DETERMINATION OF PHYSICO-CHEMICAL PARAMETERS AND PLANKTON COMPOSITION OF WAWAN-RAFI LAKE IN KAZAURE, NIGERIA

BY

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MAY, 2015.

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MAY, 2015.

DEDICATION

This work is dedicated to the Almighty Allah, my parents and my entire family.

DECLARATION

I declare that the work in this thesis entitled, "*DETERMINATION OF PHYSICO-CHEMICAL PARAMETERS AND PLANKTON COMPOSITION OF WAWAN-RAFI LAKE IN KAZAURE, NIGERIA*" has been carried out by me in the Department of Biological Sciences under the supervision of Professor S. A. Abdullahi and Professor D. S. Abolude. 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.

Ahmed USMAN ________________ ______________________

Signature Date

CERTIFICATION

This thesis entitled "**DETERMINATION OF PHYSICO-CHEMICAL PARAMETERS AND PLANKTON COMPOSITION OF WAWAN-RAFI LAKE IN KAZAURE, NIGERIA."** by Ahmed USMAN, meets the regulations governing the award of the degree of Master of Science of Ahmadu Bello University, and is approved for its contribution to knowledge and literary presentation.

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ABSTRACT

This study evaluated the Physico-Chemical parameters and plankton composition of Wawan-Rafi Lake in Kazaure, Nigeria. Monthly variation and composition of Physico-Chemical and biological (plankton) parameters of Wawan-rafi Lake were studied for a period of six months (July – December 2013). Result showed monthly variations of Physico-Chemical parameters. Means of monthly values of pH ranges between 6.00-7.12, temperature ranged between 18 – 24^{0}C, and electrical conductivity was between 273.33µs/cm – 540.00µs/cm . Dissolve oxygen (DO), Dissolved solid (DS) and Biological oxygen demand (BOD) Means of monthly values ranges between 3.53±0.03 mg/l – 6.00±0.31mg/l, 103.67±5.78mg/l - 131.00±12.01mg/l, and 5.10±0.10mg/l – 6.83±0.20mg/l respectively. While Suspended Solid (SS), sulphate, phosphate, nitrate and chemical oxygen demand (COD) their Means of monthly values ranges between 2.33±1.95mg/l – 96.00±8.96mg/l, 5.94±3.60mg/l – 14.98±0.09mg/l, 8.33±2.98mg/l – 16.73±0.88mg/l,8.97±0.63mg/l-10.37±0.38mg/l and 1.50±1.01mg/l–6.00±1.16mg/l respectively . Four Phytoplankton phyla were recorded, they were dominated by Chlorophyta then Cyanophyta followed by Euglenophyta and Bacillariophyta. The Zooplankton of the lake were made up of Protozoa, Rotifers and Cladocera. Correlation matrix showed that there were significant correlation between Phytoplankton, Zooplankton and Physico-Chemical parameters. The composition of plankton of Wawan-Rafi Lake were affected by seasonal variations and fluctuation of Physico-Chemical parameters.

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CHAPTER ONE

1.0 INTRODUCTION

1.1 Background of the Study

Global aquatic ecosystem fall into two broad classes defined as Saline or non Saline in the content, it may be freshwater or saltwater ecosystem. Freshwater ecosystem is aquatic system with low or no percentage of dissolve salt and is subjected to the influence of a wide array of physical and chemical factors. The increase and decrease of these factors frequently affect the flora and fauna which lead to the altering of their diversity in addition the factors that affect the biodiversity of aquatic ecosystem which include pressure, density buoyancy, temperature light, oxygen content, carbondioxide content, pH or hydrogen ion concentration(Achionye-Nzeh and Isimaikaiye 2010).

The aquatic habitat of lake remain vertically stratified in relation to light intensity, wavelength absorption, hydrostatic pressure, temperature etc. in lake, for example there are five well recognized horizontal strata namely .

1. Shallow water near the shore forms the littoral zone: It contains upper warm and oxygen rich circulating water layer which is called epiliminion. The littoral zone includes rooted vegetation.
2. Sub-littoral zone: Extend from rooted vegetation to the non-circulating cold water with poor oxygen content (hypoliminion).
3. Limnetic zone: Is the open water zone away from the shore. It is the zone up to depth of light penetration where rate of photosynthesis is equal to the rate of respiration.
4. Profoundal: Is the deep water area beneath limnetic zone and beyond the depth of effective light penetration.

5. Abyssal zone: Is found only in deep lakes since it begins at about 2,000 meters from the surface (Verma and Agarwal,2000;Atobatele and Ugwumba 2008).

Furthermore, lentic water of lakes is also classified on the basis of the depth of light penetration enabling photosynthesis into trophogenic zone (including littoral plus sub-littoral zones) and a tropholytic zone (upper part of profoundal zone). The former is often distinguished by abundant plant growth and dependant fauna, while it donates general absence of vegetation and habours mostly saprobes. In between two zones is the compensation level which forms a boundary between two zones. It exhibit perfect equilibrium between respiration and photosynthesis (Verma and Agarwal, 2000).

Lakes have the tendency to become thermally stratified during hot and cold, dry or wet, summer or winter to undergo definite seasonal periodicity in depth distribution of heat and oxygen. Light too penetrate only to a certain depth depending upon turbidity. These gradations of oxygen, light and temperature profoundly influence the life in the lake, its distribution and adaptation (Ibrahim *et al*., 2009).

Wawan-Rafi Lake is one of the freshwater bodies with a history of existence dated back over 100 years. It was located at Wawan-Rafi village which is 2 kilometers west of Kazaure town, Kazaure local government area of a Jigawa State.(MANR,1992).

Quality of water can be described according to its physico-chemical and plankton diversity and distribution. Planktons by definition are organisms that are unable to swim against water currents, most plankton are so small they can only be seen with the aid of a microscope. They are very numerous and form an important part of aquatic ecosystem. Phytoplanktons are producers, transforming sunlight into food energy. Producers provide food for many different primary consumers. Zooplanktons are heterotrophic planktonic animals floating in water which constitute an important food source for many species of aquatic organisms. In addition, they serve as indicator organisms of water quality. The species composition of the plankton when observed can provide an indication of environmental health, (Hassan *et al.*, 2004). The classic example is algal blooms associated with eutrophication, especially during large phytoplankton blooms known as “red tides”. During red tides, some organisms disappear completely as water quality deteriorates, and the number of species and total overall number of different organisms found in the lake decline, (Hassan *et al*., 2010).

According to Akomeah *et al*.,(2010), .plankton are usually categorized according to their feeding mode or life cycle thus, 1) feeding mode: Phytoplankton = autotrophs, Zooplankton = heterotrophs, or 2) life cycle: holoplankton (entire life cycle in water column as plankton), meroplankton (part of life cycle as plankton). The amount of phytoplankton in water depends on light availability, the amount of nutrients available, and the relative proportions of nutrients available (with nitrogen and phosphorous usually as limiting nutrients) and the temperature of the water. The amount of zooplankton in water depends generally on the amount of phytoplankton and detritus available to feed on, detritus can be food for primary consumers, (Hassan *et al*., 2010). Phytoplankton in a reservoir is an important biological indicator of water quality (Yakubu *et al*., 2000). While phytoplankton are important primary producers and are at the base of the food chain in open water, some species on the other hand can be harmful to human and other animals by releasing toxic substances (hepatoxins or neutrotoxins etc.) into the water (Whitton and Potts, 2000). Phytoplankton is recognized worldwide as bioindicator organisms in the aquatic environment (Yakubu *et al.*, 2000). Many government agencies are interested in the interaction between water use and water pollution. Nevertheless, an increasing number of environmental

protection agencies are being assigned the task of safe guarding the quality of water for multipurpose uses. It was recommended that all immediate and potential interests in the water basins are considered simultaneously in the management of water for all purposes. It has been observed that only an ecologically healthy fresh water ecosystem fulfils this global order and this can be measured by the ecology of the plankton in the water body.

Water used by man ranges from purely social needs such as recreation, religious worship and regional/cultural uses such as drinking, cooking, laundry, bathing, waste disposal, to economic needs such as irrigation, fisheries, animal production, electric power generation and navigation. For most of these uses, man depends mainly on fresh water available in inland lakes and rivers, which constitute less than 50% of the total amount of water in the biosphere (Yakubu *et al.*, 2000).

1.2 Statement of Research Problem

In recent years, there has been increasing concern about the rate at which inland waters are polluted through run offs into streams and lakes, as in Wawan-Rafi lake therefore leading to euthrophication which affect the specific composition of planktons and variation of physico-chemical parameters as well as changing the qualities of these water bodies. (Chapman and Romberg, 2008).

1.3 Justification

The quality of a given water is governed by its physical, chemical and biological parameters status in comparism with international inland and drinking water standard (Yakubu *et al.*, 2000).

Changes may had happened over a period of time in Wawan-rafi lake because of how the neighbouring communities use the lake. Rainfall, is very critical element in the area, because of its deficiency in the dry season, the neighbouring communities resort to the use of lake for agriculture, recreational, livestock and human consumption due to insufficiency of pipe borne water.

These activities of the neighbouring communities of Wawan-rafi lake may affect the physico-chemical parameters and biological (plankton) composition in relation to season as well as the quality of the water, which is the focus of the study.

1.4 Aim of the Study

The aim of this study was to determine the physico-chemical parameters and plankton diversity and distribution of Wawan-Rafi Lake.

1.5 Objectives of the Study

1) To determine the seasonal variation in physico-chemical parameters of the lake
2) To determine the phytoplankton and zooplankton composition and distribution of the Lake.
3) To determine the relationship between the physico-chemical parameters, phytoplankton and zooplankton composition and distribution in the Lake.

1.6 Research Hypotheses

1) There is no significant difference in the seasonal variation of physico-chemical parameters of the Lake.

2) There is no significant difference in phytoplankton and zooplankton seasonal composition and distribution in the Lake.

3) There is no significant relationship between physico-chemical parameters, phytoplankton and zooplankton composition and distribution in the Lake.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 Physico-Chemical Parameters

2.1.1 Temperature

Temperature 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 and Tucker, 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 and Tucker, 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;Abolude *et al.*2012).

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, AkwaIbom 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 and Tucker, 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 and Tucker, 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 (Porrow *et al.,* 1999). 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). Physico-Chemical parameters are known to affect the biotic components of an aquatic environment in various ways (Ayoade *et al.*, 2006). 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 Diaphano some 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.

CHAPTER THREE

3.0 MATERIALS AND METHODS

3.1 Study Area

The study was conducted at Wawan-Rafi lake located at Wawan-Rafi village in Kazaure local government area of Jigawa State. Wawan-Rafi Lake was, geographically located on latitude 12°34′N and longitude 8º44′E. It has the depth of 14.2 meters and crest length of 1402 meters .Wawan-Rafi Lake is an aquatic ecosystem and oldest water body of over 100 years of existence which covers almost 1.5km^{2}. History testified that the water was never dried up, only that volume of the water decreased during dry season (MANR, 1992).

3.2 Sampling Stations

The lake was divided into three sampling stations A, B, and C, for the purpose of this study. Station A was located at the shore of the lake where human activities, like bathing, washing are taking place. Station B was located at the middle of the lake where there is less human activities. Station C was located at the downstream of the lake.

3.3 Sampling Procedures

Three samples were collected between 15th and 20th of every month from each of the three sampling station in Wawan-rafi lake during morning hours (7:00am – 8:00am), for a period of six months (July – December, 2013). All the water sample were analyzed in the laboratory of Jigawa State Research Institute Kazaure. Cool box containing ice was used in transporting the samples from the sampling site to the laboratory for analysis. Precaution was taken by sterilizing the sampling materials using Autoclaving Machine to avoid contamination.

