Seasonal and spatial occurrence of plankton and environmental variables in Ogun coastal water on the Bight of Benin

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Abstract

The influence of environmental variables on the seasonal and spatial distribution of plankton was studied for 24 months between February 2015 and January 2017 in the marine coastal water of Ogun State, Nigeria. The coastline was stratified into three sampling stations, and surface water samples were collected monthly per station for physico-chemical and plankton analyses. Mean values of physico-chemical parameters were: temperature (28.60±0.27°C), salinity (29.25±0.45‰), pH (7.38±0.07), electrical conductivity (42.13±0.33µS/l), total dissolved solids (29.59±0.30mg/l), dissolved oxygen (6.48±0.07mg/l), phosphate (1.36×10^{-2}±0.39mg/l) and nitrate (2.25×10^{-2}±0.65mg/l). The dominant phytoplankton and zooplankton groups were Diatomaceae (42.06%) and Calanoids (25.42%), respectively. Spatial diversity analysis of plankton in the study area showed that the highest (19, 35) species richness and abundance (5703, 12,452) for phytoplankton and zooplankton, respectively occurred in Site 3. Seasonal species richness of phytoplankton and zooplankton was higher in the wet (27, 40) than the dry (23, 38) season. Canonical correspondence analysis explained 77.8% of the influence of environmental variables on plankton distribution. Water temperature, dissolved oxygen, salinity, phosphate, pH, TDS and nitrate were the most marked factors that affected the distribution and abundance of plankton.

Keywords: Diatoms; coastal; multivariate; diversity; physico-chemical parameters.

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Introduction

Aquatic environments are highly impacted by human activities, either by its use for resources exploitation, transportation, recreational purposes, or dumping of waste (Ojelade *et al* 2016). These highlighted anthropogenic activities have altered the abundance and distribution of the aquatic resources and the quality of water available to these aquatic organisms in their habitat. The quality of water determines the growth and survival of all aquatic organisms, and the study of the physical and chemical parameters of an aquatic ecosystem serves as a basis for understanding its biological productivity. Although each factor plays its role, the synergistic effect of various water quality parameters determines the flora and fauna's availability, composition, and productivity (FAO 2010) in an aquatic ecosystem. It is well established that the productivity of a water body depends on its ecological health (Akpan 2004). Water quality parameters such as temperature, hardness, pH, dissolved oxygen, salinity etc. must be monitored regularly to maintain a healthy habitat for the sustainable existence of fish (UNEP 2006). Environmental variables have been reported as the main drivers of biodiversity in marine ecosystems (Stenseth *et al* 2004). Changes in these parameters are believed to influence the composition and abundance of flora and fauna of marine organisms (Akaeze 2015). Thus, it is essential to monitor the environmental parameters of Ogun marine water for rational and sustainable management of the plankton, which forms the foundation of the food pyramid in the aquatic ecosystems.

Plankton are ecologically the most important biotic components of the aquatic ecosystem, influencing all the functional aspects of the ecosystems, videlicet energy flow/transfer and cycling of matter (Imabong 2013). Phytoplankton are the foundation of food web in providing a nutritional base for zooplankton and subsequently other invertebrates, shell and fin fishes (Emmanuel and Onyema 2007; Offem *et al* 2009). The existence and distribution of plankton across the aquatic ecosystem depend on several factors such as water quality, climatic factors, grazing intensity and competition.

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Plankton abundance varies horizontally, vertically and seasonally due to variability in light and nutrient availability. Studies show that most plankton species are sensitive to changes in environmental conditions; hence, a slight change in water quality affects plankton diversity, biomass and abundance (Offem *et al* 2009; Rajagopal *et al* 2010; Olomukoro and Oronsaye 2010). The plankton of other coastal regions in Nigeria have received a lot of research attention (Ekeh and Sikoki 2004; Emmanuel and Onyema 2007; Davies *et al* 2009 and Olomukoro and Oronsaye 2010) but Ogun coastal region is poorly studied. This study was therefore undertaken to provide essential information on the seasonal distribution of plankton in relation to environmental variables in Ogun coastal water on the Bight of Benin. Such information is essential for the proper management of the coast for sustainability and maintenance of biodiversity.

Materials and methods

Study area

The geographical location chosen for this study is the Ogun waterside area of Ogun State, Nigeria (Figure 1). It covers the 15km coastline of Nigeria on Benin's Bight and borders Lagos Lagoon. The study area is closely associated with other maritime states of Southwestern Nigeria. Ogun waterside area is bounded in the West by Ijebu-East local government and Lekki Lagoon, in North and East by Ondo State and in the south by Lagos State and Gulf of Guinea (Atlantic Ocean). The area comprises over 50 towns and villages with Headquarter at Abigi at 6°29′N 4°24′E/6.483°N 4.4°E. The proximity of the area to the Atlantic Ocean, Lagoon systems and the complex network of streams, rivers, and other water bodies makes the area an appropriate site for this study.

