Tropical Journal of Applied Natural Sciences
Trop. J. Appl. Nat. Sci., Vol 2 Issue 1, (2024)
ISSN: 2449-2043
https://doi.og/xxx/TJANS/XXXX.X.X.X

Seasonal Evaluation of Physico-Chemical Parameters for sustainability of *Oreochromis niloticus, Auchenoglanis occidentalis and Mormyrus rume* at River Niger, Axis, Onitsha. Nigeria.

I.E. Iloghalu [a*], V N. Arazu [b], K. N. Ibemenuga [a] and N. P. Udeh [c]

[a] *Department of Biological Sciences, Faculty of Natural Sciences, Chukwuemeka Odumegwu Ojukwu University, Uli campus, Anambra State, Nigeria.*

[b] *Department of Fisheries and Aquaculture, Faculty of Agriculture, Chukwuemeka Odumegwu Ojukwu University, Igbariam campus, Anambra State, Nigeria.*

[c] *Department of Zoology, Faculty of Biosciences, Nnamdi Azikiwe University, Awka Nigeria .*

Corresponding author: lizzyfine003@gmail.com

ABSTRACT

Human population of Anambra state is increasing at an alarming rate thus increasing the rate of anthropogenic waste into the various rivers in the state. Hence seasonal evaluation of some physicochemical parameters of River Niger, Onitsha was studied to ascertain their effect on *Oreochromis niloticus, Auchenoglanis occidentalis and Mormyrus rume* sustainability. In the method water and fish samples were collected from three sampling locations; Onitsha (marine), Ogbaru and Nsugbe from March 2022 to November 2023, fortnightly, for 18 months. Water samples were collected by dipping a sterilized 200 ml plastic container below the surface of water body for analyzing physico-chemical parameters using APHA 2005 method, only water temperature was measured in-situ, other analysis was done in the Chemistry Laboratory of Chukwuemeka Odumegwu Ojukwu University, Uli. Fish samples were collected between 9.00- 11.00 am from artisanal fishermen operating along Onitsha (marine), Ogbaru and Nsugbe locations. A total of 201 *Oreochromis niloticus*, 92 *Auchenoglanis occidentalis* and 168 *Mormyrus rume* were collected. SPSS version 25 and Microsoft Excel sheet were used to analyze and managed data collected. In the result, all the water parameters studied were significantly related to the fish species and seasons ($p<0.05$). River Niger axis Onitsha has adequate physico- chemical parameters. This study contributed to the knowledge that River Niger water condition support fish growth at wet and dry seasons.

Received Dec., 2023
Acceptable Jan., 2024
Published Feb., 2024

Keywords:

Seasons, Physico-chemical parameters, *Oreochromis niloticus, Auchenoglanis occidentalis and Mormyrus rume*. River Niger.

1 INTRODUCTION

Water is the physical support/habitat in which fish lives and carry out all their life functions such as feeding, swimming, breeding, digestion and excretion. Recently, water quality has been greatly affected as a result of anthropogenic activities such as urbanization, land reclamation, agriculture and accelerated industrialization. These human activities have led to deterioration or pollution of fresh water bodies. Notably, the physical environment, chemical quality and biological interactions of water bodies greatly influence the distribution of aquatic organisms including fish. Moreover, it is feared that inland water catches continue to decline. The result of these reductions is low fish yield in a number of water bodies. In considering fish yields, there was a link from insufficient management to the continued degradation of water bodies (Okomoda, 2017) The relationship between physico-chemical parameters of water and plankton production in fish ponds is of great importance and essential for fish culture (Islam, 2007). Water quality in fish ponds is often due to the interactions of several physico-chemical components and can have profound effects on pond productivity and fish health. River constitutes important ecosystem and food resources for a lineup of aquatic life. Human activities can speed up the rate of changes; if the causes of the changes are known, human intervention (management practices) sometimes can control or even reverse detrimental changes. To keep the aquatic habitat favorable for sustainability of living organisms, physical and chemical factors like temperature, turbidity, pH, odour, dissolved gases, salts nutrients must be monitored regularly, individually or synergistically. However, it is important to know that activity of living organisms is influenced by the seasonal and diurnal changes of these parameters (Akinyeye *et al.,* 2011). Changes in the physico-chemical parameters may positively or negatively affect the biota of water bodies in a number of ways such as their survival and growth rates, which may eventually result in disappearance of some species of organisms or its reproduction (Edward and Ugwumba, 2010). Various studies have been conducted on changes brought about by biotic and abiotic factors of the rivers as a result of damming, (Offem and Ikpi 2011). The species composition and density of aquatic organisms are influenced not only by geographical locations but also by water quality. The dumping of anthropogenic inputs such as run-off of agricultural wastes and effluent from the surrounding industries into the rivers as well as lack of information on water qualities of rivers are the major problems facing rivers today. Hence it has influenced the growth potentials and fish abundance in today's aquaculture. Thus, there is need for studies in these rivers to proffer solutions that will ameliorate the effects of these problems for proper aquaculture productivity. In the present study information was obtained on seasonal water quality parameters of River Niger axis, Onitsha to ascertain sustainability of three fish species at varying seasons in the River.

2. 0 Litrature Review

2.1 Physico- Chemical Parameters of the River

The study of the physico-chemical properties of water which is a fundamental part of limnology have been used in assessing water quality, biological productivity and trophic status (Mustapha, 2003), as well as composition, distribution and abundance of biotic organisms (Mustapha and Omotosho, 2006). For instance, low dissolved oxygen content, high biochemical oxygen demand and low alkalinity values indicate that the water bodies are unsuitable to support aquatic life (Okoye, 2016). Physico-chemical study could help in understanding the structure, function and management of river in relation to its biotic components and production. Physical and chemical features in reservoirs are governed by the prevailing hydrologic and geomorphic processes, while the local geology determines the water chemistry.

It is known that water contains a large number of chemical elements that enter into chemical complexes in aquatic ecosystems. These chemical elements found in water are equally known to have effect on biological processes which lead to inter conversion and flow of energy, nutrient cycling, production of organic materials and ultimately production of aquatic resources most especially fishes. Physical factors such as temperature, transparency, water velocity or current have also been known to interplay with the chemical factors in reservoirs to produce a sustainable ecosystem rich in phytoplankton species, (the primary producers), zooplanktons and diverse fish populations (Adebowale *et al*., 2008). It is an observable fact that aquatic ecosystems are influenced by several health stressors that remarkably deplete biodiversity. Furthermore, the loss of biodiversity and its effects are predicted to be greater for aquatic ecosystems than terrestrial ecosystems (Sudhira and Kumar, 2000). Rivers are subjected to a lot of natural processes, which are taking place in the environment, such as the hydrological cycle. As a result of unprecedented development, human beings are responsible for destroying so many rivers. Storm water runoff and discharge of sewage into rivers are two common ways that various nutrients enter the aquatic ecosystems, which often result in such ecosystems pollution (Sudhira and Kumar, 2000).

