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ECOLOGICAL ASSESSMENT OF ITAPAJI RESERVOIR STATUS IN ITAPAJI USING PLANKTON ASSEMBLAGE

***ADEBAYO, E.T.[1] AND AYOADE, A.A.[2]**
[1]Department of Fisheries and Aquaculture Technology, Federal University of Technology, Owerri, Nigeria
[2]Hydrobiology and Fisheries Unit, Department of Zoology, University of Ibadan, Ibadan, Nigeria
* Corresponding author: adebayotemitope.et@gmail.com

Abstract

Itapaji Reservoir in Ekiti State serves for municipal water supply, artisanal fishing, agricultural and domestic uses, and recently earmarked for irrigation of the adjoining land. There is paucity of information on the limnology of the reservoir, hence this study to provide relevant information on its trophic status for effective water management. Plankton samples (120) were collected with 2L plastic bottle monthly from April, 2013 to March, 2015 at five purposively selected stations along the reservoir. Plankton samples were identified and counted microscopically, using standard identification keys. Species diversity was determined with Shannon-Weiner's Index. Data were analysed using descriptive statistics, student's t-test, and ANOVA at $\alpha_{0.05}$. Among the six classes of phytoplankton encountered, Bacillariophyceae was the most abundant (40.4%). The order of dominance in phytoplankton was Bacillariophyceae> Cyanophyceae> Euglenophyceae> Chlorophyceae> Zygnemataceae and Dinophyceae. All the encountered Phytoplankton taxa showed significant spatial variation. Pollution-indicator phytoplankton (Spirulina, Oscillatoria, Synedra, Euglena, Trachelomonas and Phacus) encountered accounted for 41.9% of phytoplankton population. Zooplankton was dominated by rotifers (38.4 %). Phytoplankton and zooplankton taxa recorded mean species diversities of 1.7±0.3 and 1.1±0.2 respectively. The abundance of pollution-indicator species revealed that Itapaji Reservoir is under pollution stress.

Key Words: *Municipal, Pollution-indicator, Bio-diversity, Ecosystem*

Introduction

Water is one of the most valuable natural resources vital to the existence of any form of life (Olajuyigbe and Fasakin, 2010), the ubiquity of water in biota as the fulcrum of bio-chemical metabolism rests on its unique physical and chemical properties (Adeyemo *et al.*, 2008, and Iscen *et al.*, 2008). The quality of given water is governed by its physical, chemical and biological parameters status in comparison with international inland and drinking water standard (Yakubu *et al.*, 2000), and without any doubt, inadequate quantity and quality of water have serious impact on sustainable development. In developing countries, most of which have huge debt burdens, population explosion and moderate to rapid urbanization, people have little or no option but to accept water sources of doubtful quality, due to lack of better alternative sources or due to economic and technological constraints to treat the available water adequately before use (Calamari and Naeve, 1994; Aina and Adedipe, 1996). The scarcity of clean water and pollution of fresh water has therefore led to a situation in which one-fifth of the urban dwellers in developing countries and three quarters of their rural dwelling population do not have access to reasonably safe water supplies (Lloyd and Helmer, 1992). According to Prat and Munne (2000), water is a scarce and fading resource, and its management can have an impact on the flow and the biological quality of river and streams. Likewise Taiwo *et al.* (2012) opined that assessment of water is not only for suitability for human consumption but also in relation to its agricultural, industrial, recreational, commercial uses and its ability to sustain aquatic life. Water quality monitoring is therefore a fundamental tool in the management of freshwater resources.

Water quality plays a vital role in the distribution, abundance and diversity of aquatic organisms. A short term exposure of aquatic organisms to water of poor quality causes an alteration in the community structure due to the elimination of sensitive species and proliferation of tolerant species (Adeogun and Fafioye, 2011). However, water quality remains a major focus of interest for the general public, politicians, user groups and industry (USEPA, 2007; Wei *et al*., 2008). To underpin its importance, World Health Organization (WHO), United Nations Environment Programme (UNEP), United Nations Educational, Scientific and Cultural Organization (UNESCO) and World Meteorological Organization (WMO) launched in 1977, a water monitoring programme to collect detailed information on the quality of global ground and surface water (Taiwo *et al.,* 2012)**.** This is because man's expanding population, industrialization, intensive agricultural practices, discharge of massive amount of wastewater into the rivers and streams and poor management have resulted into deterioration of water quality (Adakole and Annune, 2003; Galadima *et al.,* 2011). The impact of these anthropogenic activities has been so extensive that the water bodies have lost their self-purification capacity to a large extent (FAO, 1994; Oben, 2000; Tyokumbor *et al.,* 2002; and Sood *et al.,* 2008). Thus the need for water quality monitoring is paramount to safeguard the public health and also to protect the water resource in Nigeria (Ekiye and Zejiao, 2010).

In assessing the health of aquatic environment, bio-assessment has become a reliable method for measuring human influence, complementing traditional physical and chemical methods (Odiete, 1999; and Esenowo and Ugwumba, 2010). Species diversity is the most frequently used parameter in biology to assess environmental health (Adakole and Annune, 2003; Hart and Zabbey, 2005; Ogbeibu and Oribhabor, 2002; Arimoro *et al.,* 2007; George *et al.,* 2009; Esenowo and Ugwumba, 2010). It reflects the number of species and individuals in a community and how evenly the species are spread through that community. The intolerant species to the effect of pollution decline in number or completely eliminated while the tolerant species proliferate and may exclude other species over which they have competitive advantage (Chessman, 2003; Adeogun and Fafioye, 2011).

Plankton communities are essential components of all aquatic environments because primary production forms the base of the food chains and food webs. Physico-chemical parameters such as temperature, salinity, pH, water Current, transparency, carbon, silicon, dissolved oxygen, nitrates and phosphates have been identified to affect plankton abundance (Ayodele and Adeniyi, 2006). Plankton organisms are ideal for theoretical and experimental population ecology studies due to several favourable features such as small size, short generation time and a relatively homogenous habit (Rothhaupt, 2000). They are also good indicators of polluted water (Onyema and Nwankwo, 2006; Keller *et al*., 2008; Edward and Ugwumba, 2010, and Ogbuagu *et al*., 2011).

A pertinent study of the abundance and composition of plankton of the reservoir is very crucial to add to the baseline information of the reservoir and to ascertain the quality of the water in order to ensure conservation of its aquatic resources.

Materials and Methods

Description of Study Area

Itapaji Reservoir is the second largest of the four reservoirs in Ekiti State and is located in Itapaji, Ikole Local Government Area of Ekiti State, South western Nigeria. The Reservoir, that has a total catchment area of 647,250.6m^2 was formed by impounding River Ele in 1972 and commissioned in 1975, with a designed capacity of 5,175m^3/day for the supply of water to 13 towns and villages in 3 local government area namely Ikole, Oye and part of Ekiti East, Local Government Area of Ekiti State. The reservoir also serves for artisanal fishing, irrigation of the adjourning farm land, and several other domestic uses.