Sampling sites and duration of the study

The Ogun 15km coastline was divided into three sampling sites at an equidistance of 5km apart along the coastline. The study was carried out between February 2015 and January 2017. Each sampling site was visited monthly; the coordinates of the three sites were geographically taken with a Global Positioning System (GARMIN GPS 12XL) meter and recorded as:

Site 1: (060.38’N, 040.36’E)
Site 2: (060.35’N, 040.39’E)
Site 3: (060.32’N, 040.41’E)

Physico-chemical parameters

Monthly monitoring of the physicochemical parameters in water samples at three different stations was undertaken during the dry and wet seasons at 08:00 hours for 24 months, at a distance of 1-10cm from the coast, according to standard methods (APHA 2012). The parameters analysed include water temperature (˚C), salinity (mg/l), dissolved oxygen (DO, mg/l), electrical conductivity (µS/l), pH, alkalinity (mg/l), phosphate (mg/l), nitrate (mg/l), and hardness (mg/l). Water temperature, pH and conductivity were measured *in-situ* using a waterproof multipurpose HANNAH instrument (combo) by dipping it to a depth of 5cm below the water surface and readings taken after it had stabilized. Dissolved oxygen (DO) samples were collected in DO bottles and fixed with 2-3 drops of manganese oxide. This was analysed *ex-situ* using Winkler's method as described in APHA (2012). Samples for other parameters such as salinity, phosphate and nitrate were collected in 0.75l sterilized bottles and transported to the laboratory for subsequent analysis. These samples were analysed in the laboratory within 24hours of collection using standard procedures of APHA (2012).

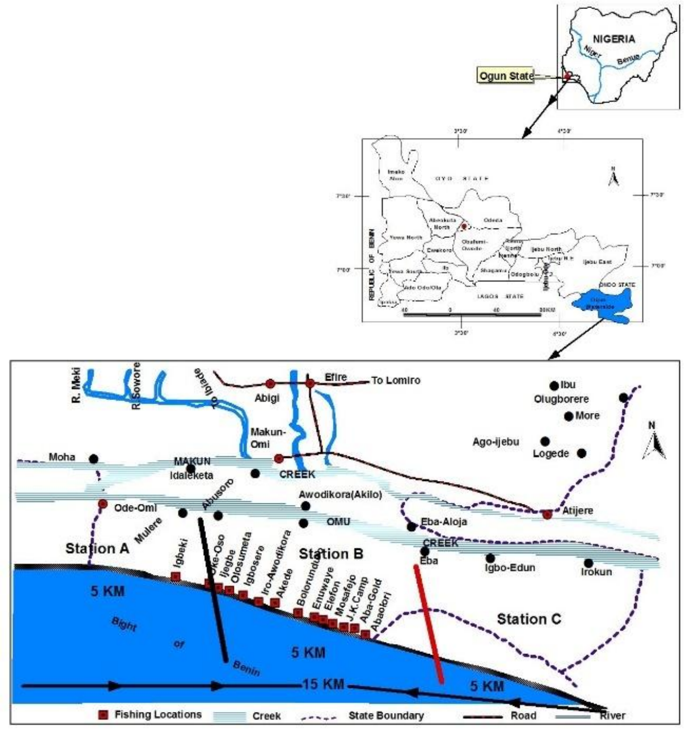

Figure 1. Map of the study area

Plankton collection and analysis

Plankton samples were collected using a 55µm mesh size standard plankton net towed across the water column. Collected plankton samples were washed into a 1.5 litre polyethene bottle and fixed immediately with 5 drops of 4% hemaxine-buffered formalin to preserve the organisms (Parsons *et al* 1984). Three (3) drops of lugol's solution was added to each of the samples and then allowed to stand for 30 minutes to settle. The samples were kept in ice boxes at 4°C during transportation to the laboratory. Plankton was identified to the genus level and enumerated using a microscope fitted with a camera (Premier equipped model) at x400 and x1000 magnification. Identification was done using guides provided by Newell and Newell (1977), Maosen (1978) and Egborge (1977).