2.2 Temperature

Temperature is basically important for its effects on the chemical and biological activities of organisms in water (N'Diaye *et al.,* 2013). It is a known fact that water temperature varies throughout the year with seasonal changes in air temperature, day length, and solar radiations. Photo period and temperature help in production of green algae. Temperature influences determination of other factors like pH, conductivity, dissolved gases and various forms of alkalinity (N'Diaye *et al.*, 2013). Temperature of water bodies may vary with time of the day, months and seasons. Ibrahim *et al.*, (2009) reported that low water temperature of Kontagora reservoir during the dry season could be as a result of seasonal changes in air temperature which could be associated with the cool dry Northeast trade winds. The air and water temperature readings indicated an increase from January to March in Makwaye Reservoir (Balogun *et al.*, 2005).

2.3 pH

Water pH is considered as an important chemical parameter that determines the suitability of water for various purposes. The pH simply put is acidity or alkalinity of water. Water of around pH 7 is considered neutral; it is of great importance to biotic communities because most of the aquatic organisms are adapted to an average pH (Surajit and Tapas, 2014). Mustaph (2008) reported that slight acidity increase in the dry season may be due to high carbon dioxide concentration from organic decomposition. High pH values promote growth of phytoplankton which most often results in algal blooms.

2.4 Dissolved oxygen (DO)

Dissolved oxygen is an essential chemical ion needed for energy metabolism of aquatic organisms. It also provides information about the biological and biochemical processes in water. Dissolved oxygen (DO) is of primary importance in natural water because most organisms except anaerobic microbes diminish rapidly when oxygen levels in water reduces, among all dissolved gases; oxygen plays the most important role in determining the potential biological quality of water. Dissolved oxygen level of 5 mg/l or greater will support healthy growth of most fishes (Hanna, 2003). Dissolved oxygen supply in water mainly comes from atmospheric diffusion and photosynthetic activity of plants. The quantity of dissolved salts and temperature greatly affects the ability of water to hold oxygen (Araoye, 2008). Photosynthetic activity and reduced turbidity enhanced dissolved oxygen concentrations (N‟Diaye *et al.,* 2013).

2.5 Biochemical oxygen demand (BOD)

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

2.6 Electricity conductivity (EC)

Conductivity of natural water is a measure of its ability to conduct an electric current. According to Brook (2002), waters with very high conductivity are not potable. Conductivity of most fresh water generally is lower during the rainy seasons than dry season (Diaz *et al*., 2007). It is due to a dilution by rain and less evaporation during the rainy season, especially in lakes with short retention time (Zinabu, 2002). This also conform with the reports of Atobatele and Ugwumba (2008), It suggested that low precipitation, elevated air temperatures leading to increased evapo-transpiration rates and total ionic concentration, and saltwater intrusions from subterranean sources might all cause an increase in electrical conductivity. The level of conductivity in water could give a good indication of the number of substances dissolved in it, such as phosphate, nitrate and nitrites. Different ions vary in their ability to conduct the electricity (Zeb *et al*., 2011). Conductivity can influence composition, abundance and distribution of biotic organisms (Mustapha, 2006). According to a 2015 study by Mihir *et al.*, conductivity and chloride ions may be connected. Furthermore, he believed that the notable shift in conductivity might have resulted from either natural flooding, evaporation, or human-caused pollution, all of which have a negative impact on the quality of water. Therefore, an abrupt rise or fall in conductivity in a body of water could be a sign of contamination. He claims that the main source of the conductivity increase could be sewage leaks or agricultural runoff because they include more phosphate, nitrate, and chloride ions.

2.7 Water hardness (WH)

Hard water contains high concentrations of alkaline earth metals while soft water has low concentrations. Calcium is used by green algae as micronutrients. The distribution of certain algae has been correlated with differing concentrations of calcium (Wetzel, 2001). High concentration of calcium ($Ca^{2+)}$ and magnesium ($Mg^{3+)}$ ions are responsible for hardiness and they are usually associated with high levels of bicarbonates (Ibrahim *et al.*, 2009). The increase in hardness value of water body can be attributed to the decrease in water volume and concomitant increase in the rate of evaporation at high temperature resulting in high exposure to organic detergents.

2.8 Total dissolved solids (TDS)

Total dissolved solids indicate organic and inorganic matter in a water sample. The solids may be organic or inorganic in nature depending upon volatility of the substances (Kolo *et al.*, 2010). The quantity of dissolved or soluble materials in water is known as total dissolved solid (TDS) and it is generally measured in (mg/l). Different ions like sodium, potassium, chloride, carbonate, sulfate, calcium, magnesium etc. contribute to the TDS of water. Survival, growth or reproduction of any aquatic organisms is very much controlled by the dissolved ions concentration in lake water. Water will be of freshwater category if its TDS value is less than 1,000 mg/l, (Mihir *et al.*, 2015). Another source of TDS to the lake is a sewage inflow into one of the lake's tributaries (Akomeah *et al.*, 2010). The low TDS concentration is due to dilution, low allochthonous inputs, microbial uptake of TDS and usage by phytoplankton (Adakole *et al.*, 2008).

2.9Alkalinity

Alkalinity or buffering capacity of freshwater is primarily due to the presence of bicarbonate; carbonate and hydroxide ions, silicates and phosphate may also contribute. Alkalinity is important for fish and other aquatic life because it buffers pH changes that occur naturally due to photosynthesis. Waters with low alkalinity often have pH of 6 to 7.5. Waters with extreme high total alkalinity may have pH values too high for fish production. Waters dominated by bicarbonate ions usually have low or no phenolphthalein alkalinity (Campbell and Wildberger, 2001).

2.10 *Oreochromis niloticus*

The fish Oreochromis niloticus has a compressed body and a deep chest. It is white vertically and bronze to brownish-gray dorsally and laterally. Its caudal fin is truncated and has a pinkish-red posterior margin with numerous thin black bars. This species, referred to as Nile tilapia, is a tropical freshwater and estuarine fish of great economic significance. It is in family of the Cichlidae and a member of tilapia fish. In aquaculture production, *Oreochromis niloticus* is the most commonly utilized species. It can weigh up to 5 kg and has a typical lifespan of 10 years. (Jerson, 2021). He claims that because, tilapia is a tropical fish, it can easily adapt to any country that produces it. This species is resilient. Because of their quantity in the water, they are referred to as the "chickens of the water" informally. Fishermen are aware of their good reproduction, fast growth, high spawning, fertilization, and larvae viability rates. They are very disease resistant, easy to manage, and quick to adjust to changes in their surroundings. Intensive farming lowers the cost of tilapia production.

