STUDIES ON ASPECTS OF LIMNOLOGY OF YARDANTSI RESERVOIR, GUSAU, ZAMFARA STATE, NIGERIA

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ZARIA, NIGERIA

AUGUST, 2018

DECLARATION

I declare that the work in this thesis entitled **“Studies on Aspects of Limnology of Yardantsi Reservoir Gusau, Zamfara State Nigeria"** has been performed by me in the Department of Biology, under the supervision of Prof. M. L. Balarabe, Prof. A. K. Adamu and Prof. W. S. Japhet. The information derived from the literature has been duly acknowledged in the text and a list of references provided. No part of this thesis was previously presented for the award of another degree or diploma at this or any other Institution.

Aminu Muhammad JABBI

Name of Student Signature Date

CERTIFICATION

This thesis entitled **“STUDIES ON ASPECTS OF LIMNOLOGY OF YARDANTSI RESERVOIR, GUSAU ZAMFARA STATE NIGERIA"** by **AMINU MUHAMMAD JABBI** meets the regulations governing the award of the degree of Doctor of Philosophy (PhD) Biologiy of the Ahmadu Bello University, and is approved for its contribution to knowledge and literary presentation.

Prof. M. L. Balarabe

(Chairman, Supervisory Committee) Signature Date

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Prof. W. S. Japhet

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Prof. M. L. Balarabe

(Head of Department) Signature Date

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(Dean, School of Post Graduate Studies) Signature Date

DEDICATION

This research work is dedicated to my affectionate parents; Malama Aminatu Abubakar Yidi and Late Alhaji Muhammad Jabbi, who died on 8 December, 2000, equivalent to 15 Ramadan, 1421AH, May the Almighty Allah grant them high place in paradise, Amen!

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"Verily with Allah is full knowledge and He is acquainted (with all things)" Quran 31:34

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ABSTRACT

Yardantsi Reservoir, Gusau, Nigeria serves multitude of purposes for the Gusau populace. It is the main source of water for domestic purpose, irrigation, and fishing. The reservoir receives both organic and inorganic waste through runoffs and seepage from the catchment area. The physico-chemical parameters of surface water and sediment, plankton composition, distribution and abundance, fisheries potentials and presence of some trace metals in the reservoir, were investigated on a monthly basis between May, 2015 and April, 2017. Surface water, sediment and plankton samples were collected from five sampling stations and analysed using standard procedures for examination of water and wastewater. Trace and alkali-alkaline earth metals concentrations in water and sediment samples were analysed using Shimadzu AA6800 Atomic Absorption Spectrophotometer. The data obtained from this study was subjected to multivariate analysis using Microsoft Office Excels, SPSS and PAST packages. The results from this study showed that surface water temperature ranged from 25.98±0.09– 32.41±0.11^{O}C, Transparency **(**12.00±0.33-59.90±1.44cm), Mean depth (1.86±0.04-2.97±0.06m), pH (6.84±0.39-9.57±0.70), Electrical conductivity (64.20±5.25- 197.90±10.14µS/cm), Total dissolved solids (41.60±6.18-109.30±1.9408mg/L), Dissolved Oxygen (5.97±0.10-8.86±0.09mg/L), Biological Oxygen Demand (1.79±0.08-3.58±0.08mg/L), Alkalinity (22.60±0.64–47.80±0.88mg/L), Hardness (23.10±0.66–67.50±0.98mg/L), NO_3-N (1.64±0.05-5.19±0.10mg/L), PO_4-P (106.50±2.60-197.90±4.44mg/L) and Chloride (29.45±0.62-89.90±0.90mg/L). As for the trace and alkali-alkaline earth metals concentrations in the reservoir, results showed that Ca ranged from 0.52±0.03^{-}4.49±0.26mg/L, K

(1.84±0.05-4.46±0.13mg/L), Mg (0.19±0.01-2.83±0.07 mg/L), Na (29.85±0.73-84.06±1.71mg/L), Cd (0.03±0.00-0.29±0.05mg/L), Cr (0.73±0.03-1.62±0.15mg/L), Cu (0.05±0.00-0.25±0.04mg/L), Fe (0.68±0.03-5.74±2.51mg/L), Ni (0.09±0.02-0.18±0.05mg/L), Pb (0.02±0.00-0.07±0.01mg/L) and Zn (0.66±0.03-1.75±0.19mg/L). Most of the values for surface water parameters with the exception of Fe, Cr, Cd, Mg, Ni, and Pb are within threshold levels set by NSDWQ, WHO and FAO. Analysis of variance showed significant seasonal variation between stations with surface water temperature, mean depth, electrical conductivity, Dissolved oxygen, phosphate, chloride, chromium and iron ($p<0.05$), while total dissolved solids, sulphate, calcium, magnesium and sodium showed highly significant seasonal variation ($p<0.01$). The concentrations of metals in surface water throughout the study period revealed the following decreasing order of magnitude; Na > K > Ca > Mg > Fe > Cu > Zn > Cr > Cd > Ni > Pb; and Na > K > Fe > Zn > Cu > Ca > Mg > Cr > Ni > Cd > Pb for dry and rainy season respectively, while Fe > Zn > Cu > Ca > Mg > Cd > Cr > K > Ni > Na > Pb was observed for sediment. Four groups of phytoplankton (viz; Bacillariophyta, Chlorophyta, Cynophyta and Dinophyta) comprising of eleven different species were observed in this study, with Chlorophyta having the highest abundance for both dry and rainy seasons (40.42% and 41.33% respectively) of the total phytoplankton population. Bacillariophyta ranged from 73 to 360 individuals per litre, Chlorophyta (105 to 529 individuals per litre), Cynophyta (31 to 131 individuals per litre) and Dinophyta (76 to 289 individuals per litre) Phytoplankton showed significant positive correlation with temperature, mean depth, nitrate-nitrogen, phosphate-phosphorus, sulphate and zooplankton ($p<0.01$). Phytoplankton showed the following order of abundance: Chlorophyta > Bacillariophyta > Dinophyta > Cyanophyta in both seasons. Three groups of zooplankton (viz; Copepoda, Cladocera and Rotifera) comprising of thirteen different species were observed in this study, with Rotifera having the highest abundance for both dry and rainy seasons (35.79% and 43.18% respectively) of the total zooplankton population. Copepoda ranged from 94 to 204 individuals per litre, Cladocera (70 to 203 individuals per litre) and Rotifera (80 to 300 individuals per litre). Zooplankton exhibited significant positive correlation with dissolved oxygen, alkalinity and chloride ($p<0.05$), and with phosphate phosphorus and phytoplankton at 0.01 level. Zooplankton showed the following order of abundance: Rotifera > Copepoda > Cladocera in both seasons. Fisheries potential was found to be higher in dry season for all stations. This coincides with higher abundance of certain zooplankton species (*Daphnia* sp., *Macrothrix* sp., *Cyclops* sp., *Brachionus patulus* Müller, and *Chromogaster* sp.) in dry seasons. This could be attributed to distortion of the aquatic habitat during water discharge. Morpho Edaphic Index exhibited significant positive correlation with transparency, total dissolved solids, electrical conductivity, dissolved oxygen, alkalinity, hardness, and chloride ($p<0.05$). Based on Shannon and Margalef diversity index, the water surveyed throughout the study period was found to be slightly polluted. The result of this survey has shown that the multitude of reservoir users and its catchment have negatively impacted on its water quality. Various management strategies such as restricting cultivation on steep slopes and periodic limnological assessment should be employed to monitor and track trend of changes to water quality and quantity, periodicity and biodiversity of the reservoirs.

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ABBREVIATIONS, DEFINITIONS AND SYMBOLS

% = Percentage

µm = Micrometre

^{o}C = Degree centigrade

µS = Micro Siemen

A = ml of titrant

$AgNO_3$ = Silver nitrate

Aliquot = Amount of sample used

Alk = Alkalinity

ANOVA = Analysis of Variance

APHA = American Public Health Association

B = mg $CaCO_3$ equivalent to 1.00 ml EDTA titrant

Ba = Barium

BDL = Below Detectable Limit

BOD = Biological oxygen demand

Ca = Calcium

$C_{background\ value}$ = Average background concentration of the metal in sediment

CBSQGs = Concentration Based Sediment Quality Guidelines for Metals

CCA = Canonical correspondence analysis

Cd = Cadmium

C_d = Degree of Contamination

CEC = Cation Exchange Capacity

C_f = Contamination Factor

cm = Centimetre

$\mathbf{C_{metal}}$ = Measured metal concentration

cmol = Centimoles

Cr = Chromium

cusec = Cubic Feet Per Second

D = Length of the water column traversed by the net

dL = Decilitre

DO = Dissolved oxygen

$\mathbf{DO_1}$ = Dissolved oxygen of sample in day one (sampling day)

$\mathbf{DO_5}$ = Dissolved oxygen after 5 days of incubation

EC = Electrical conductivity

EDTA = Ethylene diamine tetra acetic acid

EPA = Environmental Protection Agency

$\mathbf{E_R}$ **=** Enrichment ratio

et al. = *et alii* = and others

FAO = Food and Agricultural Organization

Fe = Iron

Fig. = Figure

GPS = Geographical Positioning System

$\mathbf{H_2SO_4}$ = Sulphuric acid

ha = Hectare

Hard = Hardness

L = Litre

m = Metre

M = Molarity

MEI = Morpho Edaphic Index

mg = Milligram

ml = Millilitre

Mn = Manganese

MPL=Maximum Permissible Limits

n = Average number of plankton cells in 1 ml of plankton sample

N = Nutrient value (total dissolved solids) or close correlate

N = Total number of plankton cells per litre of water filtered

Na = Sodium

NaOH = Sodium hydroxide

NH_3 = Ammonia

nm = Nanometre

NO_3-N = Nitrate nitrogen

NPK = Fertilizer (containing Nitrogen, Phosphorus and Potassium)

NSDWQ = Nigerian Standard for Drinking Water Quality

OC = Organic Carbon

P = Phosphorus

PAST = Palaeontological Statistics Software

PCA = Principal Component Analysis

PEC = Probable Effect Concentration

pH = Potential of hydrogen or hydrogen ion concentration

PO_4- P = Phosphate phosphorus

PP = Phytoplankton

ppm = Part per million

r = Radius of the net mouth

rpm = Rotation per minute

SE = Standard Error

SO_4 = Sulphate

sp. = Species (Singular)

SQGs = Sediment Quality Guidelines

SS = Sampling station

T = Titre value

TDS = Total Dissolved Solids

TEC = Threshold Effect Concentration

Temp = Temperature

Trans = Transparency

UNEP = United Nation Environmental Protection

USEPA = United State Environmental Protection Agency Guidelines

v = Volume of plankton concentrate (ml)

V = Volume of total water filtered (L)

WHO = World Health Organization

$\acute{z}$ = Mean depth or an appropriate morphometric surrogate

Zn = Zinc

ZP = Zooplankton

CHAPTER ONE

1.0 INTRODUCTION

1.1 Background

Limnology is the study of the structural and functional relationships and productivity of organisms of inland aquatic ecosystems as they are related to their dynamic physical, chemical, and biotic environments. In short, it can be defined as the study of continental waters; or the study of fresh and saline waters contained within continental boundaries (Ismael, 2009).

Reservoirs or man-made lakes are impoundments created largely by humans by damming of river valleys. Humans have created artificial lakes by damming for at least 4000 years (Ismael, 2009). It is only of recent that the damming activities have become highly significant for the purpose of flood control, irrigation, and provision of power and water supplies for urban, ever-growing populations. Apart from purposeful constructions of reservoirs, beavers have also created numerous, long-lived lakes, many of which became permanent by means of sediment deposited against the dam. Examples can be seen throughout North America and on a few European rivers. Lakes may also form accidentally when mines, gravel diggings, and quarries are abandoned. An example of artificial lakes formed in this way is the Kimberly Lake in South Africa, which is one of the deepest artificial lakes in the world (Ismael, 2009). There are several examples of man-made lakes in Nigeria. These include; Kainji, Bakalori, Goronyo and Yardantsi, Gusau Reservoir among others, all of which were constructed to support better living of humans (Magami, 2011)**.**

Limnological studies are important for the successful development, management and utilization of water resources with regards to their fisheries potentials, especially now that the Nigerian government emphasizes on the production of alternative cheap protein supplement to the inadequate beef supply (Balarabe, 1989). In order to benefit from these water resources, through aquaculture, domestic use, irrigation, hydroelectric power etc, there is need to have information on the physico-chemical characteristics of these water bodies and the algae which are the first link of the food chain with regards to ecology and taxonomy (Kramer and Botterweg, 1991).

Algae are primary producers in the aquatic ecosystem that possess chlorophyll A as the primary photosynthetic pigment. In addition, planktonic (free-floating) forms are typically small and microscopic, and mostly consist of simpler forms, benthic algae (attached to macrophytes, sand, clay/silt and stone/rock surfaces) include the entire range of morphologies, and flagellated taxa are less common (Opute and Kadiri, 2013). They are dependent on sunlight for photosynthesis and require carbon in form of carbon dioxide, oxygen, phosphates, nitrates and silicates in the case of diatoms for growth and development (Chia *et al.*, 2013).

The most important factors affecting the distribution, abundance and diversity of algae include pH, ionic strength, nutrients, velocity of water, availability of light, and grazing (Stenger-Kovacs *et al.*, 2013). These factors in turn are defined by climatic conditions, geology and bedrock topography, and land-use (Triest *et al*., 2012). Many species of algae have been found to be ubiquitous; while others appear to be restricted in distribution by climate or geography or may be endemic to some specific water bodies (Bere *et al.,* 2013). A local factor such as water chemistry that is largely affected by anthropogenic activities determines the abundance and diversity of algae (Stenger-Kovacs *et al*., 2013).

For an organism to establish a population in a given biotope, the environmental conditions must be such that the organism not only survive but also able to feed, grow and successfully reproduce. This success can only be achieved if the biotic factors which affect the biotic community fluctuates minimally (Balarabe, 1989). The most important contributions of limnology to fisheries are the ability to objectively evaluate the fish yield, which can be estimated from individual water bodies (Boyd, 1979). Muhar *et al*. (2000) reported that a study of physico-chemical characteristics provides great insight into why problems occur; help to discern the trends and asses potential remedies. Therefore monitoring of biological and physico-chemical characteristics of reservoirs is important for both short term and long term trends, which will enable appropriate decisions and action to minimize deleterious effects.

1.2 Statement of Research Problem

Although, the impacts of human activities on large reservoirs have been well documented for centuries, however, new ones have been constructed or are being proposed whose environmental impacts are downplayed or even ignored. Internal survey of World Bank Hydroelectric Dam Projects conducted in 1990 showed that 58% were planned and built without any consideration of downstream impacts, even when these impacts could be predicted to cause massive coastal erosion, pollution and other problems (Orji *et al.,* 2006). The following are some of the most serious environmental impacts of dams on rivers and the life they support, these includes; reducing the flow of water from a river which changes the landscape it flows through. This in turn can affect the ecosystem's flora and fauna. A dam holds back sediments, especially the heavy gravel and cobbles. The river, deprived of its sediment load, seeks to recapture it by eroding the downstream channel and banks, undermining bridges and other riverbank structures. Anthropogenic activities such as agriculture, industrial and domestic discharges have contributed to the deterioration of the environment (Ansari *et al*., 2014; Van Dover, 2014). Pollutants from these activities are released either directly into the aquatic ecosystem in the form of wastewater discharges, oil spillages, agricultural run-offs (Hassan *et al*., 2014a), or indirectly through deposition from soil or air within the catchment of such water bodies (Bako *et al*., 2014).

In recent years there have been increasing concern about the rate at which inland waters are polluted through human activities, such as introduction of agricultural wastes like manure, fertilizers and pesticides, which find their way through run-offs into streams and lakes there by enriching the water bodies, leading to eutrophication (Adakole *et al.,* 2003). Eutrophication becomes a nuisance in the man-made and natural lakes because of impaired water quality, fermentation processes during anoxic periods, prolific weed growth, excessive algal blooms and deteriorating fisheries (Beeton, 2002). Newcombe (1994) reported that eutrophication affects the specific composition of zooplankton through physical and chemical alterations of the environment as well as changing the composition of phytoplankton which constitute food for the zooplankton. Lakes are sometimes subjected to wastewater discharges originating from different sources with high concentrations of chemicals, such as nitrogen, phosphorus, and carbon which might distort and disrupt aquatic ecosystems. Eutrophication of these lakes has therefore deteriorated their water quality, which interferes with most of their beneficial uses (Korkeamaki and Suhenan, 2002).

Yardantsi reservoir, Gusau was selected for the purpose of this research because it is the main sources of water to Gusau populace, and the unique dynamic pattern of the physico-chemical characteristics. Human activities such as agricultural practices (cultivation on steep slopes), fishing, animals grazing and watering etc. are carried out in and/or near the reservoir, therefore increase in the concentration of organic and inorganic nutrients may cause pollution. The reservoir was constructed in December, 1989 for the purpose of domestic water supply, livestock watering, fishing and irrigation. Since its impoundment, there has not been any documented baseline information on its water quality, biota and productivity with respect to its fisheries potentials.

1.3 Justification

The north west ecological zone of Nigeria is blessed with abundant natural and artificial water bodies, which serve different purposes such as domestic uses, irrigation, livestock watering, recreation, fisheries production, flood control, and small scale independent hydroelectric power project. Agricultural, industrial, and urban activities are considered as the major sources of chemicals and nutrients to aquatic ecosystems, while atmospheric deposition could be an important source to certain constituents such as nitrogen. The concentration of these nutrients in excess can lead to pollution and in turn cause loss of biodiversity which include fishes and other aquatic biota (Magami, 2011).

Assessing the water as well as sediment quality status and seasonal changes of these reservoirs are important in evaluating the spatial and temporal variation, so as to assess their productivity and management (Korai *et al*., 2008). It was on this background that the present research work was initiated. The study will elucidate interactions between plankton diversity, fisheries potentials and other physico-chemical characteristics of the Yardantsi reservoir, Gusau.

1.4 Aim and Objectives

1.4.1 Aim

This research work is aimed at evaluating some aspects of limnology: physico-chemical parameters of surface water, sediment and plankton composition, distribution and abundance with a view of assessing the water and sediment quality as well as fisheries potentials of Yardantsi Reservoir, Gusau.

1.4.2 Objectives

The specific objectives are to determine;

i. The surface water physico-chemical parameters of Yardantsi Reservoir, Gusau.

ii. The sediment physico-chemical parameters of Yardantsi Reservoir, Gusau.

iii. The surface water and sediment trace and alkali-alkaline earth metals concentration of Yardantsi Reservoir, Gusau and their relationship with regards to seasons.

iv. The phytoplankton and zooplankton composition, distribution and abundance of the Yardantsi Reservoir, Gusau, and their relationship with surface water physico-chemical parameters.

v. The fisheries potential of the Yardantsi reservoir, Gusau, and their relationship with surface water physico-chemical parameters.

1.5 Research Hypotheses

i. There are no significant variations between surface water physico-chemical parameters among sampling stations of the Yardantsi reservoir, Gusau.

ii. There are no significant variations between sediment physico-chemical parameters among sampling stations of the Yardantsi reservoir, Gusau.

iii. The trace and alkali-alkaline earth metals concentration of surface water and sediment of Yardantsi reservoir, Gusau has no significant relationship with regards to seasonal variation.

iv. Phytoplankton and zooplankton composition, distribution and abundance is not affected by the variation in different sampling stations and have no significant relationship with the surface water physico-chemical parameters of Yardantsi reservoir, Gusau.

v. There are no significant variations in fisheries potentials with regard to seasons among sampling stations of the Yardantsi reservoir, Gusau.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 Introduction

Small reservoirs occupy a unique position in the limnology and offer immense scope for enhanced fish production by adopting extensive aquaculture techniques (Maushal and Sharma, 2001). Aquaculture is one of the fastest-growing sectors in world food production industry (Park and Marshall, 2000). Ajana *et al.* (2006) stated that the quality of any given water body is governed by its physical, chemical and biological factors, all of which interact with one another and greatly influence its productivity.

Nutrient enrichment has become a major threat to freshwater ecosystems and has consequently received considerable attention on the political agenda (Smol, 2008). Climate change in combination with human induced eutrophication of lakes via nutrient loading through agriculture, industry, sewage release, and soil erosion can lead to adverse consequences for ecosystem functioning and services. As a consequence of such anthropogenic nutrient enrichment, lakes may experience harmful algal blooms, oxygen depletion, decreased biodiversity, and massive fish kills (Schindler, 2001). Some lakes are, however, naturally nutrient-rich due to the local geological or morphological setting, whereas others can experience moderate nutrient enrichment throughout their history as a consequence of natural processes such as abiotic or plant-mediated weathering and transport of nutrients from the catchment to the lake (Engstrom *et al*., 2000; Magami, 2011). Bhuyan *et al*. (2003) stated that in recent years, activities to preserve the water quality and ecosystem of man-made reservoirs have been encouraged. For example, research on the classification of water quality of reservoirs/lakes on the basis of land use has been carried out.

There are two basic approaches to the assessment of water quality that run through literature. The first involved the use of abiotic factors of aquatic system to provide some insight in to the water quality (Thagaradjou *et al.,* 2012). The second approach is the biotic factors, which is governed by the theory, and provide a direct measure of ecological integrity by the use of response of biota to changes in environmental conditions (Joshi *et al.,* 2013). The advantage of this is that it allows for the detection of effect of long term impact of changes in water quality that are not present at the time of sample collection and analysis (Bere *et al.,* 2013). A key to the use of the aquatic biota as reliable indicators of changes in an aquatic ecosystem is unveiling the integrated environmental information in species rich assemblages (Sutela *et al.,* 2013). Biological monitoring has now become an important branch of applied ecology where the scientific and economic interests of the society meet in the management of aquatic ecosystems (Salmaso *et al.,* 2014). Physical and chemical methods are, however, important complements of biological methods, contributing to the correct assessment of the quality of lotic waters (Hassan *et al.,* 2014b).

2.2 Physico-Chemical Parameters

The study of the physico-chemical properties of water which is a fundamental part of limnology have been used in assessing water quality, biological productivity and trophic status, 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 number of chemical elements which enter into chemical complexes in aquatic ecosystems (Adakole and Abolude, 2012). The chemical elements found in water are known to have effects on biological processes that lead to conversion and flow of energy, nutrient recycling, 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 aquatic ecosystem rich in phytoplankton species (primary producers), zooplankton and diverse fish populations (Adakole and Abolude, 2012).

2.2.1 Temperature

Temperature is known to determine the rate at which metabolic processes occur in living cells, and distribution of these organisms especially animals in a functional ecosystem, it is expressed in terms of any several arbitrary scales (Fahrenheit or Celsius) indicating direction in which heat energy will spontaneously flow (Michaud, 1991). Most aquatic organisms are cold blooded (poikilothermic) meaning they are unable to internally regulate their core body temperature. Therefore, temperature exerts a major influence on the biological activities and growth of aquatic organisms to a point, the higher the water temperature, the greater the biological activities. Fishes, aquatic insects, zooplankton, phytoplankton and other aquatic species all have preferred temperature ranges. As temperatures get too far above or below this preferred range, the number of individuals of the species decreases until finally there are few or none. For example it would generally not be expected to find a thriving trout fish in ponds or shallow lakes because the water is too warm to allow adequate growth of the species (Michaud, 1991). Elevated temperatures, concentrations of oils and grease, heavy metals, sulphate and chloride are associated to present of industries around the catchment areas (Olorode and Fagade, 2012). Changes in the growth rates of cold-blooded aquatic organisms and many biochemical reaction rates can often be approximated by the rule, which says that growth rate will double if temperature increases 10°C within their preferred range (Moore, 1989).

Temperature is also important because of its influence on water chemistry. The rate of chemical reactions generally increases at higher temperature, which in turn affects biological activity. An important example of the effects of temperature on water chemistry is its impact on oxygen. Warm water holds less oxygen than cool water, so it may be saturated with oxygen but still not enough for aquatic organism’s survival: Some compounds are also more toxic to aquatic life at higher temperatures (Michaud, 1991; Magami, 2011 and Tanimu, 2015).

The most obvious reason for temperature change in lakes is the change in seasonal air temperature, daily variation may also occur, especially in the surface layers, which are warm during the day and cool at night (Michaud, 1991). In deeper lakes (typically greater than 5m for small lakes and 10m for larger ones) during summer the water separates into layers of distinctly different density caused by differences in temperature. Unlike all other fluids, however as water approaches its freezing point and cools below 4°C, the opposite effect decreases until it freezes at 0°C (Michaud, 1991). Water temperature is also known to be an important external factor that affects activities such as behaviour, feeding, reproduction of fish and generally the characteristics of natural water bodies, which includes solubility of certain chemical elements (Dillon *et al.*, 1990; Magami, 2011).

2.2.2 Turbidity and transparency

Turbidity is optical property of water that causes light to be scattered and absorbed rather than transmitted in straight lines (EPA, 1986). Korai *et al.* (2008) reported that turbidity is also the measure of suspended organic and inorganic materials in the water body. Turbidity occurs inform of plankton or clay turbidities depending on the type of materials in suspension (Lashari *et al.*, 2001; Magami, 2011). The major source of turbidity in the open water zone of most lakes is typically phytoplankton but closer to shore, particulates may also be clays and silts from surface runoff, resuspended bottom sediments and organic detritus from steam and wastewater discharges, dredging operations, channelization, increased flow rates, floods or even too many bottom feeding fish, such as *Cyprinus carpio* may strip up bottom sediments and increase the cloudiness of the water (Michaud, 1991; Magami, 2011).

Turbidity is a standard measurement in stream sampling programs where suspended sediment is an extremely important parameter to monitor. It may also be useful for estimating total dissolved solids (TDS) in lakes particularly reservoirs, since their useful lifetime depends upon how fast the main basin behind the dam fills with inflowing sediments from mainstream and tributary streams and from shoreline erosion (Moore, 1989). Lashari *et al.* (2001) also reported that excess turbidity prevents light penetration into water body; such high turbidity reduces growth and photosynthetic activities of phytoplankton which results in decreased primary productivity and low oxygen concentration of the water. They also reported that temperature increases rapidly as turbidity of water increases. Moore (1989); Michaud (1991) and Magami, (2011) also reported that pollution tends to reduce water clarity.

Watershed development and poor land use practices cause increases in erosion, organic matter, and nutrients all of which cause increases in suspended particulates and algae growth. Large amounts of suspended matter may clog the gills of fish and shellfish and kill them directly (Beeton, 2002). Suspended particles may also provide a place for harmful micro-organisms to lodge; it may also provide breeding ground for bacteria. Fish cannot see very well in turbid water and so may have difficulty in finding food, on the other hand, turbid water may make it easier for fish to hide from predators (Prakash *et al.,* 1994; Alhassan, 2015).

2.2.3 Mean depth

Mean depth is the best single indicator of morphometric conditions within a lake basin (Rawson, 1952). If mean depth is held constant within the hypothetical suite of lakes, water volume will vary on a linear basis with respect to variants of area. Mean depth also has profound influence in mixing and re-suspension from the bottom sediment (Magami, 2011). In very shallow lakes, close relationship exist between free waters and the bottom, where clean organic compounds accumulate (Rowe *et al*., 2002).

2.2.4 Hydrogen ions concentration (pH)

The balance of positive ions (H^+) and negative hydroxyl ions (OH^-) in water, determines how acidic or basic the water is (Beeton, 2002; Magami, 2011). Hydroxyl ion concentration is expressed as pH. The pH scale ranges from 0 to14, but pH 7 is considered to be neutral, substances with pH of less than 7 are acidic, substances with pH greater than 7 are basic (Michaud,1991). The pH of water determines the solubility (amount that can be dissolved in water and biological availability amount that can be utilized by aquatic life) of chemical constituents such as phosphorus, nitrogen and carbon, and heavy metals (lead, copper, cadmium etc.). The degree to which they are soluble determines their toxicity; metals tend to be more toxic at lower pH because they are more soluble (Moore, 1989; Magami, 2011).

In lake or pond, the water‘s pH is affected by its age and the chemicals discharged by communities and industries. Most lakes are basic (alkaline) when they are first formed and become more acidic with time due to the build-up of organic materials. As organic substances decay, carbon dioxide (CO_2) forms and combines with water to produce a weak acid called carbonic acid and this lower water pH (Magami, 2011). Bruton (1985) reported that when acidic water comes into contact with certain chemicals and metals, they often make them more toxic than normal water. Moore (1989) also reported that fish that usually withstand pH values as low as 4.8 will die at pH 5.5 if the water contains 0.9mg/L of iron. The optimum pH requirements for fish production in tropical regions range between 6.5 and 8.0. However, pH less than 4 and above 11 have been reported to be lethal to fish in natural freshwater bodies (Dillon *et al.,* 1990; Magami, 2011).

Shallow waters in subtropical regions that hold considerable organic matter often vary from pH 9.5 in the day time to pH 7.3 at night. Organisms living in these waters are able to tolerate these extremes or swim into more neutral waters when the range exceeds their tolerance limit (Michaud, 1991). When pollution results in higher algal and plant growth (e.g. from increased temperature or excess nutrients), pH level may increase, as allowed by the buffering capacity of the lake. Although these small changes in pH are not likely to have a direct impact on aquatic life, they greatly influence the availability and solubility of all chemical forms in the lake and may aggravate nutrient problems just as change in pH may increase the solubility of phosphorus making it more available for plant growth and resulting in greater long term demand for dissolved oxygen (Magami, 2011).

2.2.5 Total dissolved solids

Total dissolved solids (TDS) are a measure of inorganic salts, organic matter and other dissolved materials in water (EPA, 1986). Measurement of TDS do not differentiate among ions, also the concentration and composition of TDS in natural waters is determined by the geology of the drainage, atmospheric precipitate and the water balance and/or evaporation precipitate (APHA, 2005). TDS concentrations in natural waters often result from industrial effluent, changes to the water balance or by salt-water intrusion.

TDS in natural waters is a useful parameter in describing the chemical density as fitness factor and as a general measure of edaphic relationship that contributes to productivity within the water body. Rawson (1952) reported that it's possible to estimate fish yield from mean depth; the idea was also supported and used by Ryder (1981) who now refer to it as Morph edaphic index (MEI), i.e. total dissolved solids over mean depth. Total dissolved solids cause toxicity through increase in salinity, changes in the ionic composition of the water and toxicity of individual ions. Increase in salinity have been shown to cause shifts in biotic communities, limit biodiversity, exclude less-tolerant species and cause acute or chronic effects at specific life stages (Adakole *et al.,* 1998).

2.2.6 Electrical conductivity

Conductivity is the measure of concentration of dissolved ions. Also freshwater bodies with very low conductivity usually appear dark in colour, such water bodies are found in mashed land areas with high concentrations of organic materials (Rowe and Dean, 1998). Conductivity of freshwater bodies in tropical regions varies from $10\mu Scm^{-1}$ to $10000\mu Scm^{-1}$ (Rowe *et al.,* 2000). Increase in conductivity of shallow water bodies usually results in higher potential fish yield and also conductivity as higher as $380.63\ \mu Scm^{-1}$ is indicative of eutrophication of lakes in tropical regions (Dillon *et al.,* 1990). The relationship of conductivity to ionized matter concentrations varies with both the quality and quantity of the ions present (Sanjer and Sharma, 1995; Magami, 2011).

2.2.7 Dissolved oxygen

Dissolved oxygen (DO) is one of the most important and critical water quality parameters for fish and other aquatic organisms (Richardson *et al.,* 2001). Like terrestrial animals, fish and aquatic organisms need oxygen to live (Moore, 1989). As water moves fast fish gills absorb the dissolved oxygen through blood capillaries. Oxygen is also needed by virtually all algae and all macrophytes, and for many chemical reactions that are important to lake functioning (Beeton, 2002; Magami, 2011).

Oxygen levels also can be reduced through over fertilization of plants by run-off from farm fields containing phosphate and nitrates (the ingredient in NPK fertilizer). Under these conditions, the number and size of water plants increase a greater deal, and then if the weather becomes cloudy for several days, respiring plants will use much of the available DO. When these plants die they become food for bacteria, which in turn multiply and use large amount of oxygen (Beeton, 2002; Magami, 2011). The solubility of oxygen in water increases with decreasing water temperature and salinity (Dillon *et al.*, 1990). Prakash *et al.* (1994) reported that optimum dissolved oxygen level in natural water body ranged between 4 and 6mg/L. This level could rise up to 10mg/L in mid dry season (January to February) during harmattan when surface water temperature is minimal due to influence of the north east trade wind.

Oxygen is produced during photosynthesis and consumed during respiration and decomposition. Because it requires light, photosynthesis occurs only during day hours. Respiration and decomposition on the other hand, occur 24 hours a day. This difference alone can account for large daily variations in DO concentrations in water bodies. During the night, when photosynthesis cannot counter balance the loss of oxygen through respiration and decomposition, DO concentration may steadily decline to its lowest just before dawn, when photosynthesis resumes (Michaud, 1991; Magami, 2011).

Eutrophication is one of the most significant and worldwide water quality problems. It is a natural process that is influenced by man from agricultural activities which leads to nutrient enrichment that occurs over time in a body of water. This results to biological growth of mainly algae (leading to algal bloom). These algae die and settle at the hypolimnion where they decay and deplete the dissolved oxygen from the water. Also, excessive eutrophication depletes dissolved oxygen which will lead to change in fish species available in the water bodies. Excessive growth of algae and other aquatic plants renders the water and beaches unfit for recreational purposes (Henry and Heinke, 2005; Magami, 2011). Abundant algal bloom creates an unpleasant taste and odour in water supplies and plug intakes and filters in water treatment plants. Minor fractions of total dissolved solids, nutrients (ammonia, nitrogen, nitrate-nitrogen and phosphate from fertilizers) and pesticides (such as insecticides and herbicides) typically have significant negative impact on streams and lakes receiving agricultural drainage water. If soils are also washed into receiving waters, the organic matter in the soil is decomposed by natural aquatic bacteria, which can severely deplete oxygen (Moore, 1989; Magami, 2011).

2.2.8 Biological oxygen demand

Biological oxygen demand (BOD) is the measured amount of oxygen required by acclimated micro-organisms to biologically degrade the organic matter in the water (Henry and Heinke, 2005). Biological oxygen demand is the most important parameter in water pollution, as measure of organic pollution, and basis for estimating the oxygen needed for biological processes, and as an indicator of process performance (EPA, 1986).

Hellstrom (1991) reported that the more the organic matter in water, the greater the number of microbes and the more microbes there are, the greater the need for oxygen to support them. Consequently, less oxygen is available for animals especially the higher ones such as fish. BOD is therefore reliable gauge of the organic pollution of water. He also added that one of the main reasons for treating sewage or wastewater prior to its return to a water resource is to reduce its need of oxygen and there by lessen its demand from the streams or rivers into which it is released (Magami, 2011). Bennion and Battarbee (2007) found that the average BOD of water in ponds used for intensive fish culture to range from 0.12 to 0.71mg/L. Similarly, studies carried out by Orji *et al.* (2006) revealed that BOD in some catfish ponds may reach up to 0.7mg/L (Magami, 2011).

In his own investigation, Manson (2002) reported that about 31.4%, 29.9% and 13.8% of drinking water sources in Japan have BOD values less than 1mg/L, 2mg/L and 3mg/L respectively. The author added that if BOD exceeds 3mg/L, it affects coagulation and rapid sand-filtration processes, for conventional water treatment plants requiring expensive advanced water treatment, therefore BOD standards are set at 2 and 3mg/L, respectively, for class II and III waters. For class I, Fisheries BOD is set at less than 1mg/L, since oligosaprobic fishes such as salmon and smelt require water with BOD less than 2mg/L. For class II fishes, BOD is set at less than 2mg/L, since mesoprobic fish such as carp require water with BOD less than 3mg/L. For class III fishes, BOD is set at less than 3mg/L, since class III fish require water with BOD less than 5mg/L. For class E, conservation of environment, BOD is set at less than 10mg/L to prevent odour caused by anaerobic decomposition of organic matter (Muhar *et al.*, 2000; Magami, 2011).

2.2.9 Alkalinity

Alkalinity is termed as buffering capacity of water, which is primarily due to the presence of bicarbonate, carbonate and hydroxide ions, silicates and phosphate may also contribute to the buffering capacity of water. Alkalinity is important for fish and other aquatic organisms because it buffers pH changes that occur naturally due to photosynthesis, positive correlations have been established between alkalinity and fish production (Carlander, 1955; Alhassan, 2015). 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 while those with extreme high alkalinity may have pH values too high for fish production; also waters dominated by bicarbonate ions usually have low or no phenolphthalein alkalinity (Campbell and Wildberger, 2001; Sabo *et al.*, 2013).

2.2.10 Hardness

Water hardness is mainly due to the presence of calcium and magnesium ions (Boyd, 1979; Alhassan, 2015). Information about hardness of water is of importance in industrial water use since it is the main source of scale and corrosion in heat exchange equipment, boilers, pipelines, etc. From domestic point of view, hard water consumes excessive quantity of soap forming curds and depositing a film on hair, fabrics and glassware. The Hanna’s hardness scale 2003, categorized water into very soft (0 - 70mg/L), soft (71 - 150mg/L), slightly hard (151 - 250mg/L), moderately hard (251 -

320mg/L), hard (321 - 420mg/L) and very hard (421mg/L and above) (Alhassan, 2015). Calcium and magnesium ions have been reported to be the major ions used by rotifers, crustaceans, shelled animals for their shell and aquatic macrophytes for chlorophyll formation (Wetzel, 2001; Alhassan, 2015).

2.2.11 Nitrate-nitrogen

Nitrogen is a dietary requirement for all organisms, because it is a constituent of all proteins and nucleic acids (Cox, 1991). Plants consist of approximately 7.5% nitrogen (dry mass). Nitrogen is essential for plants, and can be found in air in large amounts. This elementary nitrogen must be bond and converted for instance to nitrate (Boubee *et al.*, 1997). Nitrogen ends up in the environment mainly through agricultural process and thereby ending up in water. Main sources of nitrogen compounds in water are fertilizers that mainly contain nitrate, but also ammonia, ammonium, urea and amines. The most widely applied nitrogen fertilizers are probably $NaNO_3$ and NH_4NO_3 (Raiswell, 1980).

In freshwater, nitrates and ammonia are dietary requirements for planktons causing nitrogen concentrations to be lower at the surface than in the deeper part of the water. Also, at increasing nitrogen concentrations in surface layers, plankton production increases, leading to algal blooms that occur mostly in lentic waters. Large amounts of nitrate may cause eutrophication; this may result in oxygen depletion and subsequent fish death (Cox, 1991; Magami, 2011).

Oxygen deficits in surface water generally result in nitrate reduction to elementary nitrogen or nitrous oxide. This so called denitrification process causes oxygen reserve releases, when oxygen supplies decreases to zero, in some cases nitrate may even be biologically reduced to ammonia. Ammonium compounds decrease the water oxygen concentration; because these are oxidized from nitrite to nitrate and small concentration of free ammonia may be toxic to fish (Manson, 2002; Magami, 2011). He also reported that seawater contains approximately 0.5ppm nitrogen; the amount is clearly lower at the surface being approximately 0.1ppm. Freshwater concentrations vary strongly, but are approximately 0.25ppm in general. Manson (2002) and Magami (2011) also added that depending on water properties, various inorganic nitrogen compounds may be found. In aerobic waters nitrogen is mainly present as N_2 and NO_3^- depending on environmental conditions which may also occur as NO_2, NH_3, NH_4^+, HNO_2, or HNO_3.

2.2.12 Phosphate-phosphorus

Phosphorus is a multivalent non-metal of the nitrogen group. In natural world, phosphorus is never encountered in its pure form, but only as phosphates, which consist of phosphorus atom bonded to four oxygen atoms. This can exist as negatively charged phosphate ion (PO_4^{3-}), which occurs in minerals, or as organophosphates in which there are organic molecules attached to one, two or three oxygen atoms. According to EPA (1986) phosphorus is one of the key elements necessary for growth of plants and animals. Phosphates exist in three forms; orthophosphates, metaphosphates or polyphosphates, and organically bond phosphates. Each compound contains phosphorus in a different form or proportion. Ortho forms are produced by natural processes found in sewage, poly forms are used for treating boiler waters and in detergents, in water they change into the ortho form (EPA, 1986; Magami, 2011).

Organic phosphates are important in nature; the occurrence may result from break down of organic pesticides which contain phosphates. Rainfall can cause varying amounts of phosphates to wash from farm soils through surface runoff into nearby waterways. Phosphate will stimulate the growth of plankton and other aquatic plants which provide food for fish, and consequently this may cause increase in the fish population and improve the overall water quality (Manson, 2002). If an excess of phosphate enters the water ways, algae and other aquatic plants will grow rapidly, choke up the water ways and use up large amount of oxygen, leading to eutrophication or over-fertilization of receiving waters. This rapid growth of aquatic vegetation leads to overcrowding or algal bloom and eventually death and as it decays it uses up oxygen. This process in turn causes death of aquatic life because of the lowering of dissolved oxygen levels (Cox, 1991; Magami, 2011).

Manson (2002) reported that algal blooms from excess phosphorus in lakes can lead to excessive weed growth which can have negative effects on aquatic ecosystems as well as harm human and livestock. He also added that cynophyta contain toxins that can affect the liver and nervous system; aquatic organisms and wildlife have died from consuming water containing toxins from blue-green algae. Cynophyta (*Microcystis* sp.) contain toxins (MC) which are known to causes gastroenteritis, flulike symptoms, sore thorat, blistered mouth, abdominal pain, fever, pulmonary consolidation, eye and ear irritation, vomiting, diarrhoea, primary liver cancer, colorectal cancer and death (Ludek *et al.*, 2009). Algal bloom can also plug water pumps and impair water delivery as well as produce algal serums that smell and look bad (Bruton, 1985; Magami, 2011).

2.2.13 Sulphate

Sulphate is the third most abundant ion in freshwater (Renn, 1970). The minimum permissible limit of sulphate in drinking water was set as 100 mg/L (NSDWQ, 2007). Also the safe drinking water act was established to be 400-600 mg/L of magnesium sulphate and 250-800 mg/L of calcium sulphate, values higher than these may be detrimental in domestic water supply (Hach, 2003). Higher concentration of sulphate in water can cause unpleasant taste to the water and contribute significantly to the hardness of the water and may also cause eutrophication of reservoirs (Armengol *et al.*, 1991; Alhassan, 2015).

2.2.14 Chlorides

The chlorides anions (Cl^-) concentration determines the water quality as the quality of water get worse due to elevation in concentration of this anions which limit possibilities of using of natural water for different purposes (household, agriculture, industry etc.). Principal source of the Cl^- in natural water are magmatic rock formations that include chlorine-content minerals. The second source of these anions is Ward Ocean from where considerable amount of Cl^- enter in the atmosphere. From atmosphere Cl^- enter in the natural water as a result of interaction between precipitation and soil (James, 1993).

2.3 Trace and Alkali-alkaline Earth Metals in Aquatic Ecosystem

Trace or heavy metals are regarded as serious pollutants in the aquatic environment because of their environmental persistence and tendency to concentrate in aquatic organisms. High concentrations of heavy metals in water, sediments, and organisms may result in serious ecological consequences. Most heavy metals released into the environment enter the aquatic phase as a result of direct input, atmospheric deposition and erosion due to rain (Veena *et al*., 1997). Adakole and Abolude (2012) observed that global concern about heavy metals in the environment stems from their persistence, toxicity and bioaccumulation in the trophic chain. Therefore, aquatic animals are often exposed to elevated levels of heavy metals.

Contamination of aquatic ecosystems by heavy metals has been observed in water, sediment and organisms. Heavy metals may be directly absorbed by organisms but are also transferred from lower to higher trophic levels of the food chain. The high accumulation of heavy metals in these components can result in serious ecological changes. One of the most serious results of their persistence is the biological amplification of metal in the food chain. Metals transferred through aquatic food chains and webs to fish, humans and other animals are of more environmental concern to human health (Farkas *et al*., 2001). Measuring heavy metals in aquatic organisms may be bioindicator of their impact on organism and ecosystem health, but a true evaluation of the damage inflicted by heavy metals should come from comprehensive biomarker studies. Researches over time have focused on various species and various biomarkers to determine the level of heavy metal toxicity in aquatic environments (Balarabe *et al*., 2004). In the past few decades, heavy metals accumulation in the environment has been attracting increasing attention from both researchers and policymakers because of their toxicity, persistence in the environment and subsequent accumulation in aquatic habitats (Fifi *et al.,* 2013; Guan *et al.,* 2014).

The pollution of the aquatic environment with heavy metals has become a worldwide problem in recent years because they are indestructible and most of them have toxic effects on organisms (MacFarlane and Burchett, 2000). Gadzama *et al*. (2013) reported 19 metals that were present in the analysed soft tissues of three species of bivalves (*Anodonta anatine, Anodonta marginata* and *Anodonta implicate*) studied in Kubanni reservoir. The elements vary in concentrations in the three bivalve species, with some of the elements falling below detection limit. The metals reported were Mn, Na, K, As, La, Sm, U, Sc, Cr, Fe, Co, Zn, Ba, Eu, Lu, Yb, Th, Sb and Rb.

Amman *et al.* (2002) are of the views that anthropogenic activities like mining, final disposal of treated and untreated waste effluents containing toxic metals as well as metal chelates from different industries, such as tannery, steel plants, battery, industries, thermal power plants and the indiscriminate use of heavy metals containing fertilizers and pesticides in agriculture are some of the main causes of metal pollution in the aquatic ecosystem. Although some metals like Cu, Fe, Mn, Ni, Zn and Se are essential micronutrients for life processes in plants and animals, others like Cd, Cr and Pb have no physiological importance and have been proven detrimental beyond certain limit (Abolude, 2007). Trace elements constitute natural component of the earth crust and are not biodegradable, hence persist in the environment. Heavy metals may come from natural sources, leached from rocks and soils according to their geochemical mobility or come from anthropogenic sources as a result of industrial pollution and other human land occupation (Abolude *et al.,* 2009).

Calcium occurs in water naturally, seawater contains approximately 400ppm while freshwater generally contains 1 to 2mg/L. Calcium is naturally present in water; it may dissolve from rocks such as limestone, marble, calcite, dolomite, gypsum and fluorite. Calcium is a determinant of water hardness, because it can be found in water as Ca^{2+} ions. Magnesium is the other hardness determinant (Dillon *et al.,* 1990). Calcium is used by green algae as micronutrients, as well it determine the distribution of certain algae, only very few group of freshwater animals exist in which distribution of some species has not been related to calcium concentration (Wetzel, 2001).

Large amount of minerals contain magnesium, for example, magnesium carbonate and dolomite. Magnesium is washed from rocks and subsequently ends up in water (Rowe *et al.,* 2002). Boyd (1979) reported that magnesium and other alkali-alkaline earth metals are responsible for water hardness, therefore water containing large amounts of alkali earth ions is called hard water and water containing low amounts of these ions is called soft water. Magnesium is also a dietary requirement for all organisms, it is also the central atom of the chlorophyll molecule, and is therefore a requirement for plant photosynthesis (Raiswell, 1980). Muhar *et al.* (2002) also reported that it is unusual to introduce legal limits of magnesium in drinking water because there is no scientific evidence of magnesium toxicity.

For billions of years sodium is washed out from rocks and soils, ending up in oceans, where it may remain for about 50 to 100 years. Seawater contains approximately 11000mg/L while in freshwater it is just about 9ppm (Moore, 1989). Rivers and lakes contain significant amounts of sodium concentrations; however, this depends on the geological conditions and wastewater contamination of water source (Monson, 2002). According to Panday *et al.* (2005) sodium is a dietary mineral for animals but plants however, hardly contain any sodium. He also added that sodium is responsible for nerve function, and he stated that blood serum contains 3.3mg/L sodium which regulates extracellular fluids, acid base balance with potassium (Dillon, 1990).

Freshwater generally contains about 2 to 3ppm of potassium, while seawater contains 400ppm (Manson, 2002). Potassium is non-water soluble, but potassium compounds are water soluble, examples include; dichromate with water solubility of 115mg/L, potassium permanganate with water solubility of 76mg/L, potassium iodide with a water solubility of 92mg/L, and potassium iodide of which even up to 1480mg may dissolve in one litre of water (Moore, 1989). Potassium is a dietary requirement for all organisms, because it plays an important role in nerve function (Danishwan and Shah, 1997). Potassium plays a central role in plant growth, and it often limits growth. Potassium from dead plant and animal materials is often bond to clay minerals in soils, before it dissolves in water; consequently, it is readily taken up by plants again (Kirk and Gilbert, 1990). According to Manson (2002) potassium is weakly hazardous in water but it does spread rapidly because of its relatively high mobility and low transformation potential. Potassium toxicity is usually caused by other components in a compound for example cyanide (Rowe and Dean, 1998).