The intake works include rolled earth and concrete dam with a length of 400metre and a height of 24meters, the spillway in concrete with a length of 120metres and an intake sump. It lies between latitude 07° 56' and 07° 57'N, and longitude 05° 27' and 05° 28'E at an elevation of 445 m above the sea level (Figure 1). River Ele, which took its source from the "Undifferentiated Basement Complex" hills around Osin - Ikole, is the major river in this drainage. It flows northward from source for about 20km to the dam site, 4km northwest of Itapaji. Beyond the dam site, it flows northwestward to join Rivers Osse and Kampe in Kwara State. These two later rivers join the River Niger at a point 5km north-east of Eggan. Rivers Oye and Omo are tributaries of River Ele. While River Omo took its source from the hills around Ikole - Ekiti and flows north westward of Ikole into River Ele, River Oye took its Sources from the hills, 8km north of Itapaji and flows southwardly into River Ele (Fagbohun, 2016).

The area surrounding the reservoir is hilly and lies within the northern fringes of the rain forest belt with heavy rainfall pattern year round, and characterized by two major seasons, the rainy season occurring between April and October and dry season between November and March. Total annual rainfall ranges between 1350 – 1400mm while, temperature ranges between 28°C – 30°C in dry and 22°C - 25°C in wet season. The hydrographs derived from the data collected at the gauging station downstream of the dam shows that the dam does not spill any water for a period spanning 4 - 6 months (January - June) annually (Fagbohun, 2016).

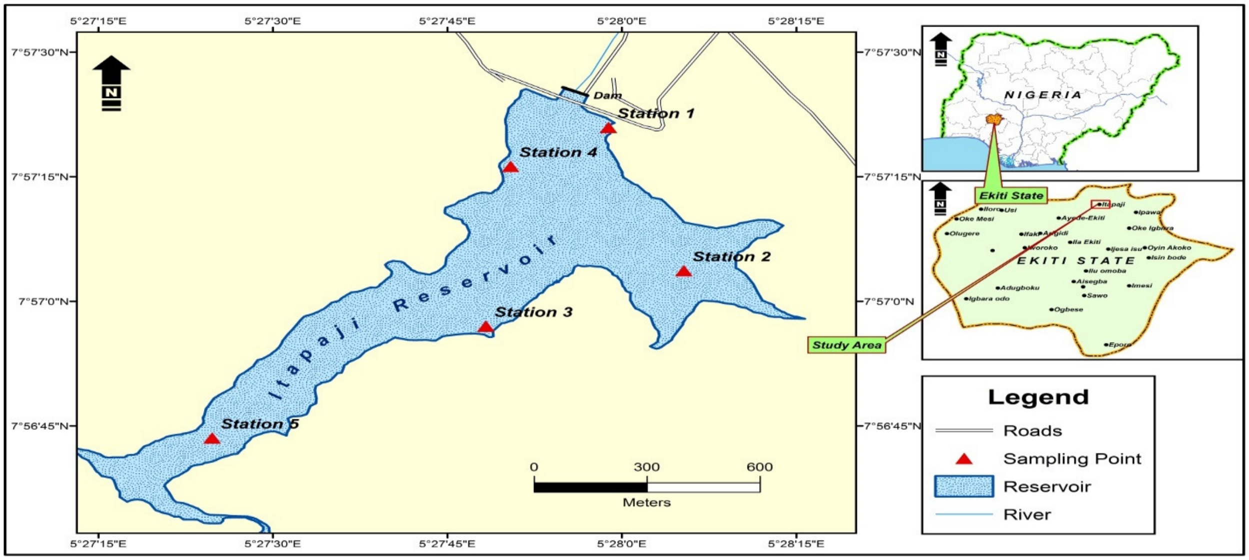

Fig. 1: The Map of Itapaji Reservoir (Source: Cartographic unit, Department of Geography, University of Ibadan, Ibadan, Nigeria)

Vegetation

The surrounding vegetation of the area is made up of trees like *Chlorophora excels, Terminalia superba*, *Elaeis guineensis*, *Borassus* sp. Traditional farmlands has however transformed some sections of the area into secondary grass land, consisting primarily of cultivated and fallow agricultural fields with some secondary growth and occasional evergreen plant such as; *Talinium triangularis, Eupatorium odorantum, Amaranthus spinosus*. Floating plants include *Echinochloa pyramidalis, Sacciolepsis africana, Rhynchospora coryinbsa, Salvina nymphellula, Nymphaea lotus, Ludwigia decurrents, Ceratophyllum submersum, Mormodica balsamina, Commelina diffusa, Cyperus articulates, Pistia stratioles* and *Lemna* sp.

Experimental Design

Five sampling stations were selected on the reservoir based on the proximity to different anthropogenic activities around the reservoir. Station 1 was seldom landing site of the artisanal fishermen, while station 2 was characterized with cocoa plantation. Several agriculture, and domestic activities ranging from cloth washing, cassava fermentation and bathing especially during the dry season were the some of the features around Station 3 besides being the major landing site of the artisanal fishermen. Station 4 had an expanse of adjoining arable land that was yearly used for cassava, and vegetables propagations, more also cassava processing industry was located at some distance away from this station, while station 5 was sited at the entering point of the River Ele into the reservoir, Cattle do visit this location to drink water.

Qualitative sampling of the plankton and surface water sampling for chemical parameters were done monthly from April 2013 to March 2015 between 08:00-11:00 hours across the five sampling stations, while temperature and transparency was measured *in-situ* using mercury-in-glass thermometer and secchi-disc. The method for determining the physico-chemical parameters are written in Adebayo and Ayoade (2017).

Provide method for collecting samples for physico-chemical parameters

Plankton Collection and Analysis

Surface samples for qualitative and quantitative plankton assemblages were collected in 2L plastic bottle (Usman, 2015; Adon *et al.,* 2012; Adesalu, 2010; Mustapha, 2009; Wetzel, 1999, and APHA, 1998). The bottle was slightly tilted over the upper surface of water with its mouth against the water current to permit undisturbed passage of the water into the bottle (Tanimu *et al.,* 2011, and Mustapha, 2009). The samples were immediately fixed with 4% formalin solution to arrest cell activity, for sedimentation and better staining (Boney, 1983; Sherr *et al.,* 1989; APHA, 1998; Anene, 2003, and Onyema, 2007). The samples were stored in a dark compartment in the laboratory for sedimentation. 0.1ml sub-sample of the concentrated plankton suspension was observed microscopically and identified at least to a generic levels using keys provided by Whitford and Schumacher (1973); Needham and Needham (1975); Jeje and Fernado, (1986); and Nwankwo (2004). The identified organisms were counted and recorded as individual/liter. Numerical estimations of both phytoplankton and zooplankton were done using the drop method described by Margalef (1974). The relative abundance of the various taxa was calculated for each sample using the formula:

$$N = \frac{a}{b}^{n}$$

Where: N = estimated number of genus/species per sample, a = volume of water sample in ml b = volume of subsample in ml, and n = number of organisms in subsample

Statistical Analysis of Data

Bivariate and multivariate statistics as provided by the SPSS Version 22.0 and MS Excel 2010 softwares were used in the analysis of the data on the physico-chemical parameters and their associations with plankton. The determination of spatial variance equality (homogeneity) in the means of the physico-chemical parameters, and plankton groups was made with one-way analysis of variance (ANOVA), further mean separation was made with the Duncan Multiple Range Test, while seasonal comparison of these variables was made with the student's t-test of significance. The analysis of the biological data was made with a combination of indices. Species diversity and evenness was determined with Shanon-Wiener's index (H), and Equitability (J) using PAST Version 3.

