AQUATIC MACROPHYTES DYNAMICS AND ITS IMPACTS ON FISH PRODUCTIVITY IN ELEYELE LAKE, IBADAN, NIGERIA

BY

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ABSTRACT

Littoral zones invasion by macrophytes could facilitate major changes in lake ecosystem especially on the composition of other aquatic assemblages. It has been established that data on environmental interplay influencing macrophytes' dynamics are needed for effective management of aquatic resources in lakes. However, information on macrophytes composition and other environmental variables required for sustainable management of fish production in Nigeria's lakes, such as Eleyele Lake (EL), is limited. Therefore, environmental factors, macrophytes diversity and their effects on fish productivity in EL were investigated.

Eleyele Lake was stratified into five zones (mouth Z1, upper Z2, middle Z3, lower Z4 and head Z5) based on the hydrological features. Three sampling points were randomly selected per zone. Water, sediment and macrophyte samples were collected from each sampling points bimonthly covering wet (May-November) and dry (December-April) seasons for 24 months. Fish samples were obtained from fishers' catches. Water samples were analysed for Temperature (^oC), Dissolved Oxygen (DO, mg/L) and Net Primary Productivity (NPP, $mgO_2/L/day$). Organic carbon and silt in sediments were determined following standard methods. Macrophytes and fish samples were counted and identified to species level. Macrophyte species diversity were determined using Simpson's (1-D) and Shannon-Weiner (H) indexes. Potential Fish Yield (PFY, Kg/ha) was calculated. Environmental Integrity (EI) and Vegetative Quality (VQ) of Macrophytes were evaluated using Aquatic Macrophytes Community Index (AMCI: 7 poorest EI to 70 highest EI) and Floristic Quality Assessment (FQA : 1-19 low VQ, 20-35 high VQ; > 35 natural VQ). Data were analyzed using descriptive statistics, ANOVA and canonical correspondence analysis, at $\alpha_{0.05}$.

Temperature, DO and NPP ranged from 25.10±1.17 (Z1) to 25.40±1.15 (Z5); 4.25±0.93 (Z2) to 4.65±1.14 (Z5); 0.26±0.13 (Z3) to 0.53±0.21 (Z4), respectively. Temperature was (25.30±1.12, 25.29±1.19) DO (4.07±1.22; 4.51±1.08) and (NPP 0.55±0.31; 0.62±0.03) were for dry and wet seasons, respectively. Organic carbon and silt varied significantly from 4.66±1.61 (Z2) to 5.19±1.37 (Z4) and 18.97±3.92 (Z1) to 21.11±3.59 (Z2), respectively. Organic carbon and silt were 4.96±1.31, 5.02±1.35 and 20.52±4.14, 20.59±3.43 for dry and wet seasons, respectively. Ten families and 14 species of macrophytes were recorded with 7 and 14 species encountered during dry and wet seasons, respectively. *Ipomoea aquatica* was most dominant (15.4%) while *Cyprerus rotundus* had the least population (23.3%). A total of 3392 fishes belonging to 7 families and 9 species were recorded. Fish catch recorded in dry season was higher (1830) than wet season (1562). Macrophyte diversity were higher during wet season (1-D=0.90, H=2.4) than dry season (1-D=0.81, H=1.70). Highest and least PFY 536.72 and 367.04 were obtained in dry and wet seasons, respectively. Least AMCI (30) was recorded in Z1 while Z2, Z3 and Z4 had 37, each. Highest and least AMCI were 42 and 33 for dry and wet season, respectively while FQA was 16.05. Macrophyte composition and NPP impacted negatively on PFY with Eigen-value of 98.6%.

Macrophyte composition in Eleyele lake is of low vegetative quality and had resulted in moderately poor environmental integrity. This has negatively impacted the aquatic diversity and fish productivity.

Keywords: Macrophyte composition, Fish productivity, Vegetative quality, Eleyele Lake
Word count: 493

CERTIFICATION

We certify that this research was carried out by Yewande Adetoke SUNDAY (Matric. No.: 160072) in the Department of Aquaculture and Fisheries Management, University of Ibadan, Nigeria under our supervision.

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DEDICATION

This work is dedicated to the Alpha and Omega; and to all my teachers.

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LIST OF ACRONYMS AND ABBREVIATIONS

%	Percentage
AMCI	Aquatic Macrophytes Community Index
ANOVA	Analysis of variance
APHA	American Public Health Association
BOD	Biochemical Oxygen Demand
C	Common
CCA	Canonical Correspondence Analysis
COD	Chemical Oxygen Demand
CR	Community Respiration
D	Dense
Do	Dissolved oxygen
FAO	Food and Agriculture Organization of United Nations
FO	Frequency of Occurrence
FQA	Floristic Quality Assessment
GPP	Gross Primary Productivity
GPS	Global Positioning System
M	Moderate
MANR	Ministry of Agriculture and Natural Resources
MEI	Morpho Edaphic index
NO_3-N	Nitrate
NP	No Plant
NPP	Net Primary Productivity
O	Occasional
PAST	Paleontological Statistics
PCA	Principal Component Analaysis
PFY	Potential Fish Yield
pH	Hydrogen ion concentration
R	Rare
RCBD	Randomized Complete Block Design
S	Sparse

TA	Total Alkalinity
TH	Total Hardness
TOC	Total Organic Carbon
TOM	Total Organic Matter
VD	Very Dense
	Chemical Symbols
Cm	Centimetre
^{0}C	Degree celcius
µS/cm	Micro siemens per centimetre
Kg	Kilogramme
mgL^{-1}	Milligramme per litre
CP	Crude Protein
CF	Crude Fibre
CFat	Crude Fat
C	Carbohydrate
Na	Sodium
Mg	Magnesium
Ca	Calcium
K	Potassium
PO_4	Phosphate
µm	Micro-meter
Mg	Milligramme
M	Meter
Cl	Chloride
μgL^{-1}	Micro-gramme per litre

CHAPTER ONE

INTRODUCTION

1.1 Background to the study

Globally, inland capture fisheries and aquaculture are the most important sector controlling the provision of food and its availability. Inland waters comprise diverse water bodies of vast biodiversity that provides livelihood and different opportunities for man (particularly employments, food security, recreation activities and lots more). Most of these aquatic biodiversity forms of inland waters, which include the plants, fish, reptiles and other aquatic resources, are of great values to humans and are needed for their survival. FAO (2005) reported 9.5 million tonnes harvest from inland capture fisheries and 29.3 million tonnes harvest from inland aquaculture. In 2008, 10 million tons of fish and crustaceans were harvested through inland fisheries (FAO Fishstat, 2010). Also in 2014, out of the 11.9 million tons of fish and crustacean produced globally, 354,466 tons was from Nigeria (FAO, 2016). Welcomme *et al*. (2001) reported that fish from all sources form and provide a single source of animal protein globally, while 36.58%, which was the one third of the total production worldwide in 2007, was from the fish. Fish generally improve the nutritional status of many people worldwide owing to their rich source of protein, vitamins, fatty acids and mineral which provide the essential micro nutrient healthy to human health (Rooset *et al.*, 2010). Fish from inland capture fisheries are of great importance to local food security as compared with other animal protein sources.

The secondary service activities provided by inland fisheries (apart from the livelihood and income through fishing activities) which include the processing, distribution, provision and maintenance of gears used for fishing, generate substantial income and serves as social safety net; even if there is any economic shift, natural disasters often fail in primary source of income (Welcomme *et al.*, 1985). These also have positive effects on the market worth of the fish products and increase the commercial worth of the products. Statisical report showed that inland capture fisheries were growing at a linear rate economically because most of the catches are reportedly not recorded; 90% of the output is going directly to household consumption due to the small scale and individual fisheries of the sector; sometimes fish are traded locally (FAO and World Fish Center, 2008). The post-harvest sector of inland fisheries also contribute to global economic value which gives opportunities to the people involved in the small scale sector, who are most women and account for 54% in the fishing industry. Inland fisheries give great support by providing job and means of livelihood for the unskilled workers who depend heavily on fishing operations and other activities associated with fishing, such as fish processing and marketing for consumption and as a major source of income.

Inland waters are used for different activities which pose a threat to the fisheries arm. These aquatic resources are opened to varying forms of anthropogenic perturbation which has caused a shift in the ecosystem status, bringing about environmental imbalance and general decline in the yield of inland fisheries (Cowx and Welcomme, 1998). Some of these activities include agriculture, power generation, tourism, navigation and recreation use, urbanization, land use practices (forest use, charging run-off and sedimentation), waste disposal, which causes pollution of the water and the environment. All these practices compete with and modify the environmental structure of the inland fisheries, which greatly affect the capacity and property of the water. Inland waters are the ultimate sink of wastes like chemicals, agricultural run-off, sewage disposal, sedimentation and other forms of pollution accumulate. The exposure of inland water globally, with increased pressure of overfishing, population growth and urbanization, affects and depletes all these diverse resources in the water bodies (Allan, 2004). Most of these factors result in decline in biodiversity, loss of habitat, degradation and overexploitation of the environment. Extinction of native species in inland water, which results in decline in these various species, always engenders loss of aesthetic and the ethical/moral values as well as nutritional values, and loss of income and livelihood (Mustapha, 2010).

Downing and Duarte (2009) reported 304 million natural lakes which cover 4.2 million km^2. The contribution of lakes and reservoir to inland water resources in terms of size and production capacity cannot be overlooked (FAO, 2012). The world population keeps increasing, with fast-growing industrialization and modernization, but there is no proper channelling of waste product or treating the effluent before it will be discharged to the environment. Most of these wastes are discharged directly into the lakes, polluting the water bodies, causing habitat loss, degradation of the environment, and bringing proliferation of aquatic macrophytes, which reduces fish productivity. These aquatic macrophytes compete with the fish for nutrients in the water, which are needed for their growth and productivity. They also affect the water quality and the quantity of nutrients that will be available for the fish as well as sediments (Olowu *et al.,* 2010).

Both the overall water quality parameters and the cumulative effect of conditions of lower biological forms will be affected in any location with the occurrence of aquatic macrophytes (APHA, 2005). In the north temperate waters, the stability of fish community assemblage has been connected with the proliferation and distribution of different species of macrophytes (Thomaz, 2009). Increase in aquatic macrophytes cover may cause reduction in the quantity of particular fish population, including white bass (*Morone chrysops)*, gizzard shad (*Dorosoma cepedianum*) and inland silverside (*Menidia beryllina).* These fish are usually reduced because of the effect of dense vegetations present (Dibble, 2009). Sometimes, some adult fish and many juveniles desire environments with aquatic flora and usually have greater statistics of fish than unvegetated parts. This is corroborated by the discoveries of Cross *et al.* (2006), with higher numbers of fish (more than 1 truckload fish) per acre in areas comprising a variety of aquatic plants.

Conversely, heavily vegetated area (with thick macrophyte covering) can limit the benefits related to passive (vegetated) environment by decreasing fish feeding capacity. This leads to a populace of fish with great countless quantities of fish which cannot mature to a bigger size (a situation which is denoted as a “stunted or underdeveloped populace”). In this kind of environment, there are some individuals feeding in densely populated area with better fodder resources but mostly for lesser folks, but with limited scavenging chances meant for bigger fishes (Dibble, 2009).The effect of aquatic macrophytes on the ecosystem, particularly light diffusion across the water column, water temperature, water flow and substrate, are very enormous (Petr, 2000). The light intensity rapidly falls with depth, within aquatic vegetation standpoint, though there are more variances within the amount of light reduction among classes (Matthew *et al*., 2008).

Macrophytes have encouraging impact on water transparency over a quantity of method used which includes refuge for flora affliated macro-invertebrates and cladocerans.The phytoplankton and epiphytes, in turn, graze on macrophytes. In most of the inland waters (lakes and reservoirs) the tropic interaction can be altered through extensive growth of aquatic plants. The population of fish (and other aquatic resources) that live constantly on planktonic algae might remain inversely disrupted through compressed macrophyte distribution. While aquatic macrophytes represent an important habitat for fish, the abundance, and diversity could also affect fish productivity and reduce fish catch during fishing activities (Petr, 2000).

Aquatic macrophytes influence a major part of the aquatic environment by contributing to the diversity of a healthy system and the general fitness of its components, in aiding the nutrient cycling and as a pointer of impurity in water quality (Oyedeji *et al.,* 2013). Also, they play a very crucial part in the composition of the communities, growth habitat complication and heterogeneity of the system, besides providing a physical structure for the aquatic environment (Sidinei and Eduardo, 2010). The young fish use the plant covers of the aquatic flora to escape raiders and also forage on the food related to algae and microfauna (such as zooplankton, insects and larvae) that live next to the aquatic plants (Dibble, 2009). Also, fish use these plant covers for spawning, breeding of young ones and protection from harsh environment. Extreme growing of these aquatic macrophytes may cause decline in fish population while some developed species of fish may travel to other exposed and spacious water bodies to reduce foraging competition (Valley *et al.,* 2004)

Various health stressors affect the aquatic ecosystem, deplete the biodiversity significantly and alter the physical and chemical constituents of the water. The loss of all these biodiversity resources and their effect on the inland water bodies are predicted to have greater influence on aquatic ecosystem than the terrestrial ecosystem in the nearest future (Sala *et al.,* 2000).

1.2 Justification for the study

Environmental safety procedures are not firmly enforced in Nigeria. This makes the inland waters (lakes, rivers, stream, reservoirs) the major discharge point for substantial magnitude of affluents stretching from sewages, surface run-off and effluents from industries (Arowomole, 1997; Adewuyi *et al.* 2010; Jenyo-Oni and Oladele, 2016). Rising growth in human population and urbanisation have also resulted in rapid economic growth and have brought about increased production of toxic chemicals (Tetsuro *et al*., 2005). In lake ecosystem, aquatic plants generally form an important component influencing the physical (light penetration into water column) and chemical constituents and human activities (Shekede *et al*., 2008). Aquatic macrophytes, especially duck weed and water hyacinth, have the potential of substituting as a biological monitoring tool for aquatic environment (Oyedeji *et al.,* 2013). The siltation of the aquatic environment affects the physico-chemical parameters of the water and leads to decline in fish population and productivity (Ayoola and Ajani, 2009).

Eleyele Lake is surrounded by households, agro-allied establishments, like agricultural farm settlements, cassava-processing industries, small-scale industries (block industry, palm kernel oil processing industry), worship centres and many others, which expose the lake to surface run-off and make it the ultimate sink for domestic discharge and effluents. All these different health stressors (pollution, urbanization, industrialization) significantly affect and deplete the biodiversity and the physico-chemical parameters of water (Arowomole, 1997; Sala *et al.,* 2000; Omitoyin and Ajani, 2007; Jenyo-Oni and Oladele, 2016). These also reduce catches during fishing activities and pose a lot of difficulties when the fishing nets are entangled with macrophytes, which affect the daily income of the fisher folks. Humans as the final consumer may also be affected ultimately by this contaminants of the water bodies (Idris *et al*., 2013). Falaye and Olaniran (1995) observe that breakdown of the aquatic bodies due to excessive exploitation of the fin-fish and shellfish resources in the inland waters will have serious impact on the sustainability of the aquatic system.

Several studies have been carried out on aquatic macrophytes, fish, water, and sediments differently. Olanrewaju *et al*. (2017) assessed the physico-chemical status of Eleyele reservoir, Ibadan, Nigeria. Mushtaq *et al.(*2016) explored the various physico-chemical parameters of surface water and sediments of Dal Lake Srinagar, Kashmir. An assessment of ecological evaluation and sustainable fish production in Erelu Reservoir, Oyo, Nigeria was carried out by Kareem (2016). An assessment of physico-chemical parameters in relation to fish abundance in Daberam Reservoir Katsina State was conducted by Lawal *et al*. (2014). A survey of fish fauna of lower Ogun River Isashi, Ogun State, Nigeria was reported by Yakubu (2012). Olaosebikan and Raji (2013) carried out a research on Nigerian freshwater fishes in New Bussa. Uka and Chukwuka (2011) considered the utilization of aquatic macrophytes in Nigerian fresh water ecosystem, while Bolaji (2010) did hydrological assessment of water resources and environmental impact on Eleyele Lake Catchment. Araoye (2009) focused on physical factors and their influence on fish species composition in Asa Lake. Offem *et al*. (2009) examined tropic ecology of commercially important fishes in Cross River State, Nigeria. Mustapha (2008) carried out an assessment of the water quality of Oyun Reservoir, Offa, Nigeria. An evaluation of Grass Carp use for aquatic weed control and its effect on water body was done by Pipalova (2006).

The anthropogenic activities and degradation of the natural environment of most inland waters cause serious damage to the aquatic ecosystem, the composition of fish species and other aquatic resources, physical and chemical qualities of the water bodies, aquatic macrophytes dynamics and productivity of the water bodies. Hence, there is the need to evaluate the current status of aquatic macrophytes dynamics and their impact on fish productivity and also update the past information from previous research on the physico-chemical parameters of Eleyele Lake, Nigeria.

Therefore, this work ascertained the current state of the physico-chemical parameters of Eleyele Lake, macrophytes dynamics and distribution and its impact on fish productivity of Eleyele Lake. The relationship between the macrophytes distribution, physico-chemical parameters, sediment constituents and fish composition were also evaluated.

1.3 Specific Objectives

1. to explore the macrophytes dynamics and distribution in Eleyele Lake;
2. to evaluate the composition, richness and floristic quality of macrophytes in Eleyele Lake based on time and space;
3. to assess spatial and temporal variations in the physico-chemical parameters of water and sediment in Eleyele Lake
4. to evaluate the fish composition, seasonal disparity and abundance and the primary productivity in Eleyele Lake; and
5. to determine relationship between macrophytes distribution, fish productivity and physico-chemical parameters of water and sediments in Eleyele Lake

CHAPTER TWO

LITERATURE REVIEW

2.0 Historical background of the study area

2.1 Eleyele Lake

Eleyele reservoir was contrived mainly for production of potable water to Ibadan by the Water Corporation of the old Western Region in1939 (Jeje *et al.*, 1997). This was done by damning of River Ona, with a strech of 62km right from its fountain to the dam site (Jeje *et al.*, 1997). The dam is situated along Eleyele wetland in the north-eastern area of Ibadan (Ido Local Government Area), south-western Nigeria between longitude N07°25'00" and N07°27'00" and latitude E03°50'00" and E03°53'00'(Tijani *et al.*, 2011)'. The area is bounded by Apete, in the east; Awotan, in the north; and Eleyele, in the south. The catchment area of Eleyele wetland is reasonably well-drained, through connection of River Ona and its tributaries (such as Ogbere, Alapata and Ogunpa). River Ona runs coarsely in the north-south route (Tijani *et al.*, 2011) and is a measure of system of inland waters chanelling into Lagos lagoon. It has a surface area of 152.76Ha and a storage capacity of 29.5 million litres, a higher depth of 12m, and a mean depth of 6.5m. Its basin is long and narrow and separated into two essential parts, with the narrow part slightly over 20m and the wider part slightly above 250m. Water flows into the dam throughout the rainy season mainly through River Ona and other nearby neigbouring little streams, in addition to water from run-offs (Jeje *et al.*, 1997).

The management of the fisheries of Eleyele Reservoir is handled by the Oyo State Ministry of Agriculture and Natural Resources, through the Department of Fisheries. The Department of Fisheries acts appropriate rules to form policies and regulations for the growth, monitoring, management, safety and security of the fisheries resources. In relation to the report given by the Department of Fisheries, management of the fisheries of the reservoir began in 1976 (Bolaji, 2010). At present, owing to a damaged switch valve (Jeje *et al*., 1997), the water body is almost stagnant, stable at a position nearly 12m all through the year (Jeje *et al.*, 1997).The main sources of livelihood for the folks around Eleyele Lake are fishing, farming, and canoe construction, making of fishing nets, cassava processing and trading. There are also small-scale industries around. These include block industries, welding shops, palm kernel oil producing industries, car mechanic workshop, horticultural gardens, and ice block-making shops. A large area of the water surface is dominated by aquatic macrophytes (the emergent macrophytes species, free floating macrophyte species and submerged macrophyte species). The increase in activities of land use type and dissemination between 1972 and 2000, percentage rise and reduction in land use type, GIS-based projected and anticipated temporal variations in the spatial level of land use types from 1984 to 2014, and the fish landing data from capture of Cooperative Fishermen of Eleyele Reservoir in1985 -1996 are presented in Tables 2.1-2.4.

2.2 Interaction between the aquatic macrophytes and fish

Nigeria is rich in various inland aquatic resources. Ita (1978) reported 149,919 km^2 of inland waters consisting of most important lakes, streams, pools, valleys, excavating and flowing rivers while Downing and Duarte (2009) recorded 304 million natural lakes covering 4.2 million km^2. Most of the natural lakes were formed as a product of normal events, which include flowing water and earthquakes; occasionally they could be an outcome of glacial disruption (Dibble, 2009). These structures were molded several decades back (more than ten thousand years ago) and were frequently vegetated by various pools of inherent and prevalent aquatic macrophytes. Hence, controlling of normal lakes varies meaningfully apart from approaches engaged in reservoirs that are typically subjugated by monocultures of intrusive species (Madsen, 2009).

Table 2.1: Land use / Land Cover Distribution 1972, 1984, 2000 in Eleyele Lake

Land use type	Area (Ha)	Area %	Area (Ha)	Area %	Area (Ha)	Area %
Built-up area	1.0689	15.18	0.7762	11.02	1.7706	25.14
Farmland	0.0447	0.63	3.7080	52.66	4.9127	69.77
Forest plantation	0.1034	1.47	0.8808	12.51	0.2280	3.24
Vegetation	5.8072	82.48	1.5357	21.81	0.0414	0.59
Water body	0.0167	0.23	0.1399	1.98	0.0879	1.25

Source: Adapted from Akingbogun *et al*. (2012)

Table 2.2: % change, increase/ decrease and annual rate of increase /decrease in 1972-1984, 1984-2000 and 1972-2000 in Eleyele Lake

Land use type	**% change 1972-1984**	**% change 1984-2000**	**% change 1972-2000**	**Increase / Decrease % 1972-2000**	**Annual Rate of increase/decrease % 1972-2000**
Built-up area	-4.16	14.12	-3.47	9.971	0.224
Farmland	52.03	17.11	-39.98	28.318	0.883
Forest plantation	11.04	-9.27	-3.11	-1.33	0.040
Vegetation	-60.67	-21.22	46.18	34.27	1.070
Water body	1.75	0.73	1.32	1.088	0.034

Source: Adapted from Akingbogun *et al*. (2012)

Table 2.3: GIS-based estimated and projected temporal changes in the spatial extent of land use types (in km^2) within the catchment of Eleyele wetland

Land Use Type (km2)	**1984+**	**1994***	**2004+**	**2014***
Dense forest	3.38	3.20	3.01	2.52
Riparian (wetland) forest	1.25	0.98	0.70	0.42
Light forest	3.84	2.46	1.09	0.01
Water body (River)	1.25	1.19	1.14	1.09
Built-up Area	4.47	5.99	7.52	9.04

+ = Estimated * = Projected

Source: Tijani *et al*. (2011)

Table 2.4: Fish landing data from catch of Cooperative Fishermen of Eleyele Reservoir between 1985 and 1996

Year	Total no of fish	Fish species occurrence	Frequency of weight %	Total weight of catch (Kg)
1985	526	1+2+3+6	98.7	114.3
1986	201	1+2+3+6+7	91.7	
		8	8.3	60.4
1995	162	1+2+3	92.5	44.2
		4	3.8	
		5	3.7	
1996	70	1+2+3	97.1	20.0
		5	5	5.0

Keys:

1. *Oreochromis niloticus*
2. *Coptodon zillii*
3. *Hemichromis fasciatus (discarded)*
4. *Synodontis eupterus*
5. *Lates niloticus*
6. *Sarotherodon galilaeus*
7. *Clarías gariepinus*
8. *Channa obscura*

*Fish catch by cooperative fishermen could not be accurately determined.

Sources: Department of Fisheries, Ministry of Agriculture and Natural Resources, Oyo State; cited from Jeje *et al.* (1997)

Aquatic plants and fish found in most lakes vary. Unlike reservoirs, most of the fish in natural lakes need a basic habitation at a certain stage of their existence. Most of these fish are plant-loving, preferring to devote a greater part of their existence to getting nurtured and developing in vegetated environments (Cross and McInerny, 2006). Various inherent and prevalent aquatic plants endow the shorelines with an extensive diversity of species that vary in dimension and configuration. This state is denoted as habitat heterogeneity (Madsen, 2009). The different environments are abodes to numerous fishes adjusted to them. These species include largemouth bass, bluegill, crappie, northern pike, muskie, young perch and walleye (Schneider, 1990).

Aquatic organisms from these freshwater bodies depend mostly on aquatic vegetation at a particular stage in the course of their existence and desire specific habitations centred on their developmental phase. Undeveloped fish utilize aquatic flora as a sustenance diet –by eating vegetation constantly (this occurs occasionally), by scavenging for the microfauna connected alongside these plants and as a concealment to get protected from predators (Valley *et al.*, 2004). Developed fish change their habitants to exposed waters so as to allow rummaging actions and devour more fish to complement their intakes (Diehl, 1998). Nesting, growing and scavenging activities of herbivores fish are encouraged by plant structure and concentration. Although different fish need differnt aquatic floras required for optimum development, extreme quantities of aquatic foliage can adversely influence development by decreasing nourishing attainment (Cross and McInerny, 2006).

2.2.1 Productivity in lakes

Algae and macrophytic plants are the source of lake efficiency. Light energy from the environment is used by the plant to produce sugar and carbohydrate, with oxygen as by-product; plants make use of the nutrients water and carbon dioxide as the main source of their own energy (Madsen, 2009). Plant eaters, which include crustaceans and insects, utilise the nutrient generated from their food for development. Fodder fish, notably minnows and bluegill, feed on these herbivores and make use of the nutrient produced in support of their development (Valley *et al.*, 2004). Piscivorous fish, like trout, bass, pike and walleye, feed on these scavenger fish and use the nutrient for development. Different phases of the nurturing stage centre on the intensity of the stages beneath them; this arrangement is often referred to as food pyramid (Cross and Mclnerny*,* 2006). Oligotrophic lakes, with little nutrients and less plant assembly, have smaller pyramids. Conversely, eutrophic lakes, with considerable advanced nutrient concentrations, additional plant development (algae and rooted plants) and abundant fish, have larger pyramids (Cross and Mclnerny*,* 2006). These peculiarities are acknowledged by aquaculture firms. In response, fertilizer is often included in production ponds to boost fish production.

Alterations in water features can boost the number of unwanted fish as well as that of required species in artificial lakes and in normal structures (Madsen, 2009). Among all the natural renewable resources, the fisheries component has the greatest challenges of being managed effectively. It is more difficult in the tropical conditions owing to many interacting factors. Notable among the changes in fish diversity are climate change, level of exploitation by fishermen, impact of other industrial activities as well as social, political and economic pressures on the market system (Omitoyin and Faturoti, 2000).

2.2.2 Primary production in an aquatic ecosystem

The production of organic composites from atmospheric or aqueous carbon dioxide in ecology is denoted as primary production. It usually occurs from the progression of photosynthesis (a process which makes use of light as the source of energy) and also from chemosynthesis (which refers to oxidation or reduction of inorganic chemical compounds as the energy source). Directly or indirectly, nearly all life forms on Earth depend on primary production. Primary producers or autotrophs are the organisms responsible for the primary production and also form the bases of the food chain. In aquatic eco-region, algae prevail in this part. Ecologist classified primary production as either net or gross. Gross primary production (GPP) is the rate of chemical energy as biomass that primary producers generate in a given length of time. Gross primary production is the frequency at which chemosynthesis or photosynthesis occurs. Minute quantity of this stable energy is utilised by primary producers for preservation of surviving tissues and cellular respiration. The residual parts of the stable energy are referred to as net primary production (NPP) (Baran and Guerin, 2012).

NPP=GPP -respiration

Both gross and net primary productions are measured in units of mass per unit area per unit time interval (Marra, 2002). In the aquatic ecosystem, primary production is usually measured using variation in oxygen concentration within a sealed bottle (developed by Gaarder and Gran in 1927). This procedure employs differences in the concentration of oxygen under diverse experimental forms to produce gross primary production.

2.3 Classification of aquatic macrophytes

Aquatic macrophytes are categorised based on their different habitats. These habitats make up their ecological region and become favourable for their development, replication and propagation (Lancar *et al.*, 2002).

2.3.1The growth of emergent macrophytes in an aquatic ecosystem

The emergent macrophyte propagates in surface water and an existing area proximate to the water bodies wherever water regresses and increases with the seasons or consistent discharges from a big water body or reservoir. This kind of occurrence can be stable in natural environment, where least and highest water intensities are constant. Such water encompasses the banks of waterways, rivers, boundary of water forms, which are commonly found in earthen dams and to some degree in masonry dams, drainage channels and water pools close to communities and farm settlements (Dibble, 2009). These macrophytes could be termed semi-aquatic; they could also be called emergent aquatic macrophytes (Lancar and Krake, 2002). Examples are presented in Table 2.5.

