AN ASSESSMENT OF THE WATER QUALITY OF LAKE BARINGO, KENYA

BY

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DECLARATION

This thesis is my own work and has not been presented for a degree in any other University.

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This thesis has been submitted for examination with my approval as a University Supervisor

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ABSTRACT

Lake Baringo is a freshwater lake with low salinity and is situated in the Kenyan Rift Valley. It is characterised by a correlatively polymictic regime and has no visible outlet. The lake is a young formation in geological time scales. Tectonism, Volcanism and Sedimentation have combined to produce the Baringo Basin. The basin is subject to heavy sedimentation due to serious erosion problems in severely overgrazed semi-arid areas in the eastern lowlands of Baringo District.

Much work has been done on many of the Kenyan Rift Valley lakes for example Lakes Nakuru, Elmenteita, Sonachi, Bogoria and Naivasha. Other Kenyan lakes have also been studied, but very little work has been done on Lake Baringo.

Samples were collected fortnightly for both lake and river sites from July, 1988 to March, 1989 and analysed for a wide range of physical, chemical and biological parameters. The samples were collected from eight sampling stations in the lake, six of them along a transect extending from the mouth of River Molo at the southern end to Lekoros Island at the northern end of the lake. The other two stations were on the eastern and western sides of the lake. Samples were also collected at four river stations on the four major rivers associated with Lake Baringo.

The higher than average rainfall during the study period

resulted in an increase in depth of the lake of 157 cm between July and November, 1988, with a subsequent decrease of 37 cm by the end of the study period in March, 1989. As expected, such large variations in lake level had a profound impact on the values of the parameters of water quality determined during the study.

The mean concentrations (mgl^{-1}) of the main parameters measured for all stations over the whole study period were as follows: sodium 158.6; total hardness 47.6 ($CaCO_3$), calcium 11.2; magnesium 4.1; total alkalinity 396.5 (HCO_3^-); orthophosphate 0.11; chloride 41.3; molybdate reactive silica 28.9; total nitrogen 1.6; total phosphorus 0.14; suspended silt 500; pH 8.6; and conductivity 793 μScm^{-1}. The corresponding mean values for the rivers were much lower except for molybdate reactive silica.

The results of the study are discussed in the light of the geographical and seasonal variation in the physical, chemical and biologial parameters observed. The impact of the river water on the water of the main lake is assessed. The ecological status of the lake as measured by the water quality studies carried out in the present study, is discussed in the light of previous data and with reference to its ability to continue to support aquatic life in the lake.

CHAPTER 1:

1.1. INTRODUCTION:

Water quality has an extremely broad spectrum of meanings. Each individual has a vested interest in water for his or her particular use, which involve commercial, industrial or recreational pursuits. Since the desirable characteristics of water vary with its intended use, there is therefore frequently unsatisfactory communication among users of water where quality is concerned (Curran, 1977).

Water quality can generally be defined as the limiting concentration of a chemical (or degree of intensity of some adverse condition e.g. pH, temperature, colour etc) which is permitted in an effluent, waterway or waterbody. Standards are established for regulatory purposes and are determined from a judgement of the criteria involved. The standards are dependent on the use (e.g. domestic, agricultural, industrial, by aquatic life) of the water to be protected.

The quality of the water can be affected by many parameters some of which could be introduced by natural phenomena and others by human activities. Water quality can be indicated by the levels of nutrients such as nitrates, ammonia, nitrites, phosphates etc. When the levels of phosphorus and nitrogen compounds become too high, then algal blooms can form which can lead to dissolved oxygen depletion which in turn can result in fish kills. On the other hand when nutrient levels in water are too low, then life is affected as there is insufficient food for the aquatic life causing some to die off, thus lowering the water quality. Heavy metals and pesticides are also potentially toxic to both animal and plant life in lake and river waters.

Some work has been done on certain East African Rift Valley lakes, for example, Lake Nakuru (Vareschi, 1982), Lake Elmenteita (Melack, 1988), Lake Sonachi (Njuguna, 1988), Lake Victoria (Foxall, et al 1984) and Lake Naivasha (Gaudet and Melack, 1981; Njuguna, 1982). Except for Lakes Naivasha, Kitangiri, Turkana and Baringo, all lakes on the floor of the Rift Valley are highly alkaline (e.g. Lake Magadi and Nakuru etc). Only Lakes Nakuru and Naivasha have been studied in great detail for an extended period, from a variety of aspects. Little data is however available for Lake Baringo. Thus, this project is designed to provide the baseline data on Lake Baringo which could be used to check the current physical and chemical status of the lake and some of its rivers. This baseline data could also be used to monitor pollution levels of the lake and to relate the chemical composition of the lake to the environmental degradation of the catchment areas. Concern has been expressed that rift valley lakes including Lake Baringo appear to be drying up and that they may be becoming more saline. The severe soil erosion and siltation associated problems in the catchment areas may result in the lake becoming shallower which in turn influences the chemical status of the lake.

Most of the data available from Lake Baringo are inconclusive because, they were obtained from spot sampling carried out irregularly in several different years. Such partial data cannot give any indication of possible geographical and seasonal variations in the water quality or the chemical composition of the lake. This study is therefore, a wider review of the relationship between the catchment activities, organic loading, rainfall and water quality in general. The project was undertaken in order to provide systematic water quality data for Lake Baringo and its associated rivers.

1.2. OBJECTIVES:

The objectives of this study were to:

1. Assess the physico-chemical and biological parameters of water body of Lake Baringo, to be used as an index of the current water quality of the lake.

This was done for the purpose of:

a. providing baseline data which can be used for comparative purposes in the future assessment of trends in the water quality.

b. assessing the suitability of the lake water for domestic, industrial and irrigation purposes.

c. evaluating the likely effects of water quality on the aquatic life on Lake Baringo and its surroundings.

ii. assessing the impact of soil erosion from Lake Baringo catchment area on the water quality.

iii. determining the relationship between the physico-chemical and biological parameters of the main inflowing rivers and those of the water body of the lake.

1.3. THE STUDY AREA:

Lake Baringo (0^0 37'N, 36^0 05'E) lies in the Baringo basin in the Rift Valley (eastern) and is located 100 Kilometres north of Nakuru town. The lake has an area of 130 square kilometres but is variable according to lake levels. Its altitude is 975 metres. The rainfall of the Baringo basin is approximately 600 millimetres per annum (Baringo Development Plan, 1985). The surrounding country is dry covered by thorn bush and much of the northern areas of the lake are rocky and sparsely vegetated. The southern end is characterised by alluvial plains. There is a large swamp at the southern end of the lake, dominated by *Cyperus papyrus* accompanied by *Pistia stratiotes* and *Nymphaea species* (water lilies).

1.3.1 THE BARINGO BASIN

Lake Naivasha, Elmenteita and Nakuru at one time may have been one large lake extending to Lake Baringo as seen from lake level evidence (Gregory, 1921). Lake Baringo is roughly 21 kilometres long and 8 kilometres wide with a mean depth of 1.6 metres. Rowntree *et al*, (1985) suggested that the Lake Baringo at one time drained northwards into Lake Turkana via the Suguta River, whereas Gregory (1921) suggested that the lake seeps through lavas and tuffs at the northern end of the lake and that this water still finds its way to the Suguta River. It is supposed that due to this underground water outlet and recharging of the lake by its rivers, that it remains a fresh water lake today.

1.3.2. DRAINAGE INTO LAKE BARINGO

Lake Baringo is a fresh water lake. Its fresh water nature was explained by Gregory (1921). Lake Bogoria and Baringo could be remnants of a once continuous lake but could have been separated by the Loboi plains, a wide extent of silt laid down by the original rivers which flowed into this extended lake. The four major rivers flowing into Lake Baringo are Rivers Mukutan, Ol-Arabel, Molo and Perkerra as shown in Figure 1, page 7.

The Perkerra River, which drains the Mau Escarpment west of Eldama Ravine and the Tugen Hills, is the largest river in the area, and extensive irrigation is carried out near Marigat, utilizing its waters. Its flow dwindles to the east of Marigat and to the north of Logumkum and losses its identity in the Lol Matatshu Swamp.

River Molo is another large river. It also drains the Mau Escarpment near Molo and Elburgon through its own headwaters and those of a major tributary, the Rongai River. The Molo River gradually narrows once the river reaches the floor of the rift valley and on entering the inter-lacustrine silt plains. Beadle (1932) suggested that there is a considerable recharge into Lake Baringo from the water tables fed by the Rivers Molo and Perkerra.

During the dry season, the flow of the Molo River is considerably reduced. At drier times of the year, owing to the quantity of the water extracted from the Greater Nakuru Water Project and the Eldume Irrigation Scheme, the flow of the river ceases completely before reaching the lake.

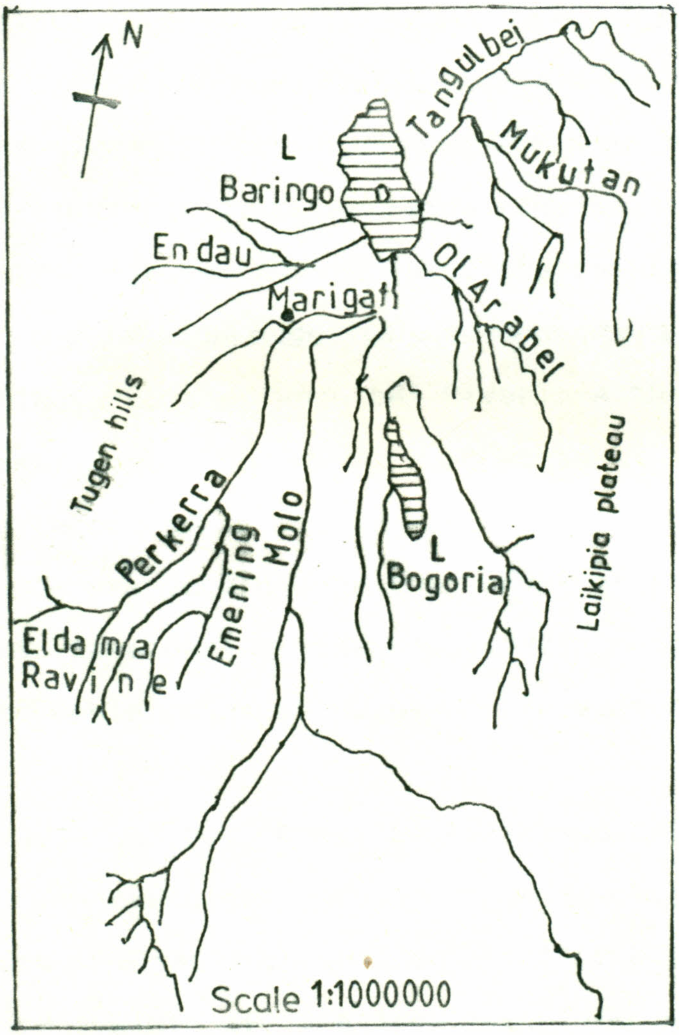


Fig. 1: Catchment Area of Lakes Baringo and Bogoria.

Map redrawn from the Atlas of Kenya, 3rd Edition, Kenya Government, 1970 (Scale 1:1000,000).

The Ol-Arabel River drains the northern part of Marmanet Forest and the Ol-Arabel Forest and drains into Lake Baringo. It is seasonal throughout most of its length, though it collects spring water below the Ngelesha Escarpment and flows permanently for a brief distance. Its tributaries which drain the whole of the Ngelesha Reserve, are all flood streams, flowing briefly after rains (Beadle, 1932).

The Mukutan River drains the Laikipia Plateau to the east of the lake through its own headwaters and those of its major tributary, the Tangulbei River. Although the river does not carry such a great body of water as the other rivers (e.g. Perkerra, Molo and Ol-Arabel), the dissolved salts of its water are much higher than those of the other rivers flowing into Lake Baringo (Beadle, 1932). The river enters the lake through a swamp at Rugus on the eastern side of the lake.

1.3.3 GEOLOGY OF THE LAKE BARINGO BASIN

The basins of Lakes Baringo and Bogoria cover the eastern part of a fault controlled axial rift extending 100 kilometres with a width of 30 kilometres. The Baringo basin exhibits a strongly symmetrical pattern and is bordered on the east of the Laikipia plateau and to the west by the Tugen Hills (Milonovsky, 1972). The rift valley floor, the step-fault platforms and scarp borders of the Lake Baringo basin are largely composed of Miocene, Pliocene and Pleistocene volcanics. Pleistocene lavas are associated with the central volcanoes to the north of Lake Baringo. Later Pleistocene lavas are typified by the Lake Baringo trachyte and lava formation from central volcanoes for example Kokwa Island, Lekoros and Parmolok Islands (Tiercelin et al, 1980).

Renaut et al, (1982) proposed the following sequences of events during the late quartenary period). At one time, one lake covered both the Bogoria and Baringo basins. The two lakes Bogoria and Baringo, became separated either by regression or delta progradation at the Sandai Delta. Minor faults and subsidence occurred in the Baringo depression and Lake Baringo levels rose as a response to the climatic conditions of the early Holocene period. Sedimentation, presently taking place in a particular location in the lake, results from local factors pertaining to the overall morphological, geological, hydrodynamics and chemical conditions of the location. The sediments of the south and west of Lake Baringo consist of diatomaceous silts, littoral sands, gravels and conquinas (Tiercelin et al, 1980).

Tectonically there has been much recent activity around Lake Baringo and the area is probably still unstable. The Tugen Hills are the result of a rapid uplift that took place about two million years ago while more recently probably early Holocene, the floor of the rift valley has suffered extensive grid faulting (Chapman,et al, 1978). The rocks of the area consist either of lava or unconsolidated sediments resulting from rapid erosion of the uplifted Tugen Hills. Such an environment is characterised by tectonic instability and recent extensive rocks. The resulting extensive unconsolidated sediments would be expected to have a high geological erosion rate (Rowntree,et al, 1985).

1.3.4 SOIL EROSION IN LAKE BARINGO'S CATCHMENT AREA

In the Baringo basin grid faulting gives rise to a broken topography over much of the rift valley floor. Subsequent rejuvenation resulted in entrenchment of rivers flowing into Lake Baringo and reworking of Pleistocene sediments. The soils in Lake Baringo basin at lower altitudes are prone to surface sealing, poor filtration and rapid run off. The lack of cohesion of the sedimentary silts increases their erodability and also enhances gullying. Locally, gravels or boulders form coarse armour which somewhat restricts erosion (Rowntree et al, 1985).

Moderate erosion has been a feature of the semi-arid area of Lake Baringo as reported by Hohnel (1894), who observed that the rivers flowing into Lake Baringo had 'brick red waters' whilst the lake flats were 'seamed with deep ruts in every direction'.

The rainfall outside of the wet season, comes as short heavy storm which can cause severe erosion. The main causes of this severe erosion in the Baringo basin are:

i. over cultivation in the uplands (Tugen Hills) due to population pressure on the arable land.

ii. over stocking of animals in the lowlands.

iii. the semi-arid climate of the area, where evapotranspiration rate recorded is 2,000 mm which is rather high.

iv. the geology and tectonic instability of the area.

Thus, the environment around Lake Baringo is very prone to erosion.

Data provided by PENCOL (1981) indicates a mean annual sediment yield from Lake Baringo's 4926 square kilometres catchment area of approximately 1015 tonnes per square kilometre. These excessively high sediment yields support the visual evidence of erosion seen from the severely gullied and water-washed hillslopes prevalent throughout the area. The main causes of erosion in this area appear to lie in a combination of physical and human factors. Deposition in Lake Baringo has been measured at 64 million cubic metres of sediments over a thirteen year period (1968-1981) or an output of 5 million cubic metres per year (PENCOL, 1981).

1.3.5 DEPTH CHANGES IN LAKE BARINGO

Two types of African lakes can be distinguished by their level changes. The first type show marked seasonal or long term changes in water levels e.g. Lakes Naivasha, Rukwa, Chad and Baringo. Most of this type are in closed (endorheic) drainage basins. Shallow lakes of open drainage systems especially those with high inflow and discharge rates (e.g. Lakes George, Kyoga and Victoria) tend to be more stable with respect to water level and biological characteristics (Breen et al, 1981).

The sources of incoming water into the lakes in the tropics are mainly through:

i. precipitation falling on the lake surface.
ii. water as surface influents.
iii. ground water seeping in through the floor.
iv. ground water entering the lake by discrete springs as in Lake Bogoria and Baringo's hot springs at Kokwa Island.

Many lakes in semi-arid regions of East Africa lie in basins without any kind of effluent, losing water only by evaporation (i.e. Lakes Nakuru, Elementaita, Magadi, Bogoria, Turkana and Sonachi). Lake Baringo loses most of its water by evaporation and possibly through seepage through fault lines as suggested by Gregory (1921). Both the rate of entry and loss of water in a lake vary seasonally in practically all lake basins, producing annual variations in water levels. The nature of the drainage basin of a lake is of considerable importance in determining the form of seasonal lake level variations. The lakes in forested areas or in catchment areas which have soils which can take up much water, might not show marked variations in their levels; while in catchment areas (e.g. Semi-arid areas) where the soil does not hold much water, the lakes in such areas show marked seasonal variations in the lake levels (Breen et al, 1981).

Within the last century significant fluctuations of Lake Baringo's water levels have been observed. High lake levels were recorded by the turn of the century in 1918, 1928 (972 metres above sea level); 1964 (971 metres above sea level) and from 1977 to 1979 (971 metres above sea level) (Rowntree et al, 1985). Rowntree et al,(1985) also suggested that the Lake Baringo's level fluctuated over a wide range within the last sixty years. Fluctuations of the lake level was mainly attributed to climatic causes, though there may have been some continued subsidence of the rift valley floor or trough (King, 1978).

In general the lakes on the East African rift valley are extremely diverse, ranging from the very alkaline Lakes Magadi and Nakuru to the freshwater Lakes Naivasha and Baringo. Because of the great range of possible climatic conditions of the East African lakes, generalizations on these lakes are difficult to make. Most of the lakes in the East African Rift Valley are in areas of semi-arid climate, with very variable rainfall throughout the region, from year to year. The climatic regimes of the tropics, particularly the unreliable rainfall, results in lakes and rivers which differ substantially from each in temperatures, chemical composition and flow regimes.

Although all the major lakes in the East African Rift Valley have to a greater or lesser extent been studied to determine their physical and chemical characteristics, the long-term studies to determine seasonal and geographical variations have not yet been conducted except for Lakes Nakuru and Naivasha. However, although thorough work has been done on Lakes Nakuru and Naivasha, there is very little data available specifically on Lake Baringo.

This investigation aims to provide the baseline data to enable an assessment of the relationship between the catchment activities, organic loading and water quality in Lake Baringo.

CHAPTER 2

LITERATURE REVIEW

2.1. LAND-WATER INTERACTIONS

In relation to the physical, chemical and biological status of Lake Baringo, regular monitoring of the lake water should be carried out to establish whether there are seasonal and geographical changes that take place in the water quality especially in relation to the rains and effluent input.

Lakes may be referred to as 'microcosm', but this term and the principles derived from studying lakes particularly large ones, cannot be applied to rivers. Instead rivers are systems that conduct all matter, solid and liquid, to the standing water bodies. If the continuous inflow-outflow is stopped, they no longer exist. At one extreme, they may dry up whilst on the other one, they may become swamps or lakes. The response of a river to rain depends on size, topography, geology and soil conditions of the catchment areas above the river (Breen et al, 1981). Small rivers, typically display a quick rise and fall of water levels after rains. Larger rivers are slower to respond to rainfall and the magnitude of the eventual response is less. After the rain has fallen, groundwater may not appear as a river flow for hours, days or weeks or even longer. Delayed groundwater flow can therefore sustain low water flows in rivers or into lakes through long dry periods (Breen et al, 1981).

Rains can cause inputs of plant nutrients into a waterbody as shown by various studies (Viner, 1975). The formation of inorganic forms of nitrogen from the breakdown of organic materials is mainly influenced by rainfall. The organic materials in soils as for other parts of the world where this has been studied, are strongly correlated to the mean quantity of annual rainfall (Birch and Friend, 1956). The amount of nutrients that are leached out of the soil and into the water are related to the amount of rainfall in the catchment area of the waterbody.

Experiments carried out on a variety of Ugandan soils showed that ammonia and nitrate nitrogen released during the wetting were markedly stimulated by previous drying (Birch, 1958). The liberation of nutrients diminishes rapidly after each wetting; the longer the dry period, the more the inorganic nitrogen produced (Birch, 1960). The nutrient concentration in the soil is therefore severely reduced by flushing out into rivers and then lakes at the onset of the rains. The seasonality of the rainfall in the catchment area of Lake Baringo would be expected to result in a seasonal variation of the input of plant nutrients from the catchment to the lake via the rivers.

The major sources of organic effluents to a waterbody are mainly from domestic refuse, run-off from agricultural land and agro-based industries (Bayly and Williams, 1973). The effects of organic material on a waterbody are more or less similar irrespective of the source and the nature (domestic or natural) of the pollutant. Many lakes nowadays are altered by man's activities and receive unnaturally large amounts of organic materials which cause a marked increase in lake productivity (eutrophication).

The water chemistry of a river or lake reflects the complex interactions of rain water with soil, rock, plants and climate. Rainwater is not pure as it contains low but measurable concentrations of dissolved gases particularly oxygen, nitrogen and carbon dioxide; positively charged ions of hydrogen, sodium, potassium, calcium, magnesium and others, and negatively charged ions (anions) such as sulphate, nitrate, chloride, silica and phosphates (Payne, 1986). Payne, (1986) also suggested that as water percolates through or runs off a catchment area, it changes chemically due to leaching of substances from the soil and are temporarily stored in soil water or, become attached to the surface of the soil colloids. Leaching of cations out of the soil system is facilitated by mobile anions particularly the bicarbonates. Bicarbonates are a product of organisms in the soil which respire and are also a common constituent of limestone bedrock. Thus soil water reaching rivers and ground water contain substantial quantities of calcium, magnesium, bicarbonate, sulphate and has a pH value of 7 or more (Payne, 1986).

2.2 PHYSICAL CONDITIONS OF RIVERS AND LAKES

A normally developed river may be expected to comprise of a mountain tract of rapid erosion which passes gradually into a valley tract with slight erosion and into plains where deposition takes place (Rzoska, 1976). Many African rivers exhibit this step profiles except rivers in Zaire and the big rivers in the continent. The drainage pattern of Africa has been disrupted principally by tectonic movement, since the Miocene Period (Beadle, 1974).

Silt is probably a component of all African rivers. Increasing destruction of vegetation and the expansion of poor farming practices have raised silt loads in rivers to a point where deleterious effects are now evident. Siltation has adversely affected dams, reducing their capacity to function in the generation of hydroelectric power e.g. Tana River, Kenya (Breen et al, 1981). Siltation has also greatly damaged the estuarine environment in the east coast of South Africa (Begg, 1978) and the Kenyan coast at the mouth of Tana River near Malindi. Although the dominant factors influencing the severity of erosion are rainfall, topography and vegetation cover (Baver, 1933) soil properties may account for variation in their erodability (Middleton, 1930).

In most rivers transparency and light penetration are controlled by particulate content of the water (Talling, 1976). Turbulence associated with river flow usually ensures good mixing of water in the main river channels and so rivers seldom show termal stratification. This also causes temperatures particularly of surface waters to follow air temperature trends fairly closely though under hot and dry conditions, it is more likely to be connected with air temperature minima owing to the cooling effect of evaporation (Welcome, 1979). Shaded waters tend to be cooler and more thermally stable than those exposed to direct sunlight.

The large surface area to volume ratio of shallow lakes in Africa means that the capacity of the water bodies of the lakes to buffer environmental effects which act over its area, is small. Water temperature for instance increases over short periods of time which affect all or most of the water column. In many of the tropical shallow lakes, diurnal temperature ranges are greater than seasonal changes (Viner and Smith, 1973). The influence of strong winds and high turbidity tend to ameliorate the intensity of diurnal temperature fluctuations in shallow lakes like Baringo, Rukwa and Chad.

Sediment water interactions are very pronounced in shallow lakes and turbulent mixing to the bottom often results in continuous resuspension of sediments. This in turn, influences the light penetration characteristics of these lakes, the physical nature of the sediment-water interface and nutrient exchange within the water column. Turbidity is greatly influenced by the resuspension of the bottom sediments in the shallow lakes (Howard - Williams et al, 1981). The continuous presence of silt in the water column of shallow lakes can cause a physiological stress on many aquatic animals by clogging the filtering apparatus or gill membranes. The presence of inorganic silts would also have the effect of reducing the relative proportion of digestible particulates in the water column (Kalk et al, 1979). The silt, just like the water's chemical composition, has a great influence on the lakes' water quality.

2.3. CHEMICAL CONDITIONS OF RIVERS AND LAKES

Freshwater has a remarkable buffering capacity that is, it maintains its chemical characteristics within certain close limits despite the input of liquid with a different composition such as rainwater or factory effluent. The system can of course be overloaded. Suspended matter from soil erosion is a concern with respect to water quality (Gaudet,, 1979). During prolonged rainy periods, sub-surface and overland flow are active in contributing to both the rain and the soil water nutrients in rivers and lakes. Water often turns brown when suspended sediments are high as is the case with Lake Baringo. At low flow periods, during the dry season, groundwater is the major contributor to the river flow and the chemical composition of the water better reflects the geology of the catchment area (Gaudet, 1979).

Water emanating from a catchment area is conditioned by the processes occurring in the catchment. The chemical characteristics of rivers cannot be regarded as fairly constant as there are many factors which influence river water chemistry. Most African waters tend to be solutions of sodium rather than calcium bicarbonate. The sodium solution arises from the dissolution of sodium silicate rocks. The geology and local climate of the catchment area also determine the degree of mineralization. The major factor influencing both the concentration and the composition of African river waters, is evaporation. The consequences of evaporation for the chemical composition of water have been discussed by Kilham (1979). Kilham demonstrated that the characteristic sodium bicarbonate-carbonate waters of Lake Nakuru develop as a result of evaporative concentration with consequent calcium ions precipitation.

Man is probably the greatest single biogenic factor affecting lake and river water quality, both directly as a result of discharges into rivers, and indirectly through his activities of land. Regional differences in phosphate concentration in streams may arise from the interaction between rainfall frequency and vegetation type (Viner, 1975). This emphasises the importance of vegetation cover as a determinant of phosphate concentration in water. The vegetation also influences the mobility of ions such as calcium, potassium and nitrates as illustrated by Thompson (1976). Swamps along river courses and shorelines of lakes are known to markedly influence river and lake chemistry. Water emanating from swamps may be acidic and contain high concentrations of dissolved organic matter (Gaudet, 1979).

The chemical composition of a river is greatly influenced by variation in flow. Concentrations of dissolved nutrients are usually higher during periods of low than of high flow (Brand *et al*, 1967; Archibald *et al*, 1969; Kemp *et al*, 1976; Fowles *et al*, 1979), so that some flushing may occur during floods. Gaudet and Melack (1981) demonstrated an inverse relationship between discharge and load. Borman *et al* (1969) on the other hand, showed a fairly constant concentration of dissolved matter and rapid increase of particulate matter with increasing discharge and the concentration of ammonia and nitrate were at a minimum during the dry period and at a maximum during the wet season (Hall *et al* , 1977). These differences could be due to the regions (e.g. tropical or temperate) where the studies were carried out.

The physical and chemical inter-relationships are probably not known for most African rivers as many have been infrequently and irregularly sampled. The importance of frequent sampling is emphasised by the observation that in rivers or streams where floods reach a peak sharply, peaks of dissolved nutrient concentrations may pass during flood periods as short as half an hour. Although the accuracy of nutrient load estimation is largely dependent upon the design of the sampling it is however further complicated by the presence of silt to which considerable quantities of nutrients may be adsorbed (Golterman, 1975; Keulder, 1974). A large proportion of the total load of phosphorus may be transported attached to the silt (Viner, 1979). The chemical composition of river water may also reflect the proportion of the flow derived from different parts of the catchment area.

There is great information on the chemical composition of inland waters globally that could be discussed from several viewpoints, the geological origin, geochemistry of the dissolved constituents, the comparative compositions of different waters and the chemical processes and equilibria within them (Beadle, 1974). A discussion of those aspects of chemical hydrology that are related to geology and limnology are to be found in Hutchinson (1957) and the data on the chemical composition of the inland waters of the world have been compiled by Livingstone (1963). Talling and Talling (1965) have recorded and discussed the comparative ionic composition of the waters of various East African lakes. The ionic composition of freshwater is dominated by dilute solutions of alkalis and alkaline earth compounds, particularly of bicarbonates, carbonates, chlorides and sulphates. The amounts of silicic acid, which occur largely in undissociated forms, are usually small but occasionally significant amounts occur in hard water lakes. The concentrations of the four major cations Ca^{2+}, Mg^{2+}, Na^{+}, K^{+} and four major anions, HCO_3^-, CO_3^{2-}, Cl^-, and SO_4^{2-}, usually constitute the total ionic salinity of the water for all purposes. Concentration of ionic components of other elements such as nitrogen (N), phosphorus (P) and iron (Fe) and numerous minor elements are of immense biological importance, but are usually minor contributors to the total salinity (Wetzel, 1975).

Every organism in an aquatic system exists in a given salinity range, so that the degree of salinity of the water will determine its presence or absence. The evolution of the chemical composition of lake waters depends on two factors:

i. the interaction of climatological and hydrological factors which determine the rate of solution of dissolved elements and their dilution,

ii. the modification of the chemical composition of the water of influent rivers when interrupted by lake basins.

In the context of these two groups, the work of Carmouze et al, (1977) on Lake Chad and Gaudet and Melack (1981) on Lake Naivasha are of great significance. Both lakes and Baringo may be considered as surface exposures of major underground seepage flows, so that while they are topographically endorheic, they are also hydrologically seepage lakes.

Recognition of the fact that these lakes could be seepage lakes offers part of the explanation of the apparent anomaly that lakes in semi-arid areas, with high evaporation rates, contain water low in dissolved salts (Allanson et al, 1981). The removal of solutes is assisted by biological, geochemical sedimentation and diagenesis (Carmouze et al, 1977). This removal of salts also occur in Lake Turkana by the formation of montmorillonites but in Lake Naivasha exchange of pelagic and littoral sediments is a major factor in maintaining freshness of the lake (Gaudet and Melack, 1981).

The hydrochemical features of sub-sahara African lakes are characterised by an ionic composition arising from the incongruent dissolution of silicate rocks (Carmouze, 1976; Gaudet and Melack, 1981; Garel and Mackenzie, 1971) and these silicates are more frequently feldspars of sodium than calcium. The subsequent evolution of the chemical composition of river-lake systems is to a great extent controlled by evaporation. This brings about changes in the concentration of dissolved salts in lakes, and also in rivers and springs.

2.4. PREVIOUS STUDIES IN LAKE BARINGO

Previous studies in Lake Baringo include brief visits to the lake by Jenkin (1936), Beadle (1932), Talling et al (1965) and Kallqvist (1980). Jenkin made the first measurement of pH (9.0) and alkalinity (640.5 mgl^{-1}, HCO_3^-) in Lake Baringo in 1929. Beadle (1932) visited the lake between 1930 and 1931 and made measurements of several chemical parameters in the lake. Beadle recorded the values of pH (8.7-8.8), alkalinity (341.6 mgl^{-1}, HCO_3^-) and other chemical parameters as indicated in Chapter 5. Beadle also analysed samples from the hot springs on the Kokwa islands, and River Tigerri (Perkerra) where their alkalinity values were found to be 1952.0 and 54.3 mgl^{-1}, HCO_3^- respectively. Otherwise no work has been done on the inflows into Lake Baringo. The values recorded by Beadle were obtained during four sampling trips on 4th and 7th December 1930, 30th and 31st January 1931 during the Cambridge expedition of East African inland lakes.

Talling and Talling (1965) examined and measured the chemical parameters in Lake Baringo on 10th May, 1962 and recorded a conductivity value of 416 $uScm^{-1}$, alkalinity (270.8mgl^{-1}, HCO_3^-) and the other chemical parameters as indicated in the discussion (Chapter 5). They also sampled the lake after the heavy rains of 1961, thus the levels of most parameters recorded during this period were low.

Between 1976-1978 Kallqvist (1980) made several brief visits to Lake Baringo and investigated several physio-chemical parameters, phytoplankton species composition and primary productivity in the lake. Kallqvist recorded conductivity values between (418-1200 $uScm^{-1}$), pH (7.8-9.1), total alkalinity (128.1-594.8 mgl^{-1}, HCO_3^-) and other chemical parameters as indicated in the discussion chapter. The work done by Kallqvist was more elaborate as it entailed the determination of many physical, chemical and biological parameters. Kallqvist also investigated the primary productivity and phytoplankton species composition in Lake Baringo and concluded that the lake is less productive as compared to the other freshwater lakes in the region (e.g. Lakes Naivasha and Victoria). The species composition of the phytoplankton recorded by Kallqvist in 1978, were mainly Microcystis aeruginosa and Aphnocapsa grevelli (Anabeana circinalis) and fish found in the lake were mainly Tilapia Nilotica, Clarius, Barbus and Protopterus.

CHAPTER 3

MATERIALS AND METHODS

3.1 SAMPLING LOCATIONS

The lake and river sampling stations for Lake Baringo and its associated rivers are indicated in Figures 2 and 3, pages 35-36 and this included eight sampling stations, six of them situated along a transect from the south to the north of the lake (Figure 4, page 37). The seventh sampling site was at the western side of the lake near Kampi ya Samaki and the other one on the eastern side of the lake at the mouth of River Mukutan. These stations were chosen in order to provide data on the rivers' influence on the lake and also to provide representative data over the whole lake. The river sampling stations were situated at the four major rivers (Rivers Mukutan, R_1; Ol-Arabel, R_2; Molo, R_3; and Perkerra, R_4). Some stations were also situated at the hot springs.

Station L_1

Station L_1 was situated on the southern end of the lake, near the mouth of river Molo. The location of this station was selected in order to provide data on the river influence on the lake's chemical composition. The station was about 200 metres from the swampy shoreline at the southern end of the lake. The depth of the station ranged between 2.0 and 3.0 metres depending on the lake levels. Floating vegetation could be seen at this station during the rainy season.

Station L_2

Station L_2 was also located at the southern end of the lake and was about 2.25 kilometres due north of the southern shoreline. The depth of this station ranged from 3.5 to 4.5 metres depending on the lake level. The location of this site was chosen in order to provide data on how far the river influence extends from the river mouth. During the rainy season floating vegetation could be seen at this station.

Station L_3

Station L_3 was located some 300 metres west of the southern tip of the Kokwa island. It was placed between Kokwa and Parmalok Islands. Some influence on this site from the hotel activities at the island camp on the Kokwa island might be expected. Sporting activities such as water skiing and wind surfing near this site was common. Transport activities may also have affected this site as there were many motor boats in use near or at the site. The depth of this station ranged between 4.5 and 5.5 metres depending on the season or water level.

Station L_4

Station L_4 was located about one kilometre west of the northern end of the Kokwa Island. There was very little direct river influence at this station. The depth of this site varied from 4.0 to 5.5 metres depending on the season. The station could be expected to give a representative picture of the lake without any direct river influence.

Station L_5

This station was located four kilometres to the north of Kokwa island with no direct river influence. There were no islands near this site to influence the water composition as was in the case of stations L_3 and L_4 . This station could be expected to represent parts of the lake with no river and island influence as it was situated in the open water. The depth of this station ranged between 4.5 and 6.0 metres. This station was in the open water towards the northern end of the lake and was frequently characterised by large patches of floating green algae.

Station L_6

Station L_6 was the northernmost station, about two kilometres to the northern tip of Lake Baringo. It was located at the southern tip of Lekoros Island. The site was expected to give representative data of the parts of the lake with no river influence as there were no rivers flowing into the lake from the northern end. The station was near the part of the lake where water is suspected to be seeping through some underground faults. The depth of this site ranged from 5.0 to 6.5 metres. Most of the time, large tracts of floating algae could be seen at this site.

Station L_7

Station L_7 was located about 300 metres from Kampi ya Samaki which is a fast growing town with tourist facilities, a fish filleting factory and a rapidly increasing population. There was no river influence at this station, but it was expected to be influenced by the urban nature of Kampi ya Samaki, whose sewage flows into the lake. The depth of this station was in the range of 2.5 and 3.5 metres depending on the water level of the lake.

Station L_8

Station L_8 was located at the mouth of River Mukutan which comes from a different geological zone from those rivers flowing into the lake at the southern end of the lake. Station L_8 was expected to be influenced by the River Mukutan water. This station was situated 100 metres from the swampy shoreline at the mouth of River Mukutan. The depth of this site ranged between 1.5 and 3.0 metres depending on the lake level. Floating vegetation could be observed at this station during the rainy season. Most of the times, large patches of floating algae could be seen at the site.

Hot Springs

The hot springs are located on the northern tip of the Kokwa island. There were about twenty five hot springs on the island but this number varied with the season. Some of these hot springs dried up during the dry season while others came up during the rains. Some of the springs were only steam jets whilst others were very muddy.

River Stations

River Mukutan Station (R_1)

River Mukutan station was situated just below the large Mukutan gorge and was fifteen kilometres upstream from the lake. The water in this river was clear over the duration of the study and the river was heavily shaded at the station.

Ol-Arabel River Station (R_2)

The Ol-Arabel river station was located at Loiminange at a point two kilometres from the lake. The river at this point was heavily shaded by large acacia trees and the river was wide. The cross-section of the river was determined at this station.

River Molo Station (R_3)

The Molo River station was eight kilometres upstream from the lake and was located at Loikumgum. The river at this station was quite narrow and partially shaded. The cross-section of the river was measured at this site.

Perkerra River Station (R_4)

The Perkerra River station was located about eight kilometres upstream from the lake. The river at this station was wide and partially shaded by acacia trees. The station was two kilometres downstream from the diversion of the water from the river to the Perkerra Irrigation Scheme. The cross-section of the river was determined at this station.

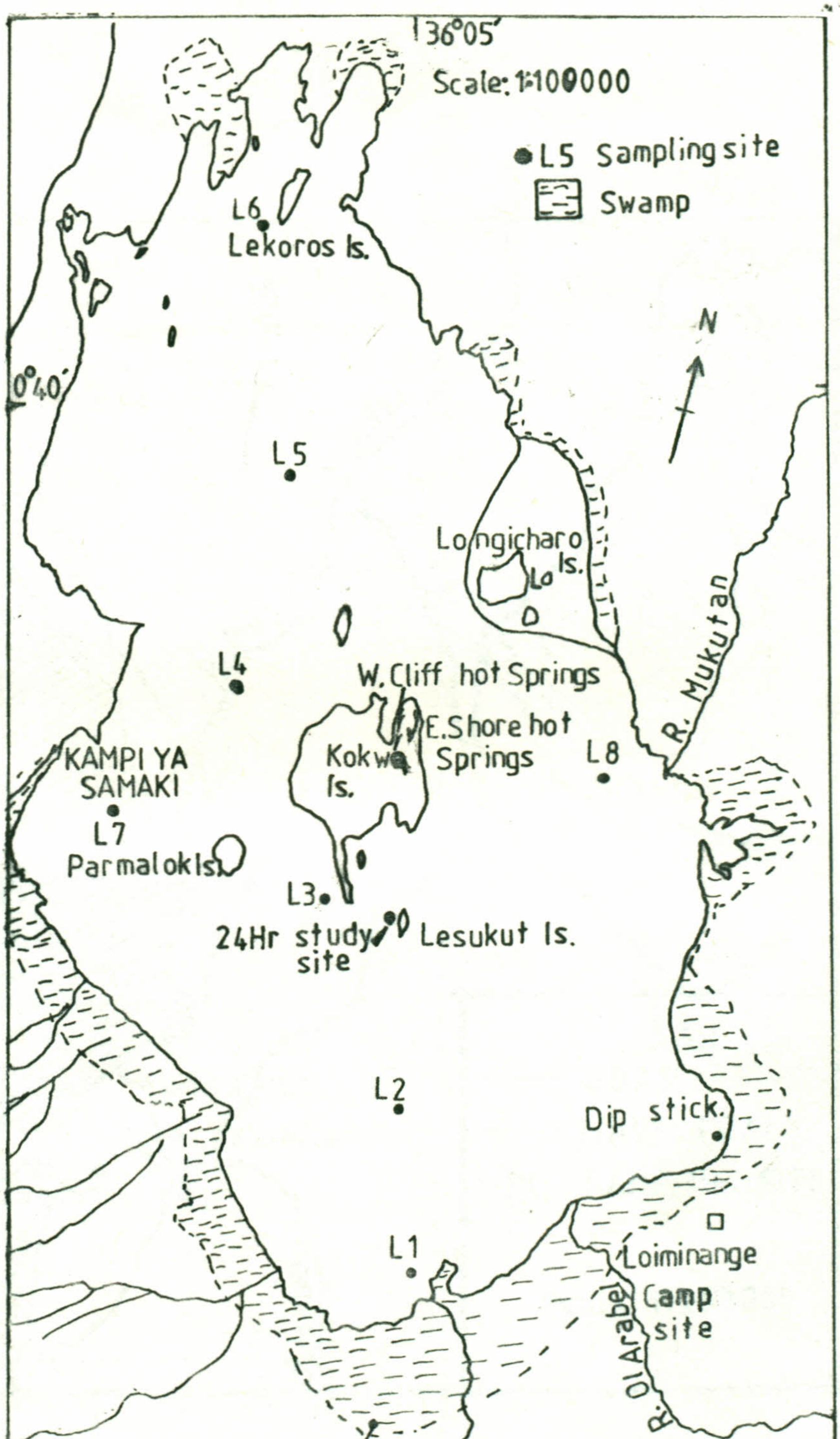


Figure 2: The Sampling Stations in Lake Baringo.
Map redrawn from the Atlas of Kenya, 3rd Edition,
Kenya Government, 1982 (Scale 1: 100,000)

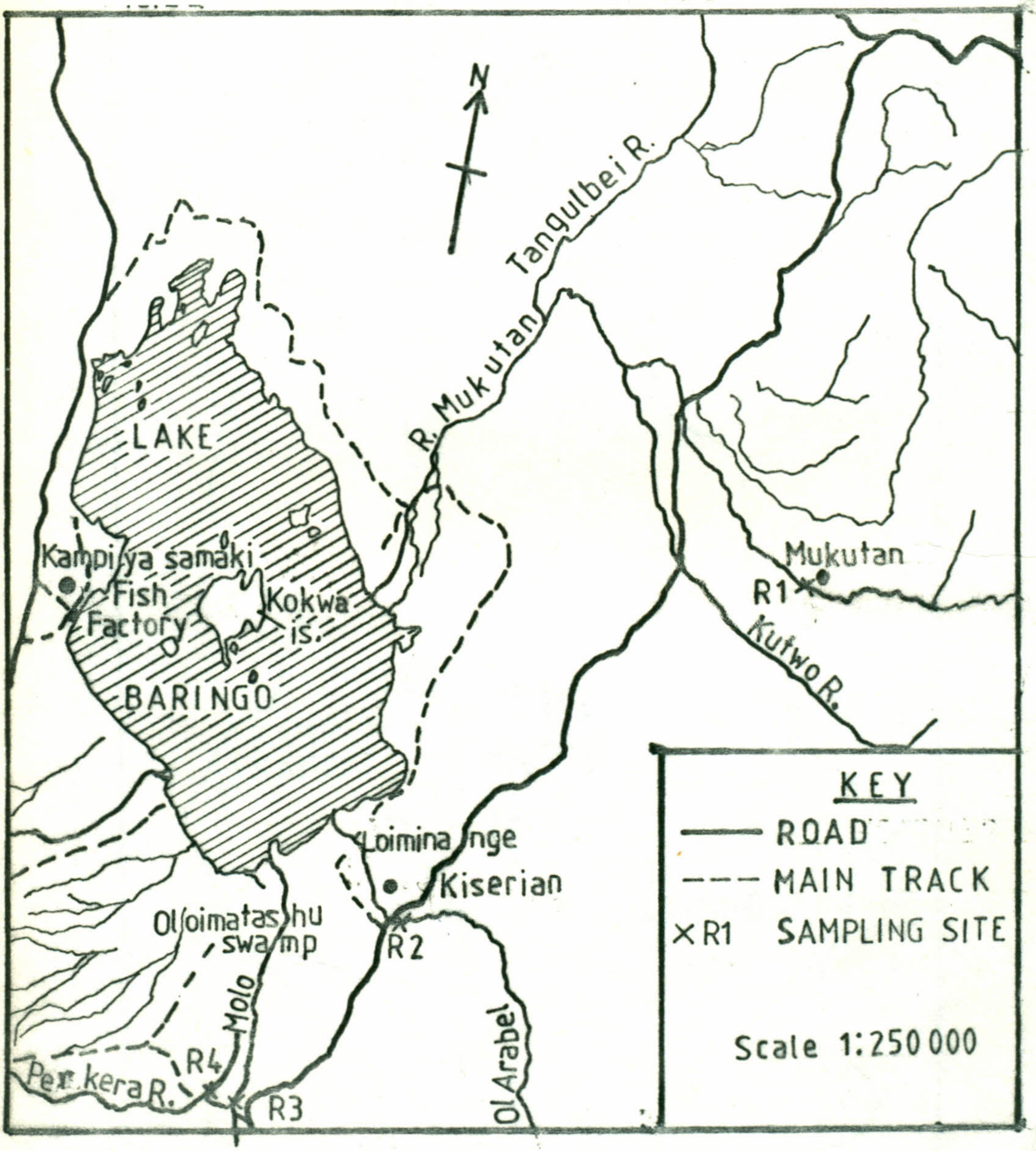


Fig. 3: The Sampling Station for the Major rivers associated with Lake Baringo.

Map redrawn from the Atlas of Kenya 2nd Edition, Kenya Government, 1970 (Scale 1:250,000).

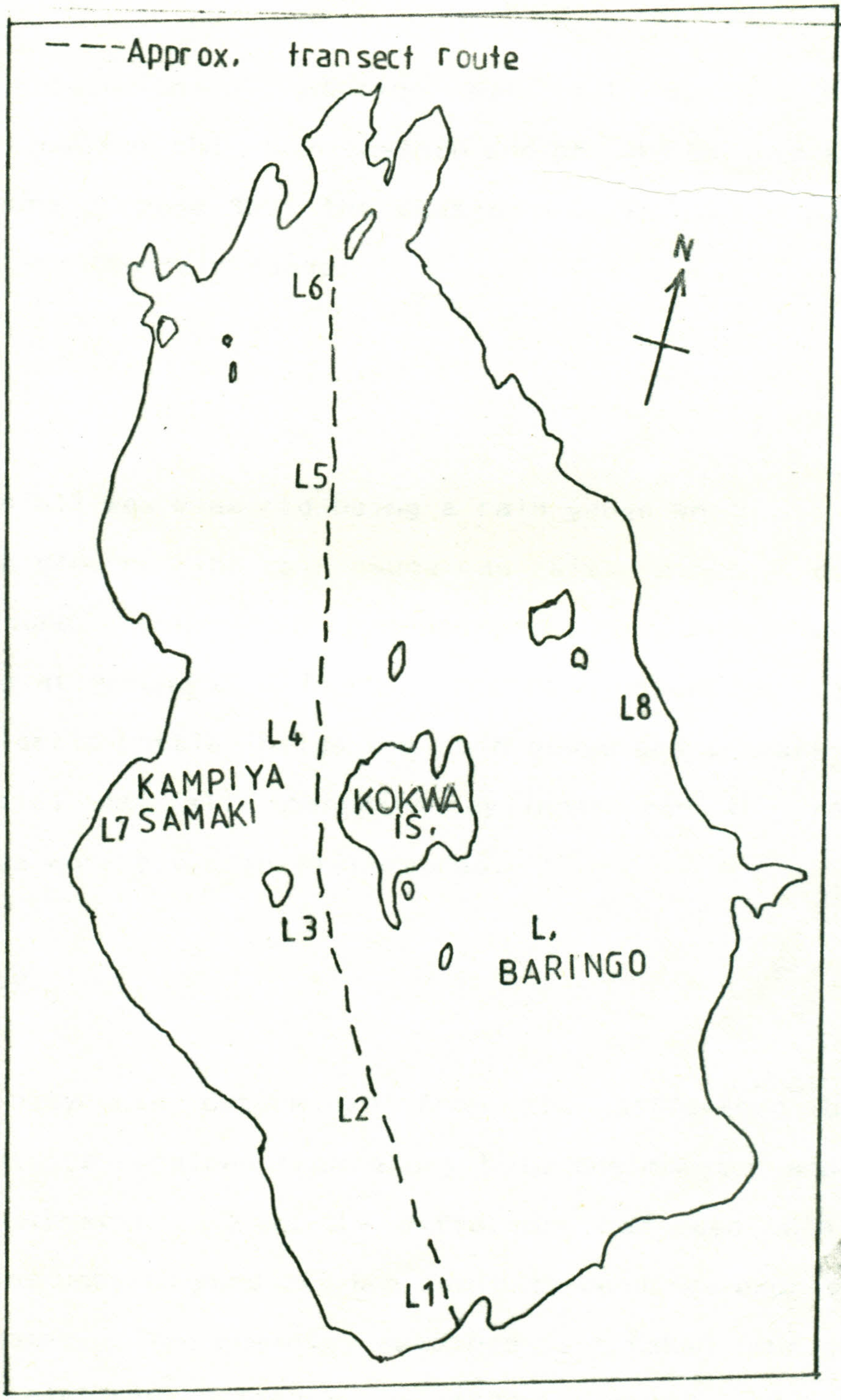


Fig. 4: The South-North Transect across Lake Baringo indicating Sampling Stations.

Map redrawn from the Atlas of Kenya 3rd Edition, Kenya Government, 1982 (Scale 1: 100,000)

3.2.1. METEOROLOGICAL DATA COLLECTION

A Meteorological Station was set up at Kiserian (Loiminange) on the south-eastern end of Lake Baringo as shown in Figure 2, page 35. the station was located under shade except for the rain gauge.