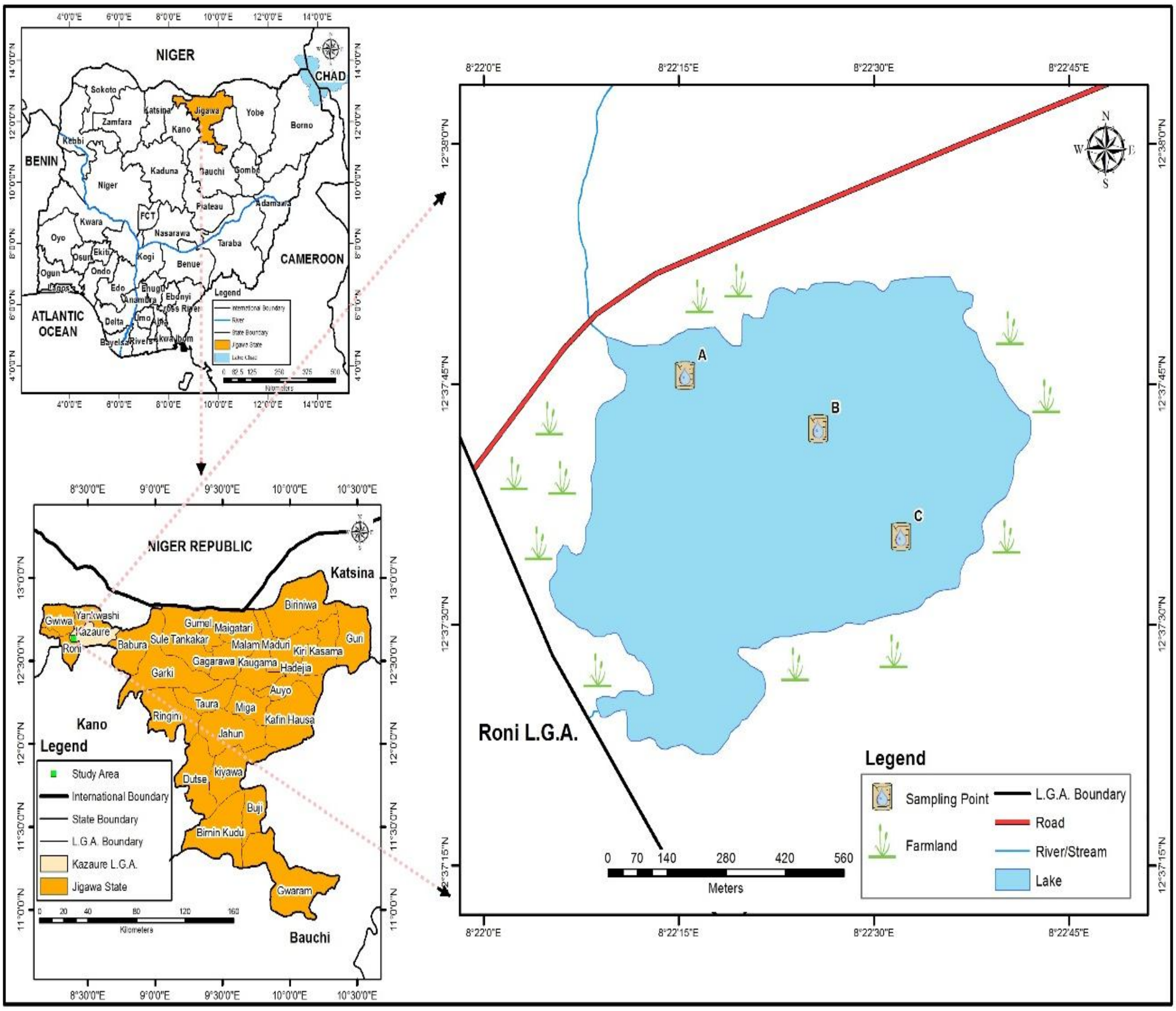


Figure 3.1: Map of Wawan- Rafi Lake showing Sampling Stations A,B and C.
Source : Modified from the Administrative Map of Kazaure L.G.A.

Plate I: View of Wawan -Rafi Lake

3.4 Physico-Chemical Parameters

3.4.1 Determination of pH

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

3.4.2 Determination of water temperature

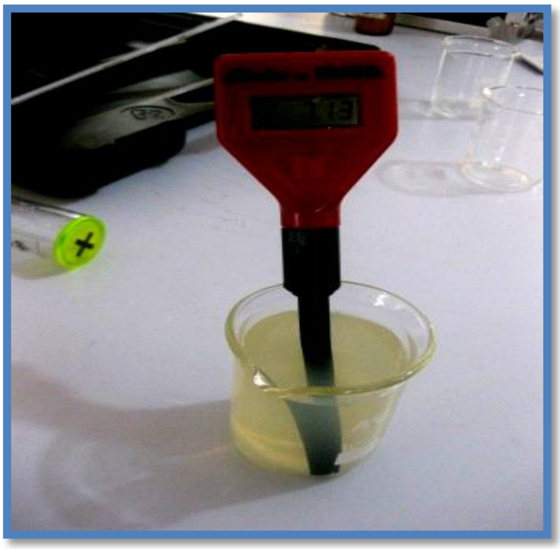
Temperature (°C) of the water was measured by dipping a mercury in glass thermometer into the water at each station for about 1-2 minutes then the readings were recorded (APHA, 1999).

3.4.3 Determination of dissolved oxygen (DO) and biochemical oxygen demand (BOD)

Hanna Dissolved Oxygen microprocessor HI 98186 was used to determine the dissolved oxygen, Plate II (b). 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 2-3 minutes. The readings were recorded in mgl^{-1}. For biochemical oxygen demand; 100ml part of the sample was incubated for five days in dark cupboard at room temperature and dissolved oxygen was determined after five of incubation, the difference between the initial value of dissolved oxygen and the value after five days of incubation was used as value of biochemical oxygen demand in the water sample (APHA, 1999; Mahar, 2003).

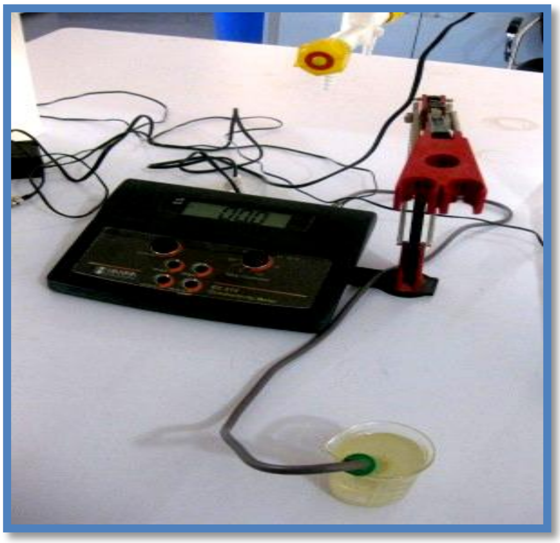
3.4.4 Determination of electrical conductivity, dissolved solids (ds) and suspended solid (ss)

These parameters were measured with WTW 320 conductivity meter; Plate II (c).



(a): pH Meter

(b): Dissolve oxygen Meter



(c): Conductivity Meter.

Plate II: Some of the apparatus used in determination of physico-chemical parameters.

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 dissolved solids were noted with the conductivity meter by changing mode of measurement to DS. 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 then suspended solid are determined using gravimetric method.

3.4.5 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}.

3.4.6 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 of strong ammonia solution. Setting the spectrophotometer at the wave length of 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).

3.5 Biological Parameters

3.5.1 Determination of phytoplankton

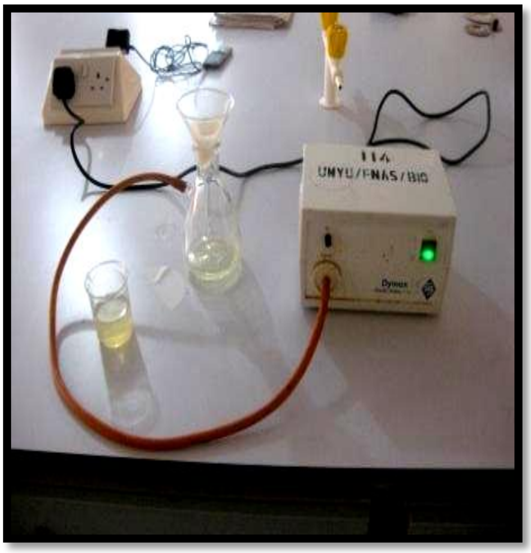
Phytoplankton samples were collected with one litter transparent plastic bottle by dipping the container bottle, sliding over the upper surface of water with it mouth against the water current to permit undisturbed passage of the water into the bottle (Tanimu, 2011). Samples were preserved with Lugol's solution and brought to the laboratory. Slides were prepared and observed under a binocular microscope; Plate 111 (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 (1990). 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). This can be seen in Appendices 1 and II.

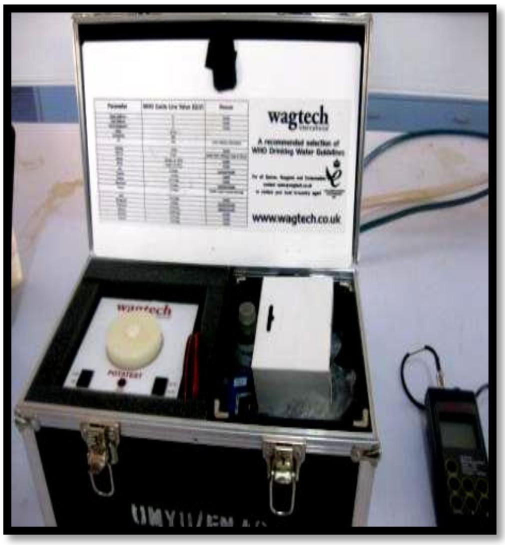
3.5.2 Determination of zooplanktons

Zooplankton samples were collected with silk plankton net of 25cm diameter of 70 microns/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 III (a-d).Identification was done using standard textbook such as Needham and Needham, (1975) and APHA (1999).

(a) Microscope.

(b) Plankton Net.





(c) Saucing Pump.

(d) Water Analysis Kit.

Plate III: Some of the apparatus used in determination of biological parameters

3.6 Community Structure Analysis

For biological data analysis, the following diversity indices were used. Margalef Index of Species Richness (D), Odum's Index (OI), Community Dominance Index (CDI), (Ogbeibu, 2005).

3.6.1 Margalef index of species richness

It is simple ratios between total species (S) and total number of individuals (N). It can be used to compare one community with another. For making comparison one must be certain that the sample size is comparable.

$$D = \frac{\mathrm{S} - 1}{\mathrm{InN}}$$

Where:

D = Margalef index

S = Number of species in the sample

N = Total number of individuals in the sample (Ogbeibu, 2005).

3.6.2 Odum's index

The Odum's index is extremely useful for comparison of various sites, and can be employed for both flowing and stagnant waters. The calculation of the index is given below, and the values decrease with rise in the level of pollution. (Ogbeibu, 2005).

$$Odum's\ Index = \frac{\text{Total no.of species in a sample x 100}}{\text{Total no.of individuals of all the species}}$$

3.6.3 Community dominance index (CDI)

The CDI is the percentage of abundance, which is contributed by the two most abundant species within the community. Species abundance is determined as a bio-mass, productivity or density.

$$CDI = \frac{Y_1 + Y_2}{Y}$$

Where:

Y_1 = abundance of the most abundant species

Y_2 = abundance of the second-most abundant species

Y = total abundance of all specie. (Ogbeibu, 2005).