2.11 *Auchenoglanis occidentalis* (Cuvier and Valenciennes)

Auchenoglanis occidentalis is originally classified in the Bagridae family, but, now a member of the Claroteidae family. They are distributed all over Africa and are generally referred to as Bubu or giraffe nosed Catfish. They are bottom dwellers that live in large rivers and lakes. According to Ikongbeh (2014), *Auchenoglanis occidentalis* inhabits shallow waters with a muddy bottom. The majority of these fish's lives are spent in the dark. When night falls, they emerge from their hiding spot and show little concern for other fish cruising through their territory.

2.12 *Mormyrus rume*

Mormyrus rume commonly known as elephant snout fishes are freshwater tropical fishes. It is a species of electric fish in the class Actinopterygii in order, Osteoglossiformes and family Mormyridae, found in the rivers. It is made up of 2 subspecies like; *Mormyrus rume proboscirostris* (Boulenger, 1898) and *Mormyrus rume* (Valenciennes, 1847). According to Igejongbe *et al.,* (2018) the family Mormyridae commonly called elephant snout fishes is represented by twenty-six different species belonging to six genera in Nigerian freshwater. Olaosebikan and Raji (2004) reported maximum size for *Mormyrus rume* adult as 100 cm. They are remarkably variable in their head and fins shape. They are covered with cycloid scales. They are characterized by upward inferior mouth that is distinct and rounded, pointing pectoral fins, narrow gill openings, small and weak eyes and a thin layer of skin. Their habitats range from bottom dwellers to top feeders of deoxygenated swamps to swift rapids (Igejongbo *et al.*, 2018).

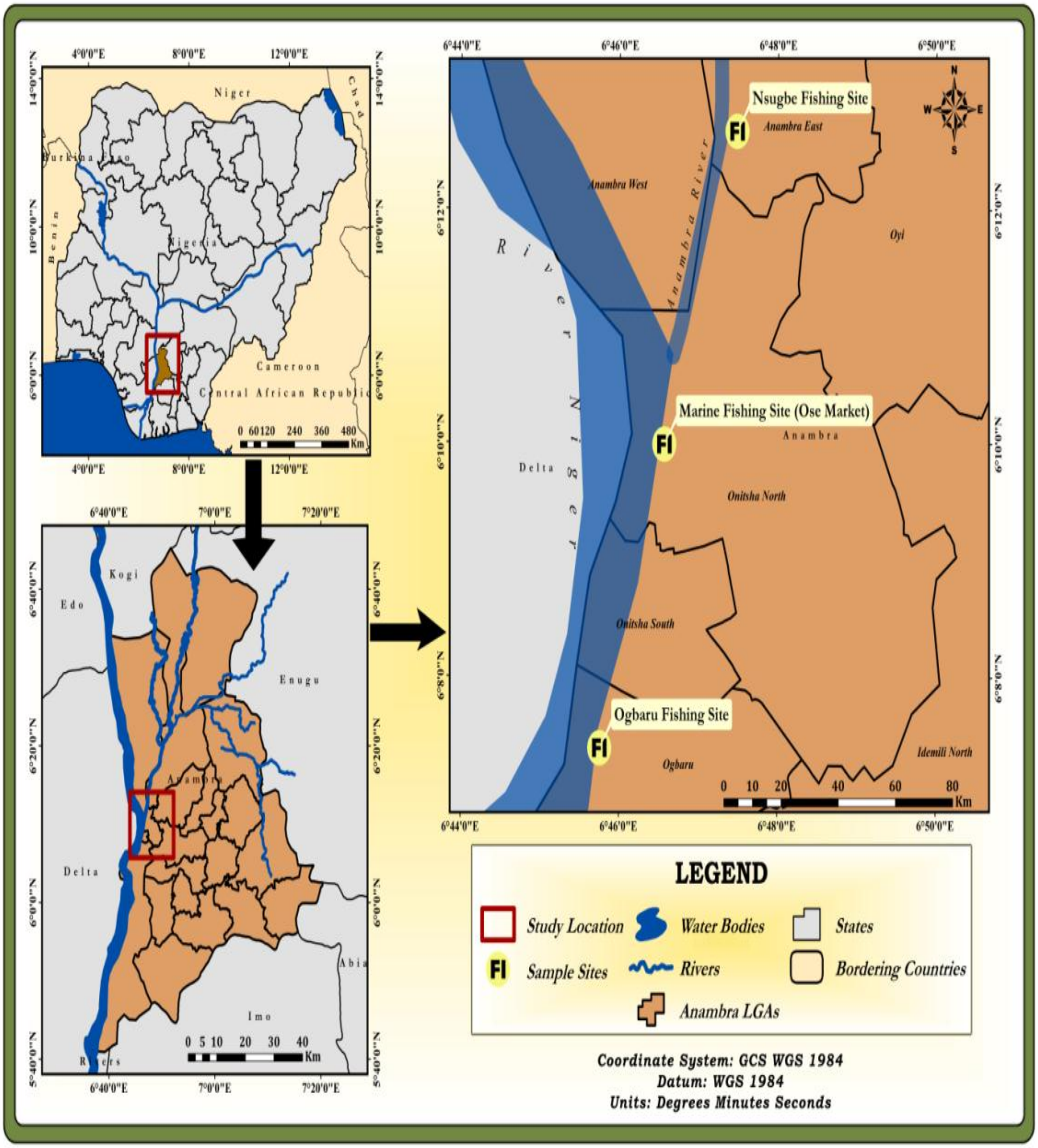
3. METHODOLOGY

In the method water and fish samples were collected from sampling sites from March 2022 to November 2023, fortnightly, for 18 months. Water samples were collected by dipping a sterilized 200 ml plastic container below the surface of water body per site for analyzing physico-chemical parameters using APHA 2005 method. Fish samples were collected between 9.00- 11.00 am from artisanal fishermen operating along Onitsha (marine), Ogbaru and Nsugbe locations. Analysis was done in the Chemistry and Biological Science Laboratories of Chukwuemeka Odumegwu Ojukwu University, Uli. Only water temperature was measured in-situ. A total of 201 *Oreochromis niloticus*, 92 *Auchenoglanis occidentalis* and 168 *Mormyrus rume* were collected and measured. SPSS version 25 and Microsoft Excel sheet were used to analyze and managed data collected.

