LIMNOLOGY AND ZOOPLANKTON OF MAKWAYE (AHMADU BELLO UNIVERSITY FARM) LAKE, SAMARU, ZARIA - NIGERIA

BY

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JUNE, 1989

D E D I C A T I O N

TO MY AFFECTIONATE PARENTS

ALHAJI BALARABE AND

HAJIYA RAKIYA IBRAHIM

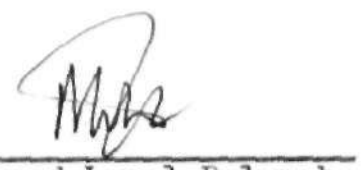
AND

MY BELOVED WIFE

HINDATU.

D E C L A R A T I O N

I hereby declare that this thesis is my own work and has not been presented in any form for another qualification at any other university or institution. Information derived from the published or unpublished works of others has been duly acknowledged in this work.



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CERTIFICATION

This thesis entitled "Limnology and Zooplankton distribution of Makwaye (Ahmadu Bello University Farm) lake Samaru, Zaria Nigeria" by Mohammad Lawal Balarabe meets the regulation governing the award of the degree of Master of Scince of Ahmadu Bello University, and is approved for its contribution to knowledge and literary presentation.

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A B S T R A C T

Physico-chemical parameters, Zooplankton and Benthos of Makwaye (Ahmadu Bello University Farm) Lake Samaru, Zaria were studied for a period of 12 months from May 1987 to April, 1988.

Three groups of zooplankton and four groups of benthos with 15 and 8 genera respectively were recorded. With the exception of temperature and B.O.D. all the biota and physico-chemical parameters exhibited a significant seasonal variation ($P< 0.05$). The concentrations of Magnesium and Sodium in both the surface water and the sediment exhibited a significant seasonal variation ($P< 0.05$).

There was a significant correlation of temperature, pH, Zn, and Co with Copepoda and Mollusca with Co, K and Ca.

Low transparency, high PO_4 -P and NO_3-N concentration were recorded throughout the study period.

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CHAPTER ONE

1.1 INTRODUCTION

The ultimate objective of limnological studies is to understand the factors upon which continued existence of species in nature depends and to find the causes of fluctuations in numbers or in some cases temporary or permanent extinction. Environmental quality directly or indirectly affects species abundance, composition and diversity.

Limnology in Nigeria is still in the primodal stage inspite of the abundant water resources. Limnological studies is important for the succesful development, management and utilization of water resources with regards to their fisheries potential, especially now that the Nigerian government emphasizes the production of alternative cheap protein supplement to the inadequate beef supply. With this in view there is the need to intensify our efforts in the field of hydrobiology. The most important contributions of limnology to fisheries is the ability to objectively evaluate the yield in fish which can be expected from individual water bodies. By providing even a rough estimate of what a lake ought to produce it is much easier to plan the scale of development, to identify the"problems of fisheries", to evaluate the need for regulation, controls and to establish quotas to ensure

continuing yields of valuable fish protein (Henderson, 1979).

Some of the available limnological studies in Nigeria are those of Eleiyele and Kainji reservoirs (Imevbore, 1967, 1968, 1970; and Adeniji, 1973). Other studies were those on lake Asejire (Egborge, 1979) and some reserviors in Plateau state of Nigeria (Khan, et al., 1983; Khan and Ejike, 1984; Wade, 1985 and Kemdirim, 1987).

In recent years there has been increasing concern about the rate at which inland waters are polluted through human activities. Agricultural wastes, manures, fertilizers and pesticides find their way through run-offs into streams and lakes and therefore enrich the water bodies (Beadle, 1974 and Gopal, et al., 1981), leading to eutrophication (Mitchell, 1975). Eutrophication becomes a nuisance in these lakes because of impaired water quality, fermentation processes during anoxic periods, prolific weed growth, excessive algal blooms and deteriorating fisheries (Gelin, 1978). Sendacz (1984) reported that eutrophication affects the specific composition of zooplankton through physical and chemical alterations

of the environment as well as changing the composition of phytoplankton which constitute food for the zooplankton.

Phytoplankton which stand at the base of aquatic food pyramid is the most important factor for the production of organic matter in the aquatic ecosystem, zooplankton are nutritionally dependent on them. Fish production depends on the production of plankton, benthos, the basic morphometry, edaphic and climatic factors (Rawson, 1952).

Biotic communities differ greatly in their response to changes in physico-chemical conditions of the environment. Margalef (1975) recognised two kinds of stability in biological communities, first is the achievement of a "steady state" of species and numbers under fairly constant conditions in the environment and secondly is the ability to return to normalcy even after marked fluctuations of the environmental parameters. For an organism to establish a population in a given biotope the environmental conditions must be such that the organism not only survive but is not caused to leave, is able to feed, grow and successfully reproduce. This success can only be achieved if the abiotic factors which affect the biotic community should fluctuate minimally.

The aim of ecological research according to Golterman (1975) is to enable us utilize our natural resources more effectively and prevent us from harming them. Thus, this research work was carried out with the aim of assessing the impact of mixed farming on water quality characteristics, nutrient levels and trace elements in relation to zooplankton and macrobenthic distribution of Makwaye (Ahmadu Bello University farm) lake Samaru, Zaria. The study will provide new data and expand on earlier work done, with a view of utilizing the results for best management of the water resource.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 The quality of a given water body is governed by physical, chemical and biological factors all of which interact with one another and greatly influence its productivity. In order to assess the potentials of such aquatic ecosystems for their essential management and effective utilization, there is the need to study these influences with a view to controlling and maintaining them within the optimum range. A study of the physico-chemical influences also provide a greater insight into why problems occur, help to discern the trends and assess potential remedies. Stent (1981) suggested that monitoring of biological and physico-chemical characteristics of a reservoir is important for both short-term and long term trends. It enables appropriate decisions to be made and action taken to minimize deleterious effects.

Homogeneity of limnological conditions within a given lake is not easily observed because of spatial variations of those conditions established by various factors (such as morphometry, wind, inflow, outflow) (Lind, 1984). Morphoedaphic index (M.E.I) is a good measure of potential lake productivity (Wade and Anadu,

1987). It is the ratio of total dissolved solids (TDS) to average depth.

The depth of water relative to the surface area imposes environmental features which influence production capabilities in the planktonic, littoral depth and benthic zones with consequent effects on the overall biomass of the impoundment ecosystem (Ridley and Steel, 1975). Water level fluctuations are inversely related to temperature (Comin et al., 1983). For very shallow lakes, the heat content is determined mainly by mean depth and heat input (Rippey and Rippey, 1986).

Hynes (1970) reported that in tropical zones, where seasonal changes are less, temperature changes are of greater significance. Positive influence of water temperature on crustacean zooplankton communities have been documented (Hazelwood and Parker, 1963). Hawkes (1975) showed that temperature is an important factor in determining the vertical distribution of some species, it is less important in the case of others and the manner in which it operates differ with different taxa. In animals exposed to heavy metals pollution, temperature modifies the lethal effects of the heavy metal to these organisms (Hodson and Sporague,

1975). Ridley and Steel (1975) reported that photosynthesis, respiration and nutrient uptake are temperature dependent. The low light tolerance of most pond algae indicates that they are probably more keyed to temperature changes than to increased light intensity (Russo, 1978).

Talling (1971) related the potential for phytoplankton growth to the depth of light penetration in relation to the lake mean depth, the amount of incoming radiation and the respiration rates of the phytoplankton. Light extinction and secchi depth are a function of the size and number of the light scattering particles and absorption by chlorophyll-a pigment (Edmonson, 1980). Lorenzen (1980) and Megard et al. (1980) showed that secchi depth is significantly influenced by chlorophyll-a content only when light extinction by particles scattering is small. In waters where light extinction by non algal materials is low, Megard et al. (1980) also suggested that the upper limit of chlorophyll-a concentration to which secchi depth is reasonably sensitive is approximately 20 to 30 Ugl^{-1}. Hence, turbidity and its relevant light wavelengths are important (Stent, 1981). Lind (1986) found that the expected relationship between secchi depth and chlorophyll-a concentration was not apparent.

Secchi depth can be used to estimate the variation of euphotic depth (Rippey and Rippey, 1986).

Hydrogen ion concentration (pH) of any water medium is a measure of its acidity or alkalinity. The principal system regulating pH in natural waters is the carbonate system which is composed of carbon dioxide, carbonic acid, bicarbonate and carbonate ions. Talling and Rzoska (1967) reported higher pH values with increasing photosynthesis and lower values as a result of increase in the concentration of carbon dioxide resulting from the decomposition of organic matter. Timms (1972) attributed the low pH values of an Australian meromictic lake, to the lower proportion of bicarbonate ($HCO_3^{=}$) and Carbonate (CO_3^{2-}) ions relative to chloride (Cl^{-}) ions. High pH can facilitate phosphate removal by accelerating the rate of calcium carbonate precipitation the carbonate sediments out with the phosphate ions adsorbed to it (Golterman, 1975). Russo (1978) reported that runoff from agricultural lands and photosynthesis account for increases in pH.

PH influences the toxicity of contaminants (Bukley, 1975). Godfrey (1980) observed that increased acidity decreases species diversity. Borg (1983) showed that a decrease in pH favours the prolonged

retention time of some metals in water. Negative correlations were found between pH and Al, Cd, Mn, Pb and Zn (Dickson, 1980, and Borg, 1983).

Conductivity and mean depth of a reservoir could be used to calculate the potential fish yield of a lake (Ryder et al., 1974). Electrical conductivity of the water is affected both by the total concentrations of the ions and other factors such as mobility of the individual ions (Beadle, 1974). Ashton and Schoeman (1983) showed that electrical conductivity and concentrations of major ions increase with depth. At low levels major ions may determine the nature of the fauna (Moss, 1980).

In lakes, oxygen distribution is important in the behaviour, growth and distribution of aquatic organisms (Wetzel, 1975). Different organisms have different oxygen requirements and as such dissolved oxygen concentration is an important factor which determine their distribution (Hawkes, 1975). Ball and Gluckman (1978) suggested that wind circulation and convection current created by local heating may play a role in transporting high concentration of oxygen to the bottom of lakes. In very shallow lakes, oxygen fluctuations may be due to mixing by wind as a result of close relationship between the

free water and the bottom where there is active decomposition (Comin *et al*., 1983).

Many lakes throughout the world are undergoing eutrophication (accelerated aging) due to man's activities. Eutrophication is a significant problem in both lakes and reservoirs whenever the rate of synthesis and input of organic matter exceeds the rates of recycling and output. Accumulation of matter occurs within the aquatic system leading to its environmental extinction. Agricultural fertilizers and animal wastes are widely recognised as factors of eutrophication (Mitchell, 1975). Anoxic conditions leads to the release of phosphorus from sediments and it may then accelerate the process of eutrophication (Wetzel, 1975).

In tropical waters most nutrients are incorporated into the living tissue and are transferred by direct ingestion, decomposition and adsorption cycles (Henderson, 1979). The total amount of phytoplankton in a lake is determined by the concentrations and loads of nitrogen and phosphorus (Forsberg and Ryding, 1980). Annual cycles of nutrients are commonly interpreted as being due to the annual of phytoplankton growth (Wetzel, 1983). Increased nutrient concentration

must according to Larsson et al. (1985) cause an increase in primary productivity and whether nitrogen or phosphorus is limiting depends on the relative amounts of the elements in relation to the needs of phytoplankton (Rippey and Rippey, 1986).

During periods of water circulation, nitrate-nitrogen contents reflects the effect of its mixing and biological activity (Ridley and Steel, 1975). It is generally at higher trophic status nitrogen becomes limiting (Forsberg and Ryding, 1980). Osborne et al. (1980) attributed lower summer nitrate-nitrogen concentrations to leaching of the nitrate formed during mineralisation of soil organic matter in autumn and winter.

Drainage from agricultural lands contributes large amount of phosphate to lakes(Mitchell, 1975). Phosphorus in most cases is the nutrient controlling maximum phytoplankton biomass (Vollenweider, 1976). Russo (1978) reported that under anaerobic condition some phosphates may be released from the sediment. Welch and Perkins (1979) showed that the hypolimnetic oxygen correlates positively with phosphorus loading. Stent (1981) reported that the net gain of phosphate during high pH may have been aided by low oxygen

concentration in the bottom waters. OECD (1982) also reported a strong relationship between phosphorus loading and oxygen depletion.

The bottom sediments of lakes and streams are valuable indicators of persistence and release patterns of heavy metals (Allan, 1975; Forstner and Muller, 1976). Metal concentration in sediments depend on input from the source, the grain size, organic matter, sulphide content, mineral composition and the rate of deposition of the sediment bulk (Forstner, 1977). High levels of zinc is associated with lowest pH values and wide range of calcium and phosphate concentrations (Whitton and Diaz, 1980). Dickson (1980) found a negative correlation between pH and Al, Cd, Mn, Pb and Zn. Borg (1983) showed that pH, humic acid and alkalinity are the main factors controlling trace metals in freshwaters.

Organisms have a wide range of tolerance to pollution condition (Hynes, 1960). High concentration of metals are generally required to cause an acute toxic response in macro-invertebrates (Warnic and Bell, 1969), but chronic toxicity studies have shown lethal and sublethal responses at very low levels (Spehar et al., 1978). Patterson and Whitton (1981)

reported that amongst algae, increasing Zn concentration causes a reduction in the number of species present, probably due to selection against those species which are unable to evolve metal tolerance or whose tolerance mechanisms are ineffective. Many metals which are essential to fish health (Cu, Zn, Mn, Cr, etc) in minute concentrations are highly toxic to fish and other aquatic organisms when present in excess even at low concentrations (Oladimeji, 1983).

The effects of food quantity and quality on the growth and reproduction of zooplankton have been studied by many workers (Hall, 1964; Vijverberg, 1976). Jones et al. (1979) reported low zooplankton productivity in reservoirs when blue green algae (Microcystis) bloomed. However, an increase in secondary production is not necessarily proportional to an increase in primary production (Hanazato and Yasuno, 1985). They concluded that temperature, food and predation are the most important factors controlling the density and production of zooplankton.

Benthos are involved in the mineralisation and recycling of organic matter produced in the water or brought from external sources, and they are important second and third links in the trophic sequence of aquatic communities (Lind, 1979). Benthic community

structure can be used to indicate both the magnitude and the probable cause of environmental stress (Lenat et al., 1980). Chester et al. (1983) reported that differences in invertebrate abundance biomass and species composition were accompanied by changes in the physico-chemical character of the sediments. Timms (1983) showed that organic detritus input, sediment characteristics, relative shallowness and exposure to wind may influence standing crops and also to a lesser extent species composition and community structure. Persson (1983) showed that seasonal density variation may result from biological events such as reproduction and migration. Meyerhoff and Lind (1987) in their study of benthic community structure of a discontinuous stream in Texas U.S.A. reported that variables associated with food availability best explain the variation in biomass, density, species diversity and species richness. They also showed that seasonal change in benthic community structure is probably a function of the type of food.

2.2 SCOPE OF THE STUDY

The research was aimed at evaluating the impact of modern agricultural practice through mechanisation

and mixed farming with the help of improved fertilizers, herbicides and pesticides and their effects on our water resources, with a view to provide additional information on the dynamic interactions among physico-chemical and biological variables.

It was further aimed at developing in terms of continuation and expansion on the few pioneering work of the lake by Anyam (1980) who studied some aspects of the freshwater ecology in relation to the algal distribution. Nwokenna (1984) studied the distribution of macrobenthic fauna during parts of the rainy and dry seasons.

2.3 OBJECTIVES

a. To study the areas not covered by Anyam (1980) with respect to zooplankton and expand on the work of Nwokenna (1984).

b. To evaluate the quantitative and qualitative distribution of the zooplankton and benthos with respect to composition and abundance.

c. To determine the monthly and seasonal variations in the physico-chemical characteristics of the lake.

d. To determine the levels of some metals like Calcium (Ca), Cobalt (Co), Copper (Cu), Magnesium (Mg), Potassium (K), Lead (Pb), Sodium (Na), Iron (Fe) and Zinc (Zn).

e. To determine the level of correlation between physical and chemical characteristics of the lake with the established biota.

CHAPTER THREE

3.0 MATERIALS AND METHODS

3.1 EXPERIMENTAL DESIGN

The detailed plan of the research involved biweekly sampling for all the physico-chemical and biological parameters.

3.2 WORKING HYPOTHESIS

Based on the aims and objectives of this study the following null hypothesis were proposed.

(i) The physico-chemical variables are independent of the sampling periods.

(ii) There is no significant correlation or interaction between distribution and abundance of zooplankton groups with respect to sampling stations and periods.

(iii) Macrobenthic abundance and distribution are independent of sampling stations and periods.

(iv) The distribution of the biota are independent of the seasonal variations of the water characteristics.

(v) There is no significant correlation in the levels of trace elements at various sampling stations.

(vi) There is no significant relationships between the biological parameters and the water quality parameters.

3.3 STATISTICAL ANALYSIS

The combined two way analysis of variance was used to investigate the effect of error, sampling stations and seasons. The F-values were calculated and where significant differences existed, the DQ test was used to test for significance.

The spearman's rank correlation coefficient was used for relationships between factors of interest. Student-t-test was also applied were necessary.

3.4 THE STUDY AREA

All the samplings took place at Makwaye (Ahmadu Bello University Farm) lake which is located at about 4 km off 17 km from Zaria on the Zaria-Funtua Road. The basin is 3352.8 metres long along its longest axis and 2926.08 metres in width (Kowal and Omolokun, 1970). The area of the lake at full capacity is 18.18 hectares while the v. lume at full capacity is 82.6 hectares (Kowal, 1970).

3.5 GEOGRAPHY AND CLIMATE

Samaru (11^{o}N latitude) is believed to be a representative of an area of some 27,360 km^2 of the Ferruginous tropical soils of Northern Guinea Savanna Zone in the central and western parts of the Northern

States of Nigeria (Kowal and Omolokun, 1970) between latitude 10° and 12°N and longitude 7° and 8° (Fig. 1).

The climate is characterized by well defined wet and dry season. The wet season lasts from the beginning of May to the beginning of October, August being usually the wettest (Motimor, 1970). The mean annual rainfall is about 1080 mm. During the study period, May 1987 to April, 1988, the total annual rainfall was 972.2 mm (Fig. 3). The dry season, which lasts for about 5 months, is severe with low relative humidity with a dry North East trade winds, the harmattan (Kowal and Omoloku, 1970). The harmattan is usually characterized by large diurnal temperature variation and absence of convectional clouds (Hore, 1970).

3.6 TOPOGRAPHY

The topography of the catchment basin on which this study is based is a fair representative of surrounding plains which can be described as undulating plain with very broad and gentle slope lying at an altitude of between 609.9 - 731.5 metres above sea level (Kowal and Omolokun, 1970).

3.7 HYDROLOGY AND GEOLOGY

The basement complex rocks consists principally of metamorphic and igneous rocks which are resistant to weathering. The mantle of the weathered material is thin, irregular and often discontinuous (Kowal and Omoloku, 1970). The average depth of the weathered material is thin probably not more than 15 metres, but occasionally extending to depth of about 60 metres (duPreez and Barber, 1965). The weathered material contains too much clay to serve as an efficient aquifer and the basement complex forms a very poor source of ground water (Kowal and Omolokun, 1970).

3.8 CATCHMENT AREA

The catchment basin covers an area of 637.25 hectares which 28.34 hectares are estimated as being non-contributing area of the ground water flow. The land use of the catchment basin as reported by Kowal and Omolokun (1970) is as follows:

2.7% of the area is covered by the lake.

6.1% is residential area.

69.0% of the land is farmland of which 22% is occupied by the experimental farm.

17.1% is uncultivated land under natural fallow.

5.1% is poor land used for range grazing by Fulanis.

Part of the eastern side of the basin is intersected by a railway embankment which does not interfere with the natural drainage (Kowal, 1970).

Presently about 337 hectares of the farmland is being used for field research by the Faculty of Agriculture and the Institute of Agriculture (I.A.R.) of Ahmadu Bello University Zaria (Fig. 2). About 15 to 30 tons of single superphosphate and compound fertilizer NPK is applied annually with about 200 to 350 litres of Grammazone, Premagrain and Cesapril herbicides are also applied along with 150 to 300 litres of Cymbush insecticides (Personal communication with the University Farm Manager, 1988). The university farm also has substantial number of livestock consisting of cattle, goats, sheep, pigs, poultry and rabbits. The crops grown mainly are maize, sorghum. cowpeas and cotton.

Prominent vegetation around the banks as reported by Nwokenna (1984) are Polygonium acuminatum, Cassia terminalis, Borreria starchydea, Dichrostachys glomerata, Terminalia macrocarpum and Pinus palustris. On the southern banks are rows of Eucalyptus saligna trees planted to check erosion.