Rainfall

Rainfall was measured using a rain gauge which was put in an open ground. The rain gauge was raised about 30 cm above the ground. The rainfall measurement was conducted every morning at around 0700 hours. The rain water was collected in a plastic bottle inside the rain gauge and transferred to a special rainfall measuring cylinder and the rainfall readings were given in millimetres.

Humidity

Humidity was determined from the difference between temperatures obtained from a dry bulb thermometer and a wet bulb thermometer. When the difference had been obtained a chart was used to read off the humidity readings expressed as percentages. The humidity readings were taken four times a day, at 0700 hours, 1300 hours, 1600 hours and 1900 hours.

Temperature

The air temperature was determined using a mercury glass thermometer placed under shade. The readings were taken four times a day throughout the study period. The minimum and maximum temperatures were measured using a minimum and maximum thermometer. The maximum and minimum temperatures were taken every morning at 0700 hours throughout the study period.

3.2.2 LAKE DEPTH MEASUREMENTS

The Lake depth measurements were started on 11th July 1988 and the lake level was fixed to be at zero mark on this day. A graduated wooden post was fixed in the lake at the shoreline near Kiserian. The post was marked from -50.0 cm to 0.0 cm and finally to +250 cm. The lake level was measured twice a day, at 0900 hours and at 1600 hours throughout the study period.

3.2.3 RIVER FLOW RATES MEASUREMENTS

The flow rates of the three rivers Ol-Arabel, Molo and Perkerra were determined. The speeds of the rivers at sampling stations R_2, R_3, and R_4 were first determined using a half filled sample bottle, which was half immersed in the river and was let to be carried by the river water flowing over a measured distance. The time it took the bottle to travel over this distance was recorded. From the time and the distance covered by the sample bottle, the speed of the bottle, which also corresponded to the speed of the water flow, was calculated. There were also reference marks on the banks of the three rivers, which were used to determine the water levels in the rivers. The cross-sections of the rivers (shown in Appendix 1,2 and 3, pages 221-223) were used to calculate the cross-sectional area occupied by the water. The multiplication of the speed of the water per second and the cross-sectional area gave the volume of the water carried by the river in cubic metres per second (m^3 /s).

3.3. SAMPLING TECHNIQUES

The river samples were obtained from the middle of the rivers, where the river flow was faster. A bucket was used to collect the water in the rivers onto the banks where two litres of the samples were put in four half-litre polythene sampling bottles. The filled sample bottles were then kept in a cool environment and taken to the laboratory at Kiserian.

Preliminary sampling at various depths in the Lake Baringo was undertaken to establish if there was any stratification in the lake. The parameters investigated in this preliminary study were temperature, dissolved oxygen and conductivity. The temperature probe of the dissolved oxygen meter was used in the investigation of thermal stratification in the lake. The dissolved oxygen meter and conductivity meters were used to determine DO and conductivity values in the lake. The results showed that the lake mixed daily and no thermal stratification existed thus the decision of using integrated samples in the lake was taken.

The lake water sampling device used was a rubber tube with an internal diameter of 2.5 cm. A weight was fixed to one end of the tube and a cord was attached to the weight. The tube was sent perpendicularly into the water to just above the bottom of the lake and while holding on to one end of the tube, the cord was pulled. The tube could be filled with water from all depths (Melack, 1976). Two litres of the integrated samples were obtained from each station and put in four 500 ml polythene sample bottles. The samples were then kept in a cool box and transported to Kiserian.

The silt samples were obtained by taking two litres of the integrated water samples from the lake stations and river station R_2, R_3 and R_4. The two litres of these water samples were put in a plastic beaker and then the pH was reduced to 2.0 using nitric acid. After 2 hours the silt had settled to the bottom of the beaker and the supernatant was decanted and the silt was sundried but was protected from any dust. The silt samples were collected twice during the study period. The samples were sent to Dr. N.M. Dickinson of Liverpool Polytechnic, UK, for analysis.

3.4. SAMPLE PRESERVATION AND STORAGE

The samples transported to Nairobi were preserved as follows: The samples for metal analysis were filtered using glass filters A, pore size 0.1-40 μm and acidified to pH 2.0 with concentrated nitric acid to preserve the sample by inhibiting fungal growth in the samples. The acidified samples were then kept in a cool environment while awaiting transportation to Nairobi, where on arrival they were kept in a deep freezer until they were analysed. The dissolved nitrogen and phosphorus samples were filtered as for the metal samples and kept in a cool environment, while the total nitrogen and phosphorus were unfiltered but kept in a cool box to be transported to Nairobi. The sulphate was analysed using the samples for metal analysis. The main preservation method for all the samples brought to Nairobi was deep freezing of the samples.

The samples which were analysed at Kiserian were kept in a cool environment and others were kept in a refrigerator while awaiting analysis.

3.5. ANALYTICAL PROCEDURES

3.5.1 GENERAL COMMENTS

All the physico-chemical parameters analysed were carried out on integrated lake samples. Table 1 shows where the analysis were carried out e.g. at the site, Kiserian, Nairobi (K.U.) or in Britain.

Table 1: Places where analysis for parameters were done

PLACE OF ANALYSIS	PARAMETERS
At Site	Air and water temperatures, pH, conductivity, Secchi depth and dissolved oxygen
Kiserian (Baringo)	Dissolved oxygen, nitrite-nitrogen, ammonia-nitrogen, orthophosphate, total alkalinity, turbidity, chlorides, fluorides, molybdate reactive silica, total hardness, magnesium, calcium and chlorophyll a
Nairobi (Kenyatta University)	Total and dissolved nitrogen, total and dissolved phosphorus, sulphate, sodium, potassium, iron, manganese and aluminium
Britain Liverpool Polytechnic	Silt samples

The analysis was carried out on the sample after the necessary preservation steps had been taken.

3.5.2 CALIBRATION OF EQUIPMENT

The field equipment used in this study included a pH meter, conductivity meter and a dissolved oxygen meter. These meters were calibrated each time before use. The conductivity meter used had an automatic temperature compensator, which corrected the conductivity to a value at 25°C. The calibration of the conductivity meter was done by dipping the electrode into a standard solution with a conductivity value of 2,000 μScm^{-1} and the necessary adjustments of the meter reading was effected. The pH meter was calibrated using two freshly prepared standard solutions with pH values of 4.0 and 8.0, respectively.

The dissolved oxygen meter was calibrated using the azide modification of the Winkler method of the determination of dissolved oxygen in water (APHA, 1975).

Calibration standards were prepared for colorimetric or spectrometric analysis. These standards were prepared using analytical grade reagents for the different parameters and distilled deionised water was used as the solvent. The calibration standards were always prepared in duplicates and a blank was included. The calibration standards used for the different parameters were as outlined in Standard chemical analysis books. Deionised water, with a conductivity of less than 2.0 μScm^{-1} was used for analytical work throughout the study. All reagents used in the study were of analytical grade.

3.5.3 REPRODUCIBILITY STUDIES

The chemical analysis for all the parameters were done in duplicates to guard against errors. The calibration standards were prepared in duplicates and blanks were also included. Reproducibility studies on all the chemical analysis methods were also undertaken. This involved subjecting between six to ten samples from the same station to the same chemical analysis procedures and observing if there was any difference in their concentrations. This checked the reproducibity of the method employed. These same procedures were repeated severally for each chemical method during the study period.

3.5.4 PHYSICO-CHEMICAL PARAMETERS

Physical parameters

pH

pH was measured using a Corning 105 pH meter.

Temperature

Air and water temperatures were measured using a mercury glass thermometer with a precision of $\pm$ 0.1^{0} C and dissolved oxygen meter temperture probe, respectively.

Conductivity

Conductivity was determined using a Chemtrix type 700 conductivity meter with a temperature compensator.

Secchi depth

A Secchi disc was used to measure the Secchi depth.

Turbidity

Turbidity was measured using a Cecil spectrophotometer CE 323, units of turbidity being Nepherometric Turbidity Units (NTU) (Owen, 1975).

Total Alkalinity

Total alkalinity was determined using acidimetric potentiometric titration method as described by Golterman _et al_ (1978).

Dissolved Oxygen

The amount of dissolved oxygen was determined using either PT I 401 dissolved oxygen meter or the azide modification of the iodometric (Winkler) method of oxygen determination as described in APHA (1975).

3.5.5. CHEMICAL PARAMETERS

Nitrate-Nitrogen

Nitrate-nitrogen was measured by Cadmium reduction followed by the diazotization method as outlined in APHA (1975).

Nitrite-Nitrogen

Nitrite-nitrogen was analysed by the diazotization method and a Cecil spectrophotometer CE 323 was used as outlined by Mackereth et al (1978).

Ammonia-Nitrogen

Ammonia-nitrogen was determined by the phenate method as described by Mackereth et al, (1978).

Total Nitrogen

Total nitrogen was determined on the unfiltered water, digested using potassium persulphate and analysed spectrometrically as outlined in APHA (1975).

Ortho-phosphate (Soluble reactive phosphate)

Ortho-phosphate was analysed spectrometrically as a blue complex as outlined by Golterman et al (1978) and Mackereth et al (1978).

Total phosphorus

Total phosphorus was determined on unfiltered samples. The sample was digested with potassium persulphate at a pressure of fifteen psi, and at a temperature of 120^0 C. Phosphorus content was then analysed by the ascorbic acid method outlined by Johnson's (1971) and Mackereth et al, (1978).

Chloride

The chloride concentration was determined using conductometric titration with silver nitrate as outlined by Golterman et al, (1978).

Fluoride

The fluoride concentration was determined using alizarin complexone method of Hanocq and Molle (1968).

Sulphate

The sulphate concentration was measured by turbidimetric method as described by Golterman et al, (1978).

molybdate reactive silica

Molybdate reactive silica was analysed by colorimetric method (Owen, 1978).

METALS

Total Hardness

Total hardness was determined using EDTA titrimetic method as described in APHA (1975).

Calcium

Calcium was analysed using the EDTA titrimetric method as outlined in APHA (1975).

Magnesium

Magnesium values were obtained by calculation from EDTA hardness and calcium titration as described in APHA (1975).

sodium and Potassium

Sodium and potassium levels were determined using a Corning EEL 400 flame photometer as outlined in the manufacturers' manual.

Iron

Iron was analysed by Perkin-elmer atomic absorption spectrophotometer model 2380 as outlined in the manufacturer's manual.

Manganese

Manganese was measured by atomic absorption Spectrophotometry as outlined in APHA (1975).

Aluminium

Aluminium was determined by atomic absorption Spectrophotometry as outlined in APHA (1975).

Silt Analysis

The silt samples were analysed using X-ray fluorescence spectroscopy as outlined in APHA (1975).

BIOLOGICAL PARAMETERS

3.5.6. Chlorophyll a

Chlorophyll a was extracted with acetone and determined spectrophotometrically as outlined in APHA (1975).

3.5.7. Geography and Morphometry

Location, surface area, breadth and altitude were obtained from relevant maps using the largest scales available (Kenya Government, 1982). Depth was measured with a weighted, calibrated nylon line.

CHAPTER 4

RESULTS

The study was carried out over a period of nine months from July, 1988 to March, 1989. Since the effect of the rains on water quality is of major importance, the results include seasonal and geographical variations in the lake. Data from the river stations are reported with their variation with rainfall. The discharges of the three rivers Ol-Arabel, Molo and Perkerra were measured. The lake levels were also measured over the whole study period.

Climatological results, including maximum and minimum temperatures, rainfall and humidity are reported in this chapter. The data were collected daily at Kiserian on the south-eastern end of the lake.

The results for all the parameters studied are described after climatological results, river discharges and lake levels. The results are described firstly on geographical variation basis, then on seasonal variation basis and finally combining all the data for the whole lake and over the study period. All the data presented in this chapter and the appendix are mean values.

4.1 CLIMATOLOGICAL RESULTS

Rainfall, minimum and maximum daily temperature and humidity data recorded during the present study are presented in Table 2, page 56 and Figure 5.a and b, page 57.

4.1.1 Rainfall

The rainfall at Kiserian, Lake Baringo was higher than the normal annual average, recording a value of 610 mm of rain during the study period of 9 months excluding the usually long rains period of April and May. The rainfall around Lake Baringo has been recorded to be 600 mm per annum (Baringo Dev. Plan, 1988). The total monthly rainfall figures are indicated in Table 2 page 56 and illustrated in Figure 5 page 57. The highest monthly rainfall of 175.1 mm was recorded in July 1988 closely followed by August 1988 (137.7 mm). With the exception of the months of December 1988 and January 1989 with rainfall values of 13.3 mm and 14.3 mm respectively, all the other months had values in the range of 60.2 - 72.8 mm. No rain was recorded in the month of March 1989.

4.1.2. Temperature and Humidity

The minimum mean monthly temperature at Kiserian had a narrow range between 17.0^{0} C and 19.2^{0} C. The highest mean monthly temperature was recorded in July 1988 whilst the lowest was recorded in the month of December 1988.

The maximum mean monthly temperature ranged from 32.8^{0} C to 37.4^{0} C. The highest maximum temperatures were recorded in the months of September, October, 1988 and March 1989, these being generally dry months. The lowest maximum temperatures were recorded in the wettest months of July and August, 1988 while the other months from November, 1988 to February, 1989 had values which were very similar, between 34.2^{0}C and 34.9^{0}C.

The means of the monthly minimum and maximum temperatures ranged between 25.3^{0} C and 30.7^{0} C. The wettest months had lower values (e.g. July and August, 1988) and the drier months such as January and March had higher values. Except for the months of July and August, 1988, and the rather hot and dry month of March, 1989 all the other months had values which were very similar, ranging between 27.4^{0} C and 28.5^{0} C.

Humidity levels for the period, July 1988 - March 1989 ranged between 45.8% in March, 1989 to 74.1% in July 1988. Although, as expected the humidity is closely related to the rainfall, and although the site of meteorological data station is quite near (0.5 kilometre) to the lake, no doubt however, the lake itself has a profound influence on the humidity at the station.

From these climatological data, it could be concluded that Lake Baringo basin or its surrounding is generally hot, dry and not very humid.

Table 2: Climatological data for the period July 1988 - March 1989, Kiserian and Lake Baringo.

MONTH	TOTAL RAINFALL (mm)	MEAN MINIMUM TEMP(^{0}C)	MEAN MAXIMUM TEMP (^{0} C)	MEAN TEMPERATURE (^{0} C)	MEAN HUMIDITY (%)
JULY 1988	175.1	19.2	33.0	25.7	74.1
AUGUST 1988	138.7	17.5	32.8	25.3	73.8
SEPTEMBER 1988	60.2	18.6	36.8	27.4	70.6
OCTOBER 1988	69.6	18.5	36.9	28.4	63.6
NOVEMBER 1988	66.1	18.6	34.6	27.7	66.6
DECEMBER 1988	13.3	17.0	34.2	27.8	62.6
JANUARY 1989	14.3	18.8	34.5	28.5	57.1
FEBRUARY 1989	72.8	18.9	34.9	27.8	58.3
MARCH 1989	0.0	18.4	37.4	30.7	45.8

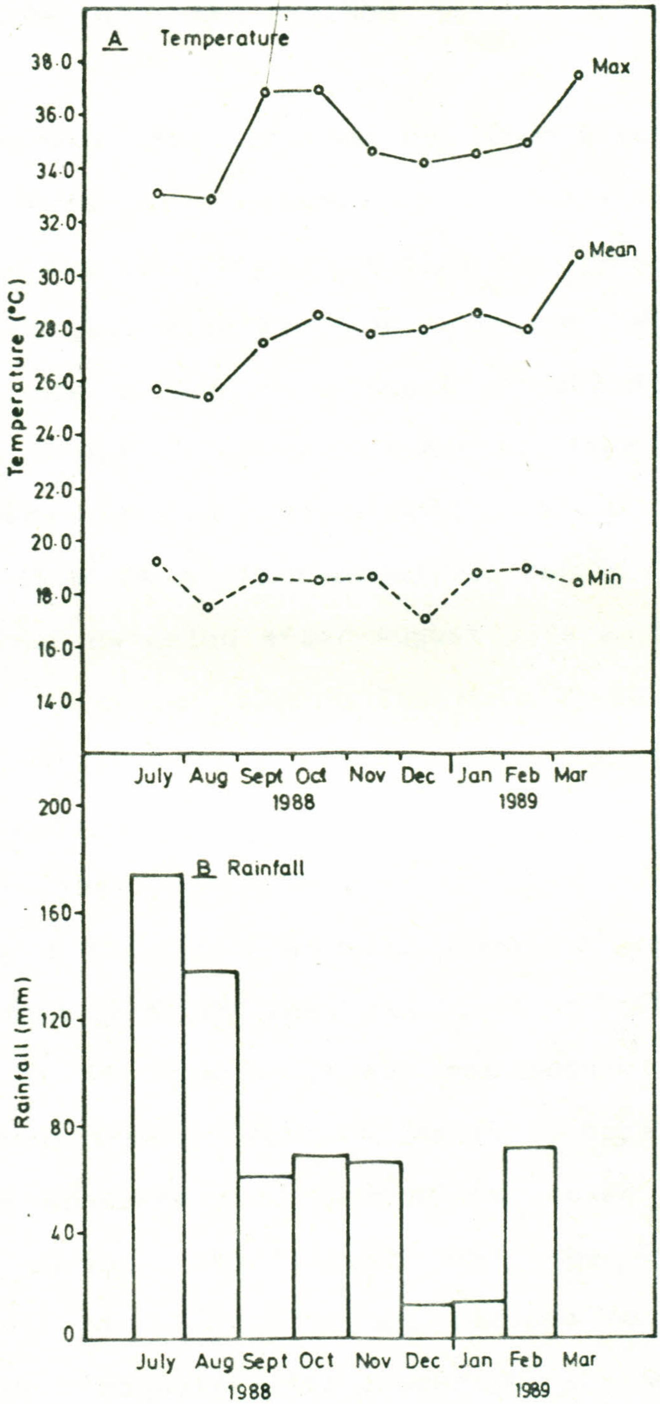


Figure 5: Climatological Variation at Kiserian and Lake Baringo, showing a. Minimum, Mean and Maximum Temperatures

b. Rainfall.

4.2. DISCHARGE INTO LAKE BARINGO

The discharges into Lake Baringo from Rivers Ol-Arabel, Molo and Perkerra were measured during every river sampling trip. During the sampling trips of July 1988 all the rivers had low discharges, with River Molo having the highest with a discharge rate of 4.8 m^3 /s and Ol-Arabel River with the lowest value of 0.4 m^3 /s. But in August, 1988 the discharge rates were very high, with River Molo having a discharge rate of at least 45 m^3 /s as it flooded its banks. The water in River Molo then dwindled after August 1988 as it reduced to 6.8 m^3 /s in September 1988. The Molo River carried huge amounts of water in the rainy season but the flow was drastically reduced thereafter (e.g. the discharge was 0.0 m^3/s in March 1989).

The Perkerra River carried huge amounts of water in August 1988 and in fact it overflooded its banks so that the accurate measurement of its discharge was not possible. From the cross-sectional area however (Appendix 3, page 223) and the rate of flow measurements, it must have been over 50 m^3 /s during this period. In October 1988, the Perkerra had a discharge rate of 33.4 m^3 /s and reduced to 2.3 m^3 /s in December 1988. Thereafter its discharge rate remained fairly constant.

The discharge rate of Ol-Arabel River also increased to a maximum of 8.2 m^3/s in August 1988 and then reduced to 1.0

m^3/s in October 1988. The rate reduced further until it reached 0.2 m^3 /s in March 1989 which was lower than the July 1988 value. The discharge of River Ol-Arabel increased rapidly after rain and reduced drastically thereafter. The discharge rate of these main rivers are shown below in Table 3 and illustrated in Figure 6, page 60. The discharge of these rivers had a very big influence on the water levels and the physico-chemical status of the lake.

Table 3: Discharge into Lake Baringo by Rivers Ol-Arabel, Molo and Perkerra (Units = m^3 /s).

MONTHS	(OL-ARABEL) R_2	(MOLO) R_3	(PERKERRA) R_4	TOTAL DISCHARGE FOR 3 RIVERS (combined)
JULY 1988	0.39	4.95	3.45	8.79
AUGUST 1988	8.25	45.00	>50.00	>100.00
SEPTEMBER 1988	6.40	6.80	6.48	19.68
OCTOBER 1988	0.93	5.70	33.50	40.13
NOVEMBER 1988	0.78	7.60	8.17	16.55
DECEMBER 1988	0.62	4.95	2.38	7.95
JANUARY 1989	0.49	2.88	1.92	5.25
FEBRUARY 1989	0.36	3.00	1.32	4.68
MARCH 1989	0.30	0.00	1.20	1.50

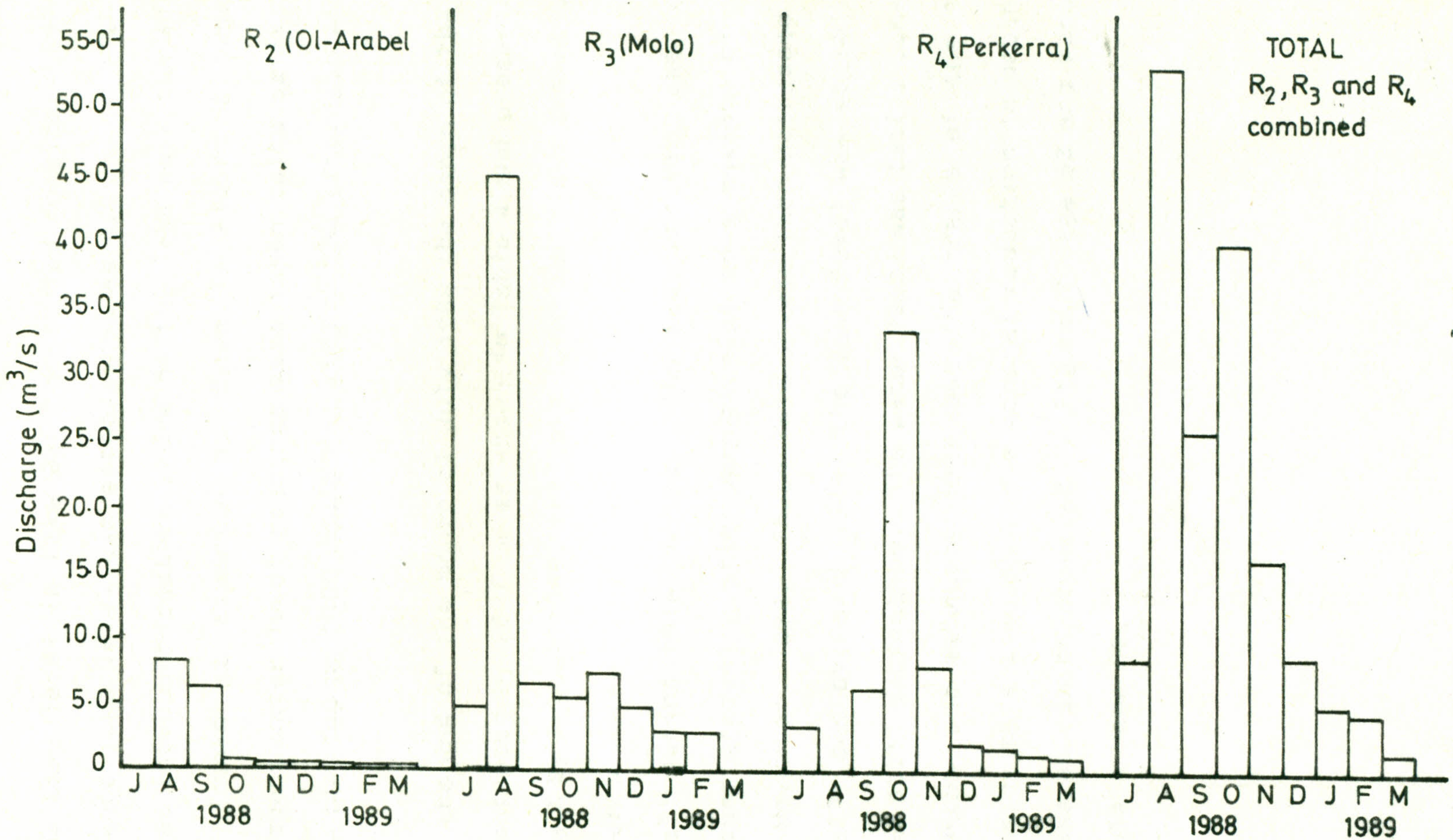


Figure 6: Discharge Into Lake Baringo by the Three rivers.

4.3. LAKE LEVEL CHANGES IN LAKE BARINGO

The Lake level in Lake Baringo varied considerably. The reference lake level was established as 0.0 cm on 11th July 1988 at the south-eastern shore of the lake near the mission water intake at Kiserian as shown in Figure 2 page 35. Subsequent water level readings were taken twice daily, once in the morning at 0900 hours and also in the afternoon at 1600 hours.

By the end of the month of July 1988 the depth of the lake had increased by 26.7 cm as shown in Table 4 and presented in Figure 7 By August 1988, the lake level had risen dramatically by over a metre, which was a reflection of the very heavy rainfall during this period. The mean monthly lake levels increased gradually after August 1988 to a maximum of 183.0 cm in November, 1988. These lake levels then decreased more gradually and by March 1989, the lake level was at 147.0 cm and was still decreasing. The water level was fairly constant in January and February 1989 but the trends of the level changes by this time showed a general reduction in depths of the lake as can be observed in Figure 7 page 63 and recorded in Table 4 page 62.

Table 4: Mean Monthly lake levels, Lake Baringo (July 1988 - March 1989).

MONTH/YEAR	WATER LEVEL (cm)
JULY 1988	26.5
AUGUST 1988	113.4
SEPTEMBER 1988	155.1
OCTOBER 1988	180.0
NOVEMBER 1988	183.0
DECEMBER 1988	166.9
JANUARY 1989	156.9
FEBRUARY 1989	156.5
MARCH 1989	146.9

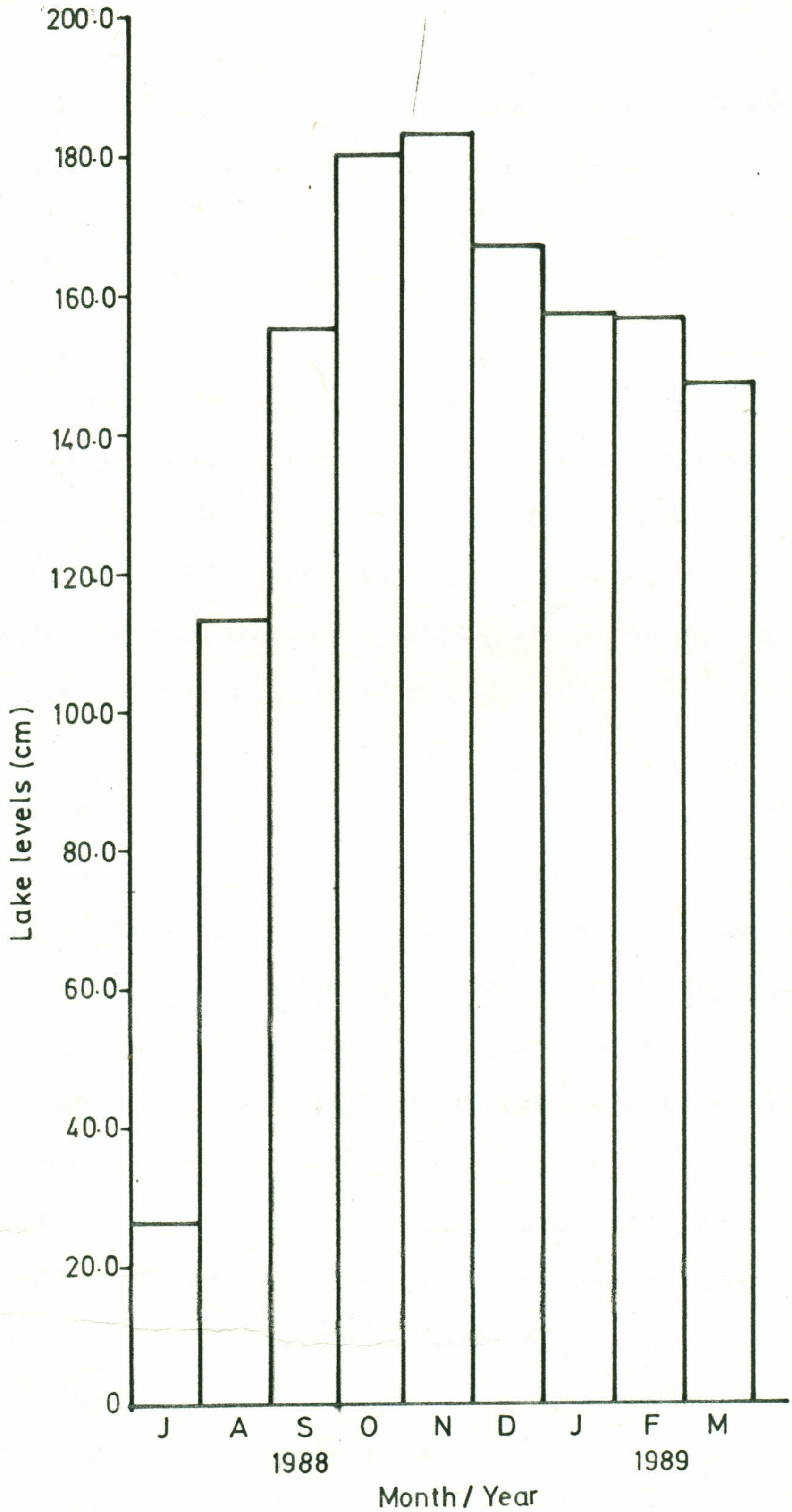


Figure 7: Mean Monthly lake levels, Lake Baringo
(July 1988 - March 1989)

4.4 VARIATION BETWEEN THE STATIONS FOR ALL THE DATA IN THE STUDY AREA (GEOGRAPHICAL VARIATION)

4.4.1 Physico-Chemical parameters:

Six physico-chemical parameters namely, temperature, conductivity, total alkalinity, dissolved oxygen, turbidity and Secchi depth are presented in Table 5 and 6, pages 69 -70 and are also illustrated in Figure 8 page 71. Mean values for each station over the whole study period are plotted separately in Figure 8, A to D page 71.

Temperature:

On each sampling trip, the samples were collected starting at Station L_1, L_2, L_7 and finally L_3; the next day the sampling trip started at station L_8, L_6, L_5 and lastly station L_4. The sampling was carried out in the morning commencing at 0800 hours when it was cool (station L_1 and L_8) and ended towards 1300 hours when it was much hotter (station L_3 and L_4). The mean monthly water temperature range was narrow (24.0^0 C - 26.0^0 C) during the study period. The lowest water temperature (24.2^0 C) was recorded in December 1988 and the highest 26.0^0 C) in August 1988.

Conductivity

The highest mean value over the whole study period was 866 μScm^{-1} recorded at station L_6 which was located at the northern end of the lake, where no inflowing rivers affected the lake. With the exception of stations L_1, L_2 and L_8 which had mean conductivity values of less than 800 μScm^{-1} all the other stations had similar mean ranging from 811-866 μScm^{-1} (Table 5, page 69). There was a general increase conductivity along the south - north transect of the lake from station L_1 (644 μscm^{-1}) to station L_6 (866 μScm^{-1})illustrated in Figure 8-A. This was due to the dilution of the rivers Molo (R_3) and Perkerra (R_4) at the southern end of the lake with much lower conductivity values of 212 μScm^{-1} and 131 μScm^{-1} respectively. Station L_8 on the other hand was close to the mouth of river Mukutan (R1) with a mean conductivity value of 520 μScm^{-1} (Table 6, page 70). The overall mean value for conductivity over all lake stations was 793 μScm^{-1} which differed significantly from the river's overall mean value of 294 μScm^{-1} .

pH

The mean pH values over the study period are shown in table 5 and 6, pages 69 - 70 and presented in Figure 8B, page 71. The pH values ranged rom 8.2 to 8.7, with station L_1 having the lowest pH value while stations L_4, L_5, L_6 and L_7 had the highest values. The trends in pH variation closely followed those of conductivity as indicated in Figures 8A and B, page 71. Except for Station L_1 (pH 8.2), the other stations had values ranging from 8.6 to 8.7 and the greatest change in pH along the south-north transect occurred between stations L_1 and L_2. With the exception of the Molo river water, the pH values for the other rivers were lower than for the lake. The Perkerra (R_4) had the lowest pH value of 7.6 whilst river Molo (R_3) had the highest (8.5). The rivers had an overall mean pH value of 7.8 which was much lower than that of the lake stations (8.6).

Total Alkalinity

The data for the mean alkalinity at the various stations over the study period are indicated in Table 5, page 69 and illustrated in Figure 8-C, page 71. The highest mean alkalinity value was recorded at station L_6 with a value of 431.9 mgl^{-1} (HCO_3^-) and the lowest was recorded at station L_1 (330.7 mgl^{-1}, HCO_3^-). The mean values for the other stations fell within a range of 380.6 - 421.5 mgl^{-1}, HCO_3^-. There was a general increase of mean total alkalinity values over the whole study period along the south-north transect, from stations L_1 to L_6 through stations L_2, L_3, L_4 and L_5. This difference was brought about by the dilution effects of the rivers at the southern end of the lake. Station L_7 which was near Kampi ya Samaki had a total alkalinity mean value of 421.5 mgl^{-1}, HCO_3^-, showing that there was little direct river influence at this station. Station L_8 had a slightly higher alkalinity mean value (397.1 mgl^{-1}, HCO_3^-) than the southern end station L_1 and L_2 because of the more ionised water from Mukutan River (R_1) with a mean total alkalinity value of 281.2 mgl^{-1}, HCO_3^{-1}. The River Molo (R_3) and Perkerra (R_4) had a much lower mean alkalinity values as compared to those originating from the eastern highlands (Ol-Arabel and Mukutan Rivers) as indicated in Table 6, page 70).

Dissolved Oxygen

The mean dissolved oxygen (DO) concentrations for each station over the whole study are shown in Table 5, page 69 and illustrated in Figure 8, page 71. The lowest DO concentration (5.8 mgl^{-1}) was recorded at station L_1, while the other stations had values varying from 6.5 mgl^{-1} to 7.3 mgl^{-1}. In all the lake stations, oxygen concentrations throughout the water column were constant with the exception of the samples taken just above the bottom sediments which showed much lower values (3.0 mgl^{-1}). There was a general increase in DO concentrations from stations L_1 to L_6, with stations L_3 having a higher value than its adjacent stations. However stations L_4 had a slightly lower value than the other stations. DO concentrations were not determined for the rivers.

Secchi Depth and Turbidity

There was very little light penetration at any of the stations in the lake throughout the study period. The Secchi depth measurements showed that all of the values were 6 cm and below. After the initial measurements indicated a constant value of less than 6 cm and that these measurements were prone to considerable error, the Secchi depth measurements were discontinued. In general, there was no significant Secchi depth variation between the stations.

The highest recorded turbidity mean value was 850 NTU at station L_7 near Kampi ya Samaki and the lowest was 704 NTU recorded at Station L_8. The data for the mean turbidity values are shown in Table 5, page 69 and 6, page 70. Along the south-north transect, station L_2 had the highest turbidity mean value of 830 NTU which was slightly less than at station L_7. Station L_1, which was subject to considerable river influence had a mean turbidity value of 724 NTU. The turbidity mean values at stations L_3, L_4, L_5 and L_6 were very similar and were found to lie between 758 NTU and 796 NTU. The river stations had turbidity values which were very dependent on rain and were much lower than for the lake stations. Perkerra River had the highest turbidity value of 440 NTU while Mukutan River had the lowest with a value of

126 NTU. Perkerra, Molo and Ol-Arabel Rivers carry high amounts of silt after rains. Turbidity values in excess of 6000 NTU have been recorded in both Rivers Molo and Perkerra immediately after rains.

Table 5. Variation in mean values per station for selected physical parameters in Lake Baringo over the study period

Parameter STATION	Conductivity (μScm^{-1})	pH	Dissolved (O_2)(mgl^{-1})	Total Alkalinity (mgl^{-1})	Turbidity (NTU)
L_1	644±148	8.2	5.8±0.4	335.5±73.2	724±148
L_2	758±134	8.6	6.5±0.3	378.2±73.2	830±167
L_3	811±100	8.6	6.9±0.3	402.6±30.5	786±164
L_4	818±146	8.7	6.7±0.6	408.6±61.0	769±131
L_5	826±144	8.7	6.9±0.5	414.8±48.8	788±109
L_6	866±161	8.7	7.0±0.9	433.1±67.1	758±130
L_7	845±145	8.7	7.3±0.7	420.9±67.1	850±150
L_8	772±118	8.6	6.5±0.9	396.5±48.8	704±154
Mean	793±65	8.6	6.7±0.4	402.6±30.5	780±46

Table 6: Variation in mean values per station in the rivers.

Station Parameters	Mukutan (R_1)	Ol-Arabel (R_2)	Molo (R_3)	Perkerra (R_4)
Conductivity (μscm^{-1})	502±100	330±89	212±94	131±37
pH	7.7	7.9	8.5	7.6
Total Alkalinity mgl^{-1}, HCO_3^-	280.6±67.1	176.9±61.0	103.7±42.7	73.2±12.2
Turbidity NTU	126±17	256±163	384±180	440±82

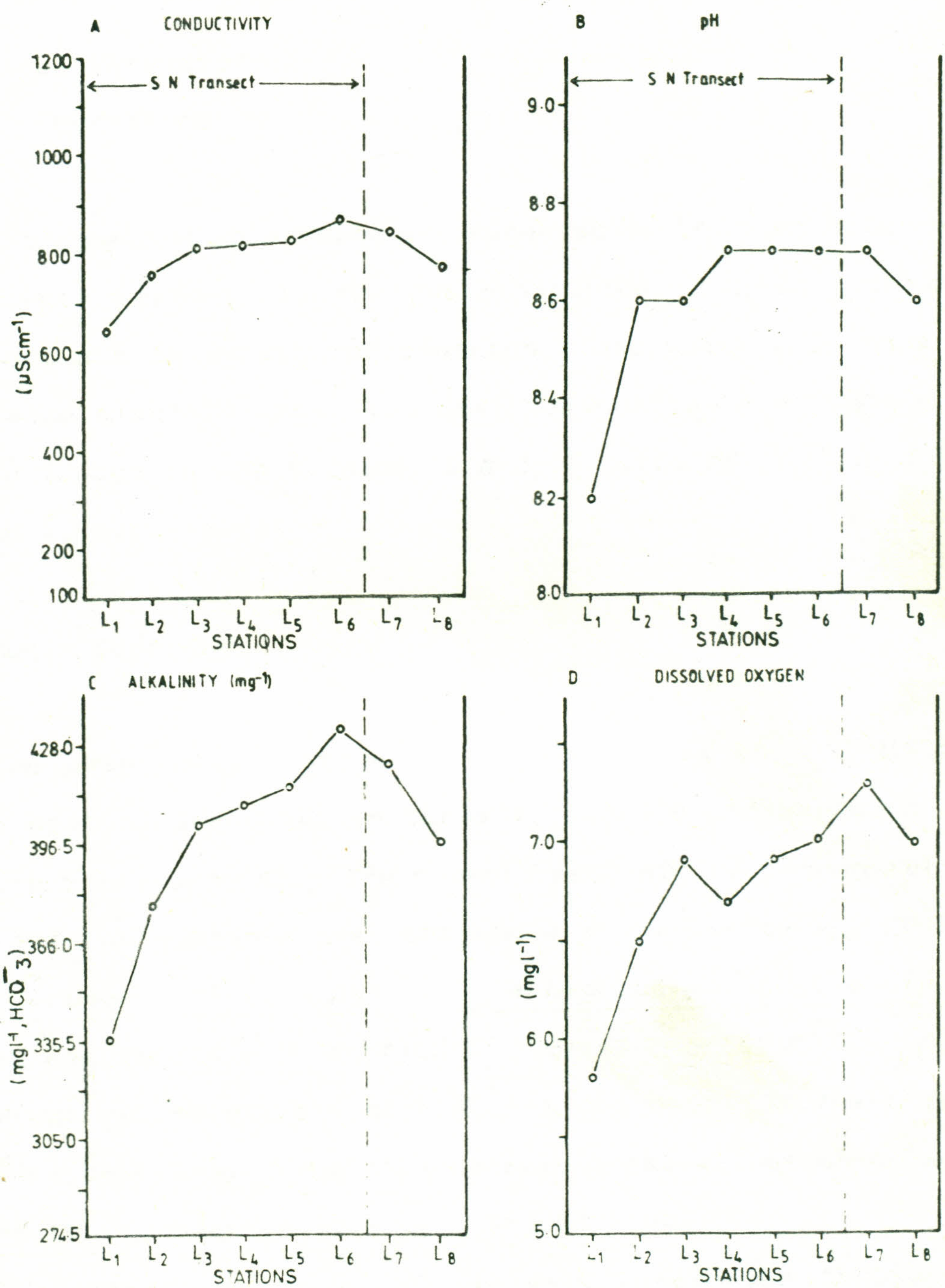


Fig 8: Variation in Mean values per station for selected physical parameters in Lake Baringo over the study period.

Chemical Parameters

4.4.2 Nutrients

Nitrogen and phosphorus are regarded as the most important nutrients responsible for eutrophication. These nutrients support a rich growth for plankton algae which culminate in nuisance algal blooms. The data for nutrients are shown in Table 7 page 78 and 8, page 79 and illustrated in Figure 9 - A to K, pages 80-81.

Nitrogen Compounds

The mean concentration of nitrate -nitrogen (NO_3^--N) for each station are shown in table 7, page 78 and presented in Figure 9 -A, page 80. The overall mean NO_3^- -N concentration for all the stations over the whole study period was 20.8 μgl^{-1} (range 17.5-27.7 μgl^{-1}). The highest mean value of NO_3^--N was recorded in Station L_3. Except for stations L_3 and L_8 which had relatively high NO_3^- -N values of 27.7 and 24.2 μgl^{-1} respectively. The other stations had values which were found to lie between 17.5 μgl^{-1} and 20.9 μgl^{-1}.

The nitrite-nitrogen (NO_2^--N) values recorded throughout the study period ranged from 2.3 to 8.2 μgl^{-1}. The data of NO_2^--N are shown in Table 7, page 78 and plotted in Figure 9-

B, page 80. The NO_2^--N concentrations were higher for the regions of the lake with no river influence. Although these NO_2^--N mean values increased from the southern to the northern end of the lake with station L_4 and L_6 having rather high values, the nitrite levels however were generally low. Levels of NO_2^--N were very low and approached its detection limits both in the lake and the rivers. The range of NO_2^- -N mean values for the rivers ranged from 1.1 μgl^{-1} in Ol-Arabel (R_2) to 4.6 μgl^{-1} in Molo (R_3), Table 8, page 79.

The data for ammonia-nitrogen (NH_3-N) concentrations are shown in Table 7 and 8, page 78-79 and plotted in Figure 9-C, page 80. Ammonia-nitrogen (NH_3-N) concentrations ranged between 10.0 μgl^{-1} at station L_2 and 18.5 μgl^{-1} at station L_4. Stations L_4 and L7 had much higher NH_3-N values of 18.0 and 18.5 μgl^{-1} respectively, whilst the other lake stations had a narrow range between 10.0 and 17.0 μgl^{-1}. The NH_3-N values for the river stations were either near or below the limits of detection.

Dissolved nitrogen (DN), particulate nitrogen (PN) and total nitrogen (TN) concentrations are shown in 7, page 78; 8, page 79 and represented in Figure 9-D to F page 80 respectively.

The DN mean concentrations for all the stations over the whole study period ranged from 0.8 mgl^{-1} at station L_1 to 1.6 mgl^{-1} at station L_2. The mean value of DN for the whole lake over the period was 1.2 mgl^{-1}. The DN value recorded at station L_8, which was at the mouth of River Mukutan (R_1) was 0.9mgl^{-1}, whilst River Mukutan(R_1) a value of 2.0 mgl^{-1}was recorded and this was higher than the range of the concentrations recorded in the lake. The other rivers had DN values within the range of the lake values as seen in Table 7 and 8, pages 78-79 and illustrated in Figure 9-D, page 80.

The mean particulate nitrogen (PN) values for all the stations are indicated in Table 7 and 8, page 78-79 and also in Figure 9-E, page 80 for the whole study period. The PN mean values ranged between 0.4 mgl^{-1} in station L_2 to 1.2 mgl^{-1} at station L_7. The PN mean values for the whole lake study over the study period was 0.6 mgl^{-1} with stations L_2, L_4, L_6, and L_8 having PN mean values below 0.5 mgl^{-1} whilst all the other lake stations had mean values in the range of 0.5-0.6 mgl^{-1}, except for the very high PN value for station L_7. In the river stations the PN values ranged from 0.,5 mgl^{-1} at River Ol-Arabel to 0.9 mgl^{-1} at station R_3 (Molo).

Total nitrogen (TN) mean values per station over the whole study period are indicated in Table 7 and 8, page 78-79 and illustrated in Figure 9-F, page 80. The TN mean values ranged between 1.5 mgl^{-1} at stations L_4 and L_6 and 1.9 mgl^{-1} at station L_7. The overall mean value for TN for all the lake stations over the study period was 1.6 mgl^{-1} whilst the overall average for the rivers was 1.8 mgl^{-1}. River Ol-Arabel (R_2) had the lowest TN mean value of 1.2 mgl^{-1} whilst Mukutan River (R_1) had the highest TN mean values of 2.5 mgl^{-1}.

Phosphorus Compounds

The mean values for the four forms of phosphorus: soluble reactive phosphate (SRP), dissolved phosphorus (DP), particulate phosphorus (PP) and total phosphorus (TP) for all the stations over the whole study period are given in Table 7, page 78 and 8, page 79 and plotted in sequence in Figure 9-G, H, I, J, page 80-81.

Soluble reactive phosphorus (SRP) mean values ranged from 0.09 mgl^{-1} at stations L_1, to 0.13 mgl^{-1} at station L_8. Except for stations L1 and L_5 with SRP values of 0.09 mgl^{-1} and 0.10 mgl^{-1} respectively, all the other stations had constant SRP values of 0.11 mgl^{-1}. The overall mean SRP value for all the lake stations combined was 0.11 mgl^{-1}, whilst the rivers had a mean value of 0.06 mgl^{-1}. The rivers had much lower SRP values ranging between 0.04 mgl^{-1} (Ol-Arabel, R_2) and 0.08 mgl^{-1} (Mukutan River, R_1).

The variation of dissolved phosphorus and SRP were in good agreement as indicated by Figure 9-G and H, page 80. Dissolved phosphorus (DP) mean values ranged between 0.11 mgl^{-1} at station L_1 and 0.14 mgl^{-1} at stations L_6, L_7 and L_8. The river stations had much lower DP mean values with station R_1 (Mukutan River) having the highest value of 0.09 mgl^{-1} whilst Ol-Arabel River (R_2) had the lowest value 0.05 mgl^{-1}).

Particulate phosphorus (PP) mean values ranged from 0.009 mgl^{-1} for station L_7 to 0.018 mgl^{-1} at station L_1. Except for station L_1, L_2 and L_3, all the other lake stations had mean PP values of less than 0.016 mgl^{-1}. The PP mean values declined from stations L_1 to L_6, except for station L_2 which had a slightly higher value (0.018 mgl^{-1}) than the adjacent stations L_1 and L_2 which had mean values of 0.016 mgl^{-1}(Figure 9-J, page 81. This could be due to the silt in the inflowing rivers and was a reflection of the higher silt levels in the southern end of the lake. The river stations had higher PP mean values than the lake stations. The range of the PP mean values for the rivers were between 0.010 mgl^{-1} (Molo River) and 0.040 mgl^{-1} at River Ol-Arabel (R_2).

Total phosphorus (TP) mean values for all the stations are shown in Table 7 and 8, pages 78-79 and plotted in Figure 9-I, page 81. The TP mean values ranged from 0.12 mgl^{-1} for station L_1 to 0.15 mgl^{-1} at station L_8. Except for stations L_1, L_5 and L_8 all the lake stations had mean TP concentrations which were similar having values of 0.14 mgl^{-1}. The mean TP concentrations across the lake, along the south-north transect, followed the same trends as those of SRP and DP. The overall mean value for all the lake stations' TP values was 0.14 mgl^{-1} whilst the rivers had a lower overall mean value of 0.10 mgl^{-1}. The mean TP values for the rivers ranged between 0.08 mgl^{-1} at station R_4 (Perkerra) and 0.013 mgl^{-1} at station R_1 (Mukutan). Except for station R_1, all the other river stations had TP mean values lower than those recorded at the lake stations.

Nutrient Ratios

There was a considerable spatial variation in the total nitrogen - total phosphorus (TN/TP) ratios for all the stations over the whole study period as indicated in Table 7 and 8, page 78-79 and illustrated in Figure 9-K, page 81. The TN/TP ratios calculated for the lake sampling stations investigated, ranged from 10 - 14, with a mean ratio of 12 for the whole study period. The TN/TP ratios were relatively high at stations L_5 and L_7, with ratios of 13.7 and 13.5 respectively, whilst the lowest mean ratio was recorded at station L_8 (10.2). The TN/TP ratios for the river stations were much higher than those of the lake stations. The overall mean value of TN/TP ratio for the rivers was 18.5 whilst the lake stations had a mean value of 12.0. The range of mean TN/TP ratios for the river stations was between 16.6 for Ol-Arabel (R_2) and 21.6 for Mukutan (R_3).

Table 7: Variation of Nutrient Mean Values per Station over the whole study period in the Lake.