3.1 Description of Study Area

River Niger at Onitsha is located in Anambra State in Eastern Nigeria and lies within latitudes 6° 46’ 27’’ E and 6^0 11’6” N and longitudes 6° 45’52” E and 6° 7’53” N. Onitsha in Anambra State, is found on the east bank of River Niger and covers an area of about 49,000 km^2. It is one of most important commercial centers in sub-Sahara African and it is a transit city in Nigeria. Anambra is rich in natural gas, crude oil, bauxite, and ceramic. It has an almost 100 percent arable soil. Anambra state has many other resources in terms of Agro-based activities such as fisheries and farming, as well as land cultivated for pasturing and animal husbandry. River Niger is a home to many rain forest rivers and its surroundings are hub of business activities such as buying and selling, fish and Agro produce landing, sand dredging and many other business activities. The two main seasons that are observed in Onitsha include dry season which begins in October and ends in March and the rainy season that starts from April to September.

Figure 1: Map of Anambra state showing River Niger at Onitsha, Ogbaru and Nsugbe.



Data Analysis

Data obtained were presented on tables, use of simple statistical tools analysis like, mean and standard deviation in order to ascertain the significance of the variables obtained. SPSS version 25 and Microsoft Excel sheet were used to analyze and managed the data.

4. RESULTS

Physico-chemichal Parameters of the three sites sampled

The results of the physico-chemical parameters of the three study sites; River Niger axis at Onitsha (Marine), Ogbaru and Nsugbe are presented on Tables 1- 10.

The results showed that the mean total pH value for the three locations studied was higher (7.27±0.321) in dry season, than wet season (6.52±0.347) (table 1). The mean total temperature value for the locations was higher (26.34±0.379°C) in wet season than in dry season (26.14 ±0.314°C) (tab. 2). The mean total dissolve oxygen (DO) value for the locations was higher (47.39±1.337 mg/L) in wet season than in dry season (40.58±0.841 mg/L) (tab 3). The mean total turbidity value for the locations was higher (2.56 NTU) in wet season than in dry season (0.14 NTU) (tab. 4). The mean total BOD value for the locations was higher (180.5±7.538 mg/L) in wet season than in dry (163.81±13.732 mg/L) (tab. 5). The mean total electrical conductivity (EC) value for the locations was higher (162.06±4.666 mmho/cm) in dry season than in wet season (155.53±1.540 mmho/cm) (tab. 6). The mean total Alkalinity content value for the locations was higher (7.55±0.284 mg/L) in wet season than in dry season (6.32±0.144 mg/L) (tab. 7). The mean total dissolved solid (TDS) value was higher (25.33±1.62 mg/1) in wet season than in dry season (20.92±3.384 mg/L) (tab. 8). The mean total chloride (Cl) value for the locations was higher (3.28±0.338/L) in wet season than in dry season (2.35±0.202 mg/L) (tab. 9). The mean water hardness value for the locations was higher (17.94±2.097/L) in wet season than in dry season (16.50±.1.540 mg/L) (tab. 10).

pH values result.

The pH value of Ogbaru site was highest (7.58 ±0.190) followed by Nsugbe (7.20 ±0.283) and then Onitsha (7.03±0.197) at dry season and at wet season Ogbaru site was highest (6.54±0.271) followed by Nsugbe then Onitsha (Tab. 1). At a closer observation the difference in their values was infinitesimal.

Table 1: Showing the mean pH and standard deviation values of the study sites at wet and dry seasons.

Location	Wet season	Dry season	Total	
Onitsha	6.47	7.03	6.75	
	(±0.380)	(±0.197	(±0.413)	
Nsugbe	6.54	7.58	7.06	
	(±0.271)	(±0.190)	(±0.578)	
Nsugbe	6.53	7.2	6.87	
	(±0.402)	(±0.283)	(±0.481)	
Total	6.52	7.27	6.89	$P < 0.05$
	(±0.347)	(±0.321)	(±0.505)	

There was significant difference in the pH values in both seasons and location.

Water Temperature results in degree centigrade (^{o}c).

Temperature was highest at Ogbaru site (26.55±0.383), followed by Nsugbe (26.48±0.336) and then Onitsha was lowest (26.01±0.1) during the wet season. At dry season Ogbaru site was also highest in temperature (26.27±0.235) followed by Onitsha (26.12±0.269) and then Nsugbe was least (26.05±0.399) (Tab. 2).

Table 2: Showing the mean and standard deviation of Temperature values in degree centigrade (^{o}c) of the study sites at wet and dry seasons.

Location	**Wet Season**	**Dry Season**	**Total**	
Onitsha	26.01	26.12	26.06	
	±0.1	±0.269	±0.206	
Ogbaru	26.55	26.27	26.41	
	±0.383	±0.235	±0.343	
Nsugbe	26.48	26.05	26.26	P < .05
	±0.336	±0.399	±0.421	
Total	26.34	26.14	26.24	
	±0.379	±0.314	±0.36	

There was significant difference in the Temperature values at both seasons and location.

Dissolved oxygen results (mg/l)

Dissolve oxygen (DO) was highest at Nsugbe site (47.83±1.193), followed by Ogbaru 47.42±1.443) then least at Onitsha during the wet season while at dry season it was highest at Onitsha (40.67±0.888) followed by Nsugbe site (40.58±0.905) then least at Ogbaru (40.5±0.905) (Tab. 3).

Table 3: Showing the mean and standard deviation of Dissolved Oxygen (DO) (mg/[) values of the studied sites at wet and dry seasons.

Location	**Wet season**	**Dry season**	**Total**	
Onitsha	46.92	40.67	43.79	
	±1.311	±0.888	±3.375	
Ogbaru	47.42	40.5	43.96	
	±1.443	±0.905	±3.724	$P < 0.05$
Nsugbe	47.83	40.58	44.21	
	±1.193	±0.793	±3.833	
Total	47.39	40.58	43.99	
	±1.337	±0.841	±3.602	

There was significant difference for Dissolve Oxygen (DO) at both seasons but no significant difference for location.