2.3.2 Floating macrophytes in an aquatic ecosystem

The floating macrophytes species are plants that develop, propagate and grow to maturity inside the water. They are of various sizes, including the single cell (algae) to large vascular plants. If the water body is dried up, the seeds and the vegetative reproductive organs of these plants are streak and distributed for propagation. These macrophytes are seen on the top of the great, bottomless and shallow depths of water bodies; bottomless constant flowing channels; and endlessly streaming rivers, big pools and reservoirs, among others. Many of these macrophytes in the environment freely drift and travel extensive expanses. However, most of them drift on the water face but plant their roots deep down and firmly to soil at the base of the water body (Cuda, 2009). These macrophyte types

Table 2.5: Examples of emergent macrophytes in an ecosystem

Botanical name	Common name	Family
Typha angustata	Cattail narrowleaved	Typhaceae
T. latifolia	Cattail common	Typhaceae
T. orientalis	Cattail	Typhaceae
Phragmites communis Trin.	Common reed	Poaceae
P karka	Common reed	Poaceae
P australis	Common reed	Poaceae
Pontederia cordata L	Pickrel weed	Pontedericeae
Commelina benghalensis L	Watergrass	Commelinaceae
Alisma plantago	Water cattail	Alismataceae
Cyperus difformis L	Umbrella plant	Cyperaceae
Ipomoea carnea Jacq.	Besharam	Convolvulaceae

Source: International Commission on Irrigation and Drainage (2002) obstruct the movement of water in a system. They also bring about loss of water through evapo-transpiration. Thus, these macrophytes could be broadly categorized into two: free-floating and rooted-floating macrophytes. Samples of the respective groups are represented in Tables 2.6 (a) and Table 2.6 (b).

2.3.3 The life cycle of submerged aquatic macrophytes in an ecosystem

Submerged aquatic macrophytes categories are suitable for the collection that sprout or shoot, develop and replicate underneath the water. Their stocks and procreative organs remain deep down, firmly in the bottomless base of the water body. Submerged macrophytes have major influence on production and bio-geochemical sequences in fresh water because they dominate key boundaries in streams and lake ecosystem (Petr, 2000). These submerged macrophytes cause severe destruction, mainly because they are not evident on the surface and obstruct the movement of water depending on the amount of their concentration, abundance and development. These macrophytes are mostly established in surface and moderately deep water bodies, constantly flowing canals and drainage channels (Lancar *et al*., 2002).

The environment offers conditions that permit the development of algae, filamentous algae, and advanced algae in surface and bottomless water. Thus, submerged macrophytes can be generally characterized as shallow water submerged macrophytes and deep water submerged macrophytes (Dibble, 2009). Illustrations of these categories are given in Table 2.7 .

2.4 Effects of aquatic macrophytes on human and his environment

Aquatic macrophytes bring about various ecological harms and create conditions which aid the development of mosquitos (Cuda, 2009). The parasites are shielded away from predators by aquatic macrophytes rhizomes and leafy growth which are the major causes for the blow out of several diseases. These diseases include malaria, yellow fever, river blindness and encephalitis. Snails are capable to reproducing and affecting an essential part in the life cycle of blood and liver flukes (parasitic worms) as they stay and survive among the root zones (Connors *et al*., 2000).

Table 2.6 (a): Free floating macrophytes in an aquatic ecosystem

Botanical name	Common name	Family
Eichhornia crassipes (Mart) Solens	Water hyacinth	Pontederiaceae
Salvinia auriculata (Mitch) Syn.	Water fern	Salviniaceae
S. molesta	Water fern	Salviniaceae
S. natans	Water fern	Salviniaceae
Pistia stratiotes L	Water lettuce	Araceae
Lemna minor	Duck weed	Lemnaceae
Spirodela polyrhiza(L) Schlcid	Giant duck weed	Lemnaceae
Azolla imbricata waxai	Water velvet	Salviniaceae
A. pinnata	Water velvet	Salviniaceae
Polygonum amphibium L	Water smart weed	Polygoneaceae

Source: Adapted from International Commission on Irrigation and Drainage (ICID) (2002)

Table 2.6(b): Rooted floating macrophytes

Botanical name	Common name	Family
*Sagittaria guayanensisn*HBK	Arrowhead	Alismataceae
Ipomea hederacea	Nilkalmi	Convolvulaceae
*Nelumbo nucifer*a G	Lotus	Nymphaceae
Nymphaea alba L	White water lily	Nymphaceae
*Zannichelli apalustris*L	Horned pond weed	Zannichelliaceae

Source: Adapted from International Commission on Irrigation and Drainage (2002)

Table 2.7(a): Shallow water submerged macrophytes

Algae

Botanical Name	**Common Name**	**Family**
Anabaena spp.	Blue green algae	Nostocaceae
Cladophora spp	Cottonmat type algae	Cladophoraceae
Pithophora spp.	Wet wool type algae	Chloraphyaceae
Spirogyra spp.	Slimy green algae	Chloraphyaceae
Charazeylanica	Musk grass	Characeae
Nitellahyalina	Stone wort	Characeae

Higher plants

Botanical name	**Common name**	**Family**
Najas minor All.	Naiad	Najadaceae
Vallisneria spiralis	Eel weed	Najadaceae
Potamogeton crispus	Curly leaf pond weed	Potamogetonaceae

Source: Adapted from International Commission on Irrigation and Drainage (2002)

Table 2.7(b): Deep water rooted submerged macrophytes

Botanical name	**Common name**	**Family**
Myriophyllum spicatumL.	Eurasion water milfoil	Holorhagaceae
Hydrilla verticillata	RoyleHydrilla	Hydrocharitaceae
Elodea canadensis	Elodea	----------------
Utricularia flexuosaVahl.	Bladderwort	Lentibulariaceae

Source: Adapted from International Commission on Irrigation and Drainage (2002)

Schistosomiasis and fuscioliasis spread as the drifting macrophytes convey the snails to different sites.The inhabiatants of such areas complain of mosquito problem (Lancar *et al.*, 2002).

Fish assembly can be disrupted by the existence of floating and submerged aquatic macrophytes (Dibble, 2009) when the growth becomes dense and shields the entire water body, which can be harmful for fish development and productivity. This deficiency of oxygen might lead to fish death. Once floating and submerged aquatic macrophytes turn out to be exceptionally thick, several fish species are incapable of existence in that kind of setting (Bini *et al*., 1999). The disintegration of massive volumes of organic mass forms a state where carbon monoxide are prepared and discharged to the environment. The breakdown phase is considerably less than disintegration of extra vegetation on land. The breakdown generates discharges of obscene and nasty odours (Zhang *et al.*, 2009a). Isolated macrophytes cover might be accepted. This is because they give refuge and shadow for fish.

Aquatic environments that are places of entertainment and beautiful serenity could be filled with undesirable aquatic macrophytes (Valley *et al.*, 2004). These macrophytes obstruct the navigation, cruising of ferries and other recreational events. The disintegration of macrophytes structure comprises silicious substances and other unsolvable substances that settle on the edges of the water body. Thick macrophyte development decelerates and sometimes obstructs the movement of water in waterways and drainage passages, permitting sediment to rest and settle down on the layer of the water body. This intensification in sediment accumulation increases the water layer stage and disturbs the existence of lakes, dams, tanks, and many others. This makes it imperative to augment expenditure for regular desilting through dredging (Dibble, 2009).

Aquatic macrophytes upset the value and features of water. These macrophytes cause savour and smell complications and boost the biological oxygen demand because of biological stocking (Cross and Mclnerny, 2006). Similarly, dense aquatic macrophytes hinder the unrestricted movement of water, which may add to augmented seepage rate. This leads to rise in water tables in the connecting areas with related water recording (Madsen, 2009). This might produce saline or alkaline disorders in the soil and also provide escalation to several other terrestrial macrophytes. Submerged and floating macrophytes spread at a fast rate. For example, a couple of *Eichhornia crassipes* (Lancar *et al.*, 2002) can replicate up to almost four thousand times in one season.

Inland waterway or ditches usually become concealed and blocked in one season, after a little sprouting or propagating of plants. The apparent floating macrophytes become intertwined and appear as compressed mats that travel downstream. Frequently, these mats compress up alongside channels and condiuts, generating vast stress that sometimes resulted in severe destruction to transportation. After a long period, if abandoned, the macrophytes may become compressed mats so thick that humans and animals can move on them, though at the peril of hurt or sinking (Valley *et al.*, 2004).

2.5 Benefits of aquatic macrophytes to fish distribution

The connection between aquatic macrophytes and fish is very important in community structure and management consideration |(Petr*,* 2000). In an area devoid of any substantial quantity of macrophyte cover, aquatic macrophytes can lead to rise in fish richness, which enhances their relationship. Fish feed directly on macrophytes; feeding on sediments stimulates fluxes of nutrients to exposed water, influencing phytoplankton biomass (transparency) (Persson and Crowder, 1998). The shadow formed by green plants is essential to several visual feeders since their discernibility for choosing preys and escaping predators is enhanced by the shadow formed. Vegetated aquatic habitats shield the young and small-size fish from predators and also make food available for them to forage on. The aquatic creatures consumed by young fish vary and are richer in vegetated environments than in areas without floras. This is largely because foliage with stalks offers a surface for connection (Persson and Crowder, 1998). Moreover, slight space in between plants can make available a space for creatures to abscond and conceal themselves from predators. As vegetated habitats turn out to be more difficult, the danger of young fish turning to food for higher animals will be reduced (Madsen, 2009). However, they can serve as fodders for animals, medicine and food for humans. But they reduce fish catch by the fishermen during fishing activities.

The competency of fish in search of food reduces as vegetated habitats become more composite (Valley *et al*., 2004). Shadows generated by foliage with stalks may make it further challenging for fish to easily locate and arrest target, although the effect of swimming obstructions that occur from condensed vegetation can upsurge exploration period by decreasing swimming movement and swaying speed. For example, the frequency at which the sunfish effectively captures prey decreases with an increase in mechanically compounded vegetated habitats. Certain fish have developed some tactics to deal with the adverse characteristics (that is, decreased food accessibility complemented by improved struggles to apprehend prey) connected with heavily vegetated areas (Parsonss *et al.*, 2009). The largemouth bass, on some occasions, changes eating tactic in composite environments and changes from vigorously chasing target to ensnaring the preys as they float or whirl by (Cross and Mclnerny, 2006).

2.6 Environmental pollution in an ecosystem

Environmental contamination is presumed to be an ancient matter damaging and disintegrating the normal environment. Contamination cannot, does not and will not stop since there is constant drive of innovations in human advancement (Olowosegun *et al.,* 2005). Globally, the situation is worsened by continuous contamination by unprocessed industrial and domestic trashes. So as to tackle this difficulty, the World Commission on Environment and Development approved sustainable development plan as a rule at the meeting on saving the human environments from advanced dilapidation (Adewuyi *et al.*, 2010).

The word “pollution” generally denotes every unwanted or adverse alteration in the normal value of a setting which brings around the corporeal, organic, or biotic factors. Ecological contamination is adverse modification of the environment due to undeviating or incidental events of man. Rise in human population, speedy enlargement in the industrial and metropolitan actions and upgrading of agriculture has given rise to generation of great amount of unwanted substances, affecting stable reduction of valued possessions and organic production (Datta, 2010).

Manufacturing impurities differ extensively. They cut across different manufacturing companies, like tissue and paper, excavating, foodstuff and drinks, pharmacological, industrial, electroplating, metal engineering, aquaculture, leather tanning, oil and gas extraction, hazardous waste, and mechanized agribusiness (Bala *et al.,* 2008). Chemicals for both pest and weed control are major ecological impurities that are tough to break down. Pesticide contamination is produced mainly from the agricultural firms through the discharge of their impurities, waste water and run-off from farmlands. The intensity of pesticide impurities discharged from these sources may consist of up to 500 mg/L (Connors *et al.,* 2000).

Deficiency in excess garbage control leads to discarding of trashes in lands and unhealthy landfills exposed to weathering and seeping by rain and other atmospheric impacts. The outcome is the discharge of harmful elements, particularly cyanides, minerals, heavy metals, and organic acids, that reach the underground water structures and inland water bodies unprocessed. These elements pollute the underground water and make it harmful for human use, recreational events and agricultural operations (Datta, 2010). Biotic life is damaged and normal ecological units are broken down. Human life is endangered and the value of ecological growth is disallowed (Rahman *et al.,* 1997).

2.7 Aquatic pollution and fish species diversity

Aquatic structures, especially rivers and lakes, have now become places for dumping of dirt and poisonous materials in many Nigerian cities and towns. Appreciable amounts of these waste materials are broken down in some of the water bodies at a particular time. The the remainder will be transported and deposited into oceans and seas (Adekunle *et al.,* 2008). The accumulative contaminant contents and the misuse of water reserves for cleaning purposes, irrigation, productions and thermal control plants to meet the needs of the ever-growing human population considerably decreases the storage capabilities of various rivers and lakes (Bala *et al*., 2008). This disrupts the structure of the natural populations occupying them. Fish is a prominent component of this arrangement communal and it is of great significance to humans for dietary and socio-economic purposes (Akan *et al.,* 2009).

Aquatic ecological units are shelter for different entities. When these organisms lack water or water supply is insufficient, they cannot thrive. The aquatic environments are frequently altered for fish and other aquatic resources. Fish diversity is the effective number of different types of fish that are represented in a collection of individual. With respect to the formation of a community, it is essential to recognize the varying numbers of the species in the biological communities. The quantity of species found in a population or an ecosystem is denoted as species richness. The relative abundance of species is also significant in fish diversity. The relative abundance of rare and common species is described as evenness. There is low evenness in a community ruled by one or few species, whereas high evenness occurs where there is uniform circulation of species. Species diversity is a measurement of both species richness and evenness. Populations with a huge amount of species that are uniformly disseminated are the maximum varied ones and populations with one or few species ruling are the least varied ones.

Sustainable management is the recruitment of biological resource such that the portion removed by harvest is replaced by growth or reproduction, thereby maintaining its length without interruption; it also makes judicious use of the means to accomplish the end (Omoike, 2004). However, there is no habitation that is boundless in its capacity to bear harmful influences. Lakes, groundwater and swamplands are all disrupted by numerous points of contamination. The important points are domestic wastes, agrochemicals, like fertilizers, herbicides and pesticides, oil-based products and exhaust or smoke from automobiles as well as industrial discharges usually channelled to watercourse. All these have excessive influences on the aquatic environment (Datta, 2010). Surface excess flow from roads, car parks, city streets, channels, and densely-populated coastline regions are eroded into neighbouring watercourse and bring about damaging traits to the biome (www.coast-nopp.org).

In line with the information from Great Lakes Commission (2003), till around 50 years before, the effects of this contamination were not perceived in the waters. The contamination was mostly in the form of metallic and glass materials, which would go down; and paper and cloth, which would decay. These days, smog is more evident since many of the synthetic substances are made of plastics, which are weightless, solid, and long-lasting. Speedy growth of the human population makes the world to be more technologically advanced. Biochemical materials have risen to hazardously high points in some regions (Datta, 2010). Due to the massiveness of the sea, it could decrease the effect of certain chemical waste products. This necessitates constant accumulation of waste for the contaminants to compress past the sea verge. Conversely, the noxious cause of unselective discharging of waste materials in aquatic environments has more outstanding effects on ponds, watercourses, streams and swamplands (www.great-lakes.net).

In inland water forms, the consequence of excess discharge into the aquatic environment and its biota is obvious (Atul and Kulkarni, 2011). Biochemical impurities that emanate from industrial areas, plantations, aquaculture, and housing zones can boost the nutrient source that is aid algal boom. This diminishes the oxygen accessible for various forms of lives, leading to loss of life (Obasohan, 2009).

Eutrophication initiated through woodland demolition is a problem of great concern. Clearing of the forest area exposes the soil to excessive flow to neighbouring watercourses, rivers and lakes. There will be rise in the rate of nitrate and phosphate production, which leads to nutrient pollution in the water. The consequence of this is rapid growth of poisonous algae known as "red tides" or "brown tides (Connors *et al.*, 2000)." Eutrophication might prompt frequent occurrences of fish infections and a large number of oceanic fish could be destroyed from this outburst (www.coast-nopp.org). In certain instances, specific algae could have some amounts of lethal constituents. These poisons turn out to be additional concentration in animals' complex in the food sequence.

This concentration harmfully disturbs the wildlife on the topmost of the food sequence; this might result in decrease in the population of (www.great-lakes.net). Zooplanktons consume poisonous algae and transfer the poisons to the topmost food sequence. This distresses consumable organisms, including clams, as well as the topmost fish, seabirds, marine mammals, and humans. The consequences of this could be sickness and at times death. With this situation, there is decline in the amount and features of fish accessible for human consumption (Olowosegun *et al*., 2005).

In addition to making this condition complex, universally human beings want to settle or stay close to water. Water offers a lot of benefits to the human race. These benefits include recreation, navigation, survival and means of livelihood, and further assests. Underground waters, aquifers, waterways, and rivers are good sources of potable water globally. Accessibility to the source of water is a major significant concern. With the increase in the number of the population that reside around coastline zone, there is more pressure and increase in the load of contaminants. Seaports or harbours, occasionally, need to be dug up. This will make the contaminant stuck at the bottom of the water to float (Olajire and Imeokparia, 2000). Datta (2010) claims that contamination causes decline in fisheries production and the quantity of valued fish commercially, which, in turn, leads to low level of income. For instance, trout and salmon quantities dwindle in seas and estuaries flop due to contaminants. Furthermore, contamination weakens the fisheries sectors. It alters the setting of water bodies and increases the bottom deposit, changing certain regions to swamp before rendering them uninhabitable to man. Contamination could hinder fish movement, as it could alter the regular pattern of the aquatic inhabitants of the region.

Contamination of shallow waters may have great influence on regular fisheries assembly. The growing human population engenders constant decrease in fisheries resources. Harvey and Lee (1982) and Bradley and Morris (1986) discuss the implications of daily increase in metallic loadings with acidification in the aquatic environment and note that the pressure from metal and acid leads to the inability of the fish to replicate, which causes decline in the population of fish. Olowosegun *et al.* (2005) assert that, in Nigeria, oil production has made most of the fishing sites unfertile. Most of the wastes from oil exploration are untreated and are discharged into the environment. They produce extremely noxious metallic substances. The people in such areas have to dig around water bodies in search of potable water. Economic development, together with technical advancement in agricultural science, has yielded more impurities (synthetic and organic) which are discharged directly into the aquatic environments as the final deposit for metallic substances (Ogbeibu and Ezeunara, 2002).

2.7.1 Impact of aquatic sediment and water quality parameters on productivity of a lake

Water quality and aquatic sediments are very important and play a major role in increasing the yield of a lake, healthy environment with nutritionally balanced diet for cultured animals. The physical and chemical constituents of the lake are influenced by the content of the bottom sediment, which is a major factor in the success of aquaculture. The bottom sediment offers nurture and refuge for the benthic organism and also serves as the deposition of nutrients for the growth of benthic algae which are food for aquatic organisms. The lake sediment plays a vital part in explicating the different developments going on in the entire lake structure, together with the external water drainage basin and rock-water interaction (Mustaq *et al.,* 2016). The bottom deposit similarly works as a defence and manages the storing and discharge of nutrients directly to the aquatic body. It aids biotic screening across the absorption of organic remnants of food, waste products and algal metabolites (Kumar *et al.,* 2012). The bottom deposit harbours a huge number of bacteria that aid the disintegration and mineralisation of organic accumulation of debris. The sediments and water pH determine the growth and healthy survival of aquatic animals. Development, existence and replication of fish have to do with the constituents of water because the fish react contrarily to different water constituents (Omitoyin, 2007).

Physical and chemical constituents of water, like temperature, total suspended solids (TSS), dissolved gasses and nutrients, affect the water quality, which as well as the healthy existence of organisms in aquatic environments. Temperature is also an essential parameter, as it affects photosynthesis in aquatic plants, physiological reactions of cultured organisms and break down of organic matter and successive bio-chemical feedbacks. Fish is a cold-blooded animal.Its body temperature fluctuates with that of the environment and this affects its metabolism and physiology and consequently upsets its production. Rise in temperature increases the frequency of bio-chemical action of micro-biota, and plant respiration, besides intensifying the demand for oxygen. Also, it affects the level of oxygen solubility and increases the amount of ammonia in water. Reduction of oxygen in water causes inadequate consumption of food for fish, malnourishment, stunted growth and high death rate of fish (Baran and Guerin, 2012).

2.7.2 Physical and chemical constituents of some Nigerian Lakes

The universal need to shield inland water fisheries has brought about intensification of study on water value, in relations to the physical and chemical constituents, which entails the pH, temperature, dissolved oxygen, transparency, total alkalinity, total hardness, electrical conductivity and total dissolved solids, among others. Most of these features function as the source of its fertility or organic production in every aquatic ecosystem (Imevbore and Bakare, 1970). The majority of the physical and chemical constituents have been examined on different large artificial water bodies in the northern region Nigeria (Adeniji, 1981). Other research on physical and chemical constituents of water in Nigeria includes Balarabe (1989), which focused on limnological and zooplankton distribution of Makwaye Lake, Zaria; Ugwumba and Ugwumba (1993), that studied the physico-chemical hydrology and plankton of Awba Lake in Ibadan; Oniye *et al.* (2002), that concentrated on certain features of the physico-chemical parameters of Zaria Dam; and Kolo and Oladimeji (2004), which assessed the water quality and various nutrient levels in Shiroro Lake, Niger State.

Lake contains natural resources that are highly valued by man in terms of their recreational values as well as aesthetic and scenic qualities (Kareem, 2016). According to Toma (2013), lakes get their inflows from surface run-off, streams flow, melting snow, rainfall and ground water. The influence of ecological alteration by impurity or toxins leads to certain modifications in aquatic creatures. Most of these creatures that cannot tolerate or adapt to these conditions gradually decline in population at the end of the day and are wiped away, whereas those that can adapt and tolerate these condition thrive and flourish (Johnson *et al.,* 1998). Oben (2000), Tyokumbur *et al.* (2002) and Yakubu (2012) observe that this condition is the consequence of alteration in the water due to the addition of impurities. The environmental changes (external effect from the atmosphere) can also affect all the recreational and aesthetic qualities, including the habitat of the living organisms and other natural resources found in the aquatic ecosystem because lakes are fragile and susceptible to change (Kalwale and Sayale, 2012)

Both the physical and chemical constituents were mostly used as population indicators (Lawson, 2011). The disparity in the physical and chemical constituents of water bodies (seasonal, diurnal or hourly) could be compared with the rainfall level and different water uses (Akin-Oriola, 2003). The visible features of Eleyele Lake take account of temperature, transparency, total dissolved solids and depth, whereas the chemical constituents comprises pH, dissolved oxygen, biochemical oxygen demand, nitrate and nitrite, electrical conductivity, CO_2, H_2S and the mineral components, which are: calcium (Ca), magnesium (Mg), potassium (K), phosphorous (P), nitrogen (N) and sodium (Na). These and the proximate composition of the various samples that will be taken from Eleyele Lake need to be ascertained.

2.8 Food and feeding habits of fish

A habitat is a specific location in which an organism exists in the environment. It is made up of all biological and physical resources accessible to a species. The ecological niche denotes the way in which an organism fits into an ecosystem or an ecological community. The collection of all the habitat areas of a species establishes its environmental collection. In fish, there are four modes of eating habit and fish are classified based on these. The first type is the carnivores, which are meat eaters. The second type is the herbivores, which are the plant eaters. The third type is the omnivores, which are voracious eaters that is, they can eat both plants and animals.

The Carnivores – These are meat-eating fish that eat life foods, like earthworms, insects, and larvae of mosquitoes or fruit flies, oysters, shrimp, lean chicken, turkey and salmon (cooked). According to Gatlin (2010), carnivorous species are very effective at consuming dietary protein and lipid for energy but less effective at consuming dietary carbohydrates. For the carnivorous fish not to be malnourished, they need at least 45% protein in their diet. Examples of such fish are *Clarias gariepinus* and *Parachanna obscura*. They belong to the secondary consumers in the tropic level.

i) **The Herbivores:** These feed mainly on plants. These fish graze plants regularly whether they are given feed supplement or not. They belong to the class of primary consumers, like *Tilapia zillii and Oreochromis niloticus. O. niloticus* exist in diverse of habitations like waterways, streams, lakes, sewage, channels and irrigation waterways (Ajani *et al.,* 2011). They feed on plants like spinach, cucumber and water lettuce.

ii) **The Omnivores:** These are voracious eaters that can feed on both plants and animals. They belong to the secondary consumer group. Nile Tilapia (*Oreochromis niloticus)* belongs to this group.

2.9 Influence of feeding habits of fish on species diversity of a lake

One of the major factors that affect the species richness of a lake is the availability and quality of food per time or from season to season. This will determine their variation in a habitat. Also, when there is overcrowding in such an environment, the food will not be sufficient (the nourishing frequency is comparative to the body mass and reductions as fish dimension rises. Nevertheless, the amount of food utilised increases per individual (Wang *et al.,* 1989) which may result in low intake of food. Some fish may migrate to another environment for foraging, which will affect the species richness of such environment. Thus, the particular species available per season will vary (FAO, 2001)

The availability of food may also be influenced by the macrophyte diversity with respect to seasonal variation of the macrophyte. This may also influence the species of fish that will be present.

2.10 Effects of sediments on fish habitat

Some fish speices make use of the sediment as their habitat (refuge) during the dry season, as well as feeding, spawning and nursery area (Osmundson *et al.* 2002). Sediments also make nutrients available to the macrophytes through the water. Human activities may dislodge the fish from their ecological habitat both in the sediment and aquatic macrophytes. This, in turn, brings ecological consequences which will make the lake microhabitats less appropriate for aquatic organisms and necessitates precise substrate composition for replication.The ecological quality of an ecosystem is influenced by the quality and amount of its sediments (Osmundson *et al.,* 2002). Analysis of sediments is equally important in assessing the potential of the entire ecosystem of a water body; this has been in practice for decades. In evaluating the test of water, sediment testing reveals the long-term quality condition irrespective of the current inputs (Kumar *et al.,* 2012). Much pollution of the water body can be lethal to fish. In fact, this high concentration can cause the fish to be killed directly. There is a typical test that can be carried out in the laboratory for over 96 hours to determine this lethality in the sediment and the pollutant concentration. This test of concentration is referred to as lethal concentration (LC) of the substance or contaminant that kills 50% test organisms within 96 hours of exposure. It is a basic toxicological test that is referred to as 96-h LC50 (Anderson, 2011).

The sediment composition and its richness have a major part to play in the variation in the quantity of species that could thrive in a specific place. This is because these macrophytes' survival will be determined by the sediments, as they contain the essential nutrients for the macrophytes. The nutrients associated with sediments can also impact the quantity of dissolved oxygen over its interfering with photosynthesis, which favour the development of plants and increases their oxygen production, which has a progressive result on the environment (UT AH State Water Plan, 2010). Sediment is a major component of a lake and its various biological functions. Sediments comprise detritus, nutrients, and organic debris of different dimensions which interact with diverse structures of life in the lake, including fish. These interactions ultimately influence the biodiversity and productivity of a lake (USEPA, 2003).

Sediments have the ability to absorb both small organic and inorganic compounds which make the sediments to be a combination of minerals, as well as inorganic and organic matter which are of great importance to biological productivity of a lake (Welcomme, 1985). Lake sediments serve as a major carrier and means of transportation of nutrients and storage agent for inorganic matters these includes nitrogen, potassium, phosphorus, and pesticides or herbicides and metals (Yang Xiaoqing, 2003; Yi *et al*., 2008).The turbidity of the water, temperature between the range of $1^{o}C$ and $18^{o}C$, season and the size of the fish can also affect the fish in the ecosystem (Servizi and Martens, 1991). The onset of mortality at $18^{o}C$ occurs at $3000 mgL^{-1}$. Also Lake and Hinch (1999) assert that the size of a suspended particle in the sediment can also affect the physiological stress (especially the juvenile) and this may lead to mortality in fish. Increase in turbidity will reduce light penetration into the water body and this will affect the productivity of the aquatic system (Lind, 2003). This will lead to reduction in plant biomass, which will lead to decrease in primary production. Also abundance of fish food organism will be affected. Consequently, the population of fish will greatly reduce.

2.11 Effects of physicochemical parameters of water on aquatic macrophytes variation

According to Dar *et al.* (2014), aquatic mancrophytes cannot thrive in an aquatic environment without the support of water parameters. The features that regulate the dissemination patterns of the aquatic macrophytes in the aquatic ecosystem are divided into two:

(a) abiotic factor and
(b) biotic factors

2.11.1 Abiotic factors

2.11.1.1 Light –Pandit (2002) mentions a powerful connection within the water transparency (water clarity) and depth distribution of plant (especially submerged plant). Light penetration largely controls the distribution pattern, composition and abundance of macrophytes because they use the light absorbed and CO_2 for their photosynthetic activities.

2.11.1.2 Temperature: It has been established by different authors (Barko *et al.*, 1986; Nekrasova *et al*. 2003; Ronzhina *et al*., 2004; Robledo and Freile-Pelegrin, 2005) that light and temperature work collectively in influencing development, photosynthesis, morphology, reproduction of macrophytes and chlorophyll composition. Owing to the internal changes that occur, there could be variations in the composition and dissemination of some classes of aquatic macrophytes (Barko *et al.,* 1986).

2.11.1.3 Sediment-related characteristics

The related factors present in the sediments, including the great organic substance constituents, nutrient limitation, lack of oxygen obtainable and the granulometric constituents, to a certain extent, are known to upset the dispersal and diversity of macrophytes (Barko *et al.,* 1991; Boedeltje *et al.,* 2001). Greater intensity of phosphorus in the sediment helps in phytoplankton production, which invariably influences the growth of rooted aquatic plants (Scheffer *et al.,* 1992).

2.11.1.4 Nutrient enrichment: Environment rich in nutrients, especially nitrate and phosphate, has great influence on the dissemination and development of aquatic macrophytes (Frankouich *et al.,* 2006). Several authors have noted that increased density, composition of macrophytes and richness of aquatic flora in a lake are greatly influenced by nutrient-rich environment (Bini *et al.,* 1999; Lougheed *et al.,* 2001; Rosset *et al*., 2010 ; Alahuhta, 2011).

