were collected. Sampling was done at 2-hour interval for 24 hours beginning at 6 a.m. Water collected by Van Dorn water sampler was filtered through 0.2 μm nuclepore filters. The picoplankton samples from the depths were mixed together to form composite samples. Samples from each of the sampling sites were divided into three glass conical flask bottles of 150 ml each. Into one of the bottles one percent solution of formalin was added (to stop picoplankton growth). The three glass bottles were then incubated at a depth of 0.7 m for 4 hours. After incubation the three glass bottles were retrieved. Lugol's solution was then added into each of the three bottles and

preserved at 4 °C in a cool box. The cool box was transported to the laboratory for analysis of picoplankton biomass and growth rate.

3.5 *Laboratory analysis*

3.6 *3.5.1 Inorganic suspended solids, nutrients, carbon and BOD*

Inorganic suspended solids were determined as described by Orlando *et al.* (1998). Total phosphorus was determined using persulfate digestion method according to Murphy and Riley (1962) as described by Wetzel and Likens (1991). Total nitrogen was determined using Kjedahl digestion method as described by Ahlgren and Ahlgren (1975). Wet oxidation technique of Maciolek (1962) as described by Wetzel and Likens (1991) was used to analyse particulate organic carbon. Dissolved organic carbon was analysed using potassium persulfate described by Wetzel and Likens (1991).

Biological oxygen demand was determined in water samples incubated in the laboratory in darkness at 20°C for five days in sealed BOD bottles using Winkler method as described by APHA (1992).

3.5.2 Picoplankton organic carbon synthesis and growth rate

100 ml of the lake water was filtered through a 0.2 μm nuclepore filter stained with acridine orange with a suction pump at low pressure (150 mm Hg) to remove flagellate predators. Stained 0.2 μm filters were used to count picoplankton cells. An epifluorescence Leitz model microscope at a magnification of x1000 was used to determine the frequency of dividing cells. A cell was considered to be in division phase from the time when the cell wall shows invagination until two distinct cells could be identified. A minimum of 200 total cells and 70 dividing cells for each sample were enumerated. Organic carbon synthesis and growth rate were determined according to Callieri *et al.* (1996): net growth rate:

$$X = l/t \ln Nt/No,$$

Where No was initial exponential phase, Nt was final exponential phase, t was time lapse between first generation and the second one. Specific growth rate;

$$X_{FDC} = 1/n \, td \sum \ln (1+fi),$$

Where n was the number of sampling intervals, fi was fraction of dividing cells for each sampling interval; td was duration of division of the picoplankton.

The rate of organic carbon synthesis (OCS) of the picoplankton was determined from;

$$OCS \ (mg \ C \ m^{-1} \ d^{-1}) = X_{FDC} \ \overline{No} \ C \ cell^{-1}.$$

Loss rate due to grazing, mortality and sedimentation was measured from the difference between net growth and specific growth rates.

3.6 *Data analysis*

Data obtained from the nine sampling sites in the three zones were transformed to natural logarithm to homogenize the variance.

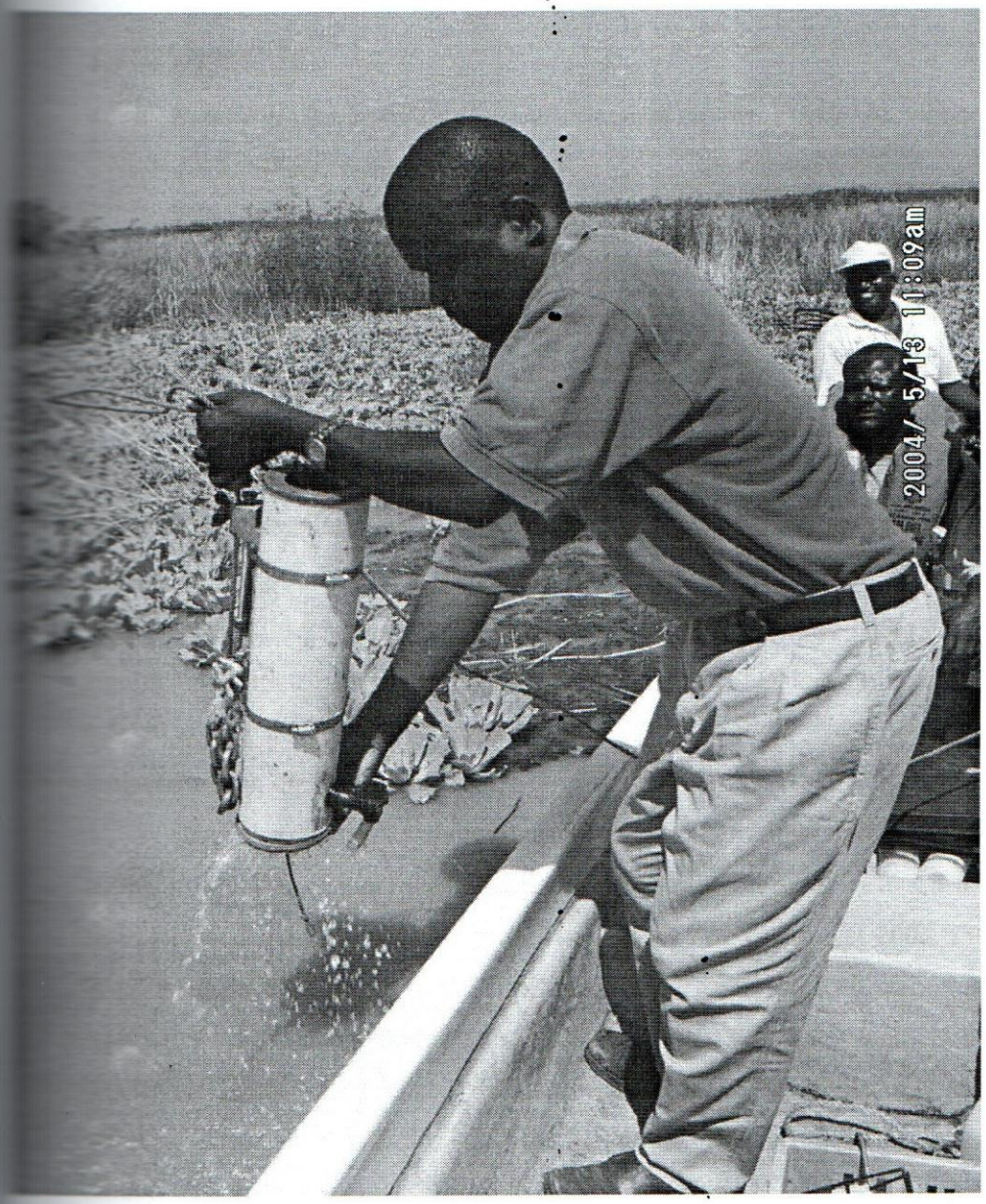


Plate 1. Field water sampling activity in Lake Baringo

Analysis of variance (ANOVA) was performed using statistical analysis software (SAS). Prediction equations for the multiple regression models relating turbidity to picoplankton organic carbon synthesis and growth rates were computed as in Fowler and Cohen (1990). Multivariate analysis of the turbidity and picoplankton growth rate data were performed using spreadsheet excels. Frequency of dividing cells was approximated at ninety five-percentage confidences. Percentage of the bacterial counts was also computed.

CHAPTER FOUR

4.0 RESULTS

4.1 Relationships between physical-chemical environmental factors in Lake Baringo

4.1.1 Water temperature

The water temperature ranged from a minimum of 20.0°C at the bottom layer to a maximum of 33.9°C at the surface layer of the lake both in the Southern zone, which had the lowest and the highest values (Appendix 1). Southern zone was also the shallowest and most disturbed by anthropogenic factors such as human and livestock. Spatial mean (23.95 ± 0.83 (S.E.) °C) of water temperature variations were recorded. Spatially, the sampling zones were significantly different (ANOVA: $F_{0.01} = 4.202$) as well as the sampling sites (ANOVA: $F_{0.01} = 4.515$) in water temperatures, with an exception of vertical depths (0 m, 0.75 m, 3 m) (ANOVA: $F_{0.05} = 1.751$), which were not significantly different. The mean temporal water temperature of 23.95 ± 0.3 (S.E.) °C was recorded for the entire lake (Table 1). There was no significant temporal variation in water temperature in the Northern and Central zones. There was a significant temporal variation (ANOVA: $F_{0.01} = 4.75$) in the monthly water temperatures in the Southern zone.

The lake reached its thermal peak in December 2003 showing a seasonal pattern. The temperature fell in January and started to rise again in February up to April 2004 (Fig 4). This rise coincided with dry months in the lake. In May up to August 2003, the temperature was low during the wet season in the lake area. During September, the temperature began to rise with a peak in October 2003. There was a short-lived low water temperature in the month of November 2003, which was relatively wet compared to October 2003. The low mean standard error for the entire lake temperatures observed showed minimized biases and randomness during the measurements in the lake (Table 1). Ambient air temperature recorded rose from 21°C at 8.00 hours to 34°C at 16.00 hours. A maximum air temperature of 38.9 was recorded in the field in the month of March 2004 with a mean of 32.4 0.2 (S.E.) °C.

It was established that the water temperature had a close relationship with the pH ($R^2 = 0.46$, $P \leq 0.148$). A model was derived which related water temperatures to POC and DOC, ($R^2 = 0.69$, $P \leq 0.18$), in the lake using regression statistics:

Ln (temperature) = -2.831 – 3.035 ln (POC) + 3.109 ln (DOC).

Temperature was also related to ISS, turbidity and TDS in the Lake ($R^2 = 0.96$, $P \leq 0.06$). A model below was derived relating these environmental factors to temperature:

In (temperature) = -1.413 – 0.189 ln (ISS) + 0.799 ln (turbidity) + 0.001 ln (TDS).

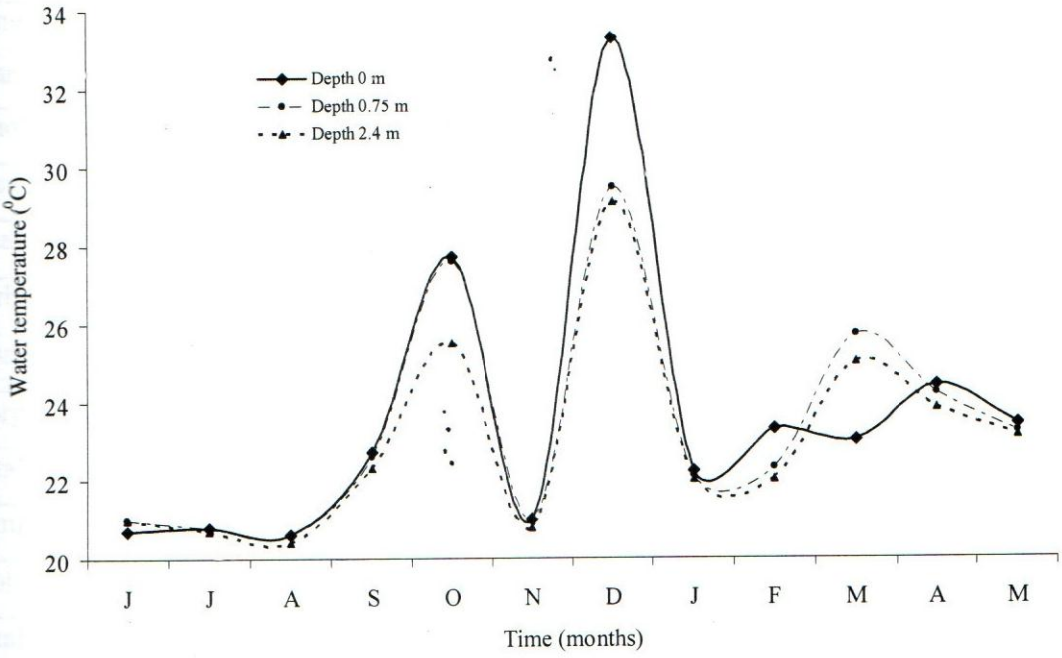


Figure 4: Seasonal variation of water temperature (°C) of Lake Baringo (June 2003 – May 2004)

4.1.2 Turbidity

In the lake, however, turbidity was as low as 289 Nephelometric units (NTU) recorded at River Molo mouth in the southern zone (Appendix 2). Southern zone had consistently low turbidity throughout the months investigated with a mean of 567 ± 13.6 (S.E.) NTU. Central zone had a mean of 733.56± 0.66 (S.E.) NTU. Northern zone had a mean of 829.4 ± 7.0 (S.E.) NTU. The spatial mean (753.57± 18.23 (S.E.) NTU) of water turbidity of the entire lake was recorded during the investigation. Spatial variations in the zones were significantly different (ANOVA: $F_{0.01} = 4.71.0396$); sampling sites were significantly different (ANOVA: $F_{0.01} = 290.9609$), while depths were not significantly different (ANOVA: $F_{0.05} = 0.166$).

Figure 5 shows the mean spatial fluctuations of turbidity in the lake. Southern zone had generally low values. In the southern zone, Molo River mouth recorded the lowest values however; Mlima Sitan and Kiserian had similar values. In the central zone, Island camp had the highest value, followed by Longicharo and Kampi Ya Samaki, respectively. Northern zone sampling sites had uniform values, recording the highest among the three zones.

Table1: Mean morphometric and physical-chemical environmental factors of Lake Baringo from June 2003 to May 2004

Zone (Variable)	Southern (Mean)	Central (Mean)	Northern (Mean)	Total (Mean)
Whole catchments area (km^2)				6820 ±30
Area (km^2)	59 ±0.03	43 ±0.01	30 ±0.02	132 ±0.11
Mean depth (m)	2.5 ±. 06	3.5 ±0.03	4.5 ±0.1	3.5 ±0.2
Turbidity (NTU)	606 ±13.6	706.56 ±2	832 ±8.1	709 ±10.9
Transparency (cm)	5.89 ±0.1	4.75 ±0.02	4.41 ±0.14	5.02 ±0.72
Inorganic suspended solids (µg/l)	103.13 ±2.	56.23± 0.4	86.99 ±4.1	79.68 ±17.7
Total dissolved solids (µg/l)	860.28 ±7	986.8 ±9	946.82 ±11	931.3 ±53.3
Temperature (^0c)	22.48 ±0.4	23.97 ±. 02	25.42 ±0.8	23.95 ±0.83
Biological oxygen demand (µg/l)	27.23 ±0.1	79.8 ±0.4	35.79 ±3	47.61 ±5.21
Total phosphorus ((µg/l)	367.08 ±4	498.83 ±7	594.89 ±1	487.17 ±1.9
Total nitrogen (µg/l)	207.56 ±3	136.81 ±2	184.61 ±. 14	176.33 ±19
Conductivity (µs/cm)	1553.06 ±4	1803.26 ±3	1738.18 ±17	1698.1 ±13
Total alkalinity (meq/l)	6.31 ±0.1	8.21 ±0.2	7.4 ±1.2	7.3 ±0.36
PH (pH – units)	7.99 ±0.3	8 ±0.28	7.62 ±0.29	7.87 ±0.28
Dissolved oxygen (mg/l)	4.72 ±0.02	4.37 ±0.02	5.34 ±0.2	4.81 ±0.01
Dissolved oxygen (% saturation)	71.2 ±. 028	59.7 ±0.21	73.3 ±0.22	68.06 ±7.25
Particulate organic carbon (µg/l)	763.2 ±3	773.32 ±4	784.6 ±4	773 ±67.6
Dissolved organic carbon (µg/l)	4419.5 ±21	3782.89 ±32	4328.22 ±31	4176.8 ±28
Specific BOCS ($mgcm^{-3}d^{-1}$)	15.49 ±0.21	14.54 ±0.23	15.39 ±0.22	15.14 ±0.22
Net BOCS ($mgcm^{-3}d^{-1}$)	8.02 ±0.2	5.8 ±0.2	7.35 ±0.1	7.06 ±0.19
Loss estimates ($mgcm^{-3}d^{-1}$)	8.22 ±0.1	8.72 ±0.12	8.11 ±0.13	8.35 ±0.11
Specific picoplankton growth rate ($mgcm^{-3}d^{-1}$)	2.54 ±0.03	2.83 ±0.04	2.6 ±0.03	2.66 ±0.03
Net picoplankton growth rate ($mgcm^{-3}d^{-1}$)	1.15 ±0.02	1.2 ±0.01	1.22 ±0.02	1.19 ±0.01
Picoplankton cell abundance ($cells*10^3ml^{-1}$)	185 ±1.12	130 ±0.18	95 ±. 1.8	136 ±1.6

This was contributed by daily afternoon mixing and resuspension of solid particles stirred from benthic sediments by Northeasterly winds. A mean temporal variation of 751.71± 87.08 (S.E.) NTU in the lake was recorded. There was no observable seasonal variation in turbidity in the individual zones studied. However, during the short wet season of September 2003 to December 2003, low values of turbidity were recorded in the Southern zone.

Figure 6 shows the mean temporal variation of turbidity in the lake. There was a steady rise in turbidity observed from June 2003 to a maximum value in August during short wet season. This was followed by a decline up to the month of December 2003. In January 2004, there was a sharp decline, which rose slightly in February but dropped again in March up to May 2004. These variations recorded were not significantly different (ANOVA: $F_{0.05}$ = 0.5168), during the investigation.

4.1.3 Inorganic suspended solids

The inorganic suspended solids ranged from a minimum of 15 μgl^{-1} to a maximum of 287 μgl^{-1} at the KMFRI office in the northern zone and Kampi Ya Samaki in the central zone respectively (Appendix 3). Southern zone had the lowest mean value (48.78 ± 0.2 μgl^{-1} (S.E.)) of ISS in the Lake. This was followed by central zone with a mean value of 56.23 ± 0.04 μgl^{-1} (S.E.). The mean spatial variation of 98.10 ± 19.41 (S.E.) μgl^{-1} (ISS) was recorded, during the investigations. Spatially, the northern zone was significantly different from the Southern zone (ANOVA: F $0_{.05}$ = 7.97). Central zone was also significantly different from Northern zone (ANOVA: F $0_{.05}$ = 5.26) and sampling sites were significantly different (ANOVA: $F_{0.05}$ = 6.83), but not the vertical depths (0 m, 0.75 m and 3 m) (ANOVA: $F_{0.05}$ = 0.01). The mean spatial variation of 98.10 ± 19.41 (S.E.) μgl^{-1} (ISS) was recorded, during the investigations. Spatially, the northern zone was significantly different from the southern zone (ANOVA: F $0_{.05}$ = 7.97). Central zone was also significantly different from northern zone (ANOVA: F $0_{.05}$ = 5.26) and sampling sites were significantly different (ANOVA: $F_{0.05}$ = 6.83), but not the vertical depths (0 m, 0.75 m and 3 m) (ANOVA: $F_{0.05}$ = 0.01). Figure 7 shows mean spatial fluctuations of ISS in the lake with the highest mean value at Kampi Ya Samaki in the central zone of 151.69± 11.2 (S.E.) μgl^{-1}. Incidentally, the entry site of Molo River in the southern zone recorded steadily high values. In this zone, values recorded decreased from River Molo mouth off shore, suggesting a steady sediments flow. Kenya Marine Offices recorded the lowest values in the northern zone with Komolion recording the highest mean value.