Sediments play a major role in determining the pollution patterns of aquatic systems. They act as both carriers and sinks for contaminants, reflecting the history of pollution, and providing a record of catchment inputs into aquatic ecosystems (Cevik *et al.,* 2009). MacDonald *et al.* (2000) reported that the sediment quality guidelines (SQGs) have been used to identify "contaminants of concern" in aquatic ecosystems and to rank "areas of concern" on a regional or national basis, and have also been used in numerous other applications, including the design of monitoring programs, interpreting historical data, conducting remedial investigations and ecological risk assessments and so on; Many different SQGs have been developed. SQGs are very important for protection of aquatic organisms in freshwater ecosystems and can be used to assess sediment ecosystem health (Cevik *et al.,* 2009).

2.4 The Biological Characteristics of Aquatic Ecosystems

The biota inhabiting the aquatic systems are a function of the nature of physical and chemical characteristics of these systems, thus providing a direct, holistic and integrated measure of the integrity of the systems (Lindstead *et al.,* 2012). Therefore, the ultimate monitor of the aquatic system is the aquatic life itself (Brabets and Ourso, 2013).

Plankton are organisms whose size, mobility, or both are at the mercy of water movements. Limnologists generally consider these to be tiny forms of life. However, this group encompasses organisms whose sizes span three orders of magnitude (Panday *et al.*, 2005). Plankton includes forms of aquatic bacteria, ultra-algae (only a few microns in diameter) and macroscopic forms of crustacean, (several millimetres long). Plankton are important components of aquatic systems in large lakes and reservoirs; they are the major primary and secondary links in trophic relationships; this significantly decreases as volume of water decreases; in small, shallower waters, the benthic forms become increasingly important. Although large rivers may have a true plankton community, most river planktons are transient, and they have been washed in from lake, pond and reservoir drainages (Friedrich *et al.*, 1996).

Plankton constitute two major groups, phytoplankton which consists of algae, diatoms and dinogiflagellets, which are all plants that contribute in producing oxygen in the water bodies, while zooplankton consisting of Cladocerans, Copepods, and large Rotifers are all animals. The mechanism and stimuli for plankton movements have interested aquatic biologists for some time now, even though planktons often serve as indicators of water quality, chemical conditions also play a part in determining the taxonomic nature of plankton and the species composition is often used not only to classify the water as polluted or free from pollution but also to suggest the quantities of various naturally occurring substances, such as nitrogen phosphorus (Maushal and Sharma, 2001).

The algae of aquatic ecosystems are important components of the ecosystems and their diversities increases as anthropogenic influences on the system increase (Kshirsaga, 2013). They purify waters by absorbing many impurities such as nutrients and heavy metals and are sites of the breakdown of bacterial and other organic matter contaminants (Salmaso *et al.*, 2014). They also play an important role in global cycling of nitrogen, phosphorus, silica and carbon (Chia *et al.*, 2013).

In dammed lakes, which are formed at the back of the relieved and accumulated structures on the running water, new organisms come into existence with the effects of different morphological structures. In the running water from the dammed lake, the normal creatures of the river are changed in time, because of the cold temperature and low oxygen of the coming water of the dam (Friedrich *et al.*, 1996). Temperature has significant impact on distribution and physiological process of the phytoplankton and zooplankton of aquatic environments.

The water quality ultimately determines the survival and growth of cultured animals and plants. Aquatic organisms need healthy environments to live and have adequate nutrients for their growth. Their productivity depends on the physico-chemical characteristics of the waters, while the maximum production is obtained when the physical parameters are at the optimum level, and when the water is unfit for these aquatic plants and animals, they could not grow and even reproduce (Kamaran *et al.*, 2003). Friedrich *et* a*l*. (1996) also reported that the growth of fishes cannot be separated from the effects of physico-chemical characteristics of their aquatic habitat.

Environmental sensitivity of species determines their geographical distribution and abundance in particular ecosystems and habitats. According to their environmental sensitivities, species may be characterized as eurytopic (wide) or stenotopic (narrow), and a wide tolerance of a specific environmental factor provides an advantage in competition. The significance of environmental sensitivity in a species, usually measured as optima and tolerances for a specific environmental factor such as temperature, is emphasized due to environmental changes. Such changes are driven, accelerated and intensified by human activities. For example, global warming is already having pronounced effects on terrestrial and aquatic ecosystems and is dramatically changing physical and chemical environments causing re-distribution and extinction of species with narrow environmental sensitivities (Maushal and Sharma, 2001).

The role of temperature in determining species's distribution and abundance is becoming accentuated. In aquatic ecosystems, such as lakes, a variety of environmental characters including; pH, dissolved oxygen, colour, littoral vegetation, bottom substrata, and temperature differ substantially even within a small geographical region. Thus, the distribution and abundance of aquatic fauna, for instance littoral Cladocerans of the family Chydoridae (Chydorids) are influenced by environmental factors, such as nutrients availability, pH, aquatic vegetation, and predation (Dillon *et al.,* 1990). In general, temperature is known to work as an important inducer for the hatching of resting eggs (Vandekerkhove *et al*., 2005).

The formation of ribbons, chains or rafts of many phytoplankton individuals may also serve as aid in floating, as well as help to protect them from being grazed by small zooplankton. Since phytoplankton are among the most rapidly growing organisms of the aquatic populations, some of them dividing several times a day under favourable conditions and the populations are very responsive to changes in the environment (Maushal and Sharma, 2001). According to Henry and Heinke (2005) all lakes undergo natural enrichment of nutrients over a long time, while discharge of untreated sewage and agricultural or industrial wastes into lakes hastens the process greatly. Lakes, in which the nutrients level is particularly high, are characterized by abundant littoral vegetation and frequent stagnation which results into algal bloom.

Most zooplankton are secondary consumers, that is, they are herbivores in nature which graze on phytoplankton, or on unicellular or colonial algae suspended in the water column (Friedrich *et al*., 1996). The productivity of the zooplankton community is ultimately limited by the productivity of the small algae upon which they feed. There are times when the biomass of the zooplankton at any given time may be similar to, or even exceed that of the phytoplankton; this occurs because the zooplankton are relatively long-lived compared with the algal cells upon which they feed, so the turnover of their biomass is much less rapid (Carter *et al.*, 1986).

CHAPTER THREE

3.0 MATERIALS AND METHODS

3.1 Study Area

Yardantsi Reservoir, Gusau is dammed across a tributary of Sokoto River (Plate I), with flanking earth dams and a mass concrete weir surmounted by five steel gates which is operated by electric motors and bar-link chains with provision for emergency manual operation. Training walls are also provided at each end of the reservoir to protect the ends of the earth dams from erosion (ECAN, 1990). The construction work on the reservoir and water supply extension project commenced as far back as 1977, but due to various reasons, 20% of the works could not be completed till December, 1989 by the then Sokoto State Government, which awarded the projects to Messrs, Julius Berger Nigeria Limited (ECAN, 1990).

The reservoir is located in Gusau Local Government Area of Zamfara State, (Figure 3.1), North-western Nigeria, located between latitude 12°10'12.86" - 12°17'02.40"N and longitude 6°39'50.83" - 6°66'41.20"E, and occupies an area of 3,364km^2. Gusau Local Government had a population of 383,162 people (NPC, 2006). The hottest months in the area are March and April with an average temperature of 38-40°C that is just before the onset of the first rains. The onset of the rains tends to bring a cooling effect with temperatures dropping below 36^{o}C. The peak of the rainy season is from July to September except towards the end of October/November when the tropical continental air masses from the Sahara predominate which leads to lower temperatures of around 17°C −20°C. The mean annual rainfall in the area is 990mm. The type of vegetation in this area is the Sudan savannah (Mamman *et al*., 2000).

3.2 Sampling Sites/Stations

The reservoir received surface run-off and seepage from a drainage basin covering some of Gusau residential area. Five sampling stations were selected, with a distance of 500m between them. Geographical positioning system (GPS) coordinates and altitudes for various sampling stations were recorded using Survey CTO Collect v1.212 (Table 3.1).

Table 3.1; GPS Coordinates for Various Sampling Stations of Yardantsi Reservoir, Gusau

Station	Latitude	Longitude	Altitude (m)	Accuracy (m)
SS 1	N12°8'50"-12°8'70"	E6°40'24"-6°40'36"	448.8	5.8
SS 2	N12°8'41"-12°8'65"	E6°40'21"-6°40'29"	442.4	5.2
SS 3	N12°8'39"-12°8'57"	E6°40'16"-6°40'24"	436.5	4.2
SS 4	N12°8'32"-12°8'40"	E6°40'11"-6°40'18"	429.6	5.0
SS 5	N12°8'26"-12°8'38"	E6°40'08"-6°40'16"	421.3	4.8

Note; SS = sampling station

3.2.1 Station one

Station one is located downstream at the first segment, the east and the deepest portion of the reservoir (Figure 3.1); it is characterized by many floating debris and aquatic macrophytes. Heaps of refuse dump and human faeces could be found on the slopes of the valley. Human activities include fishing.

3.2.2 Station two

Station two is located at the western part of station one, it is also deep in comparison to stations upstream (Figure 3.1). It is bordered by a tarred road leading to Magami and Dansadu Districts. Fishing is the only human activity being carried out.

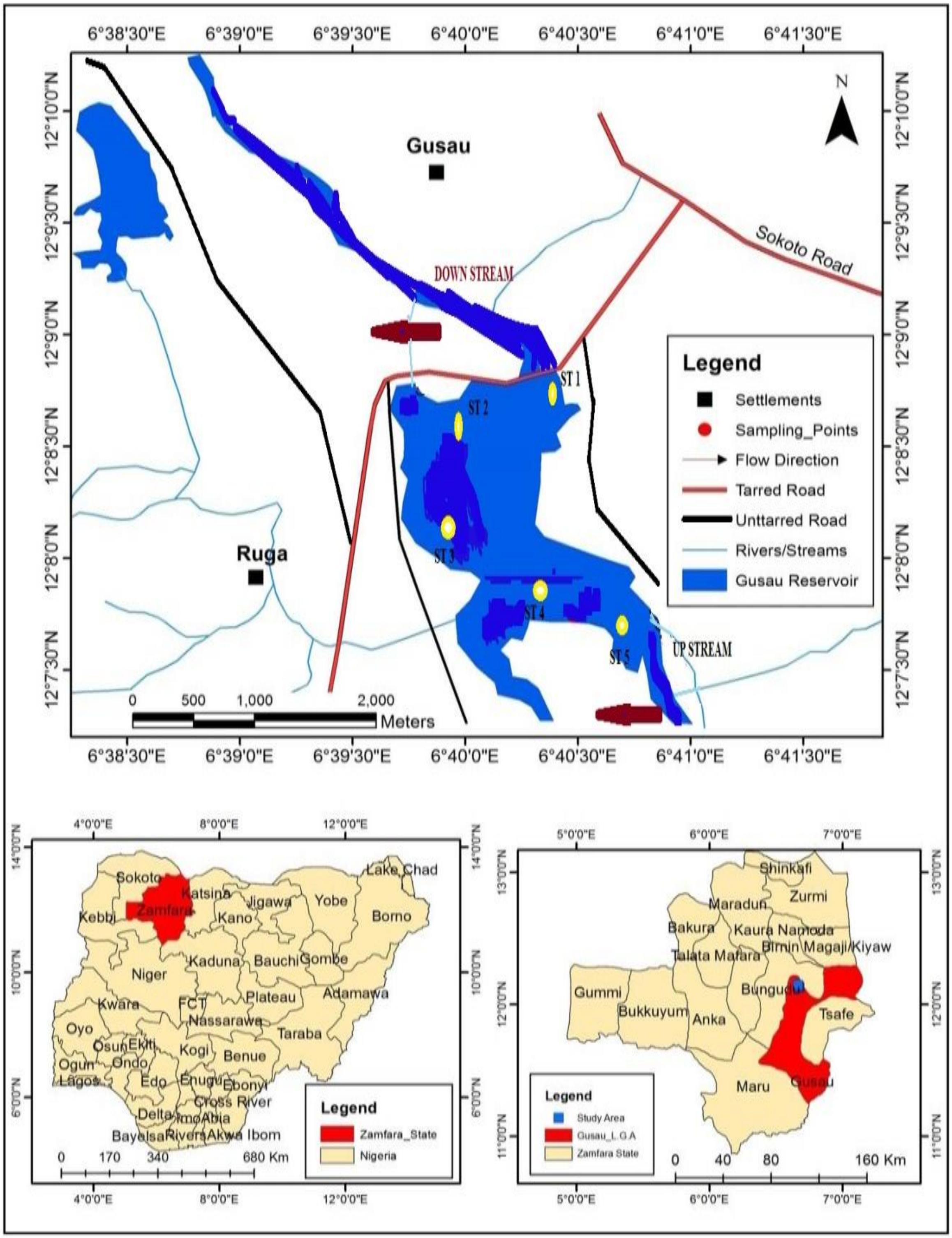

Figure 3.1: Study Area Map (Yardantsi Reservoir, Gusau)

3.2.3 Station three

Station three is located at the south western part and upstream of station two (Figure 3.1): it receives surface runoff from surrounding catchments. Fishing is the only human activity being carried out.

3.2.4 Station four

Station four is located at the south western part and upstream of station three (Figure 3.1). It receives surface runoff from surrounding catchments. Human faeces and animal dung could be found on the steep slope of the valley. Fishing and livestock watering are the activities being carried out here.

3.2.5 Station five

Station five is located along the entry of the river channel, upstream and the shallow part of the reservoir (Figure 3.1); it receives surface runoff from surrounding farm lands. Animal dungs were found on the steep slope of the valley. Fishing is the only human activity being carried out at this station.

3.3 Study Period

This study was conducted in two seasons across twenty four months that is between May 2015 and April 2017.

3.4 Collection of Samples

The Samples (Surface water, Sediments and Plankton) were collected between the hours of 6am and 7am and analysed as described by UNEP (2004); APHA (2005); Panday *et al*. (2005); and Udo *et al.* (2009). The samples collected were taken in an ice box to Hydrobiology Laboratory of Biology Department, Ahmadu Bello University for further analysis.

3.4.1 Collection of surface water samples

Surface water samples were collected in duplicate in one litre capacity plastic bottles, from each sampling station, and were kept in a water cooler prior to analyses. Each sample collected was used for determination of physico-chemical parameters. Temperature, pH, transparency, mean depth, electrical conductivity and total dissolved solids were determined *in situ*.

3.4.2 Collection of sediment samples

Sediment samples were collected from the stations at three different spots using a plastic containers and then homogenised together to form a homogenous mixture and then transferred to labelled polythene bags, which were air dried, ground into powder using pestle and a mortar and sieved through a 1.7µm mesh to remove the debris prior to analysis.

3.4.3 Collection and preservation of plankton samples

Plankton samples were collected from each station with standard cone shaped plankton net (0.01mm mesh size) and an opening diameter of 20cm was hauled over a distance of 5m at rowing speed with minimum disturbance of water to prevent avoidance reaction by plankton. The net has a collection vial of 50ml at the base; where concentrated plankton samples were collected. The collections were transferred to sterile labelled plastic bottles of 100ml capacity. For phytoplankton, two drops of

Lugol's iodine solution was added to the sample as a preservative (Perry, 2003); while zooplankton 4ml buffered formalin was added (Goswami, 2004).

3.5 Determination of Surface Water Physico-chemical Parameters

Surface water physico-chemical parameters viz; temperature, transparency, mean depth, pH, total dissolved solids, electrical conductivity, dissolved oxygen, biological oxygen demand, alkalinity, hardness, nitrate-nitrogen, phosphate-phosphorus, sulphate and chloride were determined by using methods described by UNEP, (2004); APHA (2005) and Panday *et al*., (2005).

3.5.1 Surface water temperature

The surface water temperature was measured *in situ* using portable HANNA Combo pH/EC/Temp. metre model/HI 98129. The metre was allowed to equilibrate after which the value of the surface water temperature was recorded.

3.5.2 Secchi depth (transparency)

A secchi-disc of 30cm diameter was used to determine the transparency, by lowering the disc vertically with measuring tape attached in the water; the measurement of the distance when the disk disappeared from view was recorded as $P_{1;}$ The disc was then pulled out and the distance when the disk re-appeared was measured and recorded as P_2. The transparency was calculated by taking the average of these distances, using the following formula as expressed by equation *i*:

$$\text{Transparency} = \frac{P_1 + P_2}{2} \ldots\ldots\ldots\ldots\ldots.(i)$$

3.5.3 Mean depth

Mean depth of each station was determined with string attached with a heavy object. It was lowered in to the water and the effective depth was then recorded.

3.5.4 Surface water hydrogen ion concentration (pH)

The surface water pH was measured *in situ* using portable HANNA Combo pH/EC/Temp. metre/HI 98129. The metre was allowed to equilibrate before the pH was recorded.

3.5.5 Total dissolved solids (TDS)

The surface water TDS was measured *in situ* using portable HANNA Combo pH/EC/Temp. metre/HI 98129. The metre was allowed to equilibrate before the surface water TDS was recorded.

3.5.6 Electrical conductivity

The conductivity of the water samples was measured *in situ* using portable HANNA Combo pH/EC/Temp. metre/HI 98129. The metre was allowed to equilibrate before the value of the surface water conductivity was recorded.

3.5.7 Dissolved oxygen (DO)

Two hundred and fifty (250) ml of surface water sample was measured in duplicate in to BOD stoppered bottles and then fixed with 2ml of manganous sulphate solution; this was followed by addition of 2ml of alkali-iodide-azide reagent. The resulting solution was stoppered carefully to exclude air bubbles and mixed by inverting bottle a few times and then 2ml of concentrated sulphuric acid (H_2SO_4) was added, restoppered and mixed by inverting several times until dissolution was completed. Two hundred (200ml) was then titrated against sodium thiosulphate (0.002N) until a light yellow colour remained. At this point 1ml of starch (indicator) was added turning the sample dark blue. Titration continued until the disappearance of the blue colour by the complete reduction of iodine molecules by the thiosulphate. The volume of the thiosulphate used is equivalent to the volume of the dissolved oxygen per litre, as expressed in equation *ii*.

$$\mathrm{DO} = V \ldots\ldots\ldots\ldots\ldots.(ii)$$

Where; V = ml of titrant used

3.5.8 Biological oxygen demand (BOD_5)

Two hundred and fifty (250) ml of duplicate surface water sample was collected in BOD_5 stoppered bottles and incubated in the dark for five days at room temperature. On day five, 2ml of manganous sulphate solution was added followed by the addition of 2ml of alkali-iodide-azide reagent. The resulting solution was stoppered carefully to exclude air bubbles and mixed by inverting bottle a few times and then 2ml of concentrated sulphuric acid (H_2SO_4) was then added, restoppered and mixed by inverting several times until dissolution was completed. Two hundred (200ml) was then titrated against sodium thiosulphate (0.002N) until a light yellow colour remained. At this point 1ml of Starch (indicator) was added turning the sample dark blue. Titration continued until the disappearance of the blue colour by the complete reduction of iodine molecules by the thiosulphate. The volume of the thiosulphate used is equivalent to the volume of the dissolved oxygen (DO_5) per litre as expressed by equation *iii*.

$$\mathrm{BOD_5} = \frac{\mathrm{DO_1 - DO_5}}{\mathrm{P}} \ldots\ldots\ldots\ldots\ldots.(iii)$$

Where; DO_1 = Dissolved oxygen of sample in day one (sampling day)
DO_5 = Dissolved oxygen after 5 days of incubation
P = volumetric fraction of dilution

3.5.9 Alkalinity

One hundred (100) ml of surface water sample was taken; this was followed by addition of 2 drops of methyl red indicator and then 2 drops of bromocresol green indicator. The solution was then titrated against standard sulphuric acid (0.025N) to a homogenous pink colour. The volume of standard sulphuric acid used is equivalent to the alkalinity of the water in mg/L.

3.5.10 Hardness (EDTA titration)

Hardness was determined by adding 25ml of distilled water to 25ml of surface water sample. Then 2ml of ammonium molybdate buffer (pH=10.4) was added followed by 0.8g of Eriochrome black T (an indicator dye) to the mixture. The resultant purple solution formed was then titrated against Ethylene diamine tetra acetic acid (EDTA) 0.01M, until the solution turned blue when there were no longer any free calcium and magnesium ions. This is expressed by equation *iv*.

$$\text{Hardness (EDTA)as } \mathrm{mgCaCO_3/L} = \frac{\mathrm{A \times B \times 1000}}{\text{ml of sample}} \ldots\ldots\ldots\ldots\ldots.(iv)$$

Where; A= ml of titrant and B= mg $CaCO_3$ equivalent to 1.00 ml EDTA titrant

3.5.11 Nitrate-nitrogen **(**Colourimetry)

One hundred (100) ml of surface water sample was poured into a clean dry metallic crucible and evaporated to dryness using a hot plate and was allowed to cool, after which 2ml of phenol disulphonic acid was added and swirled uniformly around the crucible and kept for ten minutes. Ten (10ml) of distilled water was added, followed by 5ml of conc. ammonia solution. The absorbance of the treated sample was read with Sherwood colorimeter 257at 430nm, using distilled water as blank. The concentration of nitrate-nitrogen (NO_3-N) was obtained from a calibration curve (Appendix I).

3.5.12 Phosphate-phosphorus **(**Colourimetry)

Two (2) ml of the surface water sample was measured into 50ml of volumetric flask, followed by the addition of 2ml phosphorus extraction solution, 2ml of ammonium molybdate and 35ml of distilled water into the flask with 1ml of fresh diluted stannous chloride. The flask was then shaken and the colour intensity was observed using Sherwood colorimeter 257 at 660 wavelength or nanometre. The reading was recorded for the calculation of phosphorus. This is expressed in equation *v*.

$$\mathrm{P} = \frac{\text{Absorbance of sample x conversion factor (0.61) x dilution factor}}{\text{Atomic weight of phosphorus}} \ldots\ldots\ldots (v)$$

The value obtained was recorded as the concentration of phosphorus in mg/L

3.5.13 Sulphate (Colourimetry)

One hundred (100) ml of surface water sample was taken; this was followed by addition of 1g of $BaCl_2$ and methylthymol blue at pH 2.3 - 3.0 producing barium sulphate and then vortexes for one minute. The pH was raised to 12.5 - 13.0 and the excess barium ions in solution complex with the methylthymol blue to produce blue colour, leaving a grey uncomplexed methylthymol blue in solution. The absorbance of the excess methylthymol blue, equivalent to the concentration of sulphate removed, was read calorimetrically (Sherwood colorimeter 257) at 460 nm using distilled water as blank. The concentration of sulphate was obtained from a calibration curve (Appendix I).

3.5.14 Chloride

One hundred (100) ml of surface water sample was taken in 300ml conical flask and then 2-3 drops of indicator (potassium chromate) was added. The content was swirled for few minutes and then titrated against silver nitrate solution until reddish precipitate was obtained. The obtained value was used to calculate the concentration of chloride as expressed in equation *vi*.

$$\text{Chloride}(mg/L) = \text{ Volume of AgNO}_3 \text{ x } 10 \ldots\ldots\ldots\ldots.(vi)$$

3.6 Determination of Surface Water Trace and Alkali-alkaline Earth Metals

The method described by APHA (2005) and Udo *et al.* (2009) was used in determination of some trace metals (viz; cadmium, chromium, copper, iron, nickel, lead and zinc) and alkali-alkaline earth metals (viz; potassium, magnesium and sodium) from surface water samples which was filtered in the field through a 0.45 μm membrane filter and preserved in a polyethylene bottle at 4^oC. Double acid digestion (HCl 0.1M and Conc. HNO_3) was used to breakdown organic matter and minerals.

The aliquot was used for determination of trace and alkali-alkaline earth metals using Shimadzu AA6800 Atomic Absorbtion Spectrophotometre (AAS).

3.6.1 Calcium (EDTA titration)

Fifty (50) ml of surface water sample was taken; this was followed by addition of 1ml of 10% NaOH to produce pH of 13-14, to which 0.2g of murexide indicator was added and then stirred. The solution turned to pink in colour, and then titrated against EDTA (0.01M). The endpoint was purple and the titre value was recorded for calculation of calcium as as expressed in equation *vii*.

$$\mathrm{Calcium}(\mathrm{mg}/L) = \frac{\mathrm{Titre\ value\ x\ 0.01\ x\ 1000}}{\mathrm{ml\ of\ aliquot}} \ldots\ldots\ldots\ldots\ldots.(vii)$$

Where: Aliquot = amount of sample used

3.6.2 Potassium (Atomic Absorption Spectrometry − Direct Aspiration)

The absorption of the sample aliquot was measured spectrometrically at 766.5 nm and compared to identically-prepared standard and blank solutions, using an air-C_2H_2 flame. The method detection limit is 0.02 mg/L.

3.6.3 Magnesium (Atomic Absorption Spectrometry − Direct Aspiration)

The shaken sample aliquot was mixed with a $LaCl_3$ solution and aspirated in an air-acetylene reducing flame. The absorbance was measured spectrometrically at 285.2 nm and compared to identically-prepared standard and blank solutions. The method detection limit is 0.001 mg/L.

3.6.4 Sodium (Atomic Absorption Spectrometry − Emission)

The sample aliquot was mixed with a lanthanum solution, as an internal standard, and the absorbance was measured spectrometrically at 589 nm, using an air-acetylene oxidizing flame. The absorbance produced is proportional to the concentration of sodium in the sample and compared to identically-prepared standard and blank solutions. The method detection limit is 0.01 mg/L

3.6.5 Cadmium (Atomic Absorption Spectrometry − Direct Aspiration)

The sample aliquot was aspirated into the flame and the absorbance was measured spectrometrically at 228.8nm and then compared to identically-prepare standard and blank solutions, using an air-acetylene oxidizing flame. The method detection limit is 0.01 mg/L.

3.6.6 Copper (Atomic Absorption Spectrometry – Direct Aspiration)

The sample aliquot was aspirated and the absorbance was measured spectrometrically at 324.7nm and then compared to identically-prepared standard and blank solutions, using an air-propane oxidizing flame. The method detection limit is 0.01 mg/L.

3.6.7 Chromium (Atomic Absorption Spectrometry – Direct Aspiration)

The sample aliquot was aspirated and the absorbance was measured at a wavelength of 358.0 nm and compared to identically-prepare chromium standard and blank solutions, using C_2H_2-air reducing flame.

3.6.8 Iron (Atomic Absorption Spectrometry – Direct Aspiration)

The sample aliquot was aspirated and the absorbance was measured spectrometrically at 248.3 nm and compared to identically-prepare standard and blank solutions, using an air-acetylene oxidizing flame. The method detection limit is 0.05 mg/L.

3.6.9 Nickel (Inductively Coupled Plasma by Optical Emission Spectrometry)

The sample aliquot was aspirated from an auto sampler. The emission was measured at 231.6nm and compared to identically prepare standard and blank solutions. The method detection limit is 0.002 mg/L.

3.6.10 Lead (Atomic Absorption Spectrometry − Direct Aspiration)

The sample aliquot was aspirated and the absorbance was measured spectrometrically at 283.3 nm and compared to identically-prepare standard and blank solutions, using an air-acetylene oxidizing flame. The method detection limit is 0.05 mg/L.

3.6.11 Zinc (Atomic Absorption Spectrometry − Direct Aspiration)

The sample aliquot was aspirated and the absorbance was measured spectrometrically at 213.8nm and then compared to identically-prepare standard and blank solutions, using an air-propane oxidizing flame. The method detection limit is 0.01 mg/L.

3.7 Determination of Sediment Physico-chemical Parameters

Sediment parameters viz; pH, electrical conductivity, organic carbon, nitrogen and phosphorus were determined using methods described by Udo *et al.,* (2009).

3.7.1 Sediment hydrogen ion concentration (pH)

Twenty (20g) of air-dried sediment was added into 100ml beaker and 20ml of distilled water was added and then mixed with glass rod, after which it was allowed to stand for 30 minutes undisturbed, then portable HANNA Combo pH/EC/Temp. metre/HI 98129 was allowed to equilibrate and the value was recorded as "soil pH measured in water" (pH H_2O).

3.7.2 Sediment electrical conductivity

Ten (10g) of air-dried sediment was added into a 100ml beaker, with 50ml of distilled water and then mixed with glass rod. The sample temperature was brought to 20°C and then portable HANNA Combo pH/EC/Temp. metre/HI 98129 was allowed to equilibrate and then the value was recorded as conductivity in µS/cm.

3.7.3 Organic carbon

Two hundred (200mg) of the air dried and ground sample was weighed into an Erlenmeyer flask. The sample was subsequently suspended in a diluted hydrochloric acid solution, which serves to break down the carbonates present in the sample and, at the same time, form the suspension medium. The suspension was homogenized for several minutes at a speed of 17,000 – 18,000 rpm using a dispersion unit. After homogenization, 90µl suspensions was then repeatedly injected and analysed within sparge-time of five minutes and then the reading was taken, while using magnetic stirrer in the auto-sampler (Shimadzu TOC-5000A Analyser) to ensure that the suspension remains homogeneous during sampling so that small particles will not sediment, but remain uniformly distributed throughout the solution. The possibility of multiple injections enables differentiation of small variations due to weighing and measured by an analyser and compared to identically-prepared inorganic carbon standard and blank. The dissolved organic Carbon is calculated by difference. The method detection limit is 0.5 mg/L.

3.7.4 Sediment nitrogen

Ten (10g) of the air-dried sediment sample was taken in a macro-Khjelder flask, followed by addition of 20ml distilled water and then swirled for few minutes and allowed to stand for 30 minutes, after which 1g of mercury catalyst, 10g K_2SO_4 and 30ml concentrated sulphuric acid were added. The mixture was then digested in the digestion chamber under fume cupboard for five hours. The content was allowed to cool, and then the digest was diluted with100ml distilled water. Distillation was carried out by adding 100ml of the digest into macro-Khjelder flask, and 100ml of 10M NaOH, and then the flask was placed on distillation apparatus. Erlenmeyer flask containing mixed boric acid (H_3BO_3) indicator was placed under the condenser. The sample was heated to distillate and then 100ml of distillate was collected, which was then used to determine the NH_4-N by titration with 0.01M H_2SO_4 until the mixture turned from green to pink. The titre value was recorded and used for calculation of the percentage nitrogen as expressed by equation *viii*.

$$\text{Nitrogen} = \frac{\text{T x M x 14 x 100}}{\text{Weight of sediment}} \ldots\ldots\ldots\ldots\ldots\ldots (viii)$$

Where; T = Titre value and
M = Molarity of H_2SO_4

3.7.5 Sediment phosphorus

Two (2g) of sediment was transferred into a 100ml conical flask with 7ml of phosphorus extraction solution vortexes for 30 minutes using mechanical shaker. The mixture was filtered and the filtrate was collected. Then 2ml of the filtrate was pipetted into 50ml volumetric flask, followed by addition of 2ml of ammonium molybdate, 1ml of fresh diluted stannous chloride and then distilled water was used to make the flask volume to 50ml capacity. The colour intensity was measured using spectrophotometer at 660nm; the value obtained was used for calculation of the concentration of phosphorus as expressed in equation *ix*.

$$\text{Phosphorus} = \frac{\text{Reading x conversion factor (0.61) x dilution factor (25)}}{\text{Atomic weight of phosphorus}} \ldots (ix)$$

3.8 Determination of Sediment Trace and Alkali-alkaline Earth Metals

The method described by APHA (2005) and Udo *et al.* (2009) was used in determination of some trace metals (viz; cadmium, chromium, copper, iron, nickel, lead and zinc) and alkali-alkaline earth metals (viz; calcium, magnesium, potassium, sodium) from sediment samples. This involved the use of hydrochloric acid (HCl) 0.1M digestion to breakdown organic matter and minerals for analysis using Shimadzu AA6800 AAS.

3.8.1 Sediment digestion and analysis

Air-dried sediment sample (5g) was taken in a 100ml beaker, 50ml of 0.1M HCl was added, homogenized with mechanical shaker for 30 minutes and the mixture heated to almost dryness on a hot plate and then filtered through a Whatman No. 42 filter paper. The filtrate was used for the determination of the trace and alkali-alkaline earth metals of interest.

3.8.2 Assessment of sediment contamination status

The contamination status of the Reservoir sediment was assessed by determining the contamination factors (C_f) or enrichment ratio (E_R), degree of contamination (C_d) and Numerical sediment quality guidelines (SQGs)

3.8.2.1 *Contamination Factor (C_f)*

The contamination factors (C_f) or enrichment ratio (E_R) and the degree of contamination (C_d) were used to determine the trace metals contamination status of sediment in the present study. Hakanson's classification for the contamination factor (Appendix II) was used for the assessment of contamination level. The degree of contamination (C_d) was defined as the sum of all contamination factors. The degree to which sediment is contaminated is often expressed as contamination factor, thus;

$$C_f = \frac{C_{metal}}{C_{background\ value}} \ldots \ldots \ldots \ldots \ldots \ldots (x)$$

Where; C_{metal} = Measured metal concentration
$C_{background\ value}$ = Average background concentration of the metal

The geochemical background concentrations of the metals under investigation (Cd = 0.2; Cr = 63.8; Cu = 32; Ni = 25.4; Pb = 20 and Zn = 129) earlier reported were used as background concentrations (Martin and Meybeck, 1979; Xu *et al.*, 2013).

3.8.2.2 *Numerical sediment quality guidelines (SQGs)*

SQGs values for metals assessments of sediment quality in this study include;

Consensus-Based Sediment Quality Guidelines for Freshwater Ecosystems:

CBSQG defined the threshold effect concentration (TEC) and a probable effect concentration (PEC) for the sediment metals (Table 5) (MacDonald, *et al.*, 2000); if the trace metals in sediments are below the TEC, harmful effects are unlikely to be observed. If the metals are above the PEC, harmful effects are likely to be observed. Similarly Müller (1979) noted in his studies that most of the TEC provide an accurate basis for predicting the absence of sediment toxicity, and most of the PECs, provide an accurate basis for predicting sediment toxicity.

United State Environmental Protection Agency Guidelines (USEPA) for Metals:

USEPA guideline for sediments was used to assess the level of metals contamination in the sediments by comparing the values obtained with guideline values (Appendix III).

3.9 Biological Monitoring Methods

Plankton collection, preservation and analysis were done in accordance with the methods described by Biggs and Kilroy (2000); Charles *et al*. (2002); Potapova and Charles (2005) and Taylor *et al*. (2007).

3.9.1 Plankton identification and counting

The preserved plankton samples were taken to Hydrobiology Laboratory, of Biology Department, Ahmadu Bello University, Zaria. Each sample was then concentrated by allowing them to settle and decanted to increase the plankton view chance, and then 1ml of concentrated sample was transferred into a Sedgwick Rafter counting chamber. The counting cell was filled with the plankton sample and placed on the mechanical stage of the microscope and viewed consecutively at x100 magnification. Plankton observed were identified by comparing with the plankton chart by Jeje and Fernando (1986) and Botes (2003). Images of some phytoplankton and zooplankton species identified were captured digitally for reference purpose (Potapova and Charles, 2005).

Thereafter, the counting cell was left for about half-an-hour for proper sedimentation. The organisms were then counted from one corner of the counting cell to the other. The Sedgwick Rafter was moved horizontally along the first row of squares and the organisms in each square of the row were thus counted. The rafter was then moved to the second row and organisms in each square were counted. The total number of cells was then computed by multiplying the number of individuals counted in transects with the ratio of the whole chamber area to the area of the counted transects. Replication of counts of 1ml sample was done for statistical treatments. The average values were taken into account for calculation. The total number of plankton (phytoplankton and zooplankton) present in a litre of water sample was then calculated using the formula (Goswami, 2004):

$$\mathrm{N} = \frac{\mathrm{n \ x \ v \ x1000}}{\mathrm{V}} \ldots\ldots\ldots\ldots\ldots (xi)$$

Where; N = Total number of plankton cells per litre of water filtered

n = Average number of plankton cells in 1 ml of plankton sample

v = Volume of plankton concentrate (ml)

V = Volume of total water filtered (L)

$$V = \pi r^2 D \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (xii)$$

Where; r = Radius of the mouth of the net

D = Length of the water column traversed by the net.

3.10 Fisheries Potentials

Morpho edaphic index (MEI) was used as described by Ryder (1965) to determine the fisheries potentials of the reservoir. MEI is therefore expressed as follows:

$$\text{Morphoedaphic index (MEI)} = \frac{N}{\acute{z}} \ldots\ldots\ldots\ldots (xiii)$$

Where; N = Nutrient value (total dissolved solids) or close correlate

$\acute{z}$ = Mean depth or an appropriate morphometric surrogate

3.11 Data Analysis

IBM SPSS Statistics software version 22 was used for the;

a. Two-way analysis of variance (ANOVA) to analyse the physico-chemical parameters results for significant difference ($p<0.05$) between the means. Where there were significant differences Duncan Multiple Range Test (DMRT) was used to separate the means.
b. Student t-test to determine the significant differences between the mean seasonal and annual variations of the various physico-chemical parameters.
c. Pearson correlation coefficient to determine the relationship between the different parameters and biota.

Palaeontological Statistics (PAST) software, version2.17c (Hammer, 2013) was used for;

a. Community structure analysis between months, which include various diversity indices (Margalef, Fisher_alpha, Simpson_1-D, Evenness_e^H/S, Equitability_J, Brillouin, Shannon_H, Dominance and Berger-Parker).
b. Correlation by Principal Components Analysis (PCA biplot) to determine the relationship between the plankton species and water physico-chemical parameters.
c. Canonical Correspondence Analysis (CCA triplot) to determine the relationship between plankton community structures and the environmental variables as well as sampling months.
d. Cluster Analysis based on Jaccard similarity measure to group correlated plankton

Microsoft office excel, 2012 was used for the computation of;

  a. Percentage composition of the plankton species
  b. The construction of graphs/charts.

CHAPTER FOUR

4.0 RESULTS

The results of this research which was carried out in two seasons (rainy and dry) over a period of twenty four (24) months revealed a wide range of variation for both physico-chemical parameters of surface water, sediment and the biota of Yardantsi Reservoir, Gusau. The analyses of the results were based on information derived from the graphs/charts, two-way analysis of variance (ANOVA), the Pearson rank correlation based on two tailed tests, principal component analysis and other known limnological principles.

4.1 Surface Water Physico-Chemical Parameters

Studies on some physico-chemical parameters were carried out on surface water for five (5) different stations of Yardantsi Reservoir, Gusau so as to establish their concentrations. Fourteen physico-chemical parameters viz; temperature, transparency, mean depth, pH, total dissolved solids, electrical conductivity, dissolved oxygen, biological oxygen demand, alkalinity, hardness, nitrate-nitrogen, phosphate-phosphorus, sulphate and chloride were monitored. The mean annual and seasonal variation of the parameters for the period of this study is presented in Table 4.1.

4.1.1 Surface water temperature

The mean monthly variations in surface water temperature for all stations are presented in Fig. 4.1a. The highest and the lowest monthly mean surface water temperatures were recorded in October (32.41°C) and January (22.55°C) respectively and were found to have a significant difference at $p<0.05$ (Appendix IV).

Table 4.1: Mean (±SE) Annual and Seasonal Variation of Different Surface Water Physico-Chemical Parameters of Yardantsi Reservoir, Gusau

	Years			**Seasons**					
Metals	**2015**	**2016**	**P-value**	**Dry Season**	**Rainy Season**	**P-value**	**NSDWQ**	**WHO**	**FAO**
Temperature (°C)	28.38±0.35	28.21±0.35	0.332	26.62±0.34	30.12±0.17	0.000			
Transparency (cm)	35.05±0.20	36.07±2.06	0.382	48.82±1.08	22.07±0.87	0.000			
Depth (m)	2.25±0.04	2.49±0.06	0.000	2.12±0.05	2.65±0.04	0.000			
pH	7.97±1.03	7.61±0.15	0.082	7.61±0.15	7.96±0.13	0.091	6.5-8.5		
TDS (mg/L)	69.14±3.91	90.54±2.80	0.000	96.00±1.95	63.70±3.68	0.000	500		
EC (µS/cm)	126.466.64	166.36±6.34	0.000	186.32±3.84	108.05±5.43	0.000	1000		
DO (mg/L)	7.29±0.12	7.45±0.11	0.150	7.80±0.11	6.91±0.10	0.000			
BOD (mg/L)	2.57±0.08	2.62±0.07	0.443	2.71±0.09	2.48±0.05	0.017			
Alkalinity (mg/L)	34.23±1.00	34.48±1.07	0.714	40.57±0.69	27.87±0.51	0.000			
Hardness (mg/L)	45.48±1.98	46.32±2.09	0.301	59.20±1.01	32.18±0.94	0.000	150		
NO$_3$-N (mg/L)	3.40±0.15	3.31±0.17	0.224	2.28±0.08	4.44±0.07	0.000	50	50	
PO$_4$-P (mg/L)	148.66±3.69	148.72±4.26	0.974	123.72±1.44	173.48±2.78	0.000			
Sulphate (mg/L)	51.07±3.06	51.86±3.20	0.449	31.62±1.45	71.80±1.82	0.000	100		
Chloride (mg/L)	55.03±2.71	57.43±2.79	0.032	74.08±1.67	37.64±0.96	0.000	250		

Note: NSDWQ =Nigerian Standard for Drinking Water Quality 2007; WHO= World Health Organization 2017 and FAOUN= Federation of Agricultural Organization UN (ICPR, 1994)

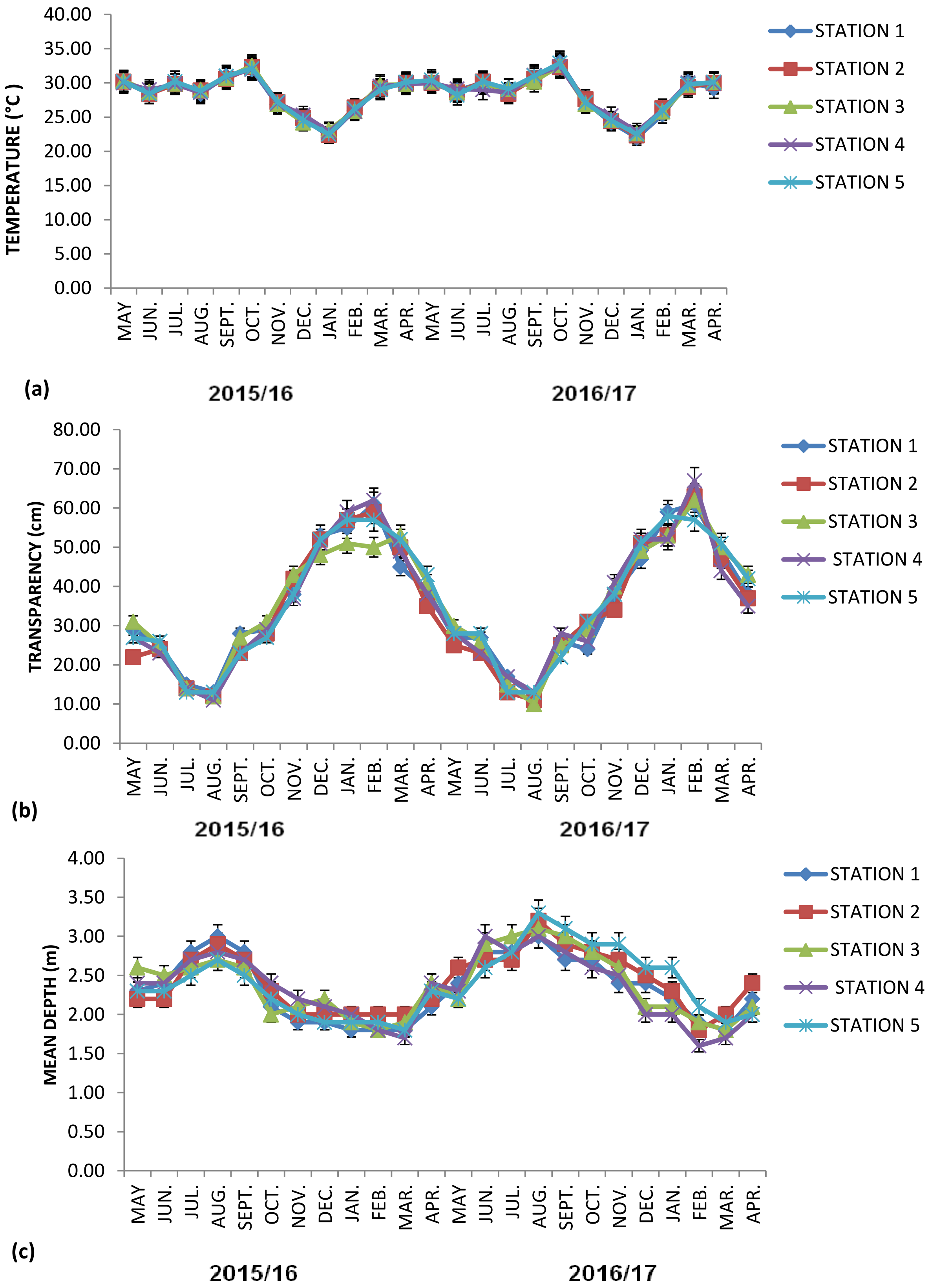

Figure 4.1: Mean Monthly Variation in Surface Water (a) Temperature (b) Transparency and (c) Mean Depth of Different Sampling Stations of Yardantsi Reservoir, Gusau

Analysis of variance (Appendix Va,b,c and d) showed no significant variation existed between years and stations ($p>0.05$) but significant variation existed between seasons and months ($p<0.05$).

Correlation coefficient analysis for all parameters over all stations (Appendix VI) revealed a highly positive significant correlation between surface water temperature and mean depth, Nitrate-nitrogen, phosphate-phosphorus and Sulphate ($p<0.01$). A highly significant negative correlation existed between surface water temperature and transparency, electrical conductivity, dissolved oxygen, biological oxygen demand, alkalinity, hardness and chloride. Also a significant negative correlation existed between surface water temperature and total dissolved solids ($p<0.05$).

4.1.2 Secchi depth (transparency)

The mean monthly variations in transparency for all stations are presented in Fig. 4.1b. The highest and the lowest monthly mean transparency were recorded in February (59.90cm) and August (12.00cm) respectively and were found to have a significant difference at $p<0.05$ (Appendix IV).

Analysis of variance (Appendix Va,b,c and d) showed no significant variation existed between years, seasons, months and stations ($p>0.05$).

Correlation coefficient analysis for all parameters over all stations (Appendix VI) revealed a highly positive significant correlation between transparency and total dissolved solids, electrical conductivity, dissolved oxygen, biological oxygen demand, alkalinity, hardness and chloride ($p<0.01$). A highly significant negative correlation existed between transparency and temperature, mean depth, nitrate-nitrogen, phosphate-phosphorus, sulphate and phytoplankton ($p<0.01$).

4.1.3 Mean depth

The mean monthly variations in mean depth for all stations are presented in Fig. 4.1c. The highest and the lowest monthly mean depth were recorded in August (2.97m) and February (1.86m) respectively and were found to have significant difference($p<0.05$) (Appendix IV).

Analysis of variance (Appendix Va,b,cand d) showed no significant variation existed between years, months and stations ($p>0.05$) but significant variation existed between seasons ($p<0.05$).

Correlation coefficient analysis for all parameters over all stations (Appendix VI) revealed a highly positive significant correlation between mean depth and temperature, nitrate-nitrogen, phosphate-phosphorus, sulphate and phytoplankton ($p<0.01$). A highly significant negative correlation existed between mean depth and transparency, total dissolved solids, electrical conductivity, dissolved oxygen, alkalinity, hardness and chloride ($p<0.01$).

4.1.4 Hydrogen ion concentration (pH)

The mean monthly variations in hydrogen ion concentration for all stations are presented in Fig. 4.2a. The highest and the lowest monthly pH were recorded in August (9.57) and March (6.84) respectively and were found to have a significant difference at $p<0.05$ (Appendix IV).

Analysis of variance (Appendix Va,b,c and d) showed no significant variation existed between years, seasons, months and stations ($p>0.05$).

Correlation coefficient analysis for all parameters over all stations (Appendix VI) revealed a positive significant correlation between hydrogen ion concentration and nitrate-nitrogen and sulphate ($p<0.05$). A significant negative correlation existed between hydrogen ion concentration and alkalinity and chloride ($p<0.05$).

4.1.5 Total dissolved solids

The mean monthly variations in total dissolved solids for all stations are presented in Fig. 4.2b. The highest and the lowest monthly total dissolved solids were recorded in April (109.30ppm) and July (41.16 ppm) respectively and were found to have a significant difference at $p<0.05$ (Appendix IV).

Analysis of variance (Appendix Va,b,c and d) showed that significant variation existed between years and months ($p<0.05$), and a highly significant variation existed between seasons ($p<0.01$), but no significant variation existed between stations ($p>0.05$).