Station Parameter	L_1	L_2	L_3	L_4	L_5	L_6	L_7	L_8	Mean Value
NO^-_3-N (μg/1)	20.9±13.5	17.5±9.2	27.7±2.4	19.2±4.2	20.6±13.1	18.0±11.4	18.5±9.7	24.2±13.9	20.8±3.5
NO^-_2-N (μg/1)	2.3±1.4	3.6±3.2	5.4±7.5	8.2±13.4	5.5±5.2	7.7±9.6	5.8±7.3	3.6±4.0	5.3±2.0
NH_4-N (μg/1)	16.1±23.9	10.0±17.1	12.2±17.0	18.5±21.0	14.1±18.9	11.4±14.4	18.0±32.5	12.4±15.3	14.1±3.1
DN (mg/1)	0.8±0.5	1.6±1.0	1.1±0.6	1.4±1.1	1.5±1.2	1.2±0.7	0.9±0.8	0.9±0.4	1.2±0.3
PN "	0.5±0.5	0.4±0.23	0.6±0.5	0.4±0.3	0.5±0.4	0.4±0.5	1.2±2.1	0.4±0.4	0.6±0.3
TN "	1.6±1.0	1.8±1.1	1.6±0.5	1.5±1.1	1.8±1.4	1.5±0.8	1.9±2.4	1.5±0.9	1.6±0.2
SRP "	0.09±0.02	0.11±0.02	0.11±0.02	0.11±0.02	0.11±0.02	0.22±0.02	0.11±0.02	0.13±0.02	0.11±0.02
DP "	0.11±0.02	0.13±0.02	0.12±0.02	0.13±0.02	0.12±0.02	0.14±0.02	0.14±0.01	0.14±0.01	0.13±0.01
PP "	0.016±0.016	0.018±0.008	0.016±0.008	0.013±0.009	0.012±0.005	0.012±0.004	0.009±0.004	0.011±0.003	0.013±0.003
TP "	0.12±0.03	0.14±0.03	0.14±0.03	0.14±0.03	0.13±0.02	0.14±0.03	0.14±0.02	0.15±0.02	0.14±0.01
TN:TP Ratio	13.5±9.6	13.2±7.6	11.9±3.9	9.4±6.1	13.3±10.3	11.0±5.2	12.6±13.4	10.1±5.7	11.9±1.5

Table 8: Variation of Nutrient mean values per station over the whole study period (In the Rivers)

Station Parameters	Mukutan (R_1)	Ol-Arabel (R_2)	Molo (R_3)	Perkerra (R_4)
NO_3^--N (μgl^-1)	B E L O W	D E T E C T I O N	L I M I T S	
NO_2^--N "	3.6±4.0	1.1±0.6	4.6±4.4	1.9±1.7
NH_3-N "	B E L O W	D E T E C T I O N	L I M I T S	
Dissolved Nitrogen (mgl^{-1})	1.9±0.80	1.0±0.2	1.0±0.2	1.2±0.4
PN (mgl^{-1})	0.9±0.5	0.5±0.4	0.9±0.8	0.5±0.4
TN "	2.5±1.6	1.2±0.6	2.1±0.7	1.6±0.8
SRP "	0.08±0.02	0.04±0.02	0.07±0.01	0.05±0.01
DP "	0.09±0.03	0.05±0.02	0.08±0.02	0.07±0.02
PP "	0.01±0.013	0.37±0.021	0.20±0.011	0.013±0.005
TP "	0.13±0.04	0.08±0.04	0.10±0.02	0.08±0.02
TN:TP Ratio	21.6±14.3	16.6±8.9	19.5±6.1	19.2±9.5

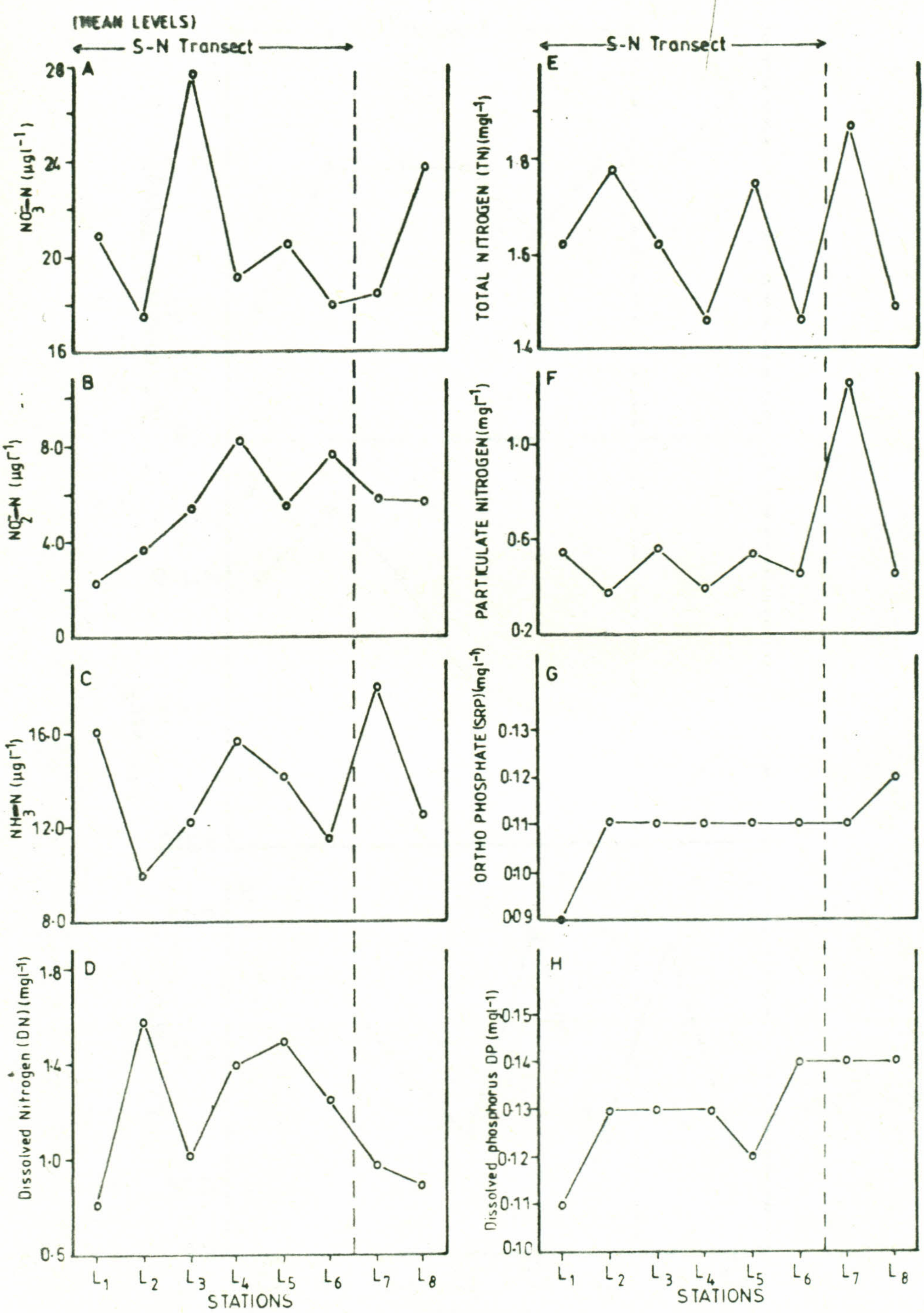


Figure 9: Mean Values Variation of Nutrient Parameters per station over the study period (mean levels).

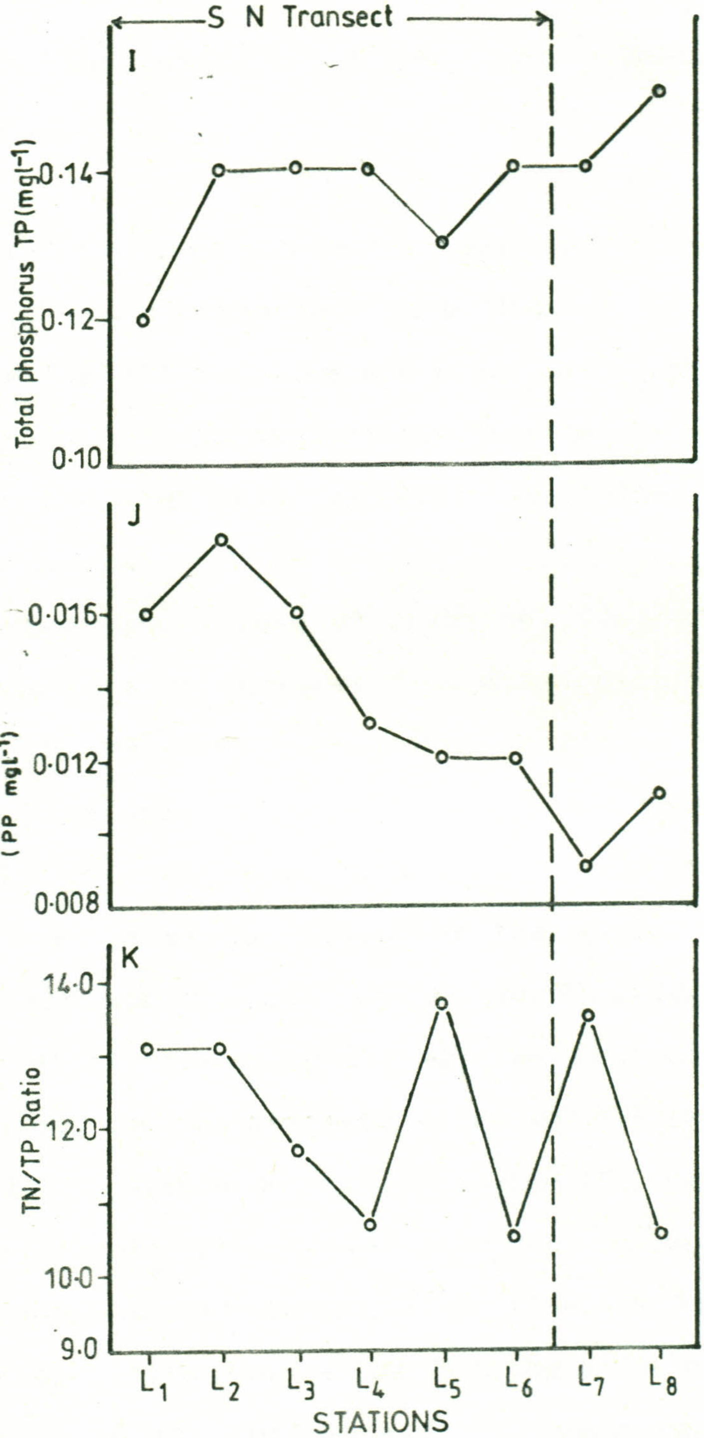


Fig. 9 (continued)

4.4.3 Non-Nutrients (Cl^-, F^-, SO_4^{2-} and Molybdate reactive SiO_2).

The data for this sub-section are shown in Table 9 and 10, page 84-85 and plotted in Figure 10-A to D, page 86. These data were for all the lake and river stations over the whole study period. The parameters investigated in this sub-section include the anions; chloride, fluoride, sulphate and molybdate reactive silica.

Concentrations levels of chloride, fluoride and sulphate all demonstrate an increase from stations L_1 to L_6 along the south-north transect as indicated in Figure 10-A, B, and C, page 86. The mean chloride concentration values ranged from 34.5 mgl^{-1} at station L_1 to 44.7 mgl^{-1} at station L_4. The overall mean chloride value over the whole lake during the study period was 41.8 mgl^{-1} whilst the fluoride had a range of 4.2 mgl^{-1} at station L_1 to 5.2 mgl^{-1} at stations L_5 and L_7. The fluoride had an overall mean value of 4.9 mgl^{-1} for all the lake stations combined. River Mukutan (R_1) had a substantial fluoride concentration level (3.5 mgl^{-1}), whilst the other three rivers had considerably lower fluoride levels. The lower fluoride concentration values for the Lake stations L_1 and L_2 were due to the influence from Rivers Perkerra and Molo which had lower fluoride concentrations of 0.6 mgl^{-1}.

The sulphate on the other hand, had a range from 16.1 mgl^{-1} (station L_1) to 22.8 mgl^{-1} (Station L_6) as indicated in Figure 10-C, page 86. The overall mean sulphate value for all the stations combined over the study period was 19.1 mgl^{-1}. The river stations had much lower sulphate values with a range of 4.9 mgl^{-1} (Ol-Arabel, R_2) to 10.2 mgl^{-1} (Perkerra, R_4). The influence of the Mukutan River (R_4) is shown by the lower values for all the three parameters at Station L_8. The substantial impact of the Molo and Perkerra Rivers are demonstrated by the substantially lower values for stations L_1 and L_2. The mean fluoride concentration of Lake Baringo (Figure 10-B, page 86) and River Mukutan are both relatively high and are substantially above the World Health Organization recommended limits for drinking water of 1.0 mgl^{-1}.

Molybdate reactive silica shows a different trend from the other anionic parameters with the maximum value (32.3 mgl^{-1}) occurring for station L_4. The concentrations of molybdate reactive silica in the rivers are comparable to those in the lake, a relatively unusual situation as the concentration of most river parameters are considerably less than the lake levels. The data for molybdate reactive silica are indicated in Table 9 and 10, pages 84-85. The overall mean value for molybdate reactive silica for the lake was 28.8 mgl^{-1} whilst the rivers had an overall mean of 30.0 mgl^{-1}, showing that most of the molybdate reactive silica in the lake are brought in by the rivers.

Table 9: Variations in mean values per station for anions (Cl^-, SO_4^{2-}, F^-, SiO_2) in Lake Baringo over the study period.

STATION	PARAMETERS			
	Cl^- (mgl^{-1})	F^-(mgl^{-1})	SO_4^{2-}(mgl^{-1})	M.R.SiO_2^-(mgl^{-1})
L_1	34.5±16.3	4.2±1.2	16.1±4.0	30.6±10.5
L_2	39.6±14.3	4.6±1.3	16.5±2.8	25.5±10.1
L_3	43.1±7.3	5.0±1.4	20.0±3.2	32.1±12.1
L_4	44.7±7.0	4.6±1.5	19.4±3.1	32.3±11.9
L_5	43.7±9.5	5.2±1.6	19.2±2.9	29.2±11.1
L_6	43.7±6.5	5.1±1.6	22.8±7.5	27.5±9.8
L_7	44.1±6.4	5.2±1.6	19.5±3.8	26.5±8.8
L_8	40.3±9.3	5.0±1.3	18.8±2.9	24.7±10.1
Overall Mean Value	41.8±3.2	4.9±0.4	19.0±2.1	28.6±2.9

Table 10: Variation in Mean Values (Cl^-, SO_4^{2-}, F^-, and SiO_2) for the Rivers.

STATION PARAMETER	MUKUTAN (R_1)	OL-ARABEL (R_2)	MOLO (R_3)	PERKERRA (R_4)
Chloride (mgl^{-1})	20.3±7.6	20.5±6.5	14.3±4.9	13.4±3.3
Fluoride (mgl^{-1})	3.5±1.4	0.7±0.3	0.6±0.3	0.6±0.2
Sulphate (mgl^{-1})	8.5±4.5	4.9±1.7	7.3±2.8	10.2±2.9
Molybdate reactive SiO_2 (mgl^{-1})	26.3±8.0	26.9±7.7	34.7±13.7	32.0±7.3

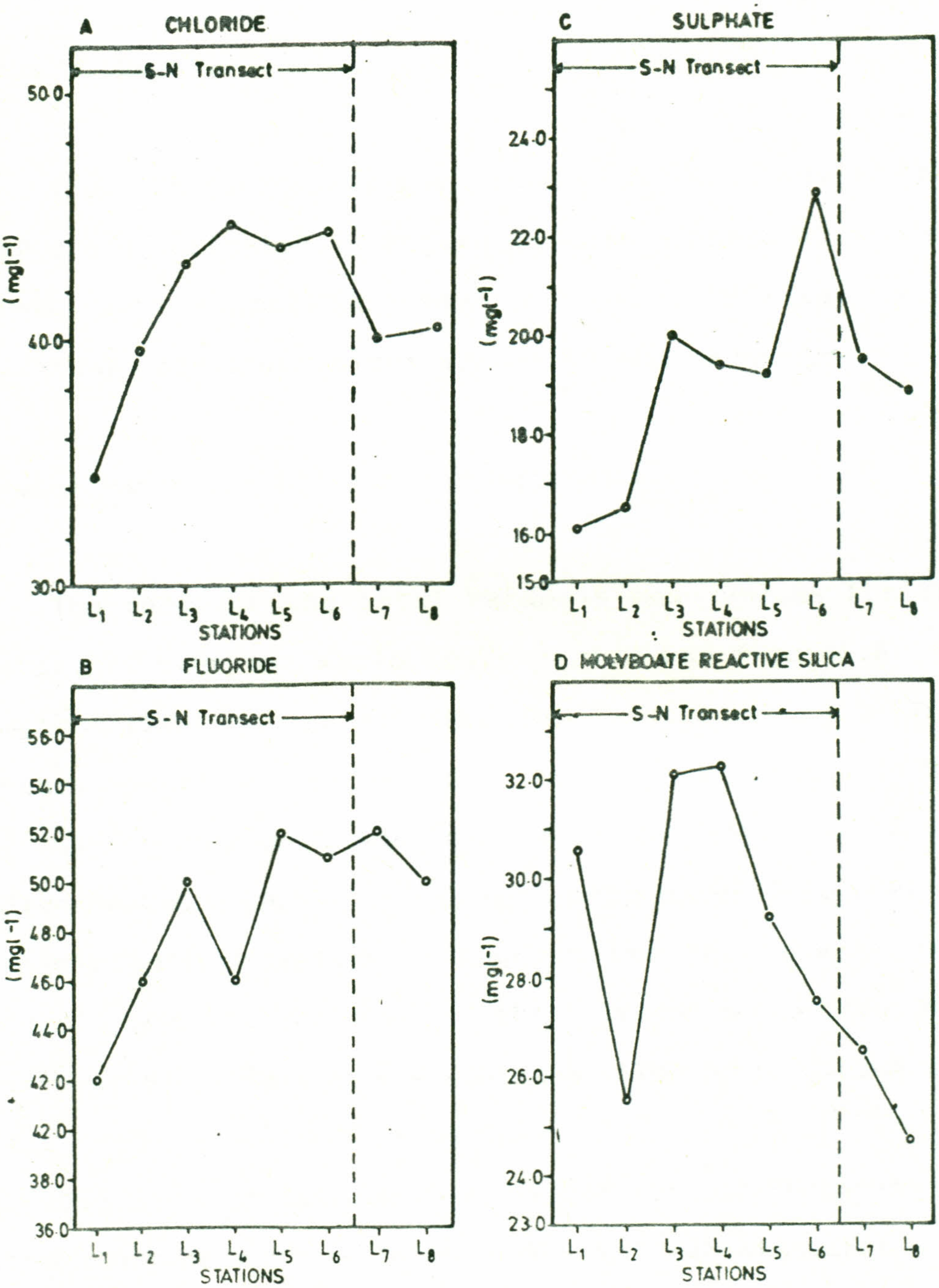


Figure 10: Variation in mean values per station for anions (Cl^-, SO_4^{2}, F^-, and SiO_2) in Lake Baringo over the study period.

4.4.4 Metals

The data for metals are shown in Table 11 and 12, page 91-92 and illustrated in Figure 11-A to H, page 93. The metals investigated included total hardness, calcium, magnesium, sodium, potassium, aluminium, iron and manganese.

Total Hardness, Calcium and Magnesium

The range of the total hardness mean values for the lake stations over the whole study period was from 45.5 mgl^{-1} (Station L_8) to 49.5 mgl^{-1} (station L_2). The lake stations had an overall mean value of 47.6 mgl^{-1}. The mean value for station L_8 was low due to the low value recorded at River Mukutan (R_1) of 17.3 mgl^{-1}. The other lake stations had fairly uniform values throughout the lake due to the high total hardness values in the rivers preventing dilution effects being felt at the stations. The total hardness values are recorded as mgl^{-1} of $CaCO_3$.

The range of calcium mean values for all the stations over the study period was between 9.8 mgl^{-1} at station L_8 and 12.9 mgl^{-1} at station L_3 and an overall mean value of 11.2 mgl^{-1} was recorded for the lake stations. The low calcium value recorded at station L_8 was due to the low Calcium concentration of River Mukutan,(R_1) (4.0 mgl^{-1}). The range of magnesium concentration was between 3.9 mgl^{-1} at station L_3 and 4.8 mgl^{-1} at station L_8 and an overall mean value of 4.1 mgl^{-1} was recorded for the lake stations. The levels of magnesium and calcium concentrations were generally uniform throughout the lake because the river values were comparable with lake values, thus dilution effects on calcium and magnesium concentrations by the rivers were not felt at the lake stations. The data for total hardness, calcium and magnesium are indicated in Table 11 and 12, pages 91-92 and illustrated in Figure 11-A, and B and C page 93.

Sodium and Potassium

The data of sodium and potassium are illustrated in Figures 11-D and E, page 93 and shown in Table 11 and 12, pages 91-92. Both parameters followed similar geographical trends to those of conductivity values. Station L_6 had the highest sodium and potassium mean values of 174.8 mgl^{-1} and 15.5 mgl^{-1} respectively, whilst station L_1 had the lowest value for both the parameters with values of 127.7 mgl^{-1} and 13.0 mgl^{-1} respectively. The values for stations L_1 and L_2 were low due to the influence of Perkerra and Molo Rivers which had much lower sodium and potassium values as can be seen from Table 12, page 92. River Mukutan (R_1) had much higher sodium concentration (100.6 mgl^{-1}) but had the lowest potassium concentrations than the other river stations. The mean values for sodium and potassium in all the stations combined over the whole study period were 158.2 mgl^{-1} and 14.2 mgl^{-1} respectively.

Aluminium

The aluminium concentration mean values (Table 11 and 12, pages 91-92) along the south-north transect were fairly constant with the exception of station L_1, influenced as usual by dilution effects of Rivers Molo (R_3) and Perkerra (R_4) and the high value at station L_7 was probably due to the urban influence of Kampi Ya Samaki and the use of alum to purify water for the hotel (Baringo Club) and the of Kampi ya Samaki. The aluminium mean values ranged between 8.6 mgl^{-1} at station L_1 and 12.3 mgl^{-1} at station L_7. Stations L_2, L_5 and L_6 had similar aluminium concentration of about 10.0-12.0 mgl^{-1}. The overall mean aluminium concentration over the whole lake during the study period was 10.4 mgl^{-1}. The river stations had much lower aluminium concentrations with a range of 1.1 mgl^{-1} (R_2) and 3.3. mgl^{-1} (R_3).

Iron and Manganese

The results of iron and manganese are indicated in Table 11 and 12, pages 91-92. There was a general increase of iron concentration mean values along the south-north transect with a maximum value being recorded at station L_6. The iron mean concentrations ranged from 5.2 mgl^{-1} at station L_1 to 8.6 mgl^{-1} at station L_6 (Figure 11-G, page 93), giving an overall mean value of iron concentration for all the lake stations of 6.9 mgl^{-1}. The river stations on the other hand had much lower iron concentration values with a range of 0.9 mgl^{-1} at station R_2 (Ol-Arabel River) to 3.5 mgl^{-1} at station R_3 (Molo River).

Manganese had an overall mean concentration value of 0.34 mgl^{-1} for all the lake stations combined. The range of manganese mean concentration values for all the stations over the study period was quite small ranging between 0.30 mgl^{-1} at station L_1 and 0.41 mgl^{-1} at station L_4 as illustrated in Figure 11-H page 93. The river stations had manganese mean values which were comparable to the lake mean values, with a range between of 0.14 mgl^{-1} at station R_2 (Ol-Arabel) and 0.33 mgl^{-1} at station R_3 (Molo River).

Table 11: Variations in mean values per station of selected metals in Lake Baringo over the study period.

Parameters	Stations								
	L_1	L_2	L_3	L_4	L_5	L_6	L_7	L_8	Mean Value
Total Hardness as $CaCO_3$ (mgl^{-1})	47.8±8.0	49.5±6.4	48.6±6.9	48.7±5.7	49.0±6.0	48.0±4.4	48.8±7.7	45.5±7.8	47.6±4.0
Ca^{2+} "	11.5±1.5	12.0±3.4	12.9±1.6	10.3±1.6	12.0±1.3	12.1±1.7	11.6±2.0	9.8±1.6	11.2±2.0
Mg^{2+} "	4.2±2.4	4.5±1.1	3.9±1.3	4.5±1.1	4.4±2.0	4.0±1.0	4.8±1.4	4.8±1.4	4.±1.1
Na^{+} "	127.7±40.3	144.0±28.1	160.3±13.8	164.8±7.3	169.8±14.4	174.8±27.9	171.5±33.3	152.4±17.7	158.0±16.0
K^{+} "	13.0±2.0	13.2±2.4	14.8±3.8	13.7±0.8	14.6±4.6	15.5±5.2	14.8±3.0	14.8±2.4	14.2±0.9
Al^{3+} "	8.6±2.1	10.0±2.8	11.1±2.7	9.5±2.2	10.2±1.2	10.2±1.2	12.3±3.5	11.1±3.1	10.4±1.1
Fe^{3+} "	5.2±1.4	7.1±2.8	6.2±3.5	6.6±2.7	8.6±7.3	8.6±7.3	7.5±2.5	6.7±3.7	6.9±1.0
Mn^{2+} "	0.34±0.20	0.30±0.10	0.35±0.20	0.41±0.50	0.32±0.10	0.31±0.20	0.33±0.20	0.38±0.30	0.34±0.04

Table 12: Variation in mean values per station (Rivers) for metals

Parameters	Stations			
	Mukutan R_1	Ol-Arabel R_2	Molo R_3	Perkerra R_4
Total hardness as $CaCO_3$ (mgl^{-1})	17.3±4.6	38.5±6.5	34.3±5.3	30.0±4.5
Ca^{2+} "	4.0±0.8	8.0±1.3	8.8±4.2	10.4±3.1
Mg^{2+} "	2.2±1.7	4.5±2.3	3.6±2.1	2.2±1.4
Na^{+} "	100.6±34.1	55.6±27.4	28.6±11.8	16.8±4.0
K^{+} "	5.9±1.0	7.3±1.8	9.9±2.9	6.2±2.1
Al^{3+} "	3.3±3.8	1.1±0.9	2.8±1.6	2.3±1.8
Fe^{3+} "	2.4±3.3	0.9±0.4	3.5±0.9	1.9±1.5
Mn^{2+} "	0.29±0.20	0.14±10	0.33±10	0.20±0.20

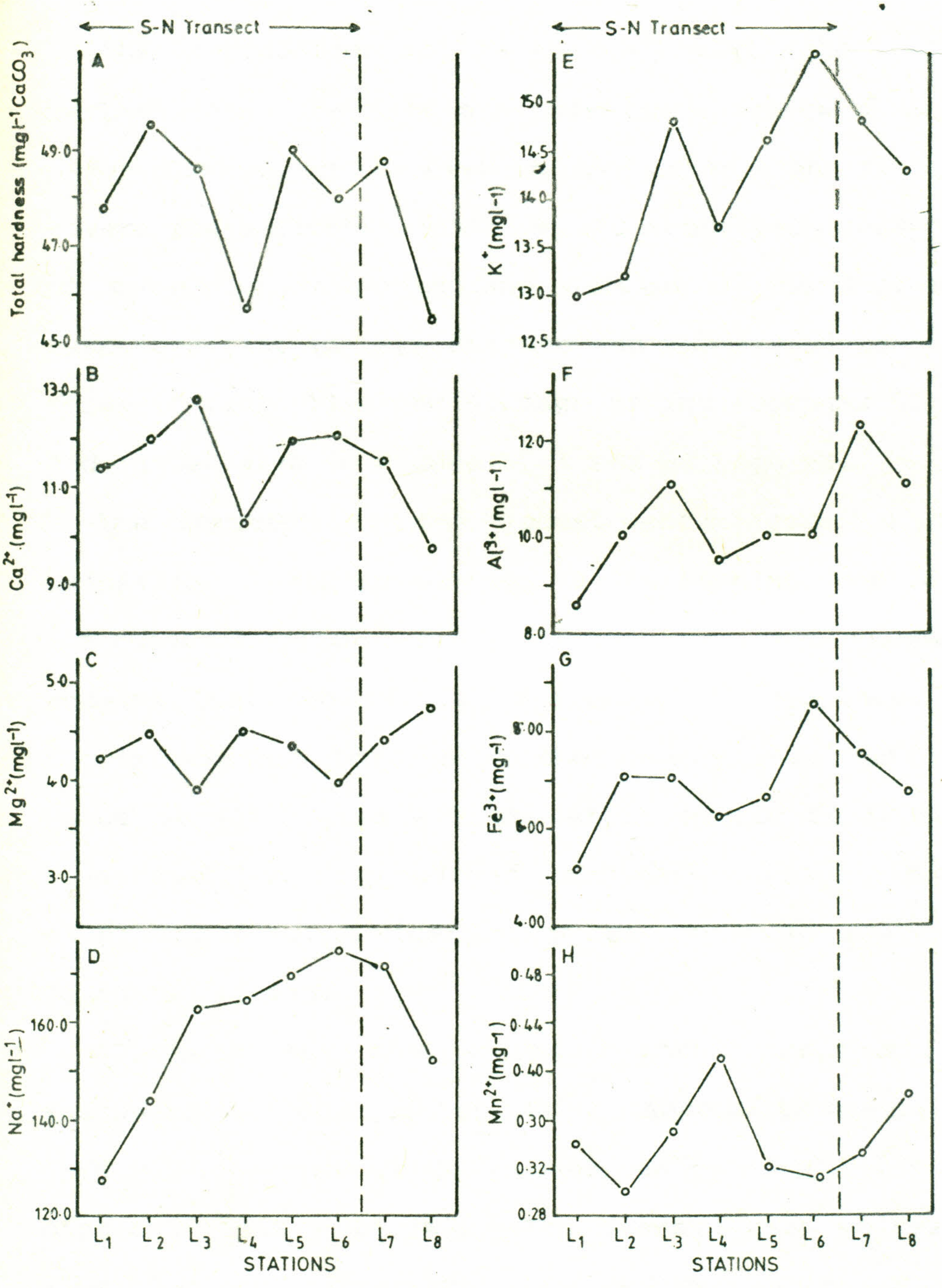


Figure 11: Variation in mean values per station of selected metals in Lake Baringo over the study period.

4.4.5 Suspended Silt

The composition of suspended silt are recorded as percentages. The silt analysis results show that the three major elements in the silt in Lake Baringo and its associated rivers are silicon, aluminium and iron, with lesser amounts of potassium, titanium and calcium. The composition of suspended silt in Lake Baringo and its associated rivers are shown in Table 13-A and B, page 97 and Appendix 32, page 252 and illustrated in Figure 12-A and B, page 98.

The component with the highest percentage value in the silt was silicon, with percentage values ranging from 55.3-58.1%. The range of silicon levels for the lake stations was narrow, showing that the silica levels in the suspended silt was fairly constant throughout the lake. The mean percentage value of silicon in all the stations was 56.7% whilst the river stations combined had a higher silicon percentage of 64.6% and also a wider range as shown in their standard deviation values.

Aluminium had the second highest percentage in the suspended silt composition with a range of 22.8 - 24.2% in the lake stations. The range however was much wider for the river stations (11.3 - 26.3%). The overall mean values for the aluminium composition for the lake and river stations were 23.7% and 17.7% respectively.

The percentage of iron in the suspended silt in both the lake and the river stations was substantial, with a narrow range in the lake stations (14.4 - 17.5%) whilst the river stations had a wider range (9.3 - 18.8%). Iron had the third highest percentage composition of the suspended silt with mean values of 15.7% and 14.7% for the lake and the river stations, respectively.

Potassium had a fairly uniform percentage value in the lake silt samples, varying from 1.7% (Stations L_1 and L_4) to 2.0% (Station L_2). The river stations had a wider range (1.3% at station R_4 to 2.7% at station R_2). The overall means of the potassium percentages for the lake and the river stations silt samples were 1.8% and 2.0% respectively. The potassium levels in the lake silt samples were fairly constant.

Titanium values for the lake silt samples ranged from 1.1% (Station L_1) to 1.3% (Station L_5), whilst the river stations had a wider range of titanium from 0.2% (Station R_4) to 1.6% (Station R_2). The overall mean percentages for titanium in the suspended silt for the lake and river stations water were 1.2% and 0.7%, respectively.

The calcium levels in the suspended silt was low, with a range between 0.3% (Station L_3) and 0.6 % (Station L_5). The rivers had much lower calcium values in the silt samples, with River Perkerra recording zero. Ol-Arabel River on the other hand had a value of 0.6% which was comparable to those recorded for the lake stations silt samples. The overall mean values of Calcium percentages in the silt samples in the lake and rivers were 0.5% and 0.2% respectively.

The percentage composition of the other components of the silt samples, magnesium, sulphur, chloride and manganese were low, with mean values less than 0.1% for both the lake and the river stations. Many of the lake and river stations had non-detectable levels of these parameters in the silt.

There was little variation in the silt level and composition in the lake stations. However, there was a greater variation in river silt sample composition. Station R_3 (Molo River) appeared to be substantially different from stations R_2 and R_4, as it had much higher silicon content and much lower iron levels in the silt samples than the other rivers.

Table 13 A, B: Results of X-ray fluorescence spectroscopy analysis of suspended silt in Lake Baringo water and some of its rivers. (All values are expressed as percentages).

A LAKE SITES	SILICON Si %	ALUMINIUM Al %	IRON Fe %	POTASSIUM K %	TITANIUM Ti %	CALCIUM Ca %
L_1	57.1	24.1	14.8	1.7	1.1	0.5
L_2	55.3	22.8	17.5	2.0	1.1	0.5
L_3	57.1	24.2	15.1	1.8	1.2	0.4
L_4	58.1	24.2	14.4	1.7	1.2	0.4
L_5	56.0	23.7	16.2	1.9	1.3	0.6
L_6	56.6	23.7	15.8	1.9	1.2	0.5
L_7	57.7	23.7	14.8	1.8	1.1	0.4
L_8	56.1	23.6	16.8	1.8	1.2	0.3
$\bar{X}$	56.7±0.9	23.7±0.4	15.7±1.0	1.8±0.1	1.2±0.1	0.5±0.04

B RIVER SITE	SILICON Si %	ALUMINIUM Al %	IRON Fe &	POTASSIUM K %	TITANIUM Ti %	CALCIUM Ca %
R_2	52.5	26.3	15.9	2.7	1.6	0.6
R_3	72.8	15.4	9.3	1.9	0.4	0.1
R_4	68.4	11.3	18.8	1.3	0.2	0.0
$\bar{X}$	64.6±8.7	17.7±6.3	14.7±4.0	2.0±0.6	0.7±0.6	0.2±0.3

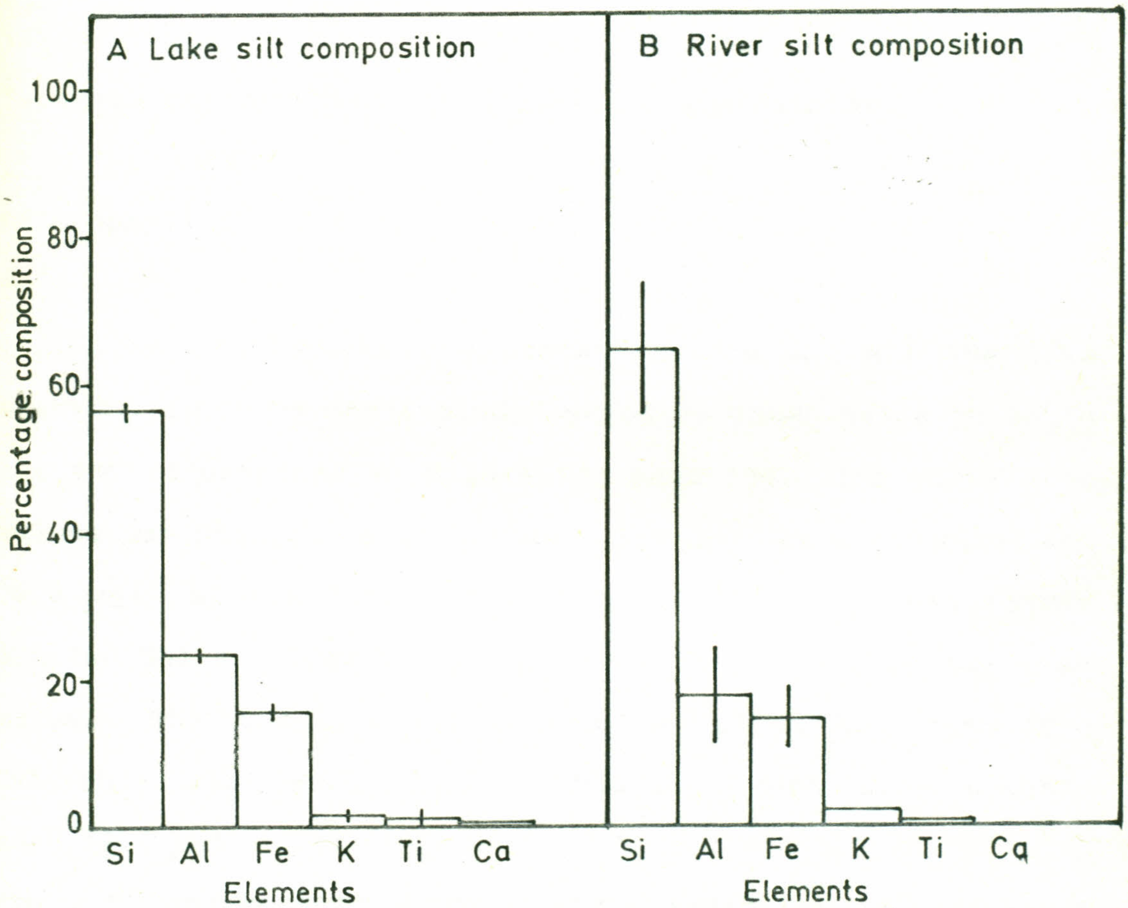


Figure 12, A and B: Percentage Composition of Silt Sample from all the lake stations combined and all the river stations combined.

4.4.6 Biotic Parameters

Geographical Variation of a biological parameter

Chlorophyll a

The mean chlorophyll a concentrations for all the lake stations over the whole study period is shown below in Table 14, and illustrated in Figure 13, page 100. The Chl a mean values per station ranged between 8.8 μgl^{-1} at stations L_4 and 20.3 μgl^{-1} at station L_8. Station L_2, L_3 and L_6 had fairly similar Chl a values while station L_8 had a much higher mean value. Stations L_4 and L_5 had chl a values less than 10.0 μgl^{-1} while stations L_1, L_7 and L_8 had Chl a mean values greater than 12.0 μgl^{-1}.

Table 14 Chlorophyll a mean values indicating geographical variations in Lake Baringo:

Stations	Chl a μgl^{-1}
L_1	12.3±9.1
L_2	11.2±3.4
L_3	10.8±2.3
L_4	8.8±2.6
L_5	8.9±1.7
L_6	11.9±4.3
L_7	13.3±4.7
L_8	20.3±8.1
Mean Value	12.2± 3.6

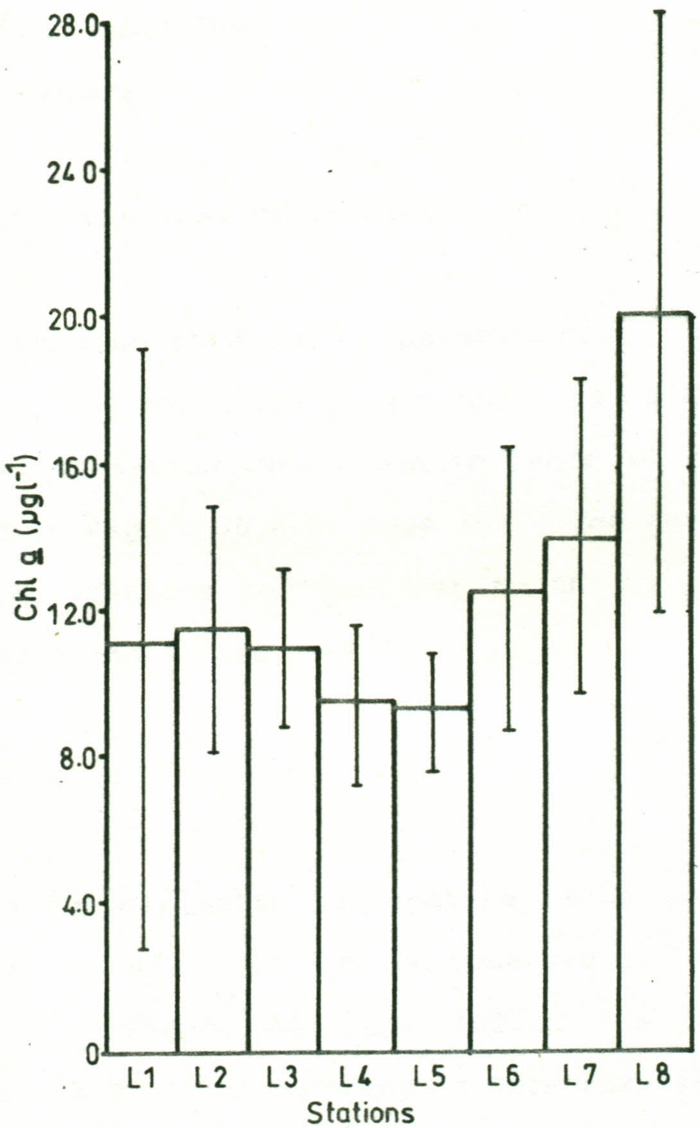


Figure 13: Geographical variations of Chlorophyll a values Lake Baringo during the study period (July 1988 to March 1989).

4.5 MONTHLY VARIATIONS IN ALL THE LAKE STATIONS COMBINED (SEASONAL VARIATION)

Abiotic Parameters

4.5.1: Physico-Chemical Parameters

Four physico-chemical parameters, temperature, conductivity, pH, dissolved oxygen and total alkalinity data for seasonal variations are shown in Table 16, page 106 and illustrated in Figure 15 A-D, page 107. The mean values for all the lake stations combined per month are used to show seasonal variation in the lake.

Temperature

The mean monthly water temperature range was 24.2 - 26.0 ^{0}C for the study period as observed in Table 15 and illustrated in Figure 15 page 103. The lowest water temperature (24.2 ^{0}C) was recorded in December 1988 whilst the highest (26.0 ^{0}C) was in August, 1988. Temperature readings were usually taken between 0800 and 1300 hours. The mean water temperatures were lower than the mean air temperatures over the whole study period except in January, 1989. During the study period, thermal stratification was never evident, with temperature difference not exceeding 1^0 C from the bottom to top. The water temperatures were slightly higher during than the months of August, September and October, 1988 but all the other months had values less than 25^0 C. The air temperatures above the water surface were in the range of 24.3 - 29.6^0 C. The highest air temperature (29.6^0 C) occurred in the relatively dry month of September, 1988. The only month with a lower air temperature than the water temperature was January, 1989.

Table 15. Mean monthly water temperatures for Lake Baringo combined.

MONTH/YEAR	MEAN MONTHLY WATER TEMPERATURE (^{0}C)
JULY, 1988	24.4
AUGUST, 1988	26.0
SEPTEMBER, 1988	25.4
OCTOBER, 1988	25.5
NOVEMBER, 1988	24.4
DECEMBER, 1988	24.2
JANUARY, 1989	24.6
FEBRUARY, 1989	24.7
MARCH, 1989	25.0

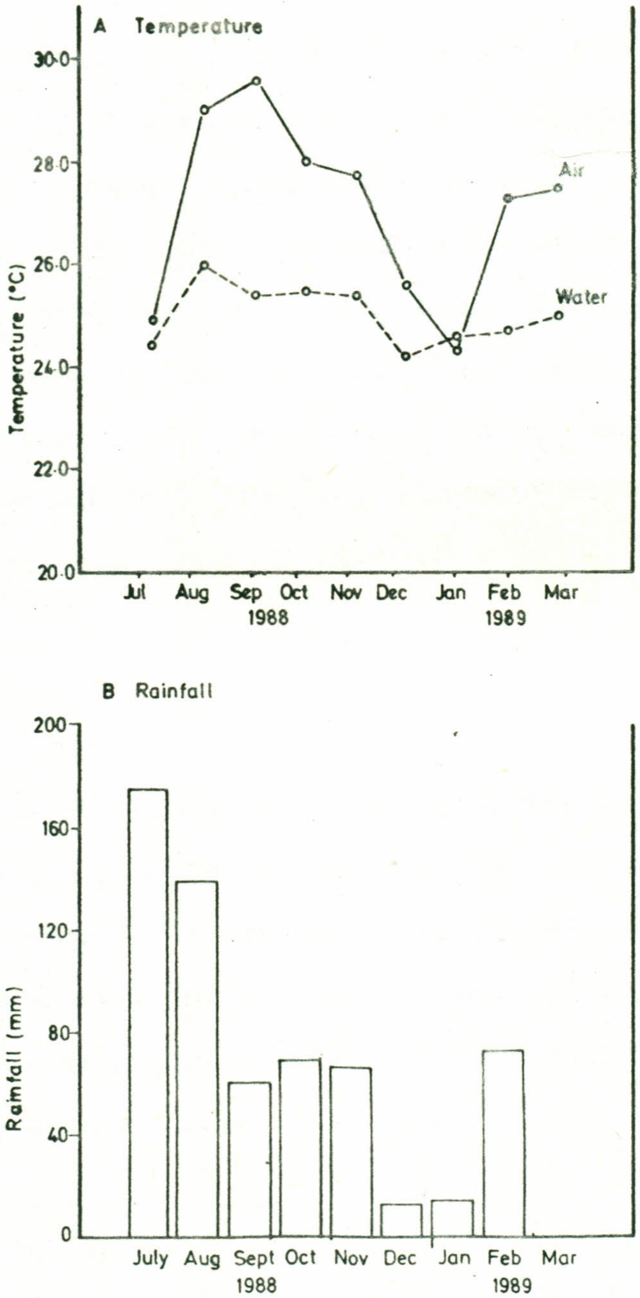


Figure 14. Monthly variations of mean air and water temperature in Lake Baringo and Rainfall Variation at Kiserian.

Conductivity

The highest mean monthly conductivity value was recorded in July 1988 with a value of 1084 μScm^{-1} and this value declined during August and September 1988 and reached a minimum in October 1988 with a value of 704 μScm^{-1}. After October, 1988 there was a gradual increase in conductivity mean monthly values to March 1988, except for the slightly lower conductivity value recorded in February, 1989 (Figure 15-A, page 107). The mean conductivity values for all the months combined was 793 μScm^{-1}.

pH

The mean monthly pH values over the whole lake fluctuated between 8.4 and 8.6, except for the somewhat unusual value of 8.9 recorded in the month of March 1988. The lowest pH mean value was recorded in the month of August 1988. Little variation in pH occurred during the study period as indicated in Figure 15.B, page 107.

Total Alkalinity

The highest mean monthly total alkalinity value was recorded in July 1988 (512.4 mgl^{-1}, HCO_3^-) whilst the lowest was recorded in December 1988 (366.0 mgl^{-1}, HCO_3^-). There was a dramatic drop in alkalinity values from a high value in July, 1988 to a low one in August 1988 followed by a general steady increase in alkalinity values towards the end of the study as shown in Figure 15-C, page 107.

Dissolved Oxygen

The mean monthly dissolved oxygen (DO) values are shown in Table 16, page 106 and plotted in Figure 15-D, page 107. The DO mean monthly values ranged from 6.3 mgl^{-1} in December 1988 to 7.3 mgl^{-1} in August 1988. A considerable variation in DO values occurred during the study period, as shown in Figure 15-D, page 107. The DO variation in the lake water could have been due to temperature changes and variation in algal activity and density in the lake during the study period.

Table 16: Monthly Variations of selected physical parameters mean values in Lake Baringo.

Month/Year	Conductivity (µS/cm)	pH	Dissolved O_2 (mgl^{-1})	Total Alkalinity (mgl^{-1}, HCO_3^-)
July 1988	1084±163	8.6	6.4±0.6	512.4±73.2
August 1988	755±277	8.4	7.3±0.8	372.1±128.1
September 1988	763±72	8.6	7.0±1.1	390.4±30.5
October 1988	704±71	8.5	6.4±0.7	384.3±12.2
November 1988	720±28	8.5	6.9±0.6	384.3±6.1
December 1988	745±12	8.6	6.3±0.2	366.0±6.1
January 1989	774±10	8.5	6.4±0.3	384.3±6.1
February 1989	763±14	8.5	6.5±0.3	396.5±6.1
March 1989	779±13	8.9	7.1±0.7	384.5±6.1
Mean Value	792±106	8.5	6.7±0.4	396.5±42.7

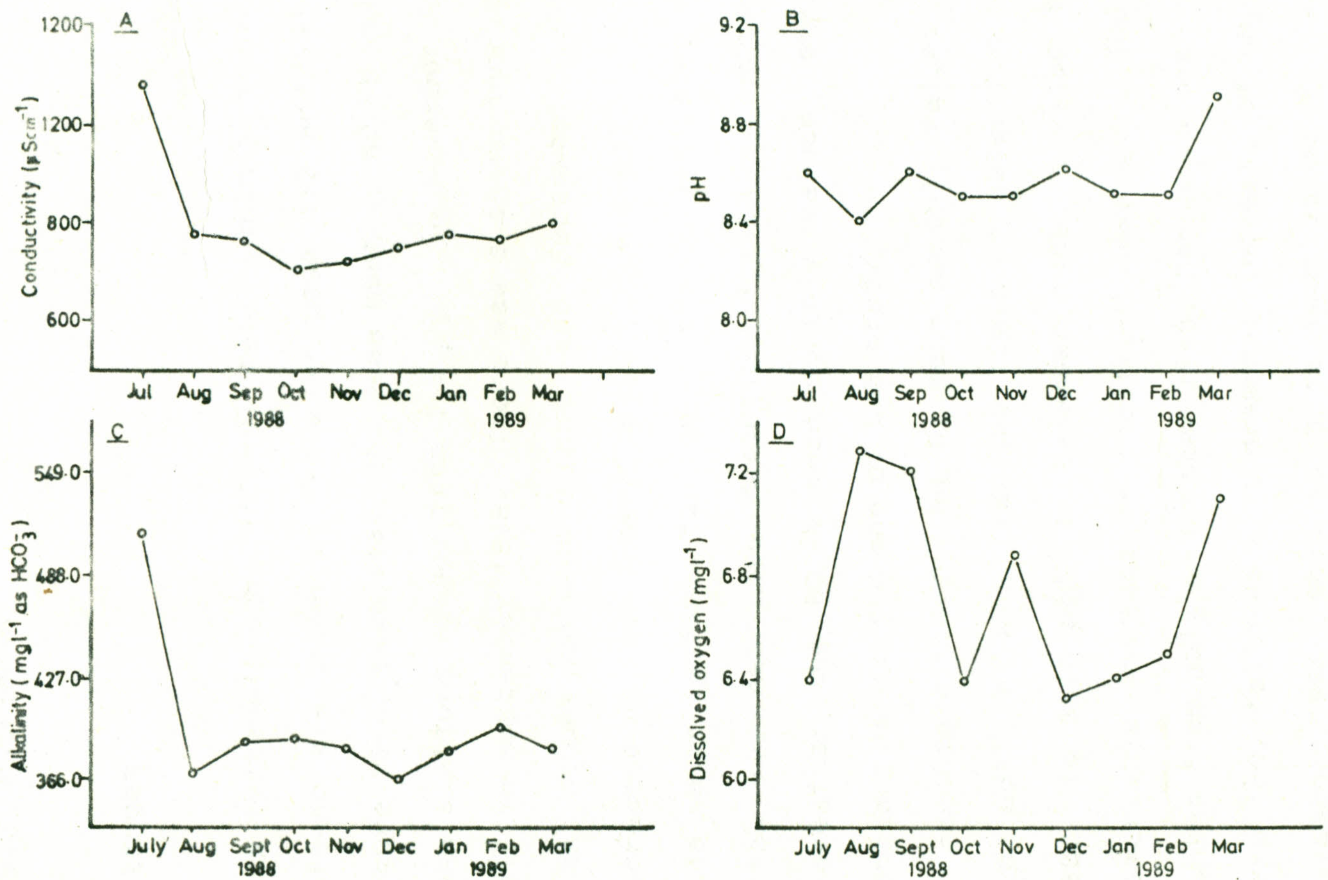


Figure 15: Monthly varition of Physical Parameters in Lake Baringo.

