FISH COMPOSITION AND PRODUCTIVITY OF LOWER RIVER NIGER, AGENEBODE, NIGERIA

BY

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ABSTRACT

Inland waterswhich are important sources of fish for food and economic security are gradually declining in productivity.Studies have shown that the fish production capacities of Nigeria's inland water bodies such as Lower River Niger (LRN) are negatively impacted by habitat modifications and other anthropogenic activities. Restoration efforts for sustainable management of LRN require updated information on its fish resources composition and productivity which are currently limited. Therefore, fish resourcescomposition,distribution and productivity of LRN at Agenebodewere investigated.

The LRN(46.4km) wasstratified spatially into downstream, midstream and upstream zones based on hydrological features. Two stations per zone were randomly selected.Water, phytoplankton and zooplankton samples were collectedbimonthly from each station for 24 months covering wet (April to October) and dry (November to March) seasons. Fish samples were obtained monthly fromthe fishers' catches. Water samples were analysedfor Temperature (^{o}C), Total Suspended Solids (TSS, mg/l), Conductivity(µS/cm), Dissolved Oxygen (DO, mg/l) and Gross Primary Productivity(GPP, g/O_2/m^3/d) using standard procedures. Phytoplankton, Zooplankton and fish samples were identified to species level. Length – Weight relationship (LWR, b >3 or <3 – allometric; b = 3 – isometric) of most dominant species was assessed. Species diversity was determined using Shannon-Weiner (H), species evenness(E) and Dominance (1–D) indices. Potential Fish Yield (PFY) was estimated. Data were analysed using descriptive statistics, ANOVA and canonical correspondence at $\alpha_{0.05}$.

Temperature were 27.4±1.9 and 27.8±1.5, TSS 51.7±8.8; 69.9±23.8, Conductivity 43.6±4.5 ; 76.4±9.8, DO 4.3±0.4 and 6.1±10.0 and GPP 0.7±0.03; 1.1±0.3, for Downstream and Ups tream, respectively.Temperature, varied from 25.3±1.8 to 27.5±1.5; TSS 43.1±6.1 to 89.7± 17.6; Conductivity 58.7±6.5 to 60.3±6.1; DO 5.3±0.6 to 5.5±0.6and GPP 0.4±0.1 to 0.8±0.1 for wet and dry seasons, respectively. Six families of phytoplankton and nine of zooplankton were encountered. Bacillariophyta (44.0%) andcopepods(48.0%) werethe most abundant phytoplankton and zooplankton, respectively. A total of 1886 fish samples comprising 20 families, 30 genera and 45 species were identified. Cichlidae constituted highest fishsamples (18.1%), followed by Mochokidae (16.97%) and Alestidae (16.70%)while the least were Dasyatidae and Ichthyboridae (0.1% each).*Oreochromisniloticus*(11.3%), *Synodontisclarias*(10.4%) and *Brycinus nurse* (9.4%) dominated the catch. Significantly higher fish sampleswere encountered in dry season (1073) than wet season (813). All the species encountered showed allometric(b<3) growth rate except *Xenomystusnigri* which was isometric (b = 3). The PFY was 565.7kg/ha. Fish diversity indices in wet season (H=3.2; E=0.6; 1-D=0.9) were higher than dry season (H=2.4; E=0.4; 1-D=0.9).Fish abundance was influenced by conductivity, pH, turbidity and GPP at 70.6% cumulative Eigen-values.

Lower River Niger at Agenebodehas rich ichthyofauna diversity dominated by members of family Cichlidae. Conductivity, pH, turbidity and gross primary productivity are major environmental factors that impacted fish composition and productivity in Lower River Niger.

Keywords: Fish resources,Lower River Niger, Plankton, Water quality

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CERTIFICATION

I certify that this work was carried out by Osaimianmionmwan Arasomwan Adeniyiin the Department of Aquaculture and Fisheries Management, University of Ibadan**.**

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DEDICATION

This work is dedicated to the almighty God, the giver of life for His grace, strength and wisdom. And also to my late husband, Pastor Olufemi Samuel Adeniyi, whose support was beyond measure spiritually, financially and morally.

TABLE OF CONTENT

LIST OF TABLES

LISTS OF PLATES

LIST OF FIGURES

ACRONYMS

FAO	–	Food and Agricultural Organization
UNDP	–	United Nation Development Program
APP	–	The Agriculture Promotion Policy
APHA	–	American Public Health Association.
MDGs	–	Millennium Developmental Goals
SDGs	–	Sustainable Developmental Goals
FDF	–	Federal Department of Fisheries
NPP	–	Net Primary Productivity
CR	–	Community Respiration
GPP	–	Gross Primary Productivity
DNS	–	Downstream
MDS	–	Midstream
UPS	–	Upstream
NESREA	–	National Environmental Standards and Regulations Enforcement Agency
GDP	–	Gross Domestic Production
BGI	–	Blue Growth Initiative
NOAA	–	National Oceanic and Atmospheric Administration
OR	–	Oxygen Production
NOP	–	Net Oxygen Production
LWR	–	Length Weight Relationship
K	–	Condition factor
NIMET	–	Nigeria Meteorological Department
GPS	–	Global Positioning System
AAS	–	Atomic Absorption Spectrometry
WHO	–	World Health Organization
UNESCO	–	United Nations Educational Scientific and Cultural Organization
UNEP	–	United Nations Environmental Programme
USEPA	–	United States Environmental Protection Agency
GEMS	–	Global Environment Monitoring System

CHAPTER ONE
INTRODUCTION

1.1 Background of the Study

Fishing has been a major source of food for humanity and also provides employment and economic benefits to those engaged in this activity (FAO, 2016). The wealth of aquatic resources was assumed to be an unlimited gift of nature. However, with increased knowledge and dynamic development of fisheries after the second world war, this myth has faded, in face of the realization that aquatic resources, although renewable are not infinite and need to be properly managed if their contribution to the nutritional, economic and social well being of the growing world's population is to be sustained (FAO, 2016). Recently, fisheries woldwide have become a dynamically developing and market driven sector of the food industry in response to growing international demand for fish and fishery products (Funge-Smith, 2018). This led to rapidly uncontrolled exploitation and development which the fisheries resources could no longer uphold; hence the urgent need for conservation and environmental considerations.

globally, fisheries is a major source of nutrition, food, income and livelihood millions of people. Oceans and inland waters have the tremendous potential to fundamentally add to nourishment, food and economic seurity to the ever increasing population globally which is expected to reach 9.7billion by 2050 (FAO, 2018).

Nigeria being the final downstream country, through which the Niger River flows, contains 28.3 percent (424,500 square kilometers) of the basin area (Tijani *et al.*, 2018), which extends across 20 of the 36 states of Nigeria with two major rivers; the Niger River and River Benue, and 20 tributaries. More than half of Nigeria's major rivers, are in the Niger River Basin. Their lengths put together accounts for about 60 percent of the total length of all important rivers in Nigeria (Tijani *et al.*, 2018).

In 2011, Nigeria population which was estimated to be 162.5million with an annual population increase rate of about 2.1% is anticipated to increase to 258 million by 2030 (UNDP 2010), and to cater for this increase food supply is expected to triple. Nigeria has had supply deficiency of about 66.5% of fish dietary necessity of her citizens between 2010

and 2015, and this was anticipated to be higher (say about 70%) for 2018 based on the estimated population projected of about 180million (APP, 2016). To ensure sustainable and sufficient production, there is need for serious and urgent action. Intensive fishing and aquaculture practices only cannot prevent the transition to scarcity of fish, but rather better management of fisheries resources.

Biodiversity has to do with the entire living organisms (plants and animals), their genetic material and their environment. Fish diversity is part of the aquatic diversity and constitute half of the total number of vertebrates in the world. They live in almost every conceivable aquatic habitats; 21,723 living species of fish have been recorded out of 39,900 species of vertebrates in which 8,411 are freshwater species and 11,650 in marine (Kar *et al.*, 2003). Biodiversity in recent years has become prominent because of the over all increase rate of extermination of a few types of animals including fish (Mace *et al*., 2005).

Fisheries with a range of species or populations are likely to have more stable catches than fisheries with a single species (Hiddink *et al.,* 2008). Biodiversity includes the quantity, variety and distribution of populations, species, communities and ecosysytems across biological scales ranging through hereditary and existence forms (Mace *et al*., 2005). It also affects the capacity of living systems in responding to changes in the environment, supports ecosystem functioning and services which support well-being of human, for example nutrient cycling, clean water (Diaz *et al.*, 2006).

Fish biodiversity globally is threatened majorly by overfishing. For example, worldwide over 40 local populations of fish species have gone extinct because of overexploitation (FAO, 2016). Local losses could be as a result of climate change, habitat disappearance; invasive species, pollution and eutrophication can heighten induced fishing decline and inhibit revitalization.

Diversity, according to Funge-Smith, (2018) is a basic property of every living system visible from the molecules to the ecosystems, and its relative abundance explain the major elements of the biodiversity.While the latter is the quantity of varied species in a specified area, the former depicts how basic a species is with respect to the different species in a

given community and are generally expressed for one trophic level (Lawason and Olusanya, 2010).

The best biodiversity is shown by fish amidst vertebrates, with about 25,000 species, making about half of them that are identified (King, 1996a). This high fish diversity could be the vital basis of numerous fisheries (tropical) being stable and this gives a solid dispute in support of conservation (King, 1996a).

Nigeria is blessed by various aquatic flora and fauna, ranging from lakes, marine, lagoons and rivers resources; and fish diversity is vital for the future sustainability of the natural resources of these water bodies (Bolorunduro, 2016). Fisheries researchers for long have seen fish inhabitants as large, accessible and reasonably consistent with worldwide spread dispersal of larval to ensure hereditary uniformity as reported by Hutchings *et al*. (2007). The rich diversity of fish which is about 25,000 species has been found to be owing to the diversity of aquatic habitats and the range of water quality in which they can live (Helfrich and Neves, 2009).

Ita (1986) in his explorations into the diversity of fish in the foremost streams of Nigeria recorded 239 fish species, and recently Olaosebikan and Raji (2013) recorded 798 species of fish in Nigeria. Recently, a severe reduction has been pragmatic among the bigger species such as *Lates niloticus, Gymnarchus niloticus*, *Protopterus annecten and Heterobranchus bidorsalis* (Obasohan and Oronsaye, 2006). There is, therefore, an urgent requirement for continuous data collection to check-list fish species for sustainable inland water management.

Water quality assessment is important for effective fishery management of any water body. Fish growth shows a close relationship with water quality, and sustainable fish production is only possible under optimum physical, chemical and biological conditions. Physical and chemical components are known to influence the biological components of the aquatic ecosystem (Reynolds, 2006; Chia *et al*., 2011). Since pollution status of water bodies is usually expressed as a function of its biological and physico-chemical parameters,

knowledge of hydrological condition and phytoplankton of water bodies is not just helpful in evaluating its productivity, but improves the understanding of the population and life cycles of the fish stock of that aquatic environment (Chia *et al*., 2009). The quality of water that is closely associated with sustainable fish production is a function of the quality of algae found in the aquatic system (Araoye, 2002).

Phytoplankton constitutes the platform of the aquatic food web and also very important factor in organic matter production of the ecosystem. Therefore, their destruction by adverse physico-chemical variation of water could affect fish productivity (Davies *et al.,* 2008). Phytoplankton growth and periodicity could be limited by physico-chemical variations of water. Turbidity for instance affects light penetration, which in turn has a negative influence on the photosynthetic ability of phytoplankton (Yisa, 2006). And also, a change in hydrogen ion concentration (pH) could transform deep water bodies into swampy habitat which can result in a reduction in phytoplankton abundance. Eutrophication related with anthropogenic activities could result in the disruption of natural equilibrium as algae proliferate and impair water quality (Davies *et al*., 2008).

With one of the world's greatest challenges on how to feed more than 9 billion people by 2050, the international community adopted the 2030 plan for sustainable development and sets aims for the contribution and conduct of fisheries and aquaculture towards nutrition and food security for the use of natural resources in order to guarantee sustainable development in economic, social and environmental terms (FAO, 2016).

After the Millennium Development Goals (MDGs), that pursues improving the living standard of the society are agriculture and nutrition security (Ibrahim *et al*., 2009), have rounded up the need for more fish is still inreasing with the ever growing population. These goals are achievable if food is made available always by mounting technical efficiency (FAO 2018). The agricultural sector of the Nigerian economy employs about 70% of active labour force and fish occupies a special position being the cheapest source of animal protein consumed by the average Nigerian (particularly in the period of Ebola and other

diseases associated with red meat), and this accounts for about 50% of the entire animal protein consumption (FDF, 2014).

1.2 Global Overview of Capture Fisheries Production

Fish provides 6.7 percent of all protein consumed by humans globally, and also provides a rich source of long-chain omega-3 fatty acids, vitamins, calcium, zinc and iron. About 57 million people are employed in the primary fish production sectors and two-third of them (38 million) is in capture fisheries (FAO, 2018). Fishery products account for one percent of total agricultural exports. In 1976, exports amounted to $8 billion worldwide and increased in 2014 to $148 billion with developing countries as the source of $80 billion of fishery exports, providing far higher net trade revenues than meat, tobacco, rice and sugar put together (FAO 2016). In the past five decades, global production of fish for human consumption has out-paced the populace increase. According to preliminary estimates, the average global capital intake in 2016 was greater than 20 kilograms, which doubled that of the 1960s (FAO, 2016).

Despite the growth in the aquaculture production globally, capture fisheries is still a larger source of employment of full time artisans in the fisheries industry in both developed and developing countries. Concerns however are being expressed by global, regional and national authorities on dwindling catches in capture fisheries world-wide due to a combination of factors including overfishing, obnoxious fishing methods, pollution (especially in the marine water bodies and large river water bodies across cities), other anthropogenic activities, climate change leading to drought and desertification, natural phenomenon like earth quake, lava flows and destruction of fish habitats through economic development activities that impact the environment negatively. The complexity of this situation is that capture fisheries in most developing countries like Nigeria are further bedevilled with low productivity in terms of fish productions (even when a water body is ecologically productive) due to a number of factors.

1.3 JUSTIFICATION FOR THE STUDY

Inland water bodies are important sources of fish for food and economic security. Studies have shown that the fish production capacities of the Nigeria inland water bodies such as Lower River Niger (LRN) are negatively impacted by various habitat modifications and anthropogenic activities around them. Fish plays very vital part in meeting the animal protein requirement of humans. Aside from being a highly nutritive protein source that is cheap, fish additionally has different integral vitamins required by the body (Helfrich and Neves, 2009). The contemporary demand for fish in Nigeria which is 3.32 million tonnes needs grave and pressing steps on how to ensure adequate and sustainable fish production (Bolorunduro, 2016). Maintaining the fish resources of water bodies is very crucial in bridging the fish demand and supply gap (Solomon *et al*., 2012)

A frequent assessment of fish population is necessary to know the status and trends in abundance which is central to informed decision making (FAO, 2018). Information on fish resource composition and abundance is a vital tool for sustainable fisheries management (Lawson and Olusanya, 2010).

There is need for appropriate management of inland waters especially Lower River Niger at Agenebode where there is paucity of information for continuous collection and documentation of data. Precise statistics of the fish resources of rivers and its adjourning floodplains is an imperative instrument for the articulation of a sound fisheries management and development of fisheries agenda in waterbodies and implementation programme in all fish commerce; hence the fish population of Nigeria's freshwater schemes has recently become study spotlight (Solomon *et. al.,* 2012).

Global increase in population with its associated anthropogenic activities leading to pressure on water bodies and its natural resources has also affected this river. In assessing and evaluating the level of dilapidation and health status of water bodies at various spatial scales, fish assemblages are used as ecological indicators (Helfrich and Neves, 2009). Considering the importance of this water body to the livelihood of the immediate communities and the several essential ecosystem services rendered by this river, it is important to also establish quantitative relationship between fishery status and water quality in order to make informed judgement concerning fishery health and setting of environmental quality standards for fishery protection.

Documented studies on fish population dynamics in Nigeria include: Balogun (2005); Fapohunda and Dodstates (2007); Komolafe and Araowolo (2008); Mustapha (2009); Ibrahim *et.al*. (2009); Lawson and Olusanya (2010), and Solomon (2012).There is, however, paucity of scientific information on the fish fauna diversity of the Lower River Niger at Agenebode despite its supports for the artisanal fishing, transportation (boats and ships), domestic use and cultural ethics in the communities. Moreover, Agenebode is fast growing into a big city with the demands of urbanization and population increase that have placed serious pressure on this natural resource, as sand generally utilized for structures and development of roads and other infrastructure has led to intensive mining of sand along the course of the river especially in the past ten years. At present there is dredging of the river for the construction of a bridge - at Agenebode / Idah villages. Hence the need to investigate and screen the state of natural assets in attaining sustainable fisheries, reducing degradation of habitat, and conserving diversity of this river.

Knowledge of fish stock composition and abundance is a vital requirement for sustainable fisheries management. Therefore, there is a necessity to have a complete updated information and baseline documentation of the fish composition and diversity of this vital river. The justification of this investigation is also because the existence of Nigeria fresh water resources including Lower River Niger at Agenebode are being threatened (NESREA, 2011) and the knowledge of the current status and trend of the fish resources of the river is vital to conserve the valuable resources from further degradation. The main aim of this study is to provide detailed documentation on the species composition, distribution, abundance and seasonal variation in fish fauna and productivity of this river. This study will provide baseline information for continuous research, and it will also be useful in policy formulation and regulatory structure`for sustainable management of fisheries resources in the lower River Niger.

Restoration efforts for sustainable management of LRN require updated information on its fish resources composition and productivity which are currently limited

1.4 OBJECTIVES OF THE STUDY

The general objective of this study is to investigate the fish resources composition, distribution and productivity of Lower River Niger at Agenebode, Edo State, Nigeria. The specific objectives are:

1. To determine the spatial and seasonal variation in the physical and chemical properties of water in the Lower River Niger at Agenebode.

2. To investigate the spatio-temporal variations in the productivity of Lower River Niger at Agenebode.

3. To evaluate the fish composition, abundance, and potential fish yield in Lower River Niger at Agenebode.

4. To assess the effect of physico-chemical parameters on fish abundance and distribution in lower River Niger at Agenebode.

CHAPTER TWO
LITERATURE REVIEW

2.1 Overview of Global Capture Fisheries Production

Among the total agricultural exports, fishery products account for one percent (FAO, 2018). Worldwide exports amounted to $8 billion in 1976 and increased up to $362 billion in 2016. $80 billion of fishery exports are from developing countries, providing higher net trade revenues than meat, tobacco, rice and sugar combined (FAO 2018). Capture fishery production in 2016 was 171 million tons of the world total, with the output from inland waters, up slightly over the previous two years (Figure 2.1). Asian countries are clear leaders in capture fisheries production with an average of over 65% of total between 2008 and 2016. There are 57 million people who are engaged in the primary fish production sectors and two-third of them (38 million) in capture fisheries (Table 2.1).

Despite the growth in the aquaculture production globally, capture fisheries is still a larger source of employment of full time artisans in the fisheries industry especially in developing countries. Concerns however are being expressed by global, regional and national authorities on dwindling catches in capture fisheries world-wide for a combination of factors which includes; overfishing, bad methods of fishing, pollution (especially in the marine water bodies and large rivers water bodies across cities), other anthropological activities, climate change leading to drought and desertification, natural phenomenon like earth quake, lava flows and destruction of fish habitats through economic development activities that impact the environment negatively. To compound this situation, capture fisheries in most developing countries like Nigeria are further

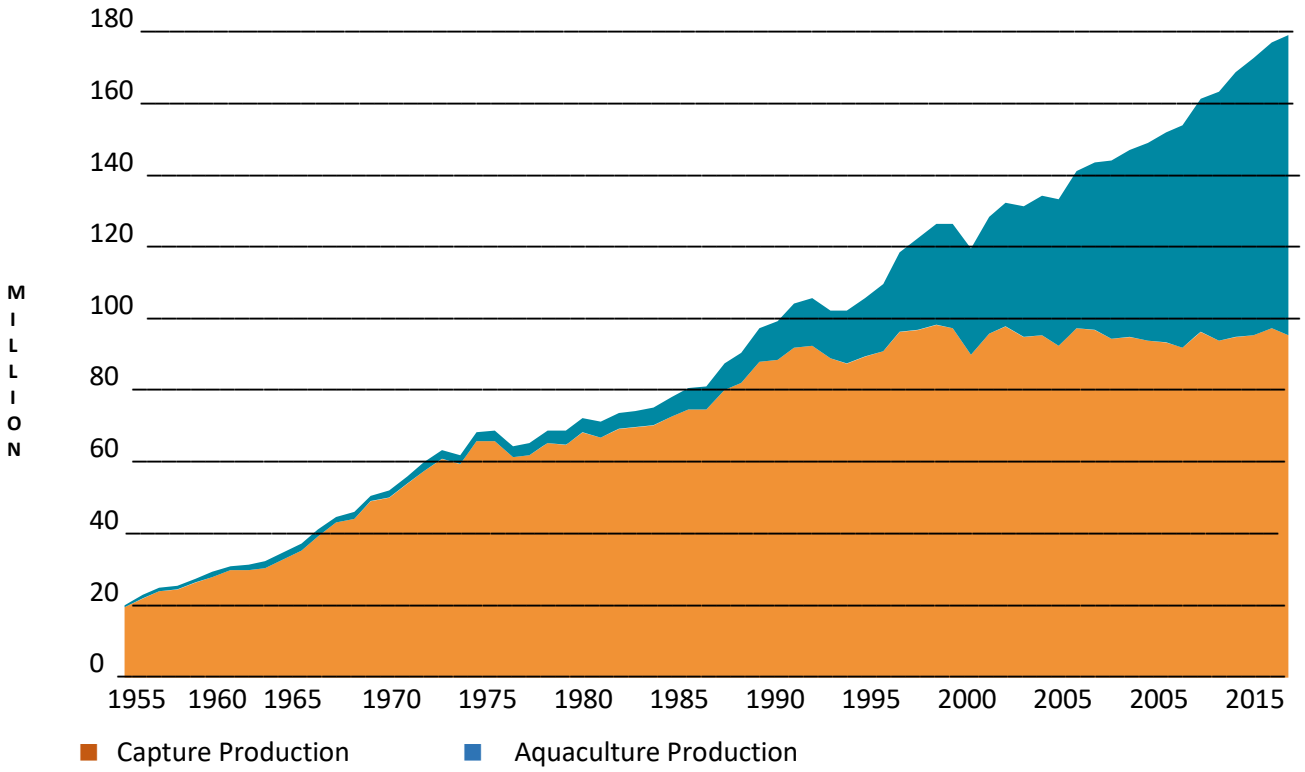


Figure 2.1: World Capture Fisheries and Aquaculture Production (1955 – 2015)
Source: Adapted from FAO (2018)

Table 2.1: Inland Waters Capture Production: Major Producer Countries

	Capture Production in Tonnes			%Variation		Variation
Country	**Average 2005 – 2014**	**2015** *(Tonnes)*	**2016**	**Average (2005-2014)** *(Percentage)*	**2015**	**2015 -2016** *(Tonnes)*
China	2252368	2277299	2318046	2.9	1.8	40747
Mexico	113854	151416	199665	75.4	31.9	48249
India	1088082	1346104	1462063	34.4	8.6	115959
Bangladesh	1018987	1023991	1048242	2.9	2.4	24251
Cambodia	422801	487905	509350	20.5	4.4	21445
Uganda	417016	396205	389244	–6.7	–1.8	–6961
Indonesia	346722	472911	432475	24.7	–8.6	–40436
Nigeria	287937	337874	377632	31.2	11.8	39758
United Republic of Tanzania	305635	309924	312039	2.1	0.7	2115
Egypt	248141	241179	231959	–6.5	–3.8	–9220
Brazil	243213	225000	225000	–7.5	0.0	0
Russian Federation	243337	285065	292828	20.3	2.7	7763
Democratic Republic of the Congo	224263	227700	229300	2.2	0.7	1600
Philippines	182205	203366	159615	–12.4	–21.5	–43751
Thailand	211927	184101	187300	–11.6	1.7	3199
Myanmar[a]	745483	863450	886780	19.0	2.7	23330
Total (16 major countries)	**8351970**	**9033490**	**9261538**	**10.9**	**2.5**	**228048**

[a]*Production Figures for 2015 and 2016 are FAO estimates.*

Source: Adapted from FAO (2018)

bedevilled with low productivity in terms of input-output relationships (even when a water body is ecologically productive) due to a number of factors.

Nutritionally, fish is an important part of most Nigerians' daily diet. Fish is a cheap protein source compare to other types of animal protein and is readily obtainable by all Nigerians in fresh, smoked, dried or frozen forms without religious taboos attached like beef or pork. The fisheries sub-sector is a huge employer of labour in Nigeria. It is estimated that 1.8m people are directly engaged in full artisanal fisheries and an additional 0.8m people as related service providers in the industry (FAO, 2016). In 2014, fisheries contributed 0.48% to the agriculture GDP and contribution of agriculture to GDP was 20.24% (FAO, 2016).

Fish has various uses which includes; aesthetic such as in aquaria or stuffed for people to admire especially ornamental fish trade which is a big business worldwide and Nigeria also having great potential to participate. Other economic products from fish are fish glue which is made by boiling the skin, bones and swim bladder of fish; oils from fish are also known for their Omega-3 fatty acid contents, which helps to reduce inflammation in the body; fish emulsion used as bio-fertilizers, and fish culture and livestock industry use fish meal as supplementary feed due to its high protein content.

With a coastline of 853 km; a continental shelf of 37,934 km^2, a network of lagoon, creeks, several natural lakes, dams and reservoirs, Nigeria is abundantly blessed with vast water resources marine, brackish and freshwater bodies. Generally, it is estimated that the fisheries sub-subsector employs 6.5m people consisting of 1.23 m in the primary sector and 5.27 m in the secondary sector. About 75% of the Figure (that is, 4.75 m) comprises of women fishers, processors and marketers.

Nigeria is a coastal country, but only 10% of her domestic fish production is sourced from commercial sea trawling fleet. In contrast, the country's 1.5m artisanal fishermen provide 905 of the total catch of some 467,098 mt, this includes 38% or 181,268 mt (15 kg/ha) from inland lakes and rivers which cover a total area of 11,666,00 ha (FAO, 2016).

Estuarine lagoons and swamps bring the total inland waters of Nigeria to 14 million hectares. Nigeria's inland waters are a valuable, albeit underexploited resource with much potential for increased fish production. The country's marine fisheries have been characterized by intense fishing pressure for decades, with decreasing size of individual fish caught, reduction in numbers of some species and decreased catch. The number of fish trawlers operating in coastal waters has reduced to only 34 vessels employing only a few hundred Nigerians. High operating costs (in foreign currency) for an aging trawling fleet and depleted waters have negatively impacted the industry. Shrimp trawlers total some 173 boats, but both fish and shrimp trawlers are greatly reduced from 70's; some 7,000mt of shrimp are caught in Nigeria's waters currently. Over fishing has been occurring for many years as indicated by the increasing percent of juvenile fish caught as no control on mesh sizes is enforced for neither demersal nor pelagic fishing. Both pelagic species are herring-like species occurring in large predominantly in shallow and turbid coastal and even estuarine waters. It is the most important commercial pelagic fish in Nigeria, and contributes over 20% of the total marine fish landings (FAO, 2016).

In Nigeria, per capita consumption of fish has been put at 13.1 kg, below the World Health Organization (WHO) required minimum requirement of 15 kg. With fish supply estimated at a little over 800,000 tons, and deficit of 1.9 mt meeting the demand for fish is unattainable unless production is boosted by more efficient capture fisheries management and development, development of aquaculture, and improvement in fish handling, processing storage and distribution (Funge and Smith, 2018).

Reducing post-harvest fish losses will increase availability of fish protein, enhance the nutritional status of the people, reduce fish importation and save the country's foreign exchange earnings. A major facilitator of huge losses recorded at post-harvest in Nigerian fisheries is the constraint imposed on traditional fish processing and preservation techniques. Traditional ovens are characterized with low batch capacity, long smoking time, labour intensive operation, high fuel consumption, and short shelf-life of products. The problems of pests and transport difficulties from landing/processing sites to consumer centres also accelerate losses. The combined effects of all these are physical losses of

products; economic losses in-terms of reduction in value or additional marketing cost in re-processing and nutritional losses because of reduction in available nutrient. The inland fisheries of Nigeria share in the liturgy of shortcomings of artisanal fisheries in developing countries (Bolorunduro, 2016). Major constraints prominent in marine artisanal fisheries (that can affect production targets) are lack of mechanization, conflict with big trawlers, lack of preservation facilities and inability to meet standards of higher value markets. Other constraints include lack of access to suitable fishing grounds due to restrictions imposed by oil extraction installations, destruction of spawning grounds and juvenile fishes through pollutions from oil spills, leaks, and discharges from oil vessels. Management weakness in monitoring control and surveillance on the part of government agencies further compounds the problems. In general, lingering problems in the industry include inadequate manpower, collapse of the Nigerian fish trawling industry, relegation of artisanal fisheries and poor state of research and training institutes.

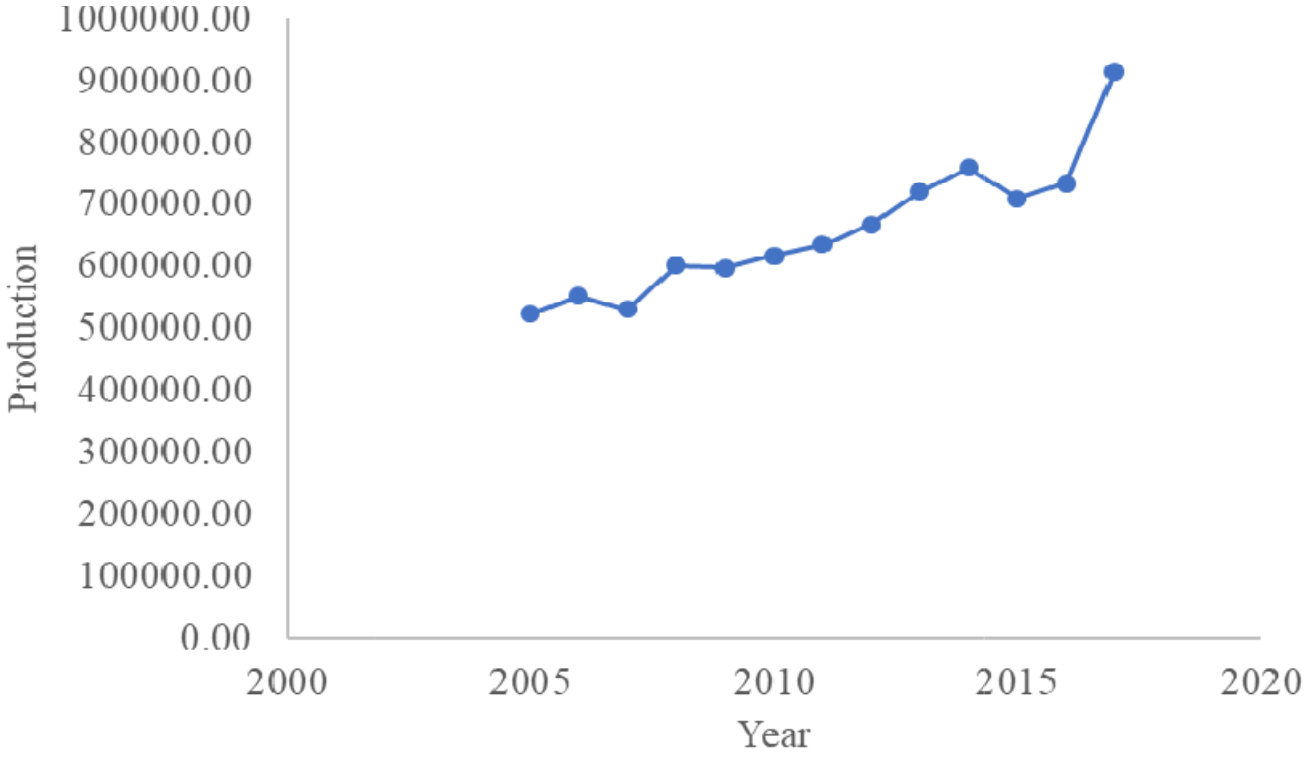
Currently in Nigeria, about 41% of the total animal protein intake by the average Nigerian comes from fish, thus the demand for fish is great in the country (FDF, 2014). Nigeria, between 2010 and 2015, has had deficit supply of 66.5% of fish nutritional requirement of her citizens and this is expected to increase to about 70% in 2025 because of the population estimated to be about 229 million (Amosun *et.al*, 2017). The domestic fish production from aquaculture, industrial fisheries and artisanal fisheries 2016 was 1.52 mt, leaving a deficit of 0.23 mt (Table 2.2).

Import bill from Nigeria's food is remarkably high. With four top imports (wheat, rice, sugar and fish) consuming over N1trillion in foreign exchange every year (APP, 2016). Nigeria ranked the largest importer of frozen fish in Africa due to the massive importation of this product. The huge shortfall in domestic fish requirements has left Nigeria with the option of importing an estimated 1.7 million metric tonnes of fish in 2015 valued at over N125 billion. This enormous sum of money could be invested in fishing activities. This fish importation can be substituted with domestic production to create jobs, alleviate poverty in rural areas where 70% of the populace reside and ease the balance of payments. Recent trends in capture fisheries production in Nigeria is shown in Figure 2.2

Table 2.2: Projected Fish Supply and Demand for Nigeria

Year	Population (million tones)	Fish demand (million tonnes)	Fish supply in domestic production (million tons)	Short fall (million tons)
2010	151.20	1.15	0.93	0.22
2011	155.50	1.18	0.96	0.21
2012	159.90	1.22	1.00	0.22
2013	164.40	1.25	1.04	0.21
2014	169.10	1.29	1.08	0.21
2015	173.90	1.32	1.12	0.20
2016	178.80	1.36	1.16	0.20
2017	183.30	1.39	1.20	0.19
2018	189.00	1.44	1.24	0.20
2019	194.40	1.48	1.28	0.20
2020	199.90	1.52	1.32	0.20
2021	205.60	1.56	1.36	0.20
2022	211.40	1.61	1.40	0.21
2023	217.40	1.65	1.44	0.21
2024	223.50	1.70	1.48	0.22
2025	229.80	1.75	1.52	0.23

Source: Modified from APP (2016) and Amosun et. al. (2017)



NB: Production in Tonnes

Figure 2.2: Trend in Capture Fisheries Production and Projecton in Nigeria
Adapted from FAO (2018)

2.2 Inland water Systems

Productive utilization of the fishery resources without compromising with environmental safeguards will enhance fish production, increase the availability of fish products as healthy foods to reduce malnutrition; ensure gainful employment in the rural areas; and development of processing industries for food and medicine along the value chain. Productivity is a key economic indicator of the relationship between input quantities and the amount of output produced (Walden, 2014).

In a natural resource industry, such as fishery, measurement of productivity change is often confounded because the stock of fish changes over time. The productivity of different ecosystems has changed and will do so similarly owing to altering environmental stipulations such as habitat loss or gain, local weather exchange and non-native species introductions. Statistical Analysis of fisheries history indicates that many fisheries systems had a good productiveness in the past (Rosenberg *et.al*., 2005), which may no longer be recoverable due to fishery depletion as a result of land use and ecosystem level changes. Inland waters consist of lakes, rivers, ponds, streams, groundwater, springs, cave waters, floodplains, as well as bogs, marshes and swamps, which traditionally are grouped as inland wetlands (FAO, 2016).

In spite of the significant input inland fisheries add to the community, it is frequently ignored in national and international deliberations on development. Therefore, other better planned segments, for instance hydro-electricity and cultivation, frequently marginalize freshwater resources in the competition for freshwater. The stress put on fisheries resource by the increase in human populace's want for fish likewise contend with the necessity for limiting management to preserve stocks.

The drivers affecting fisheries today comprises of pollution and overfishing, struggle for climate alteration and water. Less than three percentage of the world's water is fresh and greater part of the globe's individuals reside inside 3 km of a freshwater basis surface. Hence, very minute portion of entire water gives an extensive scope of important services economically, socially and ecologically. However, there is solid rivalry for freshwater

services from among a developing human populace and has been a cause of contention, nevertheless, it could likewise turn into a channel for confidence building, collaboration and, possibly, strife inhibition (FAO, 2018).

For this reason, quite numbers of different segments have an effect on administration and allotment choices for inland water systems, which influences the satisfactory, and size of fish production and the subsequent advantages. The advancement and administration of electricity, conveyance, cultivation, mining, oil and gas abstraction, forestry, leisure industry, recreation and aquasculture all apply their effect(s) on freshwater structures and their natural resources.

Weather alteration is one more important aspect that affects inland water biological communities. Worldwide energy-related ozone depleting substance emanations in 2010 achieved a high record of 49 billion tonnes (FAO, 2010). The Organization for Monetary Cooperation and Development forecast that this emission will rise to about four times by 2050, leading to ecological conditions changing, like temperature, precipitation and river runoffs. And these variations will definitely affect fisheries.

2.3 Assessment and Monitoring of Fish Stocks in Natural Water Bodies

FAO's Blue Growth Initiative (BGI) focuses on attaining fisheries that is sustainable, habitat degradation alleviation, and biodiversity preservation. In this case, information is essential to evaluate and observe the condition of the renewable endowment (like fish and aquatic ecosystems, water and land, aquatic hereditary properties), including the feat and the sustenance or maintainability of fisheries (FAO, 2016). The BGI acknowledges the fact that of primary importance for sustainable fisheries is healthy fish resources, and evaluation of fish population is also important to comprehending the total position of fishery resources.

Stock assessment is a process that is data-challenging, and it is most of the time taken as a context of data-poor situations. The accuracy of assessment results is affected by the availability and integrity of data. However, management action delays assessment

conclusions. To attend to this, management method based on a predetermined-harvest model is now generally used. It is therefore crucial for good catch, effort and other information to be readily available in an apt way and disseminated amongst participants, like scientists, decision-makers and fisher folks. Putting together of data like that into integrated databases preceding evaluation can greatly speed-up analysis. Information bases like FishBase and Sealife Base now made available convenient way environmental and biotic information. Equally, catch and effort statistics may well be collected, while absence of approved information-sharing and privacy policies is still an obstacle. Improved infotech and information management competence could be of assistance.

The allotment of stock assessment outcomes is an additional vital action in the direction of more efficient fisheries management. According to scientists, properly established data sets permitting reproduction of the investigations would augment lucidity (FAO, 2016). Evaluation of the numbers for estimated stocks in contrast to all identified stocks, and contrast of the role of evaluated fishery sources throughout stocks, types and areas, would be informative, especially for establishing significances for fishery systematic review. The Fisheries and Resources Monitoring System (FARMS) aids that type of work by gathering stock estimation results based on a full and complete record of known fish stocks.