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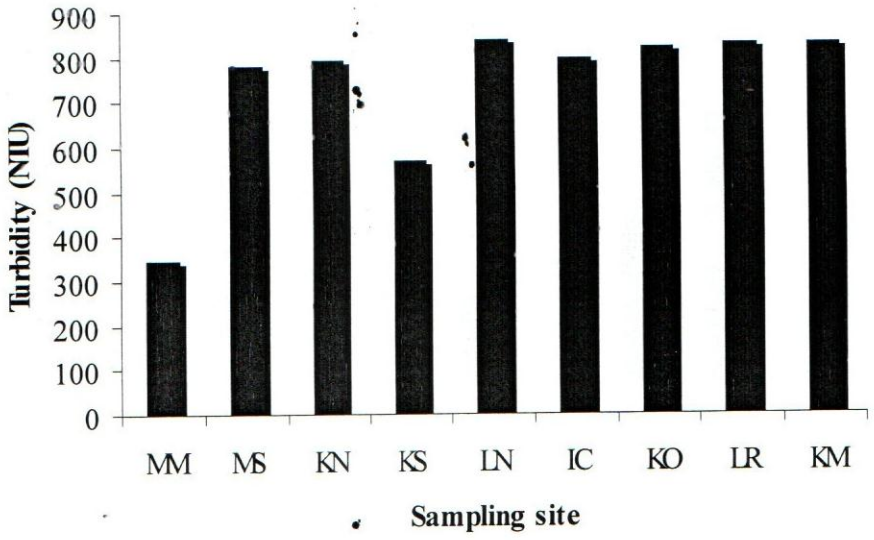


Figure 5: **Mean spatial variation of turbidity (NTU) in Lake Baringo (June 2003-May 2004)**

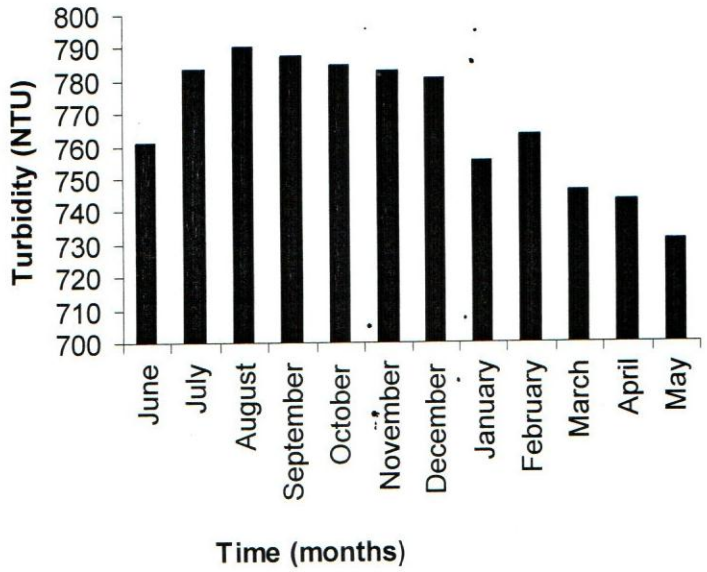


Figure 6: **Mean temporal variation of turbidity (NTU) of Lake Baringo (June 2003-May 2004)**

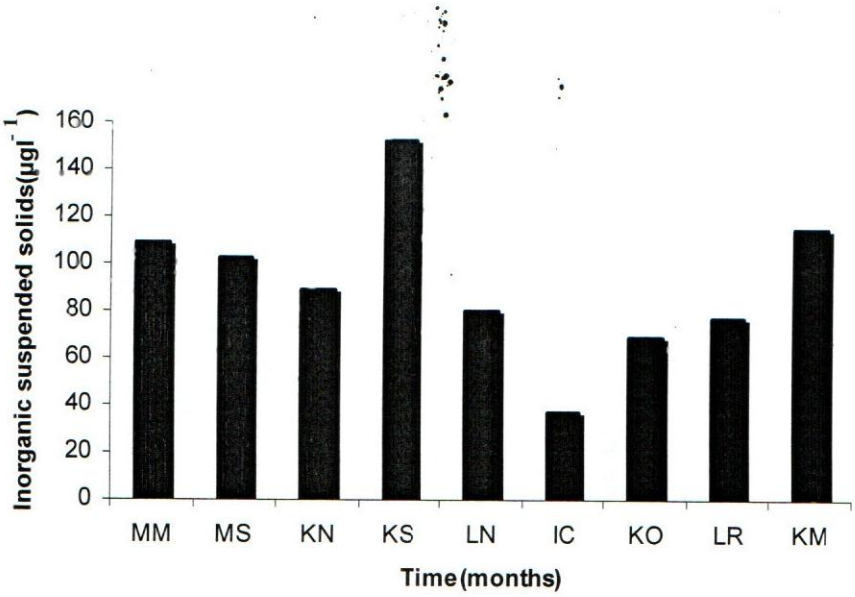


Figure 7: Mean spatial variation in inorganic suspended solids (μgl^{-1}) in Lake Baringo (June 2003-May 2004)

There was no significant mean temporal variation (ANOVA: $F_{0.005} = 1.870$) observed on ISS. There was no seasonality observed during wet and dry seasons in all the three zones.

The mean temporal variation of ISS observed was 98.01 ± 11.95 (S.E.) μgl^{-1} for the entire lake. Figure 8 shows the temporal variations of ISS in the lake. From July, the ISS rose steadily up to November 2003, when it dropped. From December 2003 to May 2004 the ISS was not changing significantly.

4.1.4 Total dissolved solids

The total dissolved solids (TDS) ranged from a minimum of 118 μgl^{-1} to a maximum of 1129 μgl^{-1} at Mlima Sitan in the southern zone and Longicharo in the central zone respectively (Appendix 4). Southern zone had a mean of 860.28 ± 30 (S.E.) μgl^{-1} while Central zone had a mean of 986.90 ± o.61 (S.E.) μgl^{-1}. Northern zone had a mean of- 946.82 ± 0.61 (S.E.) μgl^{-1}. Mean spatial variation of the entire lake for TDS was 878.96 ± 72.2 (S.E.) μgl^{-1}.

Figure 9 shows mean spatial fluctuations of total dissolved solids in the lake. Spatially, River Molo mouth in the Southern zone had the least mean value (491.91 ± 72.20 (S.E.) μgl^{-1}) while Kampi Ya Samaki in the central zone recorded the highest mean value (999.21 ± 72.20 (S.E.) μgl^{-1}). Observed values showed significant spatial variations in the study zones (ANOVA: $F_{0.01} = 28.16$) and the sampling sites (ANOVA: $F_{0.01} = 16.68$) but not at different vertical depths (ANOVA: $F_{0.05(12.90)} = 0.02$), during the investigation

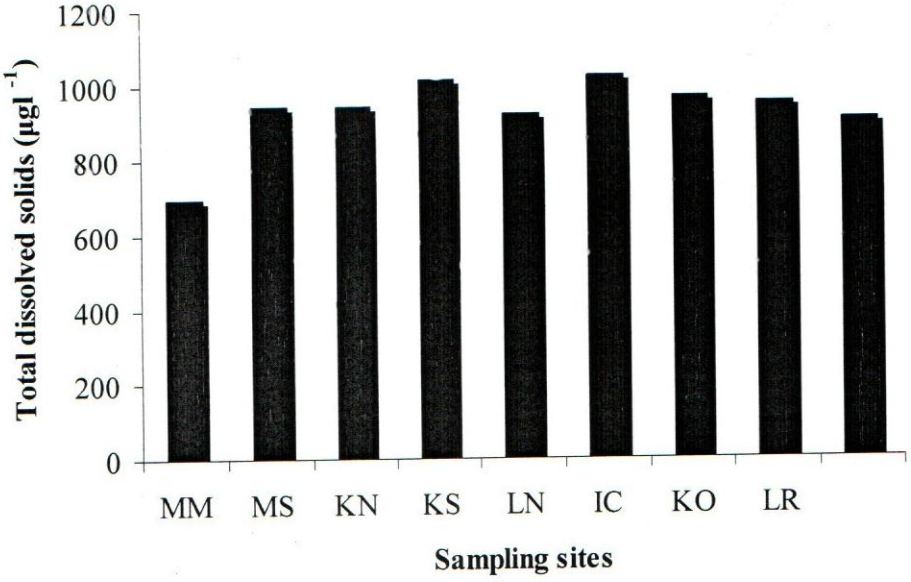


Figure 9: Mean spatial variation in total dissolved solids (μgl^{-1}) in Lake Baringo (June 2003- May 2004)

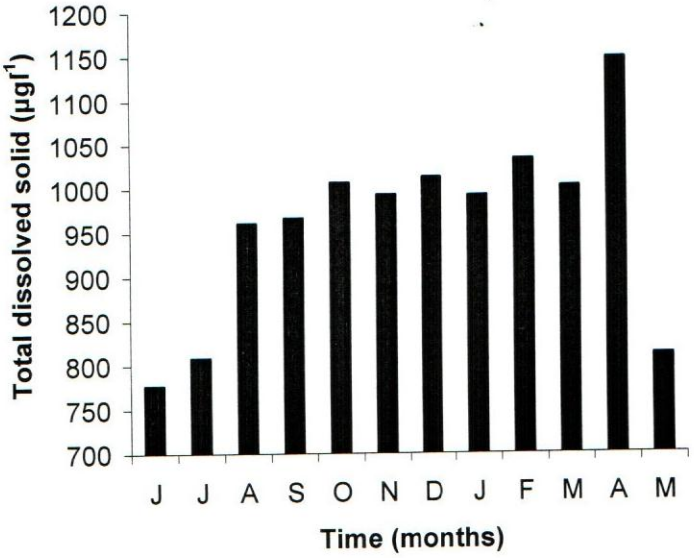


Figure 10: Mean temporal variation in total dissolved solids (μgl^{-1}) in Lake Baringo (June 2003- May 2004)

The mean temporal variation of 5.62 ± 0.6 (S.E.) cm in transparency was observed. There was no significant temporal variation in transparency (ANOVA: $F_{0.05}$= 2.0128) over the investigation period. Figure 12 shows the temporal variations in transparency in the lake. The mean transparency in June 2003 was 4.96 ± 0.72 (S.E.) cm which fell to a minimum mean of

3.28± 0.01 (S.E.) cm in August 2003. The lake's transparency increased to a maximum mean of 6.14 ± 0.54 (S.E.) cm in December 2003, showing a seasonal fluctuation.

Transparency was strongly related to ISS, TDS, turbidity and conductivity ($R^2 = 0.99$; $P \leq 0.145$) as illustrated in the following model:

Ln (Transparency) = 6.54 + 0.025 ln (ISS) + 1.203 ln (TDS) + 0.001 ln (turbidity) – 1.78 ln (conductivity).

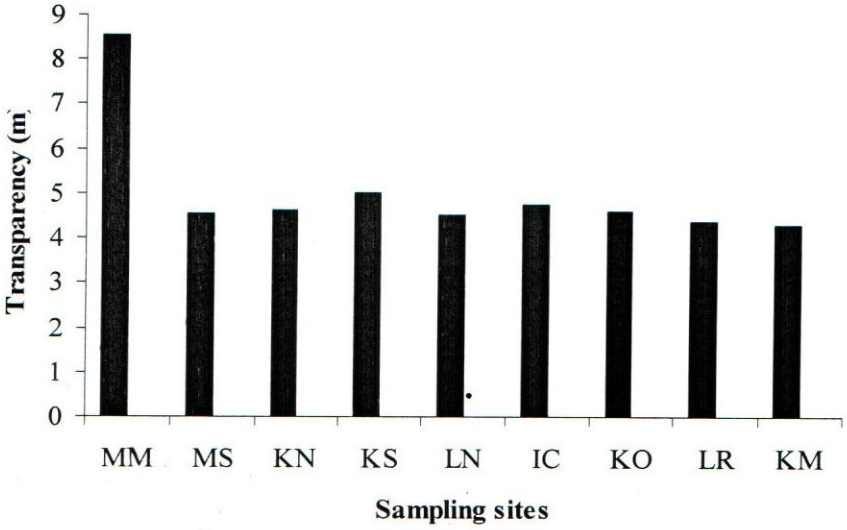


Figure 11: Mean spatial variation in transparency (m) in Lake Baringo (June 2003- May 2004)

Whereas some chemical environmental factors were observed and measured in the field (dissolved oxygen, percentage oxygen saturation, pH, conductivity), most of them were sampled and later analysed in the laboratory (BOD, total alkalinity, total phosphorus, total nitrogen, POC, DOC).

4.1.6 Dissolved oxygen and percentage oxygen saturation

Data on the spatial variations of dissolved oxygen and their corresponding percentage saturation are given in the appendices 6 and 7 respectively. Minimum (2.6 mgl^{-1}) and maximum (7.6 mgl^{-1}) dissolved oxygen were recorded at the River Molo mouth in the southern and Longicharo in the central zones respectively. Spatial mean variations (5.34 ± 0.33 (S.E.) mgl^{-1}) in dissolved oxygen were recorded over the investigation period. There was a significant spatial variation in dissolved oxygen at the zones (ANOVA: $F_{0.05} = 11.3244$), but not in different vertical depths and sampling sites. It was observed that benthic levels of

oxygen in the lake were high averaging to over 4.6 mgl^{-1}, indicating mixing up in the benthic zone.

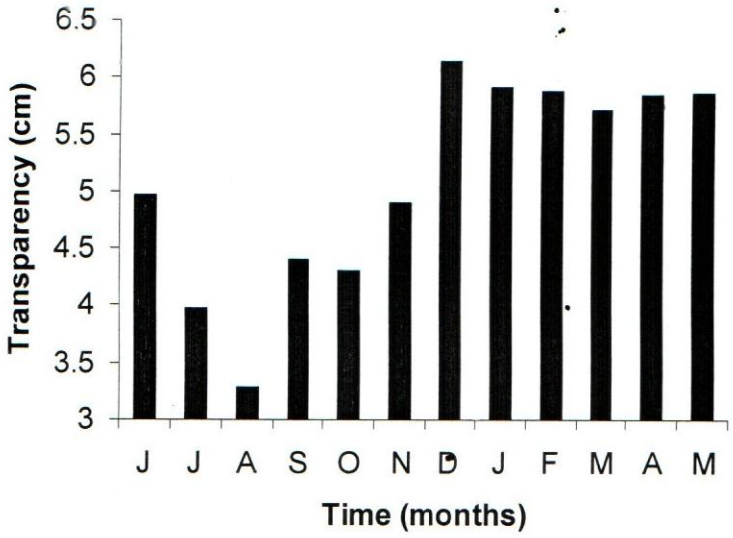


Figure 12: Mean temporal variation in transparency (m) in Lake Baringo (June 2003-May 2004)

The mean temporal dissolved oxygen measured was not significantly different in all the three zones (5.33 ± 0.23 (S.E.) mgl^{-1}). There was no significant temporal variation of dissolved oxygen in the lake over the study period (ANOVA: $F_{0.05} = 2.639$). It was observed that there were no seasonal variations in the levels of dissolved oxygen in the lake.

The mean spatial variation (90.05 ± 7.45 (S.E.)) of dissolved oxygen percentage saturation was recorded over the investigation period. A minimum (42) and maximum (132) dissolved oxygen percentage saturation were recorded at Kampi Ya Samaki in the central and River Molo mouth in the southern zones respectively. No zone was spatially significantly different from the other (ANOVA: $F_{0.05} = 2.19$). However, the sampling sites in all the three zones showed significant spatial variations (ANOVA: $F_{0.05} = 3.8$), but not vertical depths (ANOVA: $F_{0.05} = 0.210$) at the southern, central and northern zones.

The mean temporal variation of dissolved oxygen percentage saturation was observed in the lake to be 89.98 ± 3.64 (S.E.). There was a significant temporal variation (ANOVA: $F_{0.01} = 10.7832$) in dissolved oxygen percentage saturation recorded over the investigation period.

4.1.7 Biological oxygen demand

The biological oxygen demand (BOD) ranged from a minimum of 19 μg 0_2l^{-1}, 20°C 5 day^{-1} at KMFRI office in the northern zone to a maximum of 199 μg 0_2l^{-1}, 20°C 5 day^{-1} at Kampi Ya Samaki in the central zone (Appendix 8). The central zone had the highest mean (80.09 ± 1.8 (S.E.) μg 0_2l^{-1}, 20°C 5 day^{-1}) BOD values due to its proximity to Kampi Ya Samaki town, Lake Baringo Club and Island camp hotel remitting organic matter to the lake. Northern zone recorded a mean value of 36.0 ± 2 (S.E.) μg 0_2l^{-1}, 20°C 5 day^{-1} BOD. Southern zone had a mean value of 27.23 ± 3.2 (S.E.) μg 0_2l^{-1}, 20°C 5 day^{-1} BOD. The spatial variation (60.34 ± 11.85 (S.E.)) μg 0_2l^{-1}, 20°C 5 day^{-1}) of BOD in the lake was recorded over the investigation period. The three zones (southern, central and northern) showed significant spatial variations (ANOVA: $F_{0.05} = 251.93$), as well as the sampling sites (ANOVA: $F_{0.05} = 165$), but not vertical depths (ANOVA: $F_{0.05} = 0.135$).

Figure 13 shows spatial fluctuation of BOD in the lake. In the southern zone, the BOD level was low and uniform followed by northern zone with the central zone recording the highest value. The spatial variation (60.34 ± 11.85 (S.E.)) μg 0_2l^{-1}, 20°C 5 day^{-1}) of BOD in the lake was recorded over the investigation period.

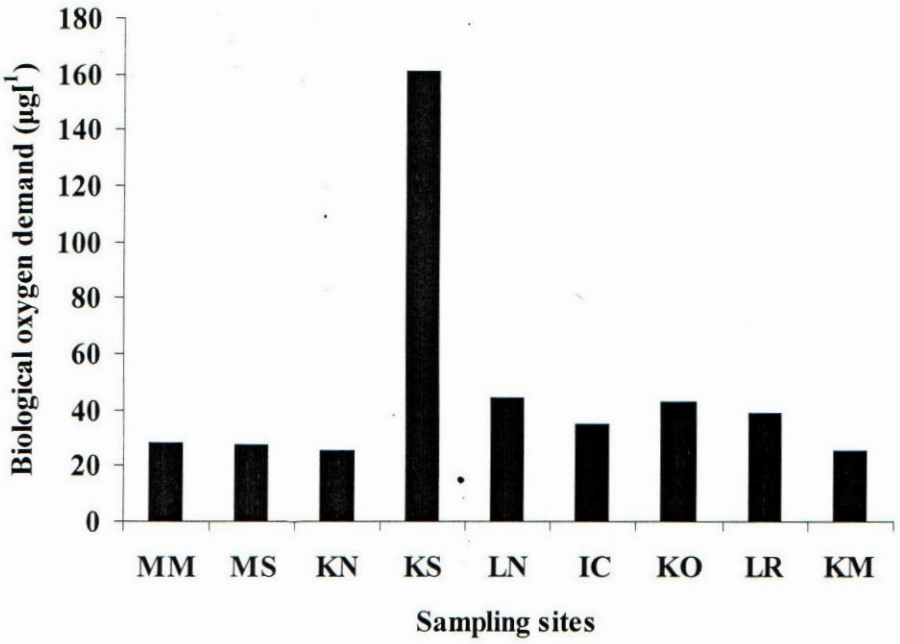


Figure 13: Mean spatial variation in biological oxygen demand (μgl^{-1}) in Lake Baringo (June 2003- May 2004)

The mean temporal variation (60.34 ± 11.85 (S.E.) µg $0_2 l^{-1}$, 20°C 5 day^{-1}) of BOD was recorded over the study period. There was no significant temporal variation (ANOVA: $F_{0.05} = 0.9826$) in BOD over the investigation period. Seasonal variation was not observed.

Figure14 shows the temporal variations in BOD of the lake. From June, there was a decrease and a rise with two observable peaks in the months of August and December 2003. From January to May 2004, the BOD levels were high in the three zones.

The BOD was closely related to the presence of total nitrogen and total phosphorus as shown by the link between BOD and the ratio between the two factors (total nitrogen and total phosphorus) computed into parameters (TN: TP; $R^2 = 0.83$; $P \leq 0.01$).

4.1.8 pH

pH values ranged from a minimum of 6.98 pH units to a maximum of 9.54 pH units at River Molo mouth in the southern zone and KMFRI office in the northern zone respectively (Appendix 10). The mean spatial variation of pH recorded during the investigation period was 8.62 ± 0.29 (S.E.) pH units. At any given sampling site, the difference of the surface and bottom pH never exceeded one pH unit. There was no significant spatial variation in the pH in the three zones (ANOVA: $F_{0.05} = 0.7229$) and vertical depths (ANOVA: $F_{0.05} = 0.2671$). Spatially, the sampling sites within the central zone were significantly different (ANOVA: $F_{0.05} = 5.9377$) in the lake.

