TROPHIC STATUS AND PHYTOPLANKTON ASSESSMENT OF TUNGAN KAWO RESERVOIR, KONTAGORA, NIGER STATE

BY

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MTECH/SLS/2018/8349

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A THESIS SUBMITTED TO THE POSTGRADUATE SCHOOL, FEDERAL UNIVERSIY OF TECHNOLOGY, MINNA, NIGERIA IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE AWARD OF THE DEGREE OF MASTER OF TECHNOLOGY IN ZOOLOGY (APPLIED HYDROBIOLOGY) OF THE FEDERAL UNIVERSITY OF TECHNOLOGY, MINNA NIGER STATE.

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ABSTRACT

This study was carried out to assess the trophic status of Tungan Kawo reservoir by evaluating physiochemical status as well as phytoplankton diversity. Surface water samples were collected from three stations monthly (February to August 2020). Samples of water were analyzed in the laboratory for physiochemical variables and other samples were analyzed for phytoplankton species. Physiochemical variables did not show much difference from February to August 2020. The temperature was highest in station 3 (30.79 ^{0}C) and lowest in station 1 (30.51 ^{0}C) pH values ranged from (6.47 – 6.66) mg/L in Station 1. Electrical Conductivity (µS/cm) recorded to have the highest mean value (107.86) in station three while the least mean value was revealed in station two (113.00 mg/L). The mean value for Alkalinity, hardness and Phosphate, ranged from 53.71 mg/L to 46.43 mg/L, 47.14 mg/L to 42.29 mg/L, 2.60 mg/L to 2.58 mg/L respectively in all stations sampled. The biological oxygen demand (BOD) level ranged from 6.09 mg/L to 6.12 mg/L while level of Nitrate recorded in the three Stations were between 2.23 mg/L to 2.09 mg/L. The phytoplankton total number was 33,583 cell/mL. However, the highest family was *Chlorophyceae* (9 genera) in station 1 with 28,083 cell/mL, followed by *Bacillariophyceae* (4 genera) with 3,240 cell/mL and *Cyanophyceae* (5 genera) with 2,260 cell/mL. Phosphate, temperature, nitrate and dissolved oxygen had positive influence on abundance of phytoplankton which indicates a productive reservoir. The reservoir's trophic state index calculated was 40.64, 41.29, and 41.44 respectively for station 1, 2 and 3, which indicates moderately clear water as in Mesotrophy for Tungan Kawo reservoir. Therefore, reservoir in terms of trophic state classification is not Eutrophic and has moderate productivity, with dominance of *Chlorophyceae, Bacillariophyceae, and Cyanophyceae* species of phytoplankton.

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CHAPTER ONE

1.0 INTRODUCTION

1.1 Background to the Study

Water is an indispensable natural resource on earth; all life forms including human beings depend on water. Freshwater systems have now become the dumping site of wastes and other pollutants emanating from anthropogenic activities (Amah-Jerry *et al*., 2017; Anyanwu and Ukaegbu, 2019). Water is one of the most precious liquid that exists on the earth; however, the introduction of pollutants into the aquatic ecosystem has set up complicated series off a complicated series of biological and chemical reactions. In Nigeria, freshwater are used for the disposal of refuse, human sewage, irrigation, waste water etc. This has cause tremendous threat to the biota (Arimoro *et al*., 2007). Trophic state is central to ecosystem structure and is inextricably linked to biotic integrity and water quality. The trophic status of reservoir describes the development and functioning of aquatic organisms. It is a useful means of classifying reservoirs or lakes and describing lake processes in terms of the productivity of the system. In reservoirs, trophic state is functionally defined by factors related to autotrophic production including algal biomass, water column nutrients and water transparency (Pulina *et al*., 2011). Phytoplankton abundance and biomass in lakes tend to increase with trophic state, these escalations being preceded or accompanied by changes in the taxonomic composition of the community (Spodniewska, 1978; Reynolds 1987; Szelag-Wsasielewska, 2007).

Multiple reservoir uses and human activities at the watershed change the nutrient inputs that induce modifications of the reservoir's trophic state, biotic assemblages and physico-chemical conditions (Molisani *et al*., 2010). Eutrophication is a phenomenon in which excess nutrients are introduced into a water body resulting to the excessive growth of aquatic plants and depletion of oxygen by the decomposing organisms leading to the death of aquatic organisms, offensive odour and colour (Environmental Protection Agency, EPA, 2002). During early stages of formation, water bodies are in a state of oligotrophy and support a pitiful aquatic life because of nutrient deficiency. Enrichment of water with mineral nutrients, such as nitrogen and phosphorus cause transformation of water bodies from oligotrophic to mesotrophic, eutrophic and finally hypertrophic (Molisani *et al*., 2010).

Among the structural changes caused by the eutrophication, there is dominance of species in community structure of phytoplankton known as primary pelagic producers, particularly in predominance of cyanobacteria in freshwater ecosystems such as lakes and reservoirs. Phytoplankton including many species is widely distributed in the aquatic ecosystem, which maintains the structural functions of ecosystem and plays an important and irreplaceable role of indicator and purifier on lake pollution, through participating in material cycle and energy flow in lakes (Lei *et al.,* 2010). Phytoplankton’s are primary producers and regarded as the starting point in aquatic food chain. They are of great relevance to the zooplankton that solely depends on it for survival I the water body. They are highly sensitive to changes in nutrients levels, temperature, pollution, level of light and increase in predation (Arimoro *et al*., 2008a).

Historically lakes (reservoirs) provide many important functions ranging from provision of protection from flooding, storage of water for consumptive purposes, provide recreational opportunities, and irrigation purposes especially during dry season and power generation to residents and industry. The benefits and detriments of reservoirs have been debated and documented throughout their history (Lei *et al.,* 2010).

1.2 Statement of the Research Problems

Lakes and reservoirs constitute very important nursery and breeding grounds for a large variety of fish species, making it crucial to feeding millions of people around the reservoir. However, these have been over-exploited, and the environment also ecologically degraded (Ajani and Omitoyin, 2004). Tungan Kawo reservoir for a long time lack appropriate management system, this combine persistent farming, traditional fishing, irrigation and other anthropogenic activities increasing domestic and industrial waste into water body, by the close communities around.

Tungan Kawo reservoir was created solely for providing good drinking water to its township; however, it has become an excellent source of fish, apart from domestic usage it is also used for dry season farming (irrigation). The clearing of the land for urban settlements and agricultural activities, changes the landscape resulting into over exploitation, siltation, quick water flow from runoff of residential and farms where both chemical and organic fertilizers are used. Till date, little or no comprehensive work has been done on phytoplankton as well as trophic status assessment of Tungan Kawo reservoir. This makes this work an important piece for present and future purposes.

1.3 Aim and Objectives of the Study

The aim of the study is to assess the trophic status in Tungan Kawo reservoir by evaluating physiochemical status as well as phytoplankton diversity.

The objectives of the study are to determine:

i. Physiochemical properties of Tungan Kawo reservoir,

ii. Estimating the Trophic status of the reservoir using Carlson Trophic State Index

iii. Phytoplankton species of Tungan Kawo reservoir.

1.4 Justification for the Study

The study area from a number of villages make it a site were many daily activities such as farming, fishing, transports, irrigation are carried out. Facing these activities and absence of adequate enforcement of environmental protection regulations, the water body is prone to high level of productivity. Tungan Kawo reservoir may receive a high amount of run-off that collect organic matter.

Monitoring trophic status of Tungan Kawo reservoir would provide information on management and sustaining the aquatic ecosystem. This serve to monitor change in Physical and chemical conditions of the reservoir, which could help to initiate policy for overall management of the ecosystem health and it productivity. In view of the above facts, it is essential to assess not only the composition and distribution of phytoplankton in the lake but also to measure related physical and chemical parameters that will be necessary to obtain or measure the trophic status of the reservoir.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 Water and its Quality

Water in the natural environment contains many dissolved substances and non-dissolved particulate matter. Dissolved salts and minerals are necessary component of good quality water as they help to maintain the health and vitality of the organisms that rely on aquatic ecosystems (Stark *et al*., 2000). Water can also contain substances that are harmful to life; these include metals such as mercury, lead, and cadmium, pesticides, organic toxins and radioactive contaminants. Decline water quality due to environmental upset threatens the stability of the biotic integrity and therefore hampers the ecosystem services and functions of the aquatic ecosystems (Carini *et al.*, 2014).

Water from natural sources almost always contains living organisms that are integral component of biogeochemical cycles in aquatic ecosystems (Stark *et al*., 2000). However, some of these particular bacteria, protists, parasitic worms, fungi, and viruses can be harmful to humans if present in water used for drinking (United Nation Environmental Protection, (UNEP), 2006). The quality of water necessary for each human use varies, as do criteria used to assess water quality. For example, the highest standards of purity are required for drinking water, whereas it is acceptable for water used in some industrial processes to be less quality (UNEP, 2006).

Study of water quality and trophic state of inland surface waters has been the topic of interests for the researchers worldwide (Kane *et al.,* 2014; Doan *et al.,* 2015; Ali and Khairy, 2016; Sivakumar, 2016; Wilkinson, 2017; Zhang *et al.*, 2017). Typically, water quality is determined by comparing the physical and chemical characteristics of a water sample with water quality guidelines or standards. Drinking water quality guidelines and standards are designed to enable provision of clean and safe water for human consumption, thereby protecting human health (UNEP, 2006). Guidelines for protection of aquatic life are more difficult to set, largely because aquatic ecosystems vary enormously in their composition both spatially and temporally, and because ecosystem boundaries rarely coincide with territorial ones. Therefore, there is movement among scientific and regulatory research community to identify natural background conditions for chemicals that are not toxic to humans or animals and to use these guidelines for protection of aquatic life (Dodds and Orkes, 2004; Wickham *et al.*, 2005; Robertson *et al.*, 2006). Other guidelines, such as those designed to ensure adequate quality for recreational, agricultural or industrial activities, set out limits for the physical, chemical and biological composition of water needed to safely undertake different activities (UNEP, 2006).