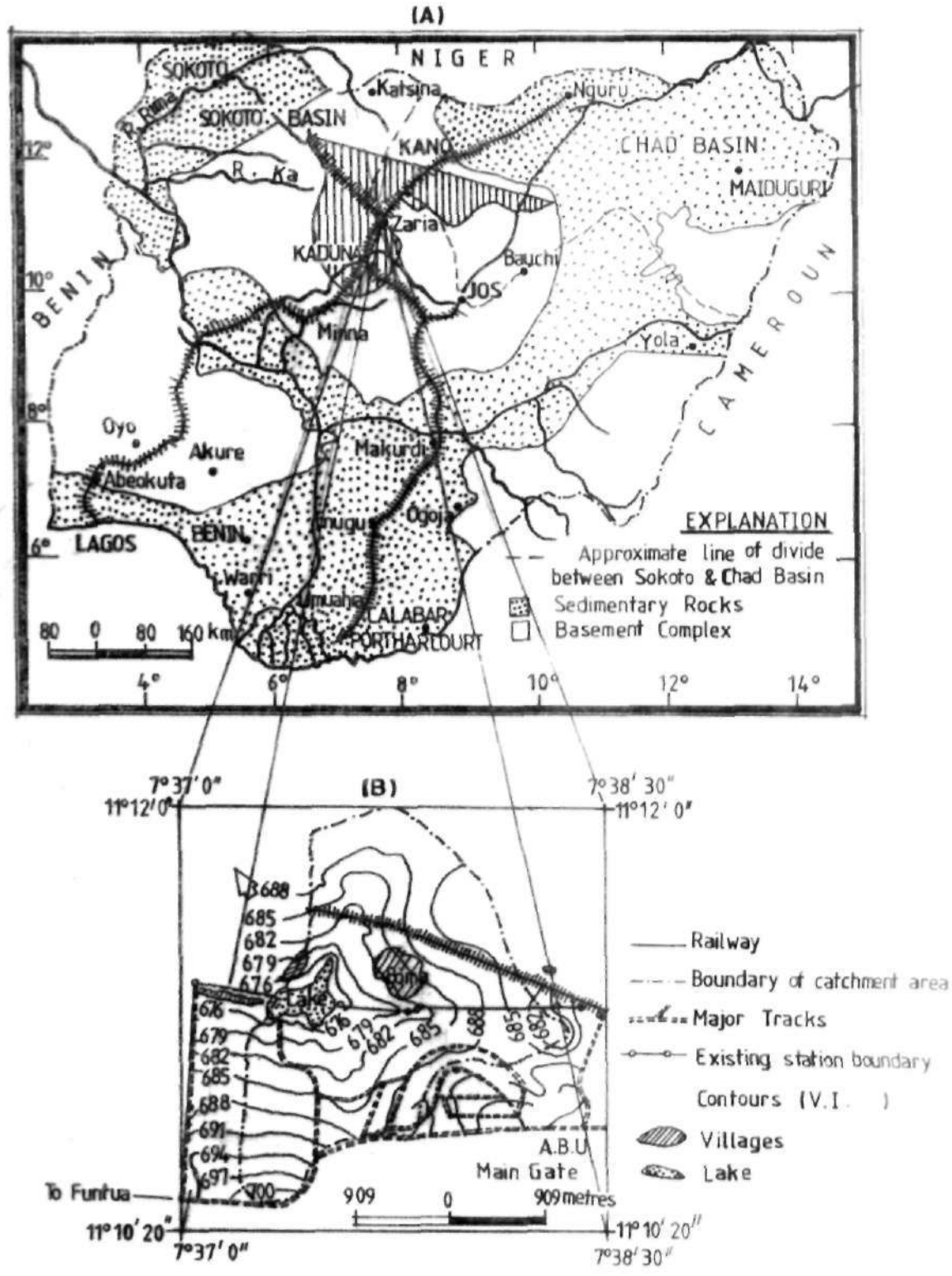


FIG. 1 : MAP OF NIGERIA SHOWING LOCATION OF THE STUDY AREA (A), (B) MAGNIFIED

Source : KOWAL AND OMOLOKUN, 1970

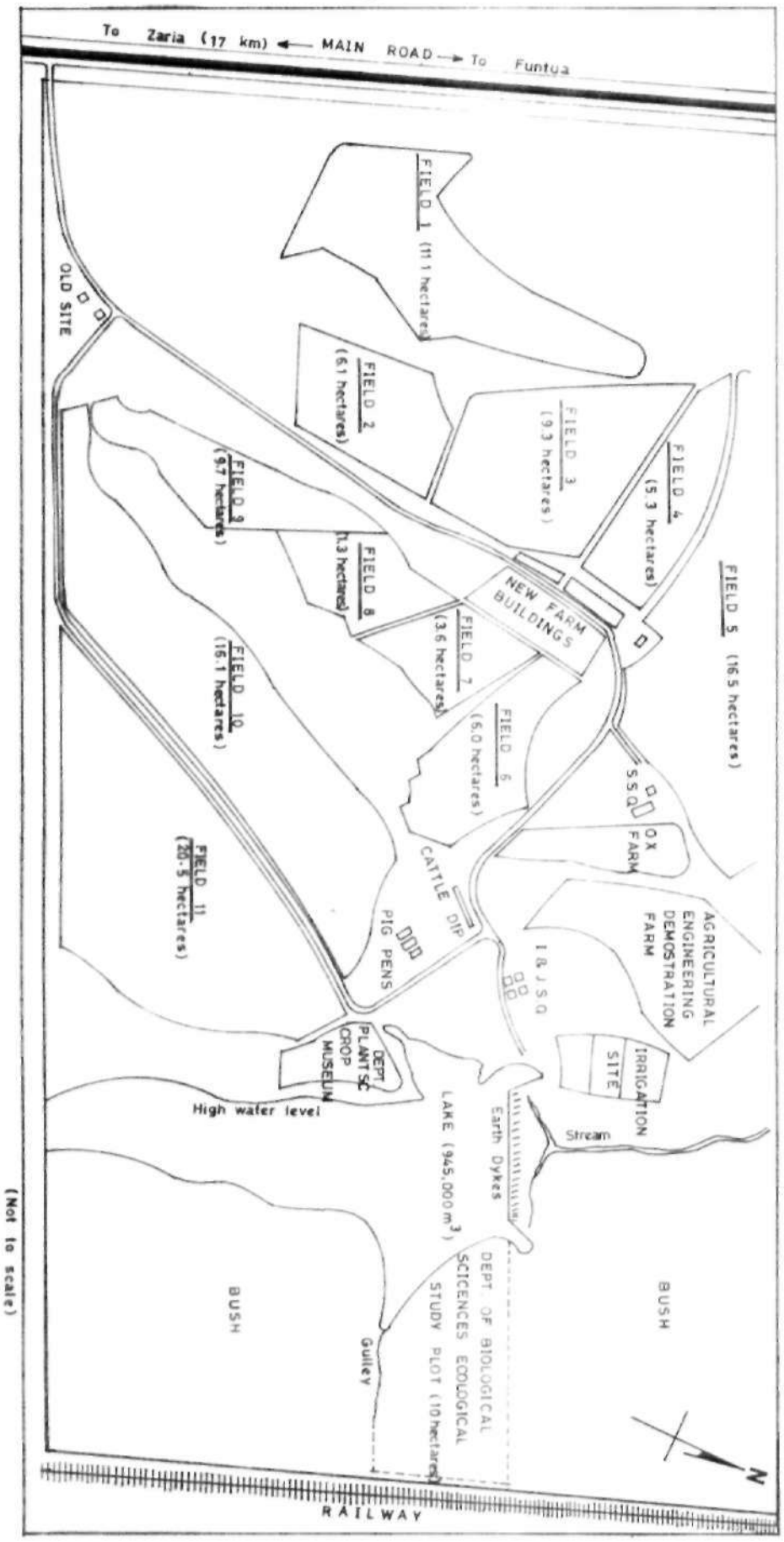


FIG. 2. AHMADU BELLO UNIVERSITY TEACHING FARM SAMARU, ZARIA.

(Not to scale)

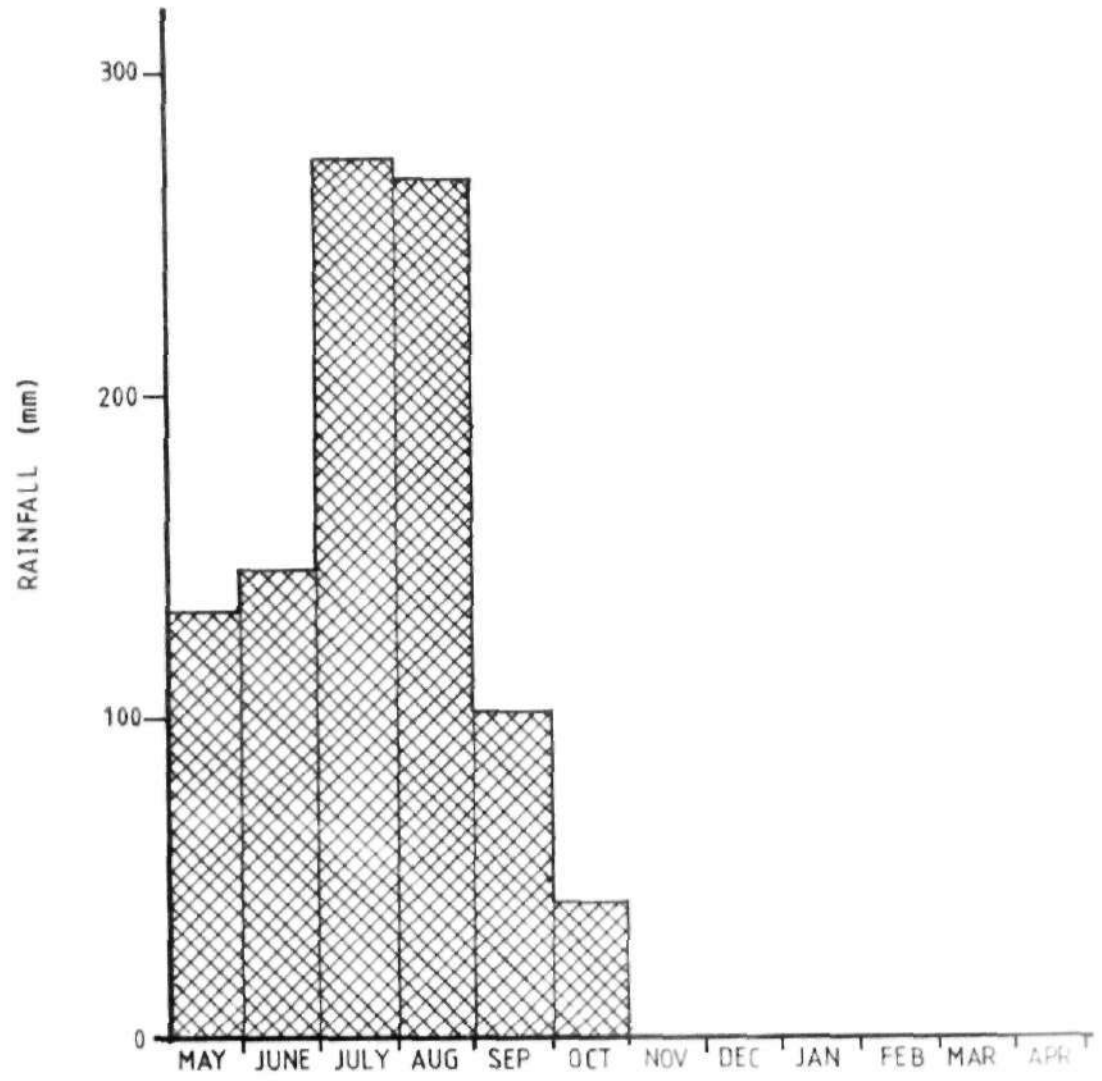


Fig. 3: MEAN MONTHLY RAINFALL DISTRIBUTION (May 1987 - April 1988) IN ZARIA, NIGERIA. (Source: Meteorological Service Register of Rainfall in 1987, I.A.R, A.B.U Zaria)

The aquatic macrophytes and phytoplankton recorded by Anyam (1980) are Nymphaea lotus, Nymphaea micrantha, Borreria verticolata, Cassia tora, Acanthospernum hispidium and Typha spp for the aquatic macrophytes. The phytoplankton were Microsteria spp, Cosmarium spp, Eragilaria spp and Arthrodesmia spp.

3.9 SAMPLING STATIONS

Based on the result of the preliminary surveys, 3 stations were chosen for the purpose of working out the set objectives. The stations were:

(i) Upper shore or S.E with little or no human or animal interferences and with absence of aquatic macrophytes is designated as station 1.

(ii) Profundal zone or the deepest station of the lake free from interferences is designated as station 2.

(iii) Littoral zone dominated by animal interferences with aquatic macrophytes, constant deposition of cow dung at the edge with occasional mixing by animals is designated as station 3.

From each station duplicate water samples were collected at 2 weeks interval for physico-chemical analysis and biological characteristics. Sampling period was between May 1987 to April, 1988.

3.10 DETERMINATION OF WATER QUALITY CHARACTERISTICS

3.10.1 DEPTH

The water level measurement was determined for each station with a simple line, made of suitable wire which does not stretch, with a mushroom weight at one end.

3.10.2 SECCHI DEPTH (TRANSPARENCY)

The Secchi-disc of 25 cm in diameter was used in the determination. The transparency was taken by lowering the Secchi disc into the water until it just ceased to be visible. The depth of disappearance and reappearance was measured to the nearest cm and then the average taken.

3.10.3 TEMPERATURE

Both air and water temperature were determined with a thermometer calibrated to the nearest 1°C. Air temperature was taken by holding the thermometer above the water for about 5 minutes until it stabilizes. Water temperature was determined by lowering the thermometer into the water in an inclined position for about 5 minutes to allow for equilibrium before recording.

3.10.4 pH DETERMINATION

3.10.4.1 WATER pH

The surface water was collected in plastic bottles from each sampling station, it is transported to the laboratory in an ice box. The pH was determined with pye unicam nodel 292 pH metre at 25°C. The metre was standardised with buffer solutions at pH 4.0, 7.0 and 9.0 before the readings were taken.

3.10.4.2 SEDIMENT pH

The soil pH was determined by 1:1 soil water ratio method as described by Welcher (1975). Twenty grammes of dried sediment soil sample was added to 50 ml distilled water and stirred at regular intervals for 30 minutes. The pH of the suspension was measured by placing the electrode deep in the suspension for 5 minutes to equilibrate and then the readings taken.

3.10.5 ELECTRICAL CONDUCTIVITY

The surface water from each sampling station was collected in plastic bottles. The conductivity meter EBA/10 model was preOrinsed and set at zero point. The reading was expressed in micro-ohms/cm (Umhos/cm).

3.10.6 DISSOLVED OXYGEN

This was determined by the modified Winkler azide method (Lind, 1979 and APHA, 1980). Duplicate water samples in 250 ml BOD stoppered bottles were fixed in the field with 2ml manganous sulphate, followed by 2ml alkaline-iodide-azide and 2ml con. H_2SO_4. They were stored in ice box prior to further analysis. In the laboratory 101 ml of the sampled water was titrated with 0.0125N thiosulphate until it turned to pale yellow, 1ml of starch solution was added which turned to blue colour. The titration continued until the blue colour disappeared. The volume of the 0.0125N sodium thiosulphate titrant used is equivalent to the mg of Dissolved oxygen per litre (Lind, 1979).

3.10.7 BIOCHEMICAL OXYGEN DEMAND

Water samples were incubated at room temperature for 5 days in the dark before titration for oxygen using modified Winkler-azide method (Lind, 1979, and APHA, 1980).

BOD(mgl^{-1}) = Dissolved oxygen on day 1 - dissolved oxygen on day 5.

3.10.8 CARBON DIOXIDE

The titration method was used (Needham and Needham, 1975). 10 drops of phenolphthalein

indicator was added to 100 ml water sample and titrated against N/44 sodium hydroxide (NaoH) till a weak pink colur end point was obtained.

Dissolved $Co_2(mgl^{-1})$ = titre value of N/44 NaoH x 10.

3.10.9 HARDNESS

This was determined by diluting 25 ml water sample to 50 ml with distilled water. 2ml of buffer solution and 0.1g Erichrome black-T-dye were added. The resultant reddish solution were titrated with EDTA-titrant drop by drop until a blue colour end point was observed. The calculation was based on the equation given by Lind (1979) and APHA (1980).

EDTA Hardness $(mgl^{-1}CaCo_3)$ = ml titration x 40

3.10.10 PHOSPHATE-PHOSPHORUS (PO_4-P)

This was determined using the Deniges method (Mackereth, 1963; Lind, 1979; APHA, 1980). 1ml of Deniges reagent and 5 drops of stannous chloride were added to 100 ml water sample. Absorbance at 690 nm was measured with a spectrophotometer, model spectrophotometer-S101, using distilled water as the blank. The PO_4-P concentration of water sample was read from a calibration curve.

3.10.11 NITRATE-NITROGEN (NO_3-N)

The phenoldisulphonic aicd method was used as described by Mackereth (1963). 100 ml of water sample was evaporated to dryness followed by the addition of 2ml phenoldisulphonic acid to the residue and left for 10 minutes. 15 ml of distilled water was added followed by 5ml strong ammonia solution. The resultant yellow mixture was stirred and allowed to cool. The absorbance was measured at 410 nm with spectrophotometer, model S101, using distilled water as the blank. The NO_3-N concentration was read from a calibration curve.

3.10.12 CHLOROPHYLL-a

The method used is described by Strickland and Parsons (1972), Vollenweider (1974) and Lind (1979). 1 litre of water sample was filtered through a 70 mm diameter Whatman glass microfibre filters of 0.45U pore size. Near the end of the filteration, 1ml of 1% aqueous suspension of magnesium carbonate ($MgCo_3$) was added to prevent phaeophytinization of pigments due to acid conditions. 15 ml of 90% acetone was used for extraction in the refrigerator overnight. The extract was centrifuged and chlorophyll absorption was measured spectrometrically with model spectrophotometer S101, in 1cm cells at 665 and 750 cn. The chlorophyll concentration value was calculated from the equation.

$$\text{Chl-a}(ugl^{-1}) = \frac{Ve.E.OD_{750}^{665}}{Vf.L} \quad \text{.....Equation 1}$$

where:

Chl-a = concentration of chlorophyll-a in Ugl^{-1}

Ve = Volume of the extract in ml (15 ml)

E = Extinction coefficient of chlorophyll-a in 90% acetone = 11.9 from the work of Talling and Driver (1963).

OD_{750}^{665} = absorbance of the extract at 665 nm

Less the absorbance at 750 nm

Vf = Volume of water filtered in litres.

L = Path length of Cuvette in cm.

After taking the readings 1 drop of INHCl was added into the Cuvettes, the readings were measured as above for phaeophytin corrections.

The amounts of chlorophyll and phaeophytin in the sample was quantified using the following equations.

$$\text{Chl-a} = \frac{Ve.A.K.\ (OD_o - OD_a)}{Vf.L} \quad \text{.....Equation 2}$$

$$\text{Phaeo-a} = \frac{Ve.A.K.\ (R(OD_a) - OD_o)}{Vf.L} \quad \text{....Equation 3.}$$

where:

Chl-a = concentration of chlorophyll-a as UgL^{-1}

Phaeo-a = concentration of phaeophytin as UgL^{-1}

Ve = Volume of extract in ml (15)

A = Absorption coefficient of chlorophyl;-a (= 11).

K = Derived factor to equate the reduction in absorbance to the initial chlorophyll concentration (= 2.43).

OD_o = absorbance at 665 nm less the absorbance at 750 nm before acidification.

OD_a = absorbance at 665 nm less the absorbance at 750 after acidification.

Vf = Volume of sample filtered in litres.

I = Path length of Cuvette in cm.

R = maximum ratio of OD_o:OD_a in the absence of phaeophytin (= 1.7).

The sum of equation 2 and 3 should equal the result of equation 1 but occasionally small and negligible differences do occur.

3.10.13 TRACE ELEMENTS ANALYSIS

3.10.13.1 WATER SAMPLE

Water sample were preserved by adding 1ml conc HNO_3 to 150 ml of the sample and kept in freezer prior to analysis. 40 ml water sample was added to 10 ml acid solution (mixture of 3:1 conc HCl and conc HNO_3) and immersed in a water bath ($90^{o}C$) for 30 minutes followed by filteration and analysis with Atomic absorption spectrophotometer (A.A.S), model A.A.S 180-80.

3.10.13.2 SEDIMENT SAMPLE

The sediment digestion method was used as described by Perkins (1971), Johnsson (1975). 1.0g of dried sediment sample was dissolved in 10 ml acid solution (mixture of 3:1 conc HCl and conc HNO_3) and diluted to 50 ml with deionized water, free from heavy metals. Samples were immersed in a water bath ($90^{o}C$) for 30 minutes, filtered and analysed in the atomic absorption spectrophotometer, model A.A.S. 180-80. The quantities of the various extractable trace elements are based on the equation:

$$\text{elements } Ugg^{-1} = \frac{(Ug/ml \text{ in sample solution})\ (50)\ (d.f)}{\text{Sample weight in gms}}$$

Where d.f. = dilution factor, i.e. if additional dilution is used.

3.10.14 BIOLOGICAL CHARACTERISTICS

3.10.14.1 ZOOPLANKTON

Zooplankton samples were collected with a silk plankton net of 25 cm diameter of 70 meshes/cm attached with a bottle of 50 ml capacity at the base. At each station the net was sunk just below the surface and then towed through a distance of 10m. The content of the collection vial was then poured into plastic bottle of 70 ml capacity and preserved in 4% formalin. Counting was done by shaking the preserved sample and pipetting 1ml of it into a sedgwick Rafter (S.R) counting cells and then mounting on a microscope. Identification was done with various text books, Ward and Whipple (1959), Needham and Needham (1975), Wetzel (1975), Pennak (1978) and APHA (1980).

3.10.14.2 BENTHOS

Ekman grab, model no 923, measuring 19 cm by 14 cm with an area of 0.0266m^2 was used in collecting the macrobenthic fauna from the three stations. At each station 3 grabs were taken and the dredged materials were washed through a U.S. Standard Seives Number 40 with 0.41 mm mesh size. The residues were immediately transferred into labelled plastic storage jars and preserved with 4% formalin prior to sorting out and identification.

Sorting was done by pouring out the contents of each jar into a separate large, shallow plastic basin. Enough water was added to disperse the materials. The organisms were picked with the aid of a pair of forceps or a pipette as required. Dissecting and compound microscopes were used in the identification of the specimens with the aid of the same texts as for the zooplankton.

CHAPTER FOUR

4.0 R E S U L T S

The results of this work reveal a wide range of variations for both the physico-chemical characteristics and the biota of Makwaye (A.B.U. Farm) lake Samaru, Zaria. The analysis of the results are based on graphs, 2-way analysis of variance (ANOVA) and rank correlation coefficient based on two tailed tests.

4.1 WATER TEMPERATURE

The mean monthly variations in water temperature for all the stations are presented on Fig. 4, while table 1a represents the dry and the rainy season means. The lowest and the highest temperatures were recorded in January (16.5^{o}C) and June (28.5^{o}C) respectively. Analysis of variance (Table 1b) showed no significant variation between seasons ($P > 0.05$) but significant variation existed between sampling stations and stations by seasons ($P < 0.05$).

Correlation coefficient analysis for all parameters over all stations (Table 1c) revealed a positive significant correlation between temperature and conductivity, dissolved carbon dioxide, chlorophyll-a

and copepoda ($P > 0.05$). A highly negative significant correlation existed between temperature with Dissolved oxygen and rotifera ($P \leq 0.05$).

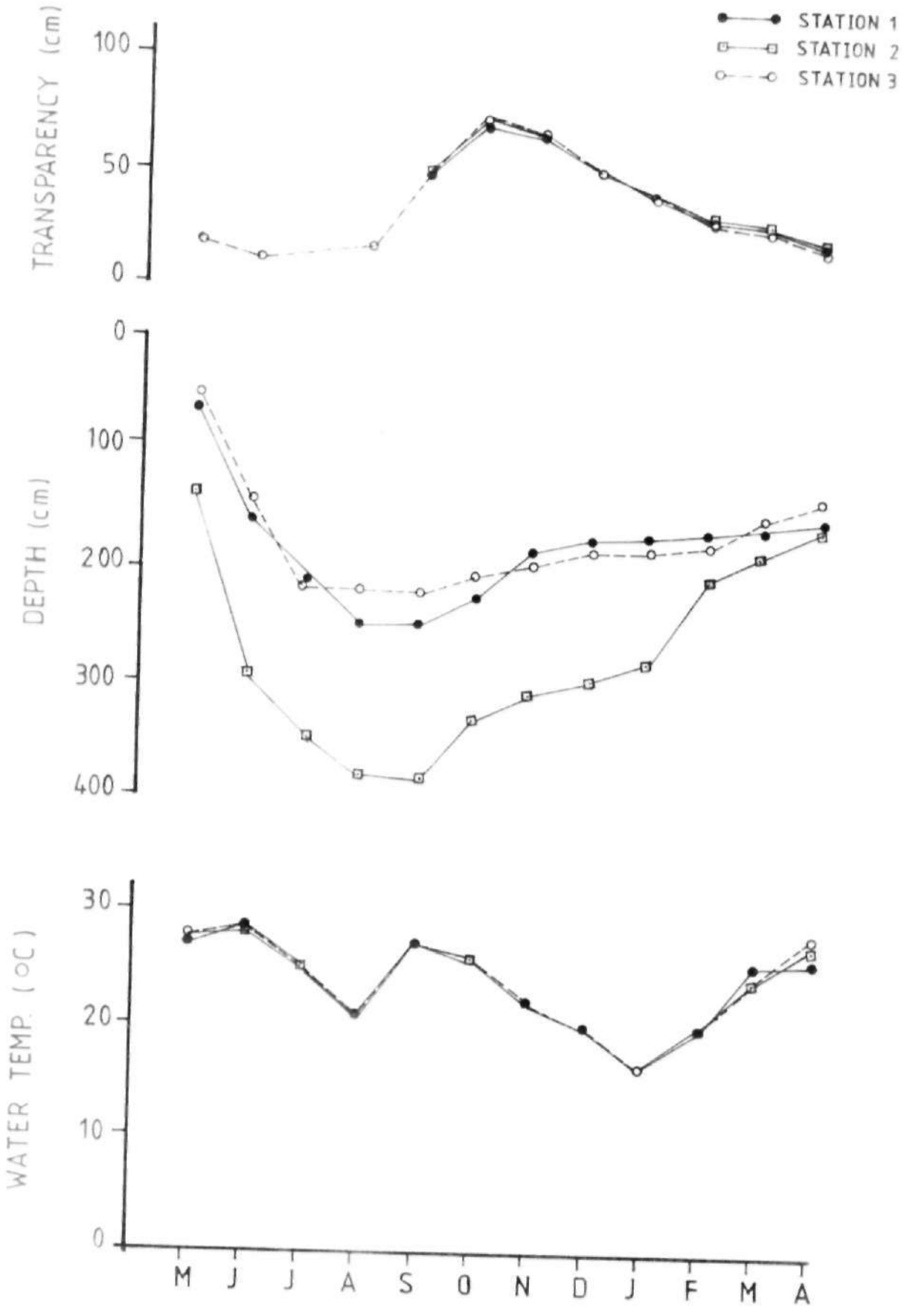


FIG. 4 : MEAN MONTHLY VARIATIONS IN TEMPERATURE, DEPTH AND TRANSPARENCY OF MAKWAYE (A.B.U. FARM) LAKE SAMARU, ZARIA.

TABLE 1a: SEASONAL VARIATION IN WATER TEMPERATURE(^{o}C) FOR STATIONS OF MAKWAYE (A.B.U. FARM) LAKE SAMARU, ZARIA

	STATIONS			
	1	2	3	S.E.D.
General stations $\bar{x}$	24.4	20.5	26.6	
Dry season $\bar{x}$ 21.6				
Rainy season $\bar{x}$ 26.0				
S.E.D between two means for months				1.066
S.E.D between two means for stations				0.533
S.E.D between two means for seasons				0.435
S.E.D between two means for stations by seasons				0.753

S.E.D = Standard Error Difference.