Turbidity (NTU) results

At wet season turbidity was highest at Nsugbe site (2.57±1.071), followed byOgbaru site (2.56±1.061) then least at Onitsha site. However, at dry season it washighest at Onitsha (0.19±0.263), followed by Nsugbe value (0.14±0.098) and least at Ogbaru site (0.09±0.054) (Tab. 4)

Table 4: Showing the mean Turbidity values of the studied sites at wet and dry seasons

Location	Wet season	Dry season	Total
Onitsha	2.55	0.19	1.37
	±1.037	±0.263	±1.413
Ogbaru	2.56	0.09	1.32
	±1.061	±0.054	±1.456
Nsugbe	2.57	0.14	1.36
	±1.071	±0.098	±1.449
Total	2.56	0.14	1.35
	±1.026	±0.165	±1.419

$P < .05$ for seasons

There was significant difference in the turbidity for seasons but not at locations.

Biological oxygen demand (BOD) mg/l results.

Highest biological oxygen demand was recorded at Nsugbe site (182±7.839), followed by Ogbaru stite (180.17±7.004) and Onitsha site least was least (179.33±8.139) during the wet season. At dry season highest BOD was recorded at Ogbaru site while Onitsha and Nsugbe sites were recorded same values (Tab.5).

Table 5: Showing the mean Biological Oxygen Demand (BOD) values of the studied sites at wet and dry seasons

Location	Wet season	Dry season	Total
Onitsha	179.33	163.67	171.5
	± 8.139	±15.029	± 14.274
Ogbaru	180.17	164.08	172.13

	± 7.004	±13.548	±13.369
Nsugbe	182	163.67	172.83
	± 7.839	±13.799	±14.427
Total	180.5	163.81	172.15
	± 7.538	±13.732	±13.843

P < .05 for seasons

There was significant difference in Biological Oxygen demand (BOD) for seasons but none at locations.

Electrical conductivity (EC) (μm/cm) results.

Electrical conductivity (EC) was highest at Ogbaru site, followed by Onitsha then Nsugbe at dry season, it was also highest at Ogbaru site, followed by Onitsha and then Nsugbe during the wet season (Tab. 6).

Table 6: Showing the mean Electrical Conductivity values of the studied sites at wet and dry seasons

Location	**Wet season**	**Dry season**	**Total**
Onitsha	155.58	162.08	158.83
	±1.165	±4.776	±4.752
Ogbaru	156.17	162.25	159.21
	±1.03	±4.634	±4.52
Nsugbe	154.83	161.83	158.33
	±2.038	±4.988	±5.164
Total	155.53	162.06	158.79
	±1.54	±4.666	±4.765

P < .05 seasons

There was significant difference in the electrical conductivity for seasons but none for location.

Alkalinity (mg/l) result.

The alkalinity of River Niger was highest at Ogbaru site (7.6±0.191), followed by Onitsha site then Nsugbe during the wet season while it was highest at Onitsha, followed by Nsugbe then Ogbaru sites at dry season (Tab. 7).

Table 7: Showing the mean Alkalinity values of the studied sites at wet and dry seasons

Location	**Wet season**	**Dry season**	**Total**
Onitsha	7.53	6.43	6.98
	±0.341	±0.142	±0.617
Ogbaru	7.6	6.27	6.93
	±0.191	±0.137	±0.7
Nsugbe	7.52	6.28	6.9
	±0.316	±0.097	±0.674
Total	7.55	6.32	6.93
	±0.284	±0.144	±0.656

$P < .05$ seasons

There was significant difference in the Alkalinity for seasons but none for locations.

Total dissolved solid (mg/l) result.

Total dissolved solid (TDS) was highest during the wet season at Ogbaru (25.42±1.443), followed by that at Onitshas and then Nsugbe sites but at dry season it was highest at Nsugbe site, followed by Onitsha then Ogbaru (Tab. 8).

Table 8: Showing the mean and standard deviation of Total Dissolve Solid (TDS) (mg/l) of the studied sites at wet and dry seasons

Location	Wet season	Dry season	Total
Onitsha	25.25 ± 1.658	20.58 ±3.476	22.92 ±3.574
Ogbaru	25.42 ± 1.443	20.50 ±3.371	22.96 ±3.569
Nsugbe	25.33 ±1.875	21.67 ±3.473	23.50 ±3.310
Total	25.33 ±1.621	20.92 ±3.384	23.13 ±3.448

P < .05 seasons

There was significant difference in the Total Dissolve Solid (TDS) for seasons but none for locations.

Chloride content (mg/l) result

Chlorid content value was highest at Nsugbe site during the wet season followed by Ogbaru site the Onitsha while at dry season it was highest at Onitsha site followed by Ogbaru then Nsugbe site (Tab. 9).

Table 9: Showing the mean chloride values of the studied sites at wet and dry seasons

Location	Wet season	Dry season	Total
Onitsha	3.25 ±0.384	2.39 ±0.196	2.82 ±0.531
Ogbaru	3.26 ±0.336	2.33 ±0.222	2.8 ±0.549

Nsugbe	3.32 ±0.316	2.32 ±0.199	2.82 ±0.572
Total	3.28 ±0.338	2.35 ±0.202	2.81 ±0.543

$P < .05$ seasons

There was significant difference in the Chloride for seasons but none for locations.

Hardness of water (mg/l) result.

Onitsha site recorded highest water hardness (20.42±0.669) during wet season followed by Ogbaru and then Nsugbe sites. It also recorded highest at dry season (18.5±0.674) followed by Ogbaru and Nsugbe (Tab.10)

Table 10: Showing the mean water hardness values of the studied sites at wet and dry season

Location	**Wet season**	**Dry season**	**Total**
Onitsha	20.42 ±0.669	18.5 ±0.674	19.46 ±1.179
Ogbaru	17.83 ±0.389	16 ±0	16.92 ±0.974
Nsugbe	15.58 ±0.793	15 ±0	15.29 ±0.624
Total	17.94 ±2.097	16.5 ±1.54	17.22 ±1.966

$P < .05$ seasons and location

There was significant difference in the Hardness of water for seasons and location.

Result on effect of Seasons on the Weight and Length of the fish species studied.

The results of the studied fish weights on Tables 11 showed that at both seasons, highest mean total weight was recorded in *A. occidentalis* (204.74±120.556) g, followed by *M. rume* weight (107.6±124.826) g and then *O. niloticus* was least (70.02±56.798) g. During wet season, it was observed that *Auchenoglanis occidentalis* had highest weight (197.27±132.877) g at Onitsha site, followed by *Mormyrus rume* (117.3±141.128) g and then *O. niloticus* (76.02±55.802) g. At dry season *A. occidentalis* was highest in weight too followed by *M. rume* then *O. niloticus* (tab. 11). At Ogbaru, highest weight was recorded in *A. occidentalis* (218.15218.15) g, in wet season and (189.85±90.479) dry seasons followed by *M. rume* and then *O. niloticus* (tab. 11), at Nsugbe the order was the same.

