THE EFFECTS OF POLLUTION ON A STRETCH OF RIVER KUBANNI, ZARIA, NIGERIA

BY

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DECLARATION

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 Information derived from the published or unpublished works of other has been duly acknowledged in this work.



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CERTIFICATION

This thesis entitled "The effects of pollution on a stretch of river Kubanni, Zaria, Nigeria" by John Ameh Adakole meets the regulation governing the award of the degree of Master of Science of Ahmadu Bello University, and is approved for its contribution to knowledge and literary presentation.

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ABSTRACT

River Kubanni a major tributary of river Galma. recieves both organic and inorganic wastes through run-offs and seepage from some residential and agricultural areas of Tudun-Wada Zaria.

Water, plankton and benthic samples were collected once a month from three stations on a stretch of the river, for eight months (February, 1994 - October, 19940. The physico-chemical parameters, plankton and benthic composition were determined and correlated to one another.

The distribution and composition of phytoplankton and benthic fauna are affected by variations through fluctuations in environmental variables such as temperature, velocity, transparency, pH, dissolved oxygen, total alkalinity, total hardness, electrical conductivity and total dissolved matter. Low alkalinity results to low phytoplankton production while a rise in total dissolved matter results to increase in electrical conductivity and turbidity but a decrease of the benthic population. The presence of Oscillatoria sp, Euglena sp, Chironomous sp, Naids sp, Glossiphonia sp and the absence of Ephemeroptera in stations 2 and 3 are indicative of organic pollution in these stations. However, the river stretch is rich for fish production with respect to water hardness

Tilapia and to some extent Alestes accumulated more trace metals than Clarias. Tilapia, may therefore be a better indicator species than Clarias for monitoring trace metal concentration in the aquatic ecosystem.

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CHAPTER ONE

INTRODUCTION

1.1 POLLUTION

River Kubanni is a major tributary of river Galma. It flows in a north-South East direction. There is a dam across its valley which is used by the Ahmadu Bello University Zaria for its water supply. River Kubanni is supplied with run-offs and seepage from a drainage basin covering some of Zaria residential area, agricultural farmlands, mechanic workshops and car washing centres. Thus organic and inorganic wastes (domestic sewage, fertilizers, pesticides, oil and oil dispersants, solid metals, detergents etc.) could be expected in the run-offs and seepage. These wastes entering the river constitute pollutants.

Water pollution means the introduction by man, directly or indirectly, of substances or energy into the aquatic environment resulting in such deleterious effects as harm to living resources, cause hazards to human health, hinder aquatic activities, including fishing, impair the quality for use of water and reduce of amenities (Modified from GESAMP, 1982). When the physical and chemical conditions of ecosystems are changed beyond their normal ranges, unusual changes, however small, may be expected to occur in individual organisms, population and communities of the ecosystem.

Pollution may be detected and measured chemically, physically and biologically, or using a combination of these.

Chemical tests are applied for such parameters as disolved oxygen, hydrogen ion concentration(PH), and the presence of particular chemical compounds or elements. Physical assays measure colour, turbidity, specific conductance and odour, among other things. The biological identification and measurement of pollution involves test and index organisms; the occurence of sudden large mortalities is often a tardy clue. Test organisms are those which are exposed to various dilutions of presumed pollutants in order to determine limits of tolerance.

In order to determine the effects of the wastes introduced into the section of river Kubanni in question, studies will be carried out to determine the changes in the physico-chemical characteristics and correlate them with changes in the biota - phytoplankton, invertebrates and fish.

1.2 BACKGROUND

Air, land and water pollution started with the first man on earth. Since then pollution has been growing in extent and pungency (Inyang, 1981 and Lumbertus, 1993). The greater the concentration of people in one area the greater the amount of pollution, and the greater the sophistication of a society the more intricate and poignant its pollution. Three decades ago, FAO carried out a brief survey of inland water pollution in East and Central Africa (Thorslud, 1971), from which it reported that although water pollution was then not a serious

problem in relation to freshwater fisheries, it could become so in future as a result of increasing urbanization and industrialization. In 1972, the ACMRR working party on aquaculture (FAO-ACMRR, 1972) warned that unless adequate measures were taken urgently, existing aquaculture might be seriously affected in many areas and further expansion made extremely difficult, and that adverse effects of pollution on aquaculture was likely to become more accute with increasing urbanization and industrialization.

The collective experience in Africa of conflicts between water quality requirements for aquaculture and other human activities is very limited compared to that, for example, in Europe or South Asia. In Nigeria, very little has been done to estimate the hazard of trace heavy metals on aquatic life while the toxicity of heavy metals to temperate fishes is well documented. In Zaria, Smith (1975) studied the effects of pollution in the upstream of river Kubanni and found that the fauna of the river was zoned according to the degree of pollution.

1.3 JUSTIFICATION

With the proliferation of chemically - based industries and the collosal increase in automobiles in Nigeria, the rate of metal pollution in our rivers is expected to affect fish production within a very short time (Oladimeji, 1983). While the demand for protein is increasing enormously with growing

population, our Rivers are being reduced to sewage depots for poisonous chemicals which kill our fish and other aquatic forms.

Agricultural wastes, manures, fertilizers and pesticides find their way through run-offs into streams and lakes and therefore enrich the water bodies (Golpal et al, 1981), leading to eutrophication (Mitchell, 1975). Eutrophication becomes a nuisance in water bodies because of impaired water quality, degradation process during anoxic periods, prolific weed growth, excessive algal blooms and deteriorating fisheries (Gelin, 1978).

Insecticides applied to control insect pests in the field may be washed into the river system where they may have significant adverse effects on non-target organisms. Herbicides also, are in general unselective and kill most aquatic plants. In turn these destroy the habitats for invertebrates and may cause deoxygenation as the plants rot (Moss, 1993). Herbicides may also be directly toxic to some animals. Repeated application can permanently destroy the habitat.

All the urban centres in Nigeria are foci of ever-increasing pollution of air, land and water (Inyang, 1981), with the pollution problem getting more serious and complex in densely populated areas than in regions of sparse settlements. In Zaria area, only few of the refuse disposal facilities are actually utilized. Municipal and industrial effluents are

channeled into the same drains and subsequently in river Kubanni. In this study, Sabon-gari/Tundun-Wada section of river Kubanni was selected because it epitomizes the growing pollution problems of agricultural practice and urban agglomeration in Zaria area.

A very important symptom of water "pollution" usually is change in the biotic components of the aquatic environment. Yet, environmental stress is usually measured in terms of chemical parameters. This sole use of chemical approach in describing water pollution is not only indirect but also has been found to be deficient (Lenat et al, 1980). Thus, the adoption of biological, physical and chemical assessment approach in this study, to obtain information about the quality of river Kubanni. Society's interest in pollution is centered on its effects on living organisms. Since organisms act as integrators of the total environment, their response to complex sets of environmental conditions can be used as monitors of water quality. In essence, total monitoring systems (biological, chemical, and physical) are essential to obtain the information necessary to apply control measures to aquatic systems if we are to manage the system to allow people make full beneficial use of the receiving capacity of natural ecosystems (Dikson et al, 1980).

1.4 OBJECTIVES

The objectives of the present study are therefore

a. To determine the physico-chemical characteristics of river Kubanni

b. To evaluate the effect of pollution on the quantitative/qualitative distribution of phytoplankton and benthic fauna of river Kubanni

c. To correlate physico-chemical characteristics of the river with the established biota.

d. To determine the extent of trace metals accumulation by fish caught from river Kubanni.

CHAPTER TWO

LITERATURE REVIEW

2.1 NATURE AND SOURCE OF AQUATIC POLLUTION

2.1.1 URBAN RUN OFF

Urban run-off may increase erosion resulting in very high sediment loads to the stream. The effects of sedimentation on streams have been well documented (Meade, 1982; Kelsey et al 1987). Sediment begins a slow movement downward through the drainage system producing changes in stream morphology and channel characteristics, as well as influencing the habitat and substrate conditions (House et al 1993).

It is difficult to chemically characterise a typical urban run-off. However, common constituents include heavy metals, pesticides putrescible organics, petroleum derivatives, ammonia, phosphorus, suspended solids, rubber and a range of other contaminants which may be specific to the catchment and land use (Porcella and Sorenson, 1980 and House et al 1993).

In a recent study of urban run-off effects on benthic invertebrates, Pedersen and Pekins (1986) observed that the urban stream was dominated by taxa which could tolerate the erosional/depositonal character of the urban stream and utilise transient, low quality food sources. Of interest, as well, in Pedersen and Perkins findings was the conclusion that there was no long-term loss of colonisation potential in an urban stream. ~~Pratt~~ Digiano et al (1975); Pratt and Coler

(1976), and Pratt et al (1981) studied the biological response of stream fish and macronivertebrate to urban run-off. They observed a decrease in species diversity and generally observed that the composition of the fauna reflected the degree of pollutant loading. Of some importance is the statement by Medeiros et al. (1983) that the variation in the composition, concentration, amplitude, rate of change and mass loading of toxicants in urban run-off prevents lotic communities from acclimating to urban run-off. The expected effect would be a community in constant flux and an ecosystem lacking essential stability. Medeiros et al also observed that run-off toxicity is associated with the river bed rather than the overlying water. They suggested a mechanism through which urban run-off delivers toxicants to the stream and hence to the river bed with the effects delayed until dry weather flow.

2.1.2 SOLID AND DOMESTIC SEWAGE WASTES

The disposal of solid wastes (a mixture of commercial and household rubbish such as paper, bottles, cans, etc) and domestic sewage have become one of the most urgent and difficult problems of the crowded urban centres of many countries and the disposal of these waste materials into the aquatic ecosystem is being practised increasingly (FAO, 1971; and Lambertus, 1993). Domestic wastes fertilize the water and increase the rate of productivity of the aquatic ecosystem. When they are overfertilized, however, the water become

eutrophic and the excessive growth of plants and algae becomes a nuisance. Rivers that have been clear and clean for thousands of years have become repulsive and malodorous within ten years after man-made effluents were introduced. Generally, sewage pollution of rivers and streams is a common occurence (Akpata, 1986). It is important to mention that only a small proportion of municipal waste waters in Nigeria are treated before they are discharged into the rivers. The effect of the effluent on aquatic flora depends partly on the physico-chemical characteristics of the pollutant.

When untreated domestic wastes without toxic materials are discharged into an aquatic environment, they are quickly attacked by bacteria and fungi which decompose them to their inorganic constituents, assimilating dissolved oxygen from the water in the process (Akpata & Ekundayo, 1983 and Moss, 1993). When this occurs in confined water bodies such as lakes, estuaries and embayments having restricted circulation, the oxygen required for decomposing the waste may exceed the oxygen content of the water. The body of water then becomes devoid of oxygen and most forms of its animal life perish. Akpata (1986) observed that, under domestic sewage/saw dust aquatic pollution condition, the physico-chemical features of the aquatic environment change. For instance there is high biochemical oxygen demand, unfavourable for aerobic microbial activities. The high turbidity also reduces phytoplankton activities and these reductions in productivity would affect

the food chain, especially the fishery resources, in the water.

Dissolved humic materials may complex with chemicals thereby affecting the physicochemical state of receiving water bodies. Through adsorption, complexation or binding, dissolved humic materials can enhance the water solubility of organic compounds (Chion et al, 1986 and Lee et al 1993) and consequently affect their bioavailability and toxicity. In many cases, the presence of dissolved humic material diminishes the toxicity of organic chemicals to various aquatic organisms, (Cary et al 1987; Day, 1991 and Goodrich et al 1991). Blooms of Oscillatoria, Lyngbya, Euglena and Phacus associated with gutters and water puddles around Lagos were attributed to organic pollution by uncontrolled disposal of domestic sewage into these water bodies (Nwankwo, 1994). Public outcry may follow either from the epidemics of cholera or typhoid associated with sewage pollution of the water supply or the demise of the fish population (Moss, 1993 and Chris, 1994).

2.1.3 AGRICULTURAL WASTES

The campaign for increased food production in Nigeria has resulted in the establishment of small and large farms by individuals and companies. Large and small scale agriculture often involve the use of fertilizers and pesticides which could be a source of pollution (Ezeigbo, 1986). The number of dams in Nigeria is increasing especially in the Northern

states of Borno, Kaduna, Sokoto and Kano. These dams serve many purposes including irrigation of agricultural crops (Akpata, 1986). Irrigation and run-off from agricultural lands during the rainy season wash nutrient into aquatic systems. Non-point source pollution of surface waters by the transport in agricultural run-off of eroded soil and chemicals such as nitrogen, phosphorus, and pesticides is recognized as one of a nations major water quality problems (USEPA, 1984 and Akpata, 1986). Nwankwo (1984) reported that Lagos experiences seasonal rainfall and flooding which impose an outstanding influx of nutrients from rivers and creeks into the lagoons. He observed an inverse relationship between the surface water phosphate - phosphorous content and salinity with maximum phosphorus values recorded at low salinity periods. Blue-green algae, that bloom at the wet season when the nutrient content is high include Microcystis aeruginosa f. flos-aquo, Mirismopedia glauca and Gomphosphaeria apomcia.

The pipe-borne water in Lagos had some odour in May, 1986 and this was traced to the eutrophication of Ogun river after a heavy down pour in the rainy season. Fertilizers from agricultural lands were washed into the river which later showed proliferation of algae (Akpata, 1986). Ogun river is the source of raw water for the Iju water works which serves Lagos with pipe-borne water. The purification process apparently did not remove the taste and odour imparted by the algal growth. The management later accomodated the new

development at the source of the raw material.

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 (Balarabe 1989). Fish production depends on the production of plankton, benthos, the basic morphometry, edaphic and climatic factors.

2.1.4 PESTICIDES

In Nigeria, the current awareness of the great need to improve food production and clean up our environment as a first step to highlighting the preventive aspects of our healthcare delivery system requires a well planned and rational pesticide management programme (Adeniyi et al, 1985). According to Iyaniwura (1991), pesticides are valuable chemicals needed to maximize food production and control insect vectors. Pesticides however, pose inherent hazards to man through our food and environmental contamination. The organochlorines (DDT, aldrin, chlordane and heptachlor of which DDT is perphaps the most well known) pose serious tissue and accumulation problems. Both freshwater and marine fish are almost universally contaminated with DDT or its decomposition products, which have physical effects similar to

DDT itself. Many pesticides are used as insecticides, fungicides, herbicides etc (FAO, 1971 and Moss, 1993).

Pesticides gets into rivers and streams through agricultural run-off, urban run-off (from domestic use of insecticides), use of chemicals such as lindane, the active ingredient of "Gammalin 20" for fishing, and use of pesticides to control other aquatic organisms (USEPA, 1984; Adeniji et al 1985; Akpata, 1986 and Moss, 1993). Adeniji et al (1985) also reported the presence of pesticide residues in all Synodontis, Barbus and Alestes species examined from Kainji and Jebba lakes. Though there was a wide variation in concentrations between fish species, the pesticide concentrations were more pronounced in the fatty tissues. They also reported the presence of DDT, DDE, HCB, and HCH in the root, stem and leaves of Echinocloa stagnina.

2.1.5 TRACE METALS AND OILS

Trace metals enter the aquatic environment from both natural and anthropogenic sources (industrial effluents, domestic effluents and urban storm-water run-off; leaching of metals from garbage and solid waste dumps; metal inputs from rural areas e.g. metals contained in pesticides; atmospheric sources, e.g. burning of fossil fuels, incineration of wastes and industrial emissions, etc). On combustion, smoke containing lead (Pb) particles is emitted into the atmosphere. When it rains, these particles are washed either directly or indirectly into rivers and streams (Oladimeji, 1983 and Biney

et al 1992). Lower pH and higher lead concentrations than those allowable by law for discharge represent the main polluting factors of storage battery industry wastewater and this mainly consist of sulphuric acid solutions containing soluble and particulate lead (Macchi, et al 1993). Apart from these sources of aquatic pollution by trace metals, there are always heavy metals in water, suspended materials, sediments and organisms from lotic ecosystems though background levels are poorly documented in the literature (Frenet, 1981; Salanki et al , 1982 and Borg, 1987). Normal metal content in such environments varies from one place to another according to the geological nature of the catchment area. Other automobile related wastes such as oils and scrap metals also find their way into rivers and streams directly or indirectly.

Chris (1994) reported that over 20 fishing communities in Okrika L.G.A. of River state have been destroyed by marine effluent pollution allegedly from the Port-Harcourt refining company. Destroyed are creeks, fishing ponds, water ways, Mangroves, as well as other water resources. According to him, inhabitats of the affected communities deserted their abode as the air there was also polluted by a fowl-smelling odour of the waste chemicals. The oily chemical substance, he observed, flows in the culvert into the creeks. The creeks and rivers were dark - coloured and foaming. Vegetation was dying off, the dry-land was filled with black-sticky substance, while fowl-smell filled the air.

2.2 EFFECTS OF HEAVY METALS ON PLANKTON

Plankton serves as a major food for fish, hence their destruction by pollution will adversely affect fish

productivity. Effects of heavy metals on phytoplankton have been reviewed by Davis (1978). Although some metal (Cu, Zn, Co, Mn and Fe) are essential for algal growth and development, these and others (Hg, Cd, Ag, Ni, Pb, Se, Cr and As) may be toxic at concentration higher than those normally found in natural systems (Oladimeji, 1983 and Annune, 1992). Although algae generally are not strongly affected by concentrations of heavy metals in the field, they do concentrate some of them and may transfer them to higher trophic levels. Davies (1973) and Anunne, (1992) stated that heavy metals appeared to be accumulated by phytoplankton through non-exchange processes that involved organic molecules and that the process is governed by the rate of diffusion across cell membrane. Boudou and Ribeyre (1981) demostrated trophic transfer of mercury from alga, Chlorella vulgaris to the daphnid, Daphnia magna. When the alga was contaminated with mercuric chloride, very little metal was transfered to D. magna. However, when contaminated with methyl mercuric chloride and fed to the daphnid, approximately 20% of the mercury on the alga was transfered at 10°C and 60% at 18°C. This shows that large amounts of the methlylated form of mercury can be transfered through food chains (Anunne, 1992). Amiard - Triquet (1979) also demonstrated trophic transfer of cobalt through a freshwater food chain composed of Chlorella species, Daphnia magna and the carp, Cyprinus carpio.

