RESPONSE OF PLANKTON ASSEMBLAGE TO NUTRIENT AND ENVIRONMENTAL PARAMETERS IN A TROPICAL COASTAL WATER

Ojelade O. C., Abdul W. O., Abdulraheem I., Ikenweiwe N. B., Salaudeen A. A. and Akaeze M. I.

Department of Aquaculture and Fisheries Management, Federal University of Agriculture, Abeokuta. P.M.B 2240, Ogun State, Nigeria

Corresponding author: Ojelade O.C ojeladeoc@funaab.edu.ng +2348032255000

(Received: ; Accepted:)

ABSTRACT

Seasonal variations of nutrients and water quality parameters in relation to plankton abundance were investigated in Ogun coastal water, Ogun State, Nigeria from February to July, 2015 at three different stations of 5 km apart along the 15 km Ogun coastal stretch line. The study revealed that nutrient concentrations were influenced by seasonal changes. Mean nutrient values and important variables determining plankton assemblages were recorded as follows: nitrate (0.73mg/l), salinity (30.95mg/l), dissolved oxygen (6.74mg/l), phosphorus (0.12 mg/l) and temperature (28.43 ^{0}C). A total population of 1571 planktons was identified which consists of 29 and 45 species of phytoplankton and zooplankton respectively. Bacillariophyceae (46.4%) dominated the phytoplankton community followed by Dinophyceae (31.0%) while the Cyanobacteria (0.95%) occurred least. Two important taxa of zooplankton i.e. Cladocera (36.2%) and Rotifera (21.4%) were encountered. An increased number of planktons was recorded during the wet season (61.3%) with a corresponding reduced diversity. Analysis of the ecological indices by the routines in Primer (v6) showed a high level of evenness (1.744 and 1.211) with a Margalef of (3.093 and 1.4412) for the phyto- and zoo-planktons respectively. A total species richness of 29 phto- and 45 zoopankton identified in the study area competes favourably when compared to other tropical aquatic ecosystems and temperate inland waters. The study revealed that water nutrient concentrations were influenced by seasonal changes; increased levels of PO_4-P and salinity were recorded during the dry season while higher NO_3–N content coupled with increased number of planktons was experienced during the wet season. This study provides considerable advances in understanding the seasonality of nutrient distribution in the study area and its effect on plankton assemblage.

Keyword: Plankton, Seasonal, Nutrient, Dynamics, Correlation, Assemblage.

INTRODUCTION

Coastal aquatic system is an environment featured by being transitional places between land and marine (sea) habitats which is noted for its dynamic systems as well as its high environmental variability in the short and long terms. Coastal marine environmental quality is thus an issue of major global concern (Smith *et al.* 1999). This is as a result of the fact that coastal areas with little or no water circulation are vulnerable to diverse dynamics of nutrients (UNEP & GPA, 2006).

However, industrial, agricultural and urban development, including an excess use of fertilizers and the increased release of human and animal wastes into the environment have elevated the fluxes of nutrients, such as nitrogen (N) and phosphorus (P)-containing substances into surface and ground waters which thereby altering the natural nutrient cycle in most aquatic environments (Ajuonu *et al.* 2011). The enhanced mobility and availability of nutrients moving through biogeochemical pathways have changed the acidity of waters and soils, thus stimulating increase in the primary producers present in the aquatic environment. This results in an increase in algae (phytoplankton) production, increased nutrients and the appearance of oxygen-depleted zones in surface water (Kusler, 2003). This scenario has resulted in a change in the abundance and variety of ecological species, in some cases transforming the entire aquatic ecosystem. The provision of appropriate and effective nutrient assessment and management continues to be a challenge for coastal water resource managers and policy makers (NRC, 2000). Difficulties in assessment and management of these nutrients are due to the fact that nutrients in coastal ecosystems may originate from a variety of sources (Perus *et al.* 2004), which can take numerous pathways as water finds its way into aquatic ecosystems. It is thus critically important that we understand the quantitative linkages that exist between nutrients and water quality in our

aquatic biotope. These linkages allow us not only to assess the risk of eutrophication-related problems in receiving waters but also to quantify the degree to which nutrient loading affects plankton abundance and, invariably, fish diversity (Emmanuel and Onyema, 2007).

There is a dearth of available materials on ecological investigation into the hydroclimatic conditions especially in relation to the composition and distribution of biota at different trophic levels within coastal aquatic ecosystems in Nigeria. A proper understanding of the abundance and species distribution of the plankton community of this water body will not only help in understanding the dynamics of its ecological health but will also give an insight into the understanding of the trophic level interrelationship within this coastal ecosystem and also serve as a reference for future studies. This study therefore, investigated the response of plankton assemblage to nutrients and environmental parameters of Ogun coastal water in Ogun State, Nigeria.