TABLE 1b: ANALYSIS OF VARIANCE (ANOVA) FOR WATER TEMPERATURE

TABLE 1b: ANALYSIS OF VARIANCE (ANOVA) FOR WATER TEMPERATURE

Source of Variation	Sum of Squares (SS)	D.F (n-1)	Means squares (MS)	F.(ratio)	Sign
Months	149092.277	11	13553.843	2.87	NS
Stations	87121.361	2	43560.680	9.223	xx
Seasons	1605.555	1	1605.555	0.339	NS
Stations by seasons	72205.194	2	36102.597	7.644	x
Residual or (Error)	259741.555	55	4722.573		
Total	569765.944	71			

xx = highly significant ($P < 0.01$)

x = significant ($P < 0.05$)

Ns = not significant ($P > 0.05$)

	DEPTH	SECCHI	WATERPH	COND	Do	BOD	Co_2	HARDNESS	No_3N	Po_4-P	CHLAA
DEPTH	1.00000										
SECCHI	.25150	1.00000									
WATERPH	-.08178	-.41503	1.00000								
COND	-.63511	-.44489	.03940	1.00000							
Do	.18603	.30093	.17224	-.53954	1.00000						
BOD	-.26787	-.38510	.09882	.41895	-.50149	1.00000					
Co_2	.08845	-.32501	-.05200	.12869	-.44531	.05763	1.00000				
HARDNESS	.14791	.72556	-.08693	-.53105	.49846	-.44459	-.52617	1.00000			
No_3N	.16437	-.31814	.15512	-.02574	-.30993	.53621	.24773	-.49606	1.00000		
Po_4-P	-.08703	-.71210	.42370	.36551	-.49798	.50270	.55472	-.74024	.60564	1.00000	
CHLAA	-.28568	-.71851	.26898	.61612	-.61499	.71208	.19780	-.69058	.62028	.73194	1.00000
ROTIFERA	-.05479	.04212	.17517	-.17478	.56356	-.12246	-.53781	-.19152	-.10605	-.26560	-.06372

COPEPODA CLADOCER ROTIFERA

	COPEPODA	CLADOCER	ROTIFERA
COPEPODA	1.00000		
CLADOCER	-.35060	1.00000	
ROTIFERA	-.66925	-.44293	1.00000

CRITICAL VALUE (1-TAIL, .05) = **0F** - .27861
CRITICAL VALUE (2-tail, .05) = **2F** - .32860

4.2 DEPTH

Table 2a and Fig. 4 show the mean monthly depth and seasonal variations respectively. For all the stations the rainy season recorded the deepest with mean depth of 221 cm. Station 3 at the centre of th the lake recorded the highest depth throughout the seasons. There was no significant variation in depth (Table 2b) between seasons, but significant variations existed between station and stations by seasons ($P < 0.05$).

TABLE 2a: SEASONAL VARIATION IN DEPTH FOR STATIONS OF MAKWAYE (A.B.U. FARM) LAKE SAMARU, ZARIA

	STATIONS 1	2	3	S.E.D.
General station $\bar{x}$	178	229.63	144.996	
Dry season $\bar{x}$	189.25 cm			
Rainy season $\bar{x}$	221.90 cm			
S.E.D between two means for months				39.676
S.E.D between two means for station				19.838
S.E.D between two means for seasons				16.198
S.E.D between two means for stations by seasons				28.055

S.E.D + Standard Error Difference

TABLE 2b: ANALYSIS OF VARIANCE (ANOVA) FOR DEPTH

Source of Variation	Sum of Squares	D.F	Means	F	Sign
Months	149092.277	11	13553.843	2.87	NS
Stations	87121.361	2	43560.68	9.223	x
Seasons	1605.555	1	1605.555	0.339	NS
Stations by seasons	72205.194	2	36102.597	7.644	x
Residual	259741.555	55	4722.573		
Total	569765.944	71			

x = Significant ($P < 0.05$)

NS = Not significant ($P > 0.05$)

4.3 TRANSPARENCY

The seasonal variation and monthly mean ranges of transparency in the station of Makwaye (A.B.U. farm) lake Samaru, Zaria are presented on Table 3a and Fig. 4. Transparency ranged from 13-86 cm for all the stations during the rainy season with the lowest in June and the highest in October. There was a progressive increase in turbidity between November through April, leading to decline in transparency of the water as the season progresses with a minimum of 19 cm in April.

Highly significant variation existed between stations and seasons by stations ($P < 0.01$) (Table 3b). Also there was a significant variation ($P < 0.05$) between seasons. Correlation coefficient analysis between transparency and other physico-chemical characteristics (Table 1c) revealed a significant positive correlation with water hardness. Negative significant correlation also existed between transparency and pH, conductivity, BOD, phosphate phosphorus and chlorophyll-a ($P \leq 0.05$).

4.4 WATER pH

The mean monthly and seasonal variations of water pH of Makwaye (A.B.U. farm) lake Samaru, Zaria are presented on Fig. 5 and Table 4a respectively. The lake was mostly alkaline throughout the seasons

with pH ranges between 7.1 to 8.6.

Analysis of variance (Table 4b) revealed a significant variations in pH with seasons ($P < 0.05$) and a highly significant variation between stations and stations by seasons ($P < 0.01$). Correlation coefficient analysis between pH and other physico-chemical characteristics revealed a positive significant correlation ($P < 0.05$) with phosphate-phosphorus.

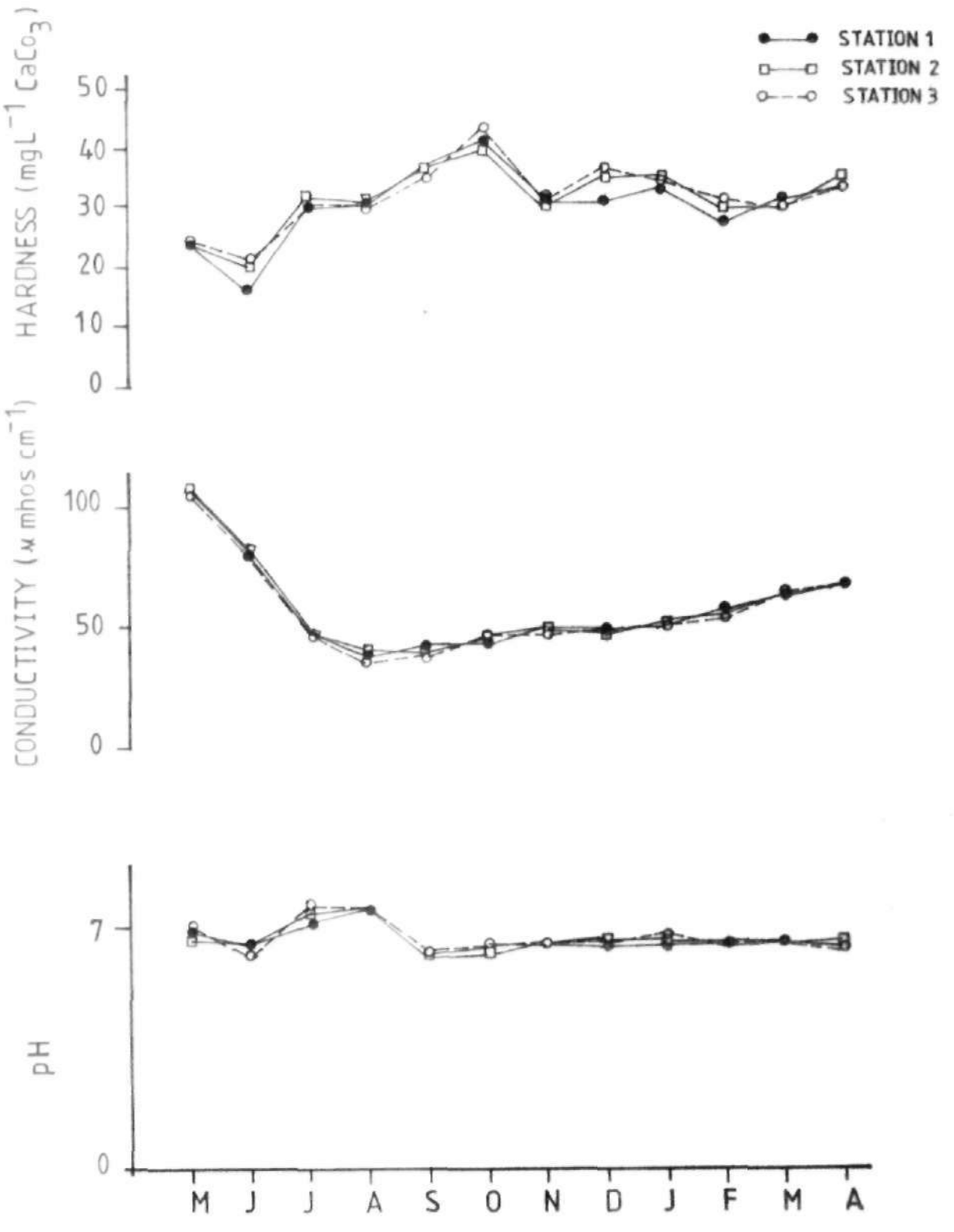


FIG. 5: MEAN MONTHLY VARIATIONS IN HYDROGEN ION CONCENTRATION (pH), CONDUCTIVITY AND HARDNESS OF MAKWAYE (ABU FARM) LAKE SAMARU, ZARIA.

TABLE 3a: SEASONAL VARIATIONS IN TRANSPARENCY FOR STATIONS OF MAKWAYE (A.B.U. FARM) LAKE SAMARU, ZARIA

	STATIONS 1	2	3	S.E.D
General stations $\bar{x}$	35.7	36.5	35.8	
Dry season $\bar{x}$	40.8 cm			
Rainy season $\bar{x}$	31.2 cm			

S.E.D between two means for months	26.189
S.E.D between two means for stations	13.094
S.E.D between two means for seasons	10.691
S.E.D between two means for stations by seasons	18.518

S.E.D + = Standard Error Difference.

TABLE 3b: ANALYSIS OF VARIANCE (ANOVA) FOR TRANSPARENCY

Source of Variation	Sum of Squares	D.R	Means Squares	F	Sign
Months	16438.819	11	1494.438	0.726	NS
Stations	60752.444	2	30376.222	14.763	xx
Seasons	10058.347	1	10058.347	4,886	x
Stations by seasons	117755.444	2	58877.722	28.615	xx
Residual	113163.263	55	2057.513		
Total	318168.319	71			

xx = highly significant ($P < 0.01$)
x = significant ($P < 0.05$)
NS = not significant ($P > 0.05$)

TABLE 4a: SEASONAL VARIATION IN HYDROGEN ION CONCENTRATION (pH) FOR STATIONS OF MAKWAYE (A.B.U. FARM) LAKE SAMARU, ZARIA

	STATIONS 1	2	3	S.E.D
General stations $\bar{x}$	7.5	7.8	7.3	
Dry season $\bar{x}$	7.5			
Rainy season $\bar{x}$	7.6			
S.E.D between two means for months				0.149
S.E.D between two means for stations				0.075
S.E.D between two means for seasons				0.061
S.E.D between two means for stations by seasons				0.106

S.E.D = Standard Error Difference.

TABLE 4b: ANALYSIS OF VARIANCE (ANOVA) FOR pH

Source of Variation	Sum of Squares	D.F	Means of Squares (MS)	F. ratio	Sign
Months	0.667	11	0.06	0.906	NS
Seasons	0	1	0.5	7.464	x
Stations	2.356	2	1.179	17.606	xx
Stations by seasons	1.54	2	0.77	11.502	xx
Residual	3.685	55	0.086		
Total	8.751	71			

xx = highly significant ($P < 0.01$)
x = significant ($P < 0.05$)
NS = not significant ($P > 0.05$).

4.5 CONDUCTIVITY

Fig. 5 and Table 5a show the mean monthly and seasonal variation in electrical conductivity of Makwaye (A.B.U. Farm) lake Samaru, Zaria respectively. Conductivity was generally higher in dry season than the rainy season in the lake. Lowest conductance of 37.5 umhos cm^{-1} was obtained in August from then it progressed gradually up to 67 umhos cm^{-1} in April.

Analysis of variance (Table 5b) revealed a highly significant variation between stations, seasons and stations by seasons ($P < 0.05$). Correlation coefficient analysis (Table 1c) for conductivity with respect to other physico-chemical characteristics exhibited a highly significant correlation between conductivity and BOD, PO_4-P and chlorophyll-a ($P < 0.05$). A highly negative significant correlation existed with Dissolved oxygen and water hardness.

4.6 WATER HARDNESS

The seasonal variation and mean monthly ranges of water hardness for the stations of the lake are presented on Table 6a and Fig. 5 respectively. There was an initial rise in water hardness during the rainy season from 16 mgl^{-1} in station 1 to a peak of 44 mgl^{-1} in October in station 3. Analysis of

variance Table 6b revealed a highly significant variation between seasons, stations and stations by seasons ($P < 0.01$).

Correlation coefficient analysis between water hardness and other physico-chemical variables (Table 1c) revealed a highly significant correlation with Ca, Mg, Transparency and Dissolved oxygen ($P < 0.05$), while negative significant correlation exists with Pb, Fe, K, electrical conductivity, BOD and Co_2.

TABLE 5a: SEASONAL VARIATION IN CONDUCTIVITY FOR STATIONS OF MAKWAYE (A.B.U. FARM) LAKE SAMARU, ZARIA

	STATIONS 1	2	3	S.E.D
General stations $\bar{x}$	70.4	48.9	54.4	
Dry season $\bar{x}$	59.8 umhos			
Rainy season $\bar{x}$	56.0 umhos			

S.E.D between two means for months	3.755
S.E.D between two means for stations	1.877
S.E.D between two means for seasons	1.533
S.E.D between two means for stations by seasons	2.655

S.E.D = Standard Error Difference

TABLE 5b: ANALYSIS OF VARIANCE (ANOVA) FOR CONDUCTIVITY

Sources of Variation	Sum of Squares	D.F	Means Squares	R. ratio	Sign
Months	289.444	11	26.313	0.622	NS
Stations	5981.027	2	2990.513	70.711	xx
Seasons	256.989	1	256.989	6.074	xx
Stations by seasons	15199.694	2	7599.847	179.699	xx
Residual	2326.055	55	42.281		
Total	24053.111	71			

xx = highly significant ($P < 0.01$)

x = significant ($P < 0.05$)

NS = not significant ($P > 0.05$).

TABLE 6a: SEASONAL VARIATION IN WATER HARDNESS FOR STATIONS OF MAKWAYE (A.B.U. FARM) LAKE SAMARU, ZARIA

	STATIONS 1	2	3	S.E.D
General stations $\bar{x}$	27.10	30.59	35.75	
Dry season $\bar{x}$	29.44 mgl^{-1} $CaCo_3$			
Rainy season $\bar{x}$	32.94 mgl^{-1} $CaCO_3$			
S.E.D between two means for months				2.547
S.E.D between two means for stations				1.274
S.E.D between two means for seasons				1.040
S.E.D between two means for stations by seasons				1.801

S.E.D = Standard Error Difference

TABLE 6b: ANALYSIS OF VARIANCE (ANOVA) FOR WATER HARDNESS

Source of Variation	Sum of Squares	D.F	Means Squares	F	Sign
Months	43.611	11	3.964	0.203	NS
Stations	912.444	2	456.222	23.434	xx
Seasons	206.722	1	206.722	10.618	xx
Stations by seasons	835.111	2	417.555	21.448	xx
Residual	1070.722	55	19.467		
Total	3068.611	71			

xx = highly significant ($P<0.01$)

NS = not significant ($P>0.05$).

4.7 DISSOLVED OXYGEN

The mean monthly and seasonal variation in dissolved oxygen (DO) are presented on Fig. 6 and Table 7a respectively. The Do fluctuated between 4.95 to 8.05 mgl^{-1} (above 50% saturation) throughout the study period. The mean seasonal variation for the two seasons (Table 7a) indicated higher dissolved oxygen concentration during the dry season than the rainy season (6.6 and 5.9 mgl^{-1} respectively), The lowest values were obtained in June (4.95 mgl^{-1}), while the highest was in January (8.05 mgl^{-1}).

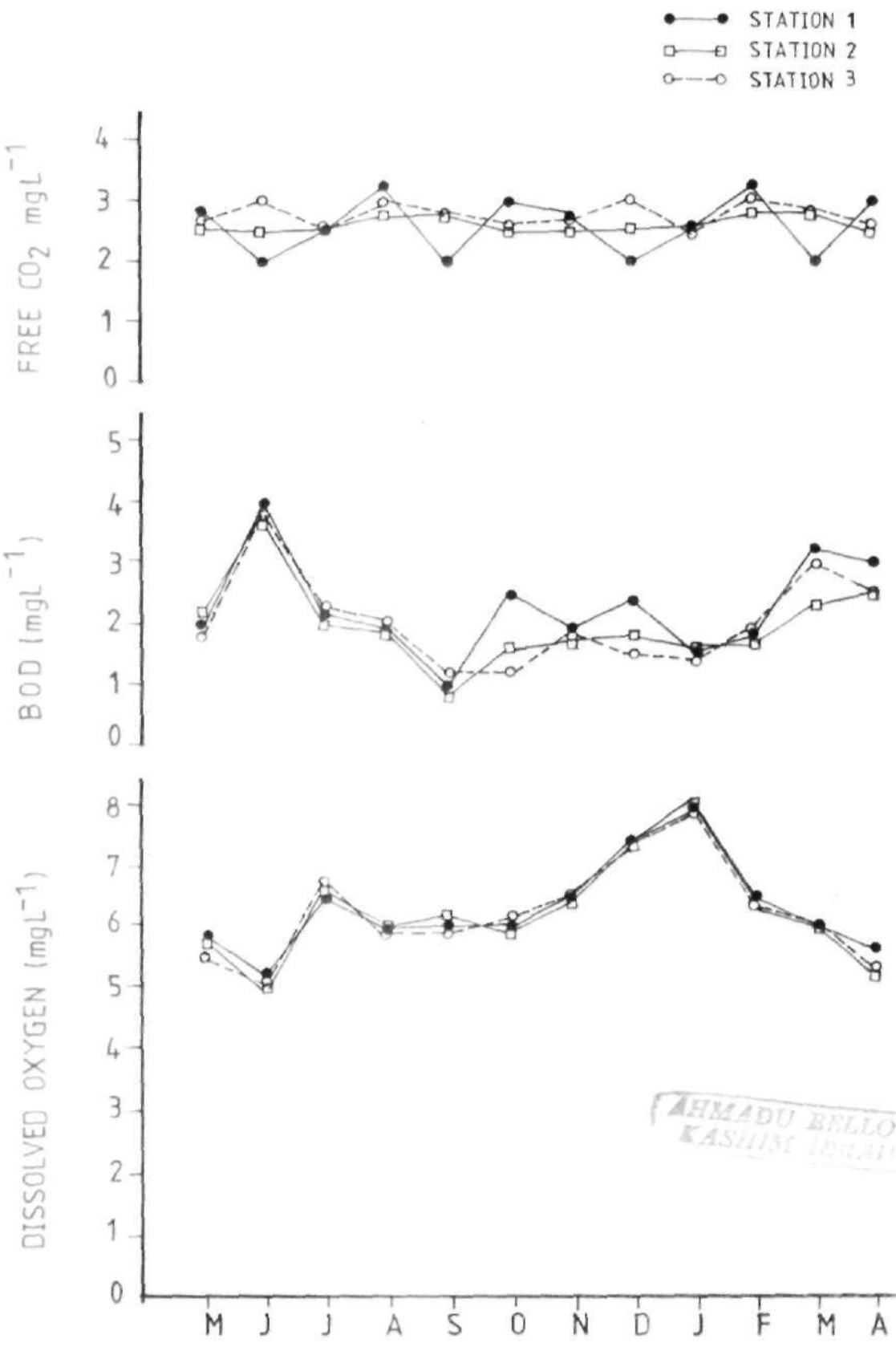
Analysis of variance (Table 7b) revealed a highly significant variation in DO between stations, seasons and stations by seasons ($P < 0.01$). Correlation coefficient analysis for DO against other parameters. (Table 1c) showed a positively significant correlation between DO and water hardness. There was a negative significant correlation with temperature, BOD_5, CO_2, PO_4-P and chlorophyll-a ($P \leq 0.05$).

4.8 BIOCHEMICAL OXYGEN DEMAND

Biochemical oxygen demand (BOD) values varied between 0.85 and 3.95 mgl^{-1} (Fig. 6). Two peaks were prominent in June (3.95 mgl^{-1}) and March (3.20 mgl^{-1}). The lowest value was in September with 0.85 mgl^{-1}. The overall picture of the trend as seen in Table 8a indicated higher BOD values during the dry season than

the rainy season though not significant. There was a significant variation between stations ($P < 0.05$), while that of station by seasons was highly significant ($P < 0.01$).

Correlation coefficient analysis (Table 1c) revealed a positive significant correlation between BOD with Cu, Fe, K and electrical conductivity ($P < 0.05$), while negative significant correlation exists with Ca, transparency, and DO.



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FIG. 6 : MEAN MONTHLY VALUES OF DISSOLVED OXYGEN, BIOCHEMICAL OXYGEN DEMAND (B.O.D) AND FREE CARBON DIOXIDE (CO_2) OF MAKWAYE (A.B.U. FARM) LAKE SAMARU, ZARIA.

TABLE 7a: SEASONAL VARIATION IN DISSOLVED OXYGEN (mgl^{-1}) FOR STATIONS OF MAKWAYE (A.B.U. FARM) LAKE SAMARU, ZARIA.

	STATIONS 1	2	3	S.E.D
General station $\bar{x}$	6.1	6.7	6.0	
Dry season $\bar{x}$ 6.6				
Rainy season $\bar{x}$ 5.9				

S.E.D between two means for months	0.334
S.E.D between two means for stations	0.167
S.E.D between two means for seasons	0.136
S.E.D between two means for stations by seasons	0.236

S.E.D = Standard Error Difference.

TABLE 7b: ANALYSIS OF VARIANCE (ANOVA) FOR DISSOLVED OXYGEN

Source of Variation	Sum of Squares	D.F	Means Squares	F. ratio	Sign
Months	6.576	11	0.597	1.79	NS
Stations	9.601	2	4.800	14.376	xx
Seasons	9.269	1	8.268	24.76	xx
Stations by seasons	10.489	2	5.242	15.698	xx
Residual	18.367	55	0.333		
Total	53.299	71			

xx = highly significant ($P<0.01$)
NS = not significant ($P>0.05$).

aTABLE 8a: SEASONAL VARIATION IN BIOCHEMICAL OXYGEN (BOD) FOR STATIONS OF MAKWAYE (A.B.U. FARM) LAKE SAMARU, ZARIA

	STATIONS 1	2	3	S.E.D
General season $\bar{x}$	3.12	3.15	3.05	
Dry season $\bar{x}$	2.14 mgl^{-1}			
Rainy season $\bar{x}$	2.10 mgl^{-1}			
S.E.D between two means for months				0.315
S.E.D between two means for stations				0.158
S.E.D between two means for season				0.129
S.E.D between two mean for station by seasons				0.223

S.E.D = Standard Error Difference.

TABLE 8b: ANALYSIS OF VARIANCE (ANOVA) FOR BIOCHEMICAL OXYGEN DEMAND (BOD)

Source of Variation	Sum of Squares	D.F	Means Squares	F. ratio	Sign
Months	5.246	11	0.476	1.6	NS
Stations	3.33	2	1.665	5.589	x
Seasons	0.027	1	0.027	0.091	NS
Stations by seasons	19.226	2	9.613	32.263	xx
Residual	16.398	55	0.297		
Total	44.22	71			

xx = highly significant ($P < 0.01$)

x = significant ($P < 0.05$)

NS = not significant ($P > 0.05$).

4.9 CARBON DIOXIDE

Mean monthly values of dissolved carbon dioxide ranged between 2.0 to 4.25 mgl^{-1} (Fig. 6). Rainy season values were higher than that of the dry season (Table 9a). Thus, the variations between seasons was highly significant (Table 9b). However, there were no significant variation between stations and stations by seasons ($P > 0.05$).

Table 1c revealed a positive significant correlation between dissolved carbon dioxide and phosphate phosphorus (PO_4-P) (P 0.05). There was a negatively significant correlation with water hardness ($P \leq 0.05$).

4.10 NITRATE NITROGEN

The seasonal concentrations of Nitrate-Nitrogen (NO_3-N) of the lake showed higher values in the rainy season than the dry season (Table 10a). All the stations exhibited the highest peak in June (rainy season) with (3.8 mgl^{-1} by station 2), this was followed by a dry season peak (2.85 mgl^{-1}) in February exhibited by station 2 (Fig. 7).