The BGI acknowledges the essential of reinstating dilapidated environments and conserving biological community so as to advance the yield and maintainability of fishery schemes.

Studies on stock assessment of some water bodies in Nigeria had been carried out (Dan-kishiya *etal*., 2012; Mustapha, 2009, Komolafe and Arawomo, 2008; Fapohunda and Godstates, 2007; Balogun, 2005), however, there is paucity of documented information on Lower River Niger at Agenebode

2.4 Water Quality of Natural Water Bodies

Water quality describes the condition of water regarding its suitability for use in a particular purpose. Water sources include oceans, estuaries, lakes, reservoirs, rivers and underground aquifers. The quality of the water from these sources is defined by measurements of the organic and inorganic particulate and dissolved solids acquired by

the water by contact with soil, geological formations or other materials (Boyd, 2015). Water also dissolves atmospheric gases such as oxygen and nitrogen. Understanding of the chemical properties of water and the chemical, physical and biological effects of the substances within it can lead to better management of fisheries (Boyd *et.al*, 2016). Water is the basis of life, a universal solvent and one of the most precious commodities required for survival of any forms of life (Funge-Smith., 2018). Its resources are essentially imperative not only to the natural ecosystem but also the human development. They grant habitat, sanctuary and food for many species of fish and wildlife, and also serve as a source of processed water to many industries (Boyd, 2015).

Water is usually classified as freshwater, brackish water or ocean water. The dissolved substances in water consist of a myriad of chemicals that include inorganic and organic ions and compounds. Collectively, these substances are known as total dissolved solids (TDS) (Boyd, 2015). Eight inorganic ions usually account for 90 to 95 percent of the TDS in freshwater and 97 to 99 percent of the TDS in brackish water and ocean water. However, even at relatively low concentrations, the plant nutrients phosphate, nitrate and ammonia nitrogen often have a greater biological effect on water quality than do the substances present at much higher concentration (Boyd *et. al*., 2016). Freshwater is usually considered to contain less than 1,000 milligrams per litre of TDS. Ocean water has an average TDS concentration of about 35,000 milligrams per litre, and brackish water (often called saline water in inland areas) is between fresh and ocean waters in TDS concentration (Boyd *et. al*., 2016). Water quality is dogged by various physico-chemical and biological factors, as they possibly, directly or indirectly affect its quality and consequently its suitability for the distribution and production of fish and other aquatic animals (Ibrahim and Balogun, 2009). The most abundant cations found in water are calcium, sodium, magnesium, and potassium. Bicarbonate, sulfate and chloride are the most abundant anions. Measurements of the ions' concentrations in water samples can be used to evaluate the chemical quality of the water according to Boyd (2015).

Many researchers have given information on the status of several water bodies (lentic and lotic) when they have received various kinds of pollutants affecting characteristics of the water quality. Every organism has bearable or acceptable confines of water quality

parameters in which they operate best. Drastic decline or raise within these limits has serious effects on their body functions (Boyd *et al.*, 2016). These parameters offer significant information about the health of a water body. Its periodical investigations remain an important part of environmental monitoring activities because when water quality is poor, it affects not only aquatic life but the surrounding ecosystem as well.

Monitoring water quality can also help to predict natural processes in the environment and determine human impacts on an ecosystem. Investigations have revealed that there is close association between the quality of the upper part of water and fish fauna variety (Mustapha, 2009; Edward *et al*., 2014). Several species of fish and/or their developmental stages will only thrive in abiotic conditions like temperature, oxygen, pH, salinity and water currents of a certain range of value (Edward *et al*., 2014; Boyd *et al*., 2016). Changes in the physic-chemical part of a waterbody will lead to an equivalent variation in the organisms relative composition and abundance of that water (Ibrahim and, 2009 and Boyd, 2015). The fluctuation in pH between day and night depends upon the abundance of aquatic plants, amount of sunlight, water temperature and alkalinity concentration of the water body (Boyd *et. al.*, 2016). The water quality of any biological community provides considerable info on the resources available that support living organisms in that biological community. Industrial waste ejections cause a grave ecological threat to water quality in natural water bodies; this continous problem is what threatens the ecosystem services to the riparian communities especially, in developing countries (Tijani *et. al.*, 2018). Water quality monitoring is very important in the resolve of the present conditions and long-term trends for effective management. It provides basic scientific information about water quality parameters and ecologically relevant toxicological threshold values to protect specific water uses (Lawson, 2011).

The growth of fish is directly related to water quality; thus monitoring water quality could be used as a guide to evaluate the state of aquatic environment which is habitat to the fish (Adesalu, 2010). Evaluation of the quality of water involves the investigation of physico-chemical, biological and microbiological parameters and addresses abiotic and biotic status of the ecosystem (Mulani *et al*., 2009). Phytoplankton is usually at the foot of aquatic food web and is the most vital biological factor for the production of organic

matter in aquatic ecosystem. Almost all water bodies will need considerable amount of phytoplankton to have productive and sustainable fisheries. The interaction of the physical, chemical and water properties most times lead to the production of phytoplankton, while their gathering (composition, distribution, diversity and abundance) is also structured by these parameters. The significance of phytoplankton in tropical aquatic ecosystems includes its usefulness in calculating potential fish yield, productivity, energy flow, trophic status and management (Lawson, 2011). These water bodies are progressively being threatened by human activities (Onuoha *et. al.*, 2010). Temperature, rainfall, pH, salinity, depth, conductivity, turbidity, dissolved oxygen and carbon-dioxide are important physic-chemical parameters affecting the aquatic ecosystem. The others include total suspended and dissolved solids, total alkalinity and acidity and heavy metal contaminants (Omitoyin and Ajani, 2007; Lawson, 2011). These parameters are the restraining factors for the survival of the flora and fauna in aquatic environment.

2.5 Primary Productivity of Natural Water Bodies

Biological systems exist as an end result of steady inputs of power to maintain the shape and order. At the level of the ecosystem, most of this energy comes from daylight that is converted into the energy of natural matter in living biomass via the system of primary production and from the imports of organic matter from adjoining ecosystems. This import of energy in natural matter is, of course, primarily established upon primary production in the "upstream" ecosystem. Thus, a serious factor of perception of the functioning of an ecosystem is a unique estimate of its rate of primary production (Howarth and Michaels, 2000).

Primary productivity is defined as the rate at which plants and other photosynthetic organisms manufacture organic compounds in an ecosystem (Davies *et al*., 2008). There are two parts of primary productivity: Gross productivity (the entire photosynthetic manufacturing of organic compounds in an ecosystem), and Net productivity (the organic materials that remain after photosynthetic organisms in the ecosystem have spent some of these compounds for their cellular energy requirements (cellular respiration)). Since oxygen is one of the most easily measured products of both photosynthesis and respiration, a good way to measure primary productivity in an aquatic ecosystem is to

measure dissolved oxygen. Since we cannot gauge gross productivity directly because the respiration, which uses up oxygen and organic compounds, is at all times occurring simultaneously with photosynthesis — but we can measure it indirectly (Omoboye and Adeniyi, 2017, Howarth and Michaels, 2000). According to Howarth and Michaels (2000), net productivity can be measured directly by measuring oxygen production in the light, when photosynthesis is occurring and respiration by measuring the oxygen consumption in the dark when photosynthesis does not occur.

Since:

Net productivity = gross productivity – respiration

Gross productivity can be calculated.

Primary productivity can be calculated in three ways according to:

1. The quantity of carbon dioxide used
2. The speed of sugar formation
3. The oxygen production rate

The primary productivity of a water body is the demonstration of its biological production. It is the final outcome of photosynthesis that forms the basis of ecosystem functioning since it makes the chemical energy and organic matter available to the entire biological community (Omoboye and Adeniyi, 2017). The organisms that contain chlorophyll make use of solar energy and convert it into chemical energy in the form of carbohydrate molecules by taking carbon dioxide and water from the environment (Kadiri and Omozusi, 2002). All freshwater ecosystems (lakes, rivers, ponds, streams, wetlands) are home to various life forms, often collectively referred to as the food chain or food web. Therefore, the numbers and variety of living organisms in a freshwater food web are dependent on the productivity of the ecosystem. Of course, the available energy is constantly changing with daily and seasonal cycles, and the raw materials are continuously cycling (water cycle, carbon cycle, nitrogen cycle, phosphorus cycle) through and within the ecosystem. These fluctuations also help to determine the shorter-term productivity of the system. The greater the primary production of an ecosystem, the more the living biomass that is supported by its food web (Omoboye and Adeniyi, 2017).

Primary production can be calculated using the rate of oxygen production according to National Oceanic and Atmospheric Administration (NOAA, 2000) as:

Net Primary Production (NPP) = final DO in light bottle (mgL^{-1}) – initial DO in light bottle (mgL^{-1})

NPP = FLDO - ILDO

Community Respiration (CR) = initial DO in dark bottle (mgL^{-1}) – final DO in dark bottle (mgL^{-1})

CR = IDDO - FDDO

Gross Primary Production (GPP) = O_2 consumed by respiration (mgL^{-1}) + Net Oxygen Production (mgL^{-1})

GPP = OR + NOP

In converting the DO (mgL^{-1}) values to $gC/m^3/h$, the factor 0.375 (12/32) is used and the values per hour is multiplied by 24hrs to obtain the productivity values per day (Michael, 1984).

2.6 Fisheries Resource – Composition, Abundance and Diversity

Biological community of Freshwater underpin large numbers of species of plants and animals. Freshwater fish comprises of 25% of living vertebrates and represent 13 – 15% of the 100,000 freshwater animal species currently known (Funge-Smith, 2018). Inland fisheries in Africa, placed alongside the shores of lakes represent large proportion; however the continent's good sized river systems are also prosperous in fisheries and may additionally produce up to one-half the complete capture from inland waters (Welcomme, 1979). Inland fisheries regularly grant solely the home market and make a little contribution to the export economic system of most under-developed nations, and because the amount of fish harvested is frequently overshadowed by means of that of marine fisheries, riverine and lake fisheries are often given low precedence by national governments. Biological diversity or biodiversity is the term given to the variety of life on Earth. It is the variety within and between all species of plants, animals and micro-organisms and the ecosystems within which they live and interact. Generally, tropical regions, with their long growing seasons, have larger biodiversity than temperate ones, while others with very harsh conditions, such as Antarctica, are low in biodiversity. It is

vital to the world's ecosystems health (different communities of living things and their environments, as well as their many interactions). The different aspects of biodiversity all have a very strong influence on each other (Rowe and Hutchings, 2006; Hutchings *et al*., 2007).

There are three major aspects to biodiversity: genetic diversity, species diversity and ecological diversity. Genetic Diversity deals with the variation in the genes of the species. The genetic makeup of species differs from each other to produce a new generation which is categorized as genetic diversity. This permits species to adjust to environmental changes especially when there is an outbreak of disease or a change in the climate. The more genetically diverse a group is the stronger and better the adaptability to change (Dankishiya *et. Al.,* 2012).

Species Diversity is a measure of the diversity within an ecological community that incorporates both species richness (the number of species in a community) and the evenness of species' abundances. Species diversity is one component of the concept of biodiversity. Species diversity is influenced by species richness. All else being equal, communities with more species are more diverse. Species diversity is also influenced by the relative abundance of individuals in the species found in a community. Evenness measures the variation in the abundance of individuals per species within a community. Communities with less variation in the relative abundance of species are more "even" than a community with more variation in relative abundance.

Ecological Diversity is the diversity of ecosystems, natural communities and habitats. It is the different ways that species interact with each other and their environment. It deals with variation in the ecological area or environment such as desert, forests, grassland, streams and coral reefs etc.; it includes the variation in both terrestrial and aquatic ecosystems. It is the largest scale of biodiversity, and within each ecosystem, there is a great deal of both species and genetic diversity. There are different habitats in every ecosystem. The loss of ecosystem and habitat is the greatest cause of biodiversity decline (FAO, 2010). People annihilate habitats all the time; when they construct bridges over water bodies, deforestation, clear land for farming and the building of houses or roads.

The alteration of natural areas changes the environment of the species that live there (Obasohan and Oronsaye, 2006). Thus, forcing the animals, plants, and microorganisms to move or go extinct. Functional Diversity is the way species behave, obtain food and use the natural resources of an ecosystem. In general, a species-rich ecosystem is presumed to have high functional diversity, because there are many species with different behaviours. Understanding an ecosystem's functional diversity can be useful to ecologists trying to conserve or restore damaged ecosystem, because knowing the behaviours and roles of species can point to gaps in a food cycle or ecological niches that are lacking species (Obasohan and Oronsaye, 2006).

Biodiversity information within an area is very important for the development of adequate conservation strategies (FAO, 2016). The species richness and their abundance structures are two fundamental characteristics of a community and their diversity promotes the stability of communities and ecosystem processes (Lawson and Olusanya, 2010). Information on the number of fish in a population is crucial to establish the effects of fishing, other anthropogenic activities or natural climatic changes is essential to detect any changes in the population (Olopade and Rufia, 2014). Human activities threaten the diversity of fish, but the most important impacts come from the modification of habitats, overfishing and exotic species (Funge-Smith, 2018).

Distribution and composition of the fish species is closely associated with various elements like the food that is available, breeding sites, water flow, deepness, topography and physic-chemical properties of water (FAO, 2010) and protracted change in hydrological and meteorological parameters may decrease fish species diversity (Tijani *et al*., 2018). In Nigeria, the species diversity is dominated by the cichlid family (Olaosebikan and Raji, 2013). Cichlids vary in size and diet, from herbivores to detritivores and are commonly caught in cast nets and gill nets in lakes and smaller reservoirs (Omitoyin and Ajani, 2007). The most interesting group of endemic fish are the 'African catfish', found in muddy, lotic and lentic water body. These fish feed on several food items depending on the richness of their habitats.

- **Ichthyodiversity**

According to century dictionary and encyclopaedia, ichthyofauna is the fish or fish fauna of a particular or any given region. The streams have higher diversity of fish than in lakes. Often found in small streams are two to ten fish species, while there are 15 to 30 species in intermediate stream, and about 20 to 40 species in the rivers. The South-eastern United States have an outstanding diversity of fishes, where as numerous as 90 fish species may live in a single river (Mustapha, 2010)

Generally, ecological communities with a high biodiversity are more stable and healthy. Biological diversity shields communities from environmental pressure and makes them to recover very quickly after disturbances. A loss of biodiversity could lead to a reduction of resources. Species richness supplies a "safety net," so that if any food source or resource becomes scarce, another can be used in its place (Helfrich and Neves, 2009).

- **Loss of Biodiversity**

Evolution of living things, made some species to become extinct, or die out totally. Extinction though a natural phenomenon, humans have been greatly accelerating the process, especially since the middle of 20th century. Human activities as estimated by scientists have been causing species to become extinct at a rate hundred to a thousand times the background, or natural (Mustapha, 2010). The destruction and fragmentation of habitats is the main aspect leading to a loss of biodiversity, due to multipurpose use of the land for agriculture, settlement, and other human activities. Others consist of global warming, pollution, overfishing and overhunting, and the introduction of species into new habitats (FAO, 2010). Many researchers claim that habitat destruction will put about half of all species on a persistent path to disappearance in the next few decades. Hence, by the mid-21st century, extinction would be several thousand times the background rate (FAO, 2010)

Several factors lead to the loss of fish species and habitat degradation, which include the dams and impoundments; pollution of water, particularly from spills of toxic wastes (i.e., oil and petroleum products, industrial acids, pesticides, and fertilizers); agricultural sedimentation, construction, and logging and mining; introduction of exotic species; and overfishing (Helfrich and Neves, *2009).* Climate change will have major impacts on

agricultural production as well as on biodiversity within both human modified landscapes and protected areas throughout the tropics (Kouadio *et. al.,* 2006). Climate change threatens biodiversity by changing the availability and distribution of suitable habitat and microclimates, thereby placing additional stress on species already threatened by deforestation, habitat degradation, hunting, and other human activities (Diaz *et al.,* 2006).

As temperatures increase and precipitation regimes change, many species will need to move to higher elevations or toward the poles to find suitable habitat, as it occurred during early Holocene warming (Boyd, 2015). Many species from around the world are threatened because of over-exploitation. This is when our use of that species or resource renders it near extinction. Over-exploitation is also a large problem in fisheries. The harvesting of forests and the extraction of oil and gas are examples of non-renewable resources whose over-use has severely impacted local environments and biodiversity (Coll *et. al.,* 2008). Every year over 80 million fish are caught for human consumption. Sometimes the way that the fishing is done destroys aquatic habitats and catches many other aquatic animals by accident. The protection and biodiversity maintainable use for food and cultivation is crucial in the fight against hunger, by ensuring sustainable environment while increasing food and agriculture production. Most importantly in a very sustainable way: cropping resources without negotiating the natural assets, including biodiversity and ecosystem services, and taking advantage on biological processes (FAO, 2016).

Reliable estimates of fish abundance and biomass in natural water bodies are important fundamentals for many purposes. Data on species composition, length distribution of a commercially used fish stock is required for sustainable fisheries management (FAO, 2006-2017). Among others, quantitative ecological investigations like food web studies may be substantially improved by consistent data on fish biomass (Funge-Smith, 2018). Among aquatic organisms, fish are relatively easy to identify, and they are an important component of aquatic ecosystems through their regulatory effects on a variety of ecosystem (Iddo-Umeh, 2003). They are commonly recognized as sensitive keystone communities that can indicate habitat change, environmental degradation, and overall ecosystem health (Eze, 2005).

2.7 Length-Weight Relationships and Condition Factor

In fishery management, length and weight relationship (LWR) of fish is an accurate vital tool. And this is obvious in calculating the mean weight of a given length group and in evaluating the comparative wellbeing of the population of fish (Bolger and Connolly, 1989). For this reason, length-weight studies on fish are broad. The condition factor depicts the prosperity of a fish dependent on the theory that the weightier fish of a specified length are in preferable state over lighter fish (Bagenal and Tesch, 1978).

The two basic components in the biology of fish species at individual and population levels are length and weght. The association between length and weight is vital aspect in the ecology of fish and the biological study of fishes (Bagenal and Tesch, 1978). According to Mahmoud (2010), LWRs have a significant importance in studying the growth, gonadal development and general well-being of fish population. It is an effective tool for appropriate utilization and management of fish stock population. As much as LWRs give important information on the habitat where the fish lives, the environmental and climatic changes and also the change in human survival practice (Mensah, 2015). For effective fishery management and successful fish farming, knowledge of the growth patterns and condition factor is necessary. According to Le Cren (1951), LWR is one of the standard methods that yield valid biological information. It establishes the mathematical relationship between the two variables, length and weight, so that unknown variable can be readily computed from the known variable. Also, it shows the variations from the expected weight, for the known length groups, this in turn reflects its fatness, general wellbeing, gonad development and suitability of environment of the fish.

The factor of condition (K) in fish reflects, through its variations, clues on the physiological state of the fish in relation to its welfare. Le Cren (1951) stated that from a nutritional perspective, there is the build-up of fat and gonadal growth. According to Angelescu *et al.* (1958), from a reproductive point of view, the highest K values are reached in some species. Condition factor also provides information when considering two populations living in certain feeding, density, climate and other conditions; when

determining the period of gonadal maturation and when following up the degree of feeding activity of a species to verify whether it is making good use of its feeding source (Bagenal and Tesch, 1978). Length-weight relationship and condition factor of fish species remain the most important biological parameters that provide vital information on the growth and condition of fish species and the entire fish community which assists in the management and conservation of natural populations (Mahmoud, 2010; Mensah, 2015). According to Froese (2006), establishment of a relationship between weight and length is essential for the calculation of production and biomass of a fish population.

Length is the primary determinant of weight of fishes. However, there can be a wide variation in weight between fish of the same length both within and between populations. The length - weight relationship differs between types of fish as indicated by their hereditary physique form and within a species in accordance to the wellbeing of individual fish. In any case, condition is dynamic and variable. The weight and the length of fish samples are not static; likewise, the length-weight relationship of fish continuously changes with time based on such factors as food availability, feeding rate, gonad development, spawning period and environmental variables (Mahmoud, 2010).
Le Cren (1951) stated that 'the analysis of length – weight data has usually been directed towards two rather different objects. Firstly, towards describing mathematically the relationship between the length and the weight of fish, primarily so that one may be converted to the other. Secondly, to measure the variation from the expected weight for length of individual fish or relevant group of individuals as indications of fatness, general 'wellbeing', gonad development, etc'.

Information on allometry, according to Froese (2006), is also indispensable to understanding the basic growth rate of a species. Among the allometric growth relationships, LWR of fishes can signify species state in an environment and depict patterns of growth. They also reported that Allometric relations take the general formula of the power law $Y = aX^b$ or its logarithmic form $\log Y = b \log X + \log a$, where X and Y are measured quantities, a is the normalization constant and b is the scaling exponent. When scaling is isometric, fish weight (equal to the volume if constant density is

assumed) will vary with the length cubed (i.e. b = 3) (Froese 2006; Mensah, 2015). The relationship is allometric if the observed value of b differs from these expectations and growth is non-isometric, the assessment of the contributing factors can throw light on the biology of species and wellbeing. Generally, the growth pattern of fish follows the cube law (Ricker, 1975). Such relationship for the fishes will be valid when the fish grows isometrically. In such cases the exponential value must be exactly 3. Practically, the actual relationship between the length and weight may depart from this, as a result of ecological conditions or condition of fish. The body of a fish constantly changes in size as it ages in nature.

There are three somatic growth types for most fish species:

- Isometric growth: This is when all fish dimensions increase at the same rate, b = 3. If b = 3, if the small specimens in the sample under consideration have the same form and condition as large specimens.
- Positive allometric growth: This is when fish increases more in weight than predicted by its increase in length, b>3. If b is greater than 3, then larger samples have increased in weight or width more than in length, either as the result of a remarkable ontogenetic change in body shape with size, which is rare, or because most large specimens in the sample were thicker than small specimens, which is common.
- Negative allometric growth: This is when fish decreases in weight than predicted by its increase in length, b<3. If b is less than 3, then large samples have changed their body shape to becomes more extended or small specimens were in better nutritional condition at the time of sampling (Mensah, 2015)

The ‘b’ value or growth coefficient from the growth equation ($W = a L^b$) indicates the rate of weight gain relative to growth in length (Froese, 2006). Mohammed *et.al.,* (2016) believed that value of ‘b’ of LWR usually lies between 2.5 and 4. But, Ricker (1975) suggested that normally, the exponent b ought to fall between 2.5 and 3.5. Meanwhile, Mohammed *et. al.* (2016) suggested that value of ‘b’ less than 2.5 can be considered as subnormal growth of fish in that given aquatic environment. Froese (2006) reviewed that the values of the coefficient ‘a’ within a species depends mainly not on the heaviness of the

fish but rather on the value of the exponent 'b'. A large value 'b' is associated with a small value of the coefficient 'a' and vice versa.

The importance of the knowledge of length – weight relationship of fish species in a given geographical region has been emphasized by many researchers like Mahmoud (2010) and Mohammed, *et al*. (2016), Mensah (2015). Furthermore, Fafioye and Oluajo (2005) concluded that the composition of both sexes gave better overview of length – weight relationship for each fish species sampled. According to Mahmoud (2010), fish growth can be estimated from morphometric features compare to standard length. Length–weight relationship can also be used in morphometric inter and intra specific population evaluation to assess indicator of well-being of the fish population.

The importance of the association of length and weight as a significant tool in the management of fishery includes:

- The value of 'b' from the growth rate (pattern) equation of LWR signifies the rate of weight gain comparative to the growth in length (Froese, 2006).
- Assessment of the wellbeing of individual fish as their life cycle changes (Bolger and Connoly, 1989; Le Cren, 1951).
- Determination of probable distinction among separate stocks of the same species (King, 1996).
- Provision of valuable information on the aquatic habitat Pauly, (1993)
- Estimation of the biomass of population and evaluating the ontogenesis of the populace of fish from various areas (Petrakis and Stergiou, 1995).
- The length-weight relationship is important in fisheries management for comparative growth studies (Mensah, 2015).
- Length – weight relationship allows fisheries scientists to convert growth – in – length equations to growth – in – weight in stock assessment models (Froese, 2006).
- Length – weight relationship is vital in assessing the status of wellbeing of fish species (fatness, breeding and feeding states) and their fitness to the environment (Mohammed *et al*., 2016; Mahmoud, 2010).

- The LWR can give information on the stock composition, growth rate, life expectancy, mortality and production of fish species and it is an important tool in fish biology, stock composition, physiology, ecology and fisheries assessment (FAO, 2013).
- For appropriate utilization and management of the fish species populace in accordance with Abowei *et al*. (2009) the length-weight relationship (LWR) is very essential
- Alex *et al*. (2012) explained that knowledge on this relationship also help to identify energy investments for growth or reproduction as a natural cyclic phenomenon of natural populations.
- Length-weight relationships are also useful for comparing life history and morphological aspects of populations inhabiting different regions (FAO, 2013).

According to Fagade (1983), growth and feeding intensity of fish are indices of condition factor which decreases with increases in length. Various types of cichlid fishes K have been documented by Fagade (1983). Alex (2012), reported that of Parac*hana obscura* in swamplands of freshwater of Niger Delta, and Abowei and Davies (2009) also reported that of *Clarotes lateceps* from the freshwater reaches of the lower Nun river. Status of fish expresses the relative fatness of the fish. The wellbeing of fish species is articulated by the "condition coefficient", represented by 'K' (also known as Fulton's K, or LWR factor, or measure of leanness (Ponderal Index)). The state of sexual development and level of nourishment is mainly reflection of the differences in a fish's coefficient of condition. This possibly will differ with the age of the fish, the seasonal variation and also sex in some other species. CF differs with species and size, the greater the values the better the fish state. If fish undergoes the cube law, the 'K' value will be indirectly influenced by age maturity, length, intensity of feeding, and other aspects.

Lower condition factors among other things have been viewed as indicators of over exploited or depleted stocks (Carscadden and Frank, 2002). CF reduces as the length increases (Fagade, 1983).

Moreover, Froese (2006) confirmed that Le Cren (1951) gave an excellent review of LWR's and CF. Le Cren further said that Fulton's condition factor evaluates the weight of a sample or a group of fishes in a length class with that of a model or perfect fish which is growing without change in form according to the cube law. Froese (2006) explained that the condition factors can only be evaluated directly if either b is not significantly different from 3 or the specimens to be evaluated are of similar length. Therefore, according to Froese (2006), to allow such evaluations Le Cren (1951) introduced the relative condition factor, that will balance the changes in form or condition with increase in length, thereby assessing the deviation of an individual from the average weight for length in the respective sample as in equation (i):

$$K_{rel} = \frac{W}{aL^b} \quad \text{..... (i)}$$

Where; W is the body weight in g

L is the Standard Length in cm,

a and b are LWR parameter (Le Cren, 1951).

To assess the wellbeing of fish, the relative condition factor (Kn) is used and Kn value of 1 or more than 1 is taken as the wellbeing of fish (Mensah, 2015). The condition factor establishes the period of gonadal maturation, and points to sexual and active spawning sizes according to Mahmoud (2010) and Mohammed *et.al.* (2016). If the value of condition factor (K<1) it means the fish lost its weight after spawning period (Froese, 2006)

2.8 Diversity Indices:

A diversity index can be defined as a mathematical measure of species diversity in a given Community based on the richness of the species (the number of species present) and species abundance (the quantity of individuals per species). The more species you have, the more varied the area. However, there are two major types of indices, the indices of dominance and information statistics.

The equations for the two indices are:

Shannon Index (H) = H' = -pi log pi

Simpson Index (D) = D = $\frac{\sum ni(n-1)}{N(N-1)}$

The Shannon index is an information statistic index, which means it assumes all species are represented in a sample and that they are randomly sampled.

In the Shannon index,

pis the proportion (n/N) of individuals of a particular species found (n) divided by the total number of individuals found (N),

lnis the natural log,

Σ is the sum of the calculations, and

sis the number of species.

A large reservoir of genetic and species variety will need to be maintained and sustainably used to handle all these challenges and worries. This diversity will further help sustain and restore productive ecosystems to provide future generations with surplus food (Bariweni, *et al.,* 2012).

Species Richness

Species Richness (S) = total number of different fish species present

Where: $S = \sum n1+n2+n3+\ldots\ldots+ni$

- Simpson index (D)

Simpson index (D) accounts for the richness and the percent of each species from a biodiversity sample within a local aquatic community. The index assumes that the proportion of individuals in an area indicates their importance to diversity.

Simpson Index (D) = $D = \frac{\sum ni(n-1)}{N(N-1)}$

Simpson's Index of Diversity = (1-D)

Simpson's Reciprocal Index = (1/D)

D = sum (Pi^2)

- Shannon-wiennier index (H)

Shannon-wiennier index (H) measures the order or disorder observed within a particular system. This order is characterized by the number of individuals observed for each species in the sample plot (Simpson 1949)

Shannon Index (H) = H' = -pi log pi

Shannon's Equitability (E_H) = H/ln*S*

Evenness (E) = e^H /S

Where:

N = Total number of all species found,

n is number of individuals of a specific species,

D = diversity index,

i = an index number for each species present in a sample,

pi = ni/N is the number of individuals within a species i divided by the total number individuals (N) present in the entire sample.

ln = natural log,

Σ = the sum the values for each species

and

S = total number of species.

4. Margalef Index:

Ma = S – 1/LnN

Where: S – the number of species

N – the number of individuals in the sample

Richness is measured by the number of species per sample. The more the species present, the richer the sample. Species richness on its own takes no account of the number of individuals of each species present. But gives as much as weight to those species which have very few

CHAPTER THREE
MATERIALS AND METHODS

3.1 Study Area

Edo State is an inland state in western Nigeria. Its capital is Benin City. It is bounded in the north and east by Kogi State, in the south by Delta State and in the west by Ondo State. It is located on latitude7° 6′18″ N and longitude 6° 41′37″ E (Figure 3.1). In 2013, the state population was estimated at 4,553,667 (NPC, 2013).

Agenebode is a serene, water-side town bounded by Ivioghe, Egor, Emokweme villages, and the River Niger in Edo State, South South geo-political zone of Nigeria and headquarters of Etsako-East local government of Edo State and the traditional capital of Weppa Wanno Kingdom. It is located between latitude 7°03′15″N and 7°09′15″N and longitude 6°39′42″E and 6°45′00″E (Figure 3.1) and divided into Ighaewo, Egbado, Otoukwe, and Igegbode (upland). The main areas of growth for the town are towards Emokweme, Egor and Ivioghe villages. Agenebode was the regional headquarters of the Royal Niger Company, a mercantile company owned by the British Colonialists and Currently the headquarters of Etsako East Local Government Area of Edo State.

Canoes, boats and ferries transport people across the River Niger to Idah in Kogi State. Traditional occupations are crop farming, fishing and canoe-building. Local agriculture produces maize, groundnuts, rice, vegeTables, potatoes, and fruits.

Agenebode is a fish commercial town in Edo State. The lower River Niger at Agenebode has six fishing communities (Kabawa, Otuokwe, Enseigbe, Igheaewo, Emekweme (ijaw) and Weppa (Urhobo)) along its bank. These areas are characterised with a lot of anthropogenic activities which include sand mining, artisanal fishing, bathing, washing and agricultural activities, transportation, abattoir base, boat base where boats are washed and repaired, residential, commercial activities in and around the river especially on market days when market women come from neighbouring villages. The main market is also located very close to the river.

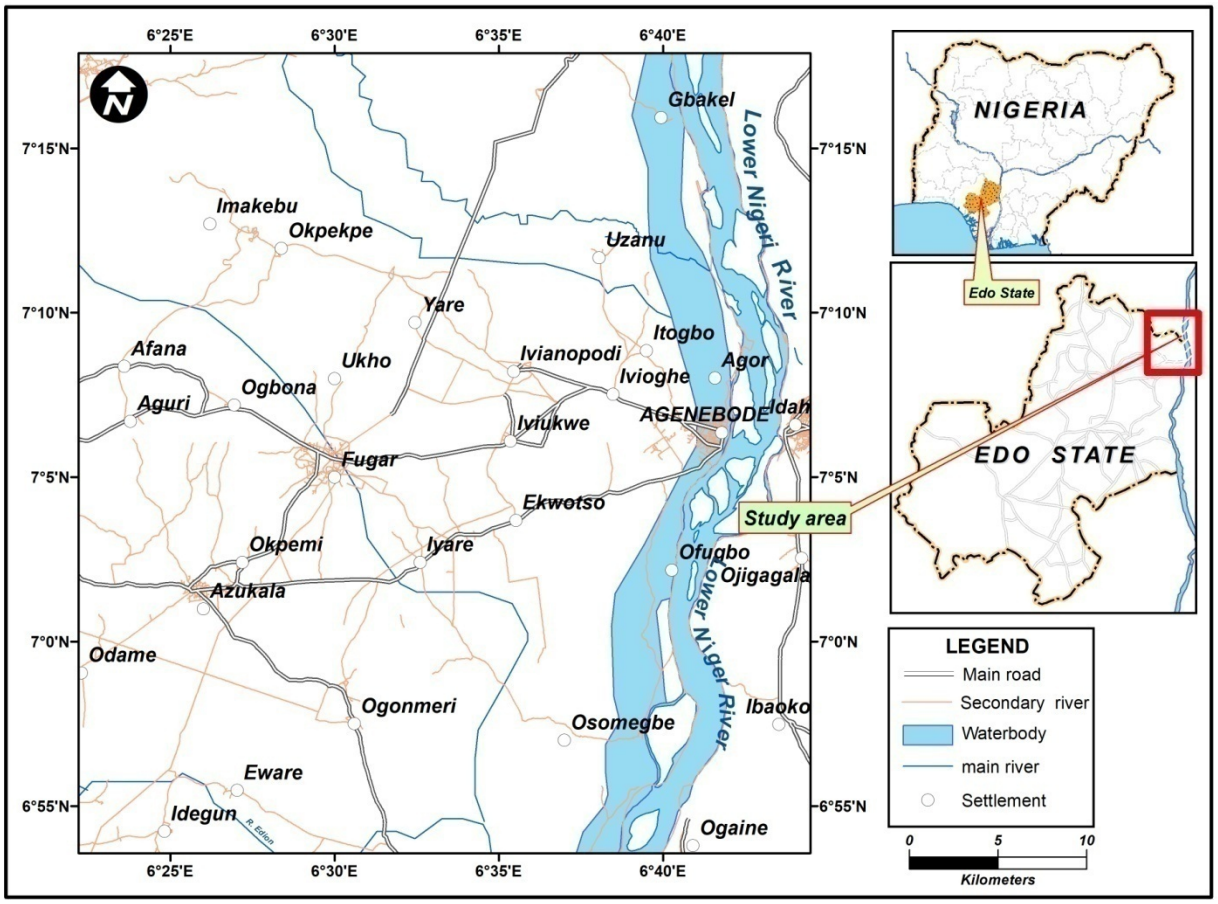


Figure 3.1: Map of Edo State showing the Location of the Study Area

3.2 Collection of Metereological Data

Data on weather parameters (rainfall, evaporation, sunshine, cold, wind, air temperature and relative humidity) for the period of study were collected from (NIMET) Nigeria Meteorological Department, Ministry of Aviation Sapele road, Benin city, Edo state .Agenebode is a typical rainforest with wet season from April to November and dry season from December to March.

3.3 Selection of Sampling Sites

The Lower River Niger at Agenebode is about 46.4km long. It is part of the long River Niger of about 1400km in Nigeria. Spatial stratification was adopted according to Southwood and Henderson (2000), in which the river was divided into three zones (Downstream, Midstream and Upstream) according to their hydrological structures and two points were selected randomly per zone and three stations were selected in each point. Sampling points were marked with the use of Global Positioning System GPS (Magellan, SporTrak PRO MARINE [IEC – 529 IPX7 Model]) kit to ensure proper location of the stations during each sampling exercise. The length of the river is 46.4km and the distance between each station was based on the six fishing communities (landing sites which are equidistant from each other) along the Lower River Niger at Agenebode (Table 3.1).

The sampling areas and site indicate downstream that stretches from Kabawa to Otuokwe is associated with sand mining/excavation, artisanal fishing, bathing, washing and agricultural activities. The midstream that extends from Enseigbe to Igheaewo is influenced by human activities, transportation, abattoir base, boat base where boats are washed and repaired, residential, commercial (where the main market is located), artisanal fishing and dredging. The upstream that spans from Emekweme (ijaw) and Weppa (Urhobo) is influenced by agricultural activities, residential and artisanal fishing (Fig. 3.2).