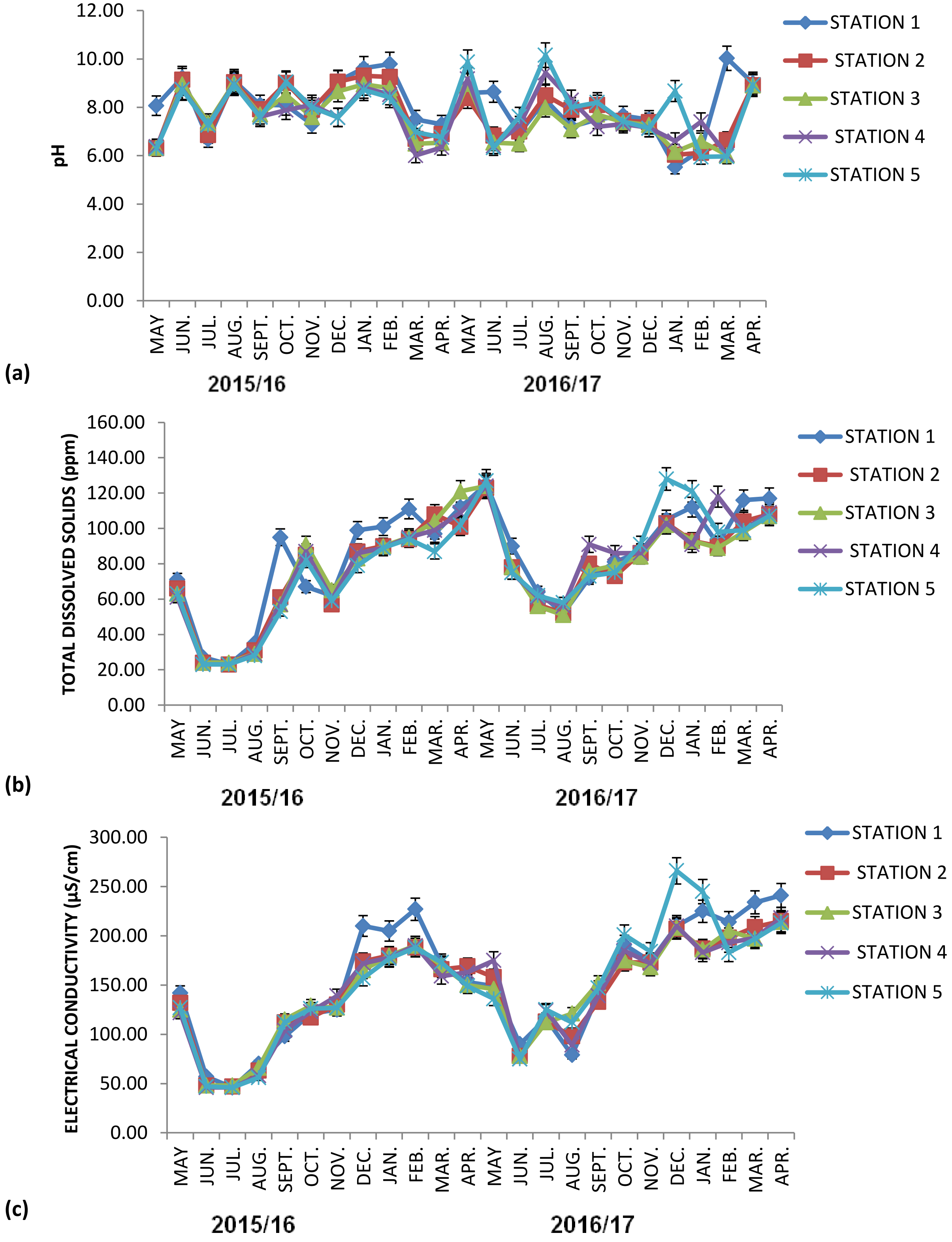

Figure 4.2: Mean Monthly Variation in Surface Water (a) pH (b) Total Dissolved Solids and (c) Electrical Conductivity of Different Sampling Stations of Yardantsi Reservoir, Gusau.

Correlation coefficient analysis for all parameters over all stations (Appendix VI) revealed a highly positive significant correlation between total dissolved solids and transparency, electrical conductivity, alkalinity, hardness and chloride ($p<0.01$). A significant positive correlation existed with dissolved oxygen ($p<0.05$). A highly significant negative correlation existed with mean depth, nitrate-nitrogen, phosphate-phosphorus, sulphate and phytoplankton ($p<0.01$), while significant negative correlation existed with temperature ($p<0.05$).

4.1.6 Electrical conductivity

The mean monthly variations in electrical conductivity for all stations are presented in Fig. 4.2c. The highest and the lowest monthly electrical conductivity were recorded in December (197.90µS/cm) and June (64.20µS/cm) respectively and were found to have a significant difference at $p<0.05$ (Appendix IV).

Analysis of variance (Appendix Va,b,c and d) showed that a highly significant variation existed between years ($p<0.01$), and a significant variation existed between seasons and months ($p<0.05$), but no significant variation existed between stations ($p>0.05$).

Correlation coefficient analysis for all parameters over all stations (Appendix VI) revealed a highly positive significant correlation between electrical conductivity and transparency, total dissolved solids, dissolved oxygen, alkalinity, hardness and chloride ($p<0.01$). A highly significant negative correlation existed with temperature, mean depth, nitrate-nitrogen, phosphate-phosphorus, sulphate and phytoplankton ($p<0.01$), while significant negative correlation existed with zooplankton ($p<0.05$).

4.1.7 Dissolved oxygen

The mean monthly variations in dissolved oxygen for all stations are presented in Fig. 4.3a. The highest and the lowest monthly dissolved oxygen were recorded in January (8.86 mg/L) and October (5.97 mg/L) respectively and were found to have a significant difference at $p<0.05$ (Appendix IV).

Analysis of variance (Appendix Va,b,c and d) showed that no significant variation existed between years, months and stations ($p>0.05$) but a significant variation existed between seasons ($p<0.05$).

Correlation coefficient analysis for all parameters over all stations (Appendix VI) revealed a highly negative significant correlation between dissolved oxygen and temperature, mean depth, nitrate-nitrogen, phosphate-phosphorus, sulphate and phytoplankton ($p<0.01$). A highly significant positive correlation existed with transparency, electrical conductivity, biological oxygen demand, alkalinity, hardness and chloride ($p<0.01$), while a significant positive correlation existed with total dissolved solids and zooplankton ($p<0.05$).

4.1.8 Biological oxygen demand

The mean monthly variations in biological oxygen demand for all stations are presented on Fig. 4.3b. The highest and the lowest monthly biological oxygen demand were recorded in January (3.58 mg/L) and October (1.79 mg/L) respectively and were found to have a significant difference at $p<0.05$ (Appendix IV).

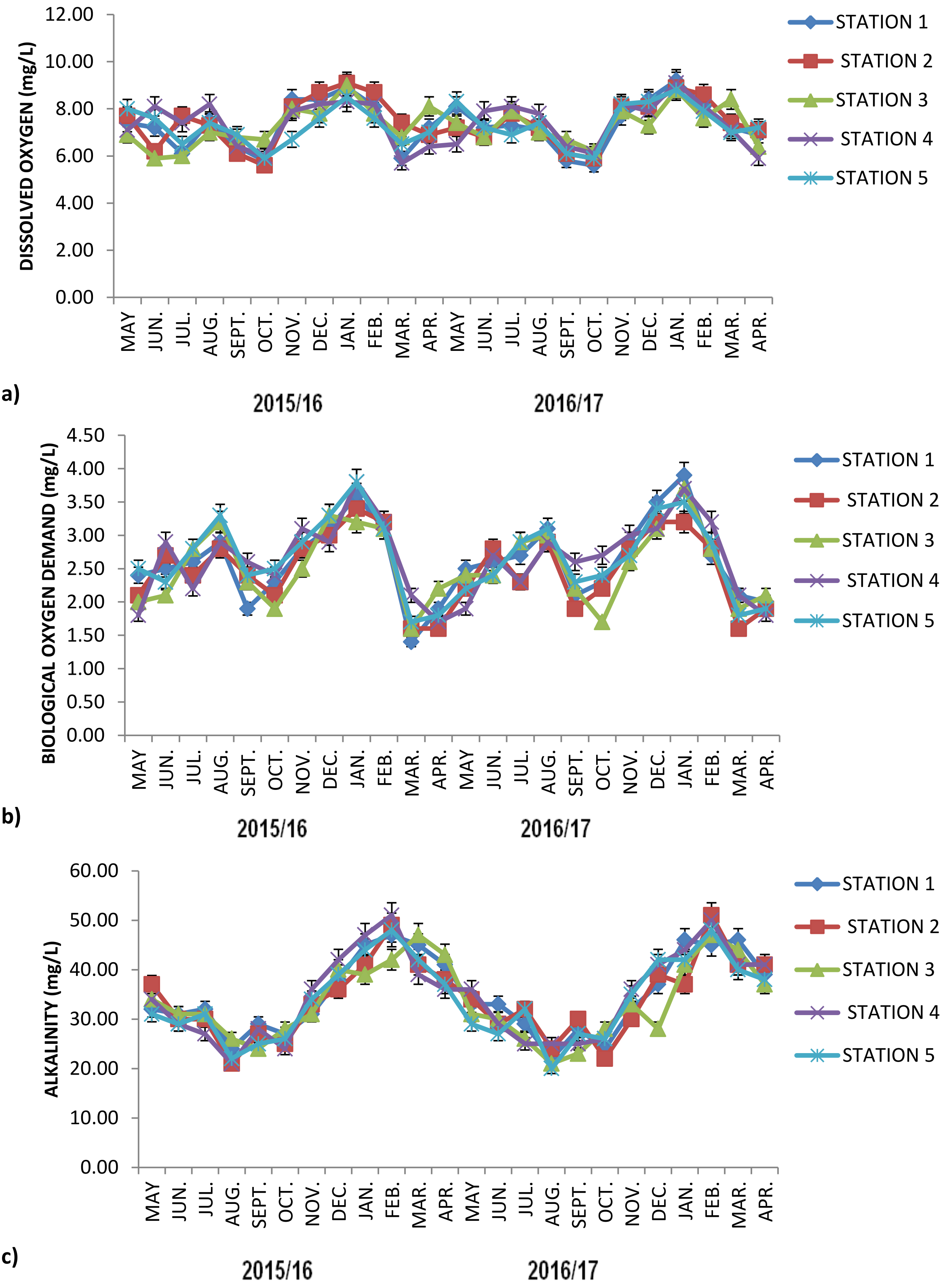

Figure 4.3: Mean Monthly Variation in Surface Water (a) Dissolved Oxygen (b) Biological Oxygen Demand and (c) Alkalinity of Different Sampling Stations of Yardantsi Reservoir, Gusau

Analysis of variance (Appendix Va,b,cand d) showed that no significant variation existed between years, seasons, months and stations ($p>0.05$).

Correlation coefficient analysis for all parameters over all stations (Appendix VI) revealed a highly negative significant correlation between biological oxygen demand and temperature, and phytoplankton ($p<0.01$). A highly significant positive correlation existed with transparency and dissolved oxygen ($p<0.01$), while a significant positive correlation existed with chloride ($p<0.05$).

4.1.9 Alkalinity

The mean monthly variations in alkalinity for all stations are presented in Fig. 4.3c. The highest and the lowest monthly alkalinity were recorded in February (47.8 mg/L) and July (22.60 mg/L) respectively and were found to have a significant difference at $p<0.05$ (Appendix IV).

Analysis of variance (Appendix Va,b,c and d) showed that no significant variation existed between years, seasons, months and stations ($p>0.05$).

Correlation coefficient analysis for all parameters over all stations (Appendix VI) revealed a highly negative significant correlation between alkalinity and temperature, mean depth, nitrate-nitrogen, phosphate-phosphorus, sulphate and phytoplankton ($p<0.01$), but a significant negative correlation existed with pH ($p<0.05$). A highly significant positive correlation existed with transparency, total dissolved solids, electrical conductivity, dissolved oxygen, hardness and chloride ($p<0.01$) while a significant positive correlation existed with total zooplankton ($p<0.05$).

4.1.10 Hardness

The mean monthly variations in hardness for all stations are presented in Fig. 4.4a. The highest and the lowest monthly hardness concentrations were recorded in March (67.50 mg/L) and August (23.10 mg/L) respectively and were found to have a significant difference at $p<0.05$ (Appendix IV).

Analysis of variance (Appendix Va,b,c and d) showed that no significant variation existed between years, seasons and stations ($p>0.05$) but significant variation existed between months ($p<0.05$).

Correlation coefficient analysis for all parameters over all stations (Appendix VI) revealed a highly positive significant correlation between hardness and transparency, total dissolved solids, electrical conductivity, dissolved oxygen, alkalinity and chloride ($p<0.01$).A highly significant negative correlation existed with temperature, mean depth, nitrate-nitrogen, phosphate-phosphorus, sulphate and phytoplankton ($p<0.01$).

4.1.11 Nitrate-nitrogen

The mean monthly variations in nitrate-nitrogen for all stations are presented in Fig. 4.4b. The highest and the lowest monthly nitrate-nitrogen concentrations were recorded in August (5.19 mg/L) and February (1.64mg/L) respectively and were found to have a significant difference at $p<0.05$ (Appendix IV). Analysis of variance (Appendix Va,b,c and d) showed that no significant variation existed between years, seasons, months and stations ($p>0.05$).

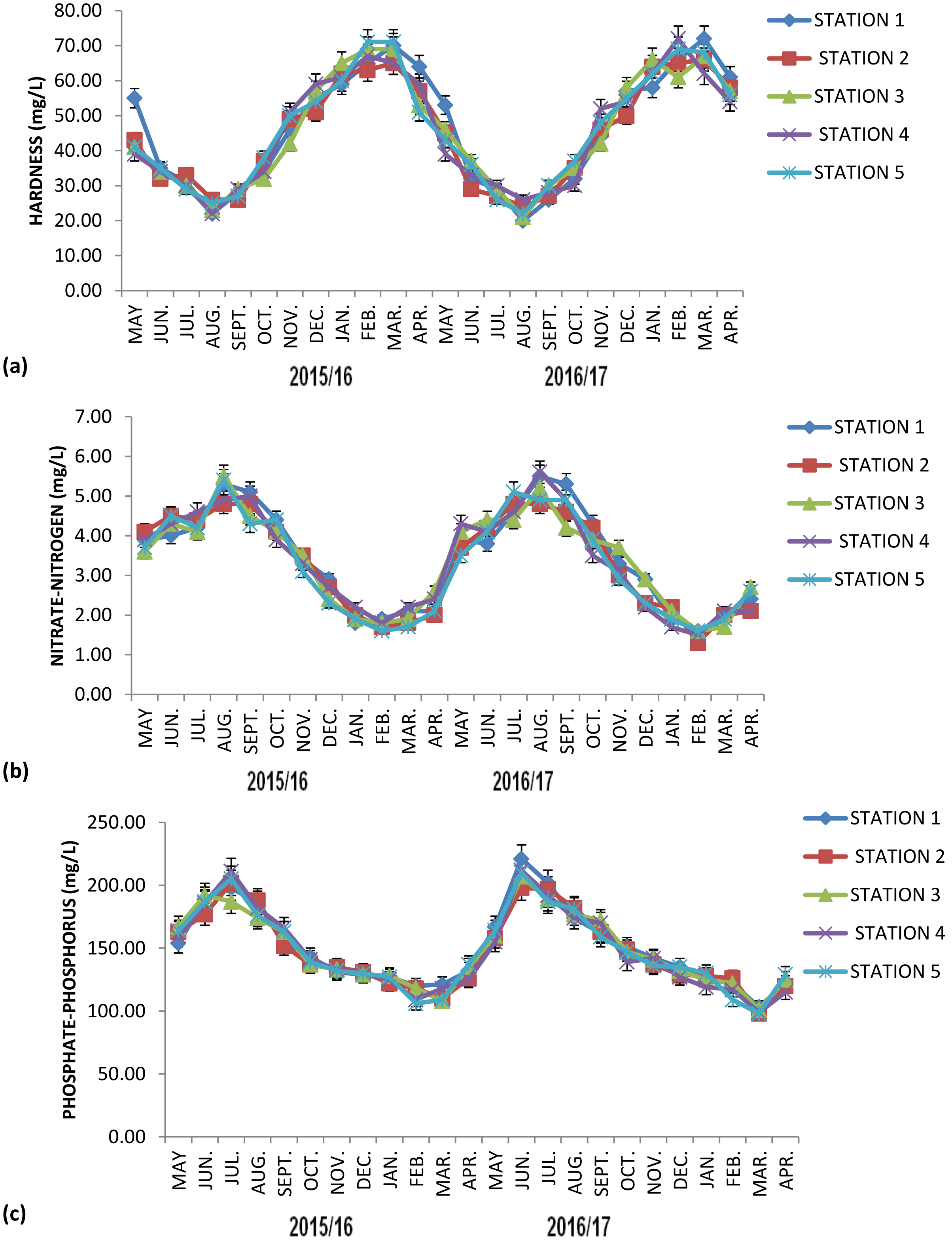

Figure 4.4: Mean Monthly Variation in Surface Water (a) Hardness (b) Nitrate-nitrogen and (c) Phosphate-phosphorus of Different Sampling Stations of Yardantsi Reservoir, Gusau

Correlation coefficient analysis for all parameters over all stations (Appendix VI) revealed a highly positive significant correlation between nitrate-nitrogen and temperature, mean depth, phosphate-phosphorus, sulphate and phytoplankton ($p<0.01$), while a positive significant correlation existed with hydrogen ion concentration ($p<0.05$). A highly significant negative correlation existed with transparency, total dissolved solids, electrical conductivity, dissolved oxygen, alkalinity, hardness and chloride ($p<0.01$).

4.1.12 Phosphate-phosphorus

The mean monthly variations in phosphate-phosphorus for all stations are presented in Fig. 4.4c. The highest and the lowest monthly phosphate-phosphorus concentrations were recorded in June (197.90mg/L) and March (106.50 mg/L) respectively and were found to have a significant difference at $p<0.05$ (Appendix IV).

Analysis of variance (Appendix Va,b,c and d) showed that no significant variation existed between years, and stations ($p>0.05$), but significant variation existed between seasons and months ($p<0.05$).

Correlation coefficient analysis for all parameters over all stations (Appendix VI) revealed a highly positive significant correlation between phosphate-phosphorus and temperature, mean depth, nitrate-nitrogen, sulphate phytoplankton and zooplankton ($p<0.01$). A highly significant negative correlation existed with transparency, total dissolved solids, electrical conductivity, alkalinity, hardness and chloride ($p<0.01$), while a significant negative correlation existed with dissolved oxygen ($p<0.05$).

4.1.13 Sulphate

The mean monthly variations in sulphate for all stations are presented in Fig. 4.5a. The highest and the lowest monthly sulphate concentrations were recorded in August (89.00 mg/L) and March (18.10 mg/L) respectively and were found to have a significant difference at $p<0.05$ (Appendix IV).

Analysis of variance (Appendix Va,b,c and d) showed that no significant variation existed between years, and stations ($p>0.05$), but significant variation existed between seasons ($p<0.05$). A highly significant variation existed between months ($p<0.01$).

Correlation coefficient analysis for all parameters over all stations (Appendix VI) revealed a highly positive significant correlation between sulphate and temperature, mean depth, nitrate-nitrogen, phosphate-phosphorus and phytoplankton ($p<0.01$), but a positive significant correlation existed with hydrogen ion concentration ($p<0.05$). A highly significant negative correlation existed with transparency, total dissolved solids, electrical conductivity, dissolved oxygen, alkalinity, hardness and chloride ($p<0.01$).

4.1.14 Chloride

The mean monthly variations in chloride for all stations are presented in Fig. 4.5b. The highest and the lowest monthly chloride concentrations were recorded in February (89.90 mg/L) and August (29.45 mg/L) respectively and were found to have a significant difference at 0.05 level (Appendix IV).

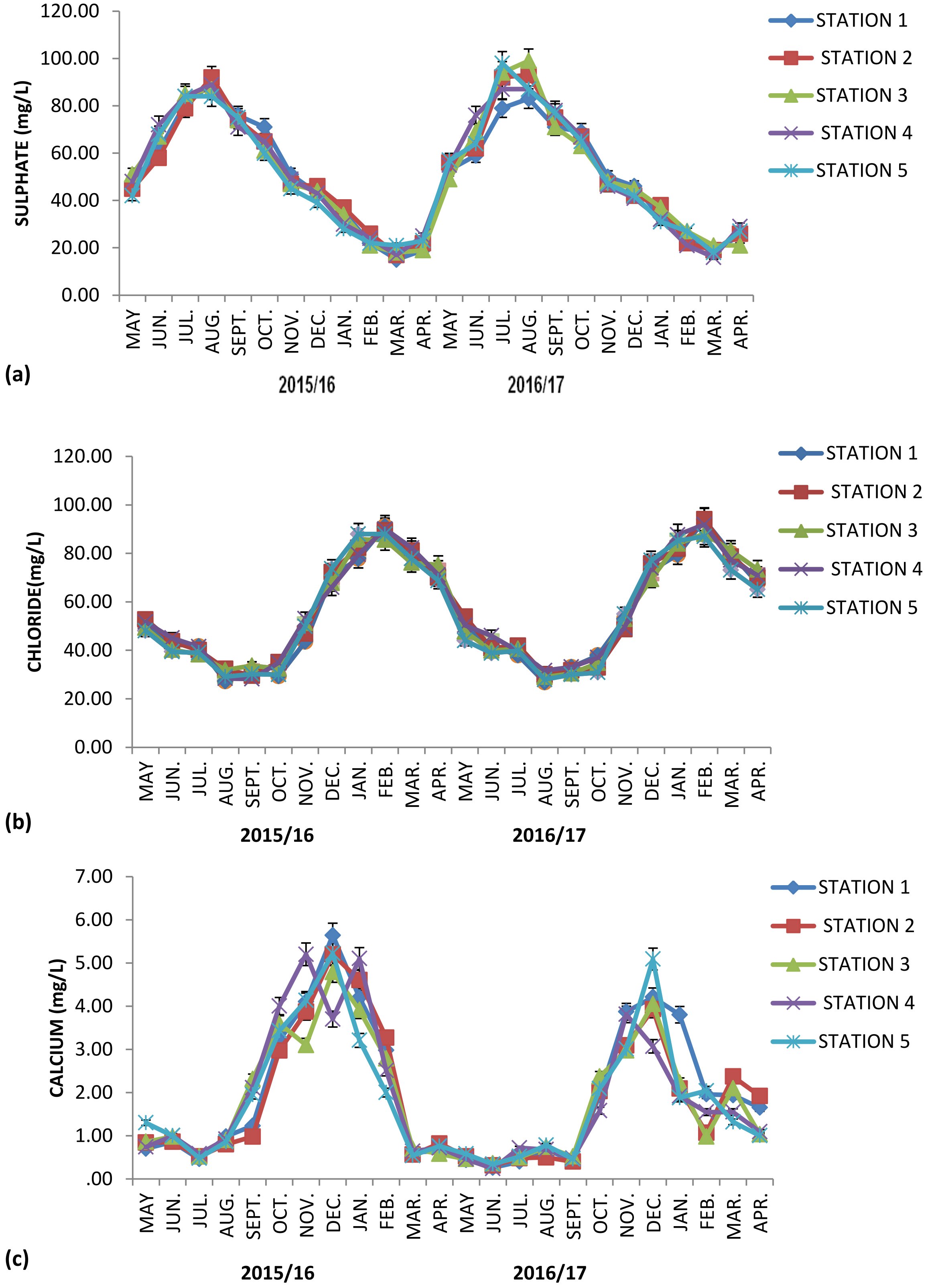

Figure 4.5: Mean Monthly Variation in Surface Water (a) Sulphate (b) Chloride and (c) Calcium of Different Sampling Stations of Yardantsi Reservoir, Gusau

Correlation coefficient analysis for all parameters of all stations (Appendix VI) revealed a highly positive significant correlation between chloride and transparency, total dissolved solids, electrical conductivity, dissolved oxygen, alkalinity and hardness ($p<0.01$), but a positive significant correlation with biological oxygen demand and zooplankton ($p<0.05$). A highly significant negative correlation existed with temperature, mean depth, nitrate-nitrogen, phosphate-phosphorus, sulphate and phytoplankton ($p<0.01$), while a significant negative correlation existed with hydrogen ion concentration ($p<0.05$).

Analysis of variance (Appendix Va,b,c and d) showed that no significant variation existed between years, months and stations ($p>0.05$), but significant variation existed between seasons ($p<0.05$).

4.2 Surface Water Trace and Alkali-alkaline Earth Metals Concentrations

Studies on alkali-alkaline earth metals (viz; calcium, magnesium, potassium, sodium) and some trace metals (viz; chromium, nickel, cadmium, zinc, iron, copper and lead) concentrations were carried out on surface water for five (5) different stations of Yardantsi Reservoir, Gusau so as to establish their concentrations. The mean annual and seasonal variations of the surface water metals (mg/L) for the period of study are presented in Table 4.2.

Table 4.2: Mean (±SE) Annual and Seasonal Variation in Surface Water Metals Concentrations of Yardantsi Reservoir, Gusau

	Years			**Seasons**					
Metals (mg/L)	**2015**	**2016**	**P-value**	**Dry Season**	**Rainy Season**	**P-value**	**NSDWQ**	**WHO**	**FAO**
Ca	2.87±0.33	1.40±0.19	0.001	2.65±0.19	1.07±0.12	0.990			
K	3.06±0.20	3.17±0.20	0.542	3.06±0.13	3.20±0.14	0.000			
Mg	2.33±0.09	0.53±0.06	0.000	2.37±0.06	0.51±0.04	0.000	0.20		
Na	72.70±1.90	41.83±1.69	0.000	72.39±1.48	41.26±1.16	0.003	200		
Cd	0.08±0.01	0.16±0.03	0.000	0.08±0.01	0.13±0.01	0.000	0.003	0.003	0.01
Cu	1.03±0.05	1.47±0.07	0.000	0.92±0.04	1.29±0.05	0.000	1	2	0.2
Cr	0.12±0.01	0.27±0.01	0.000	0.11±0.01	0.19±0.01	0.000	0.05	0.05	0.1
Fe	1.69±0.13	3.13±0.14	0.000	1.58±0.08	3.13±0.44	0.029	0.3		
Ni	0.10±0.01	0.22±0.01	0.000	0.09±0.01	0.14±0.01	0.000	0.02	0.07	0.2
Pb	0.03±0.00	0.06±0.01	0.000	0.02±0.00	0.05±0.00	0.000	0.01		
Zn	0.90±0.05	1.84±0.07	0.000	0.89±0.04	1.40±0.07	0.884	3		2

Note: NSDWQ =Nigerian Standard for Drinking Water Quality 2007; WHO= World Health Organization 2017 and FAOUN= Food and Agricultural Organization UN (ICPR, 1994)

4.2.1 Calcium

The mean monthly variations in calcium concentration for all stations are presented in Fig. 4.5c. The highest and the lowest monthly calcium concentrations were recorded in December (4.49 mg/L) and July (0.52mg/L) respectively and were found to have a significant difference at $p<0.05$ (Appendix VII).

Analysis of variance (Appendix VIIIa,b,c,d,e,f,g, and h) showed that highly significant variation existed between years and seasons ($p<0.01$), but significant variation existed between months, year by months, year by station, month by station and year by month by station ($p<0.05$). No significant variation existed between stations ($p>0.05$).

Correlation coefficient analysis for all parameters over all stations (Appendix IX) revealed a highly positive significant correlation between calcium and magnesium and sodium ($p<0.01$). A highly significant negative correlation existed with potassium, cadmium, copper, chromium, iron, lead, zinc, phytoplankton and zooplankton ($p<0.01$).

4.2.2 Potassium

The mean monthly variations in potassium concentration for all stations are presented in Fig. 4.6a. The highest and the lowest monthly potassium concentrations were recorded in March (4.46 mg/L) and September (1.84 mg/L) respectively and were found to have a significant difference at $p<0.05$ (Appendix VII).

Analysis of variance (Appendix VIIIa,b,c,d,e,f,g, and h) showed that no significant variation existed between years, seasons, months, stations, year by months, year by station, month by station and year by month by station ($p>0.05$).

Correlation coefficient analysis for all parameters over all stations (Appendix IX) revealed a highly positive significant correlation existed between potassium and cadmium, copper, iron, lead, phytoplankton and zooplankton ($p<0.01$), but a positive significant correlation existed with chromium and zinc ($p<0.05$). A highly significant negative correlation existed with calcium ($p<0.01$).

4.2.3 Magnesium

The mean monthly variations in magnesium concentration for all stations are presented in Fig. 4.6b. The highest and the lowest monthly magnesium concentrations were recorded in February (2.83 mg/L) and August (0.19 mg/L) respectively and were found to have a significant difference at $p<0.05$ (Appendix VII).

Analysis of variance (Appendix VIIIa,b,c,d,e,f,g, and h) showed that higher significant variation existed between season ($p<0.01$), and significant variation existed between months, ($p<0.05$), while no significant variation existed between years, stations, year by months, year by station, month by station and year by month by station ($p>0.05$).

Correlation coefficient analysis for all parameters over all stations (Appendix IX) revealed a highly positive significant correlation existed between magnesium and calcium and sodium ($p<0.01$), A highly significant negative correlation existed with cadmium, copper, chromium , iron, nickel, lead, zinc and phytoplankton ($p<0.01$).

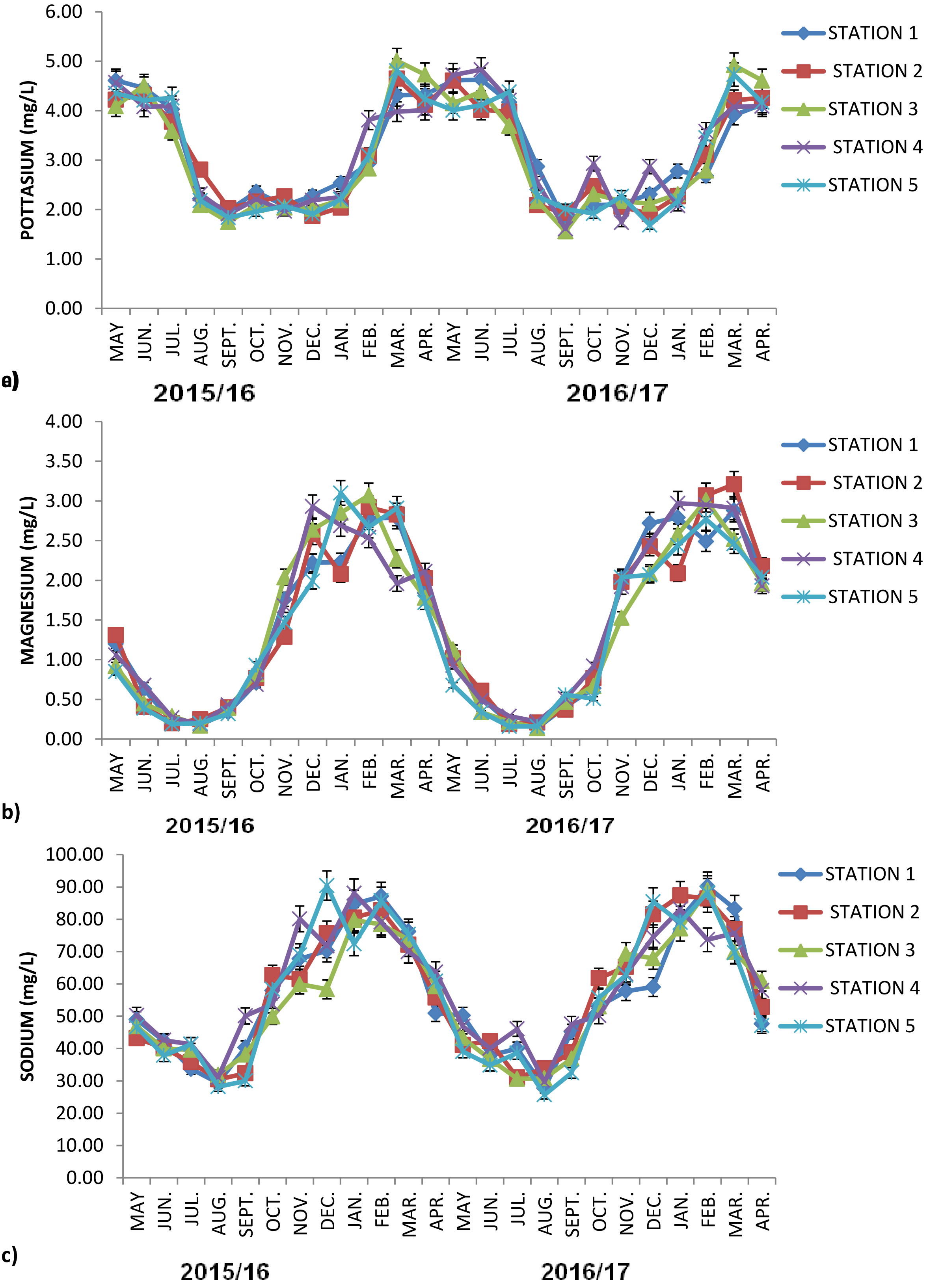

Figure 4.6: Mean Monthly Variation in Surface Water (a) Potassium (b) Magnesium and (c) Sodium of Different Sampling Stations of Yardantsi Reservoir, Gusau

4.2.4 Sodium

The mean monthly variations in sodium concentration for all stations are presented in Fig. 4.6c. The highest and the lowest monthly sodium concentrations were recorded in February (84.06 mg/L) and August (29.85 mg/L) respectively and were found to have a significant difference at $p<0.05$ (Appendix VII).

Analysis of variance (Appendix VIIIa,b,c,d,e,f,g, and h) showed that higher significant variation existed between season ($p<0.01$), and significant variation existed between months, ($p<0.05$), while no significant variation existed between years, stations, year by months, year by station, month by station and year by month by station ($p>0.05$).

Correlation coefficient analysis for all parameters over all stations (Appendix IX) revealed a highly positive significant correlation existed between sodium and calcium and magnesium ($p<0.01$). A highly significant negative correlation existed with cadmium, copper, chromium , iron, nickel, lead, zinc and phytoplankton ($p<0.01$).

4.2.5 Cadmium

The mean monthly variations in cadmium concentration for all stations are presented in Fig. 4.7a. The highest and the lowest monthly cadmium concentrations were recorded in June (0.29 mg/L) and December (0.03 mg/L) respectively and were found to have a significant difference at $p<0.05$ (Appendix VII).

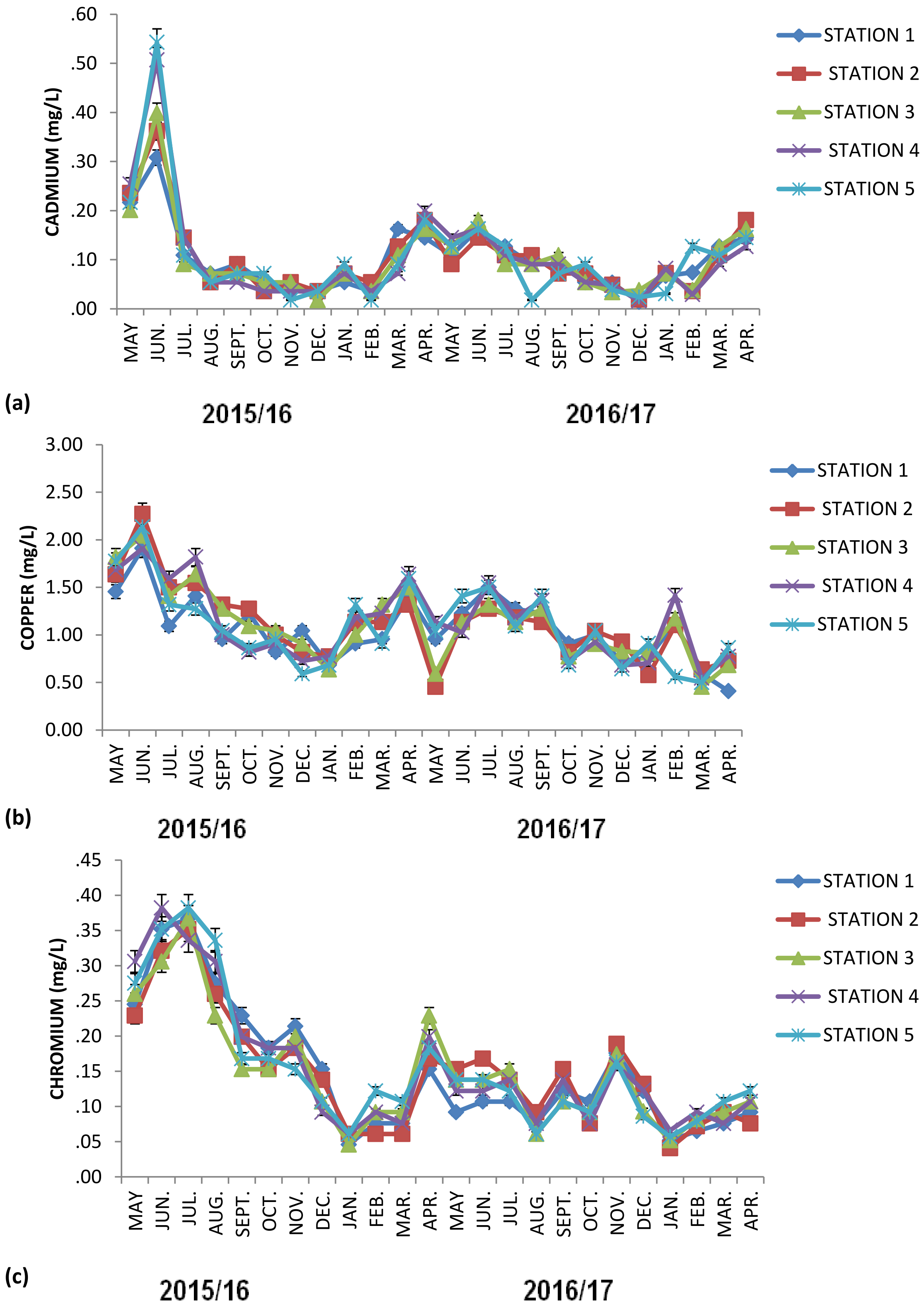

Figure 4.7: Mean Monthly Variation in Surface Water (a) Cadmium (b) Copper and (c) Chromium of Different Sampling Stations of Yardantsi Reservoir, Gusau

Analysis of variance (Appendix VIIIa,b,c,d,e,f,g, and h) showed that no significant variation existed between years, seasons, months, stations, year by months, year by station, month by station and year by month by station ($p>0.05$).

Correlation coefficient analysis for all parameters over all stations (Appendix IX) revealed a highly positive significant correlation existed between cadmium and potassium, copper, chromium, iron, lead, zinc, phytoplankton and zooplankton ($p<0.01$). A highly significant negative correlation existed with calcium, magnesium and sodium ($p<0.01$).

4.2.6 Copper

The mean monthly variations in copper concentration for all stations are presented in Fig. 4.7b. The highest and the lowest monthly copper concentrations were recorded in June (1.62 mg/L) and January (0.73 mg/L) respectively and were found to have a significant difference at $p<0.05$ (Appendix VII).

Analysis of variance (Appendix VIIIa,b,c,d,e,f,g, and h) showed that no significant variation existed between years, seasons, months, stations, year by months, year by station, month by station and year by month by station ($p>0.05$).

Correlation coefficient analysis for all parameters over all stations (Appendix IX) revealed a highly positive significant correlation existed between copper and potassium, cadmium, chromium, iron, nickel, lead, zinc, phytoplankton and zooplankton ($p<0.01$). A highly significant negative correlation existed with calcium, magnesium and sodium ($p<0.01$).

4.2.7 Chromium

The mean monthly variations in chromium concentration for all stations are presented in Fig. 4.7c. The highest and the lowest monthly chromium concentrations were recorded in July (0.25 mg/L) and January (0.05 mg/L) respectively and were found to have a significant difference at $p<0.05$ (Appendix VII).

Analysis of variance shows that significant variation existed between years and seasons (Appendix VIIIa and b) and Appendix VIIIc,d,e,f,g and h showed no significant variation existed between months, stations, years by months, year by station, month by station and year by month by station ($p>0.05$).

Correlation coefficient analysis for all parameters over all stations (Appendix IX) revealed a highly positive significant correlation existed between chromium and cadmium, copper, iron, nickel, lead, zinc and phytoplankton ($p<0.01$), but significant positive correlation existed with potassium and zooplankton ($p<0.05$). A highly significant negative correlation existed with calcium, magnesium and sodium ($p<0.01$).

4.2.8 Iron

The mean monthly variations in iron concentration for all stations are presented in Fig. 4.8a. The highest and the lowest monthly iron concentration were recorded in June (5.74mg/L) and January (0.68 mg/L) respectively and were found to have a significant difference at $p<0.05$ (Appendix VII). Analysis of variance (Appendix VIIIa,b,d,e,f,g and h) showed that significant variation existed between years, stations, years by months, years by stations, months by stations and years by months by stations ($p<0.05$). Appendix VIIIc, shows that highly significant variation existed between seasons as well as months ($p<0.01$).

Correlation coefficient analysis for all parameters over all stations (Appendix IX) revealed a highly positive significant correlation existed between iron and potassium, cadmium, copper, chromium, nickel, lead, zinc and phytoplankton ($p<0.01$), but significant positive correlation existed and zooplankton ($p<0.05$). A highly significant negative correlation existed with calcium, magnesium and sodium ($p<0.01$).

4.2.9 Nickel

The mean monthly variations in nickel concentration for all stations are presented in Fig. 4.8b. The highest and the lowest monthly nickel concentrations were recorded in August (0.18 mg/L) and January (0.02 mg/L) respectively and were found to have a significant difference at $p<0.05$ (Appendix VII).

Analysis of variance (Appendix VIIIa, b, and c) showed that significant variation existed between years, seasons, and months ($p<0.05$). Appendix VIIId,e,f,g and h shows that no significant variation existed with stations, years by months, years by stations, months by stations and years by months by stations ($p>0.05$).

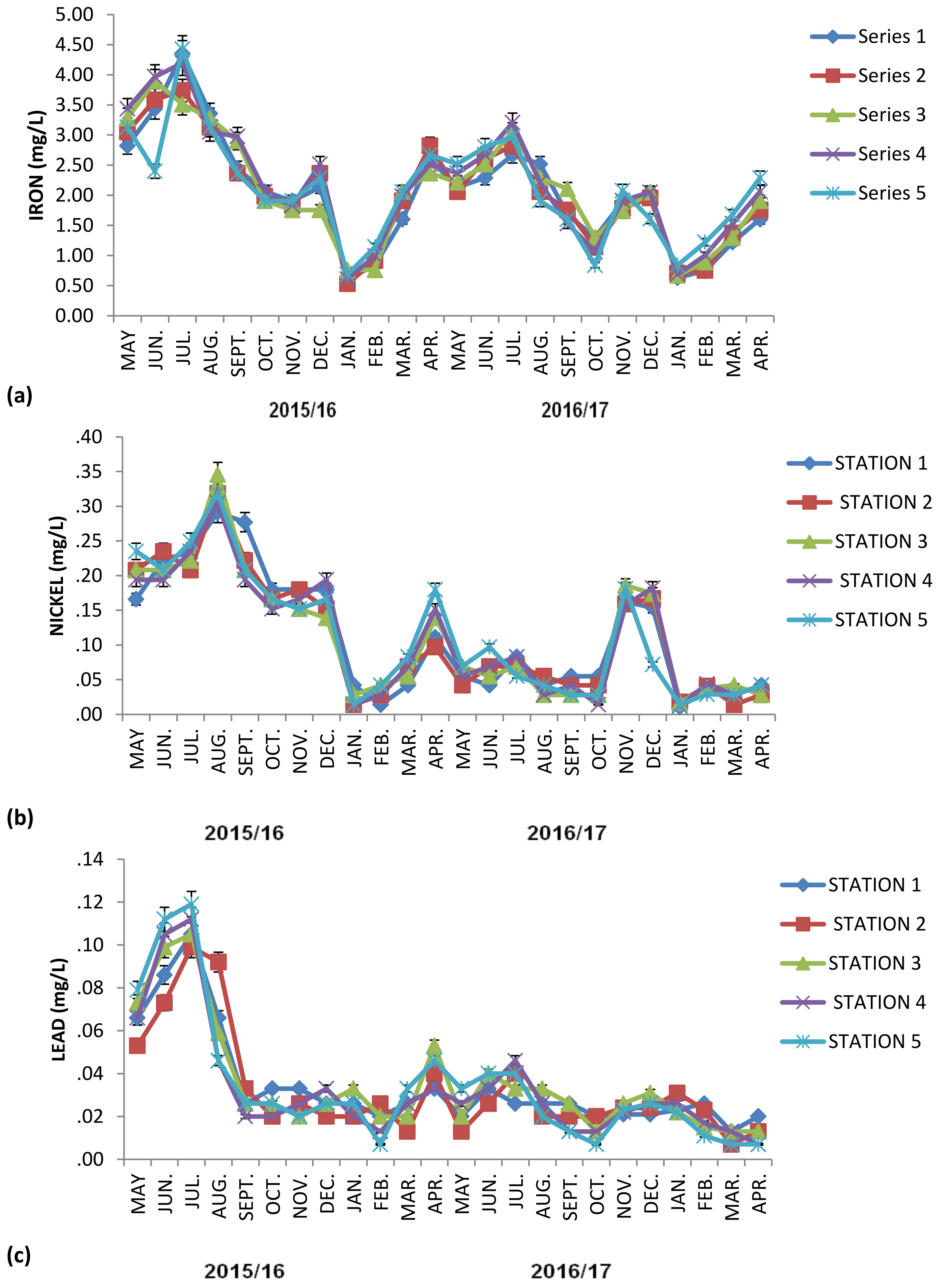

Figure 4.8: Mean Monthly Variation in Surface Water (a) Iron (b) Nickel and (c) Lead of Different Sampling Stations of Yardantsi Reservoir, Gusau

Correlation coefficient analysis for all parameters over all stations (Appendix IX) revealed a highly positive significant correlation existed between nickel and copper, chromium, iron lead and zinc ($p<0.01$), but significant positive correlation existed with phytoplankton ($p<0.05$). A highly significant negative correlation existed with magnesium and sodium ($p<0.01$).

4.2.10 Lead

The mean monthly variations in lead concentration for all stations are presented in Fig. 4.8c. The highest and the lowest monthly lead concentrations were recorded in June and July (0.07 mg/L) and February, March, September, October and November (0.02 mg/L) respectively and were found to have a significant difference at $p<0.05$ (Appendix VII).

Analysis of variance (Appendix VIIIa, b, and c) showed that significant variation existed between years, seasons, and months ($p<0.05$). Appendix VIIId,e,f,g and h shows that no significant variation existed with stations, years by months, years by stations, months by stations and years by months by stations ($p>0.05$).

Correlation coefficient analysis for all parameters over all stations (Appendix IX) revealed a highly positive significant correlation existed between lead and potassium, cadmium, copper, chromium, iron, nickel, zinc, phytoplankton and zooplankton ($p<0.01$). A highly significant negative correlation existed with calcium, magnesium and sodium ($p<0.01$).

4.2.11 Zinc

The mean monthly variations in zinc concentration for all stations are presented in Fig. 4.9. The highest and the lowest monthly zinc concentrations were recorded in June (1.75 mg/L) and January (0.66 mg/L) respectively and were found to have a significant difference at $p<0.05$ (Appendix VII).

Analysis of variance (Appendix VIIIa,b,c,d,e,f,g and h) showed that no significant variation existed between years, seasons, months, stations, years by months, years by stations, months by stations and years by months by stations ($p>0.05$).

Correlation coefficient analysis for all parameters over all stations (Appendix IX) revealed a highly positive significant correlation existed between zinc and cadmium, copper, chromium, iron, nickel, lead, phytoplankton and zooplankton ($p<0.01$) but a positive significant correlation existed with potassium. A highly significant negative correlation existed with calcium, magnesium and sodium ($p<0.01$).

4.3 Sediment Physico-Chemical Parameters

Studies on some physico-chemical parameters were carried out on sediments for five (5) different stations of Yardantsi Reservoir, Gusau so as to establish their concentrations. Five sediment's physico-chemical parameters viz; pH, electrical conductivity, phosphorus, percentage nitrogen, and organic carbon were monitored. The mean annual and seasonal variation of the physico-chemical parameters for the period of this study are presented in Table 4.3.