Heavy metals in algae may also affect survival and development of animal larvae. Biney et al (1992) fed algal contaminated with Cu, Cd and Zn to veliger larvae of the American oyster, Crassostrea virginica and noted poor growth and high mortality of the Larvae. Kuiper (1981) reported that a single dose of 0.5 ugl^{-1} mercuric chloride altered the species composition of phytoplankton with a shift to predominance of species of large size, probably because mercury reduced the number of small zooplankton herbivores. At $5ugl^{-1}$ and above, mercury inhibited growth. Saboski (1977) described the effects of mercury and tin on the frustular ultrastructure of Nitzschia liebethrutte. A high rate of abnormal morphology was caused by each metal at 1.5 ugl^{-1}., Cadmium induced an increase in filament length and a loss of cellular contents in Anabaena inaequalis (Stratton and Corker, 1979). Anunne (1992), expressed that pollution by heavy metals could decrease rates of primary productivity by algae and that remaining algae would be potentially toxic to grazing animals.

Effects of 21 metals on survival and reproduction of Daphnia magna were reported by Biesinger and Christensen (1972). Cadmium, mercury, and Cobalt were the most toxic to survival (48-h Lc50) and reproduction; Magnesium, calcium and sodium were least toxic. Weight of Daphnia magna was reduced at metal concentrations that permitted survival but impaired reproduction. Sublethal concentrations of cadmium were shown

by Griffiths (1980) to cause morphological and ultrastructural abnormalities in D. magna. Yan and Strus (1980) also showed that species richness and biomass of crustacean zooplankton in lakes contaminated with acid waste and heavy metals were strongly reduced in comparison with unpolluted lakes.

2.3 BIOACCUMULATION AND TOXICITY OF METALS TO FISH

A comparison of bioconcentration factors revealed that of Tilapia to be greater than that of Clarias lazera (Offem, 1983). This view agrees with the suggestion by Norberg (1978) that surface layers of water are biologically active and that oxidative processes are maximal; higher temperature, and light stimulate chemical changes causing a high and rapid biotic uptake of elements by organisms living close to the surface. The bioaccumulation of heavy metals from water strongly depends on physicochemical parameters influencing the chemical form of the element. A Comparism of the rate of accumulation of metals by fish tissues and whole body showed the following descending order of uptake; Gill, liver, bone, intestine, skin, whole body, then muscle (Luoma, 1983 and Offem, 1983)

There are comparatively few field studies of trace metal uptake but available evidence supports the concept of trace equilibrium being sought by fresh water fish. The relationship between trace metals in fish and its environment is a direct one (Lovett et al, 1972; Van collie & Roussean, 1974; and Abdullah et al, 1976). Neverthless, the

concentration of trace metals in food has also been shown to play an important role in determining the concentration of trace metals in fish (Singh and Ferns,1978).

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 if at low concentrations (Oladimeji, 1983). Symptoms of toxicosis show that zinc causes subacute effects that change fish behaviour. Such observed effects include lack of balance, agitated swimming, air gulping, period of quiescence and death and copious accumulation of mucus on the gill filaments and body surfaces of the dead fish (Lewis, 1978 and Anunne, 1991). Zinc is also known to retard growth and proper development of reproductive organ of fish. High concentration of lead conbines with mucus which cover the gills resulting in interference with respiration and causing immediate death, 25ppm of Cadmium caused marked damage to testicular tissues leading to a lower reproductive capacity in fish, 1.5ppm $CuSo_4$ inhibited acetylcholinesterase, caused adverse alterations in certain blood parameters and damage to the gills, liver, kidney, nervous system, endoplasmic recticulum and mitochondria (Svobodova, 1982; Rojik et al 1983, and Nemcsok et al 1987).

Trace metal toxicty has recently emerged as an important determinant of fish survival in culturally acidified waters (Baker, 1982; and Hutchinson & Sprague, 1986). Fish

mortalities have been related to toxicity of H^+ and Al (Baker, 1981), but acidified waters may also contain elevated concentrations of Mn and Zn.

2.4 PHYSICO-CHEMICAL CHARACTERISTICS OF WATER AND ITS EFFECT ON AQUATIC ORGANISMS

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 (Balarabe, 1989). In order to assess the potentials of such aquatic ecosystems for their essential management and effective ultilization, it is necessary to study these influence with a view to controlling and maintaining them within the optimum range. Stent (1981) suggested that monitoring of biological and physico-chemical characteristics of a water body is important for both short-term and long-term trends. The fishery scientist needs to understand some of the physico-chemical properties of water that affect its function as an environment for plants and animals (Royce, 1972).

The temperature of rivers and streams vary much more rapidly than those of lakes, and in the tropics, stream temperatures increase downstream until they reach equilibrium with the air temperature (Hynes,1972). Each plant or animal is adapted to a normal seasonal temperature regime and commonly affected adversely by unusual temperatures. Many

animals reproduce, feed, or migrate only within certain temprature limits which may be narrow or broad according to the species (Royce, 1972). The absorption and release of metals also depend on temperature (Reinert et al 1973).

Dissolved oxygen content of water results from the photosynthetic and respiratory activities of the biota in the open water. The benthos, and the aufwuchs; and the diffusion gradient at the air-water interface and distribution by wind-driven mixing (O'wen, 1979). Different organisms have different oxygen requirements and as such dissolved oxygen concentration is an important factor which determine their behaviour, growth and distribution (Hawkes, 1975; Wetzel, 1975).

Productivity of a body of water may be influenced by its hardness. Hardness represent the total concentration of Ca ++ and Mg++ ions expressed as $CaCO_3$ (mgl^{-1}). Hard water has not only more calcium than soft water but nearly always more of several other ions occuring in trace concentration and a higher osmotic pressure (Hynes, 1972; Owen, 1979). Excessive concentrations of phosphorous are common feature of hard water hypertrophic and eutrophic lakes (Mitchell and Prepas, 1990) and their eutrophication is largely caused by rapid internal recycling of phosphorus from the sediments (Riley and prepas, 1984). This condition causes serious water quality problems, including massive bloom of toxic blue-green algae, total water column deoxygenation and summer or winter kill of fishes.

Dissloved and particulate organic matter content of inland rivers flowing through metropolis that recieves both domestic and industrial effluents is higher than sea water and still higher than that of inland rivers that do not pass through metropolis (Akpan and Anadu, 1991). Pollution with organic matter is very complex, as it involves not only the deoxygenation of the water, but also the addition of suspended solids, the organic matter itself,and poisons such as ammonia and sulphides and in sewage one often finds also cyanides (Hynes, 1978). The biological oxygen demand (BOD) of crude sewage is around 600mg $O_2 l^{-1}$ 5 $days^{-1}$, and that of unpolluted river water is less than 5mg $O_2 l^{-1}$ (Moss, 1993). In highly polluted water bodies such as the river Rhine, considerable amounts of metals are adsorbed on to suspended ~~principal~~ particles (Schleichert, 1975).

The principal system regulating PH in natural waters is the carbonate system which is composed of carbondioxide, carbonic acid, bicarbonate and carbonate ions. The PH of most natural waters fall in the rage of 4.0 to 9.0,and much more often in the range of 6.0 to 8.0 (O'wen, 1979 and Balarabe 1989). Acid streams often have rich invertebrate fauna (Hynes, 1992) and many stream animals apparently thrive at low PH levels. Such examples include European stonefly (Nemurella Picteti), species of Leuctra, and several genera of dragon flies which occur at PH values as low as 4.4 -4.8 in streams (Hynes, 1978 and MOSS, 1993).

The greatest value of specific conductance to the limnologist is in the estimation of total concentration of dissolved ionic matter in the water, which in turn is related to water fertility. Conductivity and mean depth of a reservoir, could be used to calculate the potential fish yield of a lake (Ryder et al, 1974). At low levels, major ions may determine the nature of the fauna (MOSS,1993).

Rivers and streams are more turbid than still water,and many are always markedly cloudy. However, at times of low water, most streams and rivers are normally fairly clear, although never as clear as lakes (Hynes, 1972; O'wen, 1979). Turbidity inhibits phytoplankton photosynthesis which in turn affects zooplankton productivity.

In rapidly running rivers, the drifting zooplankton is strongly reduced in its numbers,and the rate of this fate depends on the size and shape of the animals (Ward, 1975, and Sandland, 1982).

CHAPTER THREE

MATERIALS AND METHODS

3.1.1 STUDY AREA

Zaria, situated in the Northern Guinea Savanna zone, possesses a tropical continental climate with distinct wet and dry seasons. The rainy period lasts from May to October. Zaria has a settlement pattern which consisted of Island of cultivation surrounded by woodland which is being transfered into a sea of cultivation with residual Island of bush, on shallow laterite, rocks and in gullies.

River Kubanni is a major tributary of river Galma and it flows in a North-South East direction. It is supplied with run-off and seepage from a drainage basin covering some of Zaria residential area (Fig. 1). The nature of the channel of river Kubanni varies considerably both from station to station and from time to time. Along much of its length, the channel cuts through superficial deposits of alluvium and younger laterite and consists of deeper pools seperated by shallow riffle areas.

Upstream, there is a dam across its valley which is used by the Ahmadu Bello University, Zaria for its water supply. Downstream, attempts to conserve the river water include construction of earth or sand barrages, or by artificially enlarging and deepening pools. There are two major uses of the river: Agriculture (irrigation, fishing and watering cattle) and domestic (Washing and bathing). Heaps of refuse

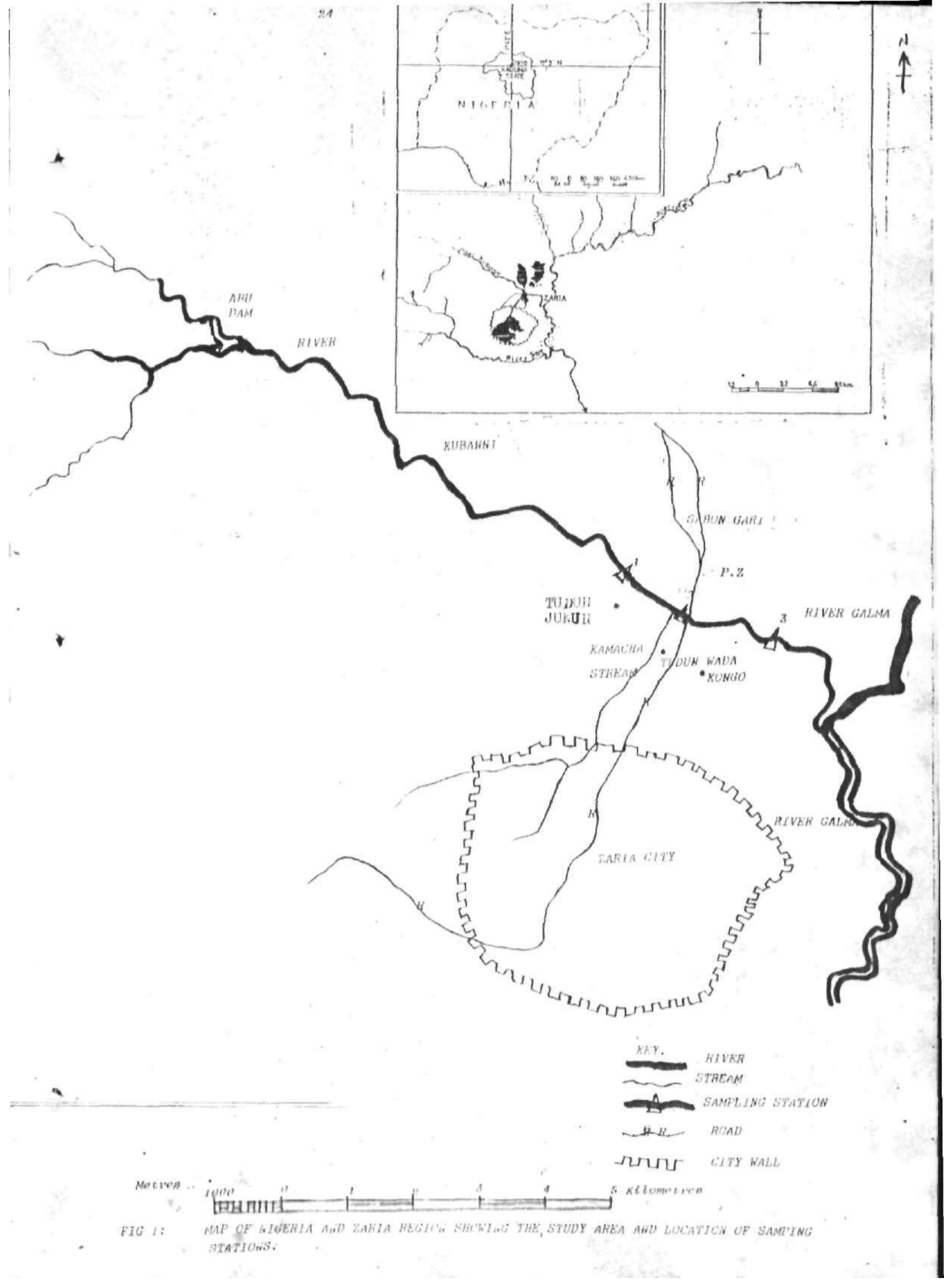


FIG 1: MAP OF NIGERIA AND ZARIA REGION SHOWING THE STUDY AREA AND LOCATION OF SAMPLING STATIONS.

dump, human feaces, cattle dungs could be found on the slopes of the valley. Municipal and industrial effluents are channelled into the same drains and subsequently into the river irrespective of their quality.

3.1.2 SAMPLING STATION

Three sampling stations were chosen for the study. Station 1, in Tudun-Jukun, is located upstream. Station 2 in Sabon-gari/Tudun-wada is 20 metres downstream after river Kubanni had received effluents from kamacha stream, which drains a local market. It is about 1.5km from station 1. Station 2 surroundings present a horific and foul odour due to indiscriminate littering of excreta mixed with domestic and industrial effluents. Station 3, close to the outskirts of the town is located about 1.3km from station 2.

3.2. DETERMINATION OF WATER QUALITY CHARACTERISTICS

3.2.1 TEMPERATURE

Air, water surface and water depth temperature were determined with a thermometer calibrated in °C. Air temperature was taken by holding the thermometer above the water for about 5 minutes until it stabilizes. Water surface temperature was determined by lowering the thermometer to about 1cm above the water for about 5 minutes until it stabilizes. Water depth temperature was determined by further lowering the thermometer into the water in an inclined

position for about 5 minutes to allow for equilibrum before recording.

3.2.2 VELOCITY

Velocity was determined from the time taken by a floating object placed on the river surface to travel over a measured distance. The value obtained was then expressed in metres per second (M/S).

3.3.3 TRANSPARENCY

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

3.2.4 pH

Water collected in bottles from each sampling station was transported to the laboratory in thick plastic thermocooler containers to maintain uniform temperature. The pH was determined with a pye unicam model 292 metre at 25°C. The metre was standardise with buffer solutions at pH 4.0, 7.0 and 9.0 before the readings were taken.

3.2.5 DISSOLVED OXYGEN

This was determined by the modified Winkler azide method (Lind, 1979 and APHA, 1980). Duplicate water samples in 250ml BOD stoppered bottles were fixed in the field with 2ml

manganous sulphate, followed by 2ml alkaline - iodide - azide and 2ml conc. H_2SO_4. The samples were then transported to the laboratory. In the laboratory 200ml of the sampled water was titrated with 0.0021m sodium thiosulphate solution until it turned to a pale straw colour. One millitre of starch solution was added which turned it to blue colour. The titration continued until the blue colour disappeared. The volume of the thiosulphate titrant used is equivalent to the mg of dissolved oxygen per litre (Lind, 1979).

3.2.6 TOTAL ALKALINITY

100 millitres of water sample was measured in 250ml Erlenmeyer flask, and 3 drops of phenolphthalein indicator added. If the sample turned pink, it was then titrated with 0.02N H_2SO_4 until the pink colour just disapeared and the millitre(s) of acid used was recorded for alkalinity calculation.

If no pink colour was produced, 3 drops of methyl orange indicator was added to the same sample, in the flask which then became yellowish. The yellowish solution obtained was tritrated with H_2SO_4 until the first change is noted from yellow to orange. And the ml of acid used was recorded.

calculation:

a) phenolphtalein alkalinity = $\frac{A \times N \times 50,000}{\text{ml of sample}}$ (as mg/l $caCo_3$)

b) Total alkalinity = $\frac{B \times N \times 50,000}{\text{ml of sample}}$ (as mg/l $CaCo_3$)

Where A = ml of titration for sample to reach phenolphthalein point

Where B = ml of titration for sample to reach methyl orange end point

Where N = Normality of acid (0.02N).

3.2.7 TOTAL HARDNESS

This was determined by diluting 25ml water sample to 50ml with distilled water. Two millilitres (2ml) of ammonia buffer solution and 0.1g Erichrome black - T 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 ($Mg1^{-1}CaCO_3$) = ml titration x 40

3.2.8 ELECTRICAL CONDUCTIVITY

The water from each sampling station was collected in glass bottles. The conductivity metre EBA/10 model was pre-rinsed and set at zero point. After pre-rinsing, the water sample was poured into the sproule container and reading noted accordingly. The reading was expressed in micro-ohms/cm (umhos/cm).

3.2.9 TOTAL DISSOLVED MATTER

Total dissolved matter was calculated by multiplying the specific conductivity value of the water from each sampling station by o.65 (O'Wen, 1979). The value obtained was then

Where A = ml of titration for sample to reach phenolphthalein point

Where B = ml of titration for sample to reach methyl orange end point

Where N = Normality of acid (0.02N).

3.2.7 TOTAL HARDNESS

This was determined by diluting 25ml water sample to 50ml with distilled water. Two millilitres (2ml) of buffer solution and 0.1g Erichrome black - T 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

3.2.8 ELECTRICAL CONDUCTIVITY

The water from each sampling station was collected in glass bottles. The conductivity metre EBA/10 model was pre-rinsed and set at zero point. After pre-rinsing, the water sample was poured into the sproule container and reading noted accordingly. The reading was expressed in micro-ohms/cm (umhos/cm).