MATERIALS AND METHODS

Study Area

The study area is marine coastal water in the western coast of the Gulf of Guinea in Ogun state, Nigeria and it is geographically situated between 06.29^{0}N, 04.24^{0}E and 06.48^{0}N, 04.42^{0}E. The study area is closely associated with other maritime states of South-western Nigeria. The Local Government Area is bounded in the West by Ijebu-East Local Government and Lekki Lagoon, in the North; and in the East by Ondo State while in the south it shares a boundary with Lagos State and the Gulf of Guinea (Atlantic Ocean). The area comprises over 50 towns and villages with headquarter at Abigi. It has an area of 1,000 km^2 and a population of 72,935 according to the 2006 census. The proximity of the area to the Atlantic Ocean, Lagoon systems and in particular, to the good, albeit complex network of streams, rivers, and other water-bodies coupled with other economic activities such as fishing, shipping, agriculture, lumbering, tourism, oil and gas exploration and exploitation make the area a choice for this study. It is also the only area of the State with a coastline on the Bight of Benin and also borders Lagos Lagoon (Odebiyi, 2013).

Collection of Water Samples and Analysis

Seasonal monitoring of the physicochemical parameters and macro-nutrients in water samples were carried out along 15km coastline of Ogun-State at three different stations selected at 5 km apart during the dry and wet seasons between February and July, 2015 at a distance of 1 - 10 cm from the coast, according to standard methods (APHA, 2005) as described in Ojelade, *et al.* (2016). The parameters analysed *insitu* include water temperature (˚C), pH, salinity (mg/l), and electrical conductivity (µs/l) which were measured using a calibrated digital multi-parameter water proof multipurpose HANNAH instrument (combo) by dipping it below the water surface and taking readings after it stabilized. Chemical parameters of the water samples were transported in an ice chest to the laboratory subsequent to analysis *exsitu* within 24hrs of collection. The chemical parameters analysed include dissolved oxygen (mg/l), alkalinity (mg/l), phosphate (mg/l), nitrate (mg/l), and total hardness (mg/l) using standard methods according to Egharevaba *et al.* (2010). Nutrient concentration of Nitrate and Phosphate were determined by phenol disulphuric acid (PDA) and Vanodo-molybdo phosphoric methods respectively using a highly equipped spectrophotometer

Plankton Collection and Analysis

Plankton samples were collected using 55µm mesh size standard plankton net by filtering 50 liters of sampled water from the coastal area. The filtrate was washed into 1.5 litres polytethylene bottle and was fixed immediately with 5 drops of 4% hemaxine-buffered formalin to preserve the organisms (Parsons *et al.* 1984). This was followed by addition of 3 drops of Lugol's solution and allowed to stand for 30 minutes in order to settle. The samples were kept in ice boxes at 4^{o}C during transportation to the laboratory. Direct enumeration and identification were performed to the genius level using a microscope connected to a camera (Premier equipped model) at x4µm and x10 µm magnification. Identification was done using guides provided by Newell and Newell (1977); Maosen (1978) and Egborge (1973).

Data Analysis

Diversity analysis of the plankton composition

and community structure were analysed and determined using the routines in PRIMER v6 Plymouth Routines in Multivariate Ecological Research (Clarke and Gorley, 2006). Ecological biotic indices of Shannon-Weiner diversity, *(H')* (Shannon and Weaver, 1963), Simpson Dominance, *(D)*, Diversity, *(1-D)*, Evenness, *(eH/S),* and Equitability, *(J)* indices (Odum, 1969) were determined. Margalef index, *(d)* (Margalef, 1969) was used to describe the plankton community. The data obtained on water nutrients were analysed for their means and results were presented using descriptive and inferential statistical tools. The nutrient parameters were correlated with water quality parameters using Spearman correlation coefficient to determine the significance of each water quality parameter to plankton abundance.

RESULTS

Water Quality Parameters

The mean values of all the coastal water attributes analysed fluctuated within the sampling period (Fig. 1). Water temperatures (26.4˚C to 30.1˚C) varied as expected with seasonal fluctuations and averaged 28.43˚C. Salinity varied seasonally with the highest (31.9 mg/L) in May and the least (29.4 mg/L) in February. The pH was slightly alkaline with a mean value of 7.67; the minimum pH value (7.60) was observed in July while the maximum (7.99) was recorded in May. The alkalinity level of Ogun coastal water fluctuated throughout the study period with a mean of 7.38 mg/L while the conductivity varied along the coast ranging from 48.35µs/l in February to 50.2µs/l in May. Total hardness of the water ranged between 0.21 mg/L and 0.36 mg/L in February and March respectively while dissolved oxygen varied between 6.25 mg/L and 7.13 mg/L with a mean value of 6.74 mg/L. The average nitrate and phosphate values were recorded as 17.14 mg/L and 14.24 mg/L respectively as indicated in Fig 2.

