FISH FAUNA AND PHYTOPLANKTON POPULATION IN RELATION TO PHYSICO-CHEMICAL PARAMETERS OF GWAIGWAYE RESERVOIR KATSINA STATE, NIGERIA

BY

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A THESIS SUBMITTED TO THE SCHOOL OF POSTGRADUATE STUDIES, AHMADU BELLO UNIVERSITY, ZARIA IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE AWARD OF A MASTER DEGREE IN BIOLOGY.

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OCTOBER, 2015.

DECLARATION

I declare that the work in this thesis entitled **“**fish fauna and phytoplankton population in relation to physico-chemical parameters of gwaigwaye reservoir katsina state, nigeria”was performed by me in the Department of Biological Sciences under the supervision of Prof. S.A. Abdullahi and Prof. M.L. Balarabe. The information derived from literature has been duly acknowledged in the text and list of references provided. No part of this work has been presented for another Diploma or Degree at any institution.

Lawal NURA ________________________ ________________________

Signature Date

CERTIFICATION

This thesis entitled "FISH FAUNA AND PHYTOPLANKTON POPULATION IN RELATION TO PHYSICO-CHEMICAL PARAMETERS OF GWAIGWAYE RESERVOIR KATSINA STATE, NIGERIA"by Lawal NURA meets the regulation governing the award of the degree of Master of Science (M.Sc.) in Biology of the Ahmadu Bello University, and is approved for its contribution on the knowledge and literary presentation.

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DEDICATION

This work is dedicated to the memories of my beloved Father and Daughter Late AlhajiNura Umar and SayyadaFatiha.The former whose moral support had always been a source of guidance and inspiration for me; may Allah grant their gentle souls Aljannatul Firdausi,Amen.

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ABSTRACT

The Studies on fish fauna and phytoplankton population in relation to physico-chemical parameters of Gwaigwaye reservoir, Katsina State, Nigeria was carried out from May 2013 to April 2014; to establish physical, chemical, and biological parameters (Phytoplankton and Fish Population) of Gwaigwaye reservoir. Four sampling stations were chosen; the physico-chemical and biological parameters were determined using standard methods and procedures. The result revealed that; Water temperature (25.02 ± 0.17^{0}C) pH (7.54 ± 0.03), Alkalinity (3.69±0.09), Conductivity (129.43 ± 5.15µS/cm), Total Dissolved Solids (50.54 ± 0.57mg/L) Nitrate-nitrogen (0.21 ± 0.04mg/L), Water hardness (134.44 ± 3.06mg/LCaCO3), Dissolved Oxygen (3.98 ± 0.10mg/L), Biochemical Oxygen Demand (2.53 ± 0.08mg/L), Phosphate-phosphorus (0.19 ± 0.02mg/L),Chloride (5.09 ± 0.15mg/L),Sulphor-sulphate (0.21± 0.01) and Calcium (2.97±0.06mg/L) varied with months and seasons. Analysis of variance indicated significant difference between seasons ($P < 0.05$); but no significant difference in fish fauna, phytoplankton distribution and abundance among the four stations ($P>0.05$). The result indicated phytoplankton percentage composition as; Chlorophyta (57.66%), Bacillariophyta (25.70%), Cyanophyta (14.73%), and Dinophyta (1.91%) while Fish fauna percentage composition were *Tilapia zilli* (17.32%), *Clariasgariepinus* (16.17%),*Oreochromisniloticus* (15.27%),*Latesniloticus* (13.80%), *Bagrus. bayad* (12.91%), *Momyrussenegalensis* (9.90%), *Labeosenegalensis* (7.41%) and *Synodontisclarias* (7.28%). Water quality of the reservoir is influenced by anthropogenic activities,the reservoir water is suitable for irrigational and domestic purposes from the results of most of the physico-chemical and biological parameters obtained. Hence, there is need for an effective anthropogenic inputs control programme in the reservoir.

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CHAPTER ONE

1.0 INTRODUCTION

1.1 Background of The Study

Reservoirs are very large natural or artificial lakes that provide habitat and food for many species of fish and wildlife (Atobatele and Ugwumba, 2008). They are constructed for domestic use where large natural lakes are sparse and unsuitable for human exploitation, enhancement of fisheries and improvement of water transport. Freshwater ecosystems have been used for the investigation of factors controlling the abundance and distribution of aquatic organisms (Esenowo and Ugwumba, 2010).

It is well established that the productivity of a reservoir depends on its ecological conditions and by monitoring the water quality; productivity can be increased to obtain maximum sustainable yield of fish (Mustapha, 2011). Maintenance of healthy aquatic environment and production of sufficient food in reservoir are primarily linked with successful reservoir culture operations. Various studies had been conducted on changes brought about by biotic and abiotic factors of river as a result of damming. However, responses of rivers and its ecosystem to damming are complex and varied as they depend on local sediment supplies, geomorphic constraint, climate, dam structure and operation (Offem and Ikpi, 2011). Life in aquatic environment is largely governed by physico-chemical characteristics and their stability. These characteristics have enabled biota to develop many adaptations that improve sustained productivity and regulate its metabolism (Olele and Ekelemu, 2008). Many of these reservoirs were built as a result of societal demand for drinking and industrial water supplies, irrigation, hydroelectric power generation, fish production and recreation. With time however, most of these reservoirs have secondary functions such as navigation, industrial processing, flood protection, urban run-off control and tourism super imposed on them (Mustapha, 2011). Impacted changes in the water quality are reflected in the biotic community structure, with the most vulnerable deing, while the most sensitive species act as indicators of pollution. In Africa, there are many shallow reservoirs, but their numbers are still few considering their functions, population demand for their resources and their roles. In order for these reservoirs to perform the purpose(s) of their establishment as well as other functions that might be super imposed on them, plankton community structure and composition of these reservoirs should be well known; this will provide a valuable insight to its effective management (Mustapha, 2011). Out of the 29,966,920 tonnes of aquatic organisms produced by freshwater aquaculture in 2005, fishes represented 96% of the total, whereas crustaceans, molluscs, amphibians and all other animals combined only represented the remainder 4%, with 1,308,547 tonnes (FAO, 2008). Nigeria is blessed with about 853,600 hectares of freshwater capable of producing over 1.5 million metric tonnes of fish annually (FAO, 2009). Because of this there is need to exploit means of using these precious resources, even though there are some hindrances, which includes effects of domestic and agricultural wastes on the water quality and aquatic life, physical and chemical factors like temperature, turbidity, pH, dissolved gases (O_2 and CO_2), salts and nutrients. It is no doubt; reservoirs have contributed to the economic growth of many nations, Nigeria inclusive **(**Watson, 2000). Reservoirs built in several parts of the world have played important role in helping communities to harness water resources for several uses. An estimated 30-40% of irrigated land worldwide now relies on reservoir water (Mustapha, 2011). In Nigeria, many researchers have conducted works on different water bodies, some of them include, Balarabe (2001) effect of limnological characteristic on zooplankton composition and distribution in Dumbi and Kwangila ponds, Zaria. Balogun *et al.* (2005) some aspects of the limnology of Makwaye (Ahmadu Bello University farm) lake, Samaru, Zaria; Ibrahim *et al.* (2009) on an assessment of the physico-chemical parameters of Kontagora reservoir, Niger state. Abubakar (2009) on the Limnological studies for the assessment of Sabke lake, Katsina state. Hassan *et al.* (2010) on the algal diversity in relation to physico-chemical parameters of three ponds in Kano metropolis.

Reservoirs constitute important ecosystem and food resources for a diverse array of aquatic life. Reservoir ecosystems are fragile and can undergo rapid environmental changes, often leading to significant declines in their aesthetic, recreational and aquatic ecosystem functions (Araoye, 2008). Human activities can further accelerate the rate of changes; if the causes of the changes are known, human intervention (management practices) sometimes can control or even reverse detrimental changes. Maintenance of healthy aquatic environment and production of sufficient foods in reservoir are primarily linked with successful reservoir culture operations. To keep the aquatic habitat favorable for existence of living organisms, physical and chemical factors like temperature, turbidity, pH, odour, dissolved gases, salts nutrients must be monitored regularly, individually or synergistically, activity of living organisms is influenced by the seasonal and diurnal changes of these parameters (Akinyeye *et al.,* 2011). Changes in the physico-chemical parameters may positively or negatively affect the biota of water bodies in a number of ways such as their survival and growth rates and these may eventually result in disappearance of some species of organisms or its reproduction (Edward and Ugwumba, 2010). Various studies has been conducted on changes brought about by biotic and abiotic factors of the rivers as a result of damming (Offem and Ikpi, 2011).

Gwaigwaye Reservoir is a man-made lake that serves as a source of water supply for domestic uses to the surrounding Communities, as such knowledge of it's fish fauna, Phytoplankton and physico-chemical parameters are of immence importance in assessing its productivity and to provide better understanding of the reservoir ecosystem.

1.2 Statement of Research Problem

The species composition and density of aquatic organisms will be influenced not only by geographical locations but also by water quality (Atobatele and Ugwumba, 2008). The Dumping of anthropogenic inputs, run-off of agricultural wastes and effluent from the surrounding anthropogenic air pollution from funtua textile plant into the reservoir are the major problems Gwaigwaye reservoir is experiencing today and the absence of any basic information on the water quality of the reservoir (Kirubavathy *et al*., 2005).

1.3 Justification

Many Nigerians rivers and reservoirs have been investigated and observed that the decrease in production and depletion of fish species is attributed to poor water quality caused by anthropogenic input from the activities of man (Cecchi, 2007; Descy and Sarmento, 2008). Other studies on aquatic ecosystem revealed impairment because of water quality deterioration and most of the researchers established that knowledge of the physico-chemical conditions of water bodies is useful not only in assessing its productivity but also permitting a better understanding of the population and the life cycle of fish community (Antia and Holzolohner, 1996).

Since phytoplankton and macrobenthos are major sources of aquatic food (Bwala *et al.,* 2009; Yisa, 2006), phytoplankton has also been reported to cause fish poisoning in so many parts of the world because of the ability of some species to form toxins during blooms (Cook *et al.,* 2004). Phytoplankton play important role as bio-indicators of water quality (Tiseer *et al.,* 2008a). However, according to several studies (Abbas, 2009; Figueredo and Giani, 2009) the tropical lakes and reservoirs do not experience marked seasonal fluctuations and thus do not exhibit variations in stocks of phytoplankton species composition. It is therefore pertinent to investigate the abundance of these plants in Gwaigwaye reservoir in order to ascertain the species of fish that inhabit the reservoir in relation to physico-chemical parameters.

1.4 Aim and Objectives of the Study

The aim of the study was to provide first hand information on the fish fauna population, phytoplankton abundance, distribution and diversity in relation to physico-chemical parameters of Gwaigwaye reservoir and the effect of seasons on these parameters.

The following are the objectives of the study:-

i. To determine the Monthly and Seasonal variations in the physico-chemical parameters of Gwaigwaye reservoir.

ii. To determine the type of phytoplankton abundance, percentage and fish landing of Gwaigwaye reservoir.

iii. To determine the relationship between phytoplankton diversity, fish fauna distribution and variation in physico-chemical parameters of Gwaigwaye reservoir.

1.5 Research Hypotheses

i. There is no significant difference in Monthly and Seasonal variations in the physico-chemical parameters of Gwaigwaye reservoir.

ii. There is no significant difference in the type of Phytoplankton abundance, percentage and fish landing of Gwaigwaye reservoir.

iii. There is no significant relationship between the fish species distribution, phytoplankton diversity and physico-chemical parameters of Gwaigwaye reservoir.

CHAPTER TWO

2. 0 LITERATURE REVIEW

2.1 Background

Water is one of the most important available substances on the earth. The survival and the quality of human life depend upon the availability of fresh water. The aquatic animal's life directly or indirectly depends on water quality status (Sayeshwara, 2010).

Reservoirs are usually the best method of impounding water; because it ensures that water is available all the year round and helps in minimizing obstruction from rivers. Reservoirs have been used for the investigation of factors controlling the abundance and distribution of aquatic organisms (Atobatele and Ugwumba, 2008; Esenowo and Ugwumba, 2010). Reservoirs are often classified according to their physical features. These include valley or dam reservoirs which are those situated in the valley (riverine) and embarked reservoirs, which are built above the ground off river. Most Nigerian reservoirs are constructed by damming a river and are called valley or dam reservoir. Based on hydrological depth, reservoirs are classified as shallow or deep. Majority of reservoirs especially in the tropics are shallow, polymitic with relatively small volume of less than 1 × 106 m^3 of water (Kalff, 2003). Such reservoirs are found in regions where evaporation approaches or exceeds precipitation with water typically derived from rivers during the rainy periods. Majority of these types of reservoirs abound in Nigeria. Size is also used for classifying reservoirs, thus there are very large, large, medium and small reservoirs and finally based on their retention time, (i.e. its ratio of volume and daily flows) reservoirs could be through flowing, intermediate and long retention (Straskraba, 1999). Using these classifications, Gwaigwaye reservoir is a small, shallow, dam reservoir with a low retention time, the ratio of its volume and daily flow is less than a year. This classification fits into Straskraba *et al*. (1993) description of shallow reservoirs as those that have maximum depth of 10m or less and are usually unstratified with low retention time and planktonic biomass not well developed. Reservoirs characteristically exhibit longitudinal (up lake-to-down lake) gradients in turbidity, nutrient concentrations, mixing depth and euphotic depth, flushing rates, chlorophyll concentrations, phytoplankton productivity, fishing standing stocks and other variables (Adakole *et al*., 2003). Reservoirs are different from natural lakes in that non-periodic unpredictable events stemming from intrinsic forces within the biota seems more evident in natural lakes, whereas the events caused by external forces and fuelled by lunar periodicity or irregular changes in wind and inflow intensity seem more common in reservoirs (Gliwicz, 1999). Other differences have been pointed out by Straskraba *et al*. (1993).

Reservoirs have high watershed/water body area, shorter but varying retention times, a rapid aging process related to watershed uses, high capability to retain organic and inorganic matter which also occurs in natural lakes (Tundisi and Matsumura-Tundisi, 2003). The physical and chemical gradients together produce trophic status that varies along the reservoir axis. Each of the regions is characterized by different transparency; different causes of light attenuation, different nutrient regimes and different biota. Lind and Davalos-Lind (1999) observed that the major difference between riverine zone and transitional zone is one of water transparency. Lind and Barcena (2003) described riverine and transition zones as shallow lacustrine habitats with favourable light and nutrients. Reservoirs also possess properties that in some ways set them apart as a group from other aquatic ecosystems (Thorton, 1990; Lind *et al.,* 1993). With time, however, most reservoirs have had secondary functions superimposed upon them such as navigation, sediment control, insect and water borne disease control, industrial processing and cooling, tourism and urban run-off control (Tundisi and Matsumura-Tundisi, 2003). Other benefits reservoirs offer includes conservation and enhancement of local environments and landscapes. Mustapha (2005) discussed how reservoirs could help in the attainment of millennium development goals (MDGs) by 2015 in terms of alleviating poverty, enhance food security. Reservoirs have facilitated industrial, economic and societal growth in many developing countries such as Nigeria. But, for most of these functions, maintenance of good water quality is of utmost importance. The healthy reservoir is dependent upon the physico-chemical and biological characteristics (Venkatesharaju *et al*., 2010). Whitton and Potts (2000) noted that multiple functions in tropical reservoirs may create conditions that facilitate the dispersal of water borne diseases vectors thus exacerbating health problems among end users of the reservoir.