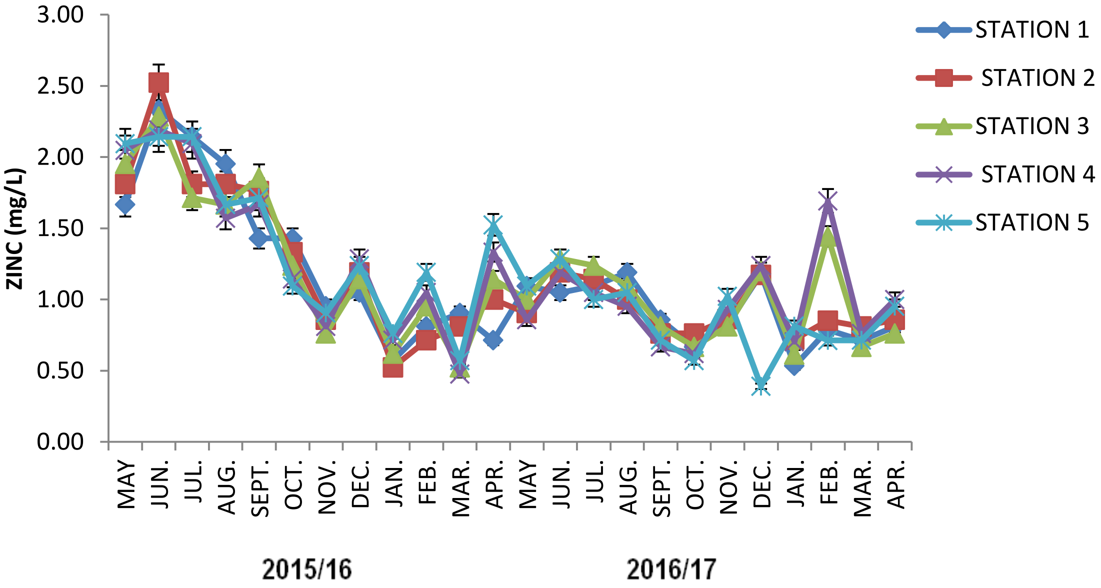

Figure 4.9: Mean Monthly Variation in Surface Water Zinc of Different Sampling Stations of Yardantsi Reservoir, Gusau

Table 4.3: Mean (±SE) Annual and Seasonal Variation of Different Sediment Physico-Chemical Parameters of Yardantsi Reservoir, Gusau

	Years			**Seasons**			**CBSQG**		
Metals(mg/L)	**2015**	**2016**	**P-value**	**Dry Season**	**Rainy Season**	**P-value**	**TEC**	**PEC**	**SQGs**
pH	6.81±0.05	8.06±1.09	0.252	6.94±0.05	7.93±1.09	0.368			
EC (µS/cm)	392.19±8.78	399.06±11.16	0.384	342.11±7.33	449.14±7.16	0.000			
OC (%)	0.36±0.01	0.35±0.00	0.620	0.34±0.01	0.37±0.00	0.002			
N (%)	0.02±0.00	0.02±0.00	0.297	0.02±0.00	0.02±0.00	0.146			
P(cmol/Kg)	9.13±0.52	10.72±0.67	0.098	9.16±0.60	10.70±0.60	0.064			
CEC(cmol/Kg)	6.17±0.13	6.40±0.08	0.177	6.38±0.11	6.19±0.11	0.226			
Ca (cmol/Kg)	3.05±0.10	2.69±0.07	0.014	2.93±0.09	2.82±0.08	0.291			
K (cmol/Kg)	0.84±0.03	1.02±0.02	0.000	0.95±0.02	0.91±0.03	0.223			
Mg (cmol/Kg)	1.92±0.06	2.34±0.04	0.000	2.15±0.04	2.11±0.07	0.531			
Na (cmol/Kg)	0.35±0.01	0.35±0.01	0.978	0.34±0.01	0.36±0.01	0.137			
Cd (cmol/Kg)	1.25±0.09	2.36±0.13	0.000	2.09±0.15	1.52±0.11	0.000	0.99	5	
Cu (cmol/Kg)	3.41±0.15	4.59±0.19	0.000	3.84±0.15	4.15±0.21	0.173	32	150	2-100
Cr (cmol/Kg)	0.81±0.0.5	1.16±0.18	0.072	0.96±0.08	1.01±0.17	0.810	43	110	1-1000
Fe (cmol/Kg)	55.32±1.53	38.09±0.04	0.000	49.44±1.24	43.97±2.65	0.064			7,000
Ni (cmol/Kg)	0.59±0.03	0.36±0.03	0.000	0.43±0.03	0.53±0.04	0.034	23	49	5-500
Pb (cmol/Kg)	0.13±0.01	0.15±0.01	0.059	0.16±0.01	0.13±0.01	0.010	36	130	2-200
Zn (cmol/Kg)	16.60±2.10	11.14±0.61	0.018	14.31±0.40	13.44±2.20	0.703	120	460	10-300

Note; TEC = Threshold Effect Concentration; PEC = Probable Effect Concentration; CBSQG = Concentration Based Sediment Quality Guidelines; SQGs = Sediment Quality Guidelines; OC = Organic Carbon; EC = Electrical Conductivity and CEC = Cation Exchange Capacity

4.3.1 Sediment hydrogen ion concentration (pH)

The mean monthly variations in hydrogen ion concentration for all stations are presented in Fig. 4.10a. The highest and the lowest monthly pH were recorded in September (13.33) and June (6.42) respectively and were found to have no significant difference at $p<0.05$ (Appendix X).

Analysis of variance (Appendix XIa,b,c,d,e,f,g and h) showed no significant variation existed between years, seasons, months, stations, years by months, years by stations, months by stations and years by months by stations ($p>0.05$).

Correlation coefficient analysis for all parameters over all stations (Appendix XII) revealed that no significant correlation between hydrogen ion concentration and other parameters ($p>0.05$).

4.3.2 Sediment electrical conductivity

The mean monthly variations in electrical conductivity for all stations are presented in Fig. 4.10b. The highest and the lowest monthly electrical conductivity concentrations were recorded in August (519.96 µS/cm) and January (278.14 µS/cm) respectively and were found to have significant difference at $p<0.05$ (Appendix X).

Analysis of variance (Appendix XIb and c) showed significant variation existed between seasons and months ($p<0.05$). Appendix XIa,d,e,f,g and h showed no significant variation existed between years, stations, years by months, years by stations, months by stations and years by months by stations ($p>0.05$).

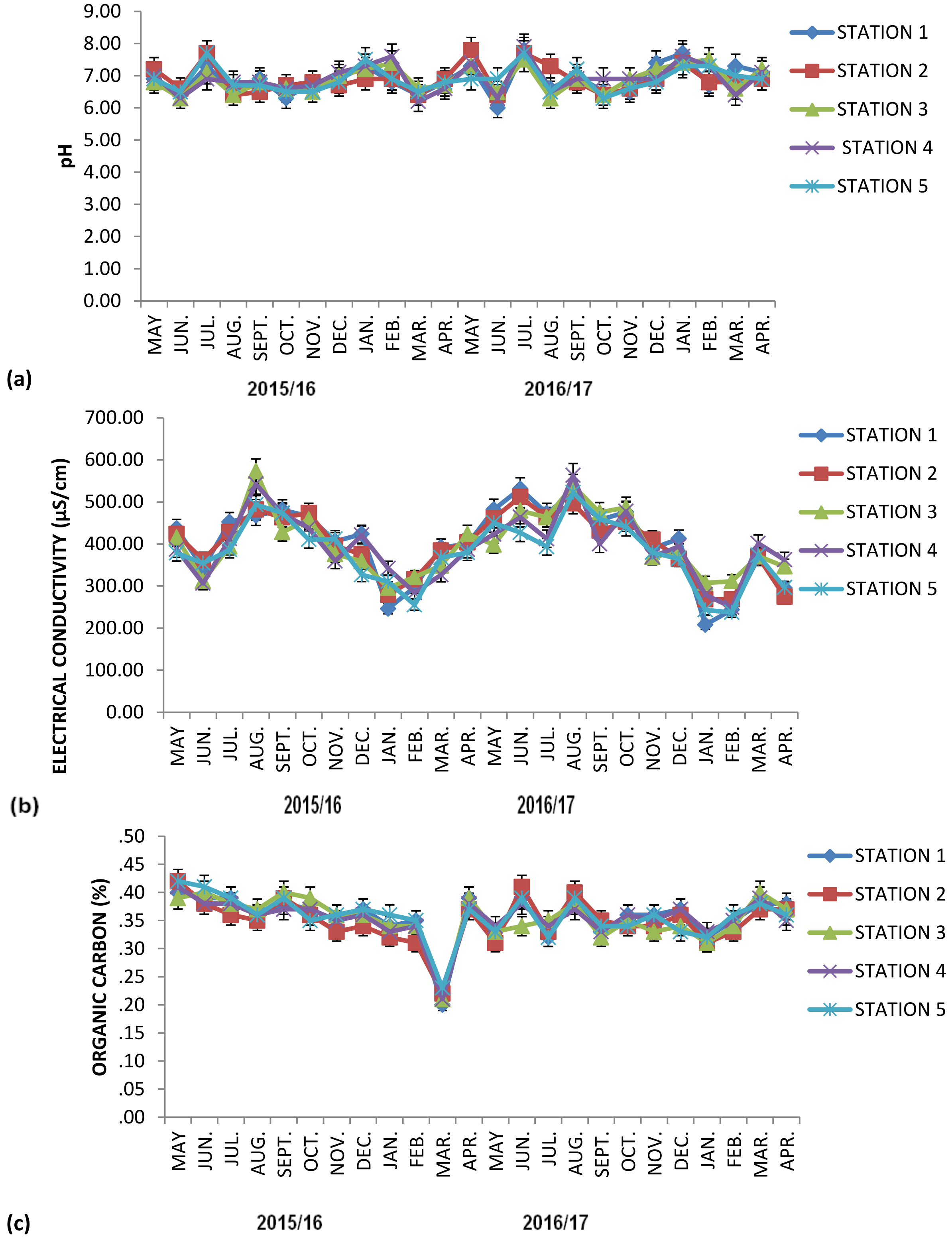

Figure 4.10: Mean Monthly Variation in Sediment (a) pH (b) Electrical Conductivity and (c) Organic Carbon of Different Sampling Stations of Yardantsi Reservoir, Gusau

Correlation coefficient analysis for all parameters over all stations (Appendix XII) revealed that highly positive significant correlation existed between electrical conductivity, organic carbon and phytoplankton ($p<0.01$), but a positive significant correlation existed with nickel ($p<0.05$). A highly negative significant correlation existed with cadmium ($p<0.01$), while negative significant correlation existed with cation exchange capacity ($p<0.05$).

4.3.3 Organic carbon

The mean monthly variations in organic carbon for all stations are presented in Fig. 4.10c. The highest and the lowest monthly organic carbon were recorded in June (0.39%) and March (0.30 %) respectively and were found to have significant difference at $p<0.05$ (Appendix X).

Analysis of variance (Appendix XIb) showed that significant variation existed between seasons ($p<0.05$). Appendix XIa,c,d,e,f,g and h showed no significant variation existed between years, months, stations, years by months, years by stations, months by stations and years by months by stations ($p>0.05$).

Correlation coefficient analysis for all parameters over all stations (Appendix XII) revealed that highly positive significant correlation existed between organic carbon and electrical conductivity and sodium ($p<0.01$), but a positive significant correlation existed with nitrogen, calcium and iron ($p<0.05$). A highly negative significant correlation existed with potassium, magnesium and copper ($p<0.01$).

4.3.4 Sediment nitrogen

The mean monthly variations in nitrogen concentrations for all stations are presented in Fig. 4.11a. The highest and the lowest monthly nitrogen concentrations were observed in May (0.023%) and January (0.016%) respectively and were found to have no significant difference at $p<0.05$ (Appendix X). Analysis of variance (Appendix XIa,b,c,d,e,f,g and h) showed that no significant variation existed between years, seasons, months, stations, years by months, years by stations, months by stations and years by months by stations ($p>0.05$).

Correlation coefficient analysis for all parameters over all stations (Appendix XII) revealed that a positive significant correlation existed between nitrogen and organic carbon and electrical conductivity and sodium ($p<0.05$). A highly negative significant correlation existed with cation exchange capacity ($p<0.01$) while negative significant correlation existed with magnesium ($p<0.05$).

4.3.5 Sediment phosphorus

The mean monthly variations in phosphorus concentrations for all stations are presented in Fig. 4.11b. The highest and the lowest monthly phosphorus concentrations were observed in July (13.63 cmol/kg) and January (5.14 cmol/kg) respectively and were found to have significant difference at $p<0.05$ (Appendix X).

Analysis of variance (Appendix XIa,b,c,d,e,f,g and h) showed that no significant variation existed between years, seasons, months, stations, years by months, years by stations, months by stations and years by months by stations ($p>0.05$).

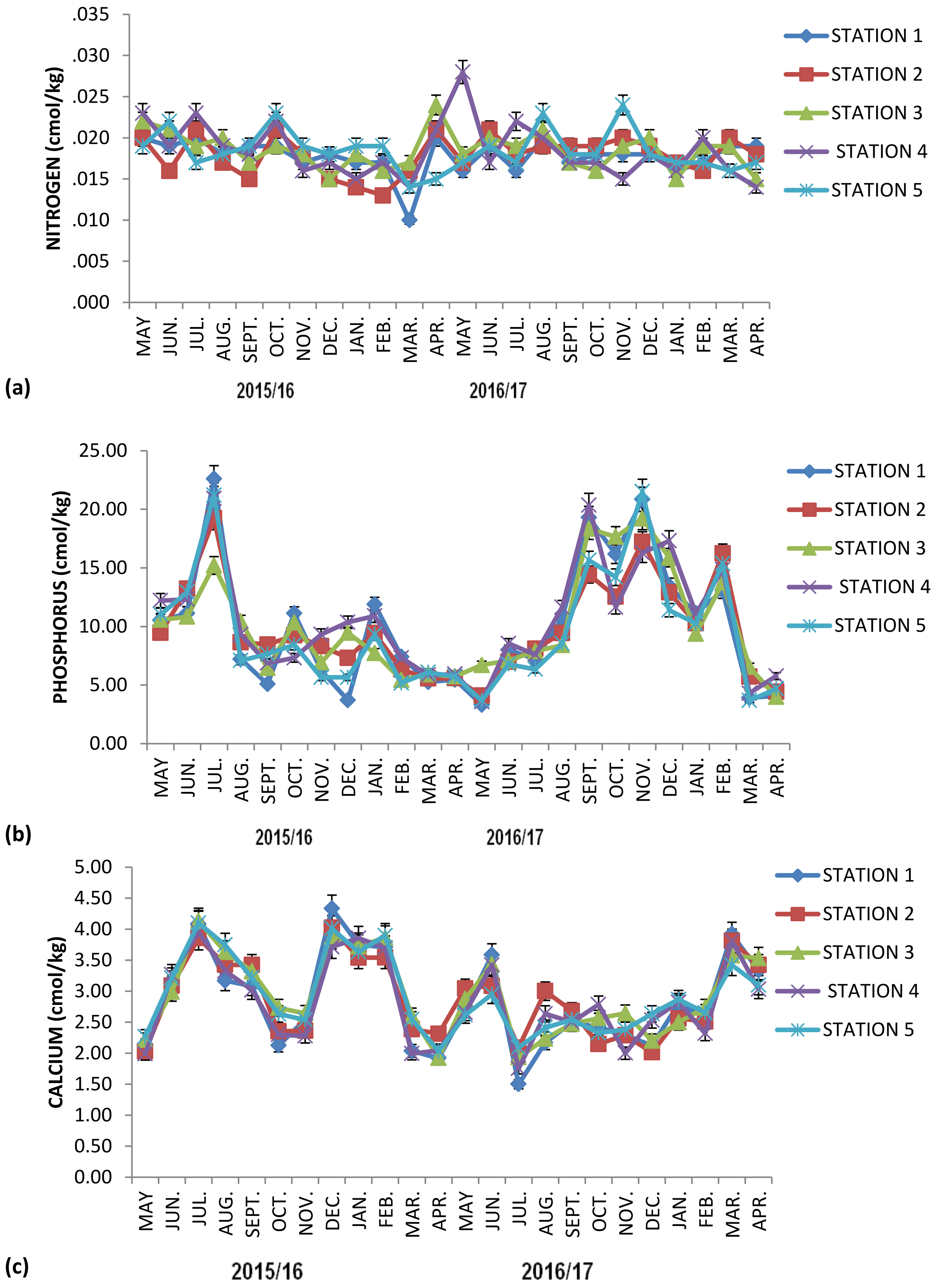

Figure 4.11: Mean Monthly Variation in Sediment (a) Nitrogen (b) Phosphorus and (c) Calcium of Different Sampling Stations of Yardantsi Reservoir, Gusau

Correlation coefficient analysis for all parameters over all stations (Appendix XII) revealed that a highly positive significant correlation existed between phosphorus and magnesium, chromium and nickel ($p<0.01$). A highly negative significant correlation existed with cadmium ($p<0.01$), and a negative significant correlation existed with sodium ($p<0.05$).

4.4 Sediment Trace and Alkali-alkaline Earth Metals Concentrations

Studies on alkali-alkaline earth metals (viz; calcium, potassium, magnesium and sodium) and some trace metals (viz; cadmium, chromium, copper, iron, nickel, lead and zinc) concentrations were carried out on sediment for five (5) different stations of Yardantsi Reservoir, Gusau so as to establish their concentrations. The mean annual and seasonal variation of the surface water metals (mg/L) for the periods of this study were presented in Table 4.3.

4.4.1 Sediment calcium

The mean monthly variations in calcium concentrations for all stations are presented in Fig. 4.11c. The highest and the lowest monthly calcium concentrations were observed in January (3.20cmol/kg) and November (2.40cmol/kg) respectively and were found to have significant difference at $p<0.05$ (Appendix XIII). Analysis of variance (Appendix XIa,b,c,d,e,f,g and h) showed that no significant variation existed between years, seasons, months, stations, years by months, years by stations, months by stations and years by months by stations ($p>0.05$).

Correlation coefficient analysis for all parameters over all stations (Appendix XII) showed that a highly positive significant correlation existed between calcium and sodium and CEC ($p<0.01$), but a positive significant correlation existed with organic carbon, cadmium and zinc ($p<0.05$). A highly negative significant correlation existed with potassium ($p<0.01$).

4.4.2 Sediment potassium

The mean monthly variations in potassium concentrations for all stations are presented in Fig. 4.12a. The highest and the lowest monthly potassium concentrations were observed in November (1.07 cmol/kg) and September (0.85cmol/kg) respectively and were found to have significant difference at $p<0.05$ (Appendix XIII). Analysis of variance (Appendix XIa) showed that highly significant variation existed between year ($p<0.01$). Appendix XIb,c,d,e,f,g and h, showed that significant variation existed between seasons, months, stations, years by months, years by stations, months by stations and years by months by stations ($p<0.05$).

Correlation coefficient analysis for all parameters over all stations (Appendix XII) revealed that a highly positive significant correlation existed between potassium and magnesium and copper ($p<0.01$). A highly negative significant correlation existed with organic carbon, calcium and iron ($p<0.01$), but a negative significant correlation existed with sodium ($p<0.05$).

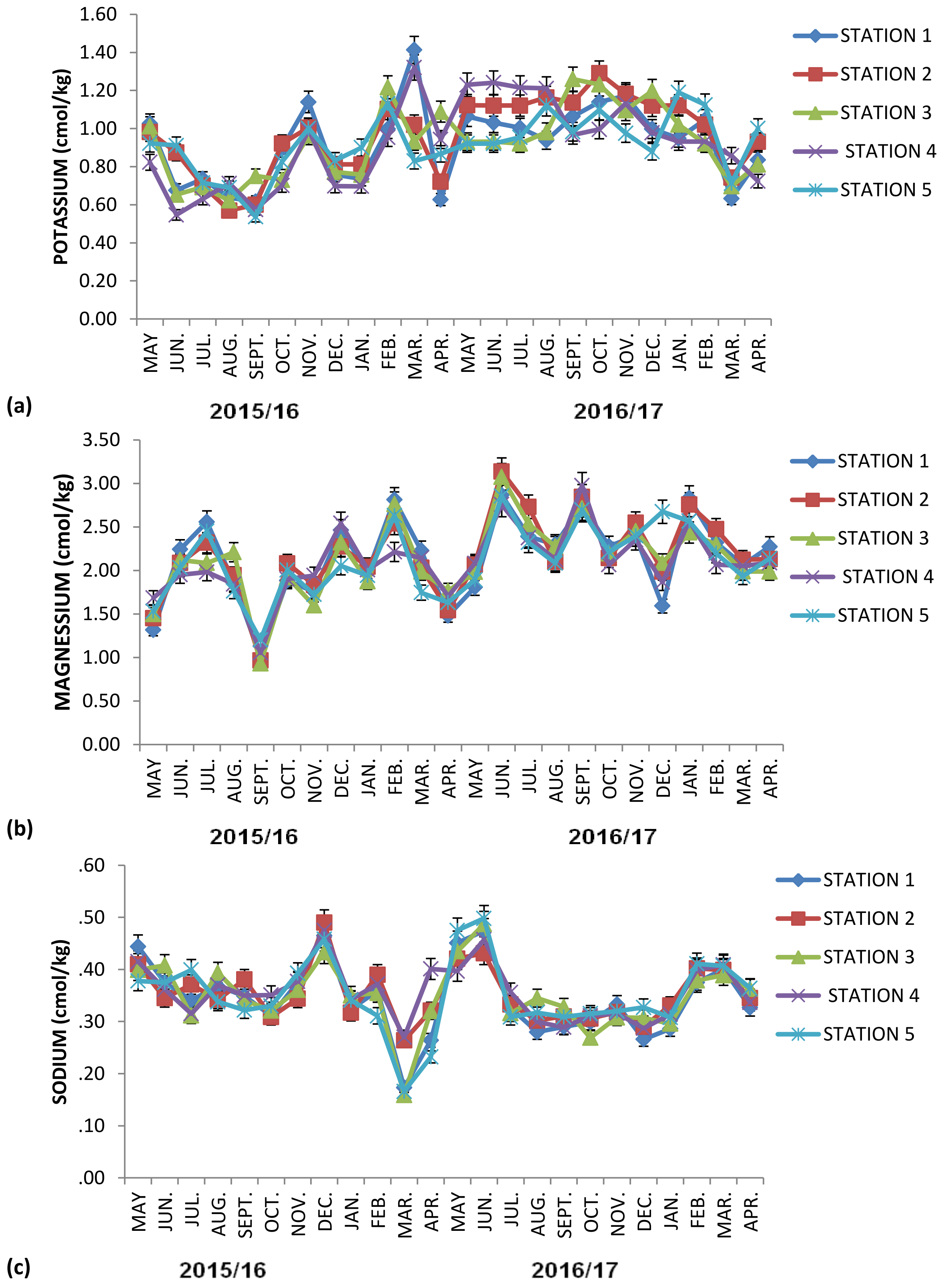

Figure 4.12: Mean Monthly Variation in Sediment (a) Potassium (b) Magnesium and (c) Sodium of Different Sampling Stations of Yardantsi Reservoir, Gusau

4.4.3 Sediment magnesium

The mean monthly variations in magnesium concentrations for all stations are presented in Fig. 4.12b. The highest and the lowest monthly magnesium concentrations were observed in February (2.43 cmol/kg) and May (1.73 cmol/kg) respectively and were found to have significant difference at $p<0.05$ (Appendix XIII).

Analysis of variance (Appendix XIa,b,c,d,e,f,g and h) showed that no significant variation existed between years, seasons, months, stations, years by months, years by stations, months by stations and years by months by stations ($p>0.05$).

Correlation coefficient analysis for all parameters over all stations (Appendix XII) revealed that a highly positive significant correlation existed between magnesium and phosphorus, potassium, cadmium, copper and CEC ($p<0.01$), but a positive significant correlation existed with lead ($p<0.05$). A highly negative significant correlation existed with organic carbon, iron and nickel ($p<0.01$), while a negative significant correlation existed with nitrogen and zinc ($p<0.05$).

4.4.4 Sediment sodium

The mean monthly variations in sodium concentrations for all stations are presented in Fig. 4.12c. The highest and the lowest monthly sodium concentrations were observed in May and June (0.42 cmol/kg) and March (0.30 cmol/kg) respectively and were found to have significant difference at $p<0.05$ (Appendix XIII).

Analysis of variance (Appendix XIa,b,c,d,e,f,g and h) showed that no significant variation existed between years, seasons, months, stations, years by months, years by stations, months by stations and years by months by stations ($p>0.05$).

Correlation coefficient analysis for all parameters over all stations (Appendix XII) revealed that a highly positive significant correlation existed between sodium and organic carbon, calcium and CEC ($p<0.01$). A negative significant correlation existed with phosphorus, potassium and chromium ($p<0.05$).

4.4.5 Cation exchange capacity

The mean monthly variations in cation exchange capacity for all stations are presented in Fig. 4.13a. The highest and the lowest monthly cation exchange capacity were observed in June (7.04 cmol/kg) and May (5.61 cmol/kg) respectively and were found to have significant difference at $p<0.05$ (Appendix X). Analysis of variance (Appendix XIa,b,c,d,e,f,g and h) showed that no significant variation existed between years, seasons, months, stations, years by months, years by stations, months by stations and years by months by stations ($p>0.05$).

Correlation coefficient analysis for all parameters over all stations (Appendix XII) revealed that a highly positive significant correlation existed between cation exchange capacity and calcium, magnesium, sodium and cadmium ($p<0.01$), but positive significant correlation existed with copper ($p<0.05$). A highly negative significant correlation existed with nitrogen and nickel ($p<0.01$), while a negative significant correlation existed with electrical conductivity and iron ($p<0.05$).

4.4.6 Sediment cadmium

The mean monthly variations in cadmium concentration for all stations are presented in Fig. 4.13c. The highest and the lowest monthly cadmium concentrations were observed in January (2.85cmol/kg) and November (0.99cmol/kg) respectively and were found to have significant difference at $p<0.05$ (Appendix XIII).

Analysis of variance (Appendix XIa,b,c,d,e,f,g and h) showed that no significant variation existed between years, seasons, months, stations, years by months, years by stations, months by stations and years by months by stations ($p>0.05$).

Correlation coefficient analysis for all parameters over all stations (Appendix XII) revealed that a highly positive significant correlation existed between cadmium and magnesium, cation exchange capacity and copper ($p<0.01$), but positive significant correlation existed with calcium ($p<0.05$). A highly negative significant correlation existed with electrical conductivity, phosphorus, iron and nickel ($p<0.01$).

4.4.7 Sediment copper

The mean monthly variations in copper concentration for all stations are presented in Fig. 4.13b. The highest and the lowest monthly copper concentrations were observed in March (5.00cmol/kg) and November (2.21cmol/kg) respectively and were found to have significant difference at $p<0.05$ (Appendix XIII).

Analysis of variance (Appendix XIa,b,c,d,e,f,g and h) showed that no significant variation existed between years, seasons, months, stations, years by months, years by stations, months by stations and years by months by stations ($p>0.05$).

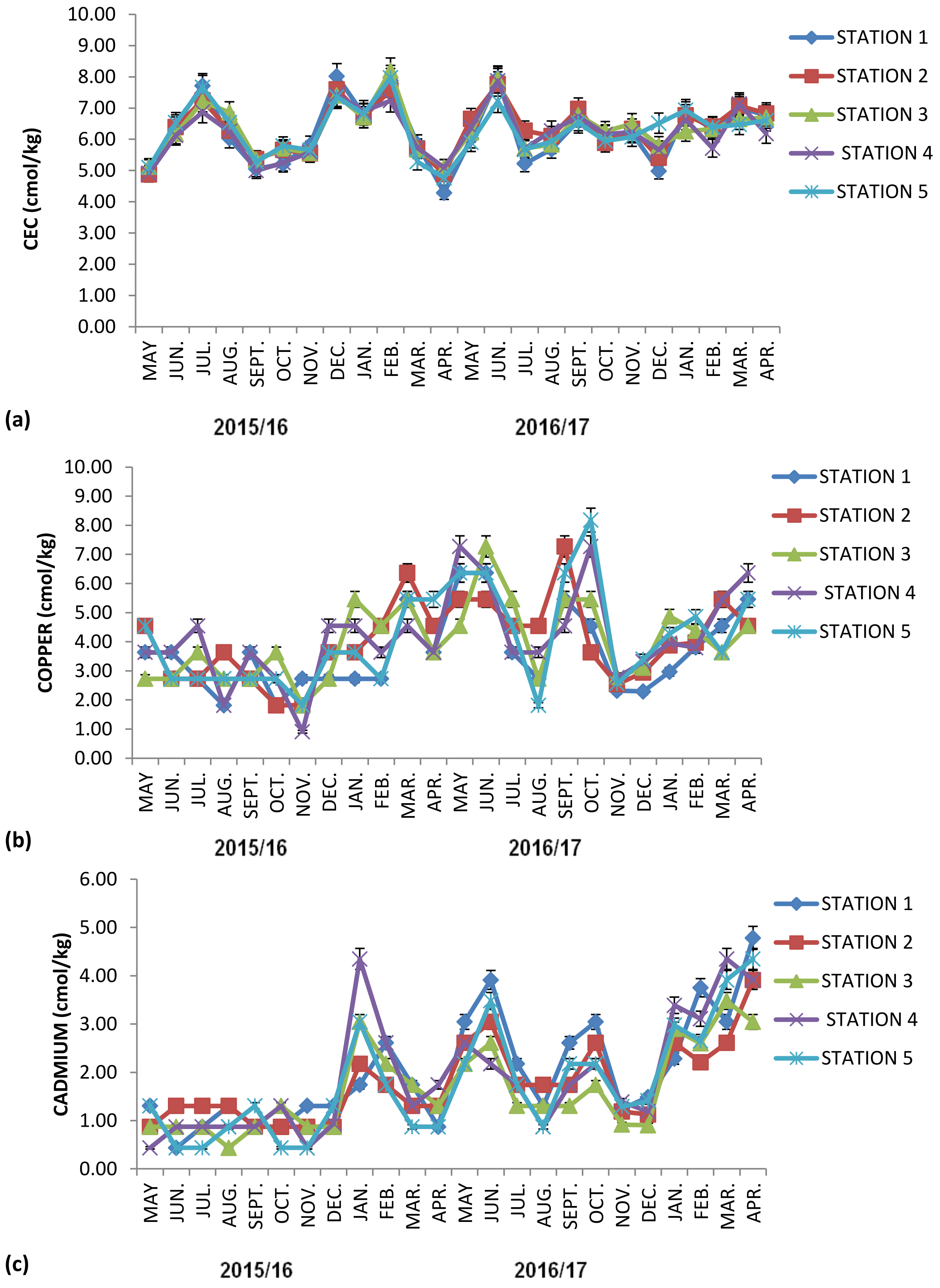

Figure 4.13: Mean Monthly Variation in Sediment (a) Cation Exchange Capacity (b) Copper and (c) Cadmium of Different Sampling Stations of Yardantsi Reservoir, Gusau

Correlation coefficient analysis for all parameters over all stations (Appendix XII) revealed that a highly positive significant correlation existed between copper and potassium, magnesium, and cadmium ($p<0.01$), but positive significant correlation existed with cation exchange capacity ($p<0.05$). A highly negative significant correlation existed with organic carbon, iron, nickel and lead ($p<0.01$).

4.4.8 Sediment chromium

The mean monthly variations in chromium concentration for all stations are presented in Fig. 4.14a. The highest and the lowest monthly chromium concentrations were observed in September (2.23 cmol/kg) and August (0.54 cmol/kg) respectively and were found to have significant difference at $p<0.05$ (Appendix XIII).

Analysis of variance (Appendix XIa,b,c,d,e,f, and g) showed that highly significant variation existed between years, seasons, months, stations, years by months, years by stations and months by stations ($p<0.01$). Appendix XIh revealed that significant variation existed between years by months by stations ($p<0.05$).

Correlation coefficient analysis for all parameters over all stations (Appendix VII) revealed that a highly positive significant correlation existed between chromium and phosphorus ($p<0.01$). A negative significant correlation existed with sodium ($p<0.01$).

4.4.9 Sediment iron

The mean monthly variations in iron concentration for all stations are presented in Fig. 4.14b. The highest and the lowest monthly iron concentrations were observed in

November (60.77 cmol/kg) and September (36.46cmol/kg) respectively and were found to have significant difference at $p<0.05$ (Appendix XIII).

Analysis of variance (Appendix XIa) showed that significant variation existed between years ($p<0.05$). Appendix XIb,c,d,e,f,g and h showed that no significant variation existed between seasons, months, stations, years by months, years by stations, months by stations and years by months by stations ($p>0.05$).

Correlation coefficient analysis for all parameters over all stations (Appendix XII) revealed that a highly positive significant correlation existed between iron and nickel and zinc ($p<0.01$), but a positive significant correlation existed with organic carbon ($p<0.05$). A highly negative significant correlation existed with potassium, magnesium, cadmium and copper ($p<0.01$), while negative significant correlation existed with cation exchange capacity ($p<0.05$).

4.4.10 Sediment nickel

The mean monthly variations in nickel concentration for all stations are presented in Fig. 4.14c. The highest and the lowest monthly nickel concentrations were observed in September (0.67cmol/kg) and January (0.19cmol/kg) respectively and were found to have significant difference at $p<0.05$ (Appendix XIII).

Analysis of variance (Appendix XIa,b,c,d,e,f,g and h) showed that no significant variation existed between years, seasons, months, stations, years by months, years by stations, months by stations and years by months by stations ($p>0.05$).

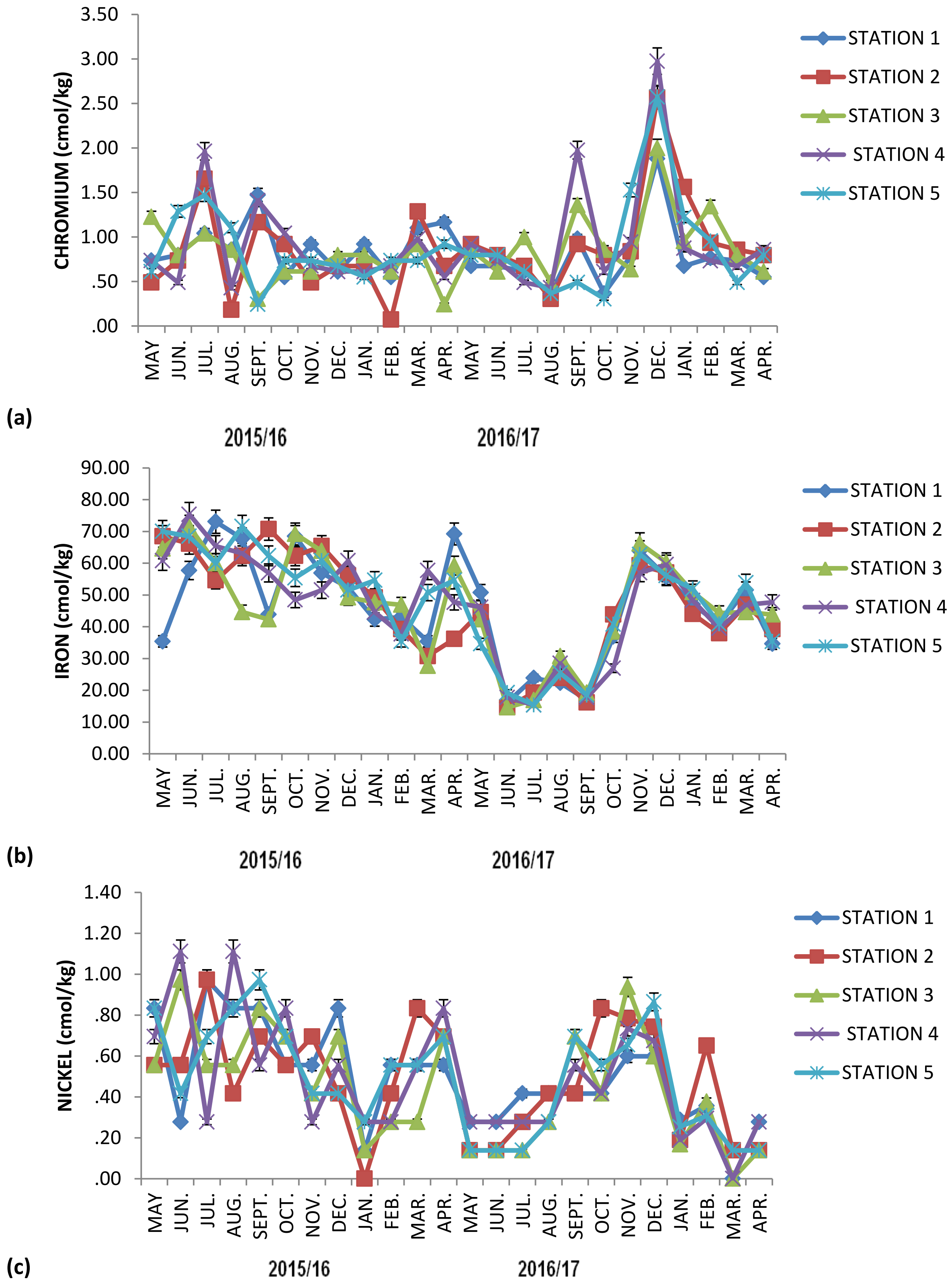

Figure 4.14: Mean Monthly Variation in Sediment (a) Chromium (b) Iron and (c) Nickel of Different Sampling Stations of Yardantsi Reservoir, Gusau

Correlation coefficient analysis for all parameters over all stations (Appendix XII) revealed that a highly positive significant correlation existed between nickel and phosphorus and iron ($p<0.01$), but a positive significant correlation existed with electrical conductivity ($p<0.05$). A highly negative significant correlation existed with magnesium, cation exchange capacity, cadmium and copper ($p<0.01$).

4.4.11 Sediment lead

The mean monthly variations in lead concentration for all stations are presented in Fig. 4.15a. The highest and the lowest monthly lead concentrations were observed in December (0.30cmol/kg) and May (0.07cmol/kg) respectively and were found to have significant difference at $p<0.05$ (Appendix XIII).

Analysis of variance (Appendix XIa,b,c,d,e,f,g and h) revealed that no significant variation existed between years, seasons, months, stations, years by months, years by stations, months by stations and years by months by stations ($p>0.05$).

Correlation coefficient analysis for all parameters over all stations (Appendix XII) revealed that a positive significant correlation existed between lead and magnesium ($p<0.05$).A highly negative significant correlation existed with copper ($p<0.01$).

4.4.12 Sediment zinc

The mean monthly variations in zinc concentration for all stations are presented in Fig. 4.15b. The highest and the lowest monthly zinc concentrations were observed in July (22.52 cmol/kg) and August (7.76cmol/kg) respectively and were found to have significant difference at $p<0.05$ (Appendix XIII).

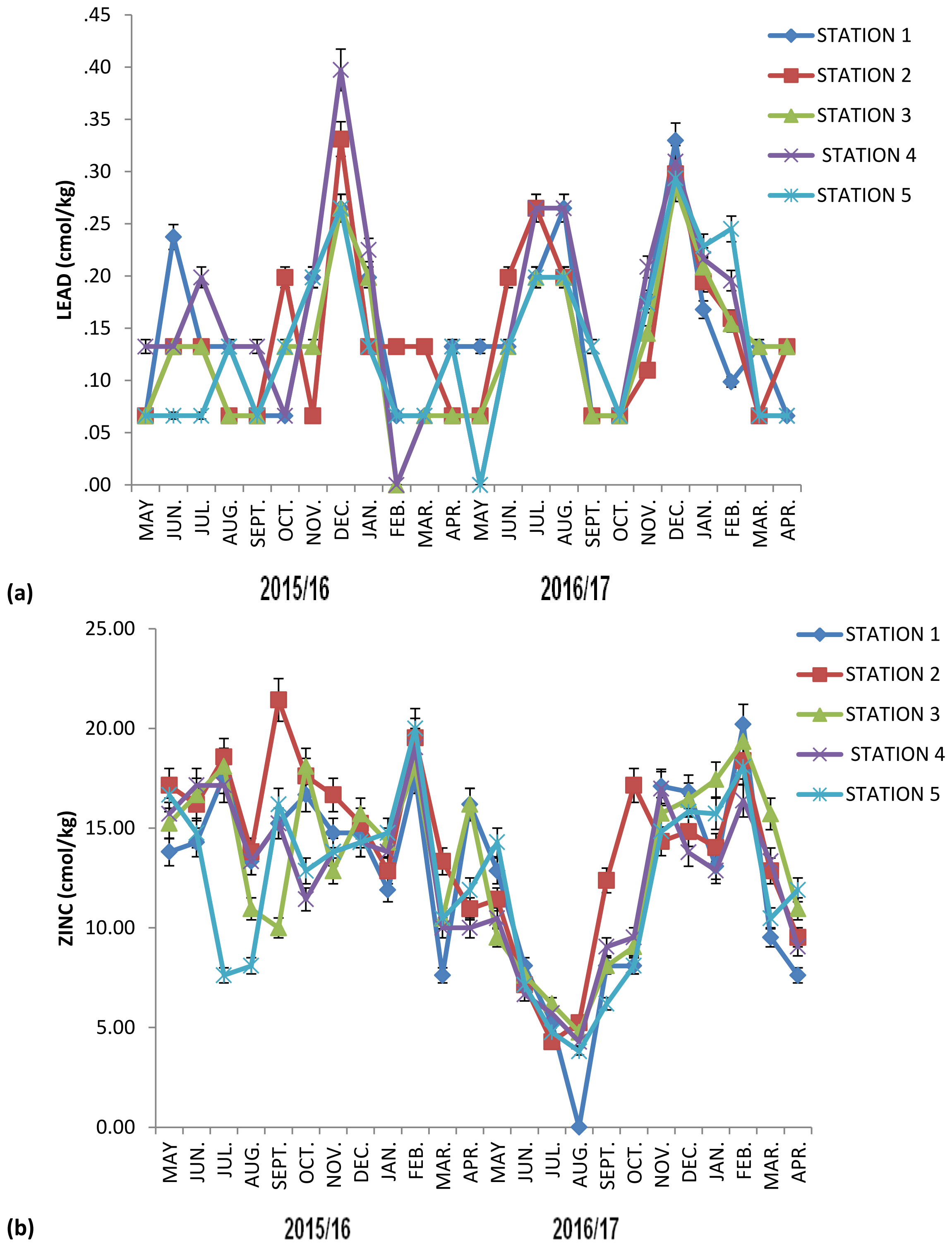

Figure 4.15: Mean Monthly Variation in Sediment (a) Lead and (b) Zinc of Different Sampling Stations of Yardantsi Reservoir, Gusau

Analysis of variance (Appendix XIa) revealed that significant variation existed between years ($p<0.05$). Appendix XIb,c,d,e,f,g and h revealed that no significant variation existed between seasons, months, stations, years by months, years by stations, months by stations and years by months by stations ($p>0.05$).

Correlation coefficient analysis for all parameters over all stations (Appendix XII) revealed that a highly positive significant correlation existed between zinc and iron ($p<0.01$), while a positive significant correlation existed with calcium ($p<0.05$).

4.5 Assessment of Sediment Trace Metals Contamination

Table 4.4 revealed that the C_f values obtained for all the metals under consideration (chromium, copper, nickel, lead and zinc) with the exception of cadmium were found to have C_f values less than one ($C_f<1$) in all the sampling months and therefore are said to be low contaminated when compared with Hakanson's classification for the contamination factor and level of contamination (Appendix II), while the cadmium C_f value was greater than six ($C_f>6$). Also the result showed that chromium, copper, nickel, lead and zinc are less than the threshold effect concentration (TEC) while cadmium had its value greater than the TEC but less than the probable effect concentration (PEC).

The sediment metals concentrations were compared with the United State Environmental Protection Agency Guidelines (Appendix III) to assess the level of metals contamination; this shows that all the metals have their concentrations lower than the contamination values in all sampling months.

Table 4.4: Sediment Heavy Metals Concentrations, CBSQG, and C_f Values

Metals(cmol/Kg)	**TEC**	**PEC**	**C_f**	**Result Obtained from Present study**
Cd	0.99	5	9.05	1.81
Cu	32	150	0.11	3.4
Cr	43	110	0.02	0.99
Fe	BDL	BDL	BDL	46.71
Ni	23	49	0.02	0.5
Pb	36	130	0.007	0.14
Zn	120	460	0.12	13.87

Note; TEC = Threshold Effect Concentration; PEC = Probable Effect Concentration; C_f = Contamination factor; and BDL = Below Detection Limit

4.6 Relationship of Surface Water and Sediment Metals Concentrations

Studies on some metals concentrations were carried out on surface water and sediment for five (5) different stations of Yardantsi Reservoir, Gusau so as to establish relationship between their concentrations. Surface water and sediment samples contained wide range of metals at different concentrations. These concentrations of trace metals in the reservoir are primarily controlled by overburden of the catchment and bedrock. Alkali-alkaline earth metals (viz; calcium, magnesium, potassium, sodium) and some trace metals (viz; chromium, nickel, cadmium, zinc, iron, copper and lead) were monitored. The mean annual and seasonal variation of the surface water and sediment metals are presented in Table 4.5 and 4.6 respectively.

Table 4.5 revealed that a highly significant difference ($p<0.01$) existed between the Surface water and sediment metals for both years, while Table 4.6 revealed that a highly significant difference ($p<0.01$) existed between the Surface water and sediment metals for both seasons, with the exception of calcium and magnesium which showed no significant difference ($p>0.05$) in dry season and then cadmium and lead which showed significant difference ($p<0.05$) in rainy season.

The sediment had higher concentration of calcium, cadmium, copper, chromium, iron, nickel, lead, and zinc in both seasons, while surface water recorded the higher concentration of potassium, magnesium and sodium. Sodium registered the highest concentration in both dry and rainy season for surface water, while zinc recorded the highest concentration in both dry and rainy season for sediment. Lead recorded the lowest concentration in both dry and rainy season for both surface water and sediment (Table 4.6).

Table 4.5: Mean (±SE) Annual Variation in Metal Concentrations of Surface Water and Sediment of Yardantsi Reservoir, Gusau

	2015			**2016**			**Water**	**Sediment**
Metals	**Water (mg/L)**	**Sediment (cmol/Kg)**	**P-value**	**Water (mg/L)**	**Sediment (cmol/Kg)**	**P-value**	**NSDWQ (mg/L)**	**TEC (cmol/Kg)**
Ca	2.87±0.33	3.05±0.10	0.006	1.40±0.19	2.69±0.07	0.010		
K	3.06±0.20	0.84±0.03	0.000	3.17±0.20	1.02±0.02	0.000		
Mg	2.33±0.09	1.92±0.06	0.000	0.53±0.06	2.34±0.04	0.000	0.20	
Na	72.70±1.90	0.35±0.01	0.000	41.83±1.69	0.35±0.01	0.000	200	
Cd	0.08±0.01	1.25±0.09	0.010	0.16±0.03	2.36±0.13	0.000	0.003	0.99
Cu	1.03±0.05	3.41±0.15	0.000	1.47±0.07	4.59±0.19	0.002	1	32
Cr	0.12±0.01	0.81±0.0.5	0.002	0.27±0.01	1.16±0.18	0.010	0.05	43
Fe	1.69±0.13	55.32±1.53	0.000	3.13±0.14	38.09±0.04	0.000	0.3	
Ni	0.10±0.01	0.59±0.03	0.000	0.22±0.01	0.36±0.03	0.006	0.02	23
Pb	0.03±0.00	0.13±0.01	0.004	0.06±0.01	0.15±0.01	0.001	0.01	36
Zn	0.90±0.05	16.60±2.10	0.000	1.84±0.07	11.14±0.61	0.000	3	120

Note; NSDWQ = Nigerian Standard for Drinking water Quality; TEC = Threshold Effect Concentration

Table 4.6: Mean (±SE) Seasonal Variation in Metal Concentrations of Surface Water and Sediment of Yardantsi Reservoir, Gusau

	Dry Season			**Rainy Season**			**Water**	**Sediment**
Metals	**Water (mg/L)**	**Sediment (cmol/Kg)**	**P-value**	**Water (mg/L)**	**Sediment (cmol/Kg)**	**P-value**	**NSDWQ (mg/L)**	**TEC (cmol/Kg)**
Ca	2.65±0.19	2.93±0.09	0.053	1.07±0.12	2.82±0.08	0.001		
K	3.06±0.13	0.95±0.02	0.000	3.20±0.14	0.91±0.03	0.000		
Mg	2.37±0.06	2.15±0.04	0.058	0.51±0.04	2.11±0.07	0.000	0.20	
Na	72.39±1.48	0.34±0.01	0.000	41.26±1.16	0.36±0.01	0.000	200	
Cd	0.08±0.01	2.09±0.15	0.000	0.13±0.01	1.52±0.11	0.012	0.003	0.99
Cu	0.92±0.04	3.84±0.15	0.000	1.29±0.05	4.15±0.21	0.005	1	32
Cr	0.11±0.01	0.96±0.08	0.001	0.19±0.01	1.01±0.17	0.010	0.05	43
Fe	1.58±0.08	49.44±1.24	0.000	3.13±0.44	43.97±2.65	0.000	0.3	
Ni	0.09±0.01	0.43±0.03	0.010	0.14±0.01	0.53±0.04	0.000	0.02	23
Pb	0.02±0.00	0.16±0.01	0.000	0.05±0.00	0.13±0.01	0.015	0.01	36
Zn	0.89±0.04	14.31±0.40	0.000	1.40±0.07	13.44±2.20	0.000	3	120

Note; NSDWQ = Nigerian Standard for Drinking water Quality; TEC = Threshold Effect Concentration

Correlation coefficient analysis for all parameters over all stations (Appendix IX) revealed a highly positive significant correlation existed between potassium and cadmium, copper, iron, lead, phytoplankton and zooplankton ($p<0.01$), but a positive significant correlation existed with chromium and zinc ($p<0.05$). A highly significant negative correlation existed with calcium ($p<0.01$).