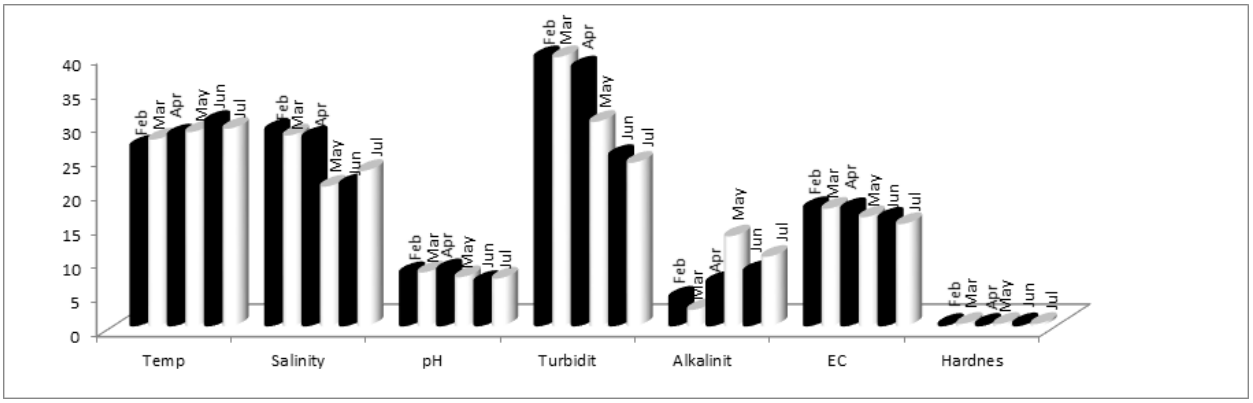

Figure 1: Mean Monthly Water Quality Parameters of Ogun Coastal Water

Nutrients Variation in Ogun Coastal Water

The study revealed that water nutrient concentrations were influenced by seasonal changes; increased levels of phosphate, nitrate and salinity were recorded in the water samples during the wet season. The nitrate values in the water analysis ranged from 0.04 to 1.55 mg/L in the dry season and 0.035 to 1.98mg/L during the rainy season. Phosphate varied from 0.0971 to 0.1165 mg/L in the dry season and to 0.0971 to 1.66 mg/L during the rainy season. July recorded the highest nitrate (1.98 mg/L) and phosphate (0.166mg/L), while the least value was recorded in February (0.04 mg/L) and May (0.097 mg/L) 2015 as indicated in Fig 2. A strong correlation between the analysed water quality parameters and nutritional variables was also observed in the study area; a positive correlation occurred between temperature and nitrate while a negative correlation existed between Dissolved Oxygen (D.O.) and phosphate at $p<0.05$ (Table 1)

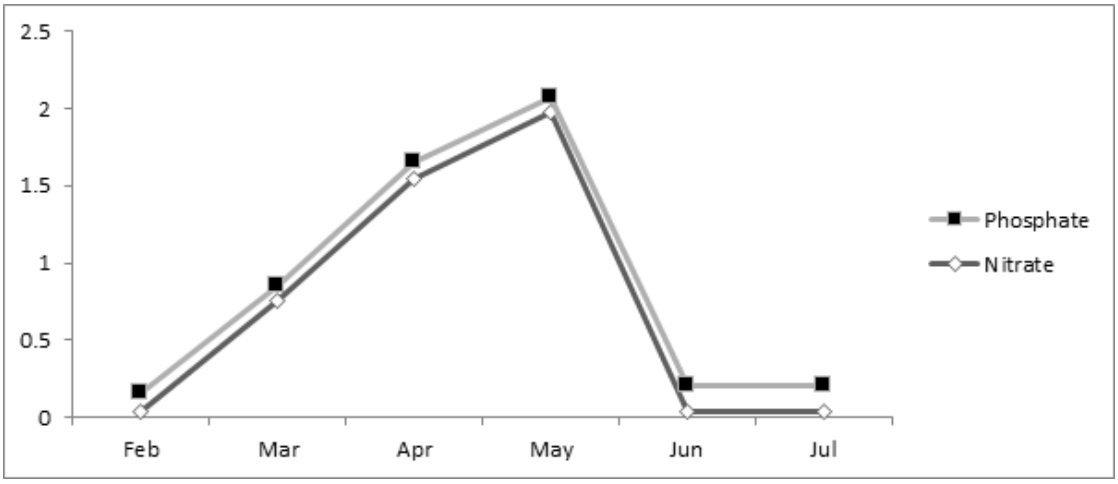

Fig 2: Monthly Variation of the Mean Values of the Water Nutrients in Ogun Coastal Water