The construction of dam is among other ways in which water is conserved globally. It is a finite and scarce resource due to increased demand for a growing population, world industrialization and other agricultural development (Obadaki and Ari, 2014). A dam is one of the artificial methods through which man modifies river and other fluvial processes. It also represents one of the methods of developing water resources by man and the best strategy for averting the effects of perennial drought in the dry lands of the world (Maigari, 2002). Obstructing the course of rivers by dams to create expanses of lentic water, as well as, excavating canals for the purpose of navigation and irrigation are two human activities that possibly co-originated with agriculture (Dumont, 1999). Today, almost every major river in the world has become equipped with series of high dams, behind which lie major impoundments. Only few river systems all over the world have escaped impoundment (Miranda, 2001). In Nigeria, there are more than 300 reservoirs with surface areas of 275,534.91 hectare (Ita *et al.,* 1985). Yet the number is still few as more reservoirs are presently been built to meet the millennium development goals of eradicating poverty and diseases of which reservoirs have major roles to perform (Watson, 2000). Reservoir ecosystems are influenced by tributaries, riparian zone and watersheds (Miranda, 2007). Reservoir have been used for the investigation of factors controlling the abundance and distribution of aquatic organisms (Atobatele and Ugwumba, 2008; Esenowo and Ugwunba, 2010). The impoundment of water through dam construction has strongly interfered with river functioning and hydro geological cycles thus producing many changes in the cycles and biodiversity of the affected rivers. As observed by Miranda (2001), impoundment of river will generally have negative impact on biodiversity.

2.2 Impact of Reservoir

The impact of reservoir construction on the main river include alterations in the natural flow regimes with subsequent changes in current speed, flow volume, water temperature, oxygen concentration and obstruction of fish breeding and migrations (Dudgeon, 2003). Dam construction by regulating river flow may also have cascading effects on downstream lakes. Other notable impact include a reduction in average body sizes of the species that constitute the fish community of the reservoir (Agostinho *et al*., 1995) and this could have an important effect on the fisheries of the reservoir. The virtual disappearance of large bodied species, will not only influence yield, but also fishing methods, fish marketing and commercial value of the fishes. A shift in species composition and abundance, with extreme proliferation of some species and reduction or elimination of others as noticed in Kainji Lake where riverine species were replaced by lacustrine species (Ita, 1978) are some of the other unavoidable effects of impoundment. Balogun (1986) also reported the reduction in the numbers of Citharinids and the dominance of Cichlids after the closure of Kainji Lake. This impact is greatly influenced by characteristics of the biota, such as reproductive strategies, migratory patterns, current, availability of food, trophic specialization, morphology and hydrology of the reservoir itself, (Agostinho *et al*., 1995). Other variables that influence this impact include presence of other reservoirs in the water shed, design and operational characteristics of the reservoir, use of the water shed (e.g. for irrigation, fisheries, urbanization) and the geology of the area. Riverine fish, suffer considerable impacts from damming because their established pathways connected to the reproductive cycles are disrupted. For instance, the construction of Lake Kainji influenced the fish community in the lake as well as in the reservoir downstream as only species able to adjust to lacustrine conditions became dominant (Welcomme, 1986). The observed changes in the fish community of the lake points towards a reduction in species richness and production (Segers *et al.*, 1992). Although reservoir are built by man and for man, activities in the catchments area before and after the building of the reservoir affects its subsequent primary function, the downstream river as well as its biodiversity. The problems that could arise are eutrophication due to run-offs from excessive application of fertilizers, siltation from catchments land erosion, and excessive loading of organic and inorganic particles from domestic and industrial effluents.

However, migration of large numbers of people increase the level of human activities in the water shed and intensifies human pressures upon the reservoir. Typical example is Moro reservoir, in Ilorin, Nigeria, where human activities have greatly modified the water quality and the biodiversity of the reservoir (Mustapha, 2006). Coincident with expanding demand for water quantity should be concerns also over the quality.

2.3 Water Quality in Reservoir

The quality and quantity of water in reservoirs are very important especially in reservoirs with multifunctional roles. Deterioration of water quality in reservoirs results from excessive nutrients inputs, eutrophication, acidification, heavy metal contaminants, organic pollutants and obnoxious fishing practices (Helfman, 2007). Water quality should be considered along with water provisions and should be an integral part of reservoir management. Water quality control and fisheries management in a reservoir require a sound knowledge of the limnology of the reservoir and its biota in relation to flow regulation and fish exploitation, especially as impoundments were designed in ignorance of its limnological importance and the fisheries potentials. Good quality of water resources depends on a large number of physico-chemical parameters and biological characteristics. To asses and monitor these parameters, it is essential to identify magnitude and source of any pollution load. These characteristics can identify certain condition for the ecology of living organisms and suggest appropriate conservation and management strategies (Thirupathaiah *et al*., 2012). Water quality is a vital issue in drinking water reservoirs, most of which are shallow. They are typically situated in plain areas accessible to intense agricultural utilization. Therefore diffuse pollution from fertilizers and other soil enrichment compounds may strongly influence the water quality of shallow reservoirs. Water quality is also of prime importance in reservoirs where fishes are exploited. Nutrient load and organic substances, riverine inputs and retention time of reservoir are known to strongly influence rates of biological processes and the resulting water quality (Straskraba, 1997).

Because of intense exchange of nutrients between water columns and sediments, shallow reservoirs are particularly sensitive to eutrophication (Ekholm *et al.,* 1997). When nutrient loading is low, shallow lakes are relatively clear with low phytoplankton. Under the influence of eutrophication, phytoplankton blooms develop and the clear lakes become turbid. This transition is usually associated with loss of structural biodiversity which results in decrease in biodiversity at higher trophic level (Scheffer, 1998). This transition often leads to loss of socio-economic functions of the reservoir like its water supply, fish production and recreational uses in which Gwaigwaye reservoir is not exceptional. In general shallow reservoirs located in warm latitudes or tropical climates devoid of eutrophication usually have increased total fish biomass than their riverine counterpart (Scheffer, 1998).

Water quality is determined by physical and chemical limnology of a reservoir and is controlled by climatic and geological characteristics of the drainage basin. Water quality includes all the physical, chemical and biological factors that influence beneficial use of water for various purposes to which the reservoir was built. The limnology of the reservoir is characterized by hydrologic impact, autogenic nutrients and biological aspects (Sidnei *et al*., 1992). Water quality has been known to play an important role in public health, recreational use and aquacultural capability of reservoir (Obadaki and Ari, 2014). Excessive amount or lack of basic nutrients and suspended particles can result in imbalance in the ecosystem, resulting in disturbance in food chain, fisheries, recreation and general ecology of the water body. Bonacina (2001) reported that eutrophication brings changes in water quality, leading to alteration or even total destruction of the food web. Campbell and Wildberger (2001) observed that abundance, diversity and distribution of aquatic organisms are easily and greatly influenced by water quality. Water quality has been shown to vary from place to place and changes through time. The management of reservoir water quality requires an understanding of the physical, chemical and biological characteristics of the water; the requirement associated with various uses, the methods of predicting changes due to environmental factors and man and the modifications of the water quality.

The study of limnology which Wetzel (2001), defined as the structural and functional relationships of organisms of inland waters (reservoirs, lakes, ponds etc) as they are affected by their dynamic physical, chemical and biotic environments is an essential ingredient for successful production of fish in reservoirs, maintenance of water quality and for achieving the purpose(s) to which the reservoir was created. The ultimate aim of many limnological investigations is fish production which in most cases is given highest priority than water quality, plankton and aging or succession studies. Other important parameters considered in reservoir limnology which influence production include flow rate, depth, seasonal fluctuations, food and habitat availability. Physicochemical parameters are known to affect the biotic components of an aquatic environment in various ways. Adakole *et al.* (2008) observed the organism, which develops in a given aquatic habitat, is indicative of environmental conditions that have occurred during the organism's development.

The extent to which fisheries can be developed, sustained or protected along riverine ecosystems is by modification of dams to reflects basin topography, geological features, watershed hydrology and climate, as well as engineering features of the dam itself and operational programmes for retention and release of water from the reservoir through dam and into the tail water (Jackson and Marmulla, 2001). Reservoir resulting from construction of dams can also have an enhance yield by stocking of environmentally sound and culturally acceptable fish species. Reservoirs provide significant contribution to global fisheries (Miranda, 1999).

In Nigeria, the contribution of reservoirs to fish production is minimal, despite their numbers in the country. This might be due to reasons Miranda (1999) pointed out as fish habitat and environmental degradation, inadequate fish assemblages, inefficient harvesting systems, stakeholder conflicts, and insufficient institutional and political recognition. Other factors could be lack of proper species stocking, over fishing and improper reservoir management. Fish biology and productivity are variable in dynamic constantly changing reservoir ecosystem. High fish productivity in terms of species diversity and abundance is often observed soon after reservoir formation. (Agostinho *et al*., 1995), but this changes afterwards with subsequent disappearance of some species especially the riverine one and the establishment and flourishing of lacustrine ones as observed by Lelek (1973) in Kainji lake. Some fish species respond very quickly to impoundment, whereas others respond gradually over the years or decades according to trophic status. The adverse response of biotic communities to impoundment is prompted by catalysts such as unsuitable water temperature, low dissolved oxygen and low habitat diversity (O'Brien, 1990).

Construction of reservoir is conducive to the establishment and maintenance of fish stocks. Changes in the physico-chemical parameters may positively or negatively affect the biota of water bodies in a number of ways such as their survival and growth rate and these may eventually result in disappearance of some species of organisms or its reproduction (Edward and Ugwumba, 2010a)

Early reservoir studies (1910-1970) concentrated on the taxonomy and geographic distribution of organisms, fish and fisheries, water quality and sanitary engineering for drinking water reservoirs and descriptive limnology related to distribution and hydro biological problems (Branco, 1999); Johnson and Hering 2009).. Some of the studies that have been done on the physico-chemical properties and fish composition of man–made lakes and Rivers in Nigeria include the works of Kolo, (1999) on Shiroro lake, Mustapha (2006) on Moro reservoir among others.

2.4 Fish as a Biological Indicators or Monitors

Fish communities, and specific species, are excellent indicators of biological and ecological integrity due to their continuous exposure to water conditions (Gardali *et al.,* 2012). Fishes display an array of biotic responses, such as changes in growth, distribution and abundance related to water pollution, critical habitat degradation, eutrophication, organic enrichment, chemical toxicity, thermal changes and food availability and thus, should be key elements of ecosystem monitoring programs, (Helfman, 2007).

Due to bioaccumulation, predatory species have also been used as sentinels for the presence of toxic chemicals in waterways (Holmlund and Hammer, 1999). Perhaps because of their fecundity, small size, and economical maintenance and use, fish models are becoming well established in many laboratories (McHugh, 2003). Due to their life history traits fishes are suitable as early-warning signals of anthropogenic stress on natural ecosystem dynamics, or conversely, as indicators of ecosystem recovery and of resilience (Moyl*e et al.*, 2012). They are sensitive to many stresses from parasites to diseases to acidification. Further, due to such factors as rapid growth rates, large body sizes, habitat choice, and trophic level, many fish have the capacity to bioaccumulate toxic substances (Holmlund and Hammer, 1999.). South American tropical fish *Apteronotus albifrons* (Gymnotiformes) have been proposed as biological early warning system to detect the presence of potassium cyanide in water by means of its electric organ discharges (EOD). Due to its possession of a neurogenic electric organ which continually emits wave from electric signals, which are very stable under constant ambient conditions, but tend to vary in the presence of pollutants. This technique could be incorporated into a system for detecting changes in the quality of surface waters (Thomas *et al*., 1996). **Fish can be use as surrogates and research models** Due to its size and abundance they are easily sampled research objects that provide information crucial for management and our understanding of freshwater ecosystems (Holmlund and Hammer, 1999). They are excellent research models in areas such as phylogenetics, evolutionary biogeography and ecology. Due to the fact that the African cichlid fish radiations are the most diverse extant animal radiations, they provide a unique system to test predictions of speciation and adaptive radiation theory (Seehausen, 2006).

The present fish fauna is living witness to climatic changes in the past, a fact that gives us information about past climate. For example, the distribution of Arctic char (*Salvelinus alpinus*) in Scandinavian lakes reveals a climatic pattern of a maximum water temperature of 16°C from the most recent glaciation period 10,000 years ago to today (Holmlund and Hammer, 1999).

Freshwater fishes are in decline worldwide because of human caused degradation of aquatic habitats (Dudgeon *et al*., 2006; Geist 2011; and Helfman, 2007). Anthropogenic climate change is further accelerating declines of many freshwater fish species, particularly in regions with arid or Mediterranean climates (Aparicio *et al*., 2000; Moyle e*t al*., 2011; Moyle *et al*., 2012). However, the migration of large numbers of people increase the level of human activities in the water shed and intensifies human pressures upon the reservoir. Typical example is Moro reservoir, in Ilorin, Nigeria, where human activities have greatly modified the water quality and the biodiversity of the reservoir (Mustapha, 2006). Coincident with expanding demand for water quantity should be concerns also over the quality. These rapid declines are a major conservation challenge, requiring setting priorities for conservation and for devising strategies to prevent widespread extinctions (Arthington, 2012). One factor hindering development of conservation strategies is limited literature on biology and status of most fishes, especially endemic species of little economic value. Consequently, there is a need for a rapid and repeatable assessment method that can incorporate expert knowledge to determine relative vulnerability of different species to climate change (Geist 2011; Gardali *et al*., 2012).

2.5 Studies on Phytoplankton

It is well established fact that more than 75% of freshwater fish feed on plankton at one or other stage of their life cycle. In the sea and in most large inland water the bulk of living matter found in water is phytoplankton and hence their biological importance is immense (Akomeah *et al.*, 2010).

Phytoplanktons are the primary producers of water bodies; these are the main source of food directly or indirectly to the fish population. Phytoplankton composition has been governed by water quality parameters. The relationship that water quality share with Phytoplankton is reciprocal as the later strongly influence water quality through carbon dioxide uptake and oxygen production. Phytoplanktons are essential component of the aquatic food chain (Janjua, *et al.*, 2008). The Phytoplanktons are the primary producers in freshwater bodies including lakes where different forms present in various locations viz: epilithic (rock) epipsamic (mud), epiphytic (plant), epipelic (sediments) and epizoic (animals) forms (Kadiri, 2002). They constitute a heterogeneous assemblage of algae whose distribution and seasonal succession are of interest to limnologist. This is why they do not only influence the food chain but are also of economic value and biological significance to man (Araoye and Owolabi, 2005). It is therefore proper that their occurrence, composition and abundance be matched with opportunities provided in their environment (Olele and Ekelemu, 2008). The observation of more Chlorophyta than Bacillariophyta (diatoms) conformed to the typical trend in tropical water bodies (Akomeah *et al.,* 2010). High diversity of desmids is an indication that the water body is largely unpolluted (Kadiri, 2002). Euglenophyta is characteristic of eutrophic or nutrient rich water bodies (Adesalu and Nwanko, 2010). Tiseer *et al.* (2008b) recorded ten species of Bacillariophyta, eleven species of Chlorophyata and one species of Euglenophyta in Samaru stream, Zaria, Nigeria. *Peridinium sp*. was the only member of Dinophyceae of plankton composition groups in Egbe reservoir during the dry and rainy seasons (Edward and Ugwumba, 2010b). The abundance of *Microcystis sp* was probably due to the availability of nutrients through sewage disposal, phosphate, detergent, agricultural runoff and high level of nitrogen (Hassan *et al.,* 2010). Kolo *et al.* (2010) reported four groups of phytoplankton (Bacillariophyceace, chlorophyceace, cyanophyceace, and desmidiaceace) in Tagwai dam Minna Nigeria.

2.5.1 Phytoplankton as a Biological Indicators or Monitors

Phytoplankton is a photosynthetic plant and is grazed by zooplankton and small fish (Buraschi *et al*., 2005). The zooplanktons which are also part of the aquatic food web are nutritionally dependent on them. Plankton studies can be used to estimate potential fish yield and productivity (Park and Shin, 2007), water quality (Walsh *et al*., 2001), and energy flow (Simcic, 2005) in reservoirs. The study of phytoplankton ecology and biogeochemical cycles by Beyruth (2000) on the drinking water reservoir of Sao Paulo, Brazil, made the management of the reservoir more effective. Models that use phytoplankton primary production as the main controlling variable for predicting fish yields in lakes and reservoirs have resulted in more successful predictions than many other methods (Knosche and Barthelmes, 1998).