2.2 Trophic Status of Lakes

Evaluation of trophic status of aquatic ecosystems is an important scientific basis for sustainable water resource management and to preserve the integrity and ecosystem function (Ndungu *et al.,* 2013). One biological classification of lakes is based on nutrient levels. Lakes are divided into four major categories: oligotrophic, mesotrophic, eutrophic, and dystrophic. Young or oligotrophic lakes are lacking in nutrients, while eutrophic lakes are nutrient rich. Oligotrophic lakes tend to be deep and oxygen rich with steep-sided basins creating a low surface to volume ratio. Although they may be high in nitrate levels, oligotrophic lakes are primarily deficient in phosphorus, the limiting nutrient for plant productivity in most freshwater ecosystems (Lawrence *et al.*, 2004). The shape of a lake can also influence its productivity. Steep-sided oligotrophic lakes are not conducive to extensive growth of rooted vegetation because there is no shallow margin for attachment. Eutrophic lakes are nutrient rich and have a relatively high surface to volume ratio. These lakes have a large phytoplankton population that is supported by the increased availability of dissolved nutrients. Low dissolved oxygen levels at the bottom of a eutrophic lake are a result of high decomposition activity. This activity leads to the release of phosphorus and other nutrients from the bottom sediments, resulting in their eventual recycling through the water column (Lawrence *et al.,* 2004). This nutrient release stimulates even further growth of phytoplankton populations such as algae. Due to sediment loading over the years, eutrophic lakes tend to be shallow and bowl shaped, which allows for the establishment of rooted plants. Dystrophic lakes receive large amounts of organic matter from the surrounding land, particularly in the form of humic (dead organic) materials. The large quantity of humic materials stains the water brown. Dystrophic lakes have highly productive littoral zones, high oxygen levels, high macrophytes productivity, and low phytoplankton numbers. Eventually, the invasion of rooted aquatic macrophytes chokes the habitat with plant growth. The lake basin is filled in, resulting in the development of a terrestrial ecosystem (Lawrence *et al*., 2004).

Nutrient loading into a lake can be affected by natural and anthropogenic processes. Human activity usually accelerates the loading of nutrients and sediments into a lake. In this way, the water quality can be adversely affected in a short period of time. Clearing away forests to construct roads and buildings with impervious surfaces increases runoff, carrying nutrients from agricultural, residential, and industrial products (such as detergent, fertilizer, and sewage) into the lake. Since phosphorus and nitrogen are the limiting nutrients to algal growth, and algal growth affects the trophic state of a lake, increases of phosphorus and nitrogen from these sources can lead to a decrease in lake water quality and eventual eutrophication (Lawrence *et al*., 2004).

Trophic state is central to ecosystem structure and is inextricably linked to biotic integrity and water quality. The trophic status of lakes describes the development and functioning of aquatic organisms. It is a useful means of classifying lakes and describing lake processes in terms of the productivity of the system. In lakes, trophic state is functionally defined by factors related to autotrophic production including algal biomass, water column nutrients and water transparency (Pulina *et al.*, 2011)

2.3 Physicochemical Parameters of Water

It is very essential and important to test the water before it is used for drinking, domestic, agricultural or industrial purpose. Water must be tested with different physicochemical parameters (Adefemi and Awokunmi, 2010). Selection of parameters for testing of water is solely depends upon for what purpose we are going to use that water and what extent we need its quality and purity. Water does contain different types of floating, dissolved, suspended and microbiological as well as bacteriological impurities (Adeyeye and Abulude, 2004). Some physical test should be performed for testing of its physical appearance such as temperature, colour, odour, pH, turbidity, TDS etc. while chemical tests should be performing for its BOD, COD, dissolved oxygen, alkalinity, hardness and other characters. For obtaining more and more quality and purity water, it should be tested for its trace metal, heavy metal contents and organic i.e. pesticide residue. It is obvious that drinking water should pass these entire tests and it should content required amount of mineral level (Adeyeye and Abulude, 2004). Only in the developed countries all these criteria's are strictly monitored (Adeyeye and Abulude, 2004).

2.3.1 Water Temperature

The measurement of temperature is one of the most primary factors, since it affects the chemistry and biology of all biotic factors. Temperature is an important biologically significant factor, which plays an important role in the metabolic activities of the organism. In an established system the water temperature controls the rate of all chemical reactions, and affects fish growth, reproduction and immunity. Drastic temperature changes can be fatal to fish (Gupta *et al.*, 2009).

2.3.2 Water pH

pH is most important in determining the corrosive nature of water. It is the scale which measures the intensity of acidity and alkalinity of water measures the concentration of H+ ions. Water pH is an important environmental factor which affect the biology and the life cycle of the biotic life. The variation of pH directly affects the life processes of biotic flora and fauna inhabiting the water bodies. The lower the pH value, the higher is corrosive nature of water. Water pH is positively correlated with electrical conductance and total alkalinity (Gupta *et al.,* 2009). The reduced rate of photosynthetic activity, the assimilation of carbon dioxide and bicarbonates which are ultimately responsible for increase in pH, the low oxygen values coincided with high temperature during the summer month. Various factors bring about changes the pH of water. The higher pH values observed suggests that carbon dioxide, carbonate-bicarbonate equilibrium is affected more due to change in physicochemical conditions (Gupta *et al.,* 2009).

2.3.3 Secchi disk (SD) transparency

This is an indicator of light availability in the water column, provides an indirect measure of the concentrations of suspended solids as well as algal component in the water (Sheela *et al.,* 2011).

2.3.4 Electrical conductivity (EC)

Electrical conductivity is the measure of a materials ability to accommodate the transport of an electric charge (Navneet and Sinha, 2010). Conductivity shows significant correlation with ten parameters such as temperature, pH value, alkalinity, total hardness, calcium, total solids, total dissolved solids, chemical oxygen demand, chloride and iron concentration of water. Navneet and Sinha (2010) suggested that the underground drinking water quality of study area can be checked effectively by controlling conductivity of water and this may also be applied to water quality management of other study areas. It is measured with the help of EC meter which measures the resistance offered by the water between two platinized electrodes.

2.3.5 Dissolved Oxygen (DO)

Dissolved oxygen is important parameter in water quality assessment as it regulates many metabolic and physiological processes of biotic components. The amount of oxygen in the lake depends on the extent of direct contact between water and air and on the circulation of water and on the amount produced and consumed by the biotic component of the lake. The DO values indicate the degree of pollution in water bodies. The lower concentration of dissolved oxygen is a sign of organic population in the lake. DO is one of the most important parameters, its correlation with water body gives direct and indirect information e.g. bacterial activity, photosynthesis, availability of nutrients, stratification etc. In the progress of summer, dissolved oxygen decreased due to increase in temperature and also due to increased microbial activity (Kataria *et al.,* 1996). The high DO is due to increase in temperature and duration of bright sunlight that has influence on the percentage of soluble gases (O_2 and CO_2). Intense sunlight seems to accelerate photosynthesis by phytoplankton, utilizing CO2 and giving off oxygen. This possibly accounts for the greater qualities of O_2 recorded during harmattan (Krishnamurthy, 1990). The dissolved oxygen concentration decreases not only as a consequence of the temperature increase, but also as an effect of increased respiration, either as a direct response to increased temperature or due to increased nutrient levels. The low DO suggest the poor quality of water indicating the slow rate of photosynthesis by phytoplankton present in the lake water (Saluja and Garg, 2017).

2.3.6 Biochemical oxygen demand (BOD)

Biochemical Oxygen Demand (BOD) is a measure of organic material contamination in water, specified in mg/L. It is the amount of dissolved oxygen required for the biochemical decomposition of organic compounds and the oxidation of certain inorganic materials (e.g., iron, sulphites). Typically, the test for BOD is conducted over a five-day period (Krishnamurthy, 1990).

2.3.7 Ammonia content

Nitrogen compounds are most wide-spread contaminants in the environment, and mostly derived from anthropogenic souses such as agricultural lands, runoff containing human and animal wastes (Pang *et al.,* 2013). It is measured spectroscopically at 425 nm radiation by making a colour complex with Nessler's reagent. The conditions of reaction are alkaline and cause severe interference from hardness in water (Dickson and Goyet, 1994).

2.3.8 Phosphate content

Addition of inorganic and/or organic phosphorous to water brings about eutrophication by increase in oxygen demand and increase in production of growth factors for algae, thus resulting in increased algal growth. These are also measured spectroscopically.

Yellow colour is developed from the action of phosphates and silicates on molybdate ion under strong acidic conditions. The intensity of colour is directly proportional to the concentration of phosphate and silicates in the sample. Phosphate complexes are reduced by weak reducing agents such as ascorbic acid or tartaric acid (potassium antimonyl tartarate) whereas silica complexes require strong reducing conditions of hydrazine or bisulphite. The colour of reduced complex is sky blue (Dickson and Goyet, 1994).

2.3.9 Water depth

Mean depth is best single indicator of morphometric conditions, within a river or lake basin. If mean depth is held constant within the hypothetical suit of rivers, volume will vary on a linear basis with respect to variants of area. Mean depth has also profound influence in mixing and re-suspension from the bottom sediments. In very shallow lakes, close relationship exists between free waters and the bottom where clean organic matter accumulates (Rowe and Wright, 1999). Phytoplanktons are composed of both eukaryotic and prokaryotic species. It colonizes the upper part of the water column, down to the limit of penetration of light (Reynolds *et al.,* 2002). The structure and abundance of the phytoplankton populations are mainly controlled by inorganic nutrients such as nitrogen, phosphorus, silica and iron. Phytoplankton usually undergoes a fairly predictable annual cycle, but some species may develop explosively and form blooms. Phytoplankton is present in both fresh and marine waters (Reynolds *et al.,* 2002).

2.3.10 Chlorophyll-a contents

This type of chlorophyll is found in almost all photosynthetic organisms, i.e. plants, algae, cyanobacteria, and aquatic species (Jordan, 1991). Previously it had been called chlorophyll α. It is found in all light harvesting complexes (LHCs) and both reaction centres (RCs) in organisms, photosystem I (PS I) and photosystem II (PS II). It absorbs mainly red light from the solar spectrum; the absorption peak is captured at 420 nm and 660 nm inorganic solvents and at 453nm and 670–480nm in photosynthetic cells (in vivo). It works as primary donor in the RCs of PSI and PSII. Subsequently, two types of chlorophyll-a, Ca 670 and Ca 680, were identified which are responsible for absorption of different wavelengths from the light spectrum. Chlorophyll-a content in surface waters is considered as indicator of algal biomass, and thus often used as a trophic state indicator of any water body (Carlson, 1977a).