3.7 Statistical Analysis

One way analysis of variance (ANOVA) was used to compare the means of various parameters between months, when difference occurred. Duncan Multiple Range Test was used to separate the means. Pearson's correlation was used to test the relationship between various parameters .Significant level was taken as $P < 0.05$. All the analyses were carried out using SAS software (20.0) version.

CHAPTER FOUR

4.0 RESULTS

4.1 Physicochemical Parameters

Table 4.1 shows mean values of physicochemical parameters of Wawan-Rafi lake during the months of July to December 2013.The result of each parameter are highlighted below

4.1.1 pH

pH was highest (7.13±0.20) during the month of October and lowest (6.00±0.29) during the month of December. Standard error of mean values showed significant differences in the pH values of the lake during the months of July to December 2013.

4.1.2 Electrical conductivity (EC)

Electrical conductivity had its highest (496.67±8.82us/cm) value during the month of October and lowest (273.33±34.57us/cm) during the month of August. Standard error analysis showed significant difference in electrical conductivity during the sampling months.

4.1.3 Temperature

The highest (24.67±0.33^{O}C) mean temperature was recorded in the month of July and the lowest (18.17±0.17^{O}C) was recorded in the month of December. Standard error of mean values showed significant variation in temperature of the lake during the months of sampling.

4.1.4 Dissolved oxygen (DO)

Dissolved oxygen was highest(6.00±0.31mg/l) during the month of December and

Table 4.1: Mean values of physico-chemical parameters of Wawan-Rafi Lake during the months of July to December, 2013.

Months	Physico -Chemical Parameters					
	pH	**EC**	**Temp.**	**DO**	**DS**	**BOD**
July	6.85 ± 0.03^{abc}	275.67 ± 27.14^{c}	23.67 ± 0.33^{a}	3.53 ± 0.03^{c}	114.67 ± 13.32^{a}	5.10 ± 0.10^{c}
August	6.38 ± 0.21^{cd}	536.67 ± 29.69^{c}	22.07 ± 0.52^{b}	3.73 ± 0.07^{bc}	121.33 ± 13.93^{a}	5.17 ± 0.17^{c}
September	7.13 ± 0.20^{ab}	540.00 ± 5.77^{b}	21.33 ± 0.67^{bc}	3.73 ± 0.13^{bc}	131.00 ± 12.01^{a}	6.83 ± 0.20^{a}
October	7.00 ± 0.06^{a}	496.67 ± 8.82^{a}	20.33 ± 0.67^{c}	4.30 ± 0.36^{b}	125.67 ± 12.20^{a}	6.43 ± 0.23^{a}
November	6.50 ± 0.17^{bcd}	403.33 ± 12.02^{a}	18.83 ± 0.17^{d}	5.73 ± 0.24^{a}	115.67 ± 13.12^{a}	5.80 ± 0.17^{b}
December	6.00 ± 0.29^{d}	273.33 ± 34.57^{a}	18.17 ± 0.17^{d}	6.00 ± 0.31^{a}	103.67 ± 5.78^{a}	5.17 ± 0.23^{c}

Values are expressed as means ± SEM (Standard error of means). Means having different superscripts along columns are significantly different at $P < 0.05$.

KEY

EC= Electrical Conductivity,

DO= Dissolved Oxygen,

DS= Dissolved Solids,

BOD= Biological Oxygen Demands.

lowest (3.53±0.03 mg/l) in the month of July. Standard error of mean showed significant differences existed in dissolved oxygen concentration in the lake during the months of the research.(Table 4.1)

4.1.5 Dissolved solid (DS)

Concentration of dissolved solid was highest (131.00±12.01mg/l) in September and lowest (103.67±5.78mg/l) in December. However, standard error of mean showed no significant difference in the concentration of dissolved solid during the months.

4.1.6 Biological oxygen demand (BOD)

Analysis showed that biological oxygen demand in the lake was highest (6.83±0.20 mg/l) in September and lowest (5.10±0.10 mg/l) in July with standard error of mean showing significant variation in biological oxygen demand during the sampling months (Table 4.1).

4.1.7 Suspended solids (SS)

Table 4.2 revealed that suspended solids were highest (96.00±8.96 mg/l) in the lake in December and lowest (2.33±1.95 mg/l) in July. Standard error of mean values revealed significant variation in the suspended solid content of the lake with regards to months.

4.1.8 Sulphate

Sulphate concentration in the lake was highest (14.98±0.09 mg/l) in September and lowest (5.94±3.60 mg/l) in December. Standard error of mean analysis showed that significant differences exist between the concentration of sulphate in July and the rest of the months.

Table 4.2: Mean values of other physico-chemical parameters of Wawan-Rafi Lake during the months of July to December (2013).

Months	**Physico-Chemical Parameters**				
	SS	**Sulphate**	**Phosphate**	**COD**	**Nitrate**
July	$2.33±1.95^{c}$	$12.31±0.61^{a}$	$8.33±2.98^{b}$	$10.35±0.24^{b}$	$2.14±1.34^{a}$
August	$3.19±2.42^{c}$	$13.34±0.58^{a}$	$16.00±0.44^{a}$	$10.27±0.21^{b}$	$2.14±1.34^{a}$
September	$46.67±7.26^{b}$	$14.98±0.09^{a}$	$16.73±0.88^{a}$	$11.60±0.36^{b}$	$6.00±1.16^{a}$
October	$46.67±4.70^{b}$	$14.89±0.19^{a}$	$9.58±2.13^{b}$	$9.90±0.21^{bc}$	$3.53±0.98^{a}$
November	$44.00±2.08^{b}$	$12.44±0.59^{a}$	$7.33±1.52^{b}$	$10.37±0.38^{a}$	$3.77±0.95^{a}$
December	$96.00±8.96^{a}$	$5.94±3.60^{b}$	$7.00±1.26^{b}$	$8.97±0.63^{c}$	$1.50±1.01^{a}$

Values are expressed as means ± SEM (Standard error of means). Means having different superscripts along columns are significantly different at $P < 0.05$.

KEY

SS = Suspended Solids,

COD = Chemical Oxygen Demand

4.1.9 Phosphate

Phosphate concentration was highest (16.73±0.88 mg/l) in September and lowest (7.00±1.26 mg/l) in December with significant differences in the concentration of phosphate with respect to months.

4.1.10 Chemical oxygen demand (COD)

Analysis revealed highest (11.60±0.36 mg/l) Chemical oxygen demand in September and lowest (8.97±0.63 mg/l) in December with significant differences in standard error of mean through the months of July to December.

4.1.11 Nitrate

Nitrate concentration was highest (6.00±1.16 mg/l) and lowest (1.50±1.01mg/l) in September and December respectively. However, standard error of mean analysis showed no significant difference in nitrate concentration during the period of this research (Table 4.2).

Table 4.3 shows the physicochemical parameters of Wawan-Rafi lake in relation to site and season. Significant difference exist in the concentration of dissolved solids in relation to site ($P < 0.05$) while season had significant effect on conductivity, temperature and dissolved oxygen ($P < 0.05$). The combined effect of site and season on pH, conductivity, temperature, dissolved oxygen, dissolved solid and biological oxygen demand was not significant ($p < 0.05$).

Table 4.4 shows the concentration of other physicochemical parameters such as suspended solids, sulphate, phosphate, chemical oxygen demand and nitrate in relation to site and season. Significant difference exist in the concentration of nitrate according to site ($P < 0.05$). Season also had a significant effect on the concentration

Table 4.3: Physico-Chemical Parameters of Wawan-Rafi Lake in relation to station and season

Source	**Dependent variable**	**Df**	**Mean square**	**F**	**P-value**
Station	pH	2	0.11	0.38	0.69
	Conductivity	2	6704.22	1.97	0.18
	Temperature	2	2.86	1.92	0.19
	DO	2	0.62	1.43	0.28
	DS	2	2438.17	20.82	0.00
	BOD	2	0.26	0.35	0.71
Season	pH	1	0.17	0.59	0.46
	Conductivity	1	192820.50	56.74	0.00
	Temperature	1	47.37	31.77	0.00
	DO	1	12.67	29.27	0.00
	DS	1	242.00	2.07	0.18
	BOD	1	0.05	0.06	0.81
Station season	pH	2	0.00	0.00	1.00
	Conductivity	2	448.67	0.13	0.88
	Temperature	2	0.14	0.10	0.91
	DO	2	0.24	0.56	0.58
	DS	2	36.17	0.31	0.74
	BOD	2	0.09	0.12	0.89

Significant level ($P < 0.05$)

Table 4.4: Concentration of other physico-chemical parameters of Wawan-Rafi Lake in relation to station and season

Source	Dependent variable	Df	Mean square	F	P-value
Station	SS	2	364.86	0.47	0.64
	Sulphate	2	12.30	0.79	0.48
	Phosphate	2	28.84	1.02	0.39
	COD	2	0.85	0.88	0.44
	Nitrate	2	11.30	3.82	0.05
Season	SS	1	9041.99	11.71	0.01
	Sulphate	1	25.70	1.65	0.22
	Phosphate	1	1.71	0.06	0.81
	COD	1	0.13	0.14	0.72
	Nitrate	1	16.98	5.74	0.03
Station season	SS	2	8.74	0.01	0.99
	Sulphate	2	6.74	0.43	0.66

Phosphate	2	5.20	0.18	0.83
COD	2	1.18	1.23	0.33
Nitrate	2	1.71	0.58	0.58

Significant level ($P < 0.05$) .

of suspended solids and nitrate ($P<0.05$). The combined effect of site and season was not significant on the concentration of suspended solids, sulphate, phosphate, chemical oxygen demand and nitrate.

4.2 Relationship between Phytoplankton, Zooplankton and some Physico-Chemical Parameters

Table 4.5 shows correlation matrix of relationship between zooplankton, phytoplankton and some physico-chemical parameters. Euglenophyta shows a significant positive correlation with Cyanophyta and Chlorophyta while Bacillariophyta shows a negative significant correlation with Chlorophyta and Euglenophyta. The occurrence of Protozoa in the lake correlates positively with

Cyanophyta and Euglenophyta. The occurrence of Rotifers also correlated positively with Chlorophyta, Euglenophyta and Protozoa. Cladocera correlated positively with Chlorophyta, Euglenophyta, Protozoa and Rotifers. Conductivity correlated negatively with Bacillariophyta. Temperature correlated positively with Euglenophyta, Rotifers and negatively with conductivity. Dissolved oxygen correlated negatively with Bacillariophyta, pH and temperature but positively with conductivity. Dissolved solids show positive correlation with Chlorophyta, Protozoa, Rotifers, and negative correlation with Bacillariophyta. Biological oxygen demand showed a positive correlation with pH. Suspended solids show positive correlation with conductivity and dissolved oxygen but negative correlation with temperature. The concentration of sulphate correlated positively with conductivity, dissolved solid and biological oxygen demand. The concentration of phosphate had a positive correlation with pH, dissolved solids, biological oxygen demand and sulphate. Nitrate

Table 4.5: Correlation matrix showing relationship between zooplankton, phytoplankton and some physico-chemical parameters

	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**
1	1																	
2	.408	1																
3	.632	.912	1															
4	-.368	-.708	-.636	1														
5	.496	.779	.812	-.398	1													
6	.377	.799	.815	-.399	.962	1												
7	.447	.609	.595	-.289	.888	.882	1											
8	.087	.276	.289	-.075	.267	.297	.231	1										
9	.199	.066	-.026	-.501	-.152	-.230	-.140	-.075	1									
10	.091	.291	.469	.053	.438	.537	.314	.396	-.787	1								
11	.214	.089	-.038	-.543	-.222	-.309	-.205	-.472	.823	-.786	1							
12	.401	.911	.903	-.581	.823	.841	.606	.454	.064	.366	-.095	1						
13	.290	.245	.273	-.033	.277	.235	.194	.621	.348	-.021	-.092	.464	1					
14	.214	.086	-.037	-.441	-.139	-.227	-.063	-.255	.840	-.751	.780	-.032	.227	1				
15	.180	.359	.290	-.177	.309	.271	.188	.106	.547	-.400	.241	.471	.568	.417	1			
16	.077	.453	.406	-.154	.421	.453	.304	.697	.142	.186	-.289	.643	.820	.085	.581	1		
17	.378	.197	.311	-.092	.140	.070	-.052	.304	.007	.195	.047	.249	.297	-.320	-.014	-.010	1	
18	.296	.466	.356	-0.666	.328	.277	.286	-.272	.641	-.409	.620	.402	.207	.722	.480	.210	-.241	1

NOTE: Red fonts imply correlation is significant at $P < 0.05$ levels

1=Cyanophyta, 2=Chlorophyta, 3=Euglenophyta, 4=Bacillariophyta, 5=Protozoa, 6=Rotifers, 7=Cladocera,8=pH,9=Conductivity, 10=Temperature, 11=Dissolved oxygen, 12=Dissolved solids,13=Biological oxygen demands (BOD), 14=Suspended solids, 15=Sulphate, 16=Phosphate, 17=Chemical oxygen, demands (COD), 18=Nitrate concentration correlated positively with conductivity, biological oxygen demand, sulphate and negatively with Bacillariophyta.

