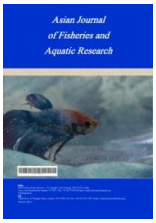

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Plankton Composition in Relation to Water Quality in the Coastal Waters of Nigeria

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Authors' contributions

This work was carried out in collaboration among all authors. Author AOA designed the study. Authors AOA and POA performed the statistical analysis and wrote the protocol. Authors AOA and JOA wrote the first draft of the manuscript. Authors AOA and POA managed the analyses of the study. Authors AHA and JOA managed the literature searches. All authors read and approved the final manuscript.

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ABSTRACT

Coastal waters of Ondo State, Nigeria have diverse assemblage of fish, yet there is dearth of information on its plankton composition. This study investigates plankton components in relation to physicochemical characteristics of the coastal waters bordering Olotu, Ayetoro and Bijimi in providing baseline information that can be used for planning and implementation of policies for monitoring, impacts assessment and conservation. Surface water samples were collected on monthly basis from March to June 2015 to analyze physicochemical parameters while plankton net of 55µm mesh size was used for collection of plankton using standard methods prescribed by APHA. The light and dark bottle method was used to determine primary productivity. Shannon-wiener, Margalef and Equitability Indices were used for diversity. Values of the physicochemical parameters observed ranged as follows: temperature, 27.47±2.06-29.27±0.31ºC; turbidity, 43.43±0.91-65.33±2.52NTU; pH, 5.54±0.31-6.12±0.30; BOD, 2.20±0.29-5.43±0.54 mg/l; COD, 6.08±2.71-6.66±1.52 mg/l; dissolved oxygen, 6.39±0.39-7.78±0.19 mg/l and salinity, 2.03±0.06-

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3.77±0.04 mg/l. Fifteen species of phytoplankton and three developmental stages of zooplankton were recorded. Phytoplankton accounted for 83.3% as against 16.7% zooplankton. Diatoms (93.3%) and dinoflagellates (6.7%) represented phytoplankton whereas 66.7% of zooplankton belonged to the phylum Arthropoda. Primary productivity ranged between 132.194±13.48$m^{-3}hr^{-1}$ and 134.48±15.27$m^{-3}hr^{-1}$. Some dominant species recorded were *Coscinodiscus, Biddulphia, Copepod, Skeletonema* and *Ditylum.* pH and Temperature were major determinant of the composition, diversity and abundance of plankton. The observed plankton group indicates the suitability of the creeks as habitat and breeding ground for diverse aquatic species. The water quality falls within acceptable range hence the environment can be classified as healthy ecosystem.

Keywords: Phytoplankton; zooplankton; physicochemical; estuarine; algae and pollution.

1. INTRODUCTION

Planktons are major contributors of biomass and are crucial to the productivity and sustainability of the aquatic ecosystem [1]. Phytoplankton constitute the base of the aquatic food chain, producing organic and inorganic substances through carbon dioxide and photosynthesis. However, their composition, distribution and abundance are largely influenced by various environmental factors from physical, biological and chemical changes. These factors include; pollution, urbanization, industrialization, anthropogenic activities, climate change etc.

Biological approaches to assessing the water quality (interacting physical and chemical factors) in aquatic ecosystems cannot be over-emphasized, considering its influence on the levels of trophic structure, primary productivity and total biomass in the aquatic food web [2]. The coastal waters of Ondo State, Nigeria which is richly blessed with favorable ecological and climatological conditions that favours optimum growth, reproduction and productivity of aquatic species [3]. These conditions support fish farming operations, thus improving the socio-economic status and livelihood of the coastal dwellers and country. However, much concern has been given to the assessment of eco-environmental quality due to the increase in agricultural, anthropogenic and industrial activities that exist in and around the area [4,5].