There are various phytoplankton classifications. Kalff (2003) classified phytoplankton based on respective pigmentations into eight divisions: 1) Cyanophyta (Blue-green algae) 2) Chlorophyta (Green algae), 3) Chrysophyta (Golden-brown algae), 4) Bacillariophyta, 5) Cryptophyta, 6) Pyrrophyta (Dinoflagellate), 7) Euglenophyta, and 8) Rhodophyta (Red algae).

Biological monitoring is valuable and method used in conservation studies to protect and preserve the biological integrity of natural ecosystem which include preventive measures. Biological indicators of pollution are useful in predicting the level and degree of pollutant before the effects of the pollution start which affects large proportion of aquatic life (Pai, 2002; Verma, 2002). Of these organisms of community to which the bioindicator species belongs (Singh and Singh, 2003; Joy and Joseph, 1995).

Qualitative and quantitative analysis of different groups of organisms have led to establishment of bioindicator, indices and systems which can be used to assess the pollution and trophic status of the water bodies. Different indices have been developed based on the tolerance of algae to the pollution levels (Battish, 2002; Bahti, 1987). Presently, biomonitoring and indices have become an integral part of water quality assessment and forms part of many water pollution studies (Mahadav *et al*., 2005; Kannel *et al*., 2007).

Growth and reproduction of organisms are related to their particular requirements. Therefore, the presence or absence of particular species indicates the conditions of an environment. The use of bioindicator in environmental monitoring has some general advantages over chemical assessment, such as (1) reducing the cost for frequent sampling and analysis (Wu *et al*., 2005), (2) the equipment is relatively cheap (3) relatively simple analysis (Zbikowski, *et al*., 2007), (4) the possibility to detect short term changes in water quality as well as long term changes in environment, and (5) sensitivity to various factors that affect the environment (Stein *et al*., 2007). This led to a global trend of using biological criteria in environmental assessment and pollution monitoring (Wu *et al*., 2005). Each organism has advantages as indicator of ecosystems, and it is important that the organism reflect the situation of the study area. Mustapha (2005) also reported that Chlorophyceae and Rotifers were the dominant phytoplankton and zooplankton respectively in Moro reservoir.

The abundance, occurrence and distribution of planktons are influenced by several abiotic and biotic factors (Achenbach and Lampert, 1997), which include light, pH conductivity dissolved substances, temperature and grazing pressure. Disturbance in the form of mixing or turbulence also plays a potential role in the ecology of planktonic communities (Reynolds, 1997). Reynolds (1994) also suggested several persistent regional factors such as discharge, water velocity, inflow and seasonal factors like grazing, light, temperature govern the algal community structure in lakes and reservoir ecosystems. The high number and diverse species of phytoplankton could present problems in reservoirs. This could occur especially if the reservoir is eutrophied. Problems that could arise include, turbidity, unpleasant taste to the water after the algal decomposition, anoxia and fish kill.

2.6 Physico-Chemical Parameters of the Reservoir

The study of the physico-chemical properties of water which is a fundamental part of limnology which have been used in assessing water quality, biological productivity and trophic status (Mustapha, 2003), as well as composition, distribution and abundance of biotic organisms (Mustapha and Omotosho, 2006). Physico-chemical study could help in understanding the structure, function and management of reservoir in relation to its biotic components and production. Physical and chemical features in reservoirs are governed by the prevailing hydrologic and geomorphic processes, while the local geology determines the water chemistry.

Water is known to contain a large numbers of chemical elements which enter into chemical complexes in aquatic ecosystems (Thirupathaiah *et al*., 2012). The chemical elements found in water are known to have effect on biological processes that lead to interconversion and flow of energy, nutrient cycling, production of organic materials and ultimately production of aquatic resources most especially fishes. Physical factors such as temperature, transparency, water velocity or current have also been known to interplay with the chemical factors in reservoirs to produce a sustainable ecosystem rich in phytoplankton species, (the primary producers) to zooplanktons and diverse fish populations(Adebowale *et al*.,2008).

2.6.1 Temperature

Temperature is an important physical and essential parameter of aquatic habitats because almost all the physical, chemical, and biological properties are controlled by temperature (Araoye, 2008).The basis of all life functions is complicated set of biochemical reactions that are influenced by physical factors such as temperature. The temperature was basically important for its effects on the chemical and biological activities of organisms in water N'Diaye *et al.* (2013).Temperature influences the oxygen contents of water, quantity and quality of autotrophs, while affecting the rate of photosynthesis and also indirectly affecting the quantity and quality of heterotrophs (Barnabe, 1994). The water temperature varies throughout the year with seasonal changes in air temperature, day length, and solar radiations (Ayoade, 2009). Stratification prevents exchange of dissolved oxygen and nutrient elements between upper and lower layers in the water column. Therefore, it can restrict photosynthesis and production (Szyper and Lin, 1990). The significance of bright sunlight and temperature helped in production of green algae. Dominance of various phytoplankton groups have been noted, for example, between 20 – 25^{0}C, diatoms, predominate and green algae at 35^{0}C (Berman and Steinman,1998).The changes in temperature and other biological factors including succession were responsible for the elimination of some aquatic plants in Jebba Lake, Nigeria (Adeniji, 1991a). Temperature influence in the determination of other factors like pH, conductivity, dissolved gases and various forms of alkalinity N'Diaye *et al.* (2013). Temperatures of water were generally higher than air temperatures in the afternoon hours except for few months (January to March), air and surface water temperatures were almost uniform in the month of October/November but most peculiarly in the morning hours and monthly variations of water temperatures surface and bottom (Araoye, 2008). The water temperature varied from winter to monsoon (June-August), higher water temperatures were recorded in lentic part of Bhagirathi and Bhilangana respectively compare to lotic portion. Water temperature of the lacustrine portion was significantly different from that of lotic and changes in physico-chemical features and Plankton (Ayoade, 2009)**.** Ibrahim *et al.* (2009) reported; the low water temperature of Kontagora reservoir during the dry season could be as a result of seasonal changes in air temperature associated with the cool dry Northeast trend winds. The air and water temperature readings indicated an increase from January to March in Makwaye Reservoir (Balogun *et al.*, 2005).

2.6.2 pH

Water pH is considered an important chemical parameter that determines the suitability of water for various purposes. The pH expresses the acidity or alkalinity of water, which is determined by means of hydrogen ion (H^{+}) and the hydroxyl ion (OH^{-}) concentration in water. Water of around pH 7 is considered neutral, it is of great important to biotic communities because most of the aquatic organisms are adapted to an average pH (Surajit and Tapas, 2014).During daylight, aquatic plants usually remove the CO_2 from the water quickly and pH increases. At night, CO_2 accumulates and pH declines (Mahar, 2003). The increased organic matter brought in by rain as a result of runoff tends to reduce dissolved oxygen through utilization of organic dehydration giving rise to a fall in pH (Atobatele *et al*., 2008). Mustapha (2008) reported the slight acidity in the dry season may be due to high carbon dioxide concentration occurring from organic decomposition. High pH values promote the growth of phytoplankton and results in algal blooms. Decomposition reduced the amount of oxygen, while increasing the amount of carbon dioxide in the affected environment (Araoye, 2008).

2.6.3 Dissolved Oxygen (DO).

Dissolved oxygen is an essential chemical ion needed for energy metabolism of aquatic organisms. It also provides information about the biological and biochemical processes in water. Dissolved oxygen (DO) has primary importance in natural water as limiting factor because most organisms other than anaerobic microbes diminish rapidly when oxygen levels in waterfalls, of all dissolved gases; oxygen plays the most important role in determining the potential biological quality of water. Dissolved oxygen level of 5mg/l or greater will support healthy growth of most fishes (Hanna, 2003). Absence of oxygen in water permits anaerobic decay of organic matter and production of toxic materials and gases such as hydrogen sulphide. Natural eutrophication of the lake is strongly influenced by anaerobic conditions at the bottom (Ciglenecki *et al*., 2005). Dissolved oxygen supply in water mainly comes from atmospheric diffusion and photosynthetic activity of plants. The quantity of dissolved salts and temperature greatly affects the ability of water to hold oxygen (Araoye, 2008).

Iqbal *et al.* (1990) described level of dissolved oxygen playing a predominant role in bringing about temporal changes in the zooplankton composition of Hub Lake.

The amount of dissolved oxygen in water has been reported not constant but fluctuates, depending on temperature, depth, wind and amount of biological activities such as degradation (Indabawa, 2009). Ibrahim *et al.* (2009) reported that the cool harmattan wind, which increased wave action, and decreased surface water temperature, might have contributed to the increased oxygen concentration surface during the dry season in Kontagora reservoir, Niger state, Nigeria. Decomposition reduced the amount of oxygen, while increasing the amount of carbon dioxide in the affected environment. Das, 1978). Photosynthetic activity and reduced turbidity enhanced dissolved oxygen concentrations (N'Diaye *et al.* 2013).

2.6.4 Biochemical Oxygen Demand (BOD)

Biological Oxygen Demand (BOD) is the amount of oxygen required to biologically breakdown a contaminant (Ayoade *et al.* 2006). It is often used as a measurement of pollutants in natural and waste waters and to assess the strength of waste, such as sewage and industrial effluent (Zeb *et al*., 2011). BOD therefore is an important parameter of water, indicating the health scenario of freshwater bodies (Bhatti and Latif, 2011). Essien-Ibok *et al.* (2010) reported the coefficient of biological oxygen demand variation was higher in the rainy season than dry season in Mbo River, Akwa Ibom state. The trend of seasonality in BOD followed that of DO concentration with higher values and variability during the rainy season than in the dry season. The wet season increase in BOD values was probably due to the increased input of decomposable organic matter into the river through surface runoff. These organic matters require oxygen for their biodegradation.

2.6.5 Electricity Conductivity (EC)

Conductivity of natural water is a measure of its ability to conduct an electric current. According to Brook Lemma (2002), waters with very high conductivity are not potable. Conductivity of most fresh water generally is lower during the rainy seasons than dry season (Diaz *et al*., 2007). It is due to a dilution by rain and less evaporation during the rainy season, especially in lakes with short retention time (Zinabu, 2002).this also conform with the reports of (Atobatele and Ugwumba, 2008), which stated that Increased in water conductivity could result from low precipitation, higher atmospheric temperatures resulting in higher evapo-transpiration rates and higher total ionic concentration, and saline intrusions from underground sources. Specific conductivity can be utilized as a rapid measurement of dissolved solids and is useful in monitoring waste streams and conducting field water quality studies. The level of conductivity in water gives a good indication of the amount of substances dissolved in it, such as phosphate, nitrate and nitrites. Different ions vary in their ability to conduct the electricity (Zeb *et al*., 2011). Conductivity can influence composition, abundance and distribution of biotic organisms (Mustapha, 2006). Generally conductivity of the natural water is directly proportional to the concentration of ions. Distilled water has a conductivity of about 1µmhos/cm, while natural water normally has conductivity of 20-1500 µmhos/cm the conductivity of solutions depends upon the quantity of dissolved salts present (Boyd, 1998). Fazio and O'Farrell (2005) reported that biodiversity diminished with increasing conductivity in Los Coipos Lake.

2.6.6 Water Hardness (WH)

Hard water contains high concentrations of alkaline earth metals while soft water has low concentrations. Hardness usually includes only Ca^{++} and Mg^{++} ions expressed in the terms of equivalent $CaCO_3$ (Abbasi, 1998). Calcium is used by green algae as micronutrients. The distribution of certain algae has been correlated with differing concentrations of calcium (Wetzel, 2001). High concentration of Ca^{2+} and Mg^{3+} ions is responsible for hardiness and they are usually associated with high levels of bicarbonates (Ibrahim *et al.,* 2009). Increase in hardness value can be attributed to the decrease in water volume and simultaneous increase in the rate of evaporation at high temperature as a result of high loading organic substances, detergents and other pollutants (Rajgopal *et al*., 2010).

2.6.7 Nitrate-Nitrogen (NO_3-N)

Nitrate-Nitrogen is required in aquatic and terrestrial ecosystem in a moderate quantity. Both Nitrate and Phosphate stimulate algal growth, but nitrate stimulates more than phosphorous (Mischke, 2005). The amount of nitrate in solution at a given time is determined by metabolic processes in water; that is production and decomposition of organic matter (Balarabe, 2001). Kigamba (2005) reported the increased level of nitrates leached into African lakes from the excessive use of nitrogen fertilizers. High concentration of Nitrate-Nitrogen could be attributed to increase in the irrigation practices close to the bank of the lake where leaching of fertilizers from the farm into the lake. Spatial variation in stream water nitrate concentrations is influenced by nitrification in upland soils, which affects the extent to which catchments retain or export nitrate via stream flow (Ude *et al.,* 2011). Nitrate-Nitrogen inputs often vary seasonally due to the effects of the growing season and hydrology, uptake of Nitrogen by terrestrial vegetation. Stream water concentrations tend to be lower during the growing season and higher during the dormant season (Ude *et al.*,2011). Drinking water containing excessive amounts of nitrates can cause infant methemoglobinemia (blue babies), a respiratory disorder where the blood does not carry oxygen and is blue in colour, adult illness and spontaneous abortion in cows (Hach, 2003). Nitrate levels above 44ppm are considered unsafe for drinking water (Campbell and Wildberger, 2001), though the concentration of nitrates in surface waters can reach 100ppm.

2.6.8 Total Dissolved Solids (TDS)

Total dissolved solids indicate organic and inorganic matter in a water sample. The solids may be organic or inorganic in nature depending upon volatility of the substances (Kolo *et al.,* 2010). A high concentration of dissolved solids increases the density of water and affects osmo-regulation of fresh water organisms, reduces solubility of gases and suitability of water for drinking, irrigational and industrial purposes (Boyd, 1998). Another source of TDS to the lake is a sewage inflow into one of the lake's tributary Akomeah *et al.* (2010). The low TDS concentration is due to dilution, low allochthonous inputs, microbial uptake of TDS and usage by phytoplankton (Adakole *et al.,* 2008).

2.6.9 Phosphate-Phosphorus (PO_4-P)

Phosphorus plays an important role in the determination of the productivity of an ecosystem, which in turn can affect the number of trophic level in a food web and its stability. The presence of nutrients and plant biomass formation in water body exhibit a complex dynamic relationship in tropical aquatic ecosystem due to various physicochemical and biological characteristic. Phosphorus enters lakes as inorganic phosphate ions, inorganic polymer and organic phosphorus compounds in living micro-organisms and dead detritus. Ude *et al.* (2011) reported that; phosphorus is the most important and limiting substance controlling organic production.

2.6.10 Sulphur-Sulphates

Sulphate is the third most abundant ion in freshwater (Renn, 1970). They get into water due to erosion of rocks and soil, biochemical oxidation of sulphur and its compounds, atmospheric precipitation, biochemical decomposition of plant and animal proteins and from industrial sewage. It is not toxic but has to be kept below a certain threshold which USEPA (1976) in accordance with safe drinking water act has established to be 400-600 mg/l of magnesium sulphate and 250-800 mg/l of calcium sulphate (Hach, 2003). Sulphate may either be beneficial or detrimental in domestic water supply. Higher concentration in water can cause unpleasant taste to the water and contribute significantly to the hardness of the water. Sulphate has also been implicated in the eutrophication of reservoirs (Armengol *et al*., 1991).

2.6.11 Alkalinity

Alkalinity or buffering capacity of freshwater is primarily due to the presence of bicarbonate, carbonate and hydroxide ions, silicates and phosphate may also contribute. Alkalinity is important for fish and other aquatic life because it buffers pH changes that occur naturally due to photosynthesis. The alkalinity of freshwater under natural condition should not be less than 20ppm (USEPA, 1976). Waters with low alkalinity often have pH of 6 to 7.5. Waters with extreme high total alkalinity may have pH values too high for fish production. Waters dominated by bicarbonate ions usually have low or no phenolphthalein alkalinity (Campbell and Wildberger, 2001).