3.2.9 TOTAL DISSOLVED MATTER

Total dissolved matter was calculated by multiplying the specific conductivity value of the water from each sampling station by 0.65 (O'Wen, 1979). The value obtained was then

expressed in milligram per litre (mgl^{-1}).

3.3 TRACE ELEMENT ANALYSIS

3.3.1 WATER SAMPLES

For each season, from each station, water samples were collected on each monthly field trip, preserved by adding 1ml conc. HNO_3 to about 150ml of the sample and then pooled. From the pool, 50ml water sample taken was filtered and concentrated to about 30ml in a 50ml standard flask and 5ml H_2NO_3 was added. It was then made up to 50ml mark with distilled water followed by analysis with unicam 919 Atomic absorption spectrophotometer (A.A.S.).

3.3.2 FISH SAMPLES

During each season of the study period, fish samples caught from Kubanni river were bought from local fishermen, identified and grouped according to species, and their weight and length measurement taken. Each sample was then dried to constant weight at 60°C. Each fish was then ashed in a muffle furnace at a temperature of 525°C. The ash obtained from 4.0g weight of fish was then cooled and dissolved in 5ml conc. HNO_3 and made up to 50ml with deionized water. This was then followed by filtration and analysis with Unicam 919 Atomic absorption spectrophotometer (A.A.S.)

3.4 BIOLOGICAL MONITORING METHODS

3.4.1 PHYTOPLANKTON SAMPLING

For qualitative examination, a plankton net with a conical bag (net mesh size of 0.01mm) 25cm long, attached to

a 50ml bottle and with a square opening measuring 10cm by 10cm was lowered just beneath the surface and towed for a distance of about 5 meters at rowing speed. The collections were transfered to small plastic vials and preserved in 4% neutral formalin as suggested by Margalef (1974). The collection made from each sweep was identified in the laboratory.

For quantitative estimation, 1ml of the 50ml water collected was counted under the miscrocope and the number of algal cells expressed per litre. Relative abundance of various taxa were calculated using the formula $N = \frac{a}{b} n$

where N = estimated number of species per sample; n = number of species in subsample; a = volume of water sample (ml) (50ml); b = volume (ml) of subsample (1ml)

The abundance of taxa in each sample was calculated using the formula.

$D = N/V$

where D = abundance of species (individuals per litre); N = estimated number of species per sample; V = volume (litres) of water originally filtered (Wade, 1985).

3.4.2 FAUNAL SAMPLING

Benthic fauna were sampled over an area measuring 2m by 0.5m using a hand net with a conical bag (net mesh size = 1mm) 25cm long, and with a circular opening 20cm in diameter. The net was dragged along the bottom like a Surber sampler to scoop the dislodged materials. Samples thus obtained were

washed from the net into a collecting tray and then put into a polythene container with 4% formalin as preservative.

In the laboratory, animals were picked out and placed in a petri-dish for counting and identification using published keys. The animals counted were then expressed per square meter.

After sorting and identification, water quality for each station was determined using the diversity (d) indices of Margalef.

$$\text{Margalef index, } d = \frac{S - 1}{\log_n N}$$

Where S = total no of species and N = total no of individuals in the sample,

$Log_n N$ = natural longarithm of N.

Margalef's water quality index values greater than 3.0 indicate clean conditions, values less than 1.0 indicate severe pollution, and intermediate values indicate moderate pollution (Lenat et al, 1980).

3.5 STATISTICAL ANALYSIS

To determine the variation due to error and effects due to sampling stations, months, seasons and interactions, the two-way analysis of variance was used and the F - values determined (Walpole, 1982). The Spearman's rank correlation coefficient was used for relationships between the physico-chemical parameters and the biota.

CHAPTER FOUR

RESULTS

The results of this investigation which was carried out over a period of 8 months reveal a wide variability in physico chemical and biological characteristics of the stretch of river Kubanni studied. The interpretation of the results is based on information derived from the graphs, 2-way analysis of variance (ANOVA) and the Spearman's rank correlation coefficient test of the experimental data and also on known limnological principles.

4.1 WATER QUALITY CHARACTERISTICS

4.1.1 TEMPERATURE

The mean monthly variation in atmospheric temperature for all stations are presented on Fig 2 while Table 1A represents the variation in the dry and the rainy season means. The lowest and the highest monthly mean temperatures were recorded in February (18.66°C) and July (24.°C) respectively. Analysis of variance (Table 1B) shows no significant variation ($P > 0.05$). Correlation coefficient analysis for all parameters over all stations combined (Table 1F) reveals a positive highly significant correlation between atmospheric temperature and water depth temperature but a positive significant correlation between atmospheric temperature and water surface temperature. A significant negative correlation existed between atmospheric temperature and water hardness.

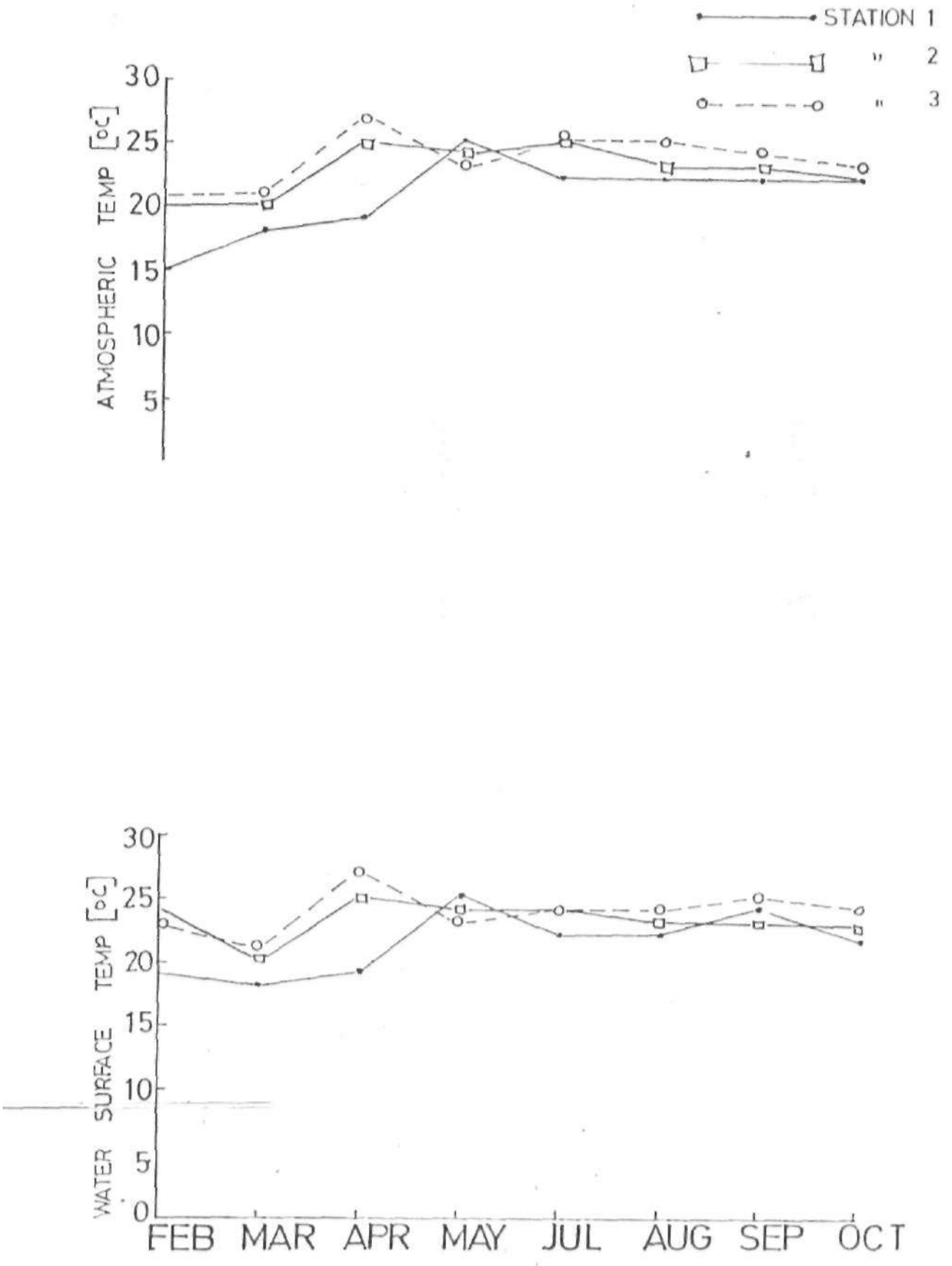


FIG 2: MONTHLY VARIATIONS IN ATMOSPHERIC TEMPERATURE AND WATER SURFACE TEMPERATURE OF STATIONS ON A STRETCH OF RIVER KUBANNI

TABLE 1A: SEASONAL VARIATION IN ATMOSPHERIC TEMPERATURE FOR STATIONS ON A STRETCH OF RIVER KUBANNI

	STATIONS			
	1	2	3	S.E.D
General Station $\overline{X}$ °C	20.62	22.75	23.62	
Dry Season $\overline{X}$ °C	21.5			
Rainy Season $\overline{X}$ °C	23.71			
S.E.D. between two means for months				1.37
S.E.D. between two means for stations				1.18
S.E.D. between two means for seasons				0.97
S.E.D between two means for stations by seasons				1.67

TABLE 1B: ANALYSIS OF VARIANCE (ANOVA) FOR ATMOSPHERIC TEMPERATURE

Source of Variation	DF	Sum of Squares	Means Squares	F ration	SIGN
Months	3	20.33	6.77	1.20	NS
Stations	2	38.08	19.04	3.37	NS
Seasons	1	16.66	16.66	2.95	NS
Stations by seasons	2	3.58	1.79	0.32	NS
Months by stations by seasons	15	84.66	5.64		
Total	23	163.33			

XX = highly significant ($P < 0.01$)
X = significant ($P < 0.05$)
NS = not significant ($P > 0.05$)

TABLE 1C: CORRELATION BETWEEN VARIABLES IN RESPECT TO STATION 1

	A temp.	W s. temp.	W d. temp.	velocity	Transp.	PH.	D.O	Tot. Alk.	Tot. hard	E. Cond.	Tot. dis. mat.	P.plank.
Wat sur. temp	0.868											
wat depth temp	0.682	0.708										
velocity	0.595	0.719	0.643									
Transp	0.069	0.025	0.183	-0.340								
PH	0.575	0.739	0.324	0.137	0.110							
D.O.	-0.177	0.055	-0.549	-0.251	-0.014	0.333						
Tot Alk	0.054	-0.104	-0.423	-0.625	-0.033	0.418	0.472					
Tot Hard	-0.781	-0.773	-0.712	-0.824	-0.146	-0.213	0.246	0.503				
E. Cond	-0.056	-0.150	-0.097	-0.957	0.022	0.387	0.022	0.736	0.630			
Tot. dis mat.	-0.040	-0.138	-0.084	-0.582	0.009	0.393	0.012	0.734	0.619	1.000		
P. Plankton	0.221	0.030	-0.165	-0.422	-0.111	0.521	0.036	0.800	0.404	0.842	0.847	
Benthos	0.100	-0.044	-0.192	-0.134	-0.344	0.049	0.159	0.495	0.345	0.551	0.556	0.517

critical value at 5% level = 0.666
critical value at 1% level = 0.798

TABLE 1D: CORRELATION BETWEEN VARIABLES IN RESPECT TO STATION 2

	A temp.	W s. temp.	W d. temp.	velocity	Transp.	PH.	D.O	Tot. Alk.	Tot. hard	E. Cond.	Tot. dis. mat.	P.plankton
Wat sur. temp	0.662											
wat depth temp	0.771	0.577										
velocity	0.388	0.221	0.359									
Transp	-0.780	-0.499	-0.591	-0.191								
PH	-0.066	-0.183	-0.026	0.357	-0.091							
D.O.	-0.040	-0.323	-0.135	-0.023	-0.522	0.174						
Tot Alk	-0.425	-0.645	-0.554	-0.121	0.685	0.248	-0.366					
Tot Hard	-0.566	-0.292	-0.645	-0.615	0.699	0.004	-0.496	0.705				
E. Cond	-0.340	0.120	-0.396	-0.166	0.676	0.045	-0.806	0.546	0.812			
Tot. dis mat.	-0.341	0.118	-0.392	-0.168	0.679	0.042	-0.810	0.547	0.812	1.000		
P. Plankton	0.426	0.314	0.333	0.358	0.133	0.233	-0.781	0.428	0.228	0.555	0.556	
Benthos	0.006	-0.377	-0.025	-0.009	-0.368	-0.073	0.711	-0.179	-0.461	-0.691	-0.691	-0.532

critical value at 5% level = 0.666
critical value at 1% level = 0.798

TABLE 1E: CORRELATION BETWEEN VARIABLES IN RESPECT TO STATION 3

	A temp.	W s. temp.	W d. temp.	velocity	Transp.	PH.	D.O	Tot. Alk.	Tot. hard	E. Cond.	Tot. dis. mat.	P.plankton
Wat sur. temp	0.866											
wat depth temp	0.701	0.799										
velocity	-0.025	-0.088	0.264									
Transp	-0.793	-0.608	-0.618	-0.098								
PH	-0.398	-0.209	0.015	0.744	0.191							
D.O.	0.310	0.176	0.092	-0.296	-0.654	-0.146						
Tot Alk	-0.415	-0.364	-0.730	-0.186	0.741	-0.017	-0.490					
Tot Hard	0.174	0.248	-0.022	0.297	0.302	0.195	-0.643	0.608				
E. Cond	-0.286	-0.189	-0.442	0.185	0.677	0.263	-0.714	0.865	0.880			
Tot. dis mat.	-0.286	-0.191	-0.448	0.178	0.678	0.262	-0.705	0.867	0.877	1.000		
P. Plankton	-0.115	-0.209	0.039	0.885	0.222	0.629	-0.530	0.175	0.567	0.530	0.526	
Benthos	0.225	-0.015	0.002	-0.196	-0.320	-0.152	0.611	-0.325	-0.304	-0.349	-0.336	-0.133

critical value at 5% level = 0.666
critical value at 1% level = 0.798

TABLE 1F: CORRELATION BETWEEN VARIABLES IN RESPECT TO ALL STATIONS COMBINED

	A temp.	W s. temp.	W d. temp.	velocity	Transp.	PH.	D.O	Tot. Alk.	Tot. hard	E. Cond.	Tot. dis. mat.	P.plankton
Wat sur. temp	0.791											
wat depth temp	0.835	0.900										
velocity	0.560	0.539	0.389									
Transp	-0.698	-0.616	-0.515	-0.179								
PH	0.911	0.342	0,101	0.696	-0.029							
D.O.	-0.066	-0.048	-0,123	0.065	-0.426	0.223						
Tot Alk	-0.507	-0.723	-0.763	-0.191	0.561	0.026	-0.370					
Tot Hard	-0.577	-0.500	-0.627	-0.447	0.491	-0.118	-0.554	0.800				
E. Cond	-0.107	-0.165	-0.281	0.089	0.408	0.176	-0.742	0.767	0.796			
Tot. dis mat.	-0.358	-0.228	-0,411	-0.038	0.524	0.157	-0.682	0.720	0.891	0.933		
P. Plankton	0.340	0.333	0,107	0.676	0.169	0.539	-0.508	0.424	0.256	0.775	0.610	
Benthos	0.252	-0.030	0,010	0.030	-0.393	-0.190	0.509	-0.162	-0.322	-0.292	-0.359	-0.118

critical value at 5% level = 0.666
critical value at 1% level = 0.798

The mean monthly variations in water surface temperature for all the stations are presented on Fig 2 while Table 2A represents the dry and the rainy season means. The lowest and the highest temperatures were recorded in March (19.66°C) and September (24.°C) respectively. Analysis of variance (Table 2B) shows significant difference only between stations ($P < 0.05$). Correlation coefficient analysis for all parameters over all stations combined (Table 1F) reveals a high significant positive correlation between water surface temperature and water depth temperature but a significant negative correlation between total alkalinity.

The mean monthly variation in water depth temperature for all the stations are presented on Fig 3 while Table 3A represents the dry and rainy season means. The lowest and the highest temperatures were recorded in March (18.33°C) and October (25.5°C) respectively. Analysis of variance (Table 3B) shows a highly significant variation between months and between seasons ($P < 0.01$). Correlation Tables 1C - F reveal insignificant negative correlation between water depth temperature with dissolved oxygen at stations 1, 2 and all stations combined but an insignificant positive correlation existed between it and total alkalinity at station 2; and with total hardness at station 1.