There were significant variations in NO_3-N between stations and stations by seasons (Table 1b) ($P < 0.05$) and a highly significant seasonal variation ($P < 0.01$). Correlation coefficient analysis (Table 1c)

exhibited a positive significant correlation between NO_3-N with Cu and BOD ($P < 0.05$). There was a negative significant correlation with Mg and water hardness ($P \leq 0.05$).

TABLE 9a: SEASONAL VARIATION IN DISSOLVED CARBON DIOXIDE FOR STATIONS OF MAKWAYE (A.B.U. FARM) LAKE SAMARU, ZARIA

	STATIONS 1	2	3	S.E.D
General station $\bar{x}mgl^{-1}$	3.13	3.15	3.05	
Dry season $\bar{x}$	2.64 mgl^{-1}			
Rainy seasons $\bar{x}$	3.58 mgl^{-1}			
S.E.D between two means for months				0.315
S.E.D between two means for stations				0.158
S.E.D between two means for seasons				0.129
S.E.D between two means for stations by seasons				0.223

S.E.D = Standard Error Difference.

TABLE 9b: ANALYSIS OF VARIANCE (ANOVA) FOR DISSOLVED CARBON DIOXIDE

Source of Variation	Sum of Squares	D.F	Means Squares	F. ratio	Sign
Months	3.054	11	0.277	0.99	NS
Stations	0.121	2	0.06	0.204	NS
Seasons	15.401	1	15.401	51.626	xx
Stations by seasons	0.26	2	0.13	0.437	NS
Residual	16.407	55	0.298		
Total	35.246	71			

xx = highly significant ($P< 0.01$)
NS = not significant ($P> 0.05$).

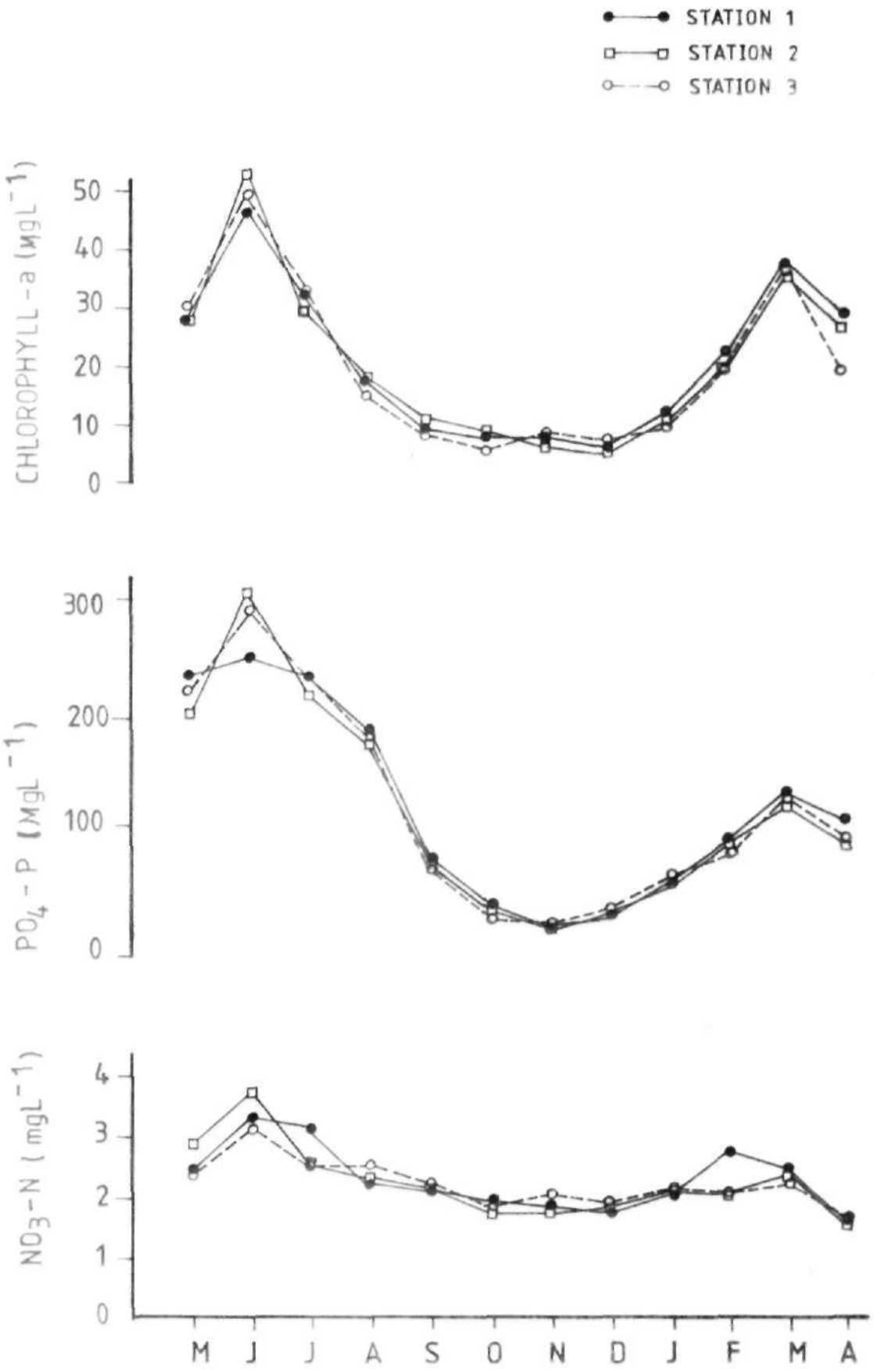


FIG. 7: MEAN MONTHLY CONCENTRATIONS OF NITRATE NITROGEN (NO_3^- N) PHOSPHATE PHOSPHORUS (PO_4- P) AND CHLOROPHYLL-a OF MAKWAYE (A.B.U. FARM) LAKE SAMARU, ZARIA.

TABLE 10a: SEASONAL VARIATIONS IN NITRATE-NITROGEN (NO_3-N) FOR STATIONS OF MAKWAYE (A.B.U. FARM) LAKE SAMARU, ZARIA

	STATIONS 1	2	3	S.E.D
General station $\bar{x}$	2.48	2.42	2.02	
Dry season $\bar{x}$	2.06 mgl^{-1}			
Rainy season $\bar{x}$	2.55 mgl^{-1}			
S.E.D between two means for months				0.320
S.E.D between two means for stations				0.160
S.E.D between two means for seasons				0.131
S.E.D between two means for stations by seasons				0.227

S.E.D = Standard Error Difference.

TABLE 10b: ANALYSIS OF VARIANCE (ANOVA) FOR NITRATE-NITROGEN (NO_3-N)

Source of Variation	Sum of Squares	D.F	Means Squares	F. ratio	Sign
Months	2.069	11	0.189	0.615	NS
Stations	2.93	2	1.465	4.76	x
Seasons	4.45	1	4.45	14.455	xx
Stations by seasons	3.991	2	1.995	6.468	x
Residual	16.832	55	0.307		
Total	30.388	71			

xx = highly significant ($P<0.01$)
x = significant ($P<0.05$)
NS = not significant ($P>0.05$).

4.11 PHOSPHATE-PHOSPHORUS

Fig. 7 and Table 11a show the mean monthly and seasonal variations of phosphate-phosphorus (PO_4-P) of the lake. Fig. 7 exhibited 2 PO_4-P maxima with the highest maximum concentration of 305 ugl^{-1} in June while the second peak was in March (141 ugl^{-1}) the minimum PO_4-P concentration (28 ugl^{-1}) was obtained in November. Table 11a indicated higher PO_4-P concentration in the rainy season (175.19 ugl^{-1}) than the dry season (78.08 ugl^{-1}).

Analysis of variance (Table 11b) revealed a very highly significant variation in PO_4-P with the seasons, stations and stations by seasons (P 0.01). Correlation coefficient analysis between PO_4-P with the other physico-chemical parameters investigated (Table 1c) showed that a highly positive significant correlation exists between PO_4-P with Pb, Fe, K, pH, BOD, CO_2, NO_3-N and conductivity ($P< 0.05$). There was a negative significant correlation with Ca, Mg, DO, hardness and transparency ($P\leqslant 0.05$).

4.12 CHLOROPHYLL-a

Chlorophyll-a concentration varied between 6.6 - 53.6 ugl^{-1} (Fig. 7). The chlorophyll-a concentration during the dry season was 18.1 ugl^{-1} while that of the rainy season was 24.52 ugl^{-1} (Table 12a). The variations

between stations and seasons were not significant ($P>0.05$). There was a significant variation between stations by seasons (Table 12b).

Correlation coefficient analysis with respect to other physico-chemical parameters revealed a positive significant correlation of chlorophyll-a with Pb, Cu, K, temperature, conductivity, BOD, NO_3-N and PO_4-P. There was a negative significant correlation between chlorophyll-a and Ca, Mg, transparency, and hardness.

TABLE 11a: SEASONAL VARIATION IN PHOPHATE-PHOSPHORUS (PO_4-P) FOR STATIONS OF MAKWAYE (A.B.U. FARM) LAKE SAMARU, ZARIA

STATIONS	1	2	3	S.E.D
General stations $\bar{x}$	143.46	145.28	91.17	
Dry season $\bar{x}$	78.08 ugl^{-1}			
Rainy season $\bar{x}$	175.19 ugl^{-1}			
S.E.D between two means for months				18.721
S.E.D between two means for stations				9.360
S.E.D between two means for seasons				7.643
S.E.D between two means for stations by seasons				13.237

S.E.D = Standard Error Difference.

TABLE 11b: ANALYSIS OF VARIANCE (ANOVA) FOR PHOSPHATE-PHOSPHORUS

Source of Variation	Sum of Squares	D.F	Means Squares	F. ratio	Sign
Months	2308.944	11	209.904	0.199	NS
Stations	45338.361	2	22669.18	21.561	xx
Seasons	169750.222	1	169750.222	161.456	xx
Stations by seasons	243947.861	2	121973.93	116.014	xx
Residual	57825.222	55	1051.367		
Total	519170.611	71			

xx = highly significant ($P < 0.01$)

NS = not significant (($P > 0.05$).

TABLE 12a: SEASONAL VARIATION IN CHLOROPHYLL-a (ugl^{-1}) FOR STATIONS OF MAKWAYE (A.B.U. FARM) LAKE SAMARU, ZARIA.

	STATIONS 1	2	3	S.E.D
General stations $\bar{x}$	23.43	21.01	20.98	
Dry season $\bar{x}$	18.01			
Rainy season $\bar{x}$	24.52			

S.E.D between two means for months	23.748
S.E.D between two means for stations	11.874
S.E.D between two means for seasons	9.695
S.E.D between two means for stations and seasons	16.792

S.E.D = Standard Error Difference.

TABLE 12b: ANALYSIS OF VARIANCE (ANOVA) FOR CHLOROPHYLL-a

Source of Variation	Sum of Squares	D.F	Means S Squares	F. ratio	Sign
Months	17599.469	11	1599.951	0.945	NS
Stations	2456.978	2	1228.489	0.726	NS
Seasons	225.073	1	225.073	0.133	NS
Stations by seasons	21976.233	2	10988.116	6.494	x
Residual	93052.309	55	1691.86		
Total	135310.063	71			

x = significant ($P < 0.05$)

NS = not significant ($P > 0.05$).

4.13.0 METALS

Studies of some metal concentrations were carried out on both surface water and sediments of the three stations of Makwaye (A.B.U. farm) lake Samaru, Zaria so as to establish their concentrations. Nine elements Ca, Na, Co, Cu, Fe, Pb, Mg, K and Zn were monitored. The mean seasonal concentration of the metals in surface water (ugl^{-1}) are presented on Table 13a.

4.13.1 METAL CONCENTRATIONS IN SURFACE WATER

The monthly concentration of various metals of the surface water are presented on Fig. 8.

4.13.1.1 CALCIUM

Monthly concentration of calcium ranged between (0.096 to 6.0 ugl^{-1}). Lower values were obtained from May through August. There was a steady rise from September through December. Even though the dry season mean was higher than that of the rainy season, there was no significant variation in calcium concentration between stations, seasons and stations by seasons (Table 14a). There was a significant negative correlation between calcium with Iron (Fe) and Potassium ($P \leq 0.05$) Table 1c.

TABLE 13a: MEAN SEASONAL VARIATION IN METAL CONCENTRATIONS OF SURFACE WATER AND SEDIMENT OF MAKWAYE (A.B.U. FARM) LAKE SAMARU, ZARIA

	WATER (ugl^{-1})		SEDIMENT (ugl^{-i})	
METAL	RAINY SEASON	DRY SEASON	RAINY SEASON	DRY SEASON
Ca	1.545	2.231	281.944	277.500
Mg	1.481	2.412	626.389	730.833
K	3.093	3.170	656.972	694.444
Na	42.840	57.667	2585.833	3141.667
Co	0.108	0.015	29.861	41.278
Cu	0.331	0.517	35.361	43.056
Fe	3.482	2.260	403.722	431.028
Pb	0.182	0.990	9.361	13.389
Zn	0.858	0.238	45.889	47.139

	Na	Ca	Mg	pH	DIPTERA	MOLLUSCA	TRICHOP	ODONATA
Na	1.00000							
Ca	.08839	1.00000						
Mg	-.16307	.31781	1.00000					
pH	-.39801	.23821	.07052	1.00000				
DIPTERA	.15661	-.54200	.17914	-.25905	1.00000			
MOLLUSCA	-.26132	.66171	-.04792	.34927	-.69562	1.00000		
TRICHOP	.15911	-.20298	-.03997	-.17986	-.16450	-.57131	1.00000	
ODONATA	..04322	-.18079	-.44575	.05346	-.38225	.14090	.03445	1.00000

CRITICAL VALUE (1 - TAIL, .05) = + **Or** - .49932
CRITICAL VALUE (2 - tail, .05) = +/- .57400

TABLE 13b: CORRELATION BETWEEN VARIABLES

	MONTH	STATION	Zn	Pb	Cu	Co	Fe	K
MONTH	1.00000							
STATION	99.99900	1.00000						
Zn	.24383	99.99900	1.00000					
Pb	-.26572	99.99900	.04392	1.00000				
Cu	.42292	99.99900	.63250	-.46149	1.00000			
Co	-.54595	99.99900	-.13153	.32360	-.21417	1.00000		
Fe	-.52990	99.99900	.18584	.43527	-.15203	.67849	1.00000	
K	-.07263	99.99900	-.02426	.12462	-.12922	.51363	.16011	1.00000
Na	-.51558	99.99900	-.08280	.30779	-.25767	.47047	.56247	.01136
Ca	-.22163	99.99900	.20729	.24869	-.22890	.04104	-.13211	
Mg	.32479	99.99900	-.01535	.28576	-.31150	.07816	-.13529	.55041
pH	.19962	99.99900	.63114	-.54065	.63103	-.14021	-.02787	.04973
DIPTERA	..44439	99.99900	.09569	.17944	-.00357	.13914	.24334	.18462
MOLLUSCA	.04717	99.99900	.19087	-.12386	.16122	-.54555	-.39165	-.63675
TRICHOP	-.47615	99.99900	-.37262	-.05649	-.28338	.47133	.21857	.69666
ODONATA	-.50786	99.99900	-.03739	.00962	.24954	.41332	.09101	-.1;695

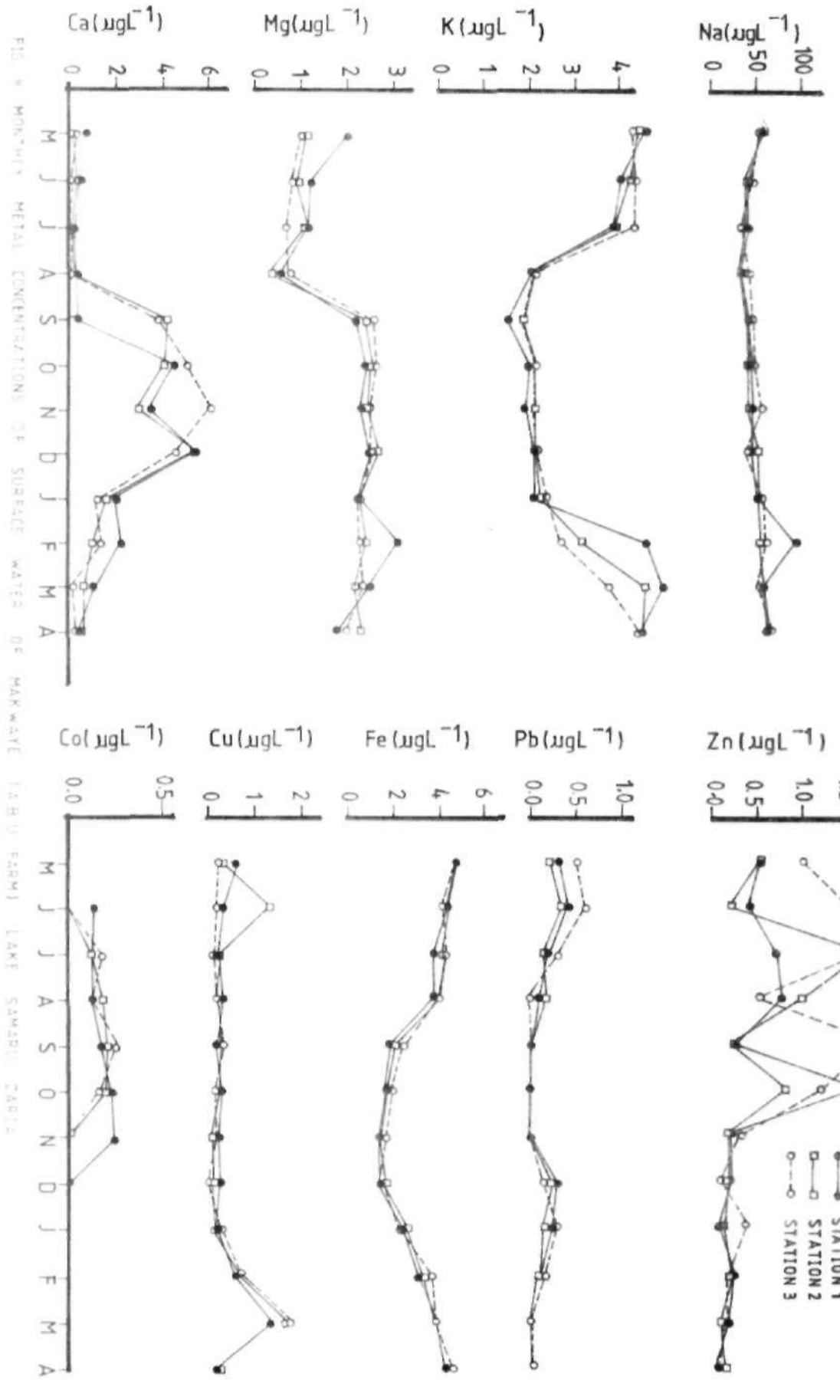


FIG 4 MONTHLY MEAN CONCENTRATIONS OF SURFACE WATER OF MAKWAYE (ABU FARM) LAKE SAMARU ZARIA

4.13.1.2 MAGNESIUM

The monthly concentrations of Magnesium in all the stations of the lake ranged from 0.30 to 3.14 ugl^{-1}. Lowest values were obtained in August; this was followed by a gradual rise in September through April. There was a highly significant variation between seasons (Table 14b). Correlation coefficient analysis (Table 1c) revealed a positive significant correlation between Mg with Ca and Na, negative significant correlation occurs with Zn, Pb and Fe (P 0.05).

4.13.1.3 POTASSIUM

Potassium concentrations ranged between 1.56 to 5.04 ugl^{-1}. There was a decline with the onset of the rains from May through September and a gradual rise from January through March. There was no significant variation in Potassium concentration with seasons, stations and stations by seasons (Table 14c). Correlation coefficient analysis (Table 1c) revealed a positive significant correlation between Potassium with Copper and Iron (P 0.05), while negative significant correlation exists with Cobalt.

4.13.1.4 SODIUM

There was a highly significant variation in Na concentration with the seasons (Table14d). Positive

significance correlation exists between Na with K ($P < 0.05$) and a negatively significant correlation with Co and Zn.

ANALYSIS OF VARIANCE (ANOVA) FOR THE CONCENTRATION OF METALS IN SURFACE WATER OF MAKWAYE (A.B.U. FARM) LAKE SAMARU, ZARIA

TABLE 14a: CALCIUM

Source Variation	Sum of Squares	D.F	Mean Squares	F. ratio	Sign
Stations	0.423	2	0.212	0.044	NS
Seasons	4.235	1	4.235	0.882	NS
Stations by seasons	1.121	2	0.560	0.117	NS
Residual Error	144.115	30	4.804		
Total	149.894	35			

TABLE 14b: MAGNESIUM

Sources Variation	Sum of Squares	D.F	Means Squares	F. ratio	Sign
Stations	0.119	2	o.060	0.148	NS
Seasons	7.810	1	7.810	19.336	xx
Stations by seasons	0.039	2	0.019	0.046	
Residual error	12.118	30	0.404		
Total	20.026	35			

xx = highly significant ($P < 0.01$)

NS = not significant ($P > 0.05$).

TABLE 14c: POTASSIUM

Source of Variation	Sum of Squares	D.F	Means Squares	F. ratio	Sign
Stations	0.135	2	0.067	0.043	NS
Seasons	0.053	1	0.053	0.034	NS
Stations by seasons	0.528	2	0.264	0.170	NS
Residual error	46.628	30			
Total	47.339	35			

NS = Not significant (P 0.05).

4.13.1.5 COBALT

Monthly variation in Co concentration ranged from 0 to 0.264 ugl^{-1}. There was a highly significant variation in the rainy season than the dry season (Table 14e). Co exhibited a positive significant correlation with Zn and a negative significant correlation with Pb.

4.13.1.6 COPPER

Dry season Cu concentration was higher than the rainy season even though the difference was not significant (Table 14f). Monthly concentration ranged between 0.096 to 0.264 ugl^{-1}. The highest concentration for all the stations was recorded in March.

4.13.1.7 IRON

There was a gradual fall in the concentration of Iron (Fe) during the rainy season months, May to October. This was followed by a steady rise from December through April. There was no significant variation with the seasons (Table 14g). Iron exhibited a positive significant correlation with Pb (Table 1c).

4.13.1.8 LEAD

The monthly concentration of Lead (Pb) ranged from 0.0 to 0.62 ugl^{-1}. The dry season concentration was higher than that of the rainy season but the variation was not significant ($P>0.05$) (Table 14h).

4.13.1.9 ZINC

The zinc content in water ranged between 0.132 to 1.764 ugl^{-1}. Analysis of variance (Table 14i) showed that zinc content varied significantly with the seasons.

TABLE 14d: SODIUM

Source of Variation	Sum of Squares	D.F	Mean Squares	F. ratio	Sign
Stations	72.975	2	36.488	0.323	NS
Seasons	1978.470	1	1978.470	17.520	xx
Stations by seasons	102.496	2	51.243	0.454	NS
Residual	3387.768	30	112.926		
Total	5541.699	35			

TABLE 14e: COBALT

Source of Variation	Sum of Squares	D.F	Mean Squares	F. ratio	Sign
Stations	0.00232	2	0.00116	0.150	NS
Seasons	0.137	1	0.137	17.675	xx
Stations by seasons	0.0012	2	0.0006	0.765	NS
Residual	0.233	30	0.0078		
Total	0.394	35			

xx = highly significant ($P < 0.001$)

NS = Not significant ($P > 0.05$).

TABLE 14d: SODIUM

Source of Variation	Sum of Squares	D.F	Mean Squares	F. ratio	Sign
Stations	72.975	2	36.488	0.323	NS
Seasons	1978.470	1	1978.470	17.520	xx
Stations by seasons	102.496	2	51.243	0.454	NS
Residual	3387.768	30	112.926		
Total	5541.699	35			

TABLE 14e: COBALT

Source of Variation	Sum of Squares	D.F	Mean Squares	F. ratio	Sign
Stations	0.00232	2	0.00116	0.150	NS
Seasons	0.137	1	0.137	17.675	xx
Stations by seasons	0.0012	2	0.0006	0.765	NS
Residual	0.233	30	0.0078		
Total	0.394	35			

xx = highly significant ($P < 0.001$)

NS = Not significant ($P > 0.05$).