2.11.2 Biotic factors: Biotic factors, such as pathogens and grazers, also contribute to the distribution of aquatic macrophytes, especially the submerged macrophytes (Nichols and Shaw, 1983). The most important biological factor that helps in shaping the aquatic macrophytes composition and distribution in freshwater is the competitive interaction between plants by the vertebrates and the invertebrates in the ecosystem (Chambers and Prepas, 1990; Connors *et al.,* 2000).

2.12 Aquatic Macrophytes Community Index (AMCI)

This is a multipurpose device established by Nichols *et al*. (2000), mainly for assessing the biological quality or integrity of the aquatic plants in a lake. It could be used to analyse the aquatic plants and the overall features for lake monitoring, development, administration or research. The constituents of the index are established on seven criteria, these are the maximum depth of plant growth, percentage of the littoral zone vegetate, Simpson's diversity index, relative frequencies of submerged plant, sensitive or exotic species and the taxa number. These parameters are scaled and grouped according to Nichols *et al*. (2000). The values of each parameter are summed up to determine the AMCI; the sum ranges between 7 and 70. This total summed-up value reflect the known impact of the lake (7 shows the poorest quality of macrophytes community in a lake, while 70 depicts the highest macrophytes community).

2.13 Floristic Quality Assessment (FQA)

This is an assessment device used to evaluate an area's ecological integrity based on the species composition of the macrophytes in the community. This tool was developed to assess if the impact (level of disturbance tolerant) to an area is irreversible or not. This impact shows various levels of disturbance which could be direct, indirect or biological disturbance.

- Direct disturbance to the plant beds could be as a result of navigation (movement of boats), chemical treatment and plant harvesting.
- Indirect disturbance might be as an outcome of factors that affect water clarity, like run-off from erosion, which might lead to sedimentation and discharge of waste which brings about increased nutrient and causes alga bloom.
- Biological disturbance could result from the grazing of plant beds by herbivorous animals or destruction of plant beds by fish population.

It helps different stakeholders (particularly ecologists and land and forest managers) to monitor their sites properly, reduce level of disturbance and set conservation policies and priorities. This concept was developed by Gerould Wilhelm in 1970. In a region, each macrophyte is given a coefficient of conservatism, which is also known as C-value, which ranges between 0 and 10. Non-native plants are excluded from the assessment or assigned 0 for C-value. The mean C-value is determined based on the inventory of the plants in a lake. The Floristic Quality Index (FQI) is evaluated by multiplying the mean C value by the square root of the total species. Average coefficient of conservatism ranges from 2.0 (most disturbance tolerant) to 9.5 (least disturbance tolerant).

Coefficient of Conservatism Mean C 0-10 description

0: Plants with a wide range of ecological tolerance. Often these plants are opportunist invaders of natural communities or native species.

1-2: Widespread taxa that are not typical of a particular community

3-5: Plants with an intermediate range of ecological tolerance that typify a stable phase of some native communities but persist under some disturbance

6-8: Plants with a moderately narrow range of ecological tolerance that typify stable late successional native plant communities.

9-10: Plants with narrow range of ecological range tolerance that exhibit great fidelity to a narrow range of stable habitat requirement (Michael, 1984)

FQA results are evaluated using the Wilhelm and Rerich rating (2017):
1-19 indicates low vegetative quality; 20-35 indicates high vegetative quality; while above 35 indicates "natural area" quality.

CHAPTER THREE

MATERIALS AND METHODS

3.0 Description of the study area

3.1 Eleyele Lake

The Water Corporation of the old Western Region, in 1939, built Eleyele reservoir for production of good drinkable water so as to overcome the problem of potable water in the developing Ibadan cosmopolitan city (Jeje *et al.,* 1997). The reservoirs were built over River Ona, using a pool storing capability of 29.5 million litres (Bolaji, 2010). The damsite is situated alongside Eleyele wetland in the north-east area of Ibadan (Ido Local Government Zone), south-west Nigeria along longitude N07°25'00" and N07°27'00" and latitude E03°50'00"and E03°53'00".

3.1 Morphometric features of Eleyele Lake

Location (Longitude and Latitude)	$07^0$25 and $03^0$55E
Altitude (above sea level)	125m (Imevbore, 1965)
Main source of water	River Ona
Catchment area	323.75 hectares (Elliot, 1979)
Year commissioned	1939 (Egborge, 1977)
Year of dam construction	1942
Length accross dam	240m
Total storage capacity (Reservoir)	5.46km^3
Maximum water elevation (at dam)	9.0m
Length of lake	2.4km
Water surface area	162ha
Depth	12.19m by dam location

Average depth	6.0m
Morpho Edaphic Index (MEI)	29.1
Flooded Area	0.5km^2

Source: Oyo State Water Cooporation, 1987.

3.2 Experimental procedures

The field experimental samples (water, macrophytes, sediments and fish) were taken twice in a month for duration of two rainy and dry seasons in every single sample site alongside the path of the water body. The fish samples were collected randomly, without preference for any precise size of fish. The physical and chemical constituents of Eleyele Lake were also assessed and included the following: dissolved oxygen, temperature, transparency, depth, pH, nitrite, alkalinity, conductivity, total dissolved solid, total solids, total hardness, chemical oxygen demand, biochemical oxygen demand, ammonia, sulphate, nitrate, macro-nutrient compositions (sodium, chloride, magnesium, calcium, potassium and phosphate).

3.2.1 Sampling procedures

The sampling was time- and space-stratified (Jan 2015- Dec 2016). Time stratification covered 24 months (two dry (Dec-April) and two rainy seasons (May -Nov) – established on the rainfall pattern of the environment). Space stratification were based on the method of Southwood and Henderson (2000), Ajani (2001), ISO (2006) and Muhammad *et al.* (2008), in which the whole lake was allocated into five regions (Z1-Z5: mouth, upper, middle, lower and head) based on the hydrological features. Three sampling points (stations) were selected in every region of the 5 zones, which resulted in fifteen sampling stations across the lake. The name of each of the sampling point represented the inlet (the entry point) of the rivers or tributaries into the main lake and the outlet (exit point) besides numerous tributaries. These morphometric features of the selected stations were presented in table 3.1. The sampling points were marked with the use of the Global Positioning System GPS (Magellan, SporTrak PRO MARINE [IEC – 529 IPX7 Model]) kit to ensure proper location of the stations during each sampling exercise. Two days were set aside for sampling twice in a month. A manual paddling canoe was used to move from one station to

Table 3.1: Some morphometric features of the selected stations on Eleyele Lake (Sampling Stations/ Design)

Zone	Station	Co-ordinates	Maximum depth (m)	Elevation
Z1	A –Oluseyi	07^{0}25'32.1"N 03^{0}51'52.4"E	6.02	180m
	B –Agbaje	07^{0}25'54.1"N 03^{0}51'61.3"E	7.50	181m
	C- Babalegba	07^{0}25'41.2"N 03^{0}51'80.2"E	5.31	180m
Z2	A -Apapa-ijokodo	07^{0}25'47.2"N 03^{0}51'60.4"E	5.80	181m
	B -Apete	07^{0}25'59.5"N 03^{0}51'64.3"E	6.83	180m
	C –elewure	07^{0}25'88.4"N 03^{0}51'88.8"E	6.00	182m
Z3	A –Oteru	07^{0}25'64.2"N 03^{0}51'43.1"E	6.41	181m
	B – idi-osan	07^{0}25'69.7"N 03^{0}51'54.4"E	5.60	181m
	C -Oniyere	07^{0}25'95.7"N 03^{0}51'36.6"E	6.10	181m
Z4	A –Dam	07^{0}25'71.3"N 03^{0}51'32.5"E	10.40	180m
	B-spillway	07^{0}25'82.5"N 03^{0}51'44.9"E	11.51	180m
	C- Ologuneru	07^{0}25'72.1"N 03^{0}51'54.2"E	9.71	181m
Z5	A-Adedokun	07^{0}25'52.3"N 03^{0}51'75.1"E	9.45	179m
	B -Igunleero	07^{0}25'63.4"N 03^{0}51'81.5"E	8.91	177m
	C –Fisheries	07^{0}25'37.7"N 03^{0}51'54.9"E	6.50	177m

another on the first day for the collection of water for the physico-chemical constitutents, macrophytes samples collection, and sediment samples collection. The second day of sampling was assigned for sampling fishermen landing (catches). Fish were procured from the fisher folks at the jetty spot and one-on-one interaction were done with the fishermen to know their fishing location. The landing sites surrounding the Eleyele Lake were five in number. Experimental samples were collected twice in a month in all the sampling points throughout the sampling period. The map of Eleyele Lake with the sampling zones were presented in Fig. 3.1.

3.3 Major features of the sampling zones

Zone 1 comprised Oluseyi, Agbaje and Babalegba: These points are the entry points for Agbaje and Babalegba stream around this particular site. Fishing and farming activities were common in this zone. Also, the zone was covered by dense aquatic macrophytes comprising floating and emergent macrophytes, such as water lettuce, water lily, stone breaker and water primrose. There are also small settlements for fishermen and churches of different denominations. Run-off from the cassava-processing unit and that of farms around the area, washing, defecation and many others pollute the water from this zone.

Zone 2 comprised Apapa Ijokodo, Apete and Elewure: This area was dominated (by water spinach and few other aquatic vegetation, like water lettuce and water primrose). Fishing activities were reduced in this zone because of the thick vegetation. There are various sources of river along this zone (Apete area). These include the Awba Dam, IITA Dam and Oke Itunu Stream. Also there is Osun River tributary which enters the lake from this axis. The zone was named after that area Elewure. Anthropogenic undertakings, which include washing, bathing, discharge of sewage, run-off from farming activities were common in this zone. Human settlements were located about 200m away from the lake.

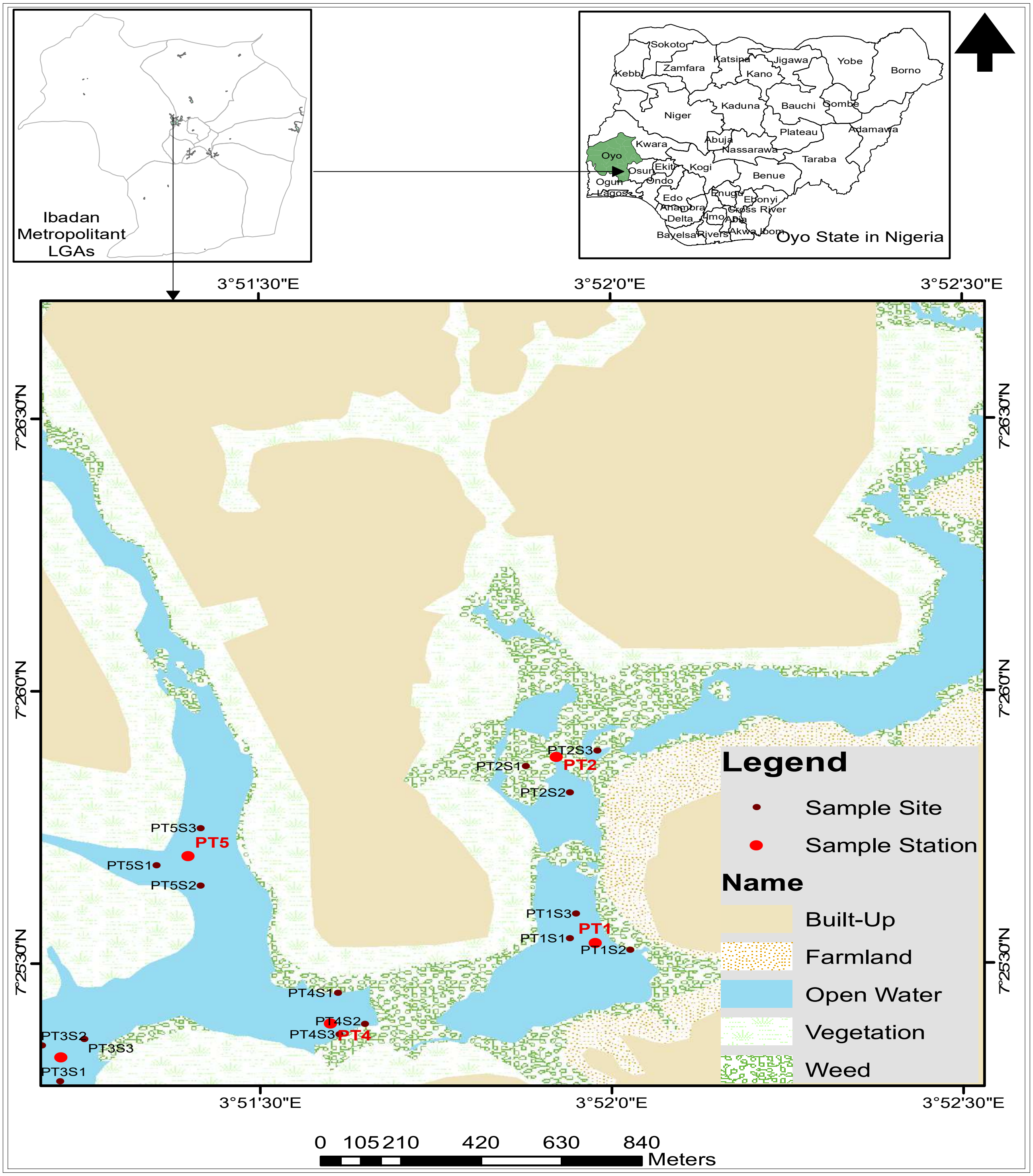

Fig 3.1: Map of Eleyele Lake

(Source: Recognisance survey- Nov., 2014)

Zone 3 comprised Oteru, Idi-osan and Oniyere: Oniyere Stream and Oteru River flow into Eleyele Lake through these tributaries. The water surface was dominated by dense aquatic vegetation (water lettuce, water primrose, water spinach water lily, nut grass, and many others). Because of the human settlement located around this area, household wastes were discharged directly into the lake. Fishing activities was prominent in this zone.

Zone 4 comprised the Dam, spillway and Ologuneru: The Arinkinkin Stream is located around this zone. The Oyo State Water Corporation's main pump is situated there; also the University of Ibadan water pump and that of FAN Milk Industry are located around this area. The deepest portion and outlets of the lake are located around this area. There were active fishing activities in this zone because aquatic features in these zones were moderate.

Zone 5 comprised Adedokun, Igunle-ero and fisheries: This zone (Station Igunle-ero) served as landing sites for people crossing the lake with canoe and boat cruising spot. Swimming activities also took place there; and it also served as fishermen's landing point. Fish processors huts were located around this area. Construction and canoe repair as well as making and repair of fishing nets were part of the features of this zone. A car mechanic workshop and a block industry were located about 50m away from the lake. The activities in the area included bathing, cleaning and washing of processed fish, washing of nets and canoes, run-off from the mechanic workshop and the block industry. Farming activities were not prominent in this zone and the aquatic macrophytes were sparsely populated.

3.3.1 Rainfall data

Rainfall data (measured in mm) on monthly basis of the experimental zone for the periods of analyses were obtained from the GIS unit, Department of Geography, University of Ibadan, Ibadan, Nigeria.

3.4 Experimental design

Randomized Complete Block Design (RCBD) was employed for this study. This design is applied when the experimental units are similar. Introduction of blocks enhances the full usage of variation among the blocks and within-blocks variation is reduced. For the RCBD, all the blocks encompass all the treatments. Inside individual block, the directive in which treatments are verified is indiscriminately evaluated.

The work was done in four seasons (two dry and two rainy seasons). The features that were measured in both seasons were the fish, the water, the sediments and the macrophytes variation in Eleyele Lake. The statistical model for the design was:

$Y_{i,j} = \mu + B_i + T_j + e_{i,j}$,

where

μ = complete mean

B_i = significance of ith block

T_i = significance of jth treatment

ei,j = random error term

3.5 Assessment of macrophytes composition and distribution in Eleyele Lake

Aquatic macrophytes composition was evaluated using point transect (point sampling to determine the cover) using a rake-based method for collection. The lake was randomly stratified in line with Nichols *et al.* (2000), Alix and Scribailo (2006), Alix (2006) and Rothrock *et al*. (2008).

3.5.1 Sampling method – Collection of aquatic macrophytes

The sampling was done through a lake survey, according to Thomaz *et al.* (2009), inside a boat going at a gentle speed in all the five zones to which the lake was spatially stratified (Ajani 2001; ISO 2006; Muhammad *et al.,* 2008). Hook was attached to a calibrated rope of 5m and fixed with the rake. This was tossed parallel to the side of the transect, which was parallel to the shore at depths of 0.25m, 0.5 and 1m. The rake was allowed to go down and then dragged to retrieve the macrophytes. The rake was tossed four times in each station (sampling point) making twelve times in each zone and total number of throws in all the zones was sixty (60) according to Rick Mc Voy (1991). These were recorded and estimated to determine the macrophytes composition and species observed in each zone.

3.5.2 Identification of macrophytes composition

After the rake was retrieved at each zone and the number of occurrence was recorded, different texts were used for the macrophyte identification, as described by Johnson (1997), Akobundu and Agyakwa (1998) and Ayeni *et al.* (1999) with data recording sheets (species identification and distribution). Aquatic macrophytes samples collected from different locations was put in a labelled polyethylene bags (the polyethylene bags was washed and preserved with 5% nitric acid, then cleaned with purified water at the spot of collection and was coated with aluminium paper) (Chioma and Isimaikaiye, 2010) and taken to University of Ibadan Herbarium (Department of Botany) for proper identification. Photographs of different species were taken at different sampling sites, according to Hassan *et al.* (2014).

3.5.3 Analytical method for macrophytes

3.5.3.1 Evaluation procedure for macrophytes composition and distribution

The total number of observation of rake that was tossed in all the stations in the five zones was sixty. The frequency of occurrence was used to evaluate the number of times each macrophyte was present in each station each time the rake was tossed.

The monthly proportion (%) of all the species, the concentration and area concealed were calculated by means of frequency of occurrence.

The frequency of occurrence was calculated to be:

$$Fo = \frac{n}{N} \times 100$$

where:

Fo = frequency of occurrence,

n = number of individual macrophytes species and

N = total number of all the macrophytes observed

3.5.3.2 Macrophytes dynamics and spatial distribution (increase and decrease in macrophytes abundance)

The population density of macrophytes was noted for rare (R), occasional (O) or common (C**),** according to Kilsh (2000), Capers (2003), Shekede *et al*. (2008) and Wersal *et al*. (2010) based on there distribution and density (area cover) seasonally. GPS coordinates recorded from the estimation of point transect during sampling were used to draw map of the macrophytes dynamics and the spatial distribution of the macrophytes, following the techniques of Parsons *et al*. (2009) and Robles *et al.*(2010), to deduce the increase and decrease in different areas covered by the macrophytes. The change that had occurred to macrophytes in the previous years (last ten years) was considered**.** Secondary data from the GIS Unit, Department of Geography, University of Ibadan were used to draw the map from 2007 to 2014, while the GPS coordinates during the study period were used for the 2014-2016 map. This approach helps in monitoring and provides the ecologist the useful tools to track down changes in their eco-zone.

3.5.4 Determination of macrophyte dynamics

This was done using different indices.

3.5.4.1 The Aquatic Macrophytes Community Index (AMCI): This is a versatile device established to evaluate natural quality or environmental integrity of the macrophytes community in a lake (Nichols *et al.*, 2000). Seven parameters were used to categorise plant communities and these parameters were given range value of 1-10. They were

- Maximum depth of the plant growth,
- Littoral area vegetated,
- Simpson's diversity index,
- Relative frequency of submerged species,
- Relative frequency of sensitive species,
- Taxa number, and
- Relative frequency of exotic species.

All values of these seven parameters of AMCI were presented in table 3.2 and was added together to determine the AMCI value, which ranged between 7(poorest quality macrophyte community) and 70 (highest quality macrophyte community).

3.5.4.2 Floristic Quality Assessment (FQA): This procedure was established by Gerould Wilhelm in 1970 to assess an area's vegetative integrity based on its plant community (Herman, *et al*., 2017).It is a device used to evaluate the ecological or vegetative integrity of an area established on its macrophyte species composition (FQA – 1-19 low VQ; 20 -35 high VQ to < 35 Natural VQ). Coefficients of conservatism (known as Mean C ranging from 0-10) were given to each plant species in each area (Herman, *et al*., 2017). Mean C was evaluated based on the inventory of plants. Floristic Quality Index was evaluated by multiplying the mean C value by the square root of the total number of species.

$$\widetilde{C}\sqrt{n}$$

where mean C = Coefficient of Conservatism

n =total number of species

Coefficient of Conservatism Mean C 0-10 description

0 – Plants with a wide range of ecological tolerance. Often these plants are opportunist invaders of natural communities or native species.

1-2: Widespread taxa that are not typical of a particular community

3-5: Plants with an intermediate range of ecological tolerance that typify a stable phase of some native communities but persist under some disturbance.

6-8: Plants with a moderately narrow range of ecological tolerance that typify a stable phase of late successional native plant communities.

9-10: Plants with narrow range of ecological range tolerance that exhibit very high fidelity to narrow range of stable habitat requirements.

3.5.4.3 The **Relevé sampling approach** that visually assessed the vegetation and the estimate abundance (per cent cover and density) was carried out in line with the methods of Nichols *et al. (*2000), Rothrock *et al.* (2008) and Wersal *et al*. (2010).

Table 3.2: Scaled values for characteristics measured in the Aquatic Macrophyte Community Index (AMCI)

MDPG (%)	value	LAV (%)	value	SS (%)	Value	TN	Value	ES	value	SDI	value	SSP	value
<1.4	1	<18	1	<34	1	<5	1	0	10	<60	1	<0.1	1
1.4-2.0	2	18-24	2	34-43	2	5&6	2	1-5	6	60-70	2	0.1-2	3
2.0-2.7	3	24-29	3	43-49	3	7&8	3	5-10	5	70-76	3	2-4	4
2.7-3.0	4	29-32	4	49-58	4	9	4	10-20	4	76-80.5	4	4-9	5
3.0-3.2	5	32-34	5	58-60	5	10&11	5	20-30	3	80.5-83.5	5	9-13	6
3.2-3.7	6	34-37	6	60-65	6	12&13	6	30-40	2	83.5-85.5	6	13-17	7
3.7-4.0	7	37-40	7	65-68	7	14&15	7	≥40	1	85.5-87.5	7	17-22	8
4.0-4.5	8	40-45	8	68-72	8	16-19	8			87.5-90	8	22-30	9
4.5-5.0	9	45-50	9	72-75	9	19-25	9			90-92	9	≥30	10
≥50	10	≥50	10	75-85	10	≥25	10			≥92	10		

Source: Adapted from Nichol *et al*., 2000

Key: MDPG – Maximum Depth of Plant Growth (m); LAV – Littoral Area Vegetated (%); SS –Submerged Species(relative %); TN-Taxa Number; ES – Exotic Species; SDI- Simpson's Diversity Index; SSP – Sensitive Species

3.5.5 Evaluation of macrophytes dynamics using biodiversity indices

Different diversity indices were used to evaluate the macrophytes dynamics of Eleyele Lake.

3.5.5.1 Simpson's Index

This involves the richness and percentage (proportion) of individual macrophyte species (Simpson, 1949). It examines the frequency of occurrence (that is, abundance) of a particular macrophyte species in a zone and also the overall number of species observed in all zones.

$$\text{Formula } D = \frac{\sum n(n-1)}{N(N-1)}$$

where N= Overall number of all individual macrophytes present in the sample

n = Number of individuals in macrophytes

Then:

Simpson's index of diversity: 1-D

3.5.5.2 Shannon Wiener Index

This index examined the richness and proportion (Shannon and Wiener, 1949) of macrophytes present in each zone. The P value for each category will be calculated first:

$$\text{Formula } H = \sum pi/npi,$$

where *pi* – frequency of occurrence of each particular macrophyte, evaluated as fraction of individuals of an assigned species to the entire figure of individuals in all the zones, that is, n/N

3.5.5.3 Margalef's richness index

Margalef index (d) **(**Margalef, 1974) was enhanced to determine the species richness.

$$D = \frac{(S-1)}{ln\ (n)},$$

Where S = the total number of macrophytes observed

n = total number of individual macrophytes observed and 'ln' is the natural or Naperian logarithm (log_a)

3.5.5.4 Equitaility (J)

The evenness with which each macrophyte was divided among the taxa present was recorded. Shannon diversity is divided by the logarithm of number of taxa.

$$J = \frac{H}{log_2 S},$$

where: J = Equitability index

H =Shannon Weiner Index

S = Total number of macrophytes

3.5.5.5 Berger-Parker Index

The Berger-Parker Index is the *Pi* value in the dataset, that is the proportionate frequency of occurrence of the highest bountiful macrophyte. It relates to the weighted comprehensive mean of the *Pi* values when q approaches infinity and therefore equals the inverse of true diversity of order infinity ($1/^{\infty}D$).

3.5.6 Determination of proximate composition of the aquatic macrophyte samples

Proximate composition of the following nutrients in aquatic macrophytes samples was evaluated with standard techniques of AOAC (2000): % moisture, % crude protein, % ash, %crude fibre, % crude fat, and % carbohydrate. The aquatic macrophytes were air-dried at room temperature in the laboratory and ground. Then, the minerals in the ash were brought into mixture by moisten digestion with concentrated HNO_3 (63%) per chloric acid (60%) and sulphuric acid (98%) in the ratio of 4: 1: 1. Potassium and calcium were evaluated using flame photometer. Phosphorous was evaluated using spectronic 20 E and the content was estimated by the standard method of AOAC (1995). The optical density of the resultant product of the spectrophotometer was measured at 400nm in a UV–VIS. Other mineral concentrations (sodium and magnesium) were evaluated by using the Buck Scientific Atomic Absorption Spectrophotometer (VGP 210/211 model) according to the standard method of AOAC (2000) in the aquatic macrophytes samples and water samples. The spectrophotometer was fixed at diverse wavelengths (380nm, 568nm) for each of the minerals for precise measurement.

3.5.6.1 Evaluation of moisture content

The sample was oven-dried at 105°C for about three hours (apart from water, other volatile matter will be loss at this temperature) (AOAC, 2000). Clean dry flat dish made of silica was used in the oven and ventilated in the desiccator. The cool dish was weighed (W1). The sample was spread in a dish and weighed accurately (W2). The dish was reverted to the oven for half an hour, cooled in the desiccator and weighed again. This process was repeated to get a constant weight (W3).

$$\% \text{ Moisture} = \frac{(W_2 - W_3)}{(W_2 - W_1)} \times 100$$

This value is the same as (a) % loss on drying

(b) % matter volatile at 105°C

3.5.6.2 Determination of the % Ash

The silica dish was cleaned, dried, ignited, cooled (in a desiccator) and weighed (W1) (AOAC, 2000). Five grams of the sample was weighed accurately into the dish (W2). A muffle furnace was set at 500°C for 7-8 hours until the sample was fully ashed and grey colour of ash was noticed. This dish was cooled with the ash in a desiccator, and then weighed (W3).

$$\% \text{ Ash} = \frac{(W_3 - W_1)}{(W_2 - W_1)} \times 100$$

3.5.6.3 Determination of % crude protein (using Micro Kjeldahl Method)

Micro-kjeldahl techniques were adopted in evaluating the crude protein percentage in the sample (AOAC, 1990). The organic nitrogen was converted to ammonium sulphate through digestion using concentrated tetraoxosulphate (VI) acid in the micro-kjeldahl flask. The solution was diluted and alkaline solution was formed with the addition of sodium hydroxide; it was then distilled. Boric acid was used to collect the ammonia liberated and this was analysed titrimetrically. The protein percentage in the sample was computed as follows:

$$\text{Protein (\%)} = (c - b) \times 4 \times 6.25/a \times 1000 \times 100,$$

where, a = sample weight;

b = volume of NaOH essential for titration and neutralizing the 25mL of $0.1NH_2SO_4$ (for sample);

c = volume of NaOH essential for titration and neutralizing 25mL of $0.1NH_2SO_4$ (for blank);

d = normality of NaOH used for titration;

6.25 = conversion factor of N to protein; and

4 = atomic weight of N

3.5.6.4 %fat evaluation (using Soxhlet method)

Principle: Continuous removal of fat with light organic solvent, for example petroleum ether or N-hexane using a gravimetric estimation of fat from a dry powered sample.

Apparatus used: (a) Soxhlet extractor with ground glass joints

(b) Tap-off receiver with ground glass joints

(c) Heating mantels (six or four channel type) or water bath of similar specification.

(d) Flat-bottom flasks with ground glass joints

Procedure: Five grams of the powered sample (W) was precisely weighed using weighing dish into a flat-bottom flask (W1) and the extractor was mounted on it while the weighed sample was carefully transferred into the thimble. The weighing dish was rinsed with the solvent (pet ether or N-hexane) and was poured into the thimble to reach about two-thirds of the volume of the flask and continuous extraction was done for five hours. When extraction was completed, the solvent was collected; using the tap-off and the residue was dried. The flask was cooled and weighed with the residue (W2) (AOAC, 2000);

$$\% \text{ Fat} = \frac{(W_2 - W_1)}{W} \times 100$$

3.5.6.5 % crude fibre evaluation

Two grams of each of the samples was weighed into different round-bottom flask; 100mL of 0.25M of tetraoxosulphate (IV) acid solution was mixed; and the combination of these solutions was heated for 30 minutes beneath reflux. The hot mixture was sieved immediately under suction while the deposits were washed carefully with hot water till the solution was acid-free. The residues were moved again to a round-bottom flask and 100mL of 0.3M of sodium hydroxide mixture was mixed. This combination was heated under reflux again for 30 minutes and sieved immediately below suction. The residues were undissolvable and were rinsed with heated water till they were free from base. An oven was used to dry the sample to constant weight at 100 ^{o}C for 2 hours; the sample was cooled in a desiccator and weighed (C1). The weighed sample was incinerated and then reweighed (C2). Percentage crude fibre = final weight – initial weight x 100

$$C2 - C1 \times 100$$

3.6 Collection of water samples

Sample bottles were cleaned two times with the water sample before the time of sampling. The desired samples were collected from the spots far from where the sampling was carried out and sample bottles were washed.