Results and Discussion

Physico-chemical Parameters

The descriptive results of the physico-chemical parameters of the Itapaji Reservoir in Ikole LGA of Ekiti State, southwestern Nigeria measured across the sampling locations from April 2013 to March 2015 has been reported in Adebayo and Ayoade (2017). Seasonal fluctuations were recorded among the physic-chemical factors. The driving forces for fluctuations were the rainy and dry seasons. Phosphate, TSS, zinc, copper, iron, lead, and chromium were observed to exceed the NESREA (2011) recommended limit for aquatic organisms (Table 1).

Table 1: Descriptive statistics of the Physico-chemical Parameters of Itapaji Reservoir

Parameter	Range	Mean ± SE	NESREA (2011)
Temperature (°C)	23.00 - 29.50	27.5 ± 0.125	a
Transparency (m)	0.49 - 2.54	1.54 ± 0.049	NS
pH	6.06 - 9.20	7.27 ± 0.058	6.5-8.5
Conductivity (µS/cm)	68.00 - 970.00	274.87 ± 20.480	NS
Total dissolved solids (mg/L)	10.54 - 108.50	43.52 ± 2.741	NS
Total suspended solids (mg/L)	7.67 - 34.81	16.64 ± 0.673	0.25
Total solid (mg/L)	19.54 - 123.50	59.68 ± 2.573	NS
Alkalinity (mg/L)	20.60 - 240.00	72.01 ± 4.647	NS
Chloride (mg/L)	18.40 - 168.63	57.03 ± 4.236	300
Total Hardness (mg/L)	16.00 - 63.00	38.57 ± 1.018	NS
Nitrate (mg/L)	2.20 - 10.20	5.45 ± 0.182	9.1
Sulphate (mg/L)	3.50 - 24.10	10.28 ± 0.619	100
Phosphate (mg/L)	2.50 - 18.60	7.23 ± 0.483	3.5
Dissolved Oxygen (mg/L)	0.50 - 8.50	4.88 ± 0.194	Not <6.0
BOD (mg/L)	0.40 - 5.00	2.42 ± 0.106	3.0
COD (mg/L)	1.02 - 6.40	2.83 ± 0.115	30.0
Sodium (mg/L)	5.60 - 16.50	11.70 ± 0.204	120.0
Potassium (mg/L)	3.40 - 19.80	12.36 ± 0.338	50.0
Calcium (mg/L)	8.46 - 24.00	15.47 ± 0.339	180.0
Magnesium (mg/L)	8.00 - 24.30	14.99 ± 0.370	40.0
Zinc (mg/L)	0.00 - 3.60	1.25 ± 0.069	0.01
Manganese (mg/L)	0.00 - 0.20	0.01 ± 0.003	NS
Copper (mg/L)	0.00 - 2.40	0.92 ± 0.819	0.001
Iron (mg/L)	0.01 - 25.60	10.96 ± 0.642	0.05
Lead (mg/L)	0.00 - 0.21	0.07 ± 0.007	0.01
Chromium (mg/L)	0.00 - 1.30	0.22 ± 0.024	0.001

SE = standard error of mean, BOD = Biochemical Oxygen Demand, COD = Chemical Oxygen Demand, NS = Not Specified, and a = [a]except in mixing zones, temperature increase by a 7-Day Average of the Daily Maximum temperatures (7-DADMax) shall not be more than 0.3 ºC above natural background conditions

Natural unpolluted environment are characterized by balanced biological conditions and contains a great diversity of plants and animal life with no one species dominating. The health of the biotic community of any aquatic system is a function of the abundance and diversity of plankton as primary producers. The perturbation effects of an altered environmental condition arising from runoff and the various water use of Itapaji Reservoir was reflected in its plankton composition, abundance, and diversity which was low compare to Mustapha (2009) report in Oyun Reservoir, Offa, Nigeria, Adesalu (2010) in River Oli, Borgu, Nigeria, and Adon *et al.* (2012) in Adzopé Reservoir, south-east of Côte d'Ivoire.

This may be adduced for by the observed high level of total suspended solid of the reservoir when compare with NESREA (2011) standard recommendation levels. The influx of external materials due to erosion of particles and runoff from the surroundings that is capable of impairing the photosynthetic activities of the phytoplankton thereby causing low population in the recorded plankton of the reservoir. Furthermore, low concentrations of the essential heavy metal such as sodium, potassium, calcium, and magnesium which are necessary for the proliferations of this plankton might as well contribute to the recorded low taxa number and populations. This observation further agreed with Campbell and Wildberger (2001) report that waters with calcium levels of 10 mg/L are usually oligotrophic and support sparse animal and plant lif*e* while waters with calcium levels of above 25 mg/L are eutrophic and support diverse plant and animal life.

Plankton Composition and Abundance

The overall plankton composition and abundance during this study period is summarized in tables 2 and 3 respectively. The qualitative and quantitative (species composition and abundance) order of dominance in phytoplankton was Bacillariophyceae> Cyanophyceae> Euglenophyceae> Chlorophyceae> Zygnemataceae and Dinophyceae.

Table 2: Relative Abundance of the phytoplankton composition of Itapaji Reservoir

