STUDIES ON THE PHYSICO-CHEMICAL PARAMETERS AND PLANKTON COMPOSITION OF AJIWA RESERVOIR KATSINA STATE, NIGERIA

BY
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DECLARATION

I declare that the work in this Thesis entitled Studies on the Physico-Chemical Parameters and Plankton Composition of Ajiwa Reservoir; Katsina State, Nigeria has been carried out by me in the Department of Biological Sciences. 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 another degree or diploma at this or any other institution.

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CERTIFICATION

This thesis entitled "STUDIES ON THE PHYSICO-CHEMICAL PARAMETERS AND PLANKTON COMPOSITION OF AJIWA RESERVOIR, KATSINA STATE, NIGERIA" by Ahmed IBRAHIM meets the regulation governing the award of the degree of Master of Science (M.Sc.) in Educational Biology of the Ahmadu Bello University, and is approved for its contribution on the knowledge and literary presentation.

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DEDICATION

This work is dedicated to the memories of my beloved Stepmother Late Hajia Hussaina Kado whose moral support had always been a source of guidance and inspiration for me; may Allah grant her gentle soul aljannatul Firdausi.
Amen.

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ABSTRACT

The Studies on the physico-chemical parameters and plankton composition of Ajiwa reservoir, Katsina State, Nigeria was carried out from May 2012 to April 2013; with the aim to establish physical, chemical, and biological parameters (Plankton) of Ajiwa reservoir. Three sampling stations were chosen; the physico-chemical and biological parameter were determined using standard methods, procedures, and instruments. The result revealed that; Water temperature (23.8 ± 0.8^{o}C), pH (6.8 ± 0.1), Turbidity (99.3 ± 3.6NTU), Conductivity (129.9 ± 4.1µS/cm), Total Dissolved Solids (17.8 ± 0.3mg/L), Nitrate-nitrogen (6.01 ± 0.3mg/L), Water hardness (88.8 ±1.4mg/L$CaCO_3$), Dissolved Oxygen (6.6 ± 0.3mg/L), Biochemical Oxygen Demand (3.2 ± 0.4mg/L), Phosphate-phosphorus (6.4 ± 0.2mg/L) and Water depth (5.4±0.3m) varied with months and seasons. Analysis of variance indicated significant difference between seasons ($P < 0.05$); but no significant difference in zooplankton and phytoplankton distribution and abundance between the three stations ($P>0.05$). The result indicated phytoplankton percentage composition as; Chlorophyta (57.66%), Bacillariophyta (25.70%), Cyanophyta (14.73%), and Dinophyta (1.91%) while Zooplankton percentage composition were Rotifera (30.55%), Copepoda (29.33%), Protozoa (22.27%), and Cladocera (17.85%); the morpho-edaphic index indicate low fish potential yield in the reservoir. Water quality of the reservoir is influenced by anthropogenic activities such as runoffs of inorganic fertilizers and pesticides; the reservoir water is suitable for irrigational and domestic purposes in terms of most of the physico-chemical and biological parameters analyzed. Hence, there is need for an effective anthropogenic inputs control programme in the reservoir.

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CHAPTER ONE

1.0 INTRODUCTION

1.1 Reservoir Ecosystem

Reservoirs constitute important ecosystem and food resources for a diverse array of aquatic life. Reservoir ecosystems are fragile and can undergo rapid environmental changes, often leading to significant declines in their aesthetic, recreational and aquatic ecosystem functions. Human activities can further accelerate the rate of changes; if the causes of the changes are known, human intervention (management practices) sometimes can control or even reverse detrimental changes.

It is well established that the productivity of a reservoir depends on its ecological conditions and by monitoring the water quality; productivity can be increased to obtain maximum sustainable yield of fish (Mustapha, 2011). Maintenance of healthy aquatic environment and production of sufficient food in reservoir are primarily linked with successful reservoir culture operations. To keep the aquatic habitat favourable for existence of living organisms, physical and chemical factors like temperature, turbidity, pH, odour, dissolved gases (Oxygen and CO_2), salts nutrients must be monitored regularly, individually or synergistically, activity of living organisms is influenced by the seasonal and diurnal changes of these parameters (Akinyeye *et al.,* 2011). Various studies had been conducted on changes brought about by biotic and abiotic factors of river as a result of damming. However, responses of rivers and it is ecosystem to damming are complex and varied as they depend on local sediment supplies, geomorphic constraint, climate, dam structure and operation (Offem and Ikpi, 2011).

Life in aquatic environment is largely governed by physico-chemical characteristics and their stability. These characteristics have enabled biota to develop many adaptations that improve sustained productivity and regulate its metabolism

(Olele and Ekelemu 2008). Many of these reservoirs were built as a result of societal demand for drinking and industrial water supplies, irrigation, hydroelectric power generation, fish production and recreation. With time however, most of these reservoirs have secondary functions such as navigation, industrial processing, flood protection, urban run-off control and tourism superimposed on them (Mustapha, 2011). Impacted changes in the water quality are reflected in the biotic community structure, with the most vulnerable dying, while the most sensitive species act as indicators of pollution.

In Africa, there are many shallow reservoirs, but their number is still few considering their functions, population demand for their resources and their roles. In order for these reservoirs to perform the purpose(s) of their establishment as well as other functions that might be superimposed on them, plankton community structure and composition of these reservoirs should be well known; this will provide a valuable insight to its effective management (Mustapha, 2011).

Nigeria is blessed with about 853,600 hectares of freshwater capable of producing over 1.5 million metric tonnes of fish annually (FAO, 2009). Because of this there is need to exploit means of using these precious resources, even though there are some hindrances, which includes effects of domestic and agricultural wastes on the water quality and aquatic life, physical and chemical factors like temperature, turbidity, pH, dissolved gases (Oxygen and CO_2), salts and nutrients. It is no doubt; reservoirs have contributed to the economic growth of many nations and Nigeria included. Reservoirs built in several part of the world have played important role in helping communities to harness water resources for several uses. An estimated 30-40% of irrigated land worldwide now relies on reservoir water (Mustapha, 2011). In Nigeria, many researchers have conducted works on different water bodies, some of them include, Balogun *et al.* (2005) some aspects of the limnology of Makwaye (Ahmadu

Bello University farm) lake, Samaru, Zaria; Balarabe (2001) effect of limnological characteristic on zooplankton composition and distribution in Dumbi and Kwangila ponds, Zaria; Ibrahim *et al.* (2009) on an assessment of the physico-chemical parameters of Kontagora reservoir, Niger state. Hassan *et al.* (2010) on the algal diversity in relation to physico-chemical parameters of three ponds in Kano metropolis and Abubakar (2009) on the Limnological studies for the assessment of Sabke lake, Katsina state. This research work is aimed to establish physical, chemical, and biological parameters of Ajiwa reservoir, and to provide better understanding of the reservoir ecosystem.

1.2 Statement of the Problem

The anthropogenic inputs from neighbouring communities such as run-offs from agricultural farms containing of manures and fertilizers are the major problem that the Ajiwa reservoir is experiencing. These inputs can cause serious effect to the water quality and subsequently affect the biodiversity of the reservoir. The role of nutrients, spatial and temporal fluctuations in controlling the species composition, diversity, and seasonal succession of planktonic composition in the reservoir has not been documented.

1.3 Justification

Most reservoir ecosystems in Nigeria are threatened by anthropogenic activities (Ibrahim *et al.,* 2009). This study on physico-chemical parameters and plankton composition of Ajiwa reservoir was initiated in order to provide baseline information on the quality of the water and propose best management practices that will enhance the productivity of the water. Planktons are very sensitive to the environment they live and any alteration in the environment leads to the change in the plankton communities in terms of tolerance, abundance, diversity and dominance in the habitat. Plankton

population observation may be used as a reliable tool for monitoring to assess fish reduction and water borne disease (Mustapha, 2009). In addition, the results of the study will be used to enlighten the communities nearby on the effect of their activities to the water body.

Ajiwa reservoir is chosen for this study because of its importance to many communities and no similar work of this nature has been conducted so far. The work is aimed to provide baseline information on the physico-chemical parameters, plankton biodiversity, and their ecological interactions.

1.4 Aim and Objectives of the Study

The aim of the study was to establish physical, chemical, and biological parameters of Ajiwa reservoir, and to provide better understanding of the reservoir ecosystem.

The following are objectives of the study:-

1. To determine the seasonal variation of physico-chemical parameters of the reservoir.
2. To determine the temporal and spatial distribution of plankton composition in the reservoir.
3. To determine the relationship between physico-chemical parameters and plankton abundance in the reservoir.

1.5 Research Hypotheses

1. There is no significant seasonal variation of physico-chemical parameters in the reservoir.
2. There is no significant difference in the temporal and spatial distribution of plankton composition in the reservoir.
3. There is no significant relationship between plankton abundance and physico-chemical parameters in the reservoir.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 Physico-Chemical Parameters

2.1.1 Temperature

It is one of the most important and essential parameter of aquatic habitats because almost all the physical, chemical, and biological properties are governed by temperature (Araoye, 2008).The basis of all life functions is complicated set of biochemical reactions that are influenced by physical factors such as temperature. The temperature was basically important for its effects on the chemical and biological activities of organisms in water N'Diaye *et al.* (2013).Temperature influences the oxygen contents of water, quantity and quality of autotrophs, while affecting the rate of photosynthesis and also indirectly affecting the quantity and quality of heterotrophs (Barnabe, 1994). The water temperature varies throughout the year with seasonal changes in air temperature, day length, and solar radiations (Ayoade, 2009). The significance of bright sunlight and temperature helped in production of green algae. The changes in temperature and other biological factors including succession were responsible for the elimination of some aquatic plants in Jebba Lake, Nigeria (Adeniji, 1991). Temperature influence in the determination of other factors like pH, conductivity, dissolved gases and various forms of alkalinity N'Diaye *et al.* (2013)

Temperatures of water were generally higher than air temperatures in the afternoon hours except for few months (January to March), air and surface water temperatures were almost uniform in the month of October/November but most peculiarly in the morning hours and monthly variations of water temperatures surface

and bottom (Araoye, 2008). The water temperature varied from winter to monsoon (June-August), higher water temperatures were recorded in lentic part of Bhagirathi and Bhilangana respectively compare to lotic portion. Water temperature of the lacustrine portion was significantly different from that of lotic and changes in physico-chemical features and Plankton (Ayoade, 2009). Ibrahim et *al.* (2009) reported; the low water temperature of Kontagora reservoir during the dry season could be as a result of seasonal changes in air temperature associated with the cool dry Northeast trend winds. The air and water temperature readings indicated an increase from January to March in Makwaye Reservoir (Balogun *et al.,* 2005).

2.1.2 Turbidity

Turbidity reduces the light penetrating depth, and hence, reduces the growth of the aquatic plants (Landau, 1992).High turbidity restricts the light penetration, which indirectly checks the phytoplankton growth (Boyd, 1998). The gradual reduction in transparency with month could be due to the effect of wind mixing in shallow reservoirs (Balogun *et al.,* 2005). The water of Tehri reservoir, India became more turbid in monsoon (June-August) due to silt being washed in with rainwater (Ayoade, 2009).

Ayoade *et al.* (2006) observed onset of rain decreased the turbidity in two mine lakes around Jos, Nigeria. Higher light penetration of sunlight energy is important in photosynthesis (Ibrahim *et al.,* 2009). The lower transparency during rainy season could be attributed to influx or turbid flood from the rivers and runoffs into the lakes thereby decreasing light penetration. It could also be due to decrease in sunlight intensity due to presence of heavy cloud in the atmosphere, which in turn reduced the quantity of light reaching the water (Atobatele and Ugwumba. 2008).

Onyedineke *et al.* (2009) reported turbidity was due to heavy rainfall leading to an increase in phytoplankton abundance and decay of organic matter in suspension in addition to surface runoff from adjacent streams carrying heavy sand and silt into the water. Ayoade *et al.* (2006) reported that the adverse effects of turbidity on freshwaters include decreased penetration of light, hence reduced primary and secondary production, absorptions of nutrient elements to suspended materials making them unavailable for plankton production, oxygen deficiency, clogging of filter feeding apparatus and digestive organs of planktonic organisms and may greatly affect the hatching of larvae.

2.1.3 Water pH

pH is considered an important chemical parameter that determines the suitability of water for various purposes. pH of water is very important for the biotic communities because most of the aquatic organisms are adapted to an average pH (Surajit and Tapas, 2014). The pH expresses the acidity or alkalinity of water, which is determined by means of hydrogen ion (H^+) and the hydroxyl ion (OH^-) concentration in water. Higher concentration of H^+ ions gives lower score on the pH scale and lower concentration of H^+ ions gives higher scores on the pH scale. Water of around pH 7 is called neutral. During daylight, aquatic plants usually remove the CO_2 from the water quickly and pH increases. At night, CO_2 accumulates and pH declines (Mahar, 2003). The increased organic matter brought in by rain as a result of runoff tends to reduce dissolved oxygen through utilization of organic dehydration giving rise to a fall in pH (Atobatele *et al*., 2008).

Mustapha (2008) reported the slight acidity in the dry season may be due to high carbon dioxide concentration occurring from organic decomposition. High pH

values promote the growth of phytoplankton and results in algal blooms. Decomposition reduced the amount of oxygen, while increasing the amount of carbon dioxide in the affected environment (Araoye, 2008).

2.1.4 Water Hardness

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

2.1.5 Dissolved Oxygen (DO)

Dissolved oxygen (DO) has primary importance in natural water as limiting factor because most organisms other than anaerobic microbes diminish rapidly when oxygen levels in waterfalls, of all dissolved gases; oxygen plays the most important role in determining the potential biological quality of water. It is essential for breakdown of organic detritus and enables completion of biochemical pathways (Boyd, 1998). Dissolved oxygen supply in water mainly comes from atmospheric diffusion and photosynthetic activity of plants. The quantity of dissolved salts and temperature greatly affects the ability of water to hold oxygen (Araoye, 2008).

Iqbal *et al.* (1990) described level of dissolved oxygen playing a predominant role in bringing about temporal changes in the zooplankton composition of Hub Lake. The amount of dissolved oxygen in water has been reported not constant but

fluctuates, depending on temperature, depth, wind and amount of biological activities such as degradation (Indabawa, 2009). Ibrahim *et al.* (2009) reported that the cool harmattan wind, which increased wave action, and decreased surface water temperature, might have contributed to the increased oxygen concentration surface during the dry season in Kontagora reservoir, Niger state, Nigeria. Decomposition reduced the amount of oxygen, while increasing the amount of carbon dioxide in the affected environment. Photosynthetic activity and reduced turbidity enhanced Dissolved oxygen concentration (N'Diaye *et al.* 2013).

2.1.6 Biochemical Oxygen Demand (BOD)

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

2.1.7 Electrical Conductivity of Water

Conductivity of natural water is a measure of its ability to conduct an electric current. Increased in water conductivity could result from low precipitation, higher

atmospheric temperatures resulting in higher evapo-transpiration rates and higher total ionic concentration, and saline intrusions from underground sources (Atobatele and Ugwumba, 2008). Specific conductivity can be utilized as a rapid measurement of dissolved solids and is useful in monitoring waste streams and conducting field water quality studies. The level of conductivity in water gives a good indication of the amount of substances dissolved in it, such as phosphate, nitrate and nitrites. Different ions vary in their ability to conduct the electricity (Zeb *et al*., 2011). Generally conductivity of the natural water is directly proportional to the concentration of ions. Distilled water has a conductivity of about 1μmhos/cm, while natural water normally has conductivity of 20-1500 μmhos/cm the conductivity of solutions depends upon the quantity of dissolved salts present (Boyd, 1998). Fazio and O'Farrell (2005) reported that biodiversity diminished with increasing conductivity in Los Coipos Lake.

2.1.8 Total Dissolved Solids (TDS)

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

2.1.9 Phosphate-Phosphorus (PO_4-P)

Phosphorus plays an important role in the determination of the productivity of an ecosystem, which in turn can affect the number of trophic level in a food web and its stability. The presence of nutrients and plant biomass formation in water body exhibit a complex dynamic relationship in tropical aquatic ecosystem due to various physico-chemical and biological characteristic (Parrow *et al.,* 1991). Phosphorus enters lakes as inorganic phosphate ions, inorganic polymer and organic phosphorus compounds in living micro-organisms and dead detritus. Ude *et al.* (2011) reported that; phosphorus is the most important and limiting substance controlling organic production.

2.1.10 Nitrate-Nitrogen (NO_3-N)

Nitrate-Nitrogen is required in aquatic and terrestrial ecosystem in a moderate quantity. The amount of nitrate in solution at a given time is determined by metabolic processes in water; that is production and decomposition of organic matter (Balarabe, 2001). Kigamba (2005) reported the increased level of nitrates leached into African lakes from the excessive use of nitrogen fertilizers. High concentration of Nitrate-Nitrogen could be attributed to increase in the irrigation practices close to the bank of the lake where leaching of fertilizers from the farm into the lake. Spatial variation in stream water nitrate concentrations is influenced by nitrification in upland soils, which affects the extent to which catchments retain or export nitrate via stream flow (Ude *et al.,* 2011). Nitrate-Nitrogen inputs often vary seasonally due to the effects of the growing season and hydrology, uptake of Nitrogen by terrestrial vegetation. Stream water concentrations tend to be lower during the growing season and higher during the dormant season (Ude *et al.,* 2011).

2.2 Biological Parameters

2.2.1 Studies on Phytoplankton

It is well established fact that more than 75% of freshwater fish feed on plankton at one or other stage of their life cycle. In the sea and in most large inland water the bulk of living matter found in water is phytoplankton and hence their biological importance is immense (Akomeah *et al.* 2010). Phytoplanktons are the primary producers of water bodies; these are the main source of food directly or indirectly to the fish population. Phytoplankton composition has been governed by water quality parameters. The relationship that water quality share with Phytoplankton is reciprocal as the later strongly influence water quality through carbon dioxide uptake and oxygen production.

Phytoplanktons are essential component of the aquatic food chain (Janjua, *et al.,* 2008). The Phytoplanktons are the primary producers in freshwater bodies including lakes where different forms present in various locations viz: epilithic (rock) epipsamic (mud), epiphytic (plant), epipelic (sediments) and epizoic (animals) forms (Kadiri, 2002). They constitute a heterogeneous assemblage of algae whose distribution and seasonal succession are of interest to limnologist. This is why they do not only influence the food chain but are also of economic value and biological significance to man (Araoye and Owolabi, 2005). It is therefore proper that their occurrence, composition and abundance be matched with opportunities provided in their environment (Olele and Ekelemu, 2008). The observation of more Chlorophyta than Bacillariophyta (diatoms) conformed to the typical trend in tropical water bodies (Akomeah *et al.,* 2010). High diversity of desmids is an indication that the water body

is largely unpolluted (Kadiri, 2002). Euglenophyta is characteristic of eutrophic or nutrient rich water bodies (Adesalu and Nwanko, 2010).

Tiseer *et al.* (2008) recorded ten species of Bacillariophyta, eleven species of Chlorophyata and one species of Euglenophyta in Samaru stream, Zaria, Nigeria. *Peridinium sp*. was the only member of Dinophyceae of plankton composition groups in Egbe reservoir during the dry and rainy seasons (Edward and Ugwumba, 2010). The abundance of *Microcystis sp* was probably due to the availability of nutrients through sewage disposal, phosphate, detergent, agricultural runoff and high level of nitrogen (Hassan *et al.,* 2010). Kolo *et al.* (2010) reported four groups of phytoplankton (Bacillariophyceace, chlorophyceace, cyanophyceace, and desmidiaceace) in Tagwai dam Minna Nigeria.

2.2.2 Studies on Zooplankton

Ecologically zooplanktons are one of the most important biotic components influencing all the functional aspects of an aquatic ecosystem such as food chains, food webs, energy flow, and cycling of matter (Park and Shin, 2007). Therefore, for better understanding of life processes in any lentic or lotic water body, adequate knowledge of zooplankton communities and their population dynamics is major requirement (Achionye-Nzeh.and Isimaikaiye, 2010). Since eutrophication influences both the composition and productivity of zooplankton and the latter are considered as indicators of environmental quality and water contamination levels in lakes and rivers (Anil *et al.,* 2014). The individual growth rate of copepods may depend on temperature alone in a global viewpoint; food condition is still considered to be an important factor affecting growth and reproduction of copepods in nature, especially in closed environment such as bays, lagoons and lakes (Syuhei, 1994).

Usha (1997) observed that among total zooplanktonic organisms, rotifers came third in the order of abundance in Gandhisagar reservoir. These exhibited a bimodal pattern with a major peak in December and a minor peak in August; also observed that among total zooplanktonic population, Cladocera came second in order of abundance in Gandhisagar reservoir, except *Diaphanosoma* and *Daphnia*, no Cladocerans could be recorded in the winter season. It may be due to low temperature and other physico-chemical factors, while a peak was recorded in summer (Jana *et al.,* 2009).Chia and Bako (2008) reported *Synechocystis* in Danmika pond (dry season) and Palladan pond (dry and wet seasons). Physicochemical parameters are known to affect the biotic components of an aquatic environment in various ways (Adeaogun *et al.,* 2004). Adakole *et al.* (2008) observed the organism, which develops in a given aquatic habitat, is indicative of environmental conditions that have occurred during the organism's development. Balogun et *al.,* (2005) reported composition of zooplankton of Makwaye as Cladocera was represented by Daphnia and Diaphanosome species. Rotifers were represented by *Keratella* and *Branchionus* species with *Keratella* forming the most abundant species. Copepoda was represented by *Diaptomus* species, Cyclops species and *Nauplus* larvae formed the most abundant.

2.3 Morpho-Edaphic Index (MEI)

Reservoir morphometry have been used in estimating potential fish yields from reservoirs. The most widely accepted method is the morpho-edaphic index (MEI) developed by Ryder (1965). The MEI is calculated by dividing the value of total dissolved solids (mg/L) or Electrical conductivity by the mean depth (m) of the water body. Adeniji (1991) applied it to African lakes and reservoirs by substituting with conductivity, which compares favourably with TDS. Recently, Janjua *et al.* (2008)

predicted a high fish production from Shahpur dam, Pakistan, using MEI derived from physico-chemical parameters, while Kantoussan *et al.* (2007) used it as indicator in evaluating fish yield in two tropical lakes of Mali, West Africa. The simplicity of the MEI and its generally good predictive capabilities has resulted in its application.

CHAPTER THREE

3.0 MATERIALS AND METHODS

3.1 Study Area

Ajiwa reservoir was constructed since 1975; it's located in a sub-desert area on Latitude 12°98'N, Longitude7°75'E, in Batagarawa Local Government, Katsina State, Nigeria (Figure.3.1) The main purpose of the reservoir is irrigation and water supply to the people of Katsina, Batagarawa, Mashi, and Mani local Governments. It has original height of 12m but after being rehabilitated in 1998 the height is now 14.7m; original reservoir crest length was 880m, but after being rehabilitated reservoir crest length is now 1491.8m. It also has the surface area of 607.0 ha. The volume of the water is almost 22,730,000m^3; the dam serves as source of livelihood to the communities nearby.

3.2 Sampling Procedures

Three sampling stations were selected based stratified method of sampling in Ajiwa reservoir. Station I was located at the downstream called Kanyar Bala, station II was located at Loko, while station III was located at upstream called Gada. The distance between stations was 200m apart (Figure: 3.2). The procedural plan of this study was monthly sampling of water and plankton from May 2012 to April 2013. The water was sampled at the surface level by dipping one litre plastic sampling bottle sliding over the upper surface of water with their mouth against the water current to permit undisturbed passage of the water into the bottle. The water samples were then transported to Biology laboratory II in the department of Biology, Umaru Musa Yar'adua University Katsina for analysis of physico-chemical and biological parameter.