Water samples for the assessment of physico-chemical constituents were taken just below the surface at each station with a 75cl-bottle that was cleaned before with mixed nitric acid and cleaned with purified water. The samples of water were taken at each designated sites near the surface approximately 50cm deepness. The samples collected were stabilised using 5ml/L of concentrated nitric acid (APHA, 2005) and kept at the lowest heat before mineral components were evaluated. Another set of water samples was put into 250ml dissolved oxygen glass bottle with a glass stopper at every location and stabilised following the procedures of Winkler's method which make use of manganese sulphate solution and alkaline potassium iodide reagents for dissolved oxygen assessment (APHA, 1998).

The acid treatment was to make sure the mineral components were not captivated at the top of the bottles throughout movement of the samples. These samples were taken to the research laboratory packed in between ice and examined for the following chemical parameters: alkalinity, total hardness, total dissolved solid, dissolved oxygen, biochemical oxygen demand, chemical oxygen demand, nitrate, phosphate, ammonia and nutrient compositions (calcium, sodium, magnesium, chloride, potassium and phosphate).

3.6.1 Analytical procedure for water

3.6.1.1 Water transparency (cm)

This was assessed with the use of Secchi disc (diameter of 20cm). The disc was let down into the water gradually till it was no more visible. The level at which the disc turned out to be absolutely unseen was noted. The disc was cautiously raised up over again, and the level at which it appeared was similarly recorded. The averages of these two records were the value of transparency.

3.6.1.2 Evaluation of pH

This signifies the hydrogen ion concentration in water. The pH of an aqueous mixture is described by this formula:

$$pH = -\log_{10} [H^+]$$

Water samples for the pH were evaluated in the laboratory and were documented by potentiometric procedure with the aid of pH meter (Mettler Toledo MP 220) previously homogenised through the use of buffer mixture of identified values preceding the analysis (Skoog *et al.*, 2007).

3.6.1.3 Evaluation of water temperature (^{o}C)

Temperature was evaluated with a mercury-in-glass thermometer at the sampling location with moveable standardized thermometer (0 ^{o}-100^{o}C). The thermometric bulb comprising the mercury was perpendicularly dipped into the water and permitted to stand for two -

three minutes until the temperature interpretation was stable and the result was documented.

3.6.1.4 Determination of water depth

The water depth was determined according to APHA (2005). A graduated rope was tied to a metal plate and this was released into the water at every sampling point at one edge of the canoe until it was confirmed that the sinker had rest at the bottom of the lake. The rope was carefully lifted and the reading on the graduated rope was taken and recorded in metre. This process was repeated at each sampling point.

3.6.1.5 Evaluation of electrical conductivity (µs/cm)

The electrical conductivity was evaluated in the laboratory with conductivity gauge (model DA-1 Code 1908). The electrodes of the gauge were immersed in the glass beaker holding the sample and the interpretations was noted and documented.

3.6.1.6 Determination of total solids

According to the method of APHA (1998), gravimetric technique was exercised to ascertain the total solids. The weight of the evaporating dish was measured and then dried at 104 ± 1^0 C for one hour, cooled and stored in a desiccator. A magnetic stirrer was used to stir the sample and a bore pipette was used to pipette a known volume to an evaporating dish. 200mg of the dried residue of the sample volume was taken and evaporated to dryness at 104 ± 1^0 C in an oven. After evaporation for one hour at 104^0C, the oven temperature was reduced by 2^0C to avoid splattering. The vaporising dish was cooled in a desiccator and then weighed up.

$$\text{Complete Solids (mg/L)} = \frac{(A\text{-}B)}{\textit{ml sample}} \times 100$$

where, A = weight of dish + deposit, mg; and

B = weight of dish, mg

3.6.1.7 Determination of Dissolved Oxygen (DO)

The DO was ascertained with the Modified Winkler's procedure as described by APHA (2005). With a separate pipette, 1ml solution of maganous sulphates and alkaline azide was included in the water sample that was collected in a 250ml-glass bottle. The precipitate formed by maganous hydroxide floc was dissolved with concentrated sulphuric acid after five minutes. The sample that was fixed was titrated against 0.025N of sodium thiosulphate mixture starting from the burette drop by drop with 1ml starch solution as indicator. The colour changed from blue to colourless and the completion stage was noticed, the major fading of the blue shade.

The volume of DO available was estimated with the expression:

$$DO\ (mg/L) = \frac{Volume\ of\ the\ titrant \times 0.2}{Volume\ of\ Sample} \times 1000$$

where, 0.2 values signify 1ml of Sodiumthiosulphate equivalent to 0.02mg of oxygen (APHA, 2005).

3.6.1.8 Determination of Total Alkalinity (TA)

The titrimetric technique was utilised to ascertain the total alkalinity according to APHA (1989). 25ml of the sample was titrated versus $0.02H_2SO_4$ solution applying one drop of methyl orange as indicator. The colour switched to red orange/pink.

$$Total\ alkalinity\ as\ CaCO_3\ (mg/L) = \frac{N \times E \times 1000 \times V}{Sample\ (ml)}$$

Where: N is normalcy of H_2SO_4 (0.02N),

E is the corresponding mass of $CaCO_3$ (50), and

V is the quantity of H_2SO_4 (ml) utilised in the course of titration

3.6.1.9 Determination of Total Hardness (TH)

The EDTA titrimetric method as described by APHA (2005) was used in the estimation of total hardness in the samples collected. Distilled water was to dilute the mixture thoroughly and mixed with 25ml water sample to 50ml in a conical flask. 2-4 ml buffer pH 10 (67.5g NH_4Cl in 570 ml conc. NH_4OH was diluted to 1 litre) was poured to the flask. 2-3 drips of Eriochrome Black-T (0.5g sodium salt of 1-(1- Hydoxy-2-naphthylazo)-5-nitro2-

naphthanol-4-sulfonic acid dye in triethanolamine 100g indicator were mixed to the sample and then titrated slowly versus 0.01M EDTA. There was intermittent shaking till the final reddish tinge colour transformed to bluish purple.

$$\text{Total Hardness (mg/L)} = \text{Ca} + \text{Mg (as } CaCO_3) = \frac{V \times M \times 100 \times 1000}{\text{Sample (mL)}}$$

where V is volume of EDTA exhausted as molarity of EDTA (0.01M) and 100 is the molecular weight of $CaCO_3$

3.6.1.10 Determination of Biochemical Oxygen Demand (BOD)

The sample of water was exposed for 5-10 minutes before it was transferred into the BOD bottle of 250ml. The initial oxygen was noted before the sample was nurtured for 5 days in darkness at a constant temperature of 20 ± 1^0C. The oxygen level was examined again after five days of incubation. The amount of oxygen consumed for biological oxidation purpose was determined by deducting the conclusive oxygen from the opening oxygen (APHA, 1989).

BOD value was computed applying this formula:

$$\text{BOD (mg/L)} = \text{DO initial} - \text{DO after 5days}$$

3.6.1.11 Evaluation of Chemical Oxygen Demand (COD)

Chemical Oxygen Demand was determined by applying the dichromate reactor digestion technique (Hach, 2003). 100ml of the water sample was pipetted inside a flask and 10ml of sulphuric acid and 10ml of 0.0125N potassium permanganate mixture was combined with the sample. Water bath was used to boil the solution for thirty minutes and after boiling 10ml of ammonium oxalate was included in the solution. While the suspension was still heated, it was titrated with standard $KMnO_4$ until pink colour was noticed.

The quantity of COD exhibit in the sample was estimated as:

$$\frac{\text{ml of } KMnO_4 \text{ used in titration} \times 100}{\text{ml of sample (100ml)}}$$

3.6.1.12 Determination of nitrate (NO_3-N)

The phenol disulfonic acid method as described by APHA, 2005 was used in estimating the nitrate level in the water sample. 50ml standard nitrate mixture (100mg/L) was positioned inside the water bathtub till it remained dry. 2ml phenol disulfonic acid reagent was used to dissolve the residue; it was then diluted with purified water to 500ml to make a mixture of 10 µgN/ml. Different quantities, viz: 0.1, 0.5, 0.7, 1.0, 1.5, 2.0, 3.5, 6.0, 10, 15 and 30 ml, of the normal nitrate mixture were transferred into a discrete 100ml flask, in which 2 ml phenol disulfonic acid and 7ml concentrated NH_4OH was included. From the quantities of phenol disulfonic acid and NH_4OH, a vacuous was formulated. Absorbances of values were declared alongside the plain at 420mm wavelength. The standardization curves were set by marking the absorbance alongside the quantity of NO_3-N. The equivalent estimate of the sample was interpreted from the pattern curve.

The quantity of nitrate-N present was computed as described below:

$$\text{Nitrate-N(mg/L)} = \frac{\text{NO3- N (mg)}}{\text{Sample volume (ml)}} \times 1000$$

3.6.1.13 Determination of phosphate

Phosphate level was estimated with the Deniger's approach, according to APHA (2005). 1ml of Deniger's reagent and five drips of stannous chloride were included in 100ml of the water sample. A blue colour was produced. The absorbance was calculated with a HACH spectrophotometer model DR-EL/2 at 690nm wavelength. The phosphate concentration was estimated from the standardization curve. The unit of dimension was in mg/L

3.6.1.14 Determination of ammonia (NH_3-N)

The iodophenols blue colour formation technique was exploited to analyse the ammonia in the water sample. 50ml (in triplicate) was measured into a clean stopper glass tube; 2ml of phenol alcohol solution was added and shaken very well. Then, 2ml of Sodium Nitro-prusside solution was added, followed by 5ml of oxidizing solution (mixture of 100ml of sodium citrate mixture and 25ml of sodium hypochloride mixture preceding the time of ultilisation) and mixed very well. Thereafter, the flask was covered with polythene sheet and permitted to stand for one hour. The absorbance of the sample was quantified in a spectrophotometer utilising the 1cm cell at 640 nm ammonia liberate MQ water as quotation (APHA, 1995).

Computation:

Calculation for feature estimate (F): F= A(st)-A (b)/conc. of standard solution,

where A (st) =Mean absorbance standards

A (b)-Mean absorbance of blanks

Analyse the concentration of ammonia

Ammonia µmol/L =F x A (s)-A (b),

where A(s) =Mean absorbance of samples

A (b) = Mean absorbance of blanks

3.6.1.15 Determination of calcium hardness (Ca)

Calcium hardness in the water was estimated with the burette titration process, following APHA (2005). An aliquot of water sample, after treating with N/10 NaOH followed by small amount of muroxide indicator was titrated against 0.01M EDTA mixture till the salmon pink turned to purple. Titration was discontinued and the quantity of titrant consumed was documented.

Calcium hardness was analysed according to the formula:

$$\frac{\text{Volume of titrant used (V2) x 1000 x 1.05 (mol. Wt. of } CaCO3)}{\text{Volume of sample}}$$

3.6.1.16 Evaluation of magnesium hardness

The magnesium substance in the water sample was estimated according to the formula given by APHA (2005):

$$\text{Magnesium content (mg/l)} = \frac{V1 - V2 \text{ x } 1000}{\text{Vol .of sample}}$$

where V1 = Volume of EDTA titrant used for measurement of total hardness

V2 = Volume of titrant used for estimation of calcium hardness

3.6.1.17 Determination of sulphate (SO_4)

Following the procedure in APHA (2005), the nephelometry method was applied to measure the sulphate level in the water sample. 100ml of the water sample was gauged into

250ml conical flask and 20mL buffer solution was included; the mixture was stirred together thoroughly. a spoonful of $BaCl_2$ crystal was included and mixed for 60 seconds. Turbidity of the sample was estimated 5 minutes the stirring had been stopped and SO_4 was prepared. $BaSO_4$ turbidity was developed and turbidity level of the standard was measured. Calibration curve between turbidity and SO_4^{2-} concentration for the sample was estimated from the standardization curve after deducting the turbidity of sample-blank from the turbidity of the treated sample.

3.6.2 Collection of sediment samples

Sediment samples were gathered with the use of a locally fabricated Van-veen grab $0.1m^2$ (wt. 25kg; ht. 20cm) made of stainless steel. At every sampling site, three replicates were obtained for sediment characteristics (% of sand, clay, and silt, organic carbon, organic matter, pH, sodium, magnesium, calcium, potassium and phosphate) in the deposited sediment. The sediment samples collected with a scoop at each station were stored in metal-free well-labelled polyethylene bags in aluminium foils for organic constituent analysis in the laboratory. The combined sediment samples were collected in labelled polyethylene bags, washed before being coated with 5% nitric acid and cleaned with purified water. The polythene bags were cleaned with water samples at the place where the sediments were obtained prior to the time the sediment samples were deposited in them. Also, the pH was analysed in accordance with the nutrient concentration in the sediment samples (Chioma and Isimaikaiye, 2010). The grab was rinsed thoroughly before redeployment.

3.6.3 Sediment analytical method

3.6.3.1 Granulometric analysis of sediments

The Cardoso *et al.* (2008) granulometric analysis procedure was used to analyse the collected sediment samples from the five sampling zones. Grain size was analysed using different mesh size sieve with smallest mesh size at the base. A collection basin was positioned under the sieve to gather the very smooth particle-size sediment. The features and description of the particle size followed these segments: clay (<0.002mm), silt (0.002-0.02mm) and sand (0.02-2mm). The sand constituent was analysed into further segments:

very fine sand (0.02-0.06mm), fine sand (0.06-0.2mm), medium sand (0.2-0.6mm), and coarse sand (0.6-2mm). A fraction of the particles was left in each different mesh-size sieves and basin, and then weighed. This was taken as the proportion of the overall sediment mass (Cardoso *et al.*, 2008).

3.6.3.2 Determination of Total Organic Carbon (TOC)

The Walkey-Black method of ASTM and APHA (1995) was used to evaluate the total organic constituent of the sediment samples. This technique rests on the theory postulated by Walkey-black that the soil sample colour defines the organic carbon constituent of that particular soil sample. 2mm mesh-size sieve was used to sieve 0.5g sediment sample, which was then measured into a conical flask of 250 mL. 10ml of potassium dichromate ($K_2Cr_2O_7$) and 20 mL of H_2SO_4 were mixed with the sample and allowed to stand for 30 min on asbestos after alternating whirls. Purified water (observer ion) of 100mL was also included. 3-4 drips of ferrous indicator was mingled to this mixture and titrated with 0.5N $FeSO_4 . 7H_2O$. Soil sample rich in organic carbon will indicate a greenish form after adding all these reagents to it; but if it is not abundant in organic carbon it will indicate an orange colour. While titrating, soil rich in organic carbon changes from green to light green and lastly to maroon red or brown, which is the concluding point.

Total organic carbon was then computed as follows:

$$\text{Organic Carbon (\%)} = \frac{\text{Titre value} - \text{Titre value x 0.195(factor) of blank sample}}{\text{Weight of soil sample (g)}}$$

3.6.3.3 Determination of Total Organic Matter (TOM)

10g of sediment sample was oven-dried to a stable weight at 80^0C and was positioned in a tarred crucible. This sample was weighed again before setting it in a muffle furnace at 550^0C for 6-8 hours; it was then ignited. The crucible with the mixture was placed in a desiccator, cooled and weighed again. Immediately it was taken out of the furnace; the weight loss was estimated. The total organic matter in the sediment sample was analysed as the percentage combustible material in the sediment (Loring and Rantala, 1977).

3.7 Fish sampling and collection

The preliminary investigation revealed that the artisanal fishermen on this dam used plank canoes, surface and bottom-set gillnets, cast-nets, ring-nets, drift-nets, hook and line, long line, traps and beach-seines of various mesh sizes for their fishing operations. The fishermen usually arrived at landing points (sites) in the morning between 7am and 11am.Wooden or dug-out canoes varying from 2.5m to 5m long were used for their fishing operation and mostly paddled by one man.

Mostly, sampling of finfish during the course of this research was done by examining and documenting the fish landed by the fishermen at an authenticated main fishing landing points in respect of regions/courses (Upper Zone: Ilaje area; Middle Zone-Ile Egbe area (two fish landing site) ; Lower Zone: Fisheries landing (two fish landing site)).

Landings from fishers were categorised; the quantity of entities for every species was calculated and documented. Several types of fish were accessible at the landing location and were procured from the fisherfolks. The fish sampling was done randomly and devoid of preference for any specific range collection of fish. The fish species were identified to the least taxonomic stage with the use of *www.fishbase.org*, Holden and Reed (1991), Idodo-Umeh (2003), Adesulu *et al*. (2007), Erk'akan *et al.* (2007) and Olaosebikan and Raji (2013).

Weight and length of the fish samples were calculated with evaluating weighing scales (g) and evaluating board (cm).The length-weight relationships (LWR) were ascertained using the parabolic equation: $W = aL^b$ (Le Cren, 1951),

where W = weight of fish in grams; L = length of fish in cm;

a = constant and b = an exponential showing connection within length-weight.

Fish were classified into trophic groups (herbivorous, omnivorous, piscivorous, and carnivorous), following King (1994) and Fish Base (2013). The season at which each fish species was found was noted; the macrophytes available during that season were also documented. This was to assess if there was any interaction between the fish and the macrophytes and also if the presence of the macrophytes influenced the types of fish present or if the macrophytes served as cover and protection against predators. The fish may also use the macrophytes as their spawning ground and also feed on them or the micro-organisms or insects that are attracted to such aquatic macrophytes.

3.7.1 Fish abundance in Eleyele Lake

Fish abundance was calculated from the mass (kg) of overall catch from specific landing sites for every single species throughout the phase of sampling in this study. Assessment of disparity between sites (stations) was done using Analysis of Variance to test the differences.

3.7.2 Determination of fish diversity using biodiversity indices

Diversity indices were applied to examine the variety of fish resources in the lake.

3.7.2.1 Species richness

It involves counting of quantity of individual species caught in the lake throughout the time of sampling.

3.7.2.2 Simpson's Index

This encompasses the richness and percentage (proportion) of individual species. It justifies the richness of a given species in a population and also the overall quantity of species observed in that particular ecosystem.

$$\text{Formula } D = \frac{\sum n(n-1)}{N(N-1)}$$

where N= Overall figure of all individuals in the sample

n = Quantity of individual in respective species

Then:

Simpson's index of diversity: 1-D.

3.7.2.3 Shannon Wiener index

The index measures the abundance and percentage of every single species. The P value for each category will be calculated first:

Formula $H = \sum pi/npi,$

where *pi* – relative abundance of respective species, estimated as relative amount of individuals of a particular species to the overall figure of individuals in the population, that is n/N

3.7.2.4 Margalef's Richness Index

Margalef index (d) (Margalef, 1974) was applied to determine the species richness.

$$D = \frac{(S-1)}{\ln(n)}$$

where:

S = the overall figure of species

n = overall figure of entities and 'ln' is the natural or Naperian logarithm ($\log_a$)

3.7.2.5 Equitaility (J)

The evenness with which individuals are divided among the taxa present was measured. Shannon diversity is divided by the logarithm of number of taxa.

$$J = \frac{H}{\log_2 S}$$

where: J = Equitability index

H =Shannon Weiner Index

S = overall figure of species

3.7.2.6 Berger-Parker Index

The Berger-Parker index is the *highest Pi* estimate in the dataset, that is the relative richness of the greatest rich species. It relates to the heaviness simplified mean of the *Pi* values when moved toward infinity and therefore equivalent to the opposite of exact variety of succession of infinity ($1/{}^{\infty}D$).

3.7.2.7 Potential Fish Yield (PFY)

Morpho-edaphic Index (MEI) was used as field yield estimator (Ryder, 1965). MEI was obtained from the abiotic characteristic of the water body. It took into account a measure of nutrients leached into the water body (that is, conductivity) with an indicator of mean depth.

MEI = Conductivity/d,

where:

d = mean depth

Yield (Y) = 23.281 x MEI 0.447

Where Y = yield in *kg/ha*

3.8 Determination of primary productivity in the Lake

Gross primary production, net primary production and community respiration in the water for each sample were analyzed bimonthly using a light and dark bottle technique (Trivedy and Goel, 1986) and the technique described in National Oceanic and Atmospheric Administration (2000).

3.8.1 Gross primary production, net primary production and community respiration in an ecosystem

At the beginning of the experiment, dissolved oxygen in the sampled water was established by Iodometric Winkler's method. Also, at the end of incubation time (24hrs), the dissolved oxygen content in fixed samples of incubated water samples in light and dark bottles were determined by Iodometric Winkler's method (Stirling, 1999).

In determining dissolved oxygen in the laboratory, 3ml of 50% hydrochloric acid was added by slot in the pipette tip near the stable precipitate in DO flask. The bottle was stopped instantly and shaken thoroughly until all precipitates dissolved. 50ml of the clear mixture was pipetted out in the conical flask and titrated with sodium thiosulphate mixture from the burette drip by drip until the colour transformed from blue to neutral using 1ml of starch as pointer.

DO was calculated using the following formula

Calculation

The quantity of DO in one liter of sample is expressed as

DO (ml/L) = 5.6 × N [BR(s) – BR(b) × V/V- 1 × 1000/a

DO (mg/L) = DO (ml/l) /0.7,

where N = normality of thiosulphate

BR(s) = titre value of the sample (mean)

BR (b) = titre value of the blank (mean)

V = volume of the sample bottle (125ml)

a = quantity of the sample titrate (50ml) (NOAA, 2000)

Productivity was estimated on the postulation that one atom is fit in for respective molecule of oxygen (32g) discharged for each molecule of carbon (12g) static (APHA, 1989). The variation in oxygen level in the dark bottle (a negative number) is equal to the oxygen consumed by respiration. The alteration in oxygen level in the light bottle (a positive number) is equal to the net oxygen production (net primary production). From these two values, the gross primary production is determined by adding the absolute value of the change in oxygen in the dark bottle to the change in oxygen in the light bottle (NOAA, 2000).

Calculation:

Net primary production (NPP)

Final DO in light bottle (mgL^{-1})- Intial DO in light bottle (mgL^{-1})

Community respiration (CR)

Initial DO in dark bottle (mgL^{-1})-Final DO in dark bottle (mgL^{-1})

Gross primary production (GPP)

=O_2 consumed by respiration (mgL^{-1}) + Net oxygen production (mgL^{-1})

In converting the DO (mgL^{-1}) estimates to $gC/m^3/h$, the factor 0.375 (12/32) was exploited and per hour estimates were multiplied by 24 to obtain the productivity estimates per daytime (Michael, 1984).

3.8.2 Chlorophyll *a* concentration

One litre of water sample was collected using non-toxic opaque sampling bottle for measurement of chlorophyll *a*. Sub-samples were obtained in opaque bottles, protected from warming and light, transported to the laboratory and filtered without delay (Alain and Francisco, 2000). 1g of $MgCO_3$ powder was diluted in 100ml volumetric flask with distilled water. The $MgCO_3$ was shaken and 1ml was pipetted from the suspension and 500ml of water sample was also shaken vigorously and sieved through Millipore filtering tools comprising a membrane fibre filter. The filters were removed and the boundaries not covered with residue were pruned. The strainer was crumpled and placed in the grinder. 2ml of 90% acetone was added to it and was ground for 1minute, and then 8ml of 90% acetone was included and it was ground for 30 minutes.

Thereafter, it was placed in a 15ml centrifuge tube and the centrifuge tube was firmly fastened and permitted to stay all night exclusively in a fridge in darkness. After 24hrs, the tubes were taken away from the fridge and made to cool in the darkness close to room temperature. The content of each tube was centrifuged at room temperature for 10 minutes at 3000 to 4000 rpm. The supernatant was poured into a 1cm path length spectrophotometer cuvette and the absorbance was measured at 665nm and 750nm with spectrophotometer set at 0.00 absorbance at every single wavelength with 90% acetone. Concentrations of chlorophyll *a* were then estimated by the formula given by Vollenweider (1969), as described in APHA (1999).

Chlorophyll *a* (µg/L) = 11.9 (A_{665}-A_{750}) V/L x1,000/S,

Where:

A_{665}= absorbance at 665nm

A_{750}= absorbance at 750nm

V = acetone extract in millimetres

L = length of light path in the spectrophotometer in centimetres

S = volume in millilitres of sample filtered

3.9 Statistical analysis

Rainfall data from the GIS Unit, Department of Geography, University of Ibadan, Ibadan were used to determine dry and wet seasons for the sampling period. Owing to the rainfall prototype of the analysed region, December to April was selected as dry season, while May to November was selected as rainy season. Fish species abundance was calculated by counting the number of individuals. The relative abundance of species (Ri) was also estimated:

Ri = (ni/N) x 100,

where ni = amount of a given species

N= overall figure of fish sampled.

Shannon Index (H^1), Equitability (J), Margalef's Index (d), Simpson's Dominance and Berger-Parker indices were computed and data were analyzed with the use of software package 'PAST' (Hammer *et al.,* 2001). The data generated for spatial and temporal variation in the physico-chemical constituents were analysed with both descriptive and inferential statistical tools. The descriptive statistical tools employed were mean and standard deviation. These were employed to express water feature constituents and the nutrient components in water, aquatic macrophytes and sediment experimental samples. The inferential statistical tools deployed were Analysis of Variance (ANOVA), t-test, and Correlation Coefficient, using Excel (2010). All these were applied to test for important disparities in nutrient components within the five sampling locations and the three sample variables (water, aquatic macrophytes and sediment), and important connections within the sample divisions and the degree of impact on temporal disparity.

The data were merged and reported as seasonal and spatial mean variance. Data were analysed with Analysis of variance (One way ANOVA; SPSS version 20) to assess variances at $P < 0.05$ according to regions. Mean values were alienated with Tukey's HSD multiple range test. Paired samples t-test was employed to analyze difference between the pooled seasonal data means. Canonical Correspondence Analysis (CCA) was done with PAST statistical package (Hammer *et al*., 2001) to elucidate the connection between fish abundance and macrophytes diversity, fish abundance and the physico-chemical constituents of water, as well as the physico-chemical constituents of water and the macrophytes in all parameters to determine which of the water nutrients influenced aquatic macrophytes diversity.

CHAPTER FOUR

RESULTS

4.1 Macrophytes dynamics and distribution in Eleyele Lake

Macrophytes dynamics and distribution (composition, increase and decrease of macrophytes across the water over the last ten years 2007 - 2016) during the period of sampling were illustrated in Figs 4.1- 4.3. The variation in increase and decrease from 2007 to 2016 was deduced from these maps (Figs 4.1- 4.3).

4.1.1 Macrophytes dynamics and spatial distribution in Eleyele Lake

Percentage changes in the area of macrophytes and water from the maps (Figs 4.1- 4.3) were presented in Table 4.1 and the distribution of macrophytes and water between 2007 and 2016 were also presented in Table 4.2 (secondary data). The changes was calculated based on the aquatic macrophytes area that remains over that period, the area of aquatic macrophytes that has been taken over by water, the area of water that has been taken over by the aquatic macrophytes and the area of water that still remains water. The area of macrophytes to macrophytes increased between 2014-2016, aquatic macrophytes to water reduced, water to aquatic macrophytes was also reduced while water to water area increased. While in Table 4.2, the area of aquatic macrophytes increased and the area of water decreased over the years.

4.1.2 Macrophytes identification and composition

The taxonomic family of the macrophytes represented were fourteen: Poaceae family had three species, Onagraceae had two species and other families had one species each. The checklist of the family and species are presented in Table 4.3. The families were Araceae, Nymphaeaceae, Costaceae, Ceratophyllaceae, Polygonaceae, Cucurbitaceae, Onagraceae, Pteridophyta, Cypreraceae, Poaceae and Convolvulaceae.