4.3 Phytoplankton

Figure 4.1 – 4.4 shows the mean monthly variation of phytoplankton in Wawan-rafi Lake in relation to months and stations. The phytoplankton phyla identified include Cyanophyta, Chlorophyta, Euglenophyta and Bacillariophyta.

4.3.1 Cyanophyta

Cyanophyta was represented by *Microcystis* sp, *Oscilatoria* sp. *Gomphospaeria* sp, *Anabaena* sp and *Nostoc* sp. The mean monthly distribution of Cyanophyta shows that the density of Cyanophyta was highest during the months of August and September and lowest in the month of July (Fig. 4.1). Table 4.6 revealed that Cyanophta shows significant association with station and station 1 had the highest occurrence with station 3 having the lowest occurrence (Fig. 4.1). The mean occurrence of Cyanophyta did not show any significant association with season. The combined effect of station and season was not significant on the occurrence of Cyanophyta (Table 4.6).

4.3.2 Chlorophyta

Chlorophyta was represented by *Scenedesmus* sp, *Spirogyra* sp , *Ulothrix* sp and *Volvox* sp. Chorophyta showed highest mean occurrence during the month of August and lowest mean occurrence during the month of December (Fig. 4.2, Table 4.7). Table 4.7 revealed that Chlorophyta showed significant association with station and station 1 had the highest occurrence while station 3 had the lowest occurrence. The mean occurrence of Chlorophyta shows significant association with season

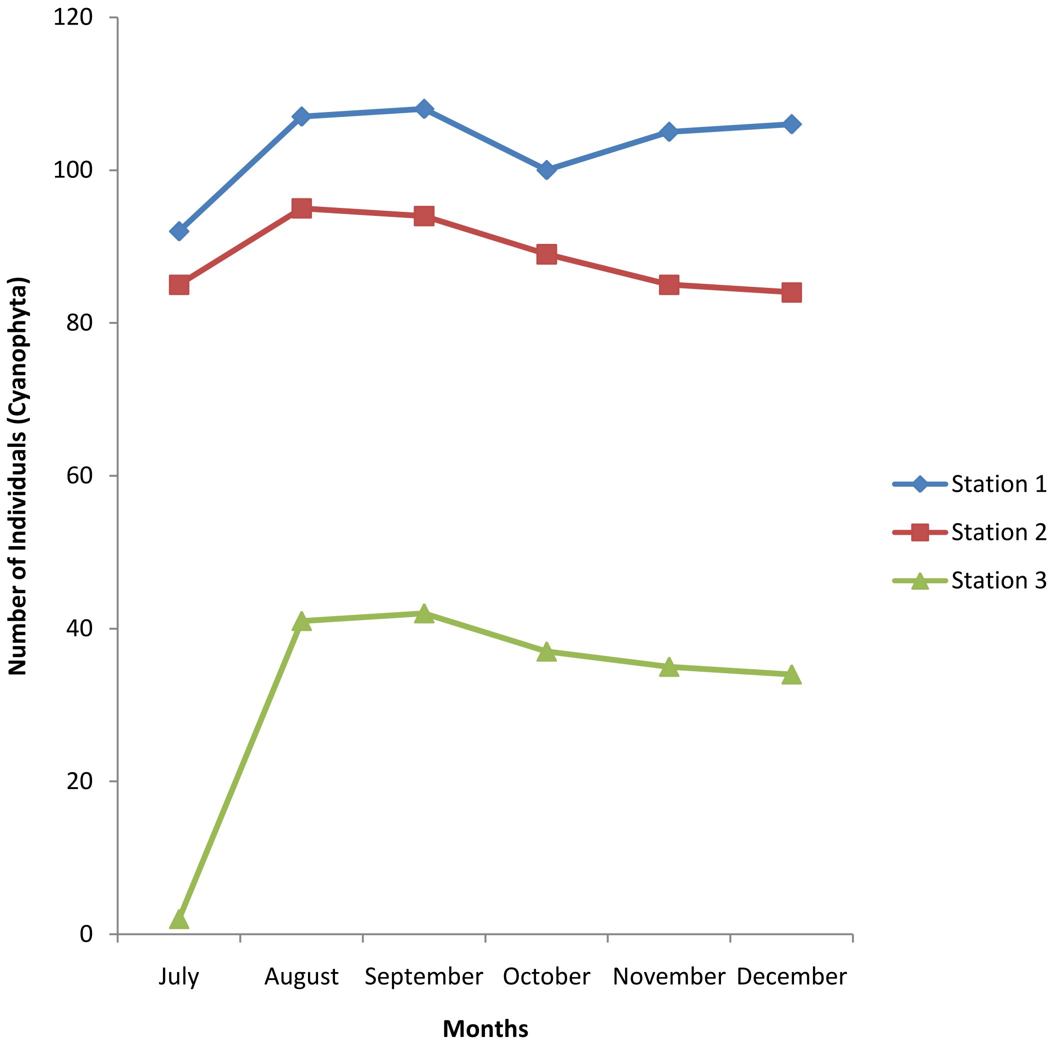


Fig. 4.1: Mean monthly variation of Cyanophyta in Wawan-Rafi Lake in relation to Months and Stations.

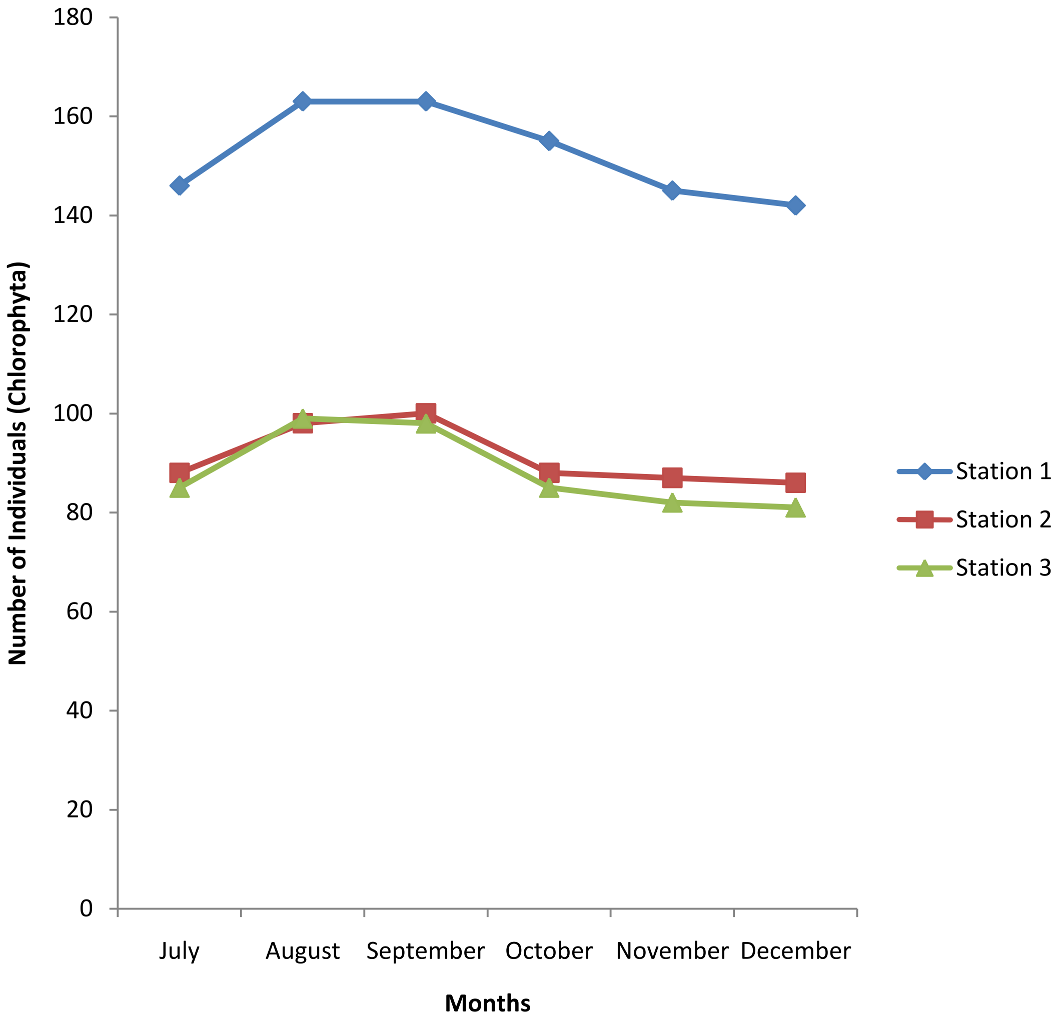


Fig. 4.2: Mean monthly variation of Chlorophyta in Wawan-Rafi Lake in relation to Months and Stations