Species Diversity, Abundance and Distribution

Phytoplankton Diversity in the Study Area

The taxonomic listing of the phytoplankton species encountered in Ogun coastal water during the study period is presented in Table 2, while the relative abundance of these organisms is shown in Figure 3. A total of 613 phytoplankton individuals belonging to 5 families and 29 species were identified during the sampling period. The family Bacillariophyceae (diatoms) dominated the phytoplankton community followed by the Dinophyceae (dinoflagellates), Chlorophyceae (green-algae), Euglenophyceae (green flagellates) and Cyanobacteria (blue-green) with percentage occurrences of 46.4%, 31.0%, 12.4%, 9.45% and 0.95% respectively. The diversity analysis of phytoplankton in the study area identified 613 individuals with a species richness of 29. A relatively-low dominance index (0.0598) indicates that all the taxa are equally present while the corresponding evenness value (1.744) shows that the individuals are equitably distributed among the sampling sites. The Margalef (3.093) result obtained indicates that there is an average level of biodiversity in the study area. The spatial distribution of phytoplankton in the study area shows a relative fair distribution of these organisms across the sampling stations.

Relative Abundance and Composition of Zooplankton Species

A Checklist of the Species composition and abundance of the various zooplanktons encountered during the survey is presented in Table 4 while the illustration in Figure 4 shows the percentage abundance of zooplankton groups along Ogun coastal water. A total of 958 individuals (i.e. holoplankton and meropankton) belonging to nine taxa including the larva forms of fish and invertebrates were identified during the research. The result of the analysis of the ecological indices obtained using Shannon-Weiner index (H) for zooplankton species diversity and Margalef index (D) for species richness showed 1.61 and 1.44 respectively while the evenness, Simpson index and dominance were 1.21, 1.65 and 0.62 respectively as shown in Table 3.

Table 1: Correlation Between Investigated Water Quality Parameters and Its Nutrients

	Temperature	**Salinity**	**pH**	**Alkalinity**	**EC**	**Hardness**	**DO**	**Nitrate**	**Phosphate**
Temperature	1								
Salinity	-.850*	1							
pH	-.806	.877*	1						
Alkalinity	.605	-.855*	-.579	1					
EC	-.797	.847*	.837*	-.764	1				
Hardness	.473	-.566	-.474	.379	-.578	1			
DO	-.769	.989**	.858*	-.860*	.804	-.575	1		
Nitrate	.968*	-.092	.385	.366	.216	.103	-.126	1	
Phosphate	.677	-.483	-.754	.253	-.740	.123	-.898*	-.726	1

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

Table 2: Taxonomic Listing and Spatial Distribution of Phytoplankton in Ogun Coastal Water

Family	**Taxa**	**Stations**		
		1	2	3
Bacillariophyceae	*Cocinodiscus sp*	+(21)	-(0)	+(12)
	Cyclotella	-(0)	-(0)	+(19)
	Diatoma	+(18)	+(14)	+(17)
	Fragillaria	-(0)	+(15)	+(7)
	Melosira	-(0)	-(0)	+(15)
	Navicula	+(12)	+(13)	+(9)
	Nitzschia	+(17)	-(0)	-(0)
	Pinnularia	-(0)	+(16)	+(10)
	Podosira	-(0)	-(0)	+(15)
	Synedra	-(0)	-(0)	+(31)
	Tabellaria	-(0)	+(23)	-(0)
Chlorophyceae	*Ankistrodesmus*	+(7)	-(0)	-(0)
	Chlamydomonas	+(6)	-(0)	+(5)
	Closterium	+(4)	+(8)	+(7)
	Scenedesmus	-(0)	-(0)	+(6)
	Spirogyra	+(6)	-(0)	-(0)
	Ulothrix	+(7)	+(5)	-(0)
	Volvox	+(9)	+(6)	-(0)
Euglenophyceae	*Euglena*	+(39)	-(0)	-(0)
	Phacus	-(0)	-(0)	+(19)
Cyanobacteria	*Anaebaena*	+(1)	+(1)	-(0)
	Chroccocus	-(0)	-(0)	+(1)
	Oscillatoria	+(1)	-(0)	-(0)
	Phormidium	-(0)	-(0)	+(1)
	Spirulina	+(1)	+(1)	+(1)
	Microcystis	+(1)	-(0)	-(0)
Dinophyceae	*Peridinium*	-(0)	+(40)	-(0)
	Ceratium	+(36)	+(33)	+(42)
	Protoperidinium sp	-(0)	-(0)	+(39)

N.B: + = Presence and - = Absence of the plankton

Table 3: Diversity Indices of Plankton in Ogun Coastal Water

Ecological indices	Phytoplankton	Zooplankton
Individuals	613	958
Dominance_D	0.05983	0.6200
Simpson_1-D	0.9402	1.6517
Shannon_H	2.923	1.61
Evenness_e^H/S	1.744	1.2110
Margalef	3.093	1.4412