CHEMICAL PARAMETERS

4.5.2 Nutrients

Nitrogen

Nitrite-nitrogen (NO_2^--N) mean monthly values for Lake Baringo are shown in Table 17 page 112 and illustrated in Figure 16-A, page 113. The mean monthly NO_2^--N values for the lake stations ranged from 1.8 μgl^{-1} in November 1988 to 20.3 μgl^{-1} in September 1988. There was a sharp increase of NO_2^--N mean values between August and September 1988 and then decreased sharply from 20.3 μgl^{-1} to 6.9 μgl^{-1} in October 1988. This value declined further to the lowest value of 1.8 μgl^{-1}, which was near its detection limits in November, 1988, thereafter the NO_2^--N mean monthly values remained fairly constant up to the end of the study.

Ammonia-nitrogen (NH_3-N) mean monthly values ranged from 0.04 μgl^{-1}, a value near the limit of detection in September 1988, to 31.0 μgl^{-1} in December 1988, a value indicating a remarkable increase in the NH_3-N levels. The first four months from July to October 1988, had NH_3-N mean values which were low, followed by a dramatic increase of NH_3-N levels in November 1988, then to a maximum value in December 1988 followed by a steady decline up to the end of the study as shown in Table 17 page 112 and illustrated in Figure 16-B, page 113.

The concentration of dissolved nitrogen (DN) showed a steady increase to a maximum value of 1.8 mgl^{-1} in September 1988, followed by a fairly rapid decrease in values, throughout the study period. The mean value of DN for the whole study period was 1.2 mgl^{-1} as shown in Table 17, page 112 and illustrated in Figure 16-D, page 113.

Particulate nitrogen (PN) mean monthly values were consistently lower than DN values over the whole study period. Except for the relatively high PN mean value recorded in August, 1988 (1.6 mgl^{-1}), all the other months recorded lower values with a range of 0.2 mgl^{-1} in December 1988 to 0.5 mgl^{-1} in January 1989 as shown in Figure 16-E, page 114. The ratio of DN to PN values ranged from 1.0 to 5.0.

The total nitrogen (TN) mean monthly values ranged from 0.8 mgl^{-1} in December 1988 to 3.2 mgl^{-1} in August 1988. There was a considerable increase of TN values in August 1988 followed by a decrease to a minimum value (0.8 mgl^{-1}) in December 1988. Thereafter, the TN values increased gradually as shown in Figure 16-C, pages 113. The mean value of TN for the whole study period was 1.6 mgl^{-1}.

Phosphorus

The data for phosphorus compounds are shown in Table 17 page 112 and illustrated in Figure 16-F to I, pages 114-115.

The soluble reactive phosphorus (SRP) concentrations reached a maximum value (0.13 mgl^{-1}) in August 1988 and thereafter, there was a general decline in levels with the exception of a secondary peak of 0.13 mgl^{-1} in January 1989 (Figure 16-F, page 114). The mean values for SRP for the whole study period was 0.11 mgl^{-1} .

The range of dissolved phosphorus (DP) was from 0.12 mgl^{-1} in the months of October, November and December 1988 to 0.15 mgl^{-1} in August 1988. The seasonal variation of DP mean values were very similar to those of SRP in all aspects except that the DP values were higher.

Particulate Phosphorus (PP) concentration reached a maximum of 0.02 mgl^{-1} in August and thereafter levels generally decreased, with the exception of a secondary peak in December 1988 as shown in Figure 16-I, page 115. The mean value of PP over the study period was 0.013 mgl^{-1}.

The range of total phosphorus (TP) for the study period was from 0.11 mgl^{-1} in February and march 1989 to 0.17 mgl^{-1} in August 1988. The TP concentration reached a maximum in August 1988 and then declined to a low value in November 1988. The TP mean values reached a secondary peak of 0.15 mgl^{-1} in

January, 1989 (Figure 16-H, page 114). The TP mean value over the study period was 0.14 mgl^{-1}. There was a similarity in seasonal variations between the phosphorus parameters as they all showed a maximum value in August 1988 and a secondary one in January 1989.

Nutrient ratio (TN/TP)

Considerable variation in TN/TP ratios occurred during the study period as indicated in Table 17, page 112 and illustrated in Figure 16-J, page 115. The TN/TP ratio peaked in August 1988 (18.9) and declined sharply to a minimum of 5.8 in December 1988, a low value that was followed by a substantial increase in the ratio towards the end of the study period. This latter increase would appear to be mainly due to a fall in total phosphorus values during the period, January - March, 1989.

Table 17: Monthly Variations of nutrients mean values for the whole Lake Stations combined.

Parameter		Month/Year									
		July 1988	August 1988	September 1988	October 1988	November 1988	Decmeber 1988	January 1989	February 1989	March 1989	Mean Values
NO^{-}_{2}-N	($\mu g l^{-1}$)	-	6.5±3.1	20.3±10.2	6.9±4.5	1.8±0.7	2.3±1.2	1.9±0.7	2.5±0.5	2.1±0.6	5.5±5.9
NH_3-N	"	0.2±0.3	0.1±0.1	0.04±0.03	1.2±1.4	15.3±21.8	31.1±1.3	29.6±17.5	25.5±26.0	-	16.06±16.14
DN	"	0.9±0.2	1.6±0.3	1.8±0.5	1.7±1.3	0.8±0.3	0.6±0.1	0.6±0.1	-	-	1.15±0.49
PN	"	0.4±0.2	1.6±1.7	0.5±0.4	0.5±0.2	0.3±0.1	0.2±0.1	0.5±0.6	-	-	0.54±0.46
TN	"	1.3±0.2	3.1±1.8	2.1±1.5	2.2±1.5	1.1±0.4	0.8±0.1	1.1±0.6	1.4±0.8	1.3±0.9	1.61±0.71
SRP	"	0.12±0.03	0.13±0.02	0.13±0.02	0.11±0.01	0.10±0.01	0.11±0.01	0.13±0.004	0.09±0.009	0.08±0.008	0.11±0.02
DP	"	0.14±0.03	0.15±0.02	0.14±0.02	0.12±0.02	0.12±0.01	0.12±0.01	0.14±0.04	-	-	0.13±0.01
PP	"	0.12±0.004	0.021±0.02	0.014±.005	0.01±.003	0.012±.006	0.015±.006	0.01±.005	-	-	0.013±.004
TP	"	0.15±0.03	0.17±0.10	0.15±0.02	0.13±0.02	0.13±0.01	0.14±0.01	0.15±0.01	0.11±0.02	0.11±0.01	0.14±0.02
TN:TP RATIO		10.2±3.8	19.6±10.6	13.9±2.7	17.3±10.2	8.7±2.6	5.8±10	7.2±4.0	12.4±5.5	12.1±9.8	11.9±4.3

— Analysis not done, thus data not available.

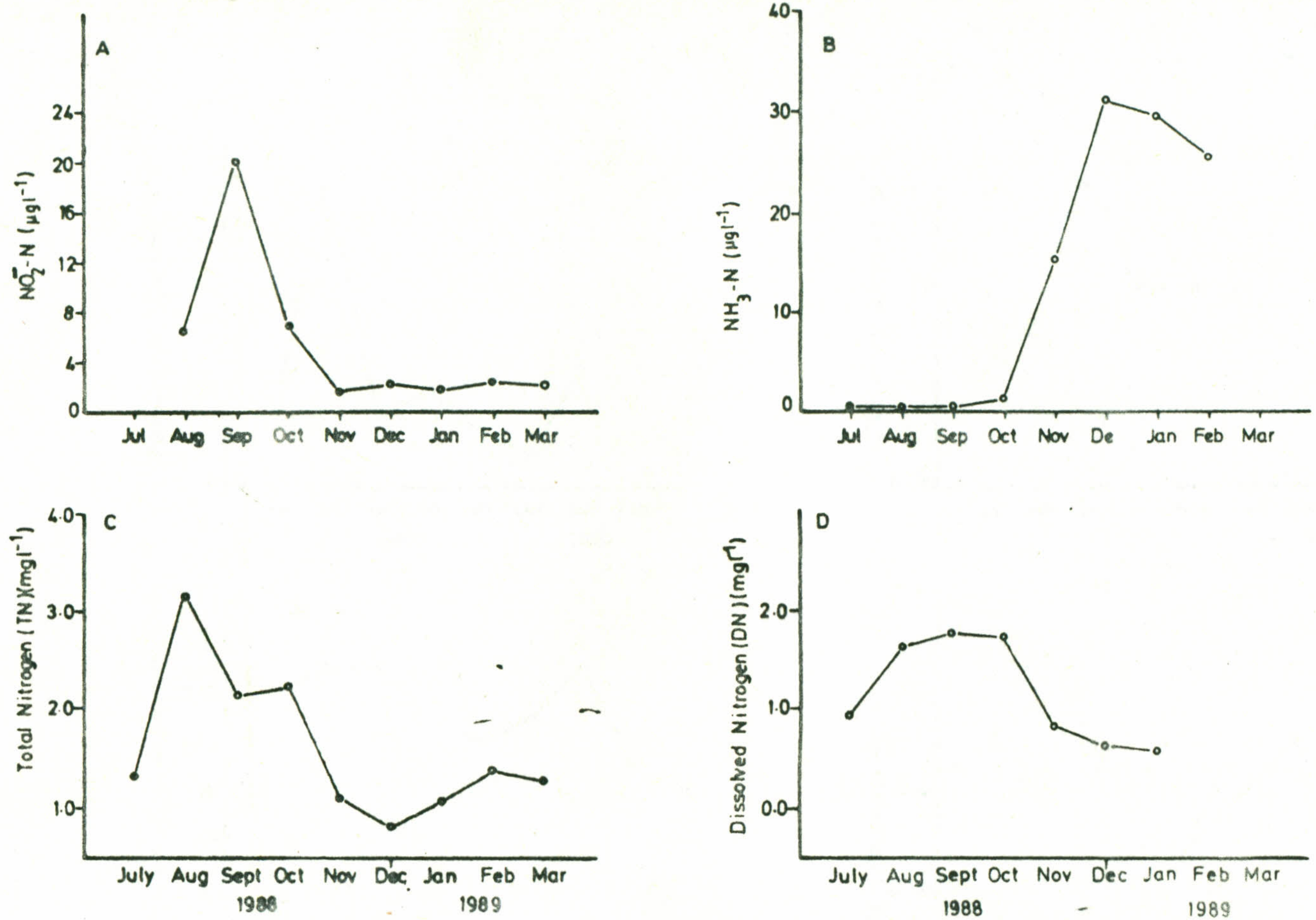


Figure 16: Monthly variations of nutrients mean values for the whole Lake Stations combined.

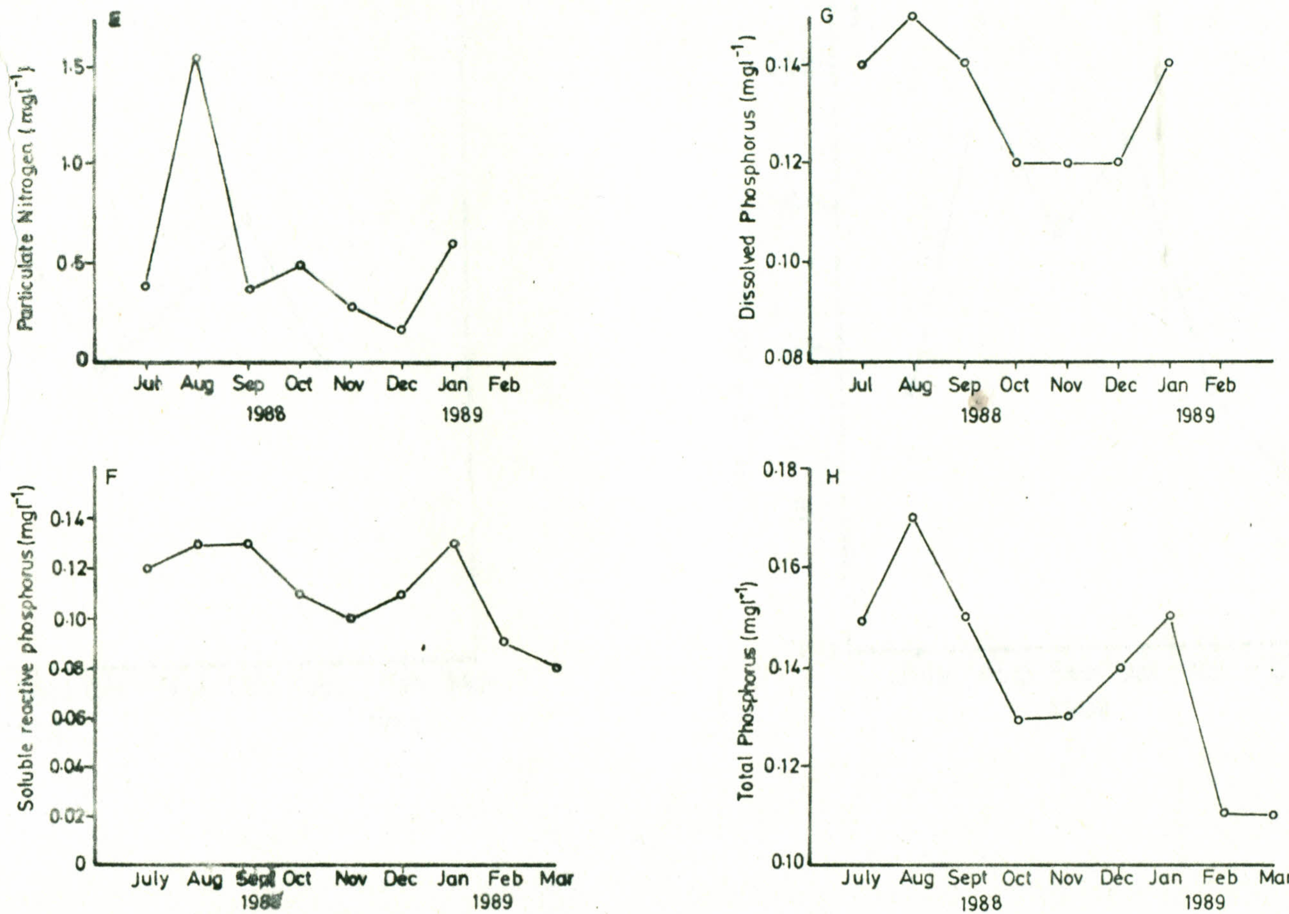


Figure 16 (Continued)

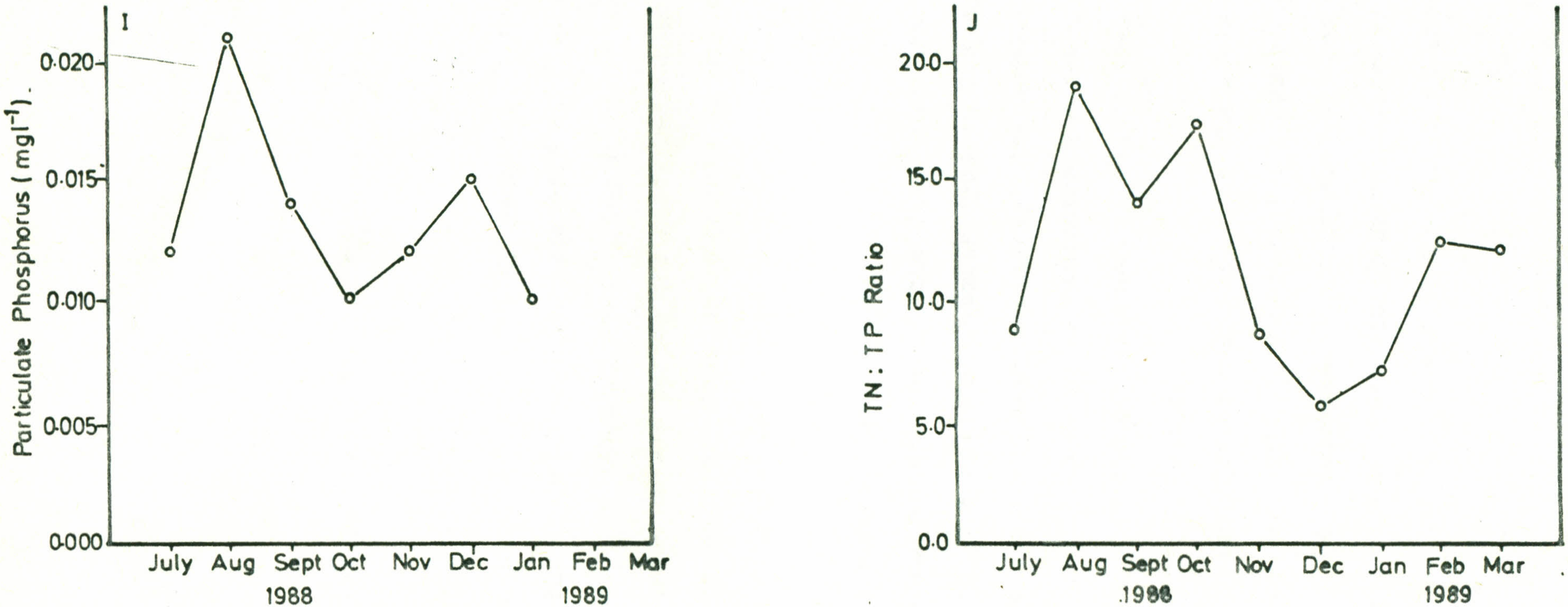


Figure 16: (Continued)

Non-nutrients

4.5.3. Non-metals (Anions, Cl^-, F^-, SO_4^{2-} and SiO_2).

The results for anions are shown in Table 18, page 118 and illustrated in Figure 17-A to D, page 119. The mean monthly values for chlorides ranged from 25.8 mgl^{-1} in August 1988 to 50.0 mgl^{-1} in January, 1989. There was a general increase in chloride levels during the study period as shown in Figure 18-A, page 119. This would likely be due to the river impacts during the wet months of July 1988 and August 1988, the river having lower Cl^- values of 17.8 and 10.6 mgl^{-1} in July and August 1988, respectively.

The fluoride concentrations in the lake over the study period ranged from 3.5 mgl^{-1} in November 1988 to 6.3 mgl^{-1} in July 1988. The fluoride mean value over the whole study period was 4.9 mgl^{-1}. The fluoride concentration trend tends to follow conductivity changes as shown in Figure 17-A, page 107 and Figure 17-B, page 119.

The sulphate values for Lake Baringo over the whole study period ranged from 18.1 mgl^{-1} in December 1988 to 23.0 mgl^{-1} in July 1988. The sulphate concentrations decreased significantly from July 1988 to December 1988 and it thereafter declined up to the end of the study as shown in Figure 17-C, page 119.

The concentrations of molybdate reactive silica (MRS) increased to a maximum (40.1 mgl^{-1}) in November 1988 and thereafter declined up to the end of the study. The range of MRS mean monthly values were from 19.3 mgl^{-1} in September 1988 to 40.1 mgl^{-1} in November 1988. The overall mean monthly value of MRS over the whole study period was 29.0 mgl^{-1}, as shown in Table 18, page 118 and also illustrated in Figure 17-D, page 119.

Table 18: Monthly variations of anions (Cl^-, SO_4^{2-}, F^-, SiO_2^- in all the lake stations combined in Lake Baringo.

PARAMETER / MONTH/YEAR	CHLORIDE $Cl^-(mgl^{-1})$	FLUORIDE $F^-(mgl^{-1})$	SULPHATE $SO_4^{2-}(mgl^{-1})$	MOLYBDATE REACTIVE SILICA (mgl^{-1})
JULY 88	30.0±16.8	6.3±1.0	23.1±8.1	-
AUG. 88	25.8± 9.0	5.8±1.1	18.9±4.4	23.4±6.1
SEPT 88	43.6± 4.3	4.5±0.4	18.4±1.8	19.3±2.5
OCT. 88	41.6±8.0	4.2±0.5	18.2±2.5	32.5±8.2
NOV. 88	45.8±2.1	3.5±0.3	18.1±1.0	40.1±2.6
DEC. 88	43.4±1.2	4.8±0.5	18.1±1.3	37.5±2.1
JAN. 89	50.0±4.2	4.1±0.4	19.8±1.2	21.1±1.6
FEB. 89	-	5.0±0.6	19.1±1.4	-
MAR. 89	-	5.8±0.4	18.9±2.2	-
X	40.0±8.1	4.9±0.9	19.2±1.5	29.0±8.1

- Analysis not done, thus the data are not available.

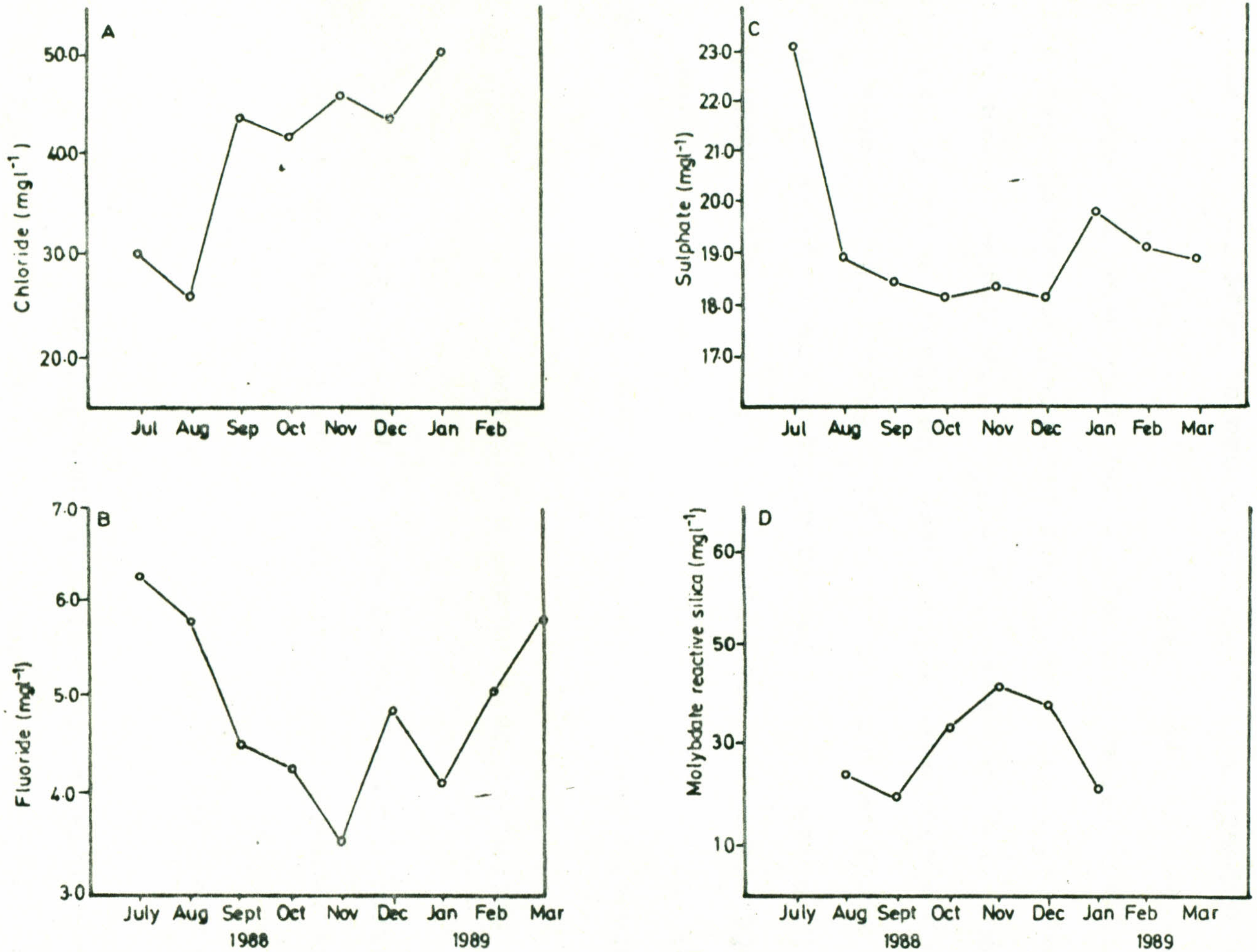


Figure 17: Monthly Variations of anions Cl^-, SO_4^{2}, F^-, SiO_2 in all the Lake Stations combined in Lake Baringo.

It is noticeable that non-nutrients (anions) do not have the August 1988 and the January 1989 peaks as do the nitrogen and phosphorus parameters with the possible exception of sulphate.

4.5.4. Metals

The results for metals are shown in Table 19, page 123 and illustrated in Figure 18 A-H, pages 124-125.

Total hardness, calcium and magnesium

Total hardness concentrations are reported in this study as mgl^{-1} of $CaCO_3$. The range of the mean monthly values of total hardness was from 39.0 mgl^{-1} in October 1988 to 55.5 mgl^{-1} in March 1989. The total hardness mean value over the whole study period was 48.1 mgl^{-1} (Figure 18 - A, page 124).

The calcium mean values over the study period for the lake stations combined was 11.6 mgl^{-1}. The highest mean monthly calcium value (13.2 mgl^{-1}) was recorded in August 1988 whilst the lowest value (9.8 mgl^{-1}) was recorded in October 1988 (Figure 18 -B, page 124).

The magnesium concentrations had a range from 3.2 mgl^{-1} in November 1988 to 5.1 mgl^{-1} in September 1988, with an overall mean value of 4.4. mgl^{-1} for the whole lake during the study period.

Total hardness, calcium and magnesium had fairly high values in August/September 1988, low values in October 1988 followed by an increase over the rest of the period as shown in Figures 18-A, B and C, page 124 respectively.

Sodium, Potassium, Aluminium, Iron and Manganese.

The results for the above metals are shown in Figure 18-D to H, pages 124-125 respectively. The range of sodium mean monthly values were from 137.1 mgl^{-1} in August to 178.1 mgl^{-1} in July 1988 while potassium had values with a range from 11.1 mgl^{-1} (November 1988) to 21.5 mgl^{-1} (July 1988). There was a significant drop in the sodium mean values in August 1988 and a slight increase from December 1988 to the end of the study period. The potassium concentrations seasonal trend tend to follow the changes of conductivity values shown in Figure 15-A, page 107. Sodium and potassium had mean values of 158.6 mgl^{-1} and 14.6 mgl^{-1}, respectively, for the study period. Maximum values were recorded in July 1988 in all cases for the metals, with a subsequent reduction in concentration giving rise to the low values in the September - November period with the exception of aluminium.

The aluminium mean monthly values ranged between 7.3 - 12.8 mgl^{-1} with July 1988 having the highest value. The aluminium mean values varied considerably throughout the study period, the values decreased from July to September and then it the values decreased from July to September and then it increased to a value of 11.9 mgl^{-1} in November 1988, thereafter declined to a minimum value of 7.3 mgl^{-1} in March, 1989. There was a significant similarity between the trends of silica (Figure 17-D, page 119) and that of aluminium concentration (Figure 18-F, page 125). The mean value of aluminium concentration over the study period was 10.5 mgl^{-1}. Iron concentrations over the study period for the whole lake combined, ranged between 4.5 mgl^{-1} in January 1989 and 12.1 mgl^{-1} in July 1988 as shown in Figure 18-G, page 125. The mean value for iron over the study period in Lake Baringo was 7.0 mgl^{-1}. There was a considerable decrease of iron mean values from July to September 1988. This decrease could have been caused by the dilution effects of the rivers and rainfall.

The highest mean monthly value for manganese (0.60 mgl^{-1}) was recorded in July 1988 and the lowest was (0.18 mgl^{-1}) observed in December 1988 and January, 1989. There was a considerable decrease of manganese mean value from 0.52 mgl^{-1} in September to 0.25 mgl^{-1} in October 1988, after which the value remained constant until November, 1988 as shown in Figure 18-H, page 125. There was a general decrease of manganese values from July 1988 to January 1989. This possibly could be due to dilution effect of the rain and river discharge into the lake.

Table 11: Variations in mean values per station of selected metals in Lake Baringo over the study period.

PARAMETER / MONTH/YR	TOTAL HARDNESS (Mgl^{-1} as $CaCO_3$)	Ca^{2+} (mgl^{-1})	Mg^{2+} (mgl^{-1})	Na^{+} (mgl^{-1})	K^{+} (mgl^{-1})	Al^{3+} (mgl^{-1})	Fe^{3+} (mgl^{-1})	Mn^{2+} (mgl^{-1})
JULY 88	-	-	-	178.1±52.3	21.5±3.5	12.8±3.3	12.1±7.4	0.60±0.10
AUG. 88	51.4±5.8	13.2±2.1	4.5±2.3	137.1±52.1	17.5±3.0	10.6±3.4	6.8±2.5	0.50±0.20
SEPT.88	53.7±2.0	13.2±2.6	5.1±1.4	160.8±12.4	13.7±1.3	10.3±1.8	5.7±1.4	0.52±0.40
OCT. 88	39.0±4.6	9.8±1.8	3.5±0.8	150.4±15.4	12.7±1.1	11.5±1.2	7.6±2.1	0.25±0.06
NOV. 88	42.3±2.9	11.5±1.4	3.2±0.9	142.4±21.4	11.1±1.0	11.9±2.3	6.7±1.8	0.25±0.05
DEC. 88	48.1±4.7	11.1±0.9	5.0±1.4	161.3±15.5	11.9±1.6	11.5±0.7	6.8±1.5	0.18±0.03
JAN. 89	44.5±2.4	10.8±1.2	4.3±0.9	165.9±11.2	13.5±0.6	7.8±0.9	4.5±2.4	0.18±0.05
FEB. 89	50.0±2.0	11.7±0.8	5.0±0.6	164.4±7.2	-	-	-	-
MAR. 89	55.5±2.4	-	-	166.9±8.9	-	7.3±0.8	6.1±1.6	0.32±0.20
$\overline{X}$	48.1±5.4	11.7±0.8	4.4±0.7	158.6±12.2	14.6±3.4	10.5±1.8	7.0±2.1	0.35±0.16

- Analysis not done, thus data not available.

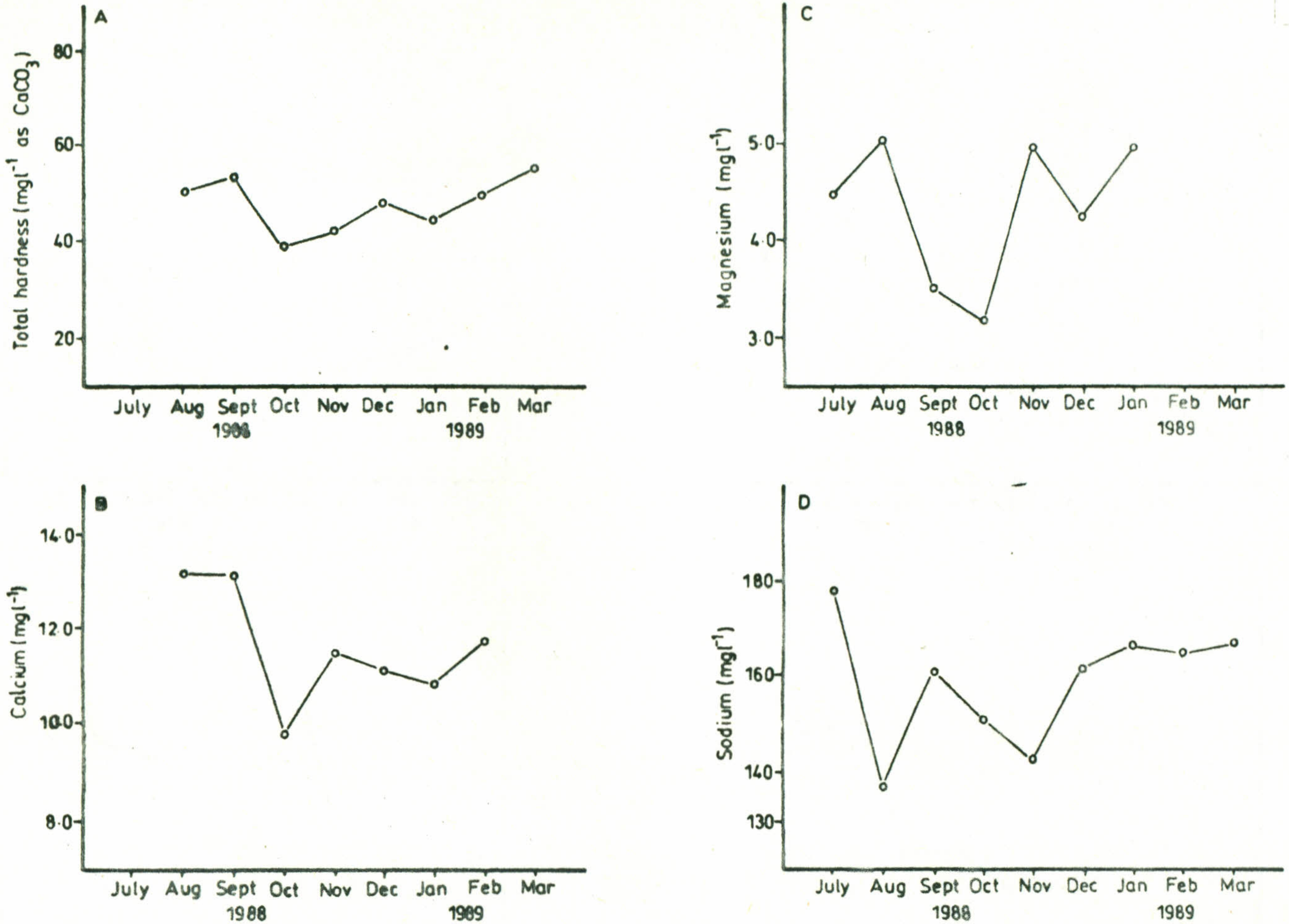


Figure 18: Monthly Variations of mean values of metals in all the Lake Stations combined.

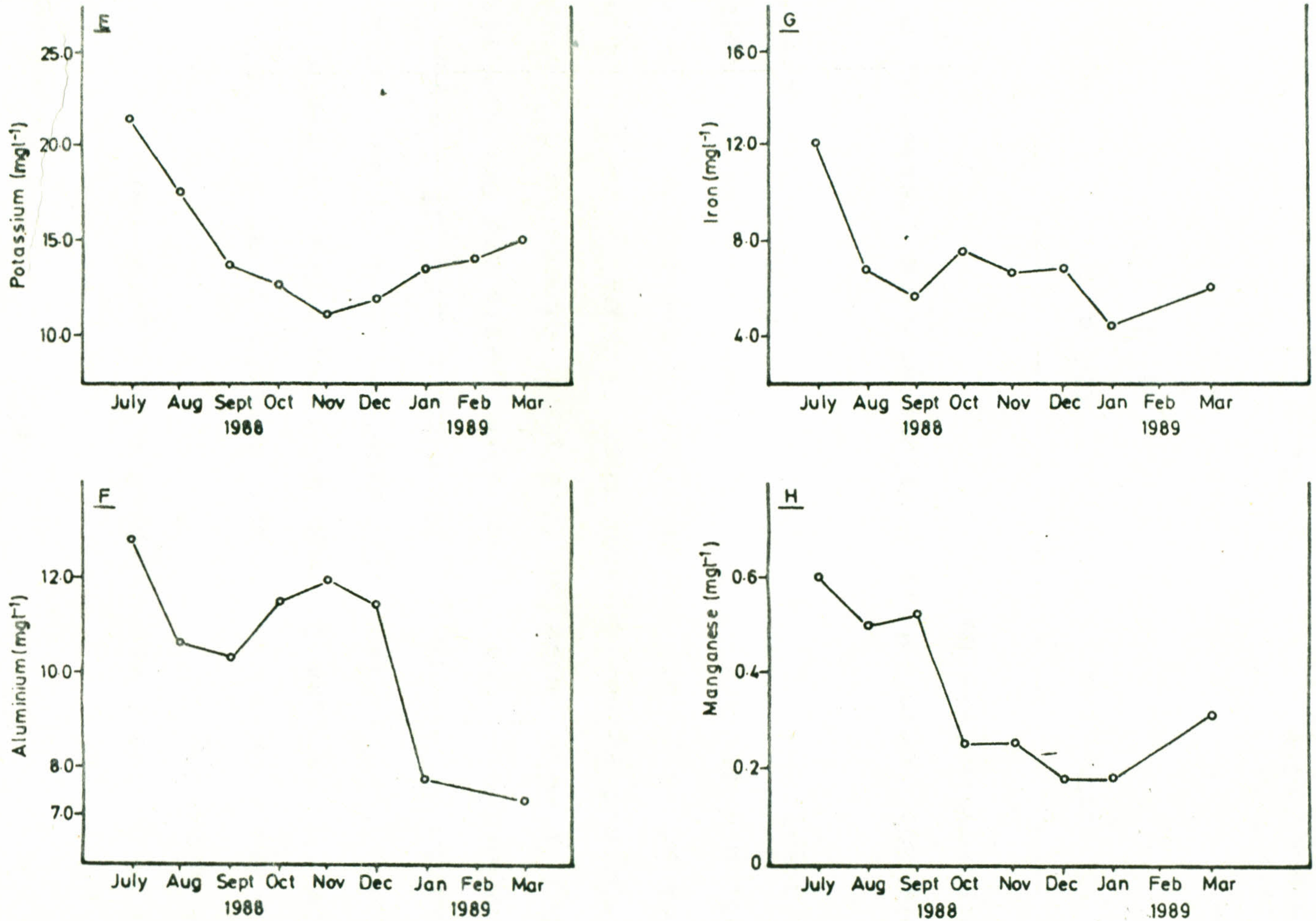


Figure 18: (continued)

4.5.5 Seasonal Variation of a biological parameter

Chlorophyll a

There was a considerable monthly variation in chlorophyll a levels in Lake Baringo as shown below in Table 20, and illustrated in Figure 19, page 127. The lowest Chl a value occurred in November, 1988 with a value of 9.5 $\mu g l^{-1}$ which coincided with the highest lake levels and October 1988 had a Chl a mean value of 11.3 $\mu g l^{-1}$, otherwise all the other months had values greater than 12.0 $\mu g l^{-1}$. A chlorophyll a value of 13.0 $\mu g l^{-1}$ was recorded in the months of September 1988, and January, 1989. The highest mean monthly value for Chl a was 14.8 $\mu g l^{-1}$ and this was recorded in December 1988.

Table 20: Chlorophyll a values showing (seasonal) monthly Variation in Lake Baringo.

Month/ Year	Chl a ($\mu g l^{-1}$)
July 1988	-
August 1988	12.0±4.7
September 1988	13.0±6.9
October 1988	11.3±5.7
November 1988	9.5±1.9
December 1988	14.8±4.3
January 1989	13.0±6.3
February 1989	12.9±9.5
March 1989	11.5±6.7
Mean Value	12.2±1.6

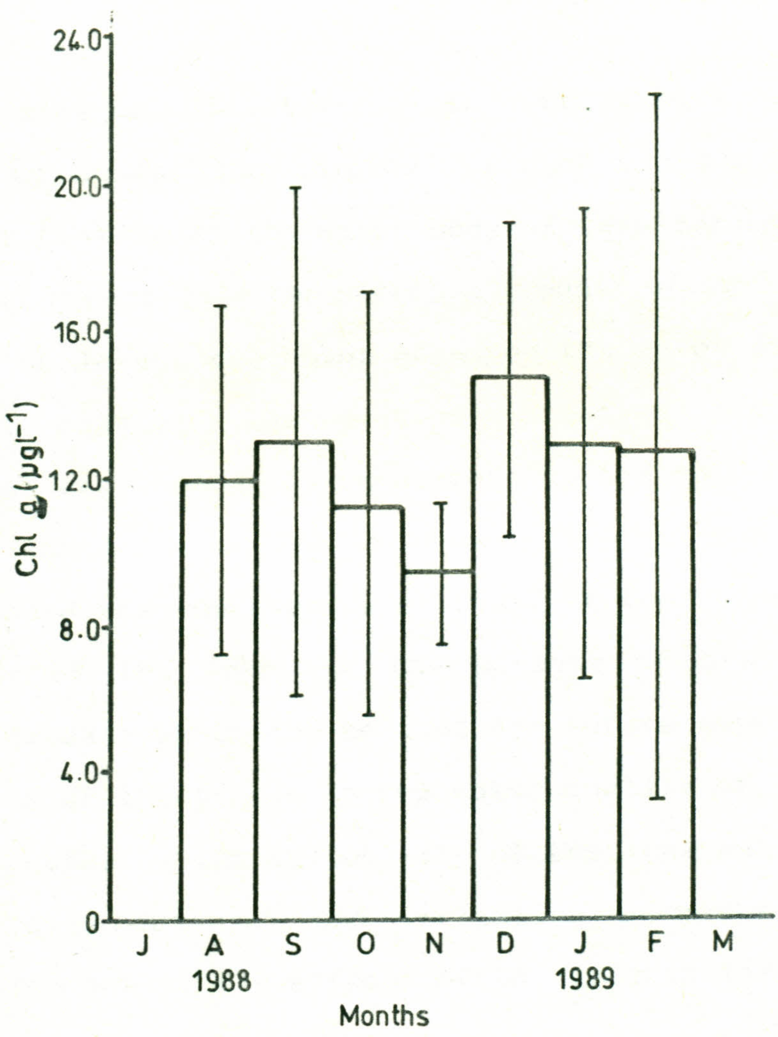


Figure 19: Seasonal (Monthly) Variations of Chlorophyll a Levels in Lake Baringo (July 1988 - March 1989)

CHAPTER 5

DISCUSSION AND CONCLUSION

The aims and objectives of this study were four-fold:

i. to assess the physico-chemical and biological characteristics of the water body of Lake Baringo.

ii. to investigate the potential impact of soil erosion from the lake's catchment areas on the water quality.

iii. to determine the relationship between the physico-chemical and biological parameters of the main inflowing rivers and those of the water body of the lake. This data could then be used as an index of the current water quality of the lake for the purpose of providing baseline data which can be used for future comparative purposes of the trends in the water quality of the lake.

iv. assessing the suitability of the lake water for domestic, industrial and irrigation purposes and assessing the likely effects of the aquatic life in Lake Baringo and it surrounding.

The results of this study will be discussed in the light of the above mentioned aims and objectives. The discussion will begin with a statement of the climatological characteristics of Lake Baringo's basin, then the current water quality of the lake including the comparison of these results and those obtained in previous studies on Lake Baringo and other East African lakes (e.g. Naivasha, Victoria, Turkana, Nakuru and Bogoria). The discussion on the geographical variation, the seasonal variation and, finally the river influence on the lake water quality including chemical status of the hot springs will be undertaken.

5.1.1 Climate

The total rainfall recorded at Kiserian during the study was 610 mm and this was higher than that recorded annually for the Baringo basin (600 mm of rain per year). The rainfall measured excluded the long rain period of April and May, of the year. Relatively the rainfall value was higher than previously recorded values, as reported in Baringo Development Plan, 1985. The rains around Lake Baringo came in storms and there was alot of rain in the last week of July, 1988 and in early August 1988. The rainfall caused alot of changes in the lake e.g. the water level increased dramatically and brought in a lot of silt through the rivers into the lake.

The difference between the maximum and minimum temperatures for Lake Baringo (Kiserian) were substantial in that the lowest temperature recorded was 17.0 ^{0}C whilst the maximum temperature was 37.4 ^{0}C. These temperature differences show that the Baringo basin can become very hot in the day and turns relatively cold at night. The minimum and maximum temperatures are correlated with rainfall, with the highest maximum temperatures being recorded in the dry months and vice-versa. The average daily temperature for Baringo basin was between 25.3 °C and 30.7 °C.

The humidity of the lake basin (Kiserian) was quite low due to the hot dry surroundings, with humidity values as low as 45.8%, being recorded in the dry months and increasing to over 70% in the rainy season. The low humidity around the lake encouraged high evaporation rates of the lake water as observed by Kilham (1979) in Lake Nakuru.

From the study, Lake Baringo basin and its surrounding can be described as hot, dry and not humid. This has a profound effect on the water level due to the much higher evaporation rates.

5.1.2 Water Level Changes in the Lake

The water level changed significantly during the study period, rising by over 1.80 metres in the first four months of the study. There was a correlation between depth and rain with a correlation coefficient of -0.756. This was the case because there was a delayed effect of rainfall on the water level, this also was the case with the combined flow rate of the rivers. This can be observed in Figure 20, page 132 where there was high rainfall at the beginning of the study though the level of the lake took time to rise. The flow of the rivers could have been much higher had the values of Perkerra River been included in the month of August, 1988. The water levels increased with both the rainfall and the increased river flow rates. However, there was a delayed effect as observed in Figure 20, page 132 which shows the variation of depth, rainfall and flow rate with time. There was a general fluctuation of lake levels in Lake Baringo, which is normally common in most shallow African lakes situated in semi-arid areas (Carmouze 1976, Melack, 1976 and 1979, Gaudet et al 1980 and Gaudet et al 1981). Suggestions that Rift Valley lakes including Baringo might be drying up have been made recently. The data for Lake Baringo does not support these suggestions, but indicates that the variation in Lake levels is more concerned with climatic and seasonal variations. These fluctuations in water levels are brought about by unreliable weather conditions (e.g. rainfall) in the catchment areas and the high evaporative rates in the basin. The other factor which affects the water depth could be the sediments from the severely eroded Baringo basin.

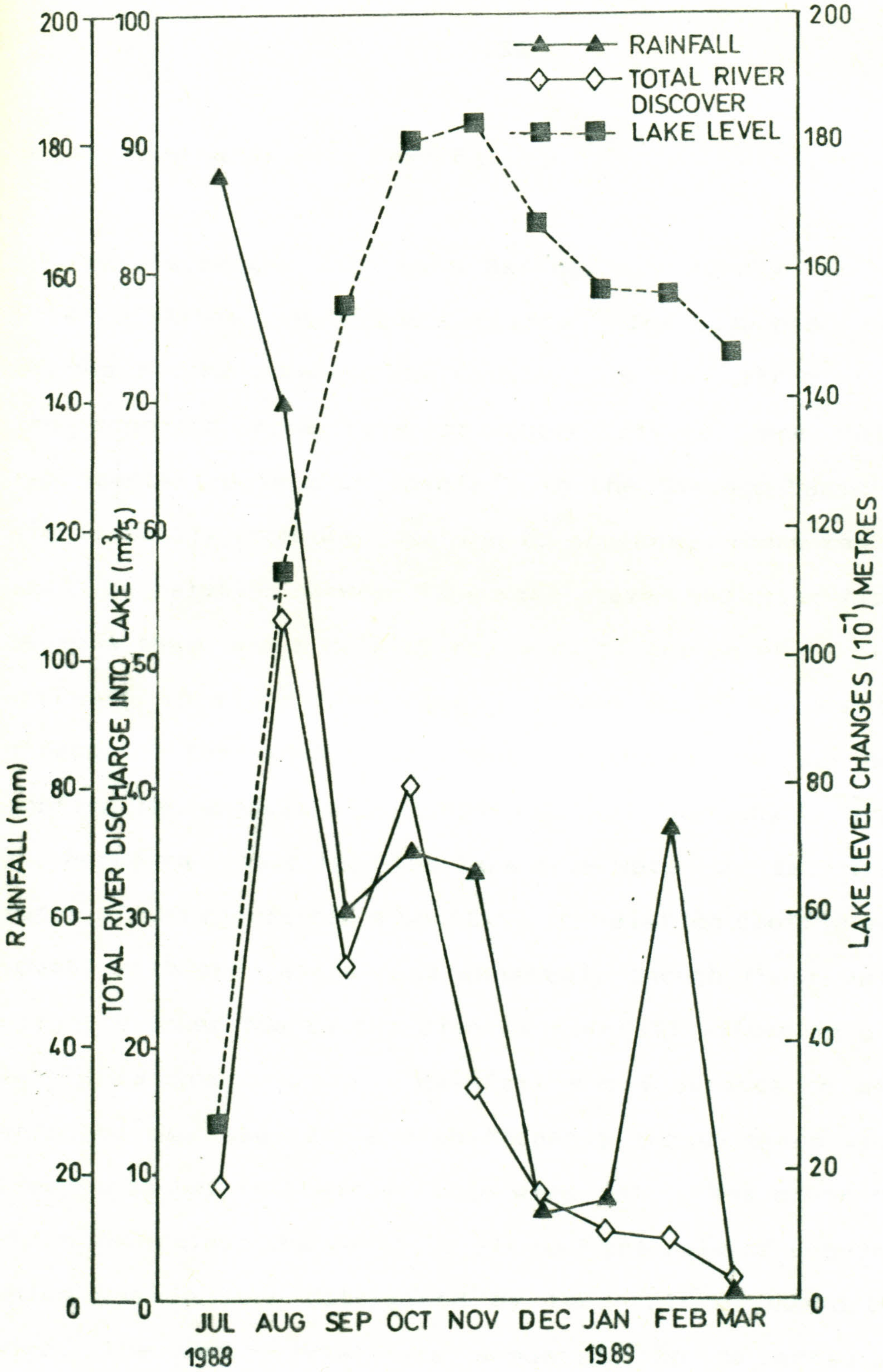


Figure 20: Monthly Variations of Rainfall at Kiserian, Total River Discharge into Lake, and the Water level change in Lake Baringo.