Family	Species	Rainy Season		Dry Season		Total	
		Abundance (Individual/L)	Percentage (%)	Abundance (Individual/L)	Percentage (%)	Abundance (Individual/L)	Percentage (%)
Zygnemataceae /Conjugatophyceae	*Spirogyra* sp.	**226**	**8.8**	**102**	**5.4**	**328**	**7.4**
Cyanophyceae	*Spirulina platensis**	73	2.9	58	3.1	131	2.9
	*Oscillatoria limosa**	161	6.3	131	6.9	292	6.6
	*Oscillatoria sanota**	72	2.8	107	5.6	179	4.0
	*Lyngbya martensiana**	70	2.7	86	4.5	156	3.5
	Microcystis aureginosa	80	3.1	81	4.3	161	3.6
	Microcystis turgidis	63	2.5	70	3.7	133	3.0
TOTAL		**518**	**20.2**	**533**	**28.2**	**1,051**	**23.6**
Chlorophyceae	*Gonatozygon* sp.	43	1.7	54	2.9	97	2.2
	Straurastrum leptocladium	96	3.8	54	2.9	150	3.4
	Closterium sp.	92	3.6	91	4.8	183	4.1
TOTAL		**231**	**9.0**	**199**	**10.5**	**430**	**9.7**
Bacillariophyceae	*Synedra fascicula**	123	4.8	117	6.2	240	5.4
	*Synedra ulna**	122	4.8	217	11.5	339	7.6
	*Pinnularia nobilis**	119	4.6	86	4.5	205	4.6
	*Pinnularia braunii**	7	0.3	30	1.6	37	0.8
	*Navicula cuspidata**	72	2.8	0	0	72	1.6
	*Navicula expansa**	57	2.2	0	0	57	1.3
	*Navicula mutica**	70	2.7	0	0	70	1.6
	*Navicula cryptocephala**	72	2.8	34	1.8	106	2.4
	Cyclotella sp.	73	2.9	52	2.7	125	2.8
	*Surirella tenera**	46	1.8	87	4.6	133	3.0
	Stephanodiscus sp.	57	2.2	0	0	57	1.3
	*Cymbella affinis**	93	3.6	47	2.5	140	3.1
	*Melosira granulata**	137	5.4	78	4.1	215	4.8
TOTAL		**1,048**	**40.9**	**749**	**39.6**	**1,797**	**40.4**
Euglenophyceae	*Euglena acus**	145	5.7	86	4.5	231	5.2
	*Trachelomonas hisipida**	133	5.2	82	4.3	215	4.8
	*Trachelomonas oblonga**	72	2.8	59	3.1	131	2.9
	Lepocinclis sp.	82	3.2	44	2.3	126	2.8
	*Phacus curvicauda**	72	2.8	38	2.0	110	2.5
TOTAL		**504**	**19.7**	**309**	**16.3**	**813**	**18.3**
Dinophyceae	*Peridinium* sp.	**33**	**1.3**	**0**	**0**	**33**	**0.7**
GRAND TOTAL		**2,560**	**100**	**1,892**	**100**	**4,452**	**100**

*= Pollution Indicator Species

Table 3: Relative abundance of the zooplankton composition of Itapaji Reservoir

Taxa	Species	Rainy Season		Dry Season		Total	
		Abundance (organism/L)	Percentage (%)	Abundance (organism/L)	Percentage (%)	Abundance (organism/L)	Percentage (%)
Cladocera	*Moina reticulata*	213	20.2	133	10.5	346	14.9
	Ceriodaphnia cornuta	144	13.6	152	12.0	296	12.7
TOTAL		**357**	**33.8**	**285**	**22.4**	**642**	**27.6**
Copepoda	*Cyclops strenus*	118	11.2	164	12.9	282	12.1
	Mesocyclops leukarti	71	6.7	152	12.0	223	9.6
	Thermocyclops nigerianus	97	9.2	193	15.2	290	12.5
TOTAL		**286**	**27.1**	**509**	**40.0**	**795**	**34.1**
Rotifera	*Keratella quadrata*	45	4.3	111	8.7	156	6.7
	Brachionus calyciflorus	153	14.5	76	6.0	229	9.8
	Monostyla hamata	14	1.3	49	3.9	63	2.7
	Lecane luna	84	7.9	84	6.6	168	7.2
	Filinia longiseta	118	11.2	157	12.4	275	11.8
TOTAL		**414**	**39.2**	**477**	**37.5**	**891**	**38.3**
GRAND TOTAL		**1,057**	**100**	**1,271**	**100**	**2,328**	**100**

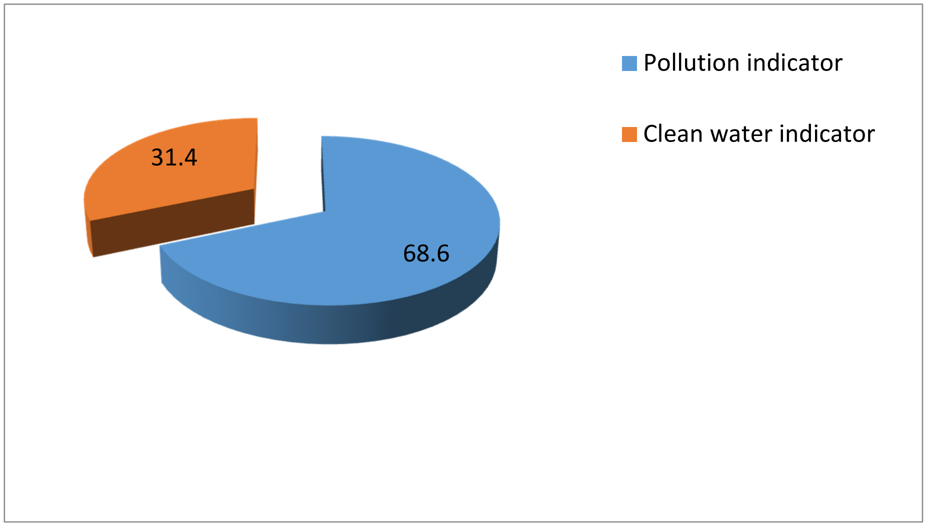

Fig. 2: Percentage indication status in phytoplankton assemblage of Itapaji Reservoir

Furthermore, pollution indicator species were found to account for 68.6% (Figure 2) of the encountered phytoplankton species, thereby dominating the recorded phytoplankton species. However, out of the three recorded taxa in zooplankton, rotifers were the most abundant (38.4%), followed by Copepods (33.8%) while the least abundant was Cladocerans accounted for 27.8% of the total zooplakton taxa.

The qualitative (species composition) and quantitative (species abundance) order of dominance Bacillariophyceae> Cyanophyceae> Euglenophyceae> Chlorophyceae> Zygnemataceae and Dinophyceae respectively, of the phytoplankton in this study followed the general pattern for most inland waters as reported by SPDC (1998), Egborge (1974), and Akoma and Imoobe (2009). The observation of Bacillariophyceae (diatom) being the most abundant phytoplankton in this study corroborates the report of the earlier researcher including Chindah and Braide (2001); Edoghotu and Aleleye-Wokoma (2007); Akoma and Imoobe (2009); and Altaf *et al.* (2010), that diatoms are the most obvious representative of the phytoplankton in tropics. Diatoms are considered as one of the most common and dominant taxa in freshwater environment. Virtually all the observed diatoms in the reservoir are pollution indicator; hence the reservoir could be considered to be under pollution stress.

The dominant blue - green alga in Itapaji Reservoir was the filamentous nitrogen fixing genus *Oscillatoria.* This might be explained by the generally low nitrate status of the reservoir which necessitates an increase in the nitrogen fixing blue- greens to ensure maximum utilization of nutrients. The other blue-green algae equally found in appreciable quantities in Itapaji reservoir were *Microcvstis, Lyngbya* and *Spirulina* which have been implicated as indicators of organic pollution in surface waters (Akin-Oriola, 2003).

The presences of some euglenoids such as *Euglena, Phacus,* and *Lepocinclis ovum* which can tolerate various levels of organically polluted waters further suggest the presence of organic pollutants in Itapaji Reservoir. Though bloom-formation was not detected in the reservoir during this period of study, but there is the possibility of bloom formation if there is excessive nutrient enrichment of the water, even as other bloom forming genera such as *Microcystis* and *Oscillatoria* are present in appreciable quantity in the reservoir. The lower abundance of Chlorophyceae in Itapaji Reservoir is an attestation to the fact that the environment was not conducive for their proliferation.