Several authors have carried out extensive analysis on the trophic status of various coastal water bodies in Nigeria [6,7] and reported changes in mean temperature, nutrient availability and hydrology to be the most crucial variables that determine the abundance, distribution of plankton and productivity of the entire ecosystem [2]. Planktons therefore become ideal for biomonitoring of the ecological changes in coastal ecosystems considering their position in the aquatic food chain. They reflect the composite influence of different parameters of water quality in the waterbody [8].

Comprehensive researches have been done in the coastal waters of Ondo State: Akegbejo-Samson [9], Asaolu [10], Adeparusi [11], Adebowale et al., [12], Abdus-Salam et al., [13]; Bayode et al*.,* [14]; Olawusi-Peters et al*.,* [15, 5]. However, the composition, diversity and abundance of plankton in the region are yet to be investigated. Thus, this study provides baseline information that bridges the existing gap in research on the diversity and abundance of plankton as it relates to the quality and productivity of the coastal waters of Ondo State, Nigeria.

2. MATERIALS AND METHODS

2.1 Study Area

This study was conducted in three communities within the coastal area of Ondo state (Ilaje Local Government Area), Nigeria. The study area falls within Latitudes 06° & 06°30[1] North and Longitudes 004°45[1] and 005°45[1] East of the Greenwich Meridian. Olotu, Ayetoro and Bijimi were purposively selected based on the human population, catch volume, diversities of the fishes and possible anthropogenic inputs in the areas. The area is positioned within the equatorial evergreen swamp forest sharing boundaries with Okitipupa Local Government Area in the North; the Atlantic Ocean in the South; Ijebu Waterside Local Government Area (Ogun State) in the West and Delta State in the East [14]. The environment has two seasons; the dry and the wet seasons and it experiences consistently high temperatures (about 32ºC) all year round. Since temperature varies only slightly, rainfall distribution, over space and time, becomes a

single crucial factor [11]. Ilaje LGA consists of over five hundred settlements spreading over 3,000 km^2 with emerging communities dispersed within the coast and an increasing population size of 2.2% annually [12].

2.2 Collection of Water Samples and Determination of Physicochemical Parameters

Water samples for the physicochemical analysis were collected on monthly basis from each station at sub-surface level, using 250 ml sampling bottles and transported in ice-chest to the laboratory for analysis according to APHA [16]. Samples were taken at the three stations on the same day and at the same sampling points for ease of reference. Temperature, pH, Turbidity, Salinity, Dissolved Oxygen, Chemical Oxygen Demand (COD) and Biological Oxygen Demand (BOD) of the water from each sampling station was determined using the Hanna multi-parameter Model HI 9828.

2.3 Sampling of Plankton

The plankton samples were collected using sampling net of 55µm-mesh size net tied to the boat towed at low speed for 10 minutes. The sample were then preserved in 4% formalin and kept refrigerated prior to analysis. In the laboratory, three replicates of each sample concentrate were observed under microscope Olympus model using standard guides for identification [17,18]. The different components of the plankton samples were determined and classified by their relative abundance.

2.4 Determination of Primary Productivity

The light and dark bottle method was used in the determination of primary productivity using three 125 ml oxygen bottles with each designated as initial, light and dark oxygen bottle [19]. The dark bottles were painted with black paint and covered with aluminum foil to prevent light penetration. All the bottles were filled with water from each depth. The initial water bottle was immediately fixed for dissolved oxygen using manganous sulphate and alkaline solutions. The bottles (light and dark) were incubated for six hours. and the dissolved oxygen concentration was determined for the initial, light and dark bottles. Thus, the primary productivity was calculated using conversion formula according to Smith et al. [20].

$$Gross\ primary\ \ productivity = \frac{(LB - DB)}{T\ (hrs)} \times 0.375 \times 1000mg\ (m^{-3}hr^{-1})$$

Where: LB = DO of light bottles
DB = DO of dark bottles
T = Incubation period
0.375 = ratio of weight of carbon to oxygen
1000 = liters in m^3

2.5 Statistical Analysis

Data were subjected to Multi-Variate Analysis of Variance (MANOVA) to evaluate statistical variation across the stations (P=0.05) using Statistical Package for Social Sciences (SPSS) version 16.0. Standard deviations were estimated. Descriptive analysis was also used to present Tables and Figures. Principal Component Analysis (PCA) was used to determine the relationship between the plankton and the physicochemical parameters using PAST software.