The concentrations of metals in dry season for surface water throughout the study period revealed the following decreasing order of magnitude; Na > K > Ca > Mg > Fe > Cu > Zn > Cr > Cd and Ni > Pb, while rainy season revealed the following decreasing order of magnitude; Na > K > Fe > Zn > Cu > Ca > Mg >Cr >Ni > Cd > Pb; While the following decreasing order of magnitude was observed in sediment concentration of metals in both dry and rainy season throughout the study period; Fe >Zn >Cu > Ca > Mg >Cd > Cr > K > Ni >Na > Pb.

4.7 Phytoplankton Composition, Distribution and Abundance

The total phytoplankton composition and mean monthly variation of phytoplankton species of Yardantsi Reservoir were presented in Appendix XIV, which revealed a significant difference between months $p<0.05$. Phytoplankton exhibited a highly positive significant correlation with the surface water temperature, depth, NO_3-N, PO_4-P,sulphur, potassium, cadmium, copper, chromium, iron, lead, zinc and zooplankton ($p<0.01$), but a positive significant correlation existed with nickel ($p<0.05$). A highly negative significant correlation existed with transparency, total dissolved solids, electrical conductivity, dissolved oxygen, biological oxygen demand, hardness, alkalinity chloride, calcium, magnesium and sodium ($p<0.01$) (Appendix VI and IX).

4.7.1 Monthly phytoplankton species structure

Eleven species were identified with their relative percentage abundance (Appendix XV), belonging to four dominant groups of phytoplankton were found in the reservoir; Bacillariophyta, Chlorophyta, Cynophyta and Dinophyta accounting for 29.90%, 40.42%, 9.43% and 20.25% for dry season and 28.42%, 41.43%, 10.94% and 19.3% for rainy season respectively. Chlorophyta and Cynophyta recorded the highest percentage in rainy season, while Bacillariophyta and Dinophyta recorded the highest percentage in dry season. The relative percentage abundance of the groups of phytoplankton are illustrated in Fig. 4.16a. The number of individuals per litre that makes up the groups was presented in Appendix VI0. Mean monthly number of zooplankton ranged from 327 to 1102 individuals per litre in November and May respectively. Their density was higher in the rainy season than in dry season.

4.7.1.1 *Bacillariophyta*

Mean monthly number of Bacillariophyta ranged from 73 to 360 individuals per litre in November and May respectively (Fig.4.17a). Three species of Bacillariophyta were identified, which include; *Asterionella formosa* Hass (*A. formosa*) were present throughout the seasons, accounting for 14.73% and 15.03% for dry and rainy season respectively; *Cymbella timida* (Bréb.) Van Hanerck (*C. timida*) (Plate II) were also present throughout the seasons, accounting for 11.67% and 9.23% for dry and rainy season respectively and *Synedra ulna* (Nitzsch) Ehrenberg (*S. ulna*) disappeared during the tail end of rainy season and reappeared in the middle of dry season, accounting for 3.50% and 4.16% for dry and rainy season respectively, out of total phytoplankton composition (Appendix XV).

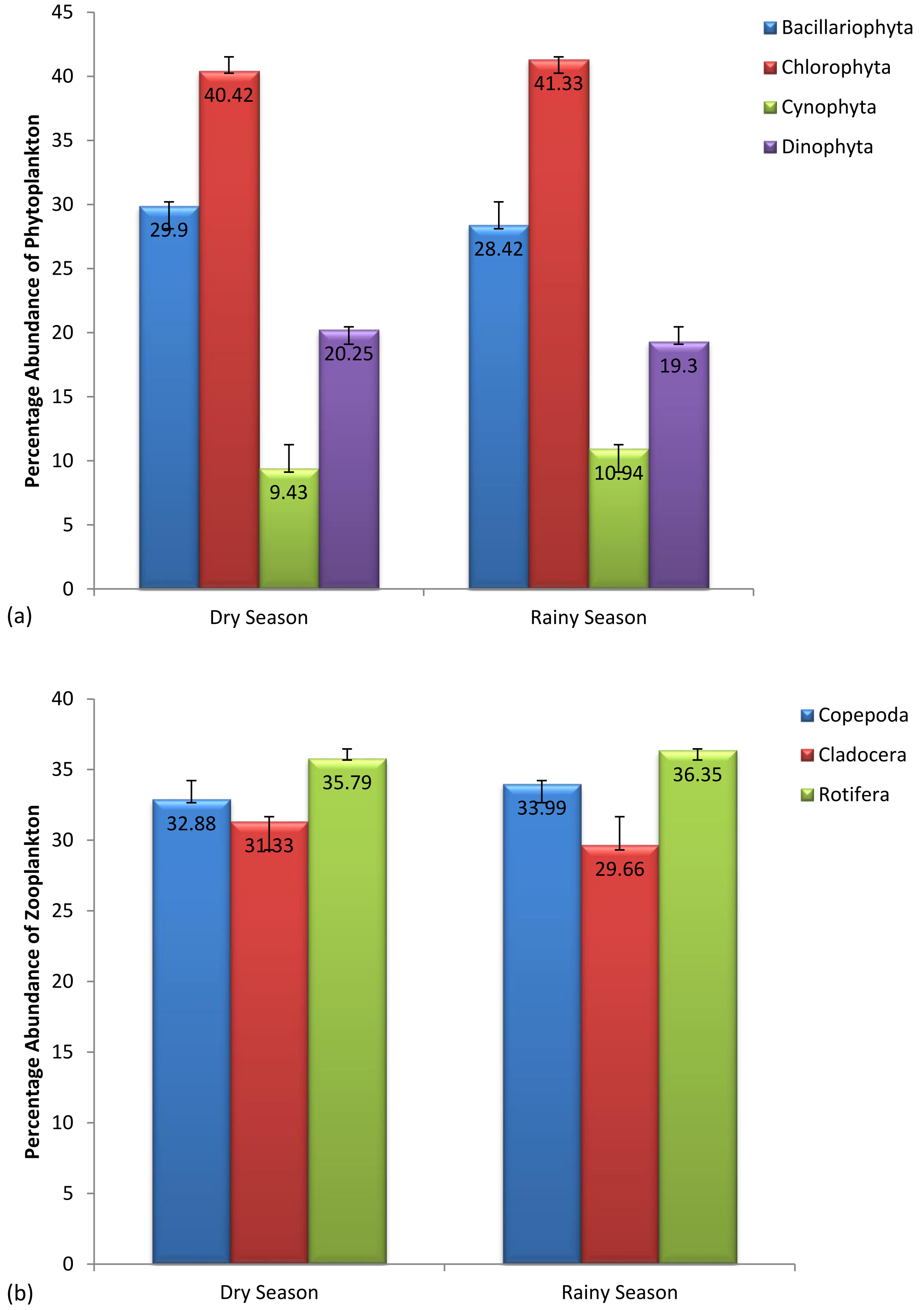

Figure 4.16: Percentage Mean Seasonal Variations of Various Groups of (a) Phytoplankton and (b) Zooplankton of Yardantsi Reservoir, Gusau

4.7.1.2 *Chlorophyta*

Mean monthly number of Chlorophyta ranged from 105 to 529 individuals per litre in December and June respectively (Fig. 4.17a). Four species of Chlorophyta were identified, which include; *Oosystis* sp. disappeared at the beginning and reappeared in the middle of rainy season and throughout dry season, accounting for 5.00% and 3.40% for dry and rainy season respectively; *Palmella* sp. (Plate III) were present throughout the seasons, accounting for 9.45% and 12.86% for dry and rainy season respectively; *Cosmarium* sp. (Plate IV) were only found in rainy season represented by 1.01%; and *Spirogyra* sp. were also present throughout the seasons, accounting for 25.97% and 25.07% for dry and rainy season respectively, out of total phytoplankton composition (Appendix XV).

4.7.1.3 *Cynophyta*

Mean monthly number of Cynophyta ranged from 31 to 131 individuals per litre in February and August respectively (Fig. 4.17a). Two species of Cynophyta were identified, which include; *Microcystis* sp. (Plate V) disappeared during the tail end of dry season and reappeared toward the end of rainy season, accounting for 1.74% and 2.02% for dry and rainy season respectively and *Oscillatoria limosa* C. Agardh ex Gomont (*O. limosa*) (Plate VI) were present throughout the seasons, accounting for 7.69% and 7.91% for dry and rainy season respectively, out of total phytoplankton composition (Appendix XV).

4.7.1.3 *Dinophyta*

Mean monthly number of Dinophyta ranged from 76 to 289 individuals per litre in January and May respectively (Fig. 4.17a). Two species of Dinophyta were identified, which include; *Ceratium hirundinella* (Müller) Dujardin (*C. hirundinella*) were present throughout the seasons, accounting for 14.94% and 15.78% for dry and rainy season respectively and *Ceratium teridenella* (Lemm) Skr. (*C. teridenella*) were present throughout the seasons except in August, accounting for 5.31% and 3.52% for dry and rainy season respectively, out of total phytoplankton composition (Appendix XV).

4.7.2 Monthly diversity indices of phytoplankton

Indices of species richness (Margalef and Fisher_alpha) (Appendix XVI) generally showed a similar trend among the months. These indices revealed that species richness was higher in January and lower in May for both indices (Fig. 4.17a).

Indices of evenness in the distribution of Phytoplankton species (Simpson_1-D, Evenness_e^H/S and Equitability_J) were observed to show similar pattern of variation among months, showing a decline in July for Simpson_1-D, and Equitability_J and July for Evenness_e^H/S index (Appendix XVI). The evenness in the distribution reaches peak in October for both indices (Fig. 4.18b). Brillouin and Shannon_H diversity indices were also found to follow the same pattern with a declined in July and a peak was attained in January (Fig. 4.19a).

Indices showing the level of dominance of species (Dominance and Berger-Parker) observed the same pattern which revealed that a peak was attained during early part of the dry season and a declined toward the end of rainy season for both Dominance and Berger-Parker indices (Fig. 4.19b). Therefore the level of evenness among the species showed significantly higher values during the early part of the rainy season and toward the peak of dry season.

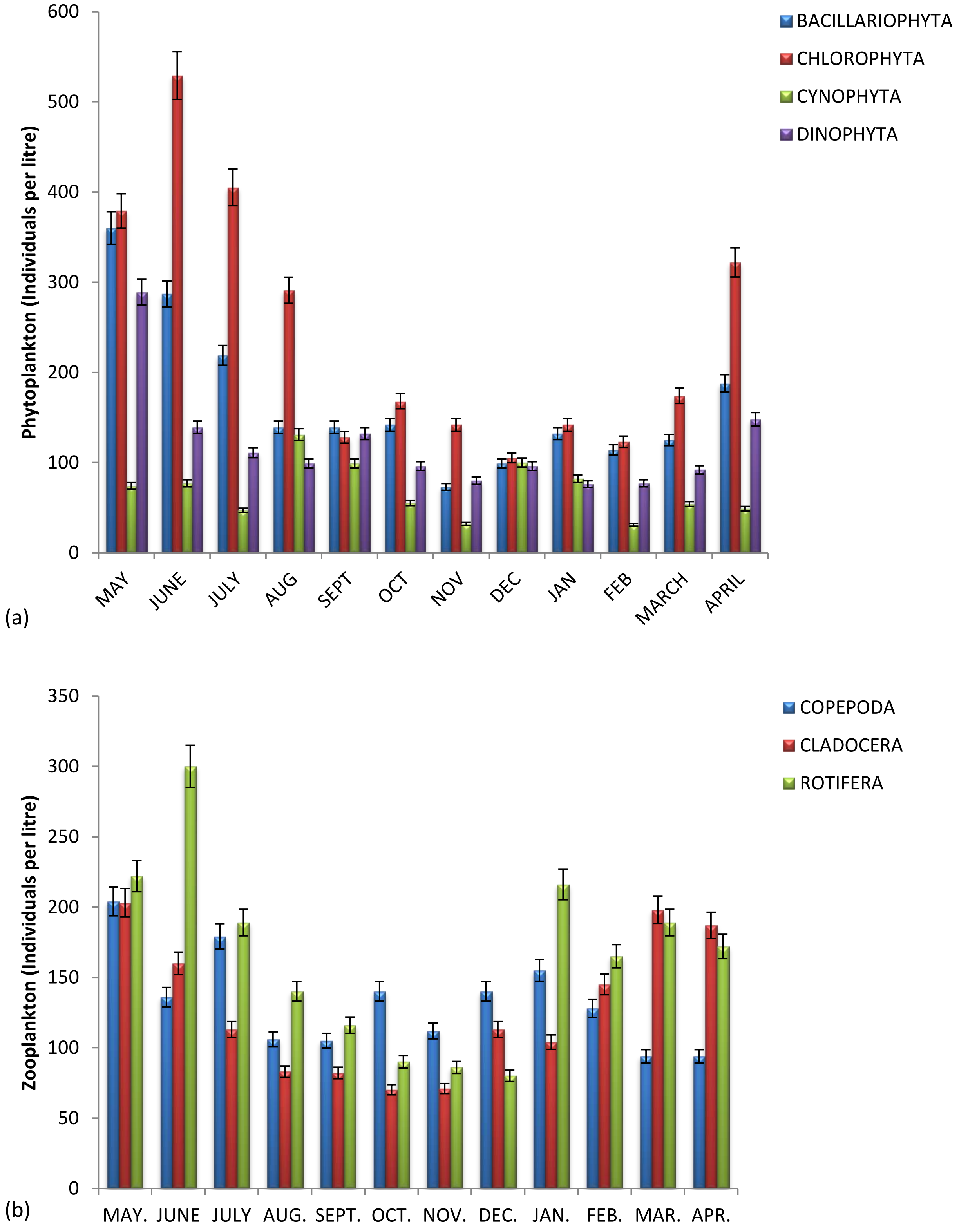

Figure 4.17: Mean Monthly Variations of Various Groups of (a) Phytoplankton and (b) Zooplankton of Yardantsi Reservoir, Gusau

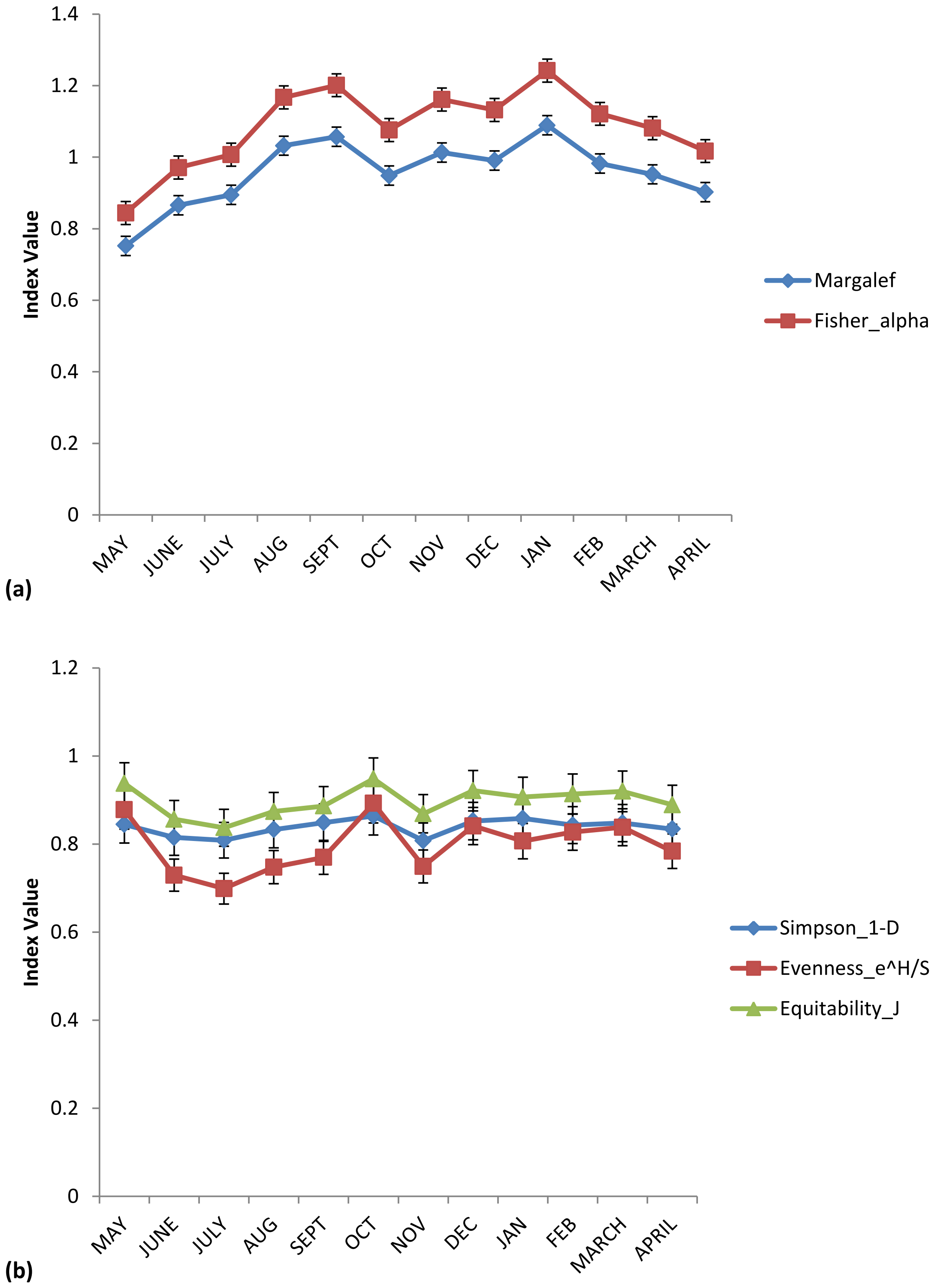

Figure 4.18: Mean Monthly Phytoplankton Indices for Species (a) Richness (Margalef and Fisher_alpha) and (b) Evenness (Simpson_1-D, Evenness_e^H/S and Equitability_J) of Yardantsi Reservoir, Gusau

4.7.3 Cluster analysis for different phytoplankton species

The Cluster analysis group phytoplankton species based on close similarities in terms of species composition and abundance per sampling month; species were clustered in to three main clusters with *Cosmarium* sp. clustered at Euclidean similarity value of 0.33, followed by *Microcystis* sp. at Euclidean similarity value of 0.66, while the rest (*A. formosa*, *C. hirundinella, C. teridenella, O. limosa, Oosystis* sp., *S. ulna, C. timida, Palmella* sp. and *Spirogyra* sp. were clustered at Euclidean similarity value of 0.76 and above (Fig. 4.20).

4.7.4 Canonical correspondence analysis (CCA) for various phytoplankton species

CCA shows the interrelationship between the phytoplankton species and physicochemical parameters in relation to months (Fig. 4.21). The first two CCA components accounted for 52.17% and 20.43% respectively, making a total of 72.61% of the total percentage variance observed. Component one revealed that all the phytoplankton species with the exception of *Oosystis* sp. and *C. teridinella* exhibited a positive correlation with pH, sulphate, PO_4-P, NO_3-N, depth and temperature, in rainy seasons, and a negative correlation existed with dissolved oxygen, biological oxygen demand, electrical conductivity, transparency, chloride, hardness, alkalinity, and total dissolved solid in dry season, while component two shows that certain species with the exception of *Microcystis* sp., *Oosystis* sp. and *Cosmarium* sp. showed a positive correlation with PO_4-P, total dissolved solid, temperature, electrical conductivity, transparency, chloride, hardness and alkalinity in the tail end of dry season (i.e. from February to April) as well as the early part of rainy season (i.e. from May to July) and then a negative correlation existed with dissolved oxygen, biological oxygen demand, NO_3-N, sulphate, depth and pH in the tail end of rainy season (i.e. from August to October) as well as the early part of dry season (i.e. from November to January).

4.8 Zooplankton Composition, Distribution and Abundance

The total zooplankton composition and mean monthly variation of zooplankton species of Yardantsi reservoir are presented on Appendix XVII, which revealed a significant difference between months at $p<0.05$.

Zooplankton exhibited a highly positive significant correlation with PO_4-P, potassium, cadmium, copper, lead, zinc and phytoplankton ($p<0.01$), but a positive significant correlation existed with dissolved oxygen, alkalinity, chloride, chromium and iron ($p<0.05$). A highly negative significant correlation existed with temperature and calcium ($p<0.01$), and a negative significant correlation with electrical conductivity ($p<0.05$). (Appendix VI and IX).

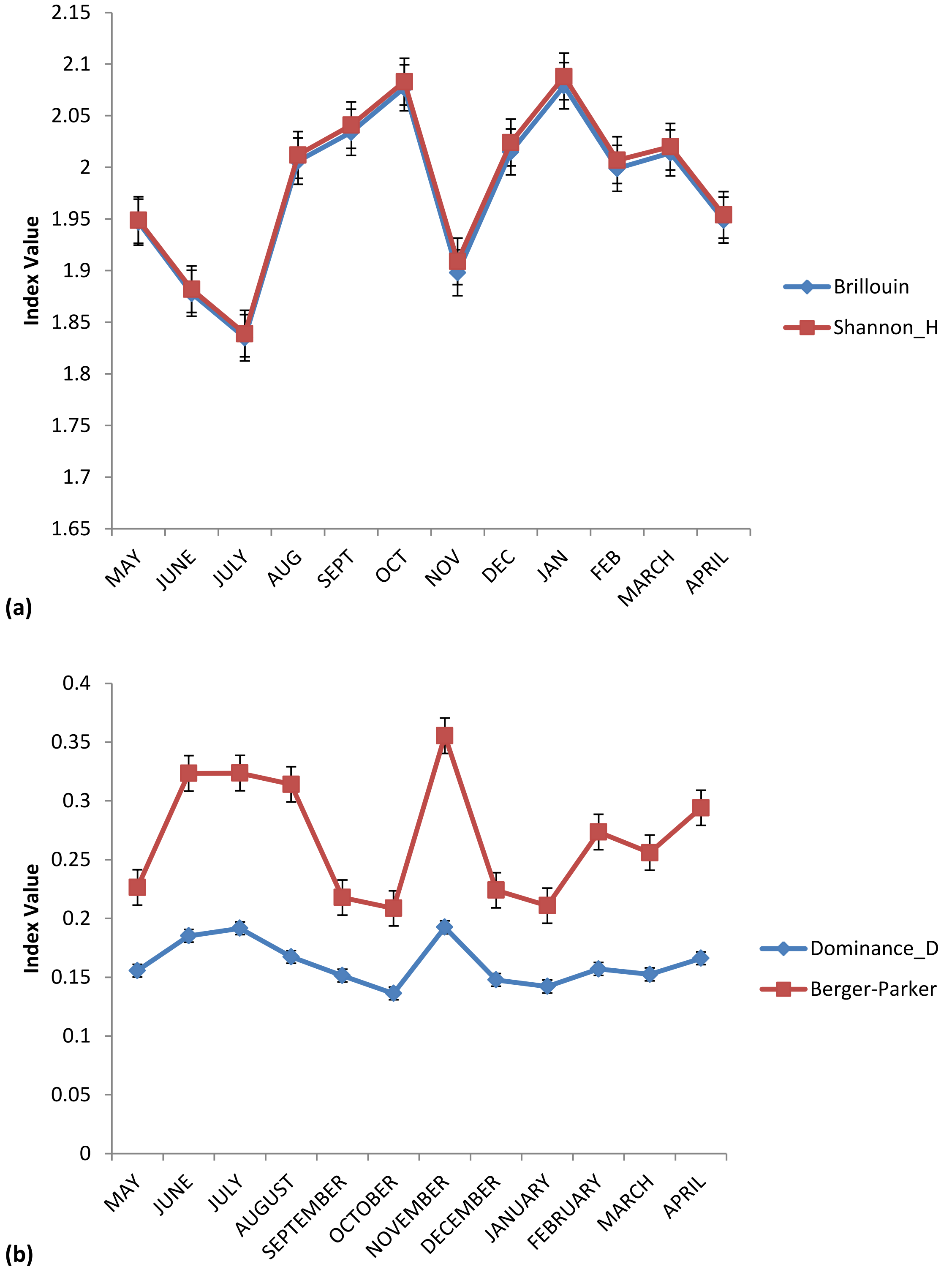

Figure 4.19: Mean Monthly Phytoplankton Indices for Species (a) Diversity (Brillouin and Shannon_H) and (b) Dominance (Dominance and Berger-Parker) of Yardantsi Reservoir, Gusau

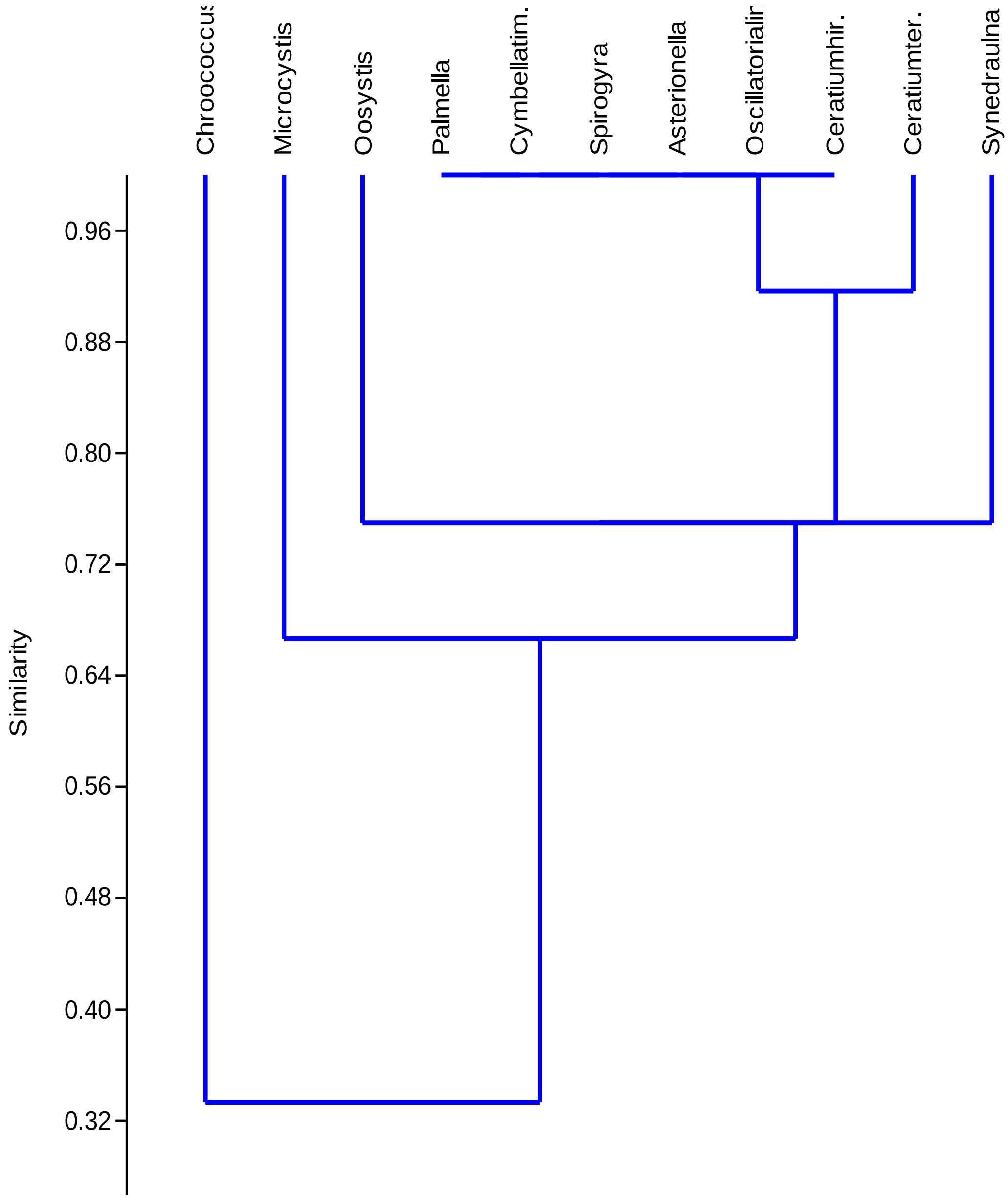

Figure 4.20: Cluster Analysis Based on Jaccard Similarity Measure at 95% Concentration Ellipse Level for Different Phytoplankton of Yardantsi Reservoir, Gusau

4.8.1 Monthly zooplankton species structure

Thirteen species were identified with their relative percentage abundance (Appendix XVIII), belonging to three dominant groups of zooplankton were found in the reservoir; Copepoda, Cladocera and Rotifera accounting for 32.88%, 31.33% and 35.79% for dry season and 33.99%, 29.66% and 36.35% for rainy season respectively. Cladocera and Rotifera recorded the highest percentage in rainy season, while Copepoda recorded the highest percentage in dry season. The relative percentage abundance of the groups are illustrated in Fig. 4.16b. The number of individuals per litre that made up the groups of the zooplankton identified were presented in Appendix XVII. Mean monthly number of zooplankton ranged from 269 to 564 individuals per litre in November and June respectively. Their density was higher in the rainy season than in dry season.

4.8.1.1 *Copepoda*

Mean monthly number of Copepoda ranged from 94 to 204 individuals per litre in April and May respectively (Fig.4.17b). Four species of Copepoda were identified, which include; *Cyclops* sp. (Plate VII**)** were present throughout the seasons, accounting for 15.57% and 4.69% in dry and rainy season respectively; *Diaptomus* sp. were also present throughout the seasons, accounting for 10.51% and 13.67% for dry and rainy season respectively; *Eubranchipus* sp. were only present during rainy season represented by 6.47% and *Thermocylops* sp. (Plate VIII) were present throughout the seasons, accounting for 6.80% and 9.16% in dry and rainy season respectively, out of the total zooplankton composition (Appendix XVIII).

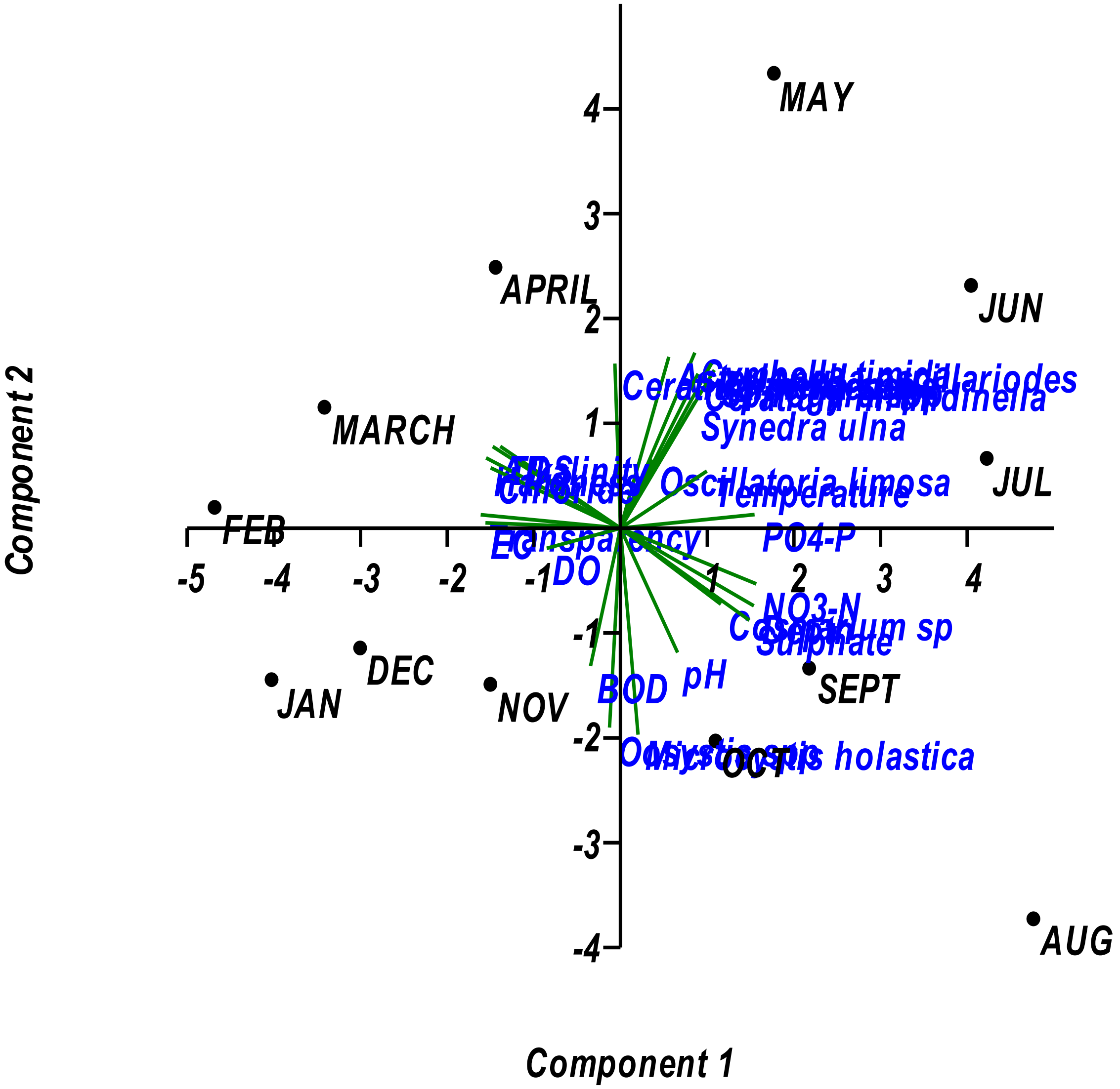

Figure 4.21: Canonical Correspondence Analysis (CCA) Triplot for Phytoplankton and Physico-Chemical Parameters of Yardantsi Reservoir, Gusau

4.8.1.2 *Cladocera*

Mean monthly number of Cladocera ranged from 70 to 203 individuals per litre in October and May respectively (Fig.4.17b). Five species of Cladocera were identified, which include; *Ceriodaphnia* sp. (Plate IX) were only present from January through August, accounting for 3.20% and 4.90% for dry and rainy season respectively; *Daphnia* sp. were present throughout the seasons except in May and June, accounting for 17.66% and 9.77% for dry and rainy season respectively; *Diaphanosoma* sp. disappeared during the tail end of rainy season and reappeared in the tail end of dry season accounting for 4.05% and 5.87% for dry and rainy season respectively; *Eurycercus* sp. were only present during rainy season represented by 8.63% and *Macrothrix* sp. disappeared during the tail end of rainy season and reappeared in dry season, accounting for 6.42% and 2.29% for dry and rainy season respectively, out of total zooplankton composition (Appendix XVIII).

4.8.1.3 *Rotifera*

Mean monthly number of Rotifera ranged from 80 to 300 individuals per litre in December and June respectively (Fig.4.17b). Four species of Rotifera were identified, which include; *Brachionus patulus* Müller (*B. patulus*) were present throughout the seasons, accounting for 6.23% and 1.74% for dry and rainy season respectively; *Chromogaster* sp. disappeared during the tail end of rainy season and reappeared in the middle of dry season, accounting for 8.68% and 8.43% for dry and rainy season respectively; *Kellitela* sp. disappeared throughout the rainy season except for June and reappeared throughout the dry season, accounting for 3.45% and 4.64% for dry and rainy season respectively and *Keratella quadrata* Müller (*K. quadrata*) (Plate X) were present throughout the seasons, accounting for 17.43% and 21.54% for dry and rainy season respectively, out of total zooplankton composition (Appendix XVIII).

4.8.2 Monthly diversity indices of zooplankton

Indices of species richness (Margalef and Fisher_alpha) (Appendix XIX) generally showed a similar trend among the months. These indices revealed that species richness was higher in June and lower in October for both indices (Fig. 4.22a).

Indices of evenness in the distribution of zooplankton species (Simpson_1-D, Evenness_e^H/S and Equitability_J) were observed to show similar pattern of variation among months, (Appendix XIX) showing a decline in August for Simpson_1-D, Evenness_e^H/S and Equitability_J and the distribution reaches peak in September for both indices (Fig. 4.22b).

Brillouin and Shannon_H Diversity indices were also found to follow the same pattern with a declined in October and a peak was attained in June (Fig.4.23a).

Indices showing the level of dominance of species (Dominance and Berger-Parker) observed the same pattern which revealed that a peak was attained in August and a declined in February for Berger-Parker and then June for Dominance (Fig. 4.23b).

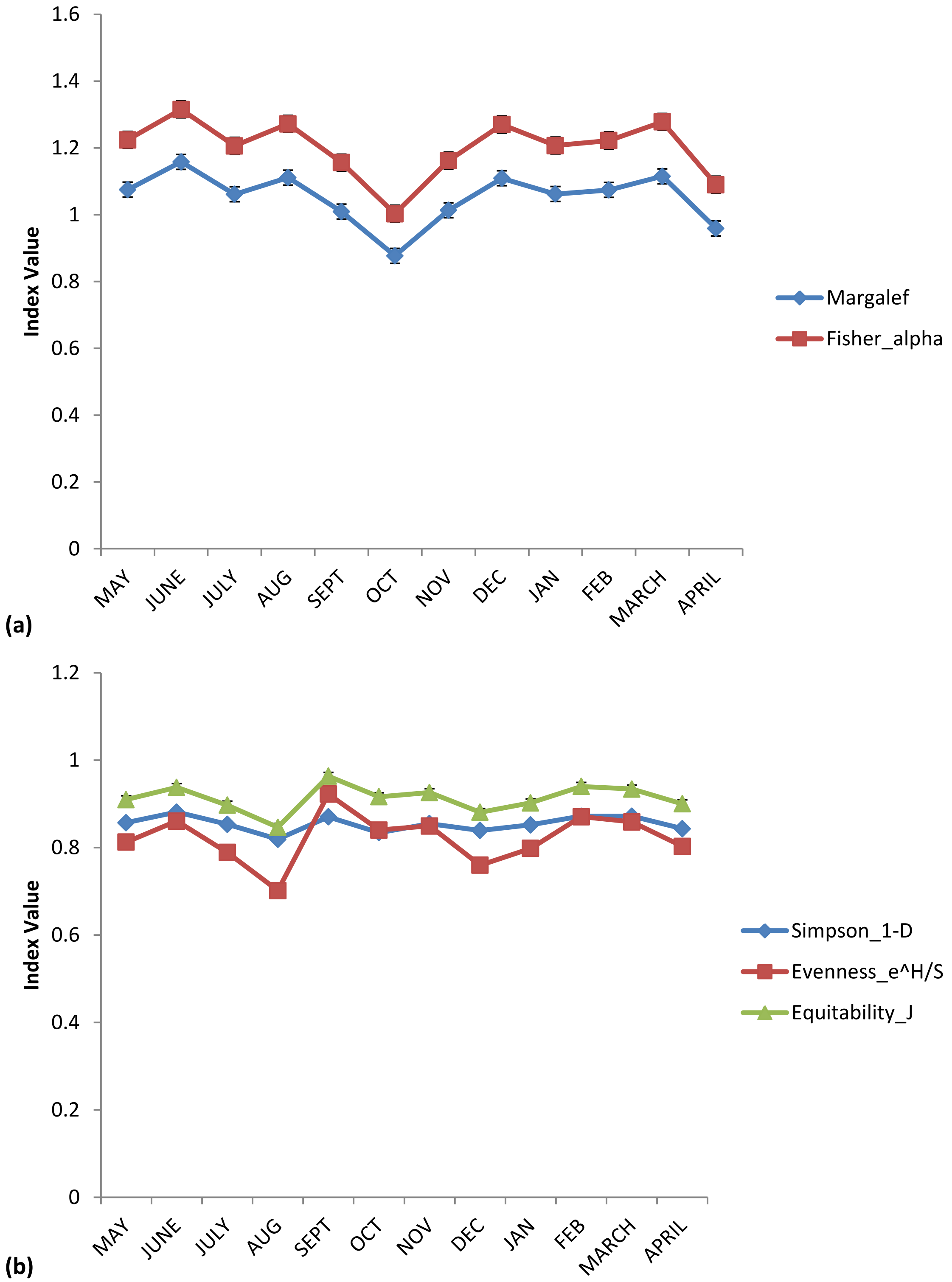

Figure 4.22: Mean Monthly Zooplankton Indices for Species (a) Richness (Margalef and Fisher_alpha) and (b) Evenness (Simpson_1-D, Evenness_e^H/S and Equitability_J) of Yardantsi Reservoir, Gusau

4.8.3 Cluster analysis for zooplankton species

The Cluster analysis group zooplankton species based on close similarities in terms of species composition and abundance per sampling month; species were clustered in to three main clusters with *Eubranchipus* sp.clustered at Euclidean similarity value of 0.40, followed by *Eurycercus* sp. at Euclidean similarity value of 0.42, while the rest (*Cyclops* sp., *Daphnia* sp., *Chromogaster* sp., *Macrothrix* sp., *B. patulus, Ceriodaphnia* sp., *Diaphanosoma* sp., *Kellitela* sp., *Thermocylops* sp., *Diaptomus* sp. and *K. quadrata*) were clustered at Euclidean similarity value of 0.48 and above (Fig. 4.24).

4.8.4 Canonical correspondence analysis (CCA) for zooplankton species

CCA shows the interrelationship between zooplankton species and physicochemical parameters in relation to months (Fig. 4.25). The first two CCA components accounted for 47.527% and 17.11% respectively, making a total of 64.637% of the total percentage variance observed. Component one revealed that all the zooplankton species with the exception of *Eubranchipus* sp. exhibited a positive correlation with pH, PO_4-P, NO_3-N, sulphate, depth and temperature, in rainy seasons, and then a negative correlation existed with dissolved oxygen, biological oxygen demand, chloride, transparency, hardness, alkalinity, electrical conductivity and total dissolved solid in dry season, while component two shows that certain species (*Dapnia* sp., *B. patulus, K. qudrata, Thermocyclops* sp., *Ceriodaphnia* sp. and *Eubranchipus* sp.) shows a positive correlation with dissolved oxygen, biological oxygen demand, chloride, PO_4-P,NO_3-N, depth, pH and sulphate in the early part of dry season (i.e. from November to February) as well as the middle part of rainy season (i.e. from June to August) and then a negative correlation existed with transparency, hardness, alkalinity, electrical conductivity and temperature at the tail end of the dry season (i.e. March to April) as well as at the beginning and then the end of the rainy season.

4.9 Fisheries Potentials

The mean seasonal variation for potential fish yield of the reservoir is presented in Table 4.7. All stations have higher yield in dry season than in rainy season. There is a significant high yield (52.98kg/ha) in station four during dry season of year two, while in the rainy season, all stations showed a significantly high yield in the rainy season of year two than year one ($p<0.05$). The mean monthly variation for stations of Yardantsi reservoir is shown on Fig. 4.26, which revealed that station four recorded the highest fish yield in February, while station two and three recorded the lowest fish yield in August.

Morpho edaphic index exhibited a highly significant positive correlation with transparency, total dissolved solids, electrical conductivity, dissolved oxygen, alkalinity, hardness, and chloride ($p<0.01$). A highly negative significant correlation existed with temperature, mean depth, nitrate-nitrogen, phosphate-phosphorus, sulphate and phytoplankton ($p<0.01$).