4.1.2 VELOCITY

Fig 3 and Table 4A show the mean monthly and seasonal variations in velocity of river Kubanni. The figure exhibits two velocity maxima with the highest (0.42m/sec) in May while

TABLE 2A: SEASONAL VARIATION IN WATER SURFACE TEMPERATURE FOR STATIONS ON A STRETCH OF RIVER KUBANNI

	STATIONS			
		1	2	3	S.E.D
General Station $\overline{X}$ °C		21.31	23.19	23.87	
Dry Season $\overline{X}$ °C	23.33				
Rainy Season $\overline{X}$ °C	23.25				
S.E.D. between two means for months					1.04
S.E.D. between two means for stations					0.90
S.E.D. between two means for seasons					0.73
S.E.D. between two means for stations by seasons					1.27

TABLE 2B: ANALYSIS OF VARIANCE (ANOVA) FOR WATER SURFACE TEMPERATURE

Source of Variation	D.F	Sum of Squares	Means of Squares	F ration	SIGN
Months	3	21.125	7.0417	2.16	NS
Stations	2	28.146	14.073	4.31	X
Seasons	1	5.0417	5.0417	1.54	NS
Stations by seasons	2	5.1458	2.5729	0.79	NS
Months Stations by seasons	15	49.000	3.2667		
Total	23	108.46			

XX = highly significant ($P < 0.01$)
X = significant ($P < 0.05$)
NS = not significant ($P > 0.05$)

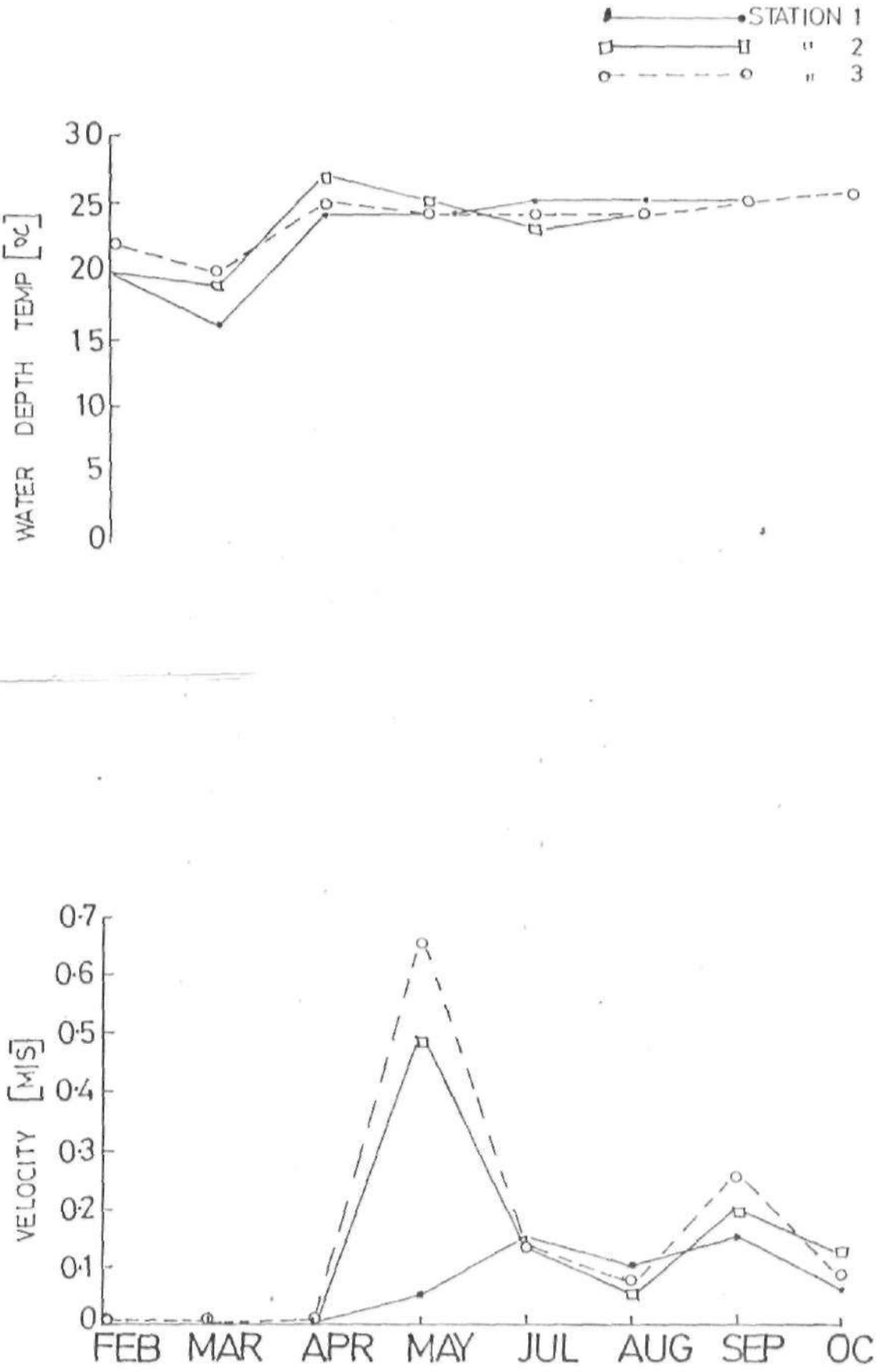


FIG3: MONTHLY VARIATIONS IN VELOCITY AND WATER DEPTH TEMPERATURE OF STATIONS ON A STRETCH OF RIVER KUBANNI

TABLE 3A: SEASONAL VARIATION IN WATER DEPTH TEMPERATURE FOR STATION ON A STRETCH OF RIVER KUBANNI

	STATIONS			
	1	2	3	S.E.D.
General Station $\bar{X}$ °C	23.06	23.56	23.69	
Dry Season $\bar{X}$ °C	22.17			
Rainy Season $\bar{X}$ °C	24.71			
S.E.D. between two means for months				0.99
S.E.D. between two means for stations				0.85
S.E.D. between two means for seasons				0.70
S.E.D. between two means for stations by seasons				1.21

TABLE 3B: ANALYSIS OF VARIANCE (ANOVA) FOR WATER DEPTH TEMPERATURE

Source of Variation	D.F	Sum of Squares	Mean of Squares	F ration	SIGN
Months	3	64.95	21.65	7.36	XX
Stations	2	1.75	0.88	0.30	NS
Seasons	1	38.76	38.76	13.18	XX
Stations by seasons	2	7.58	3.79	1.29	NS
Months by stations by seasons	15	44.12	2.94		
Total	23	157.16			

XX = highly significant ($P < 0.01$)
X = significant ($P < 0.05$)
NS = not significant ($P > 0.05$)

the second peak (0.20 m/sec) was in September. The minimum velocity (3.7×10^{-3} m/sec and 1.7×10^{-3} m/sec respectively) were obtained in February and March. The velocity was higher in the rainy season (0.13 m/sec) than the dry season (0.10 m/sec) (Table 4A).

Analysis of variance (Table 4B) reveals no significant variation in velocity. Correlation coefficient analysis (Table 1F) reveals significant positive correlation ($P < 0.05$) and insignificant positive correlation of velocity with phytoplankton and benthic fauna respectively. The correlation of velocity and conductivity was highly positively significant. At station 2 (Table 1D), velocity correlated negatively but insignificantly with benthic fauna and dissolved matter. At station 1 (Table 1C), there was a highly significant negative correlation between velocity and total hardness. The correlation between velocity and phytoplankton, benthic fauna and dissolved matter are negative and insignificant. However, at station 3, there was a significant positive correlation between velocity and pH.

4.1.3 TRANSPARENCY (SECCHI DEPTH)

The seasonal variation and monthly mean ranges of transparency on the stretch of river Kubanni, are presented in Table 5A and Fig 4. Station 2 is the most transparent (0.25m) while station 1 was the most turbid (0.15m) during the study period.

TABLE 4A: SEASONAL VARIATION IN VELOCITY FOR STATIONS ON A STRETCH OF RIVER KUBANNI

	STATIONS			
	1	2	3	S.E.D
General Station $\bar{X}$ m/sec	0.06	0.12	0.15	
Dry Season $\bar{X}$ (M/sec) 0.10				
Rainy Season $\bar{X}$ (M/sec) 0.13				
S.E.D. between two means for months				0.09
S.E.D. between two means for station				0.08
S.E.D. between two means for seasons				0.06
S.E.D. between two means for stations by seasons				0.11

TABLE 4B: ANALYSIS OF VARIANCE (ANOVA) FOR WATER VELOCITY

Source of Variation	D.F.	Sum of Squares	Mean of Squares	F ratio	SIGN
Months	3	0.1488	0.04962	1.85	NS
Stations	2	0.0317	0.01588	0.59	NS
Seasons	1	0.003	0.00303	0.11	NS
Stations by Seasons	2	0.0187	0.00938	0.35	NS
Months by stations by seasons	15	0.4022	0.0268		
Total	23	0.6047			

XX = highly significant ($P < 0.01$)
X = significant ($P < 0.05$)
NS = not significant ($P > 0.05$)

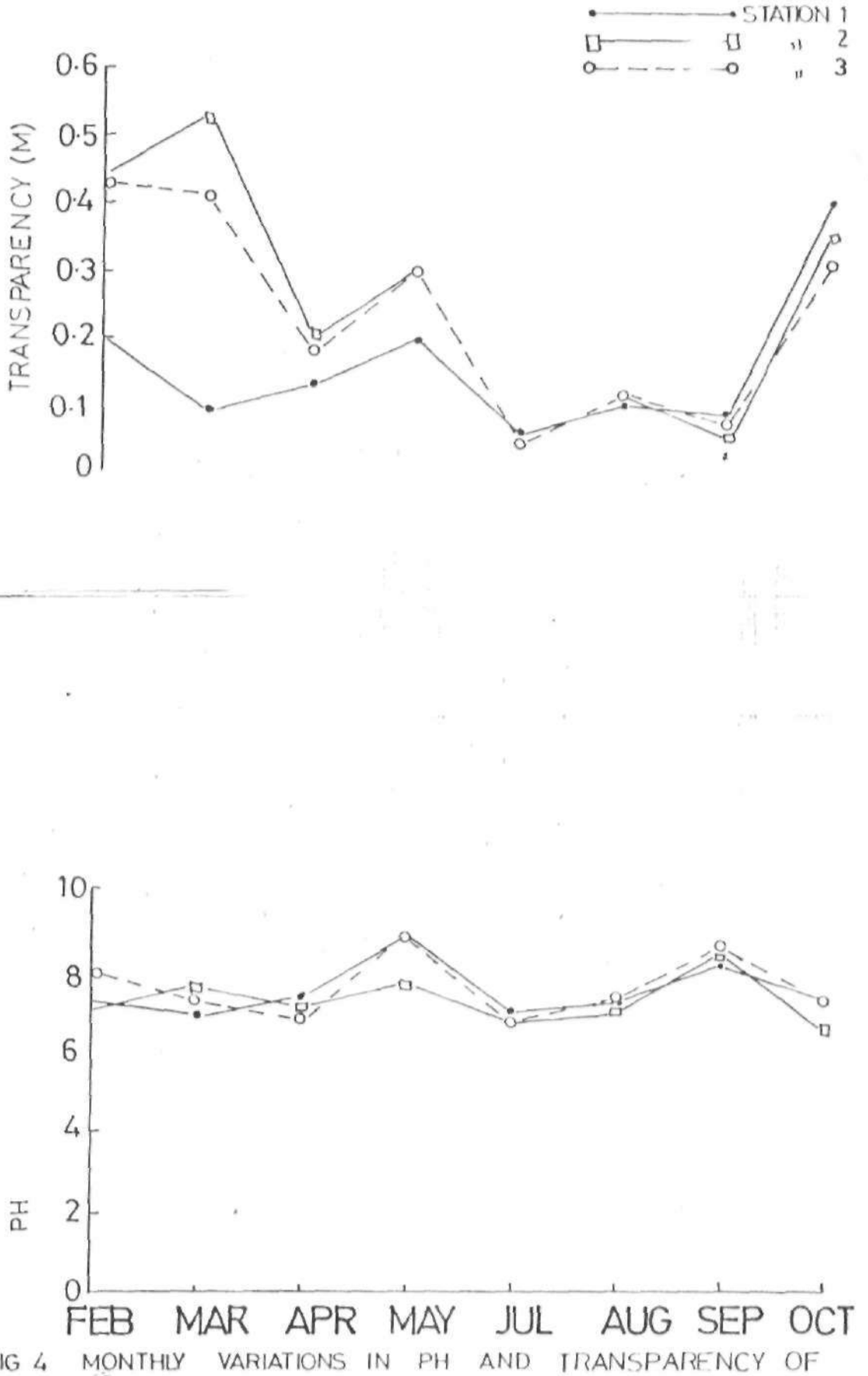


FIG 4 MONTHLY VARIATIONS IN PH AND TRANSPARENCY OF STATIONS ON A STRETCH OF RIVER KUBANNI

TABLE 5A: SEASONAL VARIATION IN TRANSPARENCY FOR STATIONS ON A STRETCH OF RIVER KUBANNI

	STATIONS			
	1	2	3	S.E.D
General Station $\bar{X}$ m	0.15	0.25	0.23	
Dry Season $\bar{X}$ m 0.28				
Rainy Season $\bar{X}$ m 0.14				
S.E.D. between two means for months				0.06
S.E.D. between two means for stations				0.05
S.E.D. between two means for seasons				0.04
S.E.D. between two means for station by seasons				0.07

TABLE 5B: ANALYSIS OF VARIANCE (ANOVA) FOR TRANSPARENCY

Source of Variation	D.F.	Sum of Squares	Mean of Squares	F ration	SIGN
Months	3	0.112	0.0373	2.98	NS
Stations	2	0.0409	0.0204	1.68	NS
Seasons	1	0.1204	0.1204	9.60	XX
Station by seasons	2	0.0634	0.0317	2.53	NS
Months by stations by seasons	15	0.1881	0.0125		
Total	23	0.5249			

XX = highly significant ($P < 0.01$)
X = significant ($P < 0.05$)
NS = not significant ($P > 0.05$)

Highly significant variation existed between seasons ($P < 0.01$) (Table 5B). Correlation of transparency with benthic fauna (Tables 1C - F) show insignificant negative correlation in all the stations including the combined station but insignificant positive correlation with phytoplankton in station 2,3 and all stations combined. At stations 2 and 3 (Tables 1D & F), there was significant positive correlation between velocity and total alkalinity, total hardness (station 2 only), conductivity and dissolved matter unlike stations 1 and all the stations combined. Transparency and dissolved oxygen show insignificant negative correlation at stations 1, 2 and all stations combined but significant negative correlation at station 3.

4.1.4 WATER PH

The mean monthly and seasonal variations of water pH of the stretch of river Kubanni are presented on Fig 4 and Table 6A respectively. In both seasons, pH remained about neutral, 7.48 and 7.24 for dry and rainy seasons respectively.

Analysis of variance (Table 6B) reveals no significant variation in pH. Similarly, at station 1 (Table 1C), correlation coefficient analysis between pH and other physico-chemical characteristics reveal an insignificant positive correlation of pH with all the parameters except total hardness which shows an insignificant negative correlation. Station 2 (Table 1D) reveals a similar pattern except with the benthic fauna which shows an insignificant negative

TABLE 6A: SEASONAL VARIATION IN PH FOR STATIONS ON A STRETCH OF RIVER KUBANNI

	STATIONS			
	1	2	3	S.E.D
General Station $\bar{X}$	7.39	7.18	7.50	
Dry Season $\bar{X}$ 7.48				
Rainy Season $\bar{X}$ 7.24				
S.E.D. between two means for months				0.42
S.E.D. between two means for stations				0.36
S.E.D. between two means for seasons				0.29
S.E.D. between two means for station by seasons				0.51

TABLE 6B: ANALYSIS OF VARIANCE (ANOVA) FOR PH

Source of Variation	D.F.	Sum of Squares	Mean of Squares	F ratio	SIGN
Months	3	1.9967	0.6655	1.25	NS
Station	2	0.4336	0.2168	0.41	NS
Seasons	1	0.3361	0.3361	0.63	NS
Stations by seasons	2	0.0095	0.0475	0.01	NS
Months by stations by seasons	15	7.9769	0.5317		
Total	23	10.753			

XX = highly significant ($P < 0.01$)
X = significant ($P < 0.05$)
NS = not significant ($P > 0.05$)

correlation. However, at station 3 (Table 1E), there is a significant positive correlation ($P < 0.05$) between pH and phytoplankton while for all stations combined (Table 1F) no significant correlation with any parameter was observed.

4.1.5 DISSOLVED OXYGEN

The mean monthly and seasonal variation in dissolved oxygen (D.O) are presented on Fig 5 and Table 7A respectively. The DO fluctuated between 0.45 and 9.0mgl^{-1} during the study period. The mean seasonal variation for the seasons (Table 7A) shows a higher dissolved oxygen concentration during the rainy season than the dry season (6.22 mgl^{-1} and 4.82mgl^{-1} respectively). The mean monthly lowest value irrespective of sampling station was obtained in April (3.33mgl^{-1}). Among the sampling stations, the DO varied between 4.25 and 7.08mgl^{-1} (stations 2 and 1 respectively) while 5.24 mgl^{-1} least value was recorded in station 3.

Analysis of variance (Table 7B) reveals a highly significant variation in DO between stations by seasons ($P < 0.01$) and significant variation between seasons ($P < 0.05$). Table 1D shows high significant negative correlation between DO and conductivity and dissolved matter while with phytoplankton, the correlation is negative but significant. Positive significant correlation was observed between DO and benthic fauna. Also in station 3 (Table 1E), there was a significant positive correlation between DO and benthic fauna.