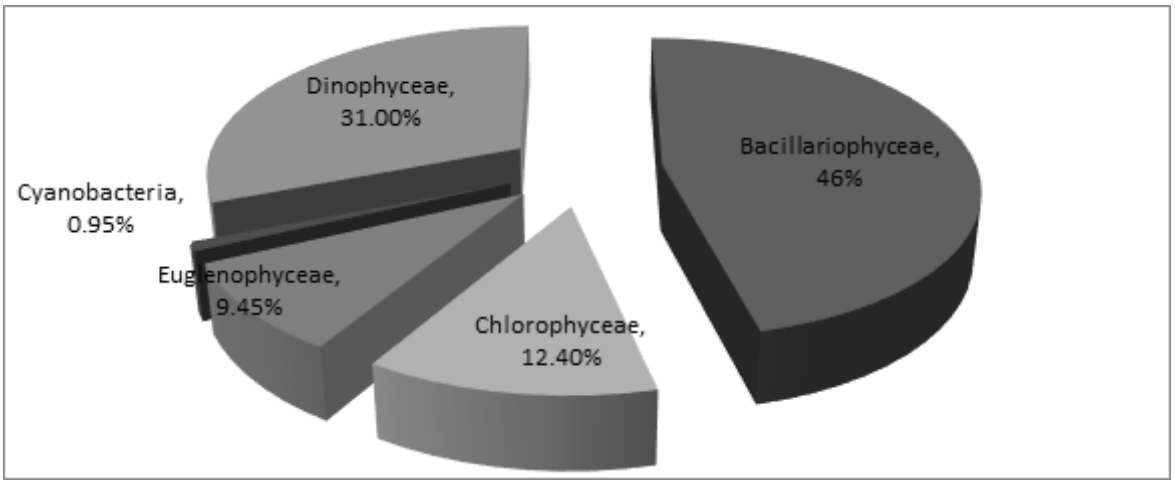

Fig 3: Percentage Occurrence of Phytoplankton Species in Ogun Coastal Water

Table 4: A Checklist of Zooplanktons Encountered During the Study Period

Phyla	Taxa	Species	Stations		
			1	2	3
Crustacean	Calanoida	*Acartia*	+(4)	+(2)	+(3)
		Calanus sp	+(1)	+(5)	+(2)
		Eucalanus sp	+(6)	-(0)	-(0)
		Microcalanus	+(3)	+(4)	-(0)
		Macrocalanus	-(0)	+(5)	+(4)
		Paracalanus	+(2)	+(1)	+(3)
		Pseudocalanus sp	+(4)	+(1)	+(3)
		Rhincalanus	-(0)	-(0)	+(5)
		Temora sp	+(2)	-(0)	-(0)
	Cyclopoida	*Cyclops sp*	+(7)	+(9)	+(6)
		Halicyclops sp	-(0)	+(12)	+(8)
		Eurycyclops sp	+(6)	+(10)	-(0)
		Mesocyclops sp	+(13)	-(0)	-(0)
		Oithona sp	+(11)	-(0)	+(12)
		Cyclopina sp	+(8)	+(10)	-(0)
		Naupli	+(16)	+(9)	+(10)
	Cladocera	*Pondon sp*	+(54)	-(0)	-(0)
		Penilia sp	+(26)	+(39)	-(0)
		Pleopsis sp	-(0)	-(0)	+(61)
		Bosmina sp	+(19)	+(23)	+(15)
		Daphnia sp	+(20)	+(11)	+(13)
		Moina sp	+(45)	-(0)	+(20)
	Chaetognatha	*Sagitta sp*	+(5)	-(0)	-(0)
		Fritilaria sp	+(4)	+(4)	-(0)
	Decapoda	Crab larvae	+(4)	-(0)	-(0)
		Nauplius larva	+(3)	+(4)	+(7)
		Zoae (crab)	+(1)	-(0)	-(0)
		Panulirus sp	+(2)	-(0)	-(0)
Rotifer	Rotifera	*Asplanchia sp*	+(18)	-(0)	+(16)
		Filinia sp	+(14)	+(8)	+(17)
		Branchionus sp	+(12)	+(19)	+(24)
		Keratella sp	+(18)	+(23)	+(20)
		Lecane sp	-(0)	-(0)	+(16)
Others	Protozoans	Chlamydomonas	+(8)	-(0)	+(9)
		Foraminiferan sp	+(6)	+(4)	+(5)
		Didinium sp	-(0)	-(0)	+(7)
		Paramecium	+(6)	+(8)	+(4)
	Polychaeta	Polychaete larva	+(1)	+(3)	+(2)
	Fish eggs & larva	Fish larva	+(23)	+(20)	+(28)
		Fish eggs	+(34)	+(35)	+(41)
	Invertebrate larva	Brachyllura larva	+(3)	-(0)	-(0)
		Brachiopod larva	+(5)	-(0)	-(0)
		Barnacule	+(2)	+(4)	+(2)