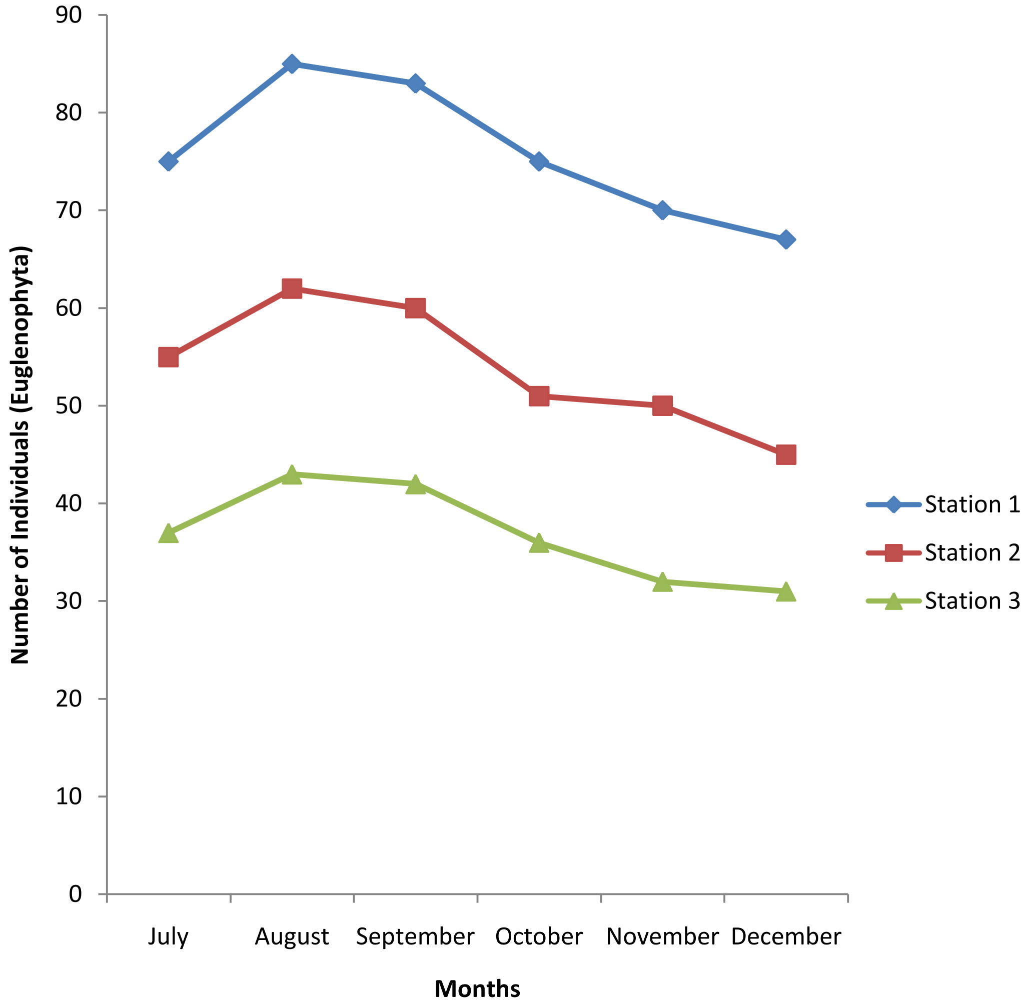


Fig. 4.3: Mean monthly variation of Euglenophyta in Wawan-Rafi Lake in relation to Months and Stations

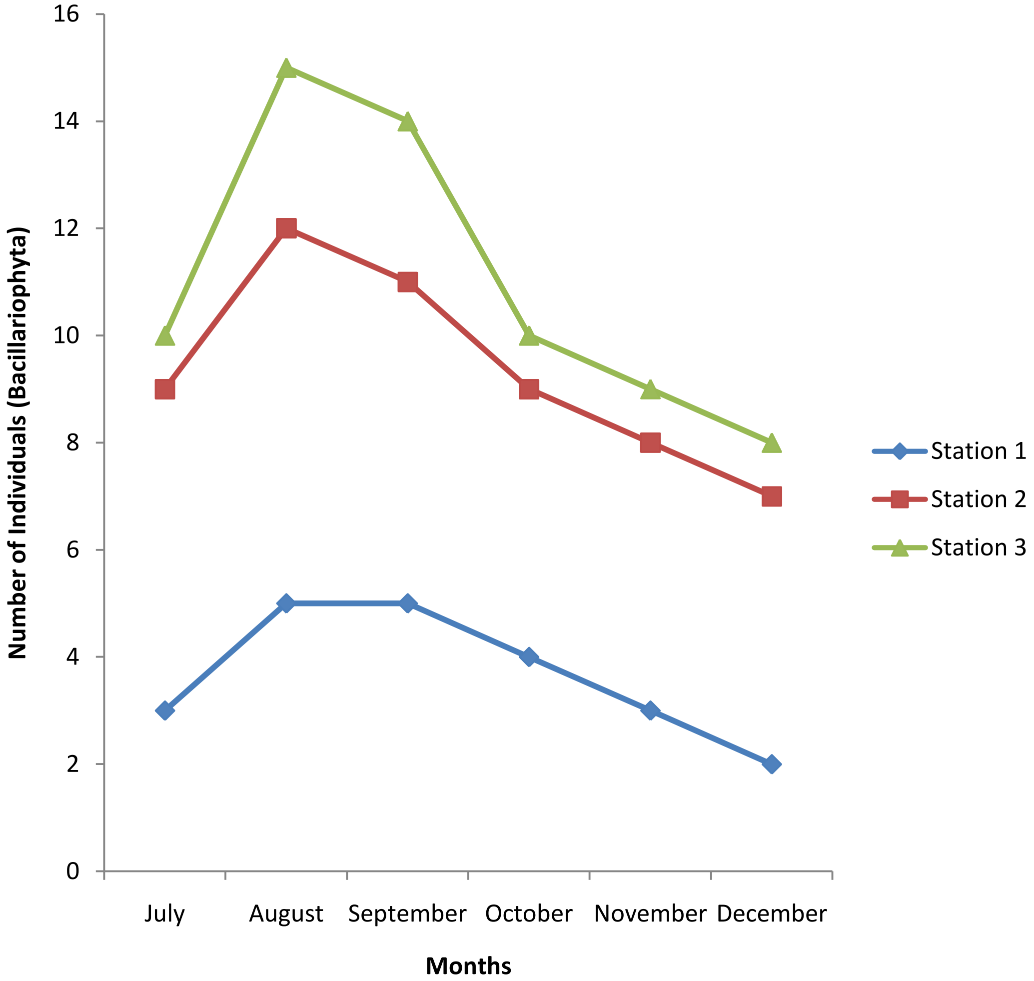


Fig. 4.4: Mean monthly variation of Bacillariophyta in Wawan-Rafi Lake in relation to Months and Stations

Table 4.6: Occurrence of plankton in Wawan-Rafi lake in relation to station and season

Source	Dependent variable	Df	Mean square	F	P-value
Station	Cyanophyta	2	4902.39	10.50	0.00
	Chlorophyta	2	7845.39	188.04	0.00
	Euglenophyta	2	2294.00	161.93	0.00
	Bacillariophyta	2	88.67	38.93	0.00
	Protozoa	2	3.72	11.17	0.00
	Rotifers	2	73.50	16.96	0.00
	Cladocera	2	0.22	4.00	0.05
Season	Cyanophyta	1	32.00	0.07	0.80
	Chlorophyta	1	440.06	10.55	0.01
	Euglenophyta	1	401.39	28.33	0.00
	Bacillariophyta	1	32.00	14.05	0.00
	Protozoa	1	2.72	8.17	0.01
	Rotifers	1	60.50	13.96	0.00
	Cladocera	1	0.22	4.00	0.07
Station Season	Cyanophyta	2	21.50	0.05	0.96
	Chlorophyta	2	3.39	0.08	0.92
	Euglenophyta	2	3.56	0.25	0.78
	Bacillariophyta	2	2.67	1.17	0.34
	Protozoa	2	1.06	3.17	0.08
	Rotifers	2	24.50	5.65	0.02
	Cladocera	2	0.22	4.00	0.05

Significant level ($P < 0.05$).

Table 4.7: Mean number of phytoplankton population in Wawan-Rafi Lake recorded at different months

Months	**Phytoplankton phyla**			
	Cyanophyta	**Chlorophyta**	**Euglenophyta**	**Bacillariophyta**
July	53.00±16.01^{a}	106.33±19.85^{c}	55.67±10.97^{b}	7.33±2.19^{b}
August	81.00±20.30^{a}	120.00±21.50^{a}	63.33±12.14^{a}	10.67±2.96^{a}
September	81.33±20.08^{a}	120.33±21.34^{a}	61.67±11.86^{a}	10.00±2.65^{a}
October	57.67±15.93^{a}	109.33±22.85^{b}	54.00±11.36^{b}	7.67±1.86^{b}
November	75.00±20.82^{a}	104.67±20.22^{c}	50.67±10.97^{bc}	6.67±1.86^{b}
December	74.67±21.30^{a}	103.00±19.55^{c}	47.67±10.48^{c}	5.67±1.86^{b}

Values are expressed as means ± SEM (Standard error of means). Means having same superscripts along columns are the same at $P < 0.05$.

(Table 4.6). Station and season jointly affected the occurrence of Chlorophyta significantly (Table 4.6).

4.3.3 Euglenophyta

Euglenophyta was represented by *Euglena* sp. The mean monthly distribution of Euglenophyta was highest during the months of August and September and lowest in December (Fig. 4.3, Table 4.7). Table 4.6 show that the occurrence of Euglenophyta is significantly associated with station. Station 1 had the highest occurrence of Euglenophyta and station 3 had the least occurrence (Fig. 4.3). The mean occurrence of Euglenophyta shows significant association with season (Table 4.6). However, station and season jointly did not significantly affect the occurrence of Euglenophyta (Table 4.6).

4.3.4 Bacillariophyta

Bacillariophyta is represented by *Cyclotella* sp, *Cymbella* sp and *Diatomella* sp. Bacillariophyta had its highest mean monthly distribution in the month of August and lowest in December (Fig. 4-4, Table 4.7). Bacillariophyta showed significant association with station. Station 3 had the highest occurrence while station 1 had the lowest occurrence. The mean occurrence of Bacillariophyta shows significant association with season (Table 4.6). However, site and season combined did not significantly affect the occurrence of Bacillariophyta.

4.4 Zooplankton

Figure 4.5 – 4.7 shows the mean monthly variation of Zooplankton in Wawan-rafi Lake in relation to months and stations. The Zooplankton identified include Protozoa, Rotifers and Cladocera.

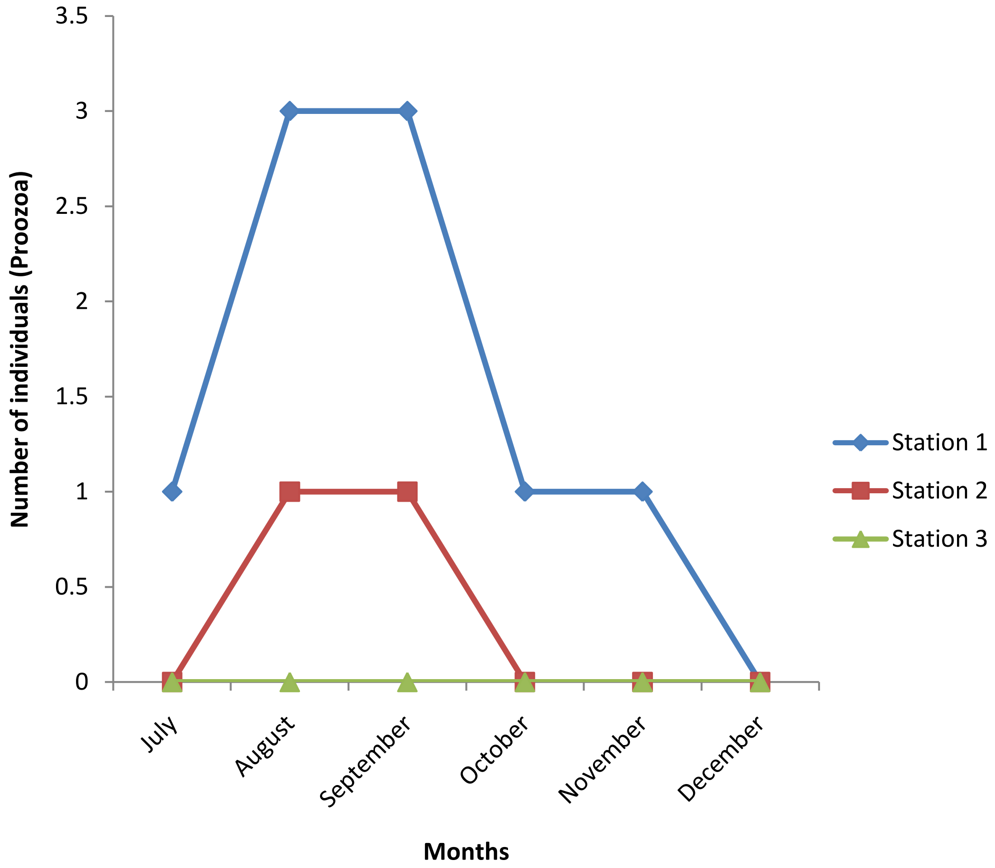


Fig. 4.5: Mean monthly variation of Protozoa in Wawan-Rafi Lake in relation to Months and Stations