Table 11: Showing the mean and standard deviation of body weight in gram (g) of *Oreochromis niloticus, Auchenoglanis occidentalis* and *Mormyrus rume* at River Niger axis: - Onitsha, Ogbaru and Nsugbe at wet and dry seasons

Location	**Seasons**	*O. niloticus*	*A. occidentalis*	*M. rume*	Total
Onitsha	Wet season	76.02	197.27	117.3	117.57
		±55.802	±132.877	±141.128	±119.568
	Dry	61.29	202.15	93.05	92.06
		±52.952	±87.506	±100.569	±90.026
	Total	69.63	198.66	108.17	107.73
		± 54.949	±121.192	±127.589	±109.733
Ogbaru	Wet	70.26	218.15	134.73	128.87
		±48.831	±124.681	±145.691	±125.432
	Dry	69.97	189.85	86.98	92.92
		±63.037	±90.479	±78.363	±82.952
	Total	70.13	210.07	117.7	114.91
		±55.685	±116.163	±127.683	±112.162
Nsugbe	Wet	74.6	206.76	118.28	122.77

		±54.579	±131.856	±140.218	±123.717
	Dry	65.95	202.23	58.87	82.33
		±64.998	±108.61	±47.533	±82.82
	Total	70.32	205.48	96.83	106.39
		±59.977	±125.154	±118.946	±110.712
Total	Wet	73.71	207.39	123.64	123.04
		±53.149	±129.48	±142.195	±122.849
	Dry	65.73	198.08	79.63	89
		±60.57	±94.912	±79.54	±85.284
	Total	70.02	204.74	107.6	109.66
		±56.798	±120.556	±124.826	±110.852

$P < 0.05$, seasons and species

There was significant difference in the body weight of fish for the seasons and by species while there is none by location.

Result of mean total length of three studied fish species on table 12, showed that *M. rume* had highest length (22.99±7.958) cm, followed by *A. occidentalis* (22.86±6.208) cm and least was *O. niloticus* (12.55±6.27) cm. However, at wet season *A. occidentalis* was highest in total length (23.65±6.002) at Onitsha site followed by *M. rume* (23.14±7.963) cm and then *O. niloticus* (11.08±5.098) cm and during the dry season *M. rume* was highest (21.3±6.777) cm followed by *A. occidentalis* then *O. niloticus*, At Ogbaru site, in wet season, *M. rume* was highest (24±8.58) followed by *A. occidentalis* and then *O. niloticus.* During the dry season for same site, it was the same. *A. occidentalis* was recorded highest (23.91±6.242) during the wet season at Nsugbe site followed by *A. occidentalis* and then *O. niloticus*.

Table 12: Showing mean and standard deviation of Total length of three studied fish species

Location	**Season**	*O. niloticus*	*A. occidentalis*	*M. rume*	Total
Onitsha	Wet season	11.08	23.65	23.14	18.7
		±5.098	±6.002	±7.963	±8.825
	Dry	12.15	20.65	21.3	16.19

		±4.876	±5.995	±6.777	±7.216
	Total	11.61	22.81	22.47	17.67
		±5.005	±6.118	±7.585	±8.291
Ogbaru	Wet	15.49	23.4	24	20.13
		±9.047	±6.32	±8.58	±9.317
	Dry	12.47	20.84	22.83	16.69
		±4.712	±5.588	±6.341	±7.21
	Total	14.23	22.69	23.63	18.89
		±7.671	±6.202	±7.934	±8.767
Nsugbe	Wet	10.74	23.91	22.89	19.21
		±5.138	±6.242	±8.34	±9.14
	Dry	12.54	20.93		14.23
		±5.183	±6.285		±6.367
	Total	11.61	23.07	22.89	17.86
		±5.226	±6.364	±8.34	±8.755
Total	Wet	12.69	23.65	23.27	19.36
		±7.251	±6.16	±8.298	±9.116
	Dry	12.38	20.81	22	15.86
		±4.917	±5.89	±6.597	±7.059
	Total	12.55	22.86	22.99	18.15
		±6.27	±6.208	±7.958	±8.62

P < P<0.05 seasons and species

There was significant difference in the total length (TL) of fish for the seasons and species while there is none by location.

5. DISCUSSION

The result of this study showed that all the Physico- Chemical parameters studied varied significantly in two sampling seasons. This variation could be due to the difference in the anthropogenic influence, physical and geological feature of the river sites. This observation was in line with the work by Obiyor *et al*. (2017) who stated that the water chemistry of an aquatic ecosystem is dependent on the physical and geological features of its drainage basin. This is significant due to atmospheric changes at different seasons, pollutants, particularly oxides of sulphur and nitrogen caused by anthropogenic events.

In the current investigation, pH range of the water samples for both dry and wet seasons is 6.51–7.27. This report conformed with the study by Ogah *et al*., (2013) who found pH range between 7.2 - 7.7 for wet and dry seasons in his study. The pH of water is an important consideration when deciding whether or not it is appropriate for a given use. The pH of natural water varies due to both biological activity and industrial pollution. In the current study, the observed pH values showed that the three river sites were not detrimental to the health of the fish. The recorded mean pH value (6.89±0.505) in this study fell within the recommended range of 6.5 - 8.5 set by the World Health Organization and National Standard for Drinking Water Quality in Nigeria (WHO, 2004; NSDWQ, 2007). This value was in agreement with the report of Akaahan *et al*. (2015) that recorded a mean pH value of 6.63±0.07 in River Benue at Makurdi, Benue State Nigeria.

The mean temperature values (26.24±0.360) of the three sites were similar with the values obtained by Okeke and Adinna (2013) who reported a mean temperature of 27.4ºC in Otamiri River Nigeria. The wet season temperature was slightly higher than dry season, this could be attributed to the humid nature of the atmosphere during the wet season.

The total mean dissolve oxygen (DO) was (47.39±1.337) at the wet season which was lower at dry season (40.58±.841), The difference may be attributed to slight environmental changes during the wet season. Dissolved oxygen (DO) is a key characteristic for the metabolism of all aquatic species with aerobic respiration. The degree of oxygen transport across the air-water interface, water temperature, salinity, flow, wind speed, rainfall, and the photosynthesis of aquatic biota are all important factors that affect DO in water (Gaghia *et al.,* 2012; Gwaski *et al*., 2013). It is an important limnological parameter which indicates the level of water quality and organic pollution in the water body. In the present study, the concentrations of DO in the three sites met the universal standard recommended minimum of 5-6 mgL-1 for aquatic life use for warm waters (WHO, 2002). This study DO values were higher than earlier reported on the river by Johnbosco and Nnaji (2011) who reported a mean DO value of 2.00 mgL-1. The high DO record by this study was an indication that the river is highly supportive of aquatic life as observed by Okoye, (2016).