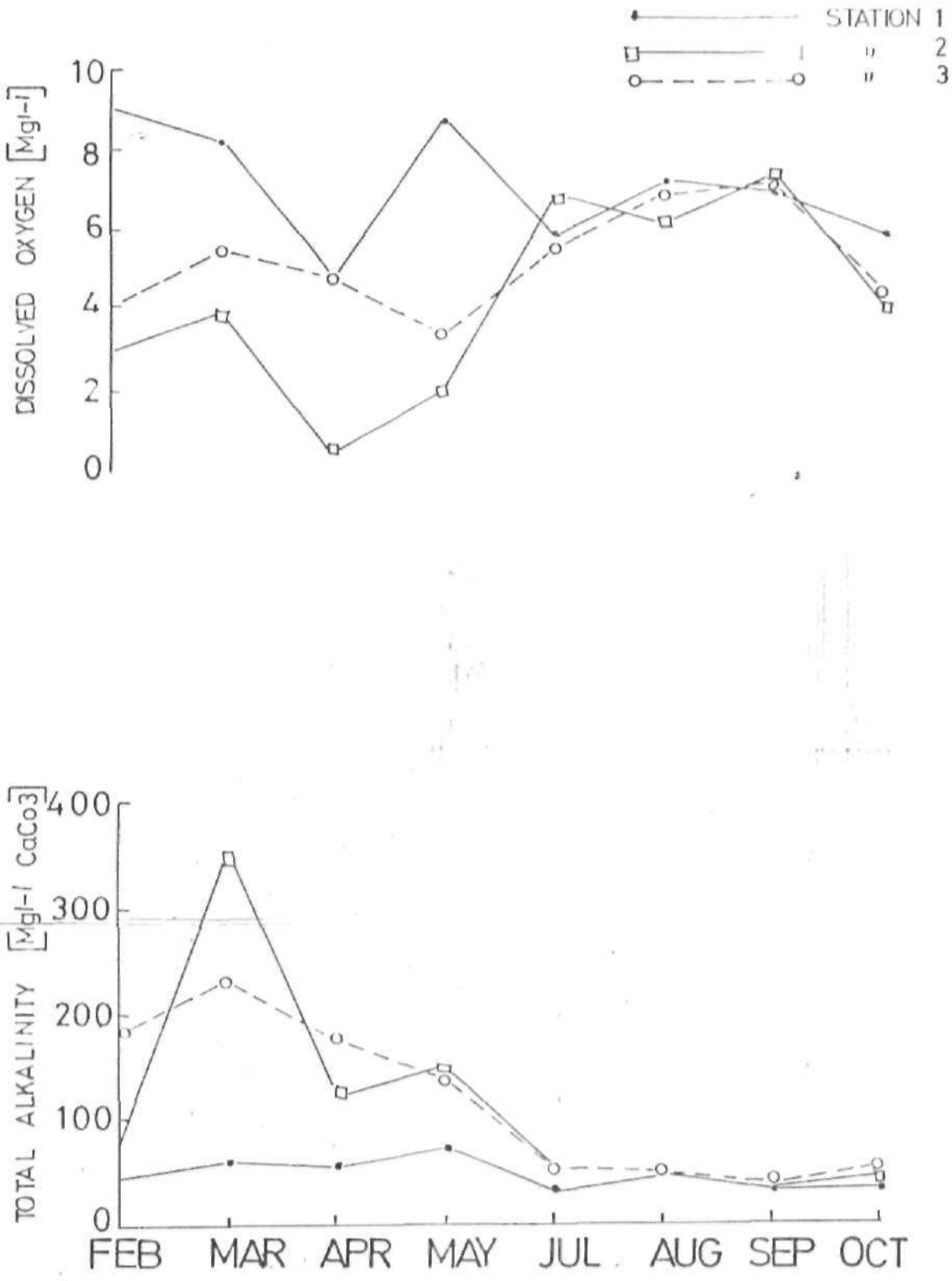


FIG5 MONTHLY VARIATIONS IN TOTAL ALKALINITY AND DISSOLVED OXYGEN OF STATIONS ON A STRETCH OF RIVER KUBANNI

TABLE 7A: SEASONAL VARIATION IN DISSOLVED OXYGEN FOR ALL STATIONS ON A STRETCH OF RIVER KUBANNI

	STATIONS			
	1	2	3	S.E.D
General Station $\bar{X}$ (Mgl^{-1})	7.08	4.25	5.24	
Dry Season $\bar{X}$ (Mgl^{-1}) 4.82				
Rainy Season $\bar{X}$ (Mgl^{-1}) 6.22				
S.E.D. between two means for months				0.75
S.E.D. between two means for stations				0.64
S.E.D. between two means for seasons				0.53
S.E.D. between two means for stations by seasons				0.91

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

Source of Variation	D.F.	Sum of Squares	Mean of Squares	F ratio	SIGN
Months	3	7.9377	2.6459	1.57	NS
Stations	2	33.175	16.587	9.82	XX
Seasons	1	11.816	11.816	7.00	XX
Stations by seasons	2	24.85	12.425	7.36	XX
Months by stations by seasons	15	25.32	1.6886		
Total	23	103.11			

XX = highly significant ($P < 0.01$)
X = significant ($P < 0.05$)
NS = not significant ($P > 0.05$)

4.1.6 TOTAL ALKALINITY

Total alkalinity varied between 29.0 mgl^{-1} $CaCO_3$ and 354mgl^{-1} $CaCO_3$ (Fig 5). The mean total alkalinity during the dry season was 137.04 mgl^{-1} $CaCO_3$ while that of the rainy season was 40.87 mgl^{-1} $CaCO_3$ (Table 8A). The mean total alkanlinity increased from station 1 (45.31 mgl^{-1} $CaCO_3$) to the highest value of 112.7 mgl^{-1} $CaCO_3$ at station 3.

Highly significant variation existed between seasons ($P < 0.01$) (Table 8A). Also, there was significant variation ($P < 0.05$) between stations. Correlation coefficient analysis with respect to other physico-chemical parameters (Tables 1C - F) reveal a highly significant positive correlation of total alkalinity with total hardness for all stations combined, positive significant correlation at station 2 while it correlated positively, but insignificantly with total hardness at stations 1 and 3. However, at station 1, there was a highly significant positive correlation between total alkalinity and phytoplankton.

4.1.7 TOTAL HARDNESS

The seasonal variation and mean monthly ranges of water hardness for the stations of the stretch of river Kubanni are presented in Table 9A and Fig 6 respectively. During the study period, most of the water hardness values obtained were below 120 mgl^{-1} $CaCO_3$. Higher water hardness values were recorded in the dry season than the rainy season. Thus, the dry and rainy season means are 199.9 and ~~$CaCO_3$~~ 70.5 mgl^{-1} $CaCO_3$

TABLE 8A: SEASONAL VARIATION IN TOTAL ALKALINITY FOR STATIONS ON A STRETCH OF RIVER KUBANNI

	STATIONS			
	1	2	3	S.E.D
General $\overline{X}$ (Mgl^{-1} $CaCO_3$)	45.37	108.8	112.7	
Dry Season $\overline{X}$ (Mgl^{-1} $CaCO_3$) 137.04				
Rainy Season $\overline{X}$ (Mgl^{-1} $CaCO_3$) 40.87				
S.E.D. between two means for months				28.63
S.E.D. between two means for stations				24.79
S.E.D. between two means for seasons				20.24
S.E.D. between two means for stations by seasons				35.06

TABLE 8B: ANALYSIS OF VARIANCE (ANOVA) FOR TOTAL ALKALINITY

Source of Variation	D.F.	Sum of Squares	Mean of Squares	F ratio	SIGN
Months	3	13833	4611.0	1.88	NS
Stations	2	22854	11427	4.65	X
Seasons	1	55488	55488	22.57	XX
Stations by seasons	2	16397	8198.6	3.33	NS
Months by stations by seasons	15	36880	2458.7		
Total	23	145450			

XX = highly significant ($P < 0.01$)
X = significant ($P < 0.05$)
NS = not significant ($P > 0.05$)

TABLE 9A: SEASONAL VARIATION IN TOTAL HARDNESS FOR STATION ON A STRETCH OF RIVER KUBANNI

	STATIONS			
	1	2	3	S.E.D
General Station $\bar{X}$ (Mgl^{-1} $CaCO_3$)	107.3	165.2	133.0	
Dry Season $\bar{X}$ (Mgl^{-1} $CaCO_3$)	199.9			
Rainy Season $\bar{X}$ (Mgl^{-1} $CaCO_3$)	70.5			
S.E.D. between two means for months				35.59
S.E.D. between two means for stations				30.83
S.E.D. between two means for seasons				25.17
S.E.D. between two means for stations by seasons				43.59

TABLE 9B: ANALYSIS OF VARIANCE (ANOVA) FOR TOTAL HARDNESS

Source of Variation	D.F	Sum of Squares	Mean of Squares	F ratio	SIGN
Months	3	13066	4355.3	1.15	NS
Stations	2	13476	6737.8	1.77	NS
Seasons	1	100450	100540	26.43	XX
Stations by seasons	2	9798.7	4899.3	1.29	NS
Months by stations by seasons	15	57012	3800.8		
Total	23	193800			

XX = highly significant ($P < 0.01$)
X = significant ($P < 0.05$)
NS = not significant ($P > 0.05$)

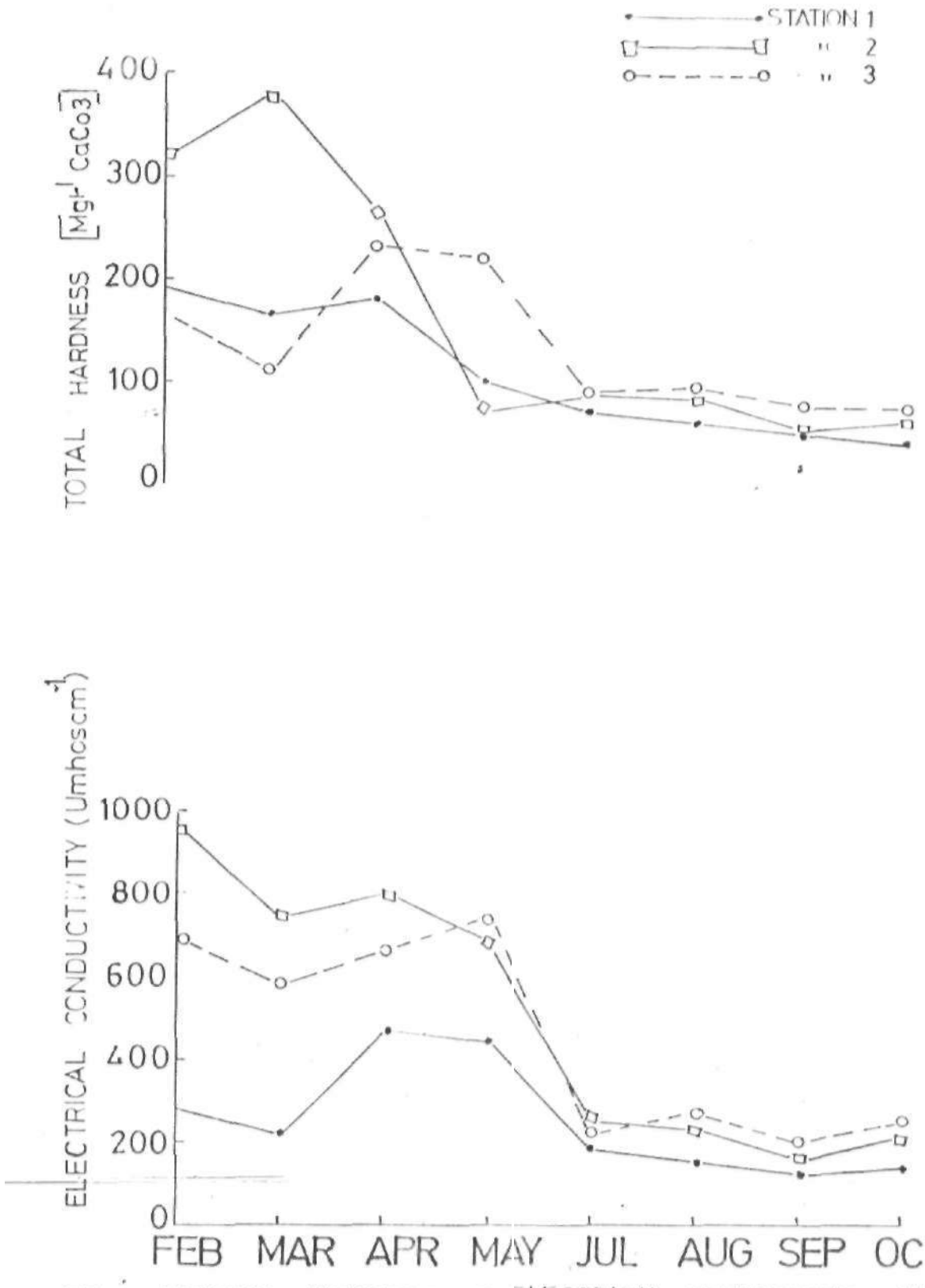


FIG 6 MONTHLY VARIATIONS IN ELECTRICAL CONDUCTIVITY AND TOTAL HARDNESS OF STATIONS ON A STRETCH OF RIVER KUBANNI.

respectively (Table 9A). Mean total water hardness among the stations is in this order: station 1 < station 3 < station 2.

Analysis of variance (Table 9B) reveals a highly significant variation between seasons. Tables 1C - F reveal highly significant positive correlation between total hardness and conductivity and dissolved matter at stations 2, 3 and the combined station.

4.1.8 ELECTRICAL CONDUCTIVITY

Fig 6 and Table 10A show the mean monthly and seasonal variation in electrical conductivity of stations on the stretch of river Kubanni respectively. Conductivity was generally higher in the dry season than in the rainy season. The lowest value of 120.00 umhos cm^{-1} was obtained in station 1 in August while the highest conductivity (960 umhos cm^{-1}) was recorded at station 2 in February. The mean conductance at station 1 was lowest (249.4 umhos cm^{-1}) while station 2 recorded the highest conductance (503.1 umhos cm^{-1}).

Analysis of variance (Table 10B) reveals a highly significant variation between stations, seasons and stations by seasons ($P < 0.05$). Tables 1C - F reveal perfect correlation (correlation coefficient close to or equal to 1) between conductivity and dissolved matter in all the different stations. In station 1, there is high significant positive correlation between conductivity and phytoplankton but insignificant positive correlation with benthic fauna. In station 2, there is a positive but insignificant and

TABLE 10A: SEASONAL VARIATION IN ELECTRICAL CONDUCTIVITY FOR STATIONS OF A STRETCH OF RIVER KUBANNI

	STATIONS			
	1	2	3	S.E.D
General Station $\bar{X}$ (umhos cm^{-1})	249.4	503.1	451.2	
Dry Season $\bar{X}$ (umhos cm^{-1})	604.6			
Rainy Season $\bar{X}$ (umhos cm^{-1})	197.9			
S.E.D. between two means for months				46.84
S.E.D. between two means for stations				40.56
S.E.D. between two means for seasons				33.12
S.E.D. between two means for stations by seasons				57.36

TABLE 10B: ANALYSIS OF VARIANCE (ANOVA) FOR ELECTRICAL CONDUCTIVITY

Source of Variation	D.F.	Sum of Squares	Mean of Squares	F ratio	SIGN
Months	3	13671	4556.9	0.69	NS
Stations	2	287560	143780	21.85	XX
Seasons	1	992270	992270	150.77	XX
Stations by seasons	2	146400	73201	11.12	XX
Months by station by seasons	15	98717	6581.1		
Total	23	1538600	6581.1		

XX = highly significant ($P < 0.01$)
X = significant ($P < 0.05$)
NS = not significant ($P > 0.05$)

significant negative correlation with phytoplankton and benthic fauna respectively. However, in station 3, the relationship of conductivity with phytoplankton and benthic fauna are insignificant.

4.1.9 TOTAL DISSOLVED MATTER

The results show that there was higher dissolved matter in dry season than the rainy season (Table 11A). The mean magnitude variation of dissolved matter along the stations during the study period is in the following increasing order; station 1 < station 3 < station 2. From the graphical representation in Fig 7, the total dissolved matter decreased with an increased volume of the river water.

Analysis of variance (Table 11B) reveals a highly significant variation between stations, seasons and stations by seasons ($P < 0.05$). Correlation coefficient analysis with respect to other physico-chemical and biological parameters (Tables 1C - F) reveal a highly significant positive correlation between total dissolved matter with phytoplankton at station 1 but significant negative correlation with benthic fauna at station 2.

4.2 TRACE ELEMENT CONCENTRATION IN WATER AND FISH

The concentration in water, of each of the elments, Cu, Pb, and Zn was higher in the dry season than in the rainy season (Fig 8). Copper is predominant at station 1 in both seasons while lead predominates in station 2.

TABLE 11A: SEASONAL VARIATION IN TOTAL DISSOLVED MATTER FOR STATIONS ON A STRETCH OF RIVER KUBANNI

	STATIONS			
	1	2	3	S.E.D
General Station $\bar{X}$ (Mgl^{-1})	160	320	290	
Dry Season $\bar{X}$ (Mgl^{-1})	390			
Rainy Season $\bar{X}$ (Mgl^{-1})	120			
S.E.D. between two means for months				30
S.E.D. between two means for stations				20
S.E.D. between two means for seasons				20
S.E.D. between two means for station by seasons				30

TABLE 11B: ANALYSIS OF VARIANCE (ANOVA) FOR TOTAL DISSOLVED MATTER

Source of Variation	D.F.	Sum of Squares	Mean of Squares	F ratio	SIGN
Months	3	5.10	1.69	0.59	NS
Stations	2	118.3	59.1	20.56	XX
Seasons	1	418.7	418.7	145.57	XX
Stations by seasons	2	61.0	30.5	10.61	XX
Months by stations by seasons	15	431.4	2.8		
Total	23	646.2			

XX = highly significant ($P < 0.01$)
X = significant ($P < 0.05$)
NS = not significant ($P > 0.05$)