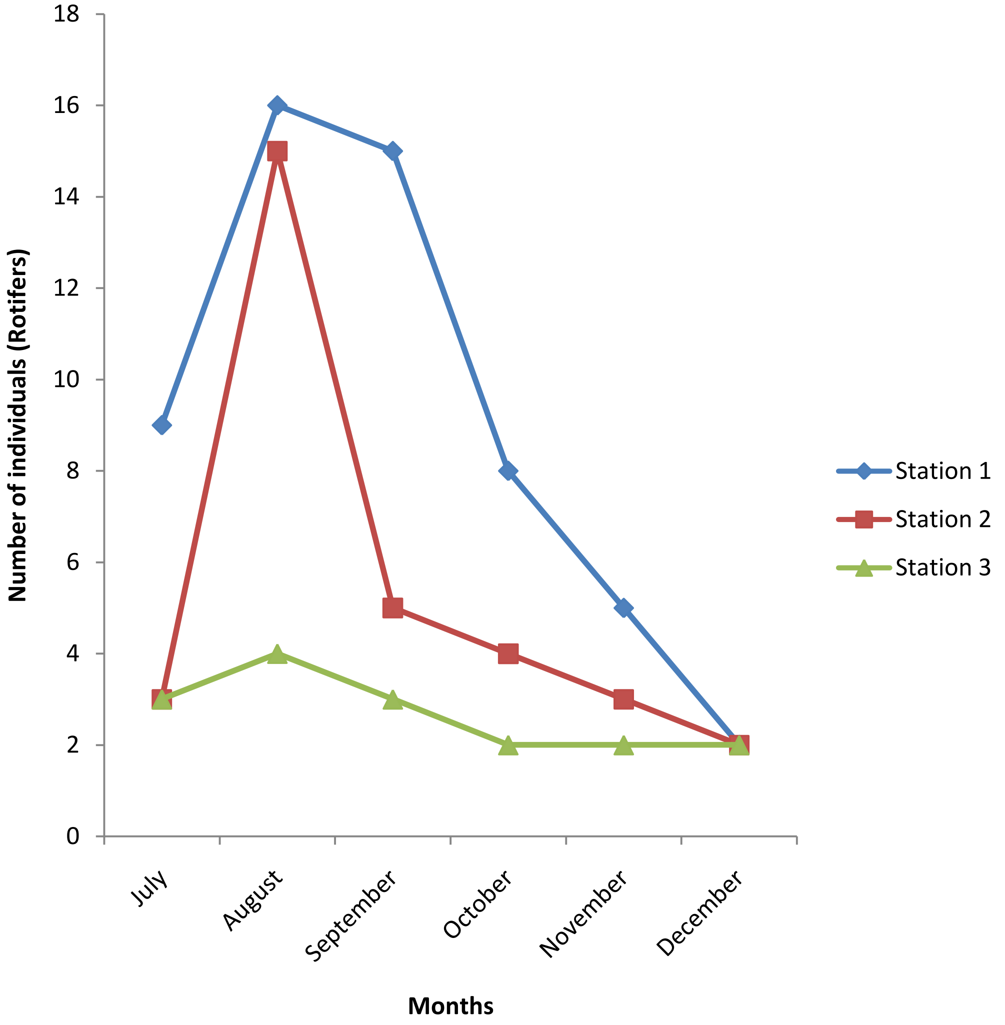


Fig. 4.6: Mean monthly variation of Rotifers in Wawan-Rafi Lake in relation to Months and Stations.

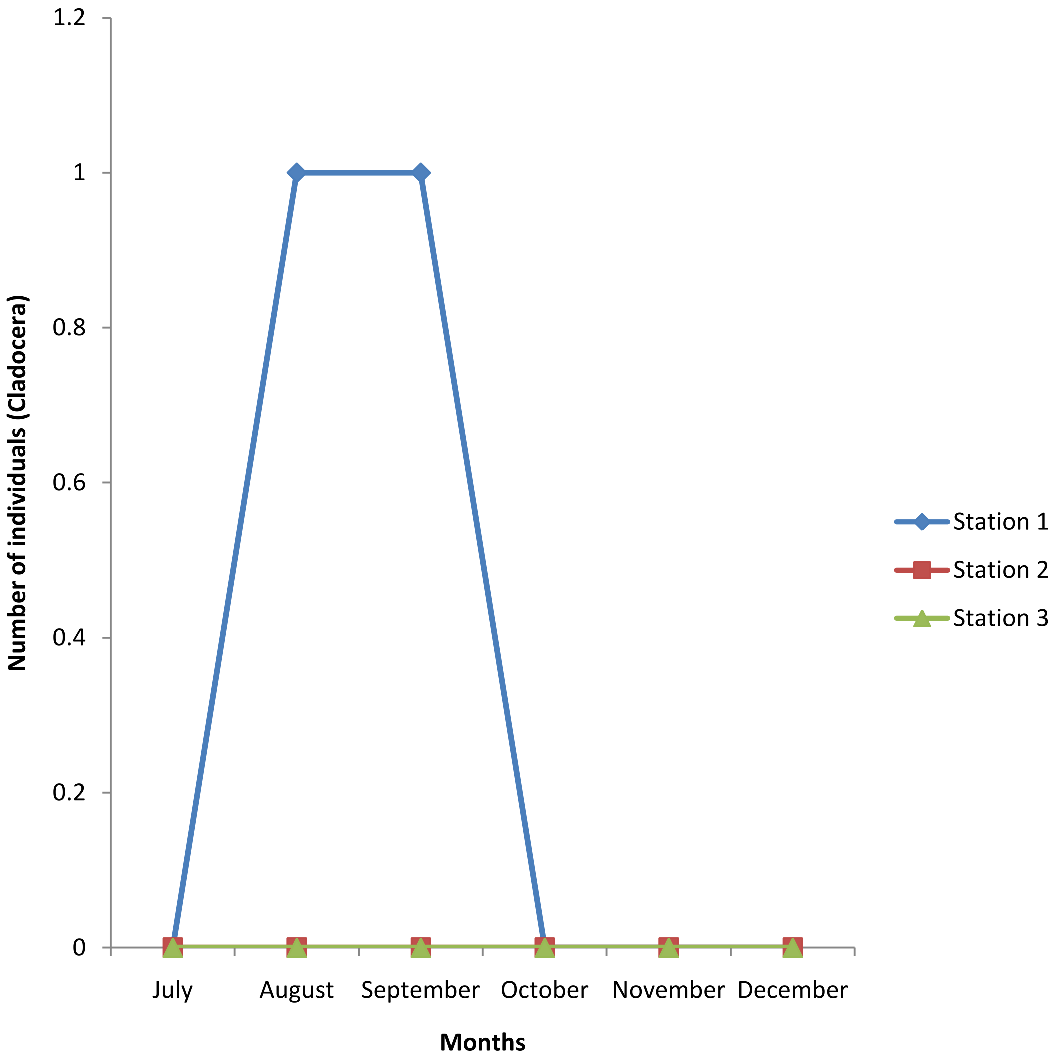


Fig. 4.7: Mean monthly variation of Cladocera in Wawan-Rafi Lake in relation to Months and Stations

4.4.1 Protozoa

Protozoa is represented by *Pelomyxa* sp, *Paramecium* sp and *Acanthometron* sp. The mean monthly distribution of Protozoa shows that the density of protozoa was highest during the month of August and no occurrence was recorded in December (Fig. 4.5, Table 4.8). The mean square occurrence of Protozoa was significantly associated with station and season. Station 1 had the highest occurrence of Protozoa and station 3 had the least occurrence. However, station and site jointly did not significantly affect the mean square occurrence of protozoa.

4.4.2 Rotifers

Rotifers is represented by *Keratella, Branchionus, Monostyla and Euclanis* sp. Rotifers had its highest monthly distribution in the month of August and least in December (Fig. 4.6, Table 4.8). The occurrence of Rotifers showed significant association with station and station 1 had the highest occurrence while station 3 had the lowest (Fig 4.6). The mean square occurrence of Rotifers shows significant association with season. Station and season jointly affected the occurrence of Rotifers significantly (Table 4.6).

4.4.3 Cladocera

Cladocera is represented by *Daphnia* sp, *Microcyclop* sp and *Bosmina* sp.The highest mean monthly distribution of Cladocera occurred in the months of August and September and no occurrence was recorded during the remaining months of the research (Fig 4.7, Table 4.8). The occurrence of Cladocera did not show any significant association with station and season though, station 1 showed highest occurrence with stations 1 and 2 having no occurrence at all (Fig. 4.7). The combined effect of station and season was not significant of the occurrence of Cladocera.

Table 4.8: Mean number of Zooplankton population in Wawan Rafi Lake recorded at different months

Months	**Zooplankton phyla**		
	Protozoa	**Rotifers**	**Cladocera**
July	$0.33{\pm}0.33^{b}$	$5.00{\pm}2.00^{b}$	$0.00{\pm}0.00^{a}$
August	$1.33{\pm}0.88^{a}$	$8.33{\pm}3.84^{a}$	$0.33{\pm}0.33^{a}$
September	$1.33{\pm}0.88^{a}$	$7.67{\pm}3.71^{a}$	$0.33{\pm}0.33^{a}$
October	$0.33{\pm}0.33^{b}$	$4.67{\pm}1.76^{b}$	$0.00{\pm}0.00^{a}$
November	$0.33{\pm}0.33^{b}$	$3.33{\pm}0.88^{c}$	$0.00{\pm}0.00^{a}$
December	$0.00{\pm}0.00^{c}$	$2.00{\pm}0.00^{c}$	$0.00{\pm}0.00^{a}$

Values are expressed as means ± SEM (Standard error of means). Means having same superscripts along columns are the same at $P < 0.05$.

CHAPTER FIVE

5.0 DISCUSSION

5.1 Physico-Chemical Parameters

The marked variation and significant differences in physico-chemical parameters of the water indicate different environmental conditions. These variations may be related to patterns of water use, temperature and rainfall (Ayoade *et al*., 2006; Atobatele and Ugwumba, 2008; Oso and Fagbenro, 2008; Abolude,2007).

The hydrogen ion concentration (pH) of water is important because many biological activities can occur only within a narrow range of pH. Thus, any variation beyond acceptable range could be fatal to aquatic organisms. The pH range observed during the study period was 6.00-7.13 throughout both seasons, and it was within the range for inland waters (pH6.5 - 8.5), as reported by Mahar (2003). Boyd and Tucker (1998), reported pH range of 6.09 - 8.45 as being ideal for supporting aquatic life including fish. Thus, the pH range obtained in this study is within the acceptable level of 6.0 to 8.5 for culturing tropical fish species and, for the recommended levels for drinking water (WHO, 1996). Federal Environmental Protection Agency FEPA (1991) recommended pH 6.5- 8.0 for drinking and 6.0-9.0 for aquatic life (Ibrahim *et al*., 2009). High mean value of pH recorded during wet season could be due to combined effects of run-off from agricultural lands (with high concentration of lime) and photosynthetic activity of macrophytes. Mustapha (2008) observed that there was increase in pH with photosynthesis. Low pH value in dry season could be attributed to anthropogenic acidification of allochthonous organic matter. The onset of the rains caused increase in pH, this dilution effect of rains ameliorates biological conditions in lakes (Baijot *et al*., 1997; Unohia, 2001). The pH range obtained in this study compares well with those of Lake Chad (7.6-8.0), Tiga Lake (6.9-7.6), Shiroro Lake (6.7-7.0) and Volta Lake (6.8-8.06) as reported by Kolo (1996).