Zooplankton plays an important role in the trophic structure of rivers as consumers of phytoplankton and as a source of food for both fin-fish and shell fish (Ayodele and Adeniyi, 2006). The abundance of the rotiferan populations was most probably due to their ability to withstand and survive in varying limnological conditions prevailing at the different seasons and their high reproductive rate. The predominance of rotifers in this reservoir in terms of species diversity and numerical abundance is generally characteristic of eutrophic systems (Dumont, 1983, and Ayodele and Adeniyi, 2006). The predominance of rotifera in some inland freshwaters has also been reported by Akin-Oriola (2003); Mustapha and Omotosho (2006); and Ayodele and Adeniyi (2006). The abundance of the genera *Brachionus,* *Lecane and Keratella* showed that the rotifer fauna was made up of a typical tropical assemblage (Jeje and Fernando, 1986). The predominance of the *Brachionus* could however be attributed to their omnivorous nutrition and widespread geographical distribution of most of the members.

Seasonal Variation in Plankton Composition

Cyanophyceae, Copepoda, and Rotifera were revealed to have higher abundant during the dry season as shown in Table 2 and 3 respectively, however, higher mean values were observed in all the encountered taxa during the dry season except in Zygnemataceae, Euglenophyceae, and Dinophyceae (Table 4), with a recorded significant seasonal differences in Zygnemataceae, Cyanophyceae, Dinophyceae, Chlorophyceae Copepoda and Rotifera at P<0.05 (Table 4).

Table 4: Seasonal variation in Plankton Densities of Itapaji Reservoir using the student t-test (P< 0.05)

Taxa	**Rainy Season (Mean ± SE)**	**Dry Season (Mean ± SE)**	**t**	**p-value**
Zygnemataceae	14.900 ± 1.433	10.200 ±0.975	2.500	0.034*
Cyanophyceae	34.800 ± 3.200	53.900±4.795	3.067	0.013*
Bacillariophyceae	68.600 ± 6.825	76.100±5.640	0.750	0.472
Euglenophyceae	32.200 ± 3.116	30.500±2.386	0.419	0.685
Dinophyceae	1.900 ± 0.547	0.000±0.000	3.475	0.007*
Chlorophyceae	15.100 ± 1.748	21.000±1.498	2.496	0.034*
Cladocera	23.100 ± 2.669	28.500±2.187	1.480	0.173
Copepoda	18.900 ± 2.063	50.900±3.698	6.965	0.000*
Rotifera	27.100 ± 3.216	47.900±3.843	3.955	0.003*

SE = Standard error of mean. Value with superscript * differed significantly

Abundance of phytoplankton in the rainy season may be ascribed to the mixing of the water during periods of heavy rainfall, which would have resulted in recycling of nutrients and probably boosted the growth and subsequent abundance of the algae more in the rainy season.

Higher phytoplankton abundance recorded during the rainy season agreed with Thomas *et al.* (2000), Amarasinghe and Vijverberg (2002), and Mustapha, (2009) reports, that high primary productivity is usually rain-induced in tropical reservoir. While the higher zooplankton abundance in the dry season could be probably due to their preference for warm water as highlighted by Dumont (1983) and Segers (2003) and availability of food, and optimum temperature.

The observed change in the order of abundance of dominant zooplankton during dry and rainy seasons in the same body of water could be due to seasonal changes in water quality. This has been well documented by Egborge (1977) in Asejire Lake, and Edward and Ugwumba (2010) on Egbe Reservoir.

Spatial Variation in Plankton Composition

Sampling location 3 recorded the highest percentage abundance (30.3%)

(Figure 3) and all the phytoplankton and zooplankton taxa encountered recorded highest values in this station (Figures 4 and 5); while location 5 recorded the least abundance (3.5%). Also, significant variation in abundance was recorded in all the families at p<0.05 across the sampling stations (Table 5).

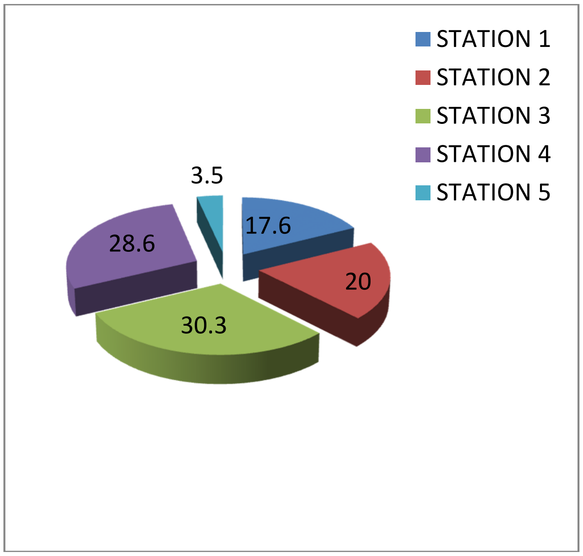

Fig. 3. Spatial abundance (%) of plankton taxa in Itapaji Reservoir

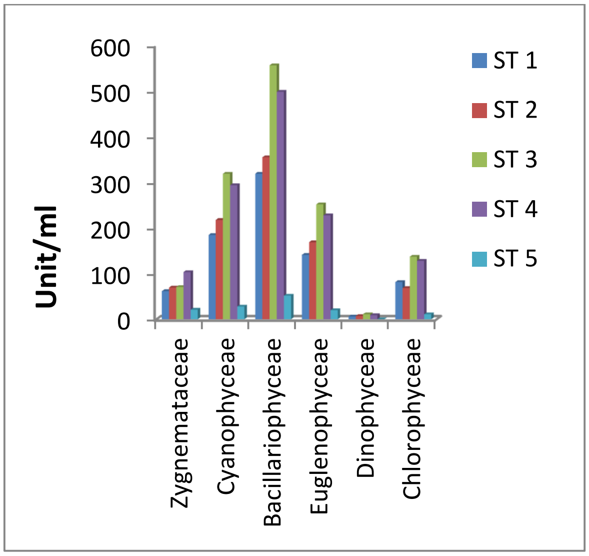

Fig. 4. Spatial variations of Phytoplankton taxa in Itapaji Reservoir

Table 5: Spatial variation in plankton abundance of Itapaji Reservoir using Duncan Multiple Range Test (P< 0.05)

Taxa	Sampling Stations				
	1	2	3	4	5
Zygnemataceae	2.50^{b}	3.33^{ab}	3.00^{b}	4.67^{a}	1.00^{c}
Cyanophyceae	8.00^{c}	9.50^{bc}	13.50^{a}	12.50^{ab}	1.00^{d}
Bacillariophyceae	12.17^{c}	15.67^{bc}	23.33^{a}	20.67^{ab}	2.00^{d}
Euglenophyceae	5.83^{b}	7.33^{b}	11.33^{a}	9.83^{a}	0.67^{c}
Dinophyceae	0.33^{ab}	0.33^{ab}	0.67^{a}	0.50^{ab}	0.00^{b}
Chlorophyceae	3.83^{b}	3.17^{b}	6.67^{a}	6.17^{a}	0.50^{c}
Cladocera	12.00^{ab}	14.33^{ab}	20.17^{a}	19.50^{a}	4.83^{b}
Copepoda	14.83^{ab}	16.67^{ab}	25.33^{a}	23.17^{a}	3.50^{b}
Rotifera	14.83^{ab}	19.17^{ab}	29.00^{a}	26.17^{a}	3.00^{b}

N.B: Values with the same superscript along same row are not significantly different at P<0.05

The phytoplankton abundance that showed spatial variation among the five sampling stations, suggest that the different anthropogenic input into reservoir is capable of imposing ecological imbalances in the reservoir.