5.1.3 Discharge Into Lake Baringo

The discharges into Lake Baringo are mainly through the River Ol-Arabel, Molo and Perkerra. The combined flow rate of the rivers depended on rainfall in the catchment areas. The combined flow rate of these rivers were not very representative in that rainfall in the Baringo basin varies significantly from one location to another. There was a very small correlation between lake water level and river flow rate because there was a delayed response of the water level to an increase in river flow rate. This could be due to the effects of the swamp at the southern end of the lake and may confirm the suggestion by Beadle (1932) that the Rivers Molo and Perkerra waters feed the lake from water tables. The flow rates of the rivers had a positive correlation coefficient (r= +0.45) with the rainfall as expected, though the r value is slightly lower due to the diverse rainfall values in all the lake's catchment areas. Rainfall and flowrates in general affected the lake levels significantly though there was some time lapse before their effects were felt. The other factor which determined the water levels was the rate of evaporation which was in turn determined by temperature, humidity and wind. The water level was suspected to be affected by underground seepage of lake water through faults at the northern end of the lake as suggested by Beadle (1932).

5.2 CURRENT STATUS OF LAKE BARINGO AND ITS ASSOCIATED RIVERS

The grand summary data for the chemical and physical parameters in Lake Baringo and its associated rivers are shown in Table 21, pages 137-138 and Table 22, pages 139-140.

The water temperature of lake Baringo was moderately high (25.7 ^{0}C). This temperature facilitated the decomposition process of organic material in the lake. There was no thermal stratification in the lake meaning that there was total mixing of the lake except during very calm days, when the surface water had temperatures above 30.^{0}C (Kiplagat, personal communication). The conductivity mean value for the lake water was 793 μScm^{-1}, which was much higher than the mean values for the rivers combined, 294 μScm^{-1}. The total alkalinity for Lake Baringo was recorded to be 396.5 mgl^{-1} (HCO_3^-) and consisted mainly of HCO_3^- and CO_3^{2-} ions. The dissolved oxygen values of 6.7 mgl^{-1} was recorded and this would support aquatic life sufficiently.

The nutrient levels in the lake were fairly high with TN recording 1.6 mgl^{-1} and TP recording 0.14 mgl^{-1}, and were comparable to the levels obtained in the rivers. The conclusion that can be reached here is that most of the nutrients come into the lake via the rivers. The N/P ratios and Chl a values shows that Lake Baringo does not suffer from eutrophication and that the lake is slightly phosphorus limiting because of the N/P ratio being slightly higher than 10:1.

The major anions in Lake Baringo are the HCO_3^-, CO_3^{2-}, Cl^- and SO_4^{2-}. The carbonate and bicarbonate make up the major anions with concentration of more than 396.5 mgl^{-1} (HCO_3^-) but the rivers had much lower values.

The fluoride concentration for the lake was high (4.9 mgl^{-1}) and was far in excess of that recommended by World Health Organization in 1984 for human consumption in that the levels were much higher than the 1.0 mgl^{-1} limit set by World Health Organization. The Mukutan river also had a high fluoride concentration of 3.5 mgl^{-1} and this was a big problem to the inhabitants of Mukutan village who use this water for domestic consumption and most of whom had dental fluorosis. The silica levels were also high in the lake probably due to the large quantities of silicates brought in by the silt into the lake via the rivers.

Sodium was the major cation in the lake, river and hot springs. The mean sodium concentration in the lake was 158 mgl^{-1} while the rivers had a mean value of 50.4 mgl^{-1}. In contrast, the hot springs had sodium values in excess of 800 mgl^{-1}. The other major cations include calcium (11.2 mgl^{-1}), magnesium (4.1 mgl^{-1}), potassium (14.2 mgl^{-1}), aluminium (10.4 mgl^{-1}) and iron (6.9 mgl^{-1}). The high aluminium and iron levels could be due to the silt in the water column and also iron and aluminium silicates which generally tend to release these metals into solution or water column. The aluminium concentrations (10.mgl^{-1}) in the lake were very high compared to those set by World Health Organization on aluminium levels in drinking water. Aluminium causes environmental health problems when taken at a concentration above 0.2 mgl^{-1} limit set by World Health Organization (1984). The manganese levels were quite low with a mean value of a mean 0.34 mgl^{-1}, which was expected as manganese concentrations in the environment are generally low. This is because manganese is needed at trace levels by biological life.

The major problem affecting Lake Baringo is the high levels of suspended silt which causes low light penetration as indicated by the low Secchi depth values (less than 6 cm) and the high turbidity values of 780 NTU for the lake and over 1100 NTU for the rivers during the rainy periods.

The silt is kept suspended in the water column either by electrical properties of the silt colloids or by the clay components in the silt. The low light penetration restricts the algal composition in the lake to those that can move to the surface, thus, the diversity of phytoplankton is restricted. The chlorophyll a values for Lake Baringo are moderate with values of 12.2 μgl^{-1}. The lake is not very productive with values of 3.8 g, O_2 M^2/day (Kiplagat, personal communication). Except for the rather high aluminium, fluoride and turbidity values of the lake water, the Lake Baringo water is of good quality for domestic use and aquatic life.

Table 21: The Overall summary of the physico-chemical, chemical and biological status of Lake Baringo during the study period.

The data in this table hides much of the variation that occur between stations, months and seasons.

Means and standard deviations for all data at all stations in Lake Baringo.

Parameter (UNITS)	Study Mean	Standard Deviation
Water Temp. (^0C)	25.7	-
Conductivity (μScm^{-1})	793.0	6.5
pH	8.6	-
Total Alkalinity (mgl^{-1}, HCO_3^-)	396.0	31.0
Dissolved Oxygen (mgl^{-1})	6.7	0.4
Turbidity (NTU)	780.0	46.0
Secchi depth (cm)	< 6	-
NO^-_3-N (μgl^{-1})	20.7	3.3
NO^-_2-N (μgl^{-1})	5.5	1.8
NH_3-N (μgl^{-1})	18.2	12.9
DN (mgl^{-1})	1.2	0.3
PN (mgl^{-1})	0.44	0.29
TN (mgl^{-1})	1.6	0.2
SRP (mgl^{-1})	0.11	0.01

Table 21 (Continued)

DP (mgl^{-1})	0.13	0.01
PP (mgl^{-1})	0.006	0.004
TP (mgl^{-1})	0.14	0.01
N/P ratio	12.0	2.0
Cl^- (mgl^{-1})	41.3	3.2
F^- (mgl^{-1})	4.9	0.3
SO_4^{2-} (mgl^{-1})	19.1	1.9
Silica (mgl^{-1})	28.9	2.3
Total Hardness (mgl^{-1}, $CaCO_3$)	47.6	4.0
Calcium (mgl^{-1})	11.2	2.0
Magnesium (mgl^{-1})	4.1	1.1
Sodium (mgl^{-1})	158.6	16.1
Potassium (mgl^{-1})	14.2	0.9
Aluminium (mgl^{-1})	10.4	1.1
Iron (mgl^{-1})	6.9	1.0
Manganese (mgl^{-1})	0.34	0.04
Silt content (mgl^{-1})	500.0	-
Chlorophyll <u>a</u> (μgl^{-1})	12.2	3.6

* Study mean refers to the mean of all data for all stations combined over the whole study period for the lake.

Table 22: Study means and standard deviation values for all data for the combined river stations (R_1, R_2, R_3, and R_4).

Parameter (UNITS)	Study Mean	Standard Deviation
Conductivity (μScm^{-1})	294.0	140
pH	7.8	-
Total Alkalinity (mgl^{-1}, HCO_3^-)	158.6	79.3
Turbidity (NTU)	1101.0	-
NO_2^--N (μgl^{-1})	2.8	1.4
DN (mgl^{-1})	1.3	0.4
PN (mgl^{-1})	0.57	0.31
TN (mgl^{-1})	1.9	0.5
SRP (mgl^{-1})	0.06	0.02
DP (mgl^{-1})	0.07	0.02
PP (mgl^{-1})	0.028	0.010
TP (mgl^{-1})	0.10	0.02
N/P ratio	18.5	1.9
Cl^- (mgl^{-1})	17.1	3.3
F^- (mgl^{-1})	1.4	1.2
SO_4^{2-} (mgl^{-1})	7.7	1.9
M.R.SiO_2 (mgl^{-1})	30.0	5.0
Total hardness (mgl^{-1}, $CaCO_3$)	31.5	8.3
Ca^{2+} (mgl^{-1})	7.8	2.4
Mg^{2+} (mgl^{-1})	3.1	1.0
Na^+ (mgl^{-1})	50.4	32.2
K^+ (mgl^{-1})	7.3	1.6
Al^{3+} (mgl^{-1})	2.4	0.8
Fe^{3+} (mgl^{-1})	2.2	0.9
Mn^{2+} (mgl^{-1})	0.24	0.09

5.2.1 THE IONIC BALANCE

Table 23: The ionic balance of Lake Baringo's water during the study period.

All concentrations of cations and anions are expressed as $meql^{-1}$

Cations	meql	Anions	$meql^{-1}$
Na^{+}	6.896	CO_3^{2-}, HCO^{-}_3	6.500
K^{+}	0.364	Cl^{-}	1.163
Ca^{2+}	0.560	SO_4^{2-}	0.390
Mg^{2+}	0.342	SiO_2^{-}	0.482
Al^{3+}	1.156	PO_4^{3-}	0.004
Fe^{3+}	0.246	F^{-}	0.258
Mn^{2+}	0.012	NO_2^{-}	0.000
NH_4^{+}	0.001	NO_3^{-}	0.002
$\sum$ Cations =	9.577	$\sum$ Anions =	8.799

The percentage error in the ionic balance for lake Baringo's water was:

$$\frac{\sum \text{Cation} - \sum \text{Anion}}{\sum \text{Cation}} = \left(\frac{9.577 - 8.799}{9.577} \right) \times 100$$

Percentage error = 8.12%

The percentage difference between the cations and the anions could be due to some minor ions which were not investigated. However ionic balance within 10% is generally acceptable for this type of study, especially in water of relatively high conductivity.

5.3 COMPARISON OF DATA FROM PREVIOUS STUDIES AND THE PRESENT STUDY.

The results of the previous studies by Beadle (1932), Jenkins (1936), Talling and Talling (1965) and Kallqvist (1980) are shown in Table 24, page 144. The physico-chemical, chemical and biological status of Lake Baringo fluctuates as climatic conditions in its catchment areas change. The reported physico-chemical results on Lake

Baringo by Beadle (1932) and Jenkins (1936) involved very few parameters. Thus for instance Jenkins analysed only for pH (9.0) and total alkalinity (640.5 mgl^{-1}, HCO_3^-), the values being rather high showing that the lake levels were either low or that the lake had more ions in its water relative to the present study where pH and alkalinity values of 8.6 and 396.5 mgl^{-1} (HCO_3^-) were recorded respectively. Contrary to the Jenkin's data, Talling and Talling (1965) recorded much lower values for most parameters (e.g. conductivity 416 μScm^{-1}, sodium 95 mgl^{-1}, alkalinity 268.4 mgl^{-1}, HCO_3^- and potassium 13.0 mgl^{-1}) whereas the present study had slightly high values for all these parameters as shown in Table 21, page 137. This implies that the lake level must have been high during the period of sampling by Talling and Talling after the heavy rains of 1961 in Kenya, thus the lake was much more dilute and the lake level much higher than in the present study.

The investigation by Kallqvist (1980) was more elaborate in that it analysed for more physico-chemical parameters than in the studies of Beadle, Jenkins and Talling. Kallqvist recorded values which were comparable to those obtained in this study although with slight variations. Kallqvist (1980) reported slightly lower conductivity values during the (1976-1978) period of 762 μScm^{-1} while a value of 793 μScm^{-1} was recorded in the present study. Sodium concentrations were also slightly lower for the 1976-78 period with a value of 155.5 mgl^{-1} where as a value of 158.6 mgl^{-1} was recorded in the

1988-89 period. Most of the other parameters were slightly lower in the Kallqvist study.

The physico-chemical status of Lake Baringo changes according to climatological conditions and depends on the water level in the lake. It is also very difficult to compare the data collected by Beadle (1932), Jenkins (1936), Talling and Talling (1965) and Kallqvist (1980) in that the samples used were obtained by spot sampling and the sampling sites were also not indicated. Spot sampling does not guarantee that the sample is representative of the whole lake. Thus a comparison as such is not very easy in that Beadle, Jenkins, Talling and Kallqvist used only one or two samples obtained from spot sampling to record their values. None of the previous studies gave either seasonal or geographical variations in the water quality status of the lake, whilst the present study was designed to achieve.

Table 24: The Previous Data reported by Beadle (1932), Jenkins (1936), Talling and Tallings (1965) and Kallqvist (1980)

Parameter	Beadle 1932	Jenkin 1936	Talling & Talling 1965	Kallqvist 1980	Present Study (1988-89)
Conductivity (μScm^{-1})	-	-	416	762	793
pH	8.7-8.8	9.0	-	8.2	8.6
Turbidity (NTU)	-	-	-	528	780
Manganese (mgl^{-1})	-	-	-	0.47	0.34
Ca^{2+} (mgl^{-1})	22.0	-	11.6	2.6	11.20
Mg^{2+} "	2.0	-	3.15	4.5	4.1
Na^{+} "	126.0	-	95.0	155.5	158.6
Total Hardness (mgl^{-1} as $CaCO_3$)	-	-	-	41.5	47.6
Total Alkalinity as mgl^{-1}, HCO_3^-	355.5	640.5	270.8	244.4	396.5
Cl^- (mgl^{-1})	36.0	-	-	57.5	41.3
F^- (")	-	-	-	2.4	4.9
SRP (")	0.6	-	-	0.275	0.11
TDS (")	-	-	-	80.0	-
Sechi depth (cm)	-	-	-	<7	<6
Chl *a* (ugl^{-1})	-	-	-	30.0	12.8
K^+ (mgl^{-1})	15.0	-	13.0	15.0	14.2
SiO_2^- "	18.2	-	-	-	28.9
SO_4^{2-} "	40.0	-	-	-	19.1

5.4 COMPARISON BETWEEN THE CHEMICAL STATUS OF LAKE BARINGO AND SOME EAST AFRICAN RIFT VALLEY LAKES (NAIVASHA, VICTORIA, NAKURU, BOGORIA AND TURKANA)

This comparison entails comparing the current physico-chemical status of Lake Baringo which is a freshwater lake with other freshwater lakes in Kenya (Naivasha, Victoria and Turkana) and a few saline water lakes e.g. Nakuru and Bogoria. The data showing the comparison for the above mentioned lakes are shown in Table 25, page 149.

Lakes Naivasha and Victoria are freshwater lakes in East Africa due to their low salinity and low ionic content as reported by Gaudet and Melack (1981) and Foxall et al (1984) respectively. Lake Turkana has moderate salinity and has freshwater fauna as reported by Yuretich and Cerling (1983). Lake Baringo water had much higher ionic content than the freshwater lakes (Naivasha and Victoria) but lower than those of Lake Turkana as shown in Table 25, page 149.

There was a substantial difference between the levels of the physical parameters in fresh water lakes Naivasha, Victoria, Baringo and Turkana and the saline Lakes Nakuru and Bogoria. Lakes Naivasha and Victoria recorded very low values in conductivity of 328 μScm^{-1} and 86 μScm^{-1}, respectively whilst lake Baringo had a slightly higher conductivity value of 793 μScm^{-1}, but Lake Turkana had the highest conductivity value of over 3000 μScm^{-1}. These conductivity values were in total contrast to those recorded in the saline Lake Nakuru (162,500 μScm^{-1}) and Bogoria (72,000 μScm^{-1}). The pH values for Lakes Naivasha and Baringo were in the same range. Lake Victoria recorded a lower pH value of 7.55 whereas the saline lakes had pH values above 9.5 as shown in Table 25, page 149. Lake Turkana had slightly higher values than Lake Baringo in all the parameters, indicating that it has more ionic content than Lake Baringo as indicated by its conductivity, pH and alkalinity values. In fact the chemical composition of Lake Turkana water is similar to those of the hot springs found on the Kokwa islands (Table 32, page 206).

There was also a difference in nutrient richness in all the lakes considered with the saline lakes having the highest nutrient levels than all the fresh water lakes. Lake Baringo had rather high PO_4-P and TP concentrations of 0.11 and 0.14 mgl^{-1} respectively. Hecky and Kilham (1973) recorded a TP value of 0.122 mgl^{-1} for the very saline Lake Nakuru, while Foxall <u>et al</u> (1984) recorded a much lower value for Lake Victoria of 0.048 mgl^{-1}. On the other hand the recorded values of nitrates show that Lake Baringo had a very low nitrate concentration of 20.8 μgl^{-1} whilst Lakes Naivasha and Victoria had values of 50 and 100 μgl^{-1} respectively.

Lakes Naivasha and Victoria are freshwater lakes with low salinity as evidenced by the data in Table 25, page 149. However, Lake Turkana had slightly higher ionic content than

Lake Baringo. It could be fair to compare the biological productivity (primary) of these lakes, as they had a comparable salinity range. The saline lakes are very productive as reported by Vareschi (1978), Talling et al (1973), Melack and Kilham (1974) and Melack (1981). Reported productivity studies show that Lakes Naivasha (Njuguna, 1982) and Victoria (Melack, 1976) are more productive than Lake Baringo. The difference could be due to the very low light penetration in Lake Baringo which limits the number of thriving algae to those capable of floating on the water surface. The productivity of Lake Victoria was recorded to be 6.8g O_2/M^3, Day (Melack, 1976), Lake Naivasha, 3.5g O_2/M^3, Day (Njuguna, 1981) and Kallqvist reported a value of 1.2g/M^3 for Lake Baringo, whilst a value of 3.8g O_2/M^2, day was recorded during the present study (Kiplagat, personal communication).

Chlorophyll a values for Lake Baringo was recorded to be 12.3 μgl^{-1} while the two lakes Naivasha and Victoria had values of 21 and 15 μgl^{-1} respectively. The major factor to these differences in primary productivity and chl a values in the three lakes could be the nutrient content in the lakes and the differences in Secchi depth or light penetration for which Lake Victoria has 2.8 metres (Foxall et al 1984), Lake Naivasha 1.0 metres (Melack, 1981) and less than 6 cm for Lake Baringo in the present study. The conductivity range for Lake Baringo might also restrict the algae that can be found in the lake as compared to the other lakes as shown by Melack (1988) for Lake Elmenteita.

The sodium values for Lakes Naivasha and Victoria were much lower e.g. 45.1 mgl^{-1} and 4.1 mgl^{-1} respectively, whereas the potassium levels were 22.6 mgl^{-1} and 2.5 mgl^{-1} respectively. The sodium level (concentration) in Lake Baringo was much higher with a value of 158.6 mgl^{-1} during the 1988-89 period.

The saline lakes Nakuru and Bogoria had very high Cl^-, So_4^{2-}, Na^+ and K^+ concentrations. The main anions in these saline lakes were the HCO_3^- and CO_3^{2-} ions as shown by their very high alkalinity values (Table 25, page 149). Lakes Naivasha and Victoria on the other hand had low Cl^-, So_4^{2-}, Na^+ and K^+ whilst Lake Turkana had slightly higher levels of these ions than Lake Baringo with the exception of Calcium and Magnesium levels. The fluoride levels were twice as much in Lake Turkana (9.7 mgl^{-1}) as in Lake Baringo (4.9 mgl^{-1}) as reported by Yuretich <u>et al</u> (1983).

TABLE 25: DATA FOR COMPARISON OF SOME RIFT VALLEY LAKES: NAIVASHA, VICTORIA, TURKANA, NAKURU, BOGORIA, AND BARINGO

LAKE	Cond (μScm^{-1})	pH	Alkalinity (mgl^{-1} HCO^-_3)	NO^-_3-N (μgl^{-1})	PO_4-P (mgl^{-1})	TP (mgl^{-1})	Cl^- (mgl^{-1})	SO_4^{2-} (mgl^{-1})	Ca_4^{2+} (mgl^{-1})	Mg^{2+} (mgl^{-1})	Na^+ (mgl^{-1})	K^+ (mgl^{-1})	SiO_2 (mgl^{-1})	F^- (mgl^{-1})
NAIVASHA Talling and Talling (1965)	328	7.7	3.4	50	-	0.90	15.2	10.3	15.2	6.9	43.0	22.1	22.1	-
VICTORIA Winam Gulf (Foxall 1984)	135	8.2	0.61	96	2.5	0.48	7.5	-	-	-	9.1	2.5	-	0.19
VICTORIA Main Lake (Foxall 1984)	84	7.55	0.23	100-109	4.8	0.48	-	-	-	-	4.1	1.5	-	0.00
TURKANA Yerutich & Cerling 1984)	2900-3200	9.2	19.5	-	-	-	445.9	40.6	4.6	2.3	753	19.9	19.8	9.7
NAKURU Hecky and Kilham 1984	162500	9.8	1440	-	-	13.6	13000	1800	-	0.9	38000	1321	730.0	129
BOGORIA Tuite 1981	72000	10.2	1500	-	33	-	3450	204	26.0	-	14360	304	26.0	1060
BARINGO Present Study 1988-1989	793	8.6	6.5	20.8	0.11	0.14	41.8	19.0	11.2	4.1	158.6	14.2	28.6	4.9

- Analysis not done, thus data not available.

The above data are from the following sources: Talling and Talling (1965), Melack and Kilham (1974), Hecky and Kilham (1973) and Tuite (1978), Foxall (1974), Njuguna (1981) and Yeretich and Cerling (1983).

5.5 VARIATIONS BETWEEN THE STATIONS FOR ALL THE DATA DURING THE STUDY PERIOD (GEOGRAPHICAL VARIATION)

The results to be discussed in this section include the mean concentrations of parameters per station over the whole study period as shown in the tables in Chapter 4. Since this is a discussion of the variation between the different stations together with the fact that the stations are arranged in a S-N transect, it is important to show the extent of the effects of the river effluent or outfall at station L_1 along the transect to station L_6. This discussion is further divided into three sub-sections; physical-chemical, nutrients and the non-nutrients.

5.5.1 Physico-Chemical Parameters

Station L_1 had lower levels than all the other stations in the S-N transect with respect to all the physico-chemical parameters investigated. This was due to the dilution effects of the Rivers Molo and Perkerra on station L_1. The influence of the rivers at station L_1 extended to station L_2, a distance of 2.25 kilometres. Station L_6 on the other hand had the highest values in all the parameters except for turbidity and

DO values. Station L_7 due to the urban influence at Kampi ya Samaki had slightly higher turbidity and DO than the other lake stations with values of 850 NTU and 7.3 mgl^{-1} respectively. The high DO values recorded at station L_7 could be due the high nutrient levels at the site, from sewage. The high nutrient levels at the site (Station L_7) caused some increase in the algal content, which culminated in increased DO at the station due to the production of Oxygen during photosynthesis.

Station L_8 also experienced the dilution effect from the Mukutan River as shown by its lower values although the Mukutan River also had lower volume of water. The river mean conductivity value was highest in River Mukutan (502 μScm^{-1}) and lowest in River Perkerra (131 μScm^{-1}). Thus the water which flowed into station L_8 was more mineralised than those flowing into station L_1, the same applied to pH and alkalinity as it concerned the dilution effects of the rivers. The dissolved oxygen concentrations varied according to the extent of mixing of the water at that particular station and also the algal distribution in the lake. The rivers affected the lake significantly, lowering the levels of the physical parameters significantly at the southern end of the lake and this influence decreased along the S-N transect as shown by conductivity measurements taken along the transect from Station L_1 to L_6 as illustrated in Figure 21, page 153 and shown in the Table in the Appendix 44-46 pages 264-266. This shows that conductivity values in Lake Baringo increased from station L_1 to L_6 for all the conductivity measurements along the S-N transect in August 1988, September 1988 and February 1989. The conductivity values in the open water and the northern end of the lake from stations L_3 to L_7 were as expected, considerably higher than those near the river mouths (Stations L_1, L_2 and L_8). The conductivity, pH and alkalinity mean values in Lake Baringo followed the same trends along the S-N transect as shown in Figure 8, page 71. The physical parameters except for DO, peak at station L_6 showing that there was a marked geographical variation, increasing from the southern end of the lake (Station L_1) to the northern end of the lake (Station L_6). Station L_7 possibly had some urban influence due to the growing town of Kampi ya Samaki, thus giving fairly high conductivity and DO mean values at the site. This urban influence may have counteracted the dilution factor expected at station L_7 due to close proximity of station L_7 to L_1 than say station L_6. There was a marked geographical variation within Lake Baringo with respect to the physical parameters, and the rivers having the most impact on the lake due to their dilution effects. Urban influence on the lake could be present but does not affect the physical status of the water quality of the lake significantly at present, possibly due to the smallness of Kampi ya Samaki. The DO concentrations in the lake water depended mainly on aeration from the atmosphere during wind mixing of the lake.

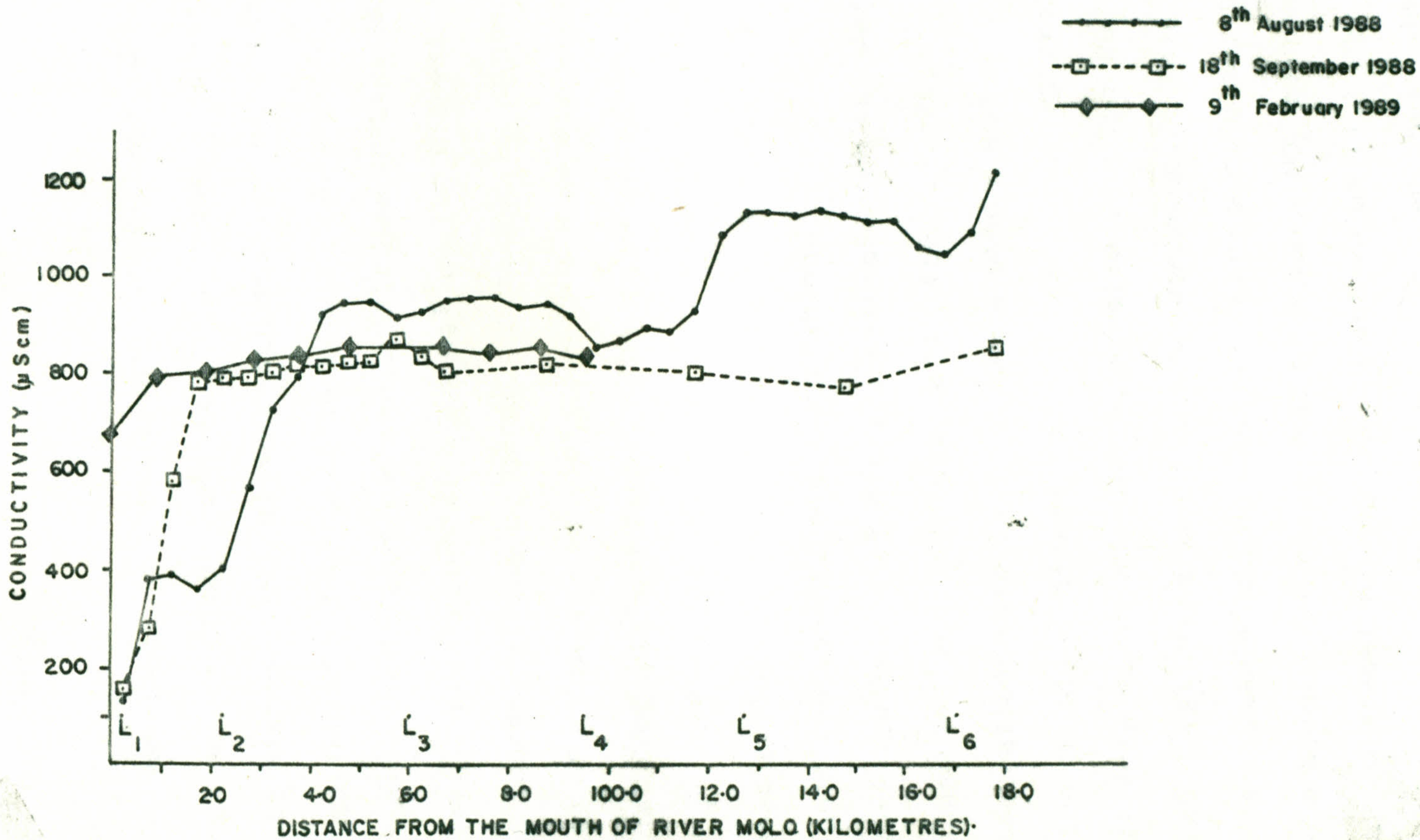


Figure 21: Conductivity changes of surface water of Lake Baringo from the mouth of River Molo through station L_1, L_2, L_3, L_4, L_5, L_6.

5.5.2 Nutrients

The variation in the levels of the nutrients in lake Baringo were rather complex. The mean concentrations of nitrate-nitrogen (NO_3-N) for each station are shown in Table 7, page 78 and illustrated in Figure 9-A, page 80. NO_3^--N was the dominating form of inorganic nitrogen in Lake Baringo with an overall mean value of 20.8 $\mu g l^{-1}$. The highest levels of NO_3^--N concentrations occurred in station L_3, suggesting high inputs of nitrates, possibly due to sewage discharge from the tourist camp (Island camp). The NO_3^--N concentration in Lake Baringo were similar to those observed in most East African freshwater lake where nitrate-N remains below 30 $\mu g l^{-1}$ but had a significant geographical variation.

Very low levels of nitrite-nitrogen (NO_2^--N) were observed throughout Lake Baringo and its rivers. Nitrite-N concentrations were lower at the southern end of the lake due to the dilution effects of the inflowing rivers which had relatively lower NO_2^--N concentrations. The NO_2^--N had the lowest level among the nitrogen compounds. This is because NO_2^- is unstable and is usually rapidly oxidised to the more stable NO_3^--N. The rivers had much lower NO_2^- mean values, with River Ol-Arabel having the lowest value (1.1 $\mu g l^{-1}$). Levels of NO_2^--N in Lake Baringo were, however, near the detection limits.

Ammonia-nitrogen (NH_3-N) concentrations in Lake Baringo were low with mean values ranging from 10.0 - 18.5 μgl^{-1} with an overall mean value of 14.1 μgl^{-1}. There was a significant geographical variation of NH_3-N levels in Lake Baringo. This variation of NH_3-N values could be due to differences in geographical distribution of biological life which excrete NH_3 (aquatic animals) and those that take it e.g. phytoplankton and other aquatic plants as reported by (Toetz, 1971). Thus the actual amount of NH_3-N present at any one time at a particular station will depend on the balance between animal excretion rates, plant uptake, and bacterial oxidation of ammonia.

Dissolved nitrogen (DN) concentrations varied significantly in the lake stations with the station (L_1 and L_8)near the river mouths having the lowest DN values though the rivers had relatively high DN values as shown in Table 8, page 79.

The level of biological activity determines the levels of DN in the lake water as the DN can be taken in or excreted by biological life as nutrients (McCarthy, 1972,; Carpenter, 1969). The DN mean value over the whole lake was 1.2 mgl^{-1}, which was much higher than the particulate nitrogen (PN) mean value (0.6 mgl^{-1}). Except for station L_7 which had a high PN mean value (1.2 mgl^{-1}) possibly due to urban influence of Kampi ya Samaki, all the other stations had fairly similar PN values. The overall mean values of PN concentrations was relatively high (0.4 mgl^{-1}) and this could be due to the high silt content in the lake water column. The DN and PN values in the rivers were comparable to those in the lake, thus the major source of DN and PN concentrations in Lake Baringo could be the river inflows.

The total nitrogen (TN) values for Lake Baringo varied from 1.5 mgl^{-1} to 1.9 mgl^{-1} with station L_7 near Kampi ya Samaki having the highest TN value. This shows that due to the urban (Kampi ya Samaki) sewage waste being drained into the lake, the nutrient levels rose in this part of the lake. Station L_6 on the other hand had a low TN value (1.5 mgl^{-1}) as there is no river nutrient inputs at this station and aquatic organism could have uptaken the nutrients and others could have settled in the sediments. There was much fluctuation of TN mean values along the S-N transect in the lake. The main source of TN in Lake Baringo could be the rivers which had elevated mean values as shown in Table 8, page 79. The high TN values compared to the sum of the inorganic form of nitrogen (NO_3^--N, NO_2^--N and NH_3-N) suggests that over 95% of the nitrogen available in Lake Baringo occurred in organically bound form.

Phosphorus compounds analysed in Lake Baringo included soluble phosphorus (SRP), dissolved phosphorus (DP), particulate phosphorus (PP) and total phosphorus (TP). The levels of SRP was lowest at station L_1 because of the dilution effect of the River Molo and Perkerra. Except for the high SRP mean value at station L_8 (0.14 mgl^{-1}) and a low value at station L_1 (0.09 mgl^{-1}) all the other stations had similar SRP mean values over the whole lake.

The DP and TP mean values seem to have the same geographical variation trends as SRP except that stations L_6 and L_7 had rather high DP values. Station L_1 was diluted by the rivers and station L_8 on the other hand had a much higher DP and Tp because of the inputs of the nutrient rich River Mukutan (0.13 mgl^{-1}), with a value comparable to that recorded at station L_3 (0.14 mgl^{-1}). Upwelling and release of phosphorus under low oxygen level in the sediments by water turbulence in Lake Baringo could be the cause of the elevated phosphorus values in the lake. Further agricultural development based on the addition of fertilizers without due consideration of soil conservation measures in the river's catchment areas is likely to increase the phosphorus content in the lake water. The phosphorus levels in Lake Baringo were low, resulting in low productivity in the lake as obtained by Kallqvist (1980) and Kiplagat (personal communication).

Particulate phosphorus (PP) concentrations were low in Lake Baringo and decreased along the south-north transect with the two southernmost station L_1 and L_2 having the highest PP mean value. Station L_7 on the other hand had the lowest PP mean value. The high PP mean values at the southern end of the lake confirm that the highest percentage of PP are brought in by the Rivers Molo and Perkerra which carry alot of silt.

Nutrient ratios

There was a considerable spatial variation in the nitrogen-phosphorus ratio (N/P) as shown in Figure 9-K, page 81. The N/P ratios calculated for the stations in the lake ranged from 10.2 to 13.7 and from 15.3 to 20.0 in the rivers. There was a very marked geographical variation in the N/P ratios within the study area. Lake Baringo nutrient ratios indicate that phosphorus was the likely algal growth limiting factor for the major part of the study as it had ratios of N/P greater than 10. The N/P ratio of 10 was given as the limit for either a lake or a river to be termed either as phosphorus or nitrogen limiting in terms of algal growth (Foxall et al, 1984). Except for station L_4 with a N/P mean ratio of 9.4 thus making it nitrogen limiting in algal growth, all the other stations in Lake Baringo could be termed as phosphorus limiting in relation to algal growth.

5.5.3 Non-Nutrients (Anions: Cl^-, F^-, SO_4^{2-} and SiO_2)

The trends in geographical variations of the conductivity values and chloride concentrations in Lake Baringo and its rivers were similar. The southern end of the lake had slightly lower chloride values due to the dilution effects of the low chloride Rivers Molo and Perkerra. The river influence along the S-N transect stretches to station

L_2. Thus chloride concentration with a mean value of 41.3 mgl^{-1} becomes a major anion in Lake Baringo beside the carbonates and bicarbonates.

The fluoride levels in Lake Baringo are relatively high and had a significant geographical variation with the southern end of the lake having the lowest value (4.2 mgl^{-1}) due to the inflow from the low level fluoride waters from Rivers Molo and Perkerra, whilst River Mukutan on the other hand had relatively high fluoride levels (3.5 mgl^{-1}).

Sulphate and molybdate reactive silica, like Cl^- and F^-, showed significant geographical variation in their mean values, despite different patterns as observed in Figure 10, page 86 for all these parameters. Except for molybdate reactive silica which seemed to have a general decrease towards the northern end of the lake, all the other three parameters Cl^-, F^-, and SO_4^{2-} generally increased along the S-N transect. The reason for this could be that the dilution effects of the rivers on the southern end of the lake do not directly stretch to the northern end of the lake. The rivers flowing in to Lake Baringo had high silica concentrations because of the high silt load of the rivers especially, Rivers Molo and Perkerra and the southern end of the lake is expected to have high silica concentrations which diminish along the S-N transect.

5.5.4 Non-Nutrients (Metals)

The geographical variation of the total hardness calcium and magnesium values were fairly similar except for small variations. Stations L_8 at the mouth of River Mukutan had the lowest total hardness and calcium concentration but had the highest magnesium levels due to the low levels of calcium and high for Mg^{2+} in the river (Table 12, page 92). There were significant fluctuations of the levels of these parameters in the lake with no clear trends being shown. Station L_4 had a rather low value yet it was not influenced by any river. The rivers at the southern end of the lake had more calcium ions than the river Mukutan. Thus, giving the reason for the higher calcium values at station L_1 than at station L_8. The magnesium levels in the lake were fairly constant despite the slight fluctuations as shown in Figure 11-C page 93. According to the classification of the water either as hard or soft using the total hardness mean values as a criteria, the Lake Baringo water can be considered as soft as its total hardness values are below 60 mgl^{-1}, $CaCO_3$, a value considered as the limit. The large difference in the river values for these parameters could be due to the different geological zones of their catchment areas.

Sodium and Potassium concentrations in Lake Baringo followed the same geographical trends as those of conductivity and alkalinity mean values which can be confirmed by the high correlation coefficients (r) between these parameters as shown below in Table 26.

Table 26: Correlation Between several abiotic parameters (Linear Regression Analysis)

	A	B	r
Sodium v Conductivity	120.3	4.25	+0.979
Sodium v Alkalinity	-48.86	31.67	+0.984
Sodium v Potassium	7.0	0.046	+0.847
Potassium v Conductivity	-153.60	66.5	+0.827
Potassium v Alkalinity	4.50	1.49	+0.856
Conductivity v Alkalinity	0.845	0.007	+0.995

The high correlation values (r) between the parameters sodium, potassium, conductivity and alkalinity show that their geographical variation are very similar and are affected to nearly the same degree by the dilution effects of the rivers. From Figure 11-D, page 93 it can be observed that the sodium mean values increase along the S-N transect just like conductivity, alkalinity (Figure 8-A, C, page 71) and potassium values, even though potassium had slight variations in its trends. The rivers originating from the Laikipia plateau, Mukutan and Ol-Arabel, had high sodium values than the rivers on the southern end of the lake. Not surprisingly, a substantial agreement exists between the geographical variation of potassium, sodium, conductivity and alkalinity levels in the lake. Linear regression analysis of sodium and potassium versus conductivity in the lake gave correlation coefficients (r) of +0.984 and 0.827 respectively.

The aluminium concentrations in Lake Baringo were rather high with a mean value of 10.4 mgl^{-1} and the geographical trend of the aluminium mean values was similar to that of iron except that their maximum values occurred at different stations. The high aluminium mean value occurred at station L_7 near Kampi ya Samaki. This high value could be due to the use of alum to purify drinking water for the residents of this small town. Thus, the high aluminium value may well be due to urban influence and also due to the suspended silt in the water column. The rivers studied had low aluminium mean values. Linear regression analysis of aluminium versus iron, molybdate reactive silica and fluoride gave positive correlation coefficients (r) or 0.58, 0.74 and 0.79 respectively.

Table 27: Linear regression analysis of selected parameters correlation coefficients (r).

	A	B	r
Aluminium v Fluoride	-1.16	2.38	+0.79
Aluminium v Iron	1.52	0.52	+0.58
Aluminium v Silica	-21.5	4.5	+0.74:

The geographical variation of iron and manganese levels in Lake Baringo were pronounced. Iron levels generally increased along the S-N transect due to the river influence which diluted the lake at the southern end of the lake as the rivers flowing into Lake Baringo had lower iron mean values than the lake water. The high iron mean values in the lake could be due to the high silt levels in the lake which had iron as a constituent. Iron and manganese levels in Lake Baringo were correlated negatively with a correlation coefficient (r) value of 0.43, meaning that as the levels of iron were increasing,the manganese concentrations or levels were decreasing. The manganese concentrations ranged from 0.30 - 0.41 mgl^{-1} over the whole lake which was a high value for manganese considering that it is needed in a water system at trace levels. The tendency of shallow lakes like Baringo to show high concentrations of iron and manganese is also known from other regions (Gorham, 1955).

Most of the parameters investigated in Lake Baringo showed marked geographical variation, with the rivers flowing into the lake at the southern end having a significant impact on the lake water quality along the S-N transect. Urban influence also appears to be having an impact on the water quality as observed at station L_7, near Kampi ya Samaki. The northern end of the lake (Station L_6) did not have any direct river influence and the levels of many parameters were higher at this station than those at the southern end of the lake.

Station L_8 on the other hand reflected on the chemical nature of River Mukutan which was more ionised than the other rivers.

5.5.5 Geographical Variation of a Biological parameter

Chlorophyll a

A marked geographical variation of chlorophyll a levels clearly existed in Lake Baringo as observed in Figure 13, page 100. The geographical variation of chl a values in Lake Baringo depended on the distribution of algae in the lake. The geographical variation of chl a levels in the lake could be due to the movement of the algae from one part of the lake to another or it could possibly be due to the difference in productivity at different sites in the lake.

Chlorophyll a is a useful index of total phytoplankton biomass in the lake but does not give information on the behaviour of the individual phytoplankton species. The main phytoplankton species recorded in Lake Baringo by Kiplagat (personal communication) was microcystis aeroginosa which floats on the lake surface and was easily transported by the waves caused by the strong winds. There was a high chl a level (20.0 μgl^{-1}) at station L_8, possibly due to the strong winds blowing towards this station from the direction of the Kokwa Island bringing floating algae to the station thus causing the elevated chl a values at the site. Large patches of floating algae could be seen at station L_6, L_7 and L_8 which explains the high chl a values at these sites.

Chlorophyll a values had positive correlation coefficients (r) with SRP (0.721) and TP (0.634) and a negative correlation coefficient (r) with N/p ratio (0.437) which was not a significantly strong correlation. Chlorophyll a values did not have any significant correlation with other parameters as shown by the low r values in Table 28, page 166. The chlorophyll a values also vary according to the dilution effects of the rivers as shown in Figure 22, page 167. This shows that the rivers have a great impact on the phytoplankton in Lake Baringo as shown by the different chl a variations at stations L_1, L_5, and L_8. The river influence on the lake can be observed from the standard deviations of Chl a values. The standard deviation values were much greater for stations L_1 and L_8 due to the influence of the rivers on the physico-chemical status of the stations near river mouths.

The degree of eutrophication in Lake Baringo varies depending on the parameter used to describe the trophic status. When algal biomass as Chlorophyll a is used to describe the trophic status, most of Lake Baringo is not eutrophic with the exception of Station L_8. The classification used is that which was developed for temperate lakes by Sakamoto (1966) and Vollenweider and Kerekes (1980). This classification used the following values as characteristics of eutrophic status: TN (1.875 mgl^{-1}), TP

(0.084 mgl^{-1}) Chl a (14.3 μgl^{-1}) and Secchi depth (2.5 metres). This classification for temperate lakes should be applied with caution since no widely agreed standards have been developed for tropical lakes.

Table 28: Summary of linear regression analyses of chlorophyll a versus nutrients and other physico-chemical parameters.

Parameter	Correlation Coefficients (r)
Chlorophyll a and oxygen	+0.005
y = 6.69 + 5.93x	
chl a and TP	
y = -21 + 247.7x	+0.634
chl a and SRP	
y = -16.00 + 255x	+0.721
chl a and N/P	
y = 24.9 - 1.04 x	-0.437
chl a and TN	
y = 40.3-0.82 x	-0.188
chl a and NO_3^--N	
y = 17.80 + 0.24x	+0.240
chl a and NH_3-N	
y=13.88 - 0.09 x	+0.240
chl a and conductivity	
y = 795 - 0.22 x	-0.341
chl a and magnesium	
y = 3.82 + 0.04x	+0.500
chl a and calcium	
y = 13.43 - 0.16x	-0.530

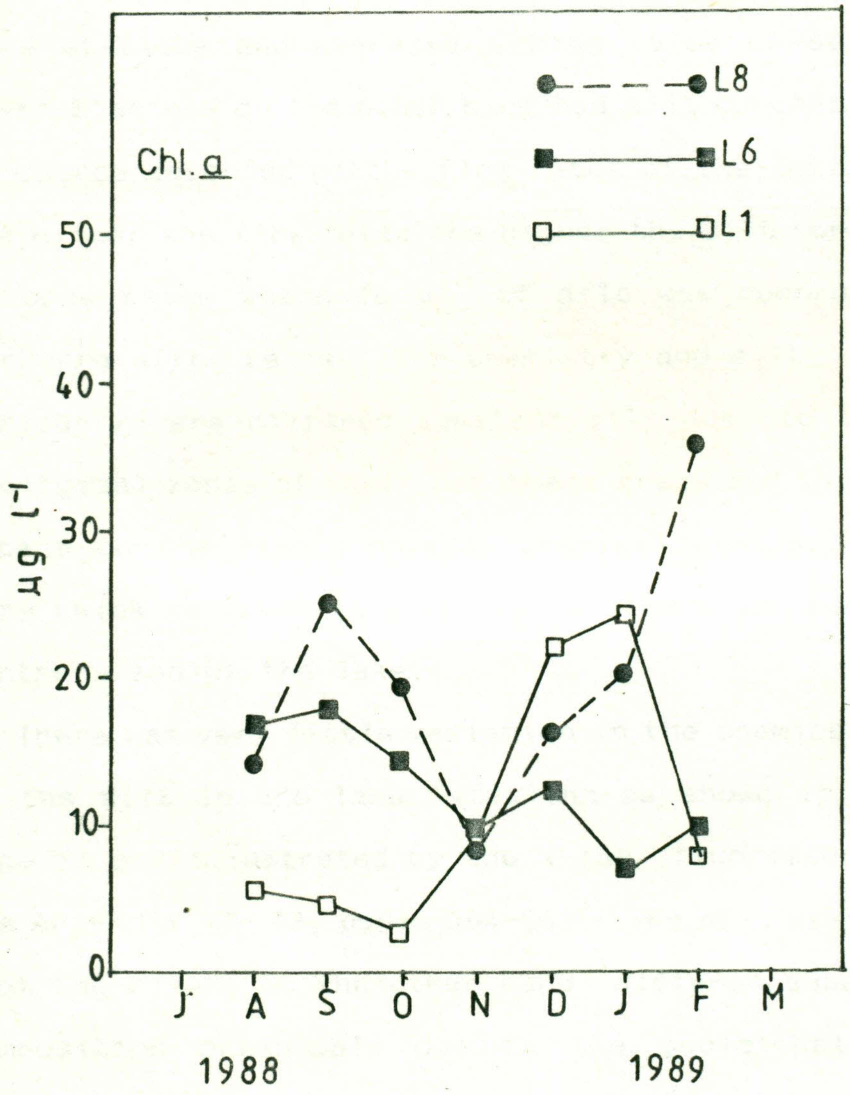


Figure 22: Monthly variation of chlorophyll a levels at stations L_1, L_6 and L_8 in Lake Baringo.

5.5.6 Suspended Silt in Lake Baringo

The suspended silt concentrations varied slightly in the lake stations and averaged a high value of 500 mgl^{-1}. The river stations on the other hand had silt concentrations which of course depended on the flow rates of the inflowing rivers. The higher the flow rates the higher the silt content as shown in some cases where 10 gl^{-1} of silt was recorded for river Perkerra after rains. The chemistry and silt content of the various rivers differed substantially due to the different geological zones of their catchment areas and this had a major impact on the lake's physico-chemical status. There was a very thick sediment layer at the southern end compared to the northern end of the lake.

There was very little variation in the chemical composition of the silt in the lake stations as shown in Table 13-A, page 97 and illustrated by the x-ray fluorescent spectra in the Appendix 34- 43, pages 254-263. The silt samples obtained from the rivers on the other hand, differed substantially in composition presumably due to the geologically different catchment areas of the respective rivers. Generally silicon, aluminium and iron formed the bulk of the suspended silt comprising over 95% of the silt for both the lake and the rivers. The major elemental component of the suspended silt is silicon which had a mean value of 56.7% for the lake and

64.6% for the rivers. The high value of aluminium (23.7%, lake and 14.7%, rivers) and iron (15.7%, lake and 14.7% rivers) suggests that the silt possibly occurs mainly as iron aluminium silicates.

River Molo had slightly different silt chemical composition with much higher silicon mean value (72.8%) and lower iron mean value (9.3%) than the other rivers which were studied. The relative proportions of the elemental components of the silt in the rivers was similar to the lake relative composition as shown in Table 13-B, page 97.

The suspended silt causes such high turbidity values in both the river and the lake water, that it becomes unfit for domestic consumption without pre-treatment. The local people around the lake used various plants to cause precipitation of the suspended silt before the use of alum was introduced to them.