N.B: + = Presence and - = Absence of the plankton

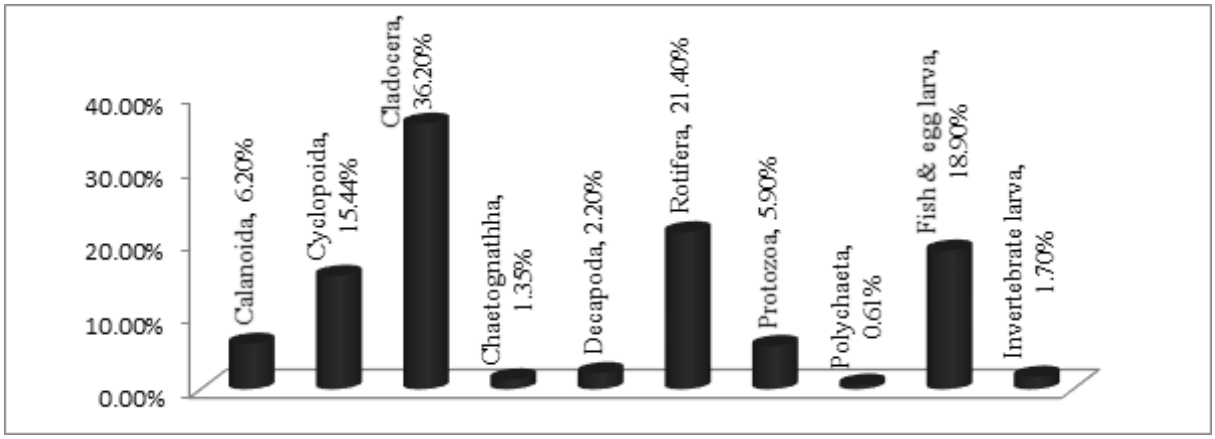

Fig 4: Percentage Occurrence of Zooplankton Species in the Study Area

DISCUSSION

This research showed the influence of nutrient variation and hydrological variables on the diversity and abundance of plankton in Ogun coastal water. The observed pattern of water quality parameters in the study area is similar to the reports of fluctuating water parameters of earlier researchers in the study area and adjoining waters (Onyema *et al.* 2003; Odulate *et al.* 2011 and Ojelade *et al.* 2016). Some variables such as temperature, dissolved oxygen, nitrate and phosphate were found to be key features that are correlated with plankton abundance and diversity in the study area. The higher level of salinity recorded in the wet season can be associated to the onset of rainy season during the sampling period increased tidal seawater incursion, coupled with water inflow from associated creeks and lagoons (Emmanuel and Onyema, 2007). The physico-chemical parameters recorded in the study in terms of mean temperature, dissolved oxygen and salinity were optimal compared to the WHO (2004) limits. Also, the alkaline pH of the coastal water during the sampling period suggested that the water body has a reasonably good buffer capacity implying optimally- good pH levels adequate for supporting a range of aquatic life; which is also beneficial to the plankton community.

Dissolved Oxygen is a very important parameter in water analysis as it serves as an indicator of the physical, chemical and biological activities of the water body. The dissolved oxygen level of the coastal water varied over the sampling period. This fluctuation might be due to the cumulative effect of wind velocity joined with heavy rainfall and the resultant freshwater mixing from the adjoining water sources (Ojelade *et al.* 2016). The recordings of highest nitrates value during the month of July which coincides with the onset of rainy season may be mainly due to the organic materials received from the catchment area with runoff during rainfall (Das and Chakrabarty, 2007; Odulate, 2010). Similar findings by other researchers reported that increased nitrates level may be due to fresh water inflow, litter fall decomposition and terrestrial run-off during the rainy months (Odulate *et al.* 2011).

The low phosphates value during the month of February and March may be attributed to the limited flow of freshwater, high salinity and utilization of phosphate by phytoplankton (Offem *et al.* 2009). The correlation matrix of the physical and chemical water quality parameters of Ogun coastal water, Ogun State, Nigeria showed a significant ($P< 0.05$) correlation; the temperature of the coastal water was positively correlated to the nitrate content of the water samples while dissolved oxygen showed a negative correlation with phosphate at 95% confidence level. This indicates that there is a mutual relationship between the listed water parameters from the study area and this corroborates the report of Mondal *et al.* (2010) and Ojelade *et al.* (2016), on the relationship between water quality parameters and the plankton diversity indices in some tropical waters.