2.6.12 Calcium

The concentration of calcium ion in natural fresh water is low. The main sources are seawater intrusion, salt bed exudation, and industrial wastewater. Calcium is considered to be a key element in many geochemical processes (Hujare, 2005). It provides healthy growth, cell wall formation, neutralization of acids, and enzymes activation during blood clothing. Deficiency of calcium leads to weakness, stunted growth in animals and poor root development in plants example phytoplanktons.

2.6.13 Chloride

Chloride refers to chlorine ions in water. The concentration of Chloride in natural fresh water is low. The main sources are seawater intrusion, salt bed exudation, and industrial wastewater. Within normal concentrations, they do no harm to the body. However, high concentration may also be found in ground water because of naturally high levels of chloride in soils in some areas or contamination by road (Hujare, 2005). Chloride can be used as an important index to assess the influence of seawater intrusion caused by groundwater over-pumping in coastal areas.

CHAPTER THREE

3.0 MATERIALS AND METHODS

3.1 Study Area

Gwaigwaye Reservoir was constructed in the year 2003 by the former president Chief Olusegun Obasanjo in Funtua Katsina State, with the aim of providing water for irrigation for the surrounding communities and drinking water for three local government areas, viz: Funtua, Faskari and Bakori Local Government areas. The climate of the area is a typical tropical savanna type with wet season (May-October) and dry season (November-April).The Reservoir has an elevation of 642M above sea level. The vegetation is the Guinea Savanna type with soil consisting of dark fertile loamy soils. The reservoir is formed by an embankment over Gwaigwaye River (lat. 11^o, 58^1 N and long. 7^o, 20^1 E) Funtua, Katsina State. The size of the reservoir is about 450m while the depth is about 130m (Figure.3.1).

3.2 Sampling Procedures

Four sampling stations were selected based on stratified method of sampling in Gwaigwaye reservoir. Station I was located at the upstream, station II was located at middle area towards east, Station III was located at middle area towards west while Station IV was located at downstream (water spill way) (Fig.3.1). The distance between stations was 20m apart. The procedural plan of this study was monthly sampling of water and Fish from May 2013 to April 2014. The water was sampled at the surface level by dipping four of the one litre plastic sampling bottle containing 2ml of $KMN0_4$ in each of the four sites for Biological Oxygen Demand (BOD) and Dissolve Oxygen (DO) together with another four of the five litre bottles by sliding them over the upper surface of water with their mouth open against the water current to permit undisturbed passage of the water into the bottle, it was then transported to hydrobiology laboratory for analysis of physico-chemical .

The fish species were caught at each sampling sites (comprising of sampling A, B, C and D). At the sampling sites, the total numbers of fish were based on months (from June to May 2013/2014) and were recorded as percentage abundance. The fish species collected from the sampling sites were also obtained based on the type of fish species and were recorded based on their relative abundance which was expressed below:

$$\frac{X}{Y} \times 100$$

Where X= number of fish species collected in each month.
Y= total number of fish species collected in each month.

The family relative abundance of the fish species caught was also recorded as follows:

1. Bagaridae- Bagrus bajad
2. Cichlidae- Tilapia zilli and Oreochromis niloticus
3. Cyprinidae- Labeo senegalensis
4. Mormyridae- Mormyrus senegalensis
5. Machokidae- Synodentis clarias
6. Latidae- Lates niloticus
7. Claridae- Clarias gariepinus

The fish samples were collected in an ice pack container from the fish landing sites based on previous arrangements with the fishermen. 10% formalin was used for sample preservation before been transported to fishery laboratory where the fish identification to species level was performed with the aid of reference materials such as Balogun (2006), Idodo-umeh (2003), Babatunde and Raji, (2004), and Pauly *et al*. (2004). Dissection for the subsequent microscopic analysis of phytoplankton was done in the fisheries laboratory in the Department of Biological Sciences ABU, Zaria.

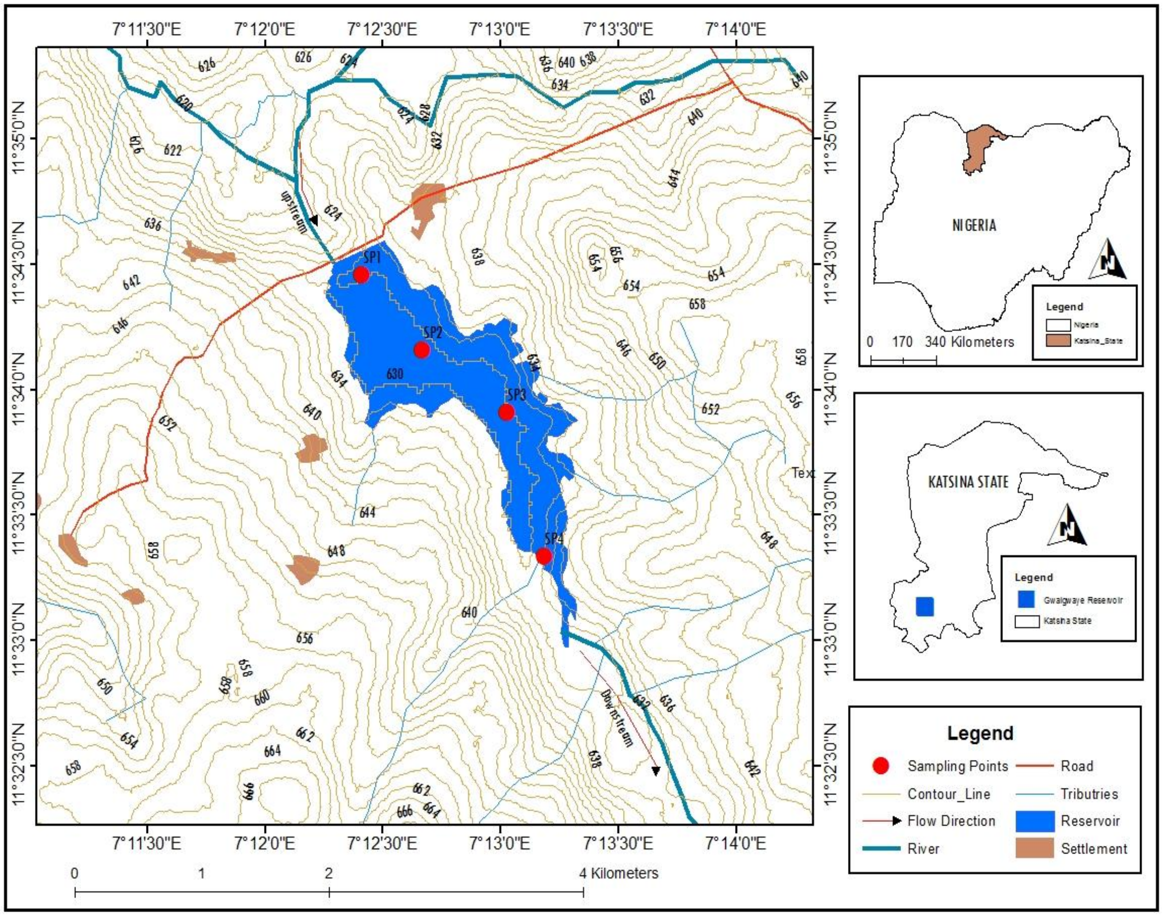

Figure 3.1: Map of Katsina State Showing Location of Gwaigwaye Reservoir and Sampling Stations. Source: Geography Department, Ahmadu Bello University, Zaria, 2014.

3.3 Physico-Chemical Parameters

3.3.1 Determination of Temperature

Temperature (°C) of the water was measured by dipping a Hanna instrument model HI 98129 in to the water at each station for about 1-2minutes then the readings were recorded (APHA, 1999).

3.3.2 Determination of pH

pH was measured by dipping a Hanna instrument model HI 98129 in to the water at each station for about 1-2minutes then the readings were recorded (APHA, 1999).

3.3.3 Determination of Dissolved Oxygen (DO)

Water sample was poured into a 300ml BOD bottle. Two milliliter (2ml) of $MnSO_4$ and 2ml alkali-iodide azide reagent was added, and then stoppered with care to exude air bobbles. It was then mixed gently by inverting the bottle a number of times until a clear supernatant was obtained. It was then allowed to settle for 2minutes after which 2 ml conc. H_2SO_4 was added by allowing the acid run down the neck of the bottle. It was stoppered again and mixed by gentle inversion until the solution was complete. 100ml of the prepared solution was transferred into a conical flask, titrated with 0.0125N of $Na_2S_2O_3.5H_2O$ solution to a pale straw/yellow color. 1ml of freshly prepared starch solution was added and the color becomes blue. Titration was continued by adding the thiosulphate drop wise until the blue color disappeared (Lind, 1979).

$$DO_2 = \frac{1000 \times 8 \times n \times v^{-1}}{v}$$

Where v^{-1} = volume of thiosulphate used (titre value)

n = normality of thiosulphate (0.0121N)

v = volume of sample used (200ml)

3.3.4 Determination of Biological Oxygen Demand (BOD)

Exactly 300ml of water sample was poured into a 200ml standard BOD bottle and covered carefully to exude air bobbles. The bottle was then kept in an incubator for 5 days. After 5 days in incubator, the bottle was brought out and 2ml of $MnSO_4$ was added followed by 2ml alkali-iodide azide reagent. The bottle was stoppered carefully to exude air bubbles, and then mixed thoroughly by inverting the bottle several times, the precipitate was allowed to settle leaving clear supernatant after which 2 ml of Conc. H_2SO_4 was added. The bottle was stoppered and mixed with gentle inversion. 100ml of the prepared solution was transferred into a conical flask, and 2ml of freshly prepared starch indicator was added. The solution was titrated with 0.0125N of sodium thiosulphate solution until disappearance of the blue color. BOD was then calculated using the formula: $(BOD)_5$ in mg/l = DO_1-DO_5 (APHA, 1999).

3.3.5 Determination of Electrical Conductivity (EC)

Electrical conductivity of the water was measured by dipping a Hanna instrument model HI 98129 in to the water at each station for about 1-2minutes then the readings were recorded. The Hanna instrument reading was calibrated for each reading taken. (APHA, 1999).

3.3.6 Determination Total Dissolved Solids (TDS)

Total dissolved solids of the water was measured by dipping a Hanna instrument model HI 98129 in to the water at each station for about 1-2minutes then the readings were recorded. The Hanna instrument reading was calibrated for each reading taken. (APHA, 1999).

3.3.7 Determination of Water Hardness

Exactly 10ml of sample was taken into conical flask with the help of pipette, 0.5mg of buffer tablet (Erichrome black-T) and 1ml of concentrated ammonium hydroxide (NH4OH) was added as indicator and then titrated with 0.1N (EDTA) solution.

Calculation

$N \times M \times 50{,}000$

Hardness ($mgCaCO_3$ L-1) = V

Where:

N = Normality of titrate 0.1N

M = Mean of three readings

V =Mean Volume of three sample

50,000 = standard value of equation. (APHA 1999).

3.3.8 Determination of Nitrate-Nitrogen

Exactly 100 ml of water sample was poured into a clean dry metallic crucible, and kept in an oven at 100^0C till evaporated to dryness, it was then removed and allowed to cool after which 2ml of phenoldisulphonic acid was added and swirled round uniformly in the crucible, it was left to stand for 10minutes and 10ml of distilled water was added followed by 5ml strong ammonia solution and allowed to cool. Color change was read at the wave length 430nm using calorimeter instrument. (APHA 1999).

3.3.9 Determination of Phosphor-Phosphate

Exactly 100ml of water sample was transferred into a conical flask, 1ml of Ammonium molybdate reagent was added and 1 drop of stannous chloride, then allowed to stand for 12 minutes, color changes was read at 600nm using calorimeter instrument (APHA 1999)..

3.3.10 Determination of Sulphur-Sulphate

Exactly 100 ml of sample was added in a conical flask, 1g of BaCl was also added and shakens, it was then let to stand for 3 minutes. The reading was taken at 430nm wavelength using calorimeter instrument (APHA 1999).

3.3.11 Determination of Alkalinity

Exactly 100 ml of water sample was transferred into a conical flask, 2 drops of bromocresol green and 2 drops of methyl red were added respectively. The mixture was swirled and titrated with solution of H_2SO_4 until color change. Total alkalinity in $CaCO_3$ mg/l = titre value ×10 (APHA 1999).

3.3.12 Determination of Calcium

Exactly 50ml of sample was taken into conical flask with the help of pipette, 1ml of NaOH was added to produce pH of 13-14 and 0.2g murexide was added as indicator and stir. Color changes to pink then titrated with 0.1N EDTA solution and note the color change pink to purple. Noted the volume of EDTA used and was recorded as value of calcium. (APHA 1999).

3.3.13 Determination of Chloride

Exactly 100 ml of water sample was transferred into a conical flask, 2-3 drops of potassium chromate was added, and content was swirled for few minutes, and then titrated against silver nitrate solution until dirty reddish precipitate was obtained. Chloride was calculated using: Cl mg//l = volume of $AgNo_3$ ×10 (APHA 1999).

3.4 Biological Parameters

3.4.1 Determination of Phytoplankton

Phytoplankton samples were collected from the gut content of the dissected fishes and introduced into 5ml containers labelled A, B, C and D with respect to the sampling sites. Samples were preserved in 5ml Lugol's solution each and brought to the physiology laboratory for microscopic analysis. Samples were kept for 24 hours and slides were prepared and observed under a binocular microscope model Olympus CH with various magnifications. Taxonomic identification of phytoplankton was carried out with the help of taxonomic keys such as Emi and Andy (2007); Verlencar (2004); Edward and David (2010). The phytoplanktons were counted from left top corner of the slide to the right corner by moving the slide horizontally. Photographs of the specimens' representative were made with Samsung digital camera Model PL 120 of 4.2 mega pixel (m.p.) with magnification of ×100 and ×400 under the binocular microscope (Mahar, 2003).

3.4.2 Identification of fish species

Fish samples were collected with ice pack containers labelled A, B, C and D respectively from the fish landing sites. Fishes were identified using standard reference materials such as Balogun (2006); Idodo-umeh (2003), and Pauly *et al.* (2004).

3.5 Statistical Analyses

Data analysis was carried out to find Mean, Mean ± Standard Error (SE),Percentage was used for phytoplankton abundance and fish population and the results obtained was subjected to analysis of variance to test the level significance at $P<0.05$; between the physico-chemical parameters and seasonal variation. Duncan's Multiple Range Tests (DMRT) was used to separate means. Pearson's correlation coefficient was used on the data using SPSS 10.0 for windows to determine significant relationships between the physico-chemical parameters, fish fauna and phytoplankton. Shannon and Simpson's diversity index was used to determine diversity. T-test was used to compare the seasonal variation of physico-chemical parameters in gwaigwaye reservoir.