Data analysis

Data for similar months were averaged to generate annual data. Plankton species richness and diversity such as Shannon-Weiner Diversity, *H'* (Shannon and Weaver, 1963), Simpson Dominance, *D*; Diversity (*1-D)*; Evenness (*e=H/S)*, and Equitability (*J)* indices (Odum, 1969) and Margalef's index (*d*) (Margalef, 1969) were computed for each site. The mean and standard deviation of the environmental data were also computed. Canonical Correspondence Analysis (CCA) was used to evaluate the effect of the environmental variables on the plankton abundance. Correlation between environmental variables was done using the Spearman's correlation. All statistical analysis was performed using Plymouth Routines in Multivariate Ecological Research (PRIMER v6) software (Clarke and Gorley 2006).

Results

Environmental variables of the coastal marine habitat in Ogun State

The mean monthly water quality parameter of the study area during the study is presented in Table 1. The water temperature ranged from 27.01°C in August to 30.04°C in May with a mean value of 28.60±0.268°C, and did not vary significantly ($p>0.05$) between the sampling months. The mean salinity was 29.25±0.446‰, and it ranged between 25.16‰ in September and 32.15‰ in March. The maximum pH value, 7.67, was recorded in February, while the minimum, 6.99, was recorded in November, and the average annual value was 7.38±0.07.

The mean conductivity of the coastal water during the sampling period was 42.13±0.325µS/cm, which fluctuated between 36.18µS/cm in May and 41.69µS/cm in January. The highest total dissolved solids (TDS) of 32.04mg/l was obtained in December, while the lowest, 26.33mg/l, was in June with a mean value of 29.59±0.304mg/l. Dissolved oxygen (DO) varied significantly ($p<0.05$) between months, and a mean value of 6.48±0.07mg/l was recorded. The maximum and minimum DO values were 6.1mg/l and 7.0mg/l in June and September, respectively. The biological oxygen demand (BOD) varied between 3.1mg/l in October and 4.5mg/l in January. There was no significant ($p>0.05$) difference between the seasons, and the average value was 3.79±0.15mg/l.

Phosphate content ranged from 1.10×10^{-2}mg/l in January to $1.80\text{x}10^{-2}$mg/l in August with a mean value of $1.39\pm0.39\times10^{-3}$mg/l. The phosphate values were significantly ($p<0.05$) higher in the wet than dry season during the study. Higher nitrate content was recorded during the wet months with a maximum value of 2.88×10^{-2}mg/l in June than the dry season value of 1.77×10^{-2}mg/l in January. The mean value was $2.25\pm0.65\times10^{-2}$mg/l, as shown in Table 1.

The correlation of the water quality parameters is shown in Table 2. A significant positive relationship ($p=0.67$) between temperature and salinity was observed with an inverse relationship ($p=-0.70$) between phosphate and temperature at a 95% confidence level. The salinity level of the coastal water positively influenced the pH and BOD at a 99% confidence level, while a negative relationship exists between the conductivity of the water and phosphate level. However, there was a significant positive relationship ($p=0.83$) between phosphate and nitrate at $p<0.01$ (Table 2).

Phytoplankton abundance in marine coastal water of Ogun State

The spatial taxonomic list of the phytoplankton species encountered in Ogun coastal water during the study period is presented in Table 3. Five (5) phytoplankton families were encountered during the study. The family Diatomaceae (Bacillariophyta) dominated the phytoplankton community, followed by the Myxophyceae (Cyanobacteria), Dinophyceae (dinoflagellates), Chlorophyceae (green algae), and Euglenophyceae (green flagellates) with a relative abundance of 42.06%, 23.45%, 19.82%, 8.78% and 5.89%, respectively. A higher (5,703) abundance was recorded in Site 3 compared to Site 1, where only 4,916 phytoplankters were recorded (Table 4).

The results showed that the highest phytoplankton species richness (19), abundance (5703), Margalef's index (2.08) and Simpson's index (0.91) values were recorded in Site 3. The lowest number of phytoplankton taxa (13), abundance (4916) and evenness (0.86) were recorded in Site 2 (Table 4). The highest taxa (27) and abundance (9,529) were recorded in the wet months.

Relative abundance and composition of zooplankton species in marine coastal water of Ogun State

A checklist of the species composition and abundance of the various zooplankters encountered during the study is presented in Table 5. The family Calanoida dominated the zooplankton community with 25.42%, followed by Cyclopoida (25.16%), while Polychaeta contributed the least with 1.07%. Nine families of zooplankters, including meroplankton were identified during the study. Also, the highest number (12,452) of zooplankton was observed in Site 3, while 10,541 and 11,209 were recorded in Site 2 and 1, respectively (Table 6).