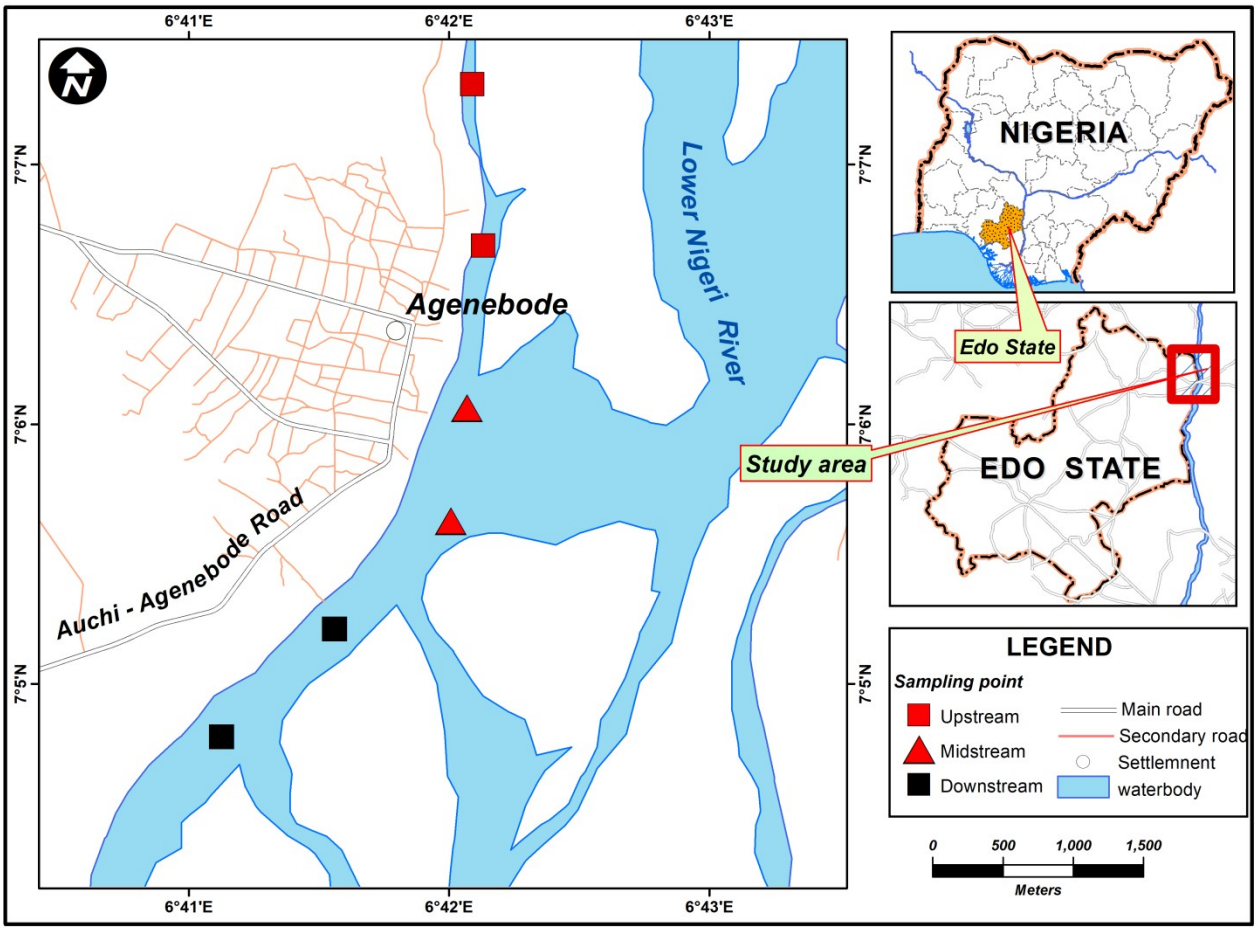


Figure. 3.2: Map of the Study Area Showing Sampling Sites

3.4 Field Procedures and Sample Collection

The sampling of water and fish was done within the period of April 2015 and March 2017 to cover two wet seasons and dry seasons. The sampling methods were season and space stratified; seasonal stratification covered wet (May to October) and dry (November to April) and spatially covered from downstream to upstream.

- **Collection of Water Samples**

A day was set aside for the collection of water. Sampling bottles were labelled prior to sampling and rinsed with the environmental water before use. The water was collected bimonthly at early hours of the morning between 6.00am and 7.00am at a depth of 20cm below the water surface (USEPA 2014) at designated points in three replicates for both physico-chemical and biological analysis. Water sample for physico-chemical parameters was collected using a 75cl bottle with screw caps and water sample for DO was collected using DO bottles and fixed with Winkler's solution (Manganese (II) chloride, Sodium Iodide and hydroxide, Sulfuric Acid, Sodium Thiosulfate and Potassium Iodate) *in situ.* And all the samples were labelled before it was taken to the laboratory in the University of Benin, Amber BOD bottles were used to collect water samples for BOD and incubated for 5days before analysis (Boyd *et.al*., 2016). The physico-chemical parameters investigated were Temperature, Transparency, Conductivity, Dissolved Oxygen, Biological Oxygen Demand, Chemical Oxygen Demand, Nitrite, and Nitrate. Measured biological variables were zooplankton, Phytoplankton and Fish abundance.

- **Collection of Fish Samples**

Three days were set aside for the collection of fish samples from the fisherfolks, two stations per day using gillnets: nine monofilament gillnets of 25.4mm (1″), 38.1mm (1.5″), 50.8mm (2.0″), 63.5mm (2.5″), 76.2mm (3.0″), 88.9mm (3.5″), 101.64mm (4.0″), 114.3mm (4.5″) and 127mm (5.0″) (FAO, 2013), were made by the fishermen contracted, Malian traps and hook and line were also used to have good representation of all the species. Each net was mounted with twine and motorized canoes used as crafts.

Nets were randomly set simultaneously by 6pm in the evening and samples retrieved from the contracted fishermen early hours of the morning (6.00am-7.30am). Malian traps and

hook and line were also used to maximize catch. The pooled fish specimens were photographed individually for easy identification using camera (Sony C650) for necessary pictures and put inside container of ice blocks to preserve their integrity and then taken to the College of Agriculture, Agenebode for sorting, identification and measurement. Identification of fish samples was done according to Olaosebikan and Raji (2013) and Froese and Pauly (2017).The Standard Length (SL, cm) and Total Weight (TW, g) of samples were recorded.

Fish specimens were collected monthly from three contracted fishermen selected from among the fishermen in the fishery association of Agenebode throughout the period of study. Species that were not caught after sampling extensively were presumed as unavailable or so sporadic as to be of negligible significance ecologically (Goodall, 1969).

3.5 Determination of Physico-chemical Parameters

The physico-chemical parameters that were analysed in this study include: Temperature, Transparency, Conductivity, Turbidity, pH, Alkalinity, Dissolved Oxygen, Biological Oxygen Demand, Chemical Oxygen Demand, Nitrate, Nitrate, Ammonia and Phosphorus.

- **Depth**

The depth of the water was measured using calibrated rope line tied to sinker of lead let down from a canoe into the river in line with APHA (2005). The rope was let down until the sinker reaches the bottom of the river. The depth at which the sinker touched the bottom was read. This was repeated three times at every sampling point to validate the findings and the mean depth recorded.

- **Temperature**

Mercury in glass thermometer calibrated in centigrade (^{0}C) was used to measure Water Temperature according to APHA (2005). The thermometer was dipped into the water from the boat to a depth of 20cm and the value of the mercury in the thermometer was read and recorded. This was repeated thrice to validite the findings and ensure objectivity and mean value used.

- **Transparency**

This was done according to Boyd (1998) using secchi disc which was attached to standardised rope and dropped slowly down from the boat until it disappears, and depth

noted, then the rope was pulled up slowly and gently and the depth at which it re-appeared was noted, the mean of the two readings was calculated and value used.

- **Hydrogen ion concentrations (pH)**

A standardized multi-meter water checker (Horiba U-12) was used to determine the pH of the water samples. The probe was dipped into the sample containers after rising with distilled water (DW) and allowed to be steady for 1minute before readings were taken. The electrode on the probe was rinsed with DW after each use (APHA, 2005).

- **Dissolved Oxygen (DO)**

The DO in the samples of water was measured using modified iodometric Winkler's method (Stirling, 1999).Three millilitres of 50% of hydrochloric acid was added to the water sample by putting the tip of the pipette near to the steady precipitate in the DO bottles. The bottle was halted instantly then shook vivaciously until everything was dissolved. 50ml of the pure mixture was pipette out through the tapered jar and titrated against sodium thiosulphate solution from the burette drip by drip until the shading turns from blue to clear (transparent) using 1ml of starch as indicator. The procedure was repeated three times and the mean burette reading was determined. DO was calculated using the following formula.

The quantity of DO in a litre of sample is given by

DO (ml/L) = $5.6 \times N \times [BR(s) - BR(b)] \times V/V - 1 \times 1000/a$

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 = volume of the sample titrates (50ml)

- **Conductivity**

Samples of surface water were collected for chemical parameters investigation using containers (75cl plastic) with screw caps. This was done early hours of the morning

(between 6.30am and 8.00am) in line with the procedure of USEPA (2014). Water samples were collected 20cm beneath the surface of the river. The bottles were tagged properly then taken for analysis in the laboratory. Conductivity was measured with a probe and a meter. Voltage was applied between two electrodes in a probe immersed in the sample water. The drop in voltage caused by the resistance of the water was usd to calculate the conductivity per centimetre. The meter then converted the probe measurement to micromhos per centimetre and displayed the resul.

- **Turbidity**

Smart- spectrophotometer manufacture by LaMotte® was used to determine the turbidity of the water samples. A well-mixed specimen of each water sample was poured into the cleaned spectrophotometer 1cm tube and directly quantified in a smart – spectro-photometer at turbidity wavelength of 390nm using MQ aqua as locus.

- **Magnessium and Calcium**

Magnesium concentrations were colourimetrically determined with the use of titanium yellow and calcium levels were measured by Atomic Absorption Spectrometer (AAS), according to Shokrollahi *et.al.* (2016). The magnesium was estimated using the scano-metric solution technique in three samples of water, with tap, river and mineral water. 45ml of each of the sample was decanted into 50ml capacity flasks and then, the flask was shaken until it became acidic, and sodium tungstate was then added to separate cations that interfered with Mg^{2+} ion determination. The solution of the sample was then filtered over filter paper. The capacity of the solution conceded reached 50Ml with two fold purified water, and 200µL of the solution cited was used for the determination of magnesium by the scanometric solution method. Furthermore, the Mg^{2+} ion substance was resolved in these samples by the atomic absorption spectroscopy (AAS) approach. The conditions for the evaluation of the Mg^{2+} content by AAS are: wavelength; 285.2 nm, cut; 0.7 nm, fire; and C_2H_2-air, likewise magnesium hallow cathode light was utilized.

The AAS is as of now used for calcium investigation of lake, stream, and river water tests in the research facility. The methodology is fast, exact, and thorough; be that as it may, a few issues have been experienced. The clear calcium concentration acquired by this

method is reliant on pH – for example as the pH is differed, the apparent calcium concentration shifts.

Calcium investigations were performed utilizing a Perkin-Elmer® atomic adsorption spectrophotometer, Model 303, Measurements were made at a wavelength of 4227 A, and a slit setting of 4. The distinctive range was utilized and the source current set at 14mA. A scale setting of 1 and an airflow rate of 5 flow-rater units was utilized. Prior to the beginning of every series of investigations, the gas (acetylene) flow rate was adjusted to give most extreme absorbance while aspirating a standard solution. This rate was typically 9.5 flowrater units. The aspiration rate was checked by utilizing a stopwatch and graduated cylinder. Plugging of the aspirator was not excessive and, when it happened, it was corrected by aspirating 1 to 1 hydrochloric acid for 1 minute.

- **Total Dissolved Solids (TDS)**

The TDS reading was emperically derived from the conductivity readings by multiplying the conductance by a factor 0.70 (Boyd *et.al.*, 2016).

- **Alkalinity**

Alkalinity of the sample of water was estimated by titrating with normal sulphuric acid. De-colorization of phenolphthalein pointer (phenolphthalein alkalinity) or a strident change from yellow to pinkish orange (total alkalinity) indicated the end point.

50ml of filtered samples was carried inside a tapered jar and two drops of aqueous methyl orange indicator were added. A pink colour solution emerges which was used to titrate with 0.02N H_2SO_4 until it became blue green to orange. The titre value was noted and used to calculate alkalinity as follows;

Estimation:

Alkalinity, mg/L $= A \times N \times 1000 / ml\ of\ sample$

Where,

A = ml of H_2SO_4 required to change from yellow to pinkish orange with methyl orange indicator.

N = normality of H_2SO_4 used

- **Nutrient Sample preparation and Analysis**

The analytical methods followed standard methods for the examination of water and waste water (APHA, 2005).

Nitrate (NO_3), Ammonia (NH_3), Phosphate (PO_4) and Sulphate in the water sampled for each set of samples were determined bi-monthly (every two months) in the laboratory with a UV spectrophotometer Hach® DR/2010 after reduction with appropriate solutions. All reagents used for the analyses were of analytical grade and in the preparation of all the solutions, bi-distilled water was used.

- **Nitrite (NO_2)**

The Nitrite in freshwater is diazotized with Sulphanilamide at pH 1.5 to 2.0 and the subsequent diazo compound is united with N – (1-naphthyl) – Ethylene diamine to profile an exceptionally coloured azodye with retention maxima at 540 nm (Boyd, 2015) About 25 ml of the sample was measured (three places) in a neat stopper glass tube and 0.5 ml of sulphanilamide was added to each tube and mixed properly. Then 0.5ml of N (1-naphthyl) – Ethylenediamine Dihydrochloride (NEDA) was added and shaken well. After allowing to stand for 15 minutes, the absorbance A (s) of the sample was measured in 1cm cell at 540 nm wavelength.

Formula

Calculating the Factor value (F):

F =A (st) - A(b)/Conc. of standard solution

Where:

A (st) = Average absorbance of standards.

A (b) = Average absorbance of blanks.

Estimating the concentrations of Nitrite-Nitrogen assisting in the sample

NO_2 –N µmol/L = $F \times A(s) - A(b)$

Where A(s) = Average absorbance of samples

A (b) = Average absorbance of blanks

- **Nitrate (NO_3)**

NO_3 in all water samples for each set of samples were analysed by the differences after reduction in a Copper-Cadmium column and quantification of the total resulting nitrites (APHA, 2005).

50 ml of the sample was measured in three places with 50 ml of cushion in 100 ml normal flask and passed through the column, the initial 50 ml was discarded, and the subsequent two portions conserved. The samples were passed through the column and continue as before for the standards. The absorbance A (NO_2+NO_3) was measured in 1 cm cell at 540 nm against Milli-Q (MQ) water (MQ water is the water that has been purified using an ion exchange cartridge), as locus. The same water sample was analysed for nitrite as described previously (NO_2) after it has been reduced to **NO_2** and the concentration of nitrite was determined in µmol/L.

Estimation

Calculation for Factor value (F):

F = A (st) – A (b)/Conc. of standard solution

Where:

A (st) = Average absorbance of standards

A (b) = Average absorbance of blanks

Estimating the concentrations of NO_3 + NO_2

C (NO_2 + NO_3) = F × (A (NO_2 + NO_3) - A(b))

The values for nitrate is corrected using the following formula

C (NO_3) µmol/L = (C (NO_2 + NO_3) - C(NO_2))

The (NO_2) concentration of **NO_2** was in µmol/L evaluated in the same sample.

- **Ammonium (NH_4)**

Ammonium (NH_4) in the water samples were analysed by the indophenols blue colour formation method.

About 50 ml of the water sample was measured out (three places) in a neat stopper tube made up of glass, 2 ml of phenol alcohol solution was added and shaken properly. Thereafter, 2ml of sodium Nitroprusside (SNP) solution was added, followed by 5 ml of oxidizing solution (Mixture of 100 ml of sodium-citrate solution and 25 ml of sodium hypochlorite solution prior to use) and well mixed. After the flasks was covered by polythene sheet and allowed to stand for one hour the absorbance of sample was measured in a spectrophotometer using 1cm cell at 640nm against ammonia free MQ water as locus. (Boyd, 1998)

Estimation:

Calculation for Factor value (F):

F =A (st) - A(b)/Conc. of standard solution

Where A (st) = Average absorbance of standards.

A (b) = Average absorbance of blanks.

Estimating the concentration of Ammonia - Nitrogen existing in the sample

Ammonia µmol/L = $F \times A(s) - A(b)$

Where: A(s) = Average absorbance of samples

A(b) = Average absorbance of blank.

- **Phosphate (PO_4)**

Soluble PO_4 (orthophosphate) in the water samples were determined by the ascorbic acid method.

Out of the sample 25 ml was measured out in a neat stopper tube made up of glass and 0.5 ml of ascorbic acid solution was added to each of the tube and the mixture was properly shaken. Then 0.5 ml of mixed reagent (mixture of Molybdate solution (125 ml)), 350 ml 9N Sulphuric acid and 20 ml of tartrate solution) was added. After the mixture was allowed to stand for 10 min for the development of blue complex, the absorbance of the sample was measures in 1 cm cell at 880 nm (As) (Boyd, 1998)

Calculation

Calculation for Factor value (F):

F =A(st) - A(b)/Conc. of standard solution

Where A (st) = Average absorbance of standards

A (b) = Average absorbance of blanks

Calculate the concentration of phosphate –phosphorus existing in the sample

$PO4^{3}$- P µmol/L = $F \times A(s) - A(b)$

Where A(s) = Average absorbance of samples

A(b) = Average absorbance of blanks

- **Biochemical Oxygen Demand**

The BOD is an experimental examination to evaluate water quality in terms of "Organic Matter" as an estimated index. A specified amount of the sample of water was transferred into the BOD bottle (250 ml volume). Before the transfer, adequate oxygen was provided by ventilating the samples for five or ten minutes. The original oxygen level was checked, and then it was incubated for 5days in the dark at a constant temperature of 20±1°C. After the 5days, the O_2 level was checked. The ultimate oxygen value was subtracted from the original, which is equivalent to the quantity of oxygen consumed for biological oxidation activities (APHA, 2005).

BOD values were determined from the following formula:

$$BOD\ (mgL^{-1}) = DO_{initial} - DO_{5days}$$

3.6 Determination of Plankton Composition

Phytoplankton and Zooplankton for each set of samples were analysed qualitatively and quantitatively every two months in the laboratory using a binocular microscope (Microstar IV Carl Zeiss®) calibrated at different magnifications (x10, x40 and x100 objectives)

- **Collection of Plankton (Phytoplankton and Zooplankton)**

Plankton specimens were obtained with the aid of No. 20 silk bolting plankton net of 54 µm netsize and opening width of 12.50 cm. The plankton net was towed along the sampling sites from the boat for five minutes and the content in the attached bottle was transfered into the sample bottles. This was done in three replicates in all the sampling sites and all conserved in 4% formalin and put to stay uninterrupted on a smooth surface for over 24hours. The bulk was later minimized to about 25 ml via draining using a fitted pipette that has a rubber tube (flexible) of 5 mm in width. The top point of the fitted pipette was tight to avoid unintended organisms loss when the siphoning was being done (Ovie *et. al*., 2011). Two drops of Rose Bengal stain were added to the water sample for the identification of phytoplankton. These were thereafter secured in 4% formalin (Zabbey *et al*., 2008) and kept in the laboratory prior to microscopic analysis.

- **Qualitative and quantitative analysis of Plankton**

The supermatant of the fixed plankton samples was cautiously poured until a volume of about 400ml was attained. 1ml of the water sample was analysed through the support of a Sedgwick Rafter chamber for counting, by the use of the drop count procedure described by Lackey (1938). For each 1 ml of water sample, ten transacts were examined comprehensively with each transact at right angle to the first. Amount of sub-samples taken was reliant on the probing of 2 to 3 consecutive subsamples without adding any of non-encountered species when comparing it to the already examined sub-samples in the same sample (APHA, 2005).

Plankton species were observed using the microscope, identified and counted using the light microscope. Organisms were observed for phytoplankton (cells, filaments, colonies) and zooplankton species (adults and juvenile stages alike). Each taxon quantity occurring in each field was recorded as number of species in each ml. The species were identified using relevant texts (Phytoplankton: Wimpenny, 1966; Compere, 1975, 1976 and 1977; Zooplankton: Wickstead, 1965) and with the assistance of a Botanist and a Zoologist in the Department of Life and Environmental Biology, University of Benin.

- **Collection of Phytoplankton Primary Productivity Samples**

In parallel with plankton sampling, water samples were collected using a Van Dorn bottle, poured in light and dark glass bottles (a black glass or covered with aluminium foil to make it opaque while the other bottle was transparent) and suspended in a vertical position in the sampling depth within the euphotic zone for 24 hours for total primary productivity determination according to the processes described by National Oceanic and Atmosphere Administration (NOAA, 2000). Evaluation of plankton was done according to the procedures described in APHA (2005).

- **Phytoplankton Primary Production Preparation and Analysis**

The gross primary production(GPP), net primary production(NPP) and community respiration(CR) in the water sample for each set of samples were analysed every two months according to Trivedy and Goel (1986) using light and dark bottles and also the

technique as described in National Oceanic and Atmosphere Administration (NOAA, 2000)

Before the analysis of the dissolved oxygen for primary production, dissolved oxygen (DO) in the sampled water was established using iodometric wrinkler's method. At the end of the incubation period of 24 hours (for photosynthetic activities in the light bottle and non-photosynthetic activity in the dark bottle, dissolved oxygen content in fixed samples of the incubated water samples in the light and dark bottles was determined by iodometric wrinkler's method (Stirling, 1999).

The change in oxygen level in the light bottle (most likely a positive number) is equal to the net production (Net primary production), while the change in oxygen level in the dark bottle (a negative number) is equal to the oxygen consumed by respiration. Based on the assumption that one atom is assimilated for each molecule of oxygen (32g) released for each molecule of carbon (12g) fixed productivity was calculated. (APHA, 2005). From these two values, the gross primary production was determined by adding the absolute value of the change in O_2 in dark container to the change in O_2 in the light (NOAA, 2000).

Calculation

Net Primary Production (NPP) = final DO in light bottle (mgL^{-1}) – initial 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}) values to $gC/m^3/h$, the factor 0.375 (12/32) was utilized and per hour values was multiplied by 24hrs to get the amount of productivity per day as described by Michael, (1984).

3.7 Assessment of Fisheries Resources

The fish specimens were conveyed to the Fisheries Technology Department Laboratory of College of Agriculture, Agenebode for further investigation – sorting, identification, and measurement. The specimens were washed with tap water and wiped with dry clean napkins, arranged and identified to species level with the aid of identification tools using the procedures of Olaosebikan and Raji (2013) and Froese and Pauly (2017).

- **Length-weight Relationship**

The Standard Length (SL) and body weight (BW) of the different fish specimen were measured for biometric data. Measuring Table was used to measure the SL with snouts of the fish facing left while Sartorius scale (model: 1106) was used for BW. SL was measured to the nearest 0.01 cm using measuring Table and BW to the nearest 0.01 g using standardised weighing scale. Sampling was done monthly for two dry and two wet seasons.

The fish condition factor was measured using the Fulton condition factor as given by Bagenal and Tesch (1978) and Le Cren (1951).

$W = aL^b$ 1

Where:

W = weight of fish (g)

L = standard length of fish (cm)

a = the regression constant (intercept)

b = the regression coefficient (slope)

The relationship of the length and weight of the most abundant fish was estimated using the correlation equation. This is to determine the status or wellbeing of the fish population.

The relationship of standard length (L) and weight (W) was articulated using the above equation (1):

The values "intercept" (a) and "slope" (b) were obtained from a linear regression of the length and weight of fish by taking the logarithm or the natural logarithms of both sides:

ln W= lnq+ b.ln L

This equation is equivalent to the regression equation:

y= a + b*x (2.2a)

This mean that;

Y is equivalent to ln W,

a which represents the y-intercept (the pointwhere the line crosses the y axis) of the regression line is equivalent to ln q,

b is the slope of the line,

and

x is equivalent to ln L.

the estimation of a and b by linear regression analysis

a = lnq

Taking the antilog of a we can calculate q of the original length-weight relationship

q = exp a

Note: exp is the inverse of ln, the base of the natural system of logarithms and equal to 2.718282.

Thus, the estimated relationship between W (in g) and L (in cm) is equal to

W = q.Lb is

Substitute the a and b values in the regression equation

y = a + b*xy

This equation is equivalent to

ln W = ln q + b*ln L

Substitute in the allometric equation W = q.Lb

to find the relationship between W (in g) and L (in cm)

The correlation between two variables is the degree of association between two variables. This degree of association is expressed by a single value called a correlation coefficient (r), which can take values ranging between-1 and +1.

The condition factor (K) of the fish sample was estimated from the relationship:

$$K = \frac{1OO\ W}{L^3}$$

Where: K= the condition factor

W= weight of the fish (g)

L= standard length of the fish (cm)

- **Fish Abundance**

Fish abundance was calculated using percentage statistics.from the equation below, the number of individual fish species (n) was determined yearly from the monthly collection

pools. The sum total of all the fish species of the different species obtained in this study was the sample size (N):

$$N = \Sigma(n_1+n_2+n_3+n_4+\ldots\ldots\ldots\ldots..+n_i)$$

n_1, n_2, n_3, n_4… and n_i are index numbers for each species

The proportion of the number of individuals that make up each species in relation to total number of individuals of all the fish species obtained is the frequency of abundance. Hence:

$$\text{Frequency of abundance} = n \times \frac{100\%}{N = \Sigma(n1+n2+n3+n4+\text{'''}\ldots\ldots\ldots+ni)}$$

The total weight of each one of a species is the biomass, while the percentage of each species biomass in relation to the total biomass of all fish species obtained is the percentage biomass. Hence:

$$\text{Percentage Biomass} = \frac{\textit{Total biomass of individuals of a species}}{\textit{Sum total biomass of all fish species encountered}} \times 100\%$$

- **Community Structure Analysis**

The diversity indices such as Shannon and Wiener, Species Equitability or Evenness, Margalef, Simpson's dominance index and Canonical Correspondence Analysis were computed for Plankton and fin fish data analysis with the use of the software package 'PAST' (Hammer *et al.,* 2001). Richness is measured by the number of species per sample. The more the species that are available, the richer the sample. Species richness on its own does not take into account the number of the individuals of every species available, but provides as much as weight to those species which have very few individuals as to those that do not have many individuals.

3.8 Data Analysis

Data gathered and collected during the period of this study were analysed using descriptive (means and standard deviations) and inferential statistics (one-way ANOVA, t-test and correlations) using Microsoft excel and SAS (statistical analysis system). Pooled data were presented as seasonal and spatial mean variances at $P < 0.05$. Average (mean) values were separated with Turkey's Honest Significant Difference (HSD), Duncan

Multiple Range Test. Paired samples t - test was employed to analyze difference between the pooled seasonal data means. Descriptive statistics and Analysis of variance (ANOVA) was done on physicochemical variables to test for significant differences among all the sampling sites. Multiple regression analysis was done using the SAS (Statistical Analysis System) software to determine the percent variation in dependent variables (fish parameters) that could be explained by variation in independent variables (Physico-chemical parameters).

To increase accuracy of multiple linear regression model, different reduction methods were done before the investigation. If two variables were highly associated ($r \geq 0.8$; Spearman's rank), the variable that exhibited the lower association to fish abundance was omitted from the final model, with the assumption that the influence of one variable were described by the other.

For Canonical Correspondence Analysis (CCA) and Correlation of species abundance against other variables were employed to reduce more and more model components that did not display any association (significant) to species abundance, in order to detect species relationship pattern directly related to the environmental variables according toTer Braak and Verdonschot (1995). This one random variable of non-parametized statistical method allow analysis of the association between species abundance and environmental factors on an individual basis and also permit the identifying of the factors that are responsible for the structure of fish fauna.

Fish diversity Indices

Species Richness and evenness of their distribution which measures fish diversity was calculated using the indices according to Simpson (1949):

- Species Richness

Species Richness (S) = the total amount of different fish species present

Where:

$S = \sum n1+n2+n3+\ldots\ldots+ni$; n is number of individuals of a specific species

- Simpson index (D) for each species

Simpson index (D) accounts for the richness and the percent of each species from a biodiversity sample within a local aquatic community. The index assumes that the proportion of individuals in an area indicates their importance to diversity.

Simpson's Index (D) = $-\frac{\Sigma n(n-1)}{N(N-1)}$

Where:

N = Total number of all species found,

n - number of individuals of a specific species

Simpson's Index of Diversity = (1– D)

Simpson's Reciprocal Index = $\frac{1}{D}$

D = sum (Pi^2)

Where :

i = an index number for each species present in a sample,

pi = ni/N is the number of individuals within a species i divided by the total number individuals (N) present in the entire sample.

- Shannon-wiennier index (H)

Shannon-wiennier index (H) is the measurement of the order or disorder that is observed within a specific system. This order can be characterized by the number of the individuals that is observed for every species that is in the sample plot according to Simpson (1949)

Shannon Diversity Index (H) = sum $(Pi\ ln(Pi)$

Shannon's Equitability($E_H = {}^{H}/_{lnS}$)

Evenness (E) = $e^{H}/$

Where:

N = Total number of all species found,

n is number of individuals of a specific species,

D = diversity index,

i = an index number for each species present in a sample,

pi = ni/N is the number of individuals within a species i divided by the total number individuals (N) present in the entire sample.

ln = natural log,

Σ = the sum of values for each species

and

S = total number of species

Margalef Index:

$$Ma = \frac{S-1}{\ln N}$$

Where:

S = the number of species

N = the number of individuals in the sample

The potential fish yield

The potential fish yield was calculated using the following:

Morpho-Edaphic Index (MEI) was used to predict the potential fish yield in kg/ha/annum in line with the procedures of Henderson and Welcome (1974).

$$MEI = \frac{Conductivity\ (\mu S/cm)}{Mean\ Depth\ m}$$

Where,

Cond = Conductivity

d = mean depth

Yield (Y) = $23.281 \times MEI^{0.447}$

Where: Y = yield in kg ha^{-1}

The estimated production per annum of the fishermen operating regularly on the river during this period of study was calculated from the sample monthly catches to get the Actual (Post-calculated) fish yield.

Total monthly Catches (kg) = No of fishermen x Average monthly Catches (kg). Therefore, Annual Catches = Total monthly Catches (kg) x 12

CHAPTER FOUR

RESULTS

4.1 Metereological Parameters

Some morphological features of the study area were taken with their co-ordinates (Table 4.1). Data on weather parameters collected on rainfall, evaporation, sunshine, cold, wind, air temperature and relative humidity for Agenebode area of Edo State from (NIMET) were represented in Tables 4.2 and 4.3. The highest air temperature (33.9^0C and 33.6^0C) values were recorded for the month of December for both years of study period while the month of August recorded the lowest value (27.9^0C).

The temporal variation in rainfall is shown in Figure 4.1. The sum of rainfall obtained was 1647.3 mm during the period of study. The average rainfall in the Lower River Niger during the period of study was 78.44 mm. The month of June produced the (maximum) peak values of rainfall in the first year and the month of August produced the peak values of rainfall for the second year. The month of December had the least values of rainfall during the period of study. The total relative humidity received during the period of study was 1625.06% as in Table 4.2. The mean relative humidity throughout the period of the study was 77.38%. The highest value of relative humidity was observed in the month of July for both years with 86.75% and 83.6% respectively. The month of January had the least value for the study period with relative humidity of 58.7% (Figure 4.2).

Table 4.1: Some Morphometric Features of the Study Area

Zone	Fishing Villages	Coordinates Longitude	Latitude	Minimum Depth (m)	Maximum Depth (m)	Mean Depth (m)
DOWNSTREAM (DNS)	Kabawa (Egoli)	$7^0$04'18.0"N	$6^0$41'05.7"E	1.74	4.20	2.77
	Otuokwe	$7^0$05'18.0"N	$6^0$41'10.7"E			
MIDSTREAM (MDS)	Eneseigbe	$7^0$05'37.0"N	$6^0$42'20.9"E	2.16	5.90	3.28
	Igheaewo	$7^0$06'37.0"N	$6^0$42'21.9"E			
UPSTREAM (UPS)	Ijaw	$7^0$07'40.7"N	$6^0$43'07.4"E	4.01	7.30	4.90
	Urhobo	$7^0$08'40.7"N	$6^0$43'08.4"E			

Table 4.2: Survey of Environmental Factor of Lower River Niger at Agenebode

MONTH		TEMPERATURE (°C)		RAINFALL (mm)			RELATIVE HUMIDITY
		Max.	Min.	Optim.	Min.	Max.	%
April	total	1004.2	750.9	91.3	17.2	108.5	71.3
2015	mean	33.5	25.0				
May	total	991.6					71.5
2015	mean	32.2					
June	total	911.6	723.4	142.2	158.	300.2	83.13
2015	mean	30.4	24.1		0		
July	total	899.3					86.75
2015	mean	29.3					
Aug.	total	875.3	720.5	166.9	49.6	210.5	86.25
2015	mean	28.2	23.2				
Sep.	total						86.00
2015	mean						
Oct.	total	979.5	726.4	182.0	89.7	271.7	84.25
2015	mean	31.6	23.4				
Nov.	total	1004.1	735.1	30.6	22.6	52.6	82.00
2015	mean	33.5	24.5				
Dec.	total	1051.6	643.4	12.1	00	12.1	81.25
2015	mean	33.9	20.8				
Jan.	total	1015.9	755.7	75.5	7.3	82.8	
2016	mean	32.8	24.4				58.63
Feb.	total	929.2	690.8	49.6	3.7	53.3	61
2016	mean	33.2	24.7				
Mar.	total	1030.6	758.6	87.1	43.3	130.4	66.3
2016	mean	33.2	24.5				
April	total	973.4	735.9	92.2	11.9	212.0	74.1
2016	mean	32.4	24.5		8		
May	total	994.5	755.6	144.8	107.	252.0	79.1
2016	mean	32.1	24.4		2		
June	total	919.5	715.8	153.4	66.9	213.1	82.2
2016	mean	30.7	23.9				
July	total	8916	730.9	153.6	120.	274.0	83.6
2016	mean	28.8	23.6		4		
Aug.	total	865.6	709.3	18.7	220.	407.5	83.5
2016	mean	27.9	22.9		5		
Sep.	total	870.5	690.9	239.3	128.	368.1	82.8
2016	mean	29.0	23.0		8		
Oct.	total	989	713	254.7	12.7	267.4	81.25
2016	mean	31.9	23.0				
Nov.	total	989	858.0	298.9	7.6	306.5	83.00
2016	mean	33.0	28.4				
Dec.	total	1040	711	35.8	13.4	49.2	81.63
2016	mean	33.5	22.9				
Jan.	total	1048.4	726.1	14.0	1.4	15.4	72.1
2017	mean	33.8	23.4				
Feb.	total	945.8	690.0	57.7	4.4	61.8	63.8
2017	mean	33.8	24.6				
Mar.	total	1047.6	772.4	121.2	5.0	126.2	67.2
2017	mean	33.8	24.9				
TOTAL				1647.3	973.	2888.3	1625.06
					3		

Source: NIMET (Benin City) 2017

Table 4.3: Monthly Mean Guage Reading, Mean Cold, Evaporation and Sunshine

MONTH	WIND Km	MEAN COLD	EVAPORATION $Kg/m^2/s$	SUNSHINE Wm-2
April 2015	67.7	7.0	3.6	4.3
May 2015				
June 2015	87.31	7.0	1.8	3.3
July 2015				
Aug. 2015	11.66	1.4	8.5	1.1
Sep. 2015				
Oct. 2015	72.82	2.3	342	4.22
Nov. 2015	66.47	3.7	6.1	5.1
Dec. 2015	91.68	7.0	11.0	5.8
Jan. 2016	101.90	7.0	3.9	4.9
Feb. 2016	94.96	7.0	4.2	2.4
Mar. 2016	104.68	7.0	4.0	3.62
April 2016	102.27	6.9	3.6	4.4
May 2016	89.90	7.0	3.2	5.1
June 2016	90.52	7.0	2.5	4.9
July 2016	93.81	7.1	1.9	2.4
Aug. 2016	114.5	7.0	1.9	2.6
Sep. 2016	95.49	7.0	1.9	3.0
Oct. 2016	72.82	2.3	342	4.22
Nov. 2016	66.47	3.7	6.1	5.1
Dec. 2016	91.68	7.0	11.0	5.8
Jan. 2017	201.1	5.5	5.8	6.5
Feb. 2017	190.3	4.8	3.8	6.8
Mar. 2017	216.3	4.3	6.2	7.0

Source: NIMET (Benin City) 2017

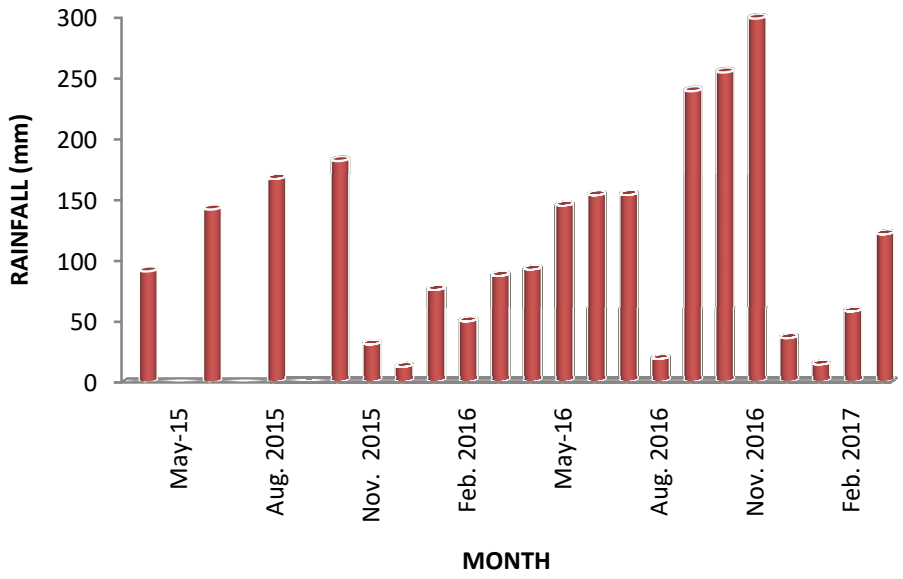


Figure 4.1:Monthly Rainfall (mm) Pattern in Lower River Niger at Agenebode

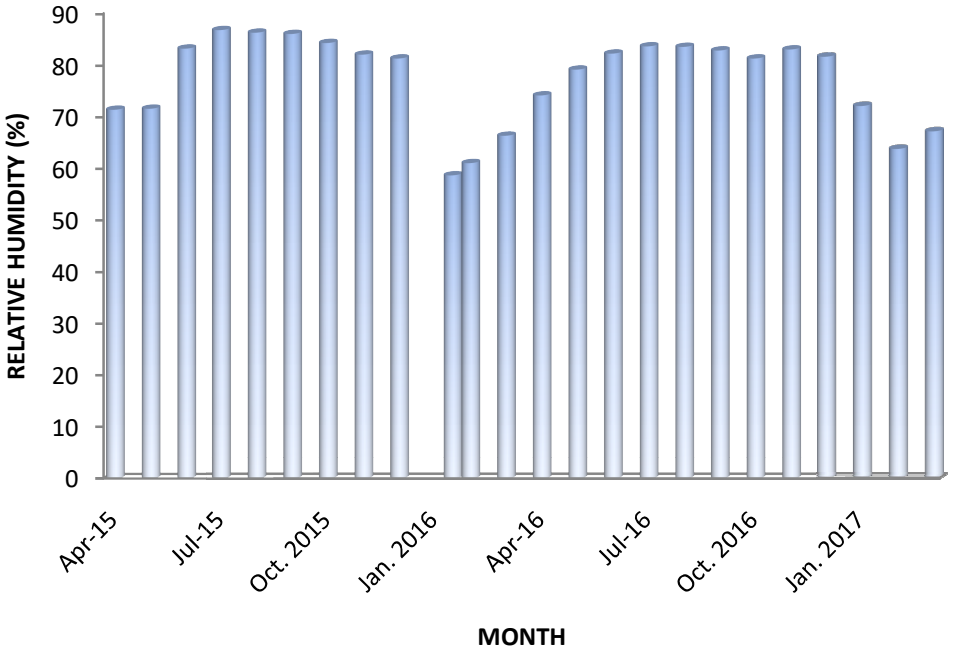


Figure 4.2:Monthly Relative Humidity (%) Pattern in Lower River Niger at Agenebode

4.2: Temporal and Spatial Variations in Physico-chemical Parameters of Lower River Niger

The mean depth of Lower River Niger recorded during the period of study was 264.00 cm; the highest (491.36 cm) mean depth was obtained for UPS while DNS recorded the lowest (174.45 cm) mean depth. Spatially, water depth was highly significant ($P< 0.01$) across the sampled stations (Table 4.4). Result of the follow up test shows that downstream and middle stream are not significantly different. There are no significant differences among the three sampling stations in terms of the water temperature and Transparency (Table 4.4).