CHAPTER FOUR

4.0 RESULTS

4.1 Physico-Chemical Parameters

The Physico-Chemical Parameters of the reservoir showed monthly mean variation (Table 4.1). The water temperature ranged between 20.63±0.04 to 27.19±0.07°C with mean ± SE value of (25.02±0.17°C); the pH values ranged between 7.10±0.04 to 8.13±0.12 with mean ± SE value of 7.54±0.03; calcium of the reservoir ranged between 1.20±0.06 to 3.84±0.03 with mean ± SE value of 2.97±0.063mgL^{-1}. The Dissolved Oxygen values in the reservoir ranged from 2.26mgL-1 to 5.65mgL^{-1}; with the mean ±SE of 3.98 ± 0.10mgL^{-1}. The Biochemical oxygen demand of the reservoir ranged between 1.25±0.08 to 3.73± 0.07 revealed monthly variations with mean ± SE value of 2.53 ± 0.08mgL^{-1}. The Electrical conductivity ranged from 89.58±0.93µS/cm to 221.50±13.55µS/cm with mean ± SE of 129.43 ± 5.15µS/cm. The water hardness in the reservoir ranged between 83.76 ±6.04 to 189.67 ±12.32 with mean ± SE of 134.44 ± 3.06mgL^{-1}($CaCO_3$); Nitrate-nitrogen in the reservoir ranged between 0.13±0.01 to 0.28± 0.003 with mean ± SE values of 0.21 ± 0.004mgL-1 during the period of study. Total dissolved solids in the reservoir has peaked value of 56.25mgL^{-1} which was recorded in the month of April while the least value of 44.33mgL^{-1} was recorded in the month of August; the mean ± SE was 50.54 ± 0.57mgL^{-1} Phosphate-phosphorus in the reservoir ranged between 0.15 ± 0.01 to 0.25 ± 0.02 with mean ± SE values of 0.19±0.002; The mean ± SE value of Chloride was 5.09±0.15mgL^{-1}; The mean ± SE value of Sulphur-Sulphate was 0.21±0.01mgL^{-1}; The mean ± SE value of Calcium was 2.97±0.06mgL^{-1}; and the value of Alkalinity ranges between 2.65±0.14 to 5.32 ±0.16 with the mean ± SE value of 3.69± 0.09 mgL^{-1}.

Table 4.1: Monthly Variation in Physico-chemical Parameters of Gwaigwaye Reservoir Funtua, Katsina State.

Months	DO (mg/L)	Chloride (mg/L)	PO_4 (mg/L)	Nitrates (mg/L)	SO_4 (mg/L)	pH	Temperature (°C)	EC	TDS (mg/L)	Hardness (mg/L)	BOD (mg/L)	Calcium (mg/L)	Alkalinity mg/L.$CaCO_3$)
June	5.46±0.04^{a}	7.58±0.14^{a}	0.21±0.003^{b}	0.28±0.003^{a}	0.25±0.01^{b}	7.16±0.05^{cd}	26.14±0.03^{bc}	106.58±1.10^{b}	52.67±0.59^{abc}	178.67±6.00^{a}	2.63±0.57^{cd}	3.30±0.06^{b}	4.13±0.13^{bc}
July	4.86±0.11^{b}	6.91±0.18^{b}	0.21±0.01^{bc}	0.28±0.003^{a}	0.24±0.01^{b}	7.10±0.04^{d}	25.17±0.02^{de}	105.83±1.14^{b}	50.67±0.96^{bcd}	162.00±7.04^{b}	3.73±0.07^{a}	3.49±0.08^{b}	3.89±0.13^{c}
August	4.68±0.36^{b}	6.84±0.26^{bc}	0.18±0.002^{de}	0.20±0.01^{c}	0.28±0.01^{a}	7.53±0.16^{b}	25.71±0.02^{cd}	89.58±0.93^{b}	44.33±0.48^{e}	122.67±1.73^{c}	3.03±0.19^{bc}	3.35±0.06^{b}	4.17±0.08^{bc}
Septemb	2.26±0.13^{e}	6.68±0.12^{bc}	0.19±0.001^{cd}	0.21±0.01^{bc}	0.27±0.01^{a}	8.13±0.12^{a}	26.48±0.02^{b}	101.67±8.89^{b}	45.67±2.02^{de}	189.67±12.32^{a}	1.25±0.08^{f}	2.78±0.08^{d}	4.34±0.11^{b}
October	3.09±0.11^{d}	6.40±0.15^{cd}	0.17±0.004^{de}	0.21±0.003^{bc}	0.25±0.01^{b}	7.97±0.11^{a}	25.87±0.39^{c}	97.75±12.80^{b}	55.67±0.73^{ab}	150.67±2.97^{b}	2.23±0.15^{de}	2.94±0.22^{cd}	5.25±0.13^{a}
Novemb	3.18±0.11^{d}	6.03±0.15^{d}	0.17±0.01^{de}	0.22±0.003^{bc}	0.24±0.01^{b}	7.91±0.10^{a}	25.53±0.40^{cde}	99.08±13.27^{b}	56.00±0.71^{a}	152.33±2.93^{b}	3.27±0.15^{ab}	3.23±0.20^{bc}	5.32±0.16^{a}
Decembe	4.15±0.16^{c}	3.35±0.16^{ef}	0.17±0.01^{e}	0.22±0.003^{b}	0.14±0.004^{e}	7.35±0.02^{bc}	25.53±0.03^{cde}	112.33±2.36^{b}	47.50±1.58^{cde}	120.00±5.55^{c}	2.40±0.11^{cde}	2.78±0.07^{d}	2.65±0.14^{e}
January	3.91±0.16^{c}	3.63±0.16^{e}	0.17±0.01^{de}	0.22±0.002^{b}	0.15±0.004^{e}	7.37±0.01^{bc}	25.69±0.05^{cd}	111.25±2.31^{b}	49.08±1.63^{cde}	127.33±5.48^{c}	2.52±0.13^{cde}	2.92±0.06^{cd}	2.88±0.16^{de}
Februar	3.23±0.11^{d}	3.69±0.22^{e}	0.17±0.01^{e}	0.13±0.01^{e}	0.17±0.01^{d}	7.35±0.07^{bc}	27.19±0.07^{a}	102.83±3.15^{b}	47.42±4.17^{cde}	83.67±6.04^{e}	2.73±0.09^{bcd}	1.20±0.06^{e}	2.93±0.16^{de}
March	5.65±0.17^{a}	3.34±0.08^{ef}	0.25±0.02^{a}	0.22±0.01^{b}	0.21±0.003^{c}	7.50±0.04^{b}	20.63±0.04^{g}	200.25±24.98^{a}	50.75±1.66^{bcd}	113.00±4.78^{cd}	2.14±0.13^{de}	3.84±0.03^{a}	2.80±0.16^{de}
April	3.13±0.17^{d}	3.05±0.07^{f}	0.18±0.003^{de}	0.16±0.11^{d}	0.14±0.004^{e}	7.60±0.05^{b}	24.95±0.36^{e}	221.50±13.55^{a}	56.25±0.58^{a}	113.33±5.40^{cd}	1.94±0.16^{e}	2.93±0.13^{cd}	3.08±0.08^{d}
May	4.15±0.14^{c}	3.55±0.08^{e}	0.15±0.01f	0.14±0.01^{e}	0.14±0.01^{e}	7.46±0.04^{b}	21.33±0.21^{f}	204.50±23.12^{a}	50.50±1.52^{bcd}	100.00±4.26^{de}	2.48±0.10^{cde}	2.90±0.08^{cd}	2.80±0.10^{de}
Total	3.98±0.10	5.09±0.15	0.19±0.002	0.21±0.004	0.21±0.01	7.54±0.03	25.02±0.17	129.43±5.15	50.54±0.57	134.44±3.06	2.53±0.08	2.97±0.06	3.69±0.09
P value	0.000**	0.000**	0.000**	0.000**	0.000**	0.000**	0.000**	0.000**	0.000**	0.000**	0.000**	0.000**	0.000**

KEY: DO – Dissolved Oxygen, Cl – Chloride, PO4 –Phosphate, N – Nitrates, SO4, - Sulphate, pH – pH value, Temp. – Temperature, EC – Electrical Conductivity, TDS – Total Dissolved Solids, H – Hardness, BOD – Biological Oxygen Demand, Ca – Calcium, Alk – Alkalinity. **-Highly Significant difference; ns-non Significant difference.

Note: Means with thesame superscripts along the same column are not significantly different (P≥0.05)

4.1.1 Temperature

Table 4.1 shows monthly variations of temperature in Gwaigwaye reservoir, there was fluctuation in temperature observed from March to May with almost a uniform temperature in June to January and the highest record in February. There was no significant difference between the water temperatures of the four stations at $P > 0.05$ (Table 4.2). Analysis of variance revealed that there was no significant difference between the temperature in the wet and dry season at $P > 0.05$ (Table 4.3). The water temperature indicated that there was no positive correlation with any of the physico-chemical parameters, while there was negative correlation with Dissolved oxygen, phosphate, Electrical conductivity and Total dissolve solids (Table**:** 4.7). The highest temperature recorded among the stations was 25.20°C at station I while the lowest temperature of 24.58°C was recorded at station IV. Both highest and lowest temperatures were recorded in February and March.

4.1.2 pH

The highest pH value of 8.13 was recorded during the wet season in September while the lowest pH value of 7.10 was recorded during the rainy season too in July (Table 4.1). There was a highly significant difference between the pH values of the four stations at $P < 0.05$ with Station I recorded the highest pH value of 7.81 while Station IV recorded the lowest pH value of 7.28 (Table 4.2). Analysis of variance revealed there was no significant difference between wet and dry season values of pH in Gwaigwaye reservoir at $P > 0.05$ with the pH values fluctuated between the months of June to October in the wet season with increase in the pH values in the month of June to September (Table 4.3). The pH indicate Positive correlation with Alkalinity while negative correlation with dissolved oxygen, Nitrate-nitrogen and Phosphate-phosphorus, Electrical Conductivity, Biological Oxygen Demand and calcium (Table: 4.7).

Table 4.2: Seasonal Variation in Physico-chemical Parameters of Gwaigwaye Reservoir Funtua, Katsina State among Sampling Stations.

Physico-Chemical Parameters	Stations				Total	P value
	I	II	III	IV		
DO (mg/L)	4.21±0.20[a]	3.74±0.17[a]	3.89±0.22[a]	4.07±0.18[a]	3.98±0.10	0.311ns
Chloride (mg/L)	5.36±0.30[a]	5.32±0.33[a]	4.74±0.30[a]	4.93±0.25[a]	5.09±0.15	0.383ns
PO_4 (mg/L)	0.20±0.01[a]	0.18±0.01[ab]	0.19±0.003[a]	0.17±0.004[b]	0.19±0.003	0.004*
Nitrates (mg/L)	0.20±0.01[a]	0.22±0.01[a]	0.21±0.01[a]	0.21±0.01[a]	0.21±0.004	0.820ns
SO_4 (mg/L)	0.20±0.01[a]	0.20±0.01[a]	0.21±0.01[a]	0.21±0.01[a]	0.21±0.010	0.578ns
pH	7.81±0.08[a]	7.56±0.07[b]	7.49±0.06[b]	7.28±0.03[c]	7.54±0.034	0.000**
Temperatures (°C)	25.20±0.33[a]	25.10±0.35[a]	25.19±0.34[a]	24.58±0.33[a]	25.02±0.17	0.512ns
EC (µS/cm)	161.81±11.69[a]	142.86±13.57[a]	107.25±5.12[b]	105.81±4.56[b]	129.43±5.15	0.000**
TDS (mg/L)	52.08±0.93[a]	51.36±0.82[a]	50.50±1.11[a]	48.22±1.52[a]	50.54±0.57	0.088ns
Hardness (mg/$CaCO_3$)	123.33±5.88[ab]	138.67±6.71[ab]	130.89±2.37[ab]	144.89±7.77[a]	134.44±3.06	0.070ns
BOD (mg/L)	2.80±0.16[a]	2.24±0.15[a]	2.60±0.15[a]	2.48±0.15[a]	2.53±0.08	0.065ns
Calcium (mg/L)	3.01±0.12[a]	3.20±0.12[a]	2.85±0.12[a]	2.83±0.11[a]	2.97±0.06	0.099ns
Alkalinity (mg/L.$CaCO_3$)	3.80±0.19[ab]	4.15±0.17[a]	3.36±0.16[b]	3.43±0.14[b]	3.69±0.09	0.003*

KEY: DO – Dissolved Oxygen, Cl – Chloride, PO4 –Phosphate, N – Nitrates, SO4, - Sulphate, pH – pH value, Temp. – Temperature, EC – Electrical Conductivity, TDS – Total Dissolved Solids, H – Hardness, BOD – Biological Oxygen Demand, Ca – Calcium, Alk – Alkalinity. * - Significant difference; **-Highly Significant difference; ns-non Significant difference

Note: Means of the same superscript along the columns are not significantly different at $p \geq 0.05$.

Table 4.3: Seasonal Variation in Physico-chemical Parameters of Gwaigwaye Reservoir Funtua, Katsina State.

Stations	Wet	Dry	Total	P value
DO (mg/L)	4.28±0.16	3.76±0.11	3.98±0.01	0.007**
Chloride (mg/L)	6.31±0.20	4.21±0.15	5.09±0.15	0.000**
PO_4 (mg/L)	0.19±0.004	0.19±0.004	0.19±0.003	0.623ns
Nitrates (mg/L)	0.22±0.01	0.20±0.01	0.21±0.004	0.007**
SO_4 (mg/L)	0.24±0.01	0.19±0.01	0.21±0.01	0.000**
pH	7.48±0.06	7.58±0.04	7.54±0.03	0.135ns
Temperatures (°C)	24.97±0.25	25.05±0.23	25.02±0.17	0.804ns
EC (µS/cm)	121.63±7.26	135.00±7.11	129.43±5.15	0..202ns
TDS (mg/L)	48.77±0.68	51.81±0.82	50.54±0.57	0.008**
Hardness (mg/$CaCO_3$)	150.60±5.41	122.91±3.00	134.44±3.06	0.000**
BOD (mg/L)	2.62±0.16	2.46±0.07	2.53±0.08	0.293ns
Calcium (mg/L)	3.16±0.05	2.83±0.09	2.97±0.06	0.006**
Alkalinity (mg/L.$CaCO_3$)	3.87±0.09	3.56±0.13	3.69±0.09	0.073ns

KEY: DO – Dissolved Oxygen, Cl – Chloride, PO4 –Phosphate, N – Nitrates, SO4, - Sulphate, pH – pH value, Temp. – Temperature, EC – Electrical Conductivity, TDS – Total Dissolved Solids, H – Hardness, BOD – Biological Oxygen Demand, Ca – Calcium, Alk – Alkalinity. * - Significant difference; **-Highly Significant difference; ns-non Significant difference.

Note: Means of the same superscript along the columns are not significantly different at $p \geq 0.05$.

Table 4.4: Monthly Fish Landing in Gwaigwaye Reservoir

Fish Fauna Species	June (%)	July (%)	August (%)	September (%)	October (%)	November (%)	December (%)	January (%)	February (%)	March (%)
Bagrus bayad	26 (14.13)	30(17.44)	20(11.43)	25 (13.97)	15 (14.29)	11 (11.70)	10 (11.49)	10 (8.20)	15 (13.64)	10 (8.93)
Tilapia zilli	25 (13.59)	36(20.93)	41(23.43)	37 (20.67)	10 (9.52)	10 (10.64)	11 (12.64)	33 (27.05)	20 (18.18)	20 (17.86)
Clarias gariepinus	34 (18.48)	43(25.00)	28(16.00)	31 (17.32)	14 (13.33)	13 (13.83)	11 (12.64)	22 (18.03)	9 (8.18)	10 (8.93)
Momyrus senegalensis	27 (14.67)	10 (5.81)	17 (9/71)	18 (10.06)	12 (11.43)	11 (11.70)	10 (11.49)	8 (6.56)	13 (11.82)	7 (6.25)
Oreochromis niloticus	31 (16.85)	17 (9.88)	27(15.43)	22 (12.29)	17 (16.19)	15 (15.96)	16 (18.39)	16 (13.11)	10 (9.09)	18 (16.07)
Synodontis clarias	16 (8.70)	11 (6.40)	14 (8.00)	9 (5.03)	4 (3.81)	5 (5.32)	7 (8.05)	12 (9.84)	8 (7.27)	7 (6.25)
Labeo senegalensis	11 (5.98)	10 (5.81)	10 (5.71)	12 (6.70)	13 (12.38)	11 (11.70)	7 (8.05)	5 (4.10)	13 (11.82)	12 (10.71)
Lates niloticus	14 (7.61)	15 (8.72)	18(10/29)	25 (13.97)	20 (19.05)	18 (19.15)	15 (17.24)	16 (13.11)	22 (20.00)	28 (25.00)
Monthly Total	**184 (11.76)**	**172(10.99)**	**175(11.18)**	**179 (11.44)**	**105 (6.71)**	**94 (6.01)**	**87 (5.56)**	**122 (7.80)**	**110 (7.03)**	**112 (7.16)**

KEY: *BB – Bagrus bayad, TZ - T. zilli, CG – Clarias gariepinus, MS – Mormyrus senegalensis, ON – Oreochromis niloticus, SC – Synodontis clarias, LS – Labio sengalensis, LN – Lates niloticus*.
Note: Means of the same superscript along the columns are not significantly different at p≥0.05.