Plankton Diversity

The results of the plankton taxa diversity analysis are presented in Tables 6 and 7, and figure 8. Phytoplankton was observed to record higher diversity index (1.702±0.280) where

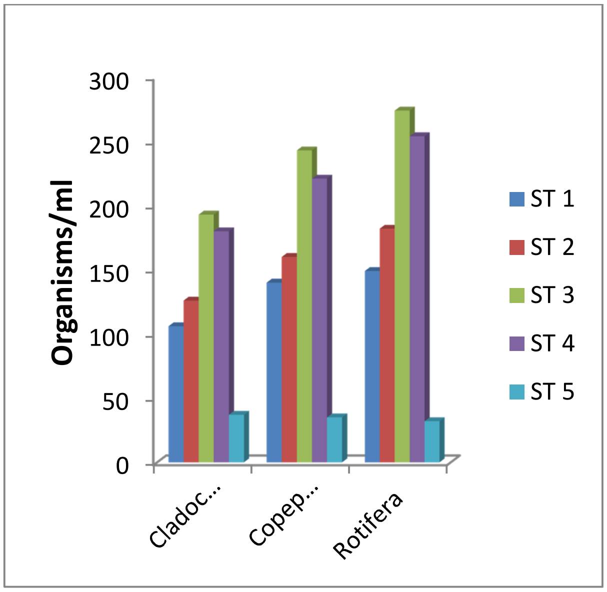

Fig. 5. Spatial variations of zooplankton taxa In Itapaji Reservoir

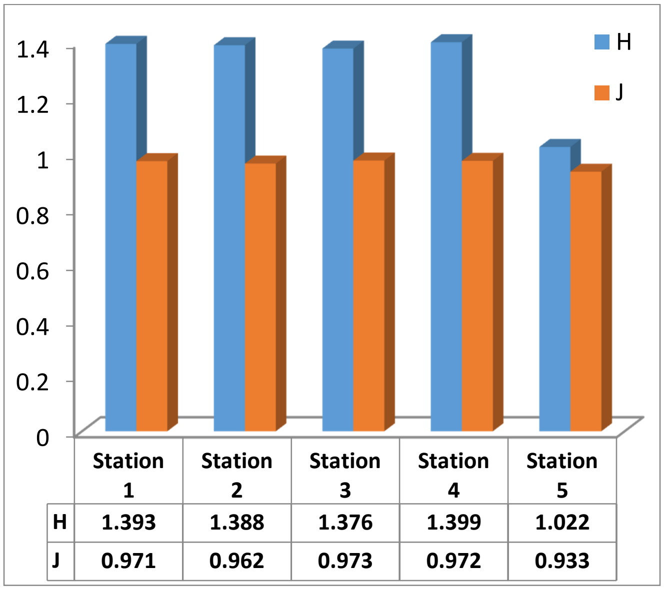

Fig. 6: Spatial diversity indices of plankton abundance in Itapaji Reservoir

Bacillariophyceae constituted the most diverse family; zooplankton was more evenly distributed (0.973±0.019) and Cladocera recorded the highest equitability (J = 0.996) during the study period (Table 6). Furthermore, phytoplankton was shown to be more diverse during the rainy season (1.693±0.294), but higher diversity index (1.114±0.250) was recorded in zooplankton during the dry season. The diversity indices order for the plankton recorded in the five sampling stations during the study period was 4>1>2>3>5 (Figure 6).

Table 6: Diversity indices of Plankton taxa in Itapaji Reservoir during the study period

Taxa	H	J
Phytoplankton		
Cyanophyceae	1.749	0.976
Bacillariophyceae	2.419	0.943
Euglenophyceae	1.577	0.980
Chlorophyceae	1.064	0.968
Mean ± SE	**1.702 ± 0.280**	**0.967 ± 0.008**
Zooplankton		
Cladocera	0.691	**0.996**
Copepoda	1.092	0.994
Rotifera	1.522	0.946
Mean ± SE	**1.102 ± 0.240**	**0.979 ± 0.016**
Total Mean ± SE	**1.402 ± 0.260**	**0.973 ± 0.012**

H = Shanon-Wiener's index, J = Equitability measure, and SE = Standard error

Table 7: Seasonal Diversity indices of plankton taxa in Itapaji Reservoir during the study period

	Rainy Season		**Dry Season**	
Taxa	**H**	**J**	**H**	**J**
Phytoplankton				
Cyanophyceae	1.728	0.965	1.758	0.981
Bacillariophyceae	2.449	0.985	2.170	0.873
Euglenophyceae	1.568	0.974	1.588	0.987
Chlorophyceae	1.025	0.933	1.088	0.991
Mean ± SE	**1.693 ± 0.294**	**0.964 ± 0.011**	**1.651 ± 0.224**	**0.958 ± 0.028**
Zooplankton				
Cladocera	0.677	0.977	0.690	0.996
Copepoda	1.072	0.976	1.094	0.996
Rotifera	1.301	0.939	1.558	0.968
Mean ± SE	**1.017 ± 0.182**	**0.964 ± 0.013**	**1.114 ± 0.250**	**0.987 ± 0.009**
Total Mean ± SE	**1.355 ± 0.238**	**0.964 ± 0.012**	**1.383 ± 0.237**	**0.973 ± 0.019**

H = Shanon-Wiener's index, J = Equitability measure, and SE = Standard error

Shannon-Weiner diversity index values above 3.0 indicate that the structure of the habitat is stable, while values less than 1.0 indicate severe pollution and intermediate values indicate moderate pollution (Shannon, 1948; and Mandaville, 2002). Based on the values obtained in this study, the pollution order of Itapaji Reservoir was observed to be higher in station 4> 1> 2> 3> and 5 respectively. The overall diversity index values (1.402±0.26) also suggest that the reservoir was moderately polluted. Individual plankton was evenly distributed across the five stations, since equitability index values were closer to 1 in all the stations.

Conclusion

The recorded dominance of the pollution indicator taxa and intermediate bio-diversity indices suggests that the Itapaji Reservoir is moderately polluted probably due to the accumulations of the suspended materials from the runoff of the adjoining land and various human activities around the reservoir. It is therefore suggested that regular pumping of the reservoir should be encouraged, while other anthropogenic activities around the reservoir should be regulated.