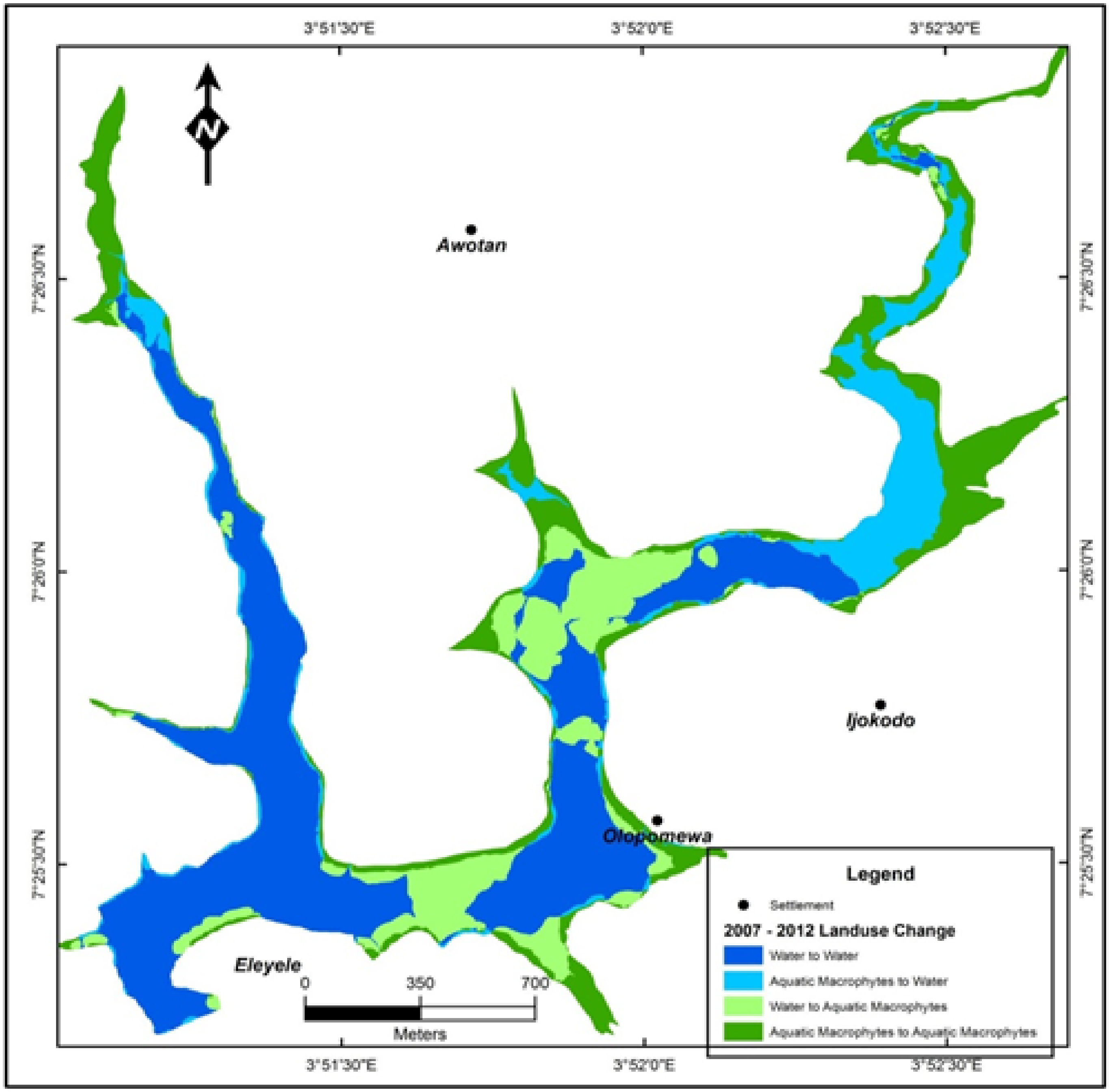

Figure 4.1: Macrophytes dynamics and spatial distribution between 2007 and 2012

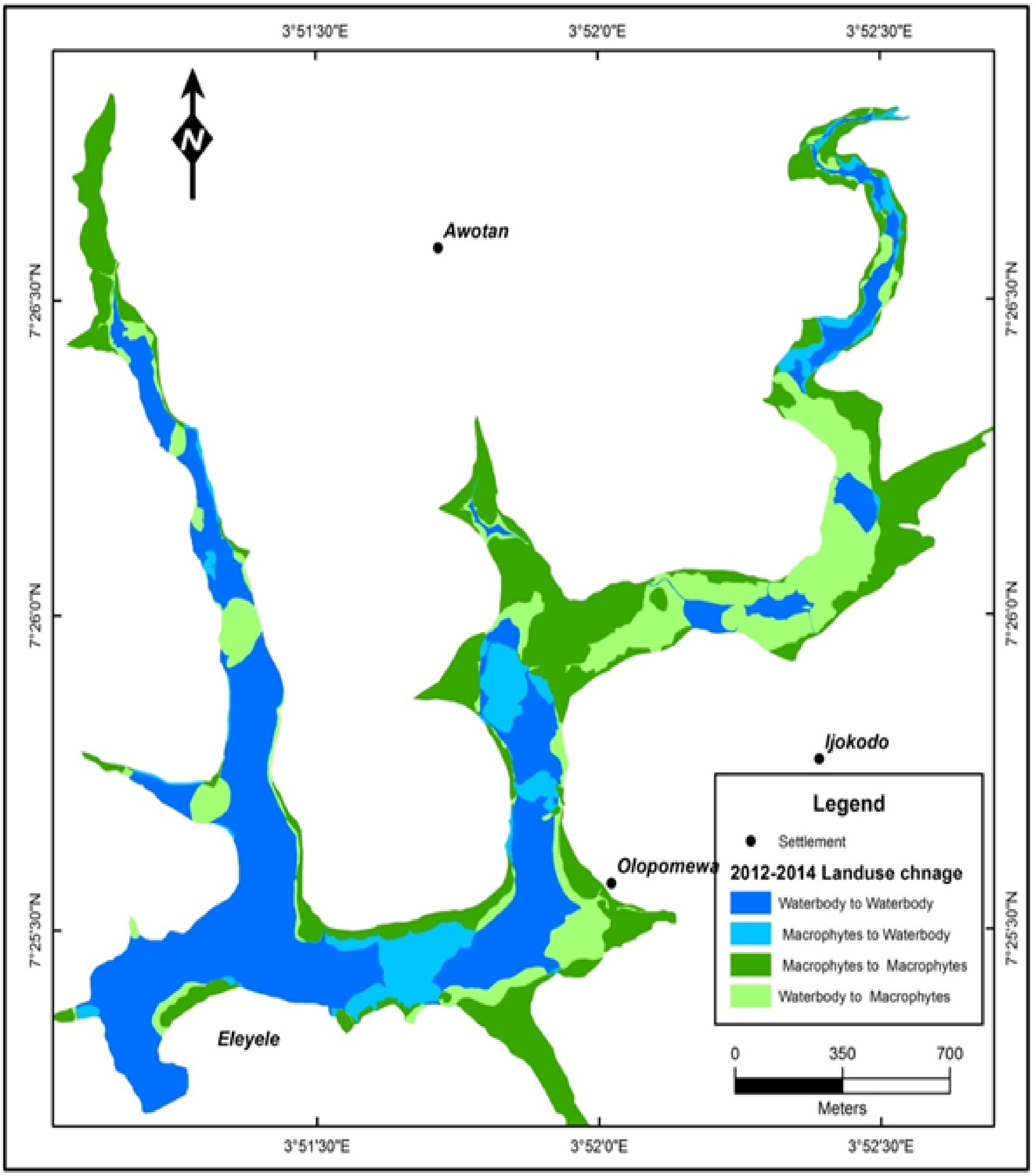

Figure 4.2: Macrophytes dynamics and spatial distribution between 2012 and 2014

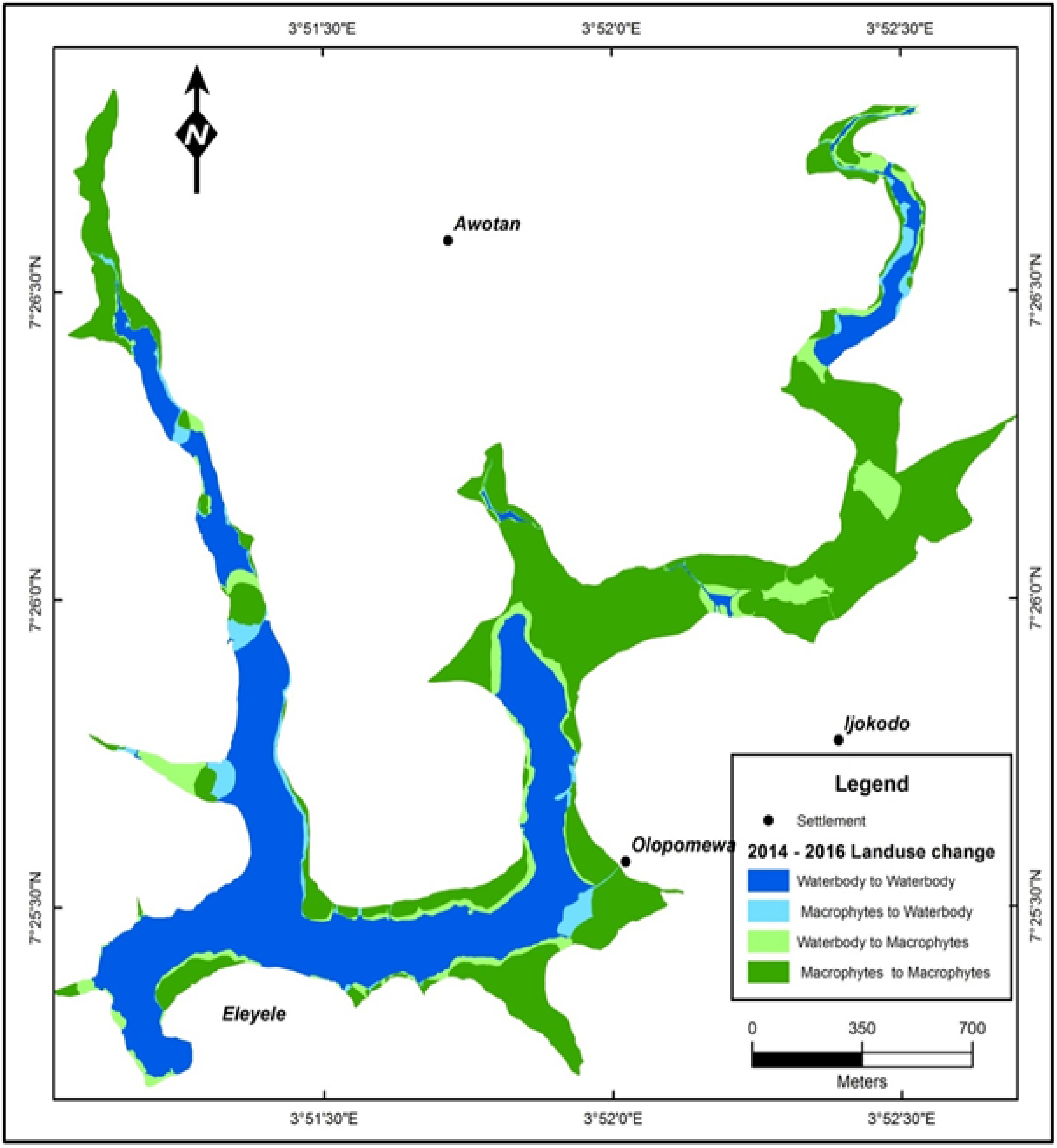

Figure 4.3: Macrophytes dynamics and spatial distribution between 2014 and 2016

Table 4.1: The increase and decrease of spatial distribution of macrophytes between 2007 and 2016 in Eleyele Lake

Macrophyte Dynamics	**2007-2012 change (%)**	**2012-2014 change (%)**	**2012-2014 Change**	**2014-2016 change (%)**	**2014-2016 Change**
Aquatic Macrophytes → Aquatic Macrophytes	23.13	32.60	9.47	**48.06**	**15.46**
Aquatic Macrophytes →Water	14.62	8.49	-6.13	**3.46**	**-5.03**
Water → Aquatic Macrophytes	15.56	20.07	4.51	**8.54**	**-11.53**
Water → Water	46.69	38.84	-7.86	**39.94**	**1.11**
TOTAL	100	100.00	0.01	**100**	**0.01**

Source: GIS Unit, Department of Geography, University of Ibadan, Ibadan

Table 4.2: Spatial Macrophyte dynamics in Eleyele Lake between 2007 and 2016

Distribution	2007(m^2)	2012(m^2)	2014(m^2)	2016(m^2)
Aqauatic Macrophyte	701413.0	688532.0	911352.0	972456.0
Water	1009920.0	1001490.0	803646.0	702139.0
TOTAL	1711333.0	169022.0	1714998.0	1674595.0

Source: GIS Unit, Geography Department, University of Ibadan, Ibadan

Table 4.3: Composition of aquatic macrophytes

Scientific name	Family	Code
Polygonum salicifolium Brouss ex Willd	Polygonaceae	22808
Pistia stratiotes linn	Araceae	22795
Cyperus rotundus linn	Cyperaceae	22796
Luffa cylindrica linn	Cucurbitaceae	22797
Sacciolepis Africana	Poaceae	22798
Acroceras zizanioides	Poaceae	22799
Leptochloa caerulescens steud	Poaceae	22803
Ludwigia abyssinica	Onagraceae	22800
Ludwigia decurrens walt	Onagraceae	22802
Ipomoea aquatica forsk	Convolvulaceae	22801
Ceratophyllum demarsum linn	Ceratophyllaeae	22804
Nephrolepis bisserrata schott	Pteridophyta	22805
Nymphaea lotus linn	Nymphaeaceae	22806
Costus afer ker-gauel	Costaceae	22807

Photograph of the four prevalent macrophytes identified are shown in Plates 1, 2, 3 and 4. They are Water lily ***(Nymphea lotus-floating plant),*** Water lettuce ***(Pistia stratotes-floating)***, Water spinach ***(Ipomoea aquatica-floating plant)*** and Horn wort ***(Ceratophyllum dermersum- Submerged plant).***

4.1.3 Temporal distribution of macrophytes

During the wet season, all the fourteen species of the macrophytes were present (Floating plant, Emergent plant and Submerged plat). Seven were present and seven were totally absent during the dry season (Six emergent plant and one submerged plant). The temporal distributions (wet and dry distribution) of the macrophytes are presented in Table 4.4. The population of the macrophytes covered were also rated as common(C), rare (R) or occasional (O).

4.1.4 Assessment of macrophytes cover

The Relevé sampling approach visually project the area cover by the vegetation on the surface of the water and estimate the abundance (density) using the assigned scale (per cent cover and density) (adapted from Protocol for PADEP, 2010: None= no plant, Sparse = 1-25% cover, Moderate = >25 - 50% cover, Dense > 50 -75% cover, Very Dense = >75-100% cover which implies that the macrophyte is very common). This is illustrated in Table 4.5. During the late rainy season, *Pistia stratiotes, Nephrolepis biserrata, Ipomoea aquatica* was very dense (very common).

4.1.5 Macrophyte encoutered and percentage frequency of occurrence

The percentage frequency of occurrence of the macrophytes and the relative percentage was calculated. The macrophyte with the highest percentage frequency observed during the study was water spinach, with 14.06% occurrence, while the percentage relative frequency was 76.67%. These are shown in Table 4.6.

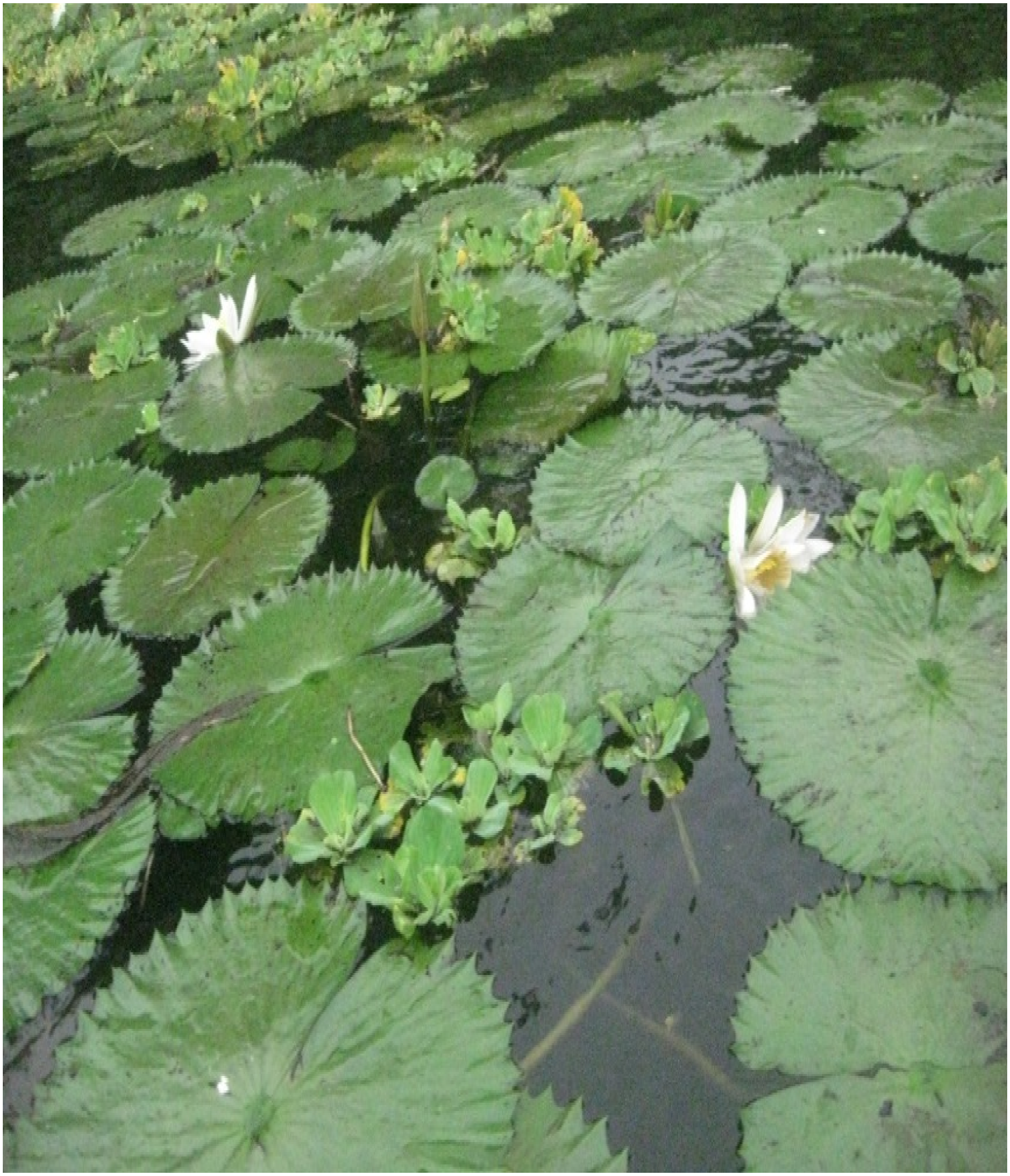

Plate 1: Water lily(***Nymphea lotus*** **- Floating plant*)* x 60**

Plate 2: Water Lettuce *(Pistia stratiotes* - Floating plant*)* x150

Plate 3: Water Spinach *(Ipomoea aquatica-* Floating plant*)* x 100

Plate 4: Horn wort (*Ceratophyllum dermersum* - Submerged plant) x 200

Table 4.4: Temporal variation of aquatic macrophytes

Macrophytes	Dry season	Wet season	Rating
Pistia stratiotes	xxx	xxx	C
Nymphaea lotus	xxx	xxx	C
Costus afer Ker-Gauel	x	xxx	O
Nephrolepis biserrata (Sw)Schott	x	xxx	O
Cyperus rotundus Linn	---	xxx	R
Polygonum salicifolium Brouss ex Willd	---	xxx	O
Luffa cylindrical (Linn) M.J Roem	---	xxx	O
Ipomoea aquatica	xxx	xxx	C
Ludwigia abyssinica A.Rich	---	xxx	C
Ludwigia decurrens Walt	x	xxx	C
Leptochloa caerulescens Steud	x	xxx	C
Acroceras zizanioides (Dandy)	---	xxx	C
Sacciolepis africana Hubb& snowden	---	xxx	R
Ceratophyllum dermersum Linn	---	xxx	O

Key -x- Present, xxx- Abundant, --- not present, C- Common, O- Occassional, R-Rare

Table 4.5: Assessment of aquatic macrophytes cover – Relevé sampling approach

Macrophytes/ Months	PS	NL	CA	LCY	CR	PS	NB	LA	AZ	IA	SA	LCA	LD	CD
January	M	S	M	NP	NP	NP	M	NP	NP	M	S	M	M	NP
February	S	S	M	NP	NP	NP	M	NP	NP	M	NP	M	M	NP
March	S	S	M	NP	NP	NP	M	NP	NP	M	NP	S	S	NP
April	S	S	S	NP	NP	NP	S	NP	NP	M	NP	S	S	NP
May	S	S	M	S	S	S	M	S	S	M	S	M	M	S
June	M	M	M	S	S	S	M	S	S	M	S	M	M	S
July	M	M	M	S	S	S	M	S	S	M	S	M	M	S
August	D	M	D	M	M	M	D	S	M	M	S	M	M	M
September	D	M	D	M	M	M	D	M	M	D	M	M	M	M
October	VD	M	D	M	M	D	VD	M	M	D	M	D	M	M
November	D	M	M	M	S	M	VD	M	M	D	M	M	S	M
December	M	M	M	S	S	S	D	S	S	M	S	M	S	S

Key:- *PS –Pistia stratiotes, AZ –Acroceras zizanioides, NL –Nymphaea lotus, CD –Ceratophyllum demersum, PS –Polygonum salicifolium, NB –Nephrolepis biserrata, LD –Ludwigia decurrens, LA –Ludwigia abyssinica, LCY –Luffa cylindrica, IA –Ipomoea aquatica, CR –Cyperus rotundus, LCA –Leptochloa caerulescens, SA –Sacciolepis africana, CA –Costus afer*. NP –No plant, S –Sparse, M –Moderate, D –Dense, VD –Very Dense

Table 4.6: Frequency of Occurrence of aquatic macrophytes in Eleyele Lake

Species name	Zone 1	Zone 2	Zone 3	Zone 4	Zone 5	Total no ob	% Frequency occurrence	Relative %
Pistia stratiotes	6	8	7	8	5	34	10.40	56.67
Nymphaea lotus	3	10	8	5	3	29	8.87	48.33
Costus afer Ker-Gauel	3	8	10	5	3	29	8.87	33.30
Nephrolepis biserrata (Sw)Schott	7	4	2	3	6	22	6.73	36.67
Cyperus rotundus Linn	0	5	5	4	0	14	4.30	23.33
Polygonum salicifolium Brouss ex Willd	0	6	7	8	0	21	6.42	35.00
Luffa cylindrical (Linn) M.J Roem	0	7	5	7	0	19	5.81	31.67
Ipomoea aquatica	8	10	9	10	9	46	14.06	76.67
Ludwigia abyssinica A. Rich	0	6	5	6	0	17	5.19	28.33

Ludwigia decurrens Walt	5	3	6	4	1	19	5.81	31.67
Leptochloa caerulescens Steud	5	4	6	5	3	23	7.03	38.33
Acroceras zizanioides (Dandy)	0	7	5	6	0	18	5.50	30.00
Sacciolepis africana Hubb & snowden	0	6	4	5	0	15	4.59	25.00
Ceratophyllum dermersum Linn	0	6	7	8	0	21	6.42	35.00
Total						327	100	

4.1.7 Diversity indices of aquatic macrophytes

Seasonal variation of Aquatic Macrophyte Community Index (AMCI) was presented in Table 4.7. While the diversity indices of each zone were presented in Table 4.8. The overall AMCI for the Lake was illustrated in table 4.9. Aquatic Macrophyte Community Index highest value for season was recorded in wet season (42) while the least in dry season (33). Spatially, highest AMCI was noted in zone 2,3 and 4 (37) and the least in zone 1(30). The overall AMCI was 41(table 4.9).

4.1.8 Floristic Quality Assessment

Coefficient of conservatism-Mean C was assigned to each of aquatic macrophytes for the Floristic Quality Index. This was presented in Table 4.10. The total mean C value was 60. This was used to calculate for the Floristic Quality Assessment

Mean C= 60/ 14= 4.29

Mean C= 4.29

FQI= $C\sqrt{n}$ n= no of species

$$4.29\sqrt{14} = 16.05$$

This result suggests that Eleyele Lake was subjected to great disturbances. Mean C-value ranged from a low 2.0 (most disturbance tolerant) to a high of 9.5 (least disturbance tolerant).

4.1.9 Diversity indices of spatial and temporal variation of aquatic macrophytes

The spatial diversity indices for the aquatic macrophyte were presented in table 4.11 and the temporal variation was illustrated in table 4.12. Spatially the Shannon Wiener index had the highest value recorded in zone 1 (2.40) and Margalef's highest value was also recorded in zone 1(2.14). Seasonally, Shannon Wiener index was higher during wet season (2.41) and Margalef's was higher also in wet season (1.60).

Table 4.7: Seasonal variation of Aquatic Macrophyte Community Index (AMCI)

Category	Dry	Value	Wet	Value
Maximum depth of plant growth(m)	2.7	3	3.5	6
Littoral area vegetated (%)	≥50	10	100	10
Submerged species (rel %)	0	1	35	2
Simpson's diversity	0.81	1	0.90	1
Taxa no	7	3	14	7
sensitive species	7	5	13	6
Exotic species	0	10	0	10
AMCI		**33**		**42**

* From a plant 'perspective' 100% of the littoral zone vegetated is the best

Table 4.8: Spatial variation of Aquatic Macrophyte Community Index (AMCI)

Categories	Z1	Value	Z2	value	Z3	value	Z4	value	Z5	Value
Maximum depth of plant	2.2	3	2.5	3	2.7	3	3.2	5	2.4	3
Littoral area vegetated	40	7	≥50	10	≥50	10	40	8	45	9
Simpson's Diversity	0.9	1	0.89	1	0.89	1	0.90	1	0.90	1
Taxa number	8	3	13	6	12	6	11	5	7	3
Submerged species	0	1	25	1	20	1	35	2	0	1
Exotic species	0	10	0	10	0	10	0	10	0	10
Sensitive species	8	5	13	6	12	6	11	6	6	5
AMCI		**30**		**37**		**37**		**37**		**33**

Table 4.9: Aquatic Macrophyte Community Index (AMCI)

Category		Value
Maximum depth of plant growth (m)	3.5	6
Littoral area vegetated (%)	100	10
Submerged species (rel %)	1	1
Simpson's diversity	0.90	1
Taxa no	14	7
Sensitive species	13	6
Exotic species	0	10
AMCI		**41**

Table 4.10: Floristic Quality Assessment (FQA) using Coefficient of conservatism (C-value) and Floristic Quality Index (FQI))

Scientific name	Family	C-value
Pistia stratiotes	Araceae	5
Nymphaea lotus	Nymphaeaceae	5
Costus afer Ker-Gauel	Costaceae	2
Nephrolepis biserrata (Sw) Schott	Pteridophyta	3
Cyperus rotundus Linn	Cyperaceae	3
Polygonum salicifolium Brouss ex Willd	Polygonaceae	3
Luffa cylindrical (Linn) M.J Roem	Cucurbitaceae	7
Ipomoea aquatica	Convolvulaceae	9
Ludwigia abyssinica A.Rich	Onagraceae	6
Ludwigia decurrens Walt	Onagraceae	7
Leptochloa caerulescens Steud	Poaceae	2
Acroceras zizanioides (Dandy)	Poaceae	2
Sacciolepis africana Hubb& snowden	Poaceae	4
Ceratophyllum dermersum Linn	Ceratophyllaceae	2
Total		60

Table 4.11: Spatial variation in diversity indices of macrophytes composition

Diversity indices	Zone 1	Zone 2	Zone 3	Zone 4	Zone 5
Dominance	0.10	0.11	0.11	0.11	0.10
Simpson 1-D	0.90	0.89	0.89	0.90	0.90
Shannon-H	2.40	2.35	2.35	2.36	2.36
Evenness_e?H/S	0.92	0.88	0.87	0.88	0.89
Margalef	2.14	2.02	1.92	1.91	2.03
Equitability	0.97	0.95	0.94	0.95	0.95
Berger -Parker	0.15	0.18	0.20	0.17	0.16

Table 4.12: Seasonal variation of diversity indices of aquatic macrophytes

Diversity indices	**Wet Season**	**Dry season**
Dominance	0.10	0.19
Simpson 1-D	0.90	0.81
Shannon-H	2.41	1.70
Evenness_e?H/S	0.92	0.91
Margalef	1.60	0.88
Equitability	0.97	0.95
Berger –Parker	0.15	0.26

4.2 The proximate composition of macrophytes

The maximum mean moisture (%) was obtained in *Ipomoea aquatica,* with the value 23.15±3.39; the lowest was obtained in *Polygonum salicifolium*, with the mean value 12.8±51.26. The *Polygonum salicifolium* had the highest mean crude protein 7.00±0.63, while *Ceratophyllum demersum* had the lowest mean crude protein, 1.46±0.07. The order of the mean variation values for the nutrients and other parameters are presented in Table 4.13.

4.3 Physico-chemical parameters of water

In Table 4.14, the seasonal (dry and wet season) disparity in physical and chemical constituents of Eleyele Lake was illustrated. In the dry season, the mean pH was 6.85±0.36, while that of the wet season was greater than the dry season (7.23±0.5). For alkalinity, the dry season had higher mean value of 104±27.95mg/L compared with wet season value of 100.69±19.81mg/L. In all the macro nutrients evaluated (chloride, sodium, potassium, magnesium and calcium) only calcium had the highest mean value in the dry season (32.71±17.34mg/L) which differd significantly from wet season (30.65±15.46 mg/L). The mean total hardness of the water was 76.48±24.24mg/L and the highest value was obtained in the wet season (93.59±36.61 mg/L). Total dissolved solid had a mean estimate of 157.23mg/L and standard deviation of 19.61; the dry season had the highest mean value of 158.28±27.23mg/L, at $p>0.05$.

Total solids indicated that the suspended solid present inside the lake were reduced throughout the dry season 247.07±121.49mg/L and higher during the rainy season 311.92±148.03, in that order. Dissolved Oxygen (DO) revealed the highest mean in the rainy season and the least in the dry season (4.51±1.22mg/L; 4.07±1.08mg/L, respectively). The mean value of BOD was 9.22±5.85mg/L in the dry season and 6.88±3.56mg/L in the wet season. Chemical Oxygen Demand (COD) had the highest mean value throughout the wet season and least in the dry season (114.83±18.72mg/L; and 93.03±55.69mg/L, respectively).