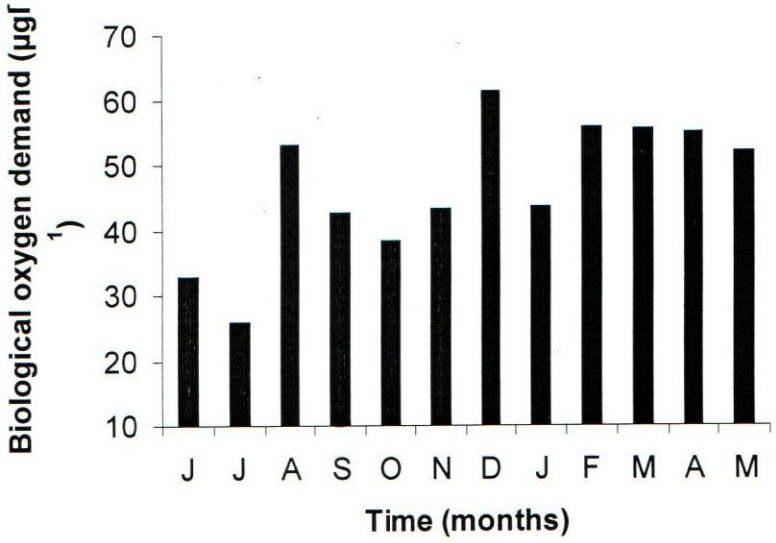


Figure 14: Mean temporal variation in biological oxygen demand ($\mu g l^{-1}$) in Lake Baringo (June 2003- May 2004)

The mean temporal variation (8.66 ± 0.15 (S.E.) pH units) of pH was recorded for the entire lake. There was a significant temporal variation (ANOVA: $F_{0.05} = 5.553$) in pH over

the period of investigation. In the wet season (April to August 2003), pH values in all the zones declined.

4.1.9 Conductivity

Water conductivity ranged from a minimum of 226 μScm^{-1} at River Molo mouth in the southern zone to a maximum of 2620 μScm^{-1} at Loruk sampling site in the northern zone. The mean spatial variations (1740.58 ± 289.60 (S.E.) μ scm^{-1}) in conductivity values were computed. The southern zone had a mean value of 1553.06 ± 10 (S.E.) μScm^{-1}. The Central zone had a mean value of 1803.06 ± 50 (S.E.) μScm^{-1}. The northern zone had a mean value of 1738.18 ± 23 (S.E.) μScm^{-1}. There was a significant variation in water conductivity in the three zones of the lake (ANOVA: $F_{0.01} = 7.2513$) and sampling sites (ANOVA: $F_{0.01} = 6.1055$), but not the vertical depths (ANOVA: $F_{0.05} = 0.052$).

Figure 15 shows spatial fluctuations in conductivity in the lake. Molo River mouth recorded the lowest mean value due to inflows from the River. The rest of the sampling sites had values approaching the general means observed throughout the study area. The mean temporal variation (1740.58 ± 289.52 (S.E.) μScm^{-1}) of conductivity was recorded. Temporal variations in the water conductivity were not significantly different (ANOVA: $F_{0.05} = 2.7354$). Throughout the study period, there was no seasonal variation observed since mean values of most of the sampling sites ranged from 1500 –2000 μScm^{-1}.

Figure16 shows temporal conductivity changes in the lake. With low values in June, there was a rise in the levels with a maximum value in September 2003. The values declined up to a minimum in January 2004. This rose slightly in February up to May 2004 when the values never changed much. Conductivity was related to turbidity in the lake ($R^2 = 0.97$, $P \leq 0.00019$).

4.1.10 Total phosphorus and total nitrogen

Total phosphorus values ranged from a minimum of 27.0 μgl^{-1} at Mlima Sitan in the southern zone to a maximum of 59.7 μgl^{-1} at Kampi Ya Samaki in the central zone. In the southern zone the mean total phosphate was 367.08 μgl^{-1} while in the central zone the mean was 498.83 μgl^{-1}.

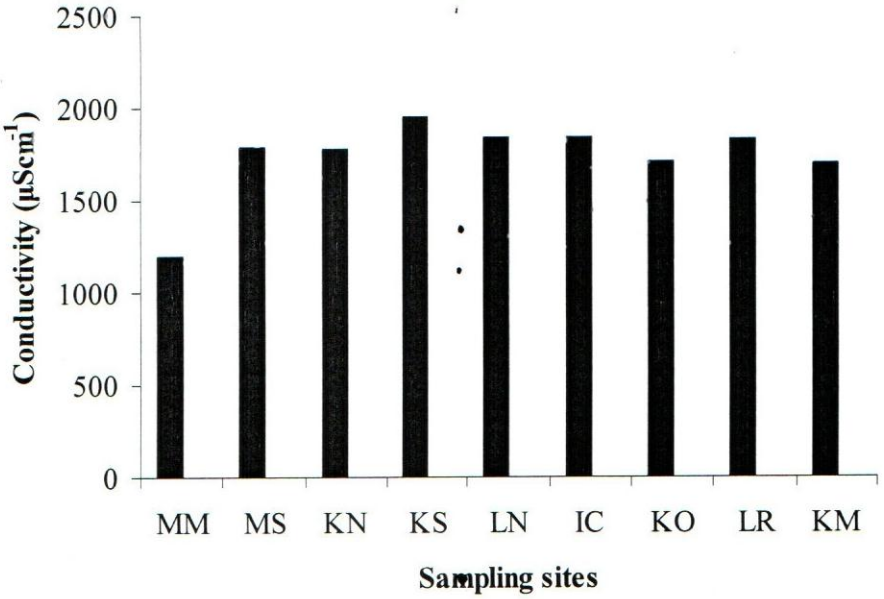


Figure 15: Mean spatial variation in conductivity (μScm^{-1}) in Lake Baringo (June 2003- May 2004)

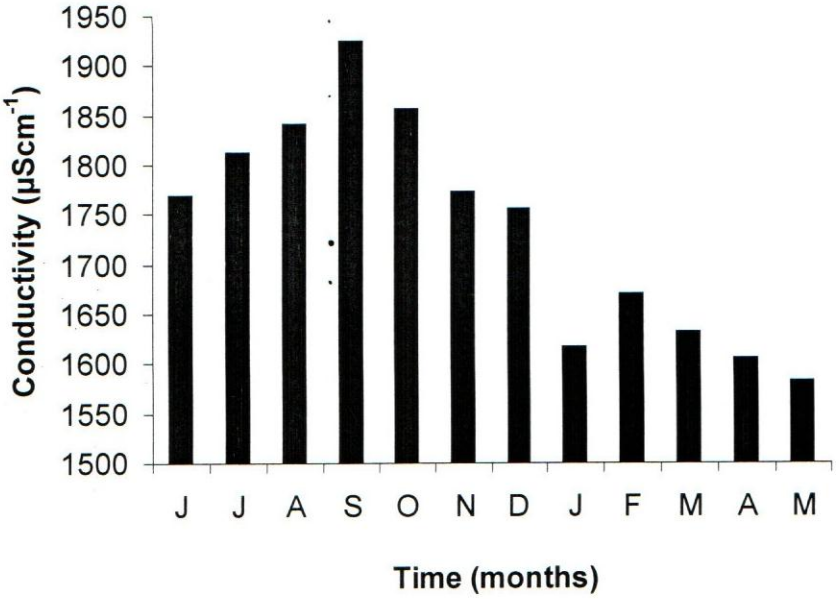


Figure 16: Mean temporal variation in conductivity (μScm^{-1}) in Lake Baringo (June 2003- May 2004)

In the northern zone the mean value was 594.89 μgl^{-1}. The mean spatial concentration of total phosphorus was 46.27 ± 2.247 (S.E.) μgl^{-1}. There was a significant spatial variation in zones (ANOVA: $F_{0.01} = 59.937$) and sampling sites (ANOVA: $F_{0.01} = 14.22$) but not for the vertical depths (ANOVA: $F_{0.05} = 0.034$) in total phosphorus concentrations. Figure 17 shows spatial

fluctuations in total phosphorus values in the lake. Molo River mouth had higher values total phosphorous than both Mlima Sitan and Kiserian in the southern zone. Kampi Ya Samaki, due to its proximity to main slaughterhouses and town influence had the highest mean value in the central zone. The northern zone sampling sites on average had the highest values of the total phosphorus.

The mean temporal concentration of total phosphorus was 46.46 ± 1.977 (S.E.) μgl^{-1}. There was no significant temporal variation in total phosphorus (ANOVA: $F_{0.05} = 1.9816$) in the lake. The highest mean value of total phosphorus was recorded in June 2003.

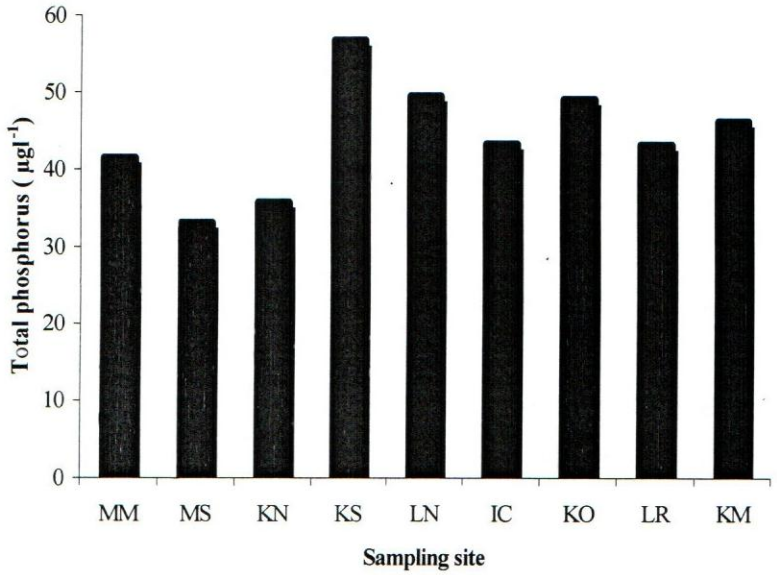


Figure 17: Mean spatial variation in total phosphorus (μgl^{-1}) in Lake Baringo (June 2003- May 2004)

Figure 18 shows temporal variations in total phosphorus with seasonal peaks in the months of June, August, December 2003 and February 2004. Total phosphorus concentration was related to a ratio between total nitrogen and total phosphorus (TN: TP, $R^2 = 0.78$; $P \leq 0.001$). Total phosphorus was also strongly related to total nitrogen to total phosphorus ratio and a square of total phosphorus ($R^2 = 0.89$; $P \leq 0.034$). The model that could define this relationship is as follows:

$\text{Ln (TN: TP)} = -6.777 + 12.414 \ln (TP) - 5.587 \ln (TP^2)$.

Total nitrogen values ranged from a minimum of 113 μgl^{-1} at River Molo mouth in the southern zone to a maximum of 281 μgl^{-1} at the same sampling site and zone. In the

southern zone the total nitrogen mean value was 207.56 while in the central zone the mean value was 136.81 μgl^{-1}. In the northern zone the mean value was 184.61 μgl^{-1}. The mean spatial concentration of total nitrogen for the entire lake was 193.98 ± 18.46 (S.E.) μgl^{-1}.

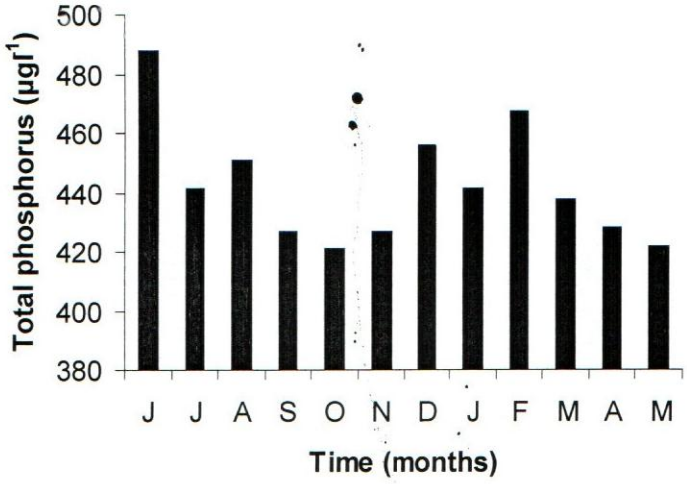


Figure 18: Mean temporal variation in total phosphorus (μgl^{-1}) in Lake Baringo (June 2003- May 2004)

There was a significant spatial variation in total nitrogen in the three zones (ANOVA: $F_{0.01} = 7.7423$) and sampling sites (ANOVA: $F_{0.01} = 9.7704$) as well as the vertical depths (ANOVA: $F_{0.05} = 4.2156$) in the lake over the investigation period.

Figure 19 shows spatial fluctuations in the mean total nitrogen values in the lake. Molo River mouth recorded the highest mean values. The entire southern zone sampling sites were on average with the highest mean total nitrogen values, due to their proximity to the inflowing rivers. The central zone sampling sites recorded the lowest mean values total nitrogen. The northern zone whose mean was slightly below the southern zone followed this.

The mean temporal concentration of total nitrogen was 193.93 ± 9.35 (S.E.) μgl^{-1}. There was a significant temporal variation (ANOVA: $F_{0.01} = 13.9876$) in total nitrogen concentration in the lake. Seasonal pattern in total nitrogen was observed within all the zones. A temporal fluctuation for the total nitrogen in the lake is shown in figure 20. From June there was a general decline in the mean total nitrogen concentration observed up to the month of October 2003. There was a peak in the mean total nitrogen in November 2003 with a decline in December and a minimum value in February 2004. There was a rise in the mean total nitrogen in March up to May 2004.

Total nitrogen was related to the ratio between total nitrogen and total phosphorus (TN: TP) ($R^2 = 0.72$, $P \leq 0.02$). Total nitrogen to total phosphorus (TN: TP) ratio parameter

was related to three other variables in water (ISS, TDS and turbidity) ($R^2 = 0.97$, $P \leq 0.053$) in the lake. The model below could define this relationship:

Ln (TN: TP) = -31.575 + 0.144 ln (ISS) + 4.633 ln (TDS) + 0.0045 ln (turbidity).

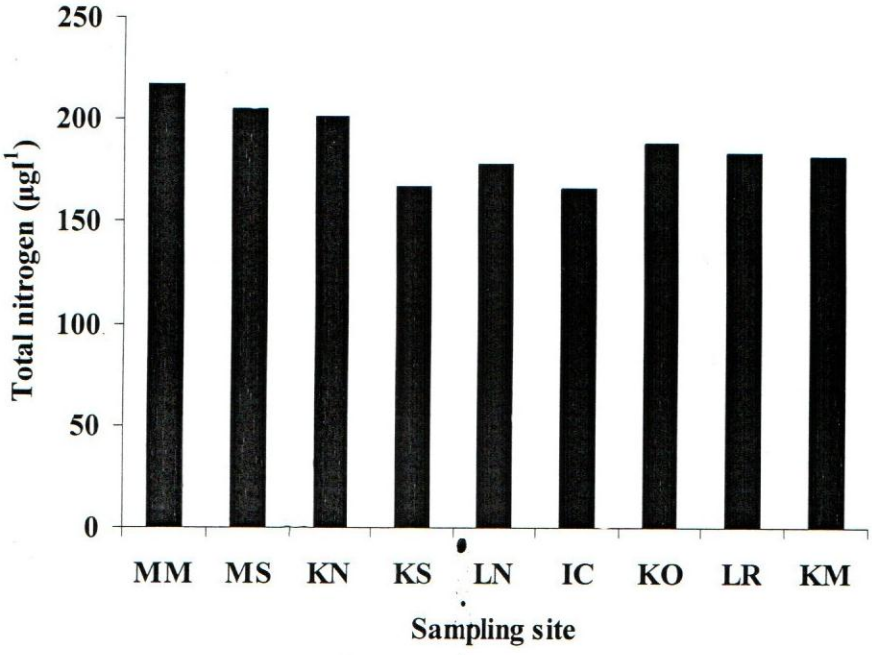


Figure 19: **Mean spatial variation in total nitrogen (μgl^{-1}) in Lake Baringo (June 2003-May)**

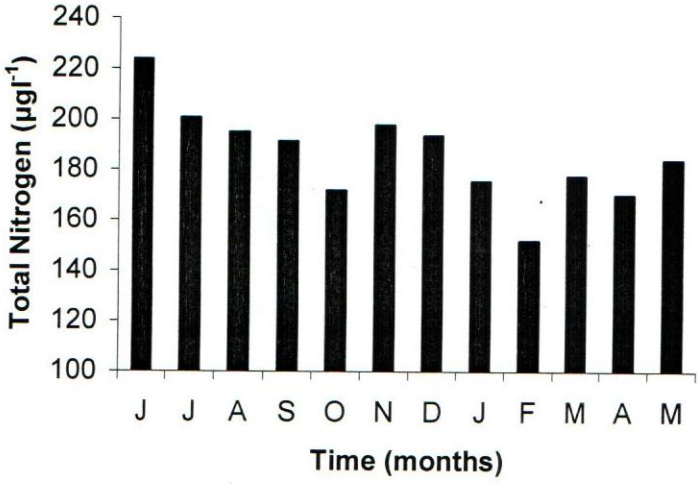


Figure 20: **Mean temporal variation in total nitrogen (μgl^{-1}) in Lake Baringo (June 2003-May 2004)**

4.1.11 Particulate organic carbon and dissolved organic carbon

Particulate organic carbon (POC) values ranged from a minimum of 430 μgl^{-1} at Loruk in the northern zone to a maximum of 1200 μgl^{-1} at Longicharo in the central zone. In the southern zone, the mean POC value was 763.2 μgl^{-1} while in the central zone the mean value was 773.32 μgl^{-1}. In the northern zone the mean POC value was 784.60 μgl^{-1}. The mean spatial concentration of POC value was 793.42 ± 72.71 (S.E.) μgl^{-1}. There was no significant spatial variation in the three zones of the Lake (ANOVA: $F_{0.05} = 1.85$) and vertical depths (ANOVA: $F_{0.05} = 0.073$). There was significant spatial variation of POC concentrations in the sampling sites within the zones (ANOVA: $F_{0.01} = 14.76$) in the Lake over the investigation period.

A spatial fluctuation in POC values in the lake is shown in figure 21. Molo River mouth recorded the highest mean value of POC. However, the Southern zone had the lowest mean value of POC. The Central zone had a higher value than the Southern zone while the Northern zone had the highest mean value of POC recorded in the lake. Due to the daily afternoon mixing of the Northern zone by the North Easterly winds observed, this zone recorded the highest mean value of POC.

The mean temporal concentrations of POC was 794.16 ± 46.26 (S.E.) μgl^{-1}. There was no significant temporal variation of mean POC concentrations (ANOVA: $F_{0.005} = 1.8064$) in the lake.

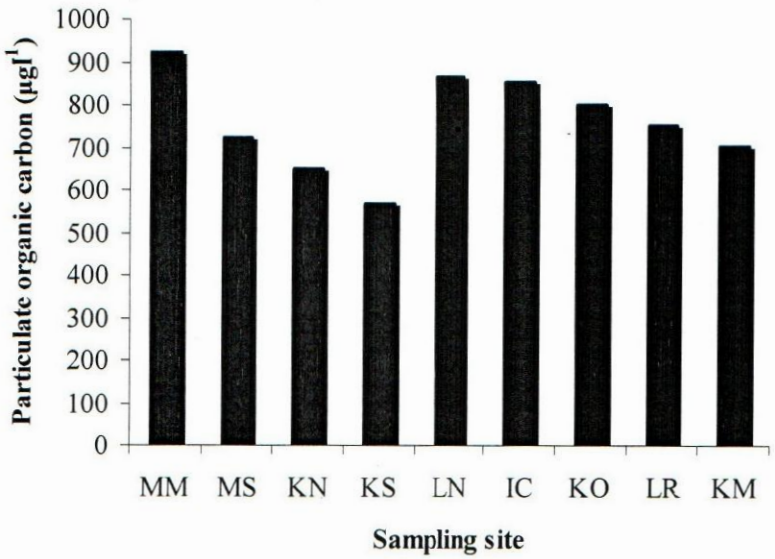


Figure 21: Mean spatial variation of particulate organic carbon (μgl^{-1}) in Lake Baringo (June2003-May2004)

Figure 22 shows the temporal fluctuations of POC with no obvious seasonal pattern from June to November 2003. In December 2003 there was an increase in POC values due to sediments settling during the short rainy season. From January 2004 up to March 2004, there was no observable seasonal change in POC mean values due to the dry season in the study area.