References

Adakole, J.A. and Annune, P.A. (2003). Benthic Macro-invertebrate as indicators of Environmental Quality of an Urban Stream, Zaria, Northern Nigeria. *J. Aqu.Sci.,* 18:85-92.

Adebayo, E.T. and Ayoade, A.A.A. (2017). Assessment of Physic0-chemical Parameters of Itapaji Reservoir, Itapaji, South-western Nigeria. *Ethiopian Journal of Environmental Studies and Management,* 10(10): 1284-1297.

Adeogun, A.O. and Fafioye, O.O. (2011). Impact of effluents on water quality and benthic macroinvertebrate fauna of Awba Stream and Reservoir. *Journal of Applied Science and Environmental Management*, 15(1): 105-113.

Adesalu, T.A. (2010). Phytoplankton Dynamics of River Oli in Kainji Lake National Park, Nigeria during Dry Season. *Journal of American Science,* 6(5): 72-76.

Adeyemo, O.K., Adedokun, O.A., Yusuf, R.K. and Adeleye, E.A.

(2008). Seasonal changes in physic-chemical parameters and nutrient load of river sediments in Ibadan city, Nigeria. *Global NEST Journal,* 10(3): 326-336.

Adon, M.P., Ouattara, A.and Gourene, G. (2012). Phytoplankton composition of a shallow African tropical reservoir (adzopé, côte d'ivoire). *Journal of Microbiology, Biotechnology and Food Sciences.* 1 (5) 1189-1204

Aina, E. O. A. and Adedipe, N. O. (1996). Water Quality Monitoring and Environmental Status in Nigeria. FEPA Monograph 6, FEPA, Abuja, Nigeria, p239.

Akin-Oriola, G.A. (2003): On the phytoplankton of Awba reservoir, Ibadan, *Nigeria Rev. Biol. Trop*., 51(1): 99-106.

Akoma, O.C. and Imoobe, T.O.T. (2009). Limnological and phytoplankton survey of Bahir Dar Gulf of Lake Tana, Ethiopia. *African Journal of Science and Technology (AJST) Science and Engineering Series*, 10(2): 91-98.

Altaf, H.G., Saltanat, P., Asif, A.K. and Maryam, H. (2010). Phytoplankton diversity at Watlab Ghat in Wular Lake, Kashmir. *Journal of Ecology and the Natural Environment,* 2(8): 140-146.

American Public Health Association-APHA. (1998). *Standard Methods for the Examination of Water and Wastewater.* 20th ed. APHA/AWWA/WEF: Washington DC. USA. 1213p

Anene, A. (2003). Techniques in Hydrobiology. *Research Techniques in Biological and Chemical Sciences*. Onyeike, E.N. and Osuji, J.O. eds. Owerri: Springfield Publishers Ltd.174-189.

Arimoro. F.O. Ikomi, R.B. and Iwegbue, C.M.A. (2007). Ecology and abundance of Oligochaetes as indicators of organic pollution in an urban stream in Southern Nigeria. *Pakistan Journal of Biological Sciences,* 10(3): 446-453.

Ayodele, H.A. and Adeniyi, I.F. (2006). The zooplankton fauna of six impoundments on River Osun, Southwest Nigeria. *The Zoologist,* 1(4): 49-67.

Boney, A.D. (1983). *Phytoplankton Publication*. Photo Books (Bristol) Ltd.1-82. Booklet No. 9. Hach Company, Loveland, Colorado, USA. 23 pp.

Calamari, D. and Naeve, H. (1994). Review of pollution in the African aquatic environment. CIFA Technical Paper No. 25, FAO, Rome, 118 pp.

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

Chessman, B.C. (2003). New sensitive grades for Australian River Macro-invertebrates. *Marine Fresh Water Res.,* 54: 95-103.

Chindah, A.C. and Braide, S.A. (2001). Crude oil spill and the phytoplankton community of a swamp forest stream. *African Journal of Environmental Studies,* 2(1):1-8.

Dumont, H.J. (1983). Biogeography of rotifers. *Hydrobiologia*, 104: 19-30.

Edoghotu, A.J. and Aleleye-Wokoma, I.P. (2007). Seasonal variations in phytoplankton composition and physicochemical properties of Ntawoba Creek, Port Harcourt, Nigeria. *International Journal of Natural and Applied Sciences,* 3(3): 344-348.

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.

Egborge, A.B.M. (1974). The seasonal variation and distribution of phytoplankton in the River Osun, Nigeria. *Freshwater Biology*, 4: 177-191.

Egborge, A.B.M. (1977). The hydrology and plankton of Lake Asejire, Nigeria. Ph.D Thesis.

Ekiye, E. and Zejiao, L. (2010). Water quality monitoring in Nigeria; Case Study of Nigeria's \industrial cities. *Journal of American Science*, 6(4): 22-28.

Esenowo, I.K. and Ugwumba, A.A.A. (2010). Composition and abundance of macro-benthos in Majidun River, Ikorodu, Lagos State, Nigeria. *Research Journal of Biological Sciences,* 5(8): 556-560.

Fagbohun, O.O. (2016). Studies on Small Hydro-Power Potentials of Itapaji Dam in Ekiti State, Nigeria. *International Journal of Engineering Science Invention.* pp. 28-36.

Food Agriculture Organization (FAO) (1994). Review of pollution in the African Environment (CIFA Technical paper). 45: 37-66.

Galadima, A., Garba, Z.N., Leke, L., Almustapha, M.N. and Adam, I.K. (2011). Domestic water pollution among local communities in Nigeria - causes and consequences. *European Journal of Scientific Research,* 52(4): 592-603.

George, A.D.I., Abowei, J.F.N. and Daka, E.R. (2009). Benthic macro-invertebrate fauna and physico-chemical parameters in Okpoka Creek sediments, Niger Delta, Nigeria. *International Journal of Animal and Veterinary Advances,* 1(2): 59-65.

Grant, I.F. (2002). Aquatic invertebrates. *Ecological Monitoring Methods for the Assessments of Pesticide impact in the Tropics*. Grant, I.F. and Tingle, C.C.D. (eds.) London: The University of Greenwich. pp183-193.

Hart, A.I. and Zabbey, N. (2005). Physico-chemistry and Benthic Fauna of Woji Creek in the Lower Niger Delta, Nigeria. *Environment and Ecology*, 23(2):361-368.

Iscen, C.F., Emiroglu, O., Ilhan, S., Arisian, N., Yilmaz, V., Ahiska, S. (2008). Application of multivariate statistical techniques in the assessment of surface water quality in Uluabat Lake, Turkey. *Turkish Environmental Monitoring and Assessment,* 144(1-3): 269-276.

Jeje, C.Y. and Fernado, C.H. (1986). A practical guide to the identification of Nigerian zooplankton (Cladocera, Copepoda and Rotifera). Kanji Lake Research Institute, New Bussa publication. 142pp.