2.4 Phytoplankton Species

Phytoplankton are composed of both eukaryotic and prokaryotic species. It colonizes the upper part of the water column, down to the limit of penetration of light (Reynolds *et al.,* 2002). The structure and abundance of the phytoplankton populations are mainly controlled by inorganic nutrients such as nitrogen, phosphorus, silica and iron. Phytoplankton usually undergoes a fairly predictable annual cycle, but some species may develop explosively and form blooms. Phytoplankton is present in both fresh and marine waters (Reynolds *et al.,* 2002). Phytoplankton form group of plants of different origin that share some similar characteristic such as autotrophic adapted to different modes of feeding where most are photoautotrophic. They make a fundamental contribution by utilizing the radiant energy for the synthesis of organic compounds from inorganic ones of high potential energy. Despite the economic importance of phytoplankton as a source of food and medicine, they also contribute to the world oxygen supply (Ogbuagu and Ayoade, 2012). The magnitude of the influence of the inflow of water through lake reservoirs depends on the volume, the extent of catchment areas and the amount of rainfall (Shukla *et al*., 2009).

Phytoplankton communities are sensitive to changes in their environment and therefore phytoplankton total biomass and many phytoplankton species are used as indicators of water quality (Reynolds *et al.*, 2002). Phytoplankton communities give more information on changes in water quality than mere nutrient concentrations or chlorophyll-a concentration. Water quality is an assemble of physical, chemical and biological characteristics of the given water. Eutrophication of freshwater is regarded as a water quality issue which results in the deterioration of the aquatic environment and impacts on water usage. Cyanobacteria have been recognized as a major symptom of eutrophication in fresh water as their blooms are prevalent in waters affected by cultural nutrient enrichment.

2.5 Phytoplankton Abundance and Biomass

Phytoplankton abundance and biomass in lakes tend to increase with trophic state, these escalations being preceded or accompanied by changes in the taxonomic composition of the community (Spodniewska, 1978, Reynolds, 1987; Szelag-Wsasielewska, 2007). Phytoplankton composition also depends on the alternation of stratified conditions in the rainy season with the deep mixing that occurs in the dry season: the seasonal mixing event not only increases the supply of dissolved nutrients in the euphotic zone, but also results in a rise of the ratio between mixed layer depth (Zm) to the euphotic layer depth (Zeu) (Sarmento *et al.*, 2006). In these conditions, phytoplankton is subjected to potential light limitation, leading to diatom dominance (Reynolds, 2006). By contrast, in the shallow mixed layer of the rainy season, the lower Zm: Zeu ratio selects for high-light adapted phytoplankton such as green algae and cyanobacteria. The trade-off between high light and nutrient limitation in the rainy season and low light and high nutrients during the dry season has been documented in classic studies in African lakes and is a key to understanding shifts in phytoplankton composition in these lakes.

Estimates of annual primary productivity in tropical lakes have been usually based on measurements of phytoplankton photosynthesis carried out over sufficiently long periods to capture the seasonal variations of incident light, water transparency, temperature, nutrients and phytoplankton biomass. Multiple reservoir uses and human activities at the watershed change the nutrient inputs that induce modifications of the reservoir’s trophic state, biotic assemblages and physico-chemical conditions (Molisani *et al.,* 2010).

The phytoplankton community forms a key component of primary production in lakes; its relative importance, compared with phytobenthos and macrophytes, increasing with lake depth. The fact that phytoplankton are short-lived and derive their nutrients from the water column makes this biological quality element the most direct and earliest indicator of impacts of changing nutrient conditions on lake ecosystems. Phytoplankton are, therefore, ideal indicators of deteriorating ecological status associated with increasing nutrient status (eutrophication), or, of ecological recovery following reductions in nutrient loads.

There are numerous socio-economic problems associated with eutrophication-related increases in phytoplankton abundance, particularly with increasing frequency and intensity of toxic cyanobacteria blooms. These include detrimental effects on drinking water quality, filtration costs for water supply (industrial and domestic), water-based activities, and conservation status (submerged macrophytes and sensitive fish species, such as salmonids and coregonids). In one or two limited contexts, increasing phytoplankton abundance could be considered as a positive feature. For example, increasing fishery productivity or a potential sink for increasing concentrations of atmospheric carbon. The phytoplankton community is a key indicator of ecological status in lakes, and particularly represents nutrient conditions and the impacts of eutrophication on environmental, social and economic value. This response of the phytoplankton community to nutrient conditions is considered in terms of the three phytoplankton related quality elements, namely; phytoplankton composition, phytoplankton abundance and its effect on transparency conditions, and planktonic bloom frequency and intensity.

Reynolds (1998) outlines a provisional scheme of phytoplankton compositional changes across a nutrient gradient that merges seasonal effects. Most algal groups, including cyanobacteria, span the entire nutrient gradient. The only exceptions to this are chrysophyte algae that are characteristic of more nutrient poor (and acid) waters. Compositional changes due to nutrient enrichment become more apparent at the generic and species level. For example, of the diatoms, Cyclotella species are frequently associated with nutrient poor lakes and Stephanodiscus species tend to dominate following enrichment. Nuisance cyanobacteria such as the large colonial and filamentous species Microcystis, Aphanizomenon and Anabaena also tend to increase in dominance and abundance in response to increasing nutrient concentrations, often resulting in dense, mono-specific blooms during summer in eutrophic waters.

The stability of the water column is also important in determining the size and shape of phytoplankton (Naselli-Flores, 2000). Physical variables such as water column stability affect the phytoplankton directly by selecting shapes depending on the intensity of the turbulence and indirectly by modifying nutrient availability. Diatoms, for example, tend to be favoured by greater mixing (Moss and Balls, 1989) whereas green algae are favoured by very high nutrient concentrations (Jeppesen *et al.*, 1998) and cyanobacteria by moderately high phosphorus levels, stability of the water mass and long water retention times (Reynolds, 2006).

Several elements are essential as vital compounds of phytoplankton cells. Among them, carbon, nitrogen, phosphorus and silicate are commonly related to limit their growth. The phytoplankton obtain nutrients from the external medium but they can only be taken up if they occur as soluble compounds present as diffusible ions or as no dissociated small molecules such as silicic acid. Several studies have attempted to elucidate the effect of nutrient dynamics within the trophic spectrum on phytoplankton organization (Rojo *et al*., 2000). In this sense, it has been pointed out that the influence of nutrients on the structure of the phytoplankton assemblages might be higher in the lower part of the trophic spectrum (Naselli-Flores, 2000), showing that nutrient limitation in oligotrophic lakes may be one of the driving forces shaping community structuring. Overall observations point out that primary producers appear to be frequently phosphorus-limited in temperate lakes and nitrogen-limited in tropical regions (Lewis, 2002). One of the most accepted explanations is that the denitrification increases with temperature, thus raising nitrogen losses. Nitrogen is the second element whose relative scarcity impinges upon the ecology of phytoplankton (Reynolds, 2006). Of the sources of nitrogen potentially available to algal uptake, nitrate, nitrite and ammonium ion are by far the most important. The phytoplankton is generally capable of active uptake of dissolved inorganic nitrogen from external concentrations as low as 0.2–0.3 μM (Reynolds, 2006).

Explanations for nutrient-related compositional shifts are not straightforward. Direct phosphorus- or nitrogen- limitation of particular species is probably rarely responsible for compositional changes, with the exception of diatom declines and silica-limitation or in the case of ultra-oligotrophic lakes (rare in the United Kingdom). Nutrient resource-ratios (Si: P or N: P) also offer limited explanation, particularly in lakes where nutrient concentrations are rarely depleted (Reynolds, 1998) although N-limitation is considered to promote dominance by cyanobacteria (Schindler, 1977). Compositional responses to nutrient conditions may be explained more by factors such as phytoplankton growth rate, surface area to volume ratio, or CO_2 concentrating capacity. Empirical models have been developed, based on phytoplankton functional groups incorporating these characteristics (Reynolds, 1999). These models can be used to predict which species should dominate under particular environmental regimes and explore how community composition will qualitatively change along an increasing nutrient gradient under particular temperature and stratification states (or altitude/latitude and depth ecotypes).

2.6 Abundance and Transparency of Phytoplankton in Showing Water Status

In general, as nutrient concentrations increase, phytoplankton abundance shows more frequent and sustained peaks throughout wet season and transparency declines. According to Reynolds (1984) explains the general seasonal patterns in phytoplankton abundance in a range of six lake types. In nutrient poor lakes, phytoplankton abundance increases over wet season to a peak in August in response to increasing water temperature, then decreases to a dry season minimum as a result of nutrient deficiency. In other larger, nutrient poor lakes phytoplankton biomass may peak earlier in spring associated with blooms of planktonic diatoms, decline due to silica limitation, with other algae peaking later in summer. A clear pattern of its peaks is most frequently characteristic of shallow (<3m), temperate mesotrophic lakes. In very shallow lakes abundant phytoplankton can be sustained throughout much of the year.

2.7 Trophic Status Index

The TSI classifies the water bodies in different trophic degrees, evaluating the water quality cue to nutrient enrichment. It was introduced by Carlson (1977b), Variables that measure phytoplankton biomass include chlorophyll—or some specific chlorophyll pigment such as chlorophyll-a, algal bio-volume, total dry weight, organic weight, organic carbon, ATP, and various estimates of turbidity. Each of these variables can contribute valuable information to an estimate of biomass, but each also ignores certain forms of biomass or includes interferences. Chlorophyll has become the most popular estimator of phytoplankton biomass, having the advantage that it measures a specific characteristic of algal biomass that is not found in bacteria, an organic carbon form that can constitute a significant fraction of the weight of living carbon in the open water. Chlorophyll-a is found largely in living algae, but is difficult to isolate and measure without using sophisticated (and expensive) techniques such as HPLC. The more common spectrophotometric chlorophyll test measures chlorophyll-a, but also includes other chlorophylls and degradation pigments, thus overestimating chlorophyll to some extent. Also, the amount of chlorophyll in a cell can vary considerably. Dry weight is an easy measure of phytoplankton weight but includes the weight of everything in the water, which may include considerable amounts of non-algal material such as bacteria, suspended sediment, inorganic particles, and detritus. Inorganic interferences can be eliminated either by a direct measure of particulate carbon or as the amount of weight lost by ignition at high temperatures. However, bacteria and non-living organic particles present still contribute to the organic weight. Turbidity, whether measured with a Secchi disk or turbidimeter, estimates the density of algal particles, but includes non-algal particles as well.