The results of the analysis of the ecological indices showed a higher (0.06) dominance level at Site 1 compared to 0.05 at Site 3. At Site 2, a relatively higher evenness value of 0.85 was recorded compared to 0.72 recorded at Site 3 (Table 6). A higher number of zooplankters and families (20,191 and 40) were reported in the wet season compared to (14,011 and 38) observed in the dry season. However, the dominance value of 0.06 was higher in the dry season in comparison to the value of 0.05 recorded in the wet season. The equitability of encountered zooplankton was higher in the wet (0.89) than dry season (0.86).

Environmental variables-plankton association

The first two CCA axes explained 77.8% of the environmental variables-plankton association (Figure 2). Water temperature,

Table 1: Mean water quality parameters of the Ogun Coastal Marine Water

WQP/ Mon	**Temp(°C)**	**Salinity(‰)**	**pH**	**EC(μS)**	**TDS(mg/l)**	**DO(mg/l)**	**BOD(mg/l)**	**PO_4^{3--} (mg/l)x10^{-2}**	**NO_3^- (mg/l)x10^{-2}**
Feb	29.07 ± 1.0^{a}	31.20 ± 0.6^{ab}	7.67 ± 0.2^{a}	38.02 ± 0.7^{b}	28.12 ± 0.6^{cd}	6.12 ± 0.1^{e}	4.20 ± 0.5^{a}	1.14 ± 0.1^{e}	1.78 ± 0.7^{e}
Mar	28.77 ± 1.2^{a}	32.15 ± 0.7^{a}	7.39 ± 0.2^{a}	37.6 ± 0.6^{b}	31.38 ± 0.9^{ab}	6.41 ± 0.2^{bcde}	4.26 ± 0.5^{a}	1.17 ± 0.6^{e}	1.80 ± 0.9^{e}
Apr	29.06 ± 1.1^{a}	31.83 ± 0.6^{a}	7.45 ± 0.3^{a}	37.16 ± 0.5^{b}	30.02 ± 0.8^{abc}	6.50 ± 0.2^{abcde}	4.11 ± 0.7^{a}	1.21 ± 0.7^{de}	1.99 ± 0.6^{de}
May	30.04 ± 0.9^{a}	31.98±0.7a	7.56 ± 0.3^{a}	36.18 ± 0.6^{b}	28.13 ± 0.7^{cd}	6.40 ± 0.1^{bcde}	3.76 ± 0.5^{a}	1.32 ± 0.7^{cde}	2.43 ± 1.1^{bc}
Jun	29.40 ± 1.2^{a}	30.23 ± 0.6^{abc}	7.62 ± 0.2^{a}	37.83 ± 0.6^{b}	26.33±0.7d	6.06 ± 0.2^{e}	3.48 ± 0.5^{a}	1.50 ± 0.9^{bc}	2.87 ± 1.3^{a}
Jul	27.09 ± 0.9^{a}	27.79 ± 1.2^{cde}	7.41 ± 0.3^{a}	39.70 ± 0.4^{a}	30.79 ± 0.9^{ab}	6.21 ± 0.1^{de}	3.39 ± 0.5^{a}	1.67 ± 0.4^{ab}	2.60 ± 0.9^{b}
Aug	27.01 ± 0.9^{a}	27.27 ± 1.0^{de}	7.36 ± 0.3^{a}	40.99 ± 0.5^{a}	30.24 ± 0.7^{abc}	6.25 ± 0.1^{cde}	3.28 ± 0.5^{a}	1.79 ± 0.7^{a}	2.58 ± 0.7^{b}
Sept	28.06 ± 0.9^{a}	25.16 ± 0.6^{e}	7.2 ± 0.4^{a}	41.40 ± 0.4^{a}	29.79 ± 0.4^{abc}	7.00 ± 0.2^{a}	3.19 ± 0.4^{a}	1.49 ± 0.6^{bc}	2.61 ± 0.7^{b}
Oct	28.12 ± 0.8^{a}	25.88±0.9e	7.02 ± 0.1^{a}	39.97 ± 0.7^{a}	29.20 ± 0.6^{bc}	6.79 ± 0.2^{abc}	3.09 ± 0.5^{a}	1.48 ± 0.7^{bc}	2.25 ± 0.6^{cd}
Nov	28.18 ± 0.6^{a}	27.87 ± 1.0^{cde}	6.99 ± 0.4^{a}	40.16 ± 0.7^{a}	29.13 ± 0.6^{bc}	6.923 ± 0.3^{ab}	4.03 ± 0.8^{a}	1.42 ± 0.6^{cd}	2.31 ± 1.0^{bc}
Dec	29.19 ± 0.8^{a}	28.89 ± 1.2^{bcd}	7.34 ± 0.2^{a}	40.07 ± 0.7^{a}	32.04 ± 0.7^{a}	6.74 ± 0.2^{abcd}	4.19 ± 0.4^{a}	1.29 ± 0.6^{cde}	1.99 ± 0.7^{de}
Jan	29.17 ± 0.7^{a}	30.79 ± 1.0^{ab}	7.51 ± 0.2^{a}	41.69 ± 0.7^{a}	29.87 ± 0.8^{abc}	6.36 ± 0.1^{cde}	4.51 ± 0.5^{a}	1.09 ± 0.6^{e}	1.77 ± 0.6^{e}
Mean	28.60±0.3	29.25±0.5	7.38±0.1	42.13±0.3	29.59±0.3	6.48±0.1	3.79±0.1	1.38±0.4	2.25±0.6