Table 4.13: Variation in mineral composition (mean ±SD) of aquatic macrophytes in Eleyele Lake

	Moisture	Ash	CP	CFIBRE	CFAT	C	Na	Mg	Ca	K	PO_4
PS	21.85±2.48	2.76±0.5	2.06±0.18	31.58±2.30	0.22±0.11	41.58±4.26	11.60±6.22	14.56±7.29	46.95±2 17	13.54±4.10	5.94±3.26
AZ	18.25±0.13	2.60±0. 1	2.74±0 .59	29.0 5.75	0.29±0.08	49.12±4.73	7.51±4.83	9.76±1.14	40.78±26.16	11.59±4.01	2.32±0.87
NL	23.15±2.59	1.87±0.17	2.58±0.13	23.75±4.39	0.14±0.03	43.05±3.52	14.58±0.87	34.48±2.19	32.23±1.40	18.83±0.49	10.63±0.71
CD	16.45±4.88	5.64±1.99	1.46±0.07	43.48±8.65	0.50±0.12	32.08±5.53	21.13±11.67	28.37±7.86	12.03±0.38	24.43±17.54	4.95±0.43
PS	12.85±1.26	4.50±0.44	7.0±0.63	38.68±1.67	0.38±0.03	34.6±0.96	5.0±0.22	78.03±10.39	14.6±0.77	9.7±0.88	3.25±0.28
NB	17.38±0.76	5.08±0.85	2.31±0.59	41.18±2.53	0.74±0.08	33.18±1.33	7.06±1.23	65.18±16.47	8.71±0.55	8.75±0.95	2.88±0.20
LD	20.85±0.93	2.17±0.39	2.94±0.79	30.30±2.45	0.29±0.08	43.00±1.20	4.69±0.83	89.38±9.76	32.83±13.43	11.57±3.81	3.73±1.66
LA	16.63±4.84	2.66±0.26	2.39±0.25	38.00±1.13	0.14±0.03	46.35±0.80	15.00±1.05	87.18±3.98	31.00±1.83	8.88±0.46	9.76±0.29
LCY	18.98±0.22	5.73±0.74	5.99±0.37	35.15±1.71	0.38±0.05	34.4±0.55	5.01±1.05	88.05±11.46	12.75±0.31	7.77±1.32	3.02±0.19
IA	23.15±3.39	2.73±0.37	2.46±0.24	30.08±2.69	0.25±0.11	40.28±3.32	6.76±2.71	64.7±3.38	22.20±9.43	9.11±3.18	5.43±3.33
CR	15.1±2.49	6.93±1.19	5.38±0.96	38.43±2.29	1.13±0.23	33.65±0.54	6.82±1.42	81.45±3.16	10.31±1.62	14.58±1.49	3.22±0.43
LCA	11.53±0.15	1.90±0.15	2.67±0.09	26.05±4.77	0.19±0.09	47.00±1.66	14.93±0.92	40.83±11.38	35.08±4.65	19.05±0.61	10.56±0.54
SA	13.22±0.21	1.52±0.17	2.43±0.44	22.11±2.33	0.16±0.07	32.11±1.54	7.01±0.45	42.11±6.51	18.61±0.78	17.51±0.87	8.61±0.73
CA	11.03±0.51	3.34±0.56	2.06±0.57	25.06±2.06	0.47±0.03	38.08±1.41	4.55±0.61	25.77±5.67	10.44±0.45	15.89±0.62	4.55±0.65

Key: Horizontal axis; CP- Crude Protein(%), CFibre-Crude Fibre(%), CFat-Crude Fat(%), C- Carbohydrate(%), Na- sodium(mg/g), Mg-Magnesium(mg/g), Ca –Calcium(mg/g), K- Potasssium(mg/g), PO_4-Phosphate(mg/g), Vertical axis, *PS-Pistia stratiotes, AZ-Acroceras zizanioides, NL-Nymphaea lotus, CD-Ceratophyllum demersum, PS-Polygonum salicifolium, NB-Nephrolepis biserrata, LD- Ludwigia decurrens, LA-Ludwigia abyssinica, LCY-Luffa cylindrica, IA-Ipomoea aquatica, CR-Cyperus rotundus, LCA-Leptochloa caerulescens, SA-Sacciolepis africana, CA-Costus afer.*

Table 4.14: Seasonal variation of physico-chemical parameters of water of Eleyele Lake

Parameters	Dry season	Wet season	P – value	Optimum range (Boyd, 1998)
pH	6.85±0.36	7.23±0.51	.000*	6.5-8.5
Temp(°C)	25.30±1.12	25.29±1.19	.945	25.0-32.0
Trans(cm)	1.63±1.25	1.53±0.28	.100	0.3-0.4
Depth(m)	6.93±1.40	7.23±1.53	.014	-
Alk(mgL^{-1})	104.66±27.95	100.69±19.81	.035	50.0-300.0
Cl(mgL^{-1})	2.51±1.71	7.10±6.58	.000*	31-50
TH(mgL^{-1})	76.48±24.24	93.59±36.61	.000*	30-180
Ca(mgL^{-1})	32.71±17.34	30.65±15.46	.000*	75-200
Mg(mgL^{-1})	3.04±1.72	4.04±2.16	.000*	<150
Na(mgL^{-1})	0.31±0.35	0.24±0.37	.018	<500
K(mgL^{-1})	0.60±0.41	0.43±0.33	.000*	0.5-10
TDS(mgL^{-1})	157.23±19.61	158.28±27.23	.599	30-200
TS (mgL^{-1})	247.07±121.49	311.92±148.03	.000*	<500
DO(mgL^{-1})	4.07±1.22	4.51±1.08	.000*	5.0-10.0
BOD(mgL^{-1})	9.22±5.85	6.88±3.56	.000*	<10.0
COD(mgL^{-1})	93.03±18.72	114.83±55.69	.000*	<50.0
Nitrate(mgL^{-1})	3.12±0.72	4.22±1.60	.000*	0.1-3.0
Phos(mgL^{-1})	1.41±0.63	1.61±0.62	.000*	6.5-8.5
Sulp (mgL^{-1})	7.0±6.99	8.16±3.68	.005	<400
Amm(mgL^{-1})	1.17±0.32	1.58±1.14	.000*	0.0-1.0
Cond	293.87±69.17	289.37±69.37	.000*	-

Legend: pH, Temp-Temperature, Trans- Transparency, Depth, Alk- Alkalinity, Cl –Chloride, TH – Total Hardness, Ca –Calcium, Mg –Magnesium, Na –Sodium, K –Potassium, TDS – Total dissolved solid, TS-Total solids, DO –Dissolved Oxygen, BOD –Biochemical Oxygen Demand, COD –Chemical Oxygen Demand, Nitrate, Phos –Phosphate, Sul –Sulphate, Amm-Ammonia, Cond- Conductivity

Temperature had the maximum mean value in the dry season 25.30±1.12ºC and the least in the rainy season 25.29±1.19 ºC, at $p>0.05$. Among nitrate, phosphate, sulphate and ammonia; sulphate had the maximum mean value in the wet season 8.16±3.68mg/L and the least in the dry season 7.0±6.99mg/L. The mean value of transparency of the water was 1.63±1.25cm for the dry season and 1.53±0.28cm for the wet season, at $p>0.05$. The depth had the highest mean value throughout the wet season 7.23m, while the least value existed in the dry season 6.93m.

Table 4.15 shows the spatial variation in physico-chemical parameters in Eleyele Lake. There was no major disparity within regions for alkalinity, total hardness, the macro nutrient (calcium, magnesium, potassium and sodium), Chemical oxygen demand (COD), phosphate, sulphate, temperature and conductivity. While significant difference existed between zones for chloride, total dissolved solid, total solids, dissolved oxygen, biochemical oxygen demand, ammonia, nitrate, transparency and depth.

All the nutrient elements (calcium, magnesium, chloride, sodium and potassium) were low compared to the set standard limit recommended by Boyd (1998). Dissolved oxygen (4.26-4.43mg/L); and Phosphate was also low. Chemical oxygen demand, nitrate, ammonia, transparency and conductivity were above the recommended limit, while others fell within the recommended limit.

4.3.1 Water pH

The highest mean value for pH was observed in the wet season (7.23±0.51) which was not significant among the seasons. Zone 3 (7.15±0.53) had the highest mean value and significant difference existed across the zones.

4.3.2 Temperature

The highest mean temperature was recorded in the dry season (25.30ºC±1.12), and there was no significant difference between the seasons ($p<0.05$) (Table 4.14). Zone 5 (25.40ºC±1.15) had the highest value among the zones and there was no significant difference across the zones.

4.3.3 Transparency

The maximum mean estimate was observed in the dry season (1.63cm ± 1.25), which was not significant ($p<0.05$). Zone 3 had the maximum mean estimate (1.71cm ±1.67) and there was significant difference across the zones.

4.3.4 Depth

The maximum mean estimate was documented in the wet season (7.23m± 1.53), which was not significant. Zone 4 had the highest mean value (8.73m ±1.84), with significant difference across the zones.

4.3.5 Alkalinity

The maximum mean estimate was observed in the dry season (104.66 ±27.95 mg/L), which was not significant between the seasons ($p<0.05$) (Table 4.14), while Zone 2 had a higher value (104.65 ± 21.13 mg/L), which was also not significant across the zones (Table 4.15).

4.3.6 Total dissolved solid

Higher mean value was observed in the wet season (158.28mg/L), which was not significant between the seasons ($p<0.05$). The highest mean estimate within the zones was found in Zone 2 (162.54mg/L) and there was significant difference across the zones.

4.3.7 Total hardness

The maximum concentration of total hardness was documented in the wet season (93.42mg/L), which was not significant. Zone 1 had the highest value (89.42mg/L) and there was no significant difference across the zones.

4.3.8 Dissolved Oxygen

The highest mean value was observed in the wet season (4.51mg/L), which was not significant between the seasons. Zone 5 (4.65mg/L) had the highest mean value, while significant difference existed within the zones.

4.3.9 Biochemical Oxygen Demand

Higher value was observed in dry season (9.22mg/L), but there was no influence between the seasons ($p<0.05$). The maximum mean estimate was documented in Zone 5 (8.25mg/L) and there was significant difference across the zones.

4.3.10 Electrical conductivity

The maximum mean estimate was observed in the dry seasons (357mg/L), which were not significant. Zone 2 (292.87mg/L) had the highest mean value recorded and no significant difference existed across the zones.

4.3.11The Macro-nutrient composition (chloride, calcium, magnesium, sodium and potassium)

Chloride had the highest mean estimate documented in the wet season (7.10mg/L), while calcium had the highest mean estimate documented in the dry season (32.71mg/L). The highest mean estimate for magnesium was documented in the wet season (4.04mg/L). The highest mean value for sodium was noted throughout the dry season (0.60mg/L). All the nutrients did differ significantly between the seasons. Among the zones, Zone 4 had the highest mean value for chloride (7.31mg/L) and significant difference existed across the zones. Zone 1 had the highest average estimate of calcium (30.89mg/L), but this was not significant across the zones. For magnesium, Zone 1 had the highest average concentration (3.77mg/L), but there was no significant difference across the zones. Sodium had the highest mean value in Zone 4 (0.31mg/L). Potassium had the highest mean value observed in Zone 2 (0.49mg/L). No significant difference existed across the zones for Ca, Mg, Na and K.

4.3.12 Nitrate

The highest mean value recorded was in the wet season (4.22mg/L), which was not significant among the seasons. Zone 2 had the highest mean value of 4.03mgL and significant difference existed across the zones.

4.3.13 Phosphate

The highest mean values were recorded in the wet season (1.61mg/L) and Zone 2 (1.54mgL), with no significant difference between the seasons and across the zones.

4.3.14 Sulphate

The maximum average rate was observed in the wet season (8.16mg/L), without significant difference between the seasons. Zone 3 (8.40mg/L) had the highest mean value, with no significant difference across the zones.

4.3.15 Ammonia

The highest variation was recorded in the dry season (1.17mg/L), but there was no significant difference in the seasons. Zone 2 had the highest mean value (1.69mg/L) and significant difference existed across the zones.

4.4.1 Seasonal variation in the physicochemical parameters of sediment samples

In Table 4.16, the temporal variation of physicochemical parameter of sediment sample is presented. During the sampling period, in the dry season, the mean variations of pH, clay, sodium, magnesium, calcium and phosphate were higher (6.27±0.38, 20.54±10.50, 18.97±7.29mg/L, 15.38±11.02mg/L, 15.96±8.51mg/L, 68.57±13.87mg/L, respectively). In the wet season, the mean organic carbon, organic matter, sand, silt and potassium were higher (5.02±1.35, 7.88±1.28, 63.61±9.62, 20.59±3.43, 34.82±6.25mg/L).

4.4.2 Spatial variation in the physicochemical parameters of the sediment samples

The spatial variation for the sediment sample is presented in Table 4.17. The mean value for pH was highest in zone 1 (6.33±0.39) and lowest in zone 2 (6.17±0.45). Organic carbon (%) had the highest value in zone 4 (5.19±1.37), whereas the lowest was documented in zone 2 (4.66±1.61). The organic matter (%) was highest in zone 4 (8.09±1.79) and lowest value was recorded in zone 3 (7.11±1.77). The mean variation (%) of sand was lowest in zone 2 (56.60±11.91), and highest in zone 1 (64.10±6.54). The clay mean variation (%) was higher in zone 1 (23.58±14.07) and the lowest value was found in zone 4 (17.45±10.15). Silt had the highest mean variation in zone 2 and lowest in zone 1 (21.11±3.59%, 18.97±3.92%). The highest mean value was obtained in zone 1 for sodium and the lowest in zone 5 (18.86±6.74, 12.15±9.16). Magnesium (13.31±10.68mg/L) and potassium (35.86±12.32mg/L) were highest in zone 2 while calcium (16.21±9.39) and phosphate (67.43±17.25mg/L) were highest in zone 3.

4.5 Correlation between physico-chemical parameters of Eleyele Lake

The correlation analysis of the physico-chemical parameters was presented in table 4.19.The Pearson correlation shows that some parameters were significantly positive or negatively correlated between themselves while some show no marked correlation. Negative correlation were found between the pH and chemical oxygen demand ($r = -0.080$), nitrate ($r = -0.088$), phosphate ($r = -0.091$) ($p<0.05$). Alkalinity was positively correlated to chloride ($r = 0.094$) ($p>0.05$). Alkalinity was negatively correlated to sulphate ($r = -0.085$; $p<0.05$) and conductivity ($r = -0.088$; $p<0.05$). Calcium exhibited positive correlation with chemical oxygen demand and nitrate ($r = 0.088, 0.098$; $p<0.05$). Negative correlation was recorded between magnesium and sulphate and conductivity ($r = .091, .078$; $p<0.05$). Sodium and phosphate indicated positive correlation($r = .080$; $p>0.05$), potassium and total dissolved solid displayed positive correlation ($r = 0.085$; $p>0.05$). Negative correlation were obtained between potassium and temperature ($r = -0.097$) while temperature and dissolved oxygen displayed positive correlation ($r = 0.095$; $p>0.05$. Biochemical oxygen demand exhibited negative correlation with nitrate ($r = -0.083$; $p<0.05$) and nitrate displayed positive correlation with sulphate ($r = 0.100$; $p>0.05$) Phosphate showed a significant positive correlation with sulphate($r = .0620$; $p>0.01$), Ammonia ($r = 0.207$; $p>0.01$) and temperature ($r = 0.119$; $p>0.01$). Ammonia exhibited strong positive correlation with temperature ($r = 0.169$; $p>0.01$) while it indicated strongly negative correlation with depth ($r = -0145$; $p<0.01$). Chlorophyll *a* showed positive correlation with depth ($r = 0.881$; $p>0.01$).

4.5.1 Rainfall data of Eleyele Lake

The mean monthly climatic condition data of Eleyele Lake was presented in table 4.20 and Figure 4.5 between January 2015 - December 2016.The peak of the rainfall was in the month of June (6.02; 6.00) for both years.

Table 4.15: Spatial variation of physico-chemical parameters of water of Eleyele Lake

Parameter / Zones	Zone 1	Zone 2	Zone 3	Zone 4	Zone 5	Optimum range (Boyd, 1998)
pH	7.08±0.49[ab]	7.10±0.48[ab]	7.15±0.53[b]	7.01±0.51[a]	7.12±0.49[ab]	6.5-8.5
Temp	25.10±1.17[a]	25.30±1.21[a]	25.31±1.19[a]	25.38±1.33[a]	25.40±1.15[a]	25.0-32.0
Trans	1.48±0.25[a]	1.55±0.23[ab]	1.71±1.67[b]	1.56±0.30[ab]	1.50±0.27[a]	0.3-0.4
Depth	6.51±0.92[a]	6.53±0.85[a]	6.85±1.18[b]	8.73±1.84[c]	6.96±1.31[b]	-
Alk	102.40±23.3[a]	104.65±21.13[a]	102.77±22.31[a]	99.36±22.38[a]	103.71±27.21[a]	50.0-300.0
Cl	6.33±7.65[b]	6.94±10.21[b]	3.05±1.46[a]	7.31±11.65[b]	3.43±1.78[a]	31-50
TH	89.42±32.88[a]	87.02±33.65[a]	83.66±34.69[a]	87.69±33.48[a]	86.01±34.74[a]	30-180
Ca	30.89±15.43[a]	30.59±16.15[a]	30.05±15.07[a]	30.04±14.65[a]	30.6±14.92[a]	75-200
Mg	3.77±1.92[a]	3.72±2.02[a]	3.55±2.01[a]	3.66±2.05[a]	3.51±2.04[a]	<150
Na	0.24±0.30[a]	0.23±0.3[a]	0.30±0.44[a]	0.31±0.45[a]	0.25±0.31[a]	<500
K	0.46±0.36[a]	0.49±0.36[a]	0.46±0.35[a]	0.47±0.37[a]	0.45±0.33[a]	0.5-10
TDS	160.78±22.62[ab]	162.54±28.69[b]	158.33±22.50[ab]	155.19±20.30[a]	155.56±27.10[a]	30-200
TS	289.89±119.41[a]	290.98±106.06[a]	341.33±151.02[b]	302.04±149.11[a]	273.82±139.5[a]	<500
DO	4.34±1.04[a]	4.25±0.93[a]	4.33±1.31[a]	4.39±1.09[ab]	4.65±1.14[b]	5.0-10.0
BOD	7.48±4.27[a]	7.41±4.02[a]	7.53±4.44[a]	7.41±4.30[a]	8.52±5.39[b]	<10.0
COD	107.88±49.03[a]	109.45±49.50[a]	102.05±44.44[a]	107.49±44.24[a]	102.49±48.22[a]	<50.0
Nitrate	3.83±1.64[ab]	4.03±2.06[b]	3.83±1.35[ab]	3.56±1.10[a]	3.94±1.07[ab]	0.1-3.0
Phos	1.51±0.62[a]	1.54±0.74[a]	1.49±0.68[a]	1.51±0.71[a]	1.44±0.68[a]	6.5-8.5
Sulp	8.05±5.40[a]	8.12±5.49[a]	8.40±5.71[a]	7.51±4.95[a]	7.04±3.55[a]	<400
Amm	1.66±1.25[b]	1.69±1.40[b]	1.36±0.61[a]	1.31±0.52[a]	1.21±0.41[a]	0.0-1.0
Cond	288.37±69.15[a]	292.87±69.85[a]	291.15±67.04[a]	292.21±69.35[a]	288.91±69.1a	

Key: pH, Temp –Temperature (^{0}C), Trans –Transparency (cm), Depth (m), Alk –Alkalinity (mgL^{-1}), Cl –Chloride (mgL^{-1}), TH –Total Hardness (mgL^{-1}), Ca –Calcium (mgL^{-1}), Mg –Magnessium (mgL^{-1}), Na –Sodium (mgL^{-1}), K –Potassium (mgL^{-1}), TDS –Total dissolved oxygen (mgL^{-1}), TS –Total solid (mgL^{-1}), DO –Dissolved oxygen (mgL^{-1}) BOD –Biochemical oxygen demand (mgL^{-1}), COD –Chemical oxygen demand (mgL^{-1}), Nitrate(mgL^{-1}), Phos –Phosphate (mgL^{-1}), Sulp –Sulphate (mgL^{-1}), Amm –Ammonia (mgL^{-1}), Cond-Conductivity (µS/cm)

Table 4.16: Seasonal variation in physicochemical parameters (mean±SD) of sediment samples

Parameters	Dry season	Wet season	Sig. value
pH	6.27±0.38	6.20±0.44	0.592
Organic carbon (%)	4.96±1.31	5.02±1.35	0.891
Organic matter (%)	7.44±1.78	7.88±1.28	0.378
Sand (%)	56.7 [illegible]).01	63.61±9.62	0.032
Clay (%)	20.54±10.50	14.23±6.98	0.031
Silt (%)	20.52±4.14	20.59±3.43	0.957
Sodium (mg/kg)	18.97±7.29	14.44±5.73	0.035
Magnesium(mg/kg)	15.38±11.02	9.61±7.39	0.060
Calcium(mg/kg)	15.96±8.51	14.03±8.13	0.469
Potassium(mg/kg)	30.49±12.72	34.82±6.25	0.181
Phosphate(mg/kg)	68.57±13.87	63.95±16.03	0.319

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Table 4.17: Spatial variation in physicochemical parameters (mean±SD) of sediment of Eleyele lake

Parameters	Z1	Z2	Z3	Z4	Z5	p-value
pH	6.33±0.39	6.17±0.45	6.29±0.40	6.27±0.47	6.18±0.29	>0.05
Organic carbon (%)	5.00±1.32	4.66±1.61	5.03±1.25	5.19±1.37	4.84±1.49	>0.05
Organic matter (%)	7.82±1.66	7.67±1.79	7.11±1.77	8.09±1.79	7.94±1.48	>0.05
Sand (%)	64.10±6.54	56.60±11.91	61.37±9.95	61.87±10.43	62.12±9.91	>0.05
Clay (%)	23.58±14.07	20.07±10.39	22.85±12.42	17.45±10.15	19.50±11.81	>0.05
Silt (%)	18.97±3.92	21.11±3.59	20.16±5.21	20.86±4.39	20.53±2.41	>0.05
Sodium (mg/kg)	18.86±6.74	15.10±7.15	14.97±6.43	16.62±7.76	12.15±9.16	>0.05
Magnesium (mg/kg)	12.61±10.39	13.31±10.68	12.84±9.18	11.48±9.76	12.43±10.62	>0.05
Calcium (mg/kg)	14.73±8.88	15.38±8.42	16.21±9.39	14.77±7.40	13.31±8.59	>0.05
Potassium (mg/kg)	33.64±10.80	35.86±12.32	33.46±10.27	32.38±10.62	33.31±11.51	>0.05
Phosphate (mg/kg)	64.72±15.00	64.25±13.74	67.43±17.45	67.23±13.54	57.78±8.18	>0.05

Table 4.18: Correlation matrix between physico-chemical parameters of water and aquatic sediment

	pH	Alk	Chl	TH	Ca	Mg	Na	K	TDS	TS	Do	BOD	COD	Sulp	NH3	Temp	Depth	Trans	Cond
pH	.016	.013	.687*	-.118	-.238	-.096	.112	-.138	.067	.094	-.057	-.163	.209	.208	.324	.373	.001	.032	-.226
OC	.428	-.142	.411	.042	.027	.152	-.168	.100	-.140	-.157	-.265	.114	-.062	-.051	.167	.290	-.325	-.068	.051
OM	.431	-.152	.407	.046	.032	.156	-.169	.104	-.149	-.161	-.268	.118	-.067	-.057	.159	.286	-.324	-.068	.056
S	.525	-.421	.275	.403	.373	.501	-.396	.430	-.421	-.464	-.570	.431	-.367	-.367	-.093	-.029	.053	-.144	.397
C	-.578	.412	-.218	-.380	-.342	-.466	.318	-.436	.426	.420	.563	-.408	.374	.350	.139	-.061	-.078	.044	-.368
Silt	.396	-.094	-.170	.024	-.019	.002	.219	.159	-.156	.047	-.150	.033	-.147	-.039	-.232	.385	.128	.400	.000
Na	.198	-.172	.063	.595	.503	.573	-.569	.444	-.235	-.520	-.539	.438	-.392	-.403	-.001	-.678*	.270	-.262	.495
Mg	.554	-.381	.205	.131	.147	.239	-.074	.236	-.361	-.214	-.322	.238	-.209	-.185	-.113	.274	-.038	-.023	.171
Ca	.333	-.270	.348	.019	.005	.099	-.032	.135	-.170	-.128	-.235	.089	-.058	-.065	.001	.517	-.128	-.232	.024
K	.223	.046	.427	-.267	-.284	-.186	.186	-.145	.083	.176	.033	-.165	.196	.216	.210	.693*	-.244	.100	-.260
P	-.376	.356	-.292	-.291	-.253	-.368	.252	-.373	.339	.360	.485	-.332	.280	.286	.129	-.175	-.252	.077	-.265

*. Correlation is significant at the 0.05 level (2-tailed).

Key: pH, Alk -Alkalinity, Chl –Chloride, TH –Total Hardness, Ca –Calcium, Mg –Magnessium, Na –Sodium, K –Potassium, TDS –Total dissolved solid, TS –Total solid, DO –Dissolved oxygen, BOD –Biochemical Oxygen Demand, COD –Chemical Oxygen Demand, N –Nitrate, Phos –Phosphate, Sulp –Sulphate, NH_3 –Ammonia, Temp –Temperature, Depth, Trans –Transparency, Condu –Conductivity; Vertical –pH, OC –Organic carbon, OM –Organic matter,S - Sand, C-Clay,Si- Silt, Na –Sodium ,Mg –Magnessium, Ca –Calcium, K –Potassium, P –Phosphate

Table 4.19: Correlation coefficient of physico-chemical parameters of water measured in Eleyele Lake

	pH	ALK	CHL	TH	Ca	Mg	Na	K	TDS	TS	Do	BOD	COD	Nitrate	Phos	Sulp	Ammonia	Temp	Trans	Depth	Chlorophyll
pH	**1**																				
ALK	**-149****	**1**																			
CHL	**-131****	**.094***	**1**																		
TH	**-0.047**	**0.067**	**.273****	**1**																	
Ca	**.154****	**.135****	**0.025**	**.191****	**1**																
Mg	**0.044**	**0.035**	**.181****	**0.06**	**.541****	**1**															
Na	**-180****	**.581****	**0.065**	**0.046**	**0.051**	**-278****	**1**														
K	**-170****	**.389****	**-0.073**	**-162****	**.164****	**.320****	**.171****	**1**													
TDS	**-.255****	**.287****	**.106****	**0.044**	**-.499****	**-245****	**.237****	**.085***	**1**												
Do	**-0.073**	**.166****	**.438****	**.371****	**-374****	**-.241****	**.143****	**-.261****	**.424****	**1**											
BOD	**0.054**	**-.150****	**-0.07**	**.146****	**-275****	**-335****	**-.105****	**-.409****	**.121****	**.314****	**1**										
COD	**-.080***	**.372****	**-.186****	**-.211****	**0.88***	**.191****	**.207****	**.566****	**0.009**	**-.405****	**-.444****	**1**									
Nitrate	**-.088***	**.130****	**.419****	**.417****	**.098***	**.151****	**0.04**	**-0.059**	**.214****	**.336****	**0.027**	**-.083***	**.483****	**1**							
Phosphate	**-.091***	**.215****	**0.068**	**.219****	**-.314****	**-.283****	**.080***	**-.209****	**.475****	**.670****	**.340****	**.196****	**.229****	**.201****	**1**						
Sulphate	**-.123****	**-.085***	**.1266****	**.288****	**-.147****	**-.099***	**-.152****	**-234****	**347****	**584****	**.366****	**-.479****	**.163****	**.100***	**.620****	**1**					
Ammonia	**-.162****	**.218****	**.684****	**.333****	**-0.042**	**0.016**	**0.063**	**-.114****	**.169****	**.414****	**0.019**	**-.110****	**.602****	**.621****	**.200****	**61**	**1**				
Temp	**-0.003**	**.133****	**.142****	**0.071**	**-221****	**-.141****	**0.041**	**-0.97***	**0.062**	**.197****	**.098***	**0.012**	**.222****	**0.051**	**.119****	**-0.035**	**.169****	**1**			
Transp	**-0.016**	**.104****	**0.021**	**-0.009**	**-0.011**	**-0.01**	**0.072**	**0.025**	**0.036**	**0.037**	**-.101****	**0.033**	**0.015**	**-0.042**	**0.031**	**0.022**	**0.007**	**0.02**	**1**		

*. Correlation is significant at the 0.05 level (2-tailed).