Turbidity is also affected by the shape of the particles, and ocular instruments such as the Secchi disk, are affected by dissolved colour. If no single variable can measure phytoplankton biomass without potential problems, how do we estimate trophic state? The earliest methods included examining a list of characteristics associated with the three or four (or five) trophic classes (oligotrophic, eutrophic, etc.) and designating the state with the trophic category that best fitted the actual lake trophic characteristics. Although this system is still used today, it relegates trophic classification into a minor role in management. For example, imagine that other potentially quantitative measures were treated similarly; a lake might only be described as shallow, eutrophic, coloured, or acidic, despite the possible sensitivity of the original measurements. Of course, these qualitative terms are actually used as shorthand terms to communicate an idea of a lake's characteristics, but we don't manage by making the lake "deep" or "oligotrophic" or alter raw drinking water by "removing the colour." Management is ultimately quantitative and we do need to know the lake's depth and pH and colour, and, in a similar manner, its trophic state. Numerous quantitative measures of trophic state have been developed. Carlson developed an index of trophic state based on chlorophyll as the primary estimator of algal biomass (Carlson, 1977a). It is called an "index" because it acknowledges that it is not measuring phytoplankton biomass, but only estimating it using chlorophyll as the estimator. Chlorophyll was chosen because it is specific to algae and can measure algal abundance even in the presence of non-algal organic and inorganic particles.

The index itself is numerical rather than using qualitative trophic types, giving the possibility of a greater sensitivity to change in trophic status. Each 10 units on the scale represent a halving or doubling of Secchi depth, a biomass measure that is directly relevant to communication with the public. Chlorophyll was incorporated into the index using regression relationships between chlorophyll and Secchi depth. Other trophic variables were also incorporated by coupling variables to Secchi depth or chlorophyll by regression models. These additional variables allow the trophic state to be estimated by variables other than chlorophyll. Each variable provides its own distinct set of information that may be missing from the other variables. Therefore, the more variables measured, the more information we can gather about the trophic status. Some variables, such as total phosphorus and nitrogen, are causal variables and link loading estimates of nutrients to trophic state. Other variables such as chlorophyll, dry weight, and transparency estimate algal biomass. Taken together, additional variables can provide a clearer picture of the nature and status of the lake. They also allow trophic state to be estimated even if chlorophyll values are not available.

CHAPTER THREE

3.0 MATERIALS AND METHODS

3.1 The Study Area

Tungan Kawo Reservoir is located between latitude 100° 21”58.51° N-10° 23”28.50°N of the equator and between longitude 5° 19”29.23°E-5° 20”59.23°E in Tungan Kawo village, northwest of Kontagora, 7 km along Kontagora-Yauri Road in Kontagora Local Government Area of Niger State. The reservoir has a catchment area of 143 km^2, a total storage capacity of 17.7 m cubic meters, 20 m high and reservoir crest length of 1000 m. The reservoir was commissioned in May 1991. It is the largest source of water supply in Kontagora Township. The dam was constructed mainly for water supply, irrigation, livestock use and ranching. The people of Tungan Kawo and its environs are predominantly farmers and fishermen.

Station 1 is the point of discharge of the main sources of pollution, such as agricultural waste and domestic effluents. Irrigation farms for sugar cane, vegetable and rice can be seen at some stages along the water channels and it serves as a washing site and fish cleaning for sale to the inhabitants of that area. Station 2 is about 20 meters away from station 1. It has a few emergent plants and animals are found. Station 3 is about 30 meters deep into the open water body. It appears to be clearer than other stations with fewer plants and animals.

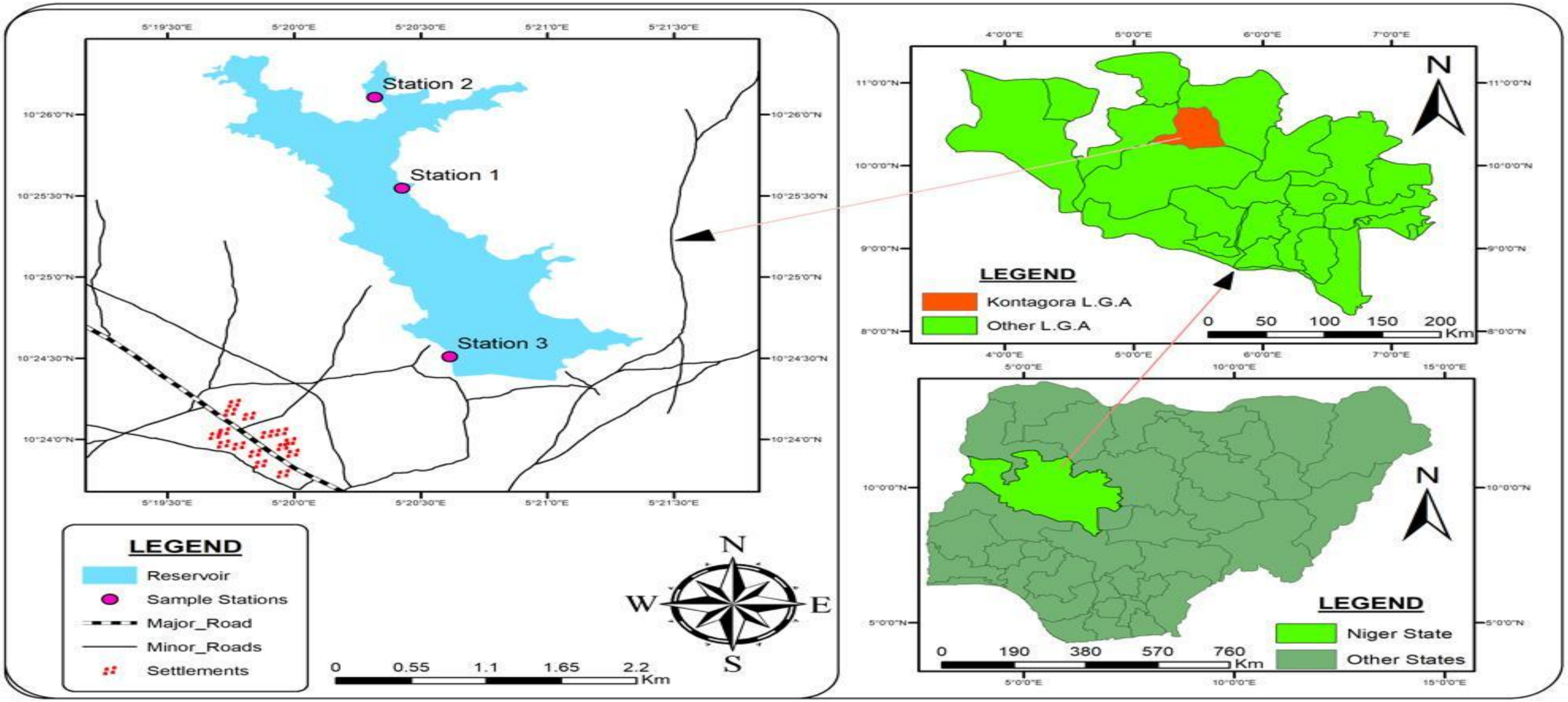

Figure 3.1: Hydrological Map of Tungan Kawo Reservoir showing the sampling stations

(Source: Remote Sensing/ Geographical information system (GIS) laboratory, Geography department, FUTMINNA).

3.2 Water Sample Collection

A total of 42 water samples were collected with labelled plastic bottles for seven consecutive months from February to August 2020 at three sampling stations. Six samples will be taken from the lake each month, three for the phytoplankton count and three for physiochemical analysis. The samples were collected using a standardized method (APHA, 2014). The phytoplankton samples were immediately fixed with 70% alcohol and Lugol's iodine for laboratory analysis. Water temperature was measured with a thermometer sensitive to 0.10C, HANNA HI 9828 multi probe metre manufactured by HANNA instruments was used for measuring values of DO, EC, TDS and pH. While the following parameters was determined in the laboratory; nitrogen (DIN, nitrate, ammonia), soluble phosphorus, BOD was determined according to standard methods described by APHA (2014).

3.3 Phytoplankton Count

Lugol's iodine was added into the sample collected and left for 24 hours for sedimentation. Then decanted by using 50mm then inserted into the counting chamber and viewed under the microscope to determine the number and specie of phytoplankton been trapped (APHA, 2014).

3.4 Determination of Physicochemical Variables

3.4.1 Water temperature

Water temperature was measured with a mercury thermometer sensitive to 0.10 C. Thermometer was lowered to the depth of few centimetres and the temperature will be recorded (APHA, 2014).

3.4.2 Water pH

Water pH was measured using HANNA HI 9828 multi probe metre manufactured by HANNA instruments inserted into the water sample and then the reading was taken from pH meter (APHA, 2014).

3.4.3 Water transparency

Secchi disc of 25cm in diameter was lowered into the river until it disappears and measurement was recorded and then Secchi disc was pulled and depth of reappearance was measured and recorded (APHA, 2014).

3.4.4 Dissolved oxygen (DO)

The determination of dissolved Oxygen (DO) was done in situ using a portable dissolved oxygen analyser following (APHA, 2014) method; Procedure: DO meter was standardized by distilled water and buffer solution. Then drop inside the water and wait for at least 1 minute, after which reading was recorded from DO meter and written down into the notebook. In the same way, the procedure was repeated in all the sampling sites but before every measurement DO meter was sink into distilled water.

3.4.5 Biological oxygen demand (BOD)

This was determined according to APHA (2014) method. At the field, the reagent bottles set aside for BOD was filled with water samples and wrapped with black polythene bags to avoid any form of light penetration. The samples was then transported to laboratory and kept in a dark cupboard. After five (5) days, the procedure for carrying out dissolved oxygen was repeated to check the amount of oxygen that has been used up by microorganisms, and results expressed in mg/L

3.4.6 Nitrate content

This was measured using micro Kjeldahl distillation method 0.2g magnesium oxide and divider alloy (0.4 g) was added to fifty milligrams of water sample in micro Kjeldahl flask and covered with cork then mounted on distillation apparatus, ten milligram of boric acid indicator was added into the conical flask and placed under the condenser. The distillation was commenced, and the distillate was collected in the conical flask and titrated with standard acid H_2SO_4 (0.01 mL) which turns from green colour to pink colour end point. Recorded titre value from burette reading, using the equation below, NO_3 was calculated in mg/L according to APHA (2014)

3.4.7 Ammonium content

This was measured using the micro Kjeldahl distillation method, 0.2g magnesium oxide was added to fifty milligram water sample in micro Kjeldahl flask and covered with cork then mounted on distillation apparatus, 10ml of boric acid indicator was added into the conical flask and placed under the condenser. The distillation was commenced, the distillate was collected in the conical flask and distillate was titrated with standard acid H_2SO_4 (0.01ml) which turns from green colour to pink colour end point. Titre value was recorded from burette reading. Using the equation below, NH_4 was calculated in mg/l, using the following expression:

3.4.8 Phosphate content

This was measured using Bray No. 1 method, two milligram of water sample was added into 50 mL volumetric flask then two milligram of phosphorus extraction solution was added, two milligram of Ammonium Molybdate was added and distilled water to half of the bottle, then one milligram of dilute Stannous Chloride was added. Distilled water was added to make volume 50 mL then the absorbance reading was taken from spectrometer at 660 nm/wavelength (APHA, 2014).