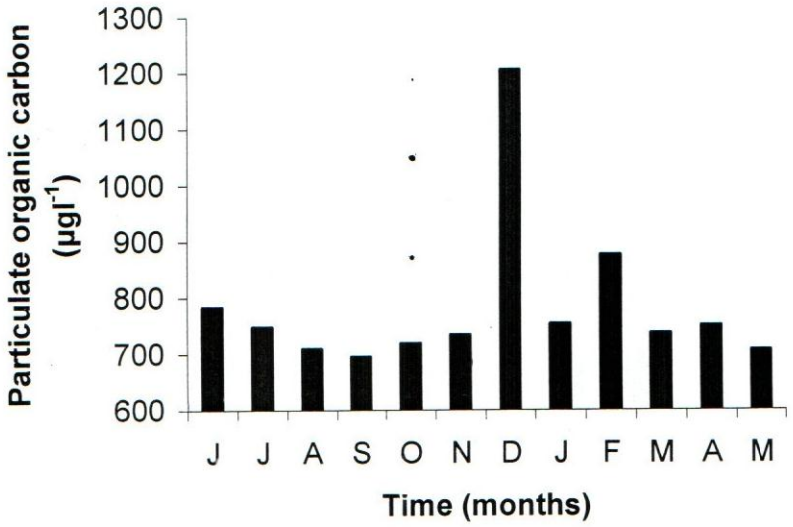


Figure 22: Mean temporal variation of particulate organic carbon (μgl^{-1}) in Lake Baringo (June2003-May2004)

Dissolved organic carbon (DOC) values ranged from a minimum of 2624 μgl^{-1} at Kampi Ya Samaki in the Central zone to a maximum of 7241 μgl^{-1} at Longicharo in the same Zone. In the Southern zone the mean DOC value was 4419.5 μgl^{-1} while in the Central zone the mean DOC value was 3782.89 μgl^{-1}. In the Northern zone, the mean value was 4328.22 μgl^{-1} and spatial mean concentration was 4759.41 ± 434.32 (S.E.) μgl^{-1}.

There was no significant spatial variation in the DOC values in the three zones (ANOVA: $F_{0.05} = 0.037$) of the lake. There was a significant spatial variation of DOC concentration in the sampling sites (ANOVA: $F_{0.01} = 15.0$) within the zones in the lake during the investigation.

Figure 23 shows spatial fluctuations in DOC values in the lake. The southern zone comprising Molo River mouth, Mlima Sitan and Kiserian had the highest average DOC values in the lake. The DOC values decreased from the lakeshore to the off shore. Longicharo site of the central zone, which is on the shore of the lake, recorded the highest value due to the macrophytes cover. The northern zone which experiences daily afternoon mixing through Northeasterly winds that stir the bottom sediments had higher values too.

The mean temporal concentrations of DOC values was 4760.05 ± 278.49 (S.E.) μgl^{-1}. There was no significant temporal variation in the DOC concentration values (ANOVA: $F_{0.05} = 2.102$) in the lake.

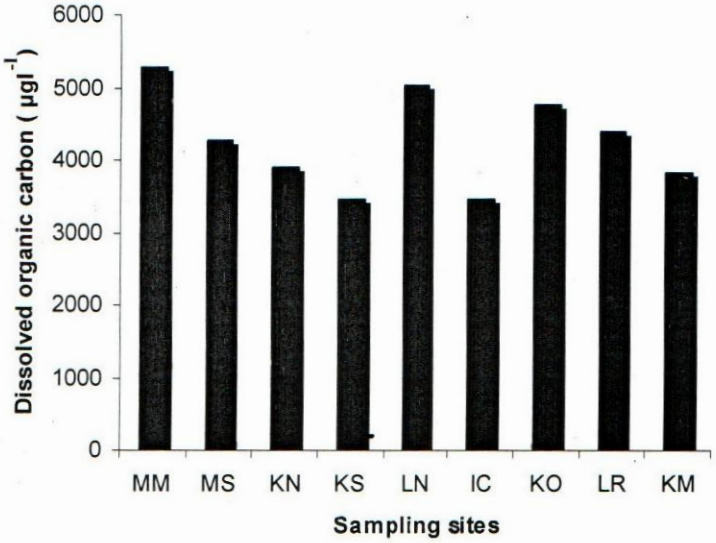


Figure 23: Mean spatial variation of dissolved organic carbon (μgl^{-1}) in Lake Baringo (June2003-May2004)

Figure 24 shows temporal fluctuations in DOC values in the lake. There were observable seasonal patterns in the DOC values in the lake. Slightly higher peaks in the months of October 2003 and February 2004 were significantly different from other months of the year. DOC parameter was strongly related to POC parameter (Fig. 25) ($R^2 = 0.99$; $P \leq 0.01$) in Lake Baringo.

4.2 Effects of physical–chemical environmental factors on picoplankton cell abundance in Lake Baringo

Picoplankton cell abundance (Appendix 15) in the lake ranged from a minimum of 22 x 10^3 cells /ml to a maximum of 60 x 10^3 cells/ml in Loruk (northern zone) and River Molo mouth (southern zone) respectively. The mean spatial cell abundance was 139.82 ± 30.33 (S.E.) x 10^3 cells/ml. It was found that study zones were significantly different from each other (ANOVA: $F_{0.05} = 9.41$). Sampling sites were also significantly different within the zones (ANOVA: $F_{0.05} = 4.21$).

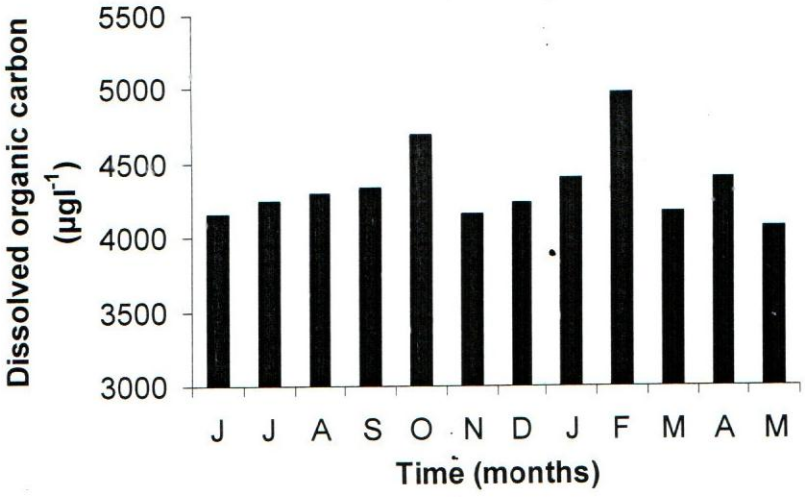


Figure 24: Mean temporal variation of dissolved organic carbon (µgl^{-1}) in Lake Baringo (June2003-May2004)

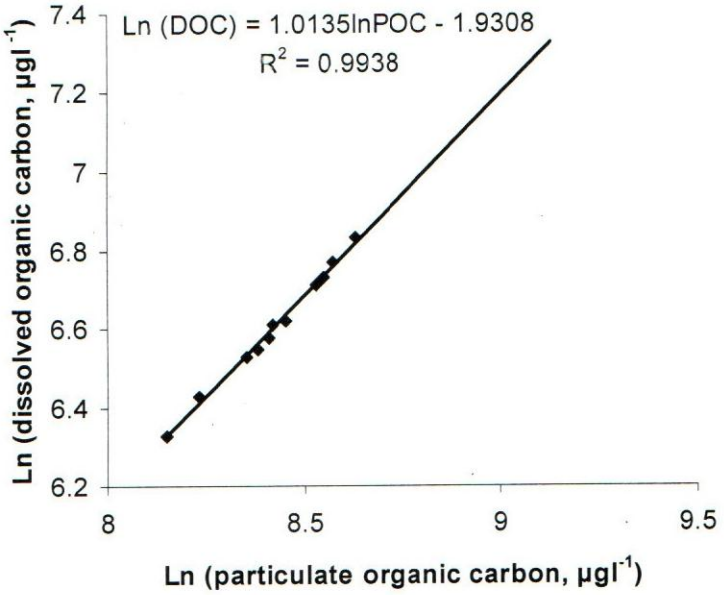


Figure 25: The relationship between ln (particulate organic carbon, µgl^{-1}) and ln (dissolved organic carbon, µgl^{-1}) in Lake Baringo (June2003- May2004)

The mean temporal cell abundance was 52.22 ± 3.03 (S.E.) x 10^3 cells/ml for the entire lake. There were significant temporal variations of cell abundance (ANOVA: $F_{0.05}$ = 43.61) during the investigation.

Figure 26 shows the monthly pattern of cell numbers for picoplankton field populations of Lake Baringo during June 2003 to May 2004. From the month of June 2003,

there was a rise in cell abundance in all the three zones, with a peak in October 2003, which was a wet season. There was a decline with minimum values from February to March, which was a dry season. From March to May there was a rise again at the beginning of a wet season with inflowing rivers bringing nutrients into the lake.

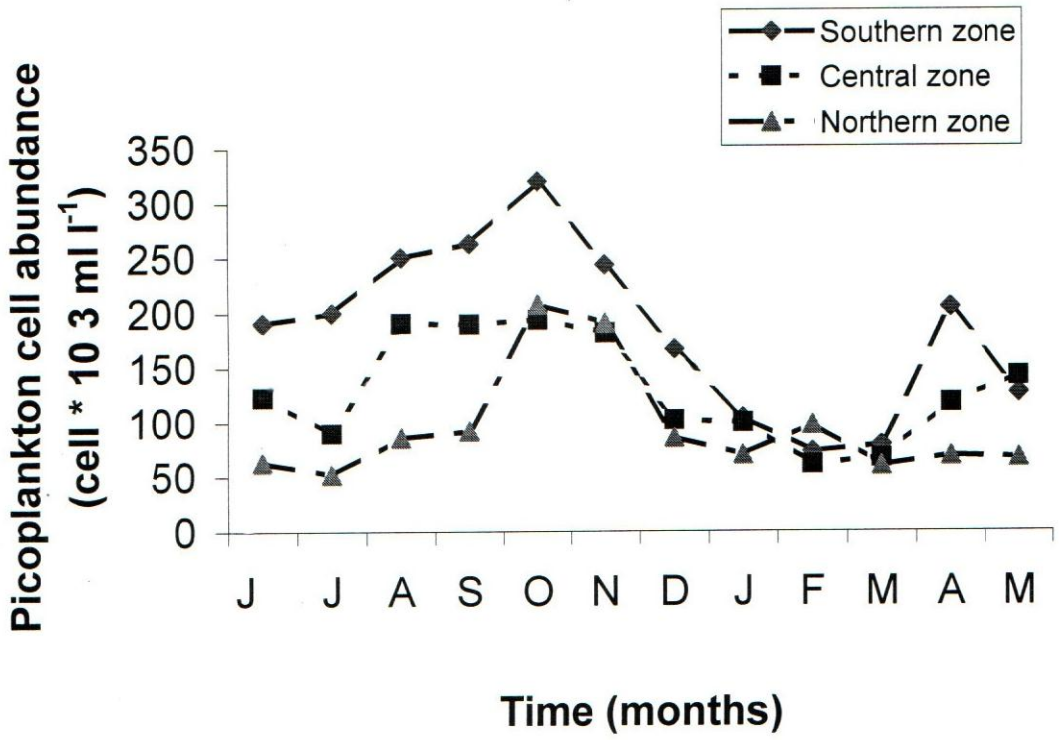


Figure 26: The mean monthly pattern of picoplankton cell abundance (cell*10^3 cells/ml) in Lake Baringo (June 2003-May 2004)

Results of this study have shown that the picoplankton abundance was related to water temperature (R^2 = 0.54, $F_{0.05}$ = 4.76, P ≤ 0.0). Further investigations showed that picoplankton abundance was related to the ratio between total phosphorus to total nitrogen in all the three zones of the lake (R^2 = 0.47, $F_{0.05}$ = 3.511, P ≤ 0.134). However, separately neither total phosphorus nor total nitrogen was significantly related to the picoplankton abundance in the lake (R^2 = 0.027, P ≤ 0.75) and (R^2 = 0.316; P ≤ 0.25) respectively. During the investigation, it was found that the peaks of percentage frequency of dividing cells (FDC) and cell density were very strongly related (R^2 = 0.56, $F_{0.05}$ = 5.19, P ≤ 0.08). Cell numbers were not significantly related to turbidity of the lake waters in all the three zones (R^2 = 0.02, $F_{0.05}$ = 0.119, P ≤ 0.747).

Picoplankton cell numbers (abundance) was related to BOD very weakly (R^2 = 0.45, $F_{0.05}$ = 3.35; P ≤ 0.14). A very strong relationship was obtained between picoplankton cell abundance and DOC of the lake waters (R^2 = 0.89, F = 33.74; P ≤ 0.004). Similarly, the picoplankton cell abundance was also strongly related to POC in the lake waters (R^2 =0.88, $F_{0.05}$ = 30.94; P ≤ 0.005).

Picoplankton cell abundance was not related to the level of dissolved oxygen in the lake (R^2 = 0.14, P ≤ 0.47). In a related event, the percentage FDC was weakly related to the lake's waters turbidity (R^2 = 0.39; $F_{0.05}$ = 2.62; P≤ 0.18) over the study period. Other environmental factors investigated did not show any significant relationships with picoplankton cell abundance in the lake.

4.3 Effects of turbidity on picoplankton organic carbon synthesis and losses estimates in Lake Baringo

The mean specific organic carbon synthesis of picoplankton in southern zone was 15.49 ± 0.21 (S.E.) mg $gcm^{-3}d^{-1}$ while in the central zone the mean was 14.52± 0.03 (S.E.) mg $gcm^{-3}d^{-1}$. In the northern zone the mean specific organic carbon synthesis of picoplankton was 15.3949 ± 0.4(S.E.) mg $gcm^{-3}d^{-1}$.

The mean spatial specific picoplankton organic carbon synthesis variation for the entire lake was 15.46 ± 0.54 (S.E.) mg cm^{-3} d^{-1}. Observed values showed significant spatial variations in the study zones (ANOVA: $F_{0.5}$ = 9.65) as well as the sampling sites within the study zones (ANOVA: $F_{0.5}$ = 3.83).

The mean temporal specific picoplankton organic carbon synthesis variations (12.56 ± 2.43 SE mg $gcm^{-3}d^{-1}$) for the entire lake were recorded. The mean monthly sample of specific picoplankton organic carbon synthesis (X_{FDC}) ranged between 6.85 and 24.10 mg $gcm^{-3}d^{-1}$ (Table 2 & 3).

There was a significant temporal variation in specific picoplankton organic carbon synthesis (ANOVA: $F_{0.05}$ = 4.21) in the lake. A seasonal decline in the Southern zone from a peak in June to a downward trend to September 2003 was observed (Table 2). There was a rise in October with a peak in December 2003 and January and decline in February and March 2004.The values rose again in April 2004. In the central zone there was a seasonal variation from June 2003 up to January 2004. In February the mean dropped and started to rise again in April when the wet season rains started. In the northern zone, there was a seasonal variation with a rise in mean picoplankton organic carbon synthesis from June 2003 to September 2003. Then there was a decline in October followed by a rise during the onset of short rains in November 2003. During a dry spell in the month of February the mean of

Pico-Cyanophyceae organic carbon synthesis (12.56 ± 0.24 (S.E.) $cm^{-3}d^{-1}$) declined rising again in April when the wet season began.

Specific picoplankton organic carbon synthesis was weakly related to the lake's water temperatures (R^2 = 0.38; $F_{0.05}$ = 2.47; P≤ 0.19). In the Southern zone, specific picoplankton organic carbon synthesis was related to the water turbidity (R^2 = 0.46; $F_{0.05}$ = 3.39; P≤ 0.14). A similar relation was observed in the central zone between X_{FDC} and the water turbidity (R^2 = 0.47; $F_{0.05}$ = 3.64; P≤ 0.13). There was a weak relationship between X_{FDC} and the lakes water turbidity in the northern zone (R^2 = 0.23; $F_{0.05}$ = 1.22; P≤ 0.33). Overall specific picoplankton organic carbon synthesis showed a weak relationship to the lake waters turbidity (R^2 = 0.37; $F_{0.05}$ = 2.36; P≤ 0.08).

Table 2. The mean monthly organic carbon synthesis and losses estimates of picoplankton in Lake Baringo from June 2003 to May 2004

Date	Specific Organic carbon synthesis X_{FDC} mg $gcm^{-3}d^{-1}$	Net organic carbon synthesis X mg $gcm^{-3}d^{-1}$	Losses $X_{FDC} - X$ mg $gcm^{-3}d^{-1}$	Cell division td d
June	24.10	3.54	20.56	0.38
July	23.99	3.50	20.49	0.32
August	19.27	13.28	5.99	0.22
September	19.21	13.00	6.21	0.21
October	12.51	7.15	5.36	0.12
November	13.00	8.00	5.00	0.11
December	15.68	4.40	11.28	0.11
January	14.99	4.40	10.59	0.11
February	6.85	2.99	3.86	0.24
March	7.10	2.99	4.11	0.23
April	13.15	11.49	1.66	0.21
May	13.15	11.40	1.75	0.20

The mean spatial net picoplankton organic carbon synthesis variations (7.01 ± 0.72 (S.E.) mg $cm^{-3}d^{-1}$) were recorded in the lake. Observed values showed significant spatial variations in the study zones (ANOVA: $F_{0.05}$ = 4.43) as well as the sampling sites within the zones (ANOVA: $F_{0.5}$ = 3.56) during the study. In the southern zone, the mean value of net

picoplankton organic carbon synthesis was 8.02 ± 0.03 (S.E.) mg $cm^{-3}d^{-1}$ while in the central zone the mean value was 5.8 ± 0.24 (S.E.) mg $cm^{-3}d^{-1}$) and in the northern zone the mean value was 7.35 ± 0.24 (S.E.) mg $cm^{-3}d^{-1}$).

Table 3. The mean monthly organic carbon synthesis and loss estimates of picoplankton in the study zones of Lake Baringo from June 2003 to May 2004

	Southern			Central			Northern		
Date	X_{FDC}	X	Losses	X_{FDC}	X	Losses	X_{FDC}	X	Losses
June	26.10	4.20	21.9	24.70	4.20	20.5	22.80	3.90	19.8
July	25.10	4.21	20.89	23.60	7.10	16.50	22.70	3.80	18.90
August	18.11	12.01	6.1	13.41	7.10	6.31	26.11	19.0	7.11
September	7.00	11.99	5.01	14.10	6.99	7.01	25.99	18.99	7.00
October	13.41	8.21	5.2	14.10	6.14	7.96	11.01	6.10	4.91
November	14.01	8.01	6.00	14.01	5.40	8.61	12.01	7.00	5.01
December	17.42	6.30	11.12	15.41	3.33	12.08	14.20	3.40	10.80
January	17.42	6.10	11.32	15.01	3.01	12.00	14.10	4.00	10.00
February	8.49	4.99	3.5	6.84	2.11	4.73	5.20	1.01	4.19
March	8.50	5.11	3.39	7.11	2.01	5.10	5.11	1.01	4.10
April	15.14	13.04	2.1	13.11	11.20	1.91	12.60	10.02	2.58
May	15.14	12.01	2.13	13.01	10.99	2.02	12.90	10.00	2.90

The mean temporal net picoplankton organic carbon synthesis (7.14 ± 1.77 (S.E.) mg $cm^{-3}d^{-1}$) was observed in the lake. The mean monthly sample net picoplankton organic carbon synthesis (X) values ranged from 2.99 to 13.28 mg $cm^{-3}d^{-1}$. Seasonality in net picoplankton organic carbon synthesis was observed with peaks in the months of August 2003 and April 2004, and low levels from December 2003 to March 2004.