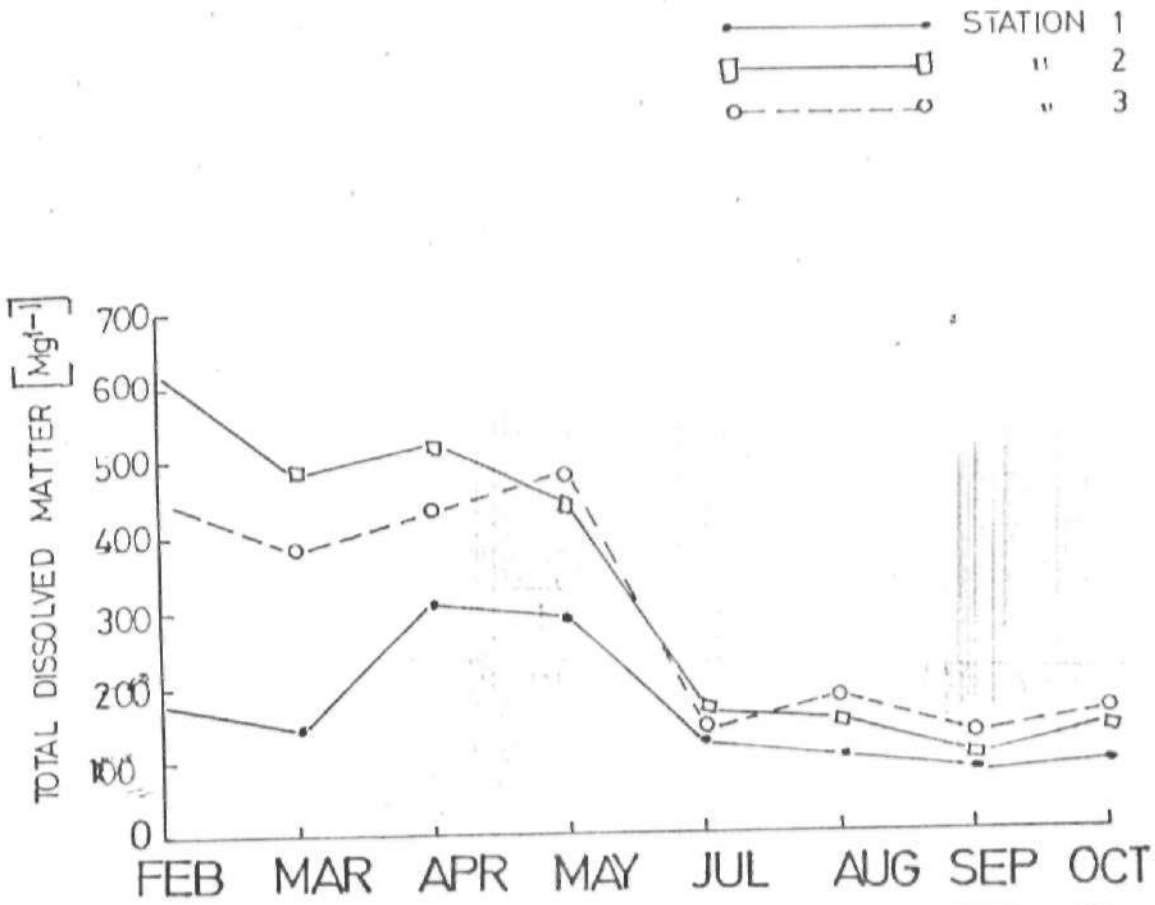


FIG 7 MONTHLY VARIATIONS IN TOTAL DISSOLVED MATTER OF STATIONS ON A STRETCH OF RIVER KUBANNI

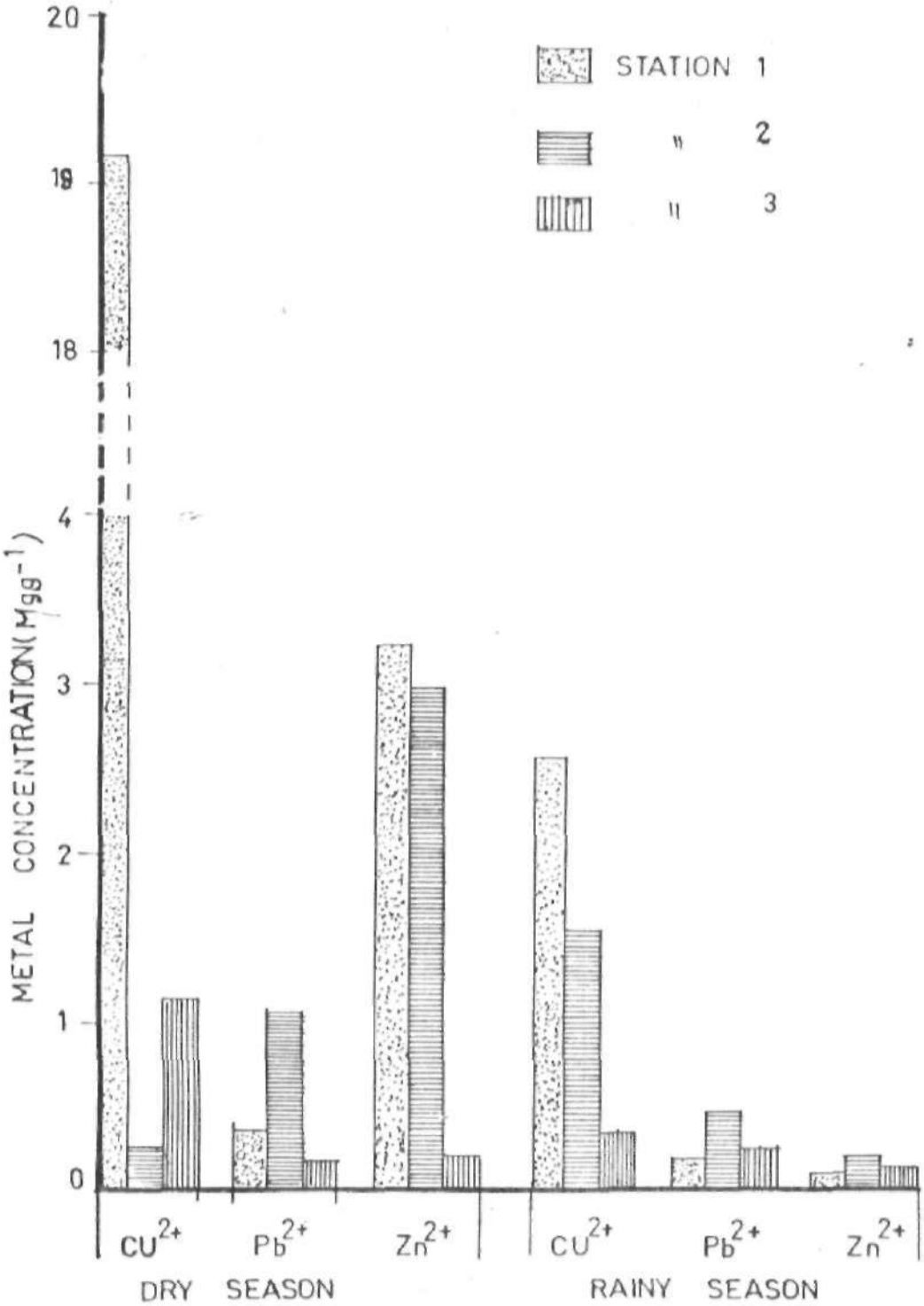


FIG:8 SEASONAL VARIATION IN SOME TRACE METAL CONCENTRATION FOR WATER OF SAMPLING STATION ON A STRETCH OF RIVER KUBANNI

Correlation coefficient analysis of the element concentration in water and fish tissue (Table 12) reveals a significant positive and positive insignificant correlation for lead and Zinc respectively and an insignificant negative correlation for copper.

Seasonal variation of some trace elements in Clarias, Tilapia and Alestes from the stretch of river Kubanni is shown on Fig 9. The accumulation of Zinc and lead by all the three fishes were higher in the dry than during the rainy season. Copper concentration in Alestes followed a similar pattern, however, Clarias and Tilapia accumulated more copper in the rainy season than in the dry season. The bioaccumulation of zinc by all the three fishes were generally high while that of lead was low.

Correlation coefficient analysis of the element concentration in water and fish tissue (Table 12) reveals an insignificant positive correlation between the copper present in the fish tissues and the lead and zinc accumulated in the fish. Also the lead in the fish tissues correlated positively but insignificant with zinc in the fish tissue.

4.3 BIOLOGICAL CHARACTERISTICS

4.3.1 PHYTOPLANKTON COMPOSITION

The dominant phytoplankton groups found in the river were Chrysophyta, Chlorophyta, Cyanophyta and Euglenophyta while pyrrophyta occured in small numbers (Fig 10). The individual species that make up the various groups are presented in

TABLE 12: CORRELATION BETWEEN TRACE METAL CONCENTRATION IN WATER AND IN FISH TISSUES

	Wat Cu.	Wat Pb.	Wat Zn.	Fish Tis Cu.	Fish Tis Pb.
Wat Pb.	-0.183				
Wat Zn	0.631	0.611			
Fish Tis Cu	-0.267	0.126	-0.293		
Fish Tis Pb	0.209	0.809	0.569	0.539	
Fish Tis Zn	0.506	0.222	0.604	0.144	0.561

critical value at 5% level = 0.796
critical value at 1% level = 0.874

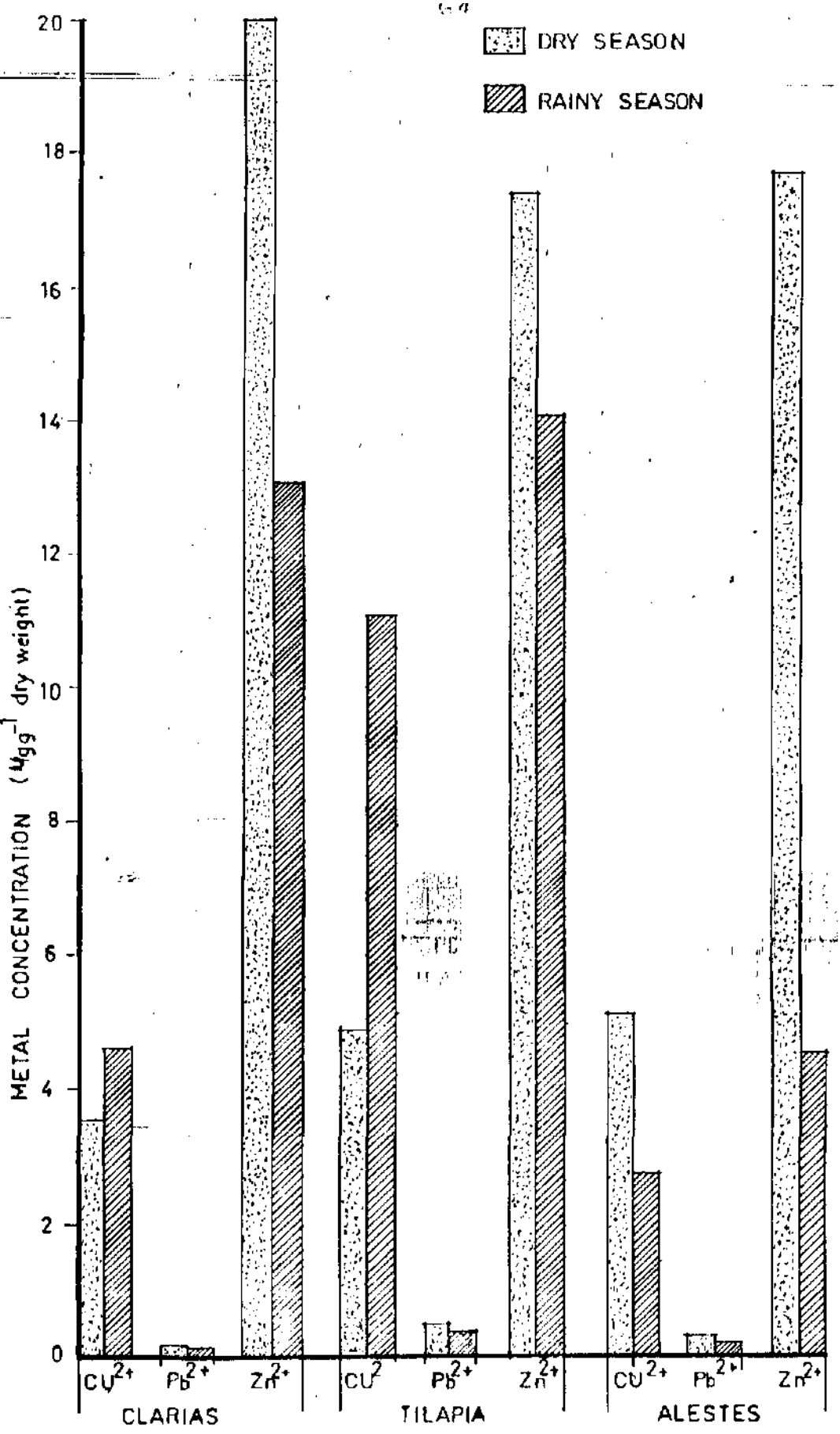


FIG. 9: SEASONAL VARIATION OF SOME TRACE METAL CONCENTRATION IN SOME FISH ON A STRETCH OF RIVER KUBANNI

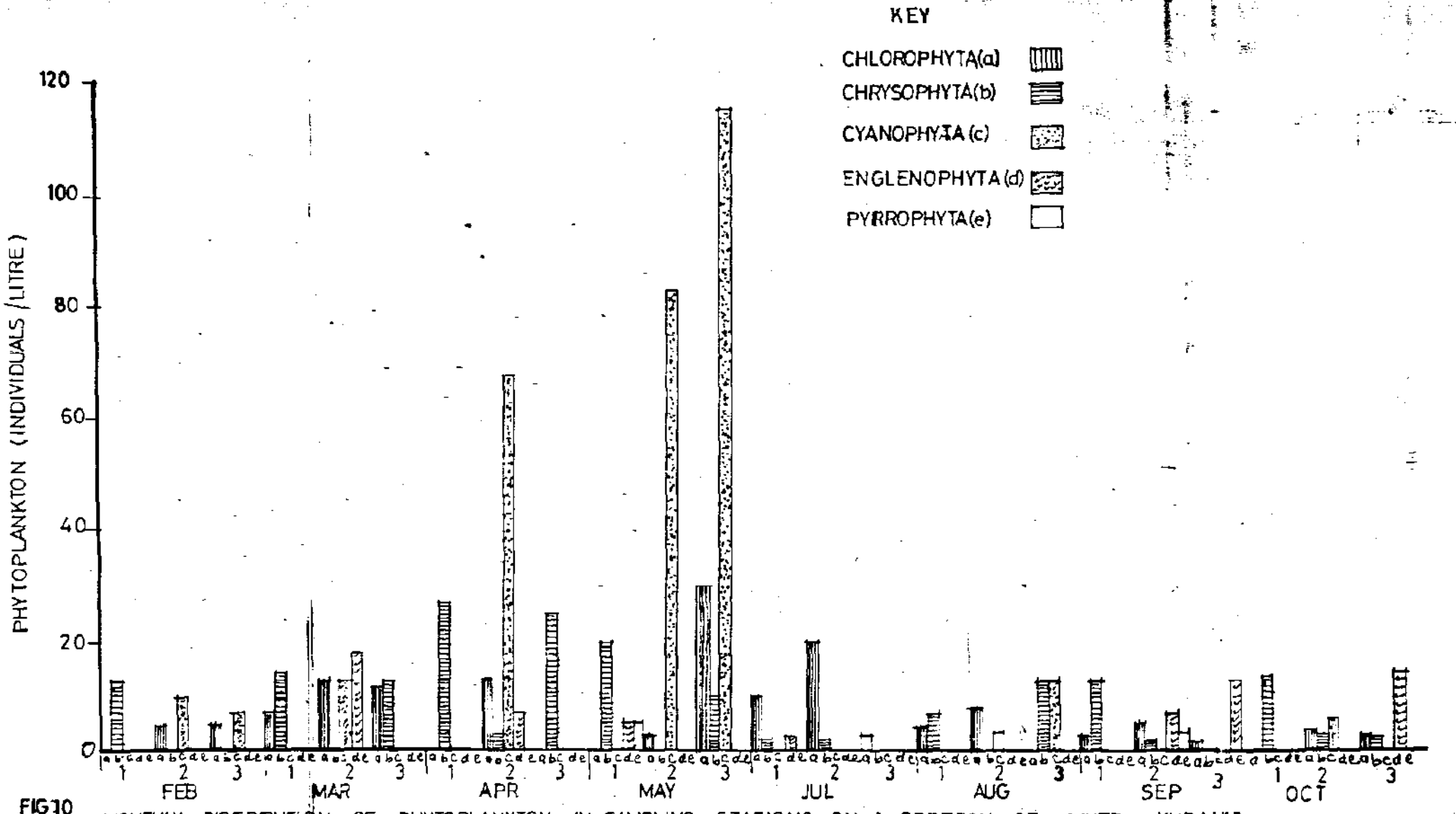


FIG 10 MONTHLY DISTRIBUTION OF PHYTOPLANKTON IN SAMPLING STATIONS ON A STRETCH OF RIVER KUBANNI-

appendix 1. Some species of interest include Cyclotella spp, Sphaerocystis sp, Ulothrix spp, Oscillatoria spp, Melosira spp, Navicula spp, Fragilaria spp, Closterium spp, Tabellaria spp etc. Cyanophyta were completely absent from station 1 but were abundant in stations 2 and 3. Chrysophyta wre more abundant in station 1 and 3 than at station 2 (Fig 10). Fig 11 shows that the three stations had their peak towards the end of the dry season. Generally, there were more phytoplankters in the dry season than during the rainy season. The phytoplankton population density in the stations is in the order: station 1 < stations 3 < station 2 (Table 13A).

Analysis of variance (Table 13B) reveals a significant variation of phytoplankton between seasons ($P < 0.05$). Correlation coefficient analysis for phytoplankton against other parameters (Tables 1C - F) show an insignificant positive correlation between phytoplankton and benthic fauna in station 1 but an insignificant negative correlation in stations 2, 3 and all the stations combined.