Mean values (average of two sampling years) with the same superscripts along the rows were not significantly ($P>0.05$) different
pH= Hydrogen ion concentration, EC= Electrical conductivity, TDS= Total dissolved solids, DO= Dissolved oxygen, BOD=Biological oxygen demand, PO_4= Phosphate, NO_3= Nitrate, WQP = Water Quality Parameters

Table 2: Correlation of water quality parameters in the study area

Correlations									
	Temperature	Salinity	pH	EC	TDS	DO	BOD	PO_4	NO_3
Temperature	1								
Salinity	0.67^{*}	1							
pH	0.52	0.73^{**}	1						
EC	-0.53	0.73^{**}	-0.50	1					
TDS	-0.45	-0.16	-0.32	0.36	1				
DO	-0.18	-0.53	-0.89^{**}	0.35	0.31	1			
BOD	0.52	0.73^{**}	0.35	-0.20	0.22	-0.14	1		
PO_4^{3-}	-0.70^{*}	-0.69^{*}	-0.33	0.33	-0.03	-0.01	-0.85^{**}	1	
NO_3^-	-0.28	-0.50	-0.12	0.08	-0.40	-0.10	-0.81^{**}	0.83^{**}	1

*. Correlation is significant at the 0.05 level (2-tailed). **. Correlation is significant at the 0.01 level (2-tailed).
pH= Hydrogen ion concentration, EC= Electrical conductivity, TDS= Total dissolved solids, DO= Dissolved oxygen, BOD=Biological oxygen demand, PO_4= Phosphate, NO_3= Nitrate

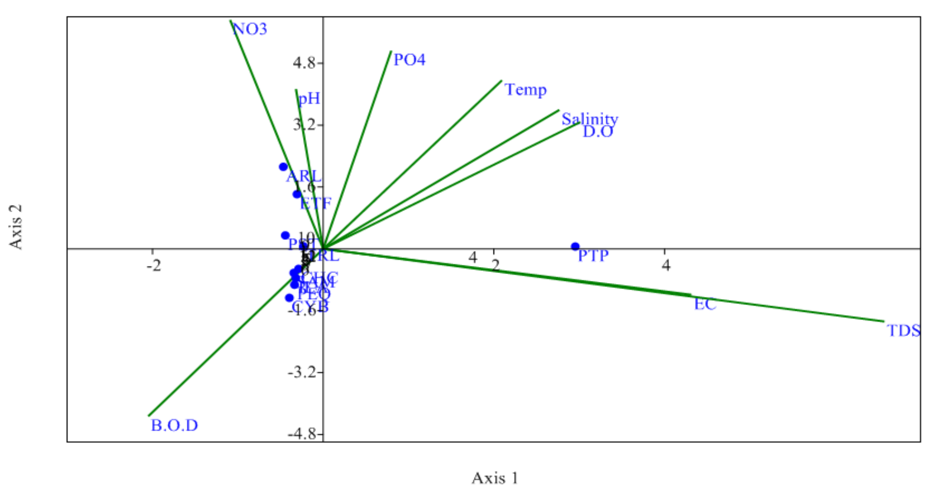

Figure 2. Canonical correspondence analysis (CCA) ordination of plankton-environmental variables
The environmental variables are: pH= Hydrogen ion concentration, EC= Electrical conductivity, TDS= Total dissolved solids, DO= Dissolved oxygen, BOD=Biological oxygen demand, PO_4= Phosphate, NO_3= Nitrate

Table 3: Taxonomic listing and spatial distribution of phytoplankton in marine coastal water of Ogun State