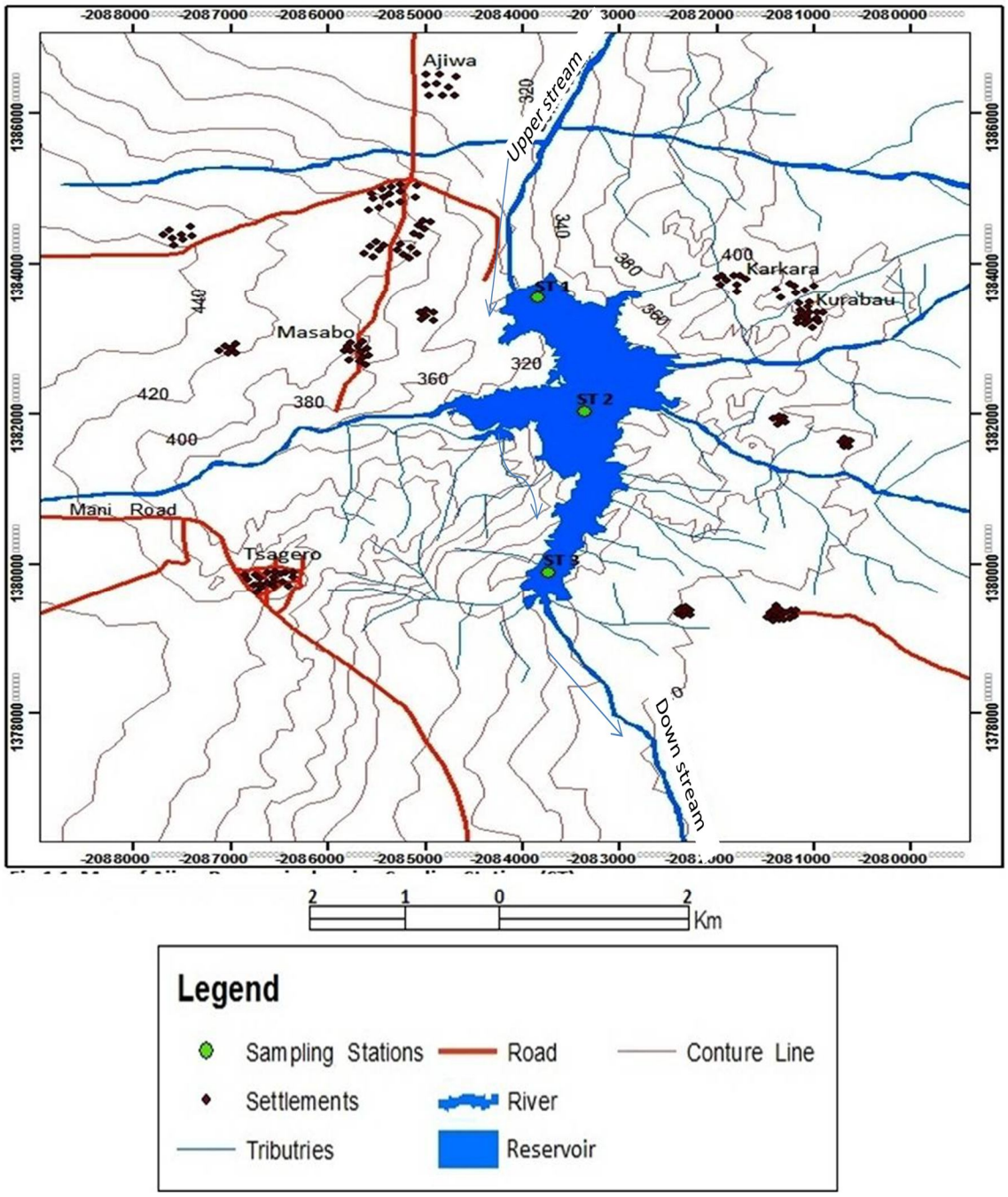


Figure 3.1 Part Map of Katsina Showing Location of Ajiwa Reservoir

Source :-(Cartography Geo. Dept. UMYU, 2013**)**

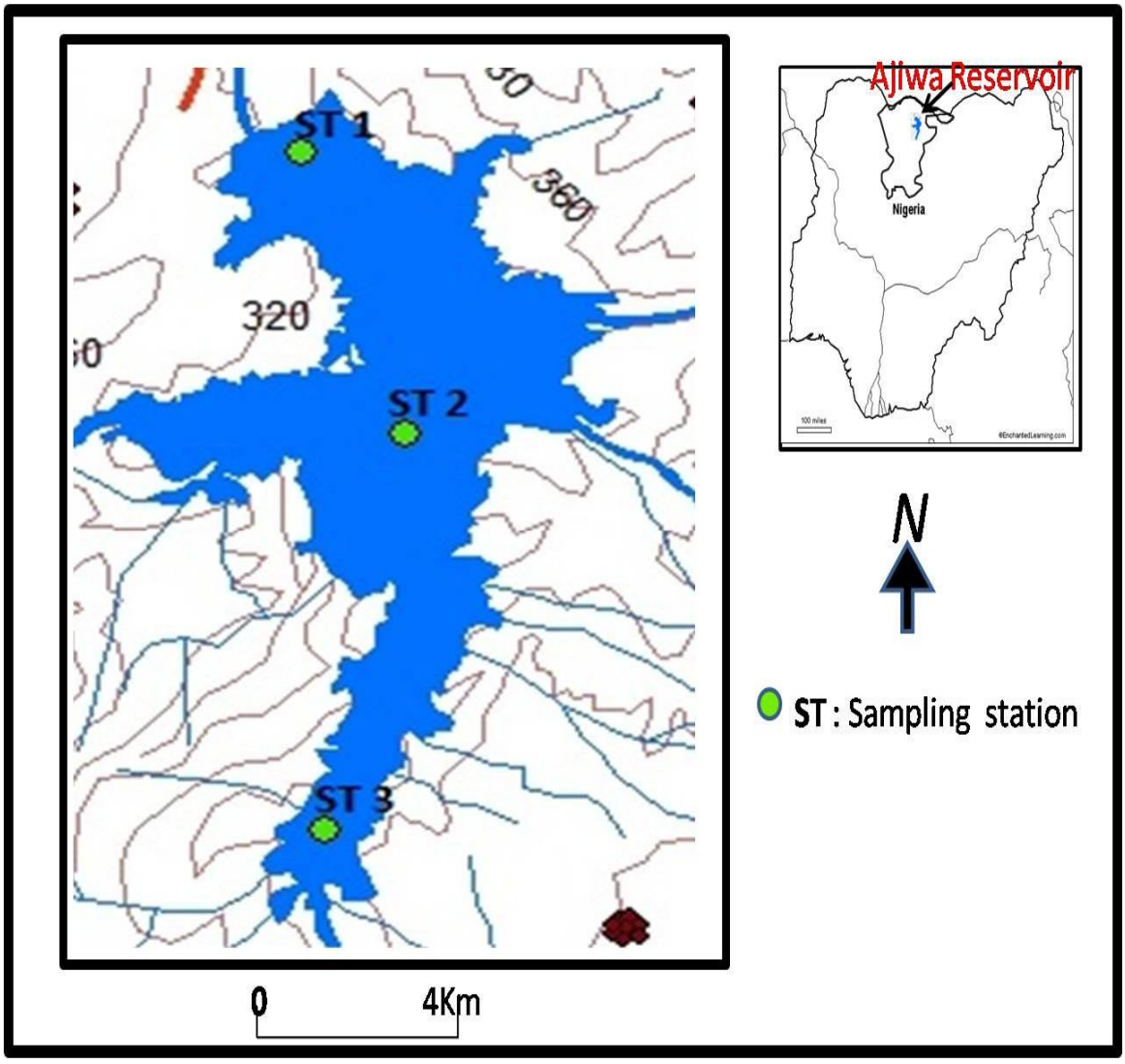


Figure 3.2 Map of Ajiwa Reservoir Showing Sampling Stations

(Cartography Geo. Dept. UMYU, 2013**)**

3.3 Physico-Chemical Parameters

3.3.1 Determination of Temperature

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

3.3.2 Determination of Turbidity

The turbidity of water was measured with turbidity tube; Plate I (a). The tube was calibrated at the bottom with "X" mark in black colour. The water sample was measured in 200ml beaker and poured gradually into the turbidity tube, while at the same time observing the calibration mark at the bottom of the tube from the upper side of the tube until the calibrated line disappeared. The depth at which it disappeared was recorded in Nephelometric Turbidity Unit (NTU) from the graduated readings of the turbidity tube (Nathanson, 2003).

3.3.3 Determination of pH

pH was measured with Hanna 420 pH meter; Plate I (b). It was calibrated according to instructional manual provided by the manufacturer. The electrode of the pH meter was dipped into the water sample for 2-3minutesand readings ware recoded (APHA, 1999).

3.3.4 Determination of Dissolved Oxygen (DO) and Biochemical Oxygen Demand (BOD)

Hanna Dissolved Oxygen microprocessor HI 98186 was used to determine the dissolved oxygen, Plate I (c). It was calibrated according to the instruction manual provided by the manufacturer. Sample of the water was collected in 100ml beaker; the electrode of Dissolved oxygen microprocessor was dipped into the beaker that contains the sample water for about 2-3minute. The readings were recorded in mgL^{-1}.

For biochemical oxygen demand; 100ml part of the sample was incubated for five days in cupboard at room temperature and Dissolved oxygen was tested, the difference between the initial value of Dissolved oxygen and the value after incubation was used as value of biochemical oxygen demand in the water sample (APHA, 1999; Mahar, 2003).

3.3.5 Determination of Water Hardness

Some 10ml of sample was taken into conical flask with the help of pipette, 0.5mg of buffer tablet (Erichrome black-T) and 1ml of concentrated ammonium hydroxide (NH_4OH) was added as indicator and then titrated with 0.1N (EDTA) solution.

Calculation

$$\text{Hardness } (mgCaCO_3\ L^{-1}) = \frac{N \times M \times 50{,}000}{V}$$

Where:

N = Normality of titrate 0.1N

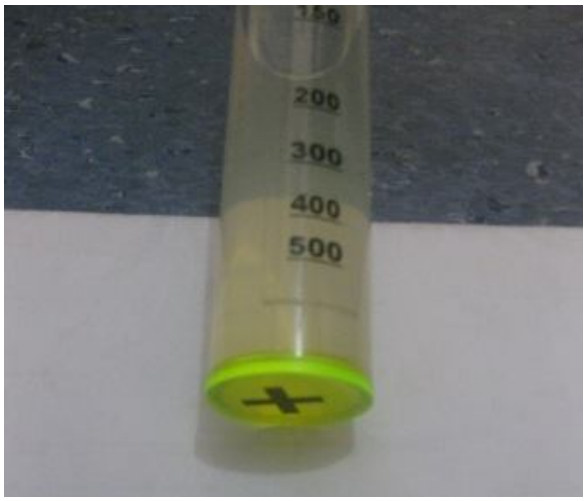
M = Mean of three readings

V =Mean Volume of three sample

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

3.3.6 Determination of Electrical Conductivity and Total Dissolved Solids (TDS)

These parameters were measure with WTW 320 conductivity meter; Plate I (d). Water samples were placed into clean beakers, conductance cell of the meter was immersed into sample solution. The resistance was measured in µS/cm, the readings of Conductivity and total dissolved solids ware noted with the conductivity meter by changing mode of measurement to TDS. The cell was rinsed in a beaker with distilled water after each reading. The calibration measurement was performed in 0.00702 NaCI solutions. This solution has a specific conductance of 0.1µS/cm at 25°C.



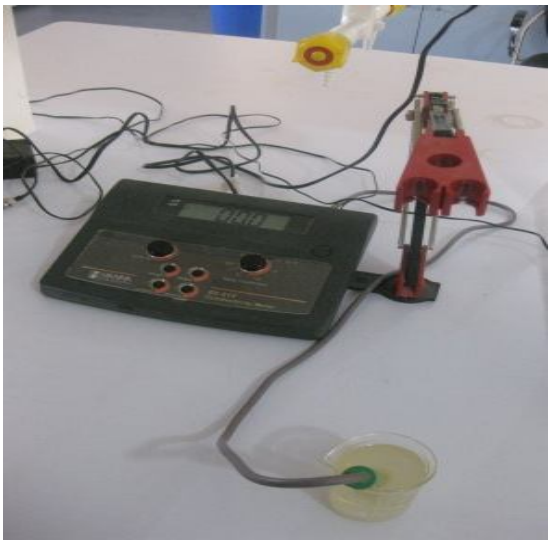
(a): Turbidity tube



(b): pH mete



(c): Dissolve Oxygen meter



(d): Conductivity meter.

Plate I: Some of the Apparatus Used In Determination of Physico-Chemical Parameters.

3.3.7 Determination of Phosphate-phosphorus

This was determined using the Deniges method APHA, (1999). Some 1ml of Deniges reagent and 5 drops of stannous chloride was added to 100ml water sample. Absorbance at 690nm was measured with spectrometer, model S101 using distilled water as the blank. The phosphate-phosphorus concentration of water sample was read from the calibration curve in mgL^{-1}.

3.3.8 Determination of Nitrate-Nitrogen

One hundred (100) ml of water sample was poured into a crucible, evaporated to dryness, and cooled. 2ml of phenoldisulphonic acid was added and smeared around the crucible, after 10minutes, 10ml of distilled water was added followed by 5ml strong ammonia solution. Setting the spectrophotometer at the wave length 430nm, absorbance of the sample treated was obtained, using distilled water as blank. The concentration of nitrate-nitrogen was obtained from the Calibration curve in mgL^{-1} (APHA, 1999).

3.3.9 Water Depth

Calibrated rope weight attached at one end was used to measure water depth, the rope was dipped down gradually until no gravity pulling it down was notice then the water level was marked and recorded in meters.

3.4. Biological Parameters

3.4.1 Determination of Phytoplankton

Phytoplankton samples were collected with one litter transparent plastic bottle by dipping the container bottle, sliding over the upper surface of water with it mouth against the water current to permit undisturbed passage of the water into the bottle (Tanimu, 2011). Samples were preserved with Lugol's solution and brought to the laboratory. Slides were prepared and observed under a binocular microscope; Plate II

(a); with various magnifications. Taxonomic identification of plankton was carried out with the help of taxonomic keys such as Emi and Andy (2007); Verlencar (2004); Edward and David (2010) and Palmer (1969). The phytoplanktons were counted from left top corner of the slide to the right corner by moving the slide horizontally. Photographs of the specimens' representative were made by camera with magnification of ×100 and ×400 under the binocular microscope (Mahar, 2003).

3.4.2 Determination of Zooplanktons

Zooplankton samples were collected with silk plankton net of 25cm diameter of 70meshes/cm attached with a collection bottle of 50ml capacity at the base. The net was sunk just below the surface and then towed through a distance of 5m. The content of the collected vial was then poured into plastic bottle of 70ml capacity and preserved in 4% formalin. Counting was done by shaking the preserved sample and pipetting 1ml of it into a Sedgwick Rafter Counting Cell and then mounted on a microscope. the apparatus used are in Plate II (a-d).Identification was done using standard textbook such as Needham and Needham, (1975) and APHA (1999).

3.5 Data Analysis

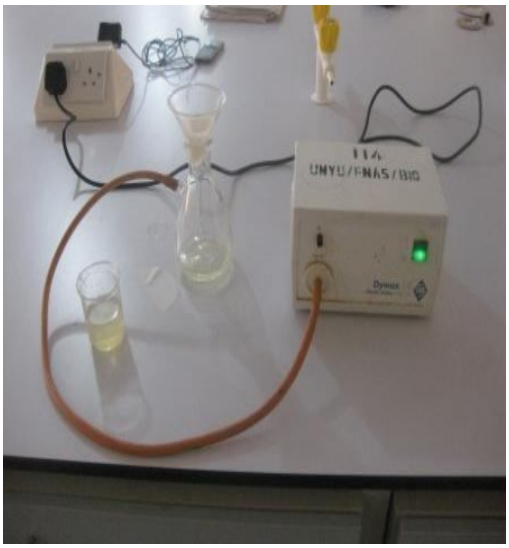
Descriptive statistics was used to calculate Mean, Mean ± Standard Error (SE), Standard deviation, Minimum and Maximum values. Percentage was used for plankton abundance and the results obtained was subjected to analysis of variance to test the level significance at $P<0.05$; between the physico-chemical parameters and seasonal variation. Least significant difference (LSD) was used to separate means. Pearson's correlation coefficient was used to test the relationship between physico-chemical parameters and plankton (zooplankton and phytoplankton abundance). Shannon and Simpson's diversity index was used to determine diversity.



(a) Microscope.



(b) Plankton net.



(c) Saucing pump.



(d) Water Analysis kit.

Plate II: Some of the Apparatus Used In Determination of Biological Parameters

CHAPTER FOUR

4.0 RESULTS

4.1 Physico-Chemical Parameters

The Physico-Chemical Parameters of the reservoir showed monthly mean variation (Table 4.1). The water temperature variation indicated mean ± SE value of (23.08 ± 0.8^{O}C); the pH values ranged between 6.5 -7.8 with mean ± SE value of 6.8 ± 0.1; Turbidity of the reservoir fluctuated with mean ± SE value of 99.3 ± 3.6NTU. The Dissolved Oxygen values in the reservoir ranged from 3.8mgL^{-1} to 7.9mgL^{-1}; with the mean ± SE of 6.6 ± 0.3mgL^{-1}. The biochemical oxygen demand in Ajiwa reservoir revealed monthly variation with mean ± SE value of 3.2 ± 0.4mgL^{-1}. The electrical conductivity ranged from 102.4µS/cm to105.1µS/cm with mean ± SE of 129.9 ± 4.1µS/cm. The hardness in the reservoir shown mean ± SE of 88.8 ± 1.4mgL^{-1}($CaCO_3$); Nitrate-nitrogen indicated mean ± SE values of 6.1 ± 0.3mgL^{-1}during the period of study. Total dissolved solids in the reservoir has peaked value of 23.8mgL^{-1} which was recorded in the month of December while the least value of 10.1mgL^{-1} was recorded in the month of July; the mean ± SE was 17.8 ± 1.5mgL^{-1} and the mean ± SE value of Phosphate-phosphorus was 2.9 ± 0.2mgL^{-1}. The mean ± SE value of depth was 5.4±0.3m.

4.1.1 Temperature

Analysis of variance revealed there was significant difference between the temperature in the wet and dry season at $P > 0.05$ and there was no significant difference between the water temperatures of the three stations at $P < 0.05$ (Table: 4.2). The water temperature indicated positive correlation with Nitrate-nitrogen, dissolved oxygen, biochemical oxygen demand, depth and conductivity, while there was negative correlation with turbidity, hardness and total dissolved

solids (Table: 4.13). Figure.4.1 shows monthly stations variations of temperature in Ajiwa reservoir, there was decrease in temperature from July to December and then temperature increased gradually from the month of January and continued to increase up to the month of April. The highest temperature of 28°C was recorded during the rainy season in June at station II and III while the lowest temperature of 18°C was recorded during the dry season in December at Station I and II.

4.1.2 pH

Analysis of variance revealed there was significant difference between wet and dry season values of pH in Ajiwa reservoir at $P > 0.05$. There was no significant difference between the pH values of the three stations at $P < 0.05$ (Table: 4.3). The pH indicated positive correlation with turbidity and total dissolved solids while negative correlation with water depth, dissolved oxygen, biochemical oxygen demand, Electrical conductivity of water, Nitrate-nitrogen and Phosphate-phosphorus (Table: 4.13). Figure 4.2 shows monthly stations variation of pH in Ajiwa reservoir. The pH values fluctuated between the months of June to October in the wet season. but there was increase in the pH values from the month of December to April. The highest pH of 7.8 was recorded during the dry season in January at station I while the lowest pH of 6.5 was recorded during the rainy season in July at Station II.

Table 4. 1: Mean, Mean ±SE, Standard Deviation, Minimum and Maximum of Monthly Physico-chemical Parameters in Ajiwa Reservoir

	Months	Temp. (°C)	PH	Turbidity (NTU)	DO (mgL^{-1})	BOD (mgL^{-1})	EC (µS/cm)	TDS (mgL^{-1})	Depth (m)	PO_4- P (mgL^{-1})	NO_3-N (mgL^{-1})	Hardness ($mg(CaCO_3L^{-1})$
Wet Season	May	26.0^{ab}	6.9^{ab}	89.3^{bc}	7.2^{a}	3.6^{ab}	102.4^{c}	14.8^{bc}	5.3^{ab}	1.7^{bc}	6.3^{ab}	83.1^{ab}
	Jun.	25.3^{ab}	6.9^{ab}	89.3^{bc}	7.3^{a}	3.6^{ab}	112.4^{c}	14.0^{bc}	5.4^{ab}	2.5^{ab}	6.4^{ab}	84.1^{ab}
	Jul.	27.7^{a}	6.7^{ab}	89.3^{bc}	7.3^{a}	3.6^{ab}	120.7^{bc}	10.1^{cd}	5.4^{ab}	2.7^{ab}	6.4^{ab}	84.1^{ab}
	Aug.	26.0^{ab}	6.5^{ab}	88.0^{bc}	7.1^{a}	3.6^{ab}	122.0^{bc}	10.2^{cd}	6.4^{a}	3.1^{a}	7.1^{a}	87.9^{a}
	Sept.	24.0^{ab}	6.9^{ab}	88.6^{bc}	7.5^{a}	3.6^{ab}	122.7^{bc}	13.4^{bc}	7.5^{a}	3.6^{a}	7.2^{a}	88.6^{a}
	Oct.	22.6^{b}	6.8^{ab}	95.7^{bc}	7.8^{a}	3.8^{a}	129.7^{b}	17.0^{bc}	6.1^{a}	3.8^{a}	6.5^{a}	84.3^{a}
Dry Season	Nov.	23.7^{ab}	6.8^{ab}	98.3^{bc}	7.7^{a}	3.9^{a}	133.3^{ab}	19.3^{ab}	5.7^{ab}	2.4^{bc}	6.6^{a}	87.3^{a}
	Dec.	18.3^{bc}	6.9^{ab}	101.3^{ab}	6.9^{ab}	4.0^{a}	136.6^{ab}	23.8^{a}	5.3^{ab}	2.7^{bc}	5.3^{bc}	90.7^{a}
	Jan.	20.6^{b}	7.0^{a}	128.3^{a}	5.7^{ab}	2.3^{bc}	140.3^{ab}	23.5^{a}	5.3^{ab}	2.4^{bc}	4.2^{c}	90.9^{a}
	Feb.	22.3^{b}	7.2^{a}	115.0^{ab}	5.2^{ab}	2.1^{bc}	144.1^{ab}	23.2^{a}	4.1^{c}	3.2^{ab}	5.4^{bc}	94.1^{a}
	Mar.	23.6^{b}	7.4^{a}	108.7^{ab}	5.0^{ab}	2.1^{bc}	144.6^{ab}	23.7^{a}	4.0^{c}	3.4^{ab}	5.9^{ab}	99.4^{a}
	Apr.	25.7^{ab}	7.8^{a}	100.0^{ab}	4.9^{bc}	2.0^{bc}	150.1^{a}	20.1^{ab}	4.0^{c}	3.2^{ab}	6.0^{ab}	91.5^{a}
	Mean ± SE	23.8±0.8	6.8±0.1	99.3±3.6	6.6±0.3	3.2±0.4	129.9±4.	17.8±1.5	5.4 ±0.3	2.9±0.2	6.1±0.3	88.8±01.4
	SD	2.7	0.3	12.9	1.7	0.9	14.3	5.5	1.0	0.9	0.9	1.9
	Min	18.3	6.5	88.6	4.9	2	102.4	10.1	4.0	1.7	4.2	83.1.1
	Max	27.7	7.8	128.3	7.8	3.8	150.1	23.8	7.5	3.8	7.2	99.4
	Standard	23-35	6.5-9	100-125	≥5	>3	3.5	150		10	10	20-200

Key: Temperature (Temp.), Nephelometric Turbidity Unit (NTU), Dissolved Oxygen (DO), Biochemical Oxygen Demand (BOD), Electrical conductivity (EC), Phosphate-Phosphorus (PO_4-P), Nitrogen-Nitrite (NO_3-N).
Note: Columns with same superscript are not significantly different.