Table 4.5: Correlation between Fish Species and Physico-chemical Parameters of Gwaigwaye Reservoir Funtua, Katsina State.

	BB	*TZ*	*CG*	*MS*	*ON*	*SC*	*L.S*	*LN*	*DO*	*Cl*	*PO4*	*N*	*SO4*	*pH*	*Temp.*	*EC*	*TDS*	*H*	*BOD*	*Ca*	*Al*
BB	1.0																				
TZ	0.6*	1.0																			
CG	0.6*	0.6*	1.0																		
MS	0.6*	0.3	0.5*	1.0																	
ON	0.5*	0.3	0.2	0.5*	1.0																
SC	0.5*	0.6*	0.6*	0.6*	0.7*	1.0															
LS	0.2	0.0	0.0	0.3	-0.2	-0.3	1.0														
LN	-0.1	0.2	-0.2	-0.1	-0.3	-0.4	0.7*	1.0													
DO	0.1	0.2	0.3	0.1	0.2	0.5*	0.0	-0.1	1.0												
Cl	0.7*	0.4	0.6*	0.7*	0.3	0.3	0.5*	0.0	0.1	1.0											
PO_4	0.3	0.3	0.1	0.1	0.2	0.2	0.4	0.5*	0.6*	0.2	1.0										
N	0.5*	0.3	0.5*	0.3	0.2	0.2	0.2	0.0	0.5	0.6*	0.6*	1.0									
SO4	0.6*	0.5*	0.4	0.5*	0.2	0.1	0.7*	0.4	0.1	0.9*	0.4	0.5*	1.0								
pH	-0.1	-0.2	-0.3	0.0	0.0	-0.6*	0.3	0.4	-0.7*	0.2	-0.2	-0.2	0.3	1.0							
Temp.	0.4	0.3	0.0	0.4	0.0	0.1	0.2	-0.1	-0.5*	0.4	-0.3	0.1	0.3	0.1	1.0						
EC	-0.3	-0.4	-0.3	-0.4	0.2	0.0	-0.4	-0.1	0.2	-0.7*	0.2	-0.4	-0.6*	-0.1	-0.8*	1.0					
TDS	-0.1	-0.6*	-0.3	-0.2	0.1	-0.3	-0.1	-0.3	-0.1	0.0	0.0	0.1	-0.1	0.2	-0.1	0.3	1.0				
H	0.6*	0.3	0.5*	0.5*	0.3	0.1	0.3	0.1	-0.1	0.8*	0.3	0.8*	0.7*	0.3	0.4	-0.5*	0.1	1.0			
BOD	0.1	0.1	0.3	-0.1	-0.2	0.1	0.0	-0.4	0.4	0.3	0.0	0.3	0.1	-0.5*	0.1	-0.3	0.1	-0.1	1.0		
Ca	0.1	0.2	0.3	0.0	0.4	0.2	-0.1	0.0	0.6*	0.3	0.5*	0.6*	0.4	0.0	-0.5*	0.2	0.2	0.4	0.1	1.0	
Alk	0.3	0.0	0.2	0.4	0.1	-0.2	0.5*	0.1	-0.3	0.8*	-0.1	0.4	0.8*	0.6*	0.4	-0.6*	0.3	0.7*	0.2	0.2	1.0

KEY: BB – Bagrus bayad, TZ - T. zilli, CG – Clarias gariepinus, MS – Mormyrus senegalensis, ON – Oreochromis niloticus, SC – Synodontis clarias, LS – Labio sengalensis, LN – Lates niloticus, DO – Dissolved Oxygen, Cl – Chloride, PO4 –Phosphate, N – Nitrates, SO4, - Sulphate, pH – pH value, Temp. – Temperature, EC – Electrical Conductivity, TDS – Total Dissolved Solids, H – Hardness, BOD – Biological Oxygen Demand, Ca – Calcium, Alk – Alkalinity.

* - strongly positive or negative correlation.

Table 4.6: Monthly Phytoplankton preference of the fish available based on Abundance and Percentage composition in Gwaigwaye Reservoir, Funtua, Katsina State.

Phytoplankton	***Bacillariophyta***	***Chlorophyta***	***Cyanophyta***	***Dinophyta***	**Monthly Total (%)**
June (%)	18 (8.22)	27 (9.03)	10 (9.90)	4 (17.39)	**59 (9.19)**
July (%)	28 (12.79)	43 (14.38)	11 (10.89)	5 (21.74)	**87 (13.55)**
August (%)	33 (15.07)	46 (15.38)	16 (15.84)	5 (21.74)	**100 (15.58)**
September (%)	32 (14.61)	38 (12.71)	13 (12.87)	4 (17.39)	**87 (13.55)**
October (%)	27 (12.33)	36 (12.04)	11 (10.89)	3 (13.04)	**77 (11.99)**
November (%)	21 (9.59)	31 (10.37)	10 (9.90)	1 (4.35)	**63 (9.81)**
December (%)	18 (8.22)	23 (7.69)	8 (7.92)	0 (0.00)	**49 (7.63)**
January (%)	10 (4.57)	13 (4.35)	3 (2.97)	0 (0.00)	**26 (4.05)**
February (%)	6 (2.74)	10 (3.34)	3 (2.97)	0 (0.00)	**19 (2.96)**
March (%)	7 (3.20)	9 (3.01)	4 (3.96)	0 (0.00)	**20 (3.12)**
April (%)	9 (4.11)	13 (4.35)	5 (4.95)	0 (0.00)	**27 (4.21)**
May (%)	10 (4.57)	10 (3.35)	7 (6.93)	1 (4.35)	**28 (4.36)**
Total (%)	**219 (34.11)**	**299 (46.57)**	**101 (15.73)**	**23 (3.58)**	**642**

4.1.3 Dissolved Oxygen (DO)

There was an increase in dissolved oxygen content in the reservoir from April to June, and a gradual decreased from July to September with a fluctuation between October to March, with the highest value of 5.46mgL^{-1} recorded in June while the lowest value of 2.26mgL^{-1} in September (Table 4.1). Station I recorded the highest value of 4.21 mgL^{-1} with the lowest record of 3.74 mgL^{-1} in station II (Table 4.2). There was no significant difference of Dissolve oxygen values in the Four stations $P > 0.05$, but there was a highly significant difference between the values of Dissolve oxygen in the wet and dry season (at $P < 0.05$) (Table 4.3). The dissolved oxygen indicated positive correlation with phosphate phosphorus and calcium while negative correlations with Temperature, pH, Hardness, Alkalinity and Total dissolve solids (Table 4.7).

4.1.4 Biochemical Oxygen Demand

There was increased in the values of biochemical oxygen demand from the month of April to August, with a decrease in September and a fluctuation between October - March. The lowest value of 1.25mgL^{-1} was recorded in the month of September in the wet season while the highest value of 3.73mgL^{-1} was recorded in the month of July (Table 4.1). Station I recorded the highest value of 2.80mgL^{-1} with the lowest value of 2.24mgL^{-1} recorded in Station II (Table 4.2). There was no significant difference between biochemical oxygen demand values in the four stations ($P > 0.05$). The analysis of variance revealed that there was no significant difference between biochemical oxygen demand values in wet and dry season at $P > 0.05$ (Table 4.3). Biochemical oxygen demand indicated only negative correlation with pH, phosphate phosphorus, Electrical Conductivity, hardness (Table 4.7).

4.1.5 Electrical Conductivity

Table 4.1 shows monthly stations variations of Conductivity in Gwaigwaye reservoir. There was a decrease between April to October with an increase in November to March. The highest value of 221.50μS/cm was recorded in April in dry season while lowest value of 89.581μS/cm was recorded in August in the wet season, with station I recorded the highest value of 161.81μS/cm with lowest value of 105. 81μS/cm recorded at station IV (Table 4.2). Analysis of variance revealed there was a significant difference between the electrical conductivity values in the Four stations ($P < 0.05$) but there was no significant difference between the wet and dry seasons in electrical conductivity of the reservoir at $P < 0.05$ (Table 4.3). Conductivity revealed only negative, correlations with Hardness, Chloride, Nitrate, Sulphate, temperature, Biochemical oxygen demand, pH and Alkalinity (Table 4.7).

4.1.6 Water Hardness

Table 4.1 shows monthly stations variation of hardness in Gwaigwaye Reservoir. There was increased in the hardness from the month of June with a fluctuation in the month of July to September and increase in October to November. The highest value of 189.6mgL^{-1} ($CaCO_3$) was recorded in the September while the lowest value of 83.6mgL^{-1} was recorded in February. Station IV recorded the highest value of 3.62mgL^{-1} in while station I recorded the lowest value of 3.08mgL^{1} .The Analysis of variance revealed that there was no significant difference in hardness between the four stations (Table 4.2) and there was a highly significant difference between the wet and dry season hardness of the reservoir at $P < 0.05$ (Table 4.3). Hardness shown positive correlation with chloride, Nitrate-nitrogen and Sulphate-Sulphur while negative correlation with Dissolve oxygen and Conductivity (Table 4.7).

4.1.7 Nitrate-Nitrogen

The highest (June) and lowest (May) values of Nitrate-Nitrogen was recorded during the wet and dry seasons, there was monthly variation in the Nitrate-Nitrogen values with little stability from August to January with decrease in February and an increase in March with an increase from April to July (Table 4.1). The highest amount of Nitrate-Nitrogen was found in station II while the lowest in station I (Table 4.2). The analysis of variance indicated there was no significant difference of Nitrate-Nitrogen concentration in the four stations ($P < 0.05$). There was a highly significant difference between wet and dry seasons at ($P < 0.05$) (Table: 4.3). Nitrate-Nitrogen revealed positive correlation with Chloride, Phosphate, and Calcium. While negative correlation with, pH, Temperature, biochemical oxygen demand and Alkalinity (Table 4.7).

4.1.8 Total Dissolved Solids

The highest value recorded during the dry season was 56.25MgL^{-1} while the lowest during the wet season was 44.33MgL^{-1} (Table 4.1). The highest value of TDS was recorded in station I as 52.08 MgL^{-1} and the lowest was 48.22 MgL^{-1} in station IV (Table 4.2). There was increased in values of total dissolved solids from August to November; then there was little stabilization between December to March (Table 4.3). Analysis of variance revealed there was no significant difference in the values of total dissolved solids recorded during the study period in the four stations ($P > 0.05$). There was highly significant difference between months and seasons at $P < 0.05$ (Table 4.1). Total dissolved solids in Gwaigwaye Reservoir indicated no positive correlation with any of the physico-chemical parameters while negative correlation with, Chloride, Sulphate, Temperature and Dissolved oxygen, (Table 4.7).

4.1.9 Phosphur-Phosphate

The highest and lowest values of Phosphate-phosphorus were recorded during the dry season (March and May). There was increased in the Phosphate-phosphorus values from May to July then the values fluctuate between August to February with decrease between March to April. (Table 4.1). Table 4.2 shows monthly stations variation of phosphate-phosphorus, the highest value of $0.20mgL^{-1}$ was recorded in station I while the lowest value of $0.17mgL^{-1}$ was recorded in station IV. The analysis of variance indicated there was a significant difference of Phosphate phosphorus concentration in the four stations ($P > 0.05$). There was no significant difference between wet and dry seasons at $P < 0.05$ (Table 4.3). Phosphate-phosphorus revealed positive correlation with Nitrate-nitrogen, Calcium, and Dissolve oxygen while negative correlation with pH, Temperature, biochemical oxygen demand and Alkalinity (Table 4.7).

4.1.10 Sulphur-Sulphate

The highest value of Sulphur-Sulphate 0.28 was recorded in August of the wet season while the lowest value of 0.14 was recorded in December, April and May of the dry season. There was Monthly variation in the Nitrate-Nitrogen values with decrease from August to December with decrease in February and an increase in january to march with stability in April to May with another increase in June July (Table:4.1). Table 4.2 shows monthly stations variation of Sulphur-Sulphate concentration, the highest value of $0.21mgL^{-1}$ was recorded in station III and IV while the lowest value of $0.20mgL^{-1}$ was recorded in station I and II. The analysis of variance indicated there was no significant difference of Nitrate-Nitrogen concentration in the four stations ($P > 0.05$). There was a highly significant difference between wet and dry seasons at $P < 0.05$ (Table: 4.3). Sulphur-Sulphate concentration revealed positive correlation with Chloride, nitrate, hardness and Alkalinity while negative correlation with Electrical Conductivity, and Total Dissolve Solids. (Table 4.7).

4.1.11 Alkalinity

There was Monthly variation in the values of Alkalinity with a stability from December to March with an increase in April and decrease in May and increase in June and gradual increase from July to November. (Table:4.1). Table 4.2 shows monthly stations variation of Alkalinity concentration, the highest value of 4.15mgL^{-1} was recorded in station II and whiles the lowest value of 3.36mgL^{-1} was recorded in station III. The analysis of variance of alkalinity indicated there was significant difference of Alkalinity concentration in the four stations ($P > 0.05$). There was no significant difference between wet and dry seasons at $P < 0.05$ (Table: 4.3). The highest value of Alkalinity 5.32mgL^{-1} was recorded during the dry season while the lowest value of 2.65mgL^{-1} was recorded in dry season. Alkalinity concentration revealed positive correlation with Chloride, Sulphate, pH and hardness. While negative correlation with Electrical Conductivity, phosphate and Dissolve oxygen. (Table 4.7).

4.1.12 Calcium

The highest value of Calcium 3.49mgL^{-1} was recorded in the July wet season while the lowest value of 1.20mgL^{-1} was recorded in February of dry season. There was Monthly variation in the values of Calcium concentration with high values and little fluctuations from June to August with an increase in September to November and decrease in December to February and decrease in march to May.(Table: 4.1). The highest value of calcium was recorded in station II while the lowest in station IV (Table: 4.2). The analysis of variance of the obtained calcium concentration indicated there was no significant difference of Calcium concentration in the four stations ($P > 0.05$). There was a highly significant difference between wet and dry seasons at $P < 0.05$ (Table: 4.3). Calcium concentration revealed positive correlation with Dissolve Oxygen, Phosphate and Nitrate while negative correlation with pH and temperature (Table 4.7).

4.1.13 Chloride

There was Monthly variation in the values of Chloride concentration with decrease from June to November with an increase in December to February and decrease in March to April and decrease in May. (Table: 4.1). Table 4.2 shows monthly stations variation of chloride concentration, the highest value of 5.36mgL^{-1} was recorded in station I and while the lowest value of 4.74mgL^{-1} was recorded in station III. The analysis of variance of chloride concentration indicated there was no significant difference of Chloride concentration in the four stations ($P > 0.05$). There was a highly significant difference between wet and dry seasons at $P<0.05$ (Table: 4.3). The highest value of Chloride 7.58mgL^{-1} was recorded in June of wet season while the lowest value of 3.05mgL^{-1} was recorded in dry season (i.e April). Chloride concentration revealed positive correlation with Hardness, Sulphate, Alkalinity and Nitrate while negative correlation with Electrical Conductivity and Total dissolve solid. (Table: 4.7).