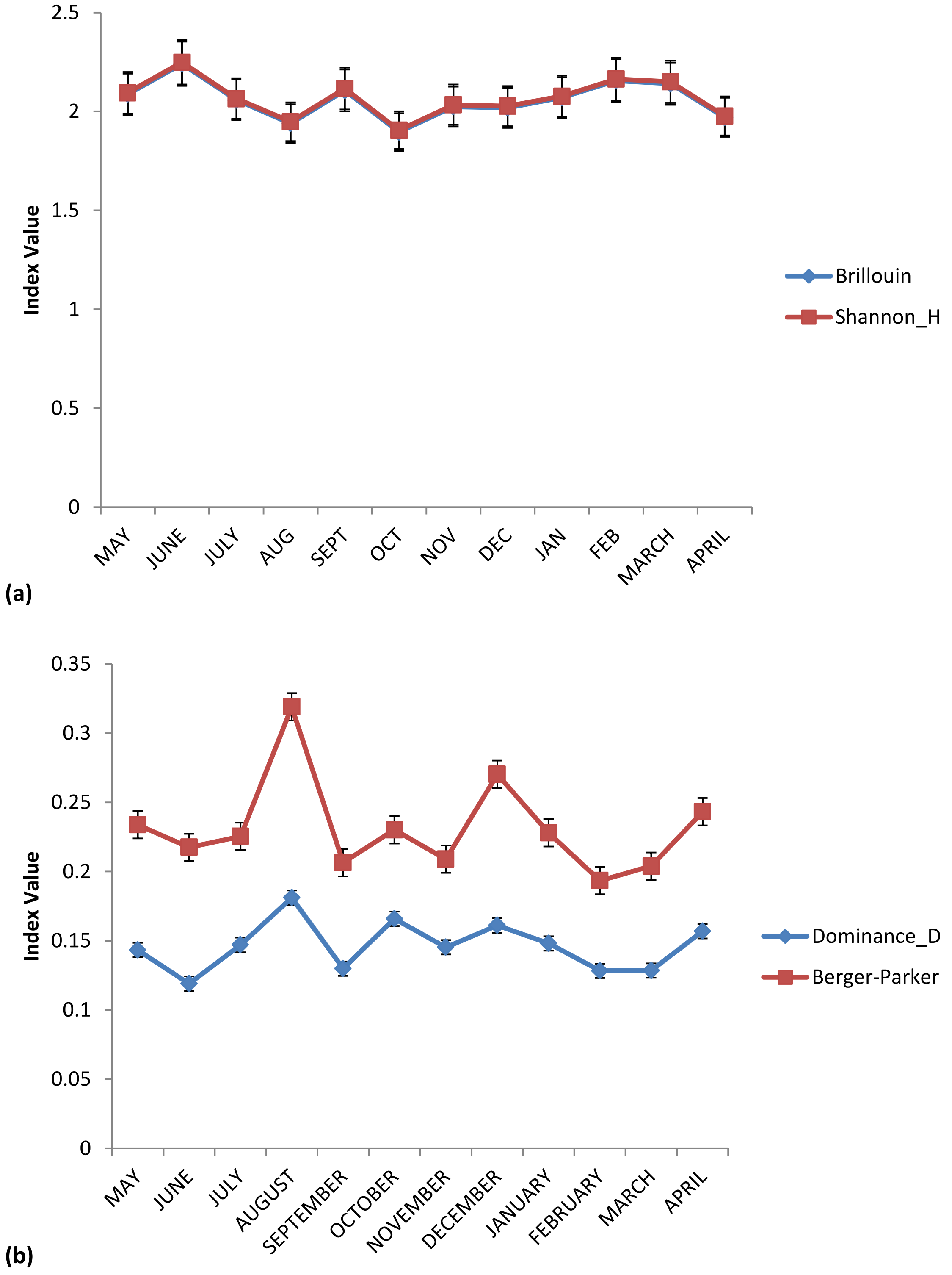

Figure 4.23: Mean Monthly Zooplankton Indices for Species (a) Diversity (Brillouin and Shannon_H) and (b) Dominance (Dominance and Berger-Parker) of Yardantsi Reservoir, Gusau

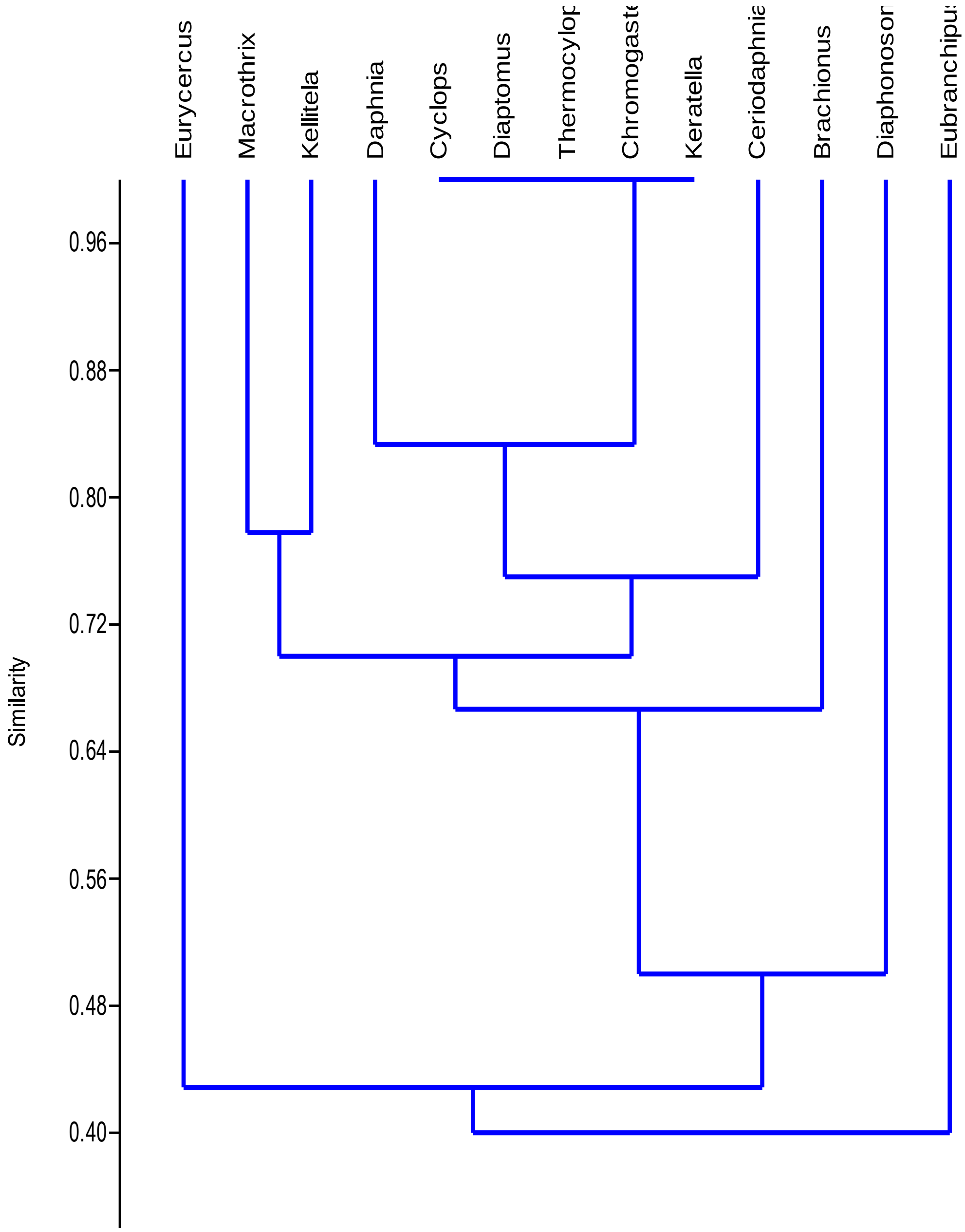

Figure 4.24: Cluster Analysis Based on Jaccard Similarity Measure at 95% Concentration Ellipse Level for Different Zooplanktons of Yardantsi Reservoir, Gusau

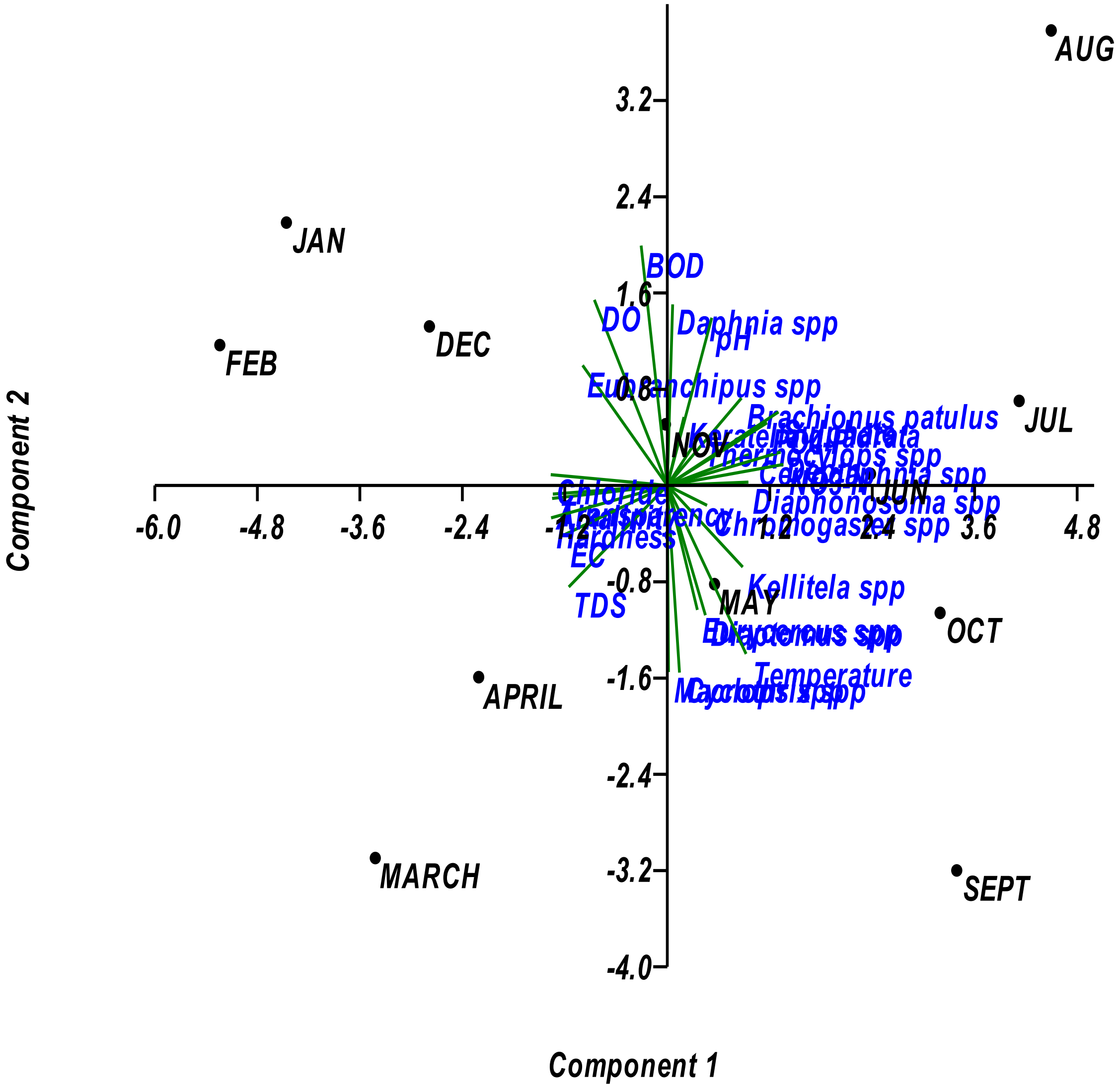

Figure 4.25: Canonical Correspondence Analysis (CCA) Triplot for Zooplankton and Physico-Chemical Parameters of Yardantsi Reservoir, Gusau

Table 4.7: Mean (±SE) Seasonal Variation of Fish Yield for Different Sampling Stations of Yardantsi Reservoir, Gusau

STATION	DRY SEASON		RAINY SEASON	
	Year 1 (Kg/ha)	Year 2 (Kg/ha)	Year 1 (Kg/ha)	Year 2 (Kg/ha)
1	51.62±4.04$_a$	49.41±3.87$_a$	21.31±4.93$_a$	30.18±4.88$_b$
2	43.98±3.44$_a$	39.08±3.58$_a$	19.94±4.81$_a$	27.87±4.33$_b$
3	45.66±3.82$_a$	46.23±3.13$_a$	20.20±5.72$_a$	28.65±5.86$_b$
4	44.86±4.35$_a$	52.98±5.37$_b$	18.54±4.53$_a$	30.82±5.18$_b$
5	43.35±3.00$_a$	46.57±3.25$_a$	19.24±4.69$_a$	29.28±5.89$_b$

Note; Mean values with the same superscript along the row were not significantly different (p>0.05)

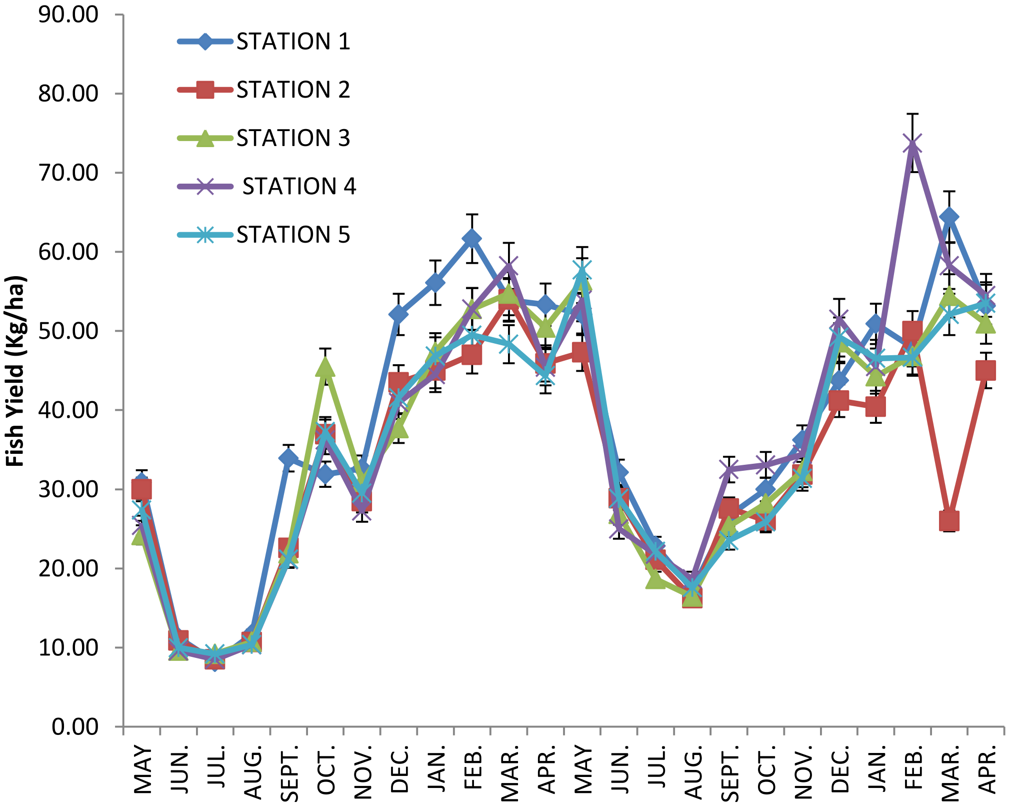

Figure 4.26; Mean Monthly Fish Yield Variation for Different Sampling Stations of Yardantsi Reservoir, Gusau

CHAPTER FIVE

5.0 DISCUSSION

This study was carried out to determine the spatial and temporal changes in the physico-chemical parameters, plankton and potential fish yield of Yardantsi reservoir Gusau. The physico-chemical parameters measured served as indicators of water quality and the suitability for fish production potentials, while the relative abundance and diversity of the biota may be considered as biological indicators as available food sources for higher trophic level like fish. Variation of these parameters may be attributed to catchment characteristics such as human activities like agriculture, deforestation along with other climatic factors such as wind and rainfall and their effects on the reservoir were also considered. Environmental variables influence the nature, composition and distribution of the planktonic communities, the trophic status and the various interaction of the reservoir with respect to different components.

5.1 Physico-Chemical Parameters

Physico-chemical parameters were determined to establish the water quality status and their impact on the aquatic biota. Pace *et al.* (2012) and Lar (2013) reported that catchment area activities are the most prominent determinants of water quality in aquatic systems.

Surface water temperatures are related to the seasonal impacts on the water regime as characterised by distinctive rainy and dry seasons. The variation in water temperature may result from either natural events or human-induced events. Temperature is also important because of its influence on water chemistry. The rate of chemical reactions generally increases at higher temperature. Water, particularly groundwater, with higher temperatures dissolves more minerals (Hai *et al.,* 2013).

The lower water temperature in December through February (Fig. 4.1a) could be attributed to the seasonal changes in air temperature resulting from the North-East trade winds popularly known as "Harmattan" which is typical of the season. This agrees with the findings of Balarabe (1989); Adakole (1995); Zelalem (2013); Magami *et al.,* (2014) and Shanur *et al.* (2015) in their studies on Makwaye Lake, Zaria; River Kubanni, Zaria; Lake Adale, Ethiopia; Shagari Reservoir and River Dakatia, Bangladesh, respectively. The moderately higher temperature as observed may be due to an increasing photoperiod and longer day, this agrees with the findings of Hai *et al.* (2013) and Mohan *et al.* (2013) in their studies on Lake Taihu, China.

The declined in surface water hydrogen ion concentration (pH) was observed in March (Fig. 4.2a), i.e. the tail end of dry season and that dry season has lower pH concentration than in the rainy season, which may be due to high rate of evaporation which increases the concentration of salts. This agrees with the findings of Ideriah *et al.* (2012), Magami *et al.* (2014) and Zelalem (2015) in their studies on Abonnema Shoreline, Nigeria; Shagari Reservoir and River Dakatia, Bangladesh respectively.

The relatively circum neutral nature of the water pH between seasons and the slight fluctuation to alkaline conditions could be regarded as normal, since the range of 6.5 to 8. 5 (NSDWQ, 2007); as obtained in this study is safe for consumption and therefore support aquatic life, including fisheries and is desirable range for fish production as reported by Adakole (1995) and Mohan *et al.* (2013). The values obtained were within the maximum permissible limits (MPL) set by Nigerian standard for drinking water quality (NSDWQ, 2007) and in relation to this the water is considered safe for human consumption and biota with respect to pH concentration. The observed variations in pH among seasons may be due to non-point source inflow of wastewater from residential areas, markets, surface run off from agricultural area; geology of the stream bedrock; as well as the hydrobiology of the catchment (Mahananda *et al.,*2010; Hassan, 2014a; Fan and Shibata, 2015; Gara and Staphanian, 2015).

The observed higher pH values in the rainy season could be attributed to the surface run off of alkaline substances i.e. the components of artificial fertilizers of alkaline earth metals in origin in the form of NPK, NH_3 $(NO_3)_2$ etc. from the catchment areas, while variation in activities such as agricultural and municipal could lead to the variation in surface water pH between the seasons and years. This agrees with the finding of Jafari and Ginale (2006).

Transparency was observed to be higher in the dry season than the rainy season (Table 4.1). The lower transparency observed during rainy season could be attributed to increase in the soil erosion, surface runoff and siltation from the catchment as well as the timely discharge of the water to control the reservoir capacity during rainy season thereby mixing the surface water with bottom water and the sediment. This also correlates significantly with the higher density of phytoplankton in rainy season, which may alter the transmission of light across water body. Similar findings were reported by Asani (2007) and Magami *et al.* (2014) in their studies on Water reuse, New York, and Shagari Reservoir respectively. Adakole (1991) in his study on River Kubanni, Zaria reported that the low light transmittance observed in all the sampling stations with the onset of the rains between July and September could be attributed to flood water, increased erosion and soil washings in to the river. Balarabe (1989) in his study on Makwaye Lake, Zaria also reported that the initial fall in pH during the early part of the rainy season may be due to decomposition of organic matter which coincided with the lower oxygen and higher biological oxygen demand (BOD).

Lower concentration of electrical conductivity in the rainy season coincided with lower total dissolved solids concentration (Table 4.1). This may be attributed to the dilution of the water as the volume increases during rainy season and continues discharge of the water to maintain a certain capacity or volume of the reservoir in prevention of flood, as the reservoir is gated. This agrees with the findings of Devangee *et al.* (2013) and Magami *et al.* (2014), in their studies on Kankariya, Vastrapur, Malav, and Chandola Lake, India, and Shagari Reservoir, respectively. Balarabe (1989) and Adakole (1995) in their studies on Makwaye, Lake and River Kubanni, Zaria respectively reported that lower values of electrical conductivity obtained in the rainy season may be due to dilution of the water. The values obtained were within the MPL sets by NSDWQ (2007) and in relation to electrical conductivity and total dissolved solids the water is considered safe for human consumption.

The gradual rise in conductivity as the dry season (Table 4.1) progressed could be attributed to the increase in the concentration of ions due to draw down in the water volume of the Reservoir sampled. Balarabe (1989) attributed the gradual rise in conductivity to the decrease in water volume during dry season in his limnological study of Makwaye Lake, Zaria. Increase in electrical conductivity results to increase in total dissolved solids and turbidity but a decrease in the plankton's composition. This also coincides with the rise in surface water temperature, which is also important because of its influence on water chemistry. The rate of chemical reactions generally increases at higher temperature. Water, particularly groundwater, with higher temperatures can dissolve more minerals from rocks. This agrees with the findings of Adakole (1995) that elevated concentration of total dissolved solids enhances the toxicity of other chemicals in water thereby negatively affecting the biota communities.

Meays and Nordin (2013) reported that conductivity is the measure of electricity conducting ions (both anions and cations such as ions of hydrogen, nitrates, phosphates, sodium, chlorides) in a water system. Sigler and Bauder (2015) reported that total dissolved solids, basically is the sum of all minerals dissolved in the water system. These include carbonate, bicarbonate, chloride, fluoride, sulphate, phosphate, nitrate, calcium, magnesium, sodium, and potassium, but other ions dissolved in the water could also contribute to the total dissolved solids observed. Meays and Nordin (2013), added that, compounds of soil organic matter such as humic and or fulvic acids are also vital components of total dissolved solids.

Highly significant positive correlation ($p<0.01$) was observed between total dissolved solids and transparency, electrical conductivity, alkalinity, hardness; this is in line with the findings of Adakole (1995) that estimation of total ionic matter in the water is related to water fertility.

The highest dissolved oxygen concentrations were observed in December through February (Fig. 4.3a), which coincided with lower surface water temperature. This observation could be attributed to the seasonal changes in air temperature resulting from the North-East trade winds (Harmattan) which is typical of the season. These findings are in agreement with the Devangee *et al.* (2013) and Magami *et al.* (2014) in their studies on Kankariya, Vastrapur, Malav, and Chandola Lake, India and Shagari Reservoir respectively.

In his limnological study, Adakole (1995) reported that highest oxygen concentrations in February coincided with the minimum water temperature, due to the cool harmattan winds. Balarabe (1989) also reported that oxygen saturation was generally above 50% throughout the seasons and that dissolved oxygen was generally higher during dry season than rainy season. The values obtained are within the MPL. Also, APHA (2005) explained that dissolved oxygen concentration of above 5 mg/L is suitable for the support of diverse biota. A significant positive correlation existed between dissolved oxygen, total dissolved solids and composition of zooplankton available ($p<0.05$). Highly significant positive correlation existed with transparency, electrical conductivity, biological oxygen demand, alkalinity, hardness and chloride ($p<0.01$).

Meays and Nordin (2013) reported that the important factors that control the dynamics in surface water dissolved oxygen concentration include; temperature, atmospheric pressure, photosynthetic activities of algae, cynobacteria and aquatic macrophytes. The highest dissolved oxygen concentrations were recorded in January which coincided with minimum temperature observed (Appendix IV).

Biological oxygen demand concentration was observed to be significantly higher in dry season at 0.05 level (Table 4.1), which could be attributed to the activities (oxygen consumption) of decomposers and draw down in water level caused by evaporation and other factors. A highly significant positive correlation existed with transparency and dissolved oxygen ($p<0.01$). The variations between seasons were significant at $p<0.05$; this could be due to inflow of organic pollutants along with surface runoff. This agrees with the findings of Hassan *et al.* (2014a) and Tanimu (2015) in their studies on River Kaduna and Hussainiya River, Holy Karbala-Iraq and Tudun Wada-Makera Drain respectively. Chukwu *et al.* (2012) reported that low dissolved oxygen concentration in polluted water is due to demand aerobic bacteria (BOD) and oxidative processes chemical species (COD) in the process of ultra-filtration.

Tanimu (2015) reported that significant higher BOD concentration observed in wet season may be attributed to inflow of organic pollutants along with surface runoff and increase in water residency time during the dry season could increase the rate of water purification by algae and aerobic bacteria, thus improving water quality by the reduction of BOD.

The significantly higher concentrations of surface water hardness ($p<0.01$) as observed in the dry season (Table 4.1) coincides with alkalinity. This could be attributed to increase in concentration of nutrients due to draw down in water level of the reservoir and action of wind which enhances the resuspension of sediment calcium and magnesium ions. The rainy season hardness could be attributed to components of artificial fertilizer of alkaline earth metals origin (NPK, NH_3 etc.) and or pesticide and herbicides from the catchment area runoff.

As observed, the lowest hardness was in August and a gradual increase from September to October (Appendix IV) which coincided with the end of rainy season which is characterized by lesser rains as well as dilution. The sharp fall in hardness and alkalinity with the onset of the rains could be possibly due to dilution. This is not in agreement with the findings of Balarabe (1989) in his study on Makwaye Lake, where he reported that higher water hardness during rainy season could be attributed to the components of artificial fertilizer of alkaline earth metals origin. He also added that the gradual rise in hardness in spite of dilution from July to October coincided with the period of fertilizer application. Meays and Nordin (2013) reported that the inflow of acidic substances during the rainy season from surface runoff, or from the atmosphere could be the reason for the significantly lower alkalinity observed in the rainy season. Gadzama and Mondo (2011) in their limnological studies on the malaco fauna of two major man-made lakes in Zaria, Nigeria reported that the high alkalinity in the dry season increases the quantitative capacity of the lakes to neutralize acidic condition. This may improve the conduciveness of the environment for aquatic molluscs. However; increased dilution from rain water could be responsible for the low values observed in the rainy season.

Hardness and alkalinity exhibited a highly positive correlation with MEI, a highly negative correlation with Phytoplankton at $p<0.01$ and the alkalinity exhibited a positive correlation with Zooplankton (Appendix VI). Adakole (1995), reported that fish production prepare a moderate hard waters with concentration of 75-150mg/L and above (Wetzel, 2001). In this studies the concentrations obtained was lower in both seasons which is suggestive of its low productivity with respect to hardness.

The surface water nitrate-nitrogen recorded the higher concentrations in the rainy season (Table 4.1); this coincided with the phosphate-phosphorus and sulphate which could be attributed to surface runoff from the catchment areas exposed to inorganic fertilizers and or due to the decomposition of sediment organic matter which resulted in the release of nitrate and other minerals in to the water body. This agrees with the findings of Balarabe (1989) and Tanimu (2015) in their studies on Makwaye Lake and Tudun Wada-Makera Drain and River Kaduna respectively. Mohammad *et al.* (2014) reported that nitrate-nitrogen in Kusalla Reservoir ranged from 5.6 to 10mg/L. The concentration was higher in the onset of the rainy season. This could be due to runoff from the farmlands into the reservoir, as a result of fertilizer application by farmers in the catchment area. Auro and Cochlan (2013) also reported that phosphorus can be introduced in to the environment in the form of phosphoric acid, phosphate fertilizers, phospholipids in dead tissues while nitrogen can be introduced to the environment in the form of urea and nitrate fertilizers, urine and other forms. The values obtained were within the MPL sets by NSDWQ (2007) and in relation to this, the water is considered safe for human consumption. Alhassan (2015) reported that the variation in nitrate concentration reflects the effects of human activities on various sections of the reservoir and that nitrate was found to have effects on the chemical properties and macrobenthic invertebrate composition and abundance in the reservoir.

Chloride concentration in surface water was found to be significantly higher in dry season than the rainy season (Table 4.1) for both years ($p<0.01$). This may be attributed to draw down in the water level, which coincided with the increase in electrical conductivity and total dissolved solids concentrations. Gadzama and Mondo (2011) in their limnological studies on the Malaco fauna of two major man-made Lakes in Zaria, Nigeria reported that the high concentration of chloride, sulphate and nitrate salts in the lakes is important for the metabolic activities in the molluscs and that the higher concentration of chloride in the rainy season is important for the metabolic activities in the biota. They also reported that the variability of the physico-chemical parameters in the rainy seasons could be as a result of enrichment of the lakes from ingress of rain water from surrounding farms after heavy down pour. The values obtained were within the MPL sets by NSDWQ (2007) and in relation to this the water is considered safe for human consumption. Chloride exhibited a highly positive correlation with dissolved oxygen ($p<0.01$). Meays and Nordin (2013) reported that sulphate occurs naturally in the aquatic environment or it may have an anthropogenic origin as a salt of calcium, iron, sodium, or magnesium.

5.2 Trace and Alkali-alkaline Earth Metals

The concentrations of trace and alkali-alkaline earth metals in the reservoir may be attributed to the nature of the catchment areas, ground water loading and the components of the various types of fertilizers, pesticides, herbicides and atmospheric sources (burning of fuels) which find their way through surface runoff. During rainy season alkali-alkaline earth metals (Ca, K, Mg, Na etc.) which form the bulk of fertilizers find their way in to the water bodies through surface runoff. This could be shown by their higher concentration in relation to other metals. Incorporation of metals in to the sediment could be attributed to elements chemisorption. Control of the solubility of these metals could involve mineral equilibria controlled by pH as decrease in pH favours the retention time of some metals in the free water. Temperature is also an important factor because of its influence on water chemistry. The rate of chemical reactions generally increases at higher temperature. Water, particularly groundwater, with higher temperatures can dissolve more minerals from the rocks.

Balarabe (1989), reported that metals concentration also depend on certain physico-chemical parameters acting on the water or sediment most especially pH and temperature. Similarly, Chia *et al*. (2013) reported that effluents from residential areas, markets, industries, as well as surface run-off from urban areas and agricultural areas may be implicated to the high concentration of nutrients observed in sampling stations. These nutrients are vital components of many waste products of biological and chemical processes.

The magnesium concentration was found to be higher in surface water than the MPL (0.20mg/L) set by NSDWQ (2007) in both years (Table 4.2), this may be attributed to the surface runoff which carries along alkali-alkaline earth metals (Ca, K, Mg, Na etc.) which form the bulk of fertilizers, this is typical of the season for both years. The mean seasonal variation was also significant at $p<0.01$ in both the surface water and the sediment (Table 4.6). Rahman *et al*. (2014) reported that simple dilutions of alkaline substances (carbonates and bicarbonates of calcium and magnesium) by rain water or concentration of such substances during the extensive dry season (lasting about six months) could be other reasons for such seasonal variation. Cadmium was also found to be slightly higher than the MPL (0.003mg/L) value sets by NSDWQ (2007) and WHO (2017) throughout the years and seasons for both the surface water and the sediment; this could be attributed to the nature of the catchment areas and ground water loading. Sodium, copper, chromium and zinc were found to have values for both the surface water and the sediment within the MPL sets by FAO (1994), NSDWQ (2007) and WHO (2017).

Nickel mean concentration in the surface water was found to be slightly higher in relation to the MPL sets by FAO (1994), NSDWQ (2007) and WHO (2017) in both the years except for January to March (Appendix VII). The mean seasonal variation was significantly higher for the surface water but the sediment values are within the MPL values for both seasons. This may be attributed to the nature of the catchment areas. Iron and lead were found to have slightly higher value than the MPL sets by NSDWQ and the World Health Organization (WHO, 2017) throughout the years and seasons for the surface water, while for the sediment the values obtained were within the guideline values (Table 4.1).

The sediment had higher concentration of metals (with the exception of sodium) than the surface water (Table 4.5 and 4.6), even though the concentrations are within the guideline values; this could be attributed to the accumulation caused by the sedimentation and or siltation. Some chemicals from agricultural activities (such as; calcium and potassium) have no established guideline values, because they occur in drinking-water or drinking-water sources at concentrations well below those of health concern (WHO, 2017).

WHO (2017) reported that certain chemicals can reach water as a consequence of disposal of general household chemicals; in particular, a number of heavy metals may be found in domestic wastewater. Where wastewater is treated, these will usually partition out into the sludge. Some chemicals that are widely used both in industry and in materials used in a domestic setting are found widely in the environment, e.g. di (2-ethylhexyl) phthalate and these may be found in water sources, although usually at low concentrations. Where latrines and septic tanks are poorly sited, these can lead to contamination of drinking-water sources with nitrate.

Balarabe (1989) reported that the control of the Ca, Fe, Mg and Zn solubility could involve mineral equilibria controlled by pH and the solubility of lead sulphate and carbonate may account for the low level of lead. He also added that watershed characteristics such as soil type and subsurface flow may also influence trace elements behaviour.

5.2.1 Sediment metals contamination

The level of sediment metals contamination was assessed by determining contamination factor (C_f values) which revealed that all the metals under consideration (chromium, copper, nickel, lead and zinc) with the exception of cadmium were found to have C_f values less than one ($C_f<1$) in all the sampling months and therefore are said to be low contaminated when compared with Hakanson's classification for the contamination factor and level of contamination and also lower than the proposed TECs, while the cadmium C_f value was greater than six ($C_f>6$) and exceeded TEC, this shows that cadmium is slightly above threshold level. The concentration of these metals in the sediments may be attributed to the fact that the reservoir receives surface runoff which introduces certain pollutants from catchment areas exposed to agricultural activities such as use of fertilizer and some form of pesticides and herbicides. This is in agreement with the findings of Abata *et al.* (2013) and Sabo *et al.* (2013) in their studies on Ala River in South-western – Nigeria and River Delimi Jos, Nigeria respectively. Fishel (2014) reported that agricultural use of products containing copper is also common, especially in pesticides applied in vineyards and orchards.

WHO (2017) reported that the minimum permissible limits of cadmium in drinking water to be 0.003mg/L, concentration above this could be hazardous to health and is toxic to kidney, which could cause kidney failure in humans.

5.3 Biological Characteristics

The aquatic habitat comprises of various communities of biotic and abiotic factors which interact with one another. The biotic component solely depends on the later for their survival. Balarabe (1989) reported that climate is a principal factor governing the seasons through distinct rainy and dry seasons which directly or indirectly alter their environment with individual organisms responding either positively or negatively to these environmental conditions. Environmental variables influenced the density of planktonic communities but did not affect their spatial distribution, which probably resulted from the eurytopic habits of species commonly found in shallow, eutrophic lakes (Tomasz, 2016).

5.3.1 Phytoplankton

Four classes of phytoplankton (viz; Bacillariophyta, Chlorophyta, Cynophyta and Dinophyta) observed in this study accounted for a wide range in diversity of species and number. The distribution and composition of these groups varied with the seasons, with the highest density during the rainy season for Chlorophyta and Cynophyta, while Bacillariophyta and Dinophyta recorded the highest density during the dry season. Phytoplankton showed the following percentage order of abundance: Cholorophyta > Bacillariophyta >Dinophyta > Cyanophyta in both seasons. The variations could be attributed to species resistivity to anthropogenic inputs of the reservoir. This disagrees with the findings of Ali *et al.* (2013) in their studies on Lower Niger River, Kogi State, Nigeria.

C. timida, Palmella sp., *Spirogyra* sp., *A. formosa, O. limosa* and *C. hirundinella* were observed to be present throughout the seasons, even though they were more prominent during the rainy season. However; some species (*S. ulna, Oosystis* sp., *Microcystis* sp. and *C. teridenella*) disappear and reappear in some months of the year while *Cosmarium* sp. disappear during dry season and reappear in rainy season. These could be attributed to the differential response to variation in biological and physiological factors.

Based on percentage composition, Chlorophyta constituted the highest abundance for both dry and rainy seasons (40.42% and 41.33% respectively) to the total phytoplankton population which coincided with the abundance of the Cladocera, this shows that Chlorophytes provide the food supplements for the Cladocerans. These findings are in agreement with the findings of Ariyadej *et al.* (2004) and Mohammad *et al.* (2014). Phytoplankton exhibited a highly positive correlation with nitrate-nitrogen, phosphate-phosphorus and sulphate ($p<0.01$). This revealed that nitrate-nitrogen, phosphate-phosphorus and sulphate stimulate phytoplankton physiology and survival.

CCA on both components revealed that more than 70% of the phytoplankton distribution and abundance were in close association with certain physicochemical parameters of the surface water especially pH, sulphate, PO_4-P, NO_3-N, depth and temperature, in the rainy seasons, this shows that these parameters are determinants of the abundance of certain species of phytoplankton and are necessary for their survival. Chia *et al.* (2011) reported the same in their studies title green algal interactions with physicochemical parameters of some manmade ponds in Zaria, Northern Nigeria. Oniye *et al.* (2014) also reported that phytoplankton and periphyton distribution and abundance was closely related to the physicochemical characteristics of the water especially nitrate and phosphate concentrations, in their studies titled Influence of *Clarias gariepinus* (teugels) cage cultures on water quality, phytoplankton and periphyton composition: a case study of Ahmadu Bello University Reservoir, Nigeria.

5.3.2 Zooplankton

Three classes of zooplankton (viz; Copepoda, Cladocera and Rotifera) observed in this study accounted for a wide range in diversity of species and number. The distribution and composition of these groups varied with the seasons, with the highest density during the rainy season. This agrees with the findings of Sharma *et al.* (2013) in their studies of Temple Pond Birpur India. Zooplankton showed the following percentage order of abundance: Rotifera > Copepoda > Cladocera in both seasons. The variations could be as a result of species resistivity to anthropogenic inputs of the reservoir.

Cyclops sp., *Diaptomus* sp., *Thermocylops* sp., *Chromogaster* sp., and *K. quadrata* were observed to be present throughout the seasons, even though they were more prominent during the rainy season (Appendix XVII), while some Copepoda species (*Ceriodaphnia* sp., *Daphnia* sp., *Diaphanosoma* sp. and *Macrothrix* sp.) and Rotifera species (*B. patulus* and *Kellitela* sp.) disappeared and reappeared in some months of the year. *Eubranchipus* sp. and *Eurycercus* sp. disappeared during dry season and reappeared in rainy season. These could be attributed to the differential response to variation in biological and physiological factors.

Based on percentage abundance of the zooplankton, rotifera constituted the highest abundance for both seasons (35.79% and 43.18% respectively) and Cladocera was the next even though it recorded the highest number of species, this could be attributed to their preferential response to their food. These findings are in agreement with the findings of Sharma *et al.* (2013). Balarabe (1989) reported that based on percentage composition Cladocerans recorded the least even though it has the highest number of genera, thus could be attributed to lack of suitable food for the Cladocera as zooplankton have preferential response to their food supply. The highest percentage abundance of rotifera coincided with that of Chlorophytes; this revealed that rotifers abundance was favoured by the availability of Chlorophytes as their main source of food. Pennak (1978) in his study on fresh water invertebrates of United States reported that cladocera feeds on algae preferably Chlorophytes, protozoa and organic detritus.

Seasonal abundance of zooplankton may be attributed to variations in the physico-chemical parameters as well as abundance and composition of the phytoplankton of the reservoir. The composition and abundance of reservoir plankton's species may be attributed to periodic changes in the ecosystem brought about by seasonal variation in the environmental conditions. These may be directly or indirectly alter the reproduction time and rate depending upon availability of food, competition, predation and mortality as evident by the seasonal fluctuation in plankton density and composition as reported by Balarabe (1989).

According to Shannon diversity index the reservoir has higher diversity of zooplankton than the phytoplankton. A value of this index above three indicates clean water, whereas values fewer than this would indicate pollution (Maiti, 2004) and the higher the value, the greater the diversity. These studies shows that the range of this index for zooplankton and the phytoplankton were from 1.839to 2.088 and 1.905 to 2.248 respectively, which revealed that the reservoir is mildly polluted. The lowest value in wet season could be attributed to sampling methods and increase in volume of water and also the high value in dry season could be attributed to sampling methods and decrease in volume of water. This finding is in line with the studies of Nkwoji and Edokpayi (2013) and Alhassan (2015). The Shanon diversity index in dry season was the lowest while the highest value was recorded in rainy season for both planktons. This could be attributed to the effect of dredging going on at the time of this study and the dilution.

CCA on both components revealed that more than 70% of the zooplankton distribution and abundance were in close association with certain physicochemical parameters of the surface water especially pH, sulphate, PO_4-P, NO_3-N, depth and temperature, in rainy seasons, this shows that these parameters are determinants of the abundance of certain species of phytoplankton and are necessary for their survival. Magami *et al.* (2014) reported the same in their studies on Shagari reservoir.

5.3.3 Fisheries potentials

Monthly data revealed that February had the highest fish yield, which declined gradually from March to August and then rose steeply from September to January. Seasonal abundance of fishes relates to changes in physico-chemical parameters, phytoplankton and zooplankton composition and density (Lindstead *et al.*, 2012).

Higher fish yield of Yardantsi reservoir was recorded in dry season in all stations. This coincides with the higher abundance of certain zooplankton species (*Daphnia* sp., *Macrothrix* sp., *Cyclops* sp., *B. patulus* and *Chromogaster* sp.) in the dry seasons. This could be attributed to the reduction in water volume of the Reservoir; higher transparency which eases their vision as well as chances to locate their food (plankton). Plankton as well as aquatic macrophytes forms the base for the ecological pyramid, that is to say zooplankton feed on the phytoplankton as well as on the detritus. Certain fish species are supported by the phytoplankton and zooplankton composition and abundance and as such serve as natural food thereby supporting a considerable portion of fish yield from the reservoir (Magami, 2011).

Fisheries potentials show a considerable significant correlation at $p<0.01$ with certain water physico-chemical parameters (Transparency, TDS, EC, DO, BOD, Alkalinity, Hardness, and Chloride). This revealed that these parameters determine the growth and survival of the fishes as most aquatic organism has a preferred pH ranges for their survival and the pH is dependants on TDS and EC (Mohan, 2013).

Importance of nutrients (phosphorus and nitrogen) in the growth and abundance of phytoplankton is well recognised; and that nutrients also have direct bearing on the cellular growth of algal flora which as well increases the abundance of zooplankton, so also fish species, which will lead to high fish yield (Panday *et al.*, 2005).

Arunava *et al.* (2008) also reported that the useful planktons were significantly present to support growth in fish, this include; *Oscillatoria* sp. whose play important role in bioremediation (accumulation of cadmium, mercury and lead) and *Synedra* sp. whose role in bioremediation is to control intracellular accumulation of mercuric chloride.

CHAPTER SIX

6.0 SUMMARY, CONCLUSION AND RECOMMENDATION

6.1 Summary

The physico-chemical parameters of surface water and sediment, composition and distribution of plankton and fisheries potential of Yardantsi Reservoir, Gusau were studied for a period of twenty four months, from May, 2015 to April, 2017 along two season. Surface water, plankton and sediment samples were collected from five sampling stations of the Reservoir and analysed according to the methods described by UNEP (2004); APHA (2005); Panday *et al.* (2005) and Udo *et al.* (2009).

Surface water temperature, mean depth, electrical conductivity, dissolved oxygen, phosphate-phosphorus and Chloride showed significant seasonal variation at 0.05 level, while total dissolved solids and sulphate showed highly significant seasonal variation at 0.01 level; while calcium, magnesium and sodium showed a highly significant seasonal variation at 0.01 level. Chromium, iron, nickel and lead also showed significant seasonal and yearly variations at 0.05 level. Analysis of variance showed that some sediment parameters such as: pH, iron and zinc to exhibited a significant variation with years at 0.05 level, and significant seasonal variation at 0.05 level with pH, electrical conductivity, organic carbon, percentage nitrogen and potassium. Chromium showed a highly significant variation with seasons and years at 0.01 level; while potassium existed a highly significant variation with years at 0.01 level. A significant monthly variation existed with pH, electrical conductivity and potassium at 0.05 level; while a highly significant monthly variation existed with chromium at 0.01 level. Variation of these parameters may be attributed to catchment characteristics such as human activities like agriculture, deforestation along with other climatic factors such as wind and rainfall and their effects on the reservoir were also considered.

The sediment concentrations of metals under consideration (chromium, copper, nickel, lead and zinc) in all the sampling months were found to be lower than the proposed TECs (Table 4.4), indicating that there are no harmful effects from these metals, also the C_f values were less than one ($C_f<1$) and therefore are said to be low contaminated. On the other hand, the concentration of cadmium exceeded TEC but lower than PEC and C_f value was greater than six ($C_f>6$) in all sampling months, this shows that cadmium is slightly above threshold level.

The concentration of some metals was higher in sediment than the surface water. This may be attributed to the sedimentation processes; and to the fact that the reservoir receives surface runoff which introduces certain pollutants from catchment areas exposed to agricultural activities such as use of fertilizer and some form of pesticides and herbicides (Abata *et al.,* 2013). Calcium, magnesium and sodium showed highly significant seasonal variation ($p<0.01$) in surface water, while in sediment chromium showed a highly significant seasonal variation ($p <0.01$).

Four groups of phytoplankton (viz; Bacillariophyta, Chlorophyta, Cynophyta and Dinophyta) comprising of eleven various species were observed in this study, with Chlorophyta having the highest abundance for both dry and rainy seasons (40.42% and

41.33% respectively) of the total phytoplankton population (Fig. 4.16a). Phytoplankton showed significant positive correlation with temperature, mean depth, Nitrate-nitrogen, phosphate-phosphorus, sulphate and zooplankton at 0.01 level.

Three groups of zooplankton (viz; Copepoda, Cladocera and Rotifera) comprising of thirteen different species were observed in these studies, with Rotifera having the highest abundance for both dry and rainy seasons (35.79% and 36.35% respectively) of the total zooplankton population (Fig. 4.16b). Zooplankton showed a significant positive correlation with dissolved oxygen, alkalinity, chloride at 0.05 level, while with phosphate-phosphorus and phytoplankton at 0.01 level. This is in agreement with the findings of Rabiu *et al.* (2014).

Fisheries potentials were determined to be significantly higher in dry season for all stations ($p<0.05$). MEI exhibited significant positive correlation with transparency; total dissolved solids; electrical conductivity; dissolved oxygen; alkalinity; hardness and chloride at ($p<0.05$).

Sampling stations shows no significant variation, probably because the activities that affect water quality upstream, also affects the processes and organisms distribution downstream, which agreed with the findings of Nagorski *et al.* (2014).

6.2 Conclusion

1. The physico-chemical parameters (temperature, transparency, pH, electrical conductivity, total dissolved solids, hardness, alkalinity, sulphate, dissolved oxygen, biochemical oxygen demand, chloride and phosphate-phosphorus) of surface water of Yardantsi Reservoir, Gusau varied significantly with months, seasons and years and as at the time of this study. Surface water parameters with the exception of some metals (Mg, Cr, Cd, Ni, Fe, and Pb) in some months were found to be within the guideline values sets by NSDWQ (2007), WHO (2017) and FAO (1994), therefore the Reservoir water is slightly contaminated with some metals (Mg, Cd, Ni, Fe, and Pb) and in a potential risk.

2. The sediment physico-chemical parameters such as; pH, electrical conductivity, organic carbon, percentage nitrogen, phosphorus, and other metals under consideration varied significantly. All metals with the exception of cadmium were found to be lower than the proposed TECs, and C_f values were found to be less than one indicating that there are no harmful effects or the sediment is said to be low contaminated from these metals. On the other hand, the concentration of cadmium (1.81 cmol/kg) exceeded TEC value (0.99 cmol/kg) but less than PEC value (5 cmol/kg) and C_f value was greater than six (C_f>6) indicating that the reservoir sediment is said to be slightly contaminated with cadmium and therefore in a potential risk.

3. The concentration of metals between the surface water and the sediment varied significantly. The sediment had higher concentration of some metals than the surface water; this could be attributed to the accumulation caused by the sedimentation. The concentration of these metals could be attributed to the contamination of the water by inorganic and organic pollutants (which results into nutrient enrichments and excessive growth of algae and macrophytic plants) introduced by the agricultural runoff, atmospheric sources and soil erosion primarily from catchment areas, leading to siltation, loss of aquatic habitats, and pesticides contamination. As such the reservoir may be classified as oligotrophic.

4. The composition, distribution and abundance of the zooplankton and phytoplankton of Yardantsi Reservoir, Gusau varied significantly. Four groups of phytoplankton (viz; Bacillariophyta, Chlorophyta, Cynophyta and Dinophyta) comprising of eleven different species were observed in these studies, with Chlorophyta having the highest abundance for both dry and rainy seasons (40.42% and 41.33% respectively) of the total phytoplankton population. Three groups of zooplankton (viz; Cladocera, Copepoda and Rotifera) comprising of thirteen different species were observed in this study, with Rotifera having the highest abundance for both dry and rainy seasons (35.79% and 36.35% respectively) of the total zooplankton population. Based on Shannon and Margalef diversity index, which was found to be less than three in both seasons; this revealed that the reservoir surveyed during the study period may be considered to be slightly polluted.

5. The fisheries potential is significantly higher in dry season than in rainy season in all stations. There was a significant high yield (52.98kg/ha) in station four during dry season of year two, while in the rainy season all stations showed a significantly high yield in the second year than the first year. There is also a significant correlation with physico-chemical parameters of the reservoir which affected the seasonal variation through fluctuations. The results of this study has shown that the multitude of users of this reservoir and its catchment have negatively impacted on its water and sediment quality.

6.2 Recommendations

Based on the findings from this study the reservoir may be managed by regulating and reducing external nutrients loading using but not limited to the followings;

i. The information derived from this study should be used as an important tool in the management, operation and conservation of the reservoir and its resources.
ii. Responsible and sustainable agricultural practices should be carried out within the catchment area, while restricting cultivation on steep slopes as some fertilizers are good sources of cadmium and other metals.
iii. Soil erosion should be controlled in the catchment area through trees planting and control of deforestation.
iv. Gusau populace should engage in consuming foods containing higher amounts calcium, iron, zinc and proteins, as they reduce the risk of cadmium harm which includes damage to the kidney, lungs and bones.

v. The reservoir input should be monitored and the sediment sources be mitigated by dredging with the view to physically remove the introduced sediments which was found to be slightly polluted.

vi. Periodic limnological assessment should be employed to monitor and track the trend of changes of the reservoir water quality and quantity, productivity, periodicity and biodiversity.

vii. Further study on this reservoir should incorporate other biological factors (microbiological, macrobenthic invertebrates, fisheries and aquatic macrophytes) that may contribute to the assessment of reservoir water quality and productivity, as they are essential indicators of pollution and are important to normal functioning of the ecosystem.