Five major classes of phytoplankton were observed in the coastal water during the study period. The Bacillariophyceae dominated the phytoplankton community structure followed by

the Dinophyceae, while the Cyanobacteria occurred least. Similar observation of diatom domination along Nigeria coastal water has been reported by Ekeh and Sikoki (2004). Most plankton species identified in the study area were mostly tropical assemblages with genus Daphnia as it is typical of most tropical waters. The species diversity of phytoplankton was higher in the dry than wet season of the study period probably as a result of the corresponding low tidal level of the coastal water; however, abundance was higher during the rains which can be as a result of the increased nutrients load from land and adjourning water during rainfall.

The qualitative and quantitative abundance of diatom in the water is worthy of note. This is because; they have been known to be good indicators of water quality and environmental conditions (Kelly, 1998). Two important taxa of zooplankton (Rotifera and Cladocera) were encountered during the study period with the later being more diverse and abundant; an increased number of zooplankton was recorded during the wet season compared to the dry season of the study period. This is in line with the assertion of earlier researchers, Kemdirim (2000) and Davies *et al.* (2009) who recorded a greater number of zooplanktons in the wet than the dry season in other tropical waters. The zooplankton abundance increased as the rain sets in and nutrients get washed into the ecosystem, which agrees with the report of Saidu *et al.* (2009). Most of the Zooplankton species recorded here has been found in other works on Nigerian waters and the Gulf of Guinea. Between February and July, 2015, cladocerans and rotifers dominated the zooplankton community structure which is a contrast to the work of Adeyemi *et al.* (2009) who reported that the protozoans dominated the zooplankton community of a lake in Kogi State, but the result of this research corroborates the findings of Saidu *et al.* (2009) who documented rotifers and cladocerans as the highest zooplankton in Nigerian tropical water. Also, the fact that the Cladoceran dominated the zooplankton community supports the fact that coastal water is a natural breeding ground for most aquatic fauna as well as a major food source for most commercial fish sp. (Perus *et al.* 2004; Onyema, 2007).

CONCLUSION

Physicochemical characteristics of surface water in the study area varied seasonally while spatial variations did not follow any specific trend. The physicochemical properties of water increased during the dry season, except for nitrates and phosphates. Some environmental parameters such as temperature and dissolved oxygen of the study area were the main factors determining seasonal variations and the associated structure of plankton assemblage. The level of plankton richness and diversity observed during the period of study makes the study area to compete favourably when compared to other tropical aquatic ecosystems. It is possible that an increased diversity of phytoplankton and hence zooplanktonic forms observed during the dry season will give rise to a richer fin- and shell-fish abundance.

REFERENCES

Adeyemi, S. O., Adikwu, L. A., Akombu, P. M. and Iyela, J. T. 2009.Survey of zooplankton and macroinvertebrates of Gbedikere Lake Bassa, Kogi State, Nigeria. *International Journal of Lakes and River* 2: 37–44.

Ajuonu N, Ukaonu S.U Oluwajoba E.O, Mbawuike B.E, Williams A B Myade E.F. 2011. The abundance and distribution of plankton species in the bonny estuary; Nigeria. *Agriculture and Biology Journal of North America* 6: 1032-1037

American Public Health Association (APHA), American Water Work Association (AWWA) and Water Pollution Control Federation (WPCF) 2005: *Standard methods for the examination of water and waste water.* 21st ed. APHA, Washington D. C., 1195pp.

Clarke, K.R., Gorley, R.N., 2006. PRIMER v6: *User Manual Tutorial* RIMER-E Ltd, Plymouth, UK.

Das SK, Chakrabarty D 2007. The use of fish community structure as a measure of ecological degradation: a case study in two rivers of India. *Biological System* 90:188–196

Davies, O. A.; Abowei, J. F. N. and Otene, B. B. 2009: Seasonal abundance and

distribution of plankton of Minichinda stream, Niger Delta, Nigeria. *American Journal of Scientific Research* 2: 20-30.

Emmanuel B. E. and Onyema I. C. 2007. The plankton and fishes of a tropical creek in south-western, Nigeria. *Turk. J. Fish. Aquat. Sci* 3:105-114

Egborge, A. B. M. 1973. A Preliminary Checklist of the Phytoplankton of River Oshun. *Freshwater Biology* 3: 569-572.

Egharevaba, N. A., Amadi, A. N., Olashinde, P. I., and Okoye, N. O. 2010. Seasonal variation in physico-chemical and bacteriological characteristics of perched aquifer from Zaria, north-central Nigeria. *Int. J. Chem. Sci.* 3**:**100-107.