Turbidity in the water might be due to flows and whenever it is high, it influences the amount of light penetration for photosynthesis of algae present to take place. In the current study the Turbidity at wet season for all location was higher (2.56±1.026) than dry season (0.14±0.165) Therefore, it becomes a constraint on primary production and potential fish yield (Ofori-Danson, 2005). The obtained value of turbidity was below the recommended standard maximum of 5.00 NTU (WHO, 2004; NSDWQ, 2007). It showed that the river sites were clear and can support light penetration for photosynthesis of phytoplankton present.

The total biological oxygen demand (BOD) values are used to establish water quality classes for designated uses. BOD was higher in wet season (180.50±7.538) and lower in dry season (163.81±13.732) in the present study. A high BOD of any water body indicates highly polluted water which could be unhealthy for aquatic life. The average mean (172.15 mg/l) BOD reported in this study for all the samples in both dry and wet seasons are outside the recommended standards. Biochemical oxygen demand (BOD) measures the amount of oxygen used by microorganisms or putrefying organisms to decay within the water sample.

Electrical conductivity is a measure of current carrying capacity. Therefore, as concentration of dissolved salts increases conductivity also increases. Many dissolved substances may produce aesthetically displeasing colour, taste and odour. Electrical conductivity obtained in this work is higher at dry season than wet season. Therefore, this work corresponds to the works of Diaz *et al.* (2007) and Atobatele and Ugwumba (2008), who reported higher electrical conductivity at dry season in their works. It is good to note that the electrical conductivity values obtained in this study are within the recommended standard, (1,200 µm/cm).

Less than 100 mg/L of alkalinity is the WHO standard for drinking water in Nigeria and is advised for residential usage. However, in a larger scale, it gives bitter taste to water, Ogah *et al*.(2013). In the present investigation the mean alkalinity of the water samples is (6.93±0.656) and it falls within the range of recommended value. In the current study too, the wet season Alkalinity is higher (7.55 mg/l) while it is lower in dry season (6.32 mg/l) the higher value recorded by the present work is not in conformity with the result of Ogah *et al*.(2013) who obtained Alkalinity values range as 0.8 to 3.8 mg/l.

The total dissolved solids (TDS) in all the water samples from the three sites analyzed in both wet (25.33±1.621) and dry (20.9167±3.38378) seasons were within the WHO standards for drinking water 500 mg/l. TDS in drinking water has been associated with anthropogenic influence like dumping of sewage, industrial wastewater, urban run-off and chemicals used in water treatment process into rivers.

Chloride is one of the most important parameters in assessing the water quality. Chandaluri *et al*. (2010) opined that whenever concentrations of chlorides become higher, it indicates higher degree of organic pollution. In the current study, the mean chloride is 2.81 mg/l for both wet and dry seasons and the WHO standard for drinking water is 250 mg/l. Following opinion of Chandaluri *et al*. (2010), the lower record of mean Chloride is an indication of ability of water to precipitate insoluble calcium and magnesium salts of higher fatty acids from soap solutions is termed hardness. Calcium, magnesium bicarbonate, carbonate, chloride, and sulphates are the main ions that cause hardness. The current values of water hardness were discovered to vary from 17.94 mg/l at wet season and to 16.50 mg/l at dry season. The calcium content in natural water varies depending on the kind of rock in the water body. *Oreochromis niloticus* is a small-sized fish, according to the data collected from the total length and weight of the studied fish species. The mean total length was 12.55 cm, and the mean total weight was 70 g. This length was consistent with the findings of Anwa-udondiah E.P. and Pepple P.C.G. (2011), who recorded the average length of Tilpia as 12.58 cm and the average body weight as 28.55 g. The three fish species that were researched in the River Niger axis had high body weights, which is a sign that the water is suitable for them to eat properly and have a healthy physique.

6. CONCLUSION

The attribute got from the current study showed that River Niger axis at Onitsha, Ogbaru and Nsugbe has adequate physico- chemical parameters which support healthy growth of *Oreochromis niloticus*, *Auchenoglanis oocidentalis* and *Mormyrus rume* at both wet and dry seasons although there is significant relationship of all the parameters studied with the fish and seasons but not to the location. Therefore, determining the seasonal fluctuations in the body weight values of *Auchenoglanis occidentalis, Mormyrus rume,* and *Oreochromis niloticus* is helpful in evaluating the health, growth, and assemblage of fish along the Niger River axis.

7. RECOMMENDATION

Government and individuals are recommended to exploit good water quality of River Niger at Onitsha by establishing big fish farms for a bumper harvest.

REFERENCES

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

Adebowale, K.O. Agunbiade, F.O. and Oluowolabi, B.I. (2008). Impacts of natural and anthropogenic multiple sources of pollution on the environmental conditions of Ondo State costal water Nigeria. *Electronic journal of environmental, agricultural and food chemistry*, **7**(4): 2797-2811.

Akaahan, T. J, Eneji, L.S. and Azua, E.T. (2015) Evaluation of water Quality Suitability in Rver Benue at Makurdi for Agriculture Production in Benue State, *Nigeria. International Scientific Research Journal.*

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

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

Anwa–udondiah E.P. and Pepple P.C.G. (2011). Length weight relationship and condition factor of Black Chin Tilapia (Sarotherodon Melanotheron) cultured in sheltered outdoor tanks. In: R.J. Kolo, A.M. Orire (Eds.). Proceedings of the 26th Annual *Conference of the Fisheries Society of Nigeria* (FISON), Minna. 28th November-2nd December. pp: 98-102

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

Atobatele, O.E. and Ugwumba, O.A. (2008). Seasonal Variation in the Physico-chemistry of a Small Tropical Reservoir (Aiba Reservoir, Iwo, Osun, Nigeria). *African Journal of Biotechnology***, 7** (12):62-171.

Balogun, J.K. (2005). Fish distribution in Kainji domestic water supply reservoir. A case study of Kangimi reservoir, Kaduna state, Nigeria. *Journal of Applied Sciences,* **1**: 50-56

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

Brook, L. (2002). Contrasting effects of human activities on aquatic habitats and biodiversity of two Ethiopian lakes. *Ethiopian Journal of Natural Resources* **4**(1): 123 – 144

Campbell, G. and Wildberger, S. (2001). The monitor's handbook. A Reference Guide for Natural Water Monitoring. LaMotte Company, Chestertown, Maryland USA. 63pp.