Table 4.2: Analysis of Variance for Temperature (°C) in Ajiwa Reservoir

Source of Variation	*SS*	*Df*	*MS*	*F*	*P-value*	*F crit*
Months	220.5333	11	24.5037	52.09449*	4.65E-11	2.456281
Stations	0.866667	2	0.433333	0.92126^{ns}	0.415988	3.554557
Error	8.466667	22	0.47037			
Total	229.8667	35				

Source of Variation	*SS*	*Df*	*MS*	*F*	*P-value*	*F crit*
Between season	18.225	1	18.225	3.007426*	0.121108	5.317655
Within season	48.48	11	6.06			
Total	66.705	12				

Table 4.3: Analysis of Variance for pH in Ajiwa Reservoir

Source of Variation	*SS*	*Df*	*MS*	*F*	*P-value*	*F crit*
Months	3.28	11	0.364444	20.01	1.28E-07	2.456281
Stations	0.018667	2	0.009333	0.512195	0.607653	3.554557
Error	0.328	22	0.018222			
Total	3.626667	35				

Source of Variation	*SS*	*Df*	*MS*	*F*	*P-value*	*F crit*
Between season	0.625	1	0.625	12.01923	0.008482	5.317655
Within season	0.416	11	0.052			
Total	1.041	12				

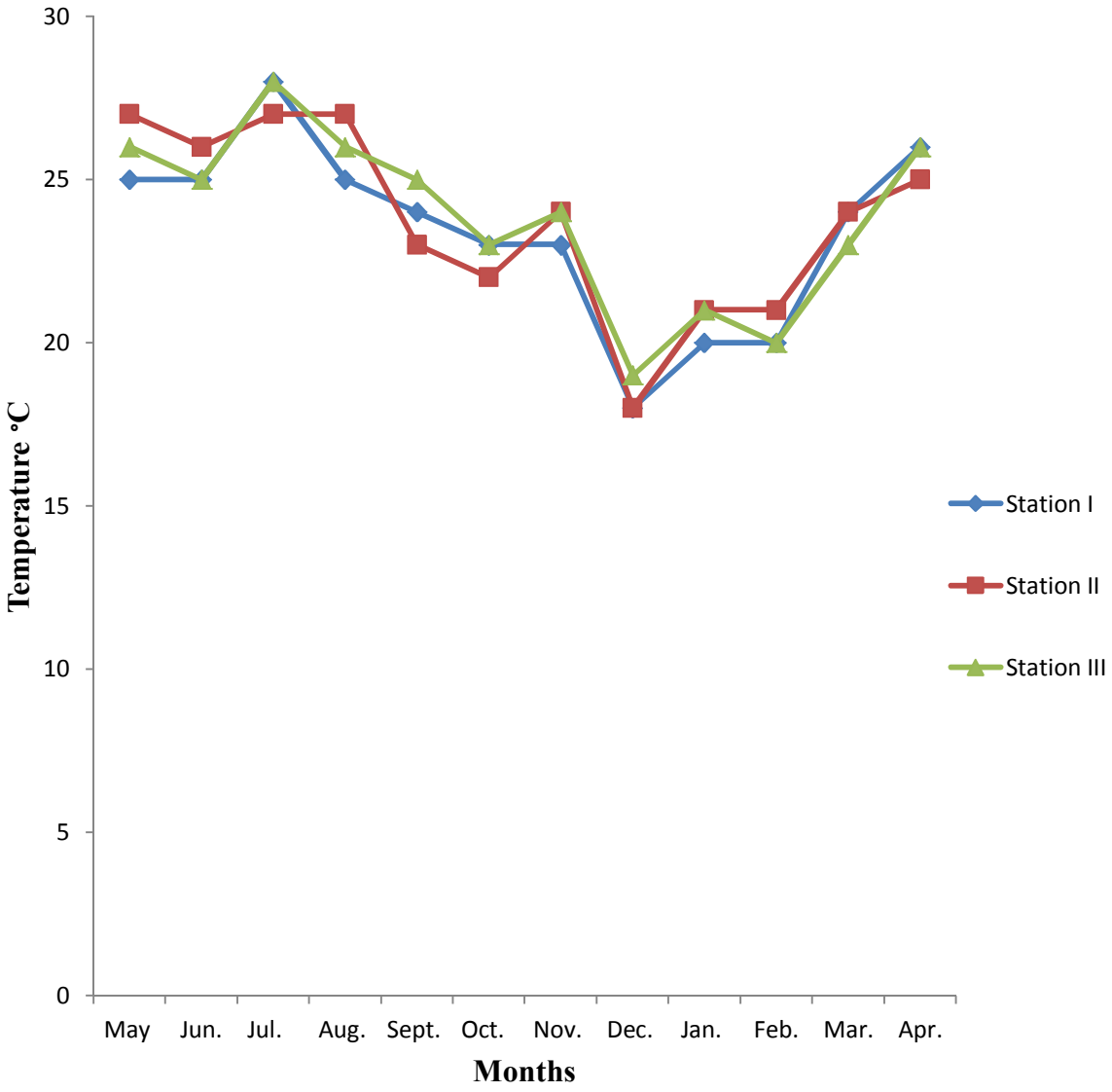


Figure 4.1: Monthly Stations Variation of Temperature in Ajiwa Reservoir

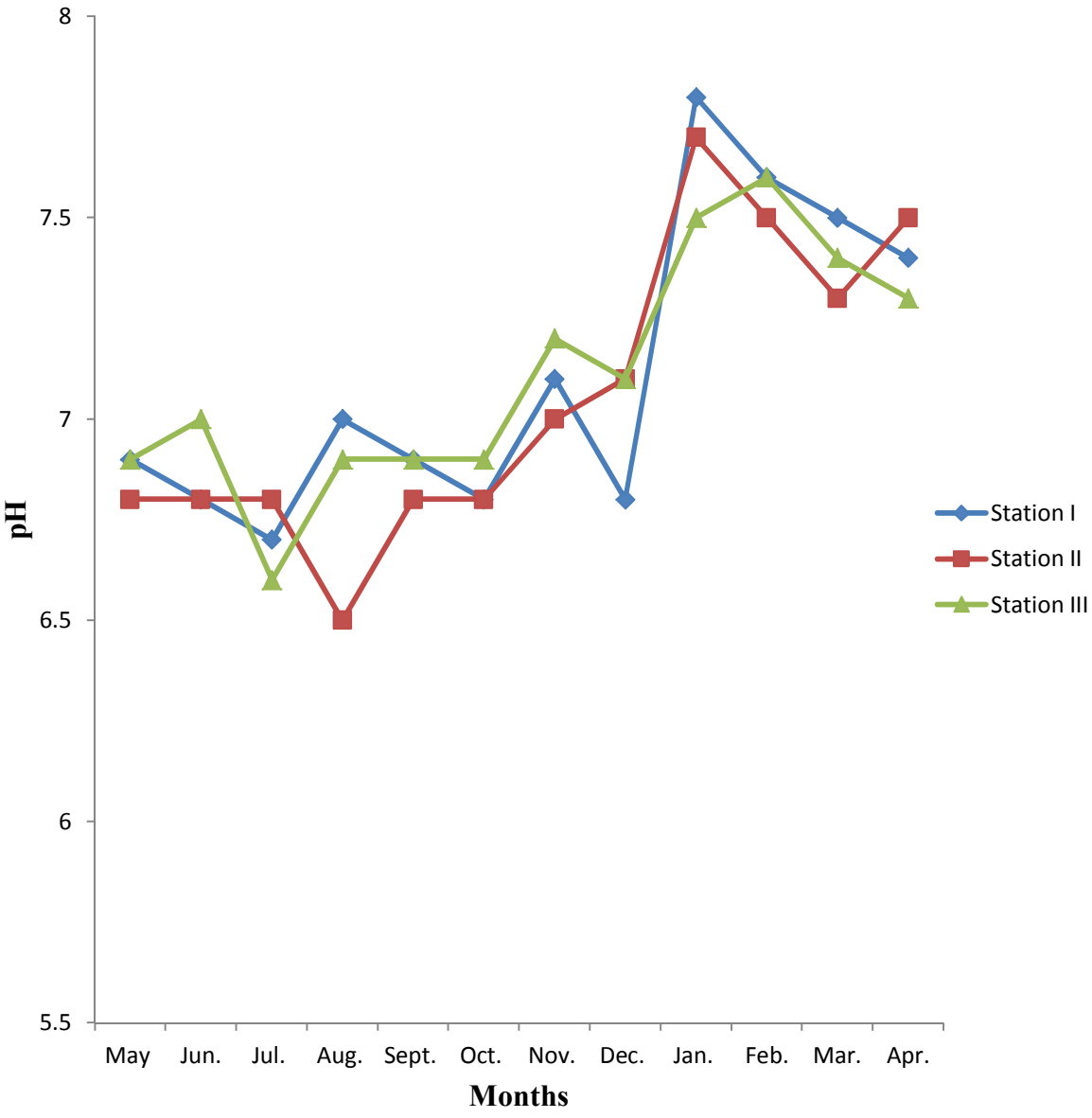


Figure 4.2: Monthly Stations Variation of pH in Ajiwa Reservoir.

4.1.3 Turbidity

There was significant difference between turbidity values of wet and dry season at $P < 0.05$ but there was no significant difference between the turbidity of the three stations at $P > 0.05$ (Table: 4. 4). The turbidity shown positive correlation with Total dissolved solids, depth, and Hardness while negative correlation with dissolved oxygen, biochemical oxygen demand, Nitrate-nitrogen and Phosphate-phosphorus(Table: 4. 13). Figure 4.3 shows monthly stations variation of turbidity in Ajiwa reservoir, there was increase in turbidity from the month of September to January were the highest value was recorded and there was slight decreased in the values of the turbidity in the month of February and April. The highest value of turbidity was recorded in dry season in the month of January at station III while the lowest was recorded in wet season in the month of August at station I.

4.1.4 Dissolved Oxygen (DO)

There was no significant difference of DO values in the three stations $P > 0.05$. but there was significant difference between the values of DO in the wet and dry season at $P < 0.05$ (Table: 4.5). The dissolved oxygen shown positive correlation with temperature, biochemical oxygen demand, conductivity and Nitrate-nitrogen while negative correlations with hardness, turbidity, depth and total dissolved solids (Table: 4.13). Figure 4.4 shows monthly stations variation of dissolved oxygen in Ajiwa reservoir, there was increased in dissolved oxygen content in the reservoir from July to November and then the values decreased gradually up to April. The highest value of $7.9mgL^{-1}$ was recorded in October at station III in wet season while the lowest value of $3.8mgL^{-1}$ was recorded in April at station III in dry season.

Table 4.4: Analysis of Variance for Turbidity (NTU) in Ajiwa Reservoir

Source of Variation	*SS*	*Df*	*MS*	*F*	*P-value*	*F crit*
Months	4484	11	498.2222	53.12796	3.93E-11	2.456281
Stations	29.86667	2	14.93333	1.592417	0.230795	3.554557
Error	168.8	22	9.377778			
Total	4682.667	35				

Source of Variation	*SS*	*Df*	*MS*	*F*	*P-value*	*F crit*
Between season	0.625	1	0.625	12.01923	0.008482	5.317655
Within season	0.416	11	0.052			
Total	1.041	12				

Table 4.5: Analysis of Variance for Dissolved Oxygen (mg/L) in Ajiwa Reservoir

Source of Variation	*SS*	*Df*	*MS*	*F*	*P-value*	*F crit*
Months	75.38133	11	8.375704	408.9403	6.11E-19	2.456281
Stations	0.064667	2	0.032333	1.578662	0.23351	3.554557
Error	0.368667	22	0.020481			
Total	75.81467	35				

Source of Variation	*SS*	*Df*	*MS*	*F*	*P-value*	*F crit*
Between season	872.356	1	872.356	11.19625	0.010139	5.317655
Within season	623.32	11	77.915			
Total	1495.676	12				

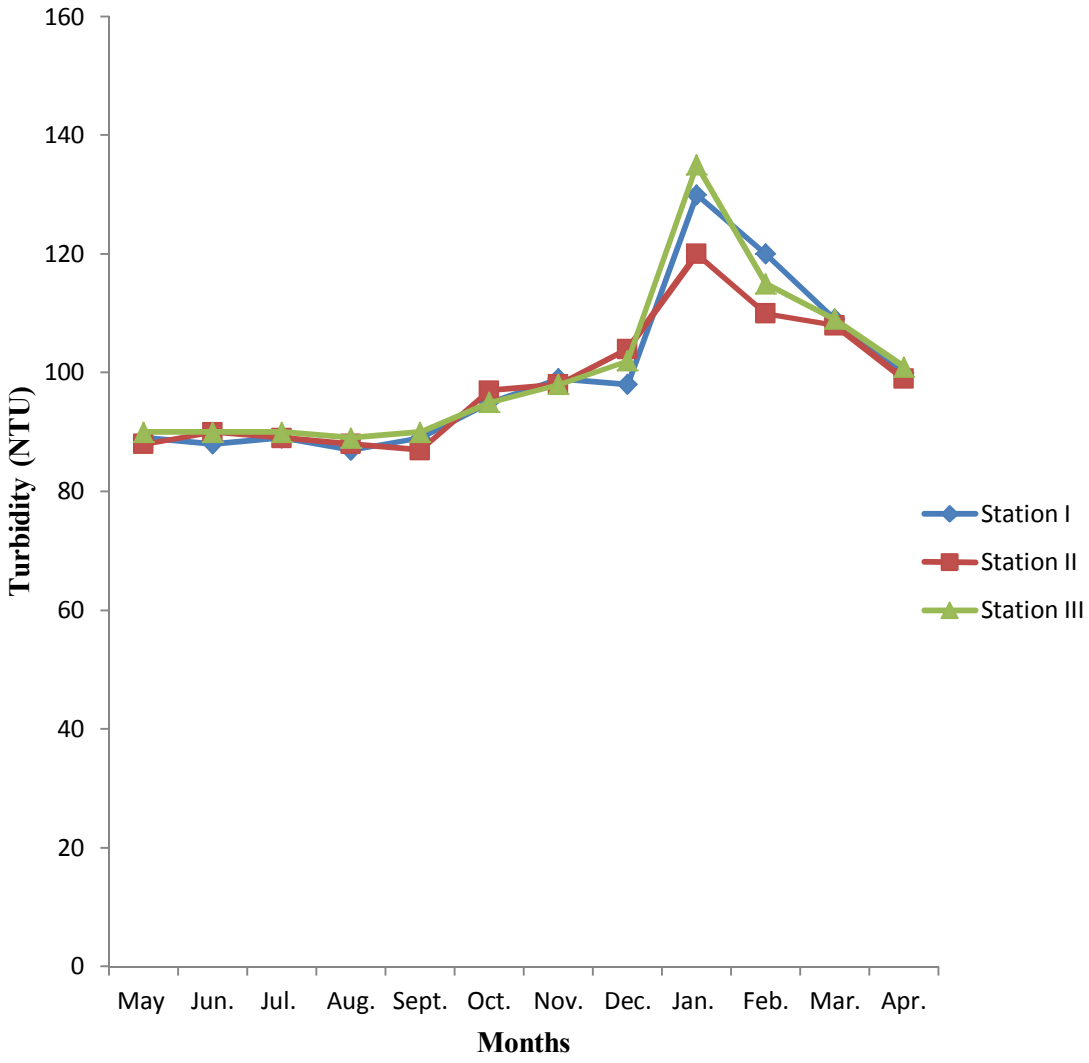


Figure 4.3: Monthly Stations Variation of Turbidity in Ajiwa Reservoir.

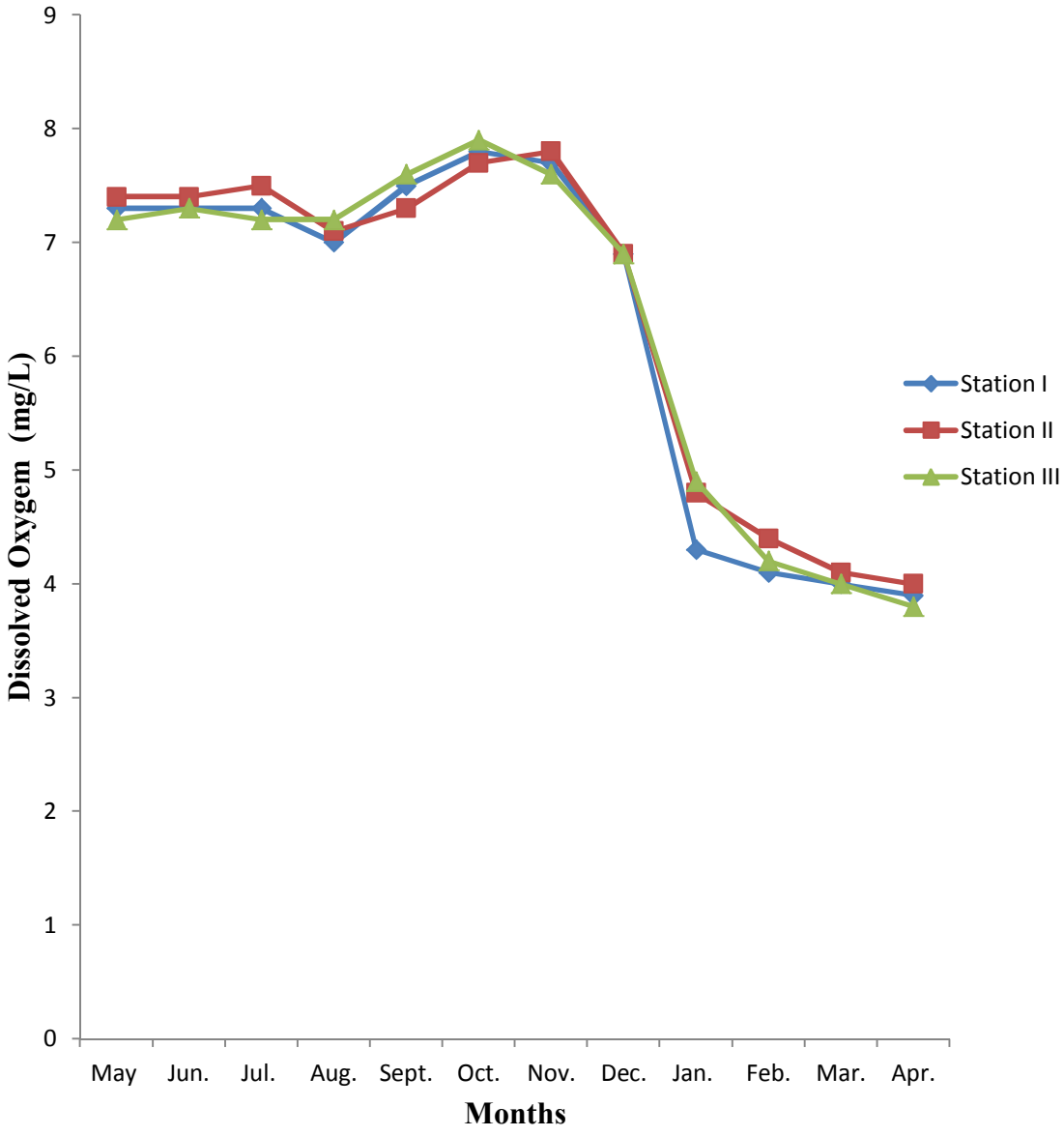


Figure 4.4: Monthly Stations Variation of Dissolved Oxygen in Ajiwa Reservoir.

4.1.5 Biochemical Oxygen Demand

There was no significant difference between biochemical oxygen demand values in the three stations ($P > 0.05$). The analysis of variance revealed there was significant difference between biochemical oxygen demand values in wet and dry season at $P < 0.05$ (Table:4.6). Biochemical oxygen demand shown positive correlation with temperature, dissolved oxygen, conductivity and Nitrate-nitrogen while revealed negative correlation with pH, turbidity, depth and total dissolved solids (Table: 4.13). Figure 4.5 shows monthly stations variation of biochemical oxygen demand. There was increased in the values of biochemical oxygen demand from the month of September to December, from then there was decreased from January to April. The lowest value of 1.8mgL^{-1} was recorded in the month of April at station III in the dry season while the highest value of 4.1mgL^{-1} was recorded in the month of December at station III.

4.1.6 Electrical Conductivity

Analysis of variance revealed there was no significant difference between the electrical conductivity values in the three stations ($P > 0.05$) but there was significant difference between the wet and dry seasons in electrical conductivity of the reservoir at $P < 0.05$ (Table: 4.7). Conductivity revealed positive correlations with temperature, biochemical oxygen demand, dissolved oxygen, Nitrate-nitrogen and phosphate-phosphorus while negative, correlations with hardness, depth, total dissolved solids, pH and turbidity (Table: 4.13). Figure 4.6 shows monthly stations variations of Conductivity in Ajiwa reservoir. There was little fluctuation of conductivity values from July to November, and there was increased in conductivity from November to April. The highest value of 150.2µS/cm was recorded in April at station II in the dry season while lowest value of 102.1µS/cm was recorded in may at station II in the wet season.

Table 4.6: Analysis of Variance for Biochemical Oxygen Demand (mg/L) in Ajiwa Reservoir

Source of Variation	*SS*	*Df*	*MS*	*F*	*P-value*	*F crit*
Months	20.075	11	2.230556	198.7624	3.79E-16	2.456281
Stations	0.064667	2	0.032333	2.881188	0.082119	3.554557
Error	0.202	11	0.011222			
Total	20.34167	35				

Source of Variation	*SS*	*Df*	*MS*	*F*	*P-value*	*F crit*
Between season	18.769	1	18.769	22.95902	0.00137	5.317655
Within season	6.54	11	0.8175			
Total	25.309	12				

Table 4.7: Analysis of Variance for Electrical Conductivity (µS/cm) in Ajiwa Reservoir

Source of Variation	*SS*	*Df*	*MS*	*F*	*P-value*	*F crit*
Months	60.923	11	6.769222	99.71031	1.67E-13	2.456281
Stations	0.104667	2	0.052333	0.770867	0.477292	3.554557
Error	1.222	22	0.067889			
Total	62.24967	35				

Source of Variation	*SS*	*Df*	*MS*	*F*	*P-value*	*F crit*
Between season	3.6	1	3.6	9.795918	0.014019	5.317655
Within season	2.94	11	0.3675			
Total	6.54	12				

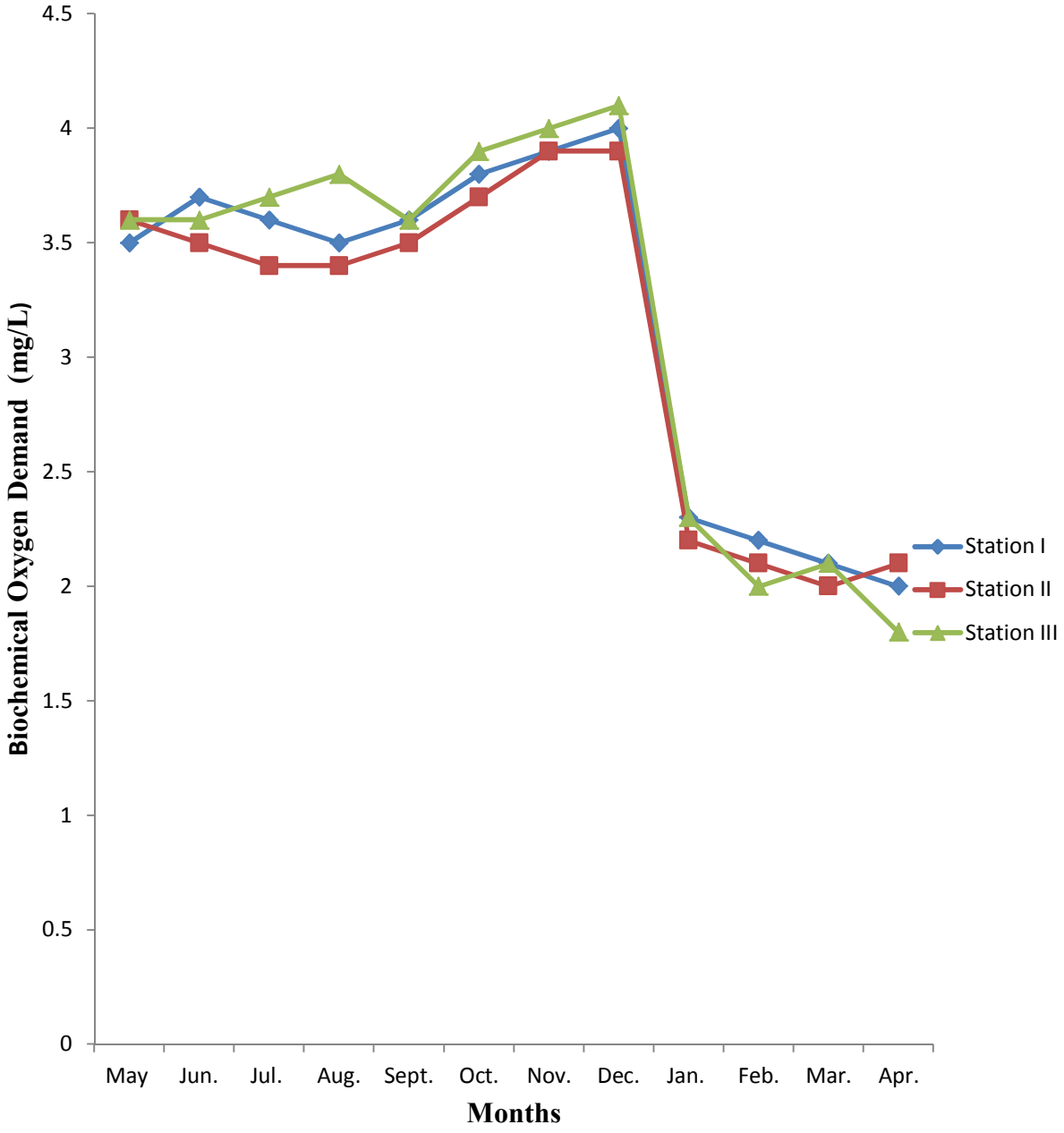


Figure 4.5: Monthly Stations Variation of Biochemical Oxygen Demand in Ajiwa Reservoir

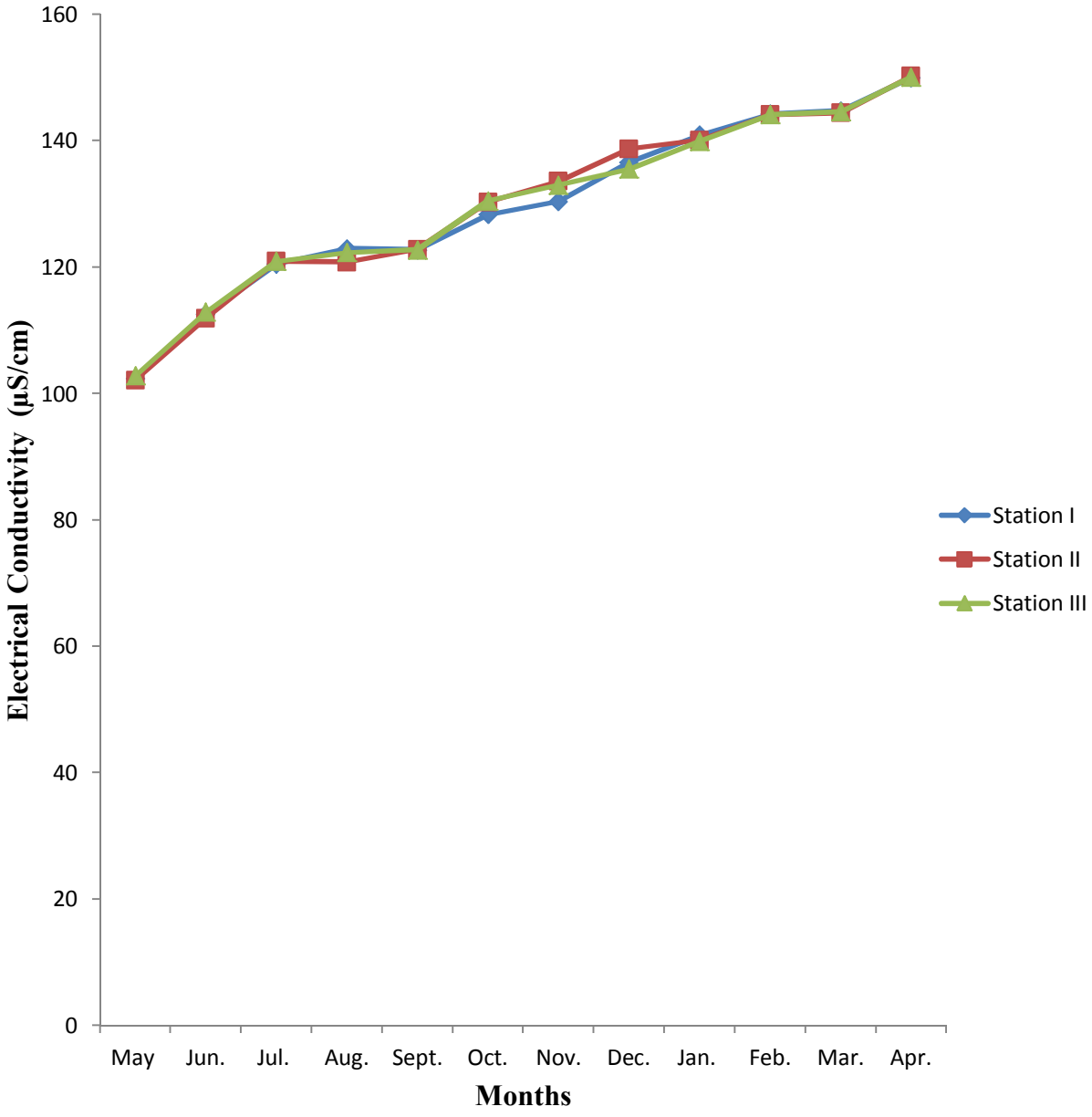


Figure 4.6: Monthly Stations Variation of Electrical Conductivity in Ajiwa Reservoir.