The Plankton data were subjected to the following ecological indices:

Index	Formula	Reference
Margalef's Diversity Index	$d = \frac{S-1}{lnN}$	Margalef (1968) [21]
Shannon-Wiener Index	$H' = (-P_1 lnP_1) + (-P_2 lnP_2) + \cdots$	Shannon and Wiener (1963) [22]
Pielou's Equitability Index	$J = \frac{H'}{ln\ (S)}$	(Pielou, 1966) [23]
Number of Occurrence Index (NOI)	$NOI = \frac{n}{N} \times 100$	Ogbeibu (2005)

Where: S = number of observed species;N = total number of individuals of all species in the catch; H' = Shannon-Wiener index; P = total proportion of each species in sample; n = number of individuals of each species in the catch

3. RESULTS

3.1 Physicochemical Parameters of Coastal Waters of Ondo State

The physico-chemical parameters of water in the three stations is presented in Table 1. The table revealed that temperature, Dissolved Oxygen (DO), salinity, BOD, COD showed no significant difference across the stations, while turbidity and pH exhibited locational variation at 95% confidence limit. The table shows that the highest mean Temperature (28.48±0.91°C) was recorded in Bijimi while the lowest temperature (27.88±1.26 °C) was recorded in Ayetoro. The lowest (51.48±7.76 NTU) and highest (53.86±8.47 NTU) mean turbidity was recorded at Bijimi and Ayetoro respectively, while the highest mean (5.86±0.23) and lowest mean pH (5.66±0.20) was recorded at Olotu and Ayetoro respectively. Moreover, the lowest (7.30±0.46 mg/l) and highest mean DO (7.42±0.31 mg/l) was recorded in Bijimi and Olotu respectively, while the lowest (3.34±1.63mg/l) and highest BOD (3.74±1.15mg/l) was recorded at Ayetoro and Bijimi respectively. The table further shows that the Salinity was highest (3.31±0.65mg/l) and lowest (3.03±0.70mg/l) at Bijimi and Ayetoro respectively, while COD was highest (6.66±1.52 mg/l) and lowest (6.08±2.71 mg/l) at Bijimi and Ayetoro respectively.

3.2 Plankton Composition and Abundance in Coastal Waters of Ondo State

The observed composition of plankton is presented in Table 2 which shows that 18 species from 15 families were recorded throughout the study. The phytoplankton community composed of 14 diatoms and one dinoflagellate while the zooplankton community was made up of fish embryo, copepod nauplii and odonata nymphs.

The abundance of plankton as shown in Table 3 reveals that *Coscinodiscus spp* had the most abundance in the three stations with 19.05% (n=8) in Olotu, 17.65% (n=6) in Ayetoro and 15.38% (n=4) in Bijimi. The table also reveals that *Biddulphia mobiliensis* 9.52% (n=4), 5.88% (n=2), 7.69% (n=2); *Copepod naupli* 4.76% (n=2), 5.88% (n=2), 7.69% (n=2); *Fish embryo* 4.76% (n=2), 5.88% (n=2),7.69% (=2); *Biddulphia aurita* 7.14% (n=3), 8.82% (n=3), 3.85% (n=1); and *Skeletonema costatum* 9.52% (n=4), 11.76% (n=4), 3.85% (n=1) were found in Olotu, Ayetoro and Bijimi accordingly.