4.3.2 BENTHIC FAUNA

The dominant benthic group encountered in the study include Coleoptera, Diptera (larva) Ephemeroptera, Hemiptera, Nematoda, Odonata (nymph) and pulmonata. Other minor groups include Amphibian (Tadpole), Ciliophora, cladocera, Hirudinae, Lepidoptera, Nemata, Neuroptera (Larva), Nostostraca, Oligochacta, pisces, plecoptera, prosobranchia, Rotifera and Trichoptera (Fig 12). The individual species composition of the various groups are presented in appendix 2. Some benthic species collected include Lymnaea spp, culex spp, Nais spp,

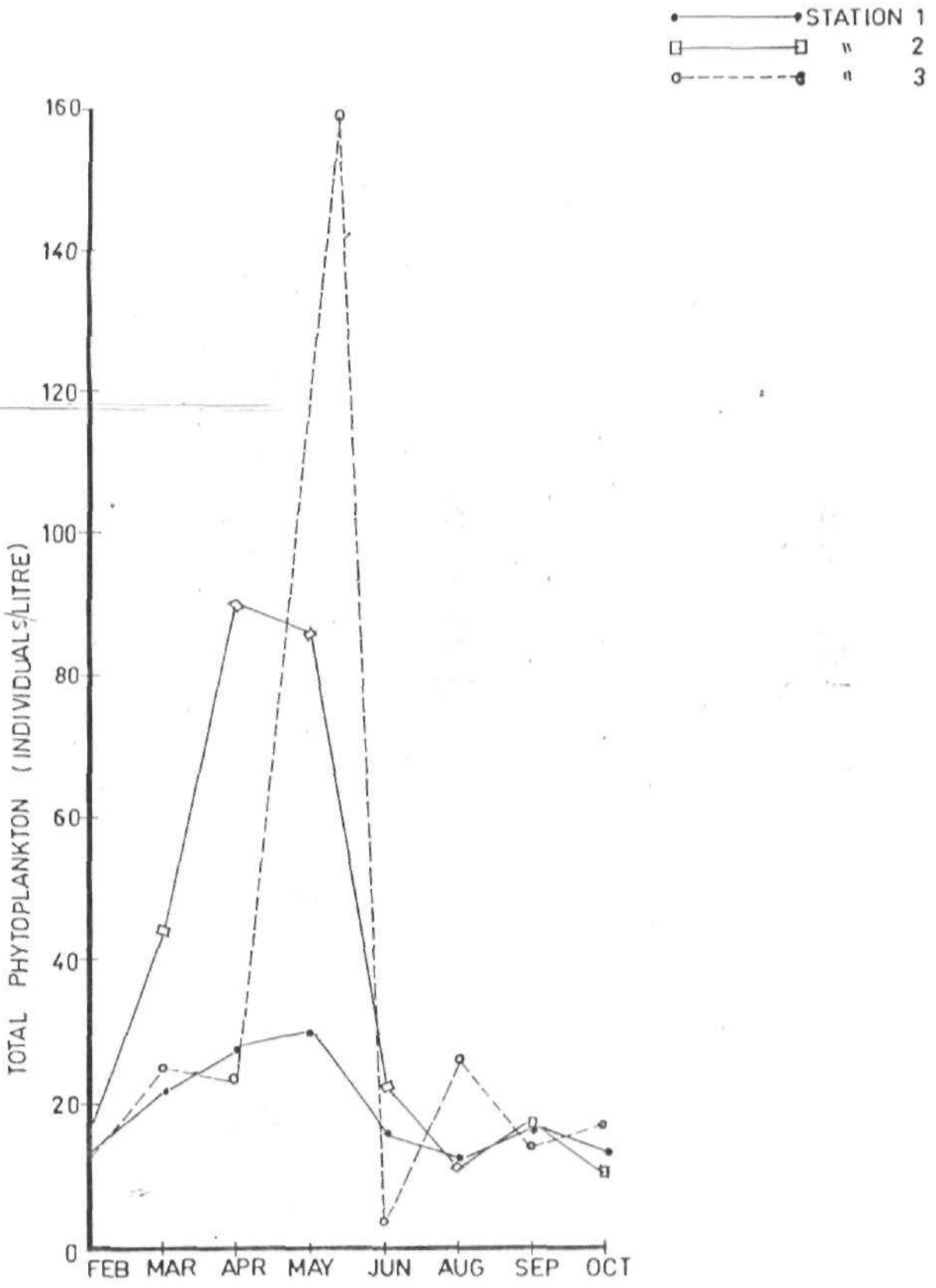


FIG.11 MONTHLY VARIATION OF TOTAL PHYTOPLANKTON ON A STRETCH OF RIVER KUBANNI

TABLE 13A: SEASONAL VARIATION OF PHYTOPLANKTON FOR STATIONS ON A STRETCH OF RIVER KUBANNI

	STATIONS			
	1	2	3	S.E.D
General Station $\bar{X}$ (individuals/L)	19	37	35	
Dry Season $\bar{X}$ (individuals/L)	45			
Rainy Season $\bar{X}$ (individuals/L)	15			
S.E.D. between two means for months				5.51
S.E.D. between two means for stations				5.78
S.E.D. between two means for seasons				4.72
S.E.D. between two means for stations by seasons				8.17

TABLE 13B: ANALYSIS OF VARIANCE (ANOVA) FOR PHYTOPLANKTON

Source of Variation	D.F.	Sum of Squares	Mean of Squares	F ratio	SIGN
Months	3	4889.7	1629.6	1.78	NS
Stations	2	1607.3	803.6	0.88	NS
Seasons	1	5642.7	5642.7	6.19	X
Stations by seasons	2	1428.6	714.3	0.78	NS
Months by stations by seasons	15	13675.8	911.7		
Total	23	27244			

XX = highly significant ($P < 0.01$)
X = significant ($P < 0.05$)
NS = not significant ($P > 0.05$)

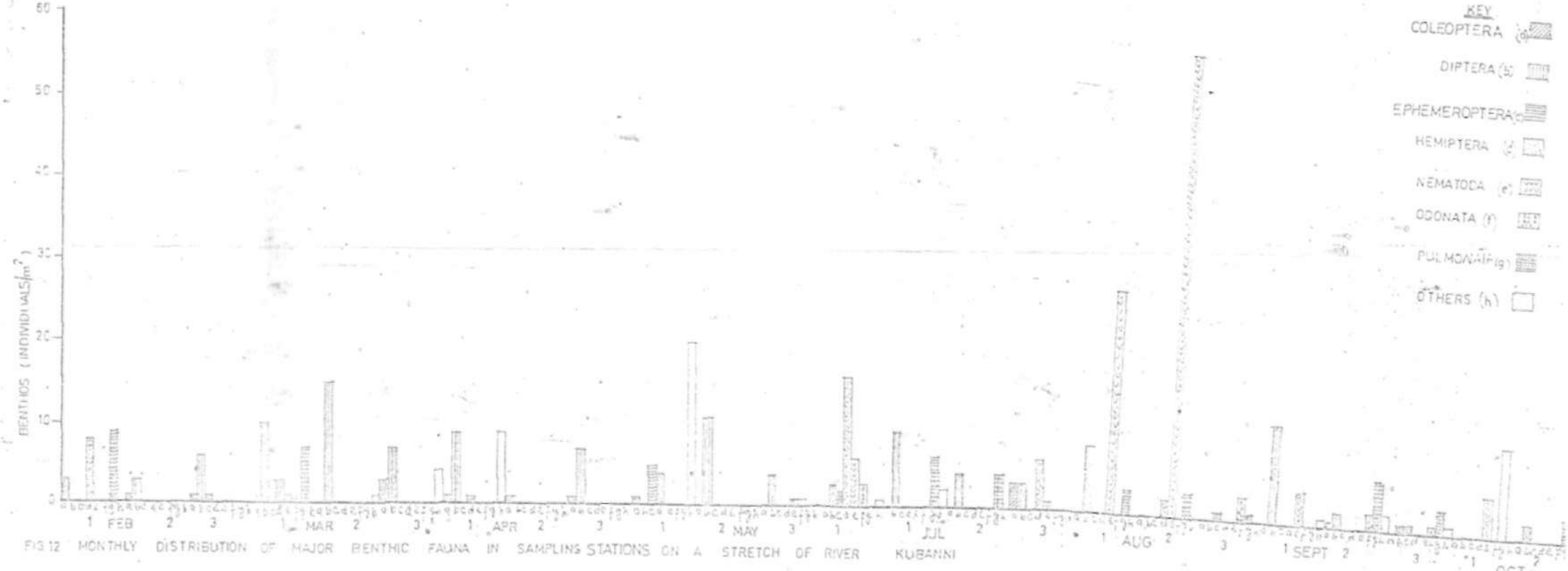


FIG 12 MONTHLY DISTRIBUTION OF MAJOR BENTHIC FAUNA IN SAMPLING STATIONS ON A STRETCH OF RIVER KUBANNI

Anisops spp, Hydrophilus spp, Ishura spp, Baetis spp, Glossiphonia sp, Chironomus spp, Tadpoles, Aedes sp, Eristalis spp etc. The number of benthic organisms ranged from one individual/m^2 in station 2 in April to 61 individuals/m^2 in station 3 in August. Station 1 had a higher benthic population density in the dry season months than station 2 and 3. However, during the rainy period (due to increased water volumed), the reverse situation was encountered (Fig 13).

Fig 13 also shows that the Margalef index value was higher for station 1 than in stations 2 and 3 for most of the months. The lowest (0.0) and the highest (3.18) Margalef index value were obtained during the dry season at station 2 and during the rainy season at station 1, indicating that the river water quality was higher in the rainy season than in the dry season. Consequently, the benthic population was higher in the rainy season than in the dry season (Table 14A) while among the stations, the population density is in the following order: station 2 < station 3 < station 1.

Though there were variations in the benthic fauna population in seasons and stations, analysis of variance (Table 14B) reveals insignificant differences. Correlation coefficient analysis of benthic fauna against other parameters (Tables 1C - F) reveal a significant positive correlation between benthic fauna and dissolved oxygen at station 2 but an insignificant negative correlation when all the station are combined.

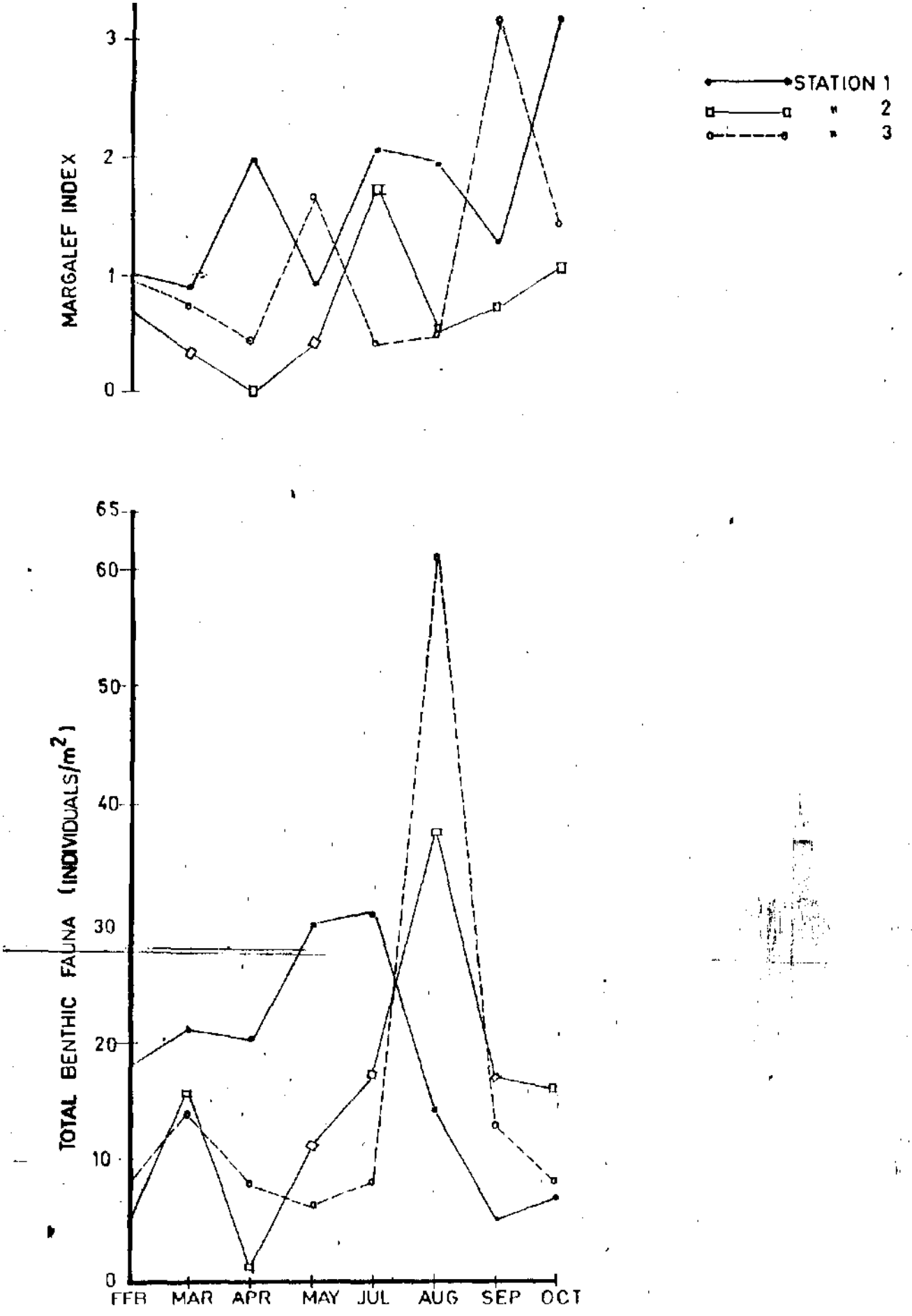


FIG:13 MONTHLY DISTRIBUTION OF TOTAL BENTHIC FAUNA AND MARGALEF INDEX IN SAMPLING STATIONSON STRETCH OF RIVER KUBANNI

TABLE 14A: SEASONAL VARIATION OF BENTHIC FAUNA FOR STATIONS ON A STRETCH OF RIVER KUBANNI

	STATIONS			
	1	2	3	S.E.D
General Station $\bar{X}$ (individuals/m^2)	18	15	16	
Dry Season $\bar{X}$ (individuals/m^2)	13			
Rainy Season $\bar{X}$ (individuals/m^2)	20			
S.E.D. between two means for months				6.67
S.E.D. between two means for stations				15.10
S.E.D. between two means for seasons				12.33
S.E.D. between two means for stations by seasons				21.35

TABLE 14B: ANALYSIS OF VARIANCE (ANOVA) FOR BENTHIC FAUNA

Source of Variation	D.F.	Sum of Squares	Mean of Squares	F ratio	SIGN
Months	3	1009.3	336.4	2.25	NS
Stations	2	46.3	23.2	0.17	NS
Seasons	1	253.5	253.2	1.90	NS
Stations by seasons	2	631.0	315.5	2.36	NS
Months by stations by seasons	15	2003.2	133.5		
Total	23	3943.3			

XX = highly significant ($P < 0.01$)
X = significant ($P < 0.05$)
NS = not significant ($P > 0.05$)

CHAPTER FIVE

5.0 DISCUSSION

This study was carried out to determine the correlation between the physico-chemical character changes with phytoplankton and benthic fauna of a stretch of river Kubanni. The physico-chemical parameters measured serve as an indication of the water quality and the suitability for fish production potentials; while the organisms were taken as biological indicators of potentialities available as food sources for the aquatic consumers such as fish. Variations of these parameters due to pollution (urban run-off, agricultural run-off, leaching from garbage dump and automobile - related wastes) along with other climatic factors such as wind and rainfall and their effects on the river were also considered.

5.1 PHYSICO - CHEMICAL QUALITY

The low temperatures recorded in February and March may be attributed to the characteristic cool dry North east trade winds popularly called the "harmattan" wind which is typical of the season. This agrees with the findings of Khan and Ejike (1984), Oladimeji and Wade (1984) and Balarabe (1989) in their studies on Lamingo reservoir, effluents from a sewage treatment plant in Kubanni river and Makwaye lake respectively.

The mean velocity was higher in the rainy season than dry season. The positive correlation between velocity and phytoplankton observed in this study is contrary to Sandlund

(1982) findings on an urban stream. This might be attributed to rainfall during some of the sampling occassion which simultaneously lead to increased velocity and large numbers of phytoplankton.

The low light transmittance observed, in all the sampling stations with the onset of the rains between July and September could be attributed to flood water, increased erosion and soil washings into the river. Similar observations have been made by David et al (1983) and Wade (1985). The consistently low secchi disc transparency of station 1 during the dry season may be due to the shallow nature of the station (was transparent to the bottom throughtout the dry season). The higher secchi disc transparency in station 2 despite its higher phytoplankton population and much effluents it receives could be due to faster sedimentation rate of suspended materials like slit and clays.

The relatively circumneutral nature of the water pH between seasons and the slight fluctuations to alkaline conditions could be regarded as normal since the range, 6.42 - 8.80, obtained in this study can support aquatic life including fish (Boyd, 1976). The comparatively lower pH values in station 2 correlated positively with the dissolved oxygen. This may be due to decomposition of organic matter which could have resulted, in lower dissolved oxygen. Rippey and Rippey (1986) made similar observation that increase in pH correlates with photosynthesis and carbondioxide consumption.

Highest oxygen concentration in February coincided with the minimum water temperature due to the cool harmattan winds. The phytoplankton correlated positively with dissolved oxygen. These findings are in agreement with Wade (1985) and Balarabe (1989) in their limnological studies of different lakes. The relatively low dissolved oxygen at station 2 could be attributed to organic effluents received from kamacha stream which drains a nearby local market. The oxygen content of the water might have been the source of the oxygen required for decomposition of the wastes. Akpata and Ekundayo (1983) and Moss (1993), reported that under such a condition, the water body could become devoid of oxygen and most forms of its animal life perish. This explains the low benthic population encountered at station 2 and also the negative correlation between the dissolved oxygen and benthic population observed in this study.

There was a sharp fall in the total alkalinity with the onset of the rains possibly due to dilution. The total alkalinity which was primarily due to bicarbonates in all the stations, positively correlated with the phytoplankton. Consistently higher alkalinity value in stations 2 and 3 may be attributed to carbonate input (possibly from Kamacha stream around station 2) as suggested by Stent (1981). The absence of phenolphthalein alkalinity in all the stations is indicative of absence of normal bicarbonate and hydroxide as suggested by Beadle (1974). The low alkalinity concentration of station 1

is suggestive of its low productivity (Khan and Ejike, 1984). This explains the comparatively few phytoplankton population encountered in station 1.

Significant positive correlation ($P < 0.05$) was observed between total hardness and total dissolved matter and conductivity. The high total hardness during the dry season could be attributed to increase in the salts concentration due to draw down in water level and action of wind which enhances the resuspension of sediment Ca^{++} and Mg^{++} ions. For fish production, moderately hard waters with concentrations between 75 - 150 mg/l $CaCO_3$ and above are prefered. In this study, the dry season and rainy season means are $199.9mgl^{-1}$ $CaCO_3$ and $70.5mgl^{-1}$ $CaCO_3$ respectively. Based on known standards of 61 - 120, and 181 and above (O'Wen, 1979 and Thurston et al 1979) It will be logical to conclude that the river is moderately hard during the rainy season and very hard in the dry season and rich for fish production with respect to hardness.

Electrical conductivity was lower in the rainy season than the dry season; this may be due to dilution of the water. In his Limnological study of Makwaye lake, zaria, Balarabe (1989) attributed the gradual fall in conductivity with the onset of the rains to reduced concentration of ions as the water volume increases. The significant positive correlation ($P < 0.05$) between conductivity and phytoplankton is in agreement with the observation of O'wen (1979) that estimation of total ion matter in the water is related to the water

fertility.

Increase in total dissolved organic matter results to increase in conductivity and turbidity but a decrease of the benthic fauna. This agrees with the observations of Chion et al (1986) and Lee et al (1993) that total dissolved humic materials enhances the toxicity of other chemicals in water, thereby negatively affecting the animal community. The higher total dissolved matter during the dry season could be attributed to the waste disposal of agricultural land clearings into the river and the low water flow which could have carried the wastes downstream.