Physico-chemical characteristics of Lower River Niger at Agenebode were recorded during period of study (Table 4.5). The mean water temperature was 27.51 °C and there were no significant difference ($P>0.05$) among the stations; There were no significant difference ($P>0.05$) for pH, Suspended Solids (SS), Turbidity, Phosphate, Phosphorus, Sulphate, Nitrate, Ammonia-N, DO, BOD, and Chloride among the sampling stations while the Electrical Conductivity was highly significant ($P<0.01$) among the sampling zones during the period of investigation as represented in Table 4.5.

Seasonally, there were no significant difference ($P>0.05$) for Conductivity, Phosphate, Phosphorus, Sulphate, DO, BOD, and Chloride among the sampling stations while Suspended Solids (SS), Turbidity, pH and Nitrate showed significant difference ($P<0.05$) among the sampling stations and Ammonia-N was highly significant ($P<0.01$). All these are represented in Table 4.6.

Table 4.4: Mean Values of Water Depth, Temperature and Transparency of Lower River Niger

	DNS	MDS	UPS	Mean ± Std. Deviation	F-value	P-value
Water Depth (cm)	174.45±119.12[a]	216.18±99.38[a]	401.36±191.78[b]	264.00±170.42	7.9106	0.002
Water Temperature ^{O}C	27.36±1.29[a]	27.36 ±1.69[a]	27.81 ± 1.54[a]	27.52 ±1.48	0.330	0.721
Water Transparency (cm)	45.55 ± 15.21[a]	53.73±12.12[a]	50.36 ± 9.03[a]	49.88 ±12.46	1.214	0.314

Values along the same rows with the same superscripts are not significantly different ($P<0.05$)

DNS - Downstream, MDS – Midstreams UPS - Upstream

Table 4. 5: The Spatial Variation of the Physico-Chemical Parameters of the Lower River Niger at Agenebode

Parameters	DNS Mean ± SE	MDS Mean ± SE	UPS Mean ± SE	P-value	Optimum Range (Boyd 2015)	Optimum Range (NESREA 2011)
PH	6.64 ± 0.18	6.66 ± 0.21	6.88 ± 0.25	0.682	6.5-8.5	6-9
Conductivity (Mg/l)	76.36^{a} ± 9.82	58.64^{b} ± 3.76	43.64^{b} ± 4.53	0.006	50-500	50-1500
Total Suspended Solids (Mg/l)	69.86^{a} ±23.83	84^{b} ± 19.8	51.68^{a} ± 8.81	0.042	10	25
Turbidity (NTU)	98.01^{a} ± 35.55	113.09^{b} ± 32.86	93.36^{a} ± 29.3	0.905	>52.7	3.5
Phosphate (Mg/l)	4.06^{a} ± 2.4	0.45^{b} ± 0.11	2.57^{a} ± 1.35	0.286		0.05-2.0
Phosphorus (Mg/l)	1.31^{a} ± 0.77	0.2^{b} ± 0.04	0.89^{b} ± 0.43	0.314	<400	0.05
Sulphate (Mg/l)	30.41 ± 7.73	35.05 ± 7.38	24.45 ± 3.11	0.513	0.1-3.0	0.1-5.0
Nitrate (Mg/l)	6.87 ± 1.68	4.93 ± 1.17	4.09 ± 1.0	0.323	0.0-1.0	0.1-3
Ammonia-N	0.68 ± 0.37	0.55 ± 0.27	0.36 ± 0.15	0.715	31.0-50.0	0-1.0
Chloride (Mg/l)	17.32 ± 2.06	16.49 ± 2.41	16.15 ± 2.76	0.94	5.0-10.0	5-25
Dissolved Oxygen (Mg/l)	6.06 ± 1	5.75 ± 0.49	4.27 ± 0.42	0.162	<10	5-10
B.O.D. (Mg/l)	4.11 ± 1.05	2.7 ± 0.57	3.22 ± 0.43	0.399	<50	<10
TDS (Mg/l)	87.10 ± 20.37	89.55 ± 32.42	87.00 ± 38.65	0.612	30.0-200	303
Alkalinity (Mg/l)	75.45 ± 24.23	84.46 ± 24.95	77.18 ± 0.43	0.261	50.0-300.0	50-300
Calcium (Mg/l)	43.64 ± 13.28	38.00 ± 14.93	34.55 ± 14.29	0.422	75.0-200.0	75-180
Magnesium (Mg/l)	2.43 ± 1.70	3.89 ± 1.81	4.84 ± 1.33	0.120	<150	<150
COD (Mg/l)	86.55^{a} ±26.97	90.12^{b} ± 22.18	75.44^{a} ±26.66	0.524	<50.0	30
Water temp. (^{0}C)	27.36 ± 1.86	27.36 ± 1.68	27.82 ± 1.54	0.425	25.0-32.0	25-32
Transparency	45.55 ± 15.21^{a}	53.73 ± 12.12^{a}	50.36 ± 9.03^{a}	0.314		0.3-0.4cm

Values along the same rows with the same superscripts are not significantly different (P<0.05)
DNS - Downstream, MDS – Midstreams UPS - Upstream

Table 4.6: The Seasonal Variation of the Physico-Chemical Parameters of the Lower River Niger at Agenebode.

Parameters	Wet season	Dry season	t-value	p-value
pH	6.5±0.12	7±0.21	-2.15	0.04*
Conductivity (Mg/l)	60.28±6.1	58.67±6.52	0.18	0.86
Suspended Solids (Mg/l)	89.67±17.56	43.13±6.1	2.32	0.03*
Turbidity (NTU)	136.19±30.54	59.83±10.13	2.2	0.04*
Phosphate (Mg/l)	3.89±1.63	0.52±0.09	1.88	0.07
Phosphorus (Mg/l)	1.29±0.52	0.21±0.04	1.89	0.07
Sulphate (Mg/l)	33.33±5.73	25.93±4.22	1	0.32
Nitrate (Mg/l)	6.81±0.92	3.48±1.12	2.32	0.03*
Ammonia-N	0.87±0.26	0.12±0.03	2.6	0.01**
Chloride (Mg/l)	14.98±1.65	18.67±2.19	-1.37	0.18
Dissolved Oxygen (Mg/l)	5.25±0.56	5.5±0.61	-0.3	0.77
B.O.D. (Mg/l)	3.08±0.53	3.66±0.7	-0.67	0.51
TDS (Mg/l)	81.10 ± 20.37	52.55 ± 32.42	2.34	0.03*
Alkalinity (Mg/l)	84.45 ± 24.23	74.46 ± 24.95	2.01	0.05
Calcium (Mg/l)	34.64 ± 13.28	48.00 ± 14.93	1.12	0.56
Magnesium (Mg/l)	2.43 ± 1.70	6.89 ± 1.81	2.41	0.03*
COD (Mg/l)	5.55^{a} ±3.97	2.59^{b} ± 22.18	2.6	0.01**
Water temp. (^{0}C)	27.36 ± 1.86	27.36 ± 1.68	0.81	0.09
Transparency(cm)	45.55 ± 15.21^{a}	53.73 ± 12.12^{a}	2.01	0.04*

Values along the same rows with the same superscripts are not significantly different (P<0.05)
DNS - Downstream, MDS – Midstreams UPS - Upstream

Note:

*P>0.05- Not Significant, *P<0.05-Significant, **P<0.01- Highly Significant*

4.2.1: Correlation (r) Between Different Physico-Chemical Parameters of Lower River Niger at Agenebode

During the period of investigation, the correlation coefficient (r) amongst every pair parameter was computed by taking the average values as shown in Table 4.7. Correlation coefficient (r) for pH, water temperature, dissolved oxygen, elecro-conductivity, nitrates, and calcium of the Lower River Niger was calculated. The degree of line association between any of the water quality parameters measured by the simple correlation coefficient (r) as presented in Table 4.7 as correlation matrix. The pH has been found to show positive correlation with water temperature (r=0.037), conductivity (r=0.087), nitrate (r= 0.121), BOD (r= 0.396), and transparency (r=0.142). Dissolved oxygen(r=-0.305), had been found to show strong association with conductivity (r=0.104), turbidity (r=0.062), phosphate (r=0.090), phosphorus (r=0.086), and correlated significantly Biochemical oxygen demand (r=0.590). Water temperature showed had a negative correlation with BOD (r= -0.072) and positive correlation with pH (r= 0.037). However, conductivity showed positive relationship with transparency (r= 0.117) and dissolved oxygen (r= -0.104) as represented in Table 4.7.

4.7: Correlation of Physical and Chemical Parameters of Lower River Niger, Agenebode

	pH	EC	Turb.	PO_4	P	SO_4	NO_3	NH_3	Chloride	DO	BOD	TSS	TDS	Alk
pH	1													
EC	.087	1												
turbidity	-.493**	-.321	1											
phosphate	-.263	-.145	.713**	1										
phosphorus	-.247	-.163	.737**	.998**	1									
sulphate	-.352*	-.133	.770**	.556**	.576**	1								
nitrate	.121	.496**	.102	.284	.280	.310	1							
ammonia	-.327	-.119	.886**	.770**	.792**	.809**	.431*	1						
chloride	-.508**	-.076	-.140	-.206	-.224	-.136	-.525**	-.347*	1					
DO	-.005	.104	.062	.090	.086	-.095	.183	.105	.060	1				
BOD	.396*	.322	-.383*	-.211	-.213	-.340	.330	-.164	-.176	.590**	1			
SS	-.494**	-.236	.928**	.648**	.674**	.797**	.191	.923**	-.110	.135	-.318	1		
TDS	-.077	.088	-.053	-.188	-.176	-.044	.021	-.027	-.067	.144	.286	-.014	1	
Alk	-.022	-.173	.213	.093	.099	.086	.052	.198	-.162	.095	-.080	.194	-.092	1
Ca	.050	.030	-.013	.073	.082	.120	.010	.043	.069	-.173	-.056	-.013	-.087	.01
Mg	.379*	-.276	-.285	-.299	-.293	-.223	-.252	-.380*	-.107	-.315	-.130	-.381*	.184	-.08
COD	.117	.046	-.184	-.180	-.183	-.002	-.079	-.162	-.088	-.168	-.032	-.234	-.142	.19
depth	-.338	-.459**	.606**	.431*	.446**	.287	-.194	.395*	.046	-.026	-.283	.434*	.220	.10
WT	.037	-.165	-.479**	-.317	-.326	-.295	-.475**	-.506**	.474**	-.234	-.072	-.418*	.048	-.15
trans	.142	.117	-.244	-.094	-.102	-.319	.144	-.190	-.016	.060	.113	-.174	-.347*	.06

Keys:
*. Correlation is significant at the 0.05 level (2-tailed).
WT. – Water temperature; EC – Electrical conductivity; Turb. – Turbidity; DO – Dissolved oxygen; TSS – Total Suspended Solid; Trans. – Transparency; BOD – Biochemical oxygen Demand; COD – Chemical Oxygen Demand; Mg – Magnesium; Ca – Calcium; Alk – Alkaline; TDS – Total Dissolved Solids

4.3 Distribution and Abundance of Plankton in Lower River Niger at Agenebode

4.3.1 Phytoplankton Distribution and abundance

A total of 49696 individual phytoplankton belonging to six major classes, 13 orders, seventeen families, 82 genera and 194 species were observed during the period of the study in Lower River Niger at Agenebode as shown in Table 4.8. The major divisions were Bacillariophyta (48.19%), Charophyta (0.00%), Chlorophycta (29.38%), Cyanophyta (17.05%), Dinophyta (0. 15%) and Euglenophyta (3.22%) as represented in Table 4.9. As compared to the others, charophyta (4) recorded the least number of species. Diatoms comprising of 21,442 individuals from 34 genera, green algae consisting 17,050phytoplanktons from 25 genera, blue-green algae (9,714 in number from 14 genera), euglenoids cells were 1,410 species from 6 genera, dinoflagellates had 2 species from 2 genera and Charophytes (1 species from 1 genera) were recorded (Tables 4.10). Diatoms were the most abundant species of phytoplankton obtained in Lower River Niger while Charophytes were the least abundant. NoTable species in order of dominance were *Aulacoseira granulata followed by Synedra acus, Merismepodia tennuissima, Spirogyra sp, Spirogyra dubia, Mougeotia calospora var. Agardh* and *Synedra ulna* while the least was *Pinularia divergens*

The spatial variation of Phytoplankton species obtained in Lower River Niger at Agenebode was highest 19,674 (39.59%) in UPS, followed by MDS 16,013 (32.22%) and DNS had the least 14,009 (28.19%) as represented in Table 4.9 and Figure 4.3. Bacillariophyta was more dominant in MDS while chlorphyta and euglenophyta were more dominant in DNS and Cyanophyta was more dominant in UPS. There were significantl ($P<0.05$) different spatially.

Phytoplankton species was more in the dry season (59.70%) than in the wet season (40.30%) with Bacillariophyta (43.15%) dominating both seasons as presented in Table 4.11 and Figure 4.5. Phytoplankton species encountered during wet and dry season are represented in Table 4.12. All the six phytoplankton classes encountered during this investigation were encountered during the season of dryness whereas during the wet

season, dinophyta was not recorded (Table 4.13). Diatoms were more frequent and dominated during both seasons. Seasonally, there was significant ($P<0.05$) difference in the phytoplankton distribution of Lower River Niger at Agenebode.

Table 4.8a: Spatial Distribution and Relative Abundance of the Phytoplankton in Lower

DIVISION	Phytoplankton *Species*	DNS		MDS		UPS	
		AB	RAB	AB	RAB	AB	RAB
BACILLARIOPHYTA	*Aulacoseira granulata v.curvata*	20	0.14	25	0.15	45	0.22
	A. granulata v. angustissima f. spiralis	25	0.18	75	0.46	70	0.34
	A. granulata	1235	9.72	3122	20.84	3824	18.46
	Actinoptychus splendens	7	0.05	1	0.01	14	0.07
	Actinolaenium cucurbitinum	6	0.04	1	0.01	26	0.15
	A. splendens	4	0.03	0	0.00	0	0.00
	Amphora ovalis	1	0.01	0	0.00	0	0.00
	Anomoeneis serians	5	0.04	0	0.00	0	0.00
	A. spectabillis	5	0.04	0	0.00	0	0.00
	Asterionella Formosa	0	0.00	0	0.00	12	0.06
	Bacillaria paradoxa	190	1.34	142	0.86	75	0.36
	Biddulphia regia	0	0.00	30	0.22	4	0.02
	Cosmarium trilobulatum	1	0.01	0	0.00	0	0.00
	Cyclotella meneghiniana	0	0.00	0	0.00	0	0.00
	Cymbella prostrate	3	0.02	0	0.00	2	0.01
	C. pusilla	0	0.00	0	0.00	10	0.05
	C. punctifera	4	0.03	5	0.03	5	0.02
	Desmogonium rabenhorstianum	0	0.00	2	0.01	0	0.00

River Niger at Agenebode

Table 4.8a Cont'd

Diploneis smithii	90	0.00	1	0.01	0	0.00
Eunotia asterionelloides	170	0.00	10	0.06	0	0.00
Eunotia flexuosa	8181	0.01	4	0.02	10	0.05
E. filum	22	0.14	36	0.22	49	0.24
Flagillaria javanica	33	0.85	0	0.00	272	1.31
F. lineatum	4	0.00	0	0.00	200	0.97
F. sp	1	4.73	782	4.75	763	3.68
Hydrosera trifoliata	5	0.01	0	0.00	0	0.00
Melosira valdii	5	0.20	4	0.02	8	0.04
M. varians Agardh	12	0.01	0	0.00	0	0.00
Navicula acus.	407	0.11	5	0.03	35	0.17
Navicula acus Cleve	34	0.53	44	0.27	48	0.23
Nitzschia. Palae	1	0.04	15	0.09	10	0.05
N. accicularis	0	0.32	25	0.15	20	0.10
N. affinis Grunow	5	0.00	0	0.00	2	0.01
Peridinium cinctum	10	0.07	8	0.05	0	0.00
Pinnularia gatunense	2	0.01	0	0.00	0	0.00
P. Dactylus	0	0.00	5	0.03	0	0.00
P. divergens	10	0.07	10	0.06	10	0.05
P. Gibba	0	0.00	0	0.00	5	0.02
P. Subcapitata	0	0.00	5	0.03	0	0.00
P. Viridis	10	0.07	0	0.00	50	0.24
P. brebisonii	0	0.00	0	0.00	5	0.02
P. nobilis	16	0.11	0	0.00	0	0.00
P. rivularis	14	0.11	0	0.00	0	0.00
P. sp	0	0.00	12	0.07	0	0.00
P. viridis	10	0.07	5	0.03	15	0.07
P. decorum	0	0.00	0	0.00	5	0.02

Table 4.8a Cont'd

	P. delicatulum	0	0.00	10	0.06	0	0.00
	Pleurosigma angulatum	0	0.00	10	0.06	0	0.00
	P. decorum	0	0.00	41	0.25	7	0.03
	P. sp.	0	0.00	0	0.00	0	0.00
	Stenopterobia pelagic	2	0.01	0	0.00	0	0.00
	S. rautenbachiae	0	0.00	0	0.00	4	0.02
	Surirella engleri	4	0.03	0	0.00	0	0.00
	S. robusta	10	0.07	12	0.07	4	0.02
	S. angusta	0	0.00	5	0.03	0	0.00
	S. muellerri	2	0.01	0	0.00	0	0.00
	S. sp.	0	0.00	17	0.10	4	0.02
	S. Elegans	0	0.00	10	0.06	0	0.00
	S. Robusta	0	0.00	10	0.06	0	0.00
	Synedra acus	798	5.63	2043	12.42	2803	13.53
	S. superb	8	0.06	6	0.04	12	0.06
	S. ulna	607	4.28	1597	9.71	1534	7.40
	Tabellaria fenestrate	0	0.00	0	0.00	2	0.01
	T. floculosa	2	0.01	0	0.00	0	0.00
	T. sp	0	0.00	0	0.00	6	0.03
	Triceratium favus	45	0.32	0	0.00	8	0.04
CHAROPHYTA	*Nitella gracilis*	0	0.00	2	0.02	0	0.00
CHLOROPHYTA	*Actinotaenium globosum*	0	0.00	5	0.03	5	0.02

Table 4.8a Cont'd

CHLOROPHYTA CONT'D	*Cladophora oligoclona*	10	0.07	10	0.06	0	0.00
	Closterium acerosum	31	0.22	30	0.18	10	0.05
	C. closteroides	0	0.00	0	0.00	5	0.02
	C. lieblenii	10	0.07	0	0.00	20	0.10
	C. pseudolulnula	5	0.04	5	0.03	0	0.00
	C. subulatum	5	0.04	0	0.00	0	0.00
	C. gracile	8	0.06	0	0.00	0	0.00
	C. incurvum	1	0.01	0	0.00	0	0.00
	C. lineatum	8	0.06	14	0.09	10	0.05
	C. lunula	54	0.45	0	0.00	0	0.00
	C. monoliferum	0	0.00	10	0.06	0	0.00
	C. striolatun	2	0.01	0	0.00	0	0.00
	C. gracile	32	0.23	36	0.22	40	0.19
	C. pronum	12	0.08	34	0.21	68	0.33
	C. microporum	74	0.52	109	0.66	200	1.15
	Cosmarium. contractum	35	0.25	30	0.18	10	0.05
	C. pseudoconnatum	10	0.07	0	0.00	24	0.12
	C. starppersii	2	0.01	0	0.00	0	0.00
	C. subcucumis	0	0.00	0	0.00	30	0.14
	C. subspeciosum	0	0.00	6	0.04	0	0.00
	C. Decoratum	5	0.04	0	0.00	0	0.00
	C. Depressum	5	0.04	0	0.00	0	0.00
	C. sp.	6	0.04	0	0.00	5	0.02

Table 4.8a Cont'd

CHLOROPHYTA CONT'D	*Euastrum pectnatum*	0	0.00	5	0.03	0	0.00
	E. sp.	5	0.04	5	0.03	0	0.00
	Eudorina elegans	31	0.22	260	1.58	110	0.53
	Gonatozygon kinghani	4	0.03	0	0.00	0	0.00
	Gonium formosum	5	0.04	5	0.03	0	0.00
	Kirchnarella lunaris	0	0.00	0	0.00	10	0.05
	Microspora sp.	5	0.04	0	0.00	0	0.00
	Mougeotia calospora Czurda	0	0.00	2	0.01	0	0.00
	M. capucina Agardh	1094	9.83	749	4.55	254	1.23
	M. sphaercarpa	15	0.11	5	0.03	25	0.12
	Oedogonium grande	0	0.00	3	0.02	0	0.00
	O. suecicum	24	0.17	0	0.00	0	0.00
	Pandorina simplex	5	0.04	0	0.00	0	0.00
	P. morum	300	2.28	490	3.59	626	3.02
	P. pallidum	0	0.00	0	0.00	130	0.63
	Pandorina sp	1290	9.09	582	3.54	578	2.79
	Pediastrum Simplex	0	0.00	5	0.03	0	0.00
	P. angulosum	3	0.02	5	0.03	6	0.03
	P. duplex	10	0.07	15	0.09	9	0.04
	P. gracillimum	9	0.06	15	0.09	80	0.39
	Pleodorina illinoisensis	5	0.07	35	0.21	121	0.58
	Pleurotaenium coronatum	16	0.11	0	0.00	0	0.00

Table 4.8a Cont'd

CHLOROPHYTA CONT'D	*Pleurotaenium trabecula*	0	0.00	0	0.00	4	0.02
	Scenedesmus ovalternans	0	0.00	5	0.03	5	0.02
	S. quadricauda	77	0.54	55	0.33	82	0.40
	S. apiculatus	5	0.04	0	0.00	0	0.00
	Selenastrum sp.	0	0.00	5	0.03	0	0.00
	Sirogonium melanosporum	242	1.71	221	1.34	337	1.63
	Spirogyra majuscula	128	0.90	145	0.88	429	2.07
	S. karnalae	3	0.02	0	0.00	16	0.08
	S. rehnhardi	9	0.06	0	0.00	6	0.03
	S. kolae Hajdu	94	0.66	357	2.17	1277	7.61
	S. communis	616	4.70	650	3.95	447	2.16
	S. dubia	1347	12.05	250	1.52	455	2.20
	S. lineatum	16	0.11	16	0.10	0	0.00
	Staurastrum leptocladium	0	0.00	0	0.00	5	0.02
	S. longispinum	0	0.00	0	0.00	10	0.05
	S. octoverrucosum	0	0.00	5	0.03	0	0.00
	S. lezae	0	0.00	0	0.00	5	0.02
	S. convergens	104	0.73	761	4.63	65	0.31
	Staurodesmus subulatus	0	0.00	5	0.03	0	0.00
	S.curvatus	0	0.00	5	0.03	5	0.02
	Stigeoclonium subsecuredum	0	0.00	16	0.10	1	0.00
	Ulothrix zonata	200	1.45	235	1.43	125	0.60

Table 4.8a Cont'd

	Ulothrix tenuissima	30	0.21	0	0.00	34	0.16
	Volvox Africana	1	0.01	24	0.15	18	0.09
	Volvox aureus	24	0.17	40	0.24	46	0.22
	Volvox sp	1	0.01	4	0.02	0	0.00
CYANOPHYTA	*Anabaena alatospora*	5	0.04	5	0.03	25	0.12
	Anabaena spiroides	40	0.28	30	0.18	5	0.02
	Aphanothece sacrum	68	0.48	0	0.00	0	0.00
	Coelosphaerium pallidum	90	0.63	121	0.74	65	0.31
	Coelosphaerium sp	978	7.05	426	2.59	592	2.86
	Gloeotrichia pisum	987	0.06	16	0.10	0	0.00
	Lyngbya aestuarii	0	0.00	0	0.00	8	0.04
	Merimespodia elegans	89	0.63	77	0.47	502	2.42
	Merismepodia tennuissima	16	0.11	0	0.00	1440	6.95
	Microcystis magnata	0	0.00	0	0.00	160	0.77
	Microcystis robusta	4	0.03	15	0.09	0	0.00
	Microcystis wesenbergi	30	0.21	150	0.91	250	1.21
	Microcystis aeruginosa	1023	7.21	831	5.05	953	4.60
	Oscillatoria princeps	0	0.00	0	0.00	120	0.58
	Plectonema sp	0	0.00	4	0.02	8	0.04
	Spirulina aeruginosa	0	0.00	8	0.05	0	0.00
	Lyngbya majuscule	5	0.04	0	0.00	10	0.05
	Oscillatoria Limosa	40	0.28	255	1.55	0	0.00
	Oscillatoria bornettia	22	0.16	47	0.29	61	0.29
	Phormidium sp.	45	0.32	44	0.27	44	0.21

Table 4.8a Cont'd

DINO PHYTA	*Ceratium fuscum*	16	0.11	18	0.11	0	0.00
	Ceratium sp	24	0.17	20	0.12	0	0.00
EUGLENOPHYTA	*Euglena allorgei*	5	0.04	0	0.00	0	0.00
	E. gracilis	0	0.00	10	0.06	5	0.02
	E. Pisciformis	5	0.04	5	0.03	0	0.00
	E. Proxima	0	0.00	5	0.03	5	0.02
	E. Rubra	10	0.07	33	0.20	12	0.06
	E. Texta	0	0.00	10	0.06	10	0.05
	E. gracilis	0	0.00	5	0.03	0	0.00
	E. hyaline	16	0.11	0	0.00	0	0.00
	E. acitissima	14	0.10	18	0.11	4	0.02
	E. acus	22	0.16	25	0.15	10	0.05
	E. hyaline	0	0.00	8	0.05	0	0.00
	E. oxyuris	2	0.01	10	0.06	0	0.00
	E. sp	48	1.04	128	0.78	32	0.15
	E. spirogyra	40	0.28	7	0.04	2	0.01
	E. viridian	18	0.13	0	0.00	56	0.27
	E. viridis	0	0.00	10	0.06	10	0.05
	E. Oblonga	10	0.07	10	0.06	0	0.00
	Gymnodinium fuscum	56	1.24	120	0.77	73	0.35
	Lepocinclis Ovum	5	0.04	15	0.09	10	0.05
	L. playfairiana	30	0.21	15	0.09	0	0.00
	L. dextrossa	20	0.14	7	0.04	2	0.01
	L. ovum	25	0.18	15	0.09	5	0.02
	L. playfairiana	5	0.04	5	0.03	10	0.05
	Phacus acuminatus	20	0.14	0	0.00	0	0.00
	Phacus acuticauda	0	0.00	0	0.00	0	0.00

Table 4.8a Cont'd

EUGLENOPHYTA CONT'D	*Phacus curvicauda*	24	0.17	16	0.10	0	0.00
	Phacus acutissimus	5	0.04	0	0.00	0	0.00
	Strombomonas australis	2	0.01	4	0.02	0	0.00
	Strombomonas fluviatilis	20	0.14	4	0.02	84	0.41
	Strombomonas sp.	40	0.28	35	0.33	15	0.07
	Trachelomonas Armata	0	0.00	0	0.00	5	0.02
	T. eurystoma	8	0.06	0	0.00	0	0.00
	T. granulose	0	0.00	0	0.00	40	0.19
	T. hispida	15	0.11	20	0.12	15	0.07
Overall Total:		**14009**	**100.00**	**16013**	**100.00**	**19674**	**100.00**

Key: DNS –Downstream MDS – Midstream UPS - Uptream
AB – Abundance RAB – Relative Abundance

Table 4.8b: Spatial Phytoplankton Distribution and Abundance and Rank of Lower River Niger at Agenebode

DIVISION	Phytoplankton Species	DNS	MDS	UPS	Abundance	Rank
BACILLARIOPHYTA	*Aulacoseira granulata v.curvata*	20	25	45	90	58
	A. granulata v. angustissima f. spiralis	25	75	70	170	39
	A. granulata	1235	3122	3824	8181	1
	Actinoptychus splendens	7	1	14	22	90
	Actinolaenium cucurbitinum	6	1	26	33	52
	A. splendens	4	0	0	4	163
	Amphora ovalis	1	0	0	1	186
	Anomoeneis serians	5	0	0	5	127
	A. spectabillis	5	0	0	5	127
	Asterionella Formosa	0	0	12	12	88
	Bacillaria paradoxa	190	142	75	407	29
	Biddulphia regia	0	30	4	34	47
	Cosmarium trilobulatum	1	0	0	1	186
	Cyclotella meneghiniana	0	0	0	0	192
	Cymbella prostrata	3	0	2	5	173
	C. pusilla	0	0	10	10	91
	C. punctifera	4	5	5	14	185
	Desmogonium rabenhorstianum	0	2	0	2	174
	Diploneis smithii	0	1	0	1	186
	Eunotia asterionelloides	0	10	0	10	91
	Eunotia flexuosa	1	4	10	15	116
	E. filum	20	36	49	105	55
	Flagillaria javanica	120	0	272	392	15
	F. lineatum	0	0	200	200	18
	F. sp	671	782	763	2216	27
	Hydrosera trifoliata	2	0	0	2	174
	Melosira valdii	18	4	8	30	61
	M. varians Agardh	1	0	0	1	186
	Navicula acus.	15	5	35	55	53
	Navicula acus Cleve	75	44	48	167	51
	Nitzschia. Palae	5	15	10	30	106
	N. accicularis	45	25	20	90	58
	N. affinis Grunow	0	0	2	2	174
	Peridinium cinctum	10	8	0	18	104

Table 4.8b Cont'd

	Pinnularia gatunense	2	0	0	2	174
	P. Dactylus	0	5	0	5	127
	P. divergens	10	10	10	30	192
	P. Gibba	0	0	5	5	127
	P. Subcapitata	0	5	0	5	127
	P. Viridis	10	0	50	60	40
	P. brebisonii	0	0	5	5	127
	P. nobilis	16	0	0	16	76
	P. rivularis	14	0	0	14	76
	P. sp	0	12	0	12	88
	P. viridis	10	5	15	30	106
	P. decorum	0	0	5	5	127
	P. delicatulum	0	10	0	10	91
	Pleurosigma angulatum	0	10	0	10	91
	P. decorum	0	41	7	48	43
	P. sp.	0	0	0	0	192
	Stenopterobia pelagic	2	0	0	2	174
BACILLARIOPHYTA CONT'D	*S. rautenbachiae*	0	0	4	4	163
	Surirella engleri	4	0	0	4	163
	S. robusta	10	12	4	26	118
	S. angusta	0	5	0	5	127
	S. muellerri	2	0	0	2	174
	S. sp.	0	17	4	21	82
	S. Elegans	0	10	0	10	91
	S. Robusta	0	10	0	10	91
	Synedra acus	798	2043	2603	5444	2
	S. superb	8	6	12	26	126
	S. ulna	607	1597	1034	3238	7
	Tabellaria fenestrate	0	0	2	2	174
	T. floculosa	2	0	0	2	174
	T. sp	0	0	6	6	121
	Triceratium favus	45	0	8	53	41
CHAROPHYTA	*Nitella gracilis*	0	2	0	2	163
CHLOROPHYTA	*Actinotaenium globosum*	0	5	5	10	127
	Cladophora oligoclona	10	10	0	20	91
	Closterium acerosum	31	30	10	71	67
	C. closteroides	0	0	5	5	127

Table 4.8b Cont'd

	C. lieblenii	10	0	20	30	71
	C. pseudolulnula	5	5	0	10	127
	C. subulatum	5	0	0	5	127
	C. gracile	8	0	0	8	111
	C. incurvum	1	0	0	1	186
CHLOROPHYTA CONT'D	*C. lineatum*	8	14	10	32	125
	C. lunula	54	0	0	54	35
	C. monoliferum	0	10	0	10	91
	C. striolatun	2	0	0	2	174
	C. gracile	32	36	40	108	119
	C. pronum	12	34	68	114	37
	C. microporum	74	109	200	383	22
	Cosmarium. contractum	35	30	10	75	58
	C. pseudoconnatum	10	0	24	34	65
	C. starppersii	2	0	0	2	174
	C. subcucumis	0	0	30	30	50
	C. subspeciosum	0	6	0	6	121
	C. Decoratum	5	0	0	5	127
	C. Depressum	5	0	0	5	127
	C. sp.	6	0	5	11	124
	Euastrum pectnatum	0	5	0	5	127
	E. sp.	5	5	0	10	127
	Eudorina elegans	31	260	110	401	17
	Gonatozygon kinghani	4	0	0	4	163
	Gonium formosum	5	5	0	10	127
	Kirchnarella lunaris	0	0	10	10	91
	Microspora sp.	5	0	0	5	127
	Mougeotia calospora Czurda	0	2	0	2	174
	M. capucina Agardh	1094	749	254	2097	6
	M. sphaercarpa	15	5	25	45	71
	Oedogonium grande	0	3	0	3	171
	O. suecicum	24	0	0	24	57
	Pandorina simplex	5	0	0	5	127
	P. morum	300	490	626	1416	13
	P. pallidum	0	0	130	130	23
	Pandorina sp	1290	582	578	2450	8
	Pediastrum Simplex	0	5	0	5	127
	P. angulosum	3	5	6	14	172
	P. duplex	10	15	9	34	123
	P. gracillimum	9	15	80	104	33

	Pleodorina illinoisensis	5	35	121	161	28

Table 4.8b Cont'd

	Pleurotaenium coronatum	16	0	0	16	76
	Pleurotaenium trabecula	0	0	4	4	163
	Scenedesmus ovalternans	0	5	5	10	127
	S. quadricauda	77	55	82	214	56
	S. apiculatus	5	0	0	5	127
CHLOROPHYTA CONT'D	*Selenastrum sp.*	0	5	0	5	127
	Sirogonium melanosporum	242	221	337	800	26
	Spirogyra majuscula	128	145	429	702	12
	S. karnalae	3	0	16	19	83
	S. rehnhardi	9	0	6	15	116
	S. kolae Hajdu	94	357	1277	1728	4
	S. communis	616	650	447	1713	16
	S. dubia	1347	250	455	2052	5
	S. lineatum	16	16	0	32	76
	Staurastrum leptocladium	0	0	5	5	127
	S. longispinum	0	0	10	10	91
	S. octoverrucosum	0	5	0	5	127
	S. lezae	0	0	5	5	127
	S. convergens	104	761	65	930	9
	Staurodesmus subulatus	0	5	0	5	127
	S.curvatus	0	5	5	10	127
	Stigeoclonium subsecuredum	0	16	1	17	81
	Ulothrix zonata	200	235	125	560	30
	Ulothrix tenuissima	30	0	34	64	48
	Volvox Africana	1	24	18	43	66
	Volvox aureus	24	40	46	110	70
	Volvox sp	1	4	0	5	169
CYANOPHYTA	*Anabaena alatospora*	5	5	25	35	68
	Anabaena spiroides	40	30	5	75	49
	Aphanothece sacrum	68	0	0	68	34
	Coelosphaerium pallidum	90	121	65	276	38
	Coelosphaerium sp	978	426	592	1996	10
	Gloeotrichia pisum	987	16	0	1003	84
	Lyngbya aestuarii	0	0	8	8	111
	Merimespodia elegans	89	77	502	668	11
	Merismepodia tennuissima	16	0	1440	1456	3
	Microcystis magnata	0	0	160	160	21
	Microcystis robusta	4	15	0	19	86
	Microcystis wesenbergi	30	150	250	430	19

	Oscillatoria princeps	0	0	120	120	24
	Plectonema sp	0	4	8	12	119

Table 4.8b Cont'd

DINOPHYTA	*Spirulina aeruginosa*	0	8	0	8	111
	Lyngbya majuscule	5	0	10	15	106
	Microcystis aeruginosa	1023	831	953	2807	20
	Oscillatoria Limosa	40	255	0	295	14
	Oscillatoria bornettia	22	47	61	130	46
	Phormidium sp.	45	44	44	133	186
	Ceratium fuscum	16	18	0	34	74
	Ceratium sp	24	20	0	44	61
EUGLENOPHYTA	*Euglena allorgei*	5	0	0	5	127
	E. gracilis	0	10	5	15	106
	E. Pisciformis	5	5	0	10	127
	E. Proxima	0	5	5	10	127
	E. Rubra	10	33	12	55	63
	E. Texta	0	10	10	20	91
	E. gracilis	0	5	0	5	127
	E. hyalina	16	0	0	16	76
	E. acitissima	14	18	4	36	87
	E. acus	22	25	10	57	85
	E. hyaline	0	8	0	8	111
	E. oxyuris	2	10	0	12	104
	E. sp	48	128	32	208	25
	E. spirogyra	40	7	2	49	44
	E. viridian	18	0	56	74	36
	E. viridis	0	10	10	20	91
	E. Oblonga	10	10	0	20	91
	Gymnodinium fuscum	56	120	73	249	31
	Lepocinclis Ovum	5	15	10	30	106
	L. playfairiana	30	15	0	45	54
	L. dextrossa	20	7	2	29	75
	L. ovum	25	15	5	45	71
	L. playfairiana	5	5	10	20	161
	Phacus acuminatus	20	0	0	20	69
	Phacus acuticauda	0	0	0	0	192
	Phacus curvicauda	24	16	0	40	64
	Phacus acutissimus	5	0	0	5	127
	Strombomonas australis	2	4	0	6	170
	Strombomonas fluviatilis	20	4	84	108	32
	Strombomonas sp.	40	35	15	90	45
	Trachelomonas Armata	0	0	5	5	127
	T. eurystoma	8	0	0	8	111
	T. granulose	0	0	40	40	42
	T. hispida	15	20	15	50	162
Overall Total:		**14009**	**16013**	**19674**	**49696**	

Key: DNS –Downstream MDS – Midstream UPS - Uptream

Table 4.9: Percentage Spatial Distribution of the Phytoplankton Taxa Across the Sampling Zones

	DNS		MDS		UPS	
DIVISION	No of individual	%	No of individual	%	No of individual	%
BACILLARIOPHYTA	4029	29.50	8135	51.34	9278	48.19
CHAROPHYTA	0	0.00	4	0.02	0	0.00
CHLOROPHYTA	6033	47.87	5269	32.63	5748	29.38
CYANOPHYTA	3442	17.52	2029	12.33	4243	20.48
DINOPHYTA	40	0.28	38	0.23	0	0.00
EUGLENOPHYTA	465	4.83	540	3.44	405	1.95
TOTAL	**14009**	**100.00**	**16013**	**100.00**	**19674**	**100.00**