The suspended silt levels also had a detrimental impact on the primary productivity in the lake due to the low light penetration in the lake as indicated by the very small Secchi depth (less than 6 cm) and the high turbidity values (780 NTU) which inhibited photosynthetic processes (primary productivity). Thus the suspended silt could make Lake Baringo less productive despite the high nutrient levels as indicated by the low primary productivity for the lake with a value of 3.80 g, O_2/M^2, Day (Kiplagat, personal communication). The algal species in the lake are also restricted to those that can move to the surface of the lake as the silt causes low light penetration in the lake water column. The algae which can float are mainly blue green algae and Kiplagat (Personal communication) observed that the most abundant algal species were the blue green Microcystis aeroginosa. Fish feed on algae or other small fish which themselves feed on algae. Thus, when the algae present is mainly Microcystis aeroginosa which is potentially poisonous, then the fish production in the lake is likely to be inhibited as observed by Mark Leonard (personal communication). The suspended silt in the lake water could clog the filtering systems of aquatic organisms (e.g. fish), thus inhibiting their healthy growth.

The silt in the water column is also likely to have effect on the nutrient levels as the nutrients get adsorbed on to the silt particles. The high particulate nitrogen and phosphorus levels (0.6 and 0.013 mgl^{-1} respectively) in the lake could possibly be the evidence of resuspension of sediments by the wind mixing of the lake. The wind mixing of the water in the lake could also be supported by the uniform elemental composition of the silt throughout the lake, showing that the silt from the rivers did not have localized effect at station L_1 as could be expected. The strong afternoon winds combined with the shallow nature of Lake Baringo to cause the total mixing of the water column in the lake. The lack of thermal stratification in the lake is an evidence of the wind mixing in the lake which in turn could have caused the resuspension of sediments in the lake. The suspended silt is unique to the lake and this gives the lake water a permanent brown colour as shown in the photograph below. The silt in Lake Baringo is kept in suspension either by the chemical nature of the silt as it is mainly composed by clay components, the particle size or electrical properties of the silt which produce a type of colloid which remains permanently suspended in the water column.

Photograph showing the permanent brown colour of Lake Baringo's water, taken near Island Camp.

5.6 MONTHLY VARIATIONS IN THE PHYSICAL AND CHEMICAL STATUS OF THE LAKE STATIONS COMBINED (SEASONAL VARIATION)

Mean values were obtained for the parameters from fortnightly sampling trips for each month so as to facilitate the comparison of the data on a monthly basis. This also gave an indication of the seasonal variation during the study period for the parameters over the whole lake. The parameter level differences from month to month indicate that the lake was in a constant state of change and therefore studying the lake by annual spot sampling is not sufficient to monitor all the changes that take place in the water body. It is therefore not acceptable to assume that Lake Baringo, because it is a tropical or equatorial lake, has a constant environment. Changes occurred in the lake when the lake levels changed and the southern end of the lake was the most affected. The seasonal changes in the concentrations of most parameters investigated depended very much on rainfall which in turn affected the water levels of the lake. The depth levels of the lake were closely related with the mean concentrations or levels of the parameters (e.g. conductivity). When the lake levels were rising the conductivity values of the lake reduced and vice-versa as shown by the negative correlation coefficient (r) of -0.957 between depth level and conductivity values for Lake Baringo on a monthly basis as shown in Figure 23, page 173.

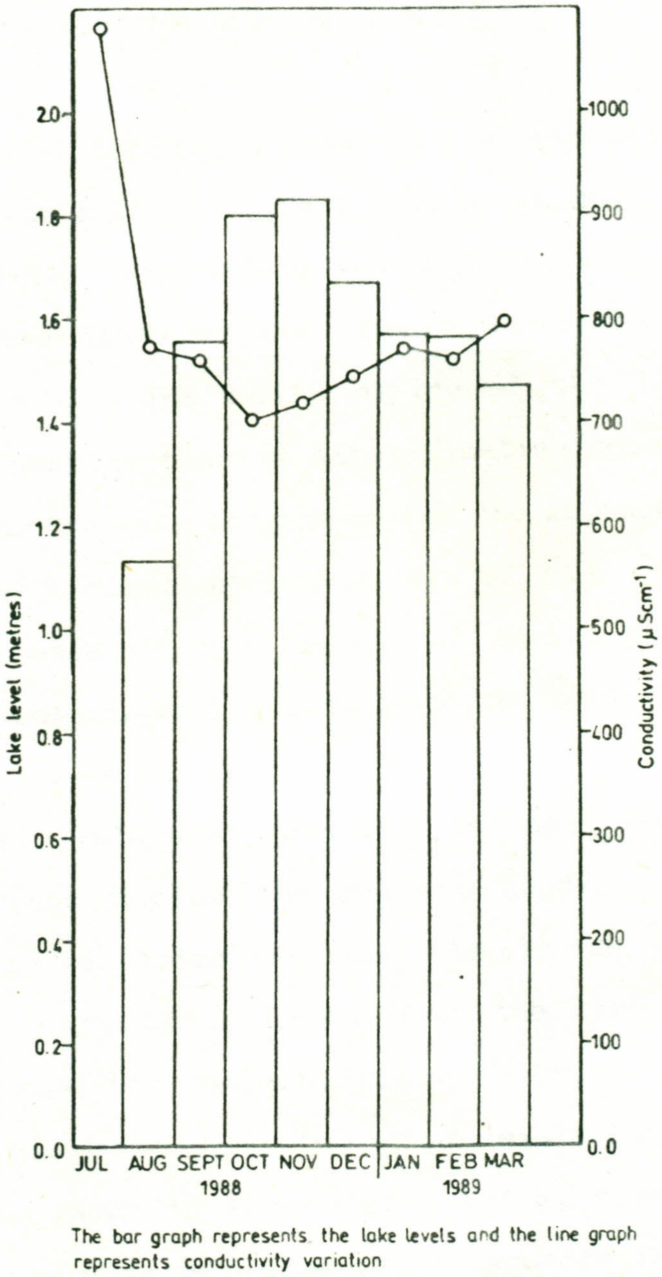


Fig. 23: Effects of Lake level variations on conductivity values of Lake Baringo.

5.6.1 Physico-Chemical Parameters

The water temperature was fairly constant during the study period with a range of 24.2-26.0 ^{0}C, suggesting that there was a very small temperature seasonal variation. This could be due to the daily mixing of the lake water by the powerful daily winds. The daily mixing of the lake by the winds ensures that no thermal stratification occur in Lake Baringo except during very calm days when the surface lake water could have high temperatures in excess of 30 ^{0}C.

Turbulence of the lake water caused by the wind mixing allowed the oxygen produced by phytoplankton and diffused from the air to exist at all depths of the water column most of the time. Values of less than 3.0 mgl^{-1} were recorded at the mud surface during the present study. There was marked seasonal variation in the levels of conductivity and alkalinity as the dilution from the river inflows affected them. Thus, the conductivity and alkalinity levels decreased during the period when the water levels were rising and vice-versa as shown in Figure 23-A and B, page 189. Except for relatively high pH value (8.9) recorded in the dry month of March 1989, the pH values did not significantly vary seasonally during the study period, whilst the DO mean values varied significantly during the study period, with the months of August 1988, September 1988, March 1989 having values more than 7.0 mgl^{-1}. There was a low correlation between dissolved oxygen and chlorophyll a values in Lake Baringo with a positive correlation coefficient (r) of 0.026 showing that the DO values in Lake Baringo could most probably be more related to the daily mixing of the lake, than the level of algal productivity or activity.

5.6.2 Nutrients

The NO_2^--N levels in Lake Baringo reached a peak when the water level was steadily rising in September 1988. This meant that the NO_2^--N levels were closely correlated with the water level. The NO_2^--N concentrations from November 1988 to the end of the study were fairly constant with the values less than 2.5 μgl^{-1} being recorded and this were near the detection limits of NO_2^--N.

The NH_3-N values were low in the first four months, then they increased abruptly in November 1988 to a value of 40.6 μgl^{-1} (Figure 16-B, page 113) which coincided with the maximum lake level during the study period.

The dissolved nitrogen (DN) and total nitrogen (TN) levels in Lake Baringo varied seasonally as observed in Figure 16-C and D, page 113. TN and DN mean values increased from July to September 1988 due to flushing out of nutrients via the rivers from the catchment areas during the rains. By October - November 1988, these nutrient inputs from the rivers had subsided and some of the DN could have been buried in the sediments or used up by the organisms in the lake. The DN and TN levels increased as the level of water increased and both parameters had similar seasonal variations. The particulate nitrogen (PN) on the one hand peaked when the rainfall was very high in August 1988, whereas particulate nitrogen values were much lower with values less than 0.5 mgl^{-1} during the drier months. The PN values were highest during the wet season as the rivers brought in a lot of organic and plant debris into the lake (Tiercelin <u>et al.</u> 1978), thus increasing the PN concentrations. In fact the initial rise in PN values was due to the heavy rains experienced in July and August, 1988. The PN values then decreased due to the settling of the PN in the sediments and its conversion to the dissolved (soluble) form. The PN values in the lake were high and most of its concentrations were brought into the lake by its associated rivers either as plant debris or attached to river silts.

The total nitrogen values in Lake Baringo varied significantly on a monthly basis. The high TN values occurred during the high lake levels. The increase of TN values during July and August 1988 could have been brought about by the flushing of the nutrients via the rivers from the catchment areas by the initial rains. The TN values then declined to a minimum of 0.8 mgl^{-1} in December 1988 (Figure 16-C, page 113). This reduction could have been due to the dilution effects of the rivers and the settling of some of the TN concentrations in the sediments and the uptake by algae. Linear regression analysis of TN versus TP and chlorophyll a values were relatively low, with r values of -0.272 and -0.182 respectively. The low coefficient correlation (r) between TN and Chl a indicates that nitrogen was not a limiting factor for algal growth as can also be observed from the TN:TP ratios.

The monthly variation of orthophosphate (SRP), dissolved phosphorus (DP) and total phosphorus (TP) follow the same seasonal trends, as is indicated in Figure 16-F to H, page 114. The initial increase of these three parameters was due to the flushing of nutrients by rainfall from the catchment areas. After the initial flushing by the rains then the phosphorus compound levels then decreased, despite the rising levels of water. This could have been due to the dilution effects of the rivers. The soluble reactive phosphorus (SRP) values lie between 0.10 mgl^{-1} and 0.13 mgl^{-1}, and did not vary significantly during the study period. The SRP values recorded accounted for a high percentage (85%) of the dissolved phosphorus in the lake. The SRP, DP, and TP values for the major rivers associated with Lake Baringo were very similar to those of the lake stations. The SRP is the form of phosphorus which is easily taken up by planktons in the water, thus its levels should have a high influence on algal growth and this is confirmed by the high correlation coefficient (r) of +0.721 between SRP and Chl a.

The DP monthly values for Lake Baringo during the study period were slightly higher than SRP values. The levels of particulate phosphorus (PP) in the lake were quite low probably due to the fact that much of the PP in the lake was buried or settled in the sediments. The TP mean values in the lake varied monthly as indicated in Table 17, page 112 and Figure 16-H, page 114. The variation of TP values was similar to those of SRP, as it increased to a maximum in August 1988 during the initial flushing in of the nutrients by rain and reduced to a minimum in November 1988. The minimum TP values coincided with the highest lake level, this was due to the dilution effects of rainfall and the inflowing rivers.

The particulate phosphorus (PP) mean monthly values for Lake Baringo followed the same trends as those of SRP, DP and TP, with slight variations even though its values were much lower. The highest PP values occurred in the month of August 1988, which coincided with the period of the highest river discharge carrying alot of silt and probably particulate phosphorus attached to it into the lake. The linear regression analysis between TN versus TP and TP versus chlorophyll a had correlation coefficients (r) of -0.272 and +0.732 respectively, suggesting that phosphorus is the phytoplankton growth limiting factor. The high r value (+0.732) and the TN:TP ration of more than 10 confirm that phosphorus could be the major algal growth limiting factor in Lake Baringo.

Nutrient Ratios

Nutrient ratios involve a complex series of interrelated biological, chemical, geological and physical processes which include photosynthesis, nitrogen fixation, nutrient cycling, alkalinity and water turbulence. Most algae seem to require nitrogen and phosphorus at a ratio of 10:1. in those lakes with ratios greater than 10, phosphorus becomes a critical factor in the growth of phytoplankton while in those with N/P ratio of less than 10, the nitrogen influence is greater. From the above conditions, the TN/TP ratios varied significantly and the lake was nitrogen limited in terms of algal growth in November, December 1988 and January 1989 whereas the rest of the months the lake could be termed as phosphorus limited. The monthly variation of the TN/TP ratio seem to follow the trends of TN and TP as shown in Figure 16-C, H and J, pages 113 - 115 and the drier months seem to have lower TN/TP ratios than the wetter months of August, September and October 1988.

5.6.3 Non-Nutrients (Anions)

Anions (Cl^-, F^-, SO_4^{2-}, and Silica)

The monthly variation of the chloride concentrations was significant, increasing from 25.8 mgl^{-1} in August 1988 to a maximum of 50.0 mgl^{-1} in January 1989. The low value observed in August 1988 was due to the dilution effects of the rivers which had high water inputs into the lake during the month. The chloride values increased tremendously in September 1988 due to the lower river inputs during the month.

The fluoride (F^-) monthly variation in Lake Baringo was very pronounced and corresponded closely with the water levels in the lake. When the water level was rising, the fluoride level was decreasing due to the dilution effects of the rivers and rain. There was a reduction of fluoride levels when the lake level was rising from 6.3 mgl^{-1} in July 1989 to 3.5 mgl^{-1} in November 1988, after which the fluoride concentrations increased as the water level in the lake declined (Figure 17-B, page 119). The fluoride loads in the rivers and the lake could well be essentially geological in origin rather than from agricultural or industrial activities. It is possible, however, that the substantial quantities of silt observed to be carried by the rivers into the lake during the study period, could make a significant contribution to fluoride concentrations in Lake Baringo. The hot springs at the north of Kokwa Island with high fluoride levels (16.0 mgl^{-1}) also act as a source of fluoride into the lake although the volume of visible springs were however relatively low. Linear regression analysis between fluoride and water levels gave a negative correlation coefficient (r) of -0.80, indicating that the main controlling feature of fluoride concentrations to be due to the dilution effects of the rivers and the lake levels.

The sulphate mean monthly variations depended on the lake water levels. Thus, the SO_4^{2-} levels declined due to the rising levels of the lake caused by inputs of the dilute rivers. The mean monthly SO_4^{2-} values increased when the water levels started to decrease. This was caused by the evaporation of the lake water in the hot, dry climate of the Baringo basin.

The monthly variations of the molybdate reactive silica concentrations could possibly be due to the changing lake levels caused by the varying river discharge into the lake and the wind mixing of the lake waters. The molybdate reactive silica declined in concentration in September 1988 (Figure 17-D, page 119). In fact the increase of silica concentrations coincided with the increase in the water levels. This could be explained from the viewpoint that a lot of silt containing silica was brought in by the rivers thus raising the silica content of the lake. The other factor which could have influenced the silica content was the wind mixing of the lake, which resuspended the silica in the sediments. Diatoms in the water may also consume or utilize silica, thus reducing the silica concentrations in the lake.

5.6.4 Non-Nutrients (Metals)

Cations (Total hardness, Mg^{2+}, Ca^{2+}, Na^{+}, K^{+}, Al^{3+}, Fe^{3+}, and Mn^{2+}).

The total hardness, magnesium and calcium mean monthly variations were very marked as seen in Figure 18-A, B, C, page 124. The total hardness levels declined with the rise in lake water level. The decrease of the water level of Lake Baringo in January to March 1989 corresponded to an increase in the total hardness level during the same period. The total hardness in Lake Baringo was predominantly calcium and magnesium ions, and all showed similar monthly trends.

The increase of magnesium levels in the lake in August 1988 may be explained by the initial flushing of ions into the lake by the rivers, thereafter decreased due to the dilution effects of the high inputs and rising lake levels. The magnesium levels enhance the growth of algae as it is used in the making of chlorophyll, which is very essential during photosynthesis. This is supported by the strong positive correlation coefficient ($r = +0.861$) between chlorophyll a and magnesium.

The calcium (Ca^{2+}) concentration monthly variation for Lake Baringo declined from August to October 1988, during the period of rising lake levels. All the monthly fluctuations of calcium levels came about due to many factors such as the varying amounts of Ca^{2+} ions in the river inputs and the release of the Ca^{2+} ions from the sediments during the wind mixing of the lake. The calcium levels in Lake Baringo were dependent on the water levels in the lake, rainfall and the river inputs into the lake.

The sodium mean monthly variation in Lake Baringo was quite significant, with values ranging from 178.1 mgl^{-1} in July 1988 to the lowest value of 137.1 mgl^{-1} in August 1988 (Figure 18-D, page 124). This huge decrease of sodium levels was due to the dilution effects of the heavy rains at the end of July and August 1988 and also corresponded to the highest increase in the lake level from 26.5 cm to 113.4 cm (Figure 7,page 63). The seasonal variation of sodium levels in Lake Baringo varied according to the lake level. Linear regression analysis between sodium levels and conductivity, sodium and potassium and sodium and water level had high correlation coefficients (r) of +0.979, +0.847 and -0.46 respectively. There was a marked seasonal variation in sodium levels in Lake Baringo.

The potassium monthly variation in the lake was very similar to that of the conductivity, giving a high positive correlation coefficient (r) of 0.827. However the variation of potassium was opposite to that of water levels. Thus, when the water level in the lake was rising, the lake got diluted and the potassium levels was lowered as can be confirmed by the high negative correlation coefficient (r) of -0.978. The minimum potassium concentration was recorded in November 1988 when the lake level was at a maximum level of 183 cm above datum level.

The aluminium mean monthly values varied significantly in that it had a wide range from 7.3 - 12.8 mgl^{-1}. The monthly variation of aluminium levels depended on the inflowing rivers which brought in alot of silt that contained aluminium silicates. The other factor of aluminium monthly variations was the resuspension of sediments which released more aluminium into the water column.

The iron concentration in Lake Baringo varied from month to month depending on the rainfall which brought in a lot of silt and the resuspension of the sediments in the lake caused by water turbulence. The trends of the iron and aluminium monthly variation were very similar (Figure 18-F, G, page 125) and had a correlation coefficient of +0.702 which was significant. The source of iron content in Lake Baringo was the silt brought in by the rivers from the catchment areas and this silt in the rivers varied according to rainfall and the other source was the resuspension of iron with the sediments during the mixing of the lake by daily winds.

The manganese monthly levels varied with the season, the highest level (0.60 mgl^{-1}) was recorded in July 1988 and the lowest (0.18 mgl^{-1}) in December 1988 and January 1989. This manganese was essentially geological in origin just like iron, and could have been brought into the lake attached to the silt. The cycling of manganese in the lake was carried out by the wind mixing which resuspended the sediments, thus releasing manganese into the water body. The manganese could still be attached to the permanently suspended silt of Lake Baringo as shown in the silt analysis.

5.6.5 Seasonal Variation of a Biological Parameter

Chlorophyll a

There was a considerable seasonal variation in chlorophyll a levels in Lake Baringo as shown in Table 20, page 126 and illustrated in Figure 19, page 127. The seasonality of the chl a levels in Lake Baringo could be due to the varying levels of nutrients in the lake during the study period. The lowest chl a level was recorded in November 1988, which coincided with the period of the highest lake level. The higher lake levels imply that the algal content of the lake water would decrease as the water column had increased, yet the algal content of Lake Baringo occurred only at the surface of the lake water. There was a significant seasonal variation in chl a values in Lake Baringo due to the varying inputs of nutrients into the lake by rain and the inflowing rivers. Lake Baringo may not described as eutrophic over most part of the study period except in December, 1988, when chl a values of 14.8 $\mu g l^{-1}$ recorded and this value was above that recommended by Sakamoto (1966) where lakes with chl a values of above 14.3 $\mu g l^{-1}$ could be described as eutrophic.

The seasonal mean values of chl a had a significantly positive correlation with those of sodium and magnesium, with correlation coefficients (r) of + 0.554 and + 0.861 respectively as shown in the correlation tables below. The low chl a levels for Lake Baringo could possibly be due to the reduced light penetration caused by the suspended silt in the lake as shown by the very low Secchi depths of less than 6 cm.

Table 29: Summary of linear regression analysis of Chlorophyll a versus nutrients and other physico-chemical parameters.

Parameters	Correlation Coefficient (r)
Chl a and O_2	-0.446
Chl a and TP	+0.210
Chl a and SRP	+0.294
Chl a and TN/TP	-0.297
Chl a and TN	-0.177
Chl a and NH_3-N	+0.449
Chl a and conductivity	+0.314
Chl a and magnesium	+0.861
Chl a and calcium	+0.078
Chl a and sodium	+0.554

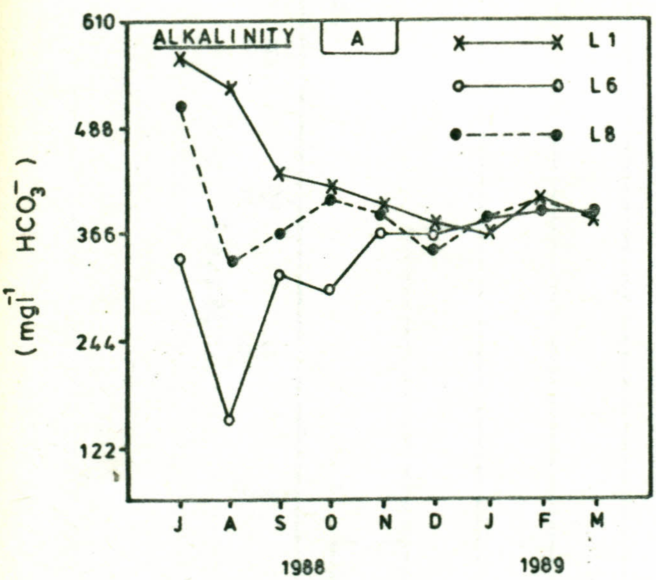
In general there was a marked monthly (seasonal) variation of all the parameters investigated and most of them depended on the level of the lake water. The rivers, which flow into

Lake Baringo, also had a major influence on the seasonal variation of the water quality of the lake as their discharge rates also varied monthly. The high aluminium, iron and silicon levels in Lake Baringo corresponded to the high percentage of these elements in the suspended silt as shown in Table 13,A page 97. Thus, the suspended silt could be contributing significantly to the high levels of aluminium, iron and silica in the lake. The silt suspended in the lake was mainly composed of aluminium silicates and this could be observed from the suspended silt composition and the high correlation coefficient (+0.734) between aluminium and molybdate reactive silica mean values.

5.7. RIVER INFLUENCE ON THE LAKE

The relative proportions of the major ions in the inflows were found to be similar to those found in the lake water. The rivers coming into Lake Baringo from the southern end (Rivers Molo, R_3 and Perkerra R_4) were more dilute than those coming from the Laikipia plateau (Rivers Mukutan, R_1 and Ol-Arabel, R_2). The physico-chemical status of the lake is mostly controlled by the inputs from the rivers into Lake Baringo because of its small water volume. Due to the small water volume of the lake, it is easily diluted during the rains or when the river discharge is high. The data for seasonal and geographical variation combined for all the physical and chemical parameters investigated are as shown in the tables in Appendix 4 to Appendix 31, pages 224-251. The results presented in this section include a few selected parameters, namely conductivity, alkalinity, TN, TP, chloride, molybdate reactive silica, sodium and aluminium. The stations considered in this discussion include stations L_1 and L_8 near the river mouths of Molo and Mukutan respectively and station L_6 at the northern end of the lake, with no direct river influence.

The seasonal and geographical variation of conductivity and alkalinity were similar with stations L_1 and L_6 having the lowest and highest values in July 1988 as shown in Figure 23 A and B, page 189. There was a dramatic decrease of conductivity and alkalinity values at stations L_1 and L_8 during August 1988 and thereafter increased up to November 1988. There was no significant difference in conductivity values in all the lake stations after November 1988. The river influence was felt most, during the wet months of July and August 1988 and the stations L_1 and L_8 were considerably diluted as compared to the other parts of the lake. The conductivity values for stations L_3 and L_6 decreased slightly as compared to stations L_1 and L_8, meaning that the dilution effects were not felt as much at these sites. By the end of the study all the stations had similar conductivity and alkalinity values with a range of 780 - 820 μScm^{-1} as compared to 695-1220 μScm^{-1} at the start of the study period, as indicated in the Appendix Table 4, page 224. The alkalinity mean values ranged from 341.6 - 585.6 mgl^{-1} HCO_3^- at the start of the study but this range was very narrow by the end of the study with a range of 378.2 - 390.4 mgl^{-1}, HCO_3^-. The difference is conductivity and alkalinity values show that the river influences on the lake varied according to the river discharge and also on the lake site e.g. the difference between the values of these two parameters at station L_1 and L_8. Station L_6 on the other hand had no direct river influence and thus did not have any drastic changes during the wet months.



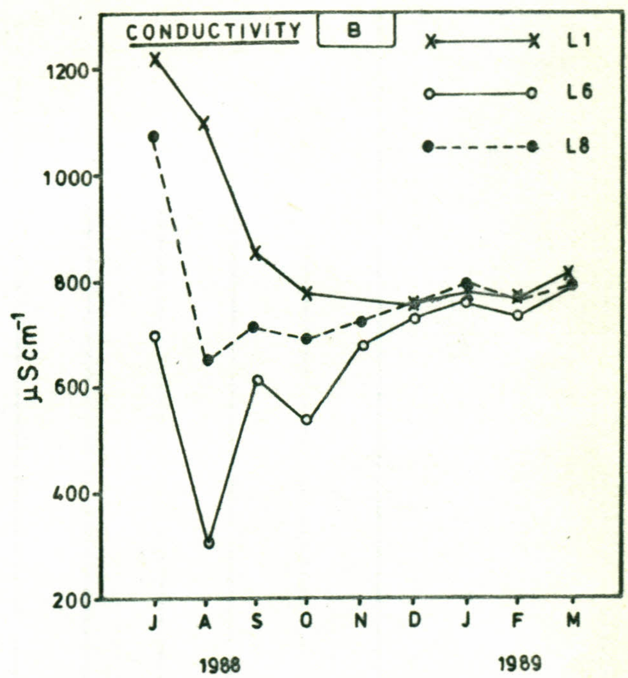


Figure 23: Monthly Variations of alkalinity and conductivity levels at various stations (L_1, L_6 and L_8) in Lake Baringo.

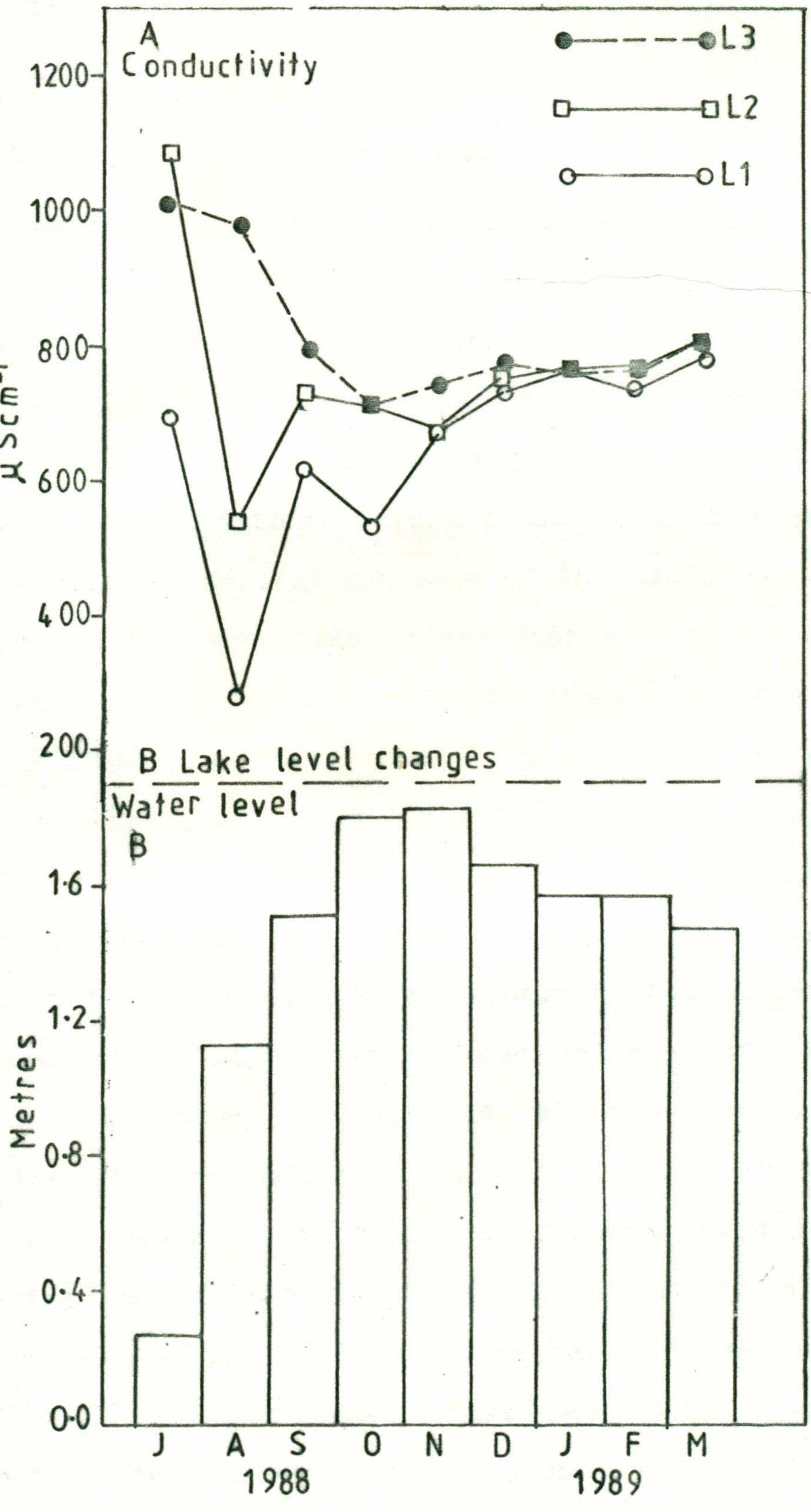


Figure 24: Monthly Variations of conductivity and Lake levels at various stations (L_1, L_2, L_3) in Lake Baringo.

The nutrients, total nitrogen (TN) and total phosphorus (TP) values fluctuated considerably as illustrated in Figure 25 A and B, page 193 and shown in Appendix tables 12 and 16, page 232 and 236. The TN mean values were low in July 1988 with stations L_8 having a value of 1.0 mgl^{-1} but these values increased tremendously during the rains at the end of July and in early August 1988 to values greater than 2.0 mgl^{-1} over the whole lake. A general decrease of TN values was observed in August to December 1988, thereafter the TN values for the stations L_6 remained low while the other station increased to over 2.0 mgl^{-1}. By March 1989 all the stations except station L_1 with a value of 3.5 mgl^{-1},had TN values less than 1.0 mgl^{-1}.

The monthly variation of TP at the various stations followed those of TN as shown in Figure 25, page 193. The highest TP values were at a maximum in August 1988. Except for station L_1 with a lower mean value (0.10 mgl^{-1}) at the start of the study in July 1988, all the other stations had similar TP mean values (0.17 mgl^{-1}). The TP mean values generally decreased in August to November 1988 as the level of water was rising but by the end of the study in March 1989, the TP mean values in the stations had a narrow range (0.10 - 0.11 mgl^{-1}). There could have been other factors which affected the seasonal and geographical variation of the nutrients in the lake such as uptake by algae, but the major influence seemed to be the river discharge which had direct influence on stations L_1 and L_8, even though station L_1 was influenced more significantly because of the higher river discharge into station L_1. The river influence on station L_6 was not very pronounced as it was not situated near a river mouth.

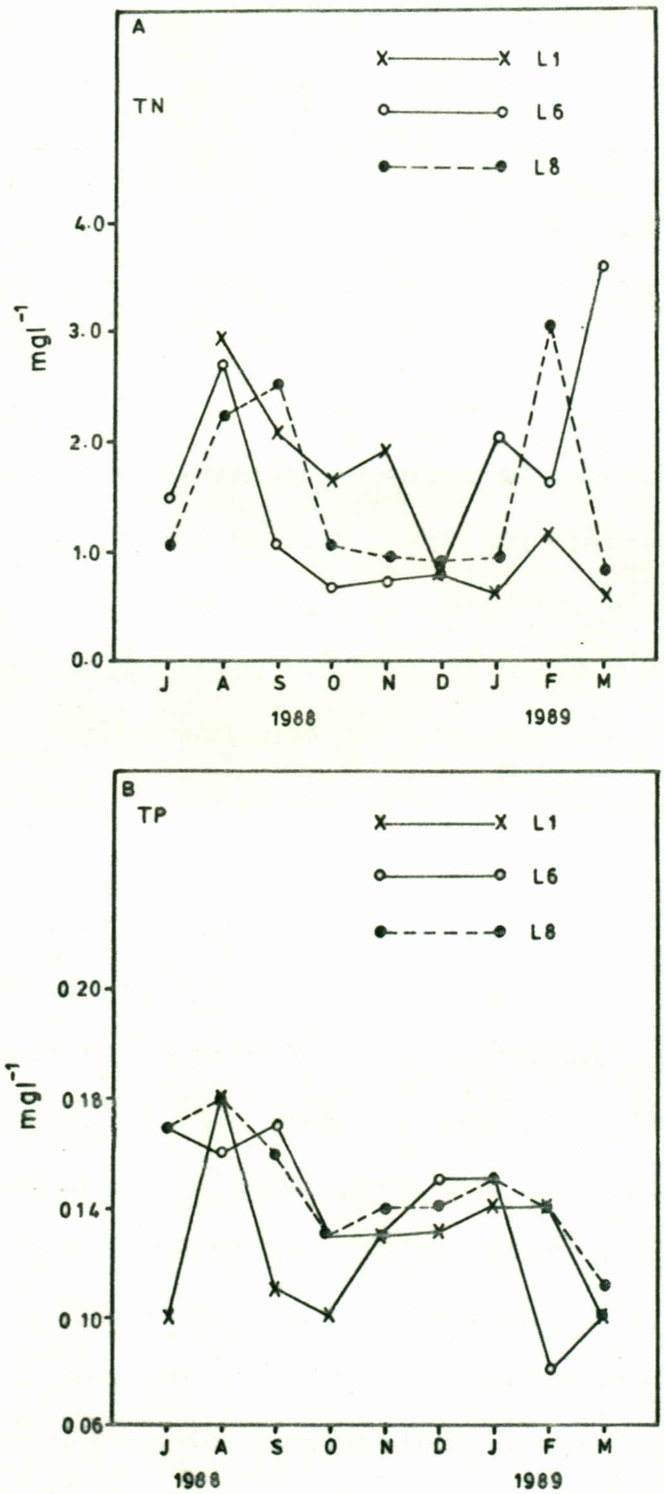


Figure 25: Monthly variations of total nitrogen (TN) and total phosphorus levels at stations L_1, L_6, and L_8 in Lake Baringo.

The Chloride concentration had a large range (12.4-49.7 mgl^{-1}). at the start of the study in July 1988 as illustrated in Figure 26,A, page 195 and the results are shown in the Appendix table 19, page 239. Station L_1 had lower chloride levels than the other stations due to the direct influence of Rivers Molo and Perkerra which had very low chloride levels but larger volumes of water. Chloride levels decreased significantly in all stations in August 1988 except for station L_1 which had a slight increase. The chloride levels in all the lake stations increased considerably in September 1988 (e.g. Station L_1 from 14.2 to 34.6 mgl^{-1} in September) this was due to the decrease in river discharge into the lake in September 1988. The chloride levels remained fairly constant with a slight increase over the whole lake and by the end of the study, station L_1 had the highest chloride value (55.0 mgl^{-1}).

The monthly variations of molybdate reactive silica at various stations in Lake Baringo are illustrated in Figure 26,B, page 195 and the data given in Appendix 22, page 242. The molybdate reactive silica mean value was highest at station L_1 for most part of the study period due to the high silt loads brought into the lake by Rivers Molo and Perkerra. The silt content in Lake Baringo consisted mainly of silica, thus the river discharge into the lake had a big influence on the silica levels in the lake. The maximum molybdate reactive silica was recorded in November 1988, station L_1 (40.5 mgl^{-1}),

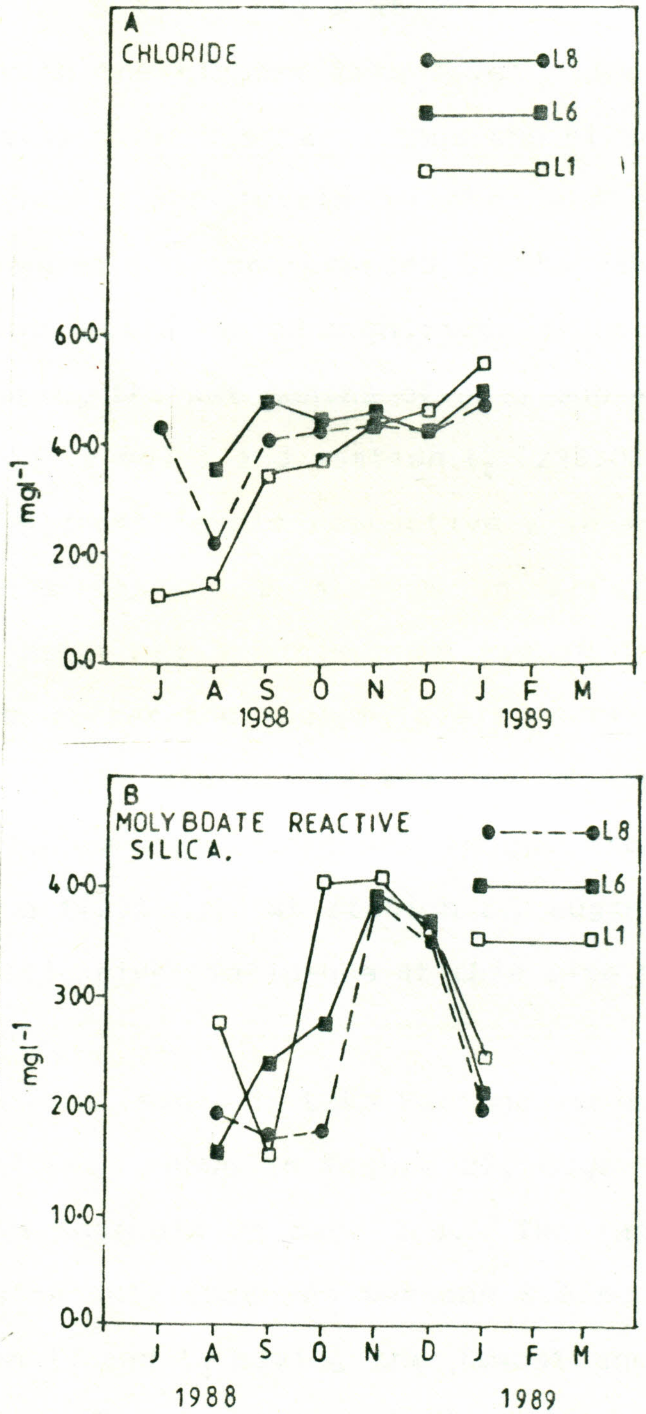


Figure 26: Monthly variation of chloride and molybdate reactive silica at station L_1, L_6 and L_8 in Lake Baringo.

Station L_6 (39.5 mgl^{-1}) and station L (38.8 mgl^{-1}), this also coincided with the highest lake level. The lake level rose with increased river discharge thus the rivers had a profound effect on the silica levels in the lake and this effects declined towards the northern end of the lake.

The sodium levels varied significantly in the various lake stations during the wet months of July and August 1988, with station L_1 (87.5 mgl^{-1}) and station L_6 (235.0 mgl^{-1}) having the lowest and highest levels respectively in August 1988. The sodium levels reached a minimum in all stations (except station L_1 which had a minimum in August 1988) in November 1988 and thereafter the sodium levels increased gradually up to the end of the study. By the end of the study in March 1989, the sodium concentrations ranged from 155.0 mgl^{-1} at station L_8 to 177.5 mgl^{-1} at station L_1, suggesting that there was very little river influence at this site by the end of the study period.

The aluminium levels in Lake Baringo varied seasonally and geographically as shown in Figure 27, page 197 and the data are shown in Appendix 28 page 248. The range of aluminium mean values in July 1988 was between 8.8 mgl^{-1} and 16.2 mgl^{-1} with station L_1 and L_8 having the lowest and highest levels respectively. The variation of aluminium concentrations at station L_1 was similar to those of molybdate reactive silica at this site, indicating that these two parameters come from the same source, that is the silt which is carried by the rivers into the lake. The aluminium concentrations is the lake varied both geographically and seasonally due to the differing aluminium inputs into the lake from the rivers. There was a wide range of the aluminium levels in the lake in July and August 1988 and thereafter the ranges narrowed considerably. There was also considerably recharge into the lake during these two months.

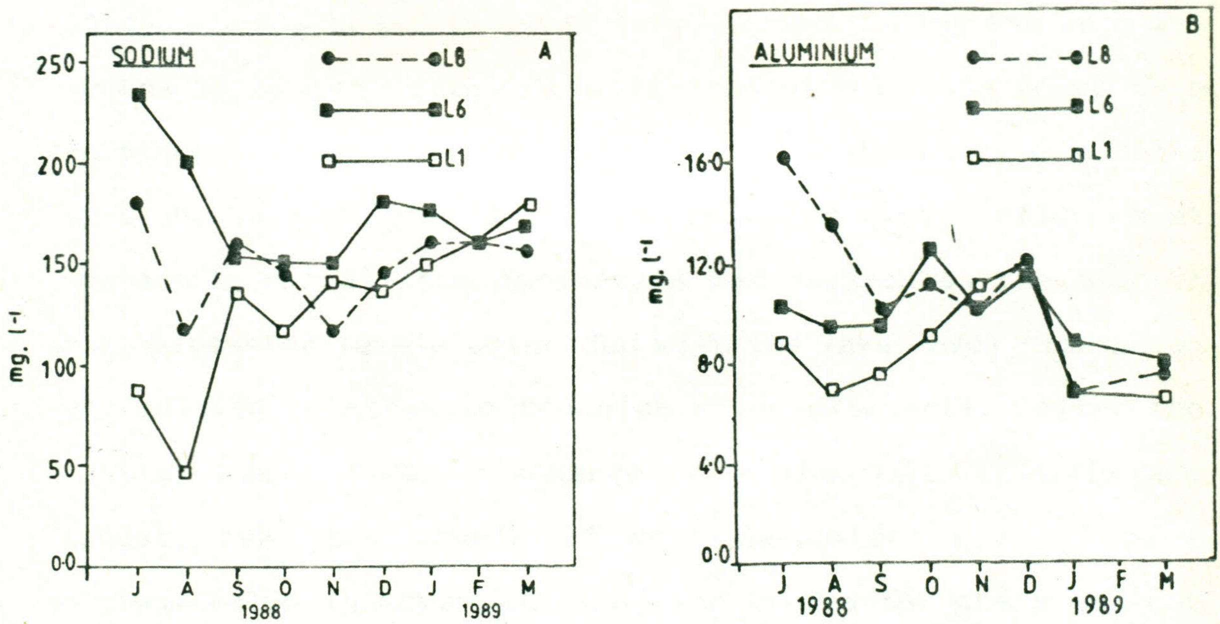


Figure 27: Monthly variations of sodium and aluminium levels at stations L_1, L_2 and L_8 in Lake Baringo.

General Comments

Except for the nutrients which appear to increase with higher river discharge into the lake due to flushing of nutrients into the lake by the rivers, all the other parameters reduced with higher river discharges. The lake levels in Baringo rose with increases in the river discharges and this corresponded to decreases in the mean values of conductivities, alkalinity, sodium, chloride and aluminium.

The impact of the river discharges was felt directly at station L_1 and L_8 and this was very evident during the very wet months of August 1988. This is indicated by the sharp drop in conductivity, alkalinity and sodium mean values in all the stations in the lake in that month. The river influence at station L_6 for all the parameters was delayed as the drop in most parameter levels coincided with the lake level rise which was delayed relative to the high river discharge. After the initial heavy river discharge into the lake in July and August, 1988 the levels of most parameters dropped to a minimum value in November 1988, and thereafter there was not much differences in the lake stations (e.g. Station L_1 and L_6) in the parameters' mean values.

The river discharges affected the nutrient levels throughout the lake in that most nutrients in Lake Baringo came in through the rivers. The total nitrogen and phosphorus mean values peaked in August 1988, and in the period of January - February 1989 in all the stations. The August 1988 peak could be due to the initial flushing of nutrients by the rivers while in the January - February peak could have been due to the decomposition of organic matter thus releasing the nutrients into the lake. At the end of the study period the lake stations had fairly similar mean values for all the parameters discussed. The river discharge influences the chemical status of the lake especially during the periods of heavy river discharges. The stations on the southern end, L_1 and L_2 were affected as seen in the Figure 24, page 190 where the variation of conductivity values at station L_3 was very different from those of stations L_1 and L_2 during the heavy river discharge into the lake.

5.8 THE HOT SPRINGS

The results of analysis of the water from the hot springs at the northern end of the Kokwa Island (Figure 1, page 7) are shown in Table 31, page 205. The data presented here include the mean values for all the springs sampled, mean values of the springs on the eastern shoreline and finally for those on the western shoreline at the northern tip of the island (Table 32, page 206).

Springs 3 and 12 as shown in Table 31, page 205 had very different chemical compositions from all the other hot springs on the Kokwa Island possibly due to their sources, which could have been from rain water as evidenced by their low ionic content and drying up during the dry months. The pH values at hot springs 3 and 12 were much lower than for the other springs, with values of 7.5 and 6.1 respectively. Springs 3 had lower levels than the other hot springs for the following parameters, conductivity (460 μScm^{-1}), total alkalinity (109.8 mgl^{-1}, HCO_3^-), sodium (15.5 mgl^{-1}) and potassium (2.5 mgl^{-1}) but had very high values for the parameters, iron (28.8 mgl^{-1}), manganese (2.2. mgl^{-1}), PO_4-P (1.6 mgl^{-1}), NO_2^--N (113.0 μgl^{-1}) and aluminium (12.0 mgl^{-1}) than all the other hot springs. Springs 12 on the other hand had a conductivity value of 2200 μScm^{-1}, which was considerable lower than those of the other hot springs which had conductivity values ranging from 3400 - 3600 μScm^{-1}. Spring 12, like spring 3 had some very high levels but much lower values in all the other parameters than the other springs.

The hot springs in Lake Baringo were alkaline with pH ranging from 8.5 - 9.1 and the conductivity values ranged from 3400 - 3600 μScm^{-1} which were much higher than the lake mean value of 793 μScm^{-1}. The nutrient levels at these hot springs were low, with PO_4-P and NO_2^--N levels having values of 0.04 mgl^{-1} and 3.7 - 6.1 μgl^{-1} respectively.

The major anions in the hot springs were found to be HCO_3^- and CO_3^{2-}. The total alkalinity values for the hot springs ranged between 1866.6 - 1976.4 mgl^{-1}, HCO_3^- and the fluoride levels were between 11.7 - 18.8 mgl^{-1}. The main cation in these hot springs was sodium with levels lying in the range of 755 - 913 mgl^{-1} and the potassium levels were also high with a range between 33.5 - 40.0 mgl^{-1}. These values were much higher than those recorded in the lake stations where the recorded sodium and potassium mean levels were 158.0 and 15.5 mgl^{-1} respectively.

The hot springs had no calcium and magnesium ions in the water and low values of iron (0.29 mgl^{-1}), manganese (0.03 mgl^{-1}), PO_4-P (0.038 mgl^{-1}), NO_2^--N (5.2 μgl^{-1}) and aluminium (0.8 mgl^{-1}) were recorded despite the high temperatures which could have assisted in the dissolution of most of these parameters from the rocks. There could have ben some precipitation of the ions in the springs (e.g. calcium and magnesium ions could have been precipitated as carbonates).

It can be concluded that most of these hot springs except springs 3 and 12 originate from deep seated sources, thus explaining their very high inorganic ion levels. The influence of the hot springs on the physical and chemical status of the lake could have been very substantial due to the high levels in some parameters' concentrations but their low discharge into the lake lessens this effects on the lake water status.

Table 30: Characteristics of the hot springs water at Kokwa Islands on the eastern shoreline.