5.2 TRACE METALS

Metal concentration in the stretch of river Kubanni studied may be attributed to the nature of the catchment area; domestic effluents, urban storm-water run-off e.g batteries and other electricals, leaching of metals from garbage and solid wastes dump, metal inputs from rural areas (metals contained in pesticides, herbicides), Atmospheric sources (burning of fuels) and Agricultural run-off (fertilizers). Okoye et al (1991) reported anthropogenic heavy metal enrichment of the Lagos lagoon with Cd, Co, Cu, Fe, Mn, Ni, Pb and Zn and implicated land based and urban and industrial waste sources. The comparatively very high copper concentration in station 1 (headstream) during the dry season may be due to leaching from nearby garbage and solid wastes.

dump while the higher concentration of lead at station 2 may be due to its closeness to the high way and battery effluents from nearby mechanic workshops. Mombeshora et al (1983) reported that the highest levels of lead concentration in water coincided with areas of high traffic density.

The bioconcentration of Cu, Pb and Zn in both seasons (except for Zn where in the dry season Clarias had a higher zn concentration than Tilapia) for Tilapia is higher than for Clarias in this study. Since bioconcentration is the concentration in the whole body tissues per unit concentration in the medium, Tilapia, may therefore be a better indicator species for monitoring trace metal concentration in fish communities. The higher accumulation of trace metals by Tilapia in this study agrees with the suggestion by Norberg et al (1978) and Offem (1983) that surface layers of water are biological active and that oxidation processes are maximal; higher temperatures and light stimulate chemical changes causing a high and rapid biotic uptake of elements by organisms living close to the surface. In this study, Tilapia and to some extent Alestes, being closer to the surface accumulated more metals (lead only in the case of Alestes) than Clarias, which is benthic in nature.

5.3 BIOLOGICAL CHARACTERISTICS

The dominance of the various phytoplankton groups is in the following order: Cyanophyta > Chryophyta > Chlorophyta >

Euglenophyta > Pyrrophyta. Based on classification by Hutchinson (1967) and Moss (1993): the presence of Fragilaria, Cyclotella, Melosira, Tabellaria in stations 1 and 3 is an indication of an infertile water (Oligotrophic); presence of Closterium, Oscillatoria and Euglena in stations 2 and 3 (few in numbers in station 3) indicates intermediate fertility (Mesotrophic). The higher numbers of Oscillatoria encountered in stations 2 may be attributed to organic effluents from Kamacha stream and nearby gutters. Nwankwo (1984) also implicated organic pollution by uncontrolled disposal of domestic sewage into gutters and water puddles as the cause of blooms of Oscillatoria, Lyngbya, Euglena and Phacus in the Lagos lagoon.

The benthic fauna were dominated by Coleoptera, Diptera, Ephemeroptera, Hemiptera, Nematoda, Odonata and Pulmonata comprising 29 genera. Diptera (Chironomous sp, Culex sp, Stichtochironomous sp etc), Nematoda (Bastiana sp) and pulmonata (Lymnaea sp) were restricted to stations 2 and 3 while Amphibia (Tadpoles), Hemiptera (Anisops sp) and Ephemeroptera (Ameletus sp, Elassoneuria sp, Isonychia sp etc) are restricted to station 1. These restriction of particular species to particular sections of the river could be attributed to the various effluents with characteristic properties into sections of the river which could have caused disruption to life cycle, reproductive cycle, food chain, caused migrations or impose physiological stress on the

benthic fauna. Those that are tolerant might have overcome these problems and adjusted to the changes and carried out their life processes. The presence of Glossiphonia sp and Nais sp in stations 2 and 3 are indication of sewage and organic pollution. Hynes (1972) found that, in the Mooi river in south Africa, "natural pollution", caused by the accumulation of fallen leaves, led to a great increase of naidid worms and a reduction in numbers of Ephemeroptera. The presence of Rotifers and Trichoptera found among the benthic collections was due to their presence in decayed organic materials. The Margalef index for station 1 was consistently high while that of station 2 was low indicating that the water quality of the sampling stations are in the following order: station 1 > station 3 > station 2.

CHAPTER SIX

SUMMARY AND CONCLUSION

River Kubanni, a major tributary of river Galma, recieves both organic and inorganic wastes through run-offs and seepage from some residential and agricultural areas of Tundun wada, zaria.

Water, plankton and benthic samples were collected once a month from 3 stations on river Kubanni, for eight months (February 1994 - October 1994). The physico-chemical parameters, plankton and benthic composition were determined and correlated to one another.

The distribution and composition of phytoplankton and benthic fauna of the stretch of the river are affected by variation through fluctuations in environmental variables such as temperature, velocity, transparency, pH, dissolved oxygen, total alkalinity, total hardness, electrical conductivity and total dissolved matter. Low alkalinity results to low phytoplankton productivity while a rise in total dissolved matter results to increase in electrical conductivity and turbidity but a decrease of the benthic population.

It was observed that although typical phytoplankton that are characteristics of infertile (Oligotrophic) water bodies are present in stations 1 and 3 while typically intermediate fertility (Mesotrophic - eutrophic) are present in stations 2 and 3, and highly fertilized (hypertrophic) species in station 2, the nature of other limnological features of the stations

seem also to have influenced the nutrient status and thus the productivity of the stations. Thus, though the river stretch is rich for fish production with respect to water hardness, there are still the presence of Oscillatoria sp, Euglena sp, Naids sp, Glossiphonia sp, Chironomous sp and the absence of Ephemeroptera in stations 2 and 3, indicating organic pollution in these stations. Furthermore, the Margalef index for station 1 was comparatively high while that of station 2 was low indicating that the water quality among the sampling stations is in the following order: station 1 > station 3 > station 2.

The metal concentration in the stretch of river Kubanni could be attributed to the nature of the catchment area; domestic effluents, urban storm - water run-off, leaching of metals from garbage and solid wastes dump, atmospheric sources (burning of fuels) and agricultural run-off. Station 2 has more lead (pb) concentration due to its comparatively closeness to the high way and battery effluents from nearby mechanic workshops. Tilapia and, to to some extent, Alestes, being close to the surface to accumulated more trace metals (lead only in the case of Alestes) than Clarias which is benthic in nature. Tilapia, may therefore be a better indicator species than Clarias for monitoring trace metal concentration in the aquatic ecosystem.

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APPENDIX I

MONTHLY DISTRIBUTION OF PHYTOPLANKTON (Individuals/litre) IN A STRETCH OF RIVER KUBANNI

Taxonomic groups	Feb.			March			Apr.			May			Jul.			Aug.			Sept.			Oct.		
	SAMPLING STATIONS																							
	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3
CHLOROPHYTA																								
Chlamydomonos **sp**	-	-	-	-	-	-	-	-	2	-	-	-	-	-	-	2	-	2	-	-	-	-	-	-
Closterium sp	-	-	5	-	3	-	-	-	25	-	3	-	5	7	-	2	5	-	-	3	-	-	-	-
Closteriopis longissma	-	-	-	-	-	3	-	3	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	2
Cylindrocapsa geminella	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-
Fragilaria capucina	-	-	-	-	-	3	-	5	17	-	-	-	-	-	-	-	-	13	-	-	-	-	-	-
Netrium sp	-	-	-	-	-	-	-	-	1	5	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Pediastrum tetras	-	-	-	-	-	8	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Schroederia setigera	-	5	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Sphaerocystis sp	-	-	-	7	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Spirogyra sp	-	-	-	-	-	-	-	-	-	-	-	-	3	3	-	-	-	-	-	-	-	-	-	-
Ulothrix zonata	-	-	-	-	-	-	-	10	-	-	-	-	7	13	-	-	-	-	-	-	-	-	-	-
Uronema elongatum	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	-	-	-	-	-	-	-

CHRYSOPHYTA																								
<u>Asterionella</u> <u>formosa</u>	-	-	-	-	-	13	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
<u>Bacillaria</u> <u>paradoxa</u>	-	-	-	-	-	-	-	-	-	-	-	-	-	2	-	-	-	-	-	-	-	-	-	-
<u>Cyclotella</u> <u>stelligera</u>	8	-	-	-	-	-	3	-	7	-	-	-	-	-	-	-	-	-	8	-	-	-	-	-
<u>Fragilaria</u> <u>capucina</u>	-	-	-	-	-	-	5	-	15	-	-	-	-	-	-	-	-	13	-	-	-	-	-	-
<u>Melosira</u> <u>granulata</u>	-	-	-	15	-	-	-	3	-	-	-	-	-	-	-	-	-	-	-	-	-	8	-	-
<u>Navicula</u> <u>radiosa</u>	-	-	-	-	-	-	7	-	-	-	-	10	-	-	-	7	-	-	-	-	-	-	-	-
<u>Nitzschia</u> sp	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	-	-	-	-
<u>Pleurosigma</u> sp	-	-	-	-	-	-	12	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
<u>Rhopolodia</u> <u>gibba</u>	-	-	-	-	-	-	-	-	-	-	-	-	2	-	-	-	-	-	-	-	-	-	-	-
<u>Stephanodiscus</u> <u>niagarae</u>	5	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
<u>Surirella</u> <u>ovata</u>	-	-	-	-	-	-	-	-	-	3	-	-	-	-	-	-	-	-	-	-	-	-	-	-
<u>Synedra</u> sp	-	-	-	-	-	-	-	-	-	17	-	-	-	-	-	-	-	-	-	-	-	-	-	-
<u>Tabellaria</u> <u>fenestrata</u>	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	5	-	-	5	2	2
CYANOPHYTA																								
<u>Anabaena</u> sp	-	10	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
<u>Anacystis</u> <u>cyanea</u>	-	-	7	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	5	-
<u>Oscillatoria</u> <u>granulata</u>	-	-	-	-	13	-	-	-	67	-	83	117	-	-	-	-	3	13	-	-	-	-	-	-

EUGLENOPHYTA																								
Astasia klebsi	-	-	-	-	-	-	-	-	-	-	-	-	2	-	-	-	-	-	-	-	-	-	-	-
Distigma proteus	-	-	-	-	18	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Euglena sp	-	-	-	-	-	-	7	-	5	-	-	-	-	-	-	-	-	-	-	7	12	-	-	13
Notosolenus apocamptus	-	-	-	-	-	-	-	-	-	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-
PYRROPHYTA																								
Peridinium sp.	-	-	-	-	-	-	-	-	5	-	-	-	-	-	-	-	-	-	-	3	-	-	-	-

APPENDIX II

MONTHLY DISTRIBUTION OF BENTHIC FAUNA (Individuals/m2) in SAMPLING STATIONS ON A STRETCH OF RIVER KUBANNI

Taxonomic groups	Feb.			March			Apr.			May			Jul.			Aug.			Sept.			Oct.		
	SAMPLING STATIONS																							
	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3
AMPHIBIA																								
Tadpole	-	-	-	-	-	-	6	-	-	20	-	-	-	-	-	-	-	-	-	-	-	-	-	-
CILIOPHORA																								
Trintinnidium **flauviatile**	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3	-	-	-	-	-	-	-	-
CLADOCERA																								
Danphia catawba	-	-	-	-	-	-	1	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
COLEOPTERA																								
Amphizo Leconteci	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-
Bidessus sp	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Helichus sp	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-
Hydraticus dosiger	-	-	-	-	-	3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Hydrophilus sp	-	1	1	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Laccophilus sp	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Potamodytes sp	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
COPEPODA																								
Synopia ultramarina	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

DIPTERA	-	-	-	-	-	-	-	-	-	-	-	3	-	-	-	-	-	-	-	-	-	-	-	-
Aedes sp																								
Chironomus sp	-	-	-	-	15	-	4	-	3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Cricotopus sp	-	-	-	-	-	-	-	-	-	-	-	-	-	14	-	-	-	-	-	-	-	-	-	-
Cryptochironomus sp	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-
Culex sp (Larva)	-	-	-	-	-	-	5	-	4	-	3	-	-	-	-	-	-	-	-	-	-	-	-	-
Eristalis sp	-	-	-	-	-	-	-	-	-	-	-	-	3	-	-	-	-	-	-	-	-	-	-	-
Helius sp	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-
Limnophora sp (Larva)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-
Simulium sp (Larva)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-
Stichtochironomus puri-pennis (Larva)	-	3	6	10	-	7	-	-	-	-	-	-	8	-	-	7	-	-	8	-	-	12	-	
Tendipes tentanus (Larva)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3	-	-	-	-	-
EPHEROPTERA Ameletus sp	-	-	-	-	-	-	-	-	-	-	-	-	5	-	-	-	-	-	-	-	-	-	-	-
Beatis bellus Bernad	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Baetis subalpinus	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Elassoneuria sp	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	-	-	-	-	-	-	-	-
Isonychia sp	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

HEMIPTERA Anisops cf. sardea	7	-	-	3	-	-	1	-	-	4	-	-	16-	-		6	-	2	-	-	-	-	-	-
HIRUDINAE Glossiphonia complanata	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1
Helobdella fusca	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
LEPIDOPTERA Pyrausta sp.	-	-	-	-	-	-	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
NEMATA Leptonema sp	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
NEMATODA Bastiana exilis	-	-	-	-	-	-	-	-	-	-	-	1	6	-	-	-27		56	-	-	-	-	5	-
Microlaimus fluviatulis	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-
Rhabdolaimus minor	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
NEUROPTERA Sialis sp	-	-	-	-	-	4	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
NOTOSTRACA Triops longicaudatus	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-
ODONATA Argrion sp	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-
Ictinogomphus sp	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-
Ishnura elegans	-	-	-	-	-	-	-	-	-	-	-	-	2	-	-	-	-	-	3	-	2	-	-	-

Zygonynx torrida	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
OLIGOCHAETA	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2
Nais sp																								
PISCES																								
Tilapia nilotica	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-
PLECOPTERA	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-
Leuctra sp																								
PROSOBRANCHIA																								
pyrgulopsis nevadensis	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-
PULMONATA																								
Lymnaea auricularia	8	-	-	7	-	-	-	-	-	-	-	-	-	6	-	-	-	-	1	-	2	1	1	-
Lymnaea columella	-	-	-	-	-	-	-	-	-	-	-	-	-	-	4	-	3	3	-	-	4	-	8	3
Gyraulus hirsutus	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	2	-
ROTIFERA																								
Hydatina sp	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-
Trichocerca longiseta	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-
TRICHOPTERA																								
Hydropsyche sp	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-

Appendix III

PHYSIO-CHEMICAL PARAMETERS OF STATIONS ON A STRETCH OF RIVER KUBANNI

	Atmospheric Temperature (°C)			Water Surface Temperature °C			Water Depth Temperature °C			Velocity (m/s)			Transparency Secchi depth (cm			pH			Dissolved Oxygen mgl^{-1}			Total Alkalinity (mgl^{-1} $CaCO_3$			Total Hardness (mgl^{-1} $CaCO_3$			Electrical Conductivity (micros cm^{-1}			Total dissolved matter (mgl^{-1}		
STATION																																
Months	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3
FEBRUARY (25/2/94)	30	30	31	29	24	27	28	27	22	0.0054	.0036	.0021	0.20	0.44	0.40	7.18	6.99	7.91	5.0	3.1	4.1	42.5	75	181	140	110	166	280	960	690	180	620	450
MARCH (29/3/94)	27	28	31	28	27	31	26	24	20	.0019	.0017	.0015	0.09	0.50	0.40	6.81	7.92	7.19	5.0	3.95	5.6	58.5	354.0	221.0	164.0	260	130	215	740	580	140	490	380
APRIL (28/4/94)	29	25	27	29	23	27	24	27	25	.0040	.0021	0.006	0.13	0.20	0.18	7.26	7.06	6.72	4.75	3.45	4.6	52.5	120.0	174.0	181.0	244.0	234.0	470	660	660	310	520	430
MAY (27/5/94)	25	24	23	24.5	24	22	24	25	24	.05	0.50	0.66	0.20	0.30	0.30	6.75	7.60	6.82	8.75	8.1	8.4	71.5	147.0	135.5	103.0	72.0	2200	440	680	740	290	447	640
JULY (29/7/94)	22	25	23	22	24	24	25	22	24	0.15	0.14	0.12	0.05	0.04	0.04	6.85	6.65	6.47	5.85	6.0	5.6	29.0	51.0	56.0	76.0	86.0	88.0	160	250	220	120	162	140
AUGUST (26/8/94)	22	22	25	22	22	24	25	24	24	0.10	0.09	0.07	0.10	0.11	0.11	7.12	6.9	7.2	7.05	6.0	6.95	45.5	46.5	47.0	88.0	94	96	150	230	270	100	150	170
SEPTEMBER (22/9/94)	22	23	24	24	23	25	25	25	25	0.15	0.20	0.26	0.08	0.05	0.07	8.06	8.34	8.51	7.8	7.41	7.2	30.5	32.0	38.0	48.0	52.0	76.0	120	155	200	90	107	120
OCTOBER (25/9/94)	22	22	23	21.5	21.5	24	25.5	25.5	25.5	0.058	0.12	0.08	0.40	0.35	0.21	7.16	6.42	7.12	5.9	4.2	4.44	32.5	42.0	52.0	42.6	62.0	74.0	140	210	250	98	140	170

APPENDIX IV

TRACE METAL CONCENTRATION IN WATER AND FISH TISSUES

SAMPLES	CONCENTRATION IN ugg^{-1} of ELEMENTS		
	Cu^{2+}	$Pb^{2}+$	Zn^{2+}
STATION ONE DRY SEASON WATER	19.16	0.33	3.25
STATION ONE RAINY SEASON WATER	2.53	0.18	0.10
STATION TWO DRY SEASON WATER	0.28	1.10	2.95
STATION TWO RAINY SEASON WATER	1.52	0.46	0.20
STATION THREE DRY SEASON WATER	1.12	0.15	0.20
STATION THREE RAINY SEASON WATER	0.32	0.29	0.15
CLARIAS SP. DRY SEASON	3.45	0.34	20.00
CLARIAS SP. RAINY SEASON	4.60	0.27	13.50
TILAPIA SP. DRY SEASON	8.86	0.42	17.40
TILAPIA SP. RAINY SEASON	11.19	0.39	14.10
ALESTES SP. DRY SEASON	5.06	0.31	17.70
ALESTES SP. RAINY SEASON	2.72	0.72	4.50