4.2 Biological Parameter

4.2.1 Phytoplankton

The Phytoplankton composition identified in the four stations belongs to four divisions, which includes; Chlorophyta, Bacillariophyta, Cyanophyta, and Dinophyta(phyrrophyta). Phytoplankton percentage composition (Table 4.6) indicated, chlorophyta has 299 which represent highest percentage composition with 46.57% of the total population of 642 identified. Bacillariophyta has the second highest population counts with the total of 219, which represent 34.11%. The Cyanophyta has the 101, which represent the third with percentage composition of 15.73%. Dinophyta has the least abundance with total of 23 which represents 3.58% of the percentage composition of Phytoplankton.

4.2.2 Chlorophyta

Table 4.6 shows monthly abundance of Chlorophyta. The highest count was recorded in August wet season while lowest in May dry season. Chlorophyta indicated positive correlation with hardness, Chloride, Sulphate, Alkalinity, Nitrate-nitrogen and phosphate-phosphorus while showed negative correlation with Dissolve Oxygen, Electrical conductivity and Total dissolved solids (Table: 4.7). The species observed are*; Oocystis sp, Scenedesmus sp, Pediastrum sp, Chlorella sp, Closterium sp, Clamydomonas sp, Ulotrix sp, Euastrum sp, Spirogyra sp, Zygnema sp, Oedegonium sp, Euglena sp* and *Volvox sp.* Among Chlorophyta *Oocystis sp* has the highest population abundance while *Volvox sp.* has the least population abundance.

Table 4.7: Correlation of Phytoplankton against the physico-chemical parameters of Gwaigwaye Reservoir

	Bac	*Chloro*	*Cyano*	*Dino*	*DO*	*Cl*	*PO_4*	*NO_3^-*	*SO4*	*pH*	*Temp.*	*EC*	*TDS*	*Hard*	*BOD*	*Ca*	*Alka*
Bac	1																
Chloro	1.0*	1															
Cyano	1.0*	0.9*	1														
Xanth	0.9*	0.9*	0.9*	1													
DO	-0.2	-0.1	0.0	0.2	1												
Cl	0.8*	0.9*	0.8*	0.9*	0.1	1											
PO4	0.0	0.0	0.0	0.2	0.6*	0.2	1										
NO_3^-	0.5*	0.5*	0.4	0.5*	0.5*	0.6*	0.6*	1									
SO4	0.8*	0.8*	0.8*	0.8*	0.1	0.9*	0.4	0.5*	1								
pH	0.4	0.3	0.3	0.0	-0.7*	0.2	-0.2	-0.2	0.3	1							
Temp	0.4	0.5*	0.3	0.3	-0.5*	0.4	-0.3	0.1	0.3	0.1	1						
EC	-0.6*	-0.7*	-0.5*	-0.5*	0.2	-0.7*	0.2	-0.4	-0.6*	-0.1	-0.8*	1					
TDS	-0.2	-0.2	-0.2	-0.2	-0.1	0.0	0.0	0.1	-0.1	0.2	-0.1	0.3	1				
Hard	0.7*	0.7*	0.6*	0.7*	-0.1	0.8*	0.3	0.8*	0.7*	0.3	0.4	-0.5*	0.1	1			
BOD	0.1	0.3	0.2	0.2	0.4	0.3	0.0	0.3	0.1	-0.5*	0.1	-0.3	0.1	-0.1	1		
Ca	0.3	0.3	0.4	0.3	0.6*	0.3	0.5*	0.6*	0.4	0.0	-0.5*	0.2	0.2	0.4	0.1	1	
Alka	0.7*	0.7*	0.7*	0.6*	-0.3	0.8*	-0.1	0.4	0.8*	0.6*	0.4	-0.6*	0.3	0.7*	0.2	0.2	1

KEY: Bac – Bacillariophyta Chloro – Chlorophyta, Cyano- Cyanophyta, Dino- Dinophyta, DO – dissolved oxygen, Cl – Chloride, PO_4 – phosphate, NO3- - nitrate, SO_4- sulphate, pH, Temp. – Temperature, Ec – Electrical conductivity, TDS – Total Dissolved Solids, Hard – Hardness, BOD – Biochemical Oxygen Demand, Ca – Calcium, Alka – Alkalinity.

4.2.3 Bacillariophyta

Table 4.6 shows monthly abundance of Bacillariophyta. The highest count was recorded in the month of August during the wet season while the lowest count was recorded in the month of February during dry season. Wet season having the highest count. Bacillariophyta shown positive correlation with Sulphate, Chloride, Hardness, Alkalinity but revealed negative correlations with Conductivity, Dissolve oxygen and Total dissolved solids (Table: 4.7). The species identified include; *Cyclotella sp, Cymbella sp, Gyrosigsma sp, Tabellaria sp, Diatoma sp* and *Anomoneis sp.* Among Bacillariophyta, *Cyclotella sp* has the highest population abundance in the reservoir while *Anomoneis sp.* has the lowest population count.

4.2.4 Cyanophyta

Table 4.6 shows monthly abundance of Cyanophyta in Gwaigwaye reservoir, the highest population count was recorded in August wet season while the lowest was recorded in January and February dry season. Wet season having the highest count. Cyanophyta showed positive correlation with, Chloride, Sulphate, Hardness, and Alkalinity while shown negative correlation with total dissolved solids, hardness, Phosphate, and Conductivity (Table:4.7). The species observed are; *Chroococcus sp, Microcystis sp, Anabaena sp, Oscillatoria sp* and *Nostoc sp.* Among the Cyanophyta, *Chroococcus sp.* has the highest species population abundance while *Nostoc sp.* has the least population abundance with presences only in the rainy season.

4.2.5 Dinophyta (Pyrrophyta)

Table 4.6 shows monthly abundance of Dinophyta in Gwaigwaye reservoir. Highest count was recorded in July and August of wet season, with the lowest count recorded in December to April of dry season. With wet season having the highest number of count than the dry season. Dinophyta shown positive correlation with Chloride, Hardness, Alkalinity, Sulphate and Nitrate-nitrogen while negative correlation with Electrical conductivity and Total dissolved solids (Table: 4.7). The species recorded are *Pridinium sp* and *Ceratium sp.* Only few population counts were observed during the rainy season with *Peridinium sp.* having the highest while *Ceratium sp.* was the least.

4.3 Fish Fauna

The total number of fishes identified in the four stations during the period of the study was 1565; which are *Bagrus bajad, Tilapia zilli, Clarias gariepinus*, *Momyrus senegalensis, Oreochromis niloticus, Synodontis clarias, Labeo senegalensis, Lates niloticus*.

4.3.1 *Tilapia zilli*

Correlation revealed there was a positive correlation with D.O, Cl^-, PO_4, NO_4, $S0_4$, Temperature, BOD, Calcium and Alkalinity and negative correlation with pH, Conductivity, Total Dissolve Solids (Table 4.5). The percentage composition of fishes (Table 4.6) indicated *Tilapia zilli* has the highest percentage with 17.32%, abundance composition. The highest number was recorded in the month of August while the lowest was recorded in the month of October and November was the least.

4.3.2. *Clarias gariepinus*

Correlation revealed there was a positive correlation with chloride and hardness and negative correlation with pH, Conductivity, total dissolve solids (Table 4.5). The percentage composition of fishes (Table 4.6) indicated *Clarias gariepinus* has the second highest population which accounted for the 16.17% of the total number of fishes count identified during the period of the study; the highest number was recorded in the month of August while the lowest count was recorded in the month of April.

4.3.3. *Oreochromis niloticus*

Correlation revealed there was a weak positive correlation with the other physico-chemical parameters and negative correlation with pH, Electrical conductivity, total dissolve solids (Table 4.5). The percentage composition of fishes (Table 4.6) indicated the total number of *Oreochromis niloticus* identified was 238 which account for 15.27% of the total fishes identified, there was monthly variation of *Oreochromis niloticus* recorded during the period of study; the highest number was recorded in the month of april and June while the lowest was in February.

4.3.4. *Lates niloticus*

Correlation revealed there was a weak positive correlation with DO, Cl^-, TDS, PO_4, Hardness, NO_4, SO_4, Temperature, EC, and negative correlation with Biochemical Oxygen and pH (Table 4.5). The percentage composition of fishes (Table 4.6) indicated the total number of *Lates niloticus* identified during the period of the study was 216, which accounted for the 13.80% of the total identified and recorded fishes during the period of the study. The highest count was recorded in wet season (i.e September) and the
lowest in dry season(i.e April).

4.3.5. *Bagrus bayad*

Correlation revealed there was a positive correlation with Chloride, Sulphide and Hardness while negative correlation with pH, Conductivity and Total dissolve solids (Table 4.5). The percentage composition of fishes (Table 4.6) indicated the total number of *Bagrus bajad* identified during the period of the study was 202, which accounted for the 12.91% of the total identified and recorded fishes during the period of the study. The highest record was in July of wet season and the lowest in January, March and May of dry season.

4.3.6 *Mormyrus senegalensis*

Correlation revealed there was a positive correlation with Chloride, Sulphide and Hardness while negative correlation with pH, Conductivity and Total dissolve solids, Biochemical Oxygen Demand and Calcium (Table 4.5). The percentage composition of fishes (Table: 4.6) indicated the total number of *Mormyrus senegalensis* identified during the period of the study was 155, which accounted for the 9.90% of the total identified and recorded fishes during the period of the study. The highest record was in June wet season and the lowest in March of dry season.

4.3.7 *Labeo senegalensis*

Correlation revealed there was a positive correlation with Chloride, Sulphide and Alkalinity while negative correlation with dissolve oxygen, conductivity, calcium and total dissolve solids (Table 4.5). The percentage composition of fishes (Table: 4.6) indicated the total number of *Labeo senegalensis* identified during the period of the study was 116, which accounted for the

7.41% of the total identified and recorded fishes during the period of the study. The highest record was in October and February while the lowest in January and April.

4.3.8 *Synodontis clarias*

Correlation revealed there was a weak positive correlation with other physico-chemical parameters while negative correlation with pH, Conductivity, Calcium and Total dissolve solids (Table 4.5). The percentage composition of fishes (Table: 4.6) indicated the total number of *Synodontis clarias* identified during the period of the study was 114, which accounted for the 7.28% of the total identified and recorded fishes during the period of the study. The highest record was in june wet season and the lowest in October dry season.

CHAPTER FIVE

5.0 DISCUSSION

5.1 Overview

The studies on the fish fauna and phytoplankton population in relation to physico-chemical parameters of Gwaigwaye reservoir; Katsina State, Nigeria was conducted with the view to contribute some knowledge about the physico-chemical and biological status of the reservoir. The investigation was based on physico-chemical factors such as Temperature, pH, Dissolved oxygen, Biochemical oxygen demand, Elecrical Conductivity, Water Hardness, Nitrate-nitrogen, T.D.S, Phosphur-phosphate,Sulphur-sulphate,Alkalinity,Calcium, Chloride, and biological parameters such as, phytoplankton, fish fauna and their seasonal variations.

5.2 Physico-Chemical Parameters

5.2.1 Water Temperature

The water temperature of the reservoir fluctuated with months, which was between 20.63°C and 27.19°C in all the four sampling stations. The low water temperature recorded in the reservoir was in the dry season, which could be as a result of seasonal changes in air temperatures associated with the cool dry North-East winds. This observation is supported by the findings of Indabawa (2009) which reported variations in water temperature in the dry season can be attributed to intensified heat radiation and effect of harmattan. The water temperature lacks significance difference with months, which was similar with observation of Tisser *et al.* (2008b) which reported the lack of significance in monthly variations of water temperature as characteristic of the tropical climate. Temperature influences the oxygen content of water, quantity and quality of autotrophs, while affecting the rate of photosynthesis and also affecting the quality and quantity of heterotrophs Temperature plays a vital role in the distribution of Zooplankton and Phytoplankton species (Tanimu, 2011).

5.2.2 pH

The water pH in the reservoir was within 7.1 to 8.1, which make the water of the reservoir to be circum-neutral during the study. This was similar to the results of Ibrahim *et al.,* (2009) which reported that hydrogen ion concentration (pH) was nearly neutral throughout both season, and it was within the range for inland water pH 6.5 - 8.5 in Kontagora reservoir, Niger state, Nigeria; which makes it suitable for optimal biological activity. The little increase in pH during the dry season may be due to decaying and decomposition of living organisms in the water coupled with the reduction in the water level during the dry season. The observation agrees with that of Mustapha (2008) which reported slight acidicity (pH=6.8) in the dry season which may be due to high carbon dioxide concentration occurring from organic decomposition in Oyun Reservoir, Offa. The little decrease in pH during the rainy season was probably due to the effect of incoming rainwater. This drop in pH was probably due to the stirring effect of the incoming flood from the rivers and streams that converged towards the lake resulting in the mixing of the poorly alkaline or acidic bottom water with alkaline surface water to reduce pH in Shahpur Dam, Pakistan (Janjua *et al.,* 2008).

5.2.3 Dissolved Oxygen

Dissolved oxygen in the reservoir indicates two peaks, high in the rainy season while low in the dry season. The higher abundance of phytoplanktons during the rainy season may be the reason for high values of dissolved oxygen. This agree with report of Araoye (2008) which reported high oxygen concentration (8.2 mg/L) recorded during the rainy season was due to an enhanced photosynthetic activities during the dry season. Dissolved oxygen supply in water mainly comes from atmospheric diffusion and photosynthetic activity of plants (Akomeah *et al*., 2010). The drop of oxygen values from December to April may be due to low temperature in the reservoir. Araoye (2008) made similar report of drop in dissolved oxygen concentration between October-December and suggested was because of the vertical mixing due to low surface water temperatures that accompanied the harmattan at this season. Oxygen plays the most important role in determining the potential biological quality of water. The negative correlation of dissolved oxygen with pH, alkalinity, hardness and total dissolved solids could be due to flooding of solid and breakdown of organic matter. Similar report was made by (Araoye, 2008) flooding of the lake came with suspended solids and dissolved salts, which also resulted in the negative correlation of DO concentration with total dissolved solids (TDS), and conductivity.

5.2.4 Biological Oxygen Demand

The reservoir revealed higher values of biochemical oxygen demand during the rainy season which may be due to extensive agricultural activities and the deposition of both organic and inorganic substances in the reservoir which contradict the findings of Ibrahim (2014) who reported the higher values of biochemical oxygen demand in Ajiwa reservoir,Katsina during the dry season, could be due to reduction of phytoplankton and decomposition of other living organisms in the reservoir. Mahar (2003) made similar observation and suggested the reason was due the depletion of oxygen in the water during decomposition in dry season. Das (1978) and Das and Pande (1980) also reported that increase in biochemical oxygen demand may be due to biological as well as natural oxidation processes which increased in the rainy season . The non significance difference between wet and dry season may be due to fluctuation in rainfall and entry of freshwater during the rainy season. The negative correlation of BOD with phosphate, conductivity and hardness may be due to low in flow of substances such as effluent from funtua textile industry, cow dung, organic waste and agricultural run-off during the rainy from the farm lands near the reservoir and evaporations in the dry season which contradicts the finding of Mustapha (2008), in oyun reservoir, offa.

5.2.5 Electrical Conductivity

The highest value was recorded in the dry season while lowest was recorded in the wet season. The high dry season values may be due to the reduction in the water level and increases in nutrients due to run off of inorganic fertilizer from nearby farm lands. Atobatele and Ugwumba (2008) suggested that decrease in conductivity values during the rainy season might be due to dilution by rainwater. The higher values may due to chemical fertilizers from irrigated farmlands around the reservoir coupled with higher rate of evaporation that reduces the level of the water during the dry season; thus conductivity of water depends upon the concentration of ions and its nutrients status.