Variation in conductivity is an indication of the extent to which the lake circulates nutrients, especially in a nutrient rich lake. The situation in the present study was such that increased conductivity during the dry season was enhanced by increased water evaporation and upwelling from wind, wave and tide (Olele and Ekelemu, 2008). However, the conductivity value of 273.33±34.57µs/cm to 540.00±5.77µs/cm shows that the conductivity level of the lake is intermediate. Conductivity levels below 50 µs/cm are regarded as low; those between 50-600 µs/cm are medium while those above 600 µs/cm are high (Anago *et al*., 2013).

Temperature is an important factor that influences primary production in lakes and it depends on the climate, sun light and depth (Lewis, 2000;Abolude, 2007). Aquatic organisms (from microorganisms to fish) depend on certain temperature range for optimal growth (APHA, 1999). The normal range to which fish is adapted in the tropics is between 8^oC and 30°C (Mustapha 2011). Temperatures were relatively higher in July and reduced progressively to December. The lowest water temperature recorded in December coincided with the period of extreme harmattan (Atobatele and Ugumba, 2008). Adebayo (1993) made similar observation of recording lowest temperature during the peak period of harmattan in Ado-Ekiti, and Balarabe (1989), also observed low water temperature in Makwaye Lake, near Zaria, during this period. Kolo and Oladimeji (2004) and Ibrahim *et al*. (2009) made similar findings in Shiroro dam and Kotangora reservoir respectively. The result agreed with previous reports that the temperatures in tropics vary between 21^oC and 32^oC (Atobatele and Ugwumba, 2008; Kramer and Botterweg,1991;

Ayoade *et al.,* 2006). Ayoade *et al*. (2006) recommended temperature range of 20 – 30°C for optimum fish growth. This implies that the temperature range in Wawan-Rafi lake is suitable for fish growth.

The dissolved oxygen in the reservoir was significantly higher during the dry season than the rainy season. The high oxygen value for the dry season coincides with periods of lowest turbidity and temperature. The amount of dissolved oxygen in water has been reported not to be constant but fluctuates, depending on temperature, depth, wind and amount of biological activities such as degradation (Adeniji, 1991; Ibe, 1993). In this study, the cool harmattan wind which increases wave action, and decrease surface water temperature might have contributed to the increased oxygen concentration during the dry season, while the torrential rains, created increased turbidity and decreased oxygen concentration during the rainy season. Oniye *et al*. (2002) and Abolude (2007) made similar observation on Zaria dam and A.B.U Zaria reservoir respectively

The dissolved solids which usually consists of organic and inorganic substances dissolved and washed into the lake by runoffs (Bala and Bolorunduro, 2011) are essential in the life of aquatic bio-community. Dissolved Solids values obtained during the study periods were relatively constant and not above recommended values all through the months as values were not significantly different at ($P < 0.05$). Dissolved solids determination are important in water quality studies, though no serious health effect has been associated with dissolved solids ingestion in water but some regulatory agencies (FME, 2001; NAFDAC, 2001) recommended a maximum dissolved solids value of 500mg/l in drinking water supplies.

Biochemical oxygen demand (BOD) indirectly depicts the amount of putressible organic matter degradable by microbial metabolism on the assumption that the water medium has no bacteriostatic effects. Adakole *et al*. (1999);Abolude (2007); Idowu and Gadzama (2011) and Abolude *et al.* (2012) reported that BOD is a fair measure of cleanliness of any water on the bases that values of less than 2 mg/l are clean, 3 -5 mg/l, fairly clean and 10 mg/l definitely bad and polluted. The results show that the Lake water was fairly clean. BOD was significantly higher at the peak of the rainy season (September and October) than in the other months used for sampling in this present research, this may be attributed to higher organic matter washed into the lake due to runoffs from surrounding lands in the rainy season.

Total suspended solids in the dry seasons were significantly higher than those observed in the wet season. Suspended solids or particulate matter in fresh or marine waters are of importance to aquaculture because they may damage fish gills and interfere with respiration. Secondly, they may cause siltation and smothering of benthos and interference with feeding of bivalve filter feeders. High turbidity due to suspended solids also reduce photosynthesis and hence production of phytoplankton and submerged periphytoplankon (Abolude *et al.,* 2012). A high content of suspended organic solids will exert a biological oxygen demand and lead to oxygen depletion. Based on FEPA (1991) guidelines the total dissolved solids in Wawan-rafi Lake are much less than the upper limit set that could cause pollution.

Sulphates naturally occur in surface water which arises from the leaching of sulphur compounds either as sulphate minerals such as gypsum or sulphite as pyrite or from sedimentary rocks. Also, the variation in concentration of sulphate at different locations could be due to the fact that the sulphate discharged to the lakes was used up as a source of oxygen by bacteria and was converted entirely to H_2S under anaerobic conditions (Kolo *et al*., 2010) A.

Phosphate and nitrate levels are a measure of level of eutrophication of a given lake (Kolo *et al*., 2010)B. Phosphate levels in the present study were significantly higher during the concluding months of the rainy season (September and October) than the other months during the sampling period and the concentration of nitrate during the sampling months was not significantly different. High values of phosphate and nitrate support algal growth and hence good plankton bloom (Ude *et al*., 2011). FEPA (1991) recommended a maximum of 20mg/litre. The importance of soluble phosphorous transport in agricultural run-off as an immediate source of phosphorus for biological uptake and thereby accelerating the eutrophication of surface waters has been well reviewed (Matagi 1996). Mohammed and Saminu (2012) highlighted that in most water bodies, phosphate appears to be the ultimate limiting factor for biological productivity. Karikari *et al*. (2007) in their study on water quality in Angaw River concluded that phosphorus is the limiting factor for algal growth. The concentration of nutrients (phosphate and nitrate) in a water body is strongly influenced by the nature of the sediment. Wetzel (2001), stated that the rate of phosphorus release into the water can double, when sediments are frequently disturbed. The phosphate level in Wawan-rafi lake may be a result of release from disturbed sediment, anoxic conditions as a result of decaying macrophytes and washing of phosphate fertilizer from nearby farmlands

Chemical oxygen demand (COD) was highest in November and lowest in December but was not associated with sampling site and season. The WHO guideline for COD is 200mg/L (O'Connor, 2004). The results of this study showed that this parameter is within the guidelines. COD investigation is employed as a measure of both organic and inorganic agents competing for DO in Lake Water. These agents are susceptible to oxidation by a strong chemical oxidant in contrast to biological oxidation in the BOD test (Zhang, 2007). Higher values of COD indicate pollution due to oxidizable organic matter and may have been due to discharges of domestic wastewater from nearby settlements, surface and ground water carrying chemicals directly from agricultural field into the Lake (Syeda *et al*., 2003;Abolude 2007;Abolude *et al.*, 2013)

5.2 Plankton Composition

The phytoplankton community in Wawan-rafi lake was characterized by four (4) phyla; namely Cyanophyta was represented by *Microcystis* sp, *Oscilatoria* sp, *Gomphospaeria* sp, *Anabaena* sp and *Nostoc* sp. Chlorophyta was represented by *Scenedesmus* sp, *Spirogyra* sp, *and Ulothrix* sp and *Volvox* sp Euglenophyta was represented by *Euglena* sp. and Bacillariophyta was represented by *Cyclotella* sp, *Cymbella* sp and *Diatomella* sp The phytoplankton was dominated by Chlorophyta followed by Cyanophyta with Bacilariophyta been the least represented (Appendix V). This result agrees with the work by Abdullahi and Indabawa (2005), on the phytoplankton content of Nguru Lake. The dominating presence of Chlorophyta shows gradual deterioration of the water quality. This could be as a result of anthropogenic activities, such as chemicals and wastes washed into it, washing of clothes and bathing done sometimes around the lake. Anago *et al*. (2013) reported that in lakes where domestic, agricultural and industrial pollution is accelerated, growth of Chlorophyta and Cyanophyta results. Abubakar (2007) indicated that Euglenophta were common in environments rich in decaying organic matter, and large populations of Euglena were favored by the presence of high levels of dissolved organic compounds and high temperatures. According to Tanimu *et al*. (2011) the increase in abundance of the Cyanophyta and Euglenophyta is an indication of organic pollution. Chlorophyta showed significant positive correlation with dissolved solids and Euglenophyta significantly correlated positively with temperature. Baccilariophyta showed a significant negative correlation with conductivity, dissolved oxygen, dissolved solids and nitrate.

Zooplankton population in Wawan-rafi Lake is characterized by Protozoa, Rotifers and Cladocera. The zooplankton is dominated by Rotifers represented by *Keratella sp, Branchionus* sp, *Monostyla* sp and *Euclanis* sp followed by Protozoa which was represented by *Pelomyxa* sp, *Paramecium* sp and *Acanthometron* sp. Cladocera was represented by *Daphnia* sp, *Microcyclop* sp and *Bosmina* sp, having the least occurrence (Appendix VI). Zooplankton had its highest occurrence at the peak of the rainy season (August) and lowest in dry season (December). Their abundance in rainy season could be due to availability of nutrients (phytoplankton) and low transparency. Their low number in dry season could have been due to high transparency which aid predation or due to high temperature. This observation is similar with the findings of Abdullahi, (1997) who researched on the zooplankton community of Hadejia–Nguru wetlands. The number of Cladocera in Wawan-rafi Lake was relatively low; this may be attributed to the absence of aquatic macrophytes, this may have accelerated the rate of predation by fish. As Sarnelle (1992) suggested that fish prefer open waters to feed on zooplankton. This was further collaborated by Kemdirim, 2000; Jeppessen *et al*. 2001 and Havens, 2002 who observed that the absence of Cladocera and the low numbers of Copepoda could be due to the effects of fish predation, which was found to be the major factor structuring zooplankton assemblages in several studies. Protozoa showed a significant positive correlation with dissolved solids and Rotifers significantly correlated positively with temperature and dissolved solids. Cladocera showed significant positive correlation with dissolved solids.

The biological indices of phytoplankton of Wawan-Rafi lake are Margalef index which was found to be 0.85, Odum's index was 0.18 and Community dominance index was 0.59 (Appendix IV).The values of the biological indices obtained were less than one (1) which indicated that the water is not yet polluted (Maiti,2004).Also the biological indices of zooplankton are Margalef index which was 0.43, Odum's index was 2.82 and Community dominance index was 0.98(Appendix IV).The values obtained was below the pollution level of above five (5) according to Maiti(2004)

CHAPTER SIX

6.0 CONCLUSION AND RECOMMENDATION

6.1 Conclusion

i. The physico-chemical parameters of Wawan-Rafi Lake, Kazaure ,Nigeria were optimal for aquatic organisms within the study period,however the phosphate concentration of (7.00mg/l-16.73mg/l) and nitrate concentration of (1.50mg/l-6.00mg/l raised concern on accumulation of these elements that can posed threat of pollution to the lake.

ii. The Phytoplankton population of Wawan-Rafi Lake,Kazaure,Nigeria was dominated by Chlorophyta (103.00±19.55. - 120.33±21.33) and the least was Bacillariophyta(5.67±1.86 – 10.67±2.96) and theZooplankton was dominated by Rotifers(2.00±0.01 – 8.33±3.84) and the least was Cladocera(0.0 – 0.33±0.03)

iii. Correlation matrix showed there were significant correlation between phytoplankton, zooplankton and physico-chemical parameters.