Key: DNS –Downstream MDS – Midstream UPS - Uptream

Table 4.10: Spatial Phytoplankton Distribution at the Various Sampling Zones on Lower River Niger at Agenebode, Nigeria

DIVISION	DNS	MDS	UPS	TOTAL	%
BACILLARIOPHYTA	4029	8135	9278	**21442**	**43.15**
CHAROPHYTA	0	4	0	**4**	**0.00**
CHLOROPHYTA	6033	5269	5748	**17050**	**34.31**
CYANOPHYTA	3442	2029	4243	**9714**	**19.55**
DINOPHYTA	40	38	0	**78**	**0.16**
EUGLENOPHYTA	465	540	405	**1410**	**2.84**
TOTAL	**14009**	**16013**	**19674**	**49696**	**100.00**
%	**28.19**	**32.22**	**39.59**	**100.00**	

Key: DNS –Downstream MDS – Midstream UPS - Uptream

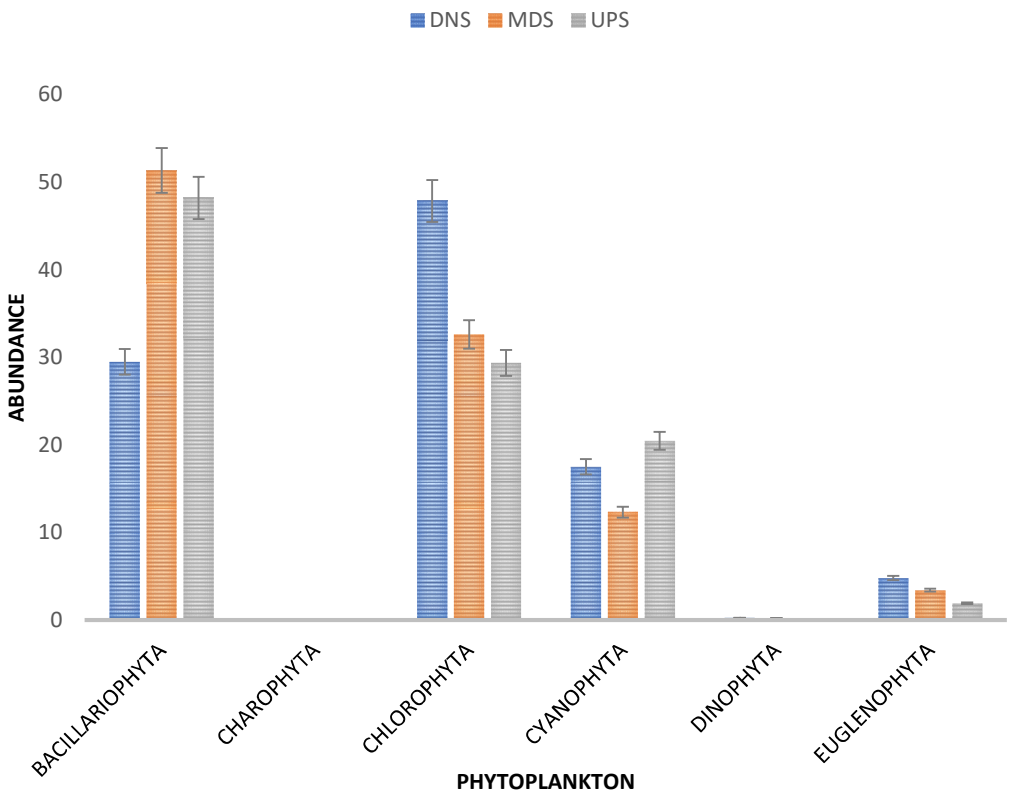


Figure 4.3: Spatial Phytoplankton Distribution at the Sampling Zones on Lower River Niger at Agenebode, Nigeria

Table 4. 11: Spatial Diversity Indices of the Phytoplankton in Lower River at Agenebode

Phytoplankton Diversity Indices	DNS	MDS	UPS
Taxa_S	133	123	117
Individuals	14185	16454	20719
Dominance_D	0.0636	0.08423	0.07773
Simpson_1-D	0.9364	0.9158	0.9223
Shannon_H	3.26	3.125	3.169
Evenness_e^H/S	0.1958	0.1851	0.2033
Menhinick	1.117	0.9589	0.8128
Margalef	13.81	12.57	11.67
Equitability_J	0.6666	0.6494	0.6654
Fisher_alpha	20.3	18.04	16.38

Key: DNS –Downstream MDS – Midstream UPS - Uptream

Table 4.12: Seasonal Distribution Phytoplankton Species in Lower River Niger at Agenebode, Nigeria

DIVISION	Phytoplankton Species	Wet Season	Dry Season	Abundance
BACILLARIOPHYTA	*Aulacoseira granulata v.curvata*	35	55	90
	A. granulata v. angustissima f. spiralis	45	125	170
	A. granulata	2235	5946	8181
	Actinoptychus splendens	7	15	22
	Actinolaenium cucurbitinum	6	27	33
	A. splendens	4	4	8
	Amphora ovalis	1	0	1
	Anomoeneis serians	5	0	5
	A. spectabillis	5	0	5
	Asterionella Formosa	0	0	0
	Bacillaria paradoxa	190	217	407
	Biddulphia regia	4	30	34
	Cosmarium trilobulatum	1	0	1
	Cyclotella meneghiniana	0	0	0
	Cymbella prostrata	3	2	5
	C. pusilla	0	10	10
	C. punctifera	5	9	14
	Desmogonium rabenhorstianum	0	2	2
	Diploneis smithii	0	1	1
	Eunotia asterionelloides	0	10	10
	Eunotia flexuosa	3	12	15
	E. filum	39	66	105
	Flagillaria javanica	142	250	392
	F. lineatum	0	200	200
	F. sp	671	1545	2216
	Hydrosera trifoliata	2	0	2
	Melosira valdii	18	12	30
	M. varians Agardh	1	0	1
	Navicula acus.	25	30	55
	Navicula acus Cleve	75	92	167
	Nitzschia. Palae	15	15	30
	N. accicularis	45	45	90
	N. affinis Grunow	2	0	2
	Peridinium cinctum	10	8	18

Table 4.12: Cont'd

	Pinnularia gatunense	2	0	2
	P. Dactylus	0	5	5
	P. divergens	10	20	30
	P. Gibba	0	5	5
	P. Subcapitata	0	5	5
	P. Viridis	10	40	50
	P. brebisonii	5	0	5
	P. nobilis	16	0	16
	P. rivularis	14	0	14
	P. sp	0	12	12
	P. viridis	10	20	30
	P. decorum	0	5	5
	P. delicatulum	0	10	10
	Pleurosigma angulatum	10	10	20
	P. decorum	7	41	48
	P. sp.	0	0	0
	Stenopterobia pelagic	2	0	2
BACILLARIOPHYTA CONT'D	*S. rautenbachiae*	7	4	11
	Surirella engleri	4	0	4
	S. robusta	10	16	26
	S. angusta	0	5	5
	S. muellerri	2	0	2
	S. sp.	4	17	21
	S. Elegans	10	10	20
	S. Robusta	5	5	10
	Synedra acus	2798	2646	5444
	S. superb	8	18	26
	S. ulna	1977	1231	3208
	Tabellaria fenestrate	0	2	2
	T. floculosa	2	0	2
	T. sp	8	6	14
	Triceratium favus	45	8	53
CHAROPHYTA	*Nitella gracilis*	0	2	2
CHLOROPHYTA	*Actinotaenium globosum*	5	5	10
	Cladophora oligoclona	10	10	20
	Closterium acerosum	31	40	71
	C. closteroides	0	5	5

Table 4.12: Cont'd

	C. lieblenii	10	20	30
	C. pseudolulnula	5	5	10
	C. subulatum	5	0	5
	C. gracile	8	0	8
	C. incurvum	1	0	1
CHLOROPHYTA	*C. lineatum*	12	20	32
CONT'D	*C. lunula*	54	0	54
	C. monoliferum	0	10	10
	C. striolatun	2	0	2
	C. gracile	32	76	108
	C. pronum	46	68	114
	C. microporum	174	209	383
	Cosmarium. contractum	40	35	75
	C. pseudoconnatum	10	24	34
	C. starppersii	2	0	2
	C. subcucumis	10	20	30
	C. subspeciosum	0	6	6
	C. Decoratum	5	0	5
	C. Depressum	5	0	5
	C. sp.	6	5	11
	Euastrum pectnatum	0	5	5
	E. sp.	5	5	10
	Eudorina elegans	80	320	400
	Gonatozygon kinghani	4	0	4
	Gonium formosum	5	5	10
	Kirchnarella lunaris	10	0	10
	Microspora sp.	5	0	5
	Mougeotia calospora Czurda	0	2	2
	M. capucina Agardh	1264	803	2067
	M. sphaercarpa	15	30	45
	Oedogonium grande	0	3	3
	O. suecicum	24	0	24
	Pandorina simplex	5	0	5
	P. morum	526	890	1416
	P. pallidum	0	130	130
	Pandorina sp	1290	1160	2450
	Pediastrum Simplex	0	5	5
	P. angulosum	9	5	14
	P. duplex	19	15	34
	P. gracillimum	44	60	104
	Pleodorina illinoisensis	105	56	161

Table 4.12: Cont'd

	Pleurotaenium coronatum	16	0	16
	Pleurotaenium trabecula	0	4	4
	Scenedesmus ovalternans	0	10	10
	S. quadricauda	177	97	274
	S. apiculatus	5	0	5
CHLOROPHYTA	*Selenastrum sp.*	0	5	5
CONT'D	*Sirogonium melanosporum*	442	358	800
	Spirogyra majuscula	257	445	702
	S. karnalae	19	0	19
	S. rehnhardi	9	6	15
	S. kolae Hajdu	371	1357	1728
	S. communis	616	1097	1713
	S. dubia	1310	705	2015
	S. lineatum	16	16	32
	Staurastrum leptocladium	5	0	5
	S. longispinum	0	10	10
	S. octoverrucosum	0	5	5
	S. lezae	5	0	5
	S. convergens	169	761	930
	Staurodesmus subulatus	0	5	5
	S.curvatus	5	5	10
	Stigeoclonium subsecuredum	1	16	17
	Ulothrix zonata	232	318	550
	Ulothrix tenuissima	30	34	64
	Volvox Africana	19	42	61
	Volvox aureus	24	86	110
	Volvox sp	1	4	5
CYANOPHYTA	*Anabaena alatospora*	5	30	35
	Anabaena spiroides	40	35	75
	Aphanothece sacrum	68	0	68
	Coelosphaerium pallidum	90	186	276
	Coelosphaerium sp	1110	886	1996
	Gloeotrichia pisum	587	416	1003
	Lyngbya aestuarii	0	8	8
	Merimespodia elegans	189	479	668
	Merismepodia tennuissima	56	1400	1456
	Microcystis magnata	0	160	160
	Microcystis robusta	4	15	19
	Microcystis wesenbergi	130	300	430
	Oscillatoria princeps	0	125	125
	Plectonema sp	4	8	12

Table 4.12: Cont'd

	Spirulina aeruginosa	0	8	8
	Lyngbya majuscule	5	5	10
	Microcystis aeruginosa	1023	1784	2807
	Oscillatoria Limosa	40	255	295
	Oscillatoria bornettia	30	100	130
	Phormidium sp.	45	88	133
DINOPHYTA	*Ceratium fuscum*	5	34	39
	Ceratium sp	6	33	39
	Euglena allorgei	0	5	5
	E. gracilis	0	15	15
	E. Pisciformis	5	5	10
	E. Proxima	0	5	5
	E. Rubra	10	45	55
	E. Texta	0	10	10
	E. gracilis	0	5	5
	E. hyalina	10	6	16
	E. acitissima	14	22	36
	E. acus	11	46	57
	E. hyaline	0	8	8
	E. oxyuris	2	10	12
	E. sp	48	160	208
	E. spirogyra	32	17	49
	E. viridian	18	56	74
	E. viridis	0	20	20
	E. Oblonga	10	10	20
EUGLENOPHYTA	*Gymnodinium fuscum*	73	206	279
	Lepocinclis Ovum	5	25	30
	L. playfairiana	30	15	45
	L. dextrossa	20	9	29
	L. ovum	20	50	70
	L. playfairiana	5	15	20
	Phacus acuminatus	20	0	20
	Phacus acuticauda	0	0	0
	Phacus curvicauda	24	16	40
	Phacus acutissimus	11	5	16
	Strombomonas australis	2	4	6
	Strombomonas fluviatilis	20	88	108
	Strombomonas sp.	20	70	9s0
	Trachelomonas Armata	0	5	5
	T. eurystoma	8	0	8
	T. granulose	0	0	0
	T. hispida	12	38	50
Overall Total:		**20039**	**29657**	**49696**

Table 4.13: Seasonal Distribution Phytoplankton Families in Lower River Niger at Agenebode, Nigeria

	Wet Season	Dry Season	TOTAL	%
BACILLARIOPHYTA	8590	12852	21442	**43.15**
CHAROPHYTA	0	2	2	**0.00**
CHLOROPHYTA	7612	9438	17050	**34.31**
CYANOPHYTA	3426	6288	9714	**19.55**
DINOPHYTA	11	67	78	**0.16**
EUGLENOPHYTA	400	1010	1410	**2.84**
Total	**20039**	**29657**	**49696**	**100**
%	**40.30**	**59.70**	**100**	

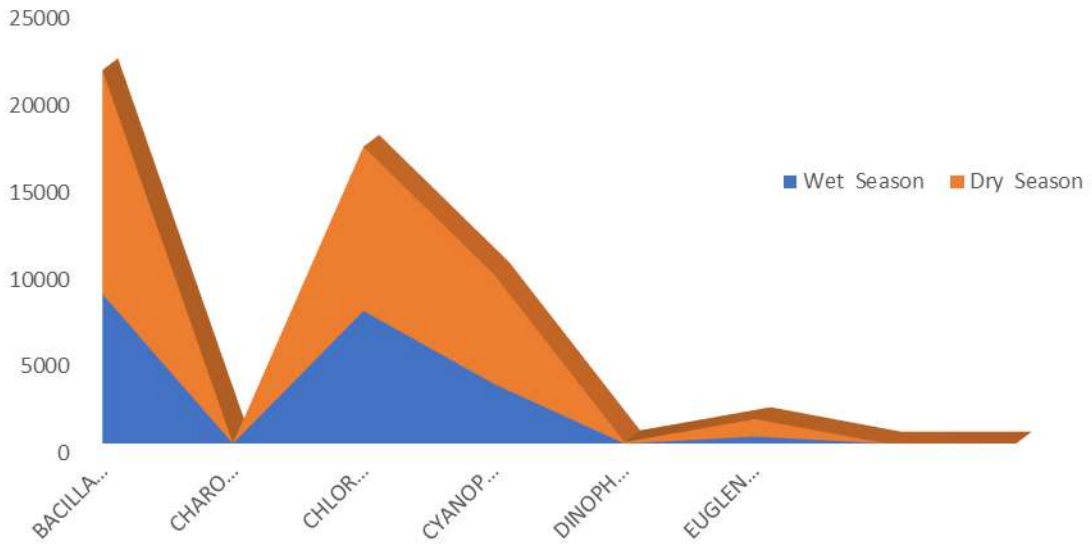


Figure 4.5: Seasonal Distribution Phytoplankton Families in Lower River Niger at Agenebode, Nigeria

4.3.2 Zooplankton Distribution and abundance in Lower River Niger at Agenebode

Spatial Zooplankton analysis of the Lower River Niger at Agenebode is represented in Table 4.14; consisting of three orders, ten families, thirteen genera and 20 species. A total of 2,897 zooplankton species were recorded during this study, with order copepod (1605 species) dominating in terms of abundance representing 55.40% of the total individual species (Table 4.16 and Figure 4.8). In this study, Cladocera (8 species) were found to be the group that have the highest number of species among the zooplankton recorded (Table 4.14). Among the planktonic identified, *Brachionus falcatus falcatus* of order Rotifera was most abundant while *Alona eximia, Moina reticulate, Diaphanosoma sp, Thermocyclops hyalinus* and *Thermocyclops taihokuensis* were least (5 species each) in abundance. Spatially, DNS was most (1054 species) abundant in zooplankton followed by UPS (953 species) and MDS (890 species) representing 36.38%, 32.90% and 30.72% respectively (Table 4.15and 4.16). Moreover, the family Cyclopidae was most (55.06%) abundant spatially in the zooplankton obtained in Lower River Niger at Agenebode while the family Chydoridae recorded the least (0.17%) (Table 4.17 and Table 4.18)

Zooplankton species composition and abundance in the season of rains were higher than in the season of dry with the month of August recording the most (496 species) and abundance was least in June (101 species) in the raining season whereas the month of April recorded the highest (444 species) and 150 species for April in the dry season (Figure 4.9). There was no (at $P<0.05$) significant difference spatially in the distribution and abundance of zooplankton, while there was (at $P<0.05$) significant difference seasonally in the distribution and abundance of zooplankton obtained in the Lower River Niger at Agenebode.

Table 4.14: Spatial Zooplankton Abundance of the Lower River Niger

TAXONOMY	SPECIES	AB	DNS RAB	AB	MDS RAB	AB
PHYLUM ARTHROPODA						
CLASS CRUSTACEA						
SUB CLASS BRANCHIOPODA						
ORDER CLADOCERA						
BOSMINIDAE						
	Bosmina longirostris	30	2.58	71	6.27	64
	Bosminopsis deitersi	38	3.07	9	0.8	10
CHYDORIDAE						
	Alona eximia	0	0	5	0.44	0
DAPHNIDAE						
	Ceriodaphnia cornuta	15	1.05	5	0.44	0
MOINIDAE						
	Moina micrura	42	4.32	28	2.47	3
	Moina reticulata	5	0.35	0	0	0
SIDIDAE						
	Diaphanosoma excisum	62	4.32	25	2.65	46
	Diaphanosoma sp	2	0.14	2	0.18	1
SUB CLASS COPEPODA						
ORDER CYCLOPOIDA						
CYCLOPIDAE	*Eucyclops serrulatus*	29	2.02	13	1.15	43
	Mesocyclops bodanicola	60	4.18	70	8.75	41
	Microcyclops varicans	20	1.39	22	1.94	15
	Thermocyclops hyalinus	5	0.35	0	0	0
	Thermocyclops neglectus	216	15.05	230	23.67	163
	Thermocyclops taihokuensis	5	0.35	0	0	0
	Tropocyclops prasinus	200	18.26	212	22.27	251
HARPACTICOIDA	*Nauplius larva of copepod*	4	0.28	6	0.53	0

Table 4.14: Cont'd

SUPERCLASS ROTIFERA CLASS MONOGONONTA ORDER PLOIMA							
BRACHIONIDAE	*Brachionus calyciflorus anuraciformis*	54	3.76	30	2.65	94	8.21
	Brachionus falcatus falcatus	257	37.83	158	25.44	220	35.48
	Brachionus sp.	4	0.28	4	0.35	0	0
LECANIDAE	*Lecane sp*	6	0.42	0	0	2	0.17
OVERALL TOTAL		**1054**	**100**	**1605**	**100**	**953**	**100**

DNS- Downstream, MDS – Midstream, UPS – Upstream

AB – Abundance *RAB – Relati*ve Abundance

Table 4.15: Percentage Spatial Distribution of the Major Zooplankton Taxa of Lower River Niger at Agenebode

Major taxa	DNS		MDS		UPS		Total	%
	No of individual	%	No of individual	%	No of individual	%		
CLADOCERA	194	18.41	145	16.29	124	13.01	463	15.98
COPEPODA	539	51.14	553	62.13	513	53.83	1605	55.40
ROTIFERA	321	30.46	192	21.57	316	33.16	829	28.62
Total	**1054**	**100**	**1605**	**100**	**953**	**100**	**2897**	**100**
%	36.38		30.72		32.90		100.00	

DNS- Downstream, MDS – Midstream, UPS – Upstream

Table 4.16: Spatial Zooplankton Major Taxa Distribution at the Various Sampling Sites on Lower River Niger at Agenebode, Nigeria.

	CLADOCERA	COPEPODA	ROTIFERA	Total	%
DNS	194	539	321	1054	36.38
MDS	145	553	192	890	30.72
UPS	124	513	316	953	32.90
Total	1054	1605	829	2897	100.00
%	15.98	55.40	28.62	100.0	

DNS- Downstream, MDS – Midstream, UPS – Upstream

Table 4.17: Spatial Zooplankton Families' Distribution of Lower River Niger at Agenebode

ZOOPLANKTON FAMILY	BOS	CHY	DAP	MOI	SID	CYC	HAR	BRA	LEC	OVERALL TOTAL	%
DNS	68	0	15	47	64	535	4	315	6	**1054**	**36.38**
MDS	80	5	5	28	27	547	6	192	0	**890**	**30.72**
UPS	74	0	0	3	47	513	0	314	2	**953**	**32.90**
Total	**222**	**5**	**20**	**78**	**138**	**1595**	**10**	**821**	**8**	**2897**	**100**
%	**7.66**	**0.17**	**0.69**	**2.69**	**4.76**	**55.06**	**0.35**	**28.34**	**0.28**	**100**	

DNS- Downstream, MDS – Midstream, UPS – Upstream

BOS – Bosminidae; CHY– Chydoridae; DAP – Daphnidae; MOI– Moinidae; SID–Sididae; CYC– Cyclopidae; HAR– Harpacticoida; BRA– Brachionidae; LEC- Lecanidae

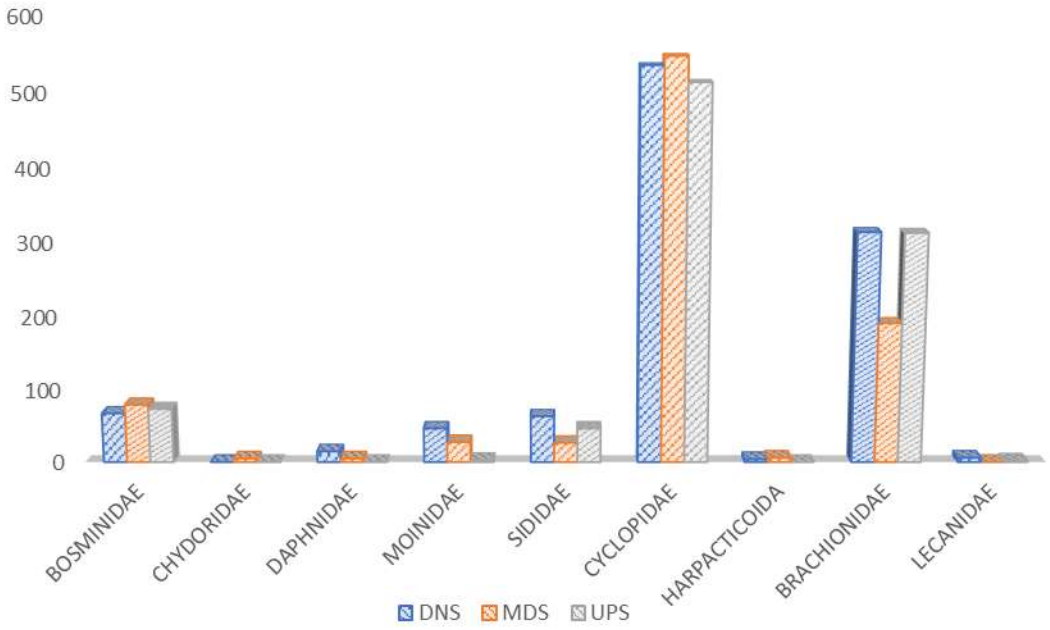


Figure 4.6: The Spatial Distribution of the Zooplankton Families in Lower River Niger at Agenebode

Table 4.18: Percentage Distribution of the Zooplankton Taxa

Taxa	%
Bosminidae	**7.66**
Chydoridae	**0.17**
Daphnidae	**0.69**
Moinidae	**2.69**
Sididae	**4.76**
Cyclopidae	**55.06**
Harpacticoida	**0.35**
Brachionidae	**28.34**
Lecanidae	**0.28**
Overall Total	**100.0**

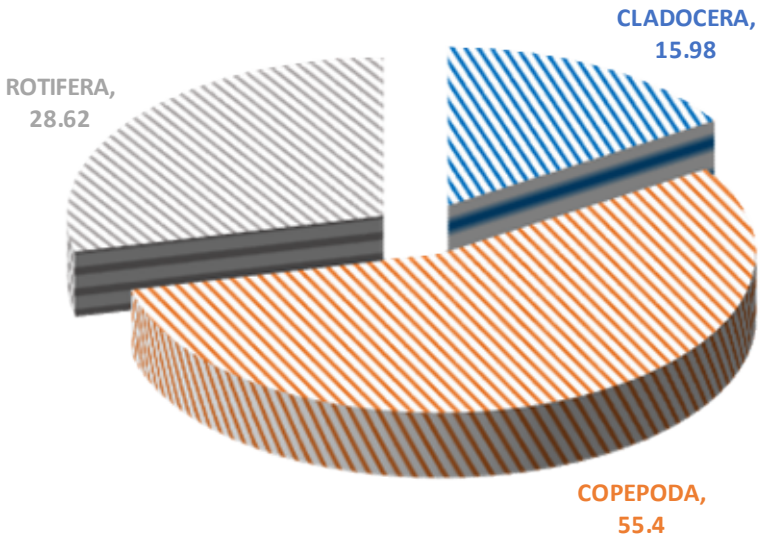


Figure 4.7: The Percentage Distribution of the Zooplankton Major Taxa in the Sampling Stations.

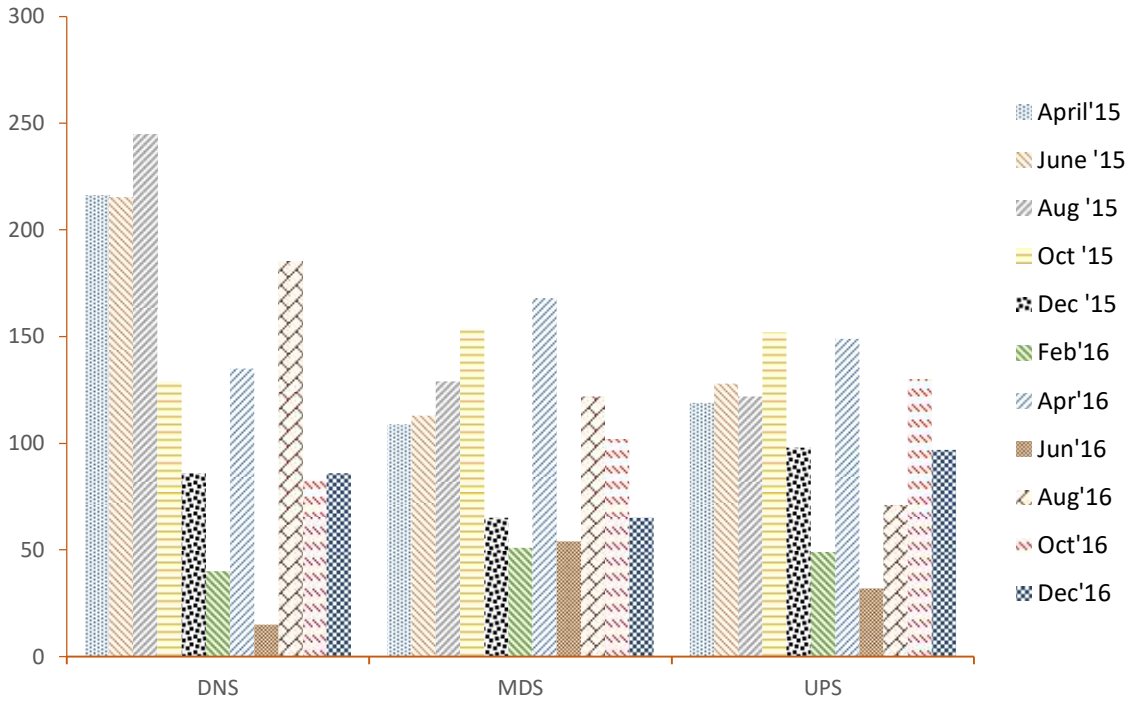


Figure 4.8: Monthly Spatial Distribution of the Zooplankton Abundance in Lower River Niger at Agenebode, Nigeria

4.4 Plankton Diversity Indices

The diversity of plankton composition of Lower River Niger at Agenebode was investigated for the period of study.

The Shannon-Weiner (H) zooplankton diversity index of the Lower River Niger for the period of study spatially ranged from 1.87 to 1.97 for UPS and MDS respectively and was highest (2.00) in DNS. The Simpson index of Diversity (1 – D) fluctuated between 0.79 and 0.82 for UPS, DNS and MDS respectively with MDS recording the highest (0.82). However, equitability values of 0.68 and 0.71 were recorded for DNS and MDS while UPS had the highest (0.73). The result of Margalef index of species richness was (2.48) for DNS, (2.13) for MDS and (1.70) for UPS as shown in (Table 4.19).

Table 4.19: Spatial Diversity Indices of the Zooplankton of Lower River Niger

Zooplankton Indices	DNS	MDS	UPS
Taxa_S	19	16	13
Individuals	1435	1132	1147
Dominance_D	0.2085	0.1846	0.2086
Simpson_1-D	0.7915	0.8154	0.7914
Shannon_H	2.002	1.968	1.865
Evenness_e^H/S	0.3897	0.4471	0.4964
Brillouin	1.972	1.936	1.839
Menhinick	0.5016	0.4756	0.3839
Margalef	2.476	2.133	1.703
Equitability_J	0.68	0.7097	0.727
Fisher_alpha	3.094	2.639	2.055

DNS- Downstream, MDS – Midstream, UPS – Upstream

4.5 Primary Productivity Studies in Lower River Niger at Agenebode

The spatial and temporal variation in primary productivity (Gross Primary Productivity, Net Primary Productivity and Community Respiration) obtained in Lower River Niger is presented in Tables 4.21 and 4.22

4.5.1 Gross Primary Productivity in Lower River Niger at Agenebode

Gross Primary Productivity (GPP) ranged from 0.73($g/O_2/m^3/d$) to 1.07 ($g/O_2/m^3/d$). The mean values were 0.73±0.03($g/O_2/m^3/d$), 0.89±0.28($g/O_2/m^3/d$) and 1.07±0.25($g/O_2/m^3/d$) for DNS, MDS and UPS respectively (Table 4.20). The grand mean value recorded for GPP was 0.897±0.29 ($g/O_2/m^3/d$). Seasonally, the higher (0.82±0.06 $g/O_2/m^3/d$) value was obtained in the dry season than the wet season (0.44±0.11 $g/O_2/m^3/d$). There was at $P>0.05$ no significant difference in the seasonal mean values of GPP (Table 4.21).

4.5.2 Net Primary Productivity in Lower River Niger at Agenebode

The mean Net Primary Productivity (NPP) ranged from 0.25±0.05 $g/O_2/m^3/d$ in DNS to 0.75±0.28 $g/O_2/m^3/d$ in UPS with spatial mean value of 0.45±0.23 $g/O_2/m^3/d$ as represented in Table 4.20. The NPP mean value of was higher (0.58±0.06 $g/O_2/m^3/d$) in season of dry than in rainy season (0.28±0.06 $g/O_2/m^3/d$). Nevertheless, there was no significant difference ($P>0.05$) in NPP average values among the seasons (Table 4.21).

4.5.3 Community Respiration in Lower River Niger at Agenebode

The mean Community Respiration (CR) value recorded in Lower River Niger at Agenebode for DNS, MDS and UPS zones were 0.48±0.12 $g/O_2/m^3/d$, 0.53±0.25 $g/O_2/m^3/d$ and 0.26±0.12 $g/O_2/m^3/d$. The highest (0.53±0.25 $g/O_2/m^3/d$) mean was recorded in the MDS zone while the lowest (0.26±0.12 $g/O_2/m^3/d$) mean value was recorded in the UPS zone. The mean CR value for the zones was 0.42±0.18 $g/O_2/m^3/d$ (Table. 4.20 and Figure 4.9). Nevertheless, there was no significant difference among the zones ($P>0.05$).

Seasonally, the mean CR obtained for the dry season (0.24±0.28 $g/O_2/m^3/d$) was higher in the dry season than the mean value of CR obtained in the wet season (0.16±0.12 $g/O_2/m^3/d$). The seasonal mean CR value recorded was 0.20±0.06 $g/O_2/m^3/d$ (Table 4.21 and Figure 4.10). However, there was no significant difference ($P<0.05$) seasonally in the CR of Lower River Niger at Agenebode.

Table 4.20: Spatial Variation of Primary Productivity of Lower River Niger at Agenebode

Parameters	DNS	MDS	UPS	P – value
Net Primary Productivity ($g/O_2/m^3/d$)	0.25 ± 0.05^a	0.36 ± 0.06^a	0.75 ± 0.28^b	0.43
Gross Primary Productivity ($g/O_2/m^3/d$)	0.73 ± 0.03^a	0.89 ± 0.28^a	1.07 ± 0.25^b	0.63
Community Respiration ($g/O_2/m^3/d$)	0.48 ± 0.12^a	0.53 ± 0.25^a	0.26 ± 0.12^b	0.20

DNS- Downstream, MDS – Midstream, UPS – Upstream

Table 4.21: Seasonal Variation Distribution of Primary Productivity of Lower River Niger at Agenebode

Parameters	Dry	Wet	P – value	Mean ± SD
Net Primary Productivity ($g/O_2/m^3/d$)	0.58±0.06	0.28 ±0.06	>0.05	0.43±0.21
Gross Primary Productivity ($g/O_2/m^3/d$)	0.82±0.06	0.44±0.11	>0.05	0.63±0.27
Community Respiration ($g/O_2/m^3/d$)	0.24 ±0.28	0.16±0.12	<0.05	0.20±0.06

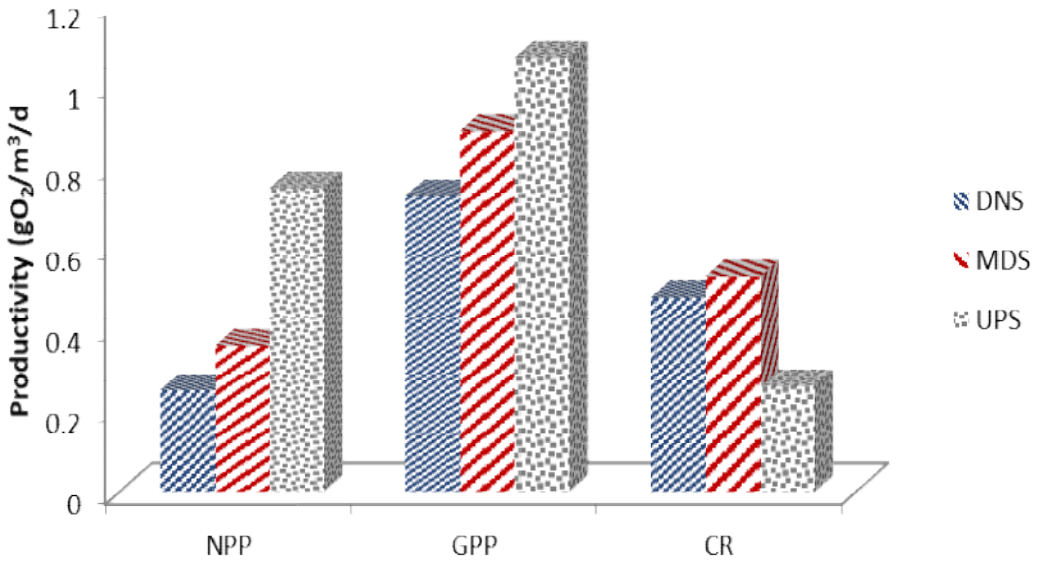


Figure 4.9: Spatial Variation of Primary Productivity in Lower River Niger at Agenebode

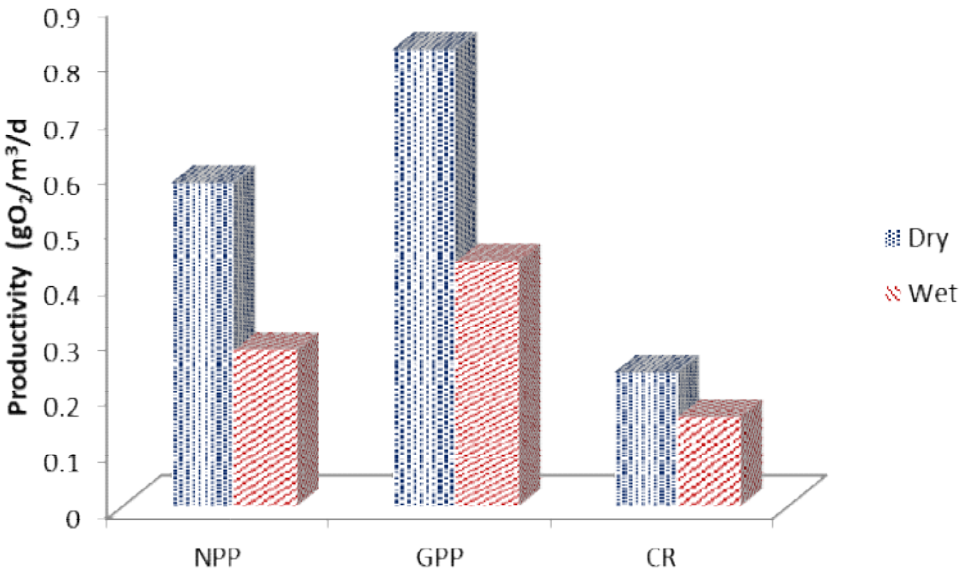


Figure 4.10: Seasonal Variation of Mean Primary Productivity (CR, NPP and GPP) of Lower River Niger at Agenebode

4.5.4 Effect of Physical Chemical Parameters on Primary Productivity of Lower River Niger at Agenebode

The effect of the physic-chemical parameters on primary productivity in the study period is presented in Table 4.22, they were severally significant. At $P<0.05$, GPP negatively correlated with phosphate ($r=-0.103$) and at $P<0.01$, it correlated negatively with water depth, temperature, DO, BOD, TSS, TDS, Alkaline, conductivity, sulphate and chloride but positively with pH, turbidity and transparency. At $P <0.05$, NPP correlated strong and positively with water depth and temperature ($r=-0.552$ and $r=0.451$ respectively) and at $P<0.01$, NPP and CR were inversely correlated with phosphate, DO, TSS, and transparency. CR correlated positively at $P<0.05$ with temperature.