Key: pH, Alk –Alkalinity, CHL –Chloride, TH –Total Hardness, Ca –Calcium, Mg –Magnesium, Na –Sodium, K –Potassium, TDS –Total dissolved solid, DO –Dissolved Oxygen, BOD –Biochemical Oxygen Demand, COD –Chemical Oxygen Demand, Nitrate, Phos –Phosphate, Sul –Sulphate, Ammonia, Temp- Temperature,Trans- Transparency

Table 4.20: Mean monthly climatic condition data (Jan 2015 - Dec 2016) of Eleyele Lake

2015				2016		
Months	Air Temp. (^oC)	Humidity (%)	Rainfall (mm)	Air Temp. (^oC)	Humidity (%)	Rainfall(mm)
Jan	27.65	64.114	0	27.32	54.312	0
Feb	28.84	71.125	0	28.72	74.607	0
March	29.7	75.709	0	29.33	76.685	0
April	29.33	78.287	0.02	28.67	75.672	0.04
May	28.31	80.395	3.90	28.09	79.284	4.02
June	25.56	82.351	6.02	24.75	82.465	6.0
July	25.87	82.285	3.72	25.85	84.128	3.61
August	26.32	80.121	2.85	25.91	79.326	2.55
Sept	26.76	78.691	3.15	25.48	81.085	3.35
Oct	27.56	80.605	2.22	26.62	77.321	2.24
Nov	27.41	83.097	0.13	26.75	63.654	0.18
Dec	28.82	71.387	0	26.14	55.777	0

Key: Months : Jan- January, Feb- February, Sept-September, Oct-October, Nov,November, Dec- December, Air Temp. - Air temperature

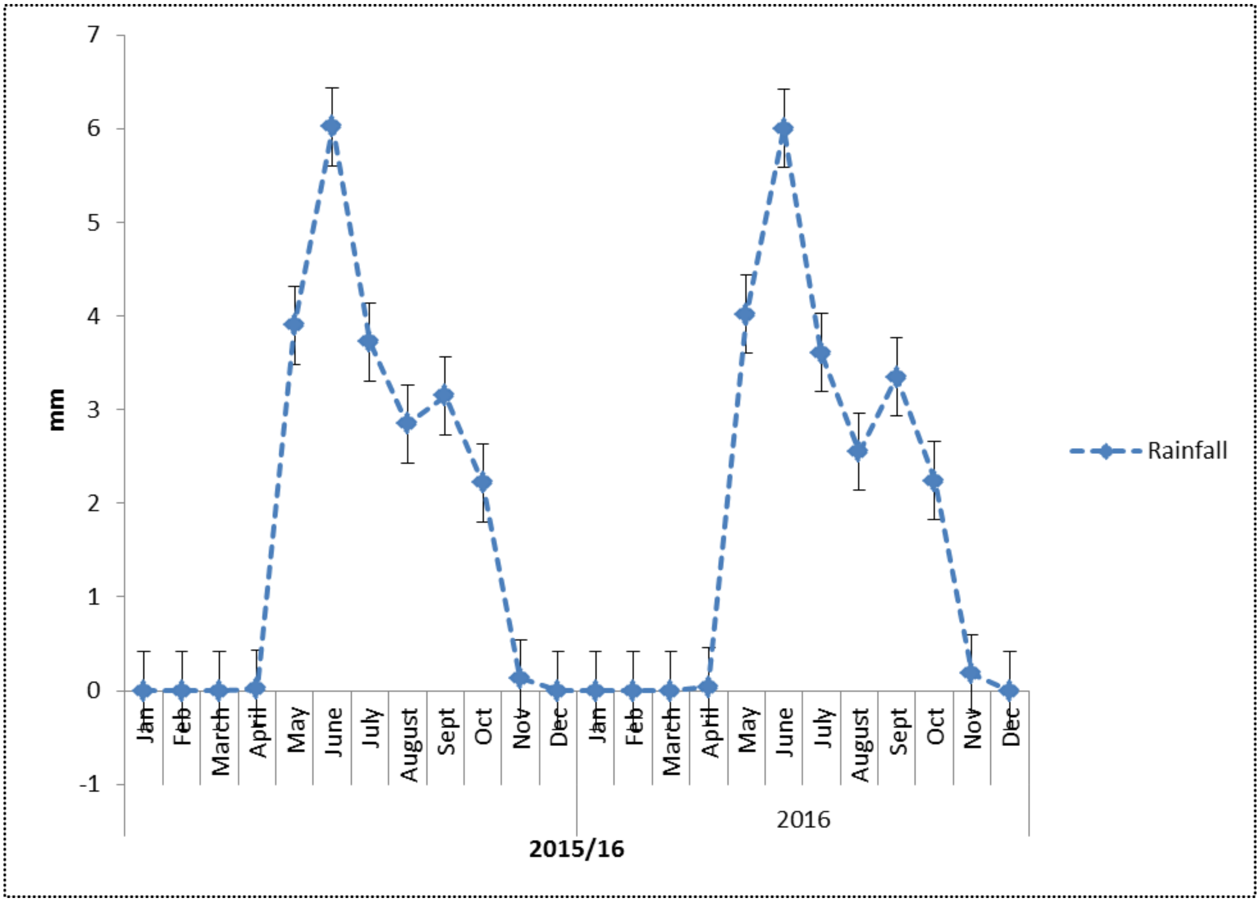

Fig 4.4: Monthly rainfall data between January 2015 and Dec 2016.

4.6 Fish species abundance, seasonal distribution and diversity

The composition, temporal distribution (wet and dry season) and diversity of the fish sampled during the study period (January 2015-Dec 2016) were recorded.

4.6.1 Fish species abundance

The total quantity of fish sampled within the sampling period was 3392 individual, which belonged to seven families and nine species. The fish composition obtained was presented in Table 4.21 and the percentage composition (by number) was illutrsted in Table 4.22. Among all the families represented, Cichlidae was the dominant family, constituting 58.34%, followed by Channidae (4.48%), and Polypteridae (3.71%). The family Cichlidae was represented with three species (*Oreochromis niloticus, Coptodon zillii, Oreochromis aureus*). The rest of the family had only one species present. With respect to their proportional mass (% weight), the highest weighed family was Cichlidae (48.97%), followed by ClariIdae (18.98%), Gymnarchidae (9.43%), Channidae (9.15%), Polypteridae (4.96%), Schilbidae (4.71%), and Hepsetidae (3.79%).

The relative abundance of fish sampled by number represented in Eleyele Lake throughout the time of survey is captured in Table 4.23. The most abundant fish species was *Oreochromis niloticus* (30.37%, 1030 specimens), *Coptodon zillii* (17.51%, 594 specimens), *Clarias gariepinus* (15.63%, 530 specimens), *Oreochromis aureus* (10.46%, 35 specimens), *Schilbe mystus* (7.07%, 240 specimens), *Gymrnachus niloticus* (5.71%, 194 specimens), *Hepsetus odoe* (5.04%, 171 specimens), *Parachanna obscura* (4.48%, 152 specimens). The least in abundance was *Polyterus bichir bichir* (3.71%; 126 specimens). The compositions of their percentage weight were as follows: *O. niloticus,* with the highest weighed specimens –27.95%; *Clarias gariepinus* -18.98%; *C.zillii* –15.14%, *G.niloticus* – 9.43%, *P. obscura* – 9.15%, *O. aureus* 5.87%, *P. bichir bichir* – 4.96%, *S. mystus* – 4.71% and *H. odoe* – 3.79%. The temporal disparity of fish population and their compositions (%) by quantity is presented in Table 4.24. A higher number of fish were caught throughout the dry season (1830) compared to the wet season (1562). *Oreochromis niloticus* and *C*. The pictures of some of the fish encountered were displayed in Plate 5,6,7,8 and 9.

Table 4.21: Checklist of the fish (family/species and season) in Eleyele Lake

Family/Species	Season
Family: Cichlidae *Oreochromis niloticus*	Available in both seasons
Family: Cichlidae *Oreochromis aurea*	Available in both seasons
Family: Cichlidae *Coptodon zillii*	Available in both seasons
Family: Clariidae *Clarias gariepinus*	More in the wet season, scanty in the dry season
Family: Schlibeidae *Schilbe mystus*	Available mostly in the dry season
Family: Hepsetidae *Hepsetus odoe*	Available in both seasons but abundant in the dry season
Family: Polypteridae *Polypterus bichir bichir*	Available in the wet season, scanty in the dry season
Family : Channidae *Parachanna obscura*	Plenty in the wet season, scanty in the dry season
Family : Gymnarchidae *Gymnarchus niloticus*	Plentiful in the wet season, scanty in the dry season

Table 4.22: Percentage composition (by number) and weight of fish families from Eleyele Lake (Jan 2015-Dec 2016)

Family	No	%	Weight(g)	%
Cichlidae	1979	58.34	159028.5	48.97
Clariidae	530	15.63	61646.1	18.98
Schilbeidae	240	7.07	15287.1	4.71
Hepsetidae	171	5.04	12331.7	3.79
Polypteridae	126	3.71	16121.3	4.96
Channidae	152	4.48	29732.2	9.16
Gymnarchidae	194	5.71	30565.4	9.43
Total	3392	100.00	324712.3	100.00

Table 4.23: Relative abundance of fish (by number and weight) between January 2015 and December 2016 in Eleyele Lake

Sp	No	%	Weight(g)	%
GN	194	5.72	30565.4	9.43
CZ	594	17.51	49188.6	15.14
ON	1030	30.37	90762.5	27.95
CG	530	15.63	61646.1	18.98
PB	126	3.72	16121.3	4.96
HO	171	5.04	12331.7	3.79
SM	240	7.07	15287.1	4.90
PO	152	4.48	29732.0	9.15
OA	355	10.46	19077.4	5.87
TOTAL	3392	100	324712.3	100

KEY: *GN-Gymnarchus niloticus, CZ –Coptodon zillii, ON –Oreochromis niloticus, CG –Clarias gariepinus, PB –Polypterus birchir birchir, HO -Hepsetus odoe, SM –Schilbe mystus, PO –Parachanna obscura, OA –Oreochromis aureus*

Table 4.24: Abundance and seasonal variation of fish species in Eleyele Lake between Jan 2015 and Dec 2016

	Wet		**Dry**		**Total abundance**	
Fish species	No	%	No	%	No	%
CG	256	16.39	274	14.97	530	15.63
ON	405	25.93	625	34.15	1030	30.37
SM	103	6.59	137	7.48	240	7.07
CZ	314	20.20	280	15.40	594	17.51
PB	54	3.46	72	3.93	126	3.72
GN	109	3.97	85	4.64	194	5.72
OA	140	8.96	215	11.74	355	10.46
HO	95	6.08	76	4.15	171	5.04
PO	86	5.51	66	3.60	152	4.48
TOTAL	1562	100.09	1830	100.06	3392	100

Key: *GN –Gymnarchus niloticus, CZ –Coptodon zillii, ON –Oreochromis niloticus, CG –Clarias gariepinus, PB –Polypterus birchir birchir, HO –Hepsetus odoe, SM –Schilbe mystus, PO –Parachanna obscura, OA –Oreochromis aureus*

Plate 5*: Scilbe mystus* x 30

Plate 6*: Hepsetus odoe* x 25

Plate 7: *Coptodon zillii* x20

4.6.2 Diversity indices

The Simpson's Index of Diversity (1-D) had a normal range of 0 to 1; the higher the estimate, the higher the species variety. In this research, Simpson's Index of Diversity (1-D) values fell between 0.46 and 0.49. The Shannon-Weiner Fish Diversity Index varied within 0.67 and 0.69. However, the Margalef Index of Species Richness for individual species ranged fom 0.14 to 0.20, while that of Equitability values varied between 0.96 and 0.99. The highest estimate of Simpson's Index (0.84) was obtained in the wet season and that of the dry season was 0.81. The species diversity indices are depicted in Table 4.25 and the seasonal diversity indices are presented in Table 4.26. For all other indices (Shannon-Weiner, Margalef, Eveness, and Equitability) the values calculated were greater in the wet season than the dry season, except for Berger-Parker Index, which was greater all through the dry season (0.34) than the wet season (0.25).

4.6.3 Potential fish yield

The potential fish yield of Eleyele Lake was presented in Table 4.27. Higher PFY was obtained in the dry season.

4.7 Interrelationship between the variables of physicochemical parameters of water and fish abundance (p=0.002 at 5% significance)

Figure 4.6 shows the variables of physico-chemical parameters and fish abundance bi-plot, which indicated the interrelationship between the parameters. Table 4.28 reveals the result of the eigen value, that the principal two axes were most significant ($P<0.001$) and recorded 97.78% of the total variation among the physico-chemical parameters and the fish abundance. Component axis 1 accounted for 77.4% of the physico-chemical variables and had a strong positive loading on sodium ($r = 2.03$), nitrate ($r =0.67$),TS ($r = 1.20$),COD ($r = 1.44$), ammonia ($r = 2.17$), Cl ($r =0.63$) and strong negative loading on BOD (-1.13), depth (-0.55), K ($r =-1.10$), Ca ($r =-1.40$), Mg (-0.96), fish abundance (-0.61). Axis 2 accounted for 20.38% of the physico-chemical variables and the fish abundance and also had a strong positive loading on Fish abundance (1.55) and phosphate (0.54) and a strong negative

Table 4.25: Species Diversity Index

SP	Dominance_ D	Simpson_ 1-D	Shannon_H	Evenness_ e?H/S	Margalef (d)	Equitability	Berger-Parker
CG	0.50	0.49	0.69	0.99	0.15	0.99	0.51
ON	0.51	0.46	0.67	0.97	0.14	0.96	0.61
SM	0.51	0.49	0.68	0.99	0.18	0.98	0.57
CZ	0.50	0.49	0.69	0.98	0.15	0.99	0.52
PB	0.51	0.48	0.68	0.98	0.20	0.98	0.57
GN	0.51	0.49	0.68	0.99	0.18	0.98	0.56
OA	0.51	0.47	0.67	0.97	0.17	0.96	0.60
HO	0.51	0.49	0.68	0.99	0.19	0.99	0.55
PO	0.51	0.49	0.68	0.99	0.19	0.98	0.56

Key: GN –Gymnarchus niloticus, CZ –Coptodon zillii, ON –Oreochromis niloticus, CG –Clarias gariepinus, PB –Polypterus birchir birchir, HO –Hepsetus odoe, SM –Schilbe mystus, PO –Parachanna obscura, OA –Oreochromis aureus

Table 4.26: Seasonal variation in diversity indices for fish species sampled

Diversity	Wet season	Dry season
Dominance_D	0.15	0.18
Simpson_1-D	0.84	0.81
Shannon_H	1.99	1.90
Evenness_e^H/S	0.81	0.74
Margalef(d)	1.08	1.06
Equitability	0.90	0.86
Berger-Parker	0.25	0.34

Table 4.27: Morpho-Edaphic Index (MEI) and Potential Fish Yield (PFY) of Eleyele Lake

Variables	Dry season	Wet season
Conductivity (µS/cm)	357.50 ±50.51	255.02±44.64
Mean depth (m)	6.93±1.40	7.23±1.53
MEI	51.58	35.27
PFY(Kg/ha^{-1})	536.77	367.04

loading on Ca (-4.36), TH (-0.74), Mg (-4.63), sodium (-2.15), nitrate (-1.18), sulphate (-0.89), ammonia (-0.85) and depth (-0.89).

Monte Carlo permutation tests (@ 1000) were insignificant for all four axes (p = 0.002). The result of the 1000 permutation test revealed that the physico-chemical parameters were not linearly related to fish abundance at 5% significance level. Some physico-chemical parameters had positive impact (pH, alkalinity, chloride, ammonia) on fish abundance, while some, like total hardness, temperature and depth, had negative impact.

4.8 Inter-relationship between aquatic macrophytes and fish abundance

Figure 4.7 reveals the relationship between fish abundance and the aquatic macrophytes. Table 4.29 show the eigen value and the percentage cumulative variability. The axis 1 accounted for 92.72% of the aquatic macrophtes variables and had a strong positive loading on *Ipomoea aquatica* (1.23), *Luffa cylindrical* (0.70) and fish abundance (0.54). Axis 2 accounted for 6.96% and had strong positive loading on *Cyperus rotundus* (1.32), *Polygonum salicifolium* (0.90), *Leptochloa caerulescens* (1.01), *Ludwigia abyssinica* (0.86) and *Ludwigia decurrens* (0.52).

Monte Carlo permutation tests (@ 1000) were insignificant for all four axes (p = 0.017). The result of the 1000 permutation test indicated that aquatic macrophyte variables were not linearly related to fish abundance at 5% significance level. Some aquatic macrophytes had positive impact (*Pistia stratiotes, Polygonum salicifolium, Luffa cylindrica, Ceratophyllum demersum)*, on fish abundance, while some, like *Costus afer, Nymphaea lotus and Acroceras zizanioides*, had negative impact.

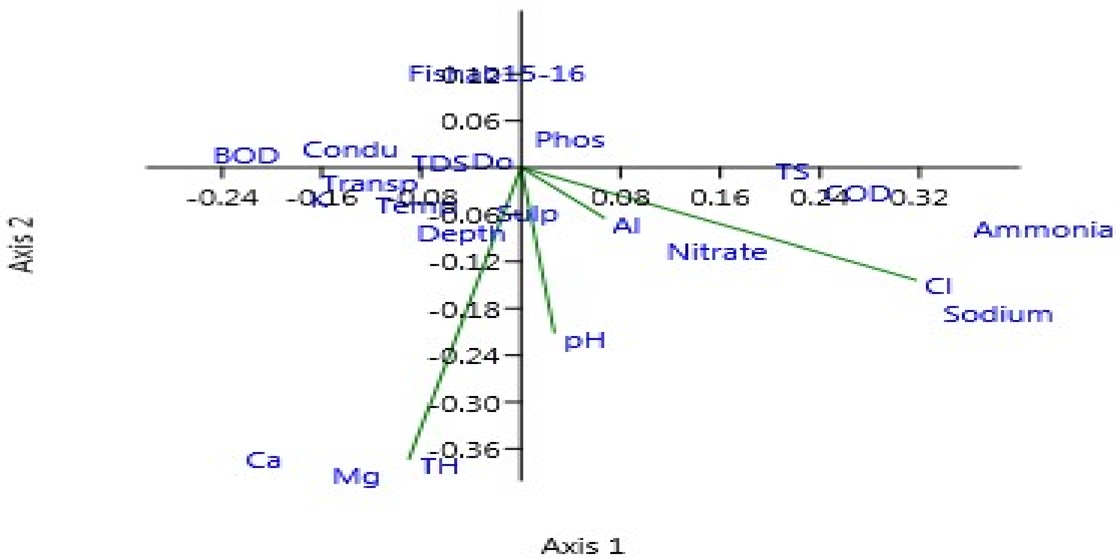

Figure 4.5: **Canonical Correspondence Analysis (CCA) bi-plot showing the inter-relationship between the physico-chemical parameters and fish abundance**

Legend: TS-Total solid, Conductivity, Mg-Magnesium, Ca-Calcium, pH, Al-Alkalinity, Nitrate, Ammonia, Sodium, Phosphate, Temperature, DO-Dissolved oxygen, Depth, Cl-Chloride, BOD- Biochemical Oxygen Demand, TDS- Total dissolve oxygen, COD – Chemical Oxygen Demand, TH – Total Hardness, Transparency, Fish abundance.

Table 4.28: Eigen values of physico-chemical parameters and fish abundance

Variables	Axis 1	Axis 2	Axis 3	Axis 4
Ca	-1.40	-4.36	0.85	0.71
Mg	-0.96	-4.63	-0.20	5.86
Na	2.03	-2.15	5.08	27.87
K	-1.10	-0.38	9.81	2.79
TDS	-0.29	-0.13	-0.43	-0.92
TS	1.20	-0.03	-0.38	0.38
Do	-0.18	-0.09	-3.78	-2.74
BOD	-1.13	0.20	7.14	-0.57
COD	1.44	-0.29	1.41	-0.85
Nit	0.67	-1.18	-0.83	2.57
Phos	0.01	0.54	1.30	-2.50
Sulp	0.15	-0.89	-4.07	4.22
Amm	2.17	-0.85	1.32	6.78
Temp	-0.37	-0.35	-1.70	-2.10
Depth	-0.55	-0.89	-1.95	-2.48
Trans	-0.44	-0.24	-0.41	-2.05
Cond	-1.00	0.08	-0.02	-0.01
Fiab	-0.61	1.55	0.35	0.85
pH	0.05	-0.42	-0.09	-0.37
Al	0.13	-0.12	0.38	-0.09
Cl	0.63	-0.28	0.01	0.01
TH	-0.17	-0.74	0.10	-0.08
Eigenvalue	0.026	0.069	0.0007	5.6427
% Variance Explained	77.4	20.38	2.22	0.443
%Cumlative Variance	77.4	97.78	100.00	100.443

Key: pH, Alk –Alkalinity, Chl –Chloride, TH –Total Hardness, Ca –calcium, Mg –Magnessium, Na –Sodium, K – Potassium, TDS – Total dissolved solid, TS –Total Solid, DO –Dissolved oxygen, BOD –Biochemical Oxygen Demand, COD –Chemical Oxygen Demand, N –Nitrate, Phos –Phosphate, Sulp –Sulphate, NH_3 –Ammonia, Temp – Temperature, Depth, Trans –Transparency , Condu – Conductivity, Fishab – Fish abundance

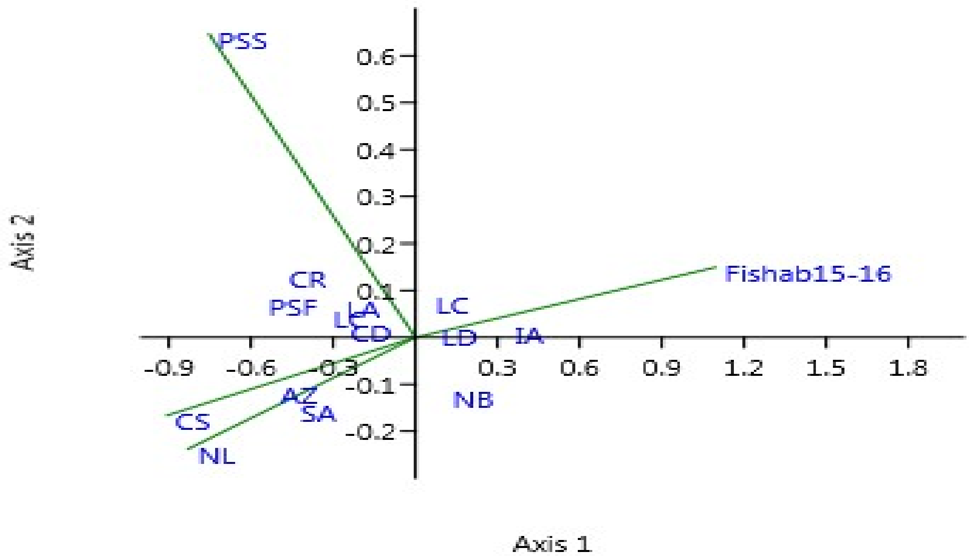

Figure 4.6: Interrelatioship between the aquatic macrophytes and fish abundance

Key: Fishab- Fish abundance, *PS-Pistia stratiotes, AZ-Acroceras zizanioides, NL-Nymphaea lotus, CD-Ceratophyllum demersum, PSA-Polygonum salicifolium, NB-Nephrolepis biserrata, LD- Ludwigia decurrens, LA-Ludwigia abyssinica, LCY-Luffa cylindrica, IA-Ipomoea aquatica, CR-Cyperus rotundus. LCA-Leptochloa caerulescens, SA-Sacciolepis africana,CS-Costus afer*

Table 4.29: Eigen values of aquatic macrophyte and the fish abundance variables

Variables	Axis 1	Axis 2	Axis 3	Axis 4
NB	0.38	-1.63	-0.68	0.79
CR	-1.23	1.31	-1.75	1.03
PSF	-1.22	0.90	-0.76	1.02
LC	-1.13	1.01	0.46	0.01
IA	1.23	0.25	-0.03	-0.01
LA	-1.11	0.86	0.87	-0.09
LD	0.23	0.21	1.50	1.52
LC	0.70	0.52	-0.38	-1.41
AZ	-1.20	-1.71	-1.77	-0.75
SA	-1.21	-1.81	1.71	-0.55
CD	-1.04	0.34	0.89	-1.99
Fiab	0.54	0.07	0.00	0.30
PSS	-0.37	0.32	0.22	0.41
NL	-0.41	-0.12	0.29	0.47
CS	-0.45	-0.08	0.34	0.44
Eigenvalue	0.0695	0.0052	0.0002	4.0812
%Var Explained	92.72	6.962	0.314	0.0054
%Cum Var	92.72	99.682	99.996	100.040

Key:Fishab- Fish abundance, *PS -Pistia stratiotes, AZ –Acroceras zizanioides, NL –Nymphaea lotus, CD –Ceratophyllum demersum, PSA –Polygonum salicifolium, NB –Nephrolepis biserrata, LD –Ludwigia decurrens, LA –Ludwigia abyssinica, LCY –Luffa cylindrica, IA –Ipomoea aquatica, CR –Cyperus rotundus, LCA –Leptochloa caerulescens, SA –Sacciolepis africana, CA –Costus afer*

4.9 The correlation coefficient among the sediment constituents and fish abundance

The Pearson correlation coefficient between sediment parameters and fish abundance is presented in Table 4.31. pH positively related to sand and calcium (r = .582, .608, P >0.05) and inversely related to clay (r = -.655, P<0.05), while pH strongly related positively to organic carbon, organic matter and potassium (r = .724, .786, .745, P>0.01), but significantly related negatively to phosphate (r = -.763, P<0.01). Organic carbon positively correlated with magnesium and potassium (r = .706, .645 = P>0.05) and inversely correlated with clay and phosphate (r = -.670, -635; P<0.05). Strong positive correlation exist between organic carbon and organic matter, sand and calcium (r = .874, .741, .769; p<0.01) organic matter showed positive correlation with calcium (r = .657, p>0.05) and negatively correlated with phosphate (r = -.686; p<0.05). Sand exhibited positive correlation with calcium and potassium (r = -706, .591 p>0.05), clay is negatively correlated with calcium (r = -.692, p<0.05) and strong negatively correlated with magnesium and potassium (r = -889 -743, p<0.01) and strong positive correlation with phosphate (.649, p>0.01). No significant relationship exist between fish abundance and physicchemical parameters of sediment.

4.10. Interrelationship between aquatic macrophyte, physicochemical parameters of water, PFY and NPP

In Figure 4.8, the relationship between physicochemical parameters, aquatic macrophytes, PFY and NPP were illustrated while the factor loading and the percentage cumulative variance was presented in Table 4.32. Figure 4.16 reveals the relationship between aquatic macrophyte, physicochemical parameters of water, PFY and NPP. The axis 1 accounted for 53.53% of the aquatic macrophytes variables and had a strong positive loading on Ammonia (5.53), NPP (3.89) and depth (3.85). Axis 2 accounted for 44.08% and had strong positive loading on NPP (1.32), while DO had strong negative loading in both axis I and 2(-0.36; -0.66).

Table 4.30: Pearson correlation coefficient between sediment parameters and fish abundance

	pH	OC	OM	Sand	Clay	Silt	Na	Mg	Ca	K	P	Fishab
pH	1											
OC	.724**	1										
OM	.786**	.874**	1									
Sand	.582*	.741**	.806**	1								
Clay	-.655*	-.670*	-.789**	-.854**	1							
Silt	.263	.054	.184	.183	-.470	1						
Na	.193	.086	.286	.324	-.170	-.394	1					
Mg	.545	.706*	.783**	.865**	-.889**	.493	-.059	1				
Ca	.608*	.769**	.657*	.706*	-.692*	.456	-.232	.809**	1			
K	.745**	.645*	.740**	.591*	-.743**	.649*	-.284	.798**	.786**	1		
P	-.763**	-.635*	-.686*	-.798**	.898**	-.542	-.122	-.784**	-.791**	-.764**	1	
Fishab	.362	.456	.463	.384	-.180	.242	.080	.386	.535	.463	-.317	1

**. Correlation is significant at the 0.01 level (2-tailed).

Key: pH, OC –Organic carbon, OM –Organic matter, Sand, Clay, Silt, Na –Sodium, Mg –Magnessium, Ca –Calcium, K –Potassium, P –Phosphate, Fishab –Fish abundance

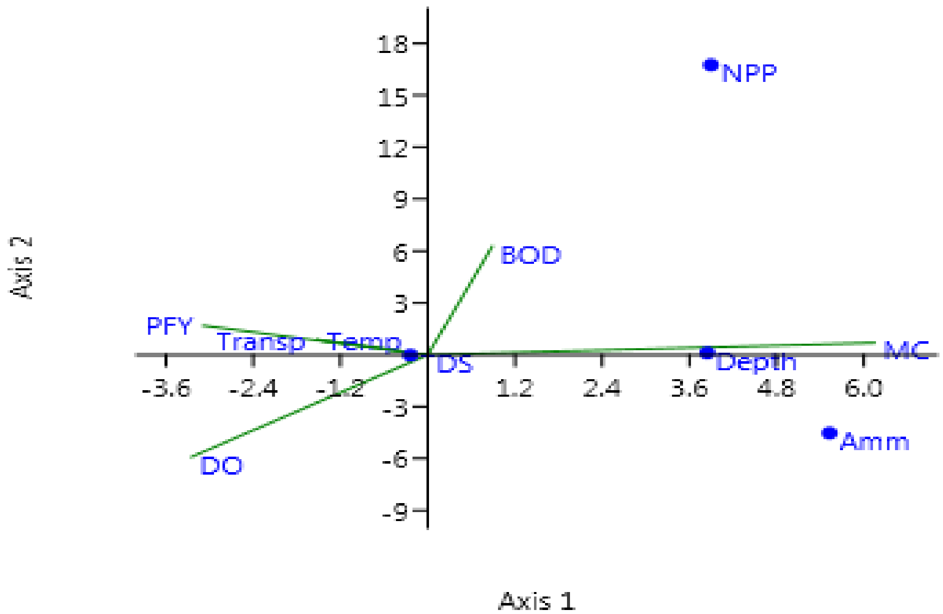

Figure 4.7: Interrelationship between, Aquatic macrophyte, Physico-chemical parameters PFY and NPP

Legend: MC-Macrophyte composition, PFY- Potential Fish Yeild, NPP- Net Primary Productivity, Temp- Temperature,Transp- Transparency, DO- Dissolved oxygen, BOD-Biochemical Oxygen demand, TDS Total dissolved solid, Depth, Amm-Ammonia

Table 4.31: Factor loading of Eigen values of different variables of physico-chemical parameters, aquatic macrophyte, potential fish yield and net primary productivity

Variables	Components		
	F1	F2	F3
Amm	5.527	-4.525	8.062
TDS	-0.238	-0.016	0.030
NPP	3.899	6.762	6.613
Depth	3.847	0.110	-2.699
MC	0.682	0.076	0.024
PFY	-0.343	0.187	-0.108
Temp	-0.169	0.096	0.089
DO	-0.361	-0.655	0.069
BOD	0.098	0.696	0.018
Transp	-0.168	0.096	0.089
Eigenvalue	0.00084	0.00069	3.7535
%Variance	53.53	44.08	2.38
% Cumulative Variance	53.53	98.61	100.00

Legend: Amm – Ammonia, TDS –Total Dissolved Solid, NPP – Net Primary Productivity, Depth, MC – Macrophytes Composition, PFY –Potential Fish Yield, Tem –Temperature, DO – Dissolved Oxygen, BOD – Biochemical Oxygen Demand, Transp - Transparency

4.11 Primary productivity

The spatial and temporal variations of net primary productivity, community respiration and Gross productivity in Eleyele Lake are presented in Tables 4.33 and 4.34, respectively and

4.11.1 Net Primary Productivity (NPP)

The mean value of NPP was lowest in zone 3(0.26±0.13$gO_2/m^3/d$) and highest in zone 4 (0.53±0.21($gO_2/m^3/d$)). The mean NPP for the wet season (0.62±0.03$gO_2/m^3/d$) was a bit higher than that of the dry season (0.55±0.31$gO_2/m^3/d$)**.**

4.11.2 Community respiration (CR)

The community respiration mean value determined for the wet season (0.30±0.27 $gO_2/m^3/d$) was lower than the dry season (0.41±0.25$gO_2/m^3/d$). The mean estimates for the spatial distribution were 0.21±0.16, 0.28±0.19, 0.32±0.08, 0.35±0.11, 0.18±0.06 $gO_2/m^3/d$, respectively (Table 4.34). However, no significant difference existed across the zones.