4.1.7 Water Hardness

The Analysis of variance revealed that there was no significant difference in hardness between the three stations and there was no significant difference between the wet and dry season hardness in the Ajiwa reservoir at $P > 0.05$ (Table: 4.8). Hardness shown positive correlation with turbidity, Nitrate-nitrogen and Phosphate-phosphorus while negative correlation with temperature and Conductivity (Table: 4.13). Figure 4.7 shows monthly stations variation of hardness in Ajiwa reservoir. There was increased in the hardness from the month of July to December and then there was decreased in the values of the hardness from January to April. The highest value of 100.2mgL^{-1}($CaCO_3$) was recorded in the March in station II while the lowest value of 80.6mgL^{-1} was recorded in the October in Station II.

4.1.8 Nitrate-Nitrogen (NO_3-N)

There was no significant difference of Nitrate-Nitrogen values between the three stations ($P > 0.05$). There was significant difference between the Nitrate-Nitrogen values recorded in the wet season and dry season at $P < 0.05$ (Table: 4.9). Nitrate-Nitrogen revealed positive correlation with temperature, dissolved oxygen, biochemical Oxygen demand, depth and conductivity while negative correlation with pH and turbidity (Table: 4.13). Figure 4.8 shows monthly stations variation of Nitrate-Nitrogen in Ajiwa reservoir, there was increase of Nitrate-Nitrogen values from July to September and there was decreased from November to January, from where it increases up to April. The highest value of 7.3mgL^{-1} was recorded in September in station III while the lowest value of 3.8mgL^{-1} was recorded in January.

Table 4.8: Analysis of Variance for Water Hardness ($mgCaCO_3\ L^{-1}$) in Ajiwa Reservoir

Source of Variation	*SS*	*Df*	*MS*	*F*	*P-value*	*F crit*
Months	116.183	11	12.90922	22.80334	4.49E-08	2.456281
Stations	5.716667	2	2.858333	5.049068	0.01817	3.554557
Error	10.19	22	0.566111			
Total	132.0897	35				

Source of Variation	*SS*	*Df*	*MS*	*F*	*P-value*	*F crit*
Between season	3.025	1	3.025	0.752488	0.410953	5.317655
Within season	32.16	11	4.02			
Total	35.185	12				

Table 4.9: Analysis of Variance for Nitrate-Nitrogen (mg/L) in Ajiwa Reservoir

Source of Variation	*SS*	*Df*	*MS*	*F*	*P-value*	*F crit*
Months	22.20533	11	2.467259	49.19941	7.57E-11	2.456281
Stations	0.024	2	0.012	0.239291	0.78965	3.554557
Error	0.902667	22	0.050148			
Total	23.132	35				

Source of Variation	*SS*	*Df*	*MS*	*F*	*P-value*	*F crit*
Between season	4.9	1	4.9	15.17028	0.004577	5.317655
Within season	2.584	11	0.323			
Total	7.484	12				

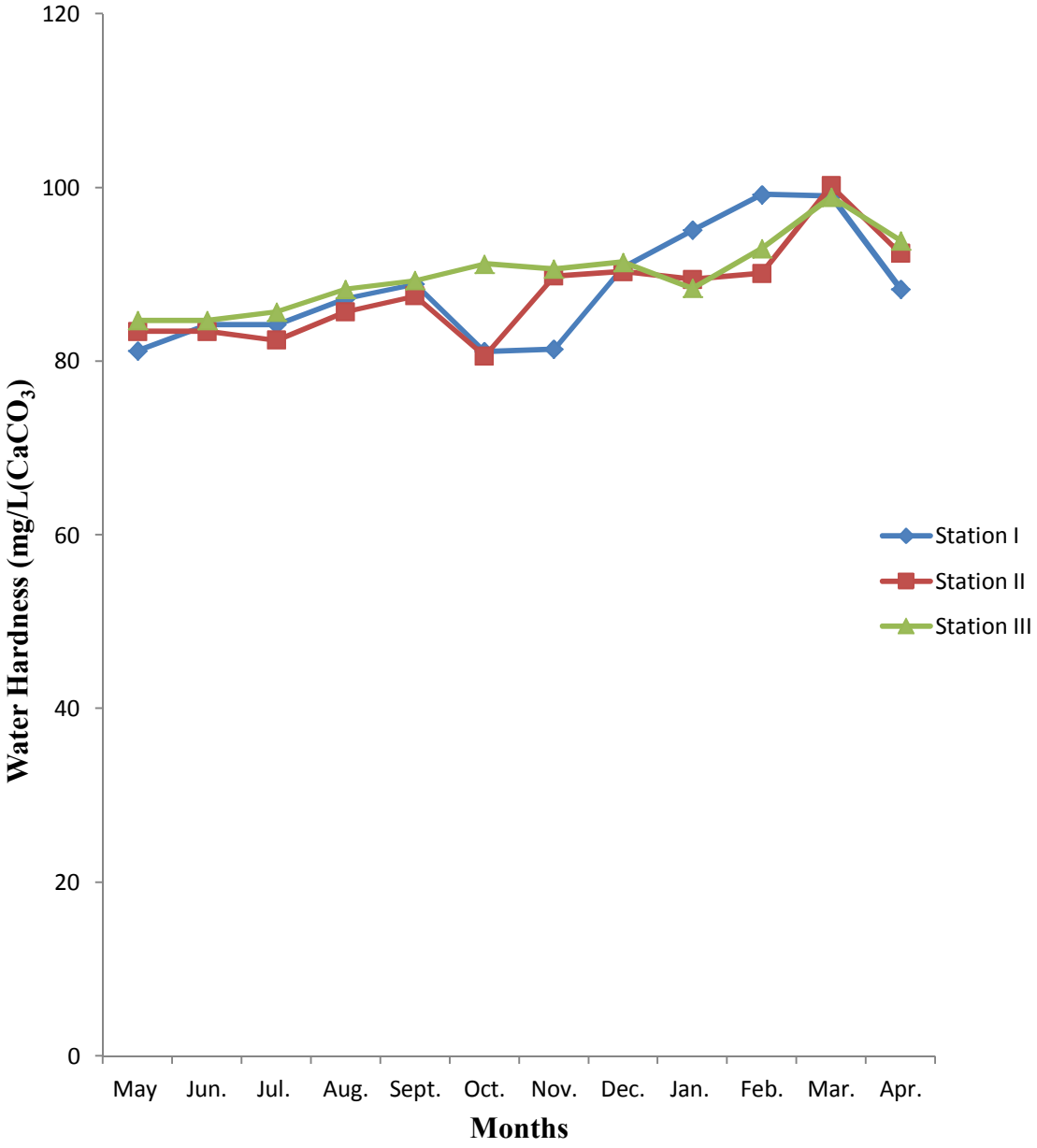


Figure 4.7: Monthly stations Variation of Water Hardness in Ajiwa Reservoir.

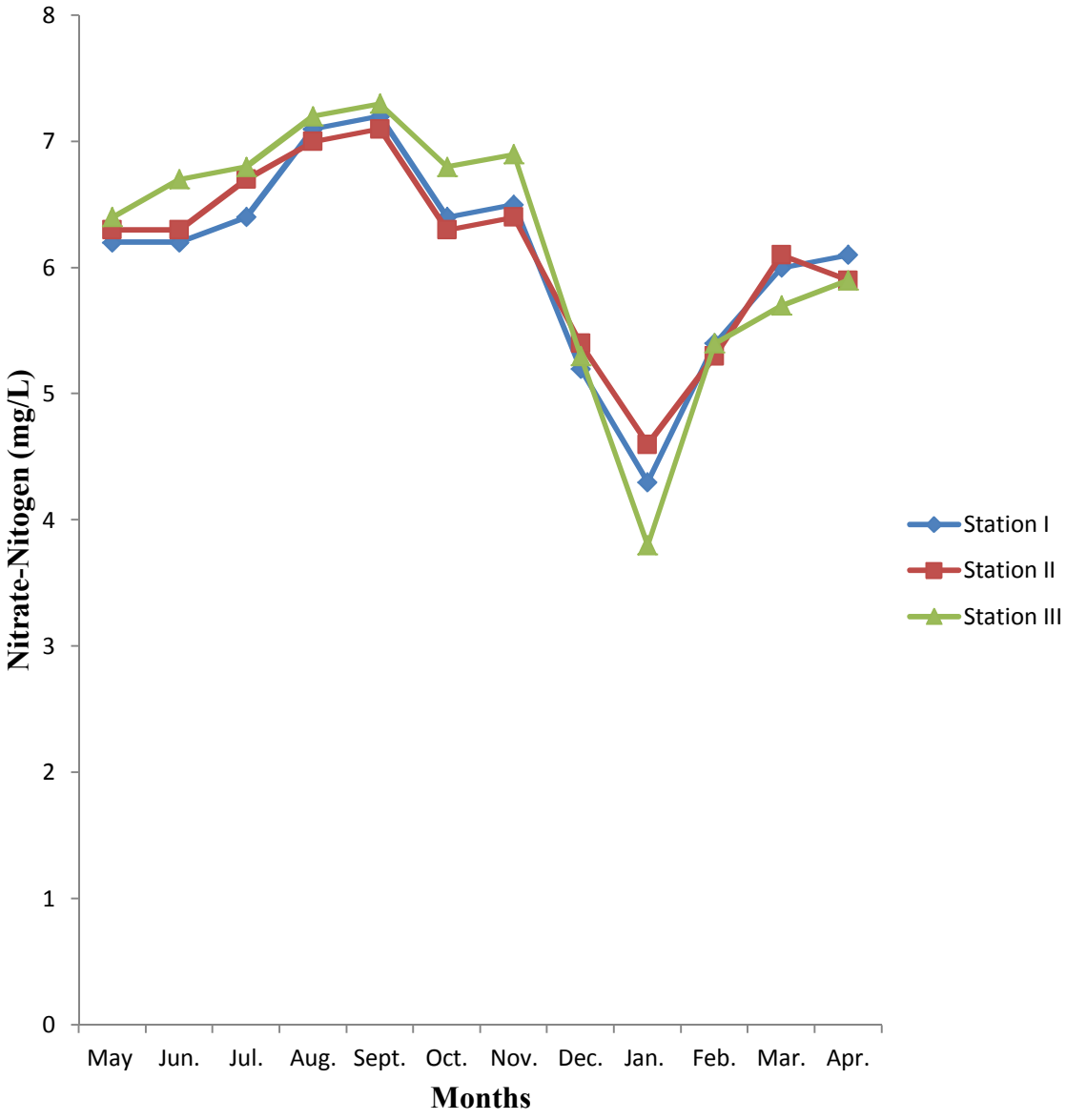


Figure 4.8: Monthly Stations Variation of Nitrate-Nitrogen in Ajiwa Reservoir.

4.1.9 Total Dissolved Solids

Analysis of variance revealed there was no significant difference in the values of total dissolved solids recorded during the study period in the three stations ($P > 0.05$). There was significant difference between months and seasons at $P < 0.05$ (Table: 4.10). Total dissolved solids in Ajiwa reservoir indicated positive correlation with turbidity, pH, depth and hardness while negative correlation with Nitrate-nitrogen, conductivity, temperature, dissolved oxygen and biochemical oxygen demand (Table: 4.13). Figure 4.9 shows monthly stations variation of Total dissolved solids in Ajiwa reservoir. There was increased in values of total dissolved solids from July to December; then there was little stabilization up to March, The highest value was recorded during the dry season in station III while the lowest during the wet season in station II.

4.1.10 Phosphate-phosphorus (PO_4-P)

The analysis of variance indicated there was no significant difference of Phosphate-phosphorus concentration in the three stations ($P > 0.05$). There was significant difference between wet and dry seasons at $P < 0.05$ (Table: 4.11). The highest value of Phosphate-phosphorus was recorded during the wet season. Phosphate-phosphorus revealed positive correlation with Nitrate-nitrogen, depth and conductivity while negative correlation with turbidity, pH and total dissolved solids (Table: 4.13). Figure 4.10 shows monthly stations variation of phosphate-phosphorus, the highest value of $4.0mgL^{-1}$ was recorded in station III while the lowest value of $1.6mgL^{-1}$ was recorded in station II. There was increased in the Phosphate-phosphorus values from May to October then the values dropped in November.

Table 4.10: Analysis of Variance for Total Dissolved Solids (mg/L) in Ajiwa Reservoir

Source of Variation	*SS*	*Df*	*MS*	*F*	*P-value*	*F crit*
Months	815.4163	11	90.60181	198.382	3.86E-16	2.456281
Stations	0.992667	2	0.496333	1.086773	0.358437	3.554557
Error	8.220667	22	0.456704			
Total	824.6297	35				

Source of Variation	*SS*	*Df*	*MS*	*F*	*P-value*	*F crit*
Between season	196.249	1	196.249	20.43409	0.001949	5.317655
Within season	76.832	11	9.604			
Total	273.081	12				

Table 4.11: Analysis of Variance for Phosphate-phosphorus (mg/L) in Ajiwa Reservoir

Source of Variation	*SS*	*Df*	*MS*	*F*	*P-value*	*F crit*
Months	18.46963	11	2.308704	42.65868	2.36E-09	2.591096
Stations	0.160741	2	0.08037	1.48503	0.2561	3.633723
Error	0.865926	22	0.05412			
Total	19.4963	35				

Source of Variation	*SS*	*Df*	*MS*	*F*	*P-value*	*F crit*
Between season	2.209	1	2.209	4.094532	0.077637	5.317655
Within season	4.316	11	0.5395			
Total	6.525	12				

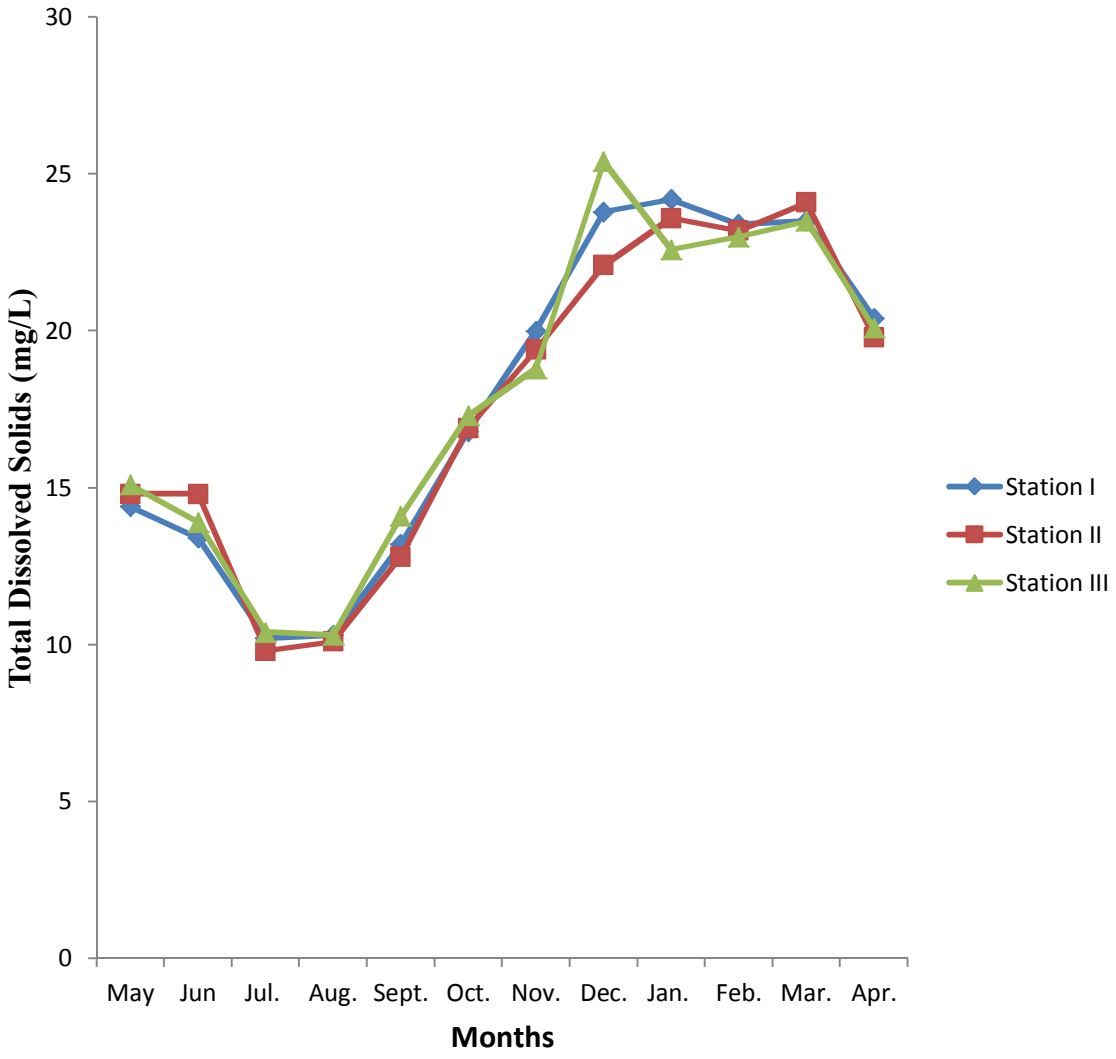


Figure 4.9: Monthly Stations Variation of Total Dissolved Solids in Ajiwa Reservoir.

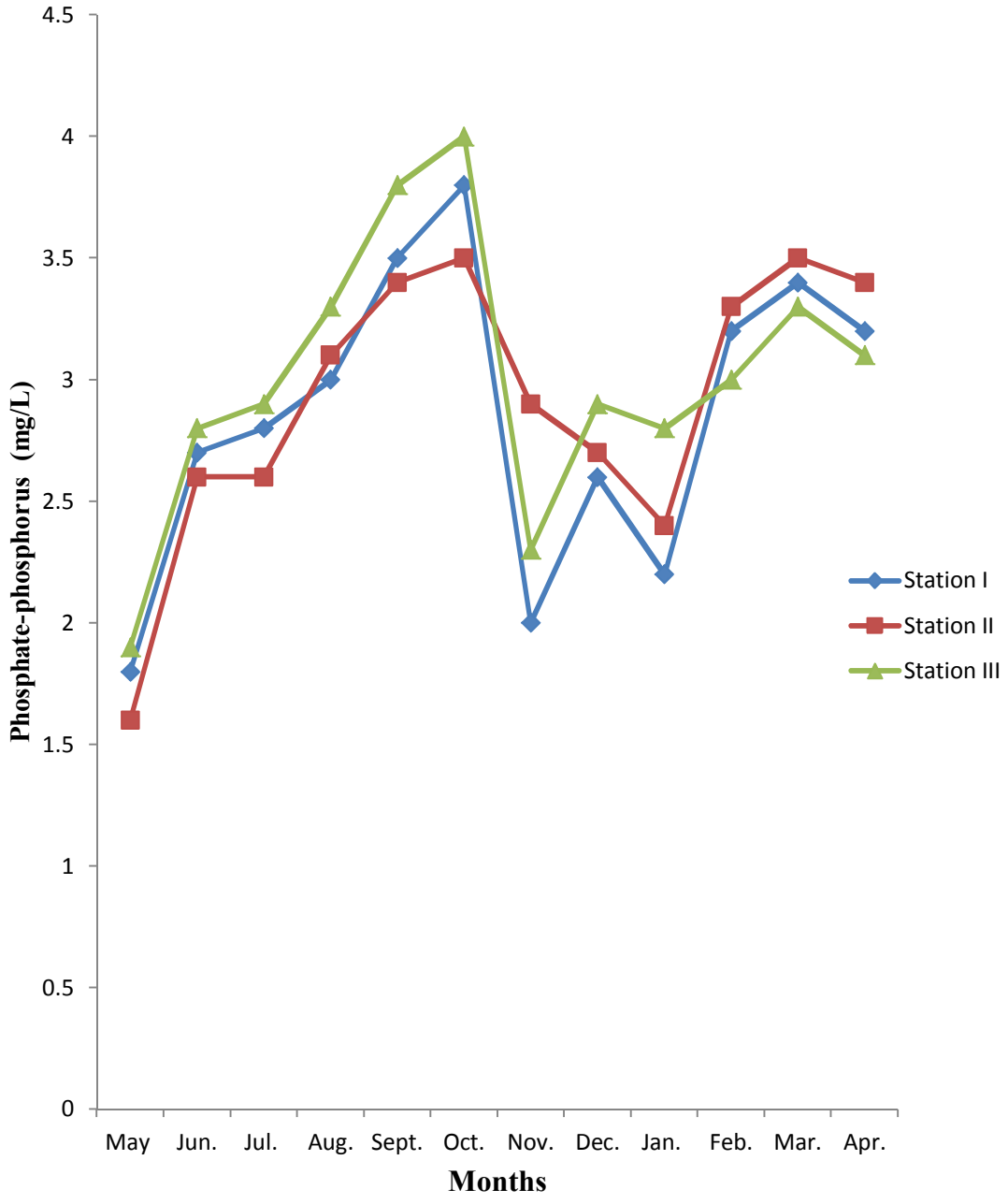


Figure 4.10: Monthly Stations Variation of Phosphate-phosphorus in Ajiwa Reservoir.

4.1.11 Water Depth

Analysis of variance revealed there was no significant difference in the values of water depth recorded during the study period in the three stations ($P > 0.05$). However, analysis of variance between the monthly values of wet and dry season revealed that there was significant difference between wet and dry season at $P < 0.05$ (Table: 4.12). Water depth indicates significant positive correlation with temperature, turbidity, Nitrate-nitrogen and Phosphate-phosphorus while negative correlation with dissolved oxygen, biochemical oxygen demand, and pH (Table 4.13). Figure 4.11show monthly stations variation of water depth, there was increase in the water depth from May to August; the peak was reached in August. The water level decreases from October to April and the lowest value of 3.8m was recorded in station I while the highest value of 7.8m was recorded in station III.

4.2. Phytoplankton

The Phytoplankton composition identified in the three stations belongs to four groups, which include Chlorophyta, Bacillariophyta, Cyanophyta, and Dinophyta (Pyrrophyta). Phytoplankton percentage composition (Table 4.14) indicated, Chlorophyta has 967 which represent highest percentage composition with 57.66% of the total population of identified. Bacillariophyta has the second highest population counts with the total of 431, which represent 25.70%. The Cyanophyta has the 247, which represent the third with percentage composition of 14.73%. Dinophyta has the least abundance with total of 32 which represents 1.91% of the percentage composition of Phytoplankton.

Table 4.12: Analysis of Variance for Water Depth (m) in Ajiwa Reservoir

Source of Variation	*SS*	*Df*	*MS*	*F*	*P-value*	*F crit*
Months	18.46963	11	2.308804	52.65868	2.36E-09	2.581096
Stations	0.160741	2	0.08037	1.48503	0.2561	3.633723
Error	0.865926	22	0.05412			
Total	19.4963	35				

Source of Variation	*SS*	*Df*	*MS*	*F*	*P-value*	*F crit*
Between season	2.209	1	2.209	44.094532	0.078637	5.317655
Within season	4.316	11	0.5395			
Total	6.525	12				

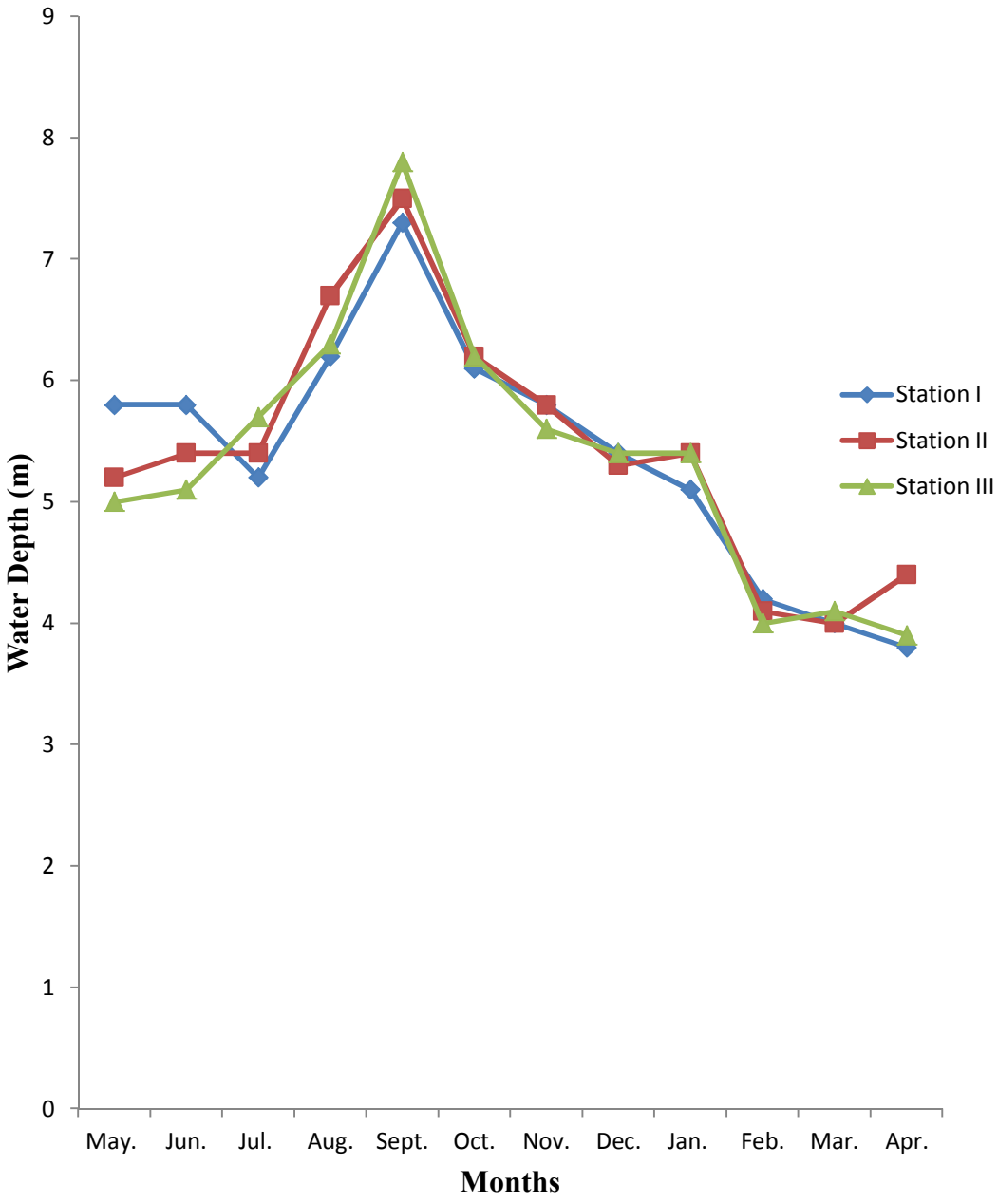


Figure 4.11: Monthly Stations Variation of Water Depth in Ajiwa Reservoir.