There was a weak relationship between net picoplankton organic carbon synthesis (X) and all other environmental factors investigated in the lake during the investigation. The picoplankton loss estimates in the lake ranged from a minimum of 1.66 to a maximum of 20.56 ± 0.22 (S.E.) mg $cm^{-3}d^{-1}$. The mean spatial picoplankton loss estimate of 8.49 ± 0.22 S.E mg $cm^{-3}d^{-1}$ was recorded. In the southern zone mean loss estimate of picoplankton was 8.22 ± 0.1 (S.E.) mg $cm^{-3}d^{-1}$ while in the central zone the mean loss estimate was 8.72 ± 0.5 (S.E.) mg $cm^{-3}d^{-1}$ and mean loss estimate in the Northern zone was 8.1 ± 0.03 (S.E.) mg $cm^{-3}d^{-1}$). Observed values of picoplankton loss estimates indicated a significant spatial variation

in the study zones (ANOVA: $F_{0.5} = 3.39$) as well as the sampling sites (ANOVA: $F_{0.5} = 4.45$) during the investigation.

The mean temporal picoplankton loss estimate (9.41 ± 2.78 S.E mg $cm^{-3}d^{-1}$) was recorded. There was a significant temporal variation (ANOVA: $F_{0.05} = 3.25$) in the lake. In the Southern zone, there was a seasonal variation in picoplankton loss estimates with peaks in June and July 2003 during the wet season. Low picoplankton loss estimates were recorded from August to October with a rise from November to January. During January 2004 to May 2004 there was no significant losses observed in this zone. In the central zone, four peaks were observed: high values during the wet season (June and July 2003), and low mean values during short rainy season (August to December 2003), January to February which are dry seasons and March to May recorded the lowest losses. In the Northern zone similar observations were made with maximum losses in June to July 2003 (wet season) and December 2003 to January 2004 (dry season). Minimum losses were observed from October to November 2003 (short rains) and April to May 2004 (long rains).

Picoplankton loss estimates and the lake waters turbidity were related though not very strongly ($R^2 = 0.44$; $F_{0.05} = 0.39$; $P \leq 0.15$). In the Southern zone, Pico-Cyanophyceae loss estimate was strongly related to the lake water turbidity ($R^2 = 0.503$; $F_{0.05} = 4.05$; $P \leq 0.11$). In the Northern Zone, water turbidity was strongly related to the Pico-Cyanophyceae loss estimate ($R^2 = 0.509$; $F_{0.05} = 4.15$; $P \leq 0.11$). However, in the Central zone, a weak relationship between picoplankton loss estimates and the lake water turbidity ($R^2 = 0.38$; $F_{0.05} = 2.5$; $P \leq 0.19$) was recorded.

4.4 Effects of turbidity on picoplankton growth rates in Lake Baringo

The sample mean specific growth rate (X_{FDC}) varied from 1.19 to 4.5 X_{FDC} d^{-1}. The growth rate measured by counting the frequency of dividing cells in the lake represents the increase of the population that could occur without loss processes, whereas the instantaneous growth rate is the net result of growth and losses (Fig. 27).

The mean spatial specific picoplankton growth rate variations were recorded (2.7 ± 0.02 (S.E.) XFDC d^{-1}). Observed values showed a significant spatial variation in the study zones (ANOVA: $F_{0.5} = 3.67$) during the investigation. In the northern zone the mean specific picoplankton growth rate was 2.56 ± 0.03 (S.E.) $XFDCd^{-1}$ while in the central zone it was 2.83 0.04 (S.E.) X_{FDC} d^{-1}) and in the northern zone it was 2.60 ± 0.03 (S.E.) $X_{FDC}d^{-1}$.

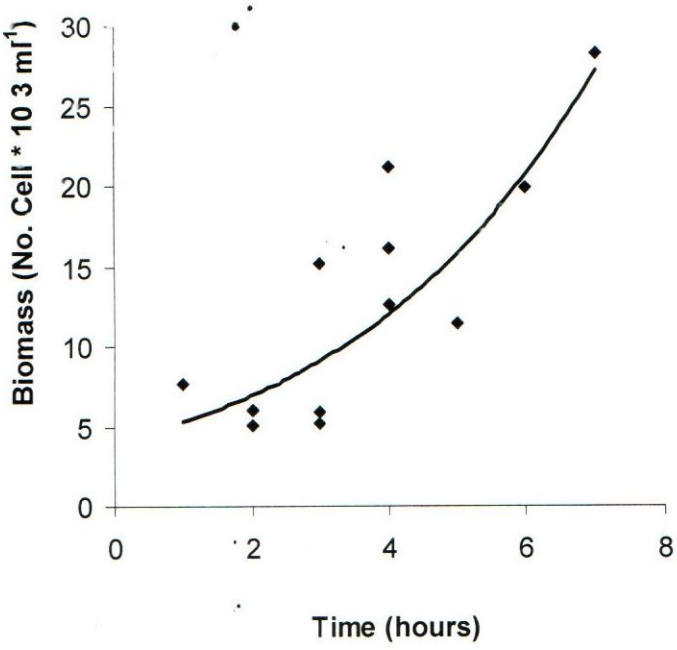


Figure 27: The rate of growth of picoplankton (no. Cell * 10 3 $ml^{-1}h^{-1}$) in Lake Baringo (June 2003- May 2004)

The mean temporal specific picoplankton growth rate variation (2.7 ± 0.46 (S.E.) X_{FDC} d^{-1}) was recorded (Table 4 & Table 5). Four seasons were observed in the southern zone: June and July 2003 having the highest mean values during the wet season, September to November 2003 during short rains the growth rate recorded was minimum. During the dry season in the months of January to March the mean growth rate observed was similar and low. This trend continued up to the beginning of long rains in April 2004 with no observable changes. In the Central zone during the wet season (June to July 2003) the mean specific picoplankton growth rate was highest. During the short rains of September to November the mean recorded was lowest. There was a rise in the dry season of December 2003 to the end of March 2004. There was no change when the wet season started in April 2004. In the Northern zone during the wet season of June to August 2003, the mean specific picoplankton growth rate was low.

However, during September to November over the short rainy season the mean specific picoplankton growth rate was lower than the rest of the months. During the dry months of December 2003 to March 2004, the levels rose significantly high compared to the rest of the months. The levels did not change at the onset of the wet season in April 2004.

Table 4. The mean monthly growth rates of picoplankton in Lake Baringo from June 2003 – May 2004

Date	X_{FDC} d^{-1}	X d^{-1}	FDC_{max} %	Time of Max (h)	No. Cell 10^3 ml^{-1} N_o	No. Cell 10^3 ml^{-1} N_t
June	4.56	0.67	44.00	14	41.94	47.96
July	4.03	0.67	22.00	16	41.90	47.09
August	2.38	1.67	21.00	14	64.26	85.40
September	2.51	1.67	15.00	16	60.21	79.04
October	1.19	0.68	10.00	16	83.43	111.70
November	1.44	0.67	10.00	16	79.99	85.00
December	3.28	0.92	30.00	14	37.93	43.73
January	2.38	0.91	16.00	16	36.01	43.71
February	2.38	1.04	21.00	14	22.84	35.42
March	2.38	2.08	21.00	16	23.01	34.41
April	2.38	2.08	21.00	16	43.86	59.97
May	2.34	2.08	21.00	16	43.81	59.04

Table 5. The mean monthly growth rates of picoplankton in the study zones of Lake Baringo from June 2003 to May 2004

Zone	Southern		Central		Northern	
	X_{FDC} d^{-1}	X d^{-1}	X_{FDC} d^{-1}	X d^{-1}	X_{FDC} d^{-1}	X d^{-1}
June	4.46	0.57	4.54	0.47	2.36	0.61
July	4.06	0.56	4.54	0.58	1.99	0.59
August	2.48	1.77	2.50	0.67	1.38	1.73
September	1.99	1.71	2.04	0.62	1.28	0.99
October	1.09	0.48	1.04	1.68	1.04	0.58
November	1.48	0.48	2.99	1.54	1.06	0.81
December	3.38	0.92	3.88	0.82	5.48	0.92
January	2.38	0.91	3.08	0.91	4.99	0.94
February	2.38	1.24	2.28	1.34	3.48	1.14
March	2.38	1.04	2.28	1.44	3.41	1.61
April	2.38	2.08	2.48	2.18	2.43	2.08
May	2.31	2.07	2.41	2.18	2.31	2.68

The mean spatial net picoplankton growth rate variations were also recorded (1.39 ± 0.21 (S.E.) XFDC d^{-1}). In the southern zone the mean net picoplankton growth rate was1.15 ± 0.11 (S.E.) X d^{-1}) while in the central zone the mean was 1.2 ± 0.31 (S.E.) X d^{-1} and in the northern zone the mean was 1.22 ± 0.21 (S.E.) X d^{-1}.). There was a significant spatial mean net picoplankton growth rate in the lake (ANOVA: $F_{0.5} = 4.62$).

The sample mean net growth rate (X), measured ranged between 0.67 and 2.08 (S.E.) X d^{-1} (Table 4). The mean temporal net picoplankton growth rate (1.18 ± 0.235 (S.E.) X_{FDC} d^{-1}) was observed in the lake. There was a significant temporal variation on the net picoplankton growth rate (ANOVA: $F_{0.5} = 9.02$). In the Southern zone, Central zone and Northern zones, four seasonal variations were observed with a wet season in June and July 2003 recording low mean values. At the onset of wet season in April 2004, the mean levels measured rose in all the three zones of the lake. Nevertheless, net picoplankton growth rate was weakly related to all the environmental factors investigated during the study in the lake.

The specific picoplankton growth rate was weakly related to the frequency of dividing cells ($R^2 = 0.41$; $F_{0.05} = 2.79$; $P \leq 0.17$). The specific growth rate was strongly related to BOD ($R^2 = 0.56$; $F_{0.05} = 5.11$; $P \leq 0.04$). Specific picoplankton growth rate was weakly related to the ratio between total phosphorus to total nitrogen ($R^2 = 0.37$; $F_{0.05} = 2.40$; $P \leq 0.04$).

Specific picoplankton growth rate was weakly related to the lake's water turbidity in the southern zone ($R^2 = 0.32$; $F_{0.05} = 1.89$; $P \leq 0.24$). In the central zone, specific growth rate was weakly related to the turbidity ($R^2 = 0.26$; $F_{0.05} = 1.42$; $P \leq 0.3$). In the northern zone specific growth rate was similarly not related to turbidity ($R^2 = 0.008$; $F_{0.05} = 0.03$; $P \leq 0.86$). Specific picoplankton growth rate (X_{FDC}) was strongly related to turbidity (NTU) for the entire lake ($R^2 = 0.61$, $F_{0.05} = 6.32$; $P \leq 0.065$).

Temporal variations of POC with no obvious seasonal pattern from June to November 2003 were observed (Fig. 22). In December 2003 there was an increase in POC values due to sediments settling during the short rainy season. From January 2004 up to March 2004, there was no observable seasonal change in POC mean values due to the dry season in the study area. Figure 22 shows the temporal fluctuations of POC with no obvious seasonal pattern from June to November 2003. In December 2003 there was an increase in POC values due to sediments settling during the short rainy season. From January 2004 up to March 2004, there was no observable seasonal change in POC mean values due to the dry season in the study area. Figure 22 shows the temporal fluctuations of POC with no obvious seasonal pattern from June to November 2003. In December 2003 there was an increase in POC values due to

sediments settling during the short rainy season. From January 2004 up to March 2004, there was no observable seasonal change in POC mean values due to the dry season in the study area.

CHAPTER FIVE

5.0 DISCUSSION

5.1 Relationships between physical–chemical environmental factors in Lake Baringo

The field and laboratory measurements of water close to the point of inflowing rivers which was not affected by erosion and siltation has physical characteristics close to that of natural water. The physical environmental factors measured in the field included water temperature, TDS and transparency. Those measured in the laboratory included turbidity and ISS.

Water temperature in Lake Baringo was higher than expected. This was attributed to higher silt load, which leads to rapid heating of the water column. The spatial differences in the water temperature were attributed to the differences in the sampling zones and sites. The inflowing rivers provided much colder water of about 3.4°C than the rest of the lake's waters. This finding is in agreement with other work elsewhere. While studying the effects of dredging, Yusoff and Sharr (1987) found that the water temperature below the dredged area where the water was turbid were one or two degrees higher than the clear water above the dredge. Similarly Yusoff and Sharr (1987) reported that incoming water from the upstream of Kemanash River was colder by 2.7°C than the Lake Zoo Negara water.

Lake Baringo was stratified between 12-16 hours when the surface temperature was about 26°C - 28°C. This was attributed to the rapid heating of the surface silt. From 6-12 hours the temperature was uniform from the surface to the bottom ranging from 24 - 26°C.

Temperature influenced the dissolved oxygen and pH often in the afternoon when water temperature was over 25°C. Oxygen on the water surface escapes leaving more concentrated oxygenated sediments-water interface that resulted into cooling of the benthos area.

In the presence of higher temperature in the lake, dissolved oxygen and pH levels recorded a significant reduction in value. This was attributed to the escape of oxygen and increased use of oxygen by picoplankton in the benthos area. POC, DOC, ISS, TDS and turbidity influenced the water temperature due to rapid absorption of heat as the solar radiation increasingly reaches these physical-chemical environmental factors.

Turbidity in the Southern zone is nearly one half of the Central and Northern zones. This is supported by secchi disk reading as low as 2.4 cm in these two zones in the lake. In the Molo River mouth (Southern zone), however, light penetrates to the benthos area. The fluctuations of turbidity in the lake are mainly regulated by the amount of suspended matter. The suspended matter got into the lake through the inflowing Rivers (Mukutan, Ol Arabel,

Molo, Perkerra, Endao) and autochthonous wind induced turbulence coupled with the settling rate of suspended solids.

Yusoff and Sharr (1987) made a similar observation when working in Lake Zoo Negara. Northern zone showed the highest level of turbidity as opposed to the southern zone. This was attributed to the Northeasterly winds inducing turbulence that led to the resuspension of bottom sediments deposits. The heavy rains (wet season-April to August) in the catchments area coupled with extremely high concentrations of suspended solids increased the level of turbidity in the lake.

The high turbidity and large loading of suspended solids into the lake especially during the rainy season (April – June) are mainly due to surface run-off from agro- pastoral activities in the catchments area which carries soil particles into the rivers which eventually flow into the lake.

Without known outlet except the underground seepage in the northern zone, high concentrations of suspended solids accumulate continuously at the benthos area. The suspended solids and the accumulated ones are stirred by wind induced turbulence, eventually increasing the level of turbidity, during dry months of September to December 2003 and January to March 2004 as opposed to the rainy season (June – August 2003) and April, May 2004. Kallqvist (1987) attributed increased turbidity in the lake to the turbulence on the sediments on the lake's bottom created by winds in contrast to observations made by Lind *et al* (1987), which attributed highest inorganic turbidity levels to high levels of rainfall. Lake Baringo requires a time lag of two months for the turbidity levels to start rising significantly while the lake levels and transparencies are reducing. This finding agrees with that of Odhiambo and Gichuki (2000) who found that the settling out of silt was favoured by increased depth.

Whereas Graeme and Kiplagat (1995) concluded that no settling of the suspensions occurs for the lake water in 24 hours, during this study, settling of the suspended solids was observed at a similar time interval. Resuspension of the settled sediments by waves due to wind induced water turbulence results into high levels of turbidity recorded in the Northern and Central zones of the lake. This finding reinforces that of Dokulil (1994) who reported that underwater light attenuation in turbid systems is a function of suspended particulates concentrations and size.

Suspended sediments or solids in Lake Baringo are considered an insidious and widespread pollutant, which reinforces the findings by Welch and Lindell (1992) in separate studies. The present finding also agrees with that of Scheffer (1998) who observed that

shallow lakes have suspensions in the water column due to wave disturbance causing higher concentration of suspensions.

Resuspension of the ISS results into high turbidity recorded in the lake. Variations observed and revealed by the data set indicate that the lake's transparency was attributed to the 99% presence of ISS, total dissolved solids, turbidity and conductivity. Total dissolved solids, thus is also an important physical factor that influences the transparency and hence light attenuation of the shallow water body studied.

Of the ten chemical environmental factors measured, only four were observed and measured directly in the field (dissolved oxygen, percentage oxygen saturation, pH and conductivity). The rest were sampled in the field and analysed in the laboratory (BOD, total alkalinity, total phosphorus, total nitrogen, POC and DOC).

In this research, it has been observed that dissolved oxygen concentration decreases from the southern zone to the northern zone. This indicates high accumulation of POC and DOC and thus high consumption of oxygen in the lake. The lowest oxygen value (2.6 mg^{-1}) gives anoxic condition which is often short lived, since turnover of the water mass occurs during rainy days (March 2004-May2004). During dry months of September - December 2003 and January – March 2004, oxygen stratification coincided with thermal stratification. Nevertheless, the shallowness of the lake coupled with wind-induced turbulence and heavy rains often destroyed such stratification.

The observed oxygen regime may be attributed to the following factors: shallowness of the three zones in the lake; insolation by solar radiation lasting over twelve hours on diurnal basis; temperature variations on diurnal basis; afternoon mixing of both euphotic and mixed depth by Northeasterly winds induced turbulence; picoplankton domination on the euphotic zone on diurnal basis providing a balanced oxygen exchange between photosynthetic and respiration processes in the water column. This argument supports that of Wetzel (1983) who asserts that the consumption of oxygen associated with bacterial decomposition of sediments organic matter outweighs the utilizations by higher plants and animals combined in a lake ecosystem. The oxygen concentration in the lake was influenced by water temperature ($R^2 = 0.778$; $P \leq 0.01$). Oxygen concentration in the lake was explained by 77% of the variance in the lake's water temperature.

Surface waters of the lake are under saturated, with values ranging from 42.00 % to 91.00 % saturation. Since the study was performed during 7–16 hours, one expects a slight super saturation mainly during mid-day, since that time oxygen production is higher due to primary production. However, super saturation of oxygen was only sparsely observed (132.00

%). This was attributed to high turbidity that greatly attenuates sunlight and consequently affects oxygen production. Saturation of as high as 88.00 % was observed at the bottom of the lake due to turnover of the water mass during heavy rains and wind mixing of the bottom water. This finding agrees with that of Oduor (2000).

The organic matter from Kampi Ya Samaki town drained directly into the lake. This enhanced the BOD at the sampling sites in the central zone (Kampi Ya Samaki, Island Camp and Longicharo). For the Southern zone, comprising Molo mouth, Kiserian and Mlima Sitan sampling sites, inflowing streams brought in allochthonous organic matter. The rich organic matter was utilized by picoplankton resulting into increased BOD levels. January to February was a dry season with reduced water levels, increased ionic concentration and increased organic matter for bacterial decomposition hence enhanced BOD. This finding agrees with that of Larson *et al.*, (1990), who worked on pelagic bacteria in subtropical marine environments.

When different sampling sites were compared using Duncan's multiple range tests, it was revealed that Kampi Ya Samaki in the central zone contributed significantly to the difference in BOD levels. This difference significantly contributed to the difference in zones observed. This was attributed to the abundance and production of pelagic picoplankton in the Lake. Secondly, hydrocarbons effluents rich in organic matter (POC and DOC) and nutrients reach the zone from Kampi Ya Samaki landing beach where outboard engines are located. This attributed to high BOD levels observed at the sampling site. A similar finding was made by Larson *et al.*, (1990) in pelagic bacteria in subtropical marine environment exposed to chronic oil contamination impacting on the water body.

It was observed that BOD was significantly correlated to the ratio of total nitrogen to total phosphorus ratio ($R^2 = 0.83$; $P \leq 0.01$). This shows that BOD measured was the oxygen used to oxidize both inorganic material (phosphate and nitrogenous demand) and biochemical degradation of organic material (carbonaceous demand).