4.11.3 Gross Primary Productivity (GPP)

The gross primary productivity mean values obtained for the wet season, 0.51±0.27$gO_2/m^3/d$ and the dry season 0.71±0.48$gO_2/m^3/d$ were recorded. The GPP mean values across the zones were 0.87±0.34; 1.22±0.10; 1.07±1.12; 0.95±0.42$gO_2/m^3/d$, respectively. Seasonal GPP mean values were not strongly influenced (P>0.05).

4.11.4 Chlorophyll *a* (μgL^{-1})

The chlorophyll *a* mean estimate obtained in the dry season (0.24±0.21) was greater than the wet season (0.20±0.18). The chlorophyll *a* values across the zones were 0.12± 0.10; 0.1±0.09; 0.29±0.23; 0.33±0.22; 0.36±0.22, respectively. No significant difference existsed across the zones.

Table 4.32: Spatial variation of Primary Productivity of Eleyele Lake

Parameters	Zone1	Zone 2	Zone 3	Zone 4	Zone 5	P value
Net Primary Productivity ($gO_2/m^3/d$)	0.41±0.03	0.37±0.02	0.26±0.13	0.53±0.21	0.43±0.11	>0.05
Gross Primary Productivity ($gO_2/m^3/d$)	0.87±0.34	1.22±0.10	1.31±0.27	1.07±1.12	0.95±0.42	>0.05
Community Respiration ($gO_2/m^3/d$)	0.20±0.16	0.28±0.19	0.32±0.08	0.35±0.11	0.18±0.06	>0.05
Chlorophyll *a* (μgL^{-1})	0.12±0.10	0.11±0.09	□0.29±0.23	0.33±0.22	0.36±0.22	>0.05

Table 4.33: Seasonal variation of primary productivity of Eleyele Lake

Parameters	Dry Season	Wet Season	P value
Net Primary Productivity ($gO_2/m^3/d$)	0.55±0.31	0.62±0.03	>0.05
Gross Primary Productivity ($gO_2/m^3/d$)	0.71±0.48	0.51±0.27	>0.05
Community Respiration ($gO_2/m^3/d$)	0.41±0.25	0.30±0.07	<0.05
Chlorophyll *a* (μgL^{-1})	0.24±0.21	0.20±0.18	<0.05

CHAPTER FIVE

DISCUSSION

5.1 Aquatic macrophytes distribution and dynamics

One of the major components of a lake ecosystem is the aquatic macrophytes which influence both the physical and chemical processes. Human activities also have their own environmental influence on the lake (Shekede *et al*., 2008). Oyedeji *et al*. (2013) assert that aquatic macrophytes have the ability to serve as a pointer to pollution in the aquatic ecosystem. Aquatic macrophytes offer refuge, nesting areas, food for fish and various classes of aquatic resources (amphibians, reptiles, birds and aquatic mammals). The aquatic macrophyte beds are very important in spawning and nursing of the young ones which also play a major role in the status of a lake's fishery (Block and Rhoad 2011). Both the in-lake and shoreline macrophytes serve as buffers from run-off and destructive wave actions. Lack of vegetation in the aquatic environments increases the vulnerability of lakeshore stability, reduces the population of available habitat, and results in lower biodiversity and overall biomass of lake ecosystem (Pennsylvania Fish and Boat Commission, 2014). In Eleyele Lake, the aquatic macrophyte has expanded from the shore of the water to the middle of the water, claiming almost one-third of the lake. This affected the rate of water transportation. Recreational activities were reduced and the catches by the fisher folks during fishing activities were very low, which invariably affected their daily income.

According to Pennsylvania Bureau of Clean Water (2014), "the estimation of plant cover could be done by visual projection of all the vegetation on the water column to the lake surface". During the sampling period in Eleyele Lake, Zone 2 (Apapa/Ijokodo) was very densely populated by macrophytes (the means of transportation was totally blocked by the macrophytes and no fishing or recreation activity took place in that zone). Zone 3 (Oteru/Arinkinkin) was densely populated (50-75% cover) by macrophytes. These macrophytes proliferation in these two zones could be as a result of domestic discharge, sewages, and run-off from farmlands surrounding these zones. In the result, there is increased level of some of the physicochemical parameters of water that may influence the proliferation of these macrophytes. Fourteen taxonomic families of the macrophytes composition were represented (Floating plant, Emergent plant and Submerged Plant) Poaceae family had three species; Onagraceae had two species; and other families had one species each. The families were Araceae, Nymphaeaceae, Costaceae, Ceratophyllaceae, Polygonaceae, Cucurbitaceae, Onagraceae, Pteridophyta, Cypreraceae, Poaceae and Convolvulaceae. During the dry season, only seven species were present out of the fourteen species. Most of the plants not present during dry season were emergent plant

The dynamics and distribution of macrophytes and water of Eleyele Lake were calculated from the map extracted from 2007 to 2016. The analysis showed that the aquatic macrophytes cover reduced between 2007 and 2012 but there was proliferation of these macrophytes from 2012 to 2016, which caused reduction in the surface area of the water in that zone. This implies that the presence of these macrophytes and diversity of different macrophytes indicated greater level of species productivity in the lake. This supported the report of Lund (2017) which state that 'the presence of plants in an aquatic system typically indicates high richness of such lake'. Also, the reduction in the area of water and increase aquatic macrophytes over the years in Eleyele Lake showed degradation of the environment through indiscriminate discharge of wastes, effleuents, run-off from farmlands and various impacts of urban development on the catchment/shoreline area. This agreed with Tijani (2011) findings.

5.2 The effects of species composition and diversity of aquatic macrophytes on fish abundance

According to Lund (2017), the presence of plants in an aquatic system typically indicates high richness of such lake; the plant depends on the sediment constituents for its essential nutrients. The fertility of such sediment invariably influences the composition and types of fish species that can thrive and survive in such an environment. Swingle (1950) observes that, in predicting the annual total produce of an aquatic ecosystem, the community make-up and species richness or composition must be well understood. Such will assist in improving the management strategies for stocking rate in an aquatic system (Tang, 1970). Akinyemi (1985) recorded 41 fish species in Asejire; Fapounda and Godstates (2007) observed 14 fish species from Owena Reservoir; Ikenweiwe *et al*. (2006) reported 38 in Oyan Lake; and Olaniran (2000) recorded 114 fish species in IITA Reservoir; Nine (9) fish species were encountered and recorded in Eleyele between 2015 and 2016, during this study. The number of fish compositionin Eleyele Lake during this sampling was lower compared to the report from different lakes and reserviors. Among the fish caught, Cichlidae family dominated the list. This indicates that the aquatic system is suitable for successful reproduction of this family and plants are available for most herbivorous fish, like the Cichlidae family. Insects and plankton will also be available due to the presence of plant. The dominance of Cichlidae family was also recorded by Balogun (2005), in Kangimi Reservoir: Ikenwiwe *et al*. (2007), in Oyan Dam; Mustapha (2010), Dan-Kishiya (2012) and Edward (2013), in Oyun Reservoir; Olopade and Rufai (2014), in Oyan dam. The nature of cichlids to bloom on an extensive diversity of food available, the highly-productive breeding system and their system of rearing their young ones all accounted for their dominance; as reported by these authors.

5.3 Aquatic Macrophyte Community Index (AMCI)

This multipurpose index tool was used to assess the overall aquatic macrophyte community quality (environmental quality) and also reflect the level of known impact in a lake. The different criteria used in evaluating the AMCI summarise the overall ecological conditions of a lake. These also emphasize the importance of macrophytes to Lake ecosystem. The seasonal result (dry season: 32, wet season: 40) showed that the values fell within the 7-70 set range of AMCI. Spatially, the values ranged between 30 and 37, while the overall value was 41, which was an average value. This showed that Eleyele Lake was moderately poor in biological quality (impact of aquatic macrophyte on the water body is poor which invariably affect the biological quality of the lake), in agreement with the set limit by Weber *et al*., 1995.

5.4 Floristic Quality Assessment (FQA)

This tool is utilised to estimate the ecological integrity based on the species structure of a lake. It also shows the impact which depicts the level of disturbance tolerant in an area. This disturbance rate could be direct, indirect or biological and may be irreversible. The range of the values for coefficient of conservatism is 0-10, which assumes that a plant occurs in an undisturbed environment. Floristic Quality Index (FQI),that is the mean of the coefficient of conservatism, for Eleyele Lake was 16.05, which showed low vegetative integrity. These implies that the aquatic macrophyte population in Eleyele Lake was among the most tolerant of disturbance (subjected to most disturbances). The low value of FQA can be related to average macrophyte dynamics or diversity. The aquatic macrophyte community occupies an essential part in the lake environment.

5.5 Water quality parameters and climatic data

Ajani (2001) states that the value of an aquatic environment is determined by the constituents of both its physical and chemical parameters. Following the standard water limit recommended by Boyd (1998) for aquatic life survival, the average rate and series of physical and chemical parameters obtained fell within these ranges except for electrical conductivity, which was above the range. The high maximum value recorded during this study in the wet season might be because of increased flow rate from the washing away of the top soil and inorganic fertilizer from surrounding farmlands. It might also be attributed to the reduction in the water level owing to vaporisation, which boosted the level of nutrients available. This finding was in tandem with Atobatele and Ugwumba (2008), who noted that the decline in conductivity rates throughout the rainy season can be related to intensity of rainfall, while the greater estimates might be related to organic fertilizers from flooded farmland near the lake together with the high frequency of vaporisation that caused decline in the quantity of water all through the dry season. Hence, the conductivity of water relies on the intensity of nutrients and ions present.

The mean value of dissolved oxygen observed was in agreement with the findings of the previous research done in Eleyele by Bolaji (2010), Olarenwaju *et al*. (2017) and other authors whose observation also supported this report, notably Mustapha and Omotosho

(2005), in Moro Lake. However, the findings of Oniye *et al*.(2002), Araoye (2007) and Ibrahim *et al.*(2009) contradicted the report of this research, which recorded higher mean value during the wet season and attributed this to decrease in surface water temperature which might result in higher fluctuation of dissolved oxygen during the wet season. Olarenwaju *et al.* (2017) state that, since the mean value of DO was lower than the standard recommended by Boyd (1998), which is $5mgL^{-1}$, and dissolved oxygen is very crucial to aquatic life, Eleyele environment was not fully suitable for the aquatic life.

A factor which is the most important index for testing the concentration of organic contamination in a lake or reservoir is the biochemical oxygen demand (Ovie *et al.*2011). Abida and Harikrshna (2008) claim that the biodegradation of organic materials increases the BOD by the oxygen tension it exerts on the water.The capacity to absorb this oxygen exerted can be evaluated by BOD. The mean value obtained from this study for both temporal and spatial dimensions fell within the recommended standard limit set by Boyd 1998), which is <10mg/L.

The lower water temperature observed in rainy season could be attributed to the rainy season effect of cloud cover which results in high humidity. These results followed the findings of Ikenweiwe and Otubusin (2005), Toma (2013) and Olarenwaju *et al*. (2017), , . However, the report contradicted that of Fafioye *et al.* (2005), which recorded higher value for temperature in the wet season. The temperature range fell within the standard recommended limit by Boyd (1998) for metabolism, physiology and survival of aquatic lifes. The pH value documented during the wet season was high but the ranges were within acceptable limits reported by Boyd (1998) for fish productivity. The high average value in the wet season might be related to human activities around the Lake, which is partly to enhance photosynthetic activities, higher water volume with greater water retention coupled with low decomposition and good buffering capacity (Inuwa, 2007; Mustapha, 2009). This related to the reports of Atobatele *et al*. (2005) and Hassan *et al*. (2014).

Higher transparency occurred throughout the dry season, which could be as a result of gradual settling of the suspended particles in the aquatic body; there was no rainfall and this slowed down the rate of water run-off. This finding supported the report of Ibrahim *et al*. (2009). Similarly the rate of temperature increased and higher transparency which favours phytoplankton development and the primary productivity of the water body. This report was consistent with that of Inuwa (2007) and Mustapha (2008). The value of total dissolved solids obtained was within the range set by Boyd (1998). Higher concentration of TDS was noted throughout the wet season. This was similar to the documentation of Araoye (1997) on Asa Lake in Ilorin, Mustapha (2009), on Oyun Reservoir in Offa, Kalwale and Sayale (2012) and Olarenwaju *et al.* (2017) on Eleyele Lake.They attributed these results to the addition of solids through run-off water during rainfall. However, the findings of Atobatele and Ugwunba (2008) contradicted these results, as they recorded higher TDS value during the dry season. They attributed the result to higher rate of evaporation due to air temperature and wind, decaying of vegetation, and increase in the turbidity rate, which reduces light penetration that, in turn, suppresses the activities of primary producer (algae).

According to Abulazeez (2015), the values of alkalinity are the reflection of the rate or capacity of bicarbonate and carbonate ions in the water showing the absence of limestone in the water basin. The higher value reported in the dry season can be related to the excessive concentration of salts due to decrease in water level. The lower estimate throughout the wet season might be because of increased water level, which could have diluted the water. This report buttressed the findings of Ibrahim *et al.* (2009). The phosphate in the study was higher than what was found in previous studies, particularly Akindele and Adeniyi (2013), in Opa Reservior, and Mustapha and Omotosho (2005), in Moro. The relatively high estimates documented for phosphate may relate to the inflow of waste (agricultural run-off) and human operations around the lake as well as the biological activities of the bacterial which cause biodegradation of organic matter.

The nitrate and ammonia reported fell outside the recommended limit set by Boyd (1998) but concurred with the results of Ovie *et al.* (2011). The finding was in consonance with the report of Kolo and Oladimeji (2004) in Shiroro Lake, Niger State, Ayoola and Ajani (2009) in wetland of Oyo State; but it contradicted the findings of Dimowo (2013) in Ogun River. The ions composition observed during the study fell within the recommended limit, while calcium, chloride and potassium were relatively low (outside the recommended limit by Boyd (1998)). Chloride was greater all through the wet season, which could be ascribed to the discharge of sewage to the water that could be more during the wet season. This was in tandem with the report of Farombi *et al.* (2014). Chloride and magnesium were higher during the wet season while sodium, calcium and potassium lower in the wet season. These findings disagreed with the findings of Mustapha (2009) and Akindele and Adeniyi (2013), who observed higher variation during the dry season in Opa and Oyun Lakes, respectively, but agreed with the findings of Golterman and Kouwe (1980), which reported similar result of calcium being predominantly dominant in the ionic composition of Eleyele Lake.

5.5.1 Rainfall

During the sampling period in Eleyele Lake and its environments, the climatic condition was characterised by a long wet season which lasted 7 months (May to November) and a short period of 5 months for the dry season (December to April). This is a usual happening in the southwestern Nigeria climate condition (Ayoade *et al*., 2006, Kareem 2016). Mustapha (2010) observed a similar trend of rainfall pattern in Oyun Reservoir.

5.6 Relationship between water parameters and fish abunance

According to Ajani (2001) the value of an aquatic environment is determined by the composition of its physicochemical parameters of the water. This shows that all the aquatic organisms depend on water for survival (Boyd, 1998). From the analysed results the relationship between water quality parameters and fish abundance using canonical correspondence analysis sshowed that chloride had strong positive influence on fish abundance. Alkalinity, pH and ammonia also had positive influence while magnesium negatively influences the fish abundance.

5.7 Relationship between the sediment parameters and the fish abundance

In support of Ongley (1996), the sediments that are chemically active are silt and clay for the transportation of nutrient because they are smaller in sizes. The bottom sediment of Eleyele Lake revealed that elements such as magnesium, sodium, calcium, chloride and phosphate showed average concentration during the sampling period, which is also a suggestion to their absolute solubility during the weathering process. This was in agreement with the report of Tijani (2011).

5.8 Fish abundance and diversity

Most Nigerian lakes and reservoirs are significantly dominated by Cichlidae. This dominance is traceable to their prolific breeding and their ability to survive on wider ranges of different food items, including the aquatic vegetation and plankton. These findings were documented by different authors: Balogun (2005), Ikenweiwe *et al*. (2007), Oso and Fagbuaro (2008), Mustapha (2010), Edward (2013) and Olopade and Rufai (2014). During the sampling period in Eleyele Lake, *Oreochromis niloticus* was the most abundant and this buttressed the findings of Offem *et al.* (2009) in the Wetland of Cross River and Edward (2013) in Egbe Reservoir in Ekiti State.

During the sampling period in Eleyele Lake, it was established by the fishermen fishing on the river that the fish stocks had decline greatly, which was in agreement with the claim of Balogun (2005) that breakdown of fisheries and lake resources normally starts with high exploitation of the resources, which lead to deterioration in fish reserves. According to Dan-Kishiya *et al.* (2012), the degeneration in fish reserves in some of the lakes concides with the extreme fishing rate, capture of immature fish, weak management and extension practices, poor capability to enforce rules and regulations and limited commitment and participation of investors in administration of fisheries resources and the fish environments. This is also the operational issues in Eleyele Lake with regard to the fish abundance (catches) of the fishermen during their fishing operation. The fish caught throughout the sampling time were very little. The fish sampled were documented all through the dry and wet seasons.

In the South-West of Nigeria, the wet season is typified by low temperature, increased rainfall, which affects the fishing activities, increased flood rate, which brings about high turbidity (reduced water transparency and clarity which affect the penetration of light into water column and also enhance the growth of planktonic algae, a good source of fish food (Boyd,1979)). All these account for the low catches recorded during the wet season. Omitoyin and Ajani (2007) reported plentiful harvest all through the dry season at Asejire and Eleyele Lakes. Ayoola and Ajani (2009) reported greater capture during the dry season in Eleyele wetland both in biomass and number. This trend of dry season abundance was also observed by Elliot (1986), Araoye (1997) and Mustapha (2010). However, Olopade and Rufai's (2014) finding in Oyan dam was different; they recorded more catches during the wet season. In South-western Nigeria, fishing operations are usually affected throughout the wet season due to increase in water volume because of the increased rate of rainfall, which may result in flooding. This increases the rate of turbidity of the water bodies, reduces the degree of temperature and light intensity penetration. Also high level of wind action may disturb the fishing operation which result in reduced catch for the fisher folks and reduces their level of income at the end of that season.

This trend of variation in catch was observed by Elliot (1986), Araoye (1997), and Mustapha (2010). Ayoola and Ajani (2009) reported with high catch during the dry season in Eleyele wetland and Omitoyin and Ajani (2007) recorded abundant capture in the dry season in Asejire and Eleyele Lake. However, Olopade and Rufai (2014) recorded high catch in Oyan Dam during the wet season, which did not agree with this report. Higher conductivity and lower mean depth depict good productivity (Ovie and Ajayi, 2009), while the level of Potential Fish Yield observed during this study was high. This was due to the high rate of conductivity which was 290.70µS/cm and the mean depth of 7.11m. Kapetsky and Petr (1984) aver that shallow lakes with small mean depth which ranges between 3cm and 10m record high levels of productivity. Boyd (1979) also support this claim, with his finding that light penetration was easier in shallow low lakes which enhanced increase production of planktonic algae, which is a rich and nutritious food for fish. The results of potential fish yield (112.59kg/h) of Edward *et al*. (2014), in Ureje; 413.9kg/h of Edward (2013), in Egbe; and 125.75kg/h of Mustapha (2010), in Oyun Reservoir showed that the potential fish yield (425.42kg/ha) of Eleyele in 2016 recorded in this study was higher, which imply moderately good yield.

5.9 Relationship between fish abundance and aquatic macrophytes

Fish use the aquatic cover as their breeding site, spawning area, nursery of their young ones and shelter against predators as well as source of food. To the fish, aquatic macrophytes have a lot of benefits, but to humans, aquatic macrophytes in excess are a nuisance.They block waterways and affect transportation and recreation activities which was the case of zone two(apapa/ ijokodo zone) during sampling in Eleyele Lake. According to Balirwa *et al*. (1998), human operations often change stability among fish classes, cause extinction of several local species and decline group of most fish species.According to Jeje (1997), some of the species encountered during its sampling (like *Synodontis eupterus, Sarotherodon galilaeus*) were not encountered again during this sampling. Sometimes, fish respond to ecological disintegration and fishing pressure, lead to overfishing. From the CCA result, *Pistia stratiotes* (floating plant) had strong positive influence on fish abundance while *Nymphaea lotus (*floating plant) and *Costus afer* (an emergent plant) had negative influence on the fish abundance.

5.10 Correlation between the physico-chemical parameters and fish abundance

Canonical correspondence analysis of the water parameters (which is the environmental factors and the fish abundance in Eleyele Lake revealed considerable positive and negative interactions. The physico-chemical parameters sometimes contribute to the increase in the fish population of a lake, which results in abundance of fish (Kirsten, 2011). The pH (Lawson, 2011), dissolved oxygen (Maes *et al.*, 2004; Hussain *et al*., 2013), temperature (Suski *et al*., 2006) support the survival of aquatic lifes which lead to increase in fish population (Boyd, 1998). Also fish and most of the aquatic resources depend on varying temperature ranges for their proper and optimum growth. This was supported by Rakocinski *et al*., (1992), Lewis (2000) and Dirican (2015) , who note that there is a good interaction among the surface temperature and increased fish abundance. The interrelationship among the aquatic macrophytes, physico-chemical parameters, potential fish yield and the net primary productivity showed NPP, ammonia and aquatic macrophyte composition had positive impact on fish yield while DO had a negative impact.

5.11 Effects of environmental changes

The outcome of all the anthropogenic operations (domestic discharge of wastes and sewage, run-off from farmlands, block industy and mechanic workshop) which occurred around the lake and at the watershed area, lead to changes in the trophic position, which was complemented by a fall in water transparency. This reduced water transparency was linked with eutrophication, which also contributed to the species diversity loss among cichlids. This was reported by Balirwa *et al*. (1998) through his finding in Lake Victoria and which was in agreement with the findings in Eleyele Lake during the study period. In most vegetated water bodies, there were ecological changes which included the availability of oxygen to all the resources in the water body.

Twongo *et al*. (1995) reported the appearance of water hyacinth in Lake Kyoga, Uganda, in 1988, and Lake Victoria, in 1989. Also, these vegetated areas act as habitat for valuable fish, such as *Clarias gariepinus* and *P. aethiopicus*. If these macrophytes are totally removed, there will be decline in the catches of these fish species (Njiru *et al*., 2002). In vegetated areas, co-existence of different fish species is facilitated and these habitats are characterised by fish types abundance (Seehausen, 1996). The assessment of Eleyele aquatic macrophytes and fish abundance (CCA) revealed that there was an increase in the loading rate of the fish abundance, as the aquatic macrophytes increased in the area (positive influence). This supported the finding of Twongo *et al.* (1995).

5.12 Primary productivity

Gross primary productivity (GPP) of Eleyele Lake for both seasons was relatively low compared with the values reported by Karlman (1973), in his classification that high values are usually >3.0 $gO_2m^{-2}day^{-1}$; and also compared with other water bodies: Jebba (5.53),Victoria (3.9), Oguta (6.75), Abadaba (2.67), Volta (2.55), Kanji (2.19), Ojiranmi (0.63). However, the GPP of Eleyele was higher than the GPPs of Dadinkowa (0.16) and Kiri (0.08), which were reported by Ovie and Ajayi (2009).

Chlorophyll *a* was used as quantitative estimation of plankton biomass (Hotzel and Croome, 1999). The whole of green vegetation contain chlorophyll *a* and the intensity of photosynthetic pigments is utilised expansively to evaluate phytoplankton because of its presence in dry mass of planktonic algae. Various pigments that ensue in phytoplankton comprise chlorophylls *b* and *c*, xanthophylls, phycobilins, and carotenes. The essential chlorophyll breakdown products found in the aquatic environment are the chlorophyllides, pheophorbides, and pheophytins (Marker *et al*., 1980). Throughout the twenty-four months of sampling period, the mean values of NPP, GPP, CR and chlorophyll *a* showed significant fluctuation across the various zones and over the seasons.

5.12.1 Fish productivity and interaction with nutrients available in the sediments

The nutrients available both in the sediment and the water are essential for vegetation growth (plants, phytoplankton and algae) which make up the primary production level of aquatic food web, these determines the productivity of the higher trophic level.

Also, sediments play a main part in the geomorphology of riverbeds and riverine habitat. This is essential for the existence of plentiful fish species throughout the dry season (Welcomme, 1985).

Reports about sediments from different authors were in agreement with the assessments and findings of sediments in Eleyele Lake during the study period. Therefore, the degradation of the riverbed will affect the populations of most aquatic organisms adjusted to these specific habitats and the ecological structure.

CHAPTER SIX

SUMMARY AND CONCLUSION

6.1 Summary

This study assessed the aquatic macrophytes composition and distribution, fish abundance and diversity with the features of the water constituents of Eleyele Lake as well as the relationship between physico-chemical parameters and the aquatic macrophytes in it.. This was done to obtain the required information for the scientific management of productivity of the lake and fisheries resources.

Aquatic macrophytes dynamics and distribution

The aquatic macrophytes present during the study were fourteen in number. Their variation and distribution were considered seasonally. All the fourteen were present during the wet season and only seven were present during the dry season.

Fish abundance and diversity

Fish diversity of Eleyele Lake fell within the range of fish obtained in other lakes in Nigeria, with *Oreochromis nilocuticus*, which belong to the family Cichlidae, dominating most of the lakes. All the fish species represented were nine in number and they belonged to seven families. The seasonal variation showed that all the fish were represented in both seasons but their abundance reduced during the wet season.

Physical and chemical constituents

Most the water parameters examined were found in the range of established units meant for a productive aquatic system. However, factors like conductivity, chemical oxygen deamand, phosphate, potassium, calcium and total hardness significantly varied within the zones.

Relationship between physico-chemical parameters, aquatic macrophytes NPP and Potential Field Yield

The relationship was evaluated using correlation matrix and canonical correspondence analysis (CCA). Most of the aquatic macrophytes present, NPP and ammonia positively correlated with fish productivity. The CCA bi-plot showed that these features impacted the components and dissemination pattern of the macrophytes. Aquatic macrophyte composition had the longest arrow, indicating that a good correlation existed between potential fish yield. This was followed by the NPP, which also showed a positive influence. DO showed negative correlation. The further away the macrophytes is to the water parameter the less the influence of such parameter; the closer it is the more the influence of such parameter on the macrophytes, either positive (which shows a positive impact) or negative (which shows a negative impact).

6.2 Conclusion

This study revealed that Eleyele Lake is a eutrophic lake with acceptable water features that fall within the set limit for aquatic ecosystem with good species diversity. Aquatic macrophytes diversity plays an important role within the lake ecosystem and improves water quality in many ways. A stable, strong aquatic plant population offers valuable fishery and wildlife reserves.The food chain pyramid level begins from plants, which give support to many levels of wildlife yield as well as oxygen required by animals, and are utilised as food and refuge by diverse fish and wildlife, and provide varieties of food, cover, spawning sites for fish and breeding of young ones.

Findings from the study showed that the agricultural run-off from the farmland that surround the lake, sewage discharge and the run-off from the mechanic and block industries that surround the lake affected its water quality and influenced the abundant growth of macrophytes on the water body. Hence, adequate monitoring measures are required to control the spread of macrophytes on Eleyele Lake. This is because most of these activities around the lake have contributed to the proliferation of macrophytes . The aquatic macrophytes in Eleyele Lake have low vegetative quality and poor environmental integrity (low tolerance disturbance), which negatively affects the aquatic diversity and productivity of the entire lake.

6.3 Contributions to knowledge

The study has contributed to knowledge in the following areas:

1. The aquatic macrophytes composition and its seasonal distribution, vegetative quality and the environmental integrity of Eleyele Lake were ascertained.

2. Positive impact of aquatic macrophytes composition on fish abundance was established.

3. The variation (both spatially and seasonally) of nutrients constituents in water, bottom deposit (sediment) and macrophytes diversity of the Lake were established.

4. The fish composition, its seasonal distribution and abundance in Eleyele Lake were documented, which will enhance the proper allocation of resources among various end-users

5. The sediment components which provide basic information on phytoplankton productivity that influences the distribution and diversity of macrophytes proliferation and its benefits to fish were ascertained.

6.4 Recommendations

Based on the findings of the study, the following are recommended:

1. The disturbance (direct, indirect and biological disturbance) of the ecological area should be curbed and monitored, because it affects the productivity of the lake, vegetative quality and decline in the aquatic resources like fish.

2. Discharge of effluents should be discouraged so as to boost the primary production and the fish productivity of the lake.

3. To easily detect, prevent and rectify any changes that occurred which can affect fish production, regular monitoring of the water body must be ensured.

4. To mitigate decline in fish catch, fishermen should ensure regular clearing and management of the aquatic macrophytes zones.

5. Enforcement of policies and regulations by the relevant agency must adhere so as to encourage fish production commercially in Nigeria.

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