6.2 Recommendations

1. The presence of pollution indicator phytoplankton and zooplankton species shows that the reservoir is under pollution stress. Immediate action needs to be taken to reduce the increasing levels of anthropogenic activities which have resulted in the pollution of the reservoir thereby reducing the water quality and making the reservoir water unfit for human consumption.
2. Adequate monitoring of the water quality and regulation of anthropogenic activities in and around the basin are recommended in order to slow down the aging process of the lake and conserve it for a longer period.

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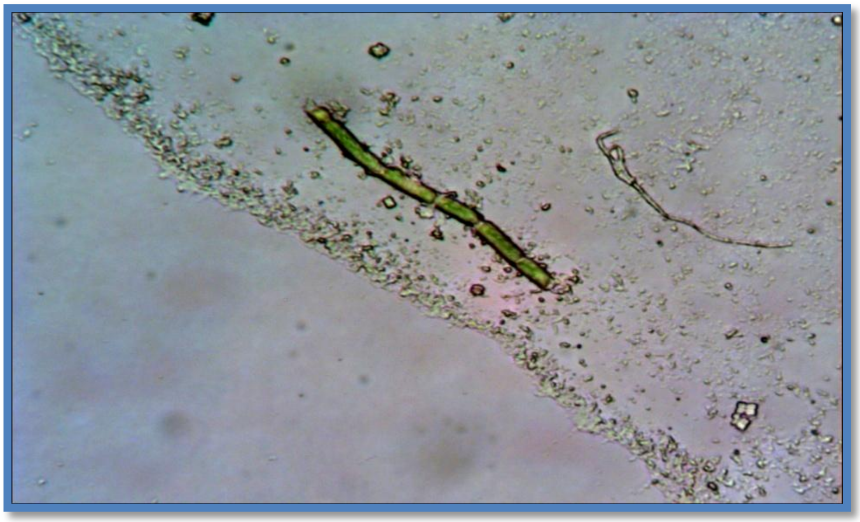
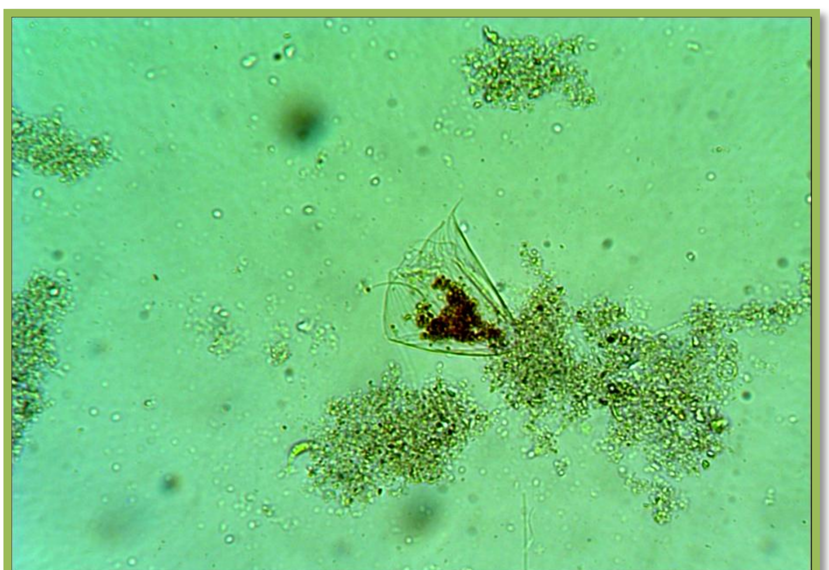
APPENDICES

Appendix I: *Oscillatoria* sp and *Microcystis* sp

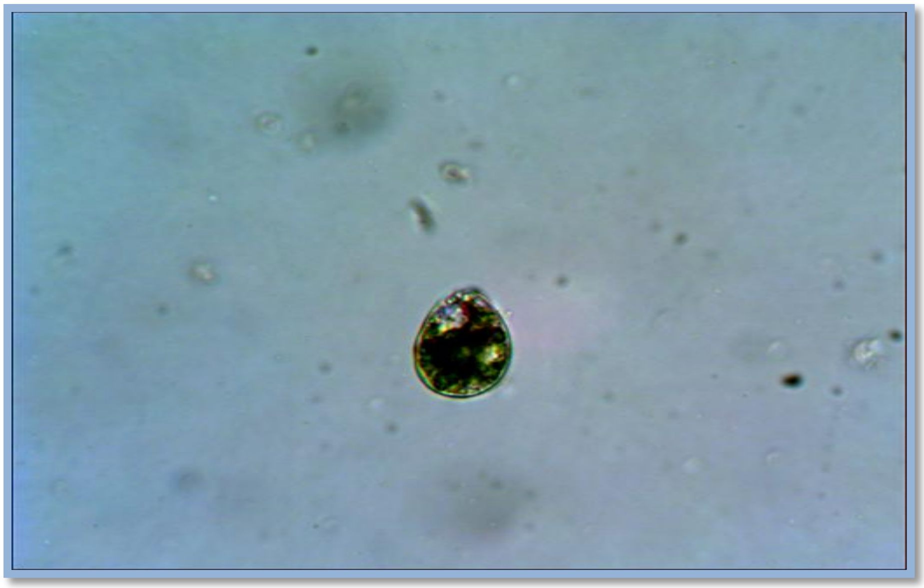


A: *Oscillatoria* sp (x 100)



B: *Microcystis* sp (x 100

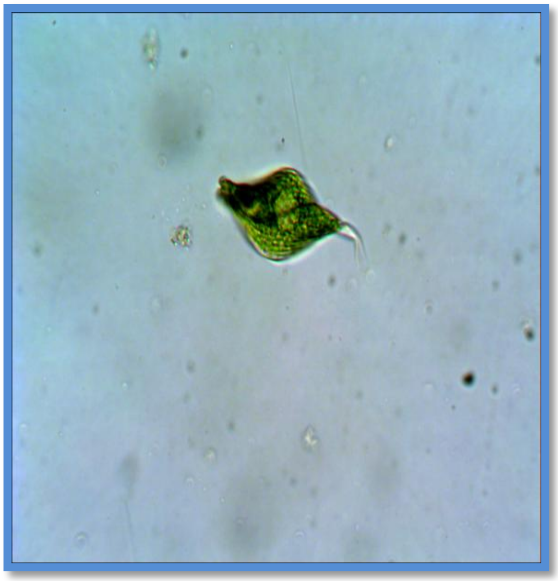
Appendix II: *Cyclotella* sp and *Ulothrix* sp



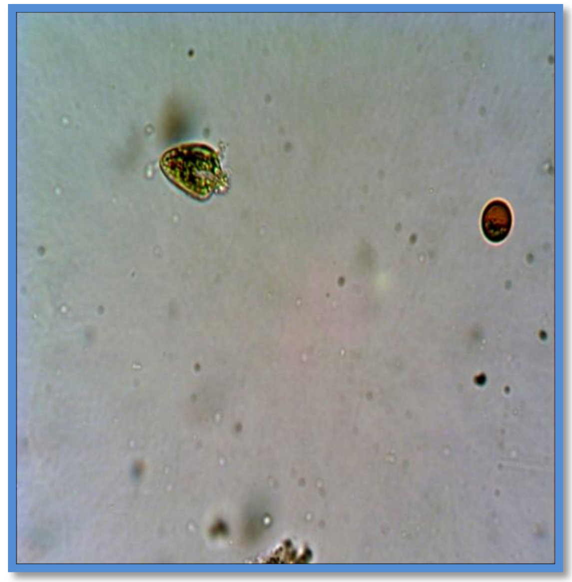
A: *Cyclotella* sp (x 100)

B: *Ulothrix* sp (x 100)

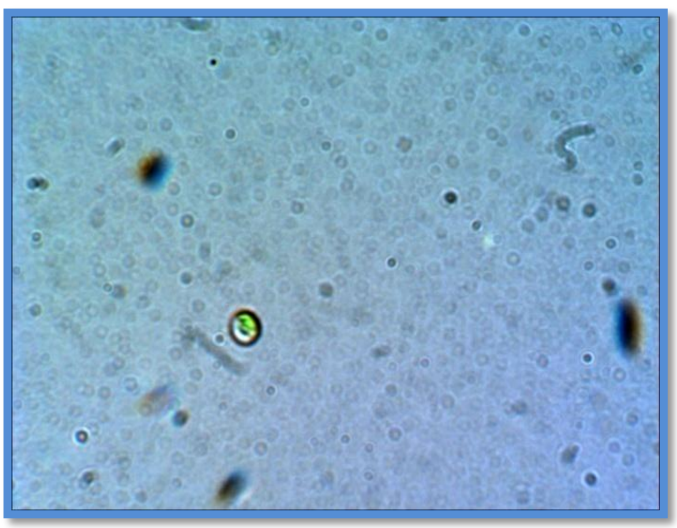
Appendix III: *Pelomyxa* sp, *Euglena* sp and *Scenedesmus* sp



A: *Pelomyxa* sp (x 100)



B: *Euglena* sp (x 100)



C: *Scenedesmus* sp (x 100)

Appendix IV: Biological Indices of Plankton

A. Phytoplankton Species Indices

Margalef Index	0.83
Odum’s Index	0.18
Community Dominance Index	0.59

B. Zooplankton Species Indices

Margalef Index	0.43
Odum’s Index	0.82
Community Dominance Index	0.98

Appendix V: Occurrence, distribution and relative abundance of phytoplankton species at sampling stations (July – December 2013)

	Sampling stations				
S/no Taxon	**A**	**B**	**C**	**Total**	
Cyanophyta					
1. *Microcystis* sp	175	-	-	175	
2. *Oscillatoria* sp	70	62	38	170	
3. *Gomphosphaeria* sp	15	12	13	40	563
4. *Anabaena* sp	50	21	19	90	
5. *Nostoc* sp	40	30	18	88	
Chlorophyta					
6. *Scenedesmus* sp	2	1	1	4	
7. *Spirogyra* sp	98	80	50	228	
8. *Ulothrix* sp	108	87	48	243	681
9. *Volvox* sp	92	91	23	206	
Euglenaphyta					
10. *Euglena* sp	`103	97	82	282	282
Bacillariophyta					
11. *Cyclotella* sp	10	20	30	60	
12. *Cymbella* sp	6	20	25	51	144
13. *Diatomella* sp	6	16	11	33	
Total	**775**	**537**	**358**	**1670**	**1670**

Appendix VI: Occurrence, distribution and relative abundance of Zooplankton species at sampling stations during the months July – December, 2013.

S/no Taxon	**Sampling stations**			**Total**
	A	**B**	**C**	
Protozoa				
1. *Paramecium*sp	10	13	14	37
2. *Pelomyxa*sp	2	1	1	4
3. *Acanthometron*sp	5	2	5	12
Rotifers				
1. *Keratella*sp	11	9	10	30
2. *Branchionus*sp	5	10	8	23
3. *Monostyla*sp	8	7	5	20
4. *Euclanis*sp	7	8	4	19
Cladocera				
1. *Daphnia* sp	6	5	1	12
2. *Microcyclop*sp	10	8	2	20
3. *Bosmina*sp	3	1	2	6
Total	**67**	**64**	**52**	**183**