Plate I: Gated Channels of Yardantsi Reservoir as Outlets for Flood Control

Plate II: *Cymbella timida* (Bréb.) Van Hanerck(Bacillariophyta) x100

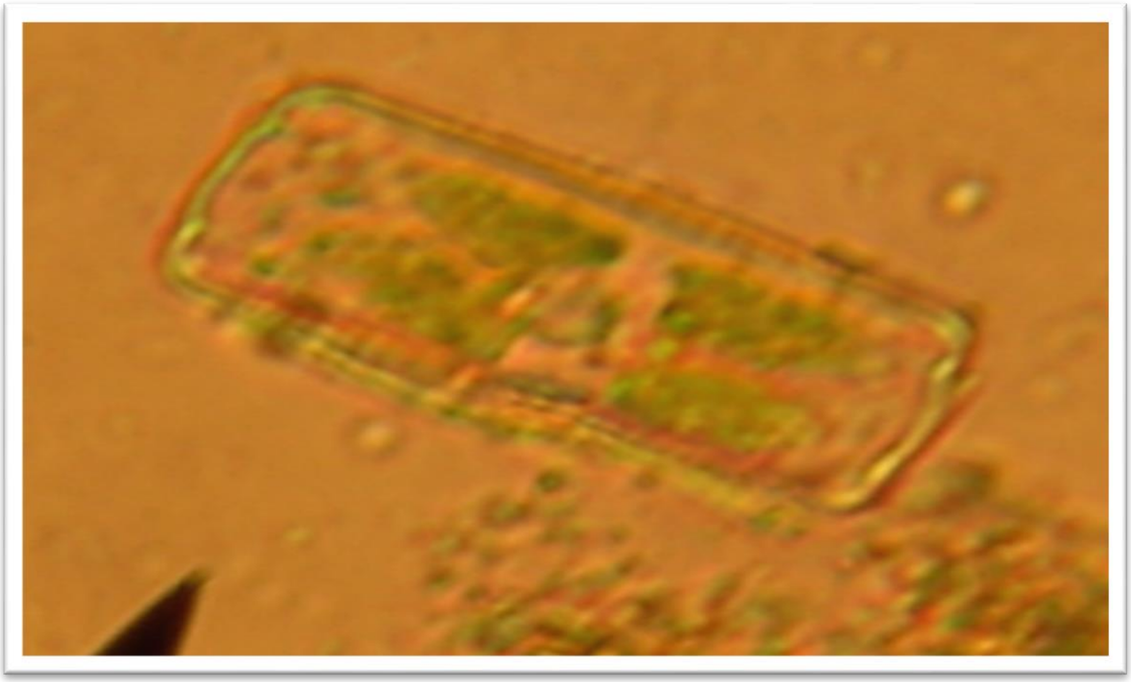

Plate III: *Palmella* sp. (Chlorophyta) x100

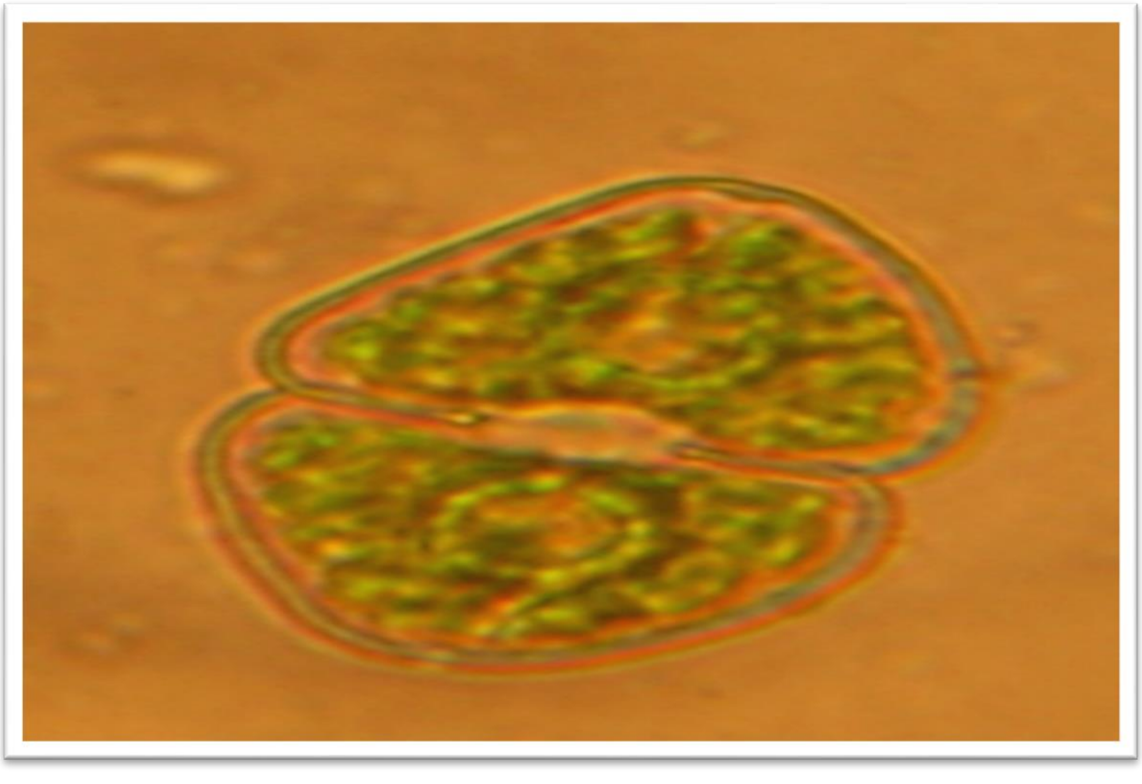

Plate IV:*Cosmarium* sp. (Chlorophyta) x100

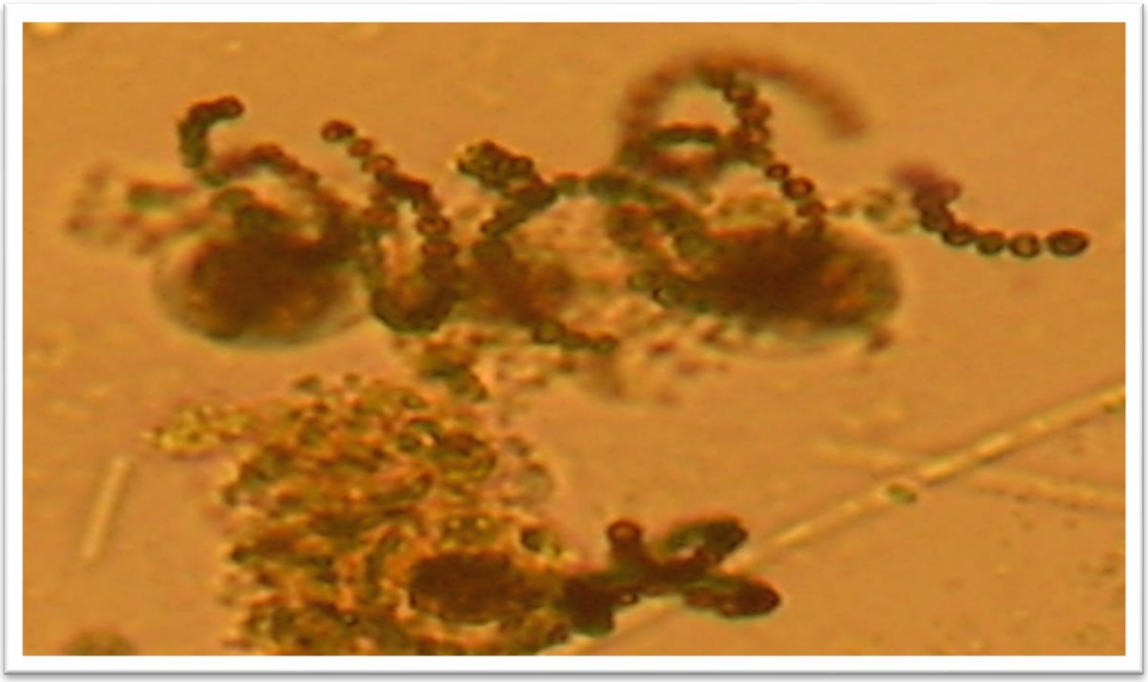

Plate V: *Microcystis* sp. (Cynophyta) x100

Plate VI: *Oscillatoria limosa* C.Agardh ex Gomont(Cynophyta) x100

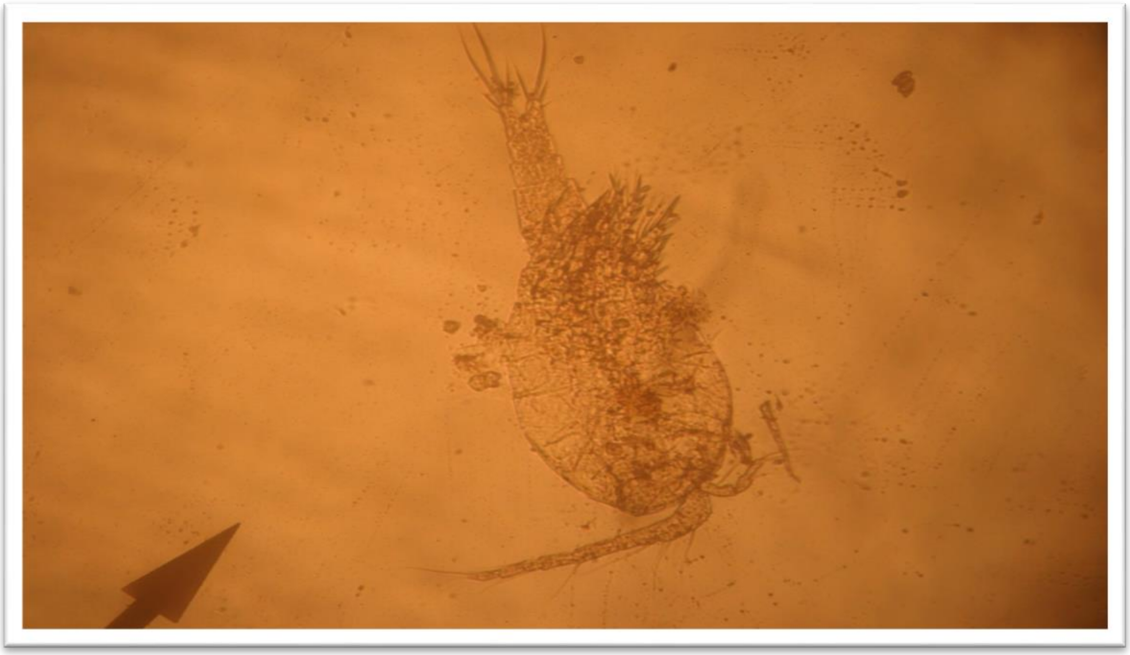

Plate VII; *Cyclops* sp. (Copepod) x100

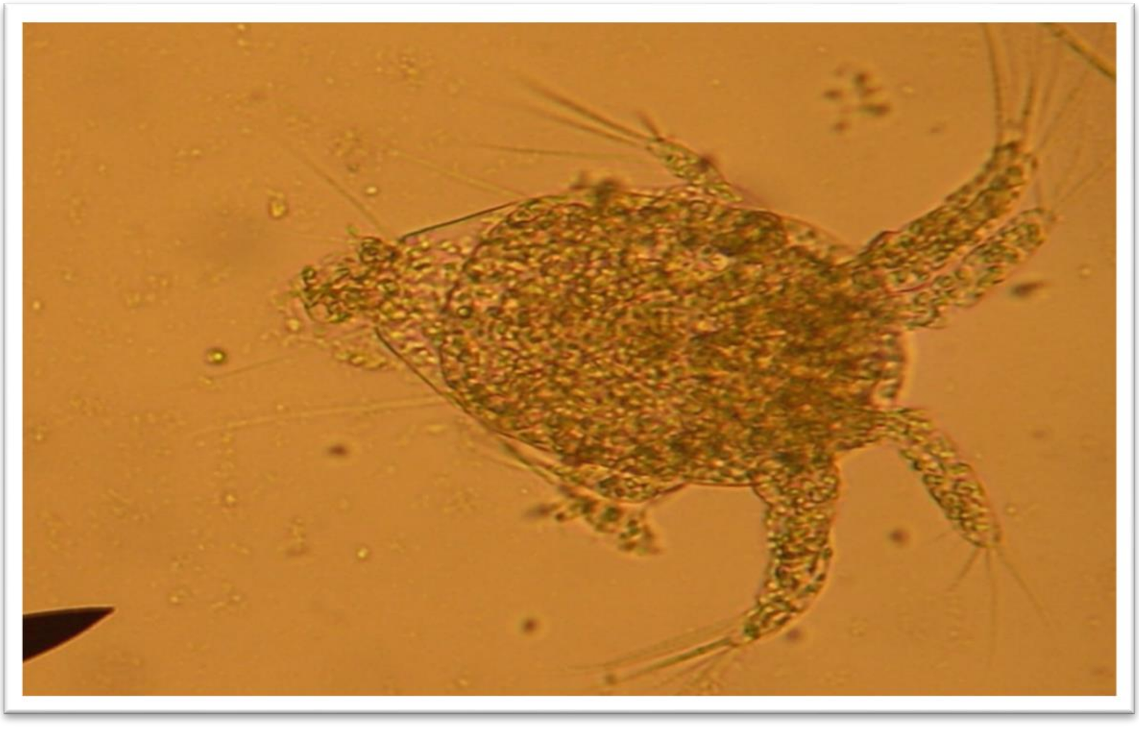

Plate VIII: *Thermocylops* sp. Kiefer (Cladocera) x100

Plate IX: *Ceriodaphnia* sp. (Copepod) x100

Plate X: *Keratella quadrata* Müller (Rotifera) x100

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APPENDICES

Appendix I; Absorbance and Concentrations of NO_3-N and SO_4 for Calibration Curve

Nitrate-nitrogen		**Sulphate**	
Conc. of standards (mg/l)	**Absorbance**	**Conc. of standards (mg/l)**	**Absorbance**
1	**0.13**	**8**	**0.06**
2	**0.25**	**16**	**0.13**
3	**0.35**	**24**	**0.17**
4	**0.4**	**32**	**0.25**
5	**0.46**	**40**	**0.31**

Appendix II; Hakanson's Classification for the Contamination Factor and Level of Contamination

Contamination Factor (C_f)	**Level of Contamination**
$C_f<1$	Low contamination
$1\leq C_f<3$	Moderate contamination
$3<C_f<6$	Considerate(high) contamination
$C_f>6$	Very high contamination

Sources; Hakanson (1980); Nasr (2006)

Appendix III; United State Environmental Protection Agency Guidelines for Sediments (mg/kg dry weights)

Metal	**Not polluted**	**Moderately polluted**	**Heavily polluted**
Cd	-	-	>6
Cr	<25	25-75	>75
Cu	<25	25-50	>50
Ni	<20	20-25	>50
Pb	<40	40-60	>60
Zn	<90	90-200	>200

Source; Saha and Hossain (2011)

Appendix IV: Mean (±SE) Monthly Variation of Different Surface Water Parameters of Yardantsi Reservoir, Gusau

Parameters	**May**	**June**	**July**	**Aug.**	**Sept.**	**Oct.**	**Nov.**	**Dec.**	**Jan.**	**Feb.**	**March**	**April**
Temperature (°C)	30.17± 0.05^{c}	28.64± 0.09^{e}	29.91± 0.12^{c}	28.81± 0.09^{e}	30.79± 0.09^{b}	32.41± 0.11^{a}	27.10± 0.07^{f}	24.65± 0.12^{g}	22.55± 0.12^{h}	25.98± 0.09^{f}	29.56± 0.12^{d}	29.89± 0.09^{c}
Transparency (m)	27.40± 0.81^{e,f}	25.00± 0.56^{f}	14.50± 0.48^{g}	12.00± 0.33^{h}	25.00± 0.70^{f}	28.50± 0.73^{e}	38.90± 0.84^{d}	50.60± 0.60^{c}	55.40± 0.95^{b}	59.90± 1.44^{a}	49.00± 0.92^{c}	39.10± 0.96^{d}
Depth (cm)	2.35± 0.05d^{e,f}	2.58± 0.08^{b,c,d}	2.74± 0.04^{a,b,c}	2.97± 0.06^{a}	2.78± 0.06^{a,b}	2.48± 0.10^{c,d,e}	2.33± 0.11^{d,e,f}	2.17± 0.08^{f,g}	2.08± 0.07^{f,g,h}	1.86± 0.04^{h}	2.04± 0.22^{f,g,h}	2.21± 0.05^{e,f,g}
pH	7.84± 0.44^{b}	7.95± 0.40^{a}	7.07± 0.11^{b}	9.57± 0.70^{a}	7.74± 0.12^{b}	8.12± 0.19^{b}	7.61± 0.09^{b}	7.84± 0.25^{b}	7.84± 0.49^{b}	7.70± 0.45^{b}	6.84± 0.39^{b}	7.85± 0.37^{b}
TDS (mg/L)	94.70± 10.00^{a,b}	51.70± 9.27^{d}	41.60± 6.18^{d}	42.10± 4.00^{d}	71.50± 4.50^{c}	80.60± 2.30^{b,c}	73.70± 4.44^{c}	97.50± 4.55^{a}	96.90± 3.51^{a}	97.50± 3.00^{a}	101.10± 2.42^{a}	109.30± 1.94^{a}
EC (µs/cm)	141.20± 5.22^{b}	64.20± 5.25^{d}	82.30± 11.97^{d}	81.20± 7.26^{d}	125.30± 6.09^{c}	154.10± 10.63^{b}	151.90± 7.63^{b}	197.90± 10.14^{a}	194.60± 7.34^{a}	197.60± 4.37^{a}	187.40± 7.43^{a}	188.50± 11.01^{a}
DO (mg/L)	7.46± 0.18^{c,d}	7.09± 0.22^{d,e}	7.17± 0.24^{d,e}	7.39± 0.12^{d,e}	6.37± 0.11^{f}	5.97± 0.10^{f}	7.92± 0.15^{b,c}	8.07± 0.13^{b}	8.86± 0.09^{a}	8.07± 0.12^{b}	6.94± 0.25^{e}	6.91± 0.19^{e}
BOD (mg/L)	2.20± 0.08^{e}	2.54± 0.08^{d}	2.59± 0.09^{d}	3.01± 0.05^{b,c}	2.27± 0.08^{e}	2.25± 0.09^{e}	2.81± 0.06^{c}	3.19± 0.06^{b}	3.58± 0.08^{a}	3.01± 0.06^{b,c}	1.79± 0.08^{f}	1.89± 0.06^{f}
Alkalinity (mg/L)	33.10± 0.77^{d}	29.80± 0.51^{e}	29.50± 0.83^{e}	22.60± 0.64^{g}	26.60 ± 0.72^{f}	25.60± 0.60^{f}	33.10± 0.67^{d}	38.20± 1.30^{c}	42.60± 1.00^{b}	47.80± 0.88^{a}	42.60± 0.86^{b}	39.10± 0.72^{c}
Hardness (mg/L)	44.50± 1.75^{d}	33.70± 0.73^{e}	29.40± 0.62^{f}	23.10± 0.66^{g}	28.00± 0.47^{f}	34.40± 0.81^{e}	47.00± 1.14^{d}	55.00± 0.92^{c}	61.90± 0.81^{b}	66.80± 1.10^{a}	67.50± 0.98^{a}	57.00± 1.21^{c}
NO_3-N (mg/L)	3.87± 0.08^{e}	4.22± 0.07^{d}	4.50± 0.10^{c}	5.19± 0.10^{a}	4.76± 0.11^{b}	4.07± 0.09^{d,e}	3.28± 0.08^{f}	2.56± 0.09^{g}	1.96± 0.05^{i}	1.64± 0.05^{j}	1.93± 0.05^{i}	2.31± 0.08^{h}
PO_4-P (mg/L)	161.10± 1.46^{c}	197.90± 4.44^{a}	197.00± 2.58^{a}	179.40± 1.63^{b}	162.50± 1.94^{c}	143.00± 1.63^{d}	136.20± 1.32^{e}	130.70± 0.83^{e,f}	125.60± 1.01^{f}	116.70± 2.08^{g}	106.50± 2.60^{h}	126.60± 2.16^{f}
S (mg/L)	50.40± 1.55^{d}	65.60± 1.85^{c}	86.30± 2.04^{a}	89.00± 1.48^{a}	74.20± 0.80^{b}	65.30± 1.08^{c}	47.70± 0.58^{d}	43.10± 0.71^{e}	33.50± 1.05^{f}	23.70± 076^{g}	18.10± 0.62^{h}	23.70± 0.76^{g}
Cl (mg/L)	49.83± 0.88^{e}	41.85± 0.77^{f}	40.05± 0.43^{f}	29.45± 0.62^{h}	31.15± 0.56^{g}	33.51± 0.91^{g}	50.35± 1.08^{e}	71.89± 1.93^{d}	83.15± 1.11^{b}	89.90± 0.90^{a}	78.65± 0.87^{c}	70.54± 0.94^{d}

Note; Mean values with the same superscript along the rows were not significantly different ($p>0.05$)

Appendix Va; Analysis of Variance (ANOVA) by Year for Different Surface Water Parameters of Yardantsi Reservoir, Gusau

Parameters	Sum of Squares	Df	Mean Square	F	Sig.
Temperature	.002	1	.002	.109	.797
Transparency	5.165	1	5.165	.	.
Mean Depth	1.928	1	1.928	96.389	.065
pH	4.039	1	4.039	1.335	.454
Total dissolved solids	13149.516	1	13149.516	1643.690	.016
Electrical Conductivity	48917.516	1	48917.516	3913.401	.010
Dissolved Oxygen	.402	1	.402	8.933	.206
Biological Oxygen Demand	.045	1	.045	2.250	.374
Alkalinity	2.188	1	2.188	.	.
Hardness	.019	1	.019	.010	.938
Nitrate-nitrogen	.080	1	.080	.	.
Phosphate-phosphorus	9.501	1	9.501	2.111	.384
Sulphate	88.769	1	88.769	7.102	.229
Chloride	37.533	1	37.533	79.782	.071

**Highly significant at the 0.01 level

*Significant at the 0.05 level

Appendix Vb; Analysis of Variance (ANOVA) by Season for Different Surface Water Parameters of Yardantsi Reservoir, Gusau

Parameters	Sum of Squares	Df	Mean Square	F	Sig.
Temperature	364.129	1	364.129	18206.440	.005
Transparency	21156.710	1	21156.710	.	.
Mean Depth	8.489	1	8.489	424.447	.031
pH	3.139	1	3.139	1.037	.494
Total dissolved solids	31168.867	1	31168.867	3896.108	.010
Electrical Conductivity	183072.557	1	183072.557	14645.805	.005
Dissolved Oxygen	23.528	1	23.528	522.843	.028
Biological Oxygen Demand	1.582	1	1.582	79.099	.071
Alkalinity	4723.497	1	4723.497	.	.
Hardness	21511.682	1	21511.682	10755.841	.006
Nitrate-nitrogen	137.263	1	137.263	.	.
Phosphate-phosphorus	73178.349	1	73178.349	16261.855	.005
Sulphate	47950.888	1	47950.888	3836.071	.010
Chloride	39187.616	1	39187.616	83298.153	.002

**Highly significant at the 0.01 level

*Significant at the 0.05 level

Appendix Vc; Analysis of Variance (ANOVA) by Month for Different Surface Water Parameters of Yardantsi Reservoir, Gusau

Parameters	Sum of Squares	Df	Mean Square	F	Sig.
Temperature	866.093	11	78.736	3936.786	.012
Transparency	27413.778	11	2492.162	.	.
Mean Depth	12.429	11	1.130	56.495	.103
pH	29.373	11	2.670	.883	.690
Total dissolved solids	62327.253	11	5666.114	708.264	.029
Electrical Conductivity	267326.488	11	24302.408	1944.193	.018
Dissolved Oxygen	70.076	11	6.371	141.567	.065
Biological Oxygen Demand	32.364	11	2.942	147.109	.064
Alkalinity	6669.427	11	606.312	.	.
Hardness	27263.296	11	2478.481	1239.241	.022
Nitrate-nitrogen	166.705	11	15.155	.	.
Phosphate-phosphorus	102701.469	11	9336.497	2074.777	.017
Sulphate	65660.383	11	5969.126	477.530	.036
Chloride	51799.622	11	4709.057	10009.685	.008

**Highly significant at the 0.01 level

*Significant at the 0.05 level

Appendix Vd; Analysis of Variance (ANOVA) by Station for Different Surface Water Parameters of Yardantsi Reservoir, Gusau

Parameters	Sum of Squares	Df	Mean Square	F	Sig.
Temperature	.614	4	.154	7.676	.264
Transparency	21.785	4	5.446	.	.
Mean Depth	.425	4	.106	5.319	.313
pH	3.248	4	.812	.268	.874
Total dissolved solids	559.176	4	139.794	17.474	.177
Electrical Conductivity	1532.140	4	383.035	30.643	.135
Dissolved Oxygen	.392	4	.098	2.181	.465
Biological Oxygen Demand	.457	4	.114	5.707	.303
Alkalinity	44.160	4	11.040	.	.
Hardness	33.126	4	8.282	4.141	.351
Nitrate-nitrogen	.183	4	.046	.	.
Phosphate-phosphorus	156.689	4	39.172	8.705	.248
Sulphate	31.875	4	7.969	.637	.721
Chloride	160.588	4	40.147	85.337	.081

**Highly significant at the 0.01 level

*Significant at the 0.05 level

Appendix Ve; Analysis of Variance (ANOVA) by Year by Month for Different Surface Water Parameters of Yardantsi Reservoir, Gusau

Parameters	Sum of Squares	Df	Mean Square	F	Sig.
Temperature	1.423	10	.142	7.113	.284
Transparency	77.551	10	7.755	.	.
Mean Depth	1.391	10	.139	6.957	.287
pH	61.816	10	6.182	2.043	.500
Total dissolved solids	8879.070	10	887.907	110.988	.074
Electrical Conductivity	8714.950	10	871.495	69.720	.093
Dissolved Oxygen	4.828	10	.483	10.728	.234
Biological Oxygen Demand	.420	10	.042	2.101	.494
Alkalinity	14.918	10	1.492	.	.
Hardness	30.901	10	3.090	1.545	.560
Nitrate-nitrogen	.854	10	.085	.	.
Phosphate-phosphorus	2275.454	10	227.545	50.566	.109
Sulphate	157.224	10	15.722	1.258	.606
Chloride	95.202	10	9.520	20.236	.171

**Highly significant at the 0.01 level
*Significant at the 0.05 level

Appendix Vf; Analysis of Variance (ANOVA) by Year by Station for Different Surface Water Parameters of Yardantsi Reservoir, Gusau

Parameters	Sum of Squares	Df	Mean Square	F	Sig.
Temperature	.122	4	.030	1.523	.537
Transparency	7.186	4	1.796	.	.
Mean Depth	.582	4	.146	7.277	.270
pH	2.548	4	.637	.211	.905
Total dissolved solids	589.223	4	147.306	18.413	.173
Electrical Conductivity	1149.475	4	287.369	22.989	.155
Dissolved Oxygen	.228	4	.057	1.269	.575
Biological Oxygen Demand	.203	4	.051	2.535	.436
Alkalinity	27.507	4	6.877	.	.
Hardness	10.617	4	2.654	1.327	.566
Nitrate-nitrogen	.161	4	.040	.	.
Phosphate-phosphorus	100.587	4	25.147	5.588	.306
Sulphate	48.117	4	12.029	.962	.634
Chloride	14.090	4	3.522	7.487	.267

**Highly significant at the 0.01 level
*Significant at the 0.05 level

Appendix Vg; Analysis of Variance (ANOVA) by Month by Station for Different Surface Water Parameters of Yardantsi Reservoir, Gusau

Parameters	Sum of Squares	Df	Mean Square	F	Sig.
Temperature	4.560	40	.114	5.700	.322
Transparency	407.568	40	10.189	.	.
Mean Depth	2.114	40	.053	2.643	.458
pH	17.502	40	.438	.145	.988
Total dissolved solids	1885.802	40	47.145	5.893	.317
Electrical Conductivity	5602.999	40	140.075	11.206	.233
Dissolved Oxygen	14.017	40	.350	7.787	.278
Biological Oxygen Demand	3.517	40	.088	4.396	.364
Alkalinity	384.068	40	9.602	.	.
Hardness	758.356	40	18.959	9.479	.253
Nitrate-nitrogen	3.422	40	.086	.	.
Phosphate-phosphorus	1553.393	40	38.835	8.630	.265
Sulphate	743.519	40	18.588	1.487	.583
Chloride	390.810	40	9.770	20.768	.173

**Highly significant at the 0.01 level

*Significant at the 0.05 level

Appendix Vh; Analysis of Variance (ANOVA) by Year by Month by Station for Different Surface Water Parameters of Yardantsi Reservoir, Gusau

Parameters	Sum of Squares	Df	Mean Square	F	Sig.
Temperature	2.336	39	.060	2.995	.433
Transparency	201.466	39	5.166	.	.
Mean Depth	2.029	39	.052	2.602	.461
pH	15.646	39	.401	.133	.991
Total dissolved solids	2266.930	39	58.126	7.266	.287
Electrical Conductivity	6116.233	39	156.826	12.546	.221
Dissolved Oxygen	5.573	39	.143	3.175	.422
Biological Oxygen Demand	.892	39	.023	1.143	.645
Alkalinity	210.899	39	5.408	.	.
Hardness	164.366	39	4.215	2.107	.505
Nitrate-nitrogen	1.900	39	.049	.	.
Phosphate-phosphorus	691.812	39	17.739	3.942	.383
Sulphate	298.926	39	7.665	.613	.791
Chloride	212.742	39	5.455	11.595	.229

**Highly significant at the 0.01 level

*Significant at the 0.05 level

Appendix VI: Pearson Correlation for Surface Water Physico-Chemical Parameters and Planktons of Yardantsi Reservoir, Gusau

	Temp	**Trans**	**Depth**	**pH**	**TDS**	**EC**	**DO**	**BOD**	**Alk**	**Hard**	**NO_3-N**	**PPO_4**	**S**	**Cl**	**MEI**	**PP**	**ZP**
Temp	1																
Trans	-0.658**	1															
Depth	0.386**	-0.715**	1														
pH	-0.002	-0.145	0.004	1													
TDS	-0.225*	0.667**	-0.404**	-0.063	1												
EC	-0.384**	0.781**	-0.447**	-0.078	0.833**	1											
DO	-0.782**	0.474**	-0.261**	-0.026	0.210*	0.291**	1										
BOD	-0.758**	0.246**	-0.084	0.177	-0.093	0.081	0.622**	1									
Alk	-0.565**	0.870**	-0.690**	-0.184*	0.596**	0.665**	0.450**	0.142	1								
Hard	-0.533**	0.909**	-0.727**	-0.172	0.683**	0.753**	0.420**	0.067	0.901**	1							
NO3-N	0.560**	-0.920**	0.697**	0.216*	-0.664**	-0.763**	-0.434**	-0.110	-0.903**	-0.953**	1						
PPO_4	0.352**	-0.835**	0.646**	0.076	-0.675**	-0.825**	-0.218*	0.002	-0.714**	-0.836**	0.818**	1					
S	0.400**	-0.876**	0.723**	0.185*	-0.711**	-0.737**	-0.295**	0.086	-0.865**	-0.943**	0.928**	0.845**	1				
Cl	-0.650**	0.909**	-0.686**	-0.193*	0.632**	00.727**	0.517**	0.203*	0.938**	0.943**	-0.951**	-0.757**	-0.890**	1			
MEI	-0.327**	0.801**	-0.712**	-0.038	0.916**	0.816**	0.267**	-0.033	0.750**	0.828**	-0.799**	-0.784**	-0.834**	0.779**	1		
PP	0.438**	-0.573**	0.280**	0.047	-0.272**	-0.548**	-0.235**	-0.355**	-0.326**	-0.393**	.443**	0.646**	0.319**	-0.382**	-0.342**	1	
ZP	-0.237**	-0.003	-0.057	-0.071	-0.124	-0.219*	0.233*	0.151	0.233*	0.080	-0.114	0.356**	-0.047	0.220*	-0.075	0.591**	1

Note; **=Correlation is significant at the 0.01 level (2-tailed); *=Correlation is significant at the 0.05 level (2-tailed); MEI=Morpho Edaphic Index; PP= Phytoplankton and ZP= Zooplankton; Alk=Alkalinity; Hard=Hardness; Trans=Transparency; Temp=Temperature

Appendix VII: Mean (±SE) Monthly Variation of Different Surface Water Metals of Yardantsi Reservoir, Gusau

						Metal(mg/l)					
Month	**Ca**	**K**	**Mg**	**Na**	**Cd**	**Cu**	**Cr**	**Fe**	**Ni**	**Pb**	**Zn**
May	0.69 ±0.08^{e,f}	4.39 ±0.08^{a}	1.02 ±0.06^{f}	45.64 ±1.21^{e}	0.17 ±0.02^{b}	1.25 ±0.16^{b,c}	0.20 ±0.02^{a,b,c}	2.70 ±0.16^{b,c}	0.13 ±0.03^{a,b,c}	0.05 ±0.01^{b}	1.45 ±0.16^{a,b,c}
June	0.62 ±0.11^{e,f}	4.36 ±0.08^{a}	0.49 ±0.04^{h}	39.46 ±0.82^{f}	0.29 ±0.05^{a}	1.62 ±0.15^{a}	0.24 ±0.04^{a,b}	5.74 ±2.51^{a}	0.14 ±0.03^{a,b,c}	0.07 ±0.01^{a}	1.75 ±0.19^{a}
July	0.52 ±0.03^{f}	4.02 ±0.08^{b}	0.22 ±0.01^{i}	37.80 ±1.56^{f}	0.12 ±0.01^{c}	1.40 ±0.05^{a,b}	0.25 ±0.04^{a}	3.50 ±0.21^{b,c}	0.15 ±0.03^{a,b,c}	0.07 ±0.01^{a}	1.54 ±0.15^{a,b}
Aug.	0.78 ±0.05^{e,f}	2.36 ±0.09^{d}	0.19 ±0.01^{i}	29.85 ±0.73^{h}	0.07 ±0.01^{d,e,f}	1.35 ±0.08^{a,b,c}	0.18 ±0.04^{a,b,c}	2.69 ±0.17^{b,c}	0.18 ±0.05^{a}	0.04 ±0.01^{b,c}	1.40 ±0.12^{a,b,c,d}
Sept.	1.09 ±0.24^{e,f}	1.84 ±0.05^{f}	0.42 ±0.02^{h}	39.18 ±2.14^{f}	0.08 ±0.01^{d,e}	1.20 ±0.05^{b,c,d}	0.16 ±0.01^{c,d}	2.57 ±0.43^{b,c}	0.13 ±0.03^{a,b,c}	0.02 ±0.00^{d}	1.32 ±0.22^{b,c,d,e}
Oct.	2.72 ±0.26^{c}	2.25 ±0.09^{d,e}	0.74 ±0.04^{g}	55.63 ±1.41^{d}	0.06 ±0.01^{e,f}	0.92 ±0.07^{d,e,f}	0.13 ±0.01^{d,e}	1.56 ±0.15^{b,c}	0.10 ±0.02^{b,c,d}	0.02 ±0.00^{d}	0.95 ±0.10^{e,f,g}
Nov.	3.72 ±0.22^{b}	2.08 ±0.05^{e,f}	1.77 ±0.09^{e}	65.63 ±2.02^{c}	0.04 ±0.00^{e,f}	0.96 ±0.02^{d,e,f}	0.18 ±0.01^{a,b,c}	1.86 ±0.03^{b,c}	0.17 ±0.00^{a,b}	0.02 ±0.00^{d}	0.87 ±0.03^{f,g}
Dec.	4.49 ±0.26^{a}	2.12 ±0.10^{de}	2.41 ±0.10^{c}	73.48 ±3.30^{b}	0.03 ±0.00^{f}	0.79 ±0.05^{f}	0.12 ±0.01^{d,e,f}	2.08 ±0.09^{b,c}	0.16 ±0.01^{a,b,c}	0.03 ±0.00^{c,d}	1.11 ±0.08^{d,e,f,g}
Jan.	3.29 ±0.38^{b,c}	2.28 ±0.07^{d,e}	2.58 ±0.12^{b,c}	81.21 ±1.51^{a}	0.07 ±0.01^{d,e,f}	0.73 ±0.03^{f}	0.05 ±0.00^{f}	0.68 ±0.03^{b}	0.02 ±0.00^{e}	0.03 ±0.00^{c,d}	0.66 ±0.03^{g}
Feb.	2.12 ±0.25^{d}	3.14 ±0.12^{c}	2.83 ±0.07^{a}	84.06 ±1.71^{a}	0.05 ±0.01^{e,f}	1.09 ±0.07^{c,d,e}	0.08 ±0.01^{e,f}	0.93 ±0.05^{c}	0.03 ±0.00^{d,e}	0.02 ±0.00^{d}	1.02 ±0.10^{d,e,f,g}
March	1.23 ±0.23^{e}	4.46 ±0.13^{a}	2.67 ±0.12^{a,b}	74.28 ±1.33^{b}	0.11 ±0.01^{c}	0.83 ±0.10^{e,f}	0.09 ±0.01^{e,f}	1.67 ±0.10^{b,c}	0.05 ±0.01^{d,e}	0.02 ±0.00^{d}	0.70 ±0.04^{g}
April	1.02 ±0.14^{e,f}	4.27 ±0.07^{a}	1.97 ±0.05^{d}	55.68 ±1.84^{d}	0.16 ±0.01^{b}	1.09 ±0.14^{c,d,e}	0.14 ±0.02^{c,d,e}	2.26 ±0.13^{b,c}	0.09 ±0.02^{c,d,e}	0.03 ±0.01^{c,d}	1.01 ±0.08^{d,e,f,g}

Note; Mean values with the same superscript along the columns were not significantly different ($p>0.05$)

Appendix VIIIa; Analysis of Variance (ANOVA) by Year for Different Surface Water Metals of Yardantsi Reservoir, Gusau

Metals	Sum of Squares	Df	Mean Square	F	Sig.
Ca	9.227	1	9.227	11533.376	.006
K	.018	1	.018	.278	.691
Mg	.081	1	.081	16.299	.155
Na	5.046	1	5.046	1.564	.429
Cd	.028	1	.028	4.759	.274
Cu	2.421	1	2.421	8.450	.211
Cr	.228	1	.228	246.093	.041
Fe	.584	1	.584	202.127	.045
Ni	.306	1	.306	3620.044	.011
Pb	.016	1	.016	2061.360	.014
Zn	6.015	1	6.015	52.655	.087

Appendix VIIIb; Analysis of Variance (ANOVA) by Season for Different Surface Water Metals of Yardantsi Reservoir, Gusau

Metals	Sum of Squares	Df	Mean Square	F	Sig.
Ca	75.094	1	75.094	93867.811	.002
K	.657	1	.657	10.136	.194
Mg	102.780	1	102.780	20555.935	.004
Na	28496.070	1	28496.070	8833.799	.007
Cd	.090	1	.090	15.162	.160
Cu	4.242	1	4.242	14.806	.162
Cr	.192	1	.192	207.950	.044
Fe	70.951	1	70.951	24567.511	.004
Ni	.082	1	.082	965.034	.020
Pb	.014	1	.014	1766.763	.015
Zn	7.750	1	7.750	67.841	.077

**Highly significant at the 0.01 level; *Significant at the 0.05 level

Appendix VIIIc; Analysis of Variance (ANOVA) by Month for Different Surface Water Metals of Yardantsi Reservoir, Gusau

Metals	Sum of Squares	Df	Mean Square	F	Sig.
Ca	207.803	11	18.891	23614.030	.005
K	128.484	11	11.680	180.253	.058
Mg	116.988	11	10.635	2127.056	.017
Na	37745.231	11	3431.385	1063.731	.024
Cd	.622	11	.057	9.522	.248
Cu	8.212	11	.747	2.605	.452
Cr	.404	11	.037	39.701	.123
Fe	193.182	11	17.562	6081.022	.010
Ni	.322	11	.029	346.802	.042
Pb	.038	11	.003	427.908	.038
Zn	12.941	11	1.176	10.298	.239

Appendix VIIId; Analysis of Variance (ANOVA) by Station for Different Surface Water Metals of Yardantsi Reservoir, Gusau

Metals	Sum of Squares	Df	Mean Square	F	Sig.
Ca	.385	4	.096	120.446	.068
K	.254	4	.064	.981	.630
Mg	.441	4	.110	22.032	.158
Na	228.833	4	57.208	17.735	.176
Cd	.001	4	.000	.033	.995
Cu	.070	4	.018	.061	.984
Cr	.002	4	.000	.429	.798
Fe	27.910	4	6.978	2416.036	.015
Ni	.001	4	.000	1.617	.524
Pb	.000	4	4.007E-5	5.008	.322
Zn	.075	4	.019	.165	.931

Appendix VIIIe; Analysis of Variance (ANOVA) by Year by Month for Different Surface Water Metals of Yardantsi Reservoir, Gusau

Metals	Sum of Squares	Df	Mean Square	F	Sig.
Ca	21.708	10	2.171	2713.517	.015
K	.317	10	.032	.489	.817
Mg	.331	10	.033	6.624	.294
Na	142.439	10	14.244	4.416	.356
Cd	.156	10	.016	2.621	.449
Cu	4.165	10	.416	1.454	.574
Cr	.078	10	.008	8.453	.262
Fe	47.447	10	4.745	1642.900	.019
Ni	.055	10	.005	64.545	.097
Pb	.010	10	.001	126.852	.069
Zn	.972	10	.097	.851	.696

Appendix VIIIf; Analysis of Variance (ANOVA) by Year by Station for Different Surface Water Metals of Yardantsi Reservoir, Gusau

Metals	Sum of Squares	Df	Mean Square	F	Sig.
Ca	.771	4	.193	241.075	.048
K	.156	4	.039	.601	.733
Mg	.202	4	.051	10.123	.231
Na	132.478	4	33.120	10.267	.229
Cd	.004	4	.001	.149	.939
Cu	.297	4	.074	.259	.879
Cr	.004	4	.001	1.034	.619
Fe	19.389	4	4.847	1678.423	.018
Ni	.001	4	.000	3.014	.405
Pb	.000	4	3.428E-5	4.285	.346
Zn	.972	10	.097	.851	.696

Appendix VIIIg; Analysis of Variance (ANOVA) by Month by Station for Different Surface Water Metals of Yardantsi Reservoir, Gusau

Metals	Sum of Squares	Df	Mean Square	F	Sig.
Ca	9.014	40	.225	281.677	.047
K	5.214	40	.130	2.012	.515
Mg	2.331	40	.058	11.654	.229
Na	2023.840	40	50.596	15.685	.198
Cd	.034	40	.001	.143	.988
Cu	1.156	40	.029	.101	.997
Cr	.021	40	.001	.574	.805
Fe	243.384	40	6.085	2106.858	.017
Ni	.016	40	.000	4.854	.348
Pb	.003	40	7.839E-5	9.798	.249
Zn	1.900	40	.048	.416	.871

**Highly significant at the 0.01 level
*Significant at the 0.05 level

Appendix VIIIh; Analysis of Variance (ANOVA) by Year by Month by Station for Different Surface Water Metals of Yardantsi Reservoir, Gusau

Metals	Sum of Squares	Df	Mean Square	F	Sig.
Ca	4.880	39	.125	156.421	.063
K	1.631	39	.042	.646	.779
Mg	1.836	39	.047	9.417	.254
Na	575.878	39	14.766	4.578	.357
Cd	.029	39	.001	.125	.993
Cu	.511	39	.013	.046	1.000
Cr	.011	39	.000	.301	.924
Fe	224.197	39	5.749	1990.530	.018
Ni	.014	39	.000	4.135	.374
Pb	.002	39	5.315E-5	6.644	.300
Zn	1.551	39	.040	.348	.902

**Highly significant at the 0.01 level

*Significant at the 0.05 level

Appendix IX: Pearson Correlation for Surface Water Metals and Planktons of Yardantsi Reservoir, Gusau

	Ca	K	Mg	Na	Cd	Cu	Cr	Fe	Ni	Pb	Zn	PP	ZP
Ca	1												
K	-0.591**	1											
Mg	0.491**	0.004	1										
Na	0.608**	-0.146	0.888**	1									
Cd	-0.467**	0.599**	-0.275**	-0.346**	1								
Cu	-0.488**	0.270**	-0.521**	-0.517**	0.586**	1							
Cr	-0.266**	0.196*	-0.528**	-0.515**	0.500**	0.665**	1						
Fe	-0.448**	0.285**	-0.639**	-0.688**	0.441**	0.616**	0.734**	1					
Ni	0.028	-0.113	-0.408**	-0.389**	0.169	0.511**	0.821**	0.622**	1				
Pb	-0.322**	0.301**	-0.458**	-0.434**	0.581**	0.679**	0.842**	0.686**	0.637**	1			
Zn	-0.285**	0.183*	-0.488**	-0.509**	0.488**	0.693**	0.791**	0.686**	0.739**	0.747**	1		
PP	-0.664**	0.678**	-0.548**	-0.629**	0.725**	0.544**	0.490**	0.582**	0.194*	0.547**	0.527**	1	
ZP	-0.351**	0.564**	-0.030	-0.057	0.582**	0.365**	0.230*	0.183*	-0.091	0.501**	0.322**	0.591**	1

Note; ** = Correlation is significant at the 0.01 level (2-tailed); * = Correlation is significant at the 0.05 level (2-tailed) ; PP= Phytoplankton and ZP= Zooplankton

Appendix X: Mean (±SE) Monthly Variation for different Sediment Physico-Chemical Parameters of Yardantsi Reservoir, Gusau

Month	pH	EC	OC	N	P	CEC
May	7.15±0.10^{a}	425.69±10.38^{c,f,h,i}	0.37±0.01^{b,c,d}	0.023±0.003^{a}	7.51±.14^{a,b}	5.61±0.22^{c,d}
June	6.42±0.07^{a}	409.06±26.48^{b,c,f}	0.39±0.01^{d}	0.019±0.001^{a}	9.78±0.82^{a,b}	7.04±0.25^{b,e}
July	7.53±0.10^{a}	427.93±10.36^{c,d,f,h,i}	0.36±0.01^{b,d,e}	0.019±0.001^{a}	13.63±2.16^{b}	6.53±0.29^{a,c,e}
August	6.60±0.09^{a}	519.96±11.08^{e}	0.37±0.01^{b,d,f}	0.019±0.001^{a}	9.14±0.47^{a,b}	6.18±0.11^{a,c,e}
September	13.33±6.52^{a}	454.22±8.25^{f}	0.36±0.01^{b,d,g}	0.018±0.000^{a}	12.25±1.88^{b,c}	5.97±0.26^{a,c,e}
October	6.52±0.06^{a}	457.99±7.26^{f,g}	0.36±0.00^{b,d,h}	0.019±0.001^{a}	11.86±1.06^{b,d}	5.80±0.11^{c,f}
November	6.68±0.05^{a}	386.76±5.91^{b,h}	0.35±0.00^{a,b,d}	0.018±0.001^{a}	13.15±2.04^{b,e}	5.95±0.11^{a,c,e}
December	6.97±0.07^{a}	382.35±9.75^{b,i}	0.36±0.00^{b,d,i}	0.018±0.000^{a}	10.74±1.38^{a,b}	6.62±0.34^{a,c,e}
January	7.36±0.07^{a}	278.14±12.29^{a}	0.33±0.00^{a,b}	0.016±0.000^{a}	10.13±0.38^{a,b}	6.74±0.06^{a,c,e}
February	7.12±0.11^{a}	278.50±10.06^{a}	0.34±0.00^{a,b,d}	0.017±0.001^{a}	10.49±1.43^{a,b}	7.00±0.28^{a,b}
March	6.62±0.10^{a}	370.17±6.73^{b,c}	0.30±0.03^{a}	0.017±0.002^{a}	5.28±0.31^{a}	6.26±0.22^{a,c,e}
April	6.90±0.06^{a}	356.72±16.37^{b}	0.37±0.00^{b,d}	0.021±0.003^{a}	5.14±0.24^{a}	5.72±0.31^{c}

Note; Mean values with the same superscript along the columns were not significantly different ($p>0.05$)

Appendix XIa; Analysis of Variance (ANOVA) by Year for Different Sediment Physico-Chemical Parameters of Yardantsi Reservoir, Gusau

Parameters	Sum of Squares	Df	Mean Square	F	Sig.
pH	47.044	1	47.044	588.048	.026
EC	661.941	1	661.941	4.041	.294
OC	.001	1	.001	10.478	.191
N	.000	1	.000	153.428	.051
P	61.801	1	61.801	1.188	.473
Ca	3.412	1	3.412	4.417	.283
K	1.045	1	1.045	42655.160	.003
Mg	5.508	1	5.508	58.482	.083
Na	4.084E-5	1	4.084E-5	.008	.943
CEC	2.289	1	2.289	1.825	.406
Cd	37.350	1	37.350	90.372	.067
Cu	39.320	1	39.320	17.347	.150
Cr	2716.644	1	2716.644	111806.274	.002
Fe	9263.651	1	9263.651	614.955	.026
Ni	1.585	1	1.585	51.988	.088
Pb	.011	1	.011	.686	.560
Zn	867.702	1	867.702	464.597	.030

**Highly significant at the 0.01 level; *Significant at the 0.05 level

Appendix XIb; Analysis of Variance (ANOVA) by Season for Different Sediment Physico-Chemical Parameters of Yardantsi Reservoir, Gusau

Parameters	Sum of Squares	Df	Mean Square	F	Sig.
pH	29.046	1	29.046	363.074	.033
EC	331967.926	1	331967.926	2026.604	.014
OC	.020	1	.020	400.764	.032
N	.001	1	.001	297.046	.037
P	72.742	1	72.742	1.398	.447
Ca	.326	1	.326	.422	.633
K	.040	1	.040	1638.242	.016
Mg	.050	1	.050	.527	.600
Na	.009	1	.009	1.877	.401
CEC	.959	1	.959	.764	.543
Cd	9.612	1	9.612	23.256	.130
Cu	2.824	1	2.824	1.246	.465
Cr	2549.182	1	2549.182	104914.198	.002
Fe	956.227	1	956.227	63.478	.079
Ni	.257	1	.257	8.443	.211
Pb	.037	1	.037	2.297	.371
Zn	18.641	1	18.641	9.981	.195

**Highly significant at the 0.01 level; *Significant at the 0.05 level

Appendix XIc; Analysis of Variance (ANOVA) by Month for Different Sediment Physico-Chemical Parameters of Yardantsi Reservoir, Gusau

Parameters	Sum of Squares	Df	Mean Square	F	Sig.
pH	392.415	11	35.674	445.926	.037
EC	534098.814	11	48554.438	296.416	.045
OC	.060	11	.005	108.221	.075
N	.003	11	.000	149.078	.064
P	853.502	11	77.591	1.492	.570
Ca	10.413	11	.947	1.225	.614
K	.603	11	.055	2237.172	.016
Mg	6.185	11	.562	5.970	.310
Na	.177	11	.016	3.227	.411
CEC	26.462	11	2.406	1.918	.515
Cd	47.138	11	4.285	10.369	.238
Cu	83.652	11	7.605	3.355	.404
Cr	27933.528	11	2539.412	104512.090	.002
Fe	5245.859	11	476.896	31.658	.138
Ni	2.177	11	.198	6.493	.298
Pb	.491	11	.045	2.793	.438
Zn	1583.394	11	143.945	77.073	.089

**Highly significant at the 0.01 level; *Significant at the 0.05 level; EC= Electrical Conductivity, OC= Organic Carbon and CEC= Cation Exchange Capacity

Appendix XId; Analysis of Variance (ANOVA) by Station for Different Sediment Physico-Chemical Parameters of Yardantsi Reservoir, Gusau

Parameters	Sum of Squares	Df	Mean Square	F	Sig.
pH	148.747	4	37.187	464.835	.035
EC	3967.130	4	991.782	6.055	.295
OC	.001	4	.000	5.684	.304
N	.001	4	.000	143.630	.062
P	13.549	4	3.387	.065	.983
Ca	.194	4	.048	.063	.984
K	.048	4	.012	485.205	.034
Mg	.098	4	.024	.260	.879
Na	.002	4	.001	.114	.959
CEC	.351	4	.088	.070	.981
Cd	1.811	4	.453	1.096	.606
Cu	3.991	4	.998	.440	.794
Cr	10237.865	4	2559.466	105337.457	.002
Fe	78.571	4	19.643	1.304	.569
Ni	.036	4	.009	.294	.861
Pb	.014	4	.004	.225	.897
Zn	639.371	4	159.843	85.585	.081

**Highly significant at the 0.01 level; *Significant at the 0.05 level; EC= Electrical Conductivity, OC= Organic Carbon and CEC= Cation Exchange Capacity

Appendix XIe; Analysis of Variance (ANOVA) by Year by Month for Different Sediment Physico-Chemical Parameters of Yardantsi Reservoir, Gusau

Parameters	Sum of Squares	Df	Mean Square	F	Sig.
pH	353.982	10	35.398	442.477	.037
EC	55648.693	10	5564.869	33.973	.133
OC	.084	10	.008	168.784	.060
N	.003	10	.000	160.262	.061
P	1238.077	10	123.808	2.380	.469
Ca	32.969	10	3.297	4.268	.361
K	.919	10	.092	3752.217	.013
Mg	6.985	10	.698	7.417	.279
Na	.219	10	.022	4.379	.357
CEC	45.248	10	4.525	3.607	.390
Cd	22.160	10	2.216	5.362	.325
Cu	23.285	10	2.329	1.027	.653
Cr	24803.687	10	2480.369	102082.118	.002
Fe	2800.435	10	280.044	18.590	.179
Ni	1.629	10	.163	5.346	.325
Pb	.080	10	.008	.499	.813
Zn	1723.351	10	172.335	92.274	.081