Table 4.13: Correlation between Physico-chemical Parameters

	Temp	*PH*	*Turbidity*	*DO*	*BOD*	*EC*	*Hardness*	*NO_3-N*	*TDS*	*PO_4-P*	*Depth*
Temperature	1										
PH	-0.28^{ns}	1									
Turbidity	-0.58*	0.86*	1								
Dissolved Oxygen	0.50*	-0.89*	-0.70*	1							
Biochemical Oxygen Demand	0.63*	-0.89*	-0.67*	0.97*	1						
Electrical Conductivity	0.75*	-0.71*	-0.88*	0.62*	0.52*	1					
Water Hardness	-0.82*	0.29^{ns}	0.59*	-0.01^{ns}	0.07^{ns}	-0.59*	1				
Nitrate-nitrogen	0.64*	-0.67*	-0.92*	0.61*	0.53*	0.89*	-0.30*	1			
Total Dissolved Solids	-0.75*	0.73*	0.81*	-0.64*	-0.52*	-0.96*	0.69*	-0.77*	1		
Phosphate-phosphorus	0.41^{ns}	-0.56*	-0.63*	0.40^{ns}	0.29^{ns}	0.67*	-0.30^{ns}	0.69*	-0.65*	1	
Depth	0.58*	-0.37	0.83*	-0.65*	-051*	0.43^{ns}	0.45^{ns}	0.53*	0.57*	0.43^{ns}	1

*= Significant; ns= Non Significant

4.2.1 Chlorophyta

Analysis of variance revealed there was no significant difference between the three stations in population abundance of Chlorophyta ($P > 0.05$). There was significant difference in population abundance of Chlorophyta between months and seasons at $P < 0.05$ (Table: 4.15). Chlorophyta also indicated positive correlation with dissolved oxygen, biochemical oxygen demand, Nitrate-nitrogen and phosphate-phosphorus while showed negative correlation with pH, turbidity, depth, hardness and total dissolved solids (Table: 4.19). The species observed are*; Oocystis sp, Scenedesmus sp, Pediastrum sp, Dictyochloris sp, Closterium sp, Tetraedron sp, Ulotrix sp, Euastrum sp, Spirogyra sp, Zygnema sp, Oedegonium sp, Euglena sp* and *Volvox sp.* Among Chlorophyta *Oocystis sp* has the highest population abundance while *Volvox sp.* has the least population abundance. There was more diversity of Chlorophyta in the wet season as it was indicated by Simpson's and Shannon diversity Index (Table 4.2.0). Figure 4.12 show monthly stations abundance of Chlorophyta. The highest count was recorded in station I while lowest in station II.

4.2.2 Bacillariophyta

The results of analysis of variance revealed that there was no significant difference between the three stations in terms of Bacillariophyta abundance ($P > 0.05$). There was significant difference between the population count between months and seasons at $P < 0.05$ (Table 4.16); with wet season having the highest count. Bacillariophyta shown positive correlation with dissolved oxygen, biochemical oxygen demand, conductivity, Nitrate-nitrogen and Phosphate-phosphorus but revealed negative correlations with turbidity, pH, hardness, depth and total dissolved solids (Table: 4.19). The species

identified include; *Cyclotella sp, Cymbella sp, Gyrosigsma sp, Epithemia sp, Diatomella sp* and *Anomoneis sp.* Among Bacillariophyta, *Cyclotella sp* has the highest population abundance in the reservoir while *Anomoneis sp.* has the lowest population count. There was more diversity of Bacillariophyta in the wet season than in the dry season as it was indicated by Simpson's and Shannon diversity index (Table 4.20). Figure 4.13 shows monthly stations abundance of Bacillariophyta. The highest count was in station III in the month of August during the wet season while the lowest count was recorded in the month of February during dry season in station III.

4.2.3 Cyanophyta

The results of analysis of variance revealed that there was significant difference in population abundance of Cyanophyta between the three stations and there was significant difference between the population abundance in the wet and dry season at $P < 0.05$ (Table: 4.17); with wet season having the highest count. Cyanophyta showed positive correlation with, dissolved oxygen, biochemical oxygen demand, conductivity, Nitrate-nitrogen and Phosphate-phosphorus while shown negative correlation with total dissolved solids, hardness, depth, pH and turbidity (Table:4.19). The species observed are; *Chroococcus sp, Gomphosphaeria sp, Microcystis sp, Anabaena sp, Oscillatoria sp* and *Nostoc sp.* Among the Cyanophyta, *Chroococcus sp.* has the highest species population abundance while *Nostoc sp.* has the least population abundance with presences only in the rainy season. Cyanophyta revealed more diversity in the wet season than in dry season as it was indicated by Simpson's and Shannon diversity index (Table 4.20). Figure 4.14 shows monthly stations abundance of Cyanophyta in Ajiwa reservoir, the highest population count was recorded in station III while the lowest was recorded in station II.

Table 4.14: Monthly Phytoplankton Abundance and Percentage in Ajiwa Reservoir .

Months	Bacillariophyta (No. of Organisms/L)	Chlorophyta (No. of Organisms/L)	Cyanophyta (No. of Organisms/L)	Dinophyta (No. of Organisms/L)
May	20	50	12	1
Jun.	36	87	22	8
Jul.	55	121	40	10
Aug.	63	117	33	7
Sept.	63	106	29	4
Oct.	53	103	26	2
Nov.	42	90	21	0
Dec.	36	81	17	0
Jan.	20	57	12	0
Feb.	12	50	9	0
Mar.	13	48	14	0
Apr.	18	57	12	0
Totals	431	967	247	32
Percentage (%)	25.70	57.66	14.73	1.91

Table 4.15: Analysis of Variance for Chlorophyta in Ajiwa Reservoir

Source of Variation	*SS*	*Df*	*MS*	*F*	*P-value*	*F crit*
Months	2416	11	268.4444	234.5631	8.71E-17	2.456281
Stations	6.066667	2	3.033333	2.650485	0.097968	3.554557
Error	20.6	22	1.144444			
Total	2442.667	35				

Source of Variation	*SS*	*Df*	*MS*	*F*	*P-value*	*F crit*
Between season	348.1	1	348.1	37.15048	0.000291	5.317655
Within season	74.96	11	9.37			
Total	423.06	12				

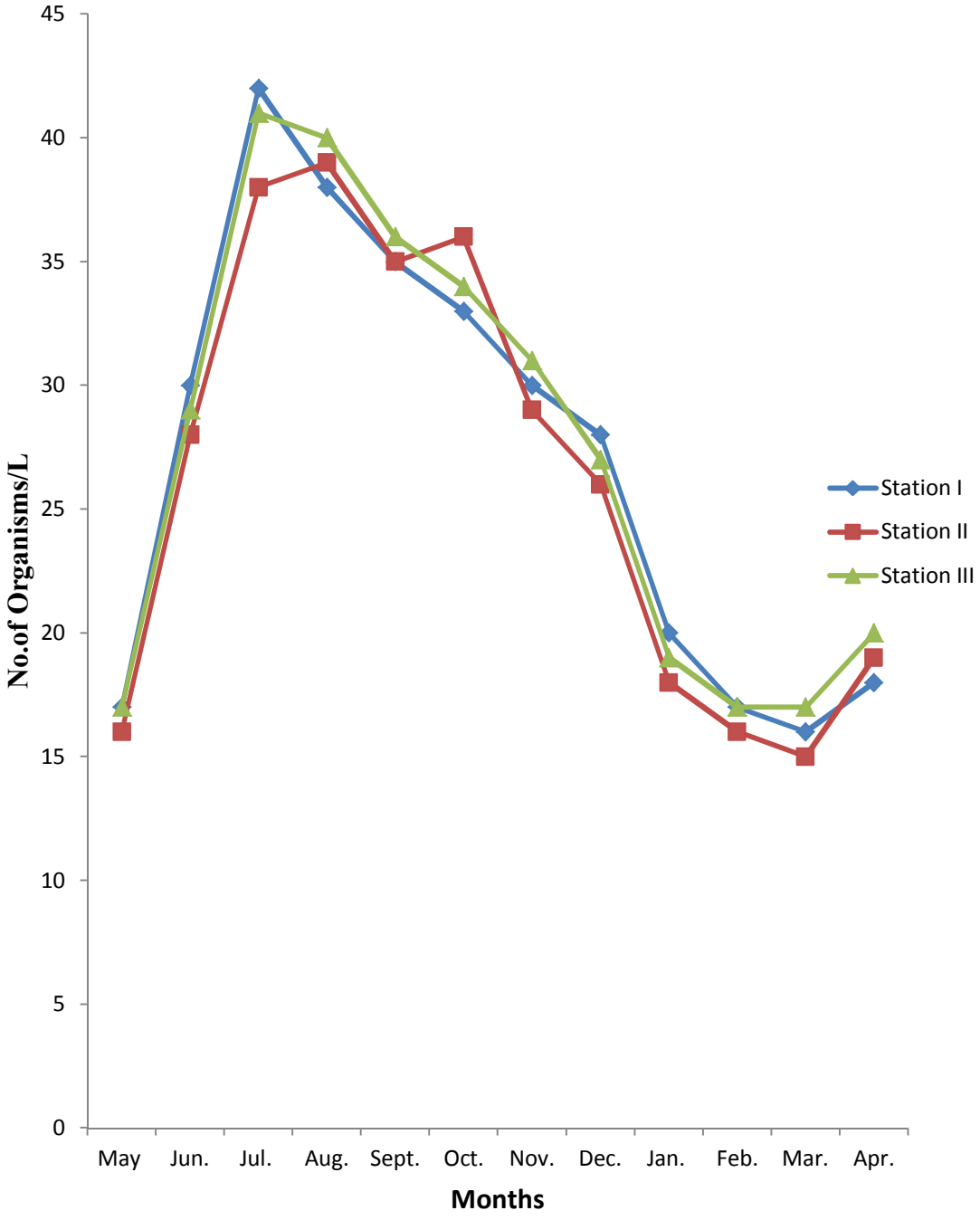


Figure 4.12: Monthly Stations Abundance of Chlorophyta in Ajiwa Reservoir.

Table 4.16: Analysis of Variance for Bacillariophyta in Ajiwa Reservoir

Source of Variation	*SS*	*Df*	*MS*	*F*	*P-value*	*F crit*
Months	1268.833	11	140.9815	26.86309	1.19E-08	2.456281
Stations	0.2	2	0.1	0.019054	0.981146	3.554557
Error	94.46667	22	5.248148			
Total	1363.5	35				

Source of Variation	*SS*	*Df*	*MS*	*F*	*P-value*	*F crit*
Between season	348.1	1	348.1	37.15048	0.000291	5.317655
Within season	74.96	11	9.37			
Total	423.06	12				

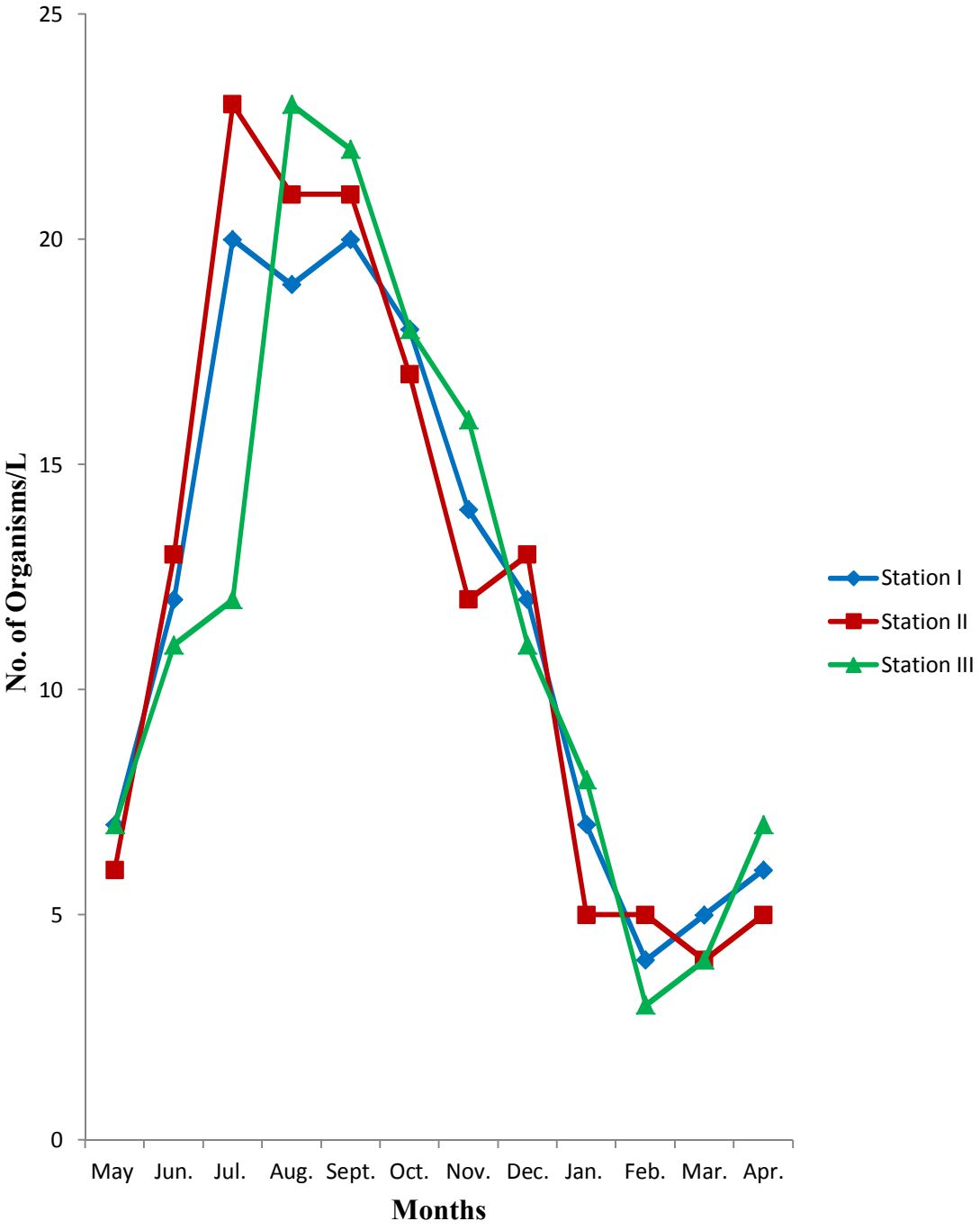


Figure 4.13: Monthly Stations Abundance of Bacillariophyta in Ajiwa Reservoir.

Table 4.17: Analysis of Variance for Cyanophyta in Ajiwa Reservoir

Source of Variation	*SS*	*Df*	*MS*	*F*	*P-value*	*F crit*
Months	201.3667	11	22.37407	16.02387	7.16E-07	2.456281
Stations	12.2	2	6.1	4.3687	0.028404	3.554557
Error	25.13333	22	1.396296			
Total	238.7	35				

Source of Variation	*SS*	*Df*	*MS*	*F*	*P-value*	*F crit*
Between season	47.089	1	47.089	18.798	0.002493	5.317655
Within season	20.04	11	2.505			
Total	67.129	12				

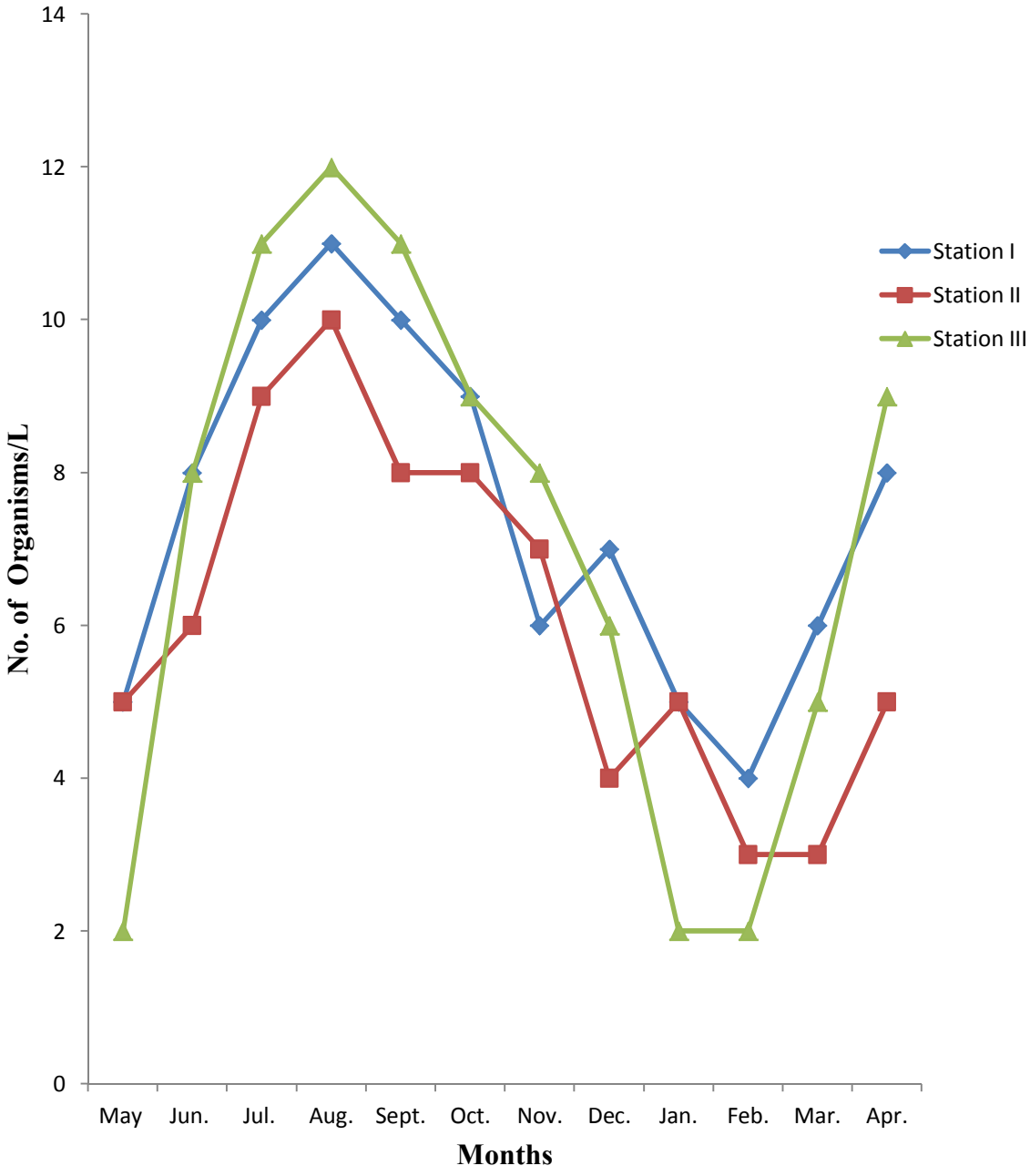


Figure 4.14: Monthly Stations Abundance of Cyanophyta in Ajiwa Reservoir.

4.2.4 Dinophyta (Pyrrophyta)

Analysis of variance revealed that there was no significant difference between the stations in terms of population abundance ($P > 0.05$). There was significant difference in population abundance of Dinophyta between the months and seasons at $P < 0.05$ (Table: 4.18); with wet season having the highest number of count than the dry season. Dinophyta shown positive correlation with dissolved oxygen, biochemical oxygen demand, Phosphate-phosphorus and Nitrate-nitrogen while negative correlation with hardness, depth, total dissolved solids, pH and turbidity (Table: 4.19). The species recorded are *Pridinium sp* and *Ceratium sp.* Only few population counts ware recorded during the rainy season with *Peridinium sp.* having the highest while *Ceratium sp.* was the least. There was more diversity of Dinophyta in the wet season than in the dry season as indicate by Simpson's and Shannon diversity index (Table 4.20). Figure 4.15 shows monthly stations abundance of Dinophyta in Ajiwa reservoir. Highest count was recorded in station I during the rainy season.

4.3 ZOOPLANKTON

The total number of Zooplanktons identified in the three stations during the period of the study was 1473; they belong to four groups, which are Copepoda, Cladocera, Protozoa, and Rotifers. The percentage composition of Zooplankton (Table: 4.21) indicated Rotifers has the highest percentage with 30.55%, abundance composition. The highest number was recorded in the month of September while the lowest was recorded in the month of March and April. The Copepods has the second highest population which accounted for the 29.33% of the total number of Zooplankton count identified during the period of the study; the highest number was recorded in the month of August while the lowest count was recorded in the month of April. The total number of protozoa

identified was 328 which account for 22.27% of the total Zooplankton identified, there was monthly variation of protozoan count recorded during the period of study; the highest number was recorded in the month of October and November while the lowest was in January. The total number of Cladocera identified during the period of the study was 263, which accounted for the 17.85% of the total Zooplankton identified during the period of the study.

4.3.1 Rotifers

There was no significant difference between the rotifers composition and abundance of the three stations ($P > 0.05$). There was significant difference between the wet and dry season and months at $P < 0.05$; with wet season having the highest population abundance than dry season (Table 4.22). Correlation revealed there was positive relationship between rotifers and dissolved oxygen, biochemical oxygen demand, conductivity, Nitrate-nitrogen and Phosphate-phosphorus while there was negative correlation with pH, turbidity, depth, hardness and total dissolved solids (Table 4.26). The species recorded include; *Brachionus sp, Monostyla sp, Euclanis sp, Keratella sp, Kellicottia sp, Chromogaster sp, Filinia sp, Lecane sp, Notholca sp,* and *Trichocerca sp.* Rotifers, *Brachionus sp.* has the highest number and highest abundance during the rainy season while *Trichocerca sp* has the least abundance with very few counts in the rainy season. There was more diversity of rotifer in the wet season than in the dry season as it was indicated by Simpson's and Shannon diversity index (Table 4.27). Figure 4.16 shows monthly stations abundance of rotifers in Ajiwa reservoir. There was increase in rotifers abundance from May to September then there was continuous decreased in the population abundance up the month of April. Station III has the highest population count in the rainy season while the lowest was in the dry season.

Table: 4.18: Analysis of Variance for Dinophyta in Ajiwa Reservoir

Source of Variation	*SS*	*Df*	*MS*	*F*	*P-value*	*F crit*
Months	1221.633	11	135.737	42.66473	2.54E-10	2.456281
Stations	2.066667	2	1.033333	0.324796	0.726823	3.554557
Error	57.26667	22	3.181481			
Total	1280.967	35				

Source of Variation	*SS*	*Df*	*MS*	*F*	*P-value*	*F crit*
Between season	291.6	1	291.6	19.48221	0.002245	5.317655
Within season	119.74	11	14.9675			
Total	411.34	12				

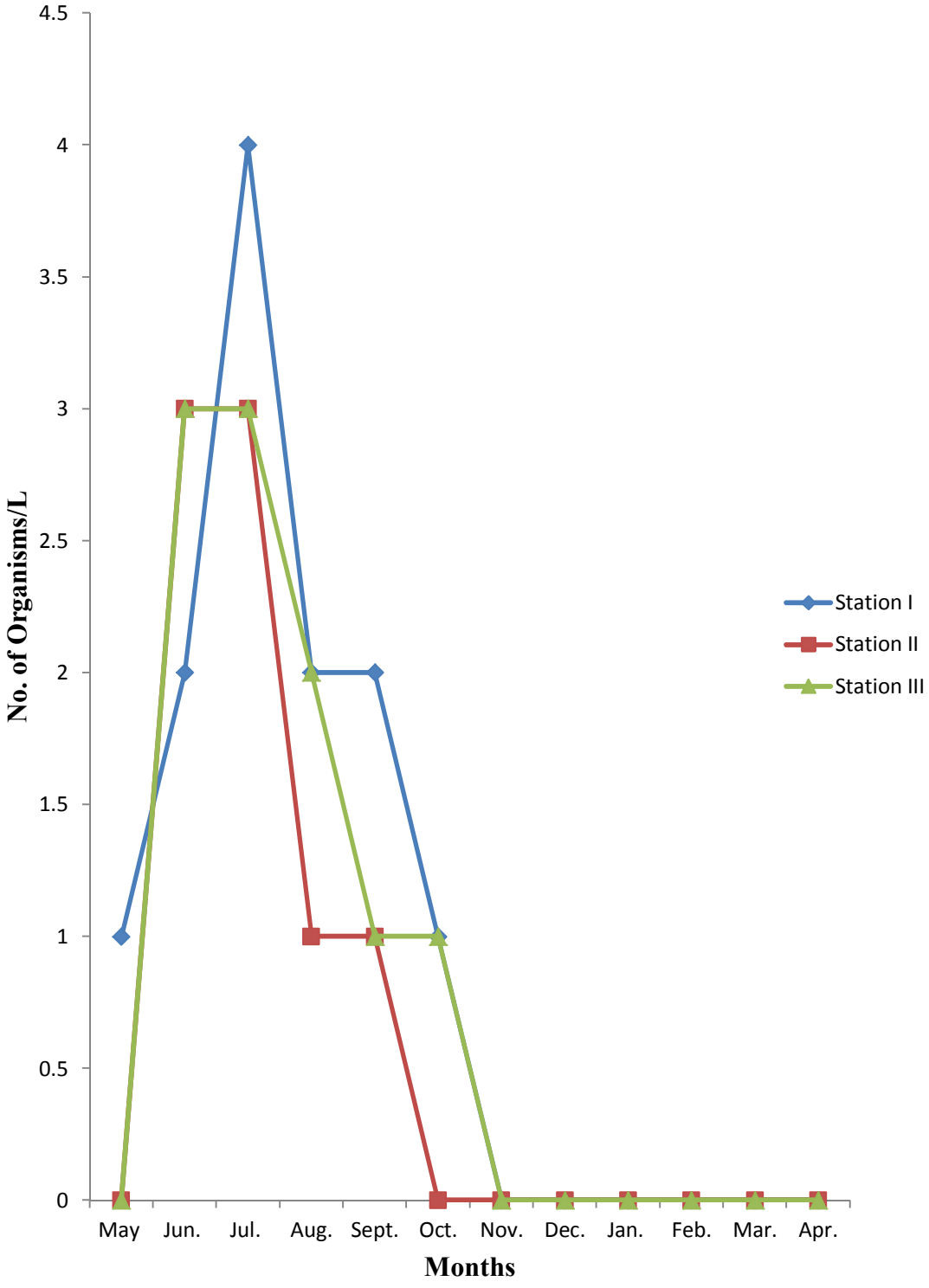


Figure 4.15: Monthly Stations Abundance of Dinophyta in Ajiwa Reservoir.