TABLE 14f: COPPER

Source of Variation	Sum of Squares	D.F	Mean Squares	F. ratio	Sign
Stations	0.069	2	0.034	0.163	NS
Seasons	0.311	1	0.311	1.483	NS
Stations by seasons	0.078	2	0.039	0.187	NS
Residual	3.299	30	0.210		
Total	6.758	35			

TABLE 14g: IRON

Source of Variation	Sum of Squares	D.F	Mean Squares	F. ratio	Sign
Stations	0.278	2	0.139	0.098	NS
Seasons	3.257	1	3.257	2.266	NS
Stations by seasons	0.017	2	0.0085	0.003	NS
Residual	42.746	30			
Total	46.239	35			

NS = Not significant ($P > 0.05$).

TABLE 14h: LEAD

Source of Variation	Sum of Squares	D.F	Mean Squares	F. ratio	Sign
Stations	0.042	2	0.021	0.787	NS
Seasons	0.062	1	0.062	2.322	NS
Stations by seasons	0.026	2	0.013	0.430	NS
Residual	0.797	30	0.027		
Total	0.926	35			

TABLE 14i: ZINC

Source of Variation	Sum of Squares	D.F	Mean Squares	F. ratio	Sign
Stations	0.289	2	0.144	1.138	NS
Seasons	3.860	1	3.860	31.759	xx
Stations by seasons	0.155	2	0.077	0.637	NS
Residual	3.646	30			
Total	7.950	35			

xx = highly significant ($P < 0.01$)

NS = not significant ($P > 0.05$).

4.13.2 SEDIMENT METAL CONCENTRATIONS

Figure 9 and Table 13a show the monthly and seasonal variations in the sediment metal concentrations (ugg^{-1}) of Makwaye (A.B.U. farm) lake Samaru, Zaria.

4.13.2.1 CALCIUM

Concentration of Calcium in the sediment fluctuated between 135 to 385 ugg^{-1} dry weight. The concentration was higher, though insignificant, during the rainy season than dry season (Table 15a).

4.13.2.2 MAGNESIUM

Mean monthly variations in Magnesium concentration of the sediment ranged from 325 to 950 ugg^{-1} dry weight. There was a highly significant variation between seasons and stations by seasons (Table 15b).

4.13.2.3 POTASSIUM

There was no significant variation between seasons in the concentration of Potassium in the sediment (Table 15c). Monthly concentration ranged between 400 and 920 ugg^{-1} dry weight.

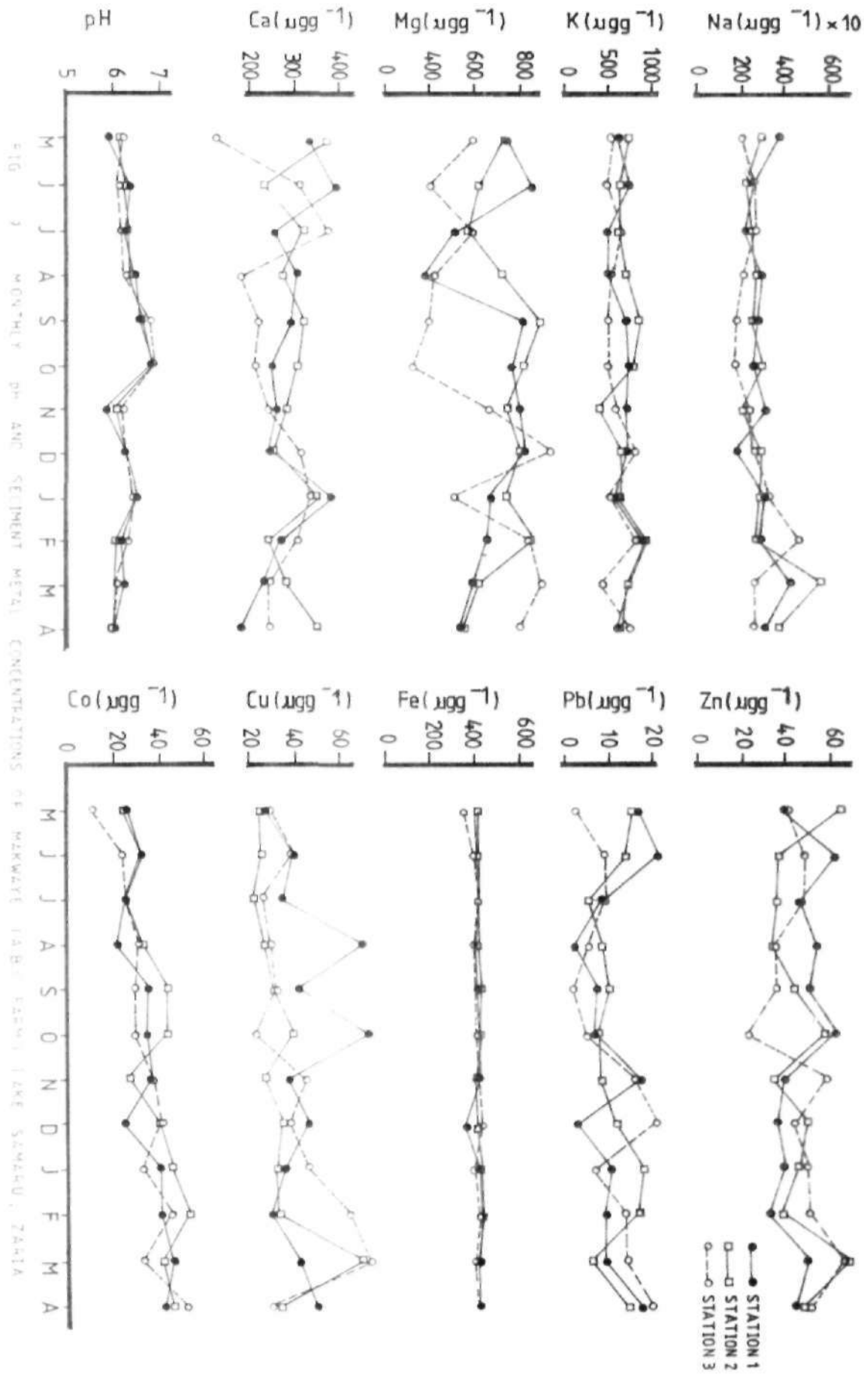
4.13.2.4 SODIUM

Concentration of Sodium in the sediment ranged between 1850 and 5600 ugg^{-1} dry weight. In relation

to other metals it exhibited the highest concentration throughout the study period. There was a high significant variation between seasons (Table 15d).

4.13.2.5 COBALT

Sediment cobalt concentration ranged between 10 to 55.5 ugg^{-1} dry weight. The cobalt concentration was higher during the dry season (Table 15e and Fig. 9).


pH
Ca(µgg⁻¹)
Mg(µgg⁻¹)
K(µgg⁻¹)
Na(µgg⁻¹)×10
Co(µgg⁻¹)
Cu(µgg⁻¹)
Fe(µgg⁻¹)
Pb(µgg⁻¹)
Zn(µgg⁻¹)
M J J A S O N D J F M A
STATION 1
STATION 2
STATION 3

ANALYSIS OF VARIANCE (ANOVA) FOR THE CONCENTRATION OF METAL IN SEDIMENT OF MAKWAYE (A.B.U. FARM) LAKE SAMARU, ZARIA

TABLE 15a: CALCIUM

Source of Variation	Sum of Squares	D.F	Mean Squares	F. ratio	Sign
Stations	9672.222	2	4336.111	1.178	NS
Seasons	177.778	1	177.778	0.048	NS
Stations by seasons	10555.556	2	5277.778	1.434	NS
Residual	110391.667	30	3679.722		
Total	123737.222	35			

TABLE 15b: MAGNESIUM

Source of Variation	Sum of Squares	D.F	Mean Squares	F. ratio	Sign
Stations	73783.056	2	36896.528	1.636	NS
Seasons	78177.778	1	98177.778	4.949	x
Stations by seasons	217376.399	2	108688.194	5.476	xx
Residual	595183.333	30	19839.444		
Total	984590.556	35			

xx = highly significant ($P < 0.01$)

x = significant ($P < 0.05$)

NS = Not significant ($P > 0.05$).

TABLE 15c: POTASSIUM

Source of Variation	Sum of Squares	D.F	Mean Squares	F. ratio	Sign
Stations	60044.042	2	30022.021	1.759	NS
Seasons	12637.507	1	12637.507	0.740	NS
Stations by seasons	61263.764	2	30631.882	1.794	NS
Residual	512111.875	30	17070.396		
Total	648057.198	35			

TABLE 15d: SODIUM

Source of Variation	Sum of Squares	D.F	Mean Squares	F. ratio	Sign
Stations	1044712.500	2	522356.250	0.922	NS
Seasons	2681406.250	1	2681406.250	5.041	x
Stations by seasons	677629.167	2	339814.583	0.637	NS
Residual	15958770.833	30	531959.028		
Total	20362518.750	35			

x = significant ($P < 0.05$)

NS = Not significant ($P > 0.05$).

4.13.2.6 COPPER

Concentration of copper in the sediment ranged between 22 to 74 ugg^{-1} dry weight. Dry season concentration was insignificantly higher than the rainy season (Table 15f). Copper showed positive significant correlation with Zn (Table 13b).

4.13.2.7 IRON

The concentration of Fe in the sediment was higher in the rainy season than the dry season although the difference was not significant (Table 15g). Monthly concentration ranged between 367 to 445 ugg^{-1} dry weight. There was a positive significant correlation between Fe and Cobalt (Table 13b).

4.13.2.8 LEAD

The range of sediment Pb concentration was 2.0 to 21.5 ugg^{-1} dry weight. Analysis of variance (Table 15h) revealed a significant variation in sediment lead concentration with the seasons ($P < 0.05$).

4.13.2.9 ZINC

Concentration of Zinc in the sediment was from 23 to 68 ugg^{-1}. Analysis of variance (Table 15i) showed a significant variation between Zinc and stations by seasons ($P < 0.05$).

TABLE 15e: COBALT

Source of Variation	Sum of Squares	D.F	Mean Squares	F. ratio	Sign
Stations	237.087	2	118.549	1.978	NS
Seasons	1173.063	1	1173.063	19.574	xx
Stations by seasons	102.042	2	51.021	0.851	NS
Residual	1797.875	30	59.929		
Total	3310.076	35			

TABLE 15f: COPPER

Source of Variation	Sum of Squares	D.F	Mean Squares	F. ratio	Sign
Stations	666.000	2	333.000	1.897	NS
Seasons	532.840	1	532.840	3.036	NS
Stations by seasons	1223.389	2	611.674	3.425	x
Residual	5265.958	30	175.532		
Total	7688.188	35			

xx = highly significant ($P < 0.01$)
x = significant ($P < 0.05$)
NS = Not significant ($P > 0.05$).

TABLE 15g: IRON

Source of Variation	Sum of Squares	D.F	Mean Squares	F. ratio	Sign
Stations	4957.542	2	2478.771	0.568	NS
Seasons	6710.340	1	6710.340	1.516	NS
Stations by seasons	7483.847	2	3741.924	0.846	NS
Residual	132752.458	30	4425.082		
Total	151904.187	35			

TABLE 15h: LEAD

Source of Variation	Sum of Squares	D.F	Mean Squares	F. ratio	Sign
Stations	9.500	2	4.750	0.179	NS
Seasons	146.007	1	146.007	5.510	x
Stations by seasons	158.722	2	79.361	2.935	NS
Residual	794.958	30	26.499		
Total	1109.187	35			

TABLE 15i: ZINC

Source of Variation	Sum of Squares	D.F	Mean Squares	F. ratio	Sign
Stations	2.181	2	1.090	0.011	NS
Seasons	14.063	1	14.063	0.141	NS
Stations by seasons	1134.875	2	567.438	5.681	x
Residual	2996.625	30			
Total	4147.743	35			

x = significant ($P < 0.05$)

NS = Not significant ($P > 0.05$).

4.14 SURFACE WATER METAL CONCENTRATIONS Vs SEDIMENT METAL CONCENTRATIONS

The concentration of metals in surface and sediment are illustrated in Figs. 8 and 9 respectively. The sediment had higher concentrations of all the metals than the surface water. Sodium (Na) registered the highest concentration in both surface water and sediment. The concentrations of metals in the sediment throughout the study period show the following decreasing order of magnitude: Na, Mg, K, Fe, Ca, Zn, Co, Cu, Pb, while that of the surface water was: Na, Fe, K, Mg, Ca, Cu, Zn, Pb and Co in the same decreasing order.

4.15 SEDIMENT pH

The seasonal and monthly variations in the sediment pH are presented in Table 16a and Fig. 9. The rainy season mean was higher than the dry season (pH of 6.43 and 6.18) respectively (Table 16a). There was a gradual rise in pH from May through October with a fall in November followed by a dry season peak in January. Analysis of variance revealed a significant variation between the reasons (Table 16b). Correlation coefficient matrix (Table 13b) exhibited a positive significant correlation between sediment pH with Zn and Cu.

4.16 BIOLOGICAL CHARACTERISTICS

Photographs of representative members of the benthic and zooplankton communities are presented in plates 1-12.

4.16.1 ZOOPLANKTON COMPOSITION

The mean monthly variations of the various zooplankton groups and total zooplankton composition are presented on Figs. 10a and 10b respectively. The relative percentage abundance of the various groups are illustrated on Fig. 11.

Three groups of zooplankton i.e Copepoda, Cladocera and Rotifera accounting for 41.3%, 25.3% and 33.4% respectively were found to be present at Makwaye (A.B.U. far farm) lake Samaru, Zaria. The early rainy season period May through July is characterised by a high total number of individuals with a peak in July which followed by a decline in the population in September. Mean monthly total number of zooplankton ranged between 197 to 852 individuals per litre (Fig. 10b).

TABLE 16a: SEASONAL VARIATIONS OF SEDIMENT HYDROGEN ION CONCENTRATION (pH) OF MAKWAYE (A.B.U. FARM) SAMARU, ZARIA

		STATIONS 1	2	3
General stations	$\bar{x}$	6.31	6.30	6.33
Rainy seasons	$\bar{x}$ 6.43			
Dry season	$\bar{x}$ 6.18			

TABLE 16b: ANALYSIS OF VARIANCE FOR SEDIMENT pH

Source of Variation	Sum of Squares	D.F	Mean Squares	F. ratio	Sign
Stations	0.00399	2	0.00194	0.026	NS
Seasons	0.444	1	0.444	6.269	x
Stations by seasons	0.00722	2	0.00361	0.001	NS
Residual	2.120	30	0.071		
Total	2.576	35			

x = significant ($P < 0.05$)

NS = Not significant ($P > 0.05$).

TABLE 17: SEASONAL VARIATION IN PERCENTAGE COMPOSITION OF THE VARIOUS ZOOPLANKTON SPECIES

	DRY SEASON	RAINY SEASON
COPEPODA		
Diaptomus sp	10.59	15.52
Cyclops sp	9.60	12.65
Eubranchipus sp	0.0	4.23
Nauplii	15.37	14.37
CLADOCERA		
Daphnia sp	7.88	5.22
Simocephalus sp	0	1.32
Ceriodaphnia sp	1.95	4.90
Macrothrix sp	4.92	3.33
Bosmina sp	4.45	1.08
Diaphanosoma sp	4.45	7.53
Polyphemus sp	3.38	2.07
Eurycercus sp	0	2.15
ROTIFERA		
Kellicottia sp	0.95	2.95
Keratella sp	26.68	14.17
Chromogaster sp	7.90	6.30
Brachionus sp	6.22	2.35

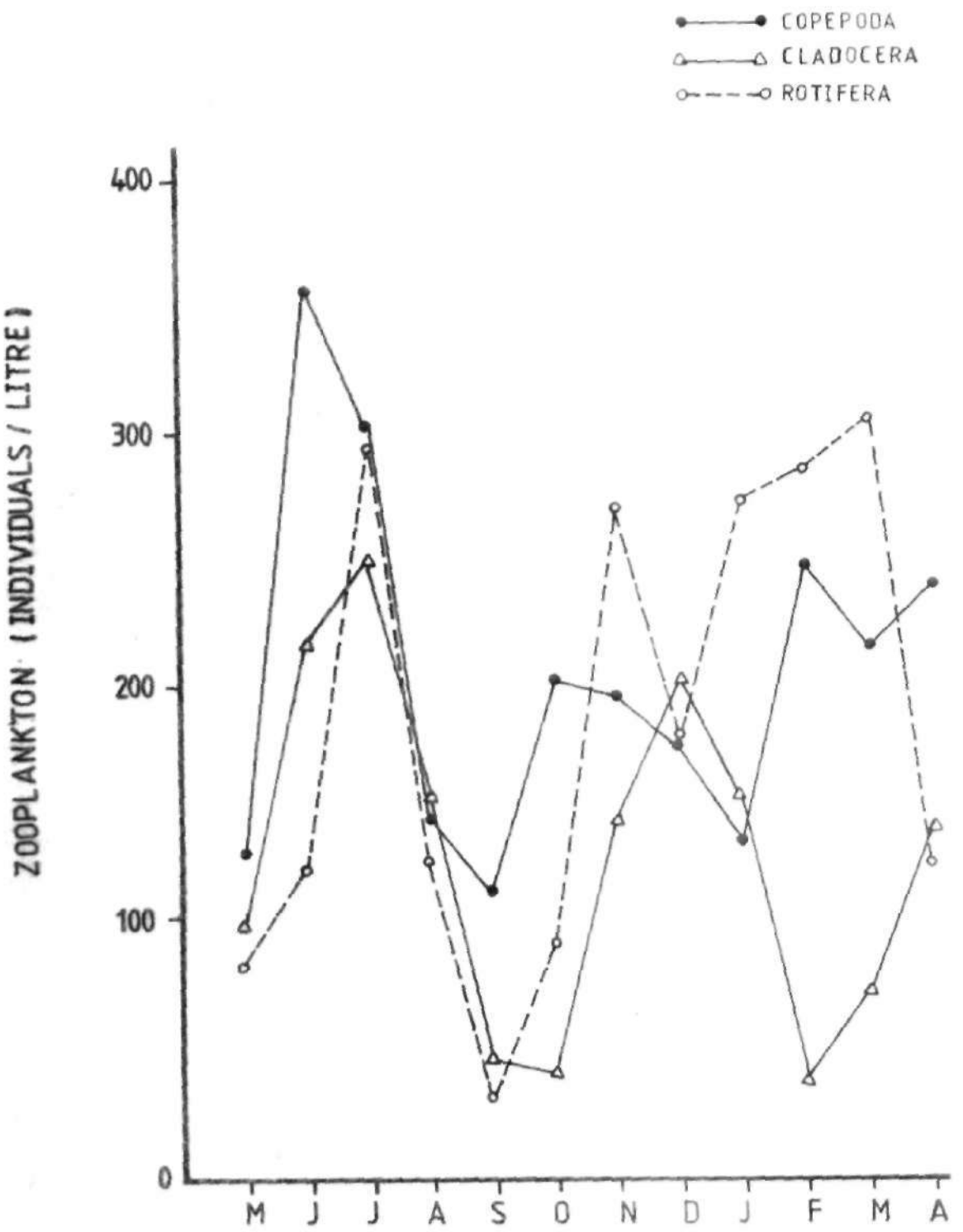


FIG. 10a: MEAN MONTHLY VARIATIONS OF MAJOR ZOOPLANKTON OF MAKWAYE (A.B.U. FARM) LAKE SAMARU, ZARIA.

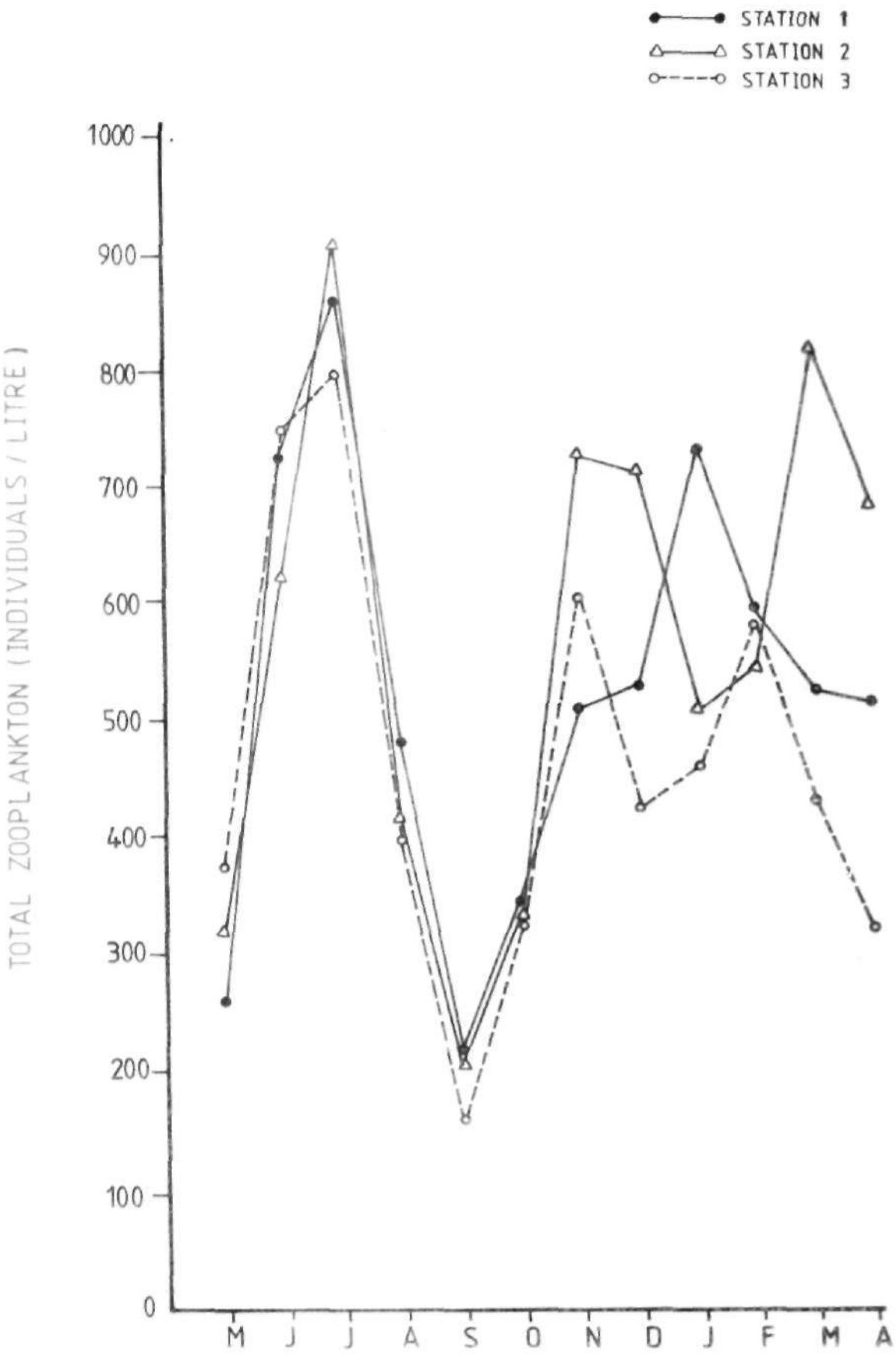


Fig. 10b: MEAN MONTHLY DENSITY OF ZOOPLANKTON IN MAKWAYE (A.B.U FARM) LAKE SAMARU, ZARIA

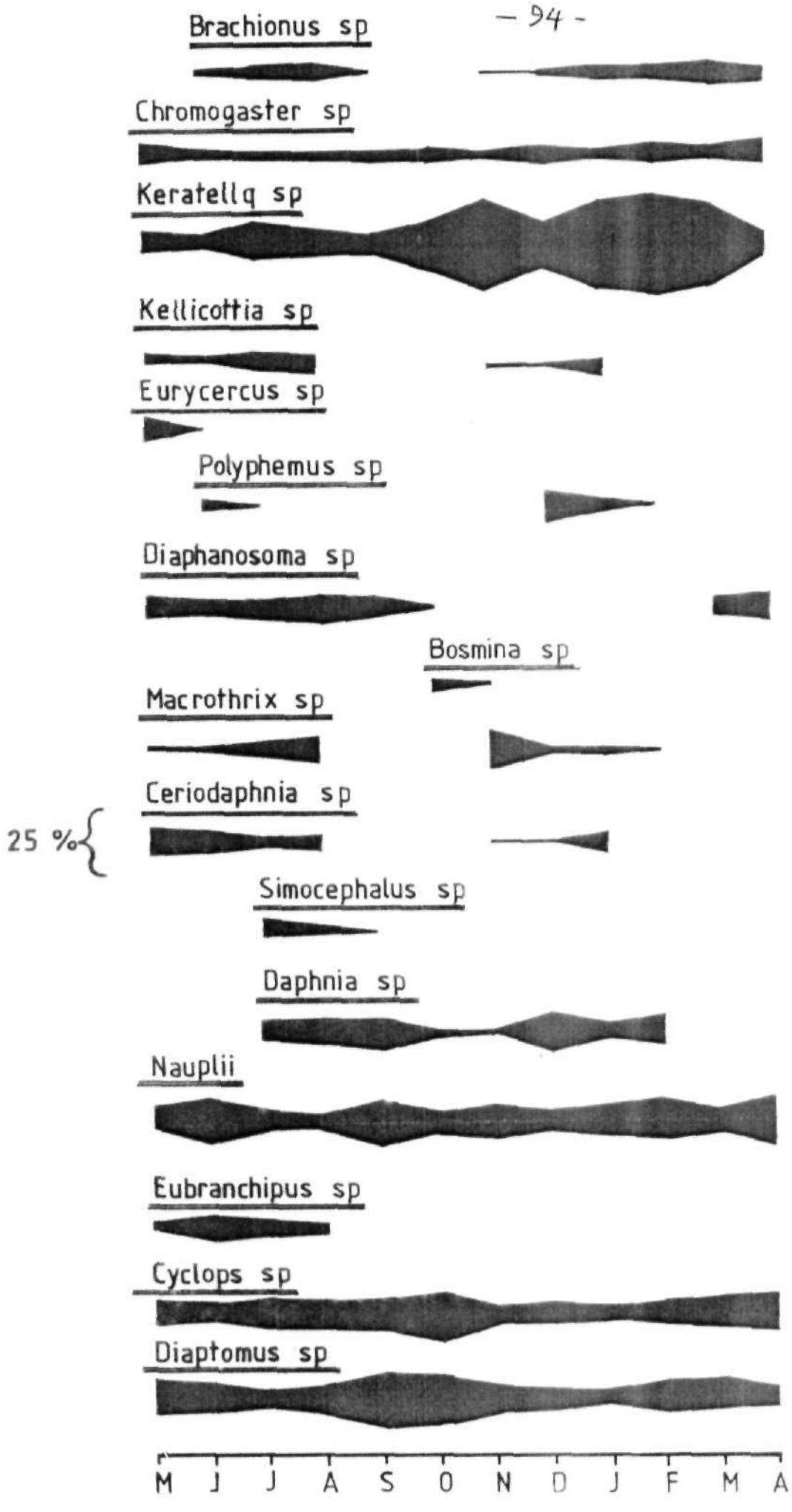


FIG. 11: RELATIVE ABUNDANCE (PERCENTAGE) OF THE VARIOUS ZOOPLANKTON SPECIES OF MAKWAYE (A.B.U. FARM) LAKE SAMARU, ZARIA.