Hot Spring Number	Appearance of Water	Temperature (^0C)
1	Steam jet	-
2	"	-
3	Muddy	94
4	Steam jet	-
5	"	-
6	Clear	80
7	"	75
8	"	81
9	Yellow	79
10	Clear	59
11	"	95.5
12	Muddy	89
13	Yellow	89
14	"	85
15	"	84

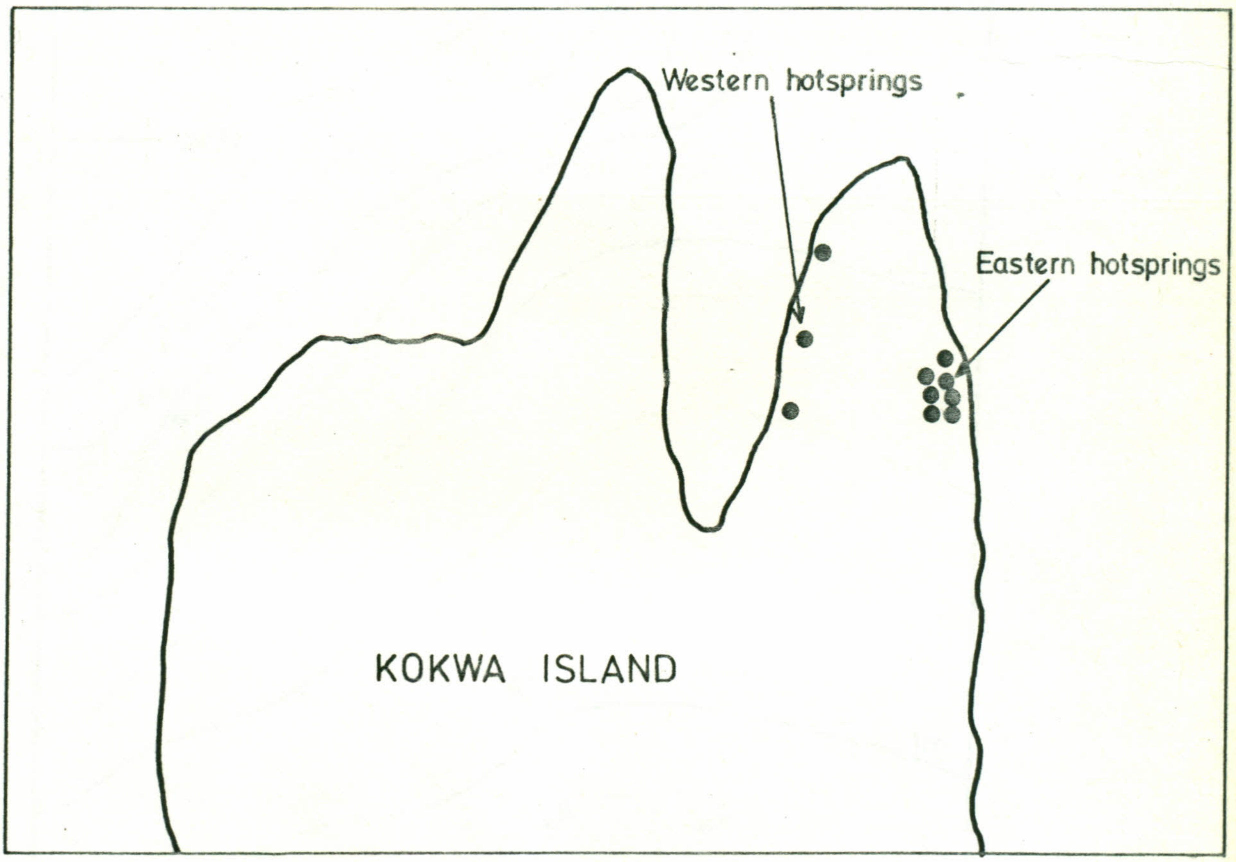


Figure 28: The hot springs at Kokwa Island in Lake Baringo.

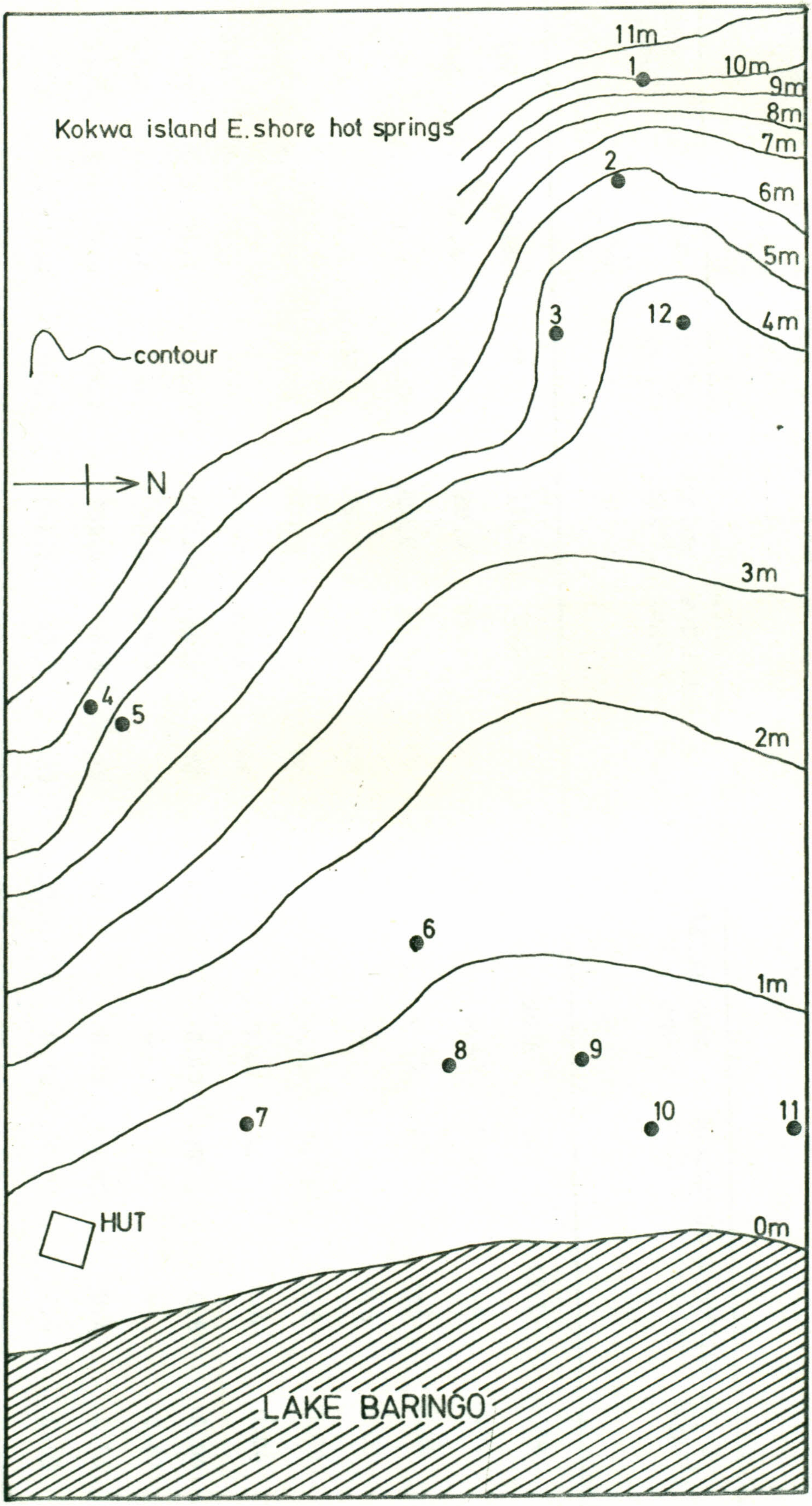


Figure 29: The contour survey of the hot springs on the eastern shoreline of the Kokwa Island.

TABLE 31: HOT SPRINGS SURVEY RESULTS

HOT SPRING NUMBER	COND. μScm^{-1}	pH	TOTAL ALK. ($meql^{-1}$) HCO_3	FLUORIDE (mgl^{-1})	SODIUM (mgl^{-1})	POTASSIUM (mgl^{-1})	CALCIUM (mgl^{-1})	MAGNESIUM (mgl^{-1})	IRON (mgl^{-1})	MANGANESE (mgl^{-1})	ALUMINIUM (mgl^{-1})	PO_4-P (mgl^{-1})	NO_2^--N (μgl^{-1})
3	460	7.5	1.8	3.0	15.5	2.5	-	-	28.8	2.2	12.0	1.59	113
6	3600	8.4	31.4	18.8	880.0	35.5	ND	ND	0.40	0.03	0.8	0.06	4.0
7	3600	8.8	31.6	16.0	800.0	39.0	ND	ND	0.35	ND	1.2	0.04	1.0
8	3500	9.4	32.0	17.0	800.0	39.0	ND	ND	-	0.03	0.8	0.03	1.4
9	3500	9.7	30.6	16.8	880.0	39.0	ND	ND	0.25	0.03	0.8	0.03	6.6
10	3400	8.2	32.2	14.6	862.5	35.5	ND	ND	0.40	ND	0.4	0.04	4.0
11	3400	8.5	31.2	11.7	887.5	35.5	ND	ND	0.40	ND	0.8	0.04	2.7
12	2200	6.1	1,8	4.1	30.5	6.4	-	-	-	-	-	0.87	288.5
13	3400	9.4	31.0	13.2	755.0	36.5	ND	ND	0.25	0.03	0.6	0.05	7.9
14	3500	8.8	32.0	16.0	862.5	40.0	ND	ND	0.10	0.03	0.4	0.03	13.8
15	3500	9.4	31.9	15.3	913.0	33.5	ND	ND	0.15	0.02	0.8	0.04	5.0

KEY: - = No analysis carried out

ND = Refers to Non-detactable.

Table 32: Summary of the Results on the Chemical Composition of the Hot Springs:

Parameter (UNITS)	Spring 3	Spring 12	Eastern Shoreline Springs	Western Shoreline Springs	Overall Mean Values
pH	7.5	6.1	8.9	9.1	8.6
Conductivity (μScm^{-1})	460	2200	3485	3466	3480
T. Alkalinity (mgl^{-1}, HCO_3^-)	109.8	109.8	1921.5	1927.6	1927.6
Fluoride (mgl^{-1})	3.0	4.2	15.3	15.1	15.2
Sodium (mgl^{-1})	15.5	-	846.0	843.5	845.0
potassium (mgl^{1-})	2.5	-	36.9	36.8	36.8
Calcium (mgl^{-1})	-	-	0.0	0.0	0.0
Magnesium (mgl^{-1})	-	-	0.0	0.0	0.0
Iron (mgl^{-1})	28.8	-	0.35	0.05	0.29
Manganese (mgl^{-1})	2.2	-	0.03	0.03	0.03
Aluminium (mgl^{-1})	12.0	-	0.90	0.40	0.8
PO_4-P (mgl^{-1})	1.6	0.9	0.04	0.04	0.04
NO_2^--N (μgl^{-1})	113.0	288.5	3.70	6.10	5.20

- Analysis not carried out, thus data not available.

GENERAL CONCLUSION

The present study shows that there are marked geographical and seasonal variations in the water quality status of Lake Baringo. The physico-chemical status of the lake is mainly influenced by the river inputs from different geological zones and these rivers cause major dilution effects at the southern end of the lake. The study is the first systematic investigation on a wide range of parameters and it established the first baseline water quality data for future reference in Lake Baringo.

Siltation and erosion associated problems are the major factors influencing the water quality of Lake Baringo as observed from the permanent brown colour of the lake water. The suspended silt make the water unsuitable for direct drinking use but the river water can be used in this respect. The suspended silt has significant effects on biological activities in the lake. The silt reduces the light penetration of the lake to less than six centimetres and this inhibits algal productivity in the lake. The algal species in the lake are limited to those that can move to the water surface. The predominance of the bloom causing blue-green algae (Microcystis aeruginosa), in the lake, however present potential problems. The silt also inhibits the fish production as their gill membranes are clogged by the silt, thereby preventing the healthy growth of the fish. The limited algal species of the lake also affects fish productivity as the algae act as fish food and blue-greens are not very suitable as fish food.

The high fluoride and aluminium concentrations pose a health risk, as both parameters have values well above the limits set by the World Health Organization (WHO) for drinking water.

Further agricultural and urban development activities around Lake Baringo are likely to exert more pressure on the lake with deleterious consequences. These activities could increase the nutrient levels in the lake, making it possible for the predominant blue-green algae to bloom.

The present quality of Lake Baringo water does not appear to pose an immediate problem to the use of the lake as a raw water resource for domestic and irrigation purposes. Lake Baringo is located in a semi-arid area and its water may be a valuable resource as a source of water for irrigation, domestic and fishing purposes by the inhabitants around the lake and thus some long term studies on the water quality of the lake should be carried out. Although the present water quality of the lake do not seem bad, it should be noted that the erosion problems within the lake's catchment areas should be curbed or erased, if the lake water quality should improve.

Further work on Lake Baringo could include:

i. Continued monitoring of the lake water quality.

ii. Study of the toxins produced by algal blooms.

iii. The effects of the suspended silt on aquatic life and the physico-chemical status of the lake.

iv. Effects of pesticide use in the catchment areas on the aquatic life (fish) in the lake.

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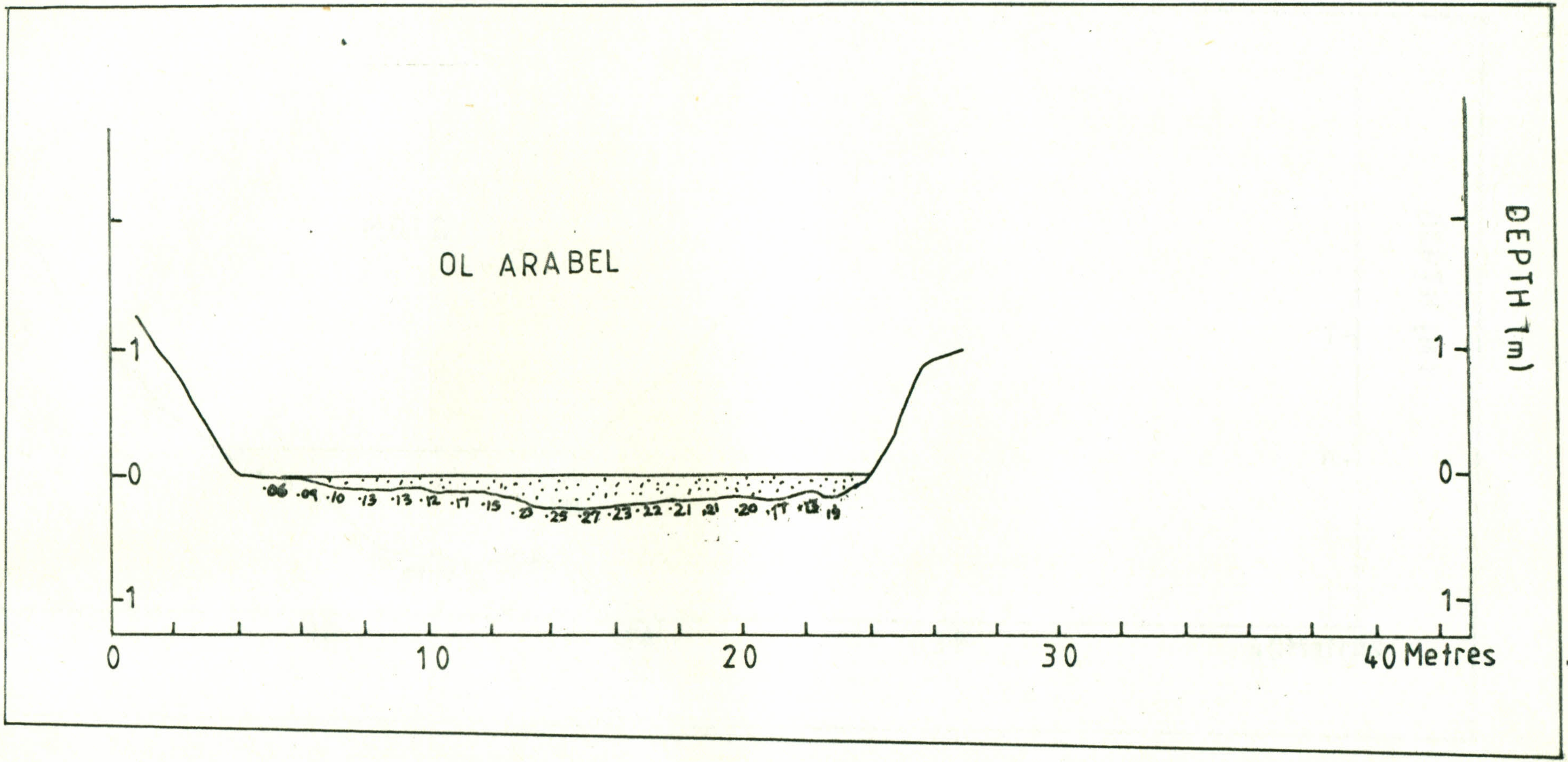
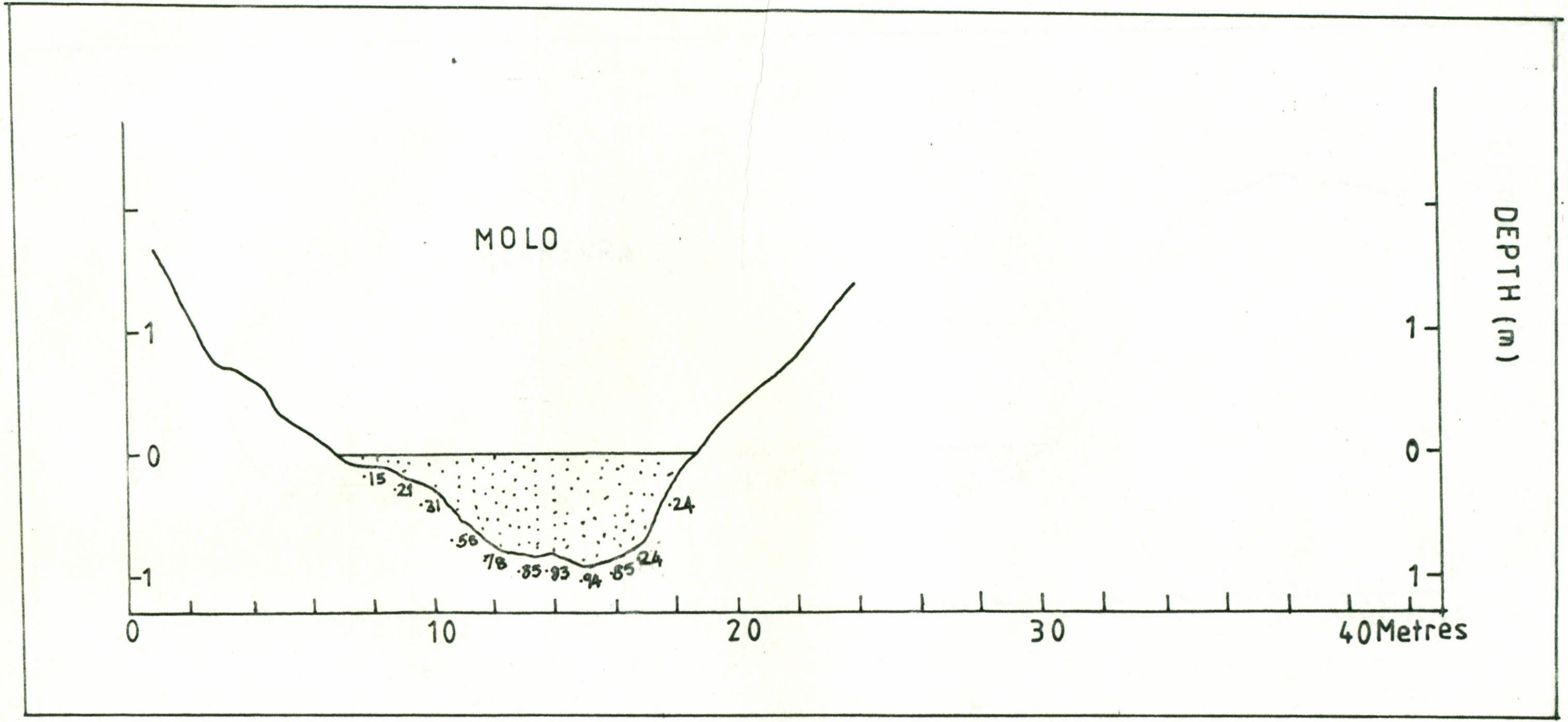
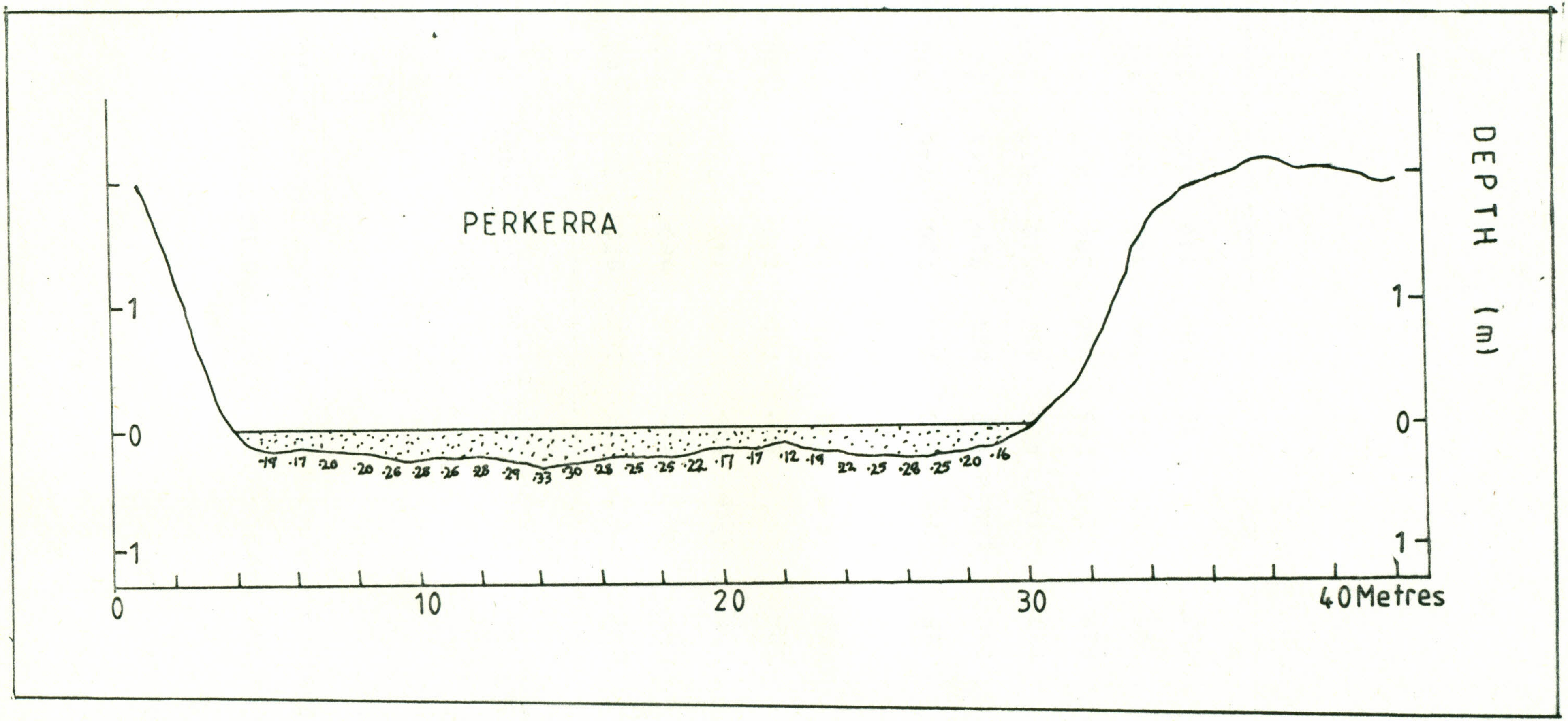
APPENDICES



APPENDIX I: Cross-Sectional diagram across Ol-Arabel River (R_2)



APPENDIX 2: Cross-Sectional diagram across Molo River (R_3)



APPENDIX 3: Cross-Sectional diagram across River Perkerra (R_4)

APPENDIX 4:

SEASONAL AND GEOGRAPHICAL VARIATION IN CONDUCTIVITY VALUES OF LAKE BARINGO AND SOME OF ITS RIVERS (UNITS = μScm^{-1})

Month Station	July 1988	Aug 1988	Sept 1988	Oct 1988	Nov 1988	Dec 1988	Jan 1989	Feb 1989	Mar 1989
L_1	695	280	615	530	670	730	760	735	780
L_2	1080	540	730	710	680	750	770	765	800
L_3	1010	980	795	710	740	770	760	770	810
L_4	1200	-	800	760	730	735	780	750	790
L_5	1200	925	770	725	745	735	780	765	785
L_6	1220	1095	850	770	755	750	780	765	810
L_7	1185	1005	835	740	720	745	770	785	820
L_8	1080	650.0	710	690	720	745	790	765	800
R_1	387	310	450	490	510	570	480	620	610
R_2	285	235	225	280	285	355	395	400	515
R_3	135	125	160	140	200	220	415	300	-
R_4	110	-	95	80	110	140	160	150	200

APPENDIX 5

SEASONAL AND GEOGRAPHICAL VARIATION IN pH VALVES FOR LAKE BARINGO AND SOME OF ITS RIVERS (UNITS = pH UNITS)

Month / Station	July 1988	Aug 1988	Sept 1988	Oct 1988	Nov 1988	Dec 1988	Jan 1989	Feb 1989	Mar 1989
L_1	8.1	8.0	8.3	8.2	8.3	8.4	8.1	8.4	9.0
L_2	8.8	8.3	8.8	8.5	8.3	8.7	8.8	8.8	8.9
L_3	8.6	8.8	8.6	8.9	8.6	8.7	8.2	8.7	8.8
L_4	8.8	-	8.7	8.6	8.5	8.7	8.8	8.6	8.9
L_5	8.9	8.7	8.8	8.6	8.5	8.7	8.2	8.7	9.0
L_6	9.0	9.0	8.9	8.6	8.6	8.7	8.9	8.4	9.2
L7	8.9	8.9	8.9	8.8	8.6	8.8	8.9	8.3	8.7
L_8	8.8	8.5	8.6	8.5	8.7	8.5	8.1	8.9	9.1
R_1	8.0	7.7	7.2	8.4	7.9	7.9	8.2	7.8	8.0
R_2	7.8	7.6	7.2	8.6	8.4	8.2	8.6	8.9	8.8
R_3	7.2	7.2	7.5	7.5	7.7	7.4	8.0	7.6	7.7
R_4	7.2	-	7.4	7.6	7.7	7.5	7.9	7.9	7.6

- Analysis not done, thus data not available.

APPENDIX 6

SEASONAL AND GEOGRAPHICAL VARIATION IN ALKALINITY LEVELS IN LAKE BARINGO AND SOME OF ITS RIVERS (UNITS = mgl^{-1} as HCO_3^-)

MONTH STATION	JULY 1988	AUG 1988	SEPT 1988	OCT 1988	NOV 1988	DEC 1988	JAN 1988	FEB 1988	MAR 1988
L_1	338.6	152.5	320.2	298.9	366.0	363.0	378.2	393.4	390.4
L_2	530.7	225.7	378.2	390.4	384.3	366.0	384.3	384.3	84.3
L_3	485.0	433.1	399.4	387.4	375.2	387.4	384.3	396.5	390.4
L_4	564.2	-	402.6	414.8	375.2	396.0	390.4	393.4	378.2
L_5	536.8	445.3	396.5	411.8	390.4	366.0	396.5	408.7	378.2
L_6	567.3	533.8	433.1	420.9	399.6	375.2	366.0	405.6	384.3
L_7	584.4	481.9	408.7	390.4	390.4	366.0	384.3	396.5	390.4
L_8	512.4	329.4	366.0	405.6	387.4	344.6	384.3	402.6	378.2
R_1	161.6	219.6	217.2	298.9	311.1	-	347.7	359.9	335.5
R_2	58.0	128.1	119.0	164.7	178.8	192.2	216.6	219.6	292.8
R_3	41.5	64.0	64.0	79.3	106.8	122.0	170.8	164.7	-
R_4	73.2	-	61.0	67.1	57.9	79.3	79.3	82.4	103.7

\- Analysis not done, thus data not available.

APPENDIX 7

SEASONAL AND GEOGRAPHICAL VARIATION OF DISSOLVED OXYGEN CONCENTRATION IN LAKE BARINGO (UNITS = mgl^{-1})

MONTH STATION	JULY 1988	AUG 1988	SEP 1988	OCT 1988	NOV 1988	DEC 1988	JAN 1989	FEB 1989	MAR 1989
L_1	5.7	6.2	5.1	5.2	5.9	5.8	6.1	6.0	6.3
L_2	6.3	6.0	6.8	6.8	7.0	6.4	6.6	6.3	6.3
L_3	7.3	7.0	7.2	6.7	7.0	6.5	7.1	6.9	6.4
L_4	6.5	-	-	6.1	7.7	6.6	6.2	6.4	7.4
L_5	-	7.6	6.9	6.4	7.3	6.4	6.4	7.0	7.4
L_6	-	7.9	8.8	6.4	6.4	6.5	6.3	6.4	7.0
L_7	7.1	8.0	8.2	7.8	7.4	6.3	6.4	6.4	8.0
L_8	5.7	8.2	6.3	5.7	6.4	6.2	6.1	6.4	8.0

- Analysis not done, thus data not available.

APPENDIX 8

SEASONAL AND GEOGRAPHICAL VARIATION IN TURBIDITY IN LAKE BARINGO AND SOME OF ITS MAJOR RIVERS (UNITS = NTU)

MONTH / STATION	AUG 1988	SEPT 1988	OCT 1988	NOV 1988
L_1		466.0	300.0	320.0
L_2		530.0	380.0	335.0
L_3		500.0	380.0	300.0
L_4		480.0	395.0	320.0
L_5		466.0	380.0	335.0
L_6		466.0	360.0	319.0
L_7		500.0	-	350.0
L_8		386.0	350.0	320.0
R_1	54.0	75.0	61.0	-
R_2	54.0	244.0	47.0	160.0
R_3	188.0	205.5	125.0	250.0
R_4	6825.0	400.0	140.0	120.0

- Analysis not done, thus data not available

APPENDIX 9

SEASONAL AND GEOGRAPHICAL VARIATION IN NITRATE-NITROGEN (NO_3-N) LEVELS IN LAKE BARINGO (UNIT = mgl^{-1})

MONTH / STATION	OCT 1988	NOV 1988	DEC 1988
L_1	21.4	34.2	7.2
L_2	21.0	24.4	7.0
L_3	26.0	30.5	26.6
L_4	23.8	18.2	15.5
L_5	21.0	29.7	11.2
L_6	17.2	29.7	7.0
L_7	27.8	19.4	8.4
L_8	9.2	32.5	30.8

APPENDIX 10:

NITRITE-NITROGEN (NO_2-N) CONCENTRATION IN LAKE BARINGO SHOWING SEASONAL AND GEOGRAPHICAL VARIATIIONS. (UNITS = $\mu g l^{-1}$)

MONTH STATION	AUG 1988	SEPT 1988	OCT 1988	NOV 1988	DEC 1988	JAN 1989	FEB 1989	MAR 1989
L_1	1.7	2.6	5.6	1.9	1.8	1.0	2.2	1.2
L_2	2.4	11.4	2.1	2.4	2.5	2.5	3.4	2.4
L_3	6.7	23.4	0.9	2.2	2.3	3.0	3.1	1.8
L_4	-	37.6	10.4	1.4	0.8	1.5	2.2	3.6
L_5	9.2	13.4	12.4	1.9	1.4	1.5	2.4	2.1
L_6	9.6	29.5	11.4	2.2	3.0	1.8	2.2.	1.8
L_7	9.5	22.5	2.1	1.6	5.0	1.3	2.8	1.8
L_8	6.2	21.6	10.3	0.2	1.3	2.5	1.8	1.8
R_1	9.5	-	-	-	-	1.8	1.7	1.2
R_2	-	-	1.2	0.7	1.5	1.2	0.04	1.8
R_3	-	-	1.2	13.2	4.3	2.1	2.3	4.4
R_4	-	-	1.5	5.3	1.5	1.0	1.4	0.9

- Analysis not done, thus data not available.

APPENDIX 11:

AMMONIA-NITROGEN (NH_3-N) CONCENTRATION IN LAKE BARINGO SHOWING SEASONAL AND GEOGRAPHICAL VARIATIONS (UNIT = $\mu g l^{-1}$)

MONTH STATION	JULY 1988	AUG 1988	SEPT 1988	OCT 1988	NOV 1988	DEC 1988	JAN 1989	FEB 1989
L_1	0.01	0.02	0.1	3.0	1.0	46.4	60.0	18.3
L_2	0.01	0.1	0.1	1.0	0.4	16.0	49.0	13.1
L_3	-	0.1	0.1	3.5	0.4	36.0	37.5	8.0
L_4	-	-	0.01	0.01	217.6	50.8	24.5	17.4
L_5	-	0.04	0.01	0.01	52.8	21.0	13.0	11.8
L_6	-	0.04	0.01	0.01	38.8	21.0	11.5	8.8
L_7	0.8	0.2	0.04	2.2	0.02	41.2	8.4	90.6
L_8	0.2	0.1	0.01	0.01	13.8	16.0	32.8	36.7

-Analysis not done, thus data not available.

APPENDIX 12:

TOTAL NITROGEN CONCENTRATION SHOWING SEASONAL AND GEOGRAPHICAL CHANGES IN LAKE BARINGO (UNITS = mgl^{-1})

MONTH STATION	JULY 1988	AUG 1988	SEP 1988	OCT 1988	NOV 1988	DEC 1988	JAN 1989	FEB 1989	MAR 1989
L_1	1.5	2.7	1.1	0.7	0.7	0.7	2.1	1.6	3.5
L_2	-	2.4	2.4	3.8	1.4	0.9	0.7	0.9	1.7
L_3	1.5	2.1	2.5	1.5	1.1	0.9	2.1	1.8	1.2
L_4	-	2.4	1.6	3.6	1.0	0.7	0.7	1.1	0.6
L_5	-	2.7	2.6	4.4	0.8	0.8	0.8	0.8	0.9
L_6	-	3.0	2.1	1.6	1.9	0.8	0.6	1.2	0.6
L_7	-	2.6	2.2	1.2	0.9	0.7	0.7	0.7	0.9
L_8	1.0	2.2	2.6	1.0	0.9	0.9	0.9	3.1	0.8
R_1	-	3.8	1.4	3.5	-	-	-	3.6	0.2
R_2	-	1.6	2.2	1.4	1.6	0.7	0.6	0.6	1.0
R_3	-	2.6	2.4	1.2	2.2	1.1	3.2	1.8	2.1
R_4	1.6	-	1.6	2.8	0.7	0.8	2.7	1.4	1.2

- Analysis not done, thus data not available.

APPENDIX 13:

DISSOLVED NITROGEN CONCENTRATION IN LAKE BARINGO SHOWING SEASONAL AND GEOGRAPHICAL VARIATION (UNITS = mgl^{-1})

MONTH / STATION	JULY 1988	AUG 1988	SEP 1988	OCT 1988	NOV 1988	DEC 1988	JAN 1989
L_1	1.2	1.7	0.6	0.4	0.5	0.6	0.6
L_2	-	1.8	2.2	3.1	1.0	0.7	0.7
L_3	0.8	1.2	2.2	1.3	0.9	0.7	0.6
L_4	-	1.2	2.1	3.3.	0.7	0.6	0.4
L_5	-	1.8	2.0	3.5	0.6	0.5	0.5
L_6	-	1.6	2.2	1.1	1.5	0.7	0.4
L_7	-	2.0	1.6	0.6	0.6	0.5	0.5
L_8	0.8	1.6	1.2	0.5	0.8	0.7	0.6
R_1	-	2.4	1.0	2.5	-	-	-
R_2	-	1.0	1.3	1.2	0.9	0.6	-
R_3	-	0.7	1.2	1.1	1.0	1.0	-
R_4	0.8	-	1.3	1.7	0.6	1.4	-

- Analysis not done, thus data not available.

1987 - 1990

APPENDIX 14

SOLUBLE REACTION PHOSPHORUS (ORTHOPHOSPHATE) CONCENTRATIONS LAKE BARINGO SHOWING SEASONAL AND GEOGRAPHICAL VARIATION (mgl^{-1})

MONTH / STATION	JULY 1988	AUG 1988	SEP 1988	OCT 1988	NOV 1988	DEC 1988	JAN 1989	FEB 1989	MAR 1989
L_1	0.08	0.08	0.10	0.08	0.10	0.09	0.12	0.10	0.07
L_2	-	0.13	0.14	0.11	0.10	0.11	0.13	0.08	0.09
L_3	0.13	0.15	0.11	0.11	0.11	0.10	0.13	0.09	0.09
L_4	-	-	0.14	0.13	0.08	0.12	0.13	0.09	0.08
L_5	-	0.12	0.14	0.10	0.08	0.10	0.12	0.09	0.96
L_6	-	0.14	0.14	0.11	0.10	0.12	0.13	0.07	0.09
L_7	-	0.15	0.12	0.12	0.12	0.11	0.13	0.09	0.07
L_8	0.15	0.15	0.14	0.10	0.11	0.12	0.12	-	-
R_1	-	0.10	0.07	0.05	-	-	0.07	0.08	0.09
R_2	0.02	0.06	0.06	0.01	0.04	0.02	0.03	0.05	0.03
R_3	0.08	-	0.07	0.04	0.06	0.07	0.08	0.07	0.08
R_4	0.01	-	0.06	0.06	0.04	0.03	0.04	0.06	0.04

- Analysis not done, thus data not available.

APPENDIX 15:

DISSOLVED PHOSPHORUS CONCENTRATION IN LAKE BARINGO SHOWING SEASONAL AND GEOGRAPHICAL VARIATION (UNITS = $mg l^{-1}$)

MONTH / STATION	JULY 1988	AUG 1988	SEPT 1988	OCT 1988	NOV 1988	DEC 1988	JAN 1989
L_1	0.09	0.13	0.11	0.08	0.12	0.11	0.13
L_2	-	0.13	0.16	0.12	0.11	0.11	0.14
L_3	0.15	0.16	0.12	0.12	0.12	0.11	0.14
L_4	-	-	0.14	0.15	0.11	0.13	0.13
L_5	-	0.13	0.15	0.11	0.09	0.11	0.14
L_6	0.15	0.15	0.15	0.12	0.12	0.14	0.14
L_7	-	0.16	0.13	0.13	0.13	0.13	0.14
L_8	0.16	0.17	0.15	0.11	0.13	0.13	0.14
R_1	-	0.12	0.08	0.07	-	-	-
R_2	-	0.07	0.07	0.02	0.05	0.03	0.04
R_3	0.10	-	0.08	0.06	0.07	0.08	0.10
R_4	0.10	-	0.07	0.07	0.05	0.05	0.08

- Analysis not done, thus data not available.

APPENDIX 16:

TOTAL PHOSPHORUS CONCENTRATION INLAKE BARINGO SHOWING SEASONAL CHANGES (UNITS = mgl^{-1})

MONTH / STATION	JULY 1988	AUG 1988	SEP 1988	OCT 1988	NOV 1988	DEC 1988	JAN 1989	FEB 1989	MAR 1989
L_1	0.10	0.18	0.11	0.09	0.12	0.13	0.14	0.14	0.10
L_2	-	0.16	0.17	0.13	0.14	0.13	0.15	0.11	0.10
L_3	0.17	0.18	0.14	0.13	0.13	0.12	0.17	0.10	0.11
L_4	-	-	0.16	0.16	0.12	0.16	0.14	0.11	0.10
L_5	-	0.15	0.17	0.12	0.10	0.12	0.14	0.10	0.11
L_6	0.17	0.16	0.17	0.13	0.13	0.15	0.15	0.08	0.10
L_7	-	0.17	0.15	0.14	0.13	0.14	0.14	0.12	0.12
L_8	0.17	0.18	0.16	0.13	0.14	0.14	0.15	0.14	0.11
R1	-	0.12	0.08	0.09	-	-	0.14	0.20	0.14
R_2	-	0.13	0.14	0.04	0.08	0.05	0.06	0.08	0.06
R_3	0.12	-	0.10	0.07	0.11	0.11	0.11	0.10	0.12
R_4	0.11	-	0.08	0.08	0.07	0.06	0.10	0.08	0.10

- Analysis not done, thus data not available.

APPENDIX 18:

TN:TP RATIO SEASONAL AND GEOGRAPHICAL VARIATION IN LAKE BARINGO AND SOME OF ITS RIVERS

MONTH STATION	JULY 1988	AUG 1988	SEP 1988	OCT 1988	NOV 1988	DEC 1988	JAN 1989	FEB 1989	MAR 1989
L_1	15.3	15.4	9.3	7.1	5.9	5.6	14.5	11.4	36.9
L_2	-	14.7	14.2	28.8	10.6	6.9	4.8	8.4	16.8
L_3	8.9	11.9	17.9	11.5	8.0	7.5	12.5	18.3	11.0
L_4	-	-	10.5	22.8	8.2	4.5	4.9	9.2	5.7
L_5	-	19.1	15.3	36.1	8.0	6.5	5.4	8.1	8.1
L_6	-	18.1	12.5	12.6	15.0	5.2	4.0	14.7	6.2
L_7	-	44.9	14.6	8.7	8.9	5.0	5.0	5.8	7.9
L_8	6.3	12.7	16.1	7.9	6.7	6.4	5.9	22.9	7.0
R_1	-	31.1	18.1	38.9	-	-	-	18.2	1.4
R_2	-	12.1	16.4	36.0	21.4	12.8	9.5	7.9	16.3
R_3	-	-	24.2	16.7	20.1	10.4	29.6	17.2	18.5
R_4	14.3	-	20.1	37.7	10.2	12.7	28.5	17.5	12.5

- Analysis not done, thus data not available.

APPENDIX 19:

SEASONAL AND GEOGRAPHICAL VARIATION IN CHRLORIDE (Cl^{-1}) CONCENTRATION IN LAKE BARINGO AND SOME OF ITS RIVERS (UNITS = mgl^{-1}).

MONTH / STATION	JULY 1988	AUG 1988	SEPT 1988	OCT 1988	NOV 1988	DEC 1988	JAN 1989
L_1	12.4	14.2	34.6	36.4	43.0	46.2	55.0
L_2	-	12.4	43.0	44.4	43.5	42.6	51.8
L_3	49.7	30.2	45.7	42.6	46.7	44.6	42.6
L_4	-	-	-	39.1	49.9	43.3	47.6
L_5	-	31.5	46.2	39.1	46.7	42.6	56.8
L_6	-	35.5	47.9	44.4	45.8	42.6	49.7
L_7	14.2	35.5	47.0	44.4	48.1	42.6	48.2
L_8	43.7	21.7	40.8	42.6	43.7	42.6	47.9
R_1	10.6	-	23.4	25.7	-	-	21.3
R_2	24.8	10.8	16.0	20.7	22.7	19.5	29.1
R_3	16.3	6.7	15.1	12.1	12.1	16.9	21.0
R_4	12.4	14.2	17.8	-	10.6	13.3	12.0

- Analysis not done, thus data not available.

APPENDIX 20:

SEASONAL AND GEOGRAPHICAL VARIATION IN FLUORIDE (F^-) CONCENTRATIONS IN LAKE BARINGO SOME OF ITS RIVERS (UNITS = mgl^{-1})

MONTH / STATION	JULY 1988	AUG 1988	SEP 1988	OCT 1988	NOV 1988	DEC 1988	JAN 1989	FEB 1989	MAR 1989
L_1	4.8	3.8	4.2	3.4	3.2	4.3	3.4	4.9	5.2
L_2	5.2	5.0	5.0	4.1	3.4	5.6	3.8	4.1	5.0
L_3	5.9	5.4	5.0	4.3	3.2	5.2	4.1	5.2	6.2
L_4	-	-	-	4.3	3.7	4.3	4.3	5.2	5.9
L_5	6.8	7.3	4.2	4.6	4.1	4.4	4.4	5.0	6.0
L_6	7.2	6.6	4.6	4.6	3.9	4.6	4.8	4.2	5.8
L_7	7.0	6.0	4.5	5.1	3.4	5.4	4.0	5.8	6.0
L_8	6.8	6.2	3.9	3.4	3.7	5.0	3.9	5.8	6.2
R_1	-	1.7	-	3.3	3.2	3.5	4.5	4.1	4.6
R_2	1.0	0.6	0.3	0.7	0.4	0.9	0.6	0.6	1.0
R_3	1.0	0.8	1.1	0.8	0.8	0.9	1.1	2.0	1.1
R_4	0.8	-	0.5	0.8	0.8	0.6	0.5	0.6	0.4

- Analysis not done, thus data not available.

APPENDIX 21:

SEASONAL AND GEOGRAPHICAL VARITIONS IN SULPHATE (SO_4^{2-}) CONCENTRATIONS IN LAKE BARINGO AND SOME OF ITS RIVERS (UNITS = mgl^{-1})

MONTH STATION	JULY 1988	AUG 1988	SEP 1988	OCT 1988	NOV 1988	DEC 1988	JAN 1989	FEB 1989	MAR 1989
L_1	13.5	11.0	16.0	13.0	17.0	17.5	20.5	-	20.0
L_2	-	13.8	16.0	18.0	17.0	16.5	18.0	-	17.5
L_3	19.5	22.0	19.5	18.0	19.0	17.0	22.0	-	23.0
L_4	-	-	18.0	21.8	18.0	18.5	20.0	-	20.0
L_5	21.5	20.0	17.0	21.0	18.8	17.5	20.0	-	17.5
L_6	40.0	24.0	20.0	19.0	20.0	21.0	19.0	-	20.0
L_7	23.0	22.2	21.0	18.0	19.0	18.0	-	-	15.0
L_8	21.0	19.2	20.0	16.5	18.0	19.0	19.0	-	18.0
R_1	3.5	10.0	-	-	-	-	12.0	12.0	5.0
R_2	6.5	4.5	4.3	5.0	4.0	5.5	6.5	-	2.5
R_3	5.0	6.5	7.5	10.0	5.0	6.5	10.5	-	[illegible]
R_4	10.0	6.5	10.2	10.0	9.0	10.5	15.0	-	10.0

- Analysis not done, thus data not available.

APPENDIX 22:

SESONAL AND GEOGRAPHICAL VARIATIONS IN MOLYDATE REACTIVE SILICA CONCENTRATIONS IN LAKE BARINGO AND SOME OF ITS RIVERS (UNITS = mgl^{-1})

MONTH / STATION	AUG 1988	SEP 1988	OCT 1988	NOV 1988	DEC 1988	JAN 1989
L_1	27.6	15.4	40.3	40.5	35.8	24.2
L_2	28.0	20.6	-	40.4	38.5	21.0
L_3	34.0	21.0	-	46.0	40.0	20.2
L_4	-	17.8	40.6	41.2	39.3	22.8
L_5	18.8	19.2	38.4	38.0	39.8	20.8
L_6	15.8	24.0	27.6	39.5	37.0	21.2
L_7	19.8	18.8	30.5	36.5	34.5	19.0
R_1	22.0	38.4	-	26.5	21.3	23.2
R_2	18.6	23.4	35.5	33.8	29.2	20.8
R_3	-	16.2	45.0	46.2	40.0	26.2
R_4	-	24.6	35.0	38.0	36.2	26.2

- Analysis not done, thus data not available.

APPENDIX 23:

SEASONAL AND GEOGRAPHICAL VARIATION IN TOTAL HARDNESS VALUE OF LAKE

BARINGO AND SOME OF ITS RIVERS (UNITS = mgl^{-1} as $CaCO_3$)

MONTH / STATION	AUG 1988	SEPT 1988	OCT 1988	NOV 1988	DEC 1988	JAN 1989	FEB 1989	MAR 1989
L_1	60.0	52.0	36.0	40.0	46.0	44.0	48.0	56.0
L_2	52.0	56.0	36.0	48.0	48.0	48.0	52.0	56.0
L_3	56.0	56.0	36.0	44.0	48.4	44.0	52.0	52.0
L_4	-	-	42.0	40.0	52.0	40.0	48.0	52.0
L_5	40.0	52.0	46.0	42.0	56.0	48.0	52.0	56.0
L_6	48.0	52.0	46.0	42.0	48.0	44.0	48.0	56.0
L_7	52.0	56.0	36.0	44.0	46.0	44.0	52.0	60.0
L_8	52.0	52.0	34.0	38.0	40.0	44.0	48.0	56.0
R_1	20.0	-	20.0	-	-	12.0	-	-
R_2	52.0	32.0	36.0	38.0	40.0	32.0	36.0	42.0
R_3	40.0	28.0	36.0	27.5	38.0	36.0	-	-
R_4	-	40.0	32.0	28.0	38.0	38.0	36.0	40.0

- Analysis not done, thus data not available.

APPENDIX 24:

MEAN MONTHLY CONCENTRATIONS OF CALCIUM (Ca^{2+}) PER STATION IN LAKE BARINGO AND SOME OF ITS RIVERS (UNITS= mgl^{-1})

MONTH STATION	AUG 1988	SEP 1988	OCT 1988	NOV 1988	DEC 1988	JAN 1989	FEB 1989
L_1	-	13.6	9.6	12.4	11.6	12.0	11.2
L_2	11.2	18.4	7.2	12.0	12.0	10.4	12.8
L_3	15.2	14.4	11.2	13.2	12.4	12.0	11.2
L_4	-	-	9.2	9.2	10.4	10.4	12.0
L_5	13.6	12.0	12.8	12.0	9.6	11.2	12.8
L_6	15.5	12.8	11.6	10.4	11.2	11.2	11.8
L_7	15.2	11.2	8.8	12.8	10.4	11.2	11.2
L_8	12.0	9.6	7.6	9.6	11.2	8.0	10.4
R_1	4.8	-	4.0	-	-	3.2	-
R_2	6.4	9.6	8.0	8.0	9.2	6.8	-
R_3	4.8	8.0	7.2	8.4	7.2	16.8	-
R_4	-	-	14.4	8.0	8.4	8.0	13.2

- Analysis not done, thus data not available.

APPENDIX 25:

MEAN MONTHLY CONCENTRATION OF MAGNESIUM (Mg^{2+}) PER STATION IN LAKE BARINGO AND SOME ITS RIVERS (UNITS = mgl^{-1}).

MONTH / STATION	AUG 1988	SEP 1988	OCT 1988	NOV 1988	DEC 1988	JAN 1989	FEB 1989
L_1	8.8	4.4	2.9	1.2	4.1	3.4	4.8
L_2	5.8	2.4	4.4	4.4	4.4	5.3	4.8
L_3	4.4	4.8	1.9	2.7	4.2	3.4	5.8
L_4	-	-	4.4	4.1	6.3	3.4	4.4
L_5	1.4	5.3	3.4	2.9	7.8	4.8	4.8
L_6	2.2	4.8	4.1	3.9	4.8	3.9	3.9
L_7	3.4	6.8	3.4	2.9	4.9	3.9	5.8
L_8	5.3	6.8	3.6	3.4	2.9	5.8	5.3
R_1	1.9	-	2.4	-	-	1.0	-
R_2	8.8	1.9	3.9	4.4	4.1	3.6	-
R_3	6.8	1.9	4.4	1.6	4.9	1.9	-
R_4	-	1.0	2.9	1.7	4.4	1.2	-

- Analysis not done, thus data not available.