Table 4.19: Correlation between Abundance of Phytoplankton and Physico-chemical Parameters in Ajiwa Reservoir

	Bacillariophyta	Chlorophyta	Cyanophyta	Dinophyta
pH	-0.89*	-0.82*	-0.83*	-0.89*
Temp	0.36^{ns}	0.44^{ns}	0.65*	0.39^{ns}
Turbidity	-0.82*	-0.82*	-0.90*	-0.82*
DO	0.89*	0.89*	0.71*	0.83*
BOD	0.84*	0.84*	0.63*	0.77*
Conductivity	0.84*	0.85*	0.88*	0.85*
Hardness	-0.29^{ns}	-0.41^{ns}	-0.52*	-0.40^{ns}
Nitrate-Nitrogen	0.75*	0.71*	0.83*	0.72*
TDS	-0.86*	-0.90*	-0.94*	-0.89*
Phosphate-Phosphorus	0.62*	0.57*	0.66*	0.72*
Depth	-0.65*	-0.78*	-0.53*	-0.54*

***=significant at P < 0.05 ns = Non significant**

Table 4.20: Phytoplankton Shannon and Simpson's Diversity index

Taxon	Diversity Index	Wet	Dry
Bacillariophyta	Taxa_S	6	5
	Individuals	332	99
	Shannon_H	0.24	0.35
	Dominance _D	0.54	0.07
	Simpson's _1-D	0.46	0.93
Chlorophyta	Taxa_S	12	10
	Individuals	434	143
	Shannon_H	0.23	0.35
	Dominance _D	0.53	0.07
	Simpson's _1-D	0.47	0.93
Cyanophyta	Taxa_S	6	5
	Individuals	181	66
	Shannon_H	0.25	0.36
	Dominance _D	0.48	0.09
	Simpson's _1-D	0.52	0.91
Dinophyta	Taxa_S	2	0
	Individuals	32	0
	Shannon_H	0	0
	Dominance_D	1	0
	Simpson's _1-D	0	0

Note: Simpson: Less than 0.5 indicate more diversity.
Higher than 0.5 indicate less diversity.

Table 4.21: Monthly Zooplanktons Abundance and Percentage in Ajiwa Reservoir

Months	Protozoa (No. Organisms/L)	Copepods (No. of Organisms /L)	Cladocera (No. of Organisms/L)	Rotifera (No. of Organisms /L)
May	24	12	24	24
Jun.	28	18	28	40
Jul.	37	42	32	54
Aug.	41	81	36	76
Sept.	22	72	52	90
Oct.	54	60	36	49
Nov.	54	44	28	40
Dec.	40	46	18	38
Jan.	28	24	9	24
Feb.	0	16	0	9
Mar.	0	10	0	3
Apr.	0	7	0	3
Totals	328	432	263	450
Percentage (%)	22.27%	29.33%	17.85%	30.55%

Table 4.22: Analysis of Variance for Rotifers in Ajiwa Reservoir

Source of Variation	*SS*	*Df*	*MS*	*F*	*P-value*	*F crit*
Months	1277.467	11	141.9407	88.91879	4.56E-13	2.456281
Stations	5.266667	2	2.633333	1.649652	0.219869	3.554557
Error	28.73333	22	1.596296			
Total	1311.467	35				

Source of Variation	*SS*	*Df*	*MS*	*F*	*P-value*	*F crit*
Between season	345.744	1	345.744	27.01231	0.000825	5.317655
Within season	102.396	11	12.7995			
Total	448.14	35				

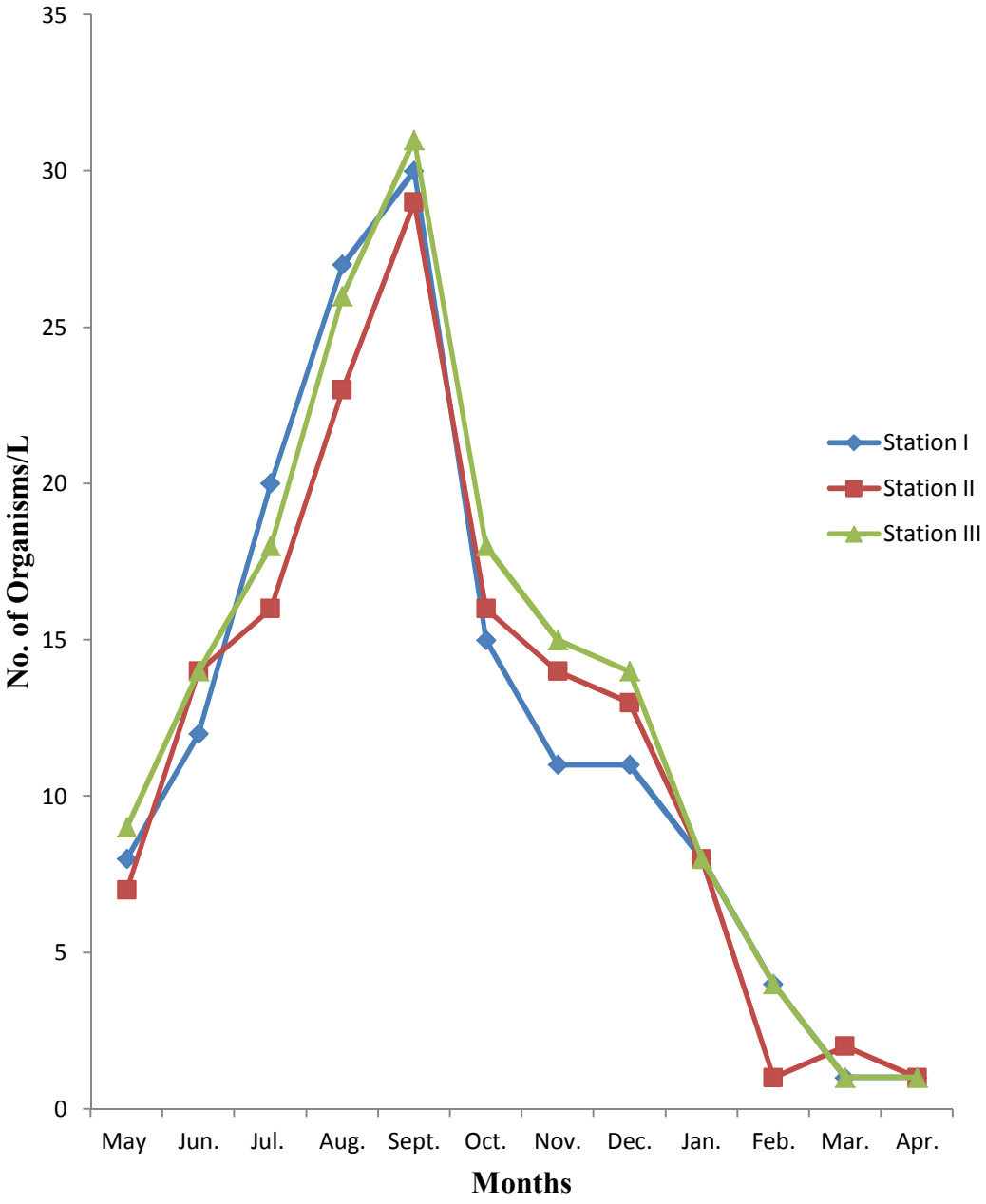


Figure 4.16: Monthly Stations Abundance of Rotifers in Ajiwa Reservoir.

4.3.2 Copepods

The result of analysis of variance revealed that there was no significant difference in the composition and abundance of Copepods in Ajiwa reservoir between the three stations ($P > 0.05$). There was significant difference between the number of Copepods identified during the wet and dry seasons at $P < 0.05$ (Table: 4.23). Copepods exhibited positive correlation with dissolved oxygen, Biochemical oxygen demand, Nitrate-nitrogen, Conductivity and Phosphate-phosphorus while negative correlation with turbidity, pH, depth, Total dissolved solids and hardness (Table 4.26). The species identified are *Eubrachipus sp. Cyclops sp. Nauplus sp. Diaptomus sp.* and *Paracyclops sp*. Among the copepods, *Eubrachipus sp* has highest species abundance then followed by *Cyclops sp.;* the species count ware more abundant in the rainy season than in the dry season. *Nauplus sp.* was third highest in copepods population abundance in the reservoir, and then followed by Paracyclops *sp.* while *Diaptomus sp.* has the least abundance. There was higher diversity of copepods during the wet season compared to that of the dry season as indicated by Simpson's and Shannon diversity index (Table 4.27). Figure 4.17shows monthly stations abundance of Copepods. Station III has the highest population count while Station II and III has the least during the dry season.

4.3.3 Cladocera

Analysis of variance revealed that there was no significant difference between the three stations ($P > 0.05$). There was significant difference between wet and dry season abundance of Cladocera in Ajiwa reservoir $P < 0.05$ (Table 4.24). Cladocera revealed positive correlation with dissolved oxygen, biochemical oxygen demand, Nitrate-nitrogen and Phosphate-phosphorus and there was negative correlation with turbidity, depth, total dissolved solids and conductivity (Table 4.26). The species observed are

Microcyclops sp, Onychocamptus sp, Heliodiaptomus sp, Daphnia sp, Polyphemus sp, Bosmina sp, and Eurycercus sp. Among the Cladocerans *Microcyclops sp* has the highest abundance during the rainy season which decreased with unset of dry season, *Polyphemus sp,* was second in abundance composition and *Daphnia sp. Heliodiaptomus sp.* has the least abundance. The wet season has more diversity of Cladocerans in the reservoir compared with dry season, as it was indicated by Simpson's and Shannon diversity index (Table 4.27). Figure 4.18 shows monthly stations abundance of Cladocera in Ajiwa reservoir. Station II has least count during the dry season while station III has the highest.

4.3.4 Protozoa

The analysis of variance revealed that there was no significant difference of protozoa abundance in the three stations ($P > 0.05$) but there was significant difference between the number of protozoa identified during the wet and dry season ($P < 0.05$) (Table: 4.25). Protozoa exhibited significant positive correlation with dissolved oxygen and biochemical oxygen demand, Nitrate-nitrogen and Phosphate-phosphorus while negative correlation with pH, depth, and total dissolve solids (Table 4.26). The species identified are *Paramecium sp.* and *Acanthometron sp. Acanthometron sp* has the highest species abundance among the protozoans in the reservoir then Paramecium *sp.* All the two species are more abundant in the rainy season than in the dry season. Protozoans indicated higher diversity in the wet season than in the dry season (Table 4.27). Figure 4.19 shows monthly stations abundance of protozoa in Ajiwa reservoir; there was higher count during the period of wet season than the dry season, there was increase in number of Protozoa from May to August. Highest count was recorded in station III while the lowest was recorded in station I.

Table 4.23: Analysis of Variance for Copepods in Ajiwa Reservoir

Source of Variation	*SS*	*Df*	*MS*	*F*	*P-value*	*F crit*
Months	1993.867	11	221.5407	153.7686	3.69E-15	2.456281
Stations	11.4	2	5.7	3.956298	0.037658	3.554557
Error	25.93333	22	1.440741			
Total	2031.2	35				

Source of Variation	*SS*	*Df*	*MS*	*F*	*P-value*	*F crit*
Between season	448.9	1	448.9	15.26871	0.004497	5.317655
Within season	235.2	11	29.4			
Total	684.1	12				

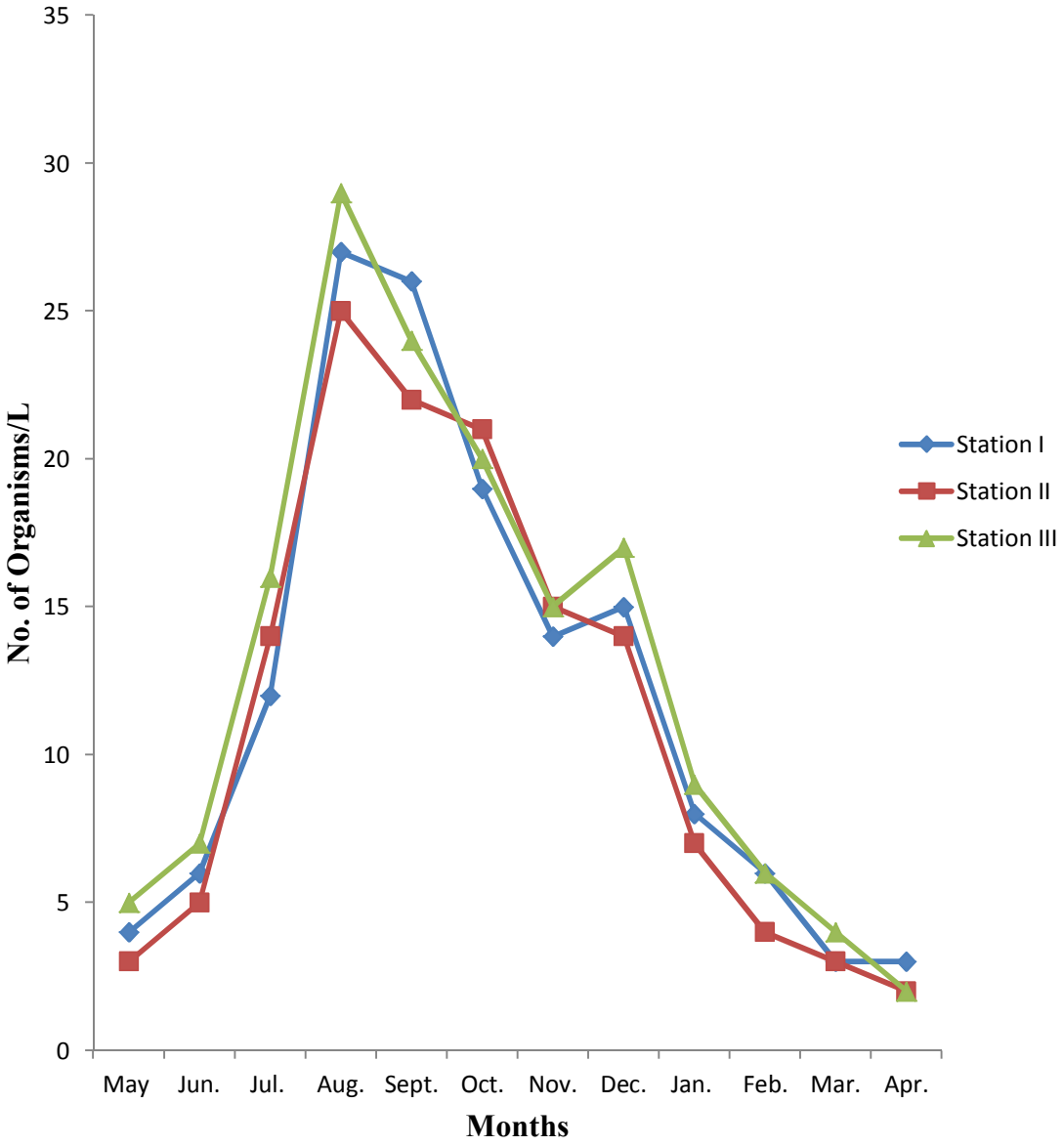


Figure 4.17: Monthly Stations Abundance of Copepods in Ajiwa Reservoir.

Table 4.24: Analysis of Variance for Cladocera in Ajiwa Reservoir

Source of Variation	*SS*	*Df*	*MS*	*F*	*P-value*	*F crit*
Months	1018.967	11	113.2185	19.68384	1.45E-07	2.456281
Stations	28.46667	2	14.23333	2.474565	0.112346	3.554557
Error	103.5333	22	5.751852			
Total	1150.967	35				

Source of Variation	*SS*	*Df*	*MS*	*F*	*P-value*	*F crit*
Between season	272.484	1	272.484	33.10259	0.000427	5.317655
Within season	65.852	11	8.2315			
Total	338.336	12				

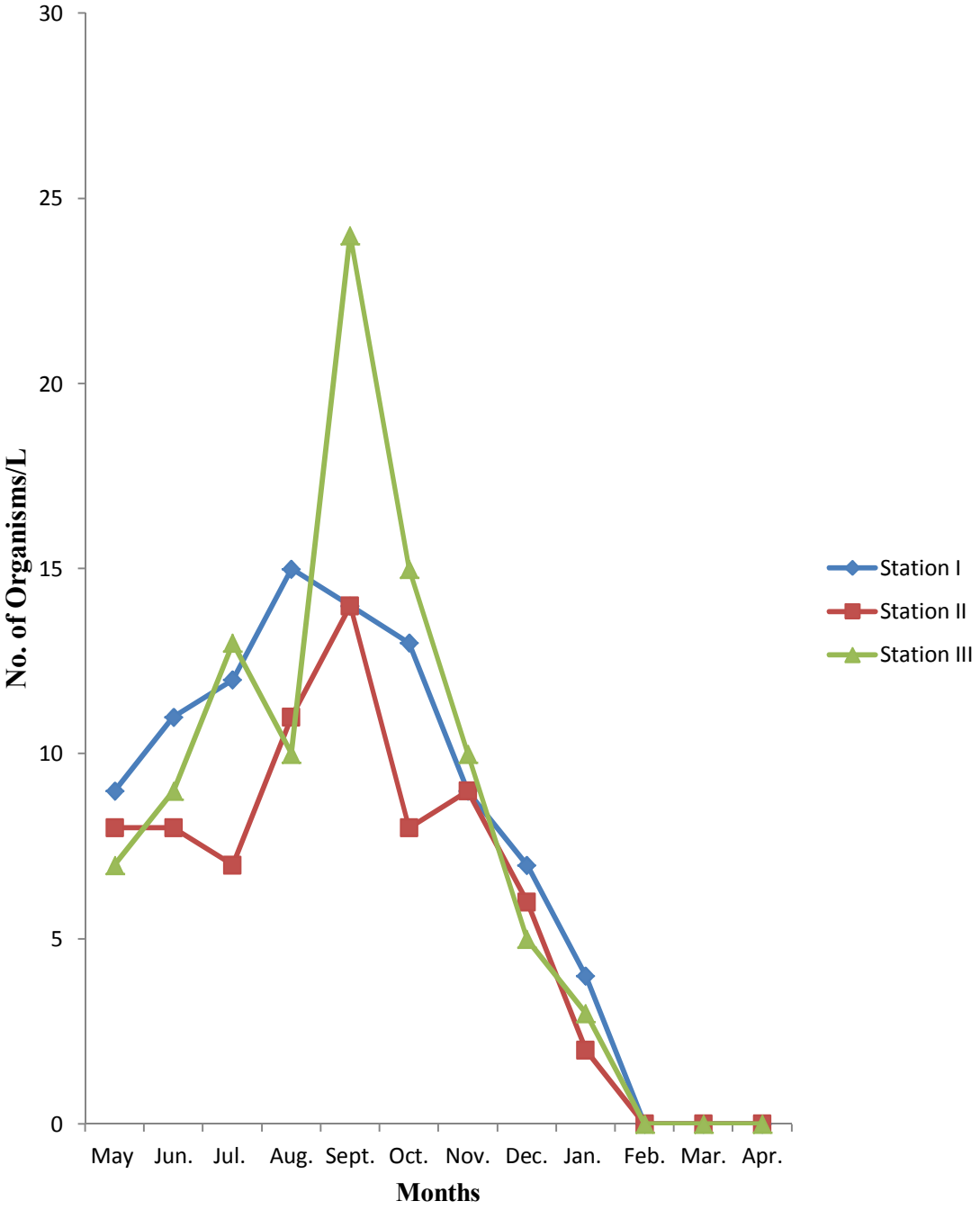


Figure 4.18: Monthly Stations Abundance of Cladocera in Ajiwa Reservoir.

Table 4.25: Analysis of Variance for Protozoa in Ajiwa Reservoir

Source of Variation	*SS*	*Df*	*MS*	*F*	*P-value*	*F crit*
Months	1688.8	11	187.6444	12.04565	6.04E-06	2.456281
Stations	80.26667	2	40.13333	2.57632	0.103764	3.554557
Error	280.4	22	15.57778			
Total	2049.467	35				

Source of Variation	*SS*	*Df*	*MS*	*F*	*P-value*	*F crit*
Between season	220.9	1	220.9	5.234597	0.051431	5.317655
Within season	337.6	11	42.2			
Total	558.5	12				

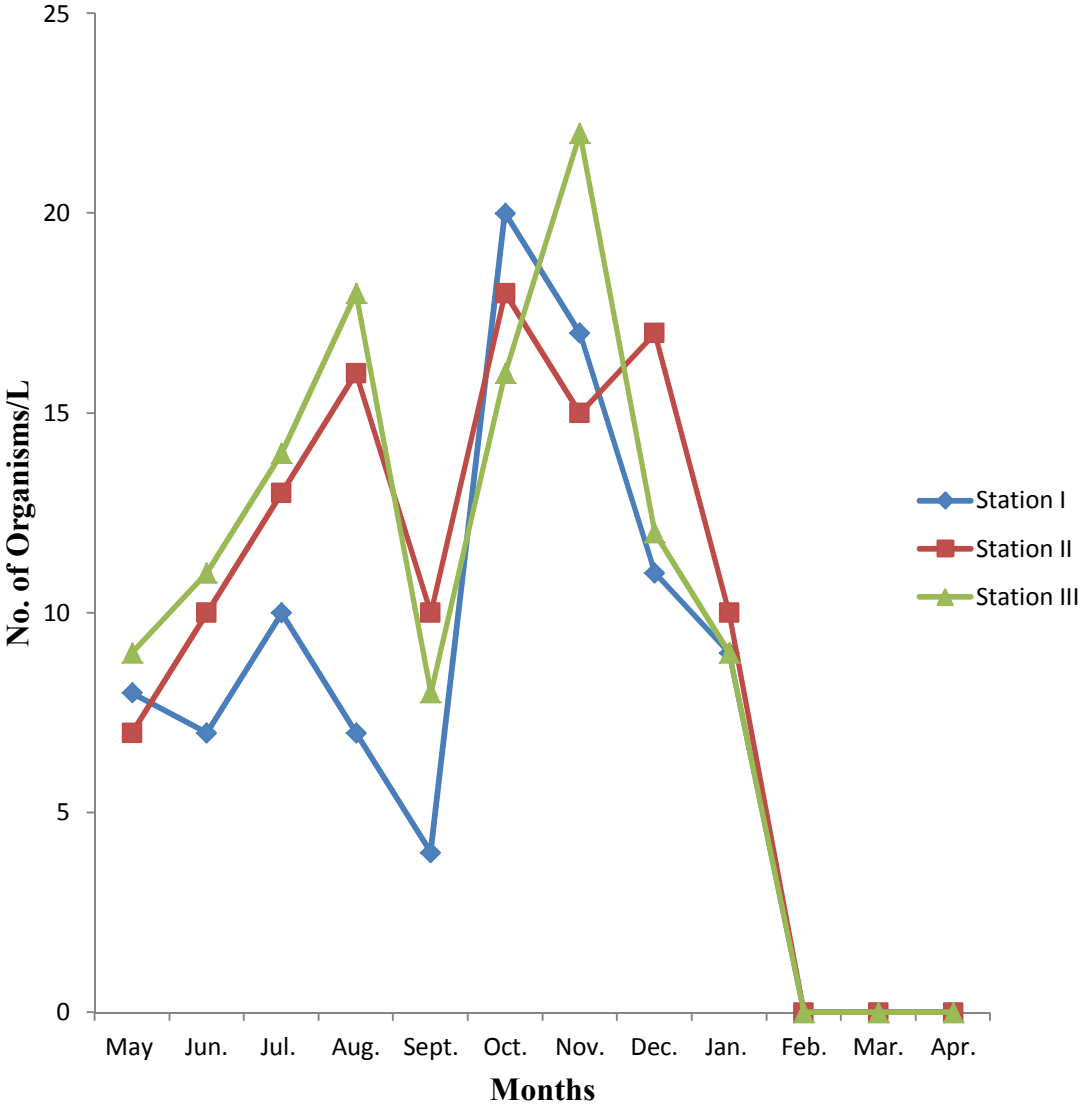


Figure 4.19: Monthly Stations Abundance of Protozoa in Ajiwa Reservoir.