**Highly significant at the 0.01 level; *Significant at the 0.05 level; EC= Electrical Conductivity, OC= Organic Carbon and CEC= Cation Exchange Capacity

Appendix XIf; Analysis of Variance (ANOVA) by Year by Station for Different Sediment Physico-Chemical Parameters of Yardantsi Reservoir, Gusau

Parameters	Sum of Squares	Df	Mean Square	F	Sig.
pH	127.884	4	31.971	399.638	.037
EC	1481.047	4	370.262	2.260	.458
OC	.002	4	.000	9.370	.240
N	.001	4	.000	142.007	.063
P	9.904	4	2.476	.048	.990
Ca	.176	4	.044	.057	.986
K	.072	4	.018	737.617	.028
Mg	.085	4	.021	.226	.897
Na	.006	4	.001	.278	.869
CEC	.360	4	.090	.072	.980
Cd	1.911	4	.478	1.156	.595
Cu	.655	4	.164	.072	.980
Cr	10303.936	4	2575.984	106017.268	.002
Fe	144.902	4	36.226	2.405	.446
Ni	.040	4	.010	.328	.844
Pb	.005	4	.001	.079	.976
Zn	438.444	4	109.611	58.689	.098

**Highly significant at the 0.01 level; *Significant at the 0.05 level; EC= Electrical Conductivity, OC= Organic Carbon and CEC= Cation Exchange Capacity

Appendix XIg; Analysis of Variance (ANOVA) by Month by Station for Different Sediment Physico-Chemical Parameters of Yardantsi Reservoir, Gusau

Parameters	Sum of Squares	Df	Mean Square	F	Sig.
pH	1411.351	40	35.284	441.047	.038
EC	44753.611	40	1118.840	6.830	.296
OC	.006	40	.000	3.183	.422
N	.011	40	.000	134.782	.068
P	126.338	40	3.158	.061	1.000
Ca	2.022	40	.051	.065	1.000
K	.612	40	.015	624.399	.032
Mg	1.037	40	.026	.275	.936
Na	.027	40	.001	.137	.990
CEC	3.197	40	.080	.064	1.000
Cd	7.947	40	.199	.481	.843
Cu	34.938	40	.873	.385	.885
Cr	100863.791	40	2521.595	103778.819	.002
Fe	2101.406	40	52.535	3.487	.405
Ni	1.198	40	.030	.983	.681
Pb	.093	40	.002	.146	.988
Zn	5438.057	40	135.951	72.793	.093

**Highly significant at the 0.01 level; *Significant at the 0.05 level; EC= Electrical Conductivity, OC= Organic Carbon and CEC= Cation Exchange Capacity

Appendix XIh; Analysis of Variance (ANOVA) by Year by Month by Station for Different Sediment Physico-Chemical Parameters of Yardantsi Reservoir, Gusau

Parameters	Sum of Squares	Df	Mean Square	F	Sig.
pH	1425.431	39	36.550	456.869	.037
EC	21899.419	39	561.524	3.428	.408
OC	.006	39	.000	3.328	.413
N	.010	39	.000	134.351	.068
P	98.193	39	2.518	.048	1.000
Ca	1.838	39	.047	.061	1.000
K	.488	39	.013	510.471	.035
Mg	1.050	39	.027	.286	.931
Na	.026	39	.001	.136	.990
CEC	3.139	39	.080	.064	1.000
Cd	6.696	39	.172	.415	.871
Cu	24.648	39	.632	.279	.934
Cr	101241.361	39	2595.932	106838.258	.002
Fe	2352.368	39	60.317	4.004	.380
Ni	1.130	39	.029	.950	.689
Pb	.097	39	.002	.155	.985
Zn	5114.706	39	131.146	70.220	.094

**Highly significant at the 0.01 level; *Significant at the 0.05 level; EC= Electrical Conductivity, OC= Organic Carbon and CEC= Cation Exchange Capacity

Appendix XII: Pearson Correlation for Sediment Physico-Chemical Parameters of Yardantsi Reservoir, Gusau

	pH	**EC**	**OC**	**N**	**P**	**Ca**	**K**	**Mg**	**Na**	**CEC**	**Cd**	**Cu**	**Cr**	**Fe**	**Ni**	**Pb**	**Zn**
pH	1																
EC	0.055	1															
OC	-0.039	0.241**	1														
N	-0.018	0.158	0.231*	1													
P	0.114	0.004	0.103	-0.012	1												
Ca	-0.042	-0.154	0.203*	-0.171	-0.101	1											
K	0.027	-0.018	-0.376**	-0.052	0.120	-0.498**	1										
Mg	0.128	-0.126	-0.235**	-0.180*	0.282**	0.113	0.413**	1									
Na	-0.058	0.054	0.460**	0.036	-0.203*	0.399**	-0.195*	0.075	1								
CEC	0.035	-0.194*	-0.019	-0.240**	0.085	0.755**	0.037	0.709**	0.384**	1							
Cd	0.049	-0.324**	-0.094	-0.169	-0.251**	0.194*	0.151	0.320**	0.161	0.364**	1						
Cu	0.155	0.043	-0.268**	-0.037	-0.177	0.000	0.239**	0.284**	0.047	0.200*	0.522**	1					
Cr	-0.039	0.007	-0.116	-0.023	0.387**	-0.117	0.105	0.155	-0.182*	0.002	-0.108	0.011	1				
Fe	-0.170	-0.174	0.226*	0.025	0.129	0.142	-0.420**	-0.494**	0.009	-0.230*	-0.421**	-0.553**	-0.088	1			
Ni	0.056	0.214*	0.109	0.109	0.329**	-0.150	-0.167	-0.281**	-0.157	-0.309**	-0.607**	-0.405**	0.139	0.456**	1		
Pb	0.001	-0.084	0.054	-0.140	0.177	-0.030	-0.013	0.197*	0.052	0.079	-0.162	-0.255**	0.108	0.021	-0.055	1	
Zn	-0.055	-0.161	0.087	-0.011	0.154	0.227*	-0.175	-0.093	-0.010	0.094	-0.127	-0.144	0.009	0.299**	0.135	-0.021	1

Note; ** = Correlation is significant at the 0.01 level (2-tailed); * = Correlation is significant at the 0.05 level (2-tailed); EC= Electrical conductivity; OC= Organic carbon; CEC= Cation exchange capacity

Appendix XIII: Mean (±SE) Monthly Variation of Different Sediment Metals of Yardantsi Reservoir, Gusau

	Metals (cmol/Kg)										
Months	**Ca**	**K**	**Mg**	**Na**	**Cd**	**Cu**	**Cr**	**Fe**	**Ni**	**Pb**	**Zn**
May	2.45± 0.12^{b}	1.00± 0.04^{a,b}	1.73± 0.09^{f}	0.42± 0.02^{a}	1.74± 0.28^{c,d,e,f}	4.91± 0.45^{a}	0.80± 0.06^{a,e,f}	51.77± 4.21^{a,b,c}	0.44± 0.09^{a,b}	0.07± 0.01^{d}	13.71± 0.82^{a,b}
June	3.22± 0.07^{a}	0.89± 0.07^{a,b}	2.51± 0.15^{a}	0.42± 0.02^{a}	1.91± 0.41^{b,c,d,e}	4.73± 0.57^{a}	0.77± 0.07^{a,e,f}	42.15± 8.67^{b,c}	0.43± 0.11^{a,b}	0.16± 0.03^{b,c}	11.57± 1.44^{a,b}
July	2.95± 0.36^{a,b}	0.87± 0.06^{a,b}	2.37± 0.07^{a,b,c}	0.34± 0.01^{b,c,d}	1.30± 0.17^{e,f}	3.82± 0.30^{a,b,c}	1.06± 0.16^{a,e,f}	40.38± 7.59^{b,c}	0.47± 0.10^{a,b}	0.18± 0.02^{b}	22.52± 12.97^{a}
August	2.97± 0.18^{a,b}	0.87± 0.08^{a,b}	2.05± 0.06^{b,c,d,e,f}	0.34± 0.01^{b,c,d}	1.09± 0.12^{e,f}	2.82± 0.29^{c,d}	0.54± 0.09^{a,d}	44.00± 6.38^{b,c}	0.54± 0.09^{a,b}	0.17± 0.02^{b}	7.76± 1.54^{b}
September	2.88± 0.12^{a,b}	0.85± 0.08^{b}	1.91± 0.30^{d,e,f}	0.33± 0.01^{c,d}	1.43± 0.19^{e,f}	4.46± 0.52^{a,b}	2.23± 0.92^{e}	36.46± 6.77^{c}	0.67± 0.06^{b}	0.09± 0.01^{d}	12.19± 1.51^{a,b}
October	2.44± 0.07^{b}	0.98± 0.06^{a,b}	2.07± 0.04^{b,c,d,e,f}	0.31± 0.01^{d}	1.65± 0.27^{d,e,f}	4.18± 0.69^{a,b}	0.68± 0.07^{b,c,d,f}	49.07± 4.53^{a,b,c}	0.60± 0.05^{b,c}	0.09± 0.01^{d}	12.85± 1.32^{a,b}
November	2.40± 0.06^{b}	1.07± 0.03^{a}	2.10± 0.12^{b,c,d,e,f}	0.35± 0.01^{b,c,d}	0.99± 0.11^{f}	2.21± 0.19^{d}	0.82± 0.09^{a,e,f}	60.77± 1.46^{a}	0.61± 0.06^{b,d}	0.16± 0.02^{b,c}	15.09± 0.47^{a,b}
December	3.15± 0.29^{a}	0.91± 0.05^{a,b}	2.19± 0.11^{a,b,c,d,e}	0.38± 0.03^{a,b}	1.14± 0.07^{e,f}	3.23± 0.20^{b,c,d}	1.74± 0.38^{a,e,f}	55.86± 1.22^{a,b}	0.64± 0.05^{b,e}	0.30± 0.01^{a}	15.20± 0.31^{a,b}
January	3.20± 0.17^{a}	0.91± 0.05^{a}	2.30± 0.12^{a,c,d}	0.32± 0.01^{a}	2.85± 0.23^{a}	3.99± 0.26^{a,b,c}	0.89± 0.10^{a,e,f}	48.05± 1.20^{a,b}	0.19± 0.03^{a}	0.20± 0.01^{a}	14.08± 0.51^{a}
February	3.15± 0.20^{a}	1.05± 0.03^{a,b}	2.43± 0.08^{a,b}	0.38± 0.01^{a,b}	2.52± 0.19^{a,b,c}	3.90± 0.23^{a,b,c}	0.74± 0.10^{a,b}	40.58± 1.09^{b,c}	0.41± 0.04^{a,b}	0.11± 0.03^{a,b}	18.67± 0.37^{a}
March	3.01± 0.24^{a,b}	0.92± 0.08^{a,b}	2.03± 0.04^{c,d,e,f}	0.30± 0.00^{d}	2.43± 0.39^{b,c,d}	5.00± 0.28^{a}	0.86± 0.07^{a,e,f}	44.62± 3.19^{b,c}	0.31± 0.09^{a,b}	0.09± 0.01^{d}	11.38± 0.75^{a,b}
April	2.66± 0.21^{a,b}	0.86± 0.05^{b}	1.87± 0.09^{e,f}	0.33± 0.02^{c,d}	2.61± 0.49^{a,b}	4.72± 0.30^{a}	0.72± 0.08^{a,c}	46.77± 3.62^{a,b,c}	0.44± 0.09^{a,b}	0.10± 0.01^{d}	11.43± 0.90^{a,b}

Note; Mean values with the same superscript along the columns were not significantly different ($p>0.05$)

Appendix XIV: Mean Monthly and Seasonal Variation in Number of Individuals (per litre) of Different Phytoplankton Species of Yardantsi Reservoir, Gusau

Phytoplankton	MAY	JUN.	JULY	AUG.	SEP.	OCT.	NOV.	DEC.	JAN.	FEB.	MAR.	APR.	DRY SEASON	RAINY SEASON
***Asterionella formosa* Hass.**	212^{c}	112^{d}	82^{e}	46^{b}	$104^{d,f}$	96^{f}	26^{g}	51^{b}	$80^{a,e}$	57^{b}	68^{a}	$74^{a,e}$	356^{a}	652^{b}
***Cymbella timida* (Bréb.) Van Hanerck**	115^{c}	117^{c}	$58^{d,f,h}$	63^{d}	30^{a}	$46^{e,i}$	$47^{e,f,i}$	$48^{g,h,i}$	31^{a}	$37^{a,e,g}$	$36^{a,e}$	78^{b}	277^{a}	429^{b}
***Synedra ulna* (Nitzsch) Ehrenberg**	$33^{b,e}$	58^{c}	79^{d}	30^{e}	5^{f}	0^{g}	0^{g}	0^{g}	21^{a}	20^{a}	21^{a}	36^{b}	98^{a}	205^{b}
***Oosystis* sp.**	0^{d}	0^{d}	0^{d}	37^{e}	15^{f}	52^{g}	20^{h}	33^{i}	$17^{a,f}$	9^{b}	$20^{a,h}$	4^{c}	103^{a}	104^{a}
***Palmella* sp.**	129^{d}	195^{e}	157^{f}	61^{g}	$31^{b,h}$	46^{a}	$26^{b,i}$	18^{i}	43^{a}	$20^{b,i}$	$40^{a,h}$	110^{c}	257^{a}	619^{b}
***Spirogyra* sp.**	250^{e}	334^{f}	248^{e}	193^{d}	$82^{a,g,h}$	$70^{g,i}$	$96^{b,c,h}$	54^{i}	$82^{a,g,h}$	$94^{a,b}$	114^{c}	208^{d}	648^{a}	1177^{b}
***Cosmarium* sp.**	0^{a}	6^{b}	16^{c}	21^{d}	0^{a}	0^{a}	0^{a}	0^{a}	0^{a}	0^{a}	0^{a}	0^{a}	0^{a}	43^{b}
***Microcystis* sp.**	0^{b}	0^{b}	0^{b}	51^{a}	31^{c}	24^{d}	15^{e}	12^{e}	47^{a}	0^{b}	0^{b}	0^{b}	94^{a}	106^{a}
***Oscillatoria limosa* C.Agardh ex Gomont**	74^{c}	71^{c}	31^{a}	59^{d}	68^{c}	31^{a}	17^{e}	88^{f}	35^{a}	31^{a}	$54^{b,d}$	49^{b}	274^{a}	334^{b}
***Ceratium hirundinella* (Müller) Dujardin**	186^{d}	112^{c}	$94^{e,g}$	$99^{c,e}$	$108^{c,e}$	$77^{f,g,i}$	16^{h}	$72^{b,i}$	$58^{a,b}$	53^{a}	$75^{b,f}$	$102^{c,e}$	376^{a}	676^{b}
***Ceratium teridenella* (Lemm) Skr.**	103^{d}	27^{b}	17^{a}	0^{e}	$24^{b,f}$	$19^{a,f,h}$	64^{g}	$24^{b,h}$	18a	24^{b}	17^{a}	46^{c}	383^{a}	190^{b}

Note; Mean values with the same superscript along the rows were not significantly different ($p>0.05$)

Appendix XV: Mean Percentage Monthly and Seasonal Variation of Different Phytoplankton Species of Yardantsi Reservoir, Gusau

Phytoplankton	**May**	**June**	**July**	**Aug.**	**Sept.**	**Oct.**	**Nov.**	**Dec.**	**Jan.**	**Feb.**	**Mar.**	**Apr.**	**Dry Season**	**Rainy Season**
***Asterionella formosa* Hass.**	19.24^{e}	10.83^{c}	10.74^{c}	7.51^{b}	21.00^{d}	20.86^{e}	9.53^{c}	16.01^{d}	20.47^{e}	16.43^{e}	15.43^{d}	10.54^{c}	14.73^{a}	15.03^{a}
***Cymbella timida* (Bréb.) Van Hanerck**	10.40^{c}	11.30^{c}	7.56^{b}	10.20^{c}	5.97^{b}	9.89^{c}	17.58^{d}	14.84^{c}	8.01^{d}	10.64^{d}	7.97^{c}	10.96^{c}	11.67^{a}	9.23^{b}
***Synedra ulna* (Nitzsch) Ehr.**	3.02^{b}	5.66^{b}	10.31^{c}	4.87^{b}	1.08^{a}	0.00^{a}	0.00^{a}	0.00^{a}	5.40^{c}	5.68^{c}	4.77^{b}	5.14^{b}	3.50^{a}	4.16^{a}
***Oosystis* sp.**	0.00^{a}	0.00^{a}	0.00^{a}	6.01^{b}	3.11^{b}	11.30^{c}	7.58^{b}	10.36^{c}	4.33^{c}	2.72^{b}	4.43^{b}	0.58^{a}	5.00^{a}	3.40^{b}
***Palmella* sp.**	11.70^{c}	18.86^{d}	20.49^{d}	9.99^{c}	6.18^{b}	9.93^{c}	9.69^{c}	5.70^{b}	10.98^{d}	5.82^{c}	9.01^{c}	15.47^{d}	9.45^{a}	12.86^{b}
***Spirogyra* sp.**	22.64^{e}	$32.34^{a,b}$	$32.36^{a,e}$	$31.41^{a,b}$	16.40^{c}	15.27^{d}	$35.54^{a,b}$	16.82^{d}	21.09^{e}	27.35^{f}	25.59^{e}	29.41^{a}	25.97^{a}	25.07^{b}
***Cosmarium* sp.**	0.00^{a}	0.60^{a}	2.05^{b}	3.42^{b}	0.00^{a}	0 .00^{a}	0.00^{a}	0.00^{a}	0.00^{a}	0.00^{a}	0.00^{a}	0.00^{a}	0.00^{a}	1.01^{b}
***Microcystis* sp.**	0.00^{a}	0.00^{a}	0.00^{a}	0.82^{a}	6.14^{b}	5.17^{b}	5.41^{b}	3.83^{b}	1.22^{b}	0.00^{a}	0.00^{a}	0.00^{a}	1.74^{a}	2.02^{a}
***Oscillatoria limosa* C.Agardh ex Gomont**	6.73^{b}	6.84^{b}	4.04^{b}	9.56^{c}	13.60^{c}	6.71^{b}	6.45^{b}	2.72^{b}	8.87^{d}	8.99^{d}	12.16^{c}	6.97^{b}	7.69^{a}	7.91^{a}
***Ceratium hirundinella* (Müller) Dujardin**	16.89^{d}	10.85^{c}	12.22^{c}	16.20^{d}	21.78^{d}	16.77^{d}	5.85^{b}	22.40^{e}	14.93^{d}	15.30^{e}	16.76^{d}	14.41^{d}	14.94^{a}	15.78^{a}
***Ceratium teridenella* (Lemm) Skr.**	9.38^{c}	2.65^{b}	0.22^{a}	0.00^{a}	4.75^{b}	4.09^{b}	2.39^{b}	7.31^{b}	4.72^{c}	7.07^{d}	3.88^{b}	6.52^{b}	5.31^{a}	3.52^{b}

Note; Mean values with the same superscript along the rows were not significantly different ($p>0.05$)

Appendix XVI; Phytoplankton Diversity Indices of Yardantsi Reservoir, Gusau

	MAY	JUNE	JULY	AUG	SEPT	OCT	NOV	DEC	JAN	FEB	MARCH	APRIL
Taxa_S	8	9	9	10	10	9	9	9	10	9	9	9
Individuals	11026.1	10321.9	7661.8	6133.4	4972.2	4603.4	2699.2	3216	3896.2	3444.6	4465.5	7081.8
Dominance_D	0.1556	0.1852	0.1916	0.1673	0.1514	0.1362	0.1925	0.1477	0.1421	0.157	0.1524	0.1661
Simpson_1-D	0.8444	0.8148	0.8084	0.8327	0.8486	0.8638	0.8075	0.8523	0.8579	0.843	0.8476	0.8339
Shannon_H	1.949	1.882	1.839	2.012	2.041	2.083	1.909	2.024	2.088	2.007	2.02	1.954
Evenness_e^H/S	0.8781	0.7293	0.6989	0.7476	0.7696	0.8923	0.7493	0.8409	0.8066	0.827	0.838	0.7837
Brillouin	1.947	1.878	1.835	2.006	2.034	2.077	1.898	2.015	2.079	1.999	2.014	1.949
Menhinick	0.07619	0.08859	0.1028	0.1277	0.1418	0.1326	0.1732	0.1587	0.1602	0.1533	0.1347	0.1069
Margalef	0.752	0.8656	0.8945	1.032	1.057	0.9485	1.013	0.9906	1.089	0.9823	0.9519	0.9024
Equitability_J	0.9375	0.8563	0.837	0.8737	0.8862	0.9481	0.8686	0.9211	0.9066	0.9135	0.9196	0.8891
Fisher_alpha	0.8441	0.9707	1.007	1.167	1.201	1.076	1.161	1.132	1.242	1.121	1.081	1.017
Berger-Parker	0.2264	0.3234	0.3236	0.3141	0.2178	0.2086	0.3554	0.224	0.2109	0.2735	0.2559	0.2941
Chao-1	8	9	9	10	10	9	9	9	10	9	9	9

Appendix XVII: Mean Monthly and Seasonal Variation in Number of Individuals (per litre) of Different Zooplankton Species of Yardantsi Reservoir, Gusau

Zooplankton	**MAY**	**JUN.**	**JUL.**	**AUG.**	**SEPT.**	**OCT.**	**NOV.**	**DEC.**	**JAN.**	**FEB.**	**MAR.**	**APR.**	**DRY SEASON**	**RAINY SEASON**
***Cyclops* sp.**	107^{c}	$17^{b,c}$	$11^{c,d}$	$10^{c,e}$	$21^{b,c}$	$29^{b,c,f}$	56^{f}	90^{a}	100^{a}	$47^{b,f}$	$22^{b,c}$	$29^{b,c,f}$	217^{a}	322^{b}
***Diaptomus* sp.**	82^{e}	57^{b}	59^{b}	57^{b}	27^{d}	$40^{a,c}$	$41^{a,c}$	25^{d}	36^{a}	60^{b}	42^{c}	24^{d}	249^{a}	301^{b}
***Eubranchipus* sp.**	0^{a}	0^{a}	7^{b}	16^{c}	40^{d}	53^{e}	0^{a}	0^{a}	0^{a}	0^{a}	0^{a}	0^{a}	0^{a}	116^{b}
***Thermocylops* sp. Kiefer**	$15^{a,d}$	62^{e}	102^{f}	$23^{b,g,h,i}$	$17^{a,h,j}$	$18^{a,i,j}$	$15^{d,j}$	$25^{b,k}$	$19^{a,g,j}$	$21^{a,g,j}$	30^{b}	41^{c}	200^{a}	188^{a}
***Ceriodaphnia* sp.**	20^{a}	57^{c}	60^{c}	7^{b}	0^{d}	0^{d}	0^{d}	22^{a}	21^{a}	20^{a}	91^{b}	$38^{b,d}$	89^{a}	247^{b}
***Daphnia* sp.**	0^{c}	0^{c}	$31^{d,h}$	$54^{e,f,g}$	$41^{d,f}$	61^{g}	24^{h}	$71^{a,g,i}$	$61^{a,e,g}$	79^{a}	$65^{a,e,g}$	102^{b}	282^{a}	307^{a}
***Diaphanosoma* sp.**	61^{c}	59^{c}	0^{a}	15^{d}	17^{d}	0^{a}	0^{a}	0^{a}	0^{a}	0^{a}	42^{b}	47^{b}	32^{a}	209^{b}
***Eurycercus* sp.**	74^{c}	71^{c}	31^{a}	59^{d}	68^{c}	31^{a}	17^{e}	9^{f}	35^{a}	31^{a}	$54^{b,d}$	49^{b}	215^{a}	314^{b}
***Macrothrix* sp.**	21^{a}	12^{d}	22^{a}	7^{e}	0^{c}	0^{c}	47^{b}	20^{a}	22^{a}	46^{b}	0^{c}	0^{c}	96^{a}	101^{b}
***Brachionus patulus* Müller**	212^{c}	112^{d}	82^{e}	46^{b}	$104^{d,f}$	96^{f}	26^{g}	51^{b}	$80^{a,e}$	57^{b}	69^{a}	$75^{a,e}$	405^{a}	605^{b}
***Chromogaster* sp.**	$33^{b,e}$	58^{c}	79^{d}	30^{e}	5^{f}	0^{g}	0^{g}	0^{g}	21^{a}	20^{a}	21^{a}	36^{b}	114^{a}	189^{b}
***Kellitela* sp.**	0^{c}	59^{d}	0^{c}	0^{c}	0^{c}	0^{c}	$11^{e,f}$	$6^{c,f}$	19^{a}	19^{a}	$17^{a,e}$	74^{b}	17^{a}	188^{b}
***Keratella quadrata* Müller**	$39^{b,e,f}$	30^{d}	$41^{b,e,f}$	$35^{d,e}$	$35^{d,f}$	14^{g}	23^{c}	9^{g}	67^{a}	$39^{b,e,f}$	42^{b}	21^{c}	157^{a}	238^{b}

Note; Mean values with the same superscript along the rows were not significantly different ($p>0.05$)

Appendix XVIII: Mean Percentage Monthly and Seasonal Variation of Different Zooplankton Species of Yardantsi Reservoir, Gusau

Zooplankton	**May**	**June**	**July**	**Aug.**	**Sept.**	**Oct.**	**Nov.**	**Dec.**	**Jan.**	**Feb.**	**Mar.**	**Apr.**	**Dry Season**	**Rainy Season**
Cyclops **sp.**	$2.48^{a,b}$	3.06^{b}	$2.27^{a,b}$	$2.96^{a,b}$	$7.46^{c,b}$	$9.90^{c,b}$	20.89^{e}	27.02^{f}	20.99^{d}	$10.74^{c,a}$	$6.81^{b,c}$	6.98^{b}	15.57^{a}	4.69^{b}
Diaptomus **sp.**	19.05^{d}	10.09^{c}	12.21^{c}	$17.26^{c,b}$	9.69^{c}	13.69^{c}	15.32^{c}	$7.60^{b,f}$	7.64^{b}	13.73^{c}	$13.04^{c,b}$	5.74^{b}	10.51^{a}	13.67^{b}
Eubranchipus **sp.**	0.00^{a}	0.00^{a}	$1.50^{a,d}$	4.83^{b}	14.23^{c}	18.24^{d}	0.00^{a}	0.00^{a}	0.00^{a}	0.00^{a}	0.00^{a}	0.00^{a}	0.00^{a}	6.47^{b}
Thermocylops **sp. Kiefer**	$3.57^{a,c}$	10.93^{c}	21.13^{e}	7.08^{c}	$6.00^{b,c}$	$6.23^{b,c}$	$5.57^{b,c}$	$7.51^{b,f}$	3.91^{b}	4.77^{b}	9.33^{c}	$9.72^{b,c}$	6.80^{a}	9.16^{b}
Ceriodaphnia **sp.**	4.60^{b}	10.12^{c}	$12.42^{c,b}$	$2.26^{a,b}$	0.00^{a}	0.00^{a}	0.00^{a}	$6.58^{b,c}$	4.34^{b}	4.56^{b}	2.83^{b}	0.91^{a}	3.20^{a}	4.90^{a}
Daphnia **sp.**	0.00^{a}	0.00^{a}	$6.46^{b,c}$	$16.47^{c,b}$	14.70^{c}	20.96^{e}	$8.83^{b,d}$	21.16^{e}	13.15^{c}	18.10^{d}	$20.39^{a,c}$	24.32^{e}	17.66^{a}	9.77^{b}
Diaphanosoma **sp.**	$14.04^{c,b}$	10.52^{c}	0.00^{a}	4.59^{b}	$6.05^{b,c}$	0.00^{a}	0.00^{a}	0.00^{a}	0.00^{a}	0.00^{a}	$13.12^{c,b}$	11.20^{c}	4.05^{a}	5.87^{b}
Eurycercus **sp.**	$23.38^{d,c}$	$5.70^{b,c}$	0.00^{a}	0.00^{a}	$8.75^{c,b}$	3.15^{b}	0.00^{a}	0.00^{a}	0.00^{a}	0.00^{a}	0.00^{a}	0.00^{a}	0.00^{a}	6.83^{b}
Macrothrix **sp.**	4.81^{b}	$2.19^{a,b}$	4.67^{b}	$2.09^{a,b}$	0.00^{a}	0.00^{a}	17.52^{d}	5.86^{b}	4.62^{b}	$10.49^{c,a}$	0.00^{a}	0.00^{a}	6.42^{a}	2.29^{b}
Brachionus patulus **Müller**	0.00^{a}	10.45^{c}	0.00^{a}	0.00^{a}	0.00^{a}	0.00^{a}	4.15^{b}	$1.92^{a,b}$	4.05^{b}	4.27^{b}	$5.28^{b,d}$	17.68^{d}	6.23^{a}	1.74^{b}
Chromogaster **sp.**	9.09^{c}	$5.25^{b,c}$	8.45^{c}	10.55^{c}	12.45^{c}	4.81^{b}	$8.37^{b,d}$	$2.70^{a,b}$	14.04^{c}	8.84^{c}	$13.00^{c,b}$	5.11^{b}	8.68^{a}	8.43^{a}
Kellitela **sp.**	9.56^{c}	9.95^{c}	8.35^{c}	0.00^{a}	0.00^{a}	0.00^{a}	$2.89^{a,b}$	5.50^{b}	4.45^{b}	5.14^{b}	2.72^{b}	0.00^{a}	3.45^{a}	4.64^{b}
Keratella quadrata **Müller**	9.41^{c}	21.75^{d}	$22.54^{d,a}$	$31.90^{d,c}$	20.65^{d}	23.02^{f}	16.45^{c}	14.14^{c}	22.80^{f}	19.35^{d}	13.48^{c}	18.36^{d}	17.43^{a}	21.54^{b}

Note; Mean values with the same superscript along the rows were not significantly different ($p>0.05$)

Appendix XIX; Zooplankton Diversity Indices of the Yardantsi Reservoir, Gusau

	MAY	JUNE	JULY	AUG	SEPT	OCT	NOV	DEC	JAN	FEB	MARCH	APRIL
Taxa_S	10	11	10	10	9	8	9	10	10	10	10	9
Individuals	4318.2	5646.1	4811.2	3295.4	2775.6	2924.8	2688.5	3335.1	4772.7	4367.7	3203.1	4188
Dominance_D	0.1433	0.119	0.147	0.1811	0.1299	0.1659	0.1453	0.1611	0.1481	0.1283	0.1285	0.1569
Simpson_1-D	0.8567	0.881	0.853	0.8189	0.8701	0.8341	0.8547	0.8389	0.8519	0.8717	0.8715	0.8431
Shannon_H	2.095	2.248	2.065	1.948	2.116	1.905	2.034	2.027	2.077	2.164	2.15	1.977
Evenness_e^H/S	0.8122	0.8606	0.7887	0.7015	0.9222	0.8399	0.8494	0.7595	0.7981	0.8703	0.8587	0.8027
Brillouin	2.087	2.241	2.058	1.939	2.106	1.896	2.024	2.018	2.07	2.156	2.14	1.97
Menhinick	0.1522	0.1464	0.1442	0.1742	0.1708	0.1479	0.1736	0.1732	0.1447	0.1513	0.1767	0.1391
Margalef	1.075	1.158	1.061	1.111	1.009	0.8771	1.013	1.109	1.062	1.074	1.115	0.9592
Equitability_J	0.9096	0.9374	0.8969	0.8461	0.9631	0.9161	0.9257	0.8805	0.902	0.9397	0.9338	0.9
Fisher_alpha	1.224	1.315	1.206	1.272	1.156	1.003	1.162	1.27	1.207	1.222	1.278	1.09
Berger-Parker	0.2338	0.2175	0.2254	0.319	0.2065	0.2302	0.2089	0.2702	0.228	0.1935	0.2039	0.2432
Chao-1	10	11	10	10	9	8	9	10	10	10	10	9

APPENDIX XX; Mean Raw Monthly Data of Different Sampling Station Surface Water Parameters of Yardantsi Reservoir Gusau

Parameters		**JAN**	**FEB**	**MAR**	**APR**	**MAY**	**JUN**	**JUL**	**AUG**	**SEPT**	**OCT**	**NOV**	**DEC**
Temp. (°C)	**ST1**	22.15	25.70	29.65	29.55	30.20	28.65	30.10	28.80	30.90	32.50	27.00	24.45
	ST 2	22.35	26.35	29.30	30.00	30.10	28.50	30.00	28.65	30.60	32.30	27.40	24.65
	ST3	22.85	25.85	29.70	29.95	30.25	28.70	29.85	29.05	30.45	32.55	26.90	24.40
	ST 4	22.90	25.90	29.75	29.85	30.00	29.05	29.40	28.60	31.00	32.20	27.05	25.25
	ST5	22.50	26.10	29.40	30.10	30.30	28.30	30.20	28.95	31.00	32.50	27.15	24.50
Transp. (cm)	**ST1**	57.00	61.00	47.00	38.50	28.00	26.00	16.00	12.50	27.00	26.50	38.00	50.00
	ST 2	55.00	61.00	48.50	36.00	23.50	23.50	13.50	11.50	24.00	29.50	38.00	51.50
	ST3	52.00	56.00	51.50	42.00	30.50	25.50	14.50	11.00	26.00	30.00	41.50	48.50
	ST 4	55.50	64.50	46.50	36.50	27.50	23.00	15.50	12.00	25.50	27.50	39.00	51.50
	ST5	57.50	57.00	51.50	42.50	27.50	27.00	13.00	13.00	22.50	29.00	38.00	51.50
Mean Depth (m)	**ST1**	2.00	1.85	1.80	2.15	2.35	2.60	2.80	3.00	2.75	2.40	2.15	2.15
	ST 2	2.15	1.90	3.00	2.30	2.40	2.45	2.70	3.05	2.80	2.55	2.35	2.25
	ST3	2.00	1.85	1.85	2.25	2.40	2.70	2.80	2.90	2.80	2.40	2.35	2.15
	ST 4	2.00	1.70	1.70	2.20	2.35	2.70	2.75	2.90	2.75	2.50	2.35	2.05
	ST5	2.25	2.00	1.85	2.15	2.25	2.45	2.65	3.00	2.80	2.55	2.45	2.25
pH	**ST1**	7.57	8.01	8.77	8.15	8.34	8.94	6.81	8.71	7.65	7.79	7.48	8.29
	ST 2	7.68	7.69	6.68	7.91	7.35	8.00	6.93	8.77	7.91	8.56	7.67	8.23
	ST3	7.56	7.69	6.26	7.72	7.65	7.74	6.93	8.50	7.40	8.11	7.49	7.97
	ST 4	7.72	7.97	6.03	7.64	7.78	7.59	7.27	9.20	7.96	7.55	7.71	7.37
	ST5	8.70	7.18	6.48	7.85	8.09	7.53	7.44	9.55	7.80	8.63	7.71	7.36
TDS (mg/L)	**ST1**	106.50	101.00	106.50	114.50	98.00	58.50	43.50	43.50	83.50	74.00	74.50	102.00
	ST 2	91.50	92.00	106.00	104.50	94.50	51.00	40.00	41.50	70.50	79.00	71.50	95.00
	ST3	91.50	92.00	101.00	114.00	93.50	51.00	40.00	40.00	66.50	85.00	74.50	92.50
	ST 4	90.00	106.50	99.00	109.00	92.50	49.00	42.00	42.50	74.00	86.50	73.00	94.50
	ST5	105.00	96.00	93.00	104.50	95.00	49.00	42.50	43.00	63.00	78.50	75.00	103.50
EC (µS/cm)	**ST1**	215.00	220.50	202.50	197.00	145.50	73.50	81.00	74.50	119.50	156.00	149.50	210.00
	ST 2	183.50	193.00	187.50	192.00	145.00	63.00	80.00	80.50	122.50	145.00	151.50	190.50

	ST3	183.00	197.50	183.50	182.00	135.50	63.00	80.00	93.50	133.50	152.00	147.50	186.50
	ST 4	180.50	191.50	178.50	190.50	148.50	60.50	85.00	73.50	121.50	154.00	155.50	191.00
	ST5	211.00	185.50	185.00	181.00	131.50	61.00	85.50	84.00	129.50	163.50	155.50	211.50
DO	**ST1**	9.05	8.10	6.55	7.05	7.75	7.20	6.70	7.30	6.10	5.70	8.05	8.40
(mg/L)	**ST 2**	9.00	8.65	7.40	7.00	7.45	6.50	7.75	7.25	6.10	5.75	8.10	8.40
	ST3	8.90	7.70	7.60	7.25	7.15	6.35	6.95	7.00	6.75	6.45	7.95	7.55
	ST 4	8.70	8.15	6.40	6.15	6.80	8.00	7.75	8.00	6.40	6.05	8.05	8.05
	ST5	8.65	7.75	6.75	7.10	8.15	7.40	6.70	7.40	6.50	5.90	7.45	7.95
BOD	**ST1**	3.75	2.90	1.75	1.95	2.45	2.55	2.65	3.00	2.00	2.30	2.85	3.30
(mg/L)	**ST 2**	3.30	3.00	1.60	1.75	2.15	2.75	2.35	2.85	2.15	2.15	2.80	3.10
	ST3	3.45	2.95	1.75	2.15	2.20	2.25	2.85	3.10	2.25	1.80	2.55	3.20
	ST 4	3.75	3.20	2.10	1.75	1.85	2.80	2.25	2.90	2.60	2.55	3.05	3.00
	ST5	3.65	3.00	1.75	1.85	2.35	2.35	2.85	3.20	2.35	2.45	2.80	3.35
Alk.	**ST1**	45.50	46.00	45.50	40.00	32.50	32.00	30.50	23.00	28.50	25.50	31.50	37.50
(mg/L)	**ST 2**	39.00	50.00	41.00	39.50	35.50	29.50	31.00	22.50	28.50	23.50	31.50	37.50
	ST3	40.00	44.50	45.50	40.00	32.50	30.50	28.50	23.50	23.50	28.00	32.00	34.00
	ST 4	45.50	50.50	40.00	38.50	35.00	29.00	26.00	23.00	26.50	25.00	36.00	41.50
	ST5	43.00	48.00	41.00	37.50	30.00	28.00	31.50	21.00	26.00	26.00	34.50	40.50
Hard.	**ST1**	58.50	65.50	71.00	62.50	54.00	33.50	30.00	21.00	27.00	33.00	45.00	56.00
(mg/L)	**ST 2**	63.00	64.00	65.50	57.50	44.00	30.50	30.00	25.00	26.50	36.00	47.50	50.50
	ST3	65.50	65.00	68.00	55.00	43.50	35.50	29.50	22.00	29.50	33.50	42.00	57.50
	ST 4	61.50	69.50	63.50	56.50	39.00	33.50	30.00	24.00	28.50	32.00	51.50	56.50
	ST5	61.00	70.00	69.50	53.50	42.00	35.50	27.50	23.50	28.50	37.50	49.00	54.50
NO_3-N	**ST1**	1.85	1.75	2.00	2.25	3.90	3.90	4.40	5.40	5.20	4.35	3.35	2.90
(mg/L)	**ST 2**	2.10	1.50	1.90	2.05	3.90	4.35	4.60	4.80	4.70	4.15	3.25	2.50
	ST3	2.00	1.70	1.80	2.65	3.85	4.35	4.25	5.35	4.35	4.00	3.60	2.65
	ST 4	1.95	1.65	2.15	2.25	4.10	4.20	4.60	5.25	4.95	3.70	3.20	2.45
	ST5	1.90	1.60	1.80	2.35	3.60	4.30	4.65	5.15	4.60	4.15	3.00	2.30
PO_4-P	**ST1**	126.00	121.00	112.00	127.00	160.50	205.00	200.00	180.00	158.50	147.00	136.50	132.00

(mg/L)	**ST 2**	125.00	122.00	104.00	123.00	160.50	187.50	199.50	185.00	157.50	143.00	136.00	130.00
	ST3	126.50	120.00	104.50	130.00	163.50	199.50	188.00	175.50	167.50	142.00	137.00	130.50
	ST 4	122.00	113.00	108.50	120.00	157.00	199.00	201.50	178.00	168.00	140.00	137.50	128.50
	ST5	128.50	107.50	103.50	133.00	164.00	198.50	196.00	178.50	161.00	143.00	134.00	132.50
S (mg/L)	**ST1**	34.00	23.50	17.00	22.00	50.50	60.00	80.00	86.00	73.50	70.00	50.50	44.50
	ST 2	37.50	24.00	18.00	24.00	50.50	60.00	85.50	92.50	74.50	66.00	47.00	44.00
	ST3	35.50	24.00	19.50	20.00	50.00	68.00	89.50	93.00	72.50	62.00	47.50	44.50
	ST 4	31.00	22.50	16.50	27.00	51.50	74.00	85.50	88.00	74.50	66.00	47.50	42.00
	ST5	29.50	24.50	19.50	25.00	49.50	66.00	91.00	85.50	76.00	62.50	46.00	40.50
Cl (mg/L)	**ST1**	78.68	92.47	79.62	70.48	50.21	42.23	39.77	27.04	32.35	33.63	48.23	71.57
	ST 2	82.09	91.82	79.83	69.99	53.32	42.27	41.00	31.19	30.63	33.99	47.81	74.02
	ST3	84.85	86.83	78.65	74.30	48.55	40.07	39.46	30.45	32.03	33.62	52.10	68.59
	ST 4	83.58	90.96	79.72	71.00	51.00	45.53	40.58	30.01	30.65	35.91	51.18	69.94
	ST5	86.57	87.47	75.44	66.95	46.07	39.15	39.43	28.56	30.09	30.43	52.42	75.36

Note; Temp. = Temperature; Trans. Transparency; TDS = Total Dissolved Solids; EC = Electrical Conductivity; Alk. = Alkalinity; Hard. = Hardness and ST = Station

APPENDIX XXI; Mean Raw Monthly Data of Different Sampling Stations Surface Water Metals of Yardantsi Reservoir, Gusau

Month	Station	Metals (mg/L)										
		Ca	K	Mg	Na	Cd	Cu	Cr	Fe	Ni	Pb	Zn
Jan.	**ST1**	4.00	2.66	2.51	82.39	.06	.72	.05	.62	.03	.02	.55
	ST 2	3.34	2.16	2.09	83.91	.07	.67	.05	.62	.02	.03	.62
	ST3	3.07	2.25	2.72	78.45	.07	.72	.05	.72	.02	.03	.62
	ST 4	3.51	2.17	2.83	85.60	.08	.74	.06	.65	.01	.02	.71
	ST5	2.55	2.19	2.77	75.70	.06	.80	.06	.76	.01	.02	.79
Feb.	**ST1**	2.47	2.81	2.64	88.62	.05	1.02	.07	.79	.02	.02	.80
	ST 2	2.17	3.10	3.00	84.61	.05	1.12	.07	.84	.03	.02	.78
	ST3	1.89	2.81	3.04	83.74	.04	1.09	.09	.83	.04	.02	1.20
	ST 4	2.03	3.70	2.75	76.38	.03	1.30	.09	1.00	.04	.02	1.37
	ST5	2.02	3.27	2.72	86.95	.07	.94	.10	1.18	.04	.01	.95
Mar.	**ST1**	1.28	4.11	2.84	79.72	.15	.77	.08	1.41	.04	.02	.81
	ST 2	1.47	4.43	3.02	74.55	.12	.89	.08	1.64	.04	.01	.81
	ST3	1.40	4.97	2.40	71.75	.12	.89	.09	1.68	.05	.02	.60
	ST 4	1.10	4.03	2.44	72.87	.08	.89	.08	1.76	.05	.02	.62
	ST5	.93	4.77	2.69	72.51	.10	.70	.11	1.87	.06	.02	.64
Apr.	**ST1**	1.15	4.23	1.98	49.30	.15	.91	.12	2.10	.08	.03	.76
	ST 2	1.37	4.19	2.11	54.31	.18	1.02	.12	2.29	.06	.03	.93
	ST3	.80	4.67	1.87	60.07	.16	1.09	.17	2.14	.08	.03	.95
	ST 4	.91	4.05	2.02	60.78	.16	1.20	.15	2.29	.10	.02	1.17

	ST5	.88	4.20	1.88	53.97	.16	1.23	.15	2.48	.11	.03	1.24
May	**ST1**	.57	4.61	1.14	49.59	.16	1.21	.17	2.48	.11	.04	1.38
	ST 2	.68	4.42	1.17	42.17	.16	1.05	.19	2.56	.13	.03	1.36
	ST3	.66	4.12	1.03	45.05	.16	1.20	.20	2.75	.14	.05	1.48
	ST 4	.60	4.65	1.00	48.54	.20	1.41	.21	2.90	.12	.05	1.45
	ST5	.94	4.18	.77	42.87	.17	1.41	.21	2.82	.15	.06	1.60
Jun.	**ST1**	.56	4.55	.58	40.10	.24	1.57	.23	2.86	.13	.06	1.69
	ST 2	.59	4.17	.51	41.18	.25	1.70	.24	3.09	.15	.05	1.86
	ST3	.67	4.45	.40	38.35	.29	1.59	.22	3.21	.13	.07	1.79
	ST 4	.62	4.46	.59	41.29	.34	1.47	.25	3.32	.13	.07	1.69
	ST5	.67	4.16	.37	36.36	.35	1.77	.25	16.22	.15	.08	1.71
Jul.	**ST1**	.43	4.10	.22	36.84	.12	1.30	.24	3.51	.16	.07	1.62
	ST 2	.50	3.88	.20	33.38	.13	1.39	.25	3.28	.14	.07	1.48
	ST3	.51	3.64	.26	35.14	.09	1.36	.26	3.28	.15	.07	1.48
	ST 4	.65	4.15	.28	43.68	.13	1.57	.24	3.70	.16	.08	1.57
	ST5	.50	4.32	.18	39.98	.12	1.41	.25	3.70	.15	.08	1.57
Aug.	**ST1**	.83	2.55	.16	28.52	.08	1.34	.18	2.94	.17	.05	1.57
	ST 2	.65	2.45	.23	32.16	.08	1.36	.18	2.60	.19	.06	1.41
	ST3	.82	2.13	.16	31.30	.08	1.39	.15	2.79	.19	.05	1.38
	ST 4	.80	2.43	.21	30.33	.07	1.50	.19	2.63	.17	.04	1.26
	ST5	.82	2.23	.18	26.95	.04	1.18	.20	2.52	.18	.03	1.36
Sept.	**ST1**	.83	1.86	.38	42.78	.09	1.09	.18	2.06	.17	.03	1.14

	ST 2	.69	1.98	.39	35.59	.08	1.23	.18	2.06	.13	.03	1.26
	ST3	1.42	1.66	.43	37.48	.09	1.27	.13	4.50	.12	.03	1.83
	ST 4	1.30	1.76	.47	48.83	.07	1.18	.17	2.25	.12	.02	1.17
	ST5	1.21	1.92	.44	31.23	.07	1.23	.14	1.98	.12	.02	1.21
Oct.	**ST1**	2.57	2.22	.68	55.48	.05	1.07	.15	1.68	.12	.03	1.05
	ST 2	2.50	2.32	.77	62.21	.05	1.05	.11	1.57	.10	.02	1.05
	ST3	2.99	2.20	.75	51.46	.05	.93	.12	1.60	.10	.02	.95
	ST 4	2.79	2.57	.80	51.98	.05	.77	.13	1.57	.08	.02	.88
	ST5	2.76	1.94	.72	57.02	.08	.77	.13	1.37	.10	.02	.83
Nov.	**ST1**	3.99	2.09	1.89	62.76	.04	.91	.20	1.90	.17	.03	.89
	ST 2	3.48	2.17	1.64	63.39	.05	1.02	.19	1.81	.17	.03	.86
	ST3	3.04	2.11	1.79	64.62	.04	.98	.19	1.75	.17	.02	.79
	ST 4	4.51	1.86	1.80	71.59	.04	.92	.17	1.87	.16	.02	.87
	ST5	3.57	2.17	1.76	65.81	.03	1.00	.16	1.99	.17	.02	.96
Dec.	**ST1**	4.93	2.30	2.47	64.66	.02	.88	.14	2.09	.17	.02	1.11
	ST 2	4.57	1.89	2.51	78.60	.03	.87	.14	2.16	.16	.02	1.18
	ST3	4.42	2.07	2.37	63.13	.03	.87	.10	1.90	.16	.03	1.17
	ST 4	3.39	2.53	2.70	73.12	.03	.70	.11	2.29	.19	.03	1.26
	ST5	5.15	1.80	2.03	87.93	.03	.62	.10	1.95	.12	.03	.81

Note; Temp. = Temperature; Trans. Transparency; TDS = Total Dissolved Solids; EC = Electrical Conductivity; Alk. = Alkalinity; Hard. = Hardness and ST = Station