Taxa	Sites 1	2	3	Total	%
Diatomaceae				6630	**42.06**
Coscinodiscus sp	504(9.8)	-	288(5.1)	792	5.02
Cyclotella	-	-	456(8.0)	456	2.89
Diatoma	432(8.4)	337(6.9)	409(7.2)	1178	7.47
Fragillaria	-	361(7.3)	168(2.9)	529	3.36
Melosira	-	-	373(6.5)	373	2.37
Navicula	411(8.0)	317(6.4)	99(1.7)	827	5.25
Nitzschia	517(10.0)		-	517	3.28
Pinnularia	-	442(8.0)	69(1.2)	511	3.24
Podosira	-	-	113(2.0)	113	0.72
Synedra	-	-	721(12.6)	721	4.57
Tubellaria	-	613(12.5)	-	613	3.89
Chlorophyceae				**1384**	**8.78**
Ankistrodesmus	104(2.02)	-	-	104	0.66
Chlamydomonas	149(2.9)	-	72(1.3)	221	1.40
Closterium	57(1.1)	312(6.3)	216(3.8)	585	3.71
Scenedesmus	-	-	82(1.4)	82	0.52
Spirogyra	55(1.07)	-	-	55	0.35
Ulothrix	121(2.4)	92(1.9)	-	213	1.35
Volvox	71(1.4)	53(1.1)	-	124	0.79
Euglenophyceae				**929**	**5.89**
Euglena	413(8.01)	-	-	413	2.62
Phacus	-	-	516(9.0)	516	3.27
Myxophyceae				**3696**	**23.45**
Anabaena	221(4.3)	191(3.9)	-	412	2.61
Chroccocus	-	-	65(1.1)	65	0.41
Oscillatoria	529(10.3)	289(6.9)	321(5.6)	1139	7.23
Phormidium	-	-	63(1.1)	63	0.40
Spirulina	662(12.9)	715(14.5)	553(9.7)	1930	12.24
Microcystis	87(1.6)	-	-	87	0.55
Dinophyceae				**3125**	**19.82**
Peridinium	-	542(11.0)	-	542	3.44
Ceratium	812(15.8)	652(13.3)	924(16.2)	2388	15.15
Protoperidinium	-	-	195(3.4)	195	1.24
Total	**5145**	**4916**	**5703**	**15764**	

- = Absence of the plankton

Table 4: Community structure of phytoplankton in marine coastal water of Ogun State

Diversity Indices	Site 1	Site 2	Site 3	Sum	Wet	Dry
Taxa_S	16	13	19	29	27	23
Abundance	5145	4916	5703	15764	9529	6235
Dominance_D	0.10	0.10	0.09	0.07	0.06	0.08
Simpson_1-D	0.90	0.90	0.91	0.93	0.90	0.92
Shannon_H	2.49	2.41	2.64	2.97	3.02	2.86
Evenness_e^H/S	0.75	0.86	0.74	0.67	0.70	0.60
Brillouin	2.48	2.40	2.63	2.96	3.00	2.84
Menhinick	0.22	0.19	0.25	0.23	0.30	0.37
Margalef	1.76	1.41	2.08	2.90	3.06	3.20
Equitability_J	0.90	0.94	0.90	0.88	0.89	0.85
Fisher_alpha	2.04	1.62	2.45	3.44	3.69	3.94
Berger-Parker	0.16	0.15	0.16	0.15	0.14	0.16

dissolved oxygen, salinity, phosphate, pH, TDS and nitrate were the most marked factors that affected the distribution and abundance of the encountered plankton (phytoplankton and zooplankton) species.