4.16.1.1 COPEPODA

This is represented by Diaptomus sp (plate 1), Cyclops sp (plate 2) and Eubrarchipus sp. Nauplii larvae were present throughout the seasons accounting for between 6.1 to 23.5 percent of the total zooplankton composition. Eubranchipus sp were present only from May through August. Copepoda exhibited two maxima, in June and February representing 50.1% and 43.4% respectively. Their density during the rainy season was higher than in the dry season (Table 18a), a highly significant variation occurred between stations and seasons (P 0.01) (Table 18b).

Copepoda exhibited a positive significant correlation with Zn, Co, and temperature. Negatively significant correlation occurred with pH and Do.

TABLE 18a: SEASONAL VARIATION IN PERCENTAGE COMPOSITION OF COPEPODA IN MAJWAYE (A.B.U. FARM) LAKE SAMARU, ZARIA

		STATIONS 1	2	3	S.E.D
General stations	$\bar{x}$	38.03	34.26	51.31	
Rainy season	$\bar{x}$	47.09			
Dry season	$\bar{x}$	35.56			

S.E.D between two means for month	4.707
S.E.D between two means for stations	2.353
S.E.D between two means for seasons	1.922
S.E.D between two means for stations by seasons	3.328

TABLE 18b: ANALYSIS OF VARIANCE FOR COPEPODA

Source of Variation	Sum of Squares	D.F	Mean Squares	F. ratio	Sign
Months	1415.855	11	128.714	1.936	NS
Stations	3794.664	2	1897.332	28.547	xx
Seasons	2393.166	1	2393.166	36.007	xx
Stations by seasons	862.017	2	431.008	6.484	x
Residual	3655.479	55	66.463		
Total	12121.183	71			

xx = highly significant ($P < 0.01$)
x = significant ($P < 0.05$)
NS = Not significant ($P > 0.05$).

4.16.1.2 CLADOCERA

This is represented by 8 genera, Daphnia sp, (plate 4) Simocephalus sp, Ceriodaphnia sp, Macrothrix sp, Bosmina sp, Diaphanosoma sp, Polyphemus sp and Eurycercus sp. With respect to distribution and abundance, Cladocera were more prominent during the rainy season than the dry season (Table 19a). Ceriodephnia sp, Macrothrix sp, Daphnia sp and Polyphemus sp disappeared during the tail end of the rainy season and reappeared later in the dry season. Eurycercus sp, Diaphanosoma sp and Simocephalus sp were present only in the rainy season. Bosmina sp were present in October and November.

Analysis of variance (Table 19b) revealed a highly significant variation between stations and seasons ($P<0.01$). Correlation coefficient analysis (Table 1c) exhibited a positive significant correlation between Cladocera and carbon dioxide (CO_2). Negatively significant correlation occurred with Na, Mg and Copepoda.

4.16.1.3 ROTIFERA

This is represented by four genera, Kellicottia sp,(plat Keratella sp, Chromogaster sp and Brachionus sp. (plate 6). Keratella sp is the most abundant genera followed by Chromogaster sp which are found in both

seasons. Brachionus sp and Kellicottia sp disappeared towards the tail end of the rainy season and reappeared later in the dry season. The percentage composition of Rotifers in relation to other zooplankton groups exhibited three maxima in July, November and March with 39.4, 44.4 and 51.1% respectively. The lowest number of Rotifera was recorded in September when they accounted for 16%. There was a highly significant variation in Rotifera population between stations and seasons (Table 20b).

Two way correlation coefficient analysis (Table 1c) between Rotifera and other biological and physico-chemical parameters revealed a positive significant correlation with dissolve oxygen. Negative significant correlation occurred with Zn, CO_2, temperature, Copepoda and Cladocera.

TABLE 19a: SEASONAL VARIATION IN PERCENTAGE COMPOSITION OF CLADOCERA IN MAKWAYE (A.B.U. FARM) LAKE SAMARU, ZARIA

	STATIONS 1	2	3
General stations $\bar{x}$	31.34	25.06	19.14
Rainy season $\bar{x}$	27.90%		
Dry season $\bar{x}$	22.47%		

S.E.D between two means for months	5.620
S.E.D between two means for stations	2.810
S.E.D between two means for seasons	2.294
S.E.D between two means for stations by seasons	3.974

TABLE 19b: ANALYSIS OF VARIANCE FOR CLADOCERA

Source of Variation	Sum of Squares	D.F	Means Squares	F. ratio	Sign
Months	419.017	11	38.092	0.401	NS
Stations	1786.593	2	893.296	9.427	xx
Seasons	530.511	1	530.511	5.598	x
Stations by seasons	935.144	2	467.572	4.934	x
Residual	5211.672	55	94.757		
Total	8882.938	71			

xx = highly significant ($P < 0.01$)
x = significant ($P < 0.05$)
NS = Not significant ($P > 0.05$).

TABLE 20a: SEASONAL VARIATION IN PERCENTAGE COMPOSITION OF ROTIFERA IN MAKWAYE (A.B.U. FARM) LAKE SAMARU, ZARIA

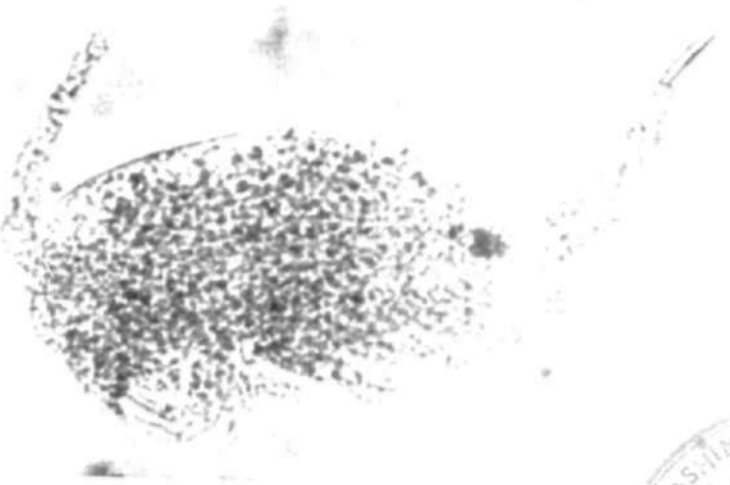
	STATIONS 1	2	3	S.E.D
General stations $\bar{x}$	30.01	40.70	29.53	
Rainy season $\bar{x}$	24.85%			
Dry season $\bar{x}$	41.98%			
S.E.D between two means for months				5.565
S.E.D between two means for stations				2.782
S.E.D between two means for seasons				2.272
S.E.D between two means for station by seasons				3.935

TABLE 20b: ANALYSIS OF VARIANCE FOR ROTIFERA

Source of Variation	Sum of Squares	D.F	Means Squares	F. ratio	Sign
Months	1252.292	11	113.844	1.225	NS
Stations	1915.448	2	957.724	10.309	xx
Seasons	5280.322	1	5281.322	56.84	xx
Stations by seasons	0.83	2	0.415	0.003	NS
Residual	5109.305	55			
Total	13558.198	71			

xx = highly significant ($P < 0.01$)

NS = Not significant ($P > 0.05$).



463460

KASIM IBRAHIM LIBRARY
RECEIVED
20 MAY 1983
ZARIA NIGERIA
Ahmadu Bello University

Plate 1: Diaptomus sp

KASIM IBRAHIM LIBRARY
RECEIVED
ZARIA, NIGERIA
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Plate 2: Cyclops sp

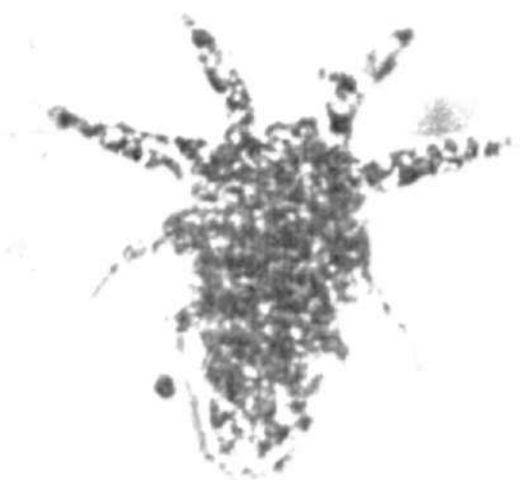


Plate 3: Nauplius

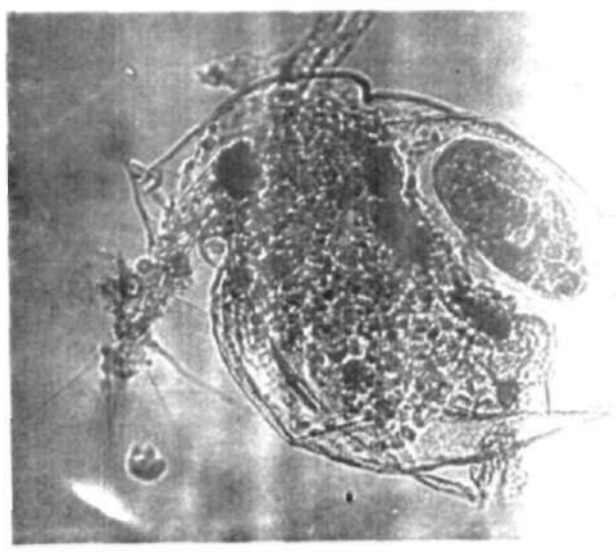


Plate 4: Daphnia sp



Plate 5: Kellicottia sp



Plate 6: Brachionus sp

4.16.2.0 BENTHIC MACROINVERTEBRATES

Figs. 12a and 12b show the various benthos group and relative percentage abundance of the benthic macroinvertebrates recorded at Makwaye (A.B.U. farm) lake Samaru, Zaria.

Four major groups of benthos were found to be present in the lake, Diptera (43.55%); Mollusca (38.96%); Trichoptera (12.03%) and Odonata (5.34%). Based on the relative abundance of the various groups, benthos showed the following decreasing order of magnitude Diptera, Mollusca, Trichoptera, Odonata.

4.16.2.1 DIPTERA

This is the most abundant group comprising of 3 genera, Culicoides sp, (plate 7), Chironomus sp (plate 8) and Chaoborus sp (plate 9). Rainy season density was significantly higher than the dry season (Tables 21a and 21b). Significant variation occurred between stations, ($P < 0.05$), while a highly significant variation existed between stations by seasons ($P < 0.01$). Culicoides sp is the most abundant genera in the group, accounting for between 10.9 to 40.1% and 19.3 to 40.8% of the total benthos during the rainy and dry seasons respectively. Chaoborus sp population accounted for between 7.6 to 26.8% and 4.9 to 18.4% of the total benthic population in the rainy season and later part

of the dry season November through January. Diptera exhibited 3 maxima in September, November and April with lowest individuals in June.

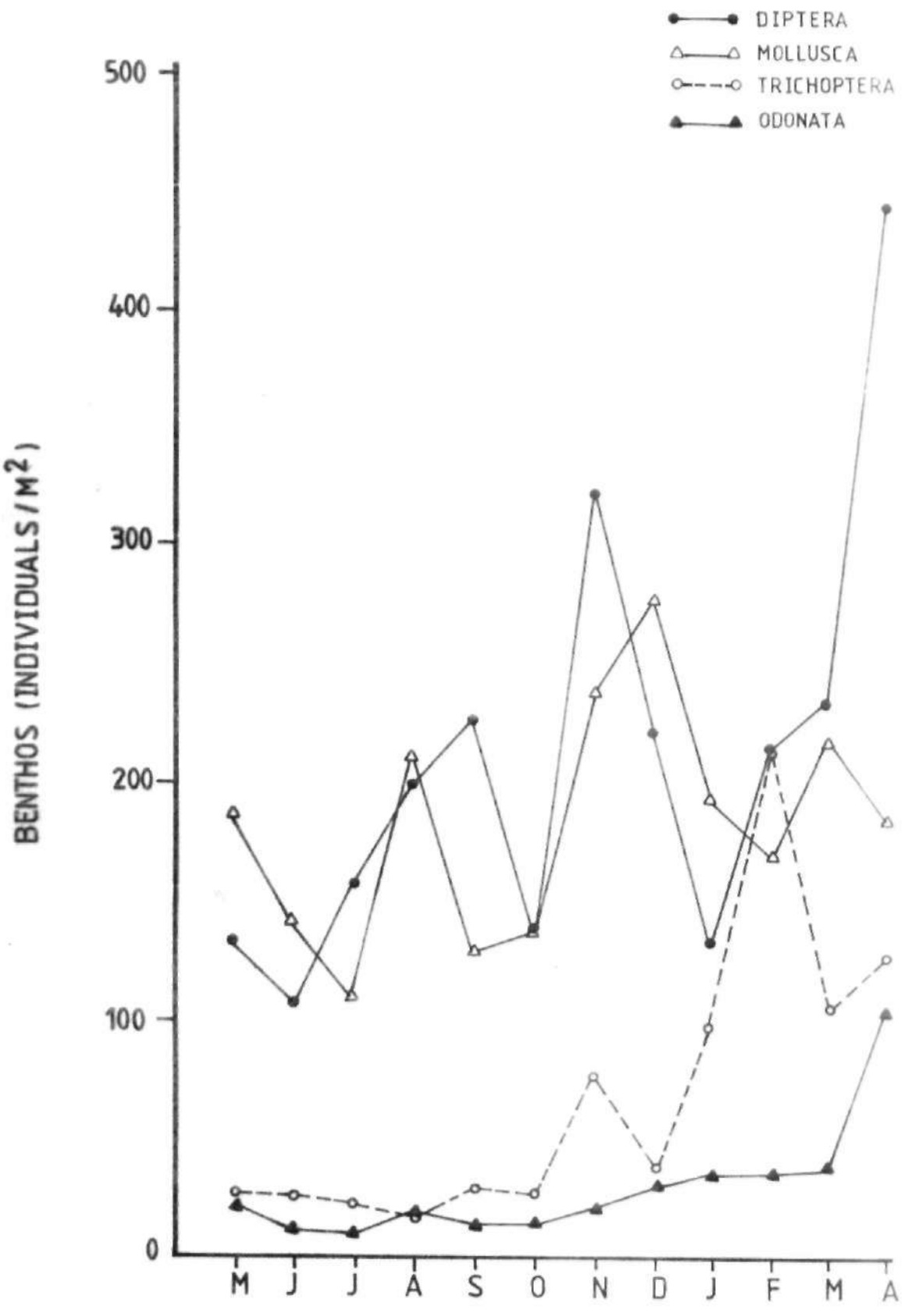


FIG. 12a : MEAN MONTHLY DENSITY OF BENTHOS OF MAKWAYE (A.B.U. FARM) LAKE SAMARU, ZARIA.

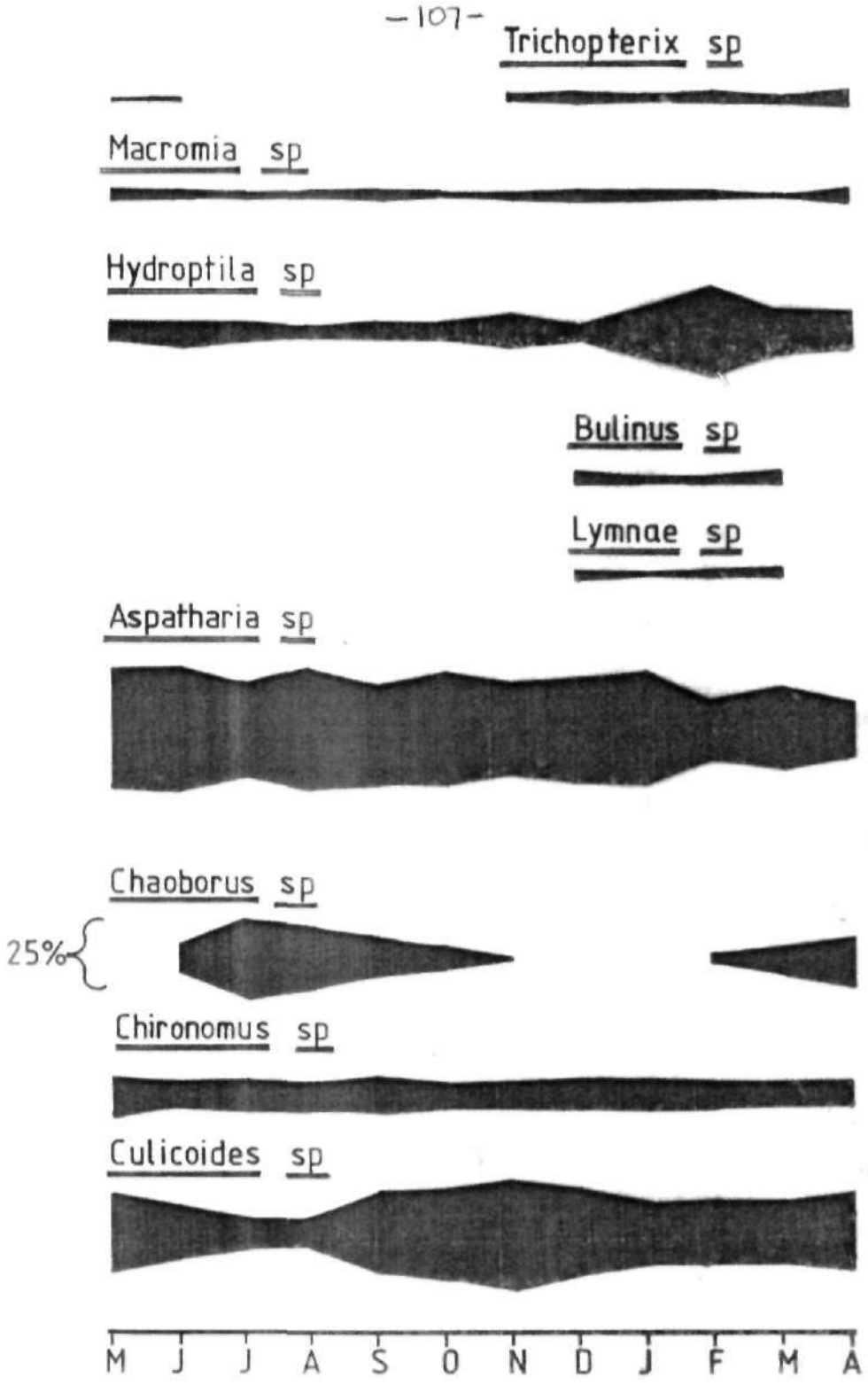


FIG. 12b: RELATIVE ABUNDANCE (PERCENTAGE) OF THE VARIOUS BENTHOS OF MAKWAYE (A.B.U. FARM) LAKE SAMARU, ZARIA.

TABLE 21a: SEASONAL VARIATION IN PERCENTAGE COMPOSITION OF DIPTERA IN MAKWAYE (A.B.U. FARM) LAKE SAMARU, ZARIA

	STATIONS 1	2	3	S.E.D
General stations $\bar{x}$	41.43	40.31	48.9	
Rainy season $\bar{x}$	45.91%			
Dry season $\bar{x}$	41.19%			
S.E.D between two means for months				4.902
S.E.D between two means for stations				2.451
S.E.D between two means for seasons				2.001
S.E.D between two means for stations by seasons				3.466

TABLE 21b: ANALYSIS OF VARIANCE FOR DIPTERA

Source of Variation	Sum of Squares	D.F	Means Squares	F. ratio	Sign
Months	797.164	11	72.469	1.005	NS
Stations	1050.136	2	525.068	7.283	x
Seasons	402.523	1	402.523	5.583	x
Stations by seasons	1679.216	2	839.608	11.646	xx
Residual	3965.046	55	72.091		
Total	7894.086	71			

xx = highly significant ($P < 0.01$)
x = significant ($P < 0.05$)
NS = Not significant ($P > 0.05$).

4.16.2.2 MOLLUSCA

This comprises of 3 genera, Aspatharia sp (plate 12), Lymnae sp and Bulinus sp (plate 11). The rainy season showed significantly higher total individuals than the dry season (Tables 22a and 22b). Aspatharis sp is the most abundant genera in this group throughout the seasons with maximum abundance of between 32.1 and 49.2% of the overall benthos population. Lymnae sp and Bulinus sp, accounting for between 1.7 to 3.5% were found to be present between December through March. They were absent throughout the rainy season.

Two way rank correlation analysis between Mollusca with other benthos and sediment metal concentration (Table 13b) revealed a strong positive significant correlation with Ca and a negatively significant correlation with K and Diptera.

4.16.2.3 TRICHOPTERA

Only Hydroptila sp was found to be present in this group. The total number of individuals recorded during the dry season was significantly higher than that for rainy season (Tables 23a and 23b). It exhibited the highest peak in February accounting for 33.1% of the total benthos. There is a strong positive significant correlation between Hydroptila sp and potassium.

TABLE 22a: SEASONAL VARIATION IN PERCENTAGE COMPOSITION OF MOLLUSCA IN MAKWAYE (A.B.U. FARM) LAKE SAMARU, ZARIA

	STATIONS 1	2	3	S.E.D
General stations $\bar{x}$	45.11	39.03	32.73	
Rainy season $\bar{x}$	42.51%			
Dry season $\bar{x}$	35.41%			
S.E.D between two means for moths				6.415
S.E.D between two means for stations				3.208
S.E.D between two means for seasons				2.619
S.E.D between two means for stations by seasons				4.536

TABLE 22b: ANALYSIS OF VARIANCE FOR MOLLUSCA

Source of Variation	Sum of Squares	D.F	Means Squares	F. ratio	Sign
Months	794.657	11	72.241	0.585	NS
Stations	1839.98	2	919.99	7.451	x
Seasons	907.167	1	907.167	7.347	x
Stations by seasons	31.248	2	15.624	0.126	NS
Residual	6790.666	55	123.466		
Total	10363.719	71			

x = significant ($P < 0.05$)
NS = Not significant ($P > 0.05$).