Table 4.22: Pearson Correlations Matrix of Water Quality and Primary Productivity

	Ph	cond	turb	phospate	phosporus	sulphate	nitrate	Ammonia	chloride	DO	BOD	SS	TDS	alk	ca	mg	COD	Depth
pH	1																	
Cond	.087	1																
Turb	-.493**	-.321	1															
phospate	-.263	-.145	.713**	1														
phosporus	-.247	-.163	.737**	.998**	1													
Sulphate	-.352*	-.133	.770**	.556**	.576**	1												
Nitrate	.121	.496**	.102	.284	.280	.310	1											
ammonia	-.327	-.119	.886**	.770**	.792**	.809**	.431*	1										
Chloride	-.508**	-.076	-.140	-.206	-.224	-.136	-.525**	-.347*	1									
DO	-.005	.104	.062	.090	.086	-.095	.183	.105	.060	1								
BOD	.396*	.322	-.383*	-.211	-.213	-.340	.330	-.164	-.176	.590**	1							
SS	-.494**	-.236	.928**	.648**	.674**	.797**	.191	.923**	-.110	.135	-.318	1						
TDS	-.077	.088	-.053	-.188	-.176	-.044	.021	-.027	-.067	.144	.286	-.014	1					
Alk	-.022	-.173	.213	.093	.099	.086	.052	.198	-.162	.095	-.080	.194	-.092	1				
Ca	.050	.030	-.013	.073	.082	.120	.010	.043	.069	-.173	-.056	-.013	-.087	.016	1			
Mg	.379*	-.276	-.285	-.299	-.293	-.223	-.252	-.380*	-.107	-.315	-.130	-.381*	.184	-.084	-.077	1		
COD	.117	.046	-.184	-.180	-.183	-.002	-.079	-.162	-.088	-.168	-.032	-.234	-.142	.194	.142	.219	1	
Depth	-.338	-.459**	.606**	.431*	.446**	.287	-.194	.395*	.046	-.026	-.283	.434*	.220	.108	-.250	.147	-.439*	
Temp	.037	-.165	-.479**	-.317	-.326	-.295	-.475**	-.506**	.474**	-.234	-.072	-.418*	.048	-.150	.143	.158	.069	-.19
Trans	.142	.117	-.244	-.094	-.102	-.319	.144	-.190	-.016	.060	.113	-.174	-.347*	.067	.061	-.114	-.184	-.22
GPP	.169	-.211	.011	-.103	-.090	.020	-.013	-.067	-.223	-.355*	-.236	-.073	-.516**	.012	-.135	.164	.054	-.01
CR	-.058	.311	.082	-.066	-.066	.268	.134	.156	-.056	.173	-.065	.229	-.005	-.131	.198	-.324	.202	-.553*
NPP	.147	-.509**	-.046	-.062	-.048	-.160	-.245	-.136	-.019	-.340	-.086	-.164	-.033	-.002	-.245	.450**	-.190	.552*

**. Correlation is significant at the 0.01 level (2-tailed).
*. Correlation is significant at the 0.05 level (2-tailed).

4.6 Fish Abundance, Distribution, Diversity, Length-weight Relationship and Potential Yield

The temporal and spatial fish composition, distribution and diversity indices were recorded for the period of study covering two wet and two dry seasons.

4.6.1 Fish Species Abundance

The species of fish recorded during the period of investigation are as summarized in Table 4.23. A total of 1886 specimen comprising of 20 families, 30 genera and 45 species were identified. The checklist of fish families in Lower River Niger throughout the duration of study is represented in Table 4.24 and Figure 4.13. The most abundant family was Ciclidae (18.13%), followed by Mochokidae (16.97%), Alestidae (16.70%), Nopteridae (13.89%), Momyridae(12.67%), Claridae (9.07%), Clarotidae (5.09.28%), Gymnarchidea (1.80%), Citharrindae (1.59%), Arapameiridea (1.07%),Chanidae (1.01%), Bagridae (0.53%), Schilbidae (0.37%), Distichodontidae (0.58%), Cyprindae (0.40%), Malapteridae (0.27%),Polypteridae (0.18%), and the least dominant families were Protopteridae, Dasyatidea and Ichthyoboridae (0.05% each) The most dominant species was *Xenomystus nigri* representing 13.81% (262) followed by *Oreochromis niloticus* (10.19%, 213), *Synodontis clarias* (10.39%, 196), *Brycinus nurse* (9.38%, 177), *Clarias gariepinus* (5.99%, 113), *Chrysichthys nigrodigitatus* (4.40%, 83) and *Alestes baramoze* (4.19%, 79)(Plate1) while the least value of 0.05% was recorded for nine species represented by *Sarotherodon galilaeus, Heterobranchus sp, Labeo cuobie, Dasyatis garouensis, Ditichodus niloticus, Phago maculates, Synodontis membranaceous* and *Schilbe senegalensis with one species each.* The relative abundance for the period of study of Lower River Niger at Agenebode is presented in Table 4.25.

Seasonal variation of fish fauna of Lower River Niger at Agenebode for the duration of investigation showed significant difference (Table 4.26).

Table 4.23: Spatial Fish Distribution and Abundance of the Lower River Niger at Agenebode

FAMILY	*Species*	Species Richness	DNS	MDS	UPS	Abundance
BAGRIDAE	*Bagrus filamentous*	2	3	1	3	7
	Bagrus bayad		0	1	2	3
CLAROTEIDAE	*Chrysichthys macropogon*	4	1	0	1	2
	Chrysichthys nigrodigitatus		30	42	11	83
	Chrysichthys longifilis		5	0	3	8
	Clarotes laticeps		0	2	1	3
CHANIDAE	*Parachanna obscura*	1	3	2	14	19
ALESTIDAE	*Brycinus nurse*	6	94	61	22	177
	Alestes baremoze		42	31	6	79
	Brycinus longipimis		12	8	5	25
	Alestes senegalensis		2	1	1	4
	Micralestes selongates		10	10	0	20
	Micralestes acutidens		8	2	0	10
CICHLIDAE	*Hemichromis fasciatus*	5	0	1	1	2
	Oreochromis niloticus		99	91	23	213
	Coptodon guineensis		23	20	9	52
	Coptodon zilliii		33	29	12	74
CITHARRINDAE	*Sarotherodon galilaeus*	2	0	1	0	1
	Cithanirus citharus		6	8	7	21
	Citharinus latus		3	5	1	9
CLARIDAE	*Clarias anguillaris*	6	4	4	16	24
	Clarias gariepinus		25	28	60	113
	Clarias fuscus		4	2	8	14
	Heterobranchus longifilis		0	2	2	4
	Heterobranchus bidorsalis		0	0	1	1
	Heterobranchus boulengeri		4	10	1	15
ARAPAIMIDAE	*Heterotis niloticus*		6	6	7	19

CYPRINDAE	*Leptocypris niloticus*	2	1	1	2	4
	Labeo cuobie		0	0	1	1
DASYATIDAE	*Dasiatys garouaensis (Ray)*	1	0	1	0	1
DISTICHODONTIDAE	*Distichodus niloticus*	2	0	0	1	1
	Distichodus rostratus		1	1	3	5
GYMNARCHIDAE	*Gymnarchus niloticus*	1	6	20	8	34
ICHTHYBORIDAE	*Phago maculatus*		0	0	1	1
MALAPTERURIDAE	*Malapterurus electricus*	1	1	2	2	5
	Synodontis membranaceous	6	0	1	0	1
	Synadontis waterloti		8	5	13	26
MOCHOKIDAE	*Synodontis clarias*		55	71	70	196
	Synodontis coutetis		1	2	7	10
	Synodontis occeillifer		24	30	28	82
	Synodontis waterloti		1	0	4	5
	Gnathonemus pictus		0	0	1	1
	Hyperopisus occidentalis		0	12	0	12
	Mormyrobs oudotis		2	9	5	16
	Mormyrus macrophthalmus	9	10	21	33	64
MOMYRIDAE	*Petrocephalus baneansorgei*		0	0	2	2
	Marcusenius psittacus		19	12	33	64
	Marcusenius isidori		25	8	22	55
	Marcusenius branchistius		5	5	8	18
	Petrocephalus bovei		0	0	7	7
NOTOPTERIDAE	*Xenomystus nigri*	1	16	31	215	262
POLYPTERIDAE	*Polypterus ansorgei*	2	0	0	1	1
	Polypterus senegalus		0	0	2	2
PROTOPTERIDAE	*Protpterus annectens*	1	0	0	1	1
	Schilbe mystus		0	1	2	3
SCHILBEIDAE	*Schilbe senegalensis*	3	1	0	0	1
	schilbe uranoscopus		0	1	2	3
TOTAL			**593**	**602**	**691**	**1886**

DNS- Downstream, MDS – Midstream, UPS – Upstream

Table 4.24: Percentage Composition of Fish Species Families by Number in Lower River Niger at Agenebode

FAMILY	SPECIES RICHNESS	NUMBER	%
Bagridae	2	10	0.53
Claroteidae	4	96	5.09
Chanidae	1	19	1.01
Alesteidae	6	315	16.70
Cichlidae	5	342	18.13
Citharrindae	2	30	1.59
Claridae	6	171	9.07
Arapaimidae	1	19	1.01
Cyprindae	2	5	0.27
Dasyatidae	1	1	0.05
Distichodontidae	2	6	0.32
Gymnarchidae	1	34	1.80
Ichthyboridae	1	1	0.05
Malapteruridae	1	5	0.27
Mochokidae	6	320	16.97
Momyridae	9	239	12.67
Notopteridae	1	262	13.89
Polypteridae	2	3	0.16
Protopteridae	1	1	0.05
Schilbeidae	3	7	0.37
Total	**58**	**1886**	**100.00**

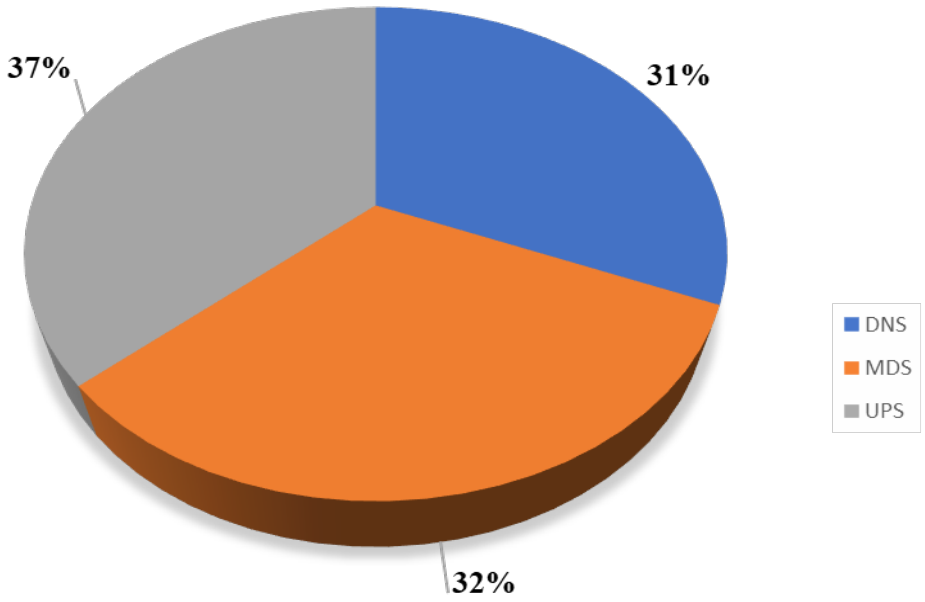


Figure 4.11: Percentage Spatial Composition and Distribution of Fish Abundance in Lower River Niger at Agenebode, Nigeria

Magnification:X20

a. *Xenomystus nigri*
b. *Synodontis clarias*
c. *Oreochromis niloticus*

Plate 1: The most Abundant Species in Lower River Niger at Agenebode

Table 4.25: Composition and Relative Abundance of the Fish Caught in Lower River Niger at Agenebode

Family	*Species*	DNS AB	RAB	MDS AB	RAB	UPS AB	RAB	TOTA AB
Bagridae	*Bagrus filamentous*	3	0.506	1	0.166	3	0.434	7
	Bagrus bayad	0	0.000	1	0.166	2	0.289	3
Claroteidae	*Chrysichthys macropogon*	1	0.169	0	0.000	1	0.145	2
	Chrysichthys nigrodigitatus	30	5.059	42	6.977	11	1.592	83
	Chrysichthys longifilis	5	0.843	0	0.000	3	0.434	8
	Clarotes laticeps	0	0.000	2	0.332	1	0.145	3
Chanidae	*Parachanna obscura*	3	0.506	2	0.332	14	2.026	19
	Brycinus nurse	94	15.852	61	10.133	22	3.184	177
	Alestes baremoze	42	7.083	31	5.150	6	0.868	79
	Brycinus longipimis	12	2.024	8	1.329	5	0.724	25
	Alestes senegalensis	2	0.337	1	0.166	1	0.145	4
	Micralestes selongates	10	1.686	10	1.661	0	0.000	20
Alestidae	*Micralestes acutidens*	8	1.349	2	0.332	0	0.000	10
	Hemichromis fasciatus	0	0.000	1	0.166	1	0.145	2
	Oreochromis niloticus	99	16.695	91	15.116	23	3.329	213
	Coptodon guineensis	23	3.879	20	3.322	9	1.302	52
	Coptodon zilliii	33	5.565	29	4.817	12	1.737	74
Cichlidae	*Sarotherodon galilaeus*	0	0.000	1	0.166	0	0.000	1
	Cithanirus citharus	6	1.012	8	1.329	7	1.013	21
Citharrindae	*Citharinus latus*	3	0.506	5	0.831	1	0.145	9
	Clarias anguillaris	4	0.675	4	0.664	16	2.315	24
	Clarias gariepinus	25	4.216	28	4.651	60	8.683	113
	Clarias fuscus	4	0.675	2	0.332	8	1.158	14
	Heterobranchus longifilis	0	0.000	2	0.332	2	0.289	4
	Heterobranchus bidorsalis	0	0.000	0	0.000	1	0.145	1
Claridae	*Heterobranchus boulengeri*	4	0.675	10	1.661	1	0.145	15
Arapaimidae	*Heterotis niloticus*	6	1.012	6	0.997	7	1.013	19

Table 4.25: Cont'd

Cyprindae	*Leptocypris niloticus*	1	0.169	1	0.166	2	0.289	4
	Labeo cuobie	0	0.000	0	0.000	1	0.145	1
Dasyatidae	*Dasiatys garouaensis (Ray)*	0	0.000	1	0.166	0	0.000	1
	Distichodus niloticus	0	0.000	0	0.000	1	0.145	1
Distichodontidae	*Distichodus rostratus*	1	0.169	1	0.166	3	0.434	5
Gymnarchidae	*Gymnarchus niloticus*	6	1.012	20	3.322	8	1.158	34
Ichthyboridae	*Phago maculatus*	0	0.000	0	0.000	1	0.145	1
Malapteruridae	*Malapterurus electricus*	1	0.169	2	0.332	2	0.289	5
Mochokidae	*Synodontis membranaceous*	0	0.000	1	0.166	0	0.000	1

	Synadontis waterloti	8	1.349	5	0.831	13	1.881	26
	Synodontis clarias	55	9.275	71	11.794	70	10.130	196
	Synodontis coutetis	1	0.169	2	0.332	7	1.013	10
	Synodontis occeillifer	24	4.047	30	4.983	28	4.052	82
	Synodontis waterloti	1	0.169	0	0.000	4	0.579	5
	Gnathonemus pictus	0	0.000	0	0.000	1	0.145	1
	Hyperopisus occidentalis	0	0.000	12	1.993	0	0.000	12
	Mormyrobs oudotis	2	0.337	9	1.495	5	0.724	16
	Mormyrus macrophthalmus	10	1.686	21	3.488	33	4.776	64
	Petrocephalus baneansorgei	0	0.000	0	0.000	2	0.289	2
	Marcusenius Psittacus	19	3.204	12	1.993	33	4.776	64
	Marcusenius isidori	25	4.216	8	1.329	22	3.184	55
	Marcusenius branchistius	5	0.843	5	0.831	8	1.158	18
Momyridae	*Petrocephalus bovei*	0	0.000	0	0.000	7	1.013	7
Notopteridae	*Xenomystus nigri*	16	2.698	31	5.150	215	31.114	262
	Polypterus ansorgei	0	0.000	0	0.000	1	0.145	1
Polypteridae	*Polypterus senegalus*	0	0.000	0	0.000	2	0.289	2
Protopteridae	*Protpterus annectens*	0	0.000	0	0.000	1	0.145	1
	Schilbe mystus	0	0.000	1	0.166	2	0.289	3
	Schilbe senegalensis	1	0.169	0	0.000	0	0.000	1
Schilbeidae	*schilbe uranoscopus*	0	0.000	1	0.166	2	0.289	3
Total		**593**	**100**	**602**	**100**	**691**	**100**	**188**

Key: AB – Abundance, RAB – Relative Abundance

DNS- Downstream, MDS – Midstream, UPS – Upstream

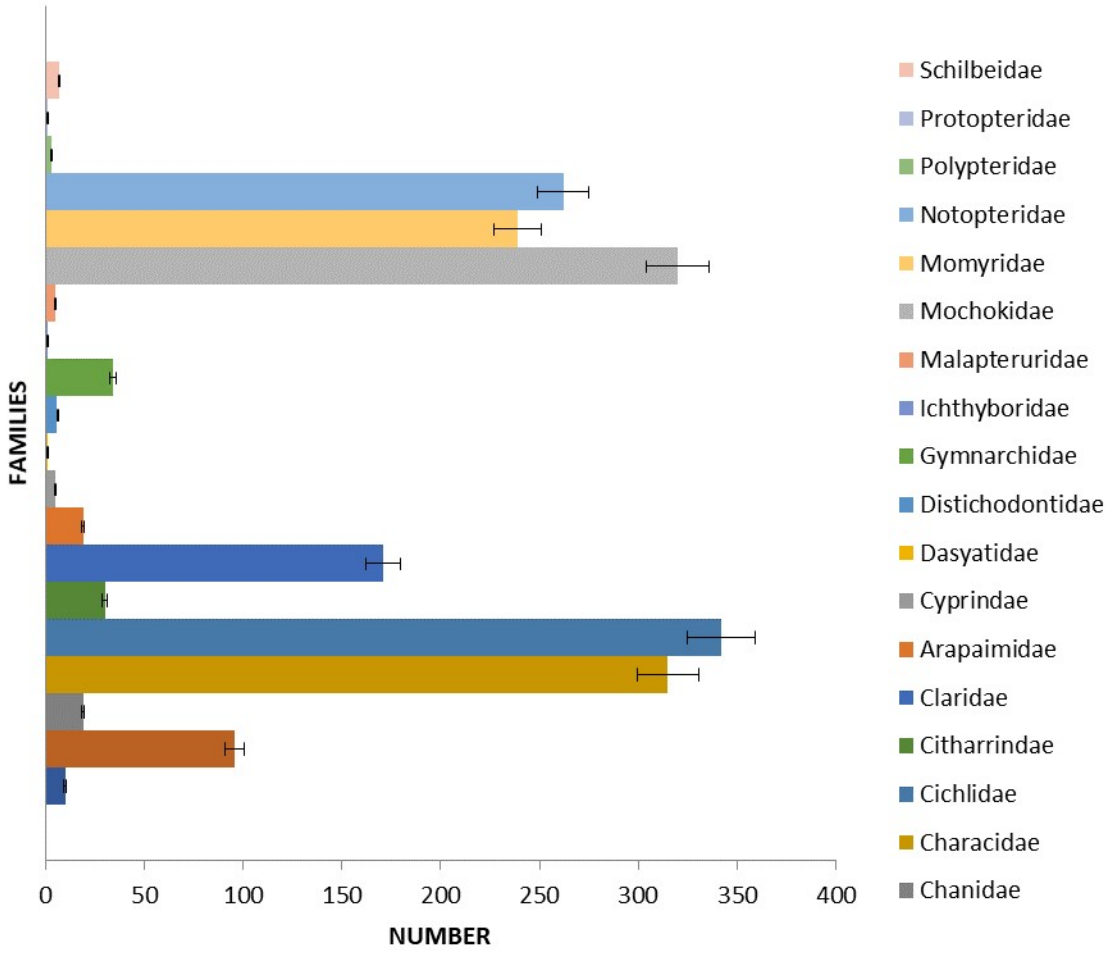


Figure 4.12: Total Fish (Families) Caught in Lower River Niger at Agenebode, Nigeria.

Table 4.26: Seasonal Composition and Relative Abundance of the Fish Caught in Lower River Niger.

Family	*Species*	Wet Season		Dry Season	
		AB	RAB	AB	RAB
Bagridae	*Bagrus filamentous*	3	0.28	4	0.37
	Bagrus bayad	1	0.12	2	0.19
Claroteidae	*Chrysichthys macropogon*	0	0.00	2	0.19
	Chrysichthys nigrodigitatus	33	4.06	50	4.66
	Chrysichthys longifilis	4	0.49	4	0.37
	Clarotes laticeps	0	0.00	3	0.28
Chanidae	*Parachanna obscura*	15	1.85	4	0.37
	Brycinus nurse	62	7.63	115	10.72
	Alestes baremoze	20	2.46	59	5.50
Alesteidae	*Brycinus longipimis*	5	0.62	20	1.86
	Alestes senegalensis	3	0.37	1	0.09
	Micralestes selongates	4	0.49	16	1.49
	Micralestes acutidens	2	0.25	8	0.75
	Hemichromis fasciatus	0	0.00	2	0.19
	Oreochromis niloticus	36	4.43	177	16.50
Cichlidae	*Coptodon guineensis*	21	2.58	31	2.89
	Coptodon zilliii	14	1.72	60	5.59
	Sarotherodon galilaeus	0	0.00	1	0.09
Citharrindae	*Cithanirus citharus*	17	2.09	4	0.37
	Citharinus latus	7	0.86	2	0.19
	Clarias anguillaris	8	0.98	16	1.49
	Clarias gariepinus	55	6.77	58	5.41
Claridae	*Clarias fuscus*	0	0.00	14	1.30
	Heterobranchus longifilis	0	0.00	4	0.37
	Heterobranchus bidorsalis	0	0.00	1	0.09
	Heterobranchus boulengeri	6	0.74	9	0.84
Arapameidae	*Heterotis niloticus*	9	1.11	10	0.93
Cyprindae	*Leptocypris niloticus*	0	0.00	1	0.09
	Labeo cuobie	2	0.25	2	0.19
Dasyatidae	*Dasiatys garouaensis (Ray)*	1	0.12	0	0.00
Distichodontidae	*Distichodus niloticus*	0	0.00	1	0.09
	Distichodus rostratus	1	0.12	4	0.37

Table 4.26 Cont'd

Gymnarchidea	*Gymnarchus niloticus*	21	2.58	13	1.21
Ichthyboridae	*Phago maculatus*	1	0.12	0	0.00
Malapteruridae	*Malapterurus electricus*	3	0.37	2	0.19
	Synodontis membranaceous	1	0.12	0	0.00
	Synadontis waterloti	15	1.85	11	1.03
Mochokidae	*Synodontis clarias*	151	18.57	45	4.19
	Synodontis coutetis	8	0.98	2	0.19
	Synodontis occeillifer	47	5.78	35	3.26
	Synodontis waterloti	3	0.37	2	0.19
Momyridae	*Gnathonemus pictus*	1	0.12	0	0.00
	Hyperopisus occidentalis	8	0.98	4	0.37
	Mormyrobs oudotis	16	1.97	0	0.00
	Mormyrus macrophthalmus	51	6.27	13	1.21
	Petrocephalus baneansorgei	2	0.25	0	0.00
	Marcusenius Psittacus	5	0.62	2	0.19
	Marcusenius isidori	53	6.52	11	1.03
	Marcusenius branchistius	15	1.85	3	0.28
	Petrocephalus bovei	50	6.15	5	0.47
Notopteridae	*Xenomystus nigri*	29	3.57	233	21.71
Polypteridae	*Polypterus ansorgei*	0	0.00	1	0.09
	Polypterus senegalus	0	0.00	2	0.19
Protopteridea	*Protpterus annectens*	0	0.00	1	0.09
Schilbeidae	*Schilbe mystus*	3	0.37	0	0.00
	Schilbe senegalensis	0	0.00	1	0.09
	schilbe uranoscopus	1	0.12	2	0.19
Total		**813**	**100.00**	**1073**	**100**

The catch composition varied seasonally, the higher number of fish was recorded in the dry season (1073) than in the wet season (813). The most dominant species during the wet season was *Synodontis clarias* (18.57%, 151), followed by *Brycinus nurse* (7.62%, 62), *Clarias gariepinus* (6.77%, 55), M*arcusenius isidori* (6.51%, 53), *Momyrus macrophthalmus* (6.27%, 51). *Xenomystus nigri* (21.71%, 233) was the most dominant species in the dry season followed by *Oreochromis niloticus* (16.50%, 177), *Brycinus nurse* (10.71%, 115), *Coptodonzillii* (5.59%, 60) and *Clarias gariepinus* (5.41%, 58). The overall mean abundance (Table 4.27 and Figure 4.14) was significantly higher than (29.10±9.48) in dry season than in wet season (25.39±82)

4.6.2 Spatial Fish Distribution

The spatial distribution of the fish fauna of Lower River Niger at Agenebode throughout the duration of investigation is as shown in Table 4.23. Upper stream (UPS) recorded the highest number of fishes (691) followed by the Mid-stream (MDS) (602), while the Downstream (DNS) had the lowest (593). All the fish species investigated were evenly distributed with *Xenomystus nigri*, *Oreochromis niloticus*, *Synodontis clarias*, *Brycinus nurse*, *Clarias gariepinus*, *Chrysichthys nigrotidigitatus* and *Coptodon zillii* leading the catches. The total abundance, (Table 4.27) was significantly higher (37.00%) in UPS followed by MDS (31.90%) while the least value (31.10%) was recorded for DNS.

Table 4.27: Percentage Composition and Seasonal Fish Family Distribution at the Various Sampling Sites on Lower River Niger at Agenebode, Nigeria

FAMILY	Wet Season		Dry Season	
	AB	RAB	AB	RAB
Bagridae	4	0.49	6	0.56
Claroteidae	37	4.55	59	5.50
Chanidae	15	1.85	4	0.37
Characidae	96	11.81	219	20.41
Cichlidae	71	8.73	271	25.26
Citharrindae	24	2.95	6	0.37
Claridae	63	7.75	93	8.67
Arapameidea	15	1.85	19	1.77
Cyprindae	2	0.25	3	0.28
Dasyatidea	1	0.12	0	0.00
Distichodontidae	1	0.12	5	0.47
Gymnarchidea	21	2.58	13	1.21
Ichthyboridae	1	0.12	0	0.00
Malapteruridae	3	0.37	2	0.19
Mochokidae	225	27.68	95	8.85
Momyridae	201	24.72	38	3.54
Notopteridae	29	3.57	233	21.74
Polypteridae	0	0.00	3	0.28
Protopteridea	0	0.00	1	0.09
Schilbeidae	4	0.49	3	0.28
TOTAL	813	100	1073	100

Note: AB – Abundance, RAB – Relative Abundance

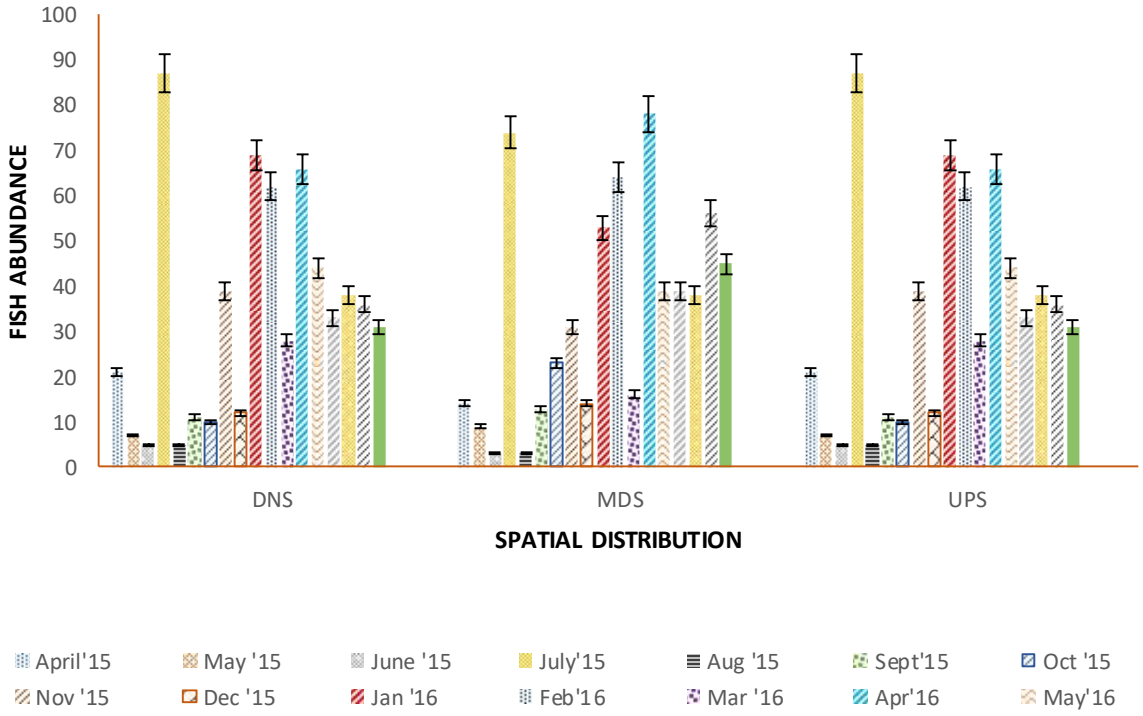


Figure 4.13: Spatio - temporal Distribution of the Fish Abundance Caught in Lower River Niger at Agenebode, Nigeria

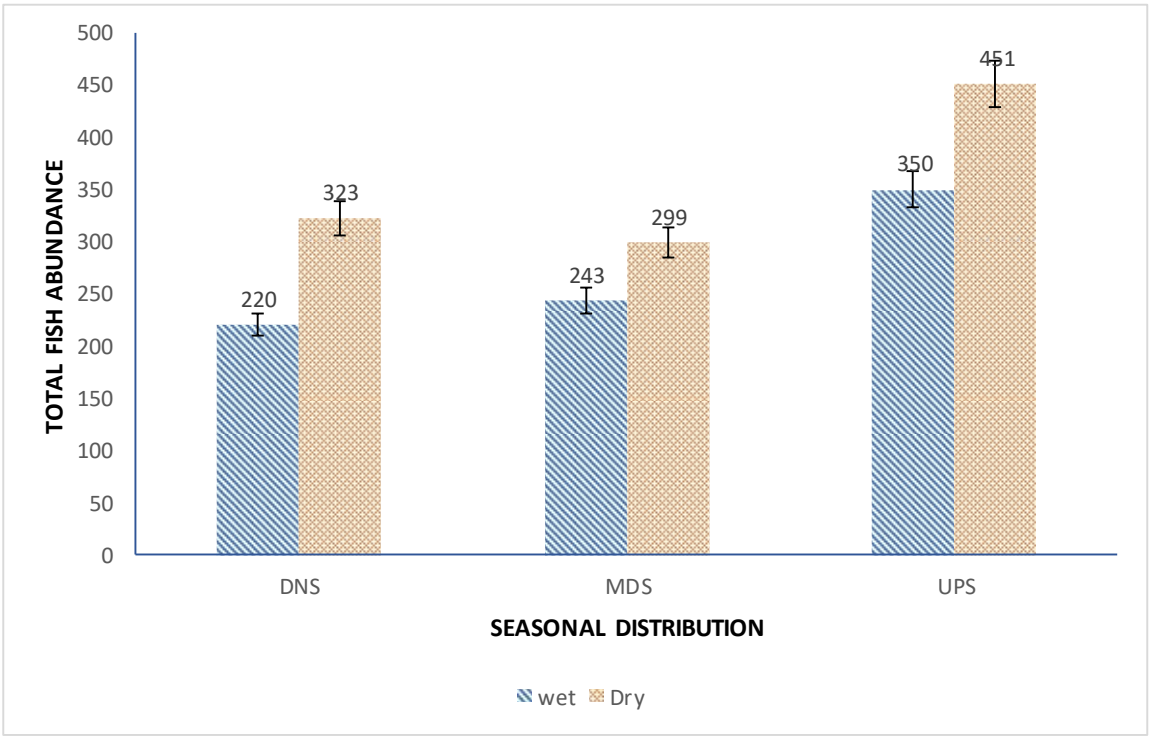


Figure 4.14: Fish Abundance in the Wet and dry Seasons across the Sampling Stations

4.6. 3 Fish Species Diversity Indices

The diversity of fish fauna in Lower River Niger at Agenebode was investigated monthly for the period of study. The study showed that there were a total of 1886 individual fish comprising of 20 families, 30 genera and 45 species were identified. The family Cichlidae (342) was the most abundance followed by Mochokidae (320), and Alesteidae (315) while the least abundance was Chanidae, Dasyatidae, and Gymnarchidae with one species each. The family Momyridea was the most dominant with nine species followed by the families Bagridae, Characidae, Mochokidae and Alesteidae with six species each, Cichlidae with five species, Malapteruridae with four species, Schilbidae with three species, the families of Citharindae, Cyprinidae, Distichodontidae and Polypteridae had two species each, and Chanidae, Dasyatis, Gymnachus, Ichthyboridae, Notopteridae and Protopteridae had one species each. The Shannon-Weiner (H) fish diversity index of the Lower River Niger for the period of study spatially ranged from 2.74 to 2.96 for UPS and DNS respectively and was highest in MDS. The Simpson index of Diversity (1 – D) fluctuated between 0.93 and 0.94 for DNS and MDS respectively while UPS recorded the lowest (0.83). However, equitability values of 0.81 and 0.82 were recorded for DNS and MDS respectively while UPS had the lowest (0.70). The result of Margalef index of species richness was (5.67) for DNS, (6.55) for MDS and (7.29) for UPS as shown in (Table 4.28).

Seasonally, the highest value of Shannon index (3.15) was obtained during the wet season in contrast to the value (2.57) for dry season (Table 4.29). The values obtained for all other diversity indices such as: Shannon evenness, Simpson, Berger Parker in wet season were higher than dry season except for Dominance in which the value was higher (0.13) in dry season than in wet season. The value of richness (58) was the same for both seasons.

Table 4.28: Spatial Diversity Indices for Fish Species in Lower River Niger

Diversity Indices	**DNS**	**MDS**	**UPS**
Species Richness	58	58	58
Taxa_S	38	44	50
Individuals	685	709	833
Dominance_D	0.07	0.06	0.15
Simpson_1-D	0.93	0.94	0.85
Shannon_H	2.96	3.08	2.74
Evenness_e^H/S	0.51	0.50	0.31
Menhinick	1.45	1.65	1.73
Margalef	5.67	6.55	7.29
Equitability_J	0.81	0.82	0.70

Table 4.29: Seasonal Diversity Indices for Fish Species in Lower River Niger

Diversity Indices	Wet Season	Dry Season
Species Richness	58	58
Dominance_D	0.06	0.13
Simpson_1-D	0.94	0.87
Shannon_H	3.15	2.57
Evenness_e^H/S	0.55	0.35
Menhinick	1.27	1.10
Margalef	5.87	5.12
Equitability_J	0.84	0.71

4.7: Length – Weight Relationship and Condition Factor

Standard Length (SL) and Somatic Weight (SW) of 1886 fish samples collected from Lower River Niger at Agenebode during the period of study were recorded. The variations in SL and SW for the dominant fish species (*Xenomystus nigri*, *Oreochromis niloticus*, *Synodontis clarias*, *Brycinus nurse*, and *Clarias gariepinus)* were obtained.

The sample size differed with each species of fish. Table 4.37 presents the length and weight relationship and condition factors of the five most abundant fish species of Lower River Niger at Agenebode. The exponential equations for the length and weight relationship are: *Xenomystus nigri* (W_t=0.21859(SL)$^{2.7981}$); *Synodontis clarias* (W_t=0.21859(SL)$^{2.2821}$) *Brycinus nurse* (W_t=-0.031452(SL)$^{2.4364}$), *Clarias gariepinus* (W_t=0.0070454(SL)$^{2.3859}$) and *Oreochromis niloticus* (W_t=-0.011683(SL)$^{2.2821}$). All the species studied *Xenomystus nigri,Synodontis clarias, Brycinus nurse, Clarias gariepinus* and *Oreochromis niloticus* exhibited allometric growth (b<3). The condition factor ranged from 0.27435 (*C. gariepinus*) to 3.17215 (*O. niloticus*).

The monthly K for each species is graphically represented as shown in Figures 4.15 to 4.19 and the Ks of all samples investigated are represented in Figure 4.20. There was significant difference in the Ks for the five fish species and the monthly K for each fish sample investigated:

Xenomystus nigri (0.76328±0.043); *Synodontis clarias* (0.60939±0.382) *Brycinus nurse (*3.125±0.018), *Clarias gariepinus* (0.27435±0.008) and *Oreochromis niloticus* (3.17215±0.003). All studied species were in good state except for *Clarias gariepinus*.