The increased BOD concentration in Lake Baringo was explained by 83 % of the existing total nitrogen. The lake water is supplied with dissolved substances largely through the inflowing rivers and rainwater surface run–off. The concentration of the lake waters was higher than that of the major inflowing rivers and streams.

The inflowing Molo River recorded a pH of 6.98. The lake water recorded pH values ranging from 6.9 – 9.54 units. The lowest pH at Molo mouth was due to the inflowing Molo River water. The highest pH at Longicharo in the Central zone was attributed to water from Kokwa hot springs. KEMFRI office water pH level was due to the net accumulation of ions

with a high mix depth: euphotic zone depth providing high rates of oxygen production that elevated pH from less than 8 to 8.94. This occurs within hours in a way that was not directly related to the chemical nature of the lake waters. The finding reinforces that of Payne (1986) who found that in tropical lakes, pH is a labile factor where solar insolation can promote production. pH was correlated to the water temperature (R^2 = 0.46; P≤ 0.01). It was established that 46 % of the lake's pH levels was explained by temperature variance. Data on the lake's pH indicate that the water of the lake is basic, confirming some previous study in the Lake (Beadle, 1981; Kallqvist, 1987; Kiplagat 1989; Oduor; 2000).

The lake's conductivity ranged from 226 – 2620 μscm^{-1} showing an increase in the conductivity values from the streams to the lake. This increase in the conductivity in the lake's sampling sites reflects the increase in the amount of ions in the water that may originate from erosion material from the watershed. In their studies of the Kelang River, Law and Mohsin (1980) reported a large increase in conductivity in the downstream reaches that also faced siltation problem.

In this study, conductivity decreased with depth, indicating there was no accumulation of ions in the bottom due to wind-induced turbulence mixing of the lake waters. Payne (1986) studied Versa lakes of the tropical Amazon flood plains that depend upon river source of dissolved salts. More so, this finding also agrees with that of Payne (1986) in Lake Kivu, which had a conductivity of 4000 μScm^{-1}. The present finding characteristically agrees with that of Yusoff and Sharr (1987) who established that the lake's concentration itself was the resultant of ionic inflows, but was increasing with depth.

The lake has a close link between it and the inflowing rivers that leads to its seasonal fluctuations in the ionic concentrations observed over the study period. Payne (1986) also observed that in drier parts of the tropics, the cycle in the lake reflects that of the rivers with ionic concentrations that are lower in the rainy season and higher in the drier season. Gaudet and Melack (1981) reached similar conclusions in their study of Lake Naivasha.

Compared to other Rift Valley lakes, Lake Baringo scored the second lowest in conductivity values for Lake Nakuru (4800 μscm^{-1}), in Lake Naivasha (30–40 μscm^{-1}), and Lake Elementaita (72000 μscm^{-1}) (Kallqvist, 1987; Melack, 1981; Moss, 1988).

Talling and Talling (1965) proposed class II lakes to be lakes with conductivity values ranging from 600 – 6000 and pH values of 8.8 – 9.5. According to this classification, Lake Baringo is a class II lake with conductivity ranging from 260 – 2620 μscm^{-1} and a pH range of 6.98 – 9.53.

The strong correlation between the lake's conductivity and turbidity ($R^2 = 0.97$; $P \leq 0.0002$) suggests that the lake has a strong ionic concentration that contributes to the attenuation of light. This is supported by the correlation between transparency, ISS, TDS, turbidity and conductivity in the lake (($R^2 = 0.99$; $P \leq 0.15$). Lake Baringo's conductivity was attributed to 97.74 % of the turbidity variance.

Baringo's total phosphorus mean levels in different zones and sampling sites ranged from 35.9 – 57.0 μgl^{-1}. According to Wetzel's; (1983) classification of lakes, Lake Baringo could be classified as a hyper-eutrophic lake. Three possible sources of total phosphorus determined in the lake were direct sediments supply, surface run-offs and the inflowing rivers. Scheffer (1998) made similar reports for shallow waters. Talling and Talling (1965) suggested that the geology of drainage rivers supplying a lake is the principal factor that determines phosphorus loading.

During decreased water depths (December-March-dry season), increased levels of phosphorus were observed in the lake in all zones. Similar observations were made by Beadle (1932) who found that decrease in water level contributed to increased levels of phosphorus in Lake Turkana.

Sediments status, inorganic suspended solids and organic matter affected the determination of the levels of total phosphorus in the lake. Further effects resulted from Northeasterly winds through mixed depth and euphotic depth wave stirring which mixed the water column in the Northern zone, coupled with inflowing rivers and surface run–off into the Southern zone of the lake. Froelich (1988) and Wetzel (1983) similarly stated that inflowing rivers, fluvial organic and inorganic sediments and lake's oxygen regime affect phosphorus loading of lakes.

It was observed that total phosphorus was limiting in the lake because sediments–water interface at the benthos area was usually oxygenated (6.5 mgl^{-1} oxygen) in the southern zone. This represents an effective, relatively permanent sink for phosphorus because of insoluble complexes formed with ions and its tendency to be absorbed by particulate organic carbon. This occurred during wet season (April to August 2003).

In the lake, total phosphorus explains 87.82 % of the TN: TP ratio variations. When the total phosphorus parameter is squared the TN: TP ratio variation is explained by 78 %. More phosphorus limitations were observed in the northern zones than the southern and central zones. This explains the significant differences in the sampling zones and sampling sites, observed over the study period.

The total nitrogen concentrations ranged from 113–281 μgl^{-1} in the southern zone. Different seasons showed significant variations in the mean total nitrogen in the lake. There was a significant variation among the zones and the sampling sites. Total nitrogen explains 72 % of the total nitrogen to total phosphorus variance. The ratio of TN: TP explains 97 % of the variation in ISS, TDS and turbidity in the lake.

The values of total nitrogen found in this research are considered and attributed to high content of organic matter favouring the recycling of phosphorus that is faster than for nitrogen. This reinforces similar findings by Yusoff and Sharr (1987) in their studies of Zoo Negara Lake in Malaysia.

Lake Baringo is oxygenated at sediments-water interface yet nitrogen is still a limiting nutrient. This was due to water column recycling for phosphorus that is apparently faster than for nitrogen. Nitrogen losses in the lake are due to particulate organic matter sinking during the mixing of the lake by the Northeasterly winds wave turbulence, which was highest in the northern zone of the lake. A shift toward nitrogen limitation at different total phosphorus concentrations shown by TN: TP ratio in Lake Baringo indicates that at very high total phosphorus, the ratio went down and vice versa, in different sampling sites, particularly during the dry season (December 2003-March 2004) in the northern zone. This finding agrees with that of Orlando *et al.*, (1998).

Lake Baringo is enriched with nitrogen in the southern zone sampling sites because of high content of organic matter in the zone bordering the lake's swampy area. Nitrate reserve in freshwater bodies (oligotrophic) is depleted as phosphate is added culturally as suggested by Thomas (1969). In the TN: TP observed in Lake Baringo, nitrogen was lost leading to the decline of the TN: TP ratio. Welch and Lindell (1992), made similar observations when they concluded that increased light attenuation makes nutrients remain unused particularly total nitrogen. Due to these limiting factors on the nutrients in Lake Baringo, picoplankton abundance, organic carbon synthesis and growth rate are limited to relatively low levels.

The Molo mouth (southern zone) and Longicharo (central zone) sampling sites had the highest POC (minimum 1010 μgl^{-1} and maximum 1200 μgl^{-1} respectively). Similarly, the same sampling sites had the highest DOC values (6011 μgl^{-1} and 7241 μgl^{-1}) respectively. This was due to these stations proximity to the lake's wetland area, which covers the Molo River and Mukutan River mouths. The high levels of particulate and dissolved organic matter characterize these areas. One of the reasons for this high level of organic carbon is that the River Molo mouth is full of allochthonous organic matter from the river's catchment's area.

Those organic matter flow into the southern zone. This finding agrees with that of Bertoni *et al.*, (1996).

The spatial changes in POC and DOC concentrations in the lake can be explained in terms of organic matter production and decomposition–mineralization set in the context of sedimentation gain and allochthonous input during the wet season (April- July, 2003) in the southern and central zones. During organic matter decomposition the DOC accumulates and is utilised by bacteria and chemo tactic processes. Such finding agrees with that of Bertoni *et al* (1989).

A significant regression (R^2 = 0.99; $P \leq 0.05$) observed suggested that the concentration of DOC increases with that of POC in direct proportions. This result indicates that both POC and DOC increase in the same proportion with increasing trophy in the lake. This did not imply a similar increase in extra cellular organic carbon release. This observation reinforces that one of Baines and Pace (1991) who showed that DOC increases with increasing productivity. In the regression model, the POC increase explains 99.9 % of the variance in DOC increase.

Two key factors contributed to the POC and DOC concentrations regime observed in the lake: allochthonous POC and DOC input from the neighbouring wetland and inflowing rivers and autochthonous organic matter leakage into the lake's fluid system. These observations reassert the phenomenon of energy storage within the POC and DOC in the lake ecosystems as suggested by de Bernadi (1991). Since DOC is more soluble than POC, DOC concentration was quickly reduced through mineralization as suggested by Bertoni *et al.*, (1996). This is in line with the present findings, which have shown that POC and DOC are strongly related in the lake. Furthermore, it shows that in Lake Baringo, the concentration of POC in contrast, is more stable in time since particle settling and particle microbial removal can be slow processes. Callieri *et al* (1986) also came to similar conclusions while studying organic carbon synthesis and mineralization processes in Lake Candia, Italy.

5.2 Effects of physical–chemical environmental factors on picoplankton cell abundance in Lake Baringo

The FDC maximum observed fell at 14.00 or 16.00H with the peaks of the cell density being very tightly coupled (R^2 = 0.56; $P \leq 0.08$). The results show that cell abundance and their activity are directly related in the field and therefore in nature. In nature, the picoplankton - population replicates at a very high rate, producing abundant cells. Cell losses, was not in essence able to offset the resulting increase in cell density. While working in

temperate lakes Callieri *et al.*, (1996), drew similar conclusions on picocyanobacteria in Lake Candia.

The cell abundance's failure to correlate with the lakes turbidity was partly explained from the point of view that turbidity measurements include the bacterial cells themselves in the field. However, since turbidity level relates with the water temperature, although the statistical assessment did not reveal any significant relationship between turbidity and cell density, turbidity and temperature influenced the lake's production levels. Inference can be made from the influence of turbidity on the lake's temperature since the temperature influences the picoplankton cell abundance ($R^2 = 0.47$; $P \leq 0.09$).

Increased water temperature was linked to picoplankton cell abundance in northern, central and southern zones in ascending order respectively in Lake Baringo, during dry season (December 2003- March 2004) as well as wet season (April 2004-May 2004).

Furthermore, a very significant relationship was found between cell abundance and POC. The process of converting POC to a more absorbable DOC proceeded well in the lake. This is supported by the close relationship observed between POC and the cell abundance ($R^2 = 0.89$; $P \leq 0.004$). POC impacted on picoplankton cell abundance in northern, central and southern zones in ascending order respectively during dry season (December 2003- March 2004).

DOC was also strongly related to cell abundance ($R^2 = 0.88$; $P \leq 0.005$) in ascending order of magnitude in the northern zone, southern zone and central zone respectively, during dry season. This was due to the mineralisation of DOC in the lake.

Total nitrogen to total phosphorus ratio's relationship to picoplankton cell abundance in the lake ($R^2 = 0.47$; $P \leq 0.13$) suggests that the two chemical factors together influence the picoplankton cells abundance. Individually, each of the chemical factors did not seem to influence cells' abundance because no relationship existed between them and cells abundance. Picoplankton cells utilized the nutrients during short rains (August 2003-October2003) more than during dry season in ascending order from central zone, northern zone and southern zone for total phosphorus. For total nitrogen, the order was southern zone followed by northern zone and finally central zone in ascending order of magnitude for nutrients uptake.

As was observed that the cell abundance was correlated to the BOD of the lake. The BOD levels were high in the dry months in the central zone, northern zone and southern zone in ascending order of magnitude. This was due to utilization of the oxygen in the water

column by the cells resulting into temporary anoxic conditions, which were measured as BOD levels.

5.3 Effects of turbidity on picoplankton organic carbon synthesis and losses estimates in Lake Baringo

From the data on Lake Baringo, the maximum potential specific picoplankton organic carbon synthesis rate of 24.0 μgcm^{-3} d^{-1} was reached in September 2003 while in January 2004 it was only 6.85 μgcm^{-3} d^{-1}. The month of September 2003 when maximum values of the specific organic carbon synthesis were obtained was a wet season in the Lake while in January 2004 it was a dry season.

The significant relationship ($R^2 = 0.46$; $P \leq 0.14$) found between specific picoplankton organic carbon synthesis and turbidity in the southern zone and the central zone ($R^2 = 0.47$; $P \leq 0.13$) suggests that turbidity impacted on this process in the lake in a significant way in the Central zone in the same way as it did in the southern zone. There was least impact of this process in the northern zone. Increased turbidity values caused an increased inhibition of specific picoplankton organic carbon synthesis rate during short rains (August-November 2003). The highest impact was experienced in the northern zone, followed by the southern and central zones the least. The reason was that turbidity intensity increases as dry season approaches. This is a unique feature of Lake Baringo. However, physical-chemical processes hardly had any links to the net picoplankton organic carbon synthesis, which was detected during the field observations and data analysis.

The high turbidity in the northern zone was caused by resuspension of sediments due to Northeasterly wind disturbance.

Turbidity of the lake is linked to sedimentation process, and therefore the picoplankton losses estimated in these zones was due to the sedimentation. Although grazing measurements, mortality and cell lyses could contribute to these losses, further experiments, including direct estimates of grazing loss rates would provide a more conclusive answer to the question of cell losses in the lake.

The present investigation shows that when used with necessary precautions, FDC methods may successfully be used in freshwater systems to allow direct estimates of the organic carbon dynamics of the picoplankton.

5.4 Effects of turbidity on picoplankton growth rates in Lake Baringo

When more data are added to confirm its accuracy in a study running for over one year in different freshwater ecosystems, the relationship between maximum FDC and the specific picoplankton growth rate may be used to predict the growth rate of the population in

the lake and other similar water bodies in Kenya and other regions. Fahnenstiel *et al.* (1991), Pick and Berube (1992) made a similar report. Measuring of maximum FDC at 14.00 or 16.00 in a natural environment can provide useful information on predicting picoplankton growth rate in freshwater ecosystems in the tropical waters.

The specific growth rate was strongly related to the lake's turbidity ($R^2 = 0.61$; $P \leq 0.07$) and BOD ($R^2 = 0.56$; $P \leq 0.04$). The importance of these relationships is more practical than theoretical bearing in mind that turbidity attenuates the light penetration.

In the southern zone, turbidity affected picoplankton growth rate by lowering the level of light penetration. The effect was observed more during short rainy season (August-November) than in the long rainy season (April-August) in the central zone. Turbidity did not affect picoplankton growth significantly during the wet season compared to the dry season (December-march). This was due to influence from rivers, which increased the volume of water entering the lake. Less disturbance in the zone also contributed to the low level observed. Least impact of turbidity observed in the northern zone was related to the picoplankton growth rates. This suggests that northern zone despite its afternoon daily Northeasterly winds disturbance, had more impact during the short rainy season than any other time (August-November 2003).

Furthermore, this affects the growth rates. The suspended solids, particularly POC contribute to the turbidity levels observed in the lake at various sampling sites, which ended up influencing the picoplankton growth rates coupled with increased BOD levels. The cumulative effect of turbidity affected growth rates at tertiary level by influencing other environmental factors such as BOD levels in the lake. Turbidity levels are significantly related to specific picoplankton growth rates in the lake.

The combined effect of total nitrogen and total phosphorus had minimal influence on the division of picoplankton cells, explaining why the ratio between total nitrogen to total phosphorus was weakly related to the growth rates in the lake. The high levels of instantaneous growth rate of picoplankton observed during this study can be explained in terms of increased allochthonous dissolved organic carbon and particulate organic carbon during the wet season (April-May 2004) in the study area.

The net growth rates (X), measured ranged between 0.67 and 2.08 d^{-1} . Observed physical-chemical and biological processes explain the difference between net and specific growth rates observed in the lake. It was observed that net picoplankton growth rates were weakly related to all the environmental factors investigated.

One of the notable anthropogenic disturbances in the lake was livestock grazing on the fringe of the southern zone swamp. Human disturbance was equally noted as a significant factor affecting the lake's picoplankton in the southern and central zones.

6.0 CONCLUSIONS AND RECOMMENDATIONS

6.1 Conclusions

Turbidity negatively influenced picoplankton abundance mostly in the southern zone, followed by central zone and least in the northern zone. Turbidity influenced picoplankton organic carbon synthesis mostly in the southern zone, followed by Central zone and least in the northern zone. Turbidity also inhibited picoplankton cell growth mostly in the southern, followed by central and northern zones respectively. Highest loss rate of picoplankton was experienced in the northern zone, followed by central zone and least in the Southern zone. Turbidity, particulate organic carbon, dissolved organic carbon, biological oxygen demand negatively influenced picoplankton. Temperature positively influenced picoplankton in the lake. The information obtained from the research would provide a useful hint for the management of the lake's turbidity and fisheries. The lake's fisheries and tourism managers and stakeholders would use the information for future environmental management.

6.2 Recommendations

The following recommendations are made for the future research work in the lake to answer existing questions and to support the application of the present findings in the scientific forum:

A link should be established between turbidity and sediments dynamics and organic carbon production in the photic zone in relation to decomposition – mineralization processes in the lake;

Inventorisation of the taxonomy and the dynamics of picoplankton in Lake Baringo efferent rivers need to be linked to the lake ecosystem;

Further research needs to be carried out to isolate picoplankton species that are toxic to the fish and other fauna in the lake.

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8.0 APPENDICES

APPENDIX 1. Raw data for Lake Baringo monthly water temperature, 0°.