Table: 4.26: Correlation between Abundance of Zooplankton and Physico-chemical Parameters in Ajiwa Reservoir

	Protozoa	Copepods	Cladocera	Rotifera
pH	-0.67*	-0.78*	-0.83*	-0.88*
Temp	0.04^{ns}	0.13^{ns}	0.25^{ns}	0.41*
Turbidity	-0.39^{ns}	-0.68*	-0.73*	-0.78*
DO	0.77*	0.87*	0.91*	0.88*
BOD	0.79*	0.83*	0.82*	0.81*
Conductivity	0.46	0.73*	0.75*	0.84*
Hardness	-0.10^{ns}	-0.06^{ns}	-0.16^{ns}	-0.41^{ns}
Nitrate-nitrogen	0.26^{ns}	0.66*	0.71*	0.68*
TDS	-0.52*	-0.72*	-0.77*	-0.89*
Phosphate-phosphorus	0.11^{ns}	0.57*	0.62*	0.56*
Depth	-.0.56*	-0.43*	-0.63*	-0.84*

Table 4.27: Zooplankton Shannon and Simpson's Diversity Index

Taxon	Diversity Index	Wet	Dry
Copepods	Taxa_S	5	5
	Individuals	334	98
	Shannon_H	0.21	0.34
	Dominance_D	0.58	0.06
	Simpson's _1-D	0.42	0.94
Cladocera	Taxa_S	6	5
	Individuals	236	27
	Shannon_H	0.12	0.26
	Dominance_D	0.76	0.01
	Simpson's _1-D	0.24	0.98
Rotifers	Taxa_S	10	9
	Individuals	373	77
	Shannon_H	0.18	0.32
	Dominance _D	0.64	0.04
	Simpson's _1-D	0.36	0.96
Protozoa	Taxa_S	2	2
	Individuals	259	69
	Shannon_H	0.22	0.35
	Dominance_D	0.56	0.06
	Simpson's _1-D	0.44	0.94

Note: Simpson: Less than 0.5 indicate more diversity.

Higher than 0.5 indicate less diversity.

4.4 MORPHO-EDAPHIC INDEX (MEI)

The Mean Electrical Conductivity (µS/cm) values and Mean Water depth were used to determine the Morpho-Edaphic index of the reservoir in which the result of calculated Morpho-Edaphic index in the reservoir indicates 24.5µS/cm.

Mean Electrical Conductivity (µS/cm) = 129.9

Mean Water depth (m) = 5.3

$$MEI = \frac{\text{Mean Electrical Conductivity}}{\text{Mean Water depth}}$$

MEI = 24.5µS/cm

CHAPTER FIVE

5.0 DISSCUSSION

The studies on the physico-chemical parameters and Plankton composition of Ajiwa reservoir; Katsina State, Nigeria was conducted with the view to contribute some knowledge about the physico-chemical and biological status of the reservoir. The investigation was based on physico-chemical factors such as temperature, turbidity, conductivity, T.D.S, pH, hardness, water depth, dissolved oxygen, biochemical oxygen demand, Nitrate-nitrogen, phosphate and biological parameters such as, phytoplankton, zooplankton and their seasonal variations.

5.1 Physico-Chemical Parameters

5.1.1 Water temperature

The water temperature of the reservoir fluctuated with months, which was between 18°C and 28°C in all the three sampling station. The low water temperature recorded in the reservoir was in the dry season, which could be as a result of seasonal changes in air temperatures associated with the cool dry North-East winds. This observation is supported by the findings of Indabawa (2009) which reports variations in water temperature in the dry season can be attributed to intensified heat radiation and effect of harmattan. The water temperature lacks significance difference with months, which was similar with observation of Tisser *et al.* (2008) which reported the lack of significance in monthly variations of water temperature as characteristic of the tropical climate. Temperature influences the oxygen content of water, quantity and quality of autotrophs, while affecting the rate of photosynthesis and also affecting the quality and quantity of heterotrophs Temperature plays a vital role in the distribution of Zooplankton and Phytoplankton species (Tanimu, 2011).

5.1.2 pH

The water pH in the reservoir was within 6.6 to 7.8, which make the water of the reservoir to be circum-neutral during the study. This was similar with the results of Ibrahim *et al.,* (2009) which reported that hydrogen ion concentration (pH) was nearly neutral throughout both season, and it was within the range for inland water pH 6.5 - 8.5 in Kontagora reservoir, Niger state, Nigeria; which makes it suitable for optimal biological activity. The little increase in pH during the dry season was due to decaying and decomposition of living organisms in the water coupled with the reduction in the water level during the dry season. The observation agrees with that of Mustapha (2008) which reported the slight acidicity (pH=6.8) in the dry season may be due to high carbon dioxide concentration occurring from organic decomposition in Oyun Reservoir, Offa. The little decrease in pH during the rainy season was probably due to the effect of incoming rainwater. This drop in pH was probably due to the stirring effect of the incoming flood from the rivers and streams that converged towards the lake resulting in the mixing of the poorly alkaline or acidic bottom water with alkaline surface water to reduce pH in Shahpur Dam, Pakistan (Janjua *et al.,* 2009).

5.1.3 Turbidity

The Turbidity of the reservoir was high during the dry season; the higher values of turbidity in the dry season may be due to settling effect of surface run-offs and suspended materials that followed the cessation of rainfall. Ayoade *et al.* (2006) observed the onset of rain decreased the Secchi-disc visibility in two mine lakes around Jos. The high values of turbidity in the dry season also coincide with low count of plankton abundance in the dry season. This supports the observation of Mustapha (2008) Turbidity of water is

affected by the amount of the suspended solids in it, and it reduces the light penetrating depth, and hence, reduces the growth of the plants. High turbidity restricts the light penetration and indirectly checks the phytoplankton growth.

The lower values of turbidity during rainy season in Ajiwa reservoir may be the reason of higher count of phytoplankton during the rainy season. (Essien-Ibok *et al.,* 2010) observed that decreasing turbidity downstream, in Mbo River may be attributed to increased tributary input of suspended materials and increased surface run-off from the drainage basin and it could probably be attributed to increased plankton abundance downstream.

5.1.4 Dissolved Oxygen

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

2008) flooding of the lake came with suspended solids and dissolved salts, which also resulted in the negative correlation of DO concentration with total dissolved solids (TDS), and conductivity.

5.1.5 Biochemical Oxygen Demand

The reservoir revealed higher values of biochemical oxygen demand during the dry season, which may be due to reduction of phytoplankton and decomposition of other living organisms in the reservoir. Mahar (2003) made similar observation and suggested the reason was due the depletion of oxygen in the water during decomposition in dry season. The significance difference between wet and dry season may be due to rainfall and entry of freshwater during the rainy season. The negative correlation with turbidity, total dissolved solids, and pH may be due to in flow of substance during the rainy from the farm lands near the reservoir and evaporations in the dry season. Mustapha, (2008) made similar observations in Oyun Reservoir, Offa.

5.1.6 Electrical Conductivity

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

5.1.7 Water Hardness

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

5.1.8 Nitrate-Nitrogen

Nitrate-nitrogen was found to exhibit variation range of 3.8mgL^{-1} to 7.3mgL^{-1}.The mean value recorded in rainy season was higher than that in dry season. The reason for this high concentration in rainy season may be due to excessive influx of nutrients from farmlands where fertilizer is used to boost crop production particularly around the reservoir, as well as input through runoff into the reservoir. The results tallies with that of Balogun *et al.* (2005) which observed mean monthly variation and significant difference between seasons of Nitrate-Nitrogen in Makwaye (Ahmadu Bello University Farm). Nitrate-nitrogen higher values in rainy season also coincide with high plankton composition and abundance in the reservoir during the rainy season. This support the observation of Olele and Ekelemu (2008) the algal species that eventually proliferate in the rainy season must not only be able to tolerate conditions of nutrient limitation but withstand and utilize other sources of nitrogen to their advantage.

5.1.9 Total Dissolved Solids

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

5.1.10 Phosphate-Phosphorus

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

significant phosphate-phosphorous variation within months and no significant variation between the sampling stations in Makwaye (Ahmadu Bello University Farm)

5.1.11 Water Depth

The water depth of the reservoir fluctuate with season, the water depth increases during the rainy season while decreases in the dry season. The decrease in water depth especially during the dry season was caused by high evapo-transpiration during the dry season. Ibrahim *et al.* (2009) made similar observation of water depth fluctuation with season in Kwantagora reservoir. The depth of the reservoir increases dissolved oxygen decrease and this affects both the phytoplankton and zooplankton abundance and distribution. Araoye (2008) reported the depth of the reservoir decreases light intensity, the light penetration depends on the available intensity of the incident light, which varies, with geographical location of the reservoir.

5.2 BIOLOGICAL PARAMETERS

5.2.1 Phytoplankton

The phytoplankton identified belonged to four groups of algae, Bacillariophyta, Cyanophyta, Chlorophyta, and Dinophyta (Pyrrophyta). In general, green (Chlorophyta) algae have higher abundance over other kinds of algae and revealed positive correlation with dissolved oxygen, which indicated the productivity of the reservoir especially during wet season. Mahar (2003) also observed, a phytoplankton community was affected by strong seasonal influence. The monthly and seasonal variation of composition and abundance of phytoplankton may be due to the fluctuations of water and physico-chemical parameters in the reservoir. Abubakar (2009) made similar observation in which

he reported that; in tropical regions the dry and rainy seasons show distinct fluctuations with abundance of phytoplankton

The higher abundance during wet season could be due to the presence of more nutrients and water level in the reservoir during the season. The higher phytoplankton count during the rainy season indicated that the reservoir was more productive during the rainy season because phytoplankton being the primary producers in freshwater and determines the link of feeding relationship in the aquatic ecosystem. This corresponds to the observation of Tisser *et al.* (2008) which reported that; phytoplankton forms the vital source of energy in the fresh water environment, they initiate the fresh water food chain by serving as food to primary consumers which include zooplankton, fish and others. Phytoplankton shown positive relation with dissolved oxygen, biochemical oxygen demand, nitrate-nitrogen, and phosphate-phosphorus; Abubakar (2009) made similar observation in Sabke lake Katsina State. The high concentration of nutrients like nitrate-nitrogen and phosphate-phosphorus results into blooming of algae that is sign of eutrophication but the concentration of both nitrogen and phosphates in the reservoir was within the acceptable range. Nutrient limitation is also an important factor for phytoplankton abundance in shallow freshwater (Araoye and Owolabi, 2005).

5.2.2 Zooplankton

Zooplanktons composition in Ajiwa reservoir was dominated by rotifers, and then copepods, which were followed by Cladocerans and protozoans. The zooplankton composition and abundance varies with month and season, which may be due to fluctuation of physic-chemical parameters and reduction in abundance of phytoplanktons, which are the primary producers. Mahar (2003) reported factors such as light intensity; food availability, dissolved oxygen, and predation affect the population

composition of zooplankton. Ajiwa reservoir had higher zooplankton composition and abundance during the rainy season. This observation coincides with that of Edward and Ugwumba (2010) in which they reported the increased number of zooplankton during the rainy season could be linked to the influx of nutrient.

The Rotifers had the highest species abundance in the reservoir that indicates the water was productive and of good quality. Mahar (2003) reported rotifers appear to be sensitive indicators of changes in water quality. The positive correlation of rotifers with dissolved oxygen and biochemical oxygen demand was an indication the reservoir was unpolluted; Balogun *et al.* (2005) in Makwaye (Ahmadu Bello University Farm) made similar observation. Cladocerans in Ajiwa reservoir, also indicates monthly variation in abundance that may be due to variations of physico-chemical parameters. Cladocera indicated positive relation with nitrogen, dissolved oxygen, biochemical oxygen demand, and Phosphate. The result was similar with that of Syuhei (1994) in which it was report that Cladocerans positive correlation with dissolved oxygen, nitrogen and temperature. The individual growth rate of copepods may depend on temperature alone in a global viewpoint; food condition is still considered an important factor affecting growth and reproduction of copepods in nature, especially in closed environment such as reservoirs and lakes (Mahar, 2003).

The Copepods exhibited monthly variation in abundance and positive correlation with nitrate-nitrogen, dissolved oxygen, biochemical oxygen demand and phosphate-phosphorus in Ajiwa reservoir. The positive correlation with dissolve oxygen was an indication the reservoir was unpolluted and productive. The protozoans also indicated variation in population abundance and composition within months but no significant between stations. The seasons revealed significant difference with wet season having

higher count. The representatives of the group identified are *Acanthometron sp. Euglena sp,* and *Paramecium sp.* Protozoans show positive relation with temperature, dissolved oxygen, pH, nitrate-nitrogen, and phosphate-phosphorus.

5.3 Morpho-Edaphic Index (MEI)

The shallowness of the reservoir coupled with low nutrient status probably explains why its morpho-edaphic index (MEI) and potential fish yield were low. Tropical and sub-tropical reservoirs are known to be more productive than temperate reservoirs and shallow smaller reservoirs are generally more productive than large reservoirs due to their high primary production (Jackson and Marmulla, 2001). Adeniji (1991) estimated the fish potential of about 25-40Kgha^{-1}; which was greater than that of Ajiwa reservoir. Balogun and Aduku estimated the potential fish yield of Kubanni reservoir of about 38Kgha^{-1}, which was also greater than that of Ajiwa reservoir.

5.4 Test of Hypotheses

Three null hypotheses ware formulated and tested with the aim to establish physical, chemical, and biological parameters of Ajiwa reservoir, and to provide better understanding of the reservoir ecosystem structure and dynamics. Hypothesis one stated there was no significant difference between the physico-chemical parameters and seasonal variation in the reservoir in which the results revealed there was significant difference of physico-chemical parameters between the wet and dry season in the reservoir, therefore hypothesis one was rejected. Hypothesis two states there was no significant difference in temporal and spatial distribution of plankton community in the reservoir, in which the result shown there was significant difference in the temporal distribution of plankton in the reservoir; the hypothesis was rejected. The third

hypothesis states; there is no significant relation between plankton community and physico-chemical parameters in the reservoir but statistics revealed there was significant relation between plankton community and physico-chemical parameters in the reservoir, therefore hypothesis three was also rejected.

CHAPTER SIX

6.0 SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS

6.1 SUMMARY

The studies on the physico-chemical parameters and plankton composition of Ajiwa reservoir; Katsina state was carried out for the period of twelve months in order to provide a baseline information on the ecological status of the reservoir. The physico-chemical parameters of the reservoir varied with months and season. The variations of physico-chemical parameters may be due to change in weather cycle during the study period that occurs in the environment. The reservoir was more productive during the rainy season, because there was higher abundance of planktons during the rainy season than the dry season. The higher abundance of Chlorophyta was an indication the reservoirs was productive. Phytoplanktons are primary producers in freshwater bodies and determine the link of feeding relationship in the aquatic ecosystem. Rotifers higher species abundance in the reservoir was an indication the reservoir water was unpolluted and productive, because rotifers are sensitive indicators of changes in water quality. Anthropogenic activities such as farming and cattle rearing that are taking place around the reservoir had some impact on the water quality of the reservoir, especially during the rainy season. The morpho-edaphic index indicates the reservoir has low fish potential yield compared to other reservoirs.

6.2 CONCLUSIONS

The physico-chemical parameters studied in Ajiwa reservoir are Water temperature, pH, turbidity, conductivity, total dissolved solids, nitrate-nitrogen, hardness, dissolved oxygen, biochemical oxygen dissolved, and phosphate-phosphorus. All the physico-

chemical parameters revealed monthly and seasonal variation, which was opposed to the hypothesis stated earlier. The Chlorophyta, Bacillariophyta, Cyanophyta, and Dinophyta all varied with months and seasons, like wise Rotifers, Copepod, Cladocerans, and Protozoans. Zooplankton and Phytoplankton composition and abundance were increased during rainy season and decreased with dry season.Water quality of the reservoir is influenced by anthropogenic activities as runoffs of inorganic fertilizers and pesticides; the reservoir water is suitable for irrigational and domestic purposes in terms of most of the physico-chemical and biological parameters analyzed. However, considering that the reservoir is a source of drinking water, the potential of the anthropogenic inputs gains significance. Hence, there is need for an effective anthropogenic inputs control program in the reservoir.

6.3 RECOMMENDATIONS

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

1. Farming activities very close to the reservoir should be discouraged, in order to reduce the runoffs of inorganic fertilizers and pesticides into the reservoir.
2. More studies should be carried out to identify the plankton composition using polymerase Chain Reaction (PCR) and other Taxonomic identification methods that are not used during this work.
3. Farmers around the reservoir should be enlightened on the effects of their activities into the body of the water, especially application of inorganic fertilizers and pesticide during period of rainy season farming and irrigation when the water level recedes.

REFERENCE

Abbasi, S.A. (1998). *Water Quality Sampling and Analysis*. 1st Ed. Discovery publishing house, New Delhi.

Abubakar, I. (2009). Limnological Studies for the Assessment of Sabke lake Katsina State, Unpublished MSc. Thesis, Ahmadu Bello University, Zaria.

Achionye-Nzeh, C. G.and Isimaikaiye A. (2010) Fauna and Flora Composition and Water Quality of a Reservoir in Ilorin, Nigeria*, International Journal of Lakes and Rivers* 3(1) pp. 7-15.

Adakole, J.A., Abulode, D.S. and Balarabe, M.L. (2008). Assessment of Water Quality of A Man-Made Lake in Zaria, Nigeria. *Proceedings of Taal*: The 12th World Lake Conference: 1373-1382.

Adesalu, T.A. and Nwankwo, D. I. (2010). Cyanobacteria of a Tropical Lagoon, Nigeria. *Journal of American Science.*6 (4).

Adeniji, H.A. (1991).Limnology and biological production in the pelagic zone of Jebba lake, Nigeria.Ph.D. Thesis, University of Ibadan, Ibadan, Nigeria.P 292.

Akinyeye, A.J., Komolafe, J.I. and OkorieT.G.(2011). Limnological Assessment of Effluents on Invertebrates from Alaro River in Oluyole industrial area of Ibadan, Oyo State, Nigeria.*Agriculture and Biology Journal of North America.* 2(7): 1053-1058. Retrieved from http://www.scihub.org/ABJNA

Akomeah, P.A., Ekhator, O. and Udoka, C. (2010). Dry Season Phytoplankton Composition Of Ibiekuma Dam, Ekpoma, Edo State. *Ethiopian Journal of Environmental Studies and Management* (3)3:36-40

Anil K.T, Girish C. and Seema K. (2014). Zooplankton diversity in shallow lake of Sultanpur national park, Gurgaon (Haryana). *International Journal of applied Biology and Pharmaceutical Technology* 5(1):35-40
Retrieved from http://www.ijabpt.com

Araoye, P.A. (2008). Physical factors and their Influence on Fish Species Composition in Asa Lake, Ilorin, Nigeria. *International Journal of Tropical Biology* 57 (1-2): 167-175.

Araoye, P.A. and O. Owolabi, (2005). Some Changes in the Animal and Fish Species Composition Due to the Construction of Kampe (Omi) dam and irrigation project in Kogi State, Nigeria. *Nigerian Journal of Pure & Applied Science* 20(1): 1781-1789.

Ayoade A. A, Fagade, S.O. and Adebisi A. A. (2006). .Dynamics of Limnological Features of Two Man-Made Lakes in Relation to Fish Production. *African Journal of Biotechnology* 5(10): 1013-1021.
Retrieved from http;//www.academicjournals.org/AJB.on23/12/2011.

Ayoade, A.A (2009). Changes in Physico-chemical Features and Plankton of Two Regulated High Altitude Rivers Garhwal Himalaya, India. *European Journal of Scientific Research*.27 (1)77-92
Retrieved from http://www.eurojournals.com/ejsr.htm on 25/12/2011

Atobatele, O.E. and Ugwumba, O.A (2008). Seasonal Variation in the Physico-chemistry of a Small Tropical Reservoir (Aiba Reservoir, Iwo, Osun, Nigeria). *African Journal of Biotechnology Vol.* 7 (12):62-171.
Retrieved from http://www.academicjournals.org/AJB on 23/12/2011

A.P.H.A.(1999). *Standard Methods for Examination of Water and Waste Water*. American Public Health Association, New York, U. S.A.

Balarabe, M.L., (2001). Effect of Limnological Characteristic on Zooplankton composition and distribution in Dumbi and Kwangila Ponds, Zaria, Nigeria.Ph.D. Thesis, Department of Biological Sciences, Ahmadu Bello University.

Balogun, J.K., Balarabe, M.L. and. Igberaese, P.M (2005) Some Aspects of the Limnology of Makwaye (Ahmadu Bello University Farm) Lake, Samaru, Zaria. *Academic Journal* 23(12):850-860
Retrieved from http;//www.academicjournals.org/AJB.on23/12/

Barnabe, G. (1994). *Aquaculture Biology and Ecology of Cultured Species*. Ellis Horwood Ltd.

Bhatti, M.T. and Latif, M. (2011). Assessment of Water Quality of a River using an Indexing Approach during the Low-flow Season Irrigation Drainage, *Journal of Agriculture and Environment* (60): 103-114.

Boyd, C.E. and Tucker, C.S. (1998).*Pond Aquaculture Water Quality Management*
Lower Academic Publishers, London.

Chia, A.M. and Bako, S.P. (2008). Seasonal Variation of Cyanobacteria in Relation to Physico-Chemical Parameters of Some Fresh Water Ecosystems in the Nigerian Guinea Savanna.Sengupta, M. and Dalwani, R (Ed). (2008) *Proceedings of Taal2007: The 12th World Lake Conference*, p: 1383-1387.

Edward G. B. and David C. S.(2010). *Freshwater Algae:Identification and Use as Bioindicators,* Wiley-BlackwellJohn Wiley & Sons, Ltd, The Atrium, Southern Gate, Chichester, West Sussex,PO19 8SQ, UK. Retrieved from www.wiley.com/wiley-blackwell

Edward, J.B. and Ugwumba, A.A.A. (2010). Physico-Chemical Parameters and Plankton Community of Egbe Reservoir, Ekiti State, Nigeria.*Research Journal of Biological Sciences* 5 (5): 356-367.

EmiY. and Andy G.(2007). *Phytoplankton Identification Guide.* University of Georgia Marine Education Centre and Aquarium.
Retrieved from http://www.marex.uga.edu/aquarium

Essien-Ibok, M.A., Akpan, A.W., Udo, M.T., Chude, L.A., Umoh, I. A., Asuquo, I. E. (2010). Seasonality in the Physical and Chemical characteristics of Mbo River, AkwaIbom state, Nigeria. *Nigerian Journal of Agriculture, Food and Environment*. 6(1&2):60-72

F.A.O (2009). The State of World Fisheries and Aquaculture.FAO Website.
www.fao.orglsoflsofialindex_en.htm.

Fazio, A. and O'Farrell, I. (2005). Phytoplankton and Water Quality in a Shallow Lake: a Response to Secondary Salinization (Argentina). *Wetlands* 25: 531-541.

Hassan, K.Y., Kutama, A.S. and Ibrahim, Y.(2010). Algal Diversity in Relation to Physico-chemical Parameters of Three Ponds in Kano Metropolis, *Nigeria Bioscience Research Communications* 22(6)
Retrieved from http://www.klobex.org/brc on 12/01/2012

Ibrahim, B.U., Auta, J. and Balogun, J.K. (2009). An Assessment of the Physico-chemical Parameters of Kontagora Reservoir, Niger state, Nigeria. *Bayero Journal of Pure and Applied Sciences,* 2(1): 64 - 69

Indabawa, I. I. (2009). Studies on Limnological Parameters and Phytoplankton Dynamics of Nguru Lake, Yobe State, Nigeria. *Bioscience Research Communications,* 21(4), 183-188.

Iqbal, M..A. Kazmi and S. Shoukat (1990). A Multivariate Analysis of Seasonal Variation in Zooplankton Composition of Hub Lake. *Pakistan Journal of Zoology***,**22(2): 123-131.

Jackson, D.C. and G. Marmulla. (2001). The Influence of Dams on River Fisheries, p. 1-44. *In G.Marmula* (Ed.). Dams, fish and fisheries, opportunities, challenges and conflict resolution. FAO Fish Tech. Pap No. 419, FAO Rome, Italy.

Jana, M. Y. Ahmad, T. and Akhtar, N. (2009). Limnology and Trophic Status of Shahpur Dam Reservoir Pakistan. *Journal of Animal and Plant Sciences* 19(4): 224-273.

Janjua, M.Y. Ahmad T. and D. Gerdeau. (2008). Comparison of Different Predictive Models for Estimating Fish Yields in Shahpur Dam, Pakistan. *Lake Reservoir Management.* (13): 319-324.

Kadiri, M.O. (2002). Limnological Studies of two Contrasting but Closely Linked Springs in Southern Nigeria. *Plant Biosystems*, 13(4), 123-131

Kantoussan, J. Ecoutin, E.C. Simmer, M. Fontelle, G. Thiaw, O.T. and Lae, R. (2007). The Relevance of Species Based Indicator as a Tool for Evaluating the Structure of Exploited Fish Assemblages: A Comparison Study of two Tropical Lakes in Mali, West Africa. *Lake Reservoir Management* 12: 135-145

Kigamba, B.M. (2005). Limnological Studies in a Fish Pond at Birdman, West Bengal, India, *Japan Journal of limnology*, 40: 10-18
Retrieved from www.ccsenet.org/enrr on 02/07/2011

Kolo, R.J. Ojutiku, R.O and Musulmi, D.T (2010). Plankton Communities of Tagwai dam Minna, Nigeria. *Continental Journal of Fisheries and Aquatic Science* 4: 1.
Retrieved from http://www.wiloludjournal.com on 22/12/2011.

Landau, M. (1992). *Introduction to Aquaculture*. JohnWillay and sons, Inc. New York.