TABLE 23a: SEASONAL VARIATION IN PERCENTAGE COMPOSITION OF TRICHOPTERA IN MAKWAYE (A.B.U. FARM) LAKE SAMARU, ZARIA

	STATIONS 1	2	3	S.E.D
General stations $\bar{x}$	8.79	15.71	11.59	
Rainy season $\bar{x}$	7.14%			
Dry season $\bar{x}$	16.92%			
S.E.D between two means for months				3.748
S.E.D between two means for stations				1.874
S.E.D between two means for seasons				1.530
S.E.D between two means for stations by seasons				2.650

TABLE 23b: ANALYSIS OF VARIANCE FOR TRICHOPTERA

Source of Variation	Sum of Squares	D.F	Means Squares	F. ratio	Sign
Months	223.509	11	20.319	0.482	NS
Stations	580.838	2	290.419	6.892	x
Seasons	1721.28	1	1721.28	40.853	xx
Stations by seasons	1109.974	2	554.987	13.172	xx
Residual	2317	55	42.132		
Total	5952.911	71			

xx = highly significant ($P < 0.01$)

x = significant ($P < 0.05$)

NS = Not significant ($P > 0.05$).

4.16.2.4 ODONATA

This is represented by Macromia sp and Trichopterix sp. Dry season had significantly higher individuals than the rainy season (Tables 24a and 24b). Trichopterix sp was present throughout the dry season and in the early rainy season, May to June. Macromia sp maintained a steady population throughout the seasons.

TABLE 24a: SEASONAL VARIATION IN PERCENTAGE COMPOSITION ODONATA IN MAKWAYE (A.B.U. FARM) LAKE SAMARU, ZARIA

	STATION 1	2	3	S.E.D
General stations $\bar{x}$	4.66	4.68	6.67	
Rainy season $\bar{x}$	4.24%			
Dry season $\bar{x}$	6.43%			

S.E.D between two means for months	1.570
S.E.D between two means for stations	0.785
S.E.D between two means for seasons	0.641
S.E.D between two means for stations by seasons	1.110

S.E.D = Standard Error Difference.

TABLE 24b: ANALYSIS OF VARIANCE FOR ODONATA

Source of Variation	Sum of Squares	D.F	Means Squares	F. ratio	Sign
Months	93.416	11	8.492	1.149	NS
Stations	63.789	2	31.894	4.315	x
Seasons	86.439	1	86.439	11.696	xx
Stations by seasons	86.357	2	43.178	5.842	x
Residual	406.471	55	7.39		
Total	736.473	71			

xx = highly significant ($P<0.01$).

x = significant ($P<0.05$)

NS = Not significant ($P>0.05$).

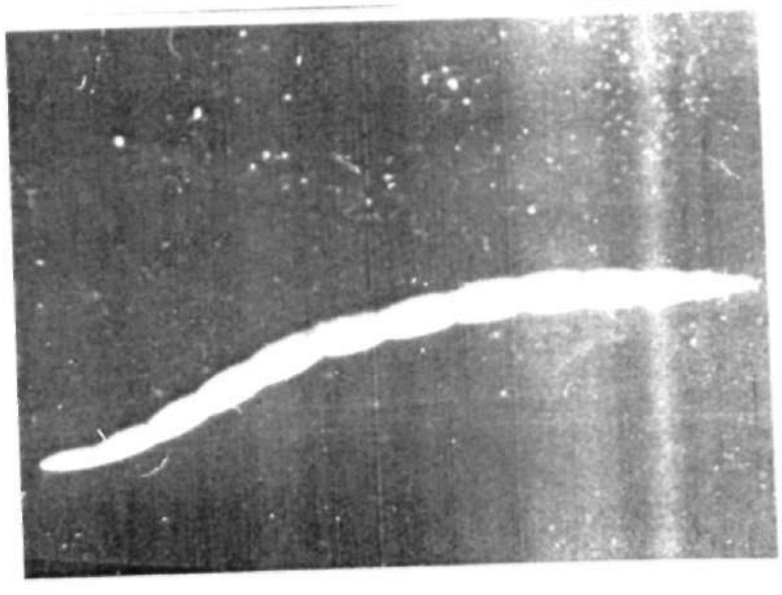


Plate 7: Culicoides sp

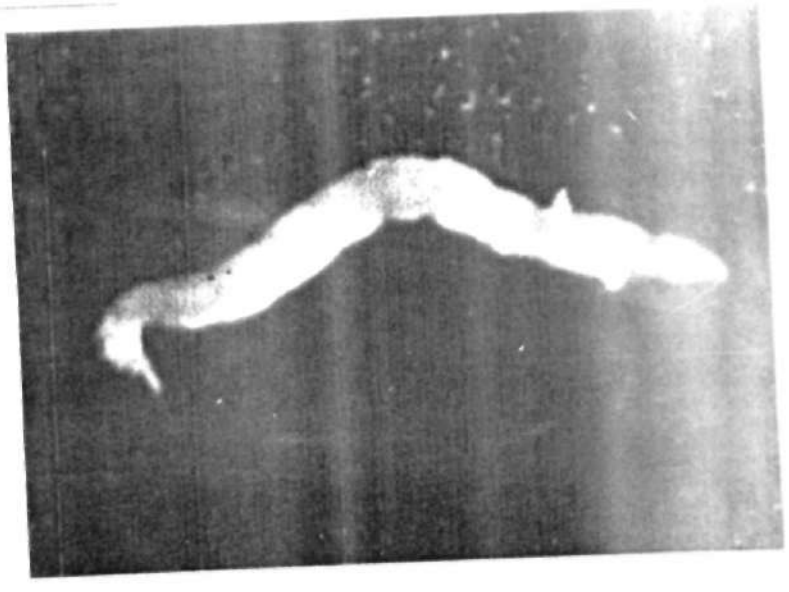


Plate 8: Chironomus sp

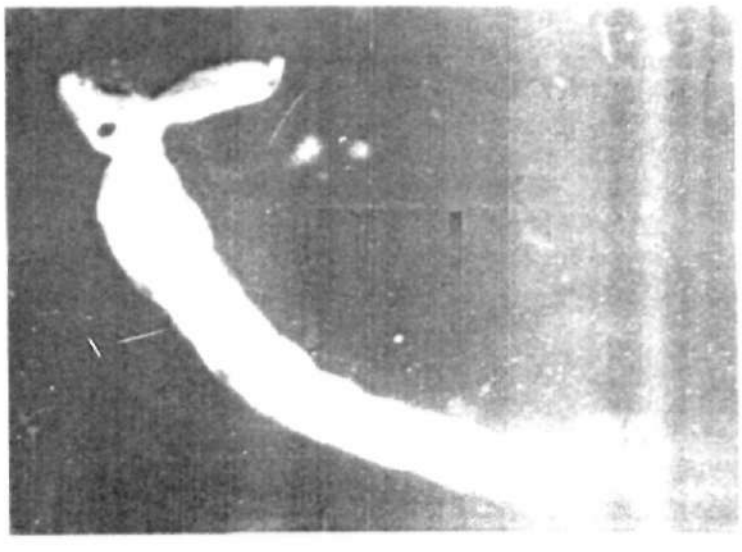


Plate 9: Chaoborus sp

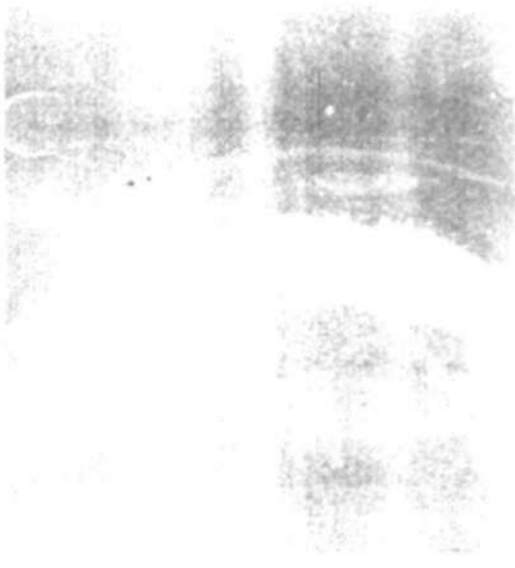


Plate 10: Hydroptila sp



Plate 11: Bulinus sp



Plate 12: Aspatharia sp

CHAPTER FIVE

5.0 DISCUSSION

This study was carried out to determine the spatial and temporal changes in the physico-chemical features, zooplankton and benthic macroinvertebrates of Makwaye (Ahmadu Bello University farm) lake Samaru, Zaria. The relative abundance and diversity of the biota may be considered as indicators of fisheries potentials of the lake. Variations of these parameters due to mixed farming, deforestation and application of fertilizers, herbicides and insecticides along with other climatic factors such as wind and rainfall and their effects on the lake were also considered.

5.1 PHYSICO-CHEMICAL

Low water temperatures were registered between December and February in response to the seasonal changes in air temperature resulting from the North-East trade winds (Harmattan). This observation was similar to the findings of Anyam (1980), Oladimeji and Wade (1984), Wade (1985), Kemdirim (1987) and Awanda (1987) in their studies of some water bodies in Nigeria. Water temperature varied seasonally Saad and Abbas, 1985). Temperature of lakes correlates with maximum air temperature and the sampling day (Rippey and Rippey, 1986).

Transparency was greater in the dry season than the rainy season. The high turbidity observed during the early part of the rainy season could be due to the increased soil erosion and siltation from the catchment area. Forsberg and Ryding (1980) considered lakes with secchi depth of less than 2.0 to 2.7m as eutrophic. Gopal et al. (1981) reported that agricultural practices in the catchment area of Jaipur Reservoir India caused an increase in siltation with addition of large quantities of nutrients, chemicals, persticides and organic matter through surface runoff. This increase in transparency at the tail end of the rainy season could be attributed to dilution and fast sedimentation. The gradual fall in transparency as the dry season progresses could be due to the effect of wind mixing because of the shallowness of the lake resulting from excessive evaporation and seapage. Comin et al. (1983) attributed repeated turbidity to the resuspension of sediments under the action of wind or algal bloom. Rippey and Rippey (1986) also reported that wind action affects water clarity in shallow lakes.

The initial fall in pH during the early part of the rainy season may be due to decomposition of organic matter which coincided with lower oxygen and highest Biochemical Oxygen Demand (B.O.D). Russo (1978) in

his study of primary production and seasonal succession of plankton in a permanent pond in England observed that runoff from agricultural lands and photozynthesis of macrophytes might have accounted for increase in pH. Saad and Abbas, (1985); Rippey and Rippey, (1986) made similar observation that increase in pH correlates with photosynthesis and carbon dioxide consumption. Friday (1987) observed that the absence or reduced number of Taxa of Trichoptera and Diptera from ponds could be consequential on pH.

Electrical conductivity was lower in the rainy than the dry season; this may be due to dilution of the water. The gradual rise in conductivity as the dry season progressed could be due to the concentration of ions as the volume decreases. In their limnological study of Gallocanta lake, Aragon, Northern Spain, Comin et al. (1983) observed that high balance of evaporation leads to reduction in water volume with an increase in salt concentration. There was a significant correlation between conductivity with PO_4-P, BOD and Chlorophyll-a content of the algae contained in the lake water. Ashton and Schoeman (1983) did not find any significant correlation with PO_4-P; Green (1986) found a linear relationship between conductivity and zooplankton in Crater lakes of Northern Pretoria, South Africa.

The relatively water during the rainy season could be attributed to the components of artificial fertilizer of alkaline earth metals in origin in the form of (CAN, NPK, NH_3 $(NO_3)_2$ etc) from the catchment area. As observed, the gradual rise in water hardness inspite of the dilution from July to October coincided with the period of fertilizer application. The dry season hardness could be attributed to increase in the concentration of salts due to draw down in water level and action of wind which enhances the resuspension of sediment Ca^{++} and Mg^{++} ions.

Oxygen saturation was generally above 50% throughout the seasons. Dissolved oxygen concentration was generally higher during the dry season than the rainy season. The lowest concentration in June coincided with the peak of Biochemical Oxygen Demand due to uptake by bacteria and other microorganisms in the decomposition of organic allochthonous and autochthonous materials. Highest oxygen concentration in January coincided with the minimum water temperature due to the cool harmattan winds. This was followed by a subsequent decline as the dry season progressed inspite of precedented increase in algal biomass (Chlorophyll-a) resulting from photosynthesis. Maitland (1978) reported that the amount of oxygen

in a water body depends upon the extent of contact with the atmosphere, the amount produced (photosynthesis by phytoplankton and aquatic macrophytes) and consumed in the system. In very shallow lakes, oxygen fluctuations could be due to close relationship between the free water and the bottom where organic matter accumulates. Variations in oxygen could be vertical, horizontal or temporal due to diurnal alternation of the predominance of photosynthesis and respiration (Kramer, 1987).

Biochemical Oxygen Demand (BOD) was higher in the dry season than the rainy season. The two peaks with the period of lower dissolved oxygen concentration. This was attributed to oxygen consumption by decomposers (bacteria and fungi) on the biogenous materials as revealed by the negative correlation with oxygen. This agreed with the findings of Awanda, (1987) in his study on the effect of industrial effluents on the biota of River Kaduna. However, Kemdirim (1987) observed no significant seasonal variation in the BOD of an upland impoundments in Plateau state of Nigeria.

The highest concentration of Co_2 observed during the rainy season could be attributed to the oxidation of organic matter accumulation from both allochthonous and autochthonous materials. This agreed with the

findings of Wade (1985) in his study of the limnology and primary production of two mine lakes in Plateau state. However, accumulation of autochthonous matter may be the chief contributor of biogenous materials in shallow lakes because during the draw down period, defaecation by animals and growth of aquatic macrophytes on the exposed littoral zones increases. With the onset of the rains the water level increases and covers the exposed portions which in turn become liable to decomposition leading to the increase in the rate of carbon dioxide evolution through the activities of microorganisms. Umorin (1987) reported that, in nature, the rate of oxidation of hydrogen was determined by the evolution of carbon dioxide.

The higher concentration of nitrate nitrogen observed in the rainy season could be attributed to surface runoff through the catchment area exposed to fertilizer application as reported by Anyam (1980), Wade (1985), Awanda (1987) and Kemidirim (1987). It could also be due to the release of nitrate from the sediments during the decomposition of organic matter. Talling and Rzoska, (1967) in their study of the relationship between plankton and hydrological regime of the blue Nile reported that flood water contained large amounts of nitrate-nitrogen and phosphate-phosphorus.

Stewart et al. (1982) reported that sediment water interface is the engine room of the aquatic nitrogen cycle through nitrification. Comin et al. (1983) observed that the peak of nitrate seems to be related to inputs from agricultural lands. The fall in nitrate concentration as the rainy season progresses may be attributed to dilution. Concentration of nitrate could be reduced by phytoplankton and macrophyte uptake or dinitrification in the sediment (Rippey and Rippey, 1986).

The highest concentration of phosphate-phosphorus in June coincided with nitrate-nitrogen and chlorophyll-a maxima. This may also be attributed to agricultural runoff from the catchment area as was the case in NO_3-N. Phosphate-phosphorus decreased with increase in algal bloom. However, additional supply of phosphorus from littoral sediments is especially important in sustaining growth during the period of high algal biomass, which is characterised by high values of pH due to CO_2 removal by photosynthesis thereby accelerating phosphorus release from the sediment (Drake and Heaney, 1987).

Chlorophyll-a as a measure of primary production varied seasonally with a highest concentration in the

rainy season. The peak of chlorophyll-a biomass coincided with the period of maximum concentration of the nutrients. It also coincided with the period of maximum algal cells in June and March as observed by Anyam, (1980). Comin et al. (1983) also observed that the peak of chlorophyll-a was associated with high phosphorus and nitrogen concentration. Also chlorophyll-a content was observed to vary strongly with species composition, cell size and physiological state of algal populations (Bakker and Vries, 1984).

5.2 METALS

Metal concentrations in the lake may be attributed to the nature of the catchment area, aground water loading and the components of the various types of fertilizer, insecticides and herbicides. Alkaline earth metals (Na, Ca, Mg, K, etc) which form the bulk of fertilizers all found their way into the lake through surface runoff. This could be shown by their higher concentrations in relation to other metals. Metal concentrations also depend on certain physico-chemical factors acting on the water or sediment, especially pH. A decrease in pH favours the retention time of some metals in the free water (Borg, 1983). The sediment had higher metal concentration than the surface water, possibly due to accumulation caused by sedimentation.

Rippey (1982) showed that incorporation of Cu, Zn, and Pb into the sediment could be by chemisorption of the elements. The control of the solubility of Ca, Mg, Fe and Zn could involve mineral equilibria controlled by pH and the solubility of lead sulphate and carbonate may account for the low levels of lead as observed by Say and Whitton, (1981). Watershed characteristics such as soil type and subsurface flow may also influence trace elements behaviour (Sprenger et al., 1987).

5.3 BIOLOGICAL CHARACTERISTICS:

An ecosystem consists of communities of organisms which interact among themselves and with the abiotic component of the environment. Climate is a principal factor governing the seasons through distinct wet (rainy) and dry seaons which directly or indirectly alter their environment with individual organisms responding either positively or negatively to these environmental conditions.

5.3.1 ZOOPLANKTON

The zooplankton consisting of copepoda, cladocera and rotifera accounted for a wide range in diversity of species and number. The distribution and composition of these groups varied with the seasons with the highest density during the early part of the rain

followed by a gradual decline as the rainy season progressed. Adeniji (1973) recorded a similar variation in zooplankton composition with the seasons. He observed low zooplankton number before the rainy season. The population rose steeply during the first month of the rain followed by a subsequent drop in number as the rainy season progressed. Similarly, in lake Broa Japan, Matsamura-Tundisi and Tundisi (1976) observed the peak of abundance in zooplankton population at the beginning of the rainy season.

Eubranchipus sp, Simocephalus sp and Eurycercus sp were found only during the rainy seasons, while Diaptomus sp and Cyclops sp were found throughout the seasons. Macrothrix sp, Ceriodaphnia sp, Diaphanosoma sp, Polyphemus sp, Kellicortia sp and Brachionus sp were found during the rainy season, later they disappeared and reappeared again in the dry season. Bosmina sp was found only in the dry season. These variations in zooplankton number and composition could be attributed to differential response to variation in environmental requirements. Differential patchness may be related to biological and physiological factors (Evans and Sell, 1983). Comin et al., (1983) in their study on the limnology of Gallocanta lake, Aragon, Northern Spain, reported that seasonal abundance of

zooplankton relates to changes in mineral salt concentrations, phytoplankton composition and density. Based on percentage composition of zooplankton, cladocera was the least even though it has the highest number of genera. This could be attributed to lack of suitable food for the cladocera as zooplankton have preferential response to their food supply. Cladocera feeds on algae preferably chlorophyta, Protozoa and organic detritus (Pennak, 1978). Wodajo and Bailey (1984) attributed the richness of rotifers population in Abiata lake Ethiopia to abundant supply of Cyanophytes. Billets and Osborne, (1985) suggested that zooplankton abundance and diversity are influenced to a greater extent by life history patterns rather than by environmental conditions. The distribution and diversity of zooplankton in (A.B.U. farm) lake may be attributed to periodic changes in the ecosystem brought about by seasonal variation in the environmental conditions. These may directly or indirectly alter the reproduction time and rate depending upon availability of food, competition, predation and mortality as evident by the seasonal fluctuations in zooplankton density and composition.

5.3.2 BENTHIC MACROINVERTEBRATES

The benthic macroinvertebrates were dominated by Mullusca, Diptera, Trichoptera and Odonata comprising

of 8 genera. Bulinus sp and Lymnae sp were found only during the tail end of the dry season, while Chaoborus sp and Trichopterix sp alternate between the seasons. The observed seasonal variations in community structure and total density could be related to seasonal differences in habitat characteristics with respect to physico-chemical and biotic influences. These variations could directly or indirectly affect the sediment stability through sediment mixing, exposure due to water level fluctuations and changes in the sediment chemistry. The biotic community may then be exposed to physiological stress, competition and predation thereby affecting the reproduction cycle. Those that are tolerant could overcome these problems and adjust to these changes during certain period of the seasons and carry out their life processes.

Aspatharia sp, Culicoides sp, Chironomus sp, Hydroptila sp and Macromia sp were found throughout the seasons in varying numbers. Reice (1980) observed that invertebrate biomass, density and species richness increase with habitat diversity and substrate size. Another factor which influences the distribution of benthic invertebrates is the nature of the substratum (Townsend, 1980). Inspite of the shallowness, higher oxygen saturation and organic matter content, the low species diversity could be due to the acidic nature

of the sediment as exhibited by lower pH values throughout the seasons. Species richness increases with age and lake size, while acidity and low levels of calcium depress diversity (Timms, 1986). Doeg et al. (1987) reported that increased sedimentation reduced the total number of macroinvertebrate species. Meyerhoff and Lind (1987) attributed seasonal changes in benthic community structure to the type of food available and the life histories evolved to use this food. However, the present investigation indicates that benthic community structure and diversity depends upon seasonal changes in both abiotic and biotic components of the sediment.

CHAPTER SIX

6.1 S U M M A R Y

The physico-chemical parameters, composition and distribution of zooplankton and benthic macroinvertebrates of Makwaye (Ahmadu Bello University farm) lake Samaru, Zaria were studied twice monthly for a period of twelve months from May 1987 to April, 1988.

Surface water samples were collected in plastic bottles of one litre capacity from 3 stations of the lake and analysed according to the methods described by Mackereth (1963), Needham and Needham (1975), Lind (1979) and A.P.H.A. (1980). Temperature was measured in the field with a mercury thermometer; transparency with secchi disc of 25 cm diameter; pH with pH meter; Oxygen by modified Winkler azide method; CO_2 by titration with N/44 NaoH with phenolphthalein as indicator; BOD by incubating water samples for 5 days prior to oxygen determination. Hardness by titration with EDTA; PO_4-P and NO_3-N were determined spectrometrically by Deniges and phenoldisulphonic acid methods respectively. Chlorophyll-a were determined spectrometrically after extraction in 90% acetone; Metal extraction by acid digestion method and analysis with Atomic absorption spectrophotometer. Zooplankton

were collected with plankton net of 25 cm width and 70 mesh/cm; and benthos with Ekman grab of 0.0266 M^2 capacity. Two way analysis of Variance and rank correlation coefficient were used to determine the level of significance and the relationship between parameters respectively.

Transparency, pH, conductivity, hardness, Dissolved Oxygen, Nitrate-nitrogen and phosphate-phosphorus showed significant seasonal variation ($P < 0.05$). The sediment had higher concentrations of all the metals than the surface water. Metal concentrations in the sediment throughout the study period show the following decreasing order of magnitude Na, Mg, K, Fe, Ca, Zn, Co, Cu, and Pb, while that of the surface water was Na, Fe, K, Mg, Ca, Cu, Zn, Pb and Co in the same magnitude. Na, Mg, Co and Zn in the surface water exhibited a significant seasonal variation ($P < 0.05$). Similarly in the sediment Mg, Pb, Co and Na exhibited the same significant seasonal variation ($P < 0.05$).

Three groups of zooplankton comprising of Copepoda, Cladocera and Rotifera accounting for 41.3%, 23.3% and 33.4% of the total population respectively were found to be present in the lake. All the zooplankton

exhibited a significant seasonal variation ($P<0.05$) with high or total number of individuals during the early part of the rainy season.

Copepods are represented by 3 genera, Diaptomus sp and Cyclops sp were present throughout the seasons, while Eubranchipus sp were present only from May through August. Cladocera were more prominent during the rainy season than in dry season. Ceriodaphnia sp Macrothrix sp, Daphnia sp and Polyphemus sp disappeared during the tail end of the rainy season and reappeared later in the dry season. Eurycercus sp, Diaphanosoma sp and Simocephalus sp were present only in the rainy season. Bosmina sp were found only in October and November. Keratella sp is the most abundant; Rotifer; followed by Chromogaster sp;they were found in both seasons. Brachionus sp and Kellicottia sp disappeared towards the end of the rainy season and reappeared later in the dry season.

Copepoda exhibited a positive significant correlation with Zn, Co and temperature ($P<0.05$), while negative significant correlation exists with pH and dissolved oxygen ($P\leq 0.05$). Similarly Cladocera exhibited a positive significant correlation with CO_2 and a negatively significant correlation with Na, Mg and Copepoda. A positively significant correlation exists between Rotifera with Dissolved Oxygen and a negative

significant correlation occurred with Zn, CO_2 temperature, Copepoda and Cladocera.