Year	2003							2004					
Month	JUNE	JULY	AUG.	SEPT.	OCT.	NOV.	DEC.	JAN.	FEB.	MAR.	APRIL	MAY	
Zone	Sampling site		Depth										
Southern	MM	22.2	21.6	21.7	22.8	25.6	22.1	24.3	21.6	27.9	25.4	28.8	22.6
		0.75	21.6	21.2	21.6	22.4	25.4	22.0	24.2	21.5	26.3	25.2	24.6
	21.5												
		2.4	21.2	21.2	21.3	22.4	25.2	22.0	24.1	21.2	26.0	25.2	24.1
	21.2												
	MS	0	25.3	25.4	23.8	24.9	26.4	23.4	25.8	23.8	27.1	23.2	23.7
	23.1												
		0.75	24.9	24.9	23.7	24.9	26.2	23.2	25.7	23.7	26.7	23.1	23.7
	23.0												
		2.4	24.8	24.9	23.5	23.0	26.1	23.1	25.6	23.5	24.4	23.0	23.4
	23.0												
	KN	0	21.2	22.3	23.7	23.2	22.9	23.0	33.9	20.4	21.9	23.0	23.8
	23.1												
		0.75	21.0	22.3	23.7	23.1	22.8	23.0	33.4	20.3	21.8	23.0	23.4
	23.0												
		2.4	21.6	22.1	23.5	22.4	22.7	22.8	33.0	20.0	21.2	22.8	22.5
	22.8												
Central													
	KS	0	20.7	20.8	20.6	22.7	27.7	21.0	33.8	22.2	23.3	24.4	23.0
	23.4												

	0.75	21.0	20.8	20.6	22.6	27.6	21.0	29.5	22.1	22.3	24.2	25.7
23.2												
	2.4	21.0	20.7	26.4	22.3	25.5	20.8	29.1	22.0	22.0	23.8	25.0
23.1												
LN	0	26.1	25.5	25.2	25.4	28.0	22.0	27.7	24.3	27.0	20.6	24.1
22.1												
	0.75	25.5	25.5	24.9	25.2	27.5	22.0	26.1	24.4	26.8	20.4	27.8
22.0												
	2.4	25.3	25.3	24.3	25.1	25.4	21.9	25.9	24.2	25.4	20.2	26.1
22.0												
IC	0	25.5	25.5	25.2	21.0	31.8	21.8	23.1	23.4	27.4	20.8	24.1
24.6												
	0.75	25.3	25.3	25.2	21.0	27.4	21.8	23.0	23.3	27.2	20.7	24.0
24.5												
	2.4	25.3	25.0	24.9	20.8	26.4	21.6	22.8	23.0	27.1	20.2	23.9
24.0												
Northern												
KO		0	32.8	21.1	28.7	21.8	32.8	21.2	31.7	23.2	25.4	21.7
25.4	22.0											
		0.75	25.3	21.0	25.0	21.7	30.0	21.2	29.6	23.1	25.3	21.7
28.9	22.0											
		2.4	24.4	21.0	24.5	21.2	28.1	21.0	29.1	23.0	25.2	21.4
27.2	21.8											
LR		0	27.1	22.2	26.7	27.3	25.4	21.1	25.8	25.4	25.2	24.6
26.0	25.4											

		0.75	25.4	22.1	25.7	27.2	25.3	21.0	24.8	25.2	24.8	24.5
26.4	25.4											
		2.4	25.2	22.0	25.2	27.0	25.2	21.1	24.7	25.0	24.2	24.4
24.0	25.3											
KM		0	25.3	25.1	25.7	25.3	26.1	23.4	25.3	25.0	25.3	24.9
24.1	25.1											
		0.75	25.2	25.1	25.7	25.3	26.0	23.2	25.2	24.8	25.3	24.5
24.0	24.9											
		2.4	25.2	25.0	25.2	25.0	24.0	23.0	25.0	24.7	25.0	24.2
23.6	24.5											

APPENDIX 2. Raw data for Lake Baringo turbidity, μgl^{-1}

Year			2003							2004		
Month			JUNE	JULY	AUG.	SEPT.	OCT.	NOV.	DEC.	JAN.	FEB.	MAR.
	APRIL	MAY										
Zone	Sampling site	Depth										
Southern	MM	0	440	420	369	369	360	369	360	360	290	290
289	289											
		0.75	439	425	370	370	360	369	355	355	289	290
290	290											
		2.4	439	425	369	369	360	369	290	290	290	290
290	290											
	MS	0	778	750	789	789	778	789	789	784	784	784
780	780											

		0.75	778	750	785	786	786	789	789	784	785	784
780	780											
		2.4	778	752	789	786	786	789	789	784	789	784
780	780											
KN		0	778	760	822	822	822	760	822	825	822	778
760	722						0.75	778	760	825	822	822
822	822	825	822	778	760	725						
		2.4	778	760	825	825	822	760	822	825	822	778
760	725											
Central												
KS		0	830	825	822	822	830	830	816	816	807	805
805	805											
		0.75	830	825	822	825	830	830	820	816	805	805
808	805											
		2.4	830	825	822	825	830	830	820	816	808	807
807	805											
LN		0	929	929	929	930	940	940	929	929	789	790
789	780											
		0.75	929	929	928	930	940	940	928	929	789	790
789	780											
		2.4	940	929	939	939	940	940	928	929	789	790
790	780											
IC		0	830	830	845	830	778	790	789	845	839	839
839	790											

		0.75	830	830	845	830	778	790	789	845	839	839
839	790											
		2.4	830	830	845	830	778	790	789	845	839	839
839	790											
Northern												
KO		0	877	875	868	868	878	878	878	878	875	764
760	760											
		0.75	877	875	868	868	877	877	877	877	875	764
759	758											
		2.4	877	875	869	869	875	875	875	875	875	764
759	758											
LR		0	829	829	833	835	835	836	836	835	835	835
833	830											
		0.75	829	828	833	835	835	836	836	835	835	835
833	830											
		2.4	829	828	833	835	835	836	836	835	835	835
833	830											
KM		0	829	829	830	835	836	833	830	830	829	829
829	823											
		0.75	829	833	833	835	836	833	830	830	829	829
829	823											
		2.4	829	829	833	836	836	833	830	830	829	829
833	823											

APPENDIX 3. Raw data for inorganic suspended solids (ISS), $\mu g l^{-1}$

Year				2003							2004		
Month				JUNE	JULY	AUG.	SEPT.	OCT.	NOV.	DEC.	JAN.	FEB.	MAR.
	APRIL	MAY											
Zone	Sampling site		Depth										
Southern	MM		0	71	71	76	80	130	130	141	142	131	115
	110	111											
			0.75	71	71	76	80	131	130	141	142	131	115
	110	111											
			2.4	71	71	76	80	131	130	141	141	131	115
	110	110											
	MS		0	46	47	92	91	120	110	110	111	114	115
	113	120											
			0.75	46	46	91	90	120	110	111	111	114	115
	113	120											
			2.4	46	46	92	90	120	110	111	111	114	115
	113	120											
	KN		0	71	72	72	71	72	111	120	110	111	72
	71	110						0.75	71	71	72	70	72
	111	120	111	110	72	71	110						
			2.4	71	71	72	70	72	111	120	111	110	72
	71	110											
Central													

116	116											
		0.75	213	213	287	287	110	110	91	91	71	111
117	117											
		2.4	213	213	287	287	110	110	91	91	71	111
117	117											
LN		0	45	46	81	81	160	150	36	36	86	86
81	81											
		0.75	45	46	80	80	161	151	31	35	86	86
81	81											
		2.4	41	44	80	80	161	151	36	35	86	86
81	82											
IC		0	43	43	45	46	46	31	31	32	33	33
50												
		0.75	43	42	45	46	46	32	31	31	31	31
49	49											
		2.4	43	42	45	46	46	32	31	31	31	33
49	49											
Northern												
KO		0	36	36	15	65	110	110	110	68	67	70
71	72											
		0.75	37	36	15	65	110	109	112	67	67	70
71	72											
		2.4	37	36	15	65	110	105	113	67	67	70
71	72											

LR		0	96	91	128	120	110	105	31	36	48	49
50	51											
		0.75	91	91	129	120	110	91	36	36	49	49
51	51											
		2.4	91	91	129	120	110	91	38	36	49	49
51	51											
KM		0	92	90	125	125	115	115	125	120	115	115
125	120											
		0.75	91	91	125	125	115	115	115	120	115	115
125	120											
		2.4	91	91	125	125	115	115	120	120	115	115
125	120											

APPENDIX 4. Raw data for total dissolved solids, TDS mgl^{-1}

Year			2003							2004		
Month			JUNE	JULY	AUG.	SEPT.	OCT.	NOV.	DEC.	JAN.	FEB.	MAR.
	APRIL	MAY										
Zone	Sampling site		Depth									
Southern	MM		0	389	370	907	910	1018	1010	1020	907	1040	169
	213	213										
			0.75	357	371	890	910	1048	1010	1020	907	1040	168
	169	212										

		2.4	370	370	890	910	1055	1044	1020	907	1040	168
180	213											
MS		0	796	790	983	984	1045	1013	1011	985	888	910
870	813											
		0.75	802	790	911	984	1044	1013	1011	785	888	910
874	813											
		2.4	865	790	947	984	1044	1013	1011	985	888	910
854	813											
KN		0	890	890	950	955	1015	1010	1013	1020	955	950
850	812						0.75	890	890	950	955	1015
1010	1013	1020	955	950	850	812						
		2.4	891	891	951	955	1015	1010	1013	1020	955	950
850	812											
Central												
KS		0	890	884	946	946	1016	1016	1045	1021	1065	1055
1032	898											
		0.75	884	883	959	946	1075	1016	1021	1021	2054	1055
1045	898											
		2.4	884	883	959	946	1074	1016	962	1021	1038	1055
1038	898											
LN		0	884	884	972	972	1120	1120	972	970	968	890
888	874											
		0.75	884	884	970	972	1129	1120	880	970	932	890
874	874											

		2.4	887	884	922	972	118	1116	889	970	896	890
898	874											
IC		0	883	883	992	991	1116	1116	1124	1124	1125	1016
960	971											
		0.75	883	883	991	991	1116	1116	1124	1124	1125	1016
961	971											
		2.4	882	880	991	991	1116	1116	1124	1124	1125	1016
961	971											
Northern												
KO		0	721	721	1037	1010	1002	1002	1024	1024	1045	1034
1034	966											
		0.75	745	745	1033	1010	994	1002	1025	1025	1035	1034
1040	966											
		2.4	783	755	966	1010	1020	1002	1029	1025	1030	1034
1031	966											
LR		0	746	746	1031	1030	1017	1004	993	967	967	968
1000	987											
		0.75	771	777	1026	1026	975	1004	985	968	971	972
999	987											
		2.4	771	771	1020	1026	975	1004	968	968	932	972
991	987											
KM		0	744	774	967	967	1001	1001	1012	968	971	967
967	771											
		0.75	742	774	787	767	1001	1001	1012	968	971	968
968	771											

		2.4	745	774	987	967	1001	1001	1012	968	971	966
668	771											

APPENDIX 5. Raw data for the transparency, secchi disc, cm

Year			2003							2004		
Month			JUNE	JULY	AUG.	SEPT.	OCT.	NOV.	DEC.	JAN.	FEB.	MAR.
	APRIL	MAY										
Zone	Sampling site	Depth										
Southern	MM	2.4	4.4	3.5	2.8	4.2	5.3	8.11	13.5	12.0	13.1	12.2
	13.2	10.4										
	MS	2.8	4.5	3.4	2.4	3.2	4.9	6.0	6.0	4.8	4.5	4.6
	4.6	5.4										
	KN	0.75	4.5	4.2	4.2	3.6	3.9	4.5	4.5	5.2	5.3	5.3
	4.6	5.4										
Central												
	KS	0.4	4.7	2.8	2.8	4.6	3.2	8.0	8.1	5.1	5.1	5.1
	5.2	5.2										

LN		1.0	5.7	3.4	2.4	5.1	3.5	4.5	4.5	5.1	5.1	4.8
5.0	5.1											
IC		1.0	4.8	4.2	4.0	5.2	3.8	4.4	4.5	5.1	5.2	5.1
5.0	5.6											
Northern												
KO		2.5	5.6	5.2	3.0	4.5	5.8	3.4	6.3	5.1	5.3	5.3
5.6	5.3											
LR		1.8	5.3	4.8	3.5	4.8	4.0	2.8	4.4	4.4	4.6	4.6
4.8												
KM		2.5	5.2	4.4	4.5	4.4	4.4	2.4	3.5	4.5	4.8	4.4
4.6	4.4											

APPENDIX 6. Raw data for dissolved oxygen concentration (absolute quantity), mg l^{-1}

Year			2003							2004		
Month			JUNE	JULY	AUG.	SEPT.	OCT.	NOV.	DEC.	JAN.	FEB.	MAR.
	APRIL	MAY										
Zone	Sampling site		Depth									
Southern	MM		0	5.2	5.2	3.8	5.2	4.7	4.7	5.3	3.8	4.3	4.7
	4.9	4.7										
			0.75	4.9	5.2	3.6	4.9	4.6	4.7	6.5	3.6	3.5	4.6
	4.8	4.6										
			2.4	4.6	4.9	2.7	4.9	3.7	4.7	5.1	3.4	1.4	4.6
	4.8	4.6										
	MS		0	4.8	4.9	5.9	4.8	5.3	5.7	5.7	4.8	5.9	5.7
	5.6	5.1										
			0.75	4.9	4.8	5.6	4.8	5.9	5.7	5.6	4.8	5.8	5.7
	5.5	5.2										
			2.4	4.5	4.8	5.6	4.5	5.9	5.4	5.6	4.6	5.7	5.6
	5.4	5.1										
	KN		0	4.6	4.9	5.9	5.9	5.4	5.2	5.9	5.0	3.5	4.7
	5.9	4.8						0.75	4.5	4.8	5.9	5.9	5.2
	5.2	5.4	4.9	3.4	4.7	5.4	4.7						
			2.4	4.5	4.8	5.4	5.9	5.1	4.9	5.4	4.8	3.4	4.6
	5.2	4.6											

Cenral													
	KS		0	3.5	5.0	6.1	6.2	3.3	5.4	6.3	3.5	5.2	5.3
	5.9	4.8											
			0.75	3.3	5.0	6.0	6.2	2.6	5.4	6.2	3.3	4.4	5.3
	5.9	4.7											
			2.4	3.1	4.9	5.9	6.0	2.6	5.2	5.9	3.9	4.1	5.2
	5.8	4.8											
	LN		0	5.0	5.0	6.3	5.0	6.2	3.3	5.3	5.0	6.1	4.9
	5.8	6.0											
			0.75	5.0	5.0	6.3	5.0	6.5	3.3	5.0	5.0	5.6	4.8
	5.7	6.0											
			2.4	4.9	4.9	6.2	4.9	7.6	3.2	4.9	5.0	5.6	4.8
	5.7	5.9											
	IC		0	4.9	4.9	6.0	6.1	4.9	5.0	4.8	5.1	4.5	5.9
	6.0	4.8											
			0.75	4.9	4.9	6.1	6.0	4.8	5.0	4.8	5.0	4.4	5.9
	6.0	4.8											
			2.4	4.8	4.9	5.9	5.9	4.7	4.9	4.7	5.0	4.4	5.8
	6.0	4.9											
Northern													
	KO		0	5.6	5.6	6.6	5.4	5.9	6.5	6.3	6.0	5.4	5.3
	6.1	6.3											
			0.75	5.4	5.6	6.5	5.4	5.8	6.4	4.7	6.0	5.5	5.2
	5.9	6.3											

		2.4	5.3	5.4	6.5	5.2	5.8	6.4	4.8	5.9	5.6	5.2
5.6	6.2											
LR		0	5.2	5.0	6.5	4.8	6.1	4.9	5.6	4.9	5.8	6.0
5.8	5.9											
		0.75	4.9	4.9	6.4	4.9	6.3	4.9	5.5	4.8	5.8	6.0
5.7	5.9											
		2.4	4.8	4.8	6.3	4.8	6.9	4.8	5.5	4.8	5.9	5.9
5.9	5.8											
KM		0	5.6	6.6	6.4	3.4	5.1	5.6	4.8	5.6	5.3	4.8
4.9	4.9											
		0.75	5.6	6.6	6.4	3.2	5.1	5.4	4.7	4.8	5.3	3.8
4.9	4.9											
		2.4	5.4	6.5	6.4	3.2	4.9	5.3	4.6	4.8	5.3	4.4
4.9	4.4											

APPENDIX 7. Raw data for percentage oxygen saturation

Year			2003						2004			
Month			JUNE	JULY	AUG.	SEPT.	OCT.	NOV.	DEC.	JAN.	FEB.	MAR.
	APRIL	MAY										
Zone	Sampling site	Depth										
Southern	MM	0	68	77	62	64	75.6	60	99	101	122	88
	132	94										

		0.75	64	76	57	60	78	57	96	101	111	84
130	90											
		2.4	52	75	56	61	78	58	94	101	102	80
131	90											
MS		0	85	80	89	86	97	45	105	68	106	83
125	77											
		0.75	77	80	86	81	93	44	100	64	100	80
125	70											
		2.4	73	77	83	81	94	44	93	63	96	80
120	70											
KN		0	76	78	84	78	65	78	78	45	73	45
70	91						0.75	75	77	78	74	65
78	79	45	70	44	71	96						
		2.4	71	76	74	70	59	74	78	44	68	46
66	91											
Central												
KS		0	62	81	86	81	65	86	107	35	87	55
94	60											
		0.75	52	80	81	80	66	81	100	35	95	50
90	66											
		2.4	42	76	80	80	66	82	88	34	94	50
81	45											
LN		0	79	77	99	78	100	64	78	45	92	102
121	120											

		0.75	76	80	96	78	97	63	76	44	87	100
121	118											
		2.4	75	80	89	77	96	60	81	44	86	100
120	110											
IC		0	45	52	62	91	95	77	83	80	20	34
125	21											
		0.75	46	71	61	91	88	73	79	80	21	33
120	28											
		2.4	44	72	61	90	84	70	79	77	21	33
118	24											
Northern												
KO		0	89	89	106	80	92.5	66	82	86	84	21
90	45											
		0.75	85	89	103	80	86.5	65	80	85	80	24
91	46											
		2.4	82	88	102	79	104	63	84	84	80	20
90	44											
LR		0	88	75	101	100	101	84	82	89	79	36
121	66											
		0.75	84	75	100	100	101	83	80	88	77	38
120	68											
		2.4	82	71	99	99	81	80	80	87	77	39
120	60											
KM		0	88	63	81	100	80	88	80	100	100	100
80	88											

		0.75	82	56	80	100	80	84	91	102	100	102
70	89											
		2.4	78	54	80	100	81	83	88	102	100	103
64	88											

APPENDIX 8. Raw data for the biological oxygen demand (BOD), µg O_2l^{-1}, 20^0 C 5 day^{-1}

Year			2003							2004		
Month			JUNE	JULY	AUG.	SEPT.	OCT.	NOV.	DEC.	JAN.	FEB.	MAR.
	APRIL	MAY										
Zone	Sampling site		Depth									
Southern	MM		0	22	29.1	32.3	28	22.5	28	32	23	32	31.2
	32	31										
			0.75	22	28	30	24	22.5	28.1	32.3	23.4	32	31.2
	33	31.1										
			2.4	22.5	30	30	24	23	28.2	33	23.6	32	31.6
	34	31.3										
	MS		0	29.3	21	31.3	20	29.3	30	31	33.4	30	29.1
	30	28.1										
			0.75	30	22	31	20	30	29	32	33.8	29	29.1
	31	28.4										
			2.4	31	20	32	21	31	29.1	32	33.6	31	29.4
	32	28.4										

KN		0	29	23	28	29	20	29	29	30	22.2	22.1
23.1	24.1						0.75	28	24	28	28	22
29	30	29	22.5	22.1	23.4	22.1						
		2.4	28	20	29	28	24	29	31	29	22.8	22.2
23.6	22.1											
Central												
KS		0	140	130	139	140	139	139	191	140	190	191
190	191											
		0.75	142	131	139	141	140	140	192	144	191	191
191	192											
		2.4	143	130	140	139	141	140	199	140	192	192
191	192.1											
LN		0	30	28	58	31	30	41	58	43	58	58
58	41											
		0.75	31	21	59	31	31	41	59	41.2	59	58
59	41											
		2.4	32	22	60	30	31	42	59	40.4	59	58.2
59	41.3											
IC		0	22	30	58	21	28	28.5	59	59.3	28	28
29.1	22											
		0.75	22	32	59	20	30	28.6	59	59.1	27	29
29.2	28											
		2.4	22	30	59	22	30	28.1	60	58.9	27	29
29.2	28											

Northern

KO		0	19	20	59	60	18.5	28	59	21.6	69	64
50	51											
		0.75	19	21	60	59	19	28	60	21	60	64
50	50											
		2.4	20	21	62	59	21	28	60	21	60	64
51	52											
LR		0	30	22	47	31	31.3	44	47	22	48	47
48	48											
		0.75	31	23	48	30	31.3	44.3	47	22.6	49	47
46	48.1											
		2.4	31	23	48	30	32	44.6	48	22.3	49	47.2
48	48.4											
KM		0	30	21	24	31	18.9	21.4	20	22	30	28
30.1	28											
		0.75	30	20	24	30	18.9	21.2	21	22	28	28
30.2	28											
		2.4	30	20	25	30	19.5	21.3	21.3	22	29	29
30.2	28											

APPENDIX 9. Raw data for Lake Baringo conductivity, µS cm^{-1}

Year				2003							2004		
Month				JUNE	JULY	AUG.	SEPT.	OCT.	NOV.	DEC.	JAN.	FEB.	MAR.
	APRIL	MAY											
Zone	Sampling site		Depth										
Southern	MM		0	1706	1702	1742	1859	1997	1918	1933	316	316	322
	316	316											
			0.75	1702	1702	1734	1838	1859	1957	1922	316	299	322
	322	316											
			2.4	1701	1702	1733	1838	1838	1957	1918	299	226	322
	340	316											
	MS		0	1722	1987	1939	1939	1987	1685	1757	1752	1804	1722
	1552	1552											
			0.75	1680	1987	1832	1932	1872	1685	1687	1752	1704	1722
	1752	1752											
			2.4	1696	1987	1939	1932	1871	1657	1685	1747	1749	1686
	1747	1952											
	KN		0	1987	1932	1939	1872	1922	1685	1555	1552	1804	1747
	1686	1555						0.75	1939	1932	1932	1871	1918
	1657	1658	1752	1704	1952	1649	1565						
			2.4	1939	1938	1934	1857	1919	1652	1658	1651	1749	1749
	1647	1548											
Central													

KS		0	1765	1933	1938	2004	2008	2040	2100	2080	1997	1933
1906	1905											
		0.75	1763	1918	1922	1944	1980	2034	2060	2070	1995	1942
1905	1904											
		2.4	1760	1904	1838	1940	1880	2040	2070	2060	1994	1936
1904	1904											
LN		0	1780	1786	1813	1980	1942	1872	1890	1942	1944	1888
1644	1942											
		0.75	1758	1725	1870	1880	1918	1871	1876	1933	1888	1864
1642	1933											
		2.4	1725	1702	1804	1765	1882	1752	1878	1904	1864	1860
1633	1918											
IC		0	1959	1959	1805	1882	1942	1871	1644	1942	1860	1842
1918	1942											
		0.75	1922	1922	1780	1886	1918	1860	1642	1704	1647	1840
1904	1933											
		2.4	1918	1780	1758	1852	1882	1820	1633	1749	1649	1860
1905	1918											
Northern												
KO		0	1804	1758	1961	1846	1046	1152	1959	1955	1955	1706
1706	1958											
		0.75	1744	1752	1758	1852	1001	1152	1958	1958	1952	1702
1702	1961											
		2.4	1552	1546	1758	1852	992	986	1957	1944	1944	1702
1701	1961											

LR		0	1770	1786	1884	2316	2620	2080	1854	1996	1996	1651
1650	1996											
		0.75	1686	1680	1831	2316	2316	2060	1852	1896	1972	1651
1651	1996											
		2.4	1680	1680	1821	2316	2176	1980	1846	1894	1964	1648
1649	1964											
KM		0	1770	1758	1752	1806	1813	1812	1706	1713	1719	1855
1913	1912											
		0.75	1682	1758	1752	1804	1812	1812	1702	1712	1719	1855
1900	1912											
		2.4	1680	1759	1752	1800	1812	1812	1700	112	1712	1822
1846	1900											

APPENDIX 10. Raw data for the pH of Lake Baringo, pH units.