3.5 Chlorophyll-a Content

Chlorophyll-a (CHLa) were analysed in laboratory conditions following the standard methods (APHA, 2014). CHLa concentration was measured by using a spectrophotometer after extraction in ethanol.

3.6 Determination of Trophic Status Index

The three trophic state indicators ($TSISD$, $TSIChla$ and $TSITP$) were computed mathematically based on the respective equations for the three parameters (transparency, chlorophyll-a, nitrogen and phosphorus), and the overall Carlson Trophic State Index. (CTSI) was calculated by averaging the TSI values obtained from the three trophic state indicators.

Table 3.1: Classes of Trophic State Index values and their Ecological Attributes

TSI	**CHL (mg/L)**	**SD (m)**	**TP (mg/L)**	**Status**	**Ecological Attributes**
<30	<0.95	>8	<6	Oligotrophy	Clear water, oxygen throughout the year in the entire hypolimnion
30–40	0.95–2.6	8–4	6–12	Hypolimnia	shallower lakes may become anoxic
40–50	2.6–7.3	4–2	12–24	Mesotrophy	Water moderately clear; increasing probability of hypolimnetic anoxia during summer
50–60	7.3–20	2–1	24–48	Eutrophy	: Anoxic hypolimnia, macrophytes problems possible
60–70	20–56	0.5–1	48–96		Blue-green algae dominate, algal scums and macrophytes problems
70–80	56–155	0.25–0.5	96–192	Hypereutrophy	(light-limited productivity): Dense algae and macrophytes, algal blooms possible throughout summer
>80	>155	<0.25	192–384		Algal scums, few macrophytes

* Adapted from Carlson (1977a). A coordinator’s guide to volunteer lake monitoring methods. Madison, USA: North American Lake Management Society**.**

3.7 Data Analysis

Mean, standard error and range were calculated for each parameter in each station and one way Analysis of Variance (ANOVA) was used to compare the parameters. Carlson Trophic State Index was used to calculate the trophic status of the reservoir. Canonical correspondence analysis (CCA) was used to evaluate relationship between phytoplankton communities and environmental variables with PAST statistical analysis.

CHAPTER FOUR

4.0 RESULTS AND DISCUSSION

4.1.1 Physicochemical parameters of Tungan Kawo reservoir

Physicochemical parameters of Tungan Kawo Lake, the mean, standard error and range of physicochemical parameters measured during the study period in Tungan Kawo Reservoir, Kontagora, between February to August, 2020 is summarized in Table 2. Water temperatures fluctuated between 30.51 and 30.79 ^{0}C in the three stations. The pH values ranged from 6.47 to 6.66. Electrical conductivity was highest (107.86 µs/cm) in station 3 while the least value was recorded in station two with the mean of 113.00 µs/cm. The highest mean value for alkalinity, water hardness and phosphate were 53.71, 47.14, and 2.59 mg/L, respectively in all stations sampled. The biological oxygen demand (BOD) level ranged from 6.04 to 6.09 mg/L while level of Nitrate recorded in the three Stations were ranged between 2.09 to 2.23 mg/L.

Table 4.1: Physicochemical Parameters of the Three Sampling Stations of Tungan Kawo Reservoir from February to August 2020

Environmental Variables	Station 1	Station 2	Station 3	**WHO	*NIS
Temperature (°C)	30.51 ± 0.51^{a} (28.95-32.70)	30.71 ± 0.51^{a} (28.70-32.40)	30.79 ± 0.59^{a} (28.60-32.80)	30-32	-
pH	6.63 ± 0.17^{a} (6.38-7.62)	6.66 ± 0.18^{a} (6.38-7.74)	6.47 ± 0.15^{a} (5.87-7.22)	6.5-8.5	6.5-8.5
Dissolved Oxygen(mg/L)	4.56 ± 0.14^{a} (4.20-5.30)	4.54 ± 0.12^{a} (4.00-4.90)	4.91 ± 0.14^{a} (4.40-5.40)	7.5	-
Electrical Conductivity(µS/cm)	106.57 ± 9.02^{a} (61.00-141.00)	113.00 ± 6.80^{a} (97.00-151.00)	107.86 ± 2.96^{a} (98.00-120.00)	1000	1000
Hardness(mg/L)	43.71 ± 2.84^{a} (30.00-50.00)	47.14 ± 2.76^{a} (38.00-58.00)	42.29 ± 1.54^{a} (36.00-48.00)	150	150
Biochemical Oxygen Demand(mg/L)	6.09 ± 0.60^{a} (3.80-8.40)	6.04 ± 0.57^{a} (4.20-8.80)	6.12 ± 0.56^{a} (4.00-8.00)	6	-
Phosphate (mg/L)	2.60 ± 0.06^{a} (2.36-2.76)	2.59 ± 0.04^{a} (2.43-2.71)	2.58 ± 0.04^{a} (2.38-2.70)	5	-
Nitrate (mg/L)	2.09 ± 0.18^{a} (1.26-2.63)	2.23 ± 0.16^{a} (1.54-2.61)	2.19 ± 0.18^{a} (1.42-2.55)	11	50

Values are presented as mean ± standard error of mean (minimum and maximum values are in parentheses). Values with different superscripts in a row are significantly different at $p < 0.05$. *Nigerian Industrial Standard (2015) ** World Health Organization (2011)

Table 4.2: Trophic Status of Tungan Kawo Reservoir from February to August 2020

Trophic Status Index	Station 1	Station 2	Station 3
Transparency	78.89	81.20	78.89
Phosphate(PO_4)(mg/)	17.93	17.87	17.82
Nitrate (NO_3) (mg/L)	65.09	66.02	65.76
Chlorophyll-a	40.16	40.63	41.08
TOTAL	40.64	41.29	41.44

4.1.2 Phytoplankton community structure and composition in Tungan Kawo reservoir

From the analysed data, visible change in phytoplankton community with regard to numerical abundance was evident in the reservoir. A total of 33,583 cells/l of phytoplankton was found through the analysis of the samples collected from the three stations from February to August 2020. *Chlorophyceae* made up the highest and a low number of *Cyanophyceae*. The most diverse specie was *Chlorophyceae* with 9 species followed by Bacillariophyceae with 4 species and Cyanophyceae with 5 species (Tables 4.3 and 4.4).

A high diversity of species was recorded in station 1 from February to May (during the dry season) (Figure 4.1). Chlorophyceae was highest (61.89 %) with 9 genus; *Staurastrum rotula*, *Scenedesmus quadricanda, Hormidium guttatum, Volvox* spp, *Selenastrum, Chlorella elipsoda, Ulothrix, Akistrodesmus* spp, *Closterium kuetzingi, Zygnema* spp. This is followed by Bacillariophyceae with 4 genus (20.81 %); *Diatomella*, *Naviculamutica, Nitzshia, Synedraulnariaceae*. The Cyanophyceae (17.3 %) with 5 genus; *Aphanocapsa ellichista, Lymbia lumnetica, Microspora, Oscillatoria, Chlorogloea microcystoides*. Biological index was used to analyse the phytoplankton community, number and composition (Plates I to IV).

Table 4.3: Genus and Number of cell of Phytoplankton per Millimetre of Water Sample in Tungan Kawo Reservoir 2020

Group (Family)	Genus	CEL/mg		
		Station1	Station 2	Station 3
Chlorophyceae	*Chlorella*	9700	9580	6360
	Scenedesmus	240	210	90
	Hormidium	150	80	40
	Volvox sp.	150	70	-
	Selenastrum	190	110	-
	Staurastrum	325	165	140
	Ulothrix	40	20	-
	Ankistrodesmus	170	100	50
	Closterium	50	40	-
	Zygnema	10	-	-
Bacillariophyceae	*Diatomela*	1210	460	410
	Synedraul	160	100	50
	Nizshia	40	60	50
	Navicula	50	50	100
Cyanophyceae	*Aphanocapsa*	720	600	200
	Lymbya	100	50	50
	Chlorogloea	230	25	25
	Microspora	120	20	-
	Oscillatoria	100	20	-

Table 4.4: Species Diversity, Total Number and Percentage of Phytoplankton Recorded in Tungan Kawo Reservoir from February to August 2020

Class	Genera Diversity	Total Number of individuals	Percentage (%)
Chlorophyceae	9	28,083	61.89
Bacillariophyceae	4	3,240	20.81
Cyanophyceae	5	2,260	17.3
Total	18	33,583	100