APPENDIX 26:

MEAN MONTHLY CONCENTRATIONS OF SODIUM (Na^+) PER STATION IN LAKE BARINGO AND SOME OF ITS RIVERS (UNITS = mgl^{-1})

MONTH / STATION	JULY 1988	AUG 1988	SEP 1988	OCT 1988	NOV 1988	DEC 1988	JAN 1989	FEB 1989	MAR 1989
L_1	87.5	44.8	135.5	116.0	141.8	136.0	150.0	160.0	177.5
L_2	-	95.0	161.5	155.0	102.5	160.0	150.0	155.4	172.5
L_3	180.0	142.5	169.5	152.5	146.3	145.0	160.0	168.7	172.5
L_4	-	-	-	163.5	154.0	168.0	175.5	160.5	167.5
L_5	145.0	168.3	170.0	148.0	177.5	186.0	182.5	178.4	172.5
L_6	235.0	200.0	153.5	150.0	149.3	181.0	175.3	161.5	167.5
L_7	240.0	194.2	175.8	172.5	118.5	152.9	168.0	171.3	150.0
L_8	181.3	115.0	160.0	145.0	115.0	145.5	160.0	158.2	155.
R_1	-	40.0	92.5	117.0	100.2	130.0	67.5	111.4	146.0
R_2	12.5	50.3	35.0	55.0	50.0	72.5	40.2	75.5	108.0
R_3	23.0	27.0	27.0	20.0	33.5	20.0	22.5	55.5	-
R_4	21.5	-	14.0	14.5	20.0	9.5	16.0	18.6	20.0

- Analysis not done, thus data not available.

APPENDIX 27:

MONTHLY CONCENTRATIONS OF POTASSIUM (K^+) PER STATION IN LAKE BARINGO AND SOME OF ITS RIVERS (UNITS = mgl^{-1})

MONTH / STATION	JULY 1988	AUG 1988	SEP 1988	OCT 1988	NOV 1988	DEC 1988	JAN 1989	FEB 1989	MAR 1989
L_1	15.0	13.0	11.5	10.5	10.3	11.5	15.0	15.3	14.5
L_2	-	18.0	13.5	11.8	9.5	12.3	13.0	13.5	14.0
L_3	22.4	20.0	13.8	13.0	10.5	12.0	13.5	13.8	14.5
L_4	-	-	-	14.0	12.3	13.5	13.5	13.0	14.5
L_5	25.0	16.7	13.0	12.2	12.8	8.8	13.5	14.8	14.5
L_6	25.5	23.0	16.0	13.0	11.0	10.8	13.0	13.0	14.5
L_7	21.5	16.6	14.3	14.0	10.5	14.5	13.0	14.5	14.5
L_8	19.8	15.5	13.5	13.3	11.8	12.0	13.5	15.0	14.5
R_1	-	7.5	5.5	6.5	6.0	6.8	5.0	4.5	5.0
R_2	10.0	6.0	5.0	6.5	6.0	6.8	7.0	7.5	10.5
R_3	13.5	11.5	6.8	6.5	8.5	7.3	13.0	12.0	-
R_4	6.0	-	9.0	3.5	4.5	3.8	7.0	7.6	8.0

- Analysis not done, thus data not available.

APPENDIX 28:

SEASONAL AND GEOGRAPHICAL VARIATION IN CONCENTRATION OF ALUMINIUM IN LAKE BARINGO AND SOME OF ITS RIVERS (UNITS = mgl^{-1})

MONTH / STATION	JULY 1988	AUG 1988	SEP 1988	OCT 1988	NOV 1988	DEC 1988	JAN 1989	FEB 1989	MAR 1989
L_1	8.8	6.8	7.5	9.1	11.5	12.0	6.8	-	6.5
L_2	-	7.5	9.1	11.5	14.5	12.0	9.1	-	6.5
L_3	10.0	14.5	10.5	12.0	15.1	10.7	7.0	-	8.8
L_4	-	-	10.0	12.7	10.5	10.0	7.5	-	6.5
L_5	14.0	7.5	11.5	12.5	8.8	12.0	8.5	-	6.8
L_6	10.3	9.4	9.5	12.5	10.0	11.5	8.8	-	8.0
L_7	17.5	15.1	14.0	10.0	14.5	11.5	8.5	-	7.5
L_8	16.2	13.5	10.5	11.5	10.5	10.5	6.8	-	7.5
R_1	-	8.8	-	2.8	-	-	-	0.8	0.8
R_2	3.1	1.2	0.4	0.8	1.2	0.8	0.8	-	0.8
R_3	6.0	1.6	2.0	2.4	2.4	2.6	-	-	-
R_4	6.0	2.4	2.4	2.4	1.2	0.8	0.8	-	

- Analysis not done, thus data not available.

APPENDIX 29:

SEASONAL AND GEOGRAPHICAL VARIATION IN IRON (Fe) CONCENTRATION IN LAKE BARINGO AND SOME OF ITS RIVERS (UNITS = mgl^{-1})

MONTH / STATION	JULY 1988	AUG 1988	SEP 1988	OCT 1988	NOV 1988	DEC 1988	JAN 1989	FEB 1989	MAR 1989
L_1	4.8	4.8	4.7	5.8	6.4	7.2	2.9	-	5.2
L_2	-	5.1	5.1	8.0	8.5	8.0	8.5	-	6.2
L_3	4.3	9.2	6.0	9.0	10.0	6.2	2.2	-	9.5
L_4	-	-	6.4	12.5	5.0	7.0	2.5	-	3.8
L_5	11.8	4.6	5.4	5.5	4.6	9.5	4.2	-	7.2
L_6	26.5	4.6	4.0	7.0	6.3	6.5	7.5	-	6.0
L_7	10.8	10.5	9.0	6.2	8.0	4.0	6.3	-	5.2
L_8	14.2	9.2	5.1	7.0	4.9	6.0	2.0	-	5.2
R_1	-	7.3	-	1.5	-	-	-	0.6	0.5
R_2	1.7	0.7	1.0	0.8	0.8	0.5	0.4	-	1.1
R_3	5.3	2.7	2.8	3.3	3.3	3.2	3.5	-	[illegible]
R_4	5.2	2.2	1.9	2.0	1.2	0.6	0.6	-	1.3

- Analysis not done, thus data not available.

APPENDIX 30:

SEASONAL AND GEOGRAPHICAL VARIATION IN MANGANESE CONCENTRATION IN LAKE BARINGO AND SOME OF ITS RIVERS

(UNITS = mgl^{-1})

MONTH / STATION	JULY 1988	AUG 1988	SEP 1988	OCT 1988	NOV 1988	DEC 1988	JAN 1989	FEB 1989	MAR 1989
L_1	0.36	0.49	0.21	0.24	0.24	0.22	0.18	-	0.75
L_2	-	0.60	0.30	0.18	0.28	0.18	0.28	-	0.30
L_3	0.65	0.60	0.39	0.22	0.30	0.17	0.16	-	0.28
L_4	-	-	1.51	0.31	0.18	0.13	0.16	-	0.17
L_5	0.55	0.35	0.49	0.37	0.22	0.18	0.16	-	0.20
L_6	0.65	0.14	0.50	0.25	0.22	0.18	-	-	0.23
L_7	0.65	0.65	0.32	0.20	0.32	0.22	0.12	-	0.28
L_8	0.85	0.70	0.45	0.20	0.20	0.18	0.20	-	0.28
R_1	-	0.60	-	0.16	-	-	-	0.20	0.18
R_2	0.22	0.10	0.14	0.14	0.10	0.06	0.05	-	0.27
R_3	0.50	0.28	0.36	0.33	0.30	0.19	-	-	-
R_4	0.50	0.16	0.20	0.30	0.10	0.10	0.03	-	-

- Analysis not done, thus data not available.

APPENDIX 31:

CHLOROPHYLL a VALUES INDICATING SEASONAL AND GEOGRAPHICAL VARIATION IN LAKE BARINGO (UNITS = $\mu g l^{-1}$)

MONTH STATION	JULY 1988	AUG 1988	SEP 1988	OCT 1988	NOV 1988	DEC 1988	JAN 1989	FEB 1989	MAR 1989
L_1		5.6	4.9	2.3	9.0	22.2	24.4	7.6	22.5
L_2		8.1	9.8	1.0	11.1	18.9	13.2	9.6	9.3
L_3		8.8	8.9	12.2	8.9	14.2	12.2	10.4	9.1
L_4		-	10.4	7.3	13.2	10.3	8.6	6.4	5.8
L_5		12.2	8.1	7.3	8.8	9.4	8.7	9.8	7.0
L_6		16.9	17.9	14.5	9.7	12.6	6.7	9.9	7.0
L_7		18.0	19.0	17.3	6.8	14.3	8.9	13.2	9.0
L_8		14.4	25.3	19.4	8.7	16.0	20.3	35.9	22.4

- Analysis not done, thus data not available.

APPENDIX 32

RESULTS OF X-RAY FLUORESCENCE SPECTOSCOPY ANALYSIS OF

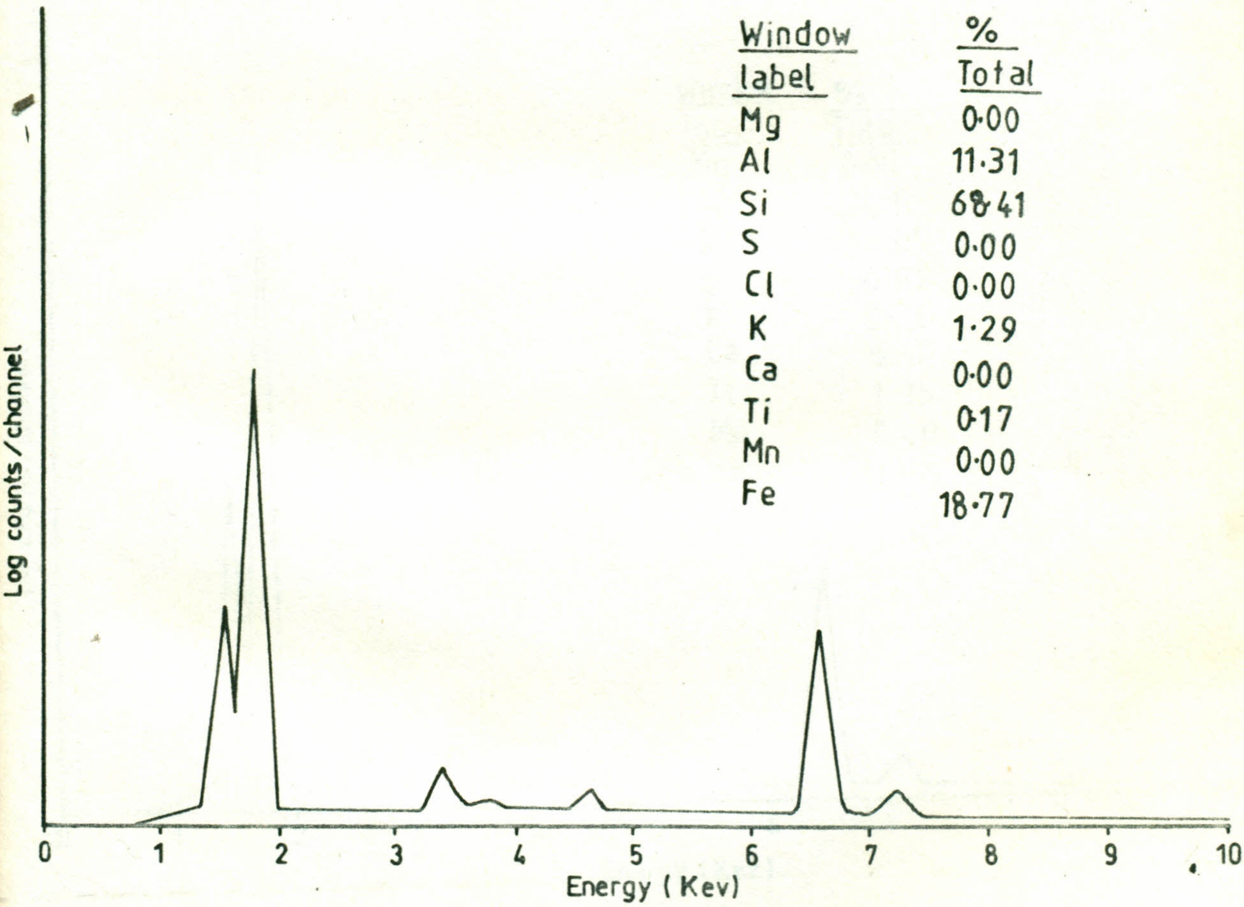
SUSPENDED SILT IN LAKE BARINGO AND SOME OF ITS MAJOR RIVERS.

SITES	Mg %	Al %	Si %	S %	Cl %	K %	Ca %	Ti %	Mn %	Fe %
L_1	0.10	24.09	57.14	0.18	0.00	1.74	0.48	1.07	0.12	14.83
L_2	0.39	22.77	55.27	0.12	0.00	1.99	0.54	1.14	0.05	17.45
L_3	0.12	24.20	57.07	0.08	0.00	1.79	0.40	1.15	0.05	15.05
L_4	0.00	24.17	58.05	0.01	0.00	1.73	0.40	1.15	0.00	14.35
L_5	0.13	23.67	56.03	0.05	0.00	1.85	0.62	1.28	0.05	16.17
L_6	0.00	23.69	56.58	0.02	0.17	1.90	0.50	1.17	0.09	15.77
L_7	0.33	23.70	57.66	0.00	0.06	1.77	0.42	1.09	0.07	14.80
L_8	0.00	23.60	56.06	0.12	0.00	1.84	0.32	1.21	0.00	16.79
R_2	0.00	23.28	52.45	0.04	0.09	2.70	0.61	1.57	0.08	15.90
R_3	0.03	15.44	72.81	0.06	0.00	1.89	0.06	0.39	0.03	9.28
R_4	0.00	11.31	68.41	0.00	0.00	0.29	0.00	0.17	0.00	16.77

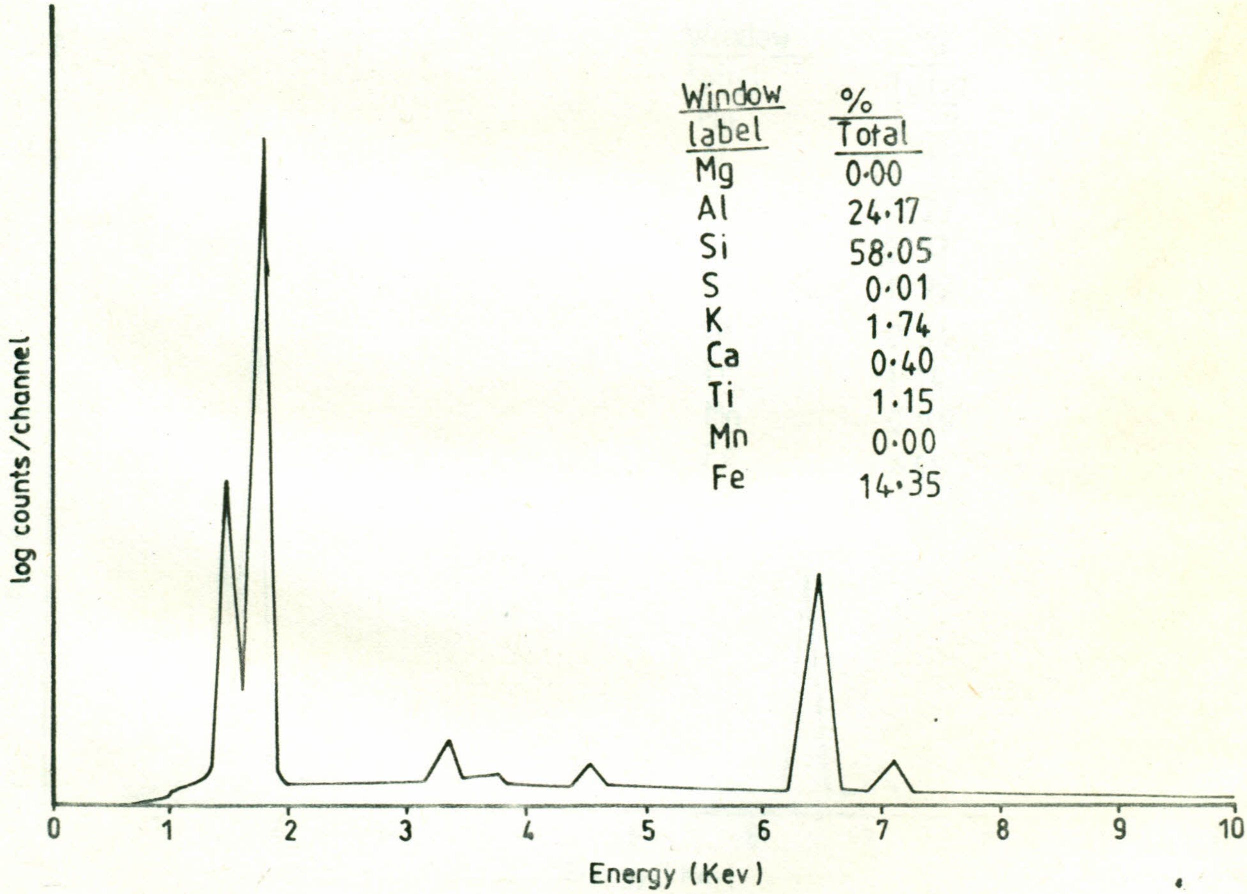
APPENDIX 33:

The X-Ray fluorescence spectra maximum peaks for silt samples occur at energies or channel numbers recorded below:

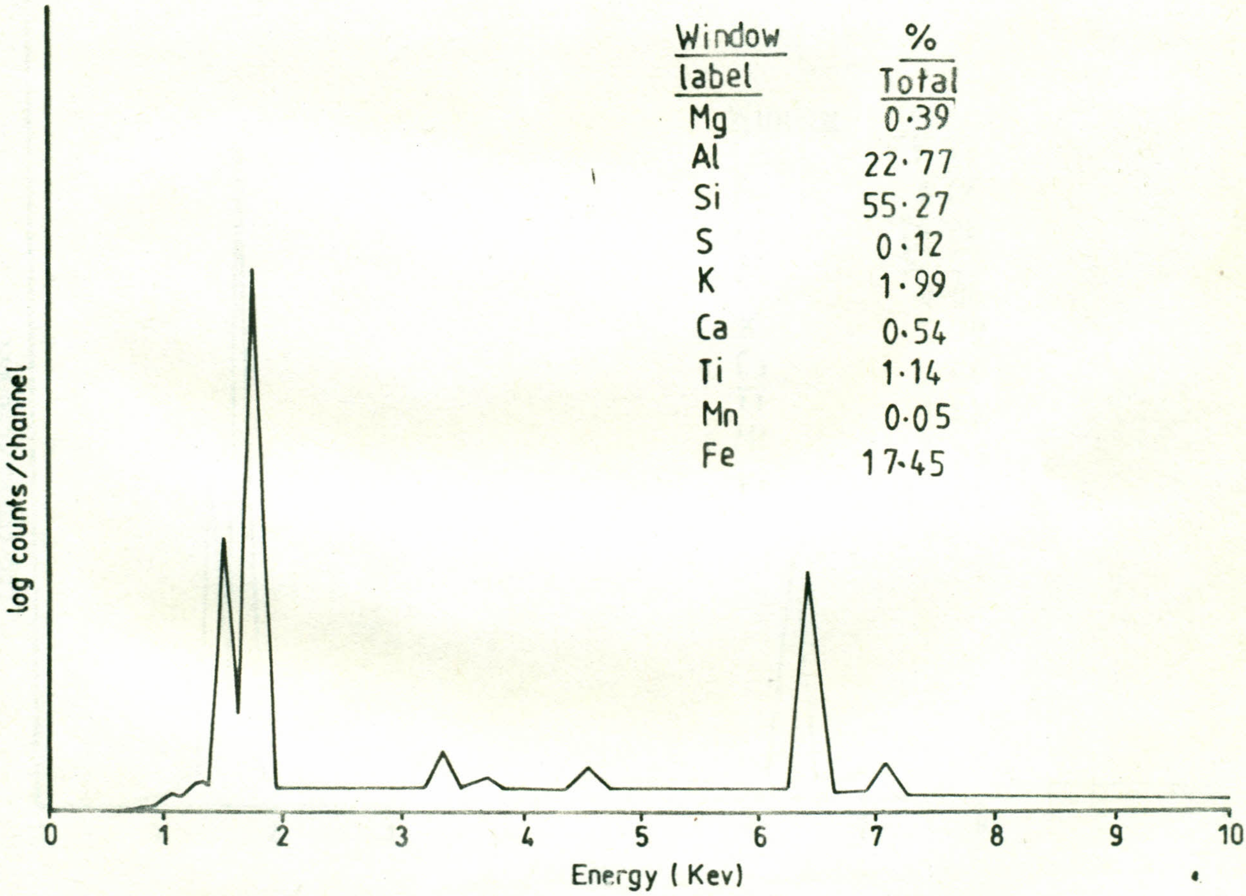
Energy (kev)/Channel Number	Parameter
1.0	Magnesium
1.5	Aluminium
1.8	Silicon
3.4	Potassium
3.8	Tin
4.6	Titanium
6.6	Iron
7.2	Manganese



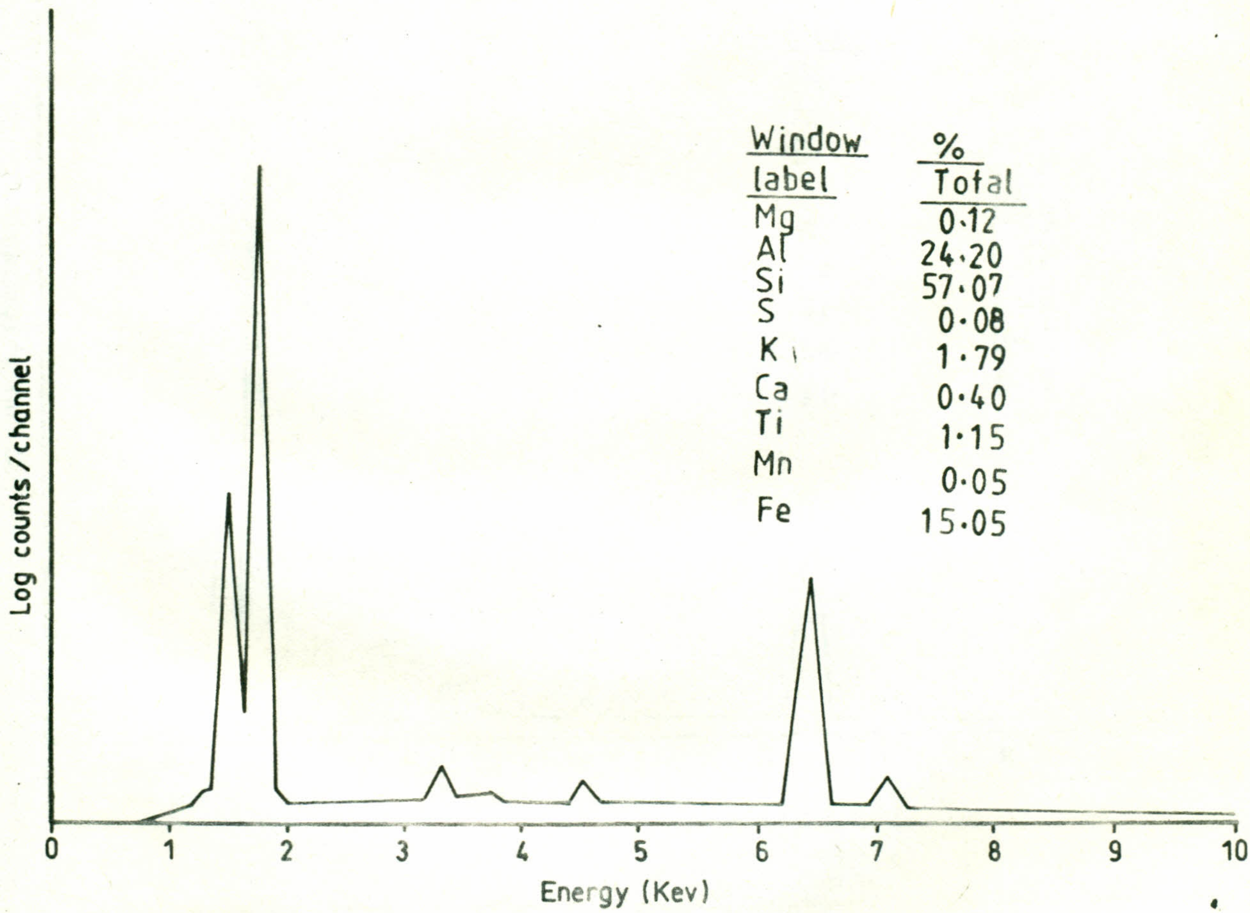
APPENDIX 34: The X-ray fluorescence spectra for suspended silt in Lake Baringo for station L_1



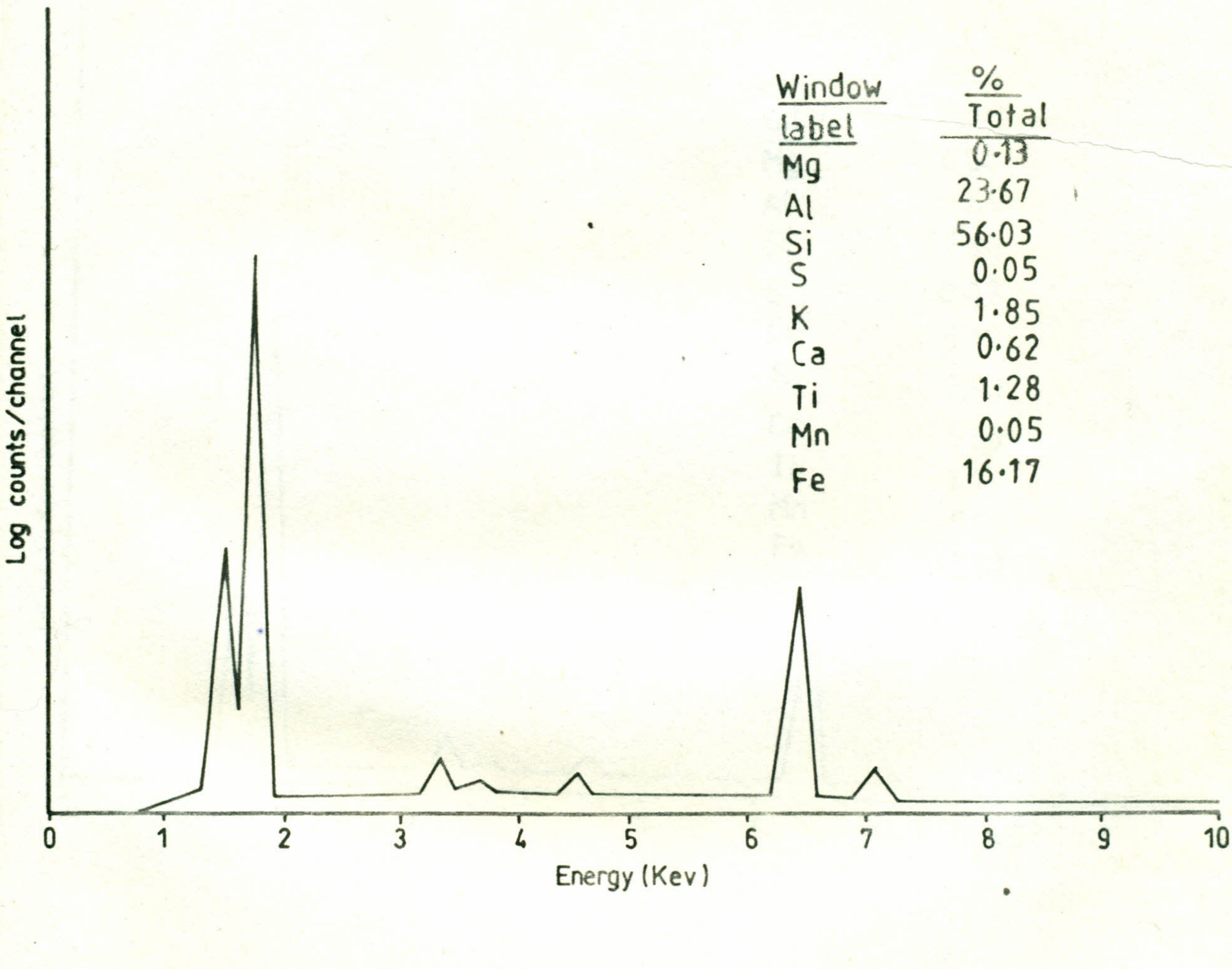
APPENDIX 35: The X-ray fluorescence spectra for suspended silt in Lake Baringo for station L_2



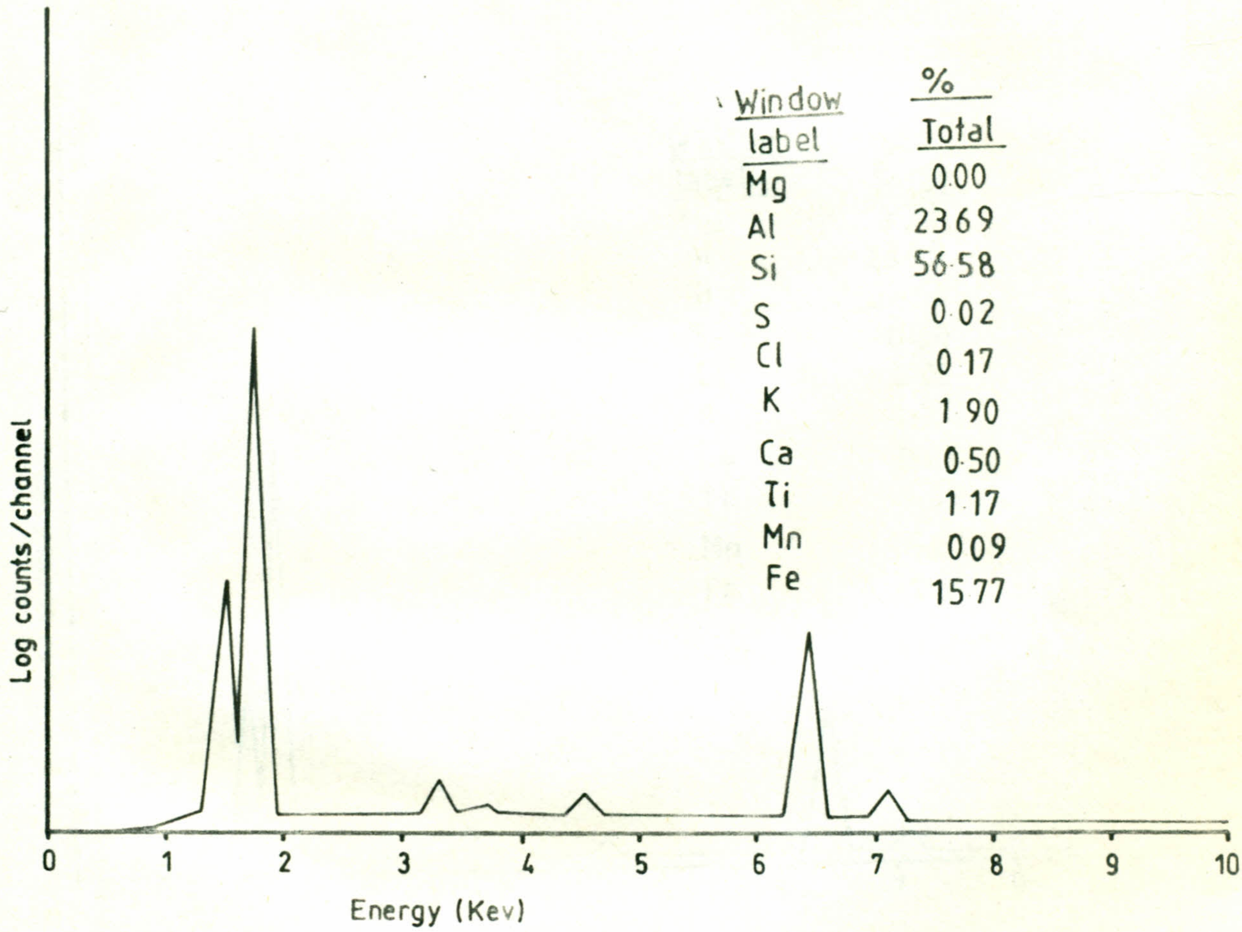
APPENDIX 36: The X-ray fluorescence spectra for suspended silt in Lake Baringo for station L_3.



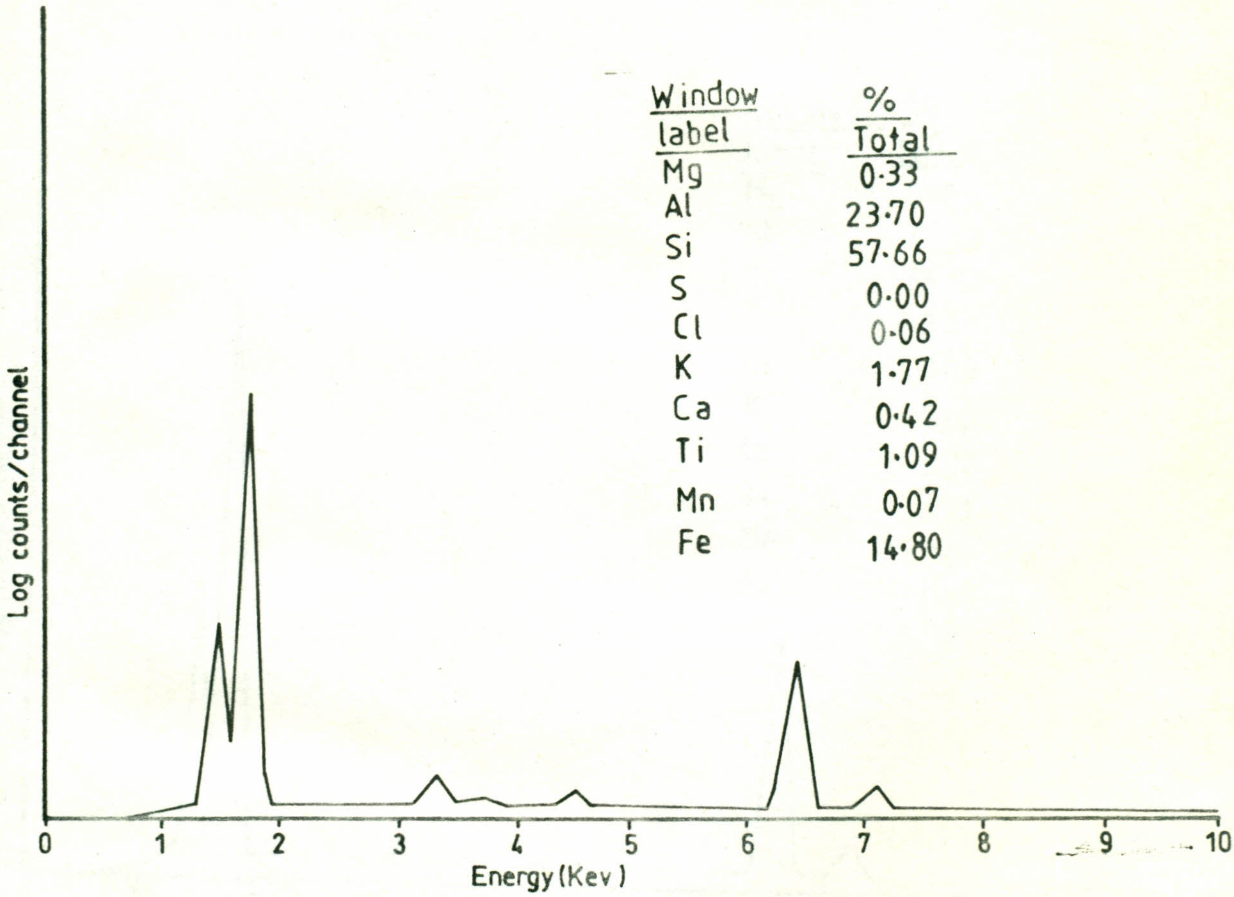
APPENDIX 37: The X-ray fluorescence spectra for suspended silt in Lake Baringo for Station L_5.



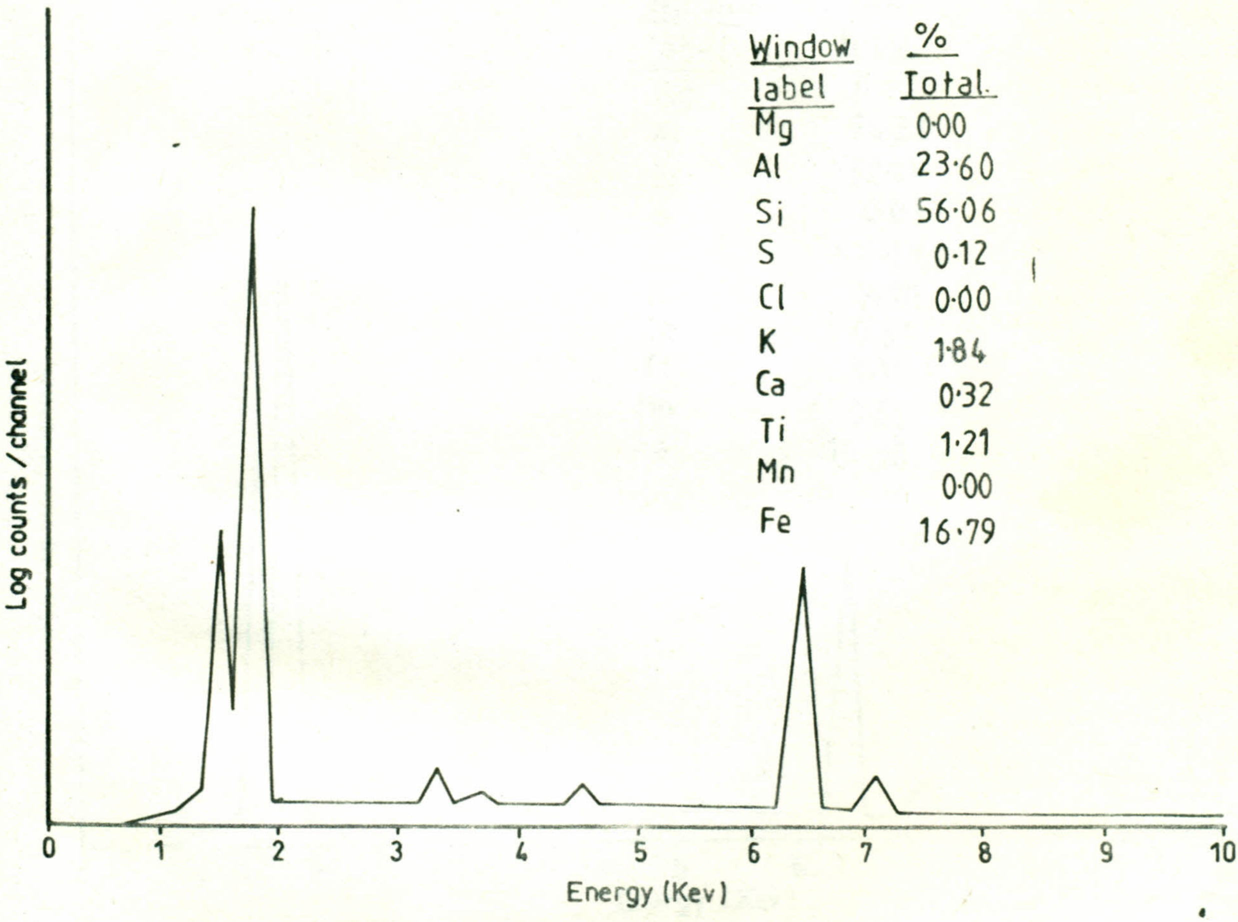
APPENDIX 38: The X-ray fluorescence spectra for suspended silt in Lake Baringo for Station L_6.



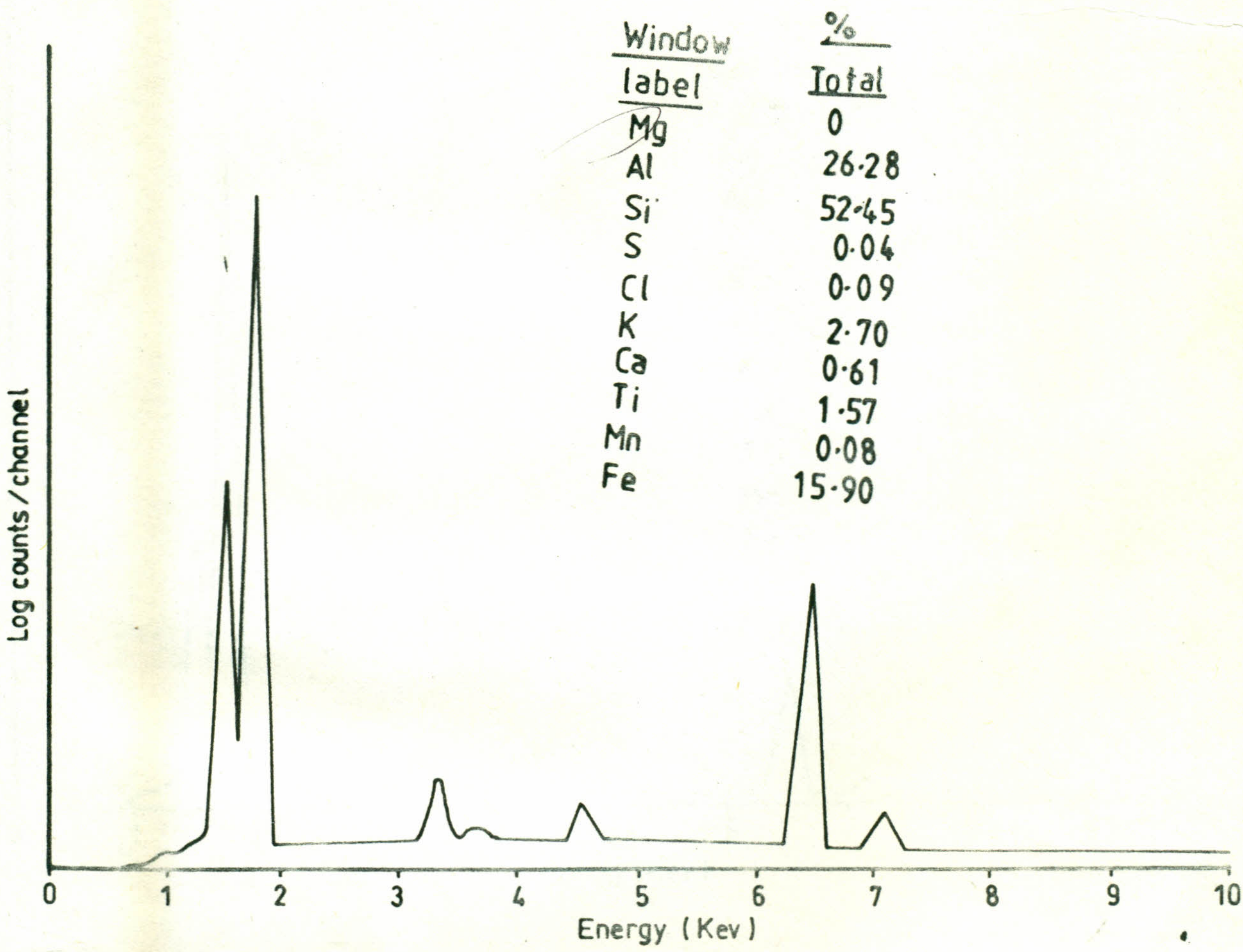
APPENDIX 39: The X-ray fluorescence spectra for suspended silt in Lake Baringo for Station L_7.



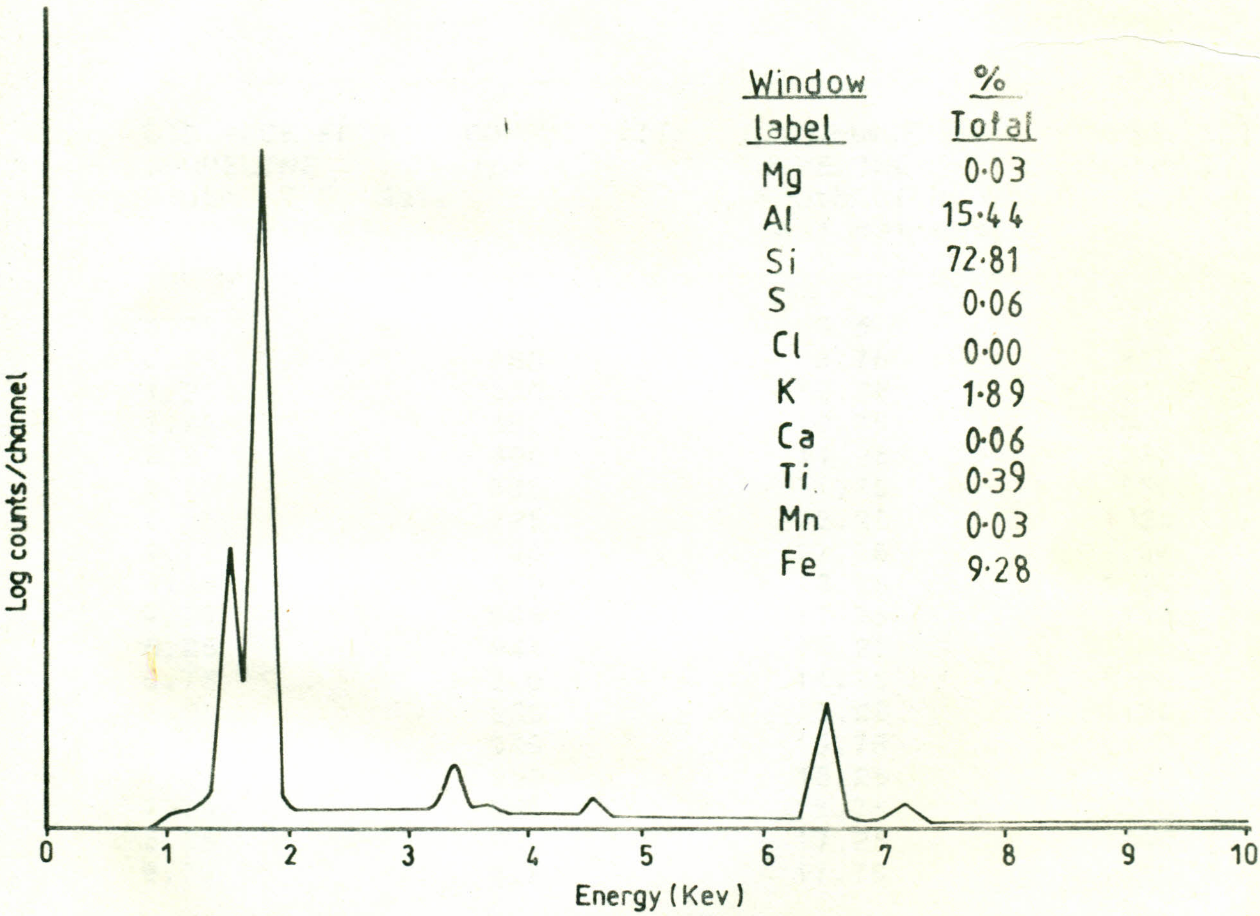
APPENDIX 40: The X-ray fluorescence spectra for suspended silt in Lake Baringo for Station L_8.



APPENDIX 41: The X-ray fluorescence spectra for suspended silt for Station R_2 (River Ol-Arabel).



APPENDIX 42: The X-ray fluorescence spectra for suspended silt for Station R_3 (River Molo)



APPENDIX 43: The X-ray fluorescence spectra for suspended silt for Station R_4 (River Perkerra).

APPENDIX 44:

CHANGES IN CONDUCTIVITY LEVELS OF SURFACE WATER OF LAKE BARINGO FROM THE MOUTH OF RIVER MOLO THROUGH L_1 TO L_6 (8TH AUGUST, 1988).

DISTANCE FROM SHORELINE Mouth of R. Molo (Kilometres)	CONDUCTIVITY (μScm^{-1})	DISTRANCE FROM SHORELINE Mouth of R. Molo (Kilometres)4	CONDUCTIVITY (μScm^{-1})
0.25	135	9.5	910
0.75	380	9.75	850
1.25	390	10.25	890
1.75	365	10.75	890
2.25	400	11.25	885
2.75	565	11.75	930
3.25	725	12.25	1085
3.75	790	12.75	1130
4.25	915	13.25	1130
4.75	945	13.75	1120
5.25	945	14.25	1130
5.75	910	14.75	1120
6.25	920	15.25	1110
6.75	945	15.75	1110
7.25	950	16.25	1055
7.75	950	16.75	1040
8.25	930	17.25	1080
8.75	815	17.75	1210

APPENDIX 45:

CHANGES IN CONDUCTIVITY VALUES ALONG A TRANSECT ACROSS LAKE BARINGO FROM STATION L_1 THROUGH L_3 TO L_6 (18TH SEPTEMBER, 1988).

DISTANCE FROM MOUTH OF RIVER MOLO (Kilometres)	CONDUCTIVITY (μScm^{-1})
0.25	157
0.75	280
1.25	583
1.75	777
2.25	785
2.75	793
3.25	803
3.75	807
4.25	807
4.75	820
5.25	823
5.75	873
6.25	830
6.75	800
8.75	820
11.75	800
14.75	770
17.75	850

APPENDIX 46:

CHANGES IN CONDUCTIVITY VALUES OF SURFACE WATER OF LAKE BARINGO ALONG A TRANSECT THROUGH STATION L_1 TO L_3 (9TH FEBRUARY, 1989).

DISTANCE FROM MOUTH OF RIVER MOLO	CONDUCTIVITY (μScm^{-1})
0.00	670
0.95	790
1.90	800
2.85	820
3.80	830
4.75	850
5.70	850
6.65	850
7.60	840
8.55	850
9.50	830