Year			2003							2004		
Month			JUNE	JULY	AUG.	SEPT.	OCT.	NOV.	DEC.	JAN.	FEB.	MAR.
	APRIL	MAY										
Zone	Sampling site		Depth									
Southern	MM		0	8.55	8.54	8.96	8.95	7.63	7.63	6.98	6.94	8.53	8.53
	8.69	8.69										
			0.75	8.47	8.48	9.01	8.96	7.71	7.63	6.99	6.94	7.79	8.52
	8.78	8.68										

		2.4	8.46	8.48	8.97	8.96	7.71	7.63	7.12	6.95	7.94	8.52
8.78	8.72											
MS		0	7.75	7.72	9.20	9.20	9.45	9.45	9.40	9.41	8.91	8.92
8.79	8.79											
		0.75	7.76	7.72	9.18	9.21	9.47	9.45	9.38	9.40	8.69	8.92
8.70	8.77											
		2.4	7.76	7.72	9.17	9.20	9.47	9.46	9.37	9.40	8.66	8.91
8.84	8.82											
KN		0	7.72	7.72	9.10	9.20	9.41	9.42	9.36	9.41	8.99	8.91
8.81	8.77						0.75	7.78	7.71	9.10	9.10	9.42
9.41	9.36	9.42	8.91	8.91	8.82	8.71						
		2.4	7.74	7.72	9.20	9.10	9.41	9.36	9.37	9.41	8.91	8.91
8.83	8.71											
Central												
KS		0	8.66	8.62	9.22	9.20	7.84	7.21	7.23	7.24	8.98	8.91
8.91	8.91											
		0.75	8.71	8.62	9.10	9.20	7.84	7.28	7.23	7.23	8.98	8.92
8.94	8.94											
		2.4	8.71	8.71	9.10	9.21	7.84	7.23	7.23	7.23	9.11	9.02
9.10	9.10											
LN		0	7.69	7.61	9.19	9.20	9.44	9.21	9.39	9.10	9.00	9.01
9.02	9.01											
		0.75	7.68	7.62	9.20	9.19	9.33	9.21	9.42	9.10	9.02	9.01
9.01	9.01											

		2.4	7.66	7.68	9.20	9.20	9.33	9.40	9.40	9.12	8.97	9.01
8.99	9.01											
IC		0	7.68	7.66	8.11	9.19	9.31	9.01	9.01	8.60	8.91	9.02
8.89	9.02											
		0.75	7.62	7.67	8.41	9.01	9.31	9.02	9.01	8.60	8.92	9.02
8.86	9.03											
		2.4	7.63	7.67	8.44	9.01	9.31	9.02	9.01	8.59	8.92	9.01
8.88	9.03											
Northern												
KO		0	7.64	7.81	8.44	8.46	9.54	9.53	9.53	9.49	8.78	8.78
8.51	8.44											
		0.75	7.47	7.82	8.45	8.47	9.53	9.52	9.51	9.49	8.79	8.79
7.79	8.41											
		2.4	7.32	7.82	8.40	8.47	9.48	9.47	9.51	9.48	8.78	8.79
7.84	8.42											
LR		0	7.64	7.44	8.89	8.44	9.35	9.41	9.49	9.41	8.86	8.61
8.91	8.90											
		0.75	7.68	7.69	8.88	8.41	9.34	9.41	9.48	9.41	8.73	8.61
8.72	8.90											
		2.4	7.69	7.69	8.89	8.41	9.35	9.41	9.47	9.40	8.71	8.61
8.69	8.91											
KM		0	7.72	7.28	7.81	7.82	8.61	7.81	9.31	7.91	8.74	8.81
8.80	8.06											
		0.75	7.73	7.29	7.82	7.82	8.61	7.81	9.20	7.92	8.74	8.81
8.80	8.06											

		2.4	7.73	7.28	7.82	7.81	8.60	7.82	9.20	7.91	8.73	8.81
8.90	8.07											

APPENDIX 11. Raw data for total phosphorus of Lake Baringo, $\mu g\ l^{-1}$.

Year			2003							2004		
Month			JUNE	JULY	AUG.	SEPT.	OCT.	NOV.	DEC.	JAN.	FEB.	MAR.
	APRIL	MAY										
Zone	Sampling site		Depth									
Southern	MM		0	43.4	43.8	48.1	39.0	33.0	33.8	34.1	41.0	48.0	45.0
	43.1	43.2										
			0.75	43.4	43.8	48.7	39.0	33.0	33.8	34.1	41.0	48.0	45.0
	43.1	43.2										
			2.4	43.6	43.9	48.7	39.5	32.9	34.0	34.7	41.2	48.7	45.5
	43.6	43.3										
	MS		0	48.1	44.3	41.3	31..0	27..0	29..1	38.0	38.0	39..0	26.0
	21.3	24.2										
			0.75	48.1	44.3	41.5	31.1	27.1	29..	38.0	38.	39..0	26.0
	21.3	24.2										
			2.4	48.2	44.5	41.5	31.1	27.1	29.	38.9	38.6	39.9	26.0
	21.5	24.										
	KN		0	48.0	39.9	29.6	32.	32.9	33.2	34.1	34.0	43.1	38.4
	34.1	33.9						0.75	48.0	39.9	29.9	32.1	32.8
	33..3	34.2	34.0	43..1	37.7	32.4	33.9						

		2.4	48.2	38.9	30.0	32.1	32.8	33.3	34.2	34.2	43.6	37.6
32.8	33.8											
Central												
KS		0	55.6	55.4	58.1	54.8	54.4	54.3	55.0	55.1	59.6	59.4
59.2	59.1											
		0.75	55.6	55..4	58.1	54.8	54.4	54.3	55.1	55.1	59.6	59.4
5.2	59..2											
		2.4	56.0	56.0	58.2	54.9	54.5	54.4	55.2	55.5	59.7	59.5
59.2	59.2											
LN		0	51.0	50.9	508	480	470	471	570	555	530	512
413	412											
		0.75	51.2	509	508	480	470	471	570	555	530	512
414	412											
		2.4	51.3	510	507	485	470	475	570	556	530	512
414	412											
IC		0	51.0	512	502	416	411	413	416	328	436	403
421	413											
		0.75	51.0	512	502	417	413	428	413	322	432	402
422	413											
		2.4	51.2	513	512	417	413	421	411	322	444	402
420	416											
Northern												
KO		0	51.3	52.6	44.4	44.9	50.4	480	526	521	514	503
413	412											

		0.75	514	526	444	449	504	502	526	521	514	503
513	413											
		2.4	514	533	445	452	503	502	530	521	514	503
513	413											
LR		0	460	420	413	419	430	433	450	428	413	412
455	452											
		0.75	461	422	413	419	430	433	450	428	413	412
455	452											
		2.4	461	423	413	422	430	438	450	424	413	414
455	428											
KM		0	442	414	416	502	501	507	528	461	412	423
516	512											
		0.75	442	414	411	502	502	510	522	465	412	423
517	512											
		2.4	438	417	412	503	502	512	522	465	413	424
516	513											

APPENDIX 12. Raw data for total nitrogen of Lake Baringo, $\mu g\ l^{-1}$

Year			2003							2004		
Month			JUNE	JULY	AUG.	SEPT.	OCT.	NOV.	DEC.	JAN.	FEB.	MAR.
	APRIL	MAY										
Zone	Sampling site		Depth									
Southern	MM		0	280	249	247	230	218	255	280	167	113	128
	218	210										

		0.75	281	249	248	230	219	255	280	166	113	128
218	210											
		2.4	281	250	248	233	218	261	279	169	113	131
213	211											
MS		0	230	222	214	220	226	226	227	217	215	162
141	140											
		0.75	235	225	215	220	228	226	227	217	213	162
143	140											
		2.4	235	225	215	221	228	222	221	225	231	163
144	142											
KN		0	230	113	221	218	216	227	222	169	163	221
211	202						0.75	230	112	222	218	216
227	222	169	163	222	208	202						
		2.4	231	112	225	219	213	229	223	169	163	222
208	203											
Central												
KS		0	231	211	160	138	114	155	230	196	115	116
115	213											
		0.75	231	211	161	138	114	155	231	196	115	117
115	213											
		2.4	230	216	167	133	115	161	230	192	115	117
115	217											
LN		0	251	213	181	188	196	210	256	148	147	144
147	144											
		0.75	252	213	182	188	196	213	257	148	147	144
147	144											

		2.4	252	216	182	190	195	213	256	149	147	148
147	142											
IC		0	116	163	180	152	147	138	114	159	210	196
190	217											
		0.75	116	163	180	152	147	138	114	159	213	199
190	217											
		2.4	118	166	182	165	149	140	116	160	213	199
192	221											
Northern												
KO		0	271	199	193	213	181	171	114	144	211	196
211	210											
		0.75	272	199	193	213	181	170	114	145	211	199
211	210											
		2.4	272	201	193	215	181	170	114	145	211	199
211	210											
LR		0	230	216	169	179	191	180	181	170	131	210
131	161											
		0.75	231	216	169	179	191	180	181	170	131	213
131	161											
		2.4	231	217	169	178	191	181	183	177	131	213
131	165											
KM		0	166	213	181	177	166	211	116	202	115	210
203	213											
		0.75	166	213	181	177	166	210	116	202	115	210
204	213											

		2.4	171	213	185	182	172	211	118	204	120	211
204	217											

APPENDIX 13. Raw data for particulate organic carbon (POC), $\mu g\ l^{-1}$.

Year			2003							2004		
Month			JUNE	JULY	AUG.	SEPT.	OCT.	NOV.	DEC.	JAN.	FEB.	MAR.
APRIL	MAY											
Zone	Sampling site	Depth										
Southern MM		0	900	910	1000	820	882	884	900	855	880	855
830	831											
		0.75	960	1000	1010	911	890	884	880	886	890	855
840	831											
		2.4	960	940	1010	921	900	891	900	889	890	857
850	832											
MS		0	600	650	750	620	590	555	529	620	1000	820
750	720											
		0.75	700	720	760	631	595	555	560	622	1010	822
750	722											
		2.4	700	730	760	632	600	560	600	650	1010	823
790	723											
KN		0	840	630	521	750	513	644	826	611	511	712
813	389						0.75	840	632	521	750	513
643	825	611	513	712	813	388						

		2.4	855	633	522	753	511	644	832	612	516	713
813	388											
Central												
KS		0	600	511	450	444	440	442	441	520	700	711
713	711											
		0.75	630	512	450	461	490	455	500	522	710	711
713	713											
		2.4	635	513	460	462	495	459	500	523	713	713
720	713											
LN		0	600	631	730	766	900	911	1100	913	900	814
1010	823											
		0.75	610	633	728	791	980	911	1200	913	910	824
1200	824											
		2.4	620	636	728	810	980	914	1200	911	930	826
1200	824											
IC		0	710	721	490	513	813	820	1819	833	1200	822
860	1010											
		0.75	713	722	491	513	813	820	1818	832	1200	822
866	1010											
		2.4	713	722	491	514	814	820	1819	833	1200	828
867	1011											
Northern												
KO		0	1010	1000	1080	713	607	601	529	743	1000	910
800	800											

		0.75	1000	1000	1000	713	601	601	600	744	1010	910
830	801											
		2.4	1010	1000	1000	714	610	602	700	744	1010	910
830	801											
LR		0	740	766	740	811	830	913	1010	912	940	511
430	360											
		0.75	730	766	740	811	830	913	1100	912	940	513
430	360											
		2.4	730	772	740	822	830	916	1100	913	940	513
430	366											
KM		0	914	813	622	711	799	821	721	740	713	461
372	712											
		0.75	914	813	632	711	790	821	721	740	713	461
373	712											
		2.4	914	812	630	713	789	822	722	740	713	462
372	712											

APPENDIX 14. Raw data for dissolved organic carbon (DOC), $\mu g\ l^{-1}$.

Year	2003							2004					
Month	JUNE	JULY	AUG.	SEPT.	OCT.	NOV.	DEC.	JAN.	FEB.	MAR.	APRIL	MAY	
Zone	Sampling site		Depth										
Southern	MM	0	5441	5462	6011	6090	5199	5180	5411	5324	5284	5090	4990	3989
		0.75	5461	5462	6051	6045	5492	5188	5292	5325	5286	5099	4896	
3990														
		2.4	5462	5461	6042	6035	5610	5188	5292	5325	5286	5098		
4811	3989													

	MS		0	3732	3742	4522	4380	3195	3260	3554	4180	6112	5230
	4522	4621											
			0.75	3735	3741	4570	4388	3372	3262	3611	4188	6114	5232
	4531	4622											
			2.4	3721	3741	4571	4389	3594	3261	3611	4188	6130	5236
	4531	4624											
	KN		0	3665	3671	2890	3060	3490	3530	3780	4171	5120	4911
	4490	3960						0.75	3660	3670	2891	3066	3495
	3533	3788	4170	5122	4912	4491	3966						
			2.4	3666	3670	2891	3066	3495	3533	3788	4171	5120	4912
	4492	3966											
Central	KS		0	3660	3760	2770	2650	2672	2631	2624	3130	4223	4223
	4278	4230											
			0.75	3665	3766	2780	2651	2995	2651	2948	3133	4213	4251
	4279	4233											
			2.4	3671	3766	2785	2751	2884	2891	3101	3134	4211	4255
	4281	4233											
	LN		0	3595	4120	4440	5120	7113	6130	5391	5360	5411	5611
	6021	4310											
			0.75	3591	4122	4391	5122	7241	6133	5881	5530	5450	5680
	7201	4314											
			2.4	3591	4122	4411	5122	7241	6133	5881	5530	5451	5690
	7201	4312											
	IC		0	2870	2780	3580	3420	3280	3811	4140	3120	2680	3113
	4280	4210											

		0.75	2871	2788	3581	3430	3288	3833	4144	3125	2688	3114
4288	4211											
		2.4	2877	2788	3582	3460	3290	3860	4144	3128	2688	3125
4288	4211											
Northern		KO		0	6067	6050	6570	4236	3213	3410	3642	3806	6100
4810	4818	3960										
		0.75	6100	6055	6222	4236	3712	3511	3652	3801	6101	4810
4817	3966											
		2.4	6090	6055	6122	4235	4211	3560	3652	3801	6200	4811
4814	3966											
LR		0	4250	4300	4520	4620	6114	5020	4993	4994	5641	3060
2894	2344											
		0.75	4250	4335	4471	4620	6711	5020	4814	4998	5641	3060
2896	2345											
		2.4	4230	4325	4501	4680	6841	5025	4111	4998	5611	3060
2894	2345											
KM		0	4120	4214	3560	2890	5030	4260	4300	4550	4130	2860
2560	3360											
		0.75	4122	4214	3566	2890	5030	4260	4300	4550	4160	2866
2560	3362											
		2.4	4120	4235	3566	2895	5060	4270	4350	4555	4160	2866
2570	3380											

APPENDIX 15. Picoplankton count (cell 10^3 ml^{-1}) for Lake Baringo and frequency of dividing cells (FDC_{max}%) from June 2003 – May 2004).

Zone/ Month	Southern	FDCmax%	Central	FDCmax%	Northern	FDCmax%

JUNE	191	44	123	45	63	43
JULY	200	23	90	21	52	22
AUG.	251	21	191	26	86	14
SEPT.	263	15	190	15	92	15
OCT.	320	10	194	8	208	12
NOV.	244	12	182	9	191	10
DEC.	167	25	102	30	86	35
JAN.	104	18	100	16	70	14
FEB.	73	24	61	24	98	15
AR.	79	22	67	20	60	21
APR.	205	16	118	26	69	21
MAY	127	21	142	21	67	209

APPENDIX 16. Picoplankton species composition of Lake Baringo (June 2003-May 2004): Sporadic = 1, rare = 2, frequent = 3, very frequent = 4, copious = 5.

Taxon (Species)	Description	Zone Southern	Central	Northern
Anabaena circinalis		2	3	3
A. torulosa		3	4	3
Aphanocapsa roseana		2	2	3
Lyngbya sp.		2	3	3
Microcystis aeruginosa		4	3	5
M. flos-aquae		4	2	3

M. novacekii	2	1	1
Merismopedia minima	1	1	1
Oscillatoria cf. Princeps	1	2	1
Oscillatoria sp.	1	1	1
Phormidium cf. Mucicola	2	3	2
P. cf. Inundatum	2	3	2
P. subicustratum	2	2	2
Raphidiopsis curvata	1	1	1
Spirulina cf. Princeps	1	2	2
Synechococcus c.f. elongatus	1	1	1
S. endogloeicus	3	4	2
Synechocystis equatillis	1	3	2
Escherichia coli	5	5	4
Streptococcus spp.	5	5	4

APPENDIX 17. Ichthyofauna of Lake Baringo drainage basin

Taxon Family & species	Lake	River	Status
Aplocheilichthyidae			
Aplocheilichthys sp baringo	X	X	Native
Cichlidae			
Oreochromis niloticus baringoensis	X	X	Native
Oreochromis spirulus	X	-	Exotic (L. Naivasha)

Clariidae			
Clarias gariepinus	X	X	Native
Cyprinidae			
Barbus intermedius	X	X	Native
Barbus aff. Lineomaculatus	X	X	Native
Babus alternialis	X	X	Native
Barbus gregorii	X	X	Native
Labeo aff. Cyndricus	X	X	Native
Poeciliidae			
Poecilia reticulata	X	-	Exotic
Protopteridae			
Protopterus aethiopicus	X	X	Exotic (L. Victoria)

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