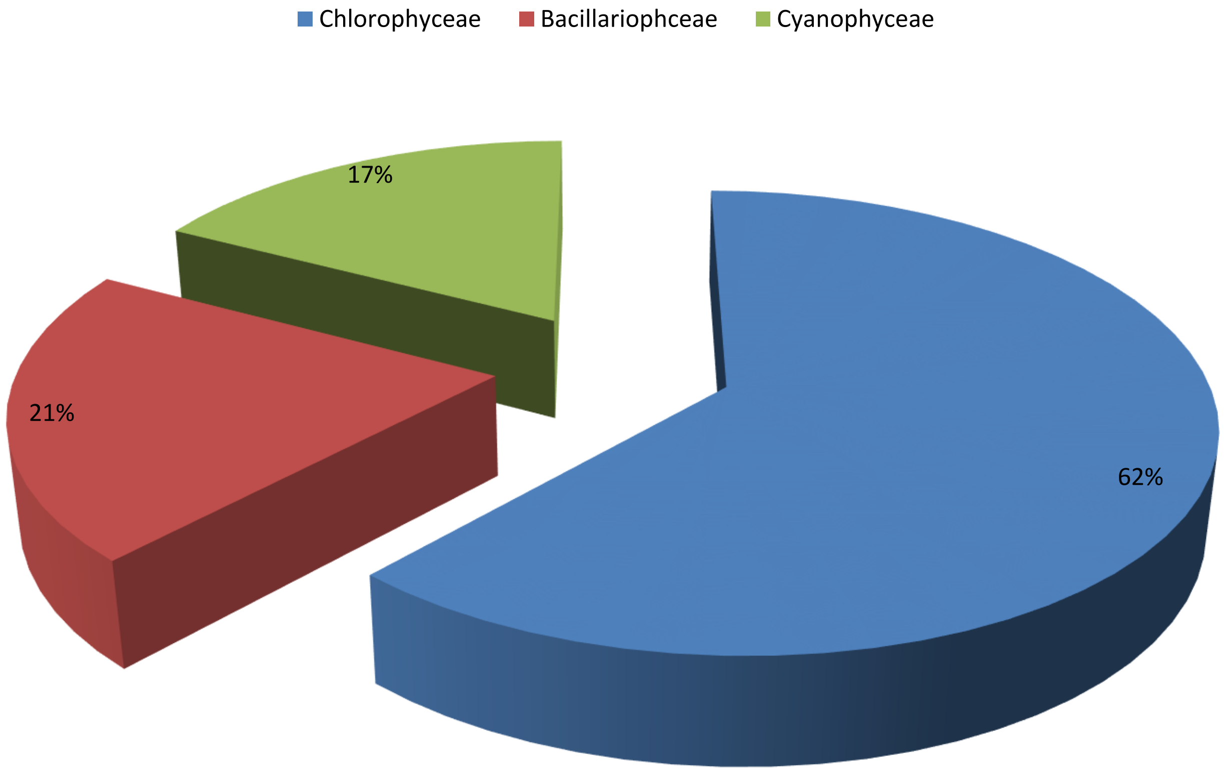

Figure 4.1: Phytoplankton Abundance in Tungan-Kawo from February to August 2020

Plate I: ***Scenedesmus quadricanda*** **(Source: Field Picture)**

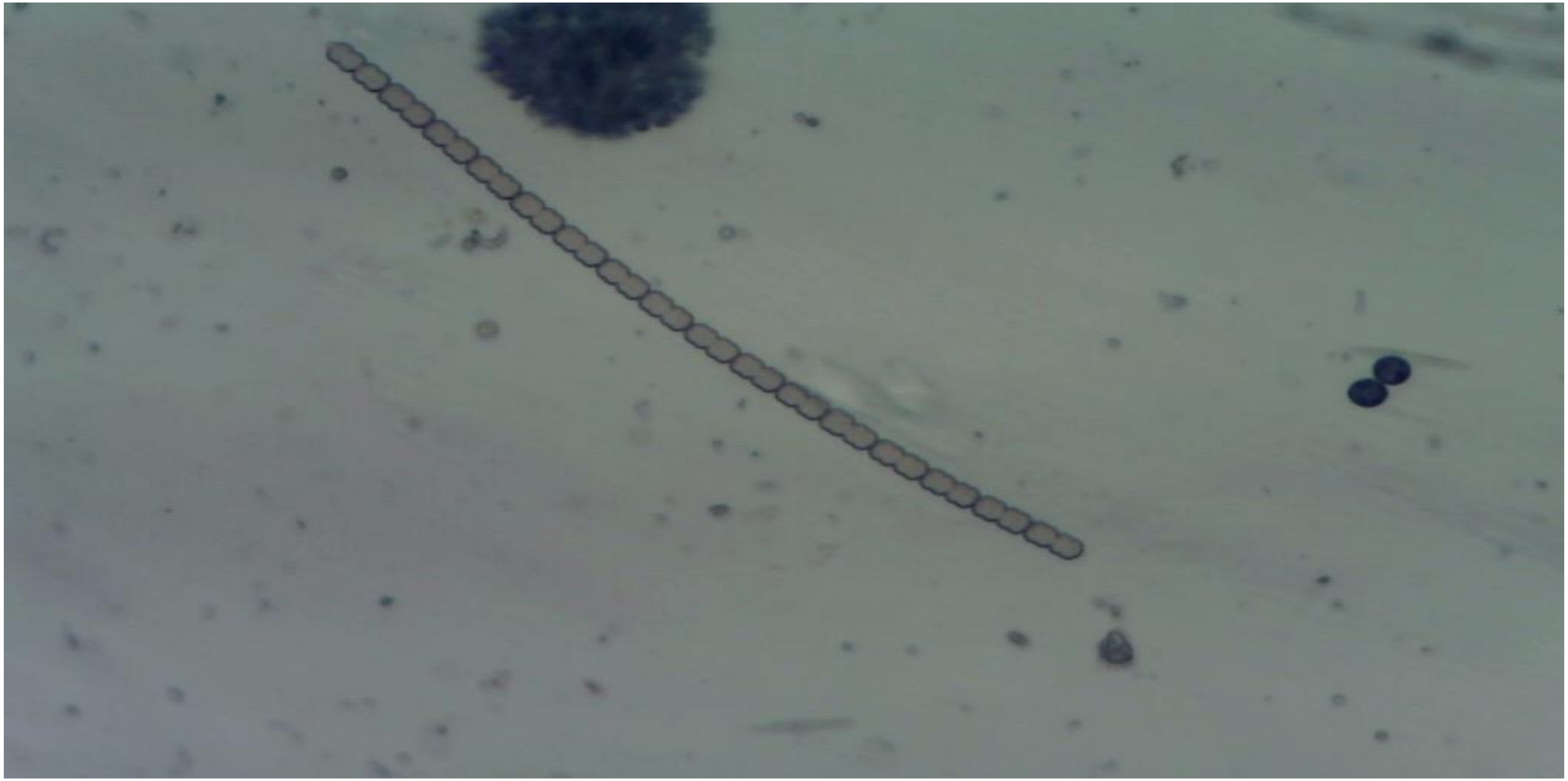

Plate II*: Melosira granulate* (Source: Field Picture)