Table 4.30: Length - Weight Relationship for the Five Most Dominant Fish Species in Lower River Niger at Agenebode

SPECIES	N	K	EXPOPNETIAL EQUATION	R
Xenomystus nigri	215.00	0.76328	$W_t=0.21859(SL)^{2.7981}$	0.20846
Oreochromis niloticus	213.00	3.17215	$W_t=-0.011683(SL)^{2.2821}$	0.05114
Synodontis clarias	196.00	0.60939	$W_t=0.31841(SL)^{2.1107}$	0.61787
Brycinus nurse	177.00	3.125	$W_t=-0.031452(SL)^{2.4364}$	0.13388
Clarias gariepinus	113.00	0.27435	$W_t=0.0070454(SL)^{2.3859}$	0.08887

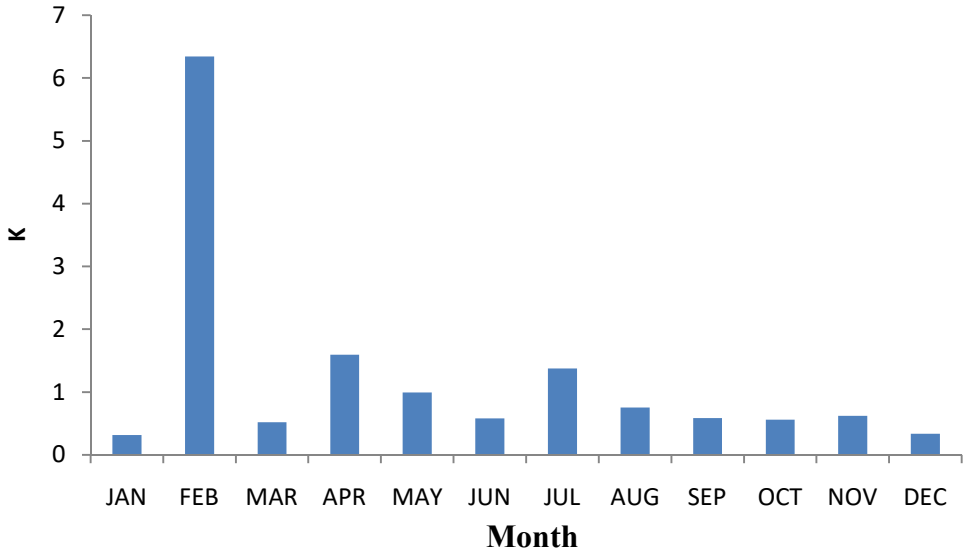


Figure 4.15: Monthly Condition Factor of *X*enomystus *nigri*

NB: K – Condition factor

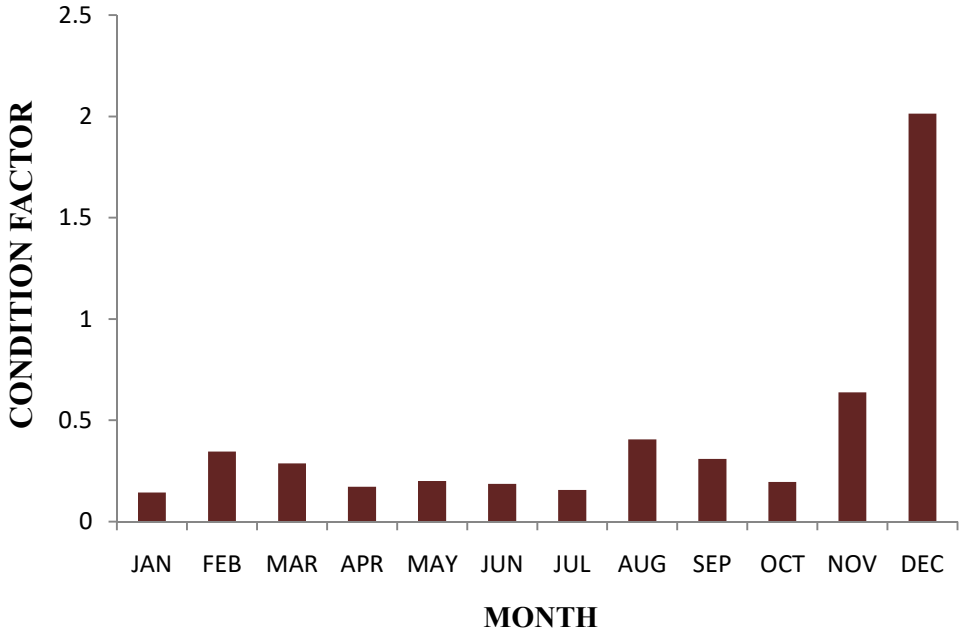


Figure 4.16: Monthly Condition Factor of *Clarias gariepinus*

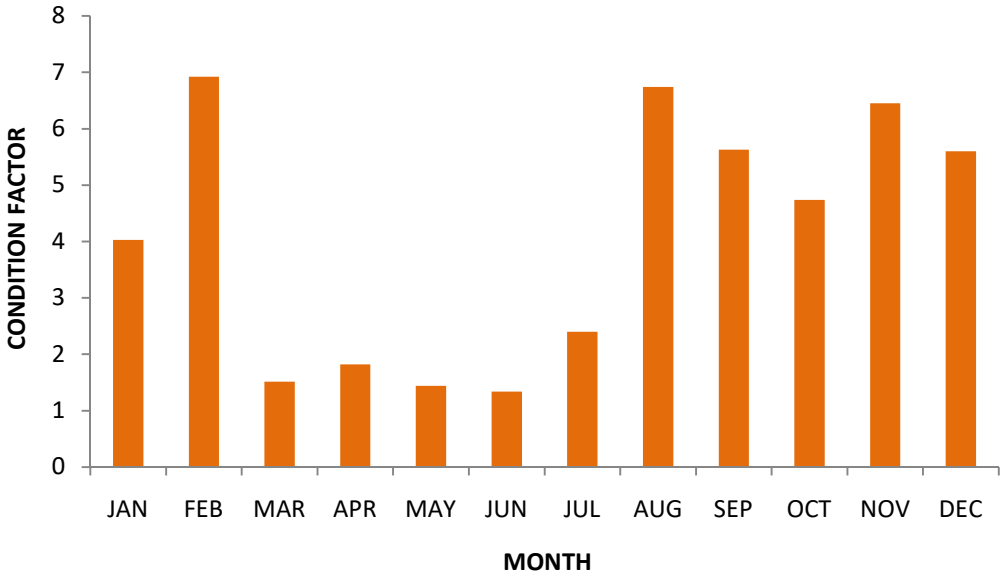


Figure 4.17: Monthly Condition Factor of *Oreochromis niloticus*

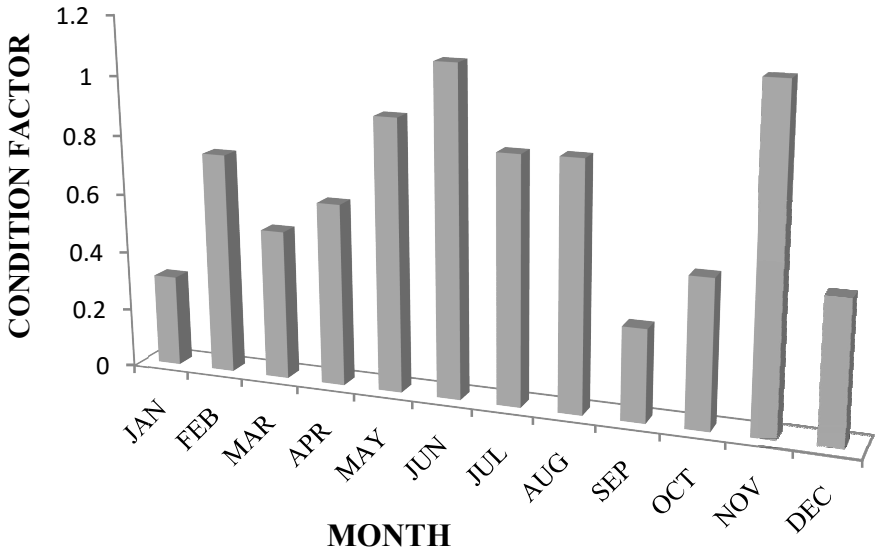


Figure 4.18: Monthly Condition Factor of *Synodontis clarias*

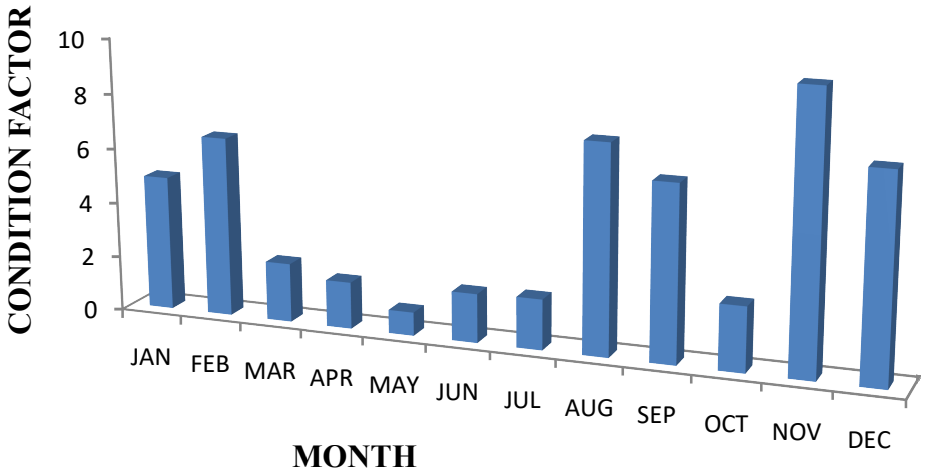


Figure 4.19: Monthly Condition Factor of Alestes nurse

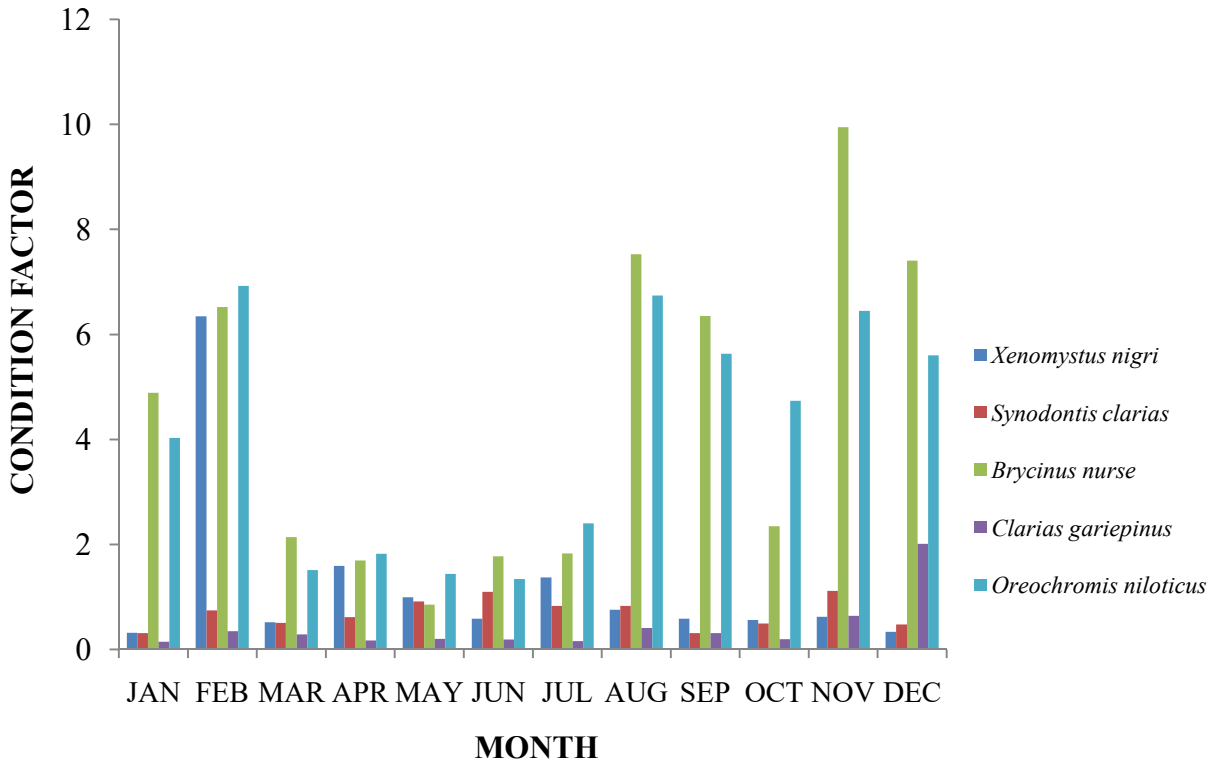


Figure 4.20: Monthly Condition Factor of the five most abundant fish species

4.8 Potential Fish Yield of Lower River Niger at Agenebode

The potential fish yield (PFY) of Lower River Niger spatially using Morpho-Edaphic Index (MEI) obtained from the mean conductivity and mean depth was 565.66kg/ha during the period of study with DNS having the highest (286.91kg/ha) potential fish yield and the lowest (92.68kg/ha) represented by UPS (Table 4.31) while the actual annual fish yield (AFY) during the period of study was 8.85kg per annum

Table 4.31: Spatial Potential fish yield in Lower River Niger at Agenebode

Variables	DNS	MDS	UPS	TOTAL
Mean Conductivity (μS/cm)	76.36	58.64	43.64	
Mean Depth (m)	2.77	3.28	4.90	
MEI	27.57	17.88	8.91	
PFY (Kg/ha)	286.91	186.07	92.68	565.66

Key: DNS- Downstream, MDS – Midstream, UPS – Upstream

4.9 Correlation (r) Between Different Physico-Chemical Parameters and Fish Abundance of Lower River Niger at Agenebode

The result of the Pearson correlation on the relationship between environmental variables and fish abundance is represented in Table 4.32 and Table 4.33. The result showed that most of the physico-chemical parameters were positively correlated with fish abundance. There was strong and positive relationship ($P<0.05$) between fish abundance and phosphate, turbidity, phosphorus, sulphate, biochemical oxygen demand, suspended solids, water depth and transparency while inverse (negative) relationship exists with water temperature, pH, nitrate, ammonia, chloride, and dissolved oxygen with the abundance of fish.

The significant of the employed environmental variables to the fish abundance as estimated by Canonical correspondence analysis (CCA) is represented in Figure 4.21 and Table 4.34.From the CCA result, conductivity, pH, turbidity and gross primary productivity has cumulative Eigen-value of 70.6% of the total environmental variables - fish abundance relationship (Table 4.34). The CCA diagram shows that the longer the vector, the bigger the effect of the variables on fish abundance along it. Moreover, the closer the parameter is either to the vector or to each other, the stronger their relationship. Conductivity and pH were the most important environmental variables in the abundance of fish species as shown by the relative length of the vectors, hence demonstrating to be the best predictors of fish abundance. The relative position along the vector indicates the type of effect. From Canonical Correspondence Analysis, fish abundance encountered in Lower River Niger at Agenebode was influenced by conductivity and pH. Conductivity was positively correlated to fish abundance.

4. 32: Correlation of Physical and Chemical Parameters of Lower River Niger, Agenebode

	pH	EC	Turb.	PO_4	P	SO_4	NO_3	NH_3	Chloride	DO	BOD	TSS	TDS	Alk	Ca	M
l	1															
C	.087	1														
dity	-.493**	-.321	1													
hate	-.263	-.145	.713**	1												
horus	-.247	-.163	.737**	.998**	1											
ate	-.352*	-.133	.770**	.556**	.576**	1										
te	.121	.496**	.102	.284	.280	.310	1									
onia	-.327	-.119	.886**	.770**	.792**	.809**	.431*	1								
ide	-.508**	-.076	-.140	-.206	-.224	-.136	-.525**	-.347*	1							
D	-.005	.104	.062	.090	.086	-.095	.183	.105	.060	1						
D	.396*	.322	-.383*	-.211	-.213	-.340	.330	-.164	-.176	.590**	1					
	-.494**	-.236	.928**	.648**	.674**	.797**	.191	.923**	-.110	.135	-.318	1				
S	-.077	.088	-.053	-.188	-.176	-.044	.021	-.027	-.067	.144	.286	-.014	1			
k	-.022	-.173	.213	.093	.099	.086	.052	.198	-.162	.095	-.080	.194	-.092	1		
a	.050	.030	-.013	.073	.082	.120	.010	.043	.069	-.173	-.056	-.013	-.087	.016	1	
g	.379*	-.276	-.285	-.299	-.293	-.223	-.252	-.380*	-.107	-.315	-.130	-.381*	.184	-.084	-.077	
D	.117	.046	-.184	-.180	-.183	-.002	-.079	-.162	-.088	-.168	-.032	-.234	-.142	.194	.142	.2
th	-.338	-.459**	.606**	.431*	.446**	.287	-.194	.395*	.046	-.026	-.283	.434*	.220	.108	-.250	.1
T	.037	-.165	-.479**	-.317	-.326	-.295	-.475**	-.506**	.474**	-.234	-.072	-.418*	.048	-.150	.143	.1
as	.142	.117	-.244	-.094	-.102	-.319	.144	-.190	-.016	.060	.113	-.174	-.347*	.067	.061	-.1

Keys:
*. Correlation is significant at the 0.05 level (2-tailed).
WT. – Water temperature; EC – Electrical conductivity; Turb. – Turbidity; DO – Dissolved oxygen; TSS – Total Suspended Solid; Trans. – Transparency; BOD – Biochemical oxygen Demand; COD – Chemical Oxygen Demand; Mg – Magnesium; Ca – Calcium; Alk – Alkaline; TDS – Total Dissolved Solids

Table 4.33a:Correlation Matrix of Physico - Chemical Parameters and Fish Abundance of Lower River Niger, Agenebode

	pH	EC	Turb.	PO4	P	SO4	NO3	NH3	chloride	DO	BOD	SS	TDS	Alk	Ca	Mg
pH	1															
EC	.087	1														
Turb.	-.493**	-.321	1													
PO4	-.263	-.145	.713**	1												
P	-.247	-.163	.737**	.998**	1											
SO4	-.352*	-.133	.770**	.556**	.576**	1										
NO3	.121	.496**	.102	.284	.280	.310	1									
NH3	-.327	-.119	.886**	.770**	.792**	.809**	.431*	1								
chloride	-.508**	-.076	-.140	-.206	-.224	-.136	-.525**	-.347*	1							
DO	-.005	.104	.062	.090	.086	-.095	.183	.105	.060	1						
BOD	.396*	.322	-.383*	-.211	-.213	-.340	.330	-.164	-.176	.590**	1					
SS	-.494**	-.236	.928**	.648**	.674**	.797**	.191	.923**	-.110	.135	-.318	1				
TDS	-.077	.088	-.053	-.188	-.176	-.044	.021	-.027	-.067	.144	.286	-.014	1			
Alk	-.022	-.173	.213	.093	.099	.086	.052	.198	-.162	.095	-.080	.194	-.092	1		
Ca	.050	.030	-.013	.073	.082	.120	.010	.043	.069	-.173	-.056	-.013	-.087	.016	1	
Mg	.379*	-.276	-.285	-.299	-.293	-.223	-.252	-.380*	-.107	-.315	-.130	-.381*	.184	-.084	-.077	1
COD	.117	.046	-.184	-.180	-.183	-.002	-.079	-.162	-.088	-.168	-.032	-.234	-.142	.194	.142	.219
Depth	-.338	-.459**	.606**	.431*	.446**	.287	-.194	.395*	.046	-.026	-.283	.434*	.220	.108	-.250	.147
Temp	.037	-.165	-.479**	-.317	-.326	-.295	-.475**	-.506**	.474**	-.234	-.072	-.418*	.048	-.150	.143	.158
Trans	.142	.117	-.244	-.094	-.102	-.319	.144	-.190	-.016	.060	.113	-.174	-.347*	.067	.061	-.114
Fishab	-.203	-.097	.351*	.285	.287	.376*	.169	.367*	-.064	-.157	-.219	.382*	-.121	.166	-.084	-.246

Keys:
**. Correlation is significant at the 0.01 level (2-tailed).
*. Correlation is significant at the 0.05 level (2-tailed).
WT. – Water temperature; EC – Electrical conductivity; Turb. – Turbidity; DO – Dissolved oxygen; TSS – Total Suspended Solid; Trans. – Transparency; BOD – Biochemical oxygen Demand; COD – Chemical Oxygen Demand; Mg – Magnesium; Ca – Calcium; Alk – Alkaline; TDS – Total Dissolved Solids, Fishab – Fish Abundance

Table 4. 33b: Pearson Correlation of Water Quality Parameters and Fish Abundance of Lower River Niger, Agenebode

Water Quality Parameters	Fish Abundance
pH	-.203
EC	-.097
Turb.	351*
$PO4^{3-}$	.285
P	.287
$SO4^{-2}$	.376*
NO^{3-}	.169
NH3	.367*
Cl^{-}	-.064
DO	-.157
BOD	-.219
TSS	.382*
TDS	-.121
Alk	.166
Ca	-.084
Mg	-.246
COD	-.450**
Depth	.247
WT	-.047
Transp	.021

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

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

WatT. – Water temperature; EC – Electrical conductivity; Turb. – Turbidity; DO – Dissolved oxygen; SS – Suspended Solid; Transp.–Transparency; BOD – Biochemical oxygen Demand; Fishab – Fish Abundance

Table 4.34: Canonical Correspondence Analysis of Environmental Variables and Fish Abundance

Parameters	Axis 1 Eigen-value	Axis 2 Eigen-value	Percentage (%)
pH	0.30	-0.55	37.86
Conductivity	0.71	-0.21	17.49
Turbidity	-0.57	1.45	8.98
Phosphate	-0.35	2.12	6.53
GPP	0.33	-1.24	6.27
Phosphorus	-0.67	1.50	5.46
Sulphate	0.97	0.50	4.25
Nitrate	4.62	0.13	3.91
Ammonia	0.67	2.42	2.84
Chloride	1.45	0.70	2.13
Dissolved Oxygen	1.67	-0.79	1.70
Biochemical Oxygen Demand	2.70	-2.20	1.04
Total Suspended Solids	0.35	1.47	0.95
Depth	-0.85	-0.70	0.41
Temp	1.19	-1.08	0.10
Transparency	1.45	-1.17	0.07
fish abundance	0.87	0.05	0.01

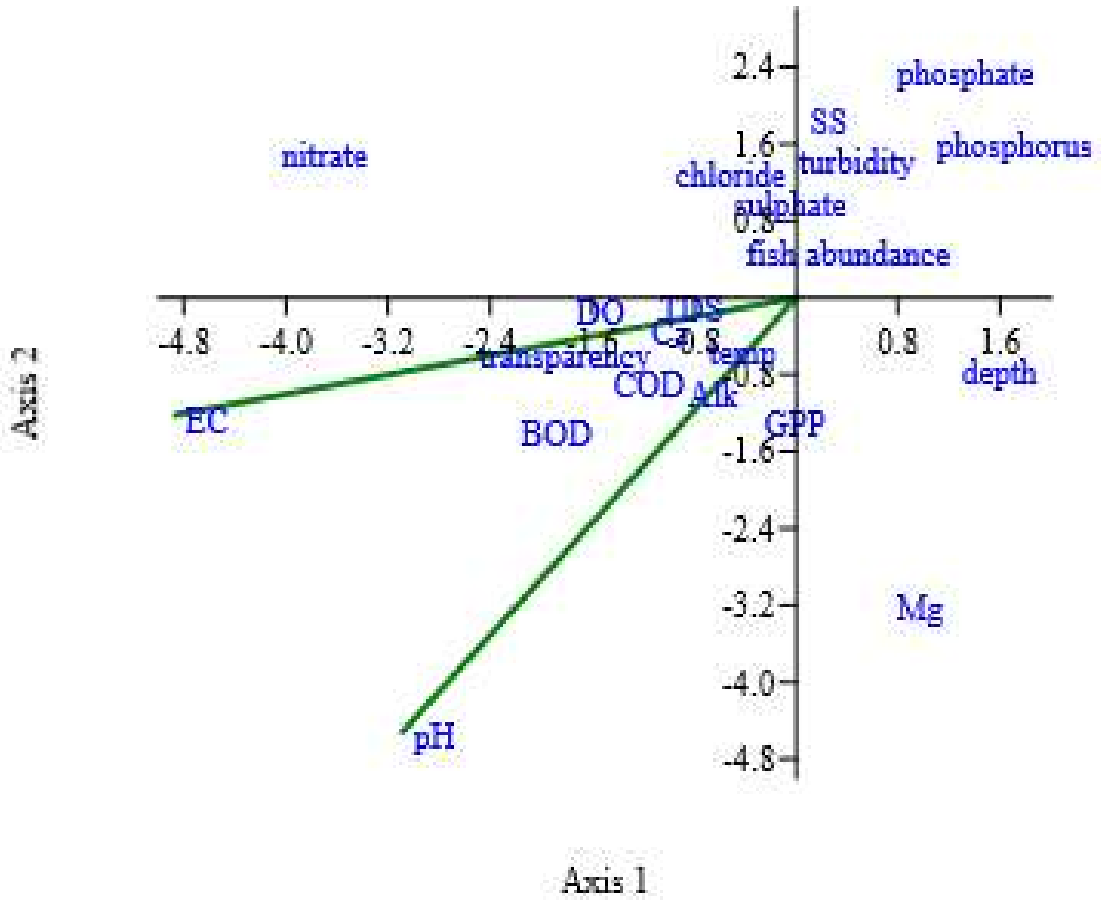


Figure 4.21 Canonical Correspondence Analysis of Environmental Variables and Fish Abundance

4.9.1 Correlation of Fish abundance and Primary Productivity of Lower River Niger at Agenebode

The influence of the primary productivity on fish abundance during the study period as represented in Table 4.35 showed both positive and negative correlation. At $P<0.05$, GPP and NPP were significantly associated with fish abundance ($r = 0.116$ and $r = 0.075$ respectively) and CR correlated negatively. At $P <0.01$ level, GPP and CR correlated significantly with NPP ($r=-0.451$ and $r= -0.0819$ respectively) and at $P<0.01$. However, CR had negative relationship with fish abundance and gross primary productivity.

Table 4.35a: Pearson Correlations Matrix of Fish Abundance and Primary Productivity

	Fishab	GPP	CR	NPP
Fishab	1			
GPP	.116	1		
CR	-.080	-.188	1	
NPP	.075	.451**	-.819**	1

Note: ***Fishab- Fish abundance, GPP – Gross primary production, NPP – Net primary production, CR – Community respiration***

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

Table 4.35b: Pearson Correlations between Fish Abundance and Primary Productivity

Parameters	Fishab
GPP	0.116
CR	-0.080
NPP	0.075

Note: ***Fishab- Fish abundance, GPP – Gross primary production, NPP – Net primary production, CR – Community respiration***

Table: 4. 36cPearson Correlation of Water Quality Parameters, Fish Abundance and Primary Productivity of Lower River Niger, Agenebode

Water Quality Parameters	Fish Abundance	GPP	CR	NPP
pH	-.203	0.169	-0.058	0.147
EC	-.097	-0.211	0.311	-0.509**
Turb.	351*	0.011	0.082	-0.046
$PO4^{3-}$	.285	-0.103	-0.066	-0.062
P	.287	-0.090	0.268	-0.048
$SO4^{-2}$	.376*	0.020	0.134	-0.160
NO^{3-}	.169	-0.013	0.156	-0.245
NH3	.367*	-0.067	-0.056	-0.136
Cl^{-}	-.064	-0.223	0.173	-0.019
DO	-.157	-0.355*	-0.065	-0.340
BOD	-.219	-0.236	0.229	-0.086
TSS	.382*	-0.073	-0.005	-0.164
TDS	-.121	-0.516**	-0.131	-0.033
Alk	.166	0.012	0.198	-0.002
Ca	-.084	-0.135	-0.324	-0.245
Mg	-.246	0.164	0.202	0.450*
COD	-.450**	0.054	-0.553**	-0.190
Depth	.247	-0.014	-0.176	0.552**
WT	-.047	-0.148	0.016	0.156
Transp	.021	0.234	-0.188	0.020

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

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

WatT. – Water temperature; EC – Electrical conductivity; Turb. – Turbidity; DO – Dissolved oxygen; SS – Suspended Solid; Transp. – Transparency; BOD – Biochemical oxygen Demand; Fishab – Fish Abundance

CHAPTER FIVE

DISCUSSION

5.1 Composition, Abundance and Diversity of Fisheries Resource of Lower River Niger at Agenebode

According to Swingle (1950), the study of the structure and community makeup of fish population in a waterbody is necessary in forecasting the population yearly harvestable crop yield. This prediction gives the basis for enhanced management of the water body Robert (2017).

The ichthyofauna assemblage of Lower River Niger at Agenebode compares favourably with earlier reported fish composition in southern Nigeria (20 families, 30 genera and 45 species). Solomon *et.al.* (2012) who reported 13 families and 26 species in lower River Niger at Idah, Kogi State; Udoidiong (1991) worked on 3 streams in Akwa Ibom State documented their species composition; that Udom stream had 17 species representative of 10 families and Nung Oku stream had 19 fish species belonging to 12 families while Mission stream recorded 22 species consisting of 12 families. Onuoha et al. (2010) also reported twenty-six fish species belonging to 7 families in the investigation of NtakInyang stream, Ikpa River, Nigeria.

Udoidiong and King (2000) studies on two first order, two second order and one third order water bodies (streams) in Akwa Ibom State, observed that their fish composition consist of a total of 55 species from 43 genera and 24 families. Of these, Ikpa stream (Ikpa River) according to these authors had the highest taxa richness of 40 species, 35 genera and 24 families. Sikoki *et. al*. (2008) studying the fish assemblages of Onu-Iyi-Ukwu stream in South Eastern Nigeria recorde 17 species belonging to 15 genera and 11 families. There is prepondence of Cichlidae family in Lower River Niger at Agenebode, which are indicative of accessibility of plant-based food in the river and aslo

conduciveenvironment for successful reproduction. Solomon *et.al*. (2012) in Idah Rivers reported similar trends. Udoidiong (1991) also recorded 6 fish species each in Nung-Oku and Udom rivers; Sikoki *et al*. (2008) reported 4 species in Onu-Iyi-Ukwu stream while Udoidiong and King (2000) encountered 9 species. In agreement with this study, Udoidiong and King (2000) also documented Cichlidae as the most abundant family in Iba-Oku Stream. Different areas differ in species dominance, Kouadio *et. al*. (2006) observed Cyprinidae and Alestidae to dominate 20 families with 44 species identified to belong to 35 genera in Mé River, while Onuoha *et.al.* (2010) recorded Characidae to be most abundant in terms of taxa.

Seasonally, there were differences occurring in the sampled species: more were observed during the dry season than in the wet period. Fishes retrieved indicated that more individual fish species were encountered in dry season than wet season. Azoic (temperature, fluctuation of water, DO, transparency), zoic (predation, available food, state of maturation), and operational (netting sizes, length of net, set time) factors (Linlokken and Haugen, 2006) stand as temporal variability drivers. This suggests that some species turn out to be easily or rarely available for catch as the year progresses according to Olin et al. (2009). Rainy season in southern Nigeria is categorised by excessive turbidity, runoff, low-slung temperature and great wind interrupting fishing activities thus, validating the lower catch chronicled in this study duration. Similar model of richness or abundance was observed by the following researchers; Ita (1978) and Mustapha (2010). Likewise, Ayoola and Ajani, (2009) reported more catches in number and mass during the dry season in Eleyele swamp or Wetland while Omitoyin and Ajani (2007) equally recorded higher catches throughout the seasons when it was dry at Asejire and Eleyele water bodies and this was ascribed to the depleted water level at the period of study. This outcome, however, is different from the findings of Onuoha *et al*. (2010) who recorded higher catches in rainy season in Ikpa River. The variances reported spatially in fish species exhibited a considerably greater number of fish in upper and middle parts of the river. In accordance to Olawusi-Peters and Bello-Olusoji (2014), fish will occupy the extremely best and richest sustenance creation or production area, until the entity benefits are reduced by the density of each. The upper portion of the river gave the best possible amount of fish, signifying that the part had the best

quality living zones for fish. Cichlidae family was the utmost abundant in quantity (18.13%) and Mochokidae in biomass (18.57%). The dominance of Cichlidae in Nigerian waterbodies like lakes, rivers and dams has been well reported by Olopade and Rufai (2014), Edward (2013) and Dan-Kishiya *et.al.* (2012). The preponderance of Cichlids according to these authors is their ability to thrive on a wide range of food items and their prolific breeding nature. According to this result *Oreochromis niloticus* of the Cichlidae family was the most abundant among the Cichlids. This is in line with the investigation of Edward (2013) and Offem *etal*. (2009) who recorded the dominance of *O. niloticus* in Egbe reservoir in Ekiti State and Wetland of Cross River respectively. Different areas differ in species dominance. Kouadio *et.al.,* (2006) reported Cyprinidae and Alestidae to dominant among 20 families comprising of 44species among 35 genera in Mé River, Dominica. Alestidae recorded as dominant species in Mé River was also encountered in this investigation but not as dominant species.

About species diversity, the family Momyridae had the highest diversity with 9 different species (*Hyperopisus occidentalis,Mormyrobs oudotis, Mormyrus macrophthalmus, Petrocephalus baneansorgei, Marcusenius Psittacus, Marcusenius isidori, Marcusenius branchistius, Petrocephalus bovei, Gnathonemus pictus*). This observation was different from the one of Ikenweiwe *et.al.*(2007); reported 6species of Cichlidae in Oyan reservoir. Many writers like Dan-Kishiya *et*. *al*. (2012) and Mustapha (2010), similarly observed the same discoveries with differences in the quantity of the species observed. Spatially, variety of species was a little more at upper stream and midstream than the lower stream. This finding contradicts Mwangi *et*. *al*. (2012), he informed that the species richness, diversity, and evenness were usually more in the middle and lower spreads of River Kisian. Certain fish families such as Protopteridae, and Hepsetidae, which have been encountered in other studies (Solomon *et*. *al*. 2012 and Onuoha et al., 2010) for different freshwater bodies, were obviously not available in this investigation. Nevertheless, Schilbeidae, Distichodontidae were observed in agreement with the cited authors above.

The PFY (565.66kgha^{-1}) using morpho-edaphic index was higher in contrast with the yield from Oyun (125.75kgha^{-1}), Ureje (112.59kgha^{-1}) and Ojirami (49.6kgha^{-1}) as

presented by Mustapha (2010), Edward *etal*. (2014) and Ovie and Ajayi (2009) respectively, was relatively good yield. Higher productivity is categorised by high conductivity and low mean depth according to Ovie and Ajayi, (2009). The high PFY observed in this investigation could be because of the high conductivity ($178.64.10\mu Scm^{-1}$) in addition to the low mean depth (6.63m). This result agrees with the records of Kapestsky and Petr (1984), who submitted that a minor waterbody with average depth between 3m and 10m maintains good productivity. Also, Boyd (1998) further clarified that the deepness level of a low lake permits sufficient light infiltration for the development of planktonic algae that serves as diet for fish. Moreover, it is also reported that there is high diversity in second and third order rivers more than the first order rivers (Sikoki *et al*., 2008) and Agenebode waterside being a third order stream is high in diversity, as a result of the extended living space and a combination of species from the first order streams joining to create successive orders in the stream hierarchy.

5.2 Length-Weight Relationship

The recorded values for the weight and length association illustrated that *Xenomystus nigri,Synodontis clarias, Brycinus nurse*, *Clarias gariepinus* and *Oreochromis niloticus* exhibited allometric growth (b<3). Diverse fish species from numerous water bodies having both isometric and allometric growth have been recorded by several authors. Abowei et al. (2009) recorded isomeric growth for *Ethmalosa fimbrata* and *Ilishia Africana* from Nkoro River, Niger-Delta Nigeria*;* King (1991) reported allometric growth patterns for *Tilapia* species from Umuoseriche Lake which is also in line with the findings of this study of Tilapia from Lower River Niger at Agenebode. Isometric pattern of growth for *Pseudotolithus elongatus* in Qua Iboe Estuary, *E. fimbriata* in Cross River estuary in Cross River State and *Chysichthys auratus* from the most southern parts of River Nile and Egypt were observed by King (1996b), and Shenouda *et al.* (1994) respectively.

According to Lagler *et al*. (1977), the renovated length over weight gives linear growth, showing the three-dimensional growth patterns of most fish species. The exponential values of the length in the length and weight relationship being isometric implies that

the fish species did not increase in weight faster than the cube of their standard lengths as seen in all the studied fish species.

The relationship of length and weight gives information on the condition and growth patterns of fish (Bagenal and Tesch, 1978). Isometric growth is exhibited by fish when length increases at the same rate with body weight for constant specific gravity. The regression co-efficient for isometric growth is '3' and values greater or lesser than '3' show allometric growth according to Gayando and Pauly (1997). The relationship is allometric if the observed value of b differs from these expectations and growth is non-isometric, the assessment of the contributing factors can throw light on the biology of species and wellbeing. Generally, the growth pattern of fish follows the cube law (Ricker, 1975). Such relationship for the fishes will be valid when the fish grows isometrically. In such cases the exponential value must be exactly 3. Practically, the actual relationship between the length and weight may depart from this, as a result of ecological conditions or condition of fish. The body of a fish constantly changes in size as it ages in nature.

There are three somatic growth types for most fish species:

- Isometric growth: This is when all fish dimensions increase at the same rate, b = 3. If b = 3, if the small specimens in the sample under consideration have the same form and condition as large specimens.
- Positive allometric growth: This is when fish increases more in weight than predicted by its increase in length, b>3. If b is greater than 3, then larger samples have increased in weight or width more than in length, either as the result of a remarkable ontogenetic change in body shape with size, which is rare, or because most large specimens in the sample were thicker than small specimens, which is common.
- Negative allometric growth: This is when fish decreases in weight than predicted by its increase in length, b<3. If b is less than 3, then large samples have changed their body shape to becomes more extended or small specimens were in better nutritional condition at the time of sampling (Mensah, 2015)

The coefficient of regression (r = 0.6) reflects strong association between length and weight. This implies that as the length of the fish increases, the weight also increases

though not in the same proportion. Alex *et. al.* (2012) reported similar positive correlation in their studies.

Condition Factor (K): In fish, K, through its variations, reflects the information on the physiological state of the fish with regards to its well-being. Looking at it from the point of nutrition, there is the build-up of fat and gonadal growth (Le Cren, 1951). When viewed from the point of reproduction, the maximum values of K are reached in some fish species (Mohammed *et al.*, 2016). Condition factor also gives information when comparing two populations living in certain feeding, density, climate and other conditions; when determining the period of gonadal maturation and when following up the degree of feeding activity of a species to verify whether it is making good use of its feeding source (Bagenal and Tesch, 1978). Considering the statements above, we may perhaps say that the five species studied reproduced in the period of May to October since these months had the lowest K (Table 4.10). Moreover, Vazzoler (1996) explained that having low values of K during the more matured gonadal stages could mean transfer of resources to the reproductive glands during the period of reproduction. Likewise, Braga (1986) disclosed that the values of K differ depending on the seasons through several authors and are impacted by ecological conditions. This is likely to be the case in this study area since the water body is affected by several zoic and azoic parameters, which underpin balance of all the species in the ecosystem.

The mean Ks varying from 0.27435 (*C. gariepinus*) to 3.17215 (*O. niloticus)* observed in this investigation was a little different from other investigations like Abowei *et. al.* (2009) reported 0.941 to 0.985 *Ethmalosa fimbrata*; K=0.77 to 0.81 for *Clarotes filamentosus* in lake Oguta; K = 0.49 to 1.48 in Andoni river were reported by Nwadiaro and Okorie (1985), Dan-Kishiya (2013) in Lower Usuma Reservoir, Ibrahim et al. (2012) in Lake Akata, and Lawal et al. (2010) in Epe Lagoon.