Chandaluri, S. R., Sreenivasa, R. A., Hariharann, V. L. N. and Manjula, R. (2010) Determination of water quality index of some areas in guntur district and hrapradesh. *International Journal of Applied Biology and Pharmaceutical Technology* (IJABPT), **1**: 79-86.

Diaz, S., Lavorel, S., Chapin, I.I., Tecco, F.S., Gurvish, P.A. and Grigulis, K. (2007). Functional diversity at the cross road between the ecosystem functioning and environmental filter. *The International Geosphere-Biosphere Programme Series*, Springer-verlag, Berlin Heidelberg.103-113.

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

Essien-Ibok, M.A., Akpan, A.W., Udo, M.T., Chude, L.A., Umoh, I. A. and Asuquo, I. E. (2010). Seasonality in the Physical and Chemical characteristics of Mbo River, Akwa Ibom State, Nigeria. *Nigerian Journal of Agriculture, Food and Environment*. **6**(1 and 2):60-67.

Gaghia, M., Surana, R. and Ansari, E. (2012). Seasonal variations in physicochemical characteristics of Tapi Estuary in Hazira Industrial Area. *Our Nature*, **10**: 249-257

Gwaski, P.A., Hati, S.S., Ndahi, N.P. and Ogugbuaja V.O. (2013). Modelling parameters of oxygen demand in aquatic environment of Lake Chad for depletion estimation. *ARPN Journal of Science Technology* **3**: 116-123.

Hanna, (2003). The Hanna Catalog. Hanna Instruments Inc. Woonsocket RI, USA.

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

Igejongbo, T. F., Adeparusi, E. O. and Dada, A. A. (2018) Fecundity, maturation and spawning frequency of Mormyrus rume (Cuvier and Valenciennes, 1894) from Epe Lagoon, Nigeria.

Ikongbeh, O.A., Ogbe, F.G. and Solomon, S.G. (2014). Food and Feeding Habits of *Auchenoglanis occidentalis* (Valenciennes,1775) from Lake Akata, Benue State, Nigeria. *Journal of Fisheries and Aquatic Science,* **9**: 229-236.

Islam, S. N. (2007). Physico-chemical Condition and Occurrence of Some Zooplankton in a Pond of Rajshahi University. *Research Journal of Fisheries and Hydrobiology* **2**(2):21- 25.

Jerson, A. C. S. (2021) Tilapia reproductive cycle**.**

Johnbosco, E.U. and Nnaji AO (2011) Influence of land use patterns on Otamiri River, Owerri and Urban Quality of life. *Pakistan J Nutri* **10**: 1053-1057.

Kolo, R.J. Ojutiku, R.O and Musulmi, D.T (2010). Plankton Communities of Tagwai dam Minna, Nigeria. Continental Journal of Fisheries and Aquatic Science **4:** 1.

Mihir, P., Nihar, R. S., Pankaj, K. R., and Malabika, B. R. (2015). Electrical Conductivity of Lake Water as Environmental Monitoring – A Case Study of Rudrasagar Lake. IOSR *Journal of Environmental Science, Toxicology and Food Technology*, **9** (3) (I): 66-71

Mustapha, M.K. (2003). A Pre-impoundment study of the limno-chemical conditions of Oyun Lake in Ilorin, Kwara State, Nigeria. *African Journal of Applied Zoology and Environmental Biology*,**5**: 44-48.

Mustapha, M.K. and Omotosho, J.S. (2006). Hydrobiological studies of Moro Lake. *Nigerian Journal of Pure and Applied Sciences*, **21:** 1948-1954.

National Standard for Drinking Water Quality (2007). Nigerian industrial standard NIS 554, Standard Organization of Nigeria, Lagos.

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

Obiyor, I. K., Nwani, C. D., Odo, G. E., Madu, J. C. and Ndudim, D. U. (2017) Benthic Fish Fauna and Physico-chemical Parameters of Otamiri River, Imo State, Nigeria. *Fish Aquarium Journal*, **8**: 1-8.

Offem, B. O. and Ikpi, G. U. (2011). Water Quality and Environmental Impact Assessment of a Tropical Waterfall System, Environment and Natural Resources Research 11(1).

Ofori-Danson PK. (2005) Studies on the current state of limno- chemistry and potential fish yield of Lake Volta (Yeji sector) after three decades of impoundment. Ghana *journal of Agricultural science* **38**: 1

Ogah, E., Eneji, I. S and Etim, E. E. (2013) Seasonal Variation of Physico-chemical Properties of Selected Rivers in North Central States of Nigeria. *International Journal of Modern Analytical and Separation Sciences,* **2**(1): 31-38.

Okeke, P. N., and Adinna, E. N. (2013) Water quality study of Otamiri River in Owerri, Nigeria. *University Journal of Environmental Research Technology*, **3**: 641-649.

Okomoda, V. T. (2017). Fish & Ocean Opj Gonadosomatic Index and Feeding Habit of Selected Fish Species of Lake Kalgwaiin Jigawa State, Nigeria.

Okoye, C. O. (2016). Comparative Limnological Studies of Nnamdi Azikiwe University, Unizik and Amansea Streams in Awka South L.G.A., Anambra State, Nigeria. *Scientific Review*, ***2***(4):53-56.

Olaosebikan, b. A., and Raji, A. (2004). Field guide to Nigerian fresh water Fishes. Federal Fisheries Technology New Bussa. Second edition :111

Sudhira H.S. and Kumar V.S. (2000). Monitoring of lake water quality in Mysore City. International Symposium on Restoration of Lakes and Wetlands: Proceedings of Lake.

Surajit, M. and Tapas, D. (2014). Studies on Seasonal Variations in Physicochemical Parameters in Bankura Segment of the Dwarakeshwar River (W.B.) India. *International Journal of Advanced Research*, **2**(3): 877-881.

Wetzel, R.G. (2001). Limnology: Lake and River ecosystems, 3rd edition. Academic Press, New York. 1006 pp.

World Health Organization, (2004). United Nations Children's Fund. Joint statement on the management of acute diarrhea. Geneva: The Organization.

World Health Organization (2004) Drinking Water Guidelines.

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

Zinabu, G.M. (2002). The Ethiopian rift valley lakes: major threats and strategies for conservation. In: Tudorancea C, Taylor WD (eds) Ethiopian rift lakes. Backhuys Publishers, Leiden: 259–281