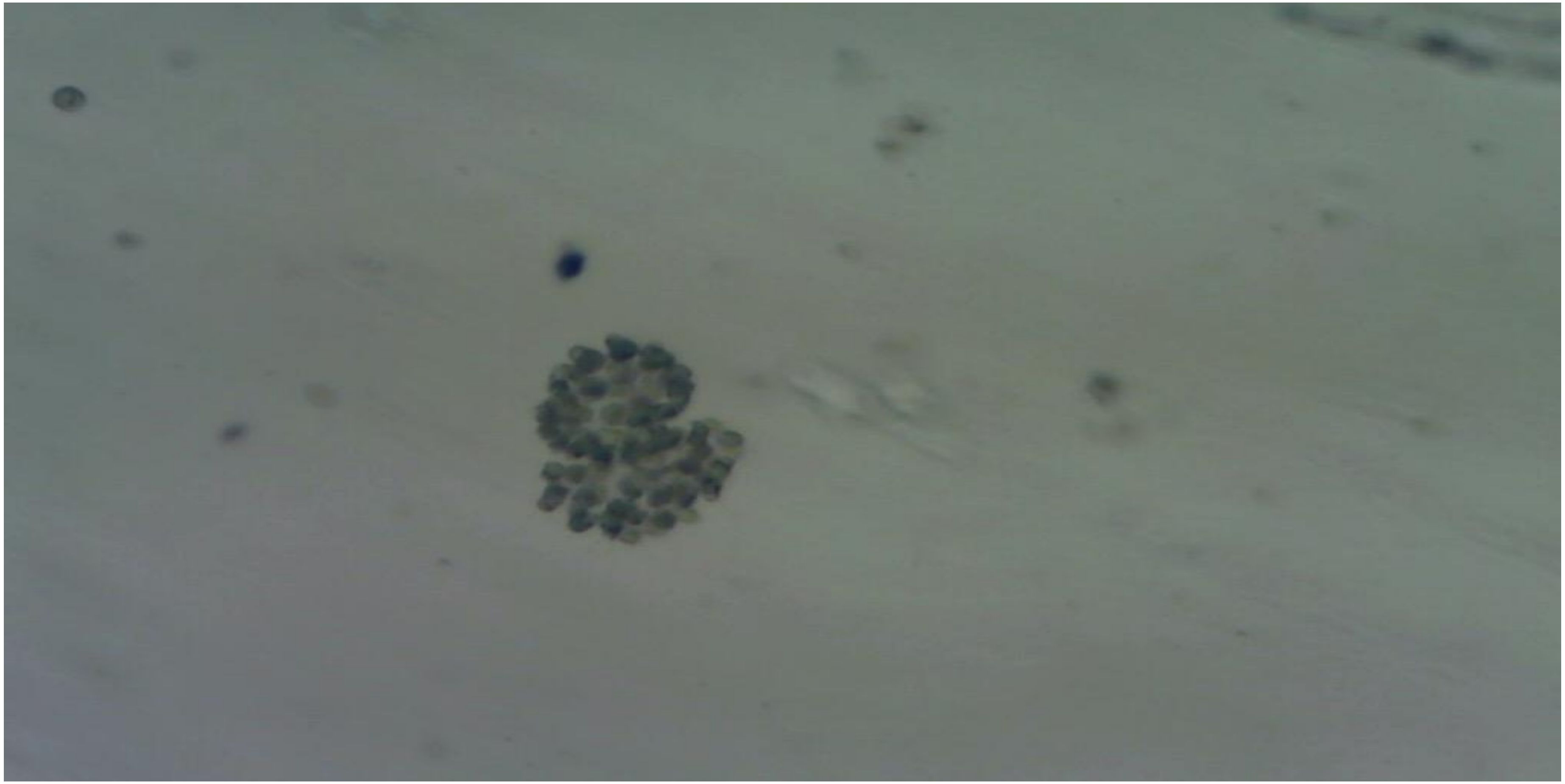

Plate III: ***Anacystis*** **spp (Source: Field Picture)**

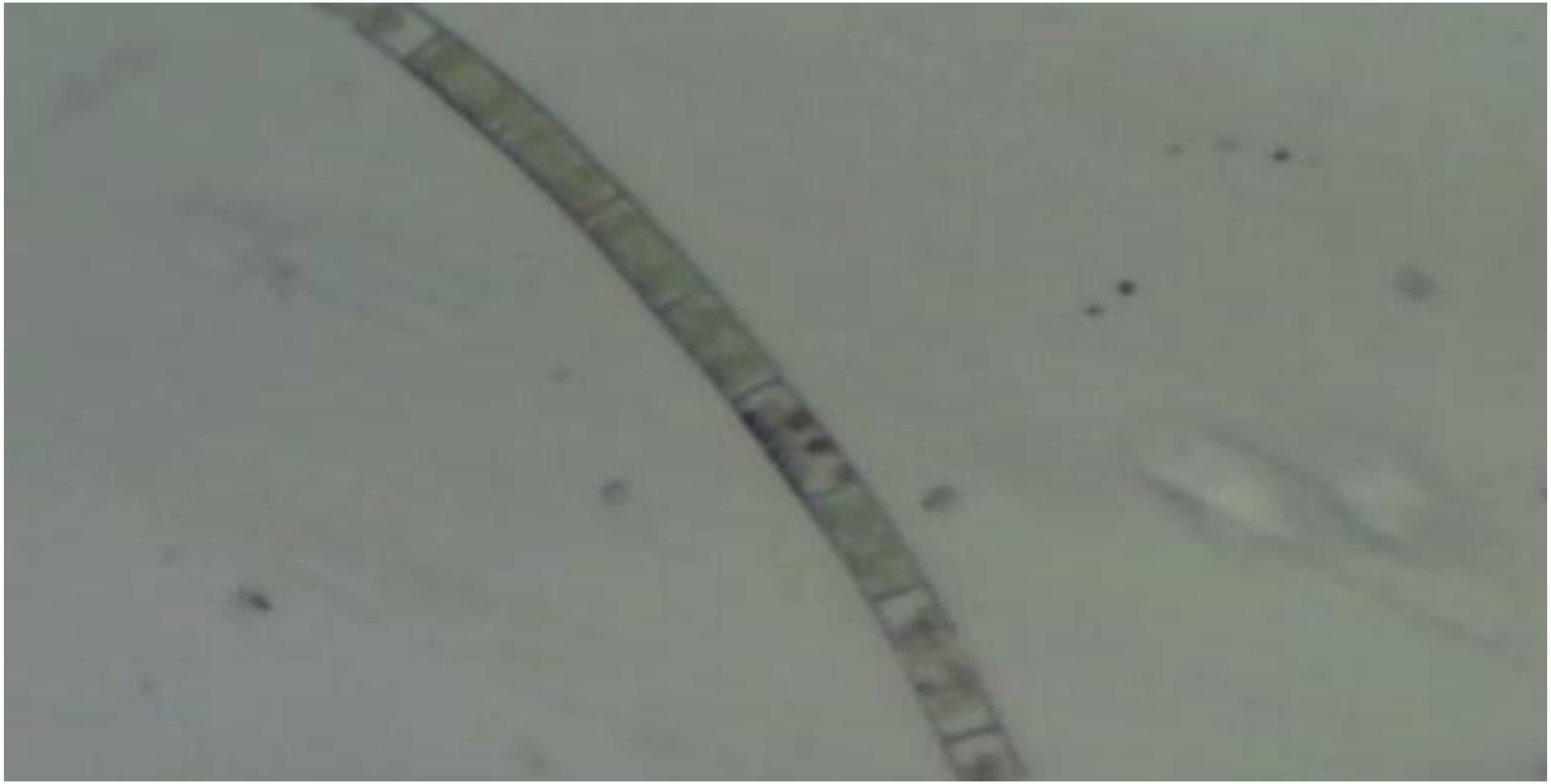

Plate IV: ***Zygnema*** **sp. (Source: Field Picture)**

4.1.3 Temporal distribution of phytoplankton in Tungan Kawo reservoir

The abundance and composition of Chlorophyta was fairly uniform throughout the study period (February to August 2000) of the total phytoplankton composition of 61.89 % (Figure 4.2). Bacillariophyta followed in composition 20.81 %. The highest percentage of Chlorophyta were recorded in July and August while that of Bacillariophyta and Cyanophyta were recorded in the months of April and May. Their composition was fairly constant but with a sudden drop in August. All phytoplankton groups increased gradually with a peak in May (Table 4.5) and gradual drop recorded from June to August apart from Chlorophyta.

4.1.4 Relationship between Phytoplankton Groups and Environmental Variables in Tungan Kawo reservoir

According to the Canonical Correspondence Analysis (CCA), Phosphate and Temperature had a stronger positive impact on the relative abundance of the phytoplankton groups than Biochemical oxygen requirement and Alkalinity, which had a greater negative impact whereas Electrical conductivity and Phosphate exerted positive influence on *bacillariophyceae* and low velocity on *Cyanophyceae* and *chlorophyceae*. However, nitrate exerted negative influence on *chlorophyceae* as show in figure 4.3.

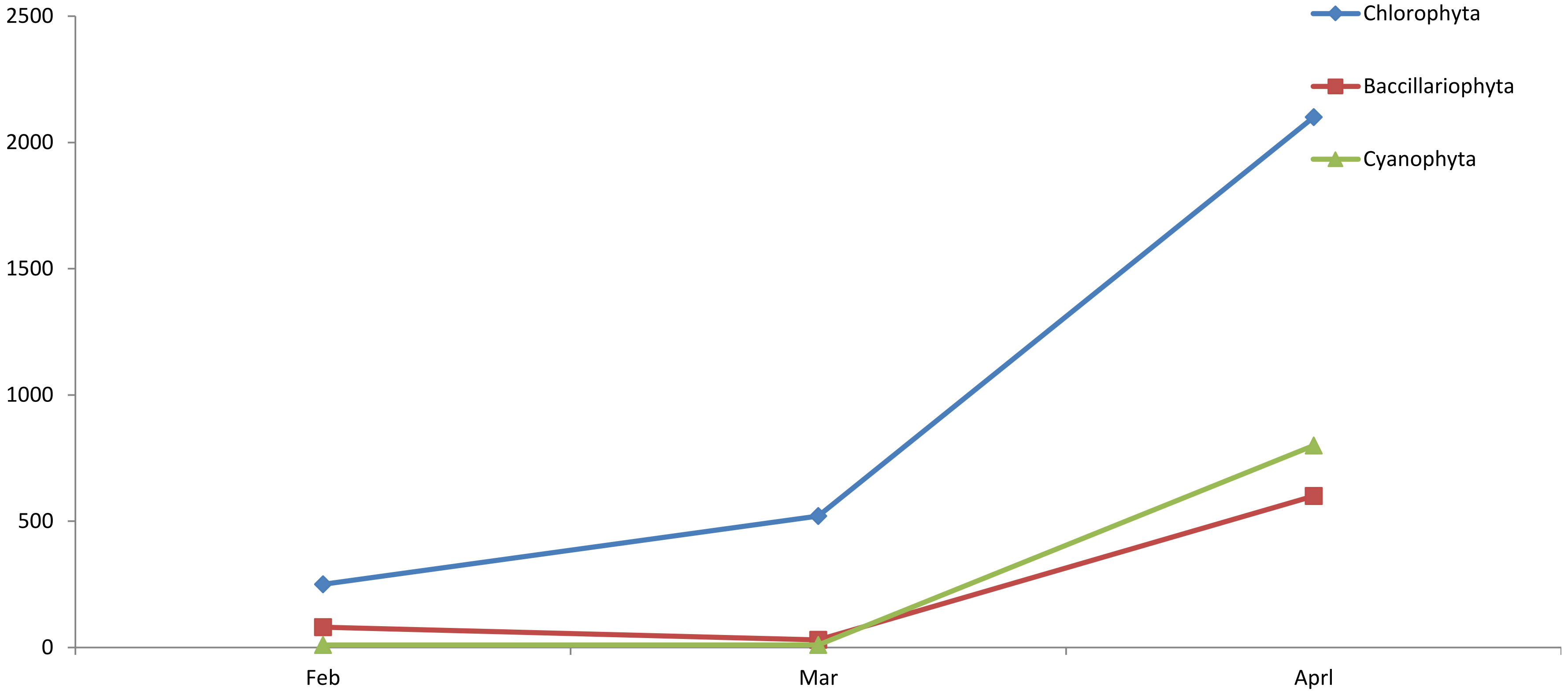

Figure 4.2: Temporal distribution of phytoplankton recorded in Tungan Kawo Reservoir February to August 2020

Table 4.5: Monthly distribution of phytoplankton recorded in Tungan Kawo Reservoir February to August 2020

Month	**February**	**March**	**April**	**May**	**June**	**July**	**August**
Chlorophyta	250	520	2100	3500	2820	5700	13250
Baccillariophyta	80	30	600	1700	50	120	150
Cyanophyta	10	10	800	1100	80	100	160

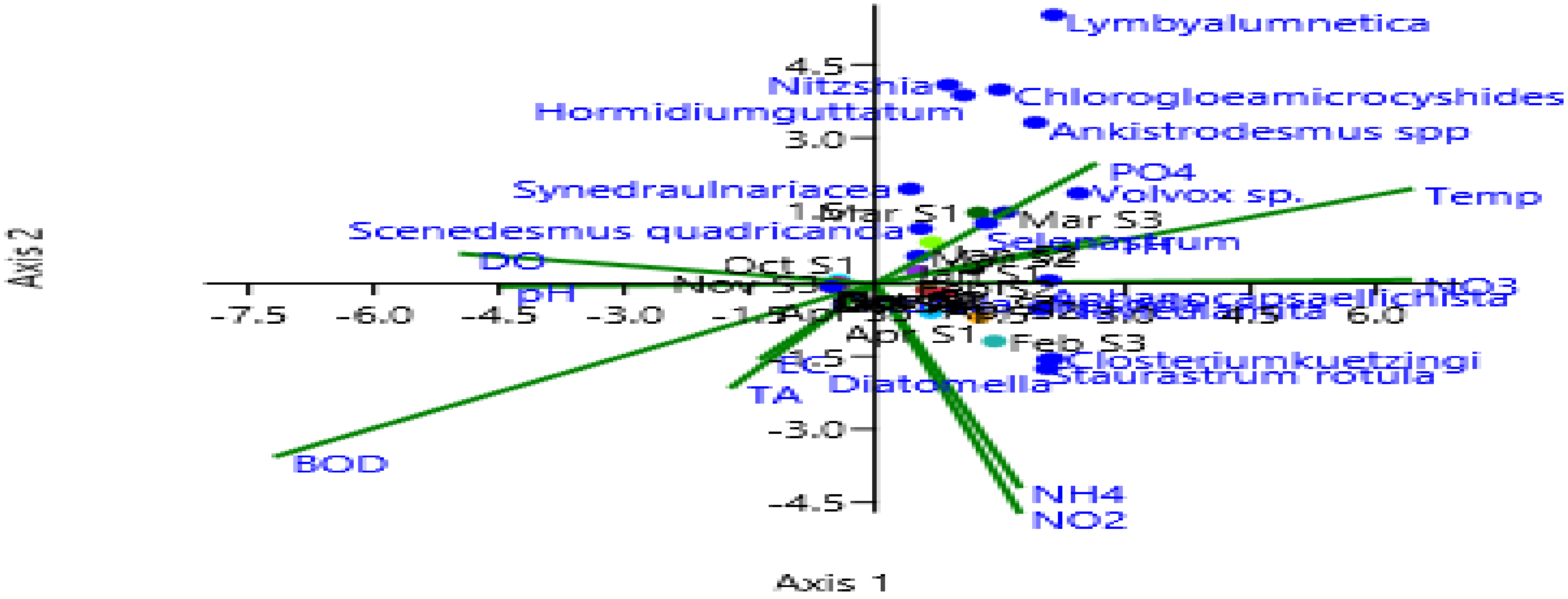

Figure 4.3: Canonical Correspondence Analysis (CCA) Ordination Showing Associations between Phytoplankton Species