Table 5: A checklist of zooplankters in marine coastal water of Ogun State

Species	Sites 1	2	3	Total	%
Crustacean					
Calanoida				**8695**	25.42
Acartia	975(8.7)	653(6.2)	819(6.6)	2447	7.15
Calanus sp	613(5.5)	384(3.6)	561(4.5)	1558	4.56
Eucalanus sp	-	-	171(1.4)	171	0.50
Microcalanus	-	721(6.8)	534(4.3)	1255	3.67
Macrocalanus	522(4.7)	417(3.9)	-	939	2.75
Paracalanus	451(4.0)	108(1.2)	221(1.8)	780	2.28
Pseudocalanus	572(5.1)	386(3.7)	436(3.5)	1394	4.08
Rhincalanus	88(0.8)	-	-	88	0.26
Temora sp	-	-	63(0.5)	63	0.18
Cyclopoida				**8604**	**25.16**
Cyclops sp	932(8.3)	855(8.1)	916(7.4)	2703	7.90
Halicyclops sp	382(3.4)	451(4.3)	-	833	2.44
Eurycyclops sp	-	337(3.2)	198(1.6)	535	1.56
Mesocyclops sp	-	-	206(1.7)	206	0.60
Oithonasp	252(2.2)		314(2.5)	566	1.65
Cyclopina sp	-	442(4.2)	236(1.9)	678	1.98
Nauplius larvae	1121(10.0)	948(8.9)	1014(8.1)	3083	9.01
Cladocera				**8234**	**24.07**
Pondonsp	-	-	69(0.6)	69	0.20
Peniliasp	-	811(7.7)	745(6.0)	1556	4.55
Pleopsis sp	327(2.9)	-	-	327	0.96
Bosmina sp	619(5.5)	725(6.9)	783(6.3)	2127	6.22
Daphnia sp	947(8.4)	922(8.7)	874(7.0)	2743	8.02
Moina sp	738(6.6)	-	674(5.4)	1412	4.13
Chaetognatha				**544**	**1.59**
Sagitta sp	-	-	114(0.9)	114	0.33
Fritilaria sp	-	196(1.9)	234(1.9)	430	1.26
Reptantian				**1543**	**4.51**
Crab larvae	-	-	52(0.4)	**52**	**0.15**
Nauplius larva	399(3.6)	456(4.3)	517(4.2)	1372	4.01
Zoea (crab)	-	-	42(0.3)	42	0.12
Panulirus sp	-	-	77(0.6)	77	0.23
Rotifera				**4495**	**13.14**
Asplanchia sp	253(2.3)	-	341(2.7)	594	1.74
Filiniasp	624(5.6)	447(4.2)	636(5.1)	1707	4.99
Brachionus sp	384(3.4)	251(2.4)	562(4.5)	1197	3.49
Keratella sp	197(1.8)	413(3.9)	278(2.2)	888	2.60
Lecan esp	109(0.9)	-	-	109	0.32
Protozoans				**915**	**2.68**
Chlamydomonas	74(0.7)	-	51(0.4)	125	0.37
Foraminiferan	181(1.6)	241(2.3)	113(0.9)	535	1.56
Didinium sp	82(0.7)	-	-	82	0.30
Paramecium	55(0.5)	76(0.7)	42(0.3)	173	0.51
Polychaeta				**367**	**1.07**
Polychaete larva	163(1.5)	108(1.0)	96(0.8)	367	1.07
Invertebrate larva					
Brachyllura larva	-	-	74(0.6)	74	0.22
Brachiopod larva	-	-	152(1.2)	152	0.44
Barnacles	149(1.3)	193(1.8)	237(1.9)	579	1.69
				805	**2.35**
Total ($x10^4$)	1.12	1.05	1.25	**3.42**	

- = Absence of the zooplankton

Table 6: Community Structure of zooplankton in Marine Coastal Water of Ogun State

Diversity Indices	Site 1	Site 2	Site 3	Sum	Wet	Dry
Taxa (No)	26	23	35	41	40	38
Abundance($x10^4$)	1.12	1.05	1.25	3.4	2.01	1.40
Dominance	0.06	0.06	0.05	0.05	0.04	0.06
Simpson	0.94	0.94	0.95	0.95	0.95	0.94
Shannon	3.00	3.00	3.22	3.24	3.29	3.13
Evenness	0.77	0.85	0.72	0.62	0.67	0.60
Brillouin	2.99	2.96	3.21	3.23	3.29	3.12
Menhinick	0.25	0.22	0.31	0.22	0.28	0.32
Margalef	2.68	2.38	3.60	3.83	3.93	3.88
Equitability	0.92	0.95	0.90	0.87	0.89	0.86
Fisher_alpha	3.18	2.79	4.40	4.60	4.79	4.76
Berger-Parker	0.1	0.10	0.08	0.09	0.08	0.09

Specifically, electrical conductivity and BOD were prominent factors that negatively affected the abundance of Cyclopoida, Calanoida, Chaetognatha, Reptantians, Polychaeta, invertebrate larva and Dinophyceae.

Discussion

Water quality influences the survival, reproduction, growth performance and overall biological and ecological production of plankton in the aquatic environment. Regular monitoring of water quality is necessary for effective management of aquatic ecosystems (Clean Water Team 2004; UNEP 2006; APHA 2012).

Temperature is a factor of great importance in any aquatic ecosystem, which affects water's chemical and physical characteristics that invariably influence organisms living in such ecosystems. The insignificant difference in temperature values across the sampling sites was probably due to the prominent wave action on the water popularly called 'Isan'. This wave action homogenized the water temperature (Abdul and Omoniyi 2007), which could also be responsible for the destruction of thermal stratification in most tropical waters. The mean temperature values were within the permissible level for marine ecosystems for survival of marine organisms (Akpan 2004; WHO 2004; Anttila 2013). Salinity fluctuated throughout the sampling months, with the highest and lowest values recorded in March and September, the peak of dry and wet seasons, respectively. Salinity values were influenced by evaporation, precipitation and freshwater influx (Egharevaba *et al* 2010; Ojelade *et al* 2016). Salinity values were not significantly different across the three sampling sites, which agreed with the reports of Moore *et al* (2008) and Ojelade *et al* (2016) in Lagos and Ogun coastal waters.