Mahar, M.A. (2003). Ecology and Taxonomy of Plankton of Manchhar lake (Distt. Dadu), Sindh, Pakistan.Unpublished PhD. Thesis University of Sindh, Pakistan.
Retrieved from: http://usindh.edu.pk.mukhatiar.ahmad/Dessertation_mukhatiar

Mustapha, M.K. (2008). Assessment of the Water Quality of Oyun Reservoir, Offa, Nigeria, using Selected Physico-chemical Parameters. *Turkish Journal of Fisheries and Aquatic Sciences,* 8, 309-319.

Mustapha, M.K. (2011). Perspectives in the Limnology of Shallow Tropical African Reservoirs in Relation to Their Fish and Fisheries. *Journal of Transdisciplinary Environmental Studies* 10(1):16-23

Nathanson, Jerry A. (2003). *Basic Environmental Technology: Water Supply, Waste Management, and Pollution Control*. Upper Saddle River, New Jersey: Prentice Hall.

Needham, J.G. and Needham, P.R. (1975). *A Guide to the Study of Freshwater Biology* 4th edition, Holden - Day Inc., San Francisco, 1683 pp. NRC (1989). National Research Council *Recommended dietary allowances,* 10th ed. Washington, DC, National Academy Press. 89pp.

N'Diaye A. D., El Kory, M.B., Sid M. O, Kankou A. O. (2013). Study of Water Quality during Rainy Season using Physico-chemical and Metallic Parameters of Senegal River in Mauritania. *Sci-Afric Journal of Scientific Issues, Research, and Essays* 1(1), pp. 01-10.
Retrieved from http://www.sci-afric.org.

Offem, B. O. and Ikpi, G. U. (2011). Water Quality and Environmental Impact Assessment of a Tropical Waterfall System, *Environment and Natural Resources Research* 11(1). Retrieved from www.ccsenet.org/enrr on 02/01/2012

Onyedineke, N.E., Nwigwe, H.C. and Emeronye, R.U. (2009). Physical and Chemical Hydrology of Abadaba Lake, Imo State, Nigeria. *Advances in Science and Technology*, 3(1):183-193.

Olele, N.F. and Ekelemu, J.K. (2008). Physicochemical and Phytoplankton Study of Onah Lake, Asaba, Nigeria. *African Journal of General Agriculture* 4(3). Retrieved from http://www.asopha.org.

Park, K.S. and Shin, H.W. (2007). Studies on Phytoplankton and-Zooplankton Composition and its Relation to Fish Productivity in a West Coast Fish Pond Ecosystem. *Journal of Environmental Biology*, (28): 415-422.

Palmer, C.M. (1969). A Composite Rating of Algae Tolerating Organic Pollution. *Journal of Phycology.* 78(5).

Porrow M.R., NanoJ. and Reid G.K.(1999). *Ecology of Inland Waters and Estuaries.* Blackwell publishers, London p45-51.

Rajagopal, T.; Thangamani, A.; Sevarkodiyone, S. P.; Sekar, M. and Archunan, G. (2010). Zooplankton Diversity and Physic-Chemical Conditions in Three Perennial Ponds of Virudhunagar district.Tamilnadu.*Journal of Environmental Biology*, 31: 265-272.

Ryder, R.A. (1965). A Method for Estimating the Potential Fish Production of North Temperate Lakes. *Transactions of the American Fisheries Society*. 94: 214-218

Singh, C.S. (1990). Limnological Studies for Bioenergetics Transformation in a Tarai Reservoir, Nanak Sagar *Advances in Limnology,* pp. 356-362.

Syuhei, B (1994). Effect of Temperature and Food Concentration on Post- Embryonic Development, Egg Production and Adult Body Size of Calanoid Copepod *Eurytemora affinis*, *Journal of Plankton Res*earch, 16(6): 721-735.

Surajit M. and Tapas. D. (2014). Studies on Seasonal Variations in Physico-chemical Parameters in Bankura Segment of the Dwarakeshwar River (W.B.) India. *International Journal of Advanced Research* (2014), Volume 2, Issue 3, 877-881. Retrieved from http://www.journalijar.com.

Tanimu, Y. (2011). Diversity and Abundance of Phytoplankton in Relation to Water Quality Status of Three Reservoirs in Kaduna State Nigeria. Unpublished, MSc. Thesis. Ahmadu Bello University, Zaria

Tiseer, F.A., Tanimu, Y. and Chia, A.M. (2008), Seasonal Occurrence of Algae and Physico-chemical Parameters of Samaru Stream, Zaria, Nigeria. *Asian Journal of Earth Sciences,* 1(1), 31-37.

Ude, E. F., Ugwu, L. L. C., Mgbenka, B. O. and Nwani, C. D (2011). Trends in Nitrate-Nitrogen, Nitrite-Nitrogen and Phosphorus Concentration in Ebonyi River, Nigeria. Continental Journal Fisheries and Aquatic Science 5 (1):1-7, 2011. Retrieved from http://www.wiloludjournal.com

Usha, C. (1997). Observations on Community Analysis of Zooplankton from GandhiSagar Reservoir MandsaaurM. P. India, pp 21-32. In Mahar, M.A. (2003). Ecology and taxonomy of plankton of Manchhar lake (Distt.Dadu), Sindh, Pakistan, Unpublished PhD. Thesis University of Sindh, Pakistan.

Verlencar X.N. (2004). *Phytoplankton Identification Manual*, National Institute of Oceanography Dona Paula, Goa India.

Zeb, B.S., A.H. Malik, A. Waseem and Q. Mahmood, (2011).Water Quality Assessment of Siran River, Pakistan.*International Journal of Physical Science*. (6): 789-798.

Appendices

Appendix I: Monthly Values of Temperature (^{o}C) at the Three Sampling Stations in Ajiwa reservoir

Month	Station I	Station II	Station III	Mean
May	25	27	26	26.0
Jun.	25	26	25	25.3
Jul.	28	27	28	27.7
Aug.	25	27	26	26.0
Sept.	24	23	25	24.0
Oct.	23	22	23	22.6
Nov.	23	24	24	23.7
Dec.	18	18	19	18.3
Jan.	20	21	21	20.6
Feb.	20	21	20	20.3
Mar.	24	24	23	23.6
Apr.	26	25	26	25.7

Appendix II: Monthly Values of pH at the Three Sampling Stations in Ajiwa Reservoir

Month	Station I	Station II	Station III	Mean
May	6.9	6.8	6.9	6.9
Jun.	6.8	6.8	7.0	6.9
Jul.	6.7	6.8	6.6	6.7
Aug.	7.0	6.5	6.9	6.9
Sept.	6.9	6.8	6.9	6.9
Oct.	6.8	6.8	6.9	6.8
Nov.	7.1	7.0	7.2	7.1
Dec.	6.8	7.1	7.1	6.9
Jan.	7.8	7.7	7.5	7.6
Feb.	7.6	7.5	7.6	7.6
Mar.	7.5	7.3	7.4	7.4
Apr.	7.4	7.5	7.3	7.4

Appendix III: Monthly Values of Turbidity at the Three Sampling Stations in Ajiwa Reservoir

Month	Station I	Station II	Station III	Mean
May	089	088	090.	89.00
Jun.	088	090	090	89.30
Jul.	089	089	090	89.30
Aug.	087	088	089	88.00
Sept.	089	087	090	88.60
Oct.	095	097	095	95.70
Nov.	099	098	098	98.30
Dec.	098	104	102	101.3
Jan.	130	120	135	128.3
Feb.	120	110	115	115.0
Mar.	109	108	109	108.7
Apr.	100	099	101	100.0

Appendix IV: Monthly Values of Dissolved Oxygen at the Three Sampling Stations in Ajiwa Reservoir

Month	Station I	Station II	Station III	Mean
May	7.30	7.40	7.20	7.20
Jun.	7.30	7.40	7.30	7.3 0
Jul.	7.30	7.50	7.20	7.30
Aug.	7.00	7.10	7.20	7.10
Sept.	7.50	7.30	7.60	7.50
Oct.	7.80	7.70	7.90	7.80
Nov.	7.70	7.80	7.60	7.70
Dec.	6.90	6.90	6.90	6.90
Jan.	4.30	4.80	4.90	4.70
Feb.	4.10	4.40	4.20	4.20
Mar.	4.00	4.10	4.00	4.00
Apr.	3.90	4.00	3.80	3.90

Appendix V: Monthly Values of Biochemical Oxygen Demand at the Three Sampling Stations in Ajiwa Reservoir

Month	Station I	Station II	Station III	Mean
May	3.50	3.60	3.60	3.60
Jun.	3.70	3.50	3.60	3.60
Jul.	3.60	3.40	3.70	3.60
Aug.	3.50	3.40	3.80	3.60
Sept.	3.60	3.50	3.60	3.60
Oct.	3.80	3.70	3.90	3.80
Nov.	3.90	3.90	4.00	3.90
Dec.	4.00	3.90	4.10	4.00
Jan.	2.30	2.20	2.30	2.30
Feb.	2.20	2.10	2.00	2.10
Mar.	2.10	2.00	2.10	2.10
Apr.	2.00	2.10	1.80	2.00

Appendix VI: Monthly Values of Electrical Conductivity at the Three Sampling Stations in Ajiwa Reservoir

Month	Station I	Station II	Station III	Mean
May	102.4	102.1	102.8	102.4
Jun.	112.5	111.9	112.9	112.4
Jul.	120.5	120.9	120.9	120.7
Aug.	122.9	120.8	122.3	122.0
Sept.	122.7	122.8	122.7	122.7
Oct.	128.3	130.3	130.5	129.7
Nov.	130.4	133.6	133.0	133.3
Dec.	136.6	138.7	135.5	136.6
Jan.	140.9	140.1	139.9	140.3
Feb.	144.2	144.1	144.1	144.1
Mar.	144.7	144.4	144.6	144.6
Apr.	150.0	150.2	150.1	150.1

Appendix VII: Monthly Values of Water Hardness at the Three Sampling Stations in Ajiwa Reservoir

Month	Station I	Station II	Station III	Mean
May	81.20	83.40	84.70	83.10
Jun.	84.20	83.40	84.70	84.10
Jul.	84.20	82.40	85.70	84.10
Aug.	87.20	85.70	88.30	87.10
Sept.	88.90	87.50	89.30	88.60
Oct.	81.10	80.60	91.20	84.30
Nov.	81.40	89.80	90.60	87.30
Dec.	90.80	90.30	91.40	90.70
Jan.	95.10	89.40	88.40	90.90
Feb.	99.20	90.10	93.00	94.10
Mar.	99.00	100.2	98.00	99.40
Apr.	88.30	92.40	93.90	91.50

Appendix VIII: Monthly Values of Nitrate-Nitrogen at the Three Sampling Stations in Ajiwa Reservoir

Month	Station I	Station II	Station III	Mean
May	6.2	6.3	6.4	6.3
Jun.	6.2	6.3	6.7	6.4
Jul.	6.4	6.7	6.8	6.7
Aug.	7.1	7.0	7.2	7.1
Sept.	7.2	7.1	7.3	7.2
Oct.	6.4	6.3	6.8	6.5
Nov.	6.5	6.4	6.9	6.6
Dec.	5.2	5.4	5.3	5.3
Jan.	4.3	4.6	3.8	4.2
Feb.	5.4	5.3	5.4	5.4
Mar.	6.0	6.1	5.7	5.9
Apr.	6.1	5.9	5.9	6.0

Appendix IX: Monthly Values of Total Dissolved Solids at the Three Sampling Stations in Ajiwa Reservoir.

Month	Station I	Station II	Station III	Mean
May	14.4	14.8	15.1	14.8
Jun	13.4	14.8	13.9	14.0
Jul.	10.2	9.80	10.4	10.1
Aug.	10.3	10.1	10.3	10.2
Sept.	13.2	12.8	14.1	13.4
Oct.	16.8	16.9	17.3	17.0
Nov.	20.0	19.4	18.8	19.3
Dec.	23.8	22.1	25.4	23.8
Jan.	24.2	23.6	22.6	23.5
Feb.	23.4	23.2	23.0	23.2
Mar.	23.5	24.1	23.5	23.7
Apr.	20.4	19.8	20.1	20.1

Appendix X: Monthly values of Phosphate-Phosphorus at the Three Stations in Ajiwa Reservoir

Month	Station I	Station II	Station III	Mean
May	1.8	1.6	1.9	1.7
Jun.	2.7	2.6	2.8	2.5
Jul.	2.8	2.6	2.9	2.7
Aug.	3-0	3.1	3.3	3.1
Sept.	3.5	3.4	3.8	3.6
Oct.	3.8	3.5	4.0	3.8
Nov.	2.0	2.9	2.3	2.4
Dec.	2.6	2.7	2.9	2.7
Jan.	2.2	2.4	2.8	2.4
Feb.	3.2	3.3	3.0	3.2
Mar.	3.4	3.5	3.3	3.4
Apr.	3.2	3.4	3.1	3.2

Appendix XI: Monthly Values of Water Depth at the Three Sampling Stations in Ajiwa Reservoir

Month	Station I	Station II	Station III	Mean
May	5.8	5.2	5.0	5.3
Jun.	5.8	5.4	5.1	5.4
Jul.	5.2	5.4	5.7	5.4
Aug.	6.2	6.7	6.3	6.4
Sept.	7.3	7.5	7.8	7.5
Oct.	6.1	6.2	6.2	6.1
Nov.	5.8	5.8	5.6	5.7
Dec.	5.4	5.3	5.4	5.3
Jan.	5.1	5.4	5.4	5.3
Feb.	4.2	4.1	4.0	4.1
Mar.	4.0	4.0	4.1	4.0
Apr.	3.8	4.4	3.9	4.0

Appendix XII: Monthly abundance of Chlorophyta at the Three Sampling Stations in Ajiwa Reservoir

Month	Station I	Station II	Station III	Mean
May	17	16	17	16.7
Jun.	30	28	29	29.0
Jul.	42	38	41	40.3
Aug.	38	39	40	39.0
Sept.	35	35	36	35.3
Oct.	33	36	34	34.3
Nov.	30	29	31	30.0
Dec.	28	26	27	27.0
Jan.	20	18	19	19.0
Feb.	17	16	17	16.7
Mar.	16	15	17	16.0
Apr.	18	19	20	19.0

Appendix XIII: Monthly abundance of Bacillariophyta at the Three Sampling Stations in Ajiwa Reservoir

Month	Station I	Station II	Station III	Mean
May	07	06	07	6.70
Jun.	12	13	11	12.0
Jul.	20	23	12	18.3
Aug.	19	21	23	21.0
Sept.	20	21	22	21.0
Oct.	18	17	18	17.7
Nov.	14	12	16	14.0
Dec.	12	13	11	12.0
Jan.	07	05	08	6.70
Feb.	04	05	03	4.00
Mar.	05	04	04	4.30
Apr.	06	05	07	6.00

Appendix XIV: Monthly abundance of Cyanophyta at the Three Sampling Stations in Ajiwa Reservoir

Month	Station I	Station II	Station III	Mean
May	05	05	02	4.00
Jun.	08	06	08	7.30
Jul.	10	09	11	10.0
Aug.	11	10	12	11.0
Sept.	10	08	11	9.70
Oct.	09	08	09	8.70
Nov.	06	07	08	7.00
Dec.	07	04	06	5.70
Jan.	05	04	03	4.00
Feb.	04	02	03	3.00
Mar.	06	03	05	4.70
Apr.	08	05	09	7.30

Appendix XV: Monthly abundance of Dinophyta at the Three Sampling Stations in Ajiwa Reservoir

Month	Station I	Station II	Station III	Mean
May	01	00	00	0.3
Jun.	02	03	03	2.7
Jul.	04	03	03	3.3
Aug.	02	01	02	1.6
Sept.	02	01	01	1.3
Oct.	01	00	01	0.7
Nov.	00	00	00	0.0
Dec.	00	00	00	0.0
Jan.	00	00	00	0.0
Feb.	00	00	00	0.0
Mar.	00	00	00	0.0
Apr.	00	00	00	0.0

Appendix XVI: Monthly abundance of Rotifera at the Three Sampling Stations in Ajiwa Reservoir

Month	Station I	Station II	Station III	Mean
May	08	07	09	08
Jun.	12	14	14	16
Jul.	20	16	18	18
Aug.	27	23	26	25
Sept.	30	29	31	30
Oct.	15	16	18	16
Nov.	11	14	15	16
Dec.	11	13	14	13
Jan.	08	08	08	08
Feb.	04	01	04	03
Mar.	01	02	01	01
Apr.	01	01	01	01

Appendix XVII: Monthly abundance of Copepods at the Three Sampling Stations in Ajiwa Reservoir

Month	Station I	Station II	Station III	Mean
May	04	03	05	04
Jun.	06	05	07	06
Jul.	12	14	16	14
Aug.	27	25	29	27
Sept.	26	22	24	24
Oct.	19	21	20	20
Nov.	14	15	15	15
Dec.	15	14	17	15
Jan.	08	07	09	08
Feb.	06	04	06	05
Mar.	03	03	04	03
Apr.	03	02	02	02

Appendix XVIII: Monthly abundance of Cladocera at the Three Sampling Stations in Ajiwa Reservoir

Month	Station I	Station II	Station III	Mean
May	09	08	07	8.00
Jun.	11	08	09	9.30
Jul.	12	07	13	10.6
Aug.	15	11	10	12.0
Sept.	14	14	24	17.3
Oct.	13	08	15	12.0
Nov.	09	09	10	9.30
Dec.	07	06	05	6.00
Jan.	04	02	03	3.00
Feb.	00	00	00	0.00
Mar.	00	00	00	0.00
Apr.	00	00	00	0.00

Appendix XIX: Monthly abundance of Protozoa at the Three Sampling Stations in Ajiwa Reservoir

Month	Station I	Station II	Station III	Mean
May	08	07	09	8.00
Jun.	07	10	11	9.30
Jul.	10	13	14	12.3
Aug.	07	16	18	14.0
Sept.	04	10	08	7.00
Oct.	20	18	16	18.0
Nov.	17	15	22	18.0
Dec.	11	17	12	13.0
Jan.	09	10	09	9.00
Feb.	00	00	00	0.00
Mar.	00	00	00	0.00
Apr.	00	00	00	0.00

Appendix XX: Composition and Abundance Phytoplanktons in Ajiwa Reservoir

	May	Jun.	Jul.	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	Totals
Bacillariophyta													
Cyclotella sp	4	5	10	12	13	12	9	8	6	4	3	4	90
Cymbella sp	3	6	10	12	11	9	8	4	3	3	2	2	75
Gyrosigama sp	2	5	9	10	11	8	7	5	3	2	1	0	62
Epithemia sp	2	4	11	10	9	8	7	4	4	0	0	0	62
Diatomella sp	3	4	8	11	8	7	5	3	0	0	0	0	49
Anomoneis sp	2	3	4	6	8	5	3	2	1	1	0	1	37
Chlorophyta													
Oocystis sp	2	5	8	9	8	9	8	7	4	3	1	2	68
Scenedesmus sp	2	3	7	8	8	7	6	5	3	2	2	1	54
Pediastrum sp	3	4	8	10	9	8	7	6	4	3	2	1	66
Dictyochloris sp	2	4	7	8	7	6	5	4	3	2	1	1	50
Closterium sp	2	3	5	7	5	5	5	4	2	1	1	0	40
Tetraedron sp	2	4	4	5	4	5	4	4	3	3	2	1	39
Ulotrix sp	1	3	3	6	5	4	3	3	2	1	1	1	33
Euastrum sp	2	3	5	7	5	6	5	4	1	2	1	1	42
Spirogyra sp			7	6	6	5	4	4	2	1	1	1	37
Zygnema sp	1	3	5	7	7	6	6	4	0	0	0	0	40
Oedegonium sp	0	2	8	7	8	6	4	3	0	0	0	0	38
Volvox sp	0	1	3	6	4	4	4	0	0	0	0	0	22
Cyanophyta													
Chroococcussp	0	0	9	8	7	8	6	5	4	3	5	4	59
Gomphosphaeria sp	0	0	6	6	5	4	3	4	2	3	3	2	38
Microcystis sp			6	5	4	5	4	3	2	1	2	3	35
Anabaena sp	0	2	7	6	6	4	3	1	1	0	0	0	30
Oscillatoria sp	1	2	7	5	4	3	3	3	2	1	1	1	33
Nostoc sp	0	3	5	4	3	3	2	0	0	0	0	0	20
Dinophyta													
Pridinium sp	0	2	7	4	3	1	0	0	0	0	0	0	17
Ceratium sp	0	0	3	2	1	0	0	0	0	0	0	0	6
Euglena	4	13	14	12	28	23	21	11	0	0	0	0	133

Appendix XXI: Composition and Percentage abundance of Zooplanktons in Ajiwa Reservoir

	May	Jun.	Jul.	Aug.	Sept.	Oct.	Nov.	Dec.	Jan. 2013	Feb.	Mar.	Apr.	Totals
Copepods													
Eubrachipus sp	2	4	8	17	17	15	10	12	7	4	3	3	102
Cyclops sp	2	3	8	15	14	13	7	7	5	3	2	1	80
Nauplus sp	3	2	8	13	12	11	8	9	6	3	1	2	78
Diaptomus sp.	2	1	5	4	3	3	3	3	0	1	2	0	27
Paracyclops sp	3	4	9	12	9	9	9	8	2	3	0	0	68
Naupalii sp	2	2	6	10	9	8	7	6	4	0	0	0	54
Cladocera													
Microcyclops sp	1	3	6	7	7	6	6	5	2	0	0	0	43
Onychocamptus sp			4	5	9	6	4	2	1	0	0	0	31
Heliodiaptomus sp	1	2	3	3	4	2	3	2	0	0	0	0	20
Daphnia sp	2	3	3	4	5	4	4	3	3	0	0	0	30
Polyphemus sp	2	3	7	8	8	6	4	0	2		0	0	39
Bosmina sp	1	2	3	5	6	4	3	1	1	0	0	0	26
Eurycercus sp	0	1	6	4	6	3	2	0	0	0	0	0	22
Rotifera													
Brachionus sp	5	7	20	26	23	21	19	12	7	2	1	2	145
Monostyla sp	3	4	18	18	15	9	4	3	1	1	0	0	76
Euclanis sp	1	2	7	7	5	3	3	2	2	1	0	1	34
Keratellasp	2	2	6	5	6	2	2	1	1	0	0	0	27
Kellicottia sp	0	2	4	5	4	3	2	2	1	0	0	0	23
Chromogaster sp	1	2	5	4	3	2	2	1	0	0	0	0	19
Filinia sp	0	2	5	3	2	3	2	3	1	0	0	0	21
Lecane sp	0	1	1	1	3	0	0	1	0	0	0	0	7
Notholca sp	0	0	0	1	2	2	2	2	2	0	0	0	11
Trichocerca sp	1	1	4	5	4	3	3	1	1	0	0	0	23
Protozoa													
Paramecium sp	2	4	14	16	15	10	9	8	5	0	0	0	82
Acanthometron sp	2	4	14	13	2	9	7	6	4	0	0	0	61

Some of the Planktons observed in Ajiwa Reservoir

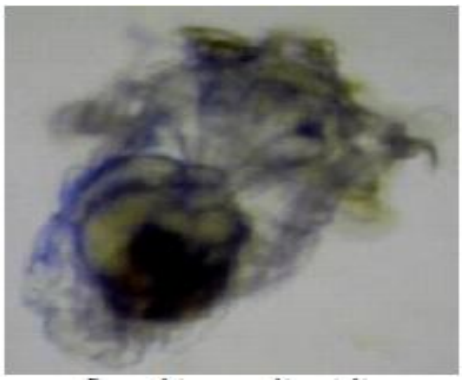


Plate III: (a) *Microcyclops sp.* (x400)

(A representative of Cladocera)



(b): 10 *Nauplius sp.* (x400)

(A representative of Copepods)



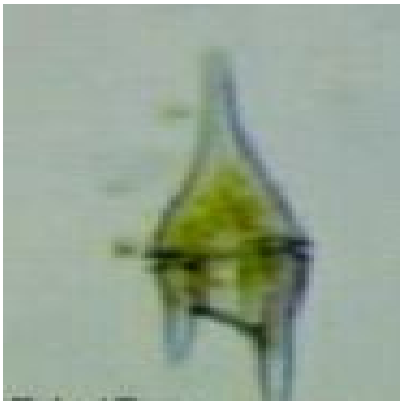
(c): *Brachionus sp* (x400)

(A representative of Rotifers)



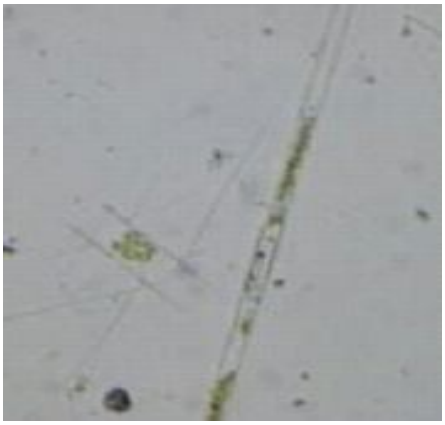
(d): *Euglena sp* (x400)

(A representative of Chlorophyta)



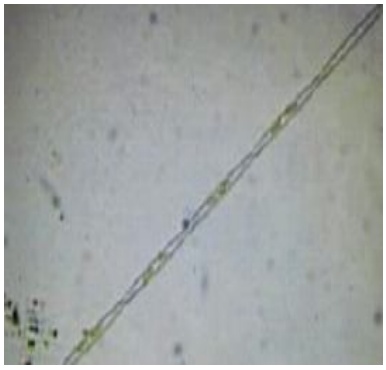
(e): *Ceratium sp.* (x400)

(A representative of Dinophyta)



(f): VIII *Cymbella sp* (x400)

(A representative of Bacillariophyta)



(g): *Spirogyra sp.* (x400)

(A representative of Chlorophyta)



(h): *Nostoc sp* (x400)

(A representative of Cyanophyta)



Plate IV: Front side view of Ajiwa Reservoir



Plate V: *Oreochromis sp* caught in Ajiwa Reservoir



Plate VI: Cattle rearing at the side of Reservoir



Plate VII: farming at the side of the Reservoir