Table 4.6: Canonical Correspondence Analysis (CCA) Ordination Showing Associations between Phytoplankton Species and Sites Sampled

Eigen value	Axis1	Axis2	Axis3
	0.4461	0.1445	0.0044
% explained	63.29	20.51	6.28
Temp	0.0982159	-0.144121	-0.468357
pH	-0.210013	-0.0797467	-0.474346
DO	**-0.320237**	-0.133224	**-0.515349**
EC	-O.755195	-0.115143	-0.407453
TA	-0.147922	-0.268133	**-0.472491**
TH	0.13892	0.0333435	-0.263252
BOD	**-0.58552**	-0.312643	-0.43504
$P0_4$	-0.0397005	-0.102583	-0.44535
NO_3	**0.459099**	-0.139379	-0.0971866
NO_2	-0.0422931	-0.15535	**-0.453593**
NH_4	**0.3242**	**-0.395923**	-0.13535

4.2 Discussion

4.2.1 Physiochemical parameters of Tungan Kawo reservoir

The productivity of the aquatic ecosystem in terms of biota is generally determined by physiochemical characteristics of the water body (Arimoro *et al*., 2018). The pH recorded in this study shows the water to be highly alkaline. The pH values recorded in this study did not have a predictable seasonal pattern. This is because the reservoir was surrounded with rocks such as limestone which increased the pH (Abdullahi *et al*., 2015). The pH values are within the permissible limit of standard organization of Nigeria (6.5 – 8.5) for fresh water bodies. This value range is in line with earlier report by Edegbene and Arimoro (2014), who recorded a value range of 6.1 – 7.6 of pH in Owan River, Niger Delta, Nigeria the work was also consistent with Auta *et al*. (2016) findings on the Izom River Gurara, which documented the greater average range (6.8–9.7) for the study period. Thus, the pH range obtained in this study is above the acceptable level of 6.5 to 8.5 for the recommended levels for drinking water (World Health Organization, WHO, 2011; Nigerian Industrial Standard, NIS, 2015). However, it can support aquatic life (Ayanwale *et al*., 2018).

The Tungan Kawo reservoir temperature ranges from 29.70 ^{o}C to 30.40 ^{o}C. The highest temperature was recorded in station 3 and the lowest in station 1. This is because of the shallowness of the sampling station and the volume of water in contact with air. This report resembles work of Masese *et al*. (2009) and Keke *et al*. (2015) who have reported that the average surface air temperature and surface water temperatures are typical for African tropical rivers and that fish grow best at 25 ^{o}C until 32 ^{o}C. According to this, the data obtained are followed by the work of Okunlola *et al.* (2014) and Oyakhilome *et al*. (2012), which documented an ideally suited mean temperature value (27.53 ^{0}C to

31.65 ^{0}C). Secchi disk transparency observations have become an integral component of large lake surveillance strategies. These measurements form the only major ‘‘optical history’’ for water bodies on a global scale (Naumenko, 2008)

The oxidisation-reduction condition of many chemical substances such as nitrate and ammonia, sulphate and sulphite, ferrous and ferric ions has been affected by dissolved oxygen (DO) in water. However, the DO documented in these studies was within the permissible limits of drinking water (NIS, 2015). The work is in agreement with Ayoade *et al*. (2007) and Abubakar *et al*. (2015) who worked on Dadin-Kowa reservoir and recorded a DO (2.73 to 4.92 mg/L) which indicates a thriving basis for aquatic organisms.

The BOD level in this study showed that Tungan Kawo was moderately clean. The higher BOD value in Station 1 can be due to the higher rate of organic matter decomposition. Similar to the report from Lewis (2002) and Idowu *et al.* (2013), which documented that tropical water at higher temperatures does not have the capacity to retain oxygen in comparison to water at lower temperatures and at higher temperatures in microbial metabolic rates. Contradicts findings Keke *et al*. (2015) reporting a high level of easily degradable and organic matter entering the river from the downstream work in Kaduna River in Zungeru where BOD is increased by1.00–5.00 mg/L.

Electrical conductivity has demonstrated that the water in all areas is fresh, but indicates that human activities have a negligible effect in the region. Conductivity sources can include an abundance of dissolved salts due to poor irrigation and rain water runoff minerals. Similarly, the findings of Idowu *et al*. (2013) and Abubakar *et al*. (2015) recording a mean value of 432 due to continuous discharge into the reservoir are consistent with this.

Nutrient availability (i.e. TN and TP) and their concentrations level have been found to be the prime factors influencing algal growth and biotic productivity of aquatic system (Okech *et al.*, 2018). TN content in lake water can be attributed to the anthropogenic sources such as runoff from nearby villages/human settlements.

4.2.2 Physiochemical community structure abundance of Tungan Kawo reservoir in Tungan Kawo reservoir

The result obtained from the phytoplankton abundance compared favourably with some Nigerian reservoir waters. *Chlorophyceae* was most abundant closely followed by *Bacillariophyceae*. The water quality was not significantly different from each other. This result however varied considerably with Edward and Ugwumba (2010) who identified 35 genera of phytoplankton and diatoms being evenly distributed in Egbe reservoir, Ekiti state, Nigeria. The distribution of *bacillariophyceae* agrees with the report of Aneni and Hassan (2003) that shows great diversity and equitability in Onireke and Kudati stream, Ibadan. The research shows that phytoplankton abundance is in the following decreasing order: *Chlorophyceae>Bacillariophyceae>Cyanophyceae*. This order of phytoplankton abundance observed is different from report of that of Chindah (2003) who said Shallow lakes will inevitably support a phytoplankton community fitted to their particular conditions and hydrodynamic factors tend to be even more important for plankton distribution in these lakes (Cardoso *et al.*, 2012). Also, these systems are often influenced by water-level variations and may show alterations in the phytoplankton structure, because of a primary effect on abiotic conditions such as light and nutrient availability (Crossetti *et al.*, 2007). Water-level fluctuations emerged as the decisive element of the hydrology, especially in shallow lakes embedded in wetlands that are particularly sensitive to any rapid change in water level and input (Coops *et al.*, 2003), as is the case for Mangueira Lake (Crossetti *et al.*, 2013). Several studies have demonstrated the influence of water level variations on the structure of phytoplankton (Izaguirre *et al*., 2004; Crossetti *et al*., 2007; Wang *et al.,* 2011).

Phytoplankton assemblages, which are key primary producers in lakes, reservoirs and various water bodies, are sensitive to variations in multiple environmental factors (Uttah *et al*., 2013). The finding in this work is in consonance with the reports of Onwudinjo and Egborge (1994) in Benin River. It has been reported that rapid currents during wet season damaged and reduced phytoplankton density whereas on the other hand moderate current enhanced the development and abundance of phytoplankton species during dry season (Ekpo *et al*., 2015). High phytoplankton density during the dry season could also be due to better penetration of sunlight, reduced effect of flood regimes, favourable high pH and stimulatory effects of heavy metals which form complexes that allows Phosphate-Phosphorous and Nitrate-Nitrogen to be available for phytoplankton productivity (Arimoro *et al*., 2008b). High phytoplankton densities observed in May, June and July could be attributed to the increase in nutrient input as a result of the rains which favoured accelerated phytoplankton growth in the early wet season. Generally, station 1 had slightly higher nutrient values (nitrate and phosphate) than the other stations because of the relatively higher impact from various human activities. This perhaps explains the rather high abundance of phytoplankton at that station. However, as a result of the unidirectional flow of water, these group of organisms would probably drift to station 2 or 3.

4.2.3. Trophic state of Tungan Kawo reservoir

Computation of trophic state index (TSI) is more realistic approach for classifying lake. This method includes numerical standardization of selected variables (i.e. water transparency, CHLa, TP and TN); and often used for the purpose of classifying and evaluating the trophic status of various regional water bodies and lentic systems (Carlson, 1977b; Matthews *et al*., 2002). Chlorophyll-a is used by all phytoplankton to capture sunlight for photosynthesis, it is simply the algal trait of the water column and function as a reliable measure of phytoplankton biomass (Swierzoski *et al*., 2000). Secchi disk transparency is a good indicator of chlorophyll-a concentration and reported to be negatively related to chlorophyll-a concentration (Almazan and Boyd, 1978). Based on Carlson (1977a) trophic state classification, Tungan Kawo reservoir may be classified as mesotrophic during both dry and wet seasons. The Trophic State Indices calculated for Tungan Kawo reservoir as shown in Table 3, the reservoir's trophic state index calculated was 40.64, 41.29, and 41.44 respectively for station 1, 2 and 3, which indicates moderately clear water as in Mesotrophy for Tungan Kawo reservoir. The mean value of 0.5 m measured for Secchi depth eutrophic system. However, this is doubtful, because the low transparency of the lake is associated with suspended inorganic matter, not algal density (Oduor *et al*., 2003).

Deviations in trophic state indices have been used to draw inferences regarding factors that may be limiting autochthonous production in lake systems. Based on Carlson (1977b) and Havens (2000), if TSICHL is less than TSISD it suggests that the seston is dominated by abiotic particles, which results in high light diminution and that light may be limiting algal production.

CHAPTER FIVE

CONCLUSION, RECOMMENDATIONS AND CONTRIBUTION OF RESEARCH TO KNOWLEDGE

5.1 Conclusion

The result of the physiochemical parameters shows that all the values obtained were within the guideline limit recommended for survival of aquatic organisms. Phytoplankton abundance shows a moderate water quality with dominance of chlorophytes. Value obtained from Carlson Trophic Status Index indicates a mesotrophic water body with moderate amount of nutrients.

5.2 Recommendation

A constant monitoring of the reservoir should be carried out in order to forestall a further degradation of the water quality and the diversity of the biota. Regular sensitization should be conducted to enlighten people on the side effects of releasing agricultural waste as well as domestic waste in the reservoir as it affect quality of the water as well as the diversity of organisms in reservoir.

5.3 Contribution of Research to Knowledge

The thesis established that the temperature (30.79 ^{o}C), pH (6.47 – 6.66), Electrical conductivity (107.86 µS/cm), hardness and Phosphate, ranged from 53.71 to 46.43 mg/L, 47.14 to 42.29 mg/L, 2.60 to 2.58 mg/L respectively and were within the standard for drinking water. The phytoplankton total number was 33,583 cell/mL. However, the highest family was *Chlorophyceae* (9 genera) in station 1 with 28,083 cell/mL, followed by *Bacillariophyceae* (4 genera) with 3,240 cell/mL and *Cyanophyceae* (5 genera) with 2,260 cell/mL.

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