Keller, B., Wolinska, J., Manka, M. and Spaak, P. (2008). Spatial, environmental and anthropogenic effects on the taxon composition of hybridizing *Daphnia. Philosophical Transactions of the Royal Society B:*

Biological Sciences, 363: 2943-2952.

Lloyd, B. and Helmer, R. (1992). Surveillance of drinking water quality in rural areas. Longman Scientific and Technical, New York: Wiley, pp34-56. Mandaville S. M. (2002). *Benthic Macroinvertebrates in Freshwater – Taxa Tolerance Values, Metrics, and Protocols, Project H - 1.* (Nova Scotia: Soil & Water Conservation Society of Metro Halifax).

Margalef, R. (1974). Estimating quantity and quality of biomass counting. In: Vollenweider, R.A (ED.). A manual on methods for measuring primary production in aquatic environments. IBP Handbook No. 12, Oxford, Blackwell Scientific Publication. 213 pp.

Mustapha, M.K. (2009). Phytoplankton assemblage of a small, shallow, tropical African reservoir. *Int. J. Trop. Biol.*, 57(4): 1009-1025,

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

National Bureau of Statistics. (2009). Social Statistics in Nigeria. 399 p. http://www.nigerianstat.gov.ng/ext/latest_release/ssd09.pdf.Accessed: 10/10/2011.

National Environmental Standards and Regulations Enforcement Agency (NESREA) (2011). National Environmental (Surface and Groundwater Quality Control) Regulations. *Federal Republic of Nigeria Official Gazette No. 49, Vol. 98.*

Needham, J.G. and Needham, P.R. (1975). A Guide to the Study of Freshwater Biology 4th edition, Holden - Day Inc., San Francisco, 1683 pp. NRC (1989). *National Research Council Recommended Dietary Allowances,* 10th ed. Washington, DC, National Academy Press.

Nwankwo, D.I. (2004). *Practical Guide to the Study of Algae.* JAS Publishers, Lagos, Nigeria. 84p.

Oben, B.O. (2000). Limnological assessment of the impact of Agricultural and domestic effluents of three man-made Lake in Ibadan, Nigeria. Ph.D. Thesis. University of Ibadan.

Odiete, W.O. (1999). Environmental Physiology of Animals and Pollution. Inno Obonna and Associates, Lagos; pp. 220-246.

Ogbeibu, A.E. and Oribhabor, B.J. (2002). Ecological impact of river impoundment using benthic macro-invertebrates as indicators. *Water Research,* 36: 2427-2436.

Ogbuagu, D. H., Chukwuocha, N. A. C., Okoli, C. G. and Njoku-Tony, R. F. (2011). Physicochemical gradients and *in situ* yields in pelagial primary production of the middle reaches of Imo River in Etche, South-eastern Nigeria. *Journal of Ecology and the Natural Environment,* 3(2): 47-53.

Olajuyigbe, A.E. and Fasakin, J.O. (2010). Citizens' willingness to pay for improved sustainable water supply in a medium-sized city in South Western Nigeria. *Current Research Journal of Social Sciences,* 2(2): 41-50.

Onyema, I.C. (2007). The phytoplankton composition abundance and temporal variation of a Polluted Estuarine Creek in Lagos, Nigeria. *Turkish Journal of Fisheries and Aquatic Science,* 7:89-96.

Onyema, I.C. and Nwankwo, D.I. 2006. The epipelic assemblage of a polluted estuarine Creek in Lagos, Nigeria. *Pollution Research,* 25(3): 459-468.

Prat, N. and Munne, A. (2000). Water use and quality and stream flow in a Mediteranea stream. *Water Resources,* 34(15): 3876-3881.

Ruttner, F. (1963). Fundamentals of Limnology 3rd Edition, University of Toronto Press. Pp 242.

Segers, H. (2003). A biogeographical analysis of rotifers of the genus *Trichocerca* Lamarck, 1801 with notes on taxonomy. Hydrobiologia 500: 103-114.

Shannon, C. (1948). A mathematical theory of communication. *Bell Systems Technol. J.,* 27: 379– 423.

Shell Petroleum Development Company of Nigeria Limited (SPDC) (1998). Environmental Impact Assessment of Obigbo Node Associated Gas Gathering Project: Final Report by Tial Trade Limited.

Sood, A., Singh, K.D., Pandey, P. and Sharma, S. (2008). Assessment of bacterial indicators and physic-chemical parameters to investigate pollution status of Gangetic River system of Uttarakhand (India). *Ecological Indicators.* 8: 709-717.

Taiwo, A.M., Olujimi, O.O., Bamgbose, O. and Arowolo, T.A. (2012). Surface Water Quality Monitoring in Nigeria: Situational Analysis and Future Management Strategy, Water Quality Monitoring and Assessment, Dr. Voudouris (Ed.), Pp 301-321.

Tanimu, Y., Bako, S.P., Adakole, J.A. and Tanimu, J. (2011). Phytoplankton as Bioindicators of Water Quality in Saminaka Reservoir, Northern-Nigeria. *Proceeding of the 2011 International Symposium on Environmental Science and Technology.* Dongguan, Guandong province, China. Published by Science press USA: 318-322.

Thomas, S., Cecchi, P., Corbin, D. and Lemoalle, J. (2000). The different primary producers in a small African tropical reservoir during a drought: temporal changes and interactions. *Freshwater Biology*, 45: 43-56.

Tyokumbor, E.T., Okorie, E.T. and Ugwumba, O.A. (2002). Limnological assessment of the effects of effluents on macroinvertebrate fauna in Awba Stream and reservoir, Ibadan, Nigeria. *The* Zoologist, 1(2): 59-69.

United Nations Environmental Programme Global Environment Monitoring System (UNEP GEMS)/Water Programme. (2006). Water quality for ecosystem and human health.

United State Environmental Protection Agency (USEPA), (2007). Recent recommended water quality criteria. United States Environmental

Usman, H. (2015). Determination of physico-chemical parameters and plankton composition of Wawan-Rafi Lake in Kazaure, Nigeria. M.sc thesis, Department of Biological Science, Ahmadu Bello University, Zaria.

Wei, S., Wang, Y.J.C.W., Lam, G.J., Zheng, M. K., So, L.W.Y., Yeung, Y., Horii, L., Chen, H., Yu, N., Yamashita, N. and Lam, P.K.S. (2008). Historical trends of organic pollutants in sediment cores from

Hong Kong. *Mar. Pollut. Bull***.** 57: 758–766.

Wetzel, R.G. (1999). Biodiversity and shifting energetic stability within freshwater ecosystems. *Arch. Hydrobiol. Spec. Issues Advances in Limnology* 54: 19-32.

Yakubu, A.F., Sikoki, F.D., Abowei, J.F.N. and Hart, S.A. (2000). A Comparative Study of Phytoplankton Communities of Some Rovers, Creeks and Burrow Pits in the Niger Delta Area. *Journal of Applied Science and Environmental Management,* 4:41-46. York. 429 pp.