Ekeh, I. B. and Sikoki, F. D. 2004. Diversity and Spatial Distribution of Phytoplankton in New Calabar River, Nigeria. *Liv. Sys. Sus. Dev.* 3: 25-31

Kelly, M. G. 1998. Use of the trophic diatom index to monitor eutrophication in rivers. *Wat. Res.* 32: 236 – 242.

Kemdirim, E. C. 2000: Diel rhythm of plankton and physico-chemical parameters in Kangimi reservoir, Kaduna State, Nigeria. *Journal of Aquatic Sciences* 15: 35-39.

Kusler, J 2003. Climate Change in Wetland Areas Part 1: Potential Wetland Impacts and Interactions. Acclimations: New York: National Wetlands Research Centre p.11

Maosen, H. 1978. *Illustration of freshwater plankton*. Agricultural Press. Wuxi City, China. 108p.

Margalef, R., 1969. *Perspectives in Ecological Theory*. The University of Chicago Press Chicago p. 111

Mondal D.K., A. Kaviraj and Saha S. 2010: Water Quality Parameters and Fish Biodiversity Indices as Measures of Ecological Degradation: A Case Study in Two Floodplain Lakes of India. *Journal of Water Resource and Protection* 2010(2):85-92

National Research Council, Committee on Toxicology, 2000. *Nitrate and Nitrite in Drinking Water,* National Academies Press, Washington, D.C.29: 321

Newell, GB; and Newell RC 1977. *Marine Plankton: A Practical Guide*. Hutchinson and Company Publishers Ltd. London 229pp.

Odebiyi, O.C. 2013. Value-Chain Analysis for Coastal Fisheries Development in Ogun Waterside Local Government Area, Ogun state, Nigeria. *A dissertation submitted to the department of Aquaculture and fisheries management, college of environmental resources management, FUNAAB.*

Odulate D.O. 2010. Diversity and Growth Parameters of Fish Population in a part of Gulf of Guinea in Ogun State, Nigeria. *PhD thesis submitted to the Department of Aquaculture and Fisheries Management.*

Odulate D. O., George F. O. A. and Idowu, A. A. 2011. Role of Women in Fisheries in Coastal Wetland Areas of Ogun State, Southwest Nigeria *Proceedings of the Environmental Management Conference, Federal University of Agriculture, Abeokuta, Nigeria, 2011*

Odum, E.P., 1969 The strategy of ecosystem development. *Science* 164: 262–270.

Offem, B.O. Y. A.Samsons and I. T. Omoniyi 2009. Trophic ecology of commercially important fishes in the cross river, Nigeria. *The Journal of Animal and Plant Sciences* 19(1): 37-44 ISSN: 1018-7081

Ojelade O.C., Abdulraheem I., Odulate D.O., Adeosun F.I., Akaeze M.I., and Sanusi A.K. 2016. Ecological Assessment of Fish Biodiversity in Relation to Hydrological variables in Ogun coastal water, Ogun state, Nigeria. *Journal of Aquatic Sciences* 31:129-141

Olomukoro J O and C. Oronsaye 2009. The Plankton Studies of the Gulf of Guinea, Nigeria. *Biosc. Res. Comm.* 1 (2): 7-11.

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 Sciences* 7*: 89-96 (2007)* Central Fisheries Research Institute (CFRI) Trabzon, Turkey and Japan International Cooperation Agency (JICA)

Onyema , I.C., Otudeko, O.G. and Nwankwo, D.I. 2003. The distribution and composition of plankton around a sewage disposal site at Iddo, Nigeria. *Journal of Scientific Research Development* 1: 11-24.

Parsons TR, Y Maita, CM Lalli. 1984. *A manual of chemical and biological methods for seawater analysis*. Oxford, UK: Pergamon Press,

173 pp.

Perus, J., Ba¨ck, S., Lax, H.-G., Westberg, V., Kauppila, P., Bonsdorff, E., 2004. Coastal marine zoobenthos as an ecological quality element: a test of environmental typology and Europeaan Water Framework Directive. *Coastline Reports* 4:27–38

Saidu, A. K.; Agbelege, O. O.; Ahmed, M. T. and Olanrewaju, A. N. 2009. Some water quality parameters and zooplankton periodicity of the Baga in-take channel of Lake Chad. *Proceedings of FISON* 1: 105–107.

Shannon C. E and Weaver W. 1963. *The Mathematical Theory of Communication*. University of Illinois Press, *Urban* 125pp.

Smith, G. D.,Tilman, and J. C.,Nekola 1999. Eutrophication: Impacts of excess nutrient inputs on freshwater, marine, and terrestrial ecosystems. *Environ. Pollution* 100**:** 179–196.

UNEP & Gems Water Programme 2006. W*ater Quality for Ecosystem and Human Health*, Ontario Canada

WHO (World Health Organization). 2004. *Guidelines for Drinking Water Quality* 3rd ed. World Health Organization, p. 516