The pH values in this study were similar to the findings of Odulate (2010) and Akaeze (2015) and were within the range of 7.5 to 8.5 commonly reported for seawater

Conductivity is an index of the total ionic content of water and therefore indicates freshness or otherwise of the water (Akpan 2004). Variation in conductivity during this study was probably due to fluctuations in TDS and salinity as reported by Clean Water Team (2004). Conductivity values were similar to reports Adeyemo (2004), Ajuonu *et al* (2011) and Odulate *et al* (2014).

Dissolved oxygen is an important environmental parameter that affects the growth, survival, distribution, behaviour and physiology of fish and other aquatic organisms (Brown *et al* 2000). High DO values during the wet season were attributed to mixing influence of wind, rain droplets and runoffs. Low DO values during the dry season were attributed to high water temperature and chemical oxidation (Davies *et al* 2009; Egharevaba *et al* (2010).

Nitrate and phosphate are essential for plant growth, and peak values were obtained in July, the peak of the wet season. This is attributed to nutrients loads carried by runoff from the adjourning land into the coastal marine waters. Nitrate is considered the first and most limiting nutrient in the marine environment for macro-algae (NRC 2000; Davies *et al* 2009 and Imabong 2013), while excessive phosphate might be a causative agent for excessive algal growth (Chidi and Ominigbo 2010). Nitrate and phosphate were homogenously distributed in the water body, probably due to the thorough mixing effect by tides (Rosenberg *et al* 2004; Ojelade *et al* 2016).

Correlation analysis revealed that some water quality variables played a key role in the distribution of plankton composition in the study area. Among the variables tested, water temperature, DO, salinity, pH and nitrate were key influencers of plankton's abundance and distribution in the study area as previously reported by Soundarapandian *et al* (2009) and Odulate *et al* (2014) in the South-east coast of India and the Gulf of Guinea, respectively.

Trophic ecology of the study area

Diatomaceae, Chlorophyceae, Euglenophyceae, Myxophyceae and Dinophyceae were the major classes of phytoplankton identified in Ogun coastal water. Diatom predominated the phytoplankton community. A similar observation of diatom dominance was reported by Ekeh and Sikoki (2004) on River Calabar. Phytoplankton species diversity was higher in the wet than the dry season; this might be connected to increased nutrients load from land and adjourning rivers occasioned by increased runoffs (Emmanuel and Onyema 2007). The abundance of diatoms recorded in Ogun coastal water is similar to the reports of Kemdrim (2000) and Kelly (2008), who categorized diatoms as a reliable indicator of good water quality and environmental conditions (Kemdrim 2000; Kelly 2008) in an aquatic ecosystem. The phytoplankton diversity in the study area further revealed high Margalef's and evenness values and low dominance values.

The Calanoids were the most abundant of the nine zooplankton taxa encountered, which contrasts some previous studies such as Das and Chakrabarty (2007), Olomukoro and Oronsaye (2010) and Ajuonu *et al* (2011). However, it is similar to the findings of Emmanuel and Onyema (2007) and Imabong (2013). More zooplankton abundance was also recorded during the wet season compared to the dry season. These findings corroborate the reports of Kemdirim (2000), Davies *et al* (2009) and Saidu *et al* (2009). They affirmed that the higher number of zooplankton in the wet season signals the inflow of excess nutrients into the aquatic ecosystems. Most of the zooplankton species recorded in this study have been previously reported for other Nigerian waters (Davies *et al* 2009; Offem *et al* 2009; Olomukoro and Oronsaye 2010). The evenness result showed that the organisms were evenly distributed across the study area. A similar result of an even distribution of plankton across an aquatic ecosystem was reported in Davies *et al* (2009) and Ajuonu *et al* (2011) in their study of the Niger Delta area and Bonny estuary of Nigeria.

Conclusion

The water quality parameters of Ogun coastal water were within the permissible level as recommended by World Health Organisation for marine ecosystems. Bacillariophyceae dominated the phytoplankton community while calanoids were the most abundant and diverse zooplankton taxa. Phytoplankton and zooplankton were more abundant in the wet season than the dry season during the study area.

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