The benthic macroinvertebrates are represented by Diptera (43.55%); Mollusca (38.96%); Trichoptera (12.03%) and Odonata (5.34%). Rainy season density of Diptera was significantly higher than that of the dry season ($P < 0.05$). Culidoides sp is the most abundant genera in the group, followed by Chironomus sp while Chaoborus sp population exhibited a break during early part of the dry season. In Mollusoa, Aspatharia sp is the most abundant accounting for between 32.1 to 49.2% of the total benthic population. Lymnae sp and Bullinus sp were found only during the later part of the dry season. Mollusca exhibited a significant positive correlation with Ca and a negative significant correlation with K and diptera. Hydroptila sp was the dominant Trichoptera. Odonata was represented by Macromia sp and Trichopterix sp.

6.2 CONCLUSION

The distribution and composition of zooplankton and benthos of Makwaye (Ahmadu Bello University farm) lake Samaru, Zaria are affected by seasonal variation through fluctuations in environmental variables such as transparency, pH, water hardness, oxygen and nutrient concentrations. The low transparency and high nutrient

status of the lake which is attributed to agricultural practices in the catchment area, may classify the lake as eutrophic.

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APPENDIX 1

PHYSICO-CHEMICAL PARAMETERS OF NAKWAYE (ABU FARM) LAKE SAMARU, ZARIA

DATE	STATION	TEMP ^{o}C	DEPTH cm	SECCHI (TRANSP) cm	PH	COND $Umcm^{-1}$	Do mgl^{-1}	BOD mgl^{-1}	Co_2 mgl^{-1}	HARDNESS Mgl^{-1}	NO_3-N Mgl^{-1}	Po_4-P Ugl^{-1}	CHL-a Ugl^{-1}
14:5:87	1	26	57	15	7.8	102	5.7	2.2	5.0	24	1.5	210	27.2
	2	27	135	16	7.6	104	5.7	2.8	3.5	24	1.3	180	26.5
	3	27	48	18	7.9	102	5.2	0.8	3.0	24	1.4	190	29.5
25:5:87	1	28	59	15	8.0	108	5.9	1.8	3.0	24	3.5	260	29.0
	2	28	136	13	7.6	108	5.9	1.6	4.0	22	4.6	230	28.0
	3.	28	50	15	8.1	106	5.7	2.9	3.0	22	3.4	260	31.0
10:6:87	1	27	152	14	7.5	82	4.3	3.6	4.5	12	3.4	260	48.5
	2	27	290	13	7.4	87	3.7	3.7	4.0	16	3.8	320	54.5
	3	28	130	14	7.2	86	4.2	3.8	4.0	16	3.4	300	50.3
24:6:87	1	29	159	14	7.3	76	6.1	4.3	3.0	20	3.5	250	46.5
	2	29	290	14	7.5	78	6.2	3.6	3.5	24	3.8	290	52.5
	3	29	148	15	7.3	72	5.8	4.1	3.5	28	2.9	290	49.2
13:7:87	1	26	180	14	8.2	56	6.4	2.1	3.0	32	3.4	240	39.4
	2	26	332	16	8.4	55	6.5	2.0	2.5	34	2.8	232	37.2
	3	26	198	15	8.6	56	6.8	2.2	4.0	32	2.8	248	41.5

APPENDIX 1 CONT'D.

DATE	STATION	TEMP ^{o}C	DEPTH cm	SECCHI (TRANSP) cm	pH	COND $Umcm^{-1}$	Do mgl^{-1}	BOD mgl^{-1}	Co_2 mgl^{-1}	HARDNESS mgl^{-1}	No_3-N mgl^{-1}	Po_4-P Ugl^{-1}	CHL-a Ugl^{-1}
27:7:87	1	24	230	16	8.4	40	6.6	2.3	3.0	28	3.0	238	25.8
	2	24	352	16	8.6	39	6.9	2.0	2.5	30	2.4	216	23.8
	3	24	218	15	8.6	39	6.8	2.4	3.0	28	2.4	232	27.5
14:8:87	1	20	242	16	7.7	36	6.1	2.2	5.0	32	2.4	240	18.6
	2	21	363	15	7.8	34	6.2	2.0	4.0	24	2.4	225	19.4
	3	21	210	15	7.9	33	6.3	2.3	4.0	24	2.6	240	17.0
27:8:87	1	21	252	22	7.4	42	5.8	1.7	3.5	28	2.1	148	18.3
	2	21	386	23	7.3	46	5.9	1.9	4.0	26	2.4	132	18.6
	3	21	225	22	7.5	42	5.6	2.0	4.0	26	2.4	136	16.4
10:9:87	1	26	258	40	7.0	41	6.4	0.9	4.0	30	1.9	110	10.8
	2	26	394	41	6.9	41	6.6	0.8	4.0	28	1.9	100	12.2
	3	26	242	41	6.9	40	6.3	1.1	4.0	32	2.5	90	9.6

APPENDIX 1 CONT'D

DATE	STATION	TEMP ^{0}C	DEPTH cm	SECCHI (TRANSP) cm	pH	COND $Umcm^{-1}$	Do mgl^{-1}	BOD mgl^{-1}	Co_2 mgl-1	HARDNESS mgl-1	No_3-N mgl-1	Po_4-P Ugl-1	CHL-a Ugl-1
29:9:87	1	28	232	60	7.2	44	5.6	1.1	3.0	44	2.4	60	8.6
	2	28	321	63	7.3	49	5.8	0.9	3.0	36	2.4	60	10.4
	3	28	202	60	7.3	43	5.5	1.3	3.0	38	2.1	67	8.4
15:10:87	1	28	232	85	7.4	44	5.7	2.9	3.0	44	2.4	48	8.4
	2	28	324	86	7.3	44	5.4	1.3	3.5	44	1.8	40	8.7
	3	28	202	86	7.4	44	5.6	1.2	3.0	48	1.8	30	7.2
29:10:87	1	24	220	61	7.4	46	6.4	2.1	5.0	40	1.6	47	8.1
	2	24	321	60	7.3	47	6.5	1.9	3.5	36	1.8	40	8.4
	3	24	194	61	7.4	47	6.6	1.1	3.0	40	1.9	46	6.0
12:11+87	1	22	180	69	7.3	48	6.7	2.0	3.0	34	1.9	25	9.1
	2	22	306	71	7.3	50	6.3	1.8	2.5	32	1.8	22	7.6
	3	22	190	71	7.4	49	6.6	2.0	3.0	36	2.2	24	8.2

APPENDIX 1 CONT'D.

DATE	STATION	TEMP °C	DEPTH cm	SECCHI (TRANSP) cm	pH	COND $Umcm^{-1}$	Do mgl^{-1}	BOD mgl^{-1}	Co_2 mgl^{-1}	HARDNESS mgl^{-1}	No_3-N mgl^{-1}	Po_4-P Ugl^{-1}	CHL-a Ugl^{-1}
24:11:87	1	22	177	62	7.4	47	6.2	1.7	2.5	28	1.9	32	7.5
	2	22	303	65	7.4	49	6.4	1.8	2.5	28	1.8	34	7.9
	3	22	188	65	7.4	49	6.5	1.7	2.5	26	2.1	36	8.6
9:12:87	1	20	172	59	7.4	47	7.3	2.0	2.0	30	1.9	35	6.6
	2	20	294	58	7.5	47	7.2	1.6	2.0	34	1.9	36	6.2
	3	20	183	58	7.5	48	7.2	1.4	3.5	36	1.9	40	6.8
23:12:87	1	20	171	53	7.4	49	7.5	2.8	2.0	34	1.7	39	7.0
	2	20	298	54	7.7	47	7.6	2.0	3.0	38	1.9	36	6.6
	3	20	181	54	7.5	48	7.6	1.6	2.5	38	1.9	44	7.4
13:1:88	1	16	171	43	7.4	52	8.1	1.4	2.5	36	2.1	60	12.1
	2	16	282	44	7.6	53	8.2	1.6	2.5	38	1.9	60	11.4
	3	16	180	43	7.8	52	8.1	1.5	2.5	38	2.1	61	9.9

APPENDIX 1 CONT'D.

DATE	STATION	TEMP ^{o}C	DEPTH cm	SECCHI (TRANSP) cm	pH	COND $Umcm^{-1}$	Do mgl^{-1}	BOD mgl^{-1}	Co_2 mgl^{-1}	HARDNESS mgl^{-1}	No_3-N mgl^{-1}	Po_4-P Ugl^{-1}	CHL-a Ugl^{-1}
27:1:88	1	17	169	39	7.5	52	7.8	1.6	2.5	32	2.1	66	12.6
	2	17	154	40	7.5	52	7.9	1.6	2.5	34	2.3	65	11.7
	3	17	178	39	7.5	52	7.8	1.4	2.5	32	2.1	71	11.8
10:2:88	1	18	168	32	7.4	56	6.3	1.8	3.0	28	2.9	80	23.7
	2	18	210	33	7.4	55	6.1	1.6	2.5	32	1.8	75	21.3
	3	18	173	32	7.4	56	6.2	1.9	2.5	36	1.6	75	19.6
22:2:88	1	21	162	30	7.5	58	6.5	1.9	3.5	28	2.8	120	24.2
	2	22	206	31	7.6	58	6.4	1.8	3.0	28	2.5	115	20.6
	3	22	170	30	7.5	58	6.5	1.9	3.5	28	2.7	110	22.1
10:3:88	1	23	162	30	7.4	63	6.3	3.6	2.0	32	2.8	150	40.2
	2	23	186	32	7.6	64	6.3	2.0	2.5	32	2.6	142	37.0
	3	23	154	30	7.6	63	6.4	3.4	2.5	32	2.6	146	39.4

APPENDIX I CONT'D.

DATE	STATION	TEMP ^{o}C	DEPTH cm	SECCHI (TRANSP) cm	pH	COND $Umcm^{-1}$	Do mgl^{-1}	BOD mgl^{-1}	Co_2 $mgl^{-1}q$	HARDNESS mgl^{-1}	No_3-N mgl^{-1}	Po_4-P Ugl^{-1}	CHL-a Ugl^{-1}
24:3:88	1	28	158	28	7.3	64	5.8	2.8	2.0	32	2.2	132	38.5
	2	25	172	29	7.3	64	5.8	2.6	3.0	30	2.2	120	36.1
	3	25	142	28	7.3	64	5.7	2.7	3.0	32	2.0	132	37.4
8:4:88	1	26	154	22	7.4	66	5.8	3.0	2.5	32	1.8	120	32.4
	2	26	160	23	7.5	66	5.1	2.0	2.4	34	1.8	94	27.7
	3	26	135	20	7.3	66	5.2	2.5	2.5	32	2.0	104	20.3
22:4:88	1	26	146	18	7.4	68	5.4	3.0	3.5	36	1.4	116	28.6
	2	27	152	19	7.5	68	5.3	3.0	2.6	38	1.4	98	27.1
	3	28	127	18	7.5	68	5.4	2.5	2.5	36	1.4	96	18.3

APPENDIX 2

METAL CONCENTRATIONS OF SURFACE WATER OF MAKWAYE (A.B.U. FARM) LAKE SAMARU ZARIA

MONTH	STATION	Ca	Mg	K	Na	Co	Cu	Fe	Pb	Zn
MAY	1	0.60	2.04	4.56	56.4	0.00	0.60	4.62	0.30	0.54
	2	0.09	1.08	4.44	58.8	0.00	0.36	4.68	0.20	0.56
	3	0.36	0.90	4.32	55.8	0.00	0.25	4.69	0.50	1.64
JUNE	1	0.48	1.26	4.08	38.4	0.00	0.31	4.20	0.04	0.44
	2	0.24	0.96	4.20	39.6	0.132	1.36	4.34	0.35	0.26
	3	0.18	0.84	4.32	42.6	0.00	0.24	4.212	0.62	1.15
JULY	1	0.24	1.12	3.84	42.0	0.132	0.24	3.80	0.24	0.76
	2	0.11	0.14	3.84	37.2	0.132	0.24	4.21	0.15	1.76
	3	0.01	0.78	4.32	39.6	0.192	0.19	4.32	0.30	1.69
AUGUST	1	0.30	0.58	2.04	33.6	0.132	0.31	3.82	0.10	0.76
	2	0.11	0.30	2.16	30.0	0.192	0.19	3.96	0.00	1.02
	3	0.12	.78	2.16	43.8	0.132	0.19	3.98	0.15	0.59

APPENDIX 2 CONT'D.

MONTH	STATION	Ca	Mg	K	Na	Co	Cu	Fe	Pb	Zn
SEPT	1	0.24	2.22	1.56	37.2	0.192	0.19	1.92	0.00	0.24
	2	4.32	2.46	1.80	41.4	0.192	0.22	2.05	0.00	0.22
	3	3.84	2.58	1.80	45.0	0.192	0.26	2.52	0.00	1.75
OCT	1	5.52	2.40	2.04	42.6	1.69	0.29	2.04	0.00	1.61
	2	5.04	2.58	2.10	42.0	1.72	0.26	2.10	0.00	0.82
	3	6.00	2.64	2.10	45.12	1.93	0.24	2.10	0.00	1.20
NOV	1	3.36	2.34	1.92	45.36	0.26	0.24	1.44	0.00	0.23
	2	2.52	2.52	2.10	40.80	0.00	0.14	1.45	0.00	0.19
	3	6.00	2.52	2.16	55.20	0.00	0.19	1.74	0.00	0.38
DEC	1	5.41	2.54	2.10	46.80	0.00	0.32	1.58	0.30	0.22
	2	5.46	2.70	0.10	52.80	0.00	0.17	1.62	0.25	0.20
	3	4.56	2.50	2.10	44.40	0.00	0.10	1.60	1.18	0.13

APPENDIX 2 CONT'D.

MONTH	STATION	Ca	Mg	K	Na	Co	Cu	Fe	Pb	Zn
JAN	1	1.92	2.32	2.16	50.40	0.00	0.20	2.46	0.25	0.14
	2	1.68	2.34	2.28	52.80	0.00	0.144	2.65	0.15	0.17
	3	1.20	2.33	2.40	52.80	0.00	0.312	2.47	0.30	0.42
FEB	1	2.28	3.14	4.68	94.80	0.00	0.62	3.29	0.10	0.29
	2	0.96	2.40	3.12	56.48	0.00	0.71	3.41	0.10	0.23
	3	1.44	2.36	2.72	62.40	0.00	0.72	3.72	0.15	0.20
MARCH	1	0.96	2.52	5.04	62.40	0.00	1.32	3.74	0.00	0.18
	2	0.72	2.28	4.62	60.00	0.00	1.78	3.76	0.00	0.13
	3	0.36	0.38	3.84	57.84	0.00	1.78	3.76	0.00	0.16
APRIL	1	0.42	1.84	4.56	67.20	0.00	0.13	4.26	0.00	0.10
	2	0.48	2.32	4.56	67.20	0.00	0.25	4.44	0.00	0.14
	3	0.42	2.06	4.56	68.40	0.00	0.7	4.46	0.00	0.13

APPENDIX 3

SEDIMENT pH AND METAL CONCENTRATION (Ugg^{-1}) OF MAKWAYE (A.B.U. FARM) LAKE SAMARU - ZARIA

MONTH	STATION	pH	Ca	Mg	K	Na	Co	Cu	Fe	Pb	Zn
MAY	1	5.9	330	755	625	3800	27.5	26.0	425.5	17.0	38.5
	2	6.1	370	765	745	2900	25.0	25.0	425.0	16.5	65.5
	3	6.2	130	600	575	2000	10.0	28.0	367.0	3.0	40.0
JUNE	1	6.4	395	855	790	2650	33.0	40.0	427.5	22.5	63.5
	2	6.2	225	625	655	2350	33.0	26.0	432.5	14.5	37.0
	3	6.1	310	400	525	2650	25.0	40.0	420.0	9.50	49.0
JULY	1	6.3	250	525	530	2350	27.5	35.0	428.0	9.5	47.5
	2	6.3	320	575	650	2550	27.5	23.0	427.5	6.0	36.0
	3	6.2	375	600	675	2600	27.5	26.0	427.5	9.0	48.0
AUGUST	1	6.5	305	375	515	2955	22.0	71.5	415.0	3.5	55.0
	2	6.4	270	725	720	2800	33.0	27.0	435.5	9.5	33.0
	3	6.3	185	425	550	2200	30.5	30.0	427.5	6.0	35.5

APPENDIX 3 CONT'D.

MONTH	STATION	pH	Ca	Mg	K	Na	Co	Cu	Fe	Pb	Zn
SEPT	1	6.6	295	825	730	2800	36.0	42.0	437.8	8.0	50.0
	2	6.6	320	900	900	2620	44.5	30.0	439.0	11.0	44.5
	3	6.8	220	400	515	1975	27.5	31.0	426.0	2.0	36.5
OCT	1	6.9	255	775	790	2625	36.0	74.0	435.0	7.0	63.5
	2	6.9	825	825	820	3050	44.5	40.0	436.0	9.0	59.5
	3	6.9	325	325	515	1850	27.5	22.0	425.0	5.0	23.5
NOV	1	5.9	265	800	710	3250	38.5	37.0	435.0	10.0	40.0
	2	6.1	280	750	425	2100	27.5	27.0	415.0	9.0	35.5
	3.	6.2	240	685	625	2350	38.5	46.0	436.5	17.0	59.5
DEC	1	6.3	240	820	725	1850	25.0	47.0	370.0	3.5	36.5
	2	6.3	250	800	650	2950	41.5	35.0	435.0	12.5	49.5
	3	6.3	310	950	850	2850	41.5	39.0	440.0	21.5	44.0

APPENDIX 3 CONT'D.

MONTH	STATION	pH	Ca	Mg	K	Na	Co	Cu	Fe	Pb	Zn
JAN	1	6.5	385	685	595	3150	41.5	36.0	435.0	11.0	39.5
	2	6.5	355	755	590	2900	47.0	32.0	437.5	18.5	46.5
	3	6.5	340	500	550	3200	33.0	46.5	417.0	6.5	49.5
FEB	1	6.2	265	675	920	2750	55.5	33.0	445.0	17.0	37.5
	2	6.1	240	875	920	2750	55.5	33.0	445.0	17.0	37.5
	3	6.3	305	860	860	4650	47.0	64.0	440.0	14.0	51.0
MARCH	1	6.2	235	600	780	4200	47.0	42.0	439.0	9.5	49.5
	2	6.1	280	625	760	5600	41.5	71.5	434.5	6.0	68.0
	3	6.1	240	900	400	2600	33.0	74.0	420.0	14.5	66.5
APRIL	1	6.0	180	525	670	2950	44.5	50.0	440.5	18.5	44.0
	2	6.0	345	550	690	3700	47.0	35.0	438.0	14.0	48.0
	3	6.0	240	800	780	2650	52.0	30.0	442.5	20.5	51.0

APPENDIX 4

INDIVIDUALS AND TOTAL ZOOPLANKTON (PER LITRE) OF MAKWAYE (A.B.U. FARM) LAKE SAMARU, ZARIA

DATE	STATION	COPEPODA	CLADOCERA	ROTIFERA	TOTAL
14:5:87	1	79	123	33	235
	2	135	89	67	291
	3	164	57	135	156
25:5:87	1	77	132	87	287
	2	138	112	98	348
	3	198	95	95	388
10:6:87	1	315	192	169	676
	2	303	193	68	564
	3	461	180	123	764
24:6:87	1	336	324	122	784
	2	334	206	133	673
	3	382	205	142	729
13:7:87	1	330	295	208	833
	2	302	318	310	930
	3	296	172	384	852
27:7:87	1	390	235	248	873
	2	266	268	350	884
	3	238	216	286	740
14:8:87	1	220	184	208	612
	2	187	208	163	558
	3	148	167	151	466
27:8:87	1	107	143	102	352
	2	117	86	62	265
	3	107	138	82	327

APPENDIX 4 CONT'D.

DATE	STATION	COPEPODA	CLADOCERA	ROTIFERA	TOTAL
10:9:87	1	113	66	34	213
	2	119	29	74	222
	3	94	67	22	184
29:9:87	1	139	67	22	228
	2	128	33	33	194
	3	101	28	10	139
15:10:87	1	125	34	45	304
	2	168	45	45	258
	3	168	23	45	236
29:10:87	1	125	54	110	389
	2	204	52	145	401
	3	195	44	177	416
12:11:78	1	101	90	291	482
	2	225	180	292	697
	3	224	135	203	562
24:11:87	1	130	108	296	534
	2	238	186	328	752
	3	246	174	218	638
9:12:87	1	158	237	141	536
	2	262	288	212	762
	3	138	176	161	475
23:12:87	1	134	215	173	522
	2	242	182	238	662
	3	110	126	131	367

APPENDIX 4 CONT'D

DATE	STATION	COPEPODA	CLADOCERA	ROTIPERA	TOTAL
13:1:88	1	213	169	225	707
	2	79	101	282	462
	3	94	157	181	432
27:1:88	1	221	205	329	755
	2	110	130	307	547
	3	98	173	219	490
10:2:88	1	252	56	270	587
	2	281	0	237	518
	3	192	34	304	530
22:2:88	1	267	34	311	612
	2	279	56	234	569
	3	212	50	353	615
10:3:88	1	191	79	271	540
	2	280	101	404	785
	3	147	54	225	426
24:3:88	1	206	96	216	518
	2	299	112	451	862
	3	171	11	257	439
8:4:88	1	184	142	149	475
	2	270	221	166	657
	3	208	90	74	372
22:4:88	1	198	194	165	557
	2	402	161	148	711
	3	174	46	62	282

APPENDIX 5

INDIVIDUALS AND TOTAL BENTHOS (PER M^2) OF MAKWAYE

(A.B.U. FARM) LAKE SAMARU, ZARIA

DATE	STATION	DIPTERA	MOLLUSCA	TRICHOPTERA	ODONATA	TOTAL
14:5:87	1	218	137	39	26	420
	2	139	108	39	26	312
	3	176	299	26	13	514
25:5:87	1	40	93	13	0	146
	2	113	166	0	13	292
	3	150	313	26	39	528
10:6:87	1	121	124	13	13	271
	2	52	167	13	13	245
	3	134	143	26	0	303
24:6:87	1	95	110	39	13	257
	2	106	133	26	0	265
	3	140	65	0	39	244
13:7:87	1	169	130	52	26	377
	2	182	39	39	0	260
	3	208	97	26	13	344
27:7:87	1	91	104	0	0	195
	2	130	91	13	0	234
	3	156	189	0	13	358
14:8:87	1	117	306	39	13	475
	2	71	183	13	13	280
	3	273	325	39	26	663

APPENDIX 5 CONT'D.

DATE	STATION	DIPTERA	MOLLUSCA	TRICHOPTERA	ODONATA	TOTAL
27:8:87	1	221	110	0	13	344
	2	189	195	0	0	384
	3	325	182	26	39	572
10:9:87	1	208	137	13	13	371
	2	221	65	39	13	338
	3	286	169	52	21	533
29:9:87	1	182	97	26	0	305
	2	195	169	26	13	403
	3	260	117	13	26	416
15:10:87	1	98	52	65	26	241
	2	144	105	26	13	288
	3	195	208	26	52	481
29:10:87	1	188	118	0	13	319
	2	52	143	13	0	208
	3	131	182	26	13	352
12:11:87	1	325	69	69	26	489
	2	228	143	91	13	475
	3	546	234	104	39	923
24:11:87	1	247	231	87	52	617
	2	292	325	13	0	630
	3	300	416	91	26	833
9:12:87	1	273	292	52	39	656
	2	136	82	26	39	283
	3	234	293	52	26	605

APPENDIX 5 CONT'D.

DATE	STATION	DIPTERA	MOLLUSCA	TRICHOPTERA	ODONATA	TOTAL
23:12:87	1	195	228	78	39	540
	2	176	230	0	13	419
	3	312	539	26	26	903
13:1:88	1	69	390	65	26	550
	2	109	52	91	26	278
	3	136	183	182	91	592
27:1:88	1	101	130	26	39	296
	2	163	122	13	0	298
	3	216	273	208	13	710
10:2:88	1	189	93	293	26	601
	2	137	166	222	39	564
	3	228	208	324	65	825
22:2:88	1	279	167	137	26	609
	2	189	108	52	13	362
	3	266	260	262	52	840
10:3:88	1	234	150	91	39	514
	2	118	192	143	39	492
	3	189	234	208	13	644
24:3:88	1	222	188	65	13	488
	2	260	108	39	13	420
	3	397	442	78	52	969

APPENDIX 5 CONT'D.

DATE	STATION	DIPTERA	MOLLUSCA	TRICHOPTERA	ODONATA	TOTAL
8:4:88	1	365	93	52	130	640
	2	166	69	39	78	352
	3	539	298	91	91	1019
22:4:88	1	415	245	104	52	816
	2	302	87	117	26	532
	3	891	326	315	221	1753