5.2.6 Water Hardness

Water hardness was higher during the rainy season than the dry season; this could be because of high inflow of concentration of nutrients as a result of sewage dumping by the surrounding normadic Fulani. Balogun *et al.* (2005) observed water hardness was highly significant between stations and within months in Makwaye (Ahmadu Bello University Farm). The result was in contrast with Ibrahim *et al.* (2009) which reported the water hardness is higher in the dry season and lowers in the rainy season and suggested it could be due to low water levels with its attendant concentration of salts and the lower value in the rainy season could be due to dilution. The significant difference between stations and seasons could be because of water high levels and concentration carbonates,

5.2.7 Nitrate-Nitrogen

Nitrate-nitrogen was found to exhibit variation range of 0.13mgL-1 to 0.28mgL-1.The mean value recorded in rainy season was higher than that in dry season. The reason for this high concentration in rainy season may be due to excessive influx of nutrients from farmlands where fertilizer is used to boost crop production particularly around the reservoir, as well as input through run off into the reservoir. The results tallies with that of Balogun *et al.* (2005) which observed mean monthly variation and significant difference between seasons of Nitrate-Nitrogen in Makwaye (Ahmadu Bello University Farm). Nitrate-nitrogen higher values in rainy season also coincide with high plankton composition and abundance in the reservoir during the rainy season. This support the observation of Olele and Ekelemu (2008) the algal species that eventually proliferate in the rainy season must not only be able to tolerate conditions of nutrient limitation but withstand and utilize other sources of nitrogen to their advantage.

5.2.8 Total Dissolved Solids

The reservoir has higher value of TDS during the dry season; this could be due to decaying of vegetation, higher rate of evaporation caused by increase in air temperature and wind during the dry season. Similar observation was made by Atobatele and Ugwumba (2008) which they reported increase in the values of total dissolved solids during the dry season which may be due to most of the vegetation was decaying so there was a rise in amount of dissolved solids. However, during rainy season the amount of total solids was low, may be due to the dilution of water. The total dissolved solids negative correlation with dissolved oxygen and biochemical oxygen demand may be due inflow of substance during the rainy season and settling effect the substance in dry season. Similar observation was made by (Araoye, 2008) which reported, the flooding of the lake came with suspended solids and dissolved salts which also resulted in the negative correlation of DO concentration with Total dissolved solids (TDS), Hardness and alkalinity.

5.2.9 Phosphate- Phosphorus

The highest values of Phosphate-phosphorus in the reservoir during the dry season may be due to reduce water volume, intensive agricultural activities around the reservoir involving the use of fertilizers and pesticides to produce dry season crops like vegetables and maize. Farmers were also using the water from the reservoir for domestic activities including washing of cloths with detergents that increase phosphate-phosphorus level of the water. Ibrahim *et al.* (2009) reported high dry season mean value of Phosphate phosphorus ($PO_4^{3-}P$) could be due to concentration effect because of reduced water volume in Kwantagora reservoir. The result of Phosphate-phosphorus variation with season also conform with the result of Balogun *et al.* (2005) which observed highly significant phosphate-phosphorous variation within months and significant variation between the sampling stations in Makwaye (Ahmadu Bello University Farm).

5.2.10 Sulphur-Sulphate

In the present study the values of Sulphate was found to exhibit variation range of $0.14mgL^{-1}$ to $0.28mgL^{-1}$. The mean value recorded in rainy season was higher than that in dry season. The reason for this could be due to the location of the reservoir close to textile plant that releases it sulphide ions in form of air pollution which when react with rain it forms acid rain. Cl^{-} and SO_4^{2-} ions also contributing to the total solute load. This present study was also in conformity with the observations of Głowacki and Krawczyk, (2002) of water chemistry in Hornsund who suggested that some of the sulphates that did not derive from sea salt had anthropogenic origins. Depending on weather conditions, they may have come from anthropogenic air pollution from distant sources. A similar observation was made by Kirubavathy *et al.* (2005), that the higher value of sulphates were recorded in summer month and lower value of sulphates measured in winter month.

5.2.11 Alkalinity

The value of Alkalinity observed in the study ranged between 5.32 to 2.65 all in dry season. The low value of Alkalinity indicate the reduction in water size and the present of bicarbonate and carbonate ions. In this study the amount of Alkalinity indicates the water is productive for both flora and fauna (USEPA, 2008). This was also in conformity with the observation of Campbell and Wilberger (2001), who stated that waters dominated by bicarbonate ions usually have low or no phenopthalene alkalinity.

5.2.12 Calcium

The higher value of calcium observed in rainy season could be due to entries of industrial waste water (Funtua textile industry) from the surrounding and salt bed exudation.

5.2.13 Chloride

In this study Chloride ranged from 3.05 to 7.58 mgl^{-1}. Chloride plays an important role in water quality determination. High chloride value during rainy season and low value during dry season could be due to entry of industrial waste water or salt bed exudation (Głowacki and Krawczyk, 2002). Similar observation was made by Lendh and Yeragi (2004). Cl^{-} and SO_4^{2-} ions also contributing to the total solute load. This present study was also in conformity with the observations of Głowacki and Krawczyk (2002) of water chemistry in Hornsund who suggested that some of the sulphates that did not derive from sea salt had anthropogenic origins due to the increase in sulphate ion concentrations in the reservoir during the rainy season.

5.3 Biological Parameters

5.3.1 Phytoplankton

The phytoplankton identified belonged to four division of algae, Bacillariophyta, Cyanophyta, Chlorophyta and Dinophyta (Pyrrophyta). In general, green (Chlorophyta) algae have higher abundance over other kinds of algae and revealed positive correlation with dissolved oxygen, which indicated the productivity of the reservoir especially during wet season. Mahar (2003) also observed, a phytoplankton community was affected by strong seasonal influence. The monthly and seasonal variation of composition and abundance of phytoplankton may be due to the fluctuations of water and physicochemical parameters in the reservoir. Abubakar (2009) also made similar observation in which he reported that; in tropical regions the dry and rainy seasons show distinct fluctuations with abundance of phytoplankton. The higher abundance during wet season could be due to the presence of more nutrients and water level in the reservoir during the season. The higher phytoplankton count during the rainy season indicated that the reservoir was more productive during the rainy season because phytoplankton being the primary producers in freshwater and determines the link of feeding relationship in the aquatic ecosystem. This corresponds to the observation of Tisser *et al.* (2008) which reported that; phytoplankton forms the vital source of energy in the fresh water environment, they initiate the fresh water food chain by serving as food to primary consumers which include zooplankton, fish and others. Phytoplankton shown positive relation with dissolved oxygen, biochemical oxygen demand, nitrate-nitrogen, and phosphate-phosphorus. The high concentration of nutrients like nitrate-nitrogen and phosphate-phosphorus results into blooming of algae that is sign of eutrophication but the concentration of both nitrogen and phosphates in the reservoir was within the acceptable range. Nutrient limitation is also an important factor for phytoplankton abundance in shallow freshwater (Araoye and Owolabi, 2005).

5.3.2 Fish fauna

Fish fauna composition in Gwaigwaye reservoir was dominated by *Tilapia zilli,* and then *Clarias gariepinus*, which were followed by *Oreochromis niloticus* and *Lates niloticus*,*Bagrus bajad*, *Momyrus senegalensis*, *Synodontis clarias* and *Labeo senegalensis.* The fish fauna composition and abundance varies with months and seasons, which may be due to fluctuation of physico-chemical parameters and reduction in abundance of phytoplanktons, which are the primary producers. Mahar (2003) reported factors such as light intensity; food availability, dissolved oxygen, and predation affect the population composition of zooplankton including fish fauna. Gwaigwaye reservoir had higher fish fauna composition and abundance during the rainy season which could be due to Land use around riverine areas in Nigeria which is predominantly for farming (Adeyemi *et al.,* 2009); this could be a possible explanation for the high levels of PO_4^-P that may result from run-offs during rainy season as observed in this study.This observation coincides with that of Edward and Ugwumba (2010) in which they reported the increased number of zooplankton including fish fauna during the rainy season that was linked to the influx of nutrient. All the fish fauna and phytoplankton indicated high productivity in the rainy season and decrease to dry season, the mean values of 0.21 for NO_3^-N were also found to be above expected concentration range of natural unpolluted waters of 0.1 mg/l (UNESCO/WHO/UNEP, 1996). High nitrate levels (> 1mg/l) are not good for aquatic life (Johnson *et al.,* 2000). This could be the reason why all the fish fauna indicated positive correlation to other physico-chemical parameters with only negative correlation to Total dissolved solids, Conductivity, Calcium, pH and Alkalinity. The high level of nitrate observed is in line with the findings of Wolfhard and Reinhard (1998), who concluded that nitrate are usually built up during dry seasons and that high levels of nitrates are only observed during early rainy season which correspond to the period of the research work. This also played a vital role in the abundance of both fish and phytoplankton .*Tilapia zilli* like other fishes appears to be sensitive indicator of changes as they have a temperature tolerance range of 25°C to 30°C with less alkalinity of 16 to 20 ppt compared to ammonia in their natural waters. *Clarias gariepinus* have possessed an ability to tolerate adverse water quality and difficulty in aquaculture. *Lates niloticus* are found to be less abundant in oxygen poor condition in water quality. The positive correlation of most fishes like cladocerans with dissolved oxygen and biochemical oxygen demand was an indication the reservoir was unpolluted; Balogun *et al.* (2005) in Makwaye (Ahmadu Bello University Farm) made similar observation. Fish and phytoplankton in Gwaigwaye reservoir, also indicated monthly variation in abundance that may be due to variations of physico-chemical parameters. Food condition is still considered an important factor affecting growth and reproduction of zooplankton including fish fauna in nature, especially in closed environment such as reservoirs and lakes (Mahar, 2003).

5.4 Test of Hypotheses

Three null hypotheses were formulated and tested with the aim to establish physical, chemical, and biological parameters of Gwaigwaye reservoir, and to provide better understanding of the reservoir ecosystem, structural dynamics and seasonal variations.

1. Hypothesis one stated that there was no significant monthly and seasonal difference in the distribution of physico chemical parameters in Gwaigwaye reservoir, in which the results revealed there was a highly significant monthly and seasonal difference in the

distribution of physico-chemical parameters of Gwaigwaye reservoir, therefore hypothesis one was rejected.

2. Hypothesis two states there was no significant difference in the type of phytoplankton abundance, percentage and fish landing of Gwaigwaye reservoir, in which the result showed that there was a significant difference of phytoplankton distribution and diversity of fish species in the reservoir between wet and dry season; therefore hypothesis two was rejected too.

3. The third hypothesis states; there was no significant relation between fish species distribution, phytoplankton diversity and physico-chemical parameters in the reservoir, but statistics revealed there was a significant relation between fish species distribution, phytoplankton diversity and physico-chemical parameters of the reservoir, therefore hypothesis three was also rejected.

CHAPTER SIX

6.0 SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

6.1 Summary

The studies on the fish and phytoplankton population in relation to physico-chemical parameters of Gwaigwaye reservoir; Katsina state was carried out for the period of twelve months in order to provide a baseline information on the ecological status of the reservoir.

1. The physicochemical parameters of the reservoir varied with months and season. The variations of physico-chemical parameters may be due to change in weather cycle during the study period that occurs in the environment. The reservoir was more productive during the rainy season, because there was higher abundance of phytoplanktons during the rainy season than the dry season.

2. The higher abundance of Chlorophyta was an indication that the reservoir was productive. Phytoplanktons are primary producers in freshwater bodies and determine the link of feeding relationship in the aquatic ecosystem. Most of the fish fauna identified have higher species abundance in the reservoir was an indication the reservoir water was unpolluted and productive, because fishes are sensitive bio-monitors or indicators of any changes in water quality.

3. Anthropogenic activities such as farming, sewage disposal, and cattle rearing that are taking place around the reservoir had some impact on the water quality of the reservoir, especially during the rainy season.

6.2 Conclusions

1. The physico-chemical parameters studied in Gwaigwaye reservoir are Water temperature with a total mean of monthly and seasonal variations of: 25.02^{o}C, pH: 7.54, Alkalinity: 3.69mg/l, Conductivity: 129.43µS/cm, Total dissolved solids: 50.54mg/l, Nitrate-nitrogen: 0.21mg/l, Hardness: 134.44mg/l, Chloride: 5.09mg/l, Dissolved Oxygen: 3.98mg/l, Biochemical Oxygen Demand: 2.53mg/l, Calcium: 2.97mg/l, Phosphate-Phosphorus: 0.19mg/l and Sulphur-sulphate: 0.21mg/l. All the physico-chemical parameters revealed monthly and seasonal variation, which was opposed to the hypothesis stated earlier.

2. The phytoplankton, all varied with months and seasons were *Chlorophyta* had a toal mean and percentage of: 299 (46.57), *Bacillariophyta*: 219 (34.11), *Cyanophyta*: 101 (15.73) and *Dinophyta*: 23 (3.58). Likewise the fish faunas were *Bagrus bayad* had a toal mean and percentage of :202 (12.91), *Tilapia zilli* 271 (17.32), *Clarias gariepinus*: 253 (16.17), *Mormyrus senegalensis*: 155 (9.90), *Oreochromis niloticus*: 238 (15.21), *Synodontis clarias*: 114 (7.28), *Labeo senegalensis*: 116 (7.41) and *Lates niloticus*: 216 (13.80). All the biological parameters composition and abundance were increased during rainy season and decreased with dry season.

3. The Water quality of the reservoir is influenced by anthropogenic activities as runoffs of both organic, inorganic fertilizers and chemical pesticides; the reservoir water is suitable for irrigational and domestic purposes in terms of most of the physico-chemical and biological parameters analyzed. However, considering that the reservoir is a source of drinking water, the potential of the anthropogenic inputs gains significance. Hence, there is need for an effective anthropogenic inputs control measures in the reservoir to be put in place.

6.3 Recommendations

Water quality of the reservoir is influenced by anthropogenic activities as runoffs of both organic, inorganic fertilizers and chemical pesticides. Therefore, it is recommended that:-

1. Farming activities during rainy and dry seasons very close to the reservoir should be discouraged, in order to reduce the runoffs of inorganic fertilizers and pesticides into the reservoir.

2. More studies should be carried out on other physico-chemical parameters of the reservoir that are not included during this work.

3. Farmers around the reservoir should be enlightened on the effects of their activities into the body of the water, especially application of both organic and inorganic fertilizers and chemical pesticides during period of rainy season farming and irrigation when the water level reduces.

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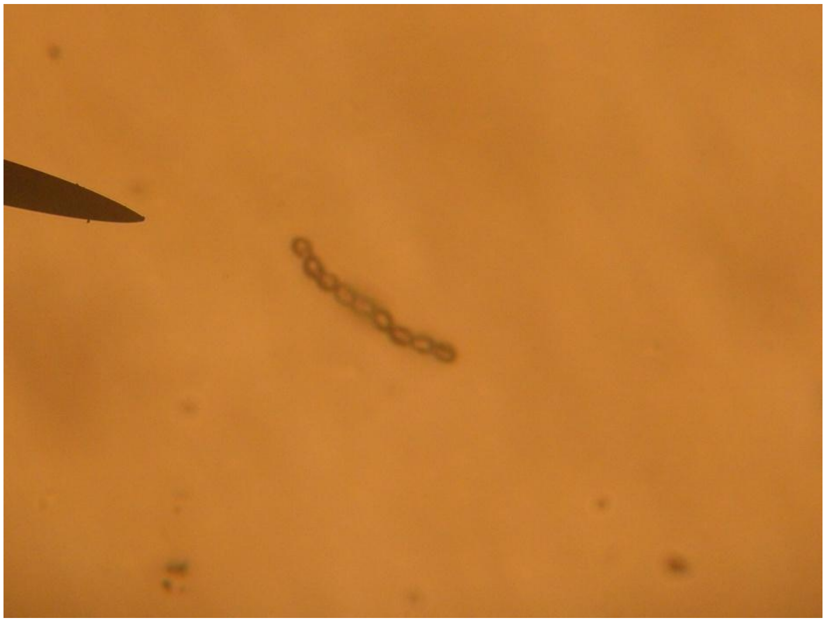
APPENDIX

Plate I: Some Selected Dissected Species of Fish

(a)

(b)

Plate II: Fish fauna (a) *Bagrus bayad* (b) *Tilapia zilli*



(a)

Plate III: Phytoplankton (a) *Nostoc species.*