Some have also studied length-weight relationship of some fish species. Adaka *et.al*. (2015) studied the LWRs and Ks of *Oreochromis niloticus* in Oramiri-Ukwa river, Southeast Nigeria. They observed that the population of *O. niloticus* comprised of adult fish with length group of 17.5cm. The analysis of length-weight relationship showed

that ‘b’ value of 2.90 for male, 2.99 for female and 2.94 for combined sexes. The ‘b’ values of both sexes were not significantly different. The condition factor for *O. niloticus* ranged between 1.93 (October) and 2.26 (May) with a mean of 2.09±0.1. They observed that sampled fish were in better condition in the wet season than dry season.

Abowei *et.al.* (2009) studied the relative abundance, K and the length-weight relationship of 1800 specimen of *C. senagalensis* from Nkoro River in the Niger Delta part of Nigeria. Out of the 1800 fish specimens, condition factor (K) value was 1.00 and b value of LWR was 3.066 indicating an isometric growth pattern. Also Hart and Abowei (2007) studied the LWR and condition factors of ten species of fish from the lower Nun River for duration of two years; using different fishing gears. All the fish species showed allometric growth pattern with their length exponents ranging from 2.73 *(Synodonts schall)* to 2.93 *(Brycinus baremose)* except *Parailia pellucid,* which exhibited an isometric growth with length exponent “b” = 3.03.

Also, Adaka *et.al.,* (2015) showed that all the fish investigated in Omariri-Ukwu River exhibited negative allometric growth patterns with regression analyses exponents’ bvalues less than 3, except for *Papyrocranus afer*, which exhibited a positive isometric growth pattern with exponent (b) value of 3.04. This is similar to the result of all fish species exhibiting negative allometric growth pattern reported by Obasohan *et. al*. (2012). The following correlation coefficient (r) value 0.908, 0.950, 0.939, 0.9751, 2.185 and 6.600 at $P > 0.05$ indicated high degree of positive correlation between the standard lengths and body weights of fish.

In addition, Achakzai *et. al*. (2013) studied the length – weight of *Oreochromis mossambicus* by looking at 364 fish samples (186 Male and 78female) sampled from August 2011 to July 2012, in Manchar Lake. The fish samples were 10 – 26 cm in Standard Length and 19.8 – 295 g in weight. This length and weight range is in adult range. Their result showed that b = 3.06 (combined population), b = 3.04 (male population) and b = 3.06 (female population), which was seen to be isometric. The relative condition factor (Kn) for all the population put together was 0.87 – 1.07, while for male 0.86 – 1.09 and females 0.87 – 1.07.

Atama *et.al.* (2013) examined the LWR and condition factor of six cichlid (Cichlidae: Perciformes) species of Anambra River, Nigeria. Three of these species were tilapia species i.e. *O. niloticus, Pelmatotilapia mariae and C. zillii.* Their result showed that none of the fish species exhibited isometric growth. While Wu *et. al*. (2017) estimated the LWR parameters for five endemic fish species collected from the Liaodong BayBohai Sea, China, the length-weight relationship, b values ranged from 2.96 to 3.38 showing both isometric and allometric growth pattern. Imam *et. al*. (2010) also studied the length-weight relationship and condition factor of four fish species i.e. *C. zillii, Oreochromis niloticus, Hermichromis bimaculatus and Clarias gariepinus* from Wasai Reservoir in Kano. Six hundred and sixty-six (660) fish samples were collected by artisanal fishermen using various gears. The results indicate negative pattern of allometric growth in which all of the species b values analysed were less than 3 in line with the present study. Fafioye and Oluajo (2005) investigated the LWR of 320 fish populaces of *Clarias gareipinus* (Burch), *Illisha Africana* (Bloch), *Chrysichthys nigrodigitatus* (Lacepede), *Chrysichthys walker* (Gunther) and *Ethmalosa fimbriata* (Bowdich) collected at Epe market fish landing site. The condition factor values significantly ($P<0.001$) range between 0.64 and 1.99, while the b values varied between 2.790 and 3.210 with the mean b = 3.0072 at $P<0.001$. This shows almost isometric relationship with 60% of the variant in body weight accounted for by changes in length. This shows almost isometric association having 60% of the variation in the heaviness of the body accounted for by changes in length.

The relationship between length and weight of six fish species of economic and ecological importance along with the condition factor was studied by Egbal *et.al.*(2011) in Atbara River and Khashm el-Girba reservoir. One thousand, one hundred and eighteen samples of fish were encountered by employing numerous netting sizes of gillnets with lengths varying from 12 to 93cm while the masses were between 125 and 2100g. The coefficient of growth (b) values recorded for the six fish species ranged from 2.278 to 3.680 and significantly varied at $P<0.005$ from 3. This shows that many of the species of fish (61.1%) had negative allometric growth pattern. The 61.1% of the

species of fish showed negative allometric growth condition factor ranging from 0.506±0.416 to 3.415±0.707.

Moreover, Obasohan *et. al*. (2012) examined the LWR and K of five freshwater fishes gotten in Ibiekuma stream, Ekpoma, Nigeria. The value of standard length (SL) varied between 10.6 and 34.1cm while body weight was between 61.9 – 169.1g. The results of the length – weight analysis showed that the entire fishes displayed negative allometric growth rate with the values of b lesser than 3, between 1.16 and 1.94. The correlation coefficients (r) gotten ranged between 0.850 and 0.963. Their result also showed that the condition factor was between 0.5 and 3.78.

5.3 Relationship between Physico-chemical parameters and Fish Abundance

The fish composition and distribution in Lower River Niger at Agenebode is in agreement with southern Nigeria fish composition reported earlier by Solomon *et.al.* (2012) in Idah axis of the Lower River Niger, Kogi State; Okereke (1990) in Otamiri River, Abia State and Onuoha *et. al*. (2010) in Ntak Inyang stream. The domination of the family Cichildae in Lower River Niger at Agenebode was in accordance with Olopade and Rufai (2014), Edward (2013), Dan-Kishiya *et. al*. (2012), and Mustapha (2010). The quality of an aquatic ecosystem is dependent on the physico-chemical qualities of water (Adesalu, 2010). The range and average value of physico-chemical parameters obtained during the period of this study fall within the normal range acceptable for the survival of aquatic life (Boyd, 2005; WHO, 2006). Results of variations in physical and chemical characteristics of Lower River Niger at Agenebode revealed some significant ecological tendencies of a lake system. The appropriate equilibrium of physical, chemical and biotic characteristics of ponds, lakes and reservoirs water is an important element for the production of fish and other aquatic renewable resource successfully [Mustapha, 2010].

However, only few (BOD, temperature, EC, total alkalinity, total hardness and ions) amid the experimented factors are within optimal acceptable limit for development and existence.

The concentration of dissolved oxygen recorded was similar to the range observed by Ovie *et al*. (2011) in Omi dam, Oyan (Ikenweiwe and Otubusin, 2005), Moro (Mustapha, 2010) and Oyun (Mustapha, 2009). However, Edward *etal*. (2014) reported higher values of DO (5.10 – 11.24mg/l) in Ureje reservoir, Ado Ekiti. Dissolved oxygen is documented to be inversely proportional to water temperature (Ali, 1999) and consequently affects the solubility and availability of nutrients (Lawson, 2011). This was thus, reflected in the strong positive correlation that existed between DO and fish abundance. BOD remains a basic index to test the level of organic pollution in a water body. Ovie *et al*., (2011) observed that organic substances concentration in water and their ability to take in oxygen from water could be estimated by biochemical oxygen demand (BOD). The mean BOD value obtained falls within the recommended limits of <10mg/l set by Boyd (1998). COD had a strong significant correlation with temperature and fish abundance.

Water transparency varied with the obtained effect of colour and turbidity. The mean range of secchi disc transparency reflected the depth of light penetration and this could probably explain why fish diversity was high in the river. Boyd (2015) has given a range of 0.3 m to 0.6 m secchi disc visibility as adequate for fish production. The mean value of transparency recorded in Lower River Niger at Agenebode compared favourably with the findings of Mustapha (2009) in Oyun (1.62 m) and Ovie *et al*. (2011) in Omi dam (2 m). Lind (2003) observed that a change in light regime may shifts the relative abundance of species, hence, the positive correlation with fish abundance. The surface water temperature, in this study was within the recommended levels for aquatic organism's survival, metabolism and physiology (Boyd, 1998). The result also agrees with the results of Mustapha (2009) and Ovie *et. al*. (2011) in Omi dam. The fluctuation in water temperature of the lakes according to Toma (2013) depends mainly on the climatic conditions, sampling time, the number of sun-shine hours and is also affected by specific characteristics of water environment such as turbidity, wind force, plant cover and humidity (Mahmoud, 2002). The negative correlation found between fish abundance and temperature implies that increasing temperature reduces fish abundance.

The highest conductivity value recorded is within the medium range of 50 – 1500 µScm^{-1}, which according to Egborge (1970) is synonymous with high nutrient content. Stone *et. al*. (2013) who stated that freshwater fish generally thrive over a wide range of electrical conductivity corroborated this observation. The high-level medium of conductivity in an area could be attributed to use of agrochemical as asserted by (USEPA, 2014). The mean conductivity result obtained in this study agrees with the findings of Mustapha, (2009) who reported mean conductivity value that ranged from 80.40 – 178.80 µS/cm in Oyun reservoir, Offa. However, this result contradicts the findings of Ovie, *et. al*. (2011) who did groundwork study on the assessment of limnology, primary production and PFY of Omi Dam, Nigeria. The authors found higher mean conductivity value of 229.43 µS/cm. The seasonal conductivity distribution during the investigation period indicated a slight significant rise in rainy seasons. The same opinion was also recorded for other water bodies in Nigeria (Mustapha, 2009; Anago *et. al*., 2013). Ibrahim *et al*. (2009), however, observed lofty EC in the dry season as reported in Shiroro Lake. Ionic concentrations (pH) indicate the alkalinity or acidity of a solution on a scale of 1 – 14 and it affects many chemical and biological processes in water (Vyas and Bhawsar, 2013). The mean pH (6.5 – 8.5), is adequate for fish productions reported by (Boyd, 1998). Lower River Niger at Agenebode like other tropical rivers could be said to have neutral pH with slight fluctuation to alkaline conditions (Ugwumba, 1990; Idowu and Ugwumba, 2005). This could be related to higher water volume, with greater water retention, low decomposition and good buffering capacity of total alkalinity (Mustapha, 2009). The negative correlation of fish abundance with pH indicates that fish abundance is influenced by change in pH.

Nitrates and Nitrites are nitrogenous waste products found in water though relatively non-toxic to fish and of no health hazard except at exceedingly high levels (Boyd, 1998). The range and mean of nitrate observed in this study fell within the optimum range (0.1-3 mg/l) suitable for fish production and domestic use as recommended by Boyd (1998). Nitrate was positively correlated with fish abundance in Lower River Niger at Agenebode which shows good nutrient load for use. The ammonia and phosphate level found during this investigation fell within the limits of WHO/FEPA and

Boyd, (1998) for fresh-water. The major effects of ammonia and phosphate on the variables of productivity confirmed their important functions in ecological systems. The negative correlation between ionic compounds (calcium and magnesium) and fish abundance indicate that fish does not thrive well with increase in these ionic levels as present in Lower River Niger at Agenebode. The mean range of chemical oxygen demand (84.03 ± 25.37) indicated the river to be contaminated as it obviously was higher than the optimal standard acceptable range for both drinking and aquatic life (Boyd, 1998). Chemical oxygen demand concentration observed was higher in the wet season than in dry season. The high level of COD in Lower River Niger at Agenebode could be attributed to the large release of industrial wastes and other anthropogenic activities into the river as stated by Mustapha [2009], consequently, a signal of pollution. The mean value of COD observed in Lower River Niger at Agenebode was relatively higher than values reported in Karola River [Mandal *et al*., 2013], Oyun Reservoir (Mustapha, 2009) and Moro lake (Mustapha, 2008).

The distribution of most fish species recorded in the study area was influenced by DO, BOD, and transparency, but the correlations were inversed with temperature and pH. However, the contribution of the vectors studied to fish abundance was estimated as 70.6% from the Eigen and inertia values calculated. This observation is further supported by the report of Ter Braak and Verdonschot (1995) that 50.00% Eigen value is satisfactory for balanced aquatic ecosystem productivity. Turbidity, Ammonia and total suspended solids were positively correlated with dissolved oxygen and fish abundance. This could be as a result of addition of various decomposable contaminants from household wastes, metropolis' dirts, overflow from farming activities etc. that encourage the development of microbes that use the DO for putrefaction and hence the fish abundance. Thus, the concentration of dissolved oxygen gradually depletes. This is also in line with the findings reported by Stone *etal*. (2013).

5.4 Plankton Abundance and Distribution

Several authors have emphasized the numerous influences of natural or altered conditions on plankton dynamics and compositions in an aquatic environment, including

Chattopadhyay and Barik, (2009) and Altafe *et.al*., (2010). Resident organisms exhibit various response patterns to these changes, including death, physiological alterations, or total migration to other habitats. The Lower River Niger at Agenebode when likened to the study of Rai, *et. al*. (2006) and Egborge, (1994) in some river systems documented relatively low plankton abundance and diversity, especially of the zooplankton. This dearth could be attributed to environmental perturbations (Abdul *et.al.,* 2017; USEPA, 2014), particularly from constant intense in-stream sand excavation by local residents and dredging, which leads to increase in turbidity and thus, decreased plankton productivity. Okogwu and Ugwumba, (2006) made similar observations. This may have adverse effects on fish production; leading to low catches by fishers.

The wellbeing of the biological population of any water system is dependent on the availability and diversity of planktons as primary producers. The much lower abundance of zooplankton than phytoplankton conforms to ecological tropism, whereby there are usually more primary producers than consumers in a food chain. However, prolonged effects from industrial wastes and other anthropogenic activities in the area could not be fingerprinted to this observation, though Grant, (2002) observed that a steady input of pollutants over time could result to changes in the biological community composition of water bodies.

Nonetheless, this study recorded higher number of phytoplankton abundance when compared with the preliminary work conducted on Imo river in Oyigbo LGA, Niger Delta (Zabbey *et. al*., 2008), especially in the numbers of phytoplankton and zooplankton genera. In their study in March and October 2003, Zabbey (2008)recorded a total of 37 and 23 genera of phytoplankton and zooplankton respectively (total of 60 genera). Converse to the current study, Clarke (2004) recorded totals of 107 combined plankton genera in Ologe Lagoon/Rivers Owo, Ondo State, Nigeria. However, whereas the study by Zabbey *et al*. (2008) recorded a total of 101 species of phytoplankton in those two months (March and October 2003), the current study recorded 194 species of phytoplankton. Separate studies by Edoghotu (1998) in the non-tidal Oginigba Creek and Ogamba *et al.* (2004) in Elechi Creek, all in the Niger Delta recorded 148 and 243

phytoplankton species, respectively. Akoma and Imoobe (2009) recorded lower phytoplankton genera (26), 46 species in Bahir Dar Gulf of Lake Tana, Ethiopia, even as Chattopadhyay and Benerjee (2007) recorded much lower 7 genera, 43 species in Lake Krishnasayer, Burdwan, India. While in the present study only zooplankton of 13genera comprising 20species were recorded, Chattopadhyay and Barik, (2009) reported 32genera consisting of 34 zooplankton species in Krishnasayer, India humid freshwater.

The qualitative order (bacillariophyceae > chlorophyceae > cyanophyceae > euglenophyceae > Dinophyceae > Charophyceae), as well as the quantitative order (bacillariophyceae > chlorophyceae > cyanophyceae > euglenophyceae > Dinophyceae > Charophyceae), of dominance of the phytoplankton in this study followed the general pattern for most Nigerian inland waters as reported by Egborge (1974), Akoma and Imoobe (2009) and Abdul *et.al*. (2015, 2016) The qualitative order of domination of the zooplankton in this study (cladocera > copepod > rotifer >) had earlier been observed in Imo river in Oyigbo LGA by Zabbey *et al.* (2008) and in Warri River by Egborge (1994). The dominance of diatoms in the study has also been reported in many other rivers in the Niger Delta (Edoghotu and Aleleye-Wokoma, 2007; and Zabbey *et al.,* 2008) and elsewhere by Akoma and Imoobe (2009) in Lake Tana, Ethiopia, and Altafe *et al.* (2010) in Wular Lake, Kashmir. This dominance could be attributed to the baccilariophyceaen ability to grow under the conditions of optimum tropical weather conditions, such as high solar radiation and high ambient temperature prevalent in the study area. This reason however is opposed to the findings of Altafe *et al.* (2010) that the dominance of diatoms was because of weak light and low temperature prevalent in their study area.

After the dominance of the bacillariophyceaens, came the cyanophyceans whose abundance disagrees with the finding of Altafe *etal*. (2010); that the blue-green algae have worldwide distribution and that majority of species are cosmopolitan in the tropics. They further attributed their habitat preference successes to inherent high photosynthetic abilities, as well as the ability of certain species (e.g. *Anabaena sp.*) of the group in freshwater to fix atmospheric nitrogen to supplement their nitrogen requirements

(Kapoor and Arora, 2000). The abundance of the rotiferan populations (*Brachionus falcatus falcatus)* over some other zooplankton was due perhaps to the capacity to survive and also live in various ecological environments predominant at the diverse seasons. Certain rotifers are described to be primary consumers that forage on several phytoplanktons while some are known as ravening hunters that consume bacterial and debris substances (Abdul *et.al*., 2015)

5.5 Biotic (Zoic) Diversity

In general, zoic diversity was high, in comparism with the study of Zabbey *etal*. (2008) on Imo River in Oyigbo LGA and Ogamba *etal*. (2004) in Elechi Creek Complex, all in the Niger Delta. While Zabbey *etal*. (2008) documented an average phytoplankton Margalef's diversity of up to 5. 395, the present investigation reported an average Margalef's value of 12.683 in the duration of investigation. Amadi *etal*. (1997) also recorded zero diversity in plankton assemblages of a water body in Port Harcourt.

Nevertheless, Zabbey *etal*. (2008) reported an average zooplankton Margalef's diversity of 0.882, compared to the present study value of 0.926. This value could be ascribed to disturbance in aquatic columns, particularly from sand excavation activates, that must have exerted choosy effects on the biotic community (GESAMP, 1995). Zabbey *etal*. (2008) likewise reported sand removal as being accounTable for the low plankton abundance and diversity in the Imo River, just like Tamuno (2005) had also recognised the activity as applying lethal impact on plankton communal composition in the Niger Delta area. The dominance in diversity by the diatoms in this investigation agrees with several other works by hydro-biologist, for example Chindah and Brasides (2001) and Oduwole (1997).

For the zooplankton, the cladocerans were most diverse while the insect was least diverse. The low species similarities across the sampling locations, especially of the zooplankton related to trophic niche and relationships between the groups of animals and phytoplankton. The highest phytoplankton and zooplankton diversities recorded in UPS could be attributed to less anthropogenic activities while the lower diversities

recorded in the other locations (DNS and MDS) could be due to intense human activities. Increasing perturbations on the ecosystems has always been associated with increasing population all over the world (Amad et al., 1997; Ogamba *et al*., 2005). The higher diversities recorded for plankton in the dry than rainy season could be attributed to the availability of more nutrients (resulting from less dilution) and less turbidities during the dry season.

5.6 Spatial and Seasonal Distribution of Plankton Species

The distinctive seasonality pattern recognised for various zooplankton in Nigerian fresh-water bodies, whereby abundance hits the highest point in the season of low water level and low densities or entire absence reported in the rainy season was similarly noticed in the present investigation. Egborge (1994) ascribed this observation to low water current velocities, more stability, nutrients concentration, and subsequent increase in biomass of food organisms.

Two wide groupings of phytoplankton which are; the stable and fluctuating genera, were also noticed in this investigation. As stated by Kilham and Hecky (1988), the genera that are stable could be viewed as k-selected for the reason that they were made up of individuals able to adventure many microhabitats offered. The enormous seasonal effect on the bounty of the green algae as previously reported by Oduwole (1997) and Sowunmi (2001) was also confirmed in this study, such that increases were observed during the season of dry and declines in the rainy season. This algal biomass upsurge is also recognised to meaningfully surpass less physiologically modified species for nutrients and sunlight (Sowunmi, 2001).

The marked variation recorded in plankton abundance between first year and second year sampling periods, especially in UPS reflects the impact of increasing instream sand mining activities on the numerical abundance of the aquatic organisms. Sand mining, which was not observed in UPS during the first year of sampling, had become a thriving activity in all the sampling locations by the second year. Anthropogenic perturbations (such as habitat modifications from sand mining) have been known to threaten and

exacerbate biological diversity losses (Spaak and Bauchrowitz, 2010). Tamuno (2005) noted that sand mining in particular could impoverish aquatic sediments of essential nutrients necessary for a thriving biological diversity.

The upstream that observed the maximum species abundance also had the least human activities (other than sand mining) than the rest of the locations. The remaining zones were in commercial parts of the community where extra human actions were unending. Moreso, it was observed that sand mining became more intense in the second year of sampling in the study area. These less anthropogenic activities perhaps motivated steadiness and development of more plankton species in the location. The lesser abundance observed during the rainy season can superlatively be ascribed to more reduction of important growth nutrients (Egborge, 1994). The presence of pollution-tolerant algal species in the Lower River Niger at Agenebode reflects some degree of pollution associated with minor, localized organic contaminations arising from domestic activities of the inhabitants.

5.7 Water Quality Parameters and Primary Productivity

The Nigeria climate is tropical, and it is typified by lofty humidity with lofty temperatures in addition to distinct rainy and sunny seasons Adesalu (2010). Earlier ecological researches of some Nigerian water bodies like dams, lakes, springs and rivers have likewise been documented (Olele and Ekelemu, 2008; Jackson, 2009).

The temperature for all the sampling sites were within acceptable range for a tropical water body and this is in line with values between 26.5 and 32.8 ^{0}C recorded by Zabbey *et.al.*(2008) for tropical rivers, and Imoobe and Oboh (2003) also had the same observation. However, the temperature is within the recommended level (24-31 ^{0}C) for warm water fish (World Health Organization, 2004). DO in water is a vital aspect that determines the existence and abundance of aerobic organisms in water. Thus, the more dissolved oxygen available in water, the more the organisms it will support (Chia, *et. al*., 2009). All the DO values were within the range (≥4 mg/L) recommended for warm water fish (Ajani *et.al.*, 2011; Tiseer, *et. al.,* 2008)

The pH values recorded in all the stations fell within the International Standard for freshwaters, and are optimum for fish culture Yakubu, and Ugwumba, (2009). This is supported by the reccommendation of World Health Organization (2004) that pH of 5.5 to 10 is suitable for tropical fishes. However, they all tend towards alkalinity which agrees with some researchers (Atobatele *et. al.*, (2005) and Indabawa (2009).The relatively high values of electrical conductivity observed are because of the loss of liquid, from a more quantity of salt in a smaller size of water (Idowu and Ugwumba (2005).

The rainfall data showed a seven-month wet season period with five months dry season cycle though the months of rains are not high in rainfall as observed in other parts of the state. Ayoade *etal*. (2006), Abowei and George (2009) and Deekae *etal*. (2010) have reported this similar rainfall pattern. The highest ambient air temperature and lowest relative humidity were observed in the middle of the dry season due to the characteristic cool dry tropical wind and intense sunlight between November and February. This is in line with the observation of Mustapha, (2008). Moreover, Mustapha (2008), Ayoade *etal*. (2006) and Kadiri (2000) asserted that meteorological conditions such as solar radiations and rainfall are the main climatic factors that influence most physical and chemical hydrology of water bodies.

Water temperature regulates activities (both abiotic and biotic) of an aquatic ecosystem (Abdul *et.al.,* 2018; Adaka *et.al*., 2015). It remains as a major factor that determines primary production in reservoirs (Abdul *et.al,.* 2015). The surface temperatures of 23.3^0C to 31.0^0C fall within the range documented for typical tropical lakes and reservoirs. Hassan et al., 2014; Ayoola and Ajani, 2009; Mustapha, 2009; Idowu and Ugwumba, 2005; corroborated this observation. It was discovered from this work, that surface water temperatures closely follow the ambient air temperatures (Welcome, 1979). Manikannan *etal*. (2011) and Adaka *et.al.* (2015) also reported similar observation from different wetlands.

Spatial and vertical difference in temperature is as a result of inflowing water, vertical mixing of water as well as processes such as exchange of heat with the atmosphere and

other localized phenomena (Shinde and Ningwal, 2014). High water temperature in the period of drought could be ascribed to higher aridity, low clime and lofty clearness. Atobatele and Ugumba (2008) attributed the lesser heat observed in December and January to the influence of turbulence breeze and the peak temperature observed in March was ascribed to the hit of the highest point in the drought period when isolation was at its maximum. This corroborated the trend observed in the present investigation. Temperature was least in January and maximum in March as reported for Oyan and Asejire Lakes (Ayoade *etal*., 2006) and Ero Reservoir (Oso and Fagbuaro, 2008). The present observation also compares with the earlier records that heat in the tropical region range amid 21^0C and 32 ^{0}C (Ugwumba and Ugwumba, 1993; Ayoade *et.al*., 2006. Boyd (2005) suggested temperature variation of 20 – 30^0C for optimal fish development. Therefore, the temperature variation of 25.3 ^{0}C – 31.0 ^{0}C observed in Lower River Niger at Agenebode during the course of this study falls within the optimal range for fish growth.

Seasonally, the differences amid the examined factors were not significant ($p<0.05$) statistically apart from Total Suspended Solids (TSS). TSS are solid materials, including organic and inorganic, that are suspended in water. These would include silt, planktons and industrial waste. The marked higher TSS recorded during the rainy season months could be attributed to periods of high rainfall and subsequent erosion during flooding; when particulate materials from within and outside the river's geographical boundaries are carried into the water body. Tamuno (2005) also pointed out the contributory effect of sand mining and dredging on TSS of Kolo and Otuoke communities in Niger Delta. This is also in line with Eze (2005) and Eborge (1994). Pratt *et.al*. (1971) classified water with TSS of 278 mg/l and above as grossly polluted, while NESREA (2011) recommends value not greater than 0.25 mg/l for aquatic life in surface waters. This therefore makes the Lower River Niger at Agenebode with TSS value of 68.51±10.27 mg/l a polluted water body and unsuitable for aquatic. Total suspended Solids are an important water quality parameter in assessing water pollution (USEPA, 2012). Suspended solids can harbour pathogens which contribute to water borne diseases that can infect aquatic or human life.

The BOD concentrations values were within the regulated limits of <4 mg/l by Boyd, (2015) and FEPA (1991). This view in line with the discoveries of Ibrahim (2009) and Inuwa (2007) in Wasai dam (Jakara dam) and Challawa stream respectively.

Water visibility or clarity is a parameter of water quality that fluctuates with the collective influence of turbidity and colour. Turbidity is influenced by suspended solid materials such as clay, silt, colloidal organic matter, planktons and remains a major cause of low transparency. Rise in the uproar of waters generally increases all the dangling matters, especially in low waters. Inside a river the secchi depth measurement could be influenced by features like period of the day, lucidity of the cloud at the time of taking it (whether or not it's cloudy), and suspended solids in water which include phytoplankton. Transparency was lowest during the month of September, which coincides, with the peak of the raining season due to over flooding. It could also be as a result of decrease in sunlight strength occasioned by occurrence of hefty rain cloud in the sky, which ultimately reduces the amount of sunlight getting to the water (Oso and Fagbuaro, 2008) and consequently declining sunlight infiltration. The higher transparency observed during the dry season could also be due to reduction in allochthonous substances that find their ways into the river with flood (Ikomi *etal*., 2003). The same views were reported by Idowu and Ugumba (2005) in Eleyele Reservoir, Ayoade *et.al*. (2006) in Asejire and Oyan lakes, Oso and Fagbuaro (2008) in Ero Reservoir. Water transparency was greater in the period of dry than in the wet period. According to Mustapha (2009) and Ibrahim *etal*. (2009), the lower water transparency observed during the rainy season could be attributed to high water run-off from the water shed into the reservoir. However, the range of Secchi disc transparency recorded in this study reflects high depth of lights penetration, which enhances photosynthesis and hence primary productivity (APHA, 2005).

The electrical conductivity value obtained in Lower Niger River compared favourably with the trend obtained in Oyun reservoir (Mustapha, 2009) and Eleyele wetlands (Ayoola and Ajani, 2009) and was within the optimum value (Boyd, 2015). However, there was variation and significant difference in observed spatial conductivity; this could

be attributed to utilization of the ions by flora and fauna. Similarly, the highest conductivity value obtained in DNS could be linked to its closeness to the most sand mining activity area of the river leading to high invasion of flood water which consists of suspended and dissolved materials (Mustapha, 2009). The higher values recorded during the rainy season was in line with Mustapha (2009), in Oyun Reservoir and differed from the results obtained by Eze (2005). Enough storm water runoff from soil erosion and the washing of ions into the water channel in the rainy season were responsible for the higher values.

According to UNEP GEMS (2006), the importance of pH in aquatic environment lies in its close link to biological productivity, even as the tolerance of individual species varies. pH is among the very significant chemical characteristic of all waters, which explains certain significant biotic and abiotic ecological characteristics of aquatic systems in general. The ionic concentrations (pH) balance in an ecosystem is maintained when it is within the acceptable value of 5.5 to 8.5 (Chandrasekhar *et. al*., 2003). Ionic concentration (pH) of a water body is a diurnally erratic property which depends on temperature variation in the system (Ojha and Mandloi, 2004). Kaul and Handoo (1980) linked raised surface pH in water bodies to increased metabolic activities of autotrophs, which utilizes carbon (iv) oxide and liberate oxygen thereby dropping or lowering the pH. Kataria *etal*. (1995) pointed out that a suitable pH 6 to 8.5 is necessary for fish survival in water bodies and acid waters reduce the appetite of fish and hence their growth. According to ICMR (1975) and WHO (2006) safe pH limit is 7 to 8.5. A pH range of 6 to 8.5 is normal according to the United States Public Health Association (APHA, 2005). The absence of marked spatial variation in pH at the locations in Lower River Niger at Agenebode indicates stable habitat, which could be linked to its stable photosynthetic rates measured as primary productivity. According to Grant (2002), the pH of water is affected considerably as photosynthetic activities remove carbon (IV) oxide from water and shifts the carbonate-bicarbonate equilibrium.

The slightly acidic pH range of 6.00 – 6.88 recorded in this study conformed to values previously reported in Niger Delta freshwaters (Ombu 1987; Yakubu *et al*., 1996; Solomon, 2012). The pH range also falls within (6.5-8.5) recommended limits for

aquatic life. This pH makes it quite suitable for fish production in this river (Adekole *et al*., 2003). The direct correlation relationship existing between pH and calcium content does not conform to the established bioavailability of more trace elements in increasingly acidic media (Fleischer *et al.,* 1993).

The range obtained for nitrate fall within the optimum value (50 mg/l) for drinking water by WHO (2006) and NESREA (2011) and 9.10 mg/l for aquatic life. This value is higher than 0.02-0.03 mgl^{-1}recorded by Medudhula *et*. *al*. (2012) in Lower Manair Reservoir but lower than 52.7±1.3 mgl^{-1} reported by Ikenweiwe and Otubusin (2005) in Oyan Lake in South-western Nigeria. According to Mustapha, (2009), the variation in nitrate concentration reflects the effects of human activities on various sections of the river. However, the values are comparable to the works conducted in the South-south water bodies by Amadi *et al.* (1997) and Edoghotu and Adeleye – Wokoma (2007). The positive correlation observed between nitrate and TDS indicates that nitrate ions also contributed to the total dissolved components of the river. The non-significant spatial variation in nitrate concentrations at several sampling locations indicates homogeneity in natural and anthropogenic inputs at those locations. However, there was significant ($P<0.05$) difference in the mean values of nitrate obtained in Lower Niger River seasonally. Also, higher nitrates value was observed during wet season than dry season and this compares favourably per the report of Ayoola and Ajani (2009) on Wetland parts of Oyo State, Nigeria.

Like other nutrients, the sources of phosphate in aquatic environments has been identified as natural weathering of materials in the drainage basin, biological decomposition, and runoff from human activities in urban and agricultural areas (UNEP GEMS, 2006). The observed higher phosphate values recorded during the rainy season therefore could be attributed to increased leaching and surface runoff associated with rainfall and flooding from the catchment areas of the river. This observation though differed from that of Obunwo *et al*. (2004) in MInichida stream in Port Harcourt
The range of PO_4^{2-} ions in this study was within optimum limits for drinkale water and aquatic life (Boyd, 2015). Values recorded in this study also within the range of many

Nigerian inland waters as reported by Egborge (1994). However, they were higher than those recorded for Minichia stream (Obunwo *et al*. (2004) and River Ogunpa (Atobatele *et al*., 2005). Phosphate and nitrate are also important for plankton bloom and eutrophication (Kiely, 1998). The absence of marked spatial variation in phosphate concentration in the study area implies homogenous natural and anthrogenic inputs at these stations. The positive correlations between phosphate, TDS and conductivity reveal the importance of nutrient ions in the overall dissolved and ionic compositions of an aquatic system.

The primary productivity of the present study (0.73±0.03 to 1.07±0.25) is low. The mean gross productivity (GPP) of Lower Niger River was relatively low when compared with mean value for most Nigerian lakes, Lake Kainji (2.19) (Karlman, 1973), NIFFR Reservoir (3.17) (Bwala *et*. *al*. 2010), Samaan (1971) in Nasser Lake (3.21-5.23, mean=4.405 $gO_2m^{-2}d^{-1}$), Mbagwu and Adeniji (1994) in Maruit Lake (0.01-10.57, mean=4.481 $gO_2m^{-2}d^{-1}$) and Ikenweiwe and Otubusin, (2005) in Oyan Lake, South-Western Nigeria (2.2-6.0, mean=3.9 $gO_2m^{-2}d^{-1}$). However, the GPP was significantly higher than the findings of 0.00125 $gO_2m^{-2}d^{-1}$ reported by Adeniji (1980) in Bakolori Lake, Sokoto State and Ovie and Ajayi (2009) in Dadinkowa and Kiri reservoirs. It is also greater than the value of 0.63 reported by Ovie *etal*. (2011) in Ojirami reservoir. Twenty-four months average value of NPP, GPP and CR revealed significant fluctuations over seasons and across the different zones. This low productivity corresponds with the relatively low phytoplankton abundance recorded in the study area and could be attributed to several possible reasons.

Reportedly, low nutrient levels- especially considering the high relative humidity prevalent in the area (Field *et al*., 1998) and high turbidity (Adakole *et al*., 2003) are all productivity-limiting factors that exert influence on photosynthesis by the autotrophs. Of these, the present study could best fingerprint the observed low productivity to high turbidity, which blankets off sunlight- a major player in photosynthesis. This position is assumed since other studies in the Niger Delta aquatic system (Chindah *et al*. 1999; Edoghotu and Adeleye-Wokoma, 2007) that recorded higher autotrophic algae abundance, also had nutrient levels similar to the present study. Accordingly, net

primary productivity (NPP) and community respiration (CR) values closely followed the trend of gross primary productivity (GPP). This indicates a stable community composition of autotrophs utilizing part of the gross production.

Spatially, the study revealed consistencies in plankton abundance and primary productivity. UPS that recorded highest primary productivity also recorded highest abundance of the photosynthetic phytoplankton. The significantly higher primary production recorded in the dry than rainy seasons ($P > 0.05$) corresponds with higher phytoplankton abundance in the season. The negative correlations recorded between production and depth, BOD and TSS could be explained. February was due to reduced water depths, as was also reported by Ikenweiwe and Otubusin (2005) in Oyan Lake, in addition to rise in sunshine durations (Marra, 2002).

Adeniji (1980) similarly reported that production decreases per depths. Highly turbid waters, as well as those with more suspended particulates led to reduced production through reduction in light penetrations necessary for photosynthesis. Oxygen-demanding pollutants in the water column must have deprived the autotrophs of oxygen; an essential requirement for productions. The observed significant positive relationship between primary production and magnesium ions points to the reported important role of the micronutrient in aquatic production. The significant direct influence of pH on gross primary productivity indicates the requirement for optimum pH during the process of photosynthesis in a hydrocarbon-rich environment.

However, the semblances observed in effects of physicochemical variables on primary production and phytoplankton abundance confirm the fact that phytoplankton are the autotrophs/primary producers in the ecosystem

CHAPTER SIX

6.0 SUMMARY AND CONCLUSION

6.1 Summary

The fish assemblage, physico-chemical parameters and primary productivity in Lower River Niger at Agenebode, Edo State Nigeria were investigated to generate scientific information required for sustainable management of the fisheries resources.

6.2 Conclusion

The study revealed useful and baseline information on the species composition, abundance in Lower River Niger at Agenebode, the factors that influence it and the effect of these on the environment.

There was high ichthyofauna population, species richness and evenness and low productivity. Though all dominant species studied exhibited good growth pattern indicating a good state of well being, however, its, primary productivity was low compare to those of most inland water bodies in and outside Nigeria. This may portend negative implications on fisheries of the river. There is therefore, need for adequate management of the river for sustainable productivity. Policies on conservation are immediately needed to preserve the fishery and trim down sand excavation and other human and agricultural discharges in the river. Nevertheless, extension work is very necessary to educate communities living around this river on the effect of their activities on the Ichtyofauna of the water body. In-stream sand mining (excavation) appeared to exacerbate negative impacts on the physico-chemical regime, plankton abundance and primary productivity of the river.

6.3 Contribution to knowledge

The study reviewed the current status of the fish resource and productivity of Lower River Niger and establish that:

1. Fish abundance is more during the dry season than wet season and species are evenly distributed
2. The family Cichlidae is most abundant family while family Mormyridae was the most diverse with nine species
3. *Synodontisclarias* is more abundant during the wet season while *Xenomystus nigri* is more abundant in the dry season
4. The potential fish yield of the river ranges from 92.68kg/ha to 286.91
5. Conductivity, pH, turbidity and gross primary productivity are major environmental factors that impacted fish composition and productivity in Lower River Niger.
6. The primary productivity ranged from 0.73 to 1.07 ($g/O_2/m^3/d$)

6.4 Recommendations

1. Regular monitoring of the physical, chemical and biological state of this river is required to detect and correct any changes that can hinder fish production
2. The unregulated uses of Lower River Niger at Agenebode have to be monitored via the implementation of laws and regulations by the different agencies that are concerned, as there will be loss of biodiversity if these should continue
3. Primary productivity status (GPP - 2.69±0.21 ($g/O_2/m^3/d$) of the river should be improved to enhance fish production.
4. Agricultural and other anthropogenic activities around the river should be discouraged to prevent further degradation of the water body (COD 84.03 ± 25.37 mg/l, TSS 68.51±10.27 mg/l, Chloride - 16.65± 2.40 mg/l)
5. There is necessity to continually collect data probably on annual basis to document fish diversity for proper management.

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