The ecological indices including Margalef's diversity index (*d*), Pielou's measure of evenness (*J'*) Shannon-Wiener index (H'), and the number of species (S) caught across the three stations are presented in Table 4. The number of species caught throughout the period of study ranged between 12 and 14 with the highest recorded at Bijimi and lowest in Ayetoro. The Margalef's diversity index (*d*) of the plankton ranged from 7.18 (Ayetoro) to 8.48 (Bijimi), while the Shannon-Wiener index (H_s) ranged from 2.36 (Ayetoro) to 2.50 (Olotu). The Pielou's measure of evenness (*J'*) range from of 2.18 (Olotu) to 2.22 (Bijimi). The table also reveals that the primary productivity of the three stations were not significantly different from one another with the highest value (134.48±15.27) recorded at Olotu while the lowest value (132.19±13.48) was recorded at Ayetoro.

The initial component matrix indicates that most physico-chemical parameters showed high values in the first principal component (PC1) which means that 38% of the total variance loads heavily on BOD (0.976), COD (0.957), salinity (0.971), turbidity (0.871) and DO (0.676). The

Table 1. Physicochemical parameters of coastal waters of Ondo State

Parameter	Stations		
	Olotu	Ayetoro	Bijimi
Temperature (ºC)	27.91±1.13[a]	27.88±1.26[a]	28.48±0.91[a]
Turbidity (NTU)	52.04±6.94[ab]	53.86±8.47[b]	51.48±7.76[a]
pH	5.86 ±0.23[b]	5.66 ±0.20[a]	5.80 ±0.25[ab]
DO (mg/l)	7.42±0.31[a]	7.35±0.64[a]	7.30±0.46[a]
BOD (mg/l)	3.50±1.48[a]	3.34±1.63[a]	3.74±1.15[a]
Salinity (mg/l)	3.16±0.67[a]	3.31±0.65[a]	3.03±0.70[a]
COD (mg/l)	6.61±2.57[a]	6.08±2.71[a]	6.66±1.52[a]

second principal component (PC2) which accounts for 30% of the total variance, exhibited elevated loadings for Shannon-Wiener Index (0.679), Margalef's Index (0.293), Evenness Index (0.558), pH (0.877) and Temperature (0.744) as shown in Fig. 1 and Table 5.

Table 2. Composition of plankton in coastal waters of Ondo State

Species	Family	Type of plankton
Coscinodiscus sp	Coscinodiscaceae	Phytoplankton (Diatom)
Biddulphia mobiliensis	Biddulphiales	Phytoplankton (Diatom)
Biddulphia aurita	Biddulphiales	Phytoplankton (Diatom)
Skeletonema costatum	Skeletonemataceae	Phytoplankton (Diatom)
Ditylum brightwelli	Lithodesmiaceae	Phytoplankton (Diatom)
Odontella sp	Eupodiscaceae	Phytoplankton (Diatom)
Thalassiora sp	Thalassiosiraceae	Phytoplankton (Diatom)
Rhizosolenia	Rhizosoleniaceae	Phytoplankton (Diatom)
Pseudo-nitzschia	Bacillariaceae	Phytoplankton (Diatom)
Brachionus falcatus	Branchionidae	Phytoplankton (Diatom)
Brachionus quadridentatus	Lepadellidae	Phytoplankton (Diatom)
Lepadella patella	Lithodesmiaceae	Phytoplankton (Diatom)
Asplanchna brightwelli	Lithodesmiaceae	Phytoplankton (Diatom)
Filinia oponienses	Trichoshaeridae	Phytoplankton (Diatom)
Ceratium hirundinella sp	Ceratiaceae	Phytoplankton (Dinoflagellate)
Copepod nauplii	Copepoda	Zooplankton
Fish embryo	Osteichthyes	Zooplankton
Odonata nymphs	-	Zooplankton

Table 3. Number of occurrence index (% and n) of plankton in coastal waters of Ondo State

Species	Olotu		Ayetoro		Bijimi	
	NOI (%)	n	NOI (%)	N	NOI (%)	N
Copepod nauplii	4.76	2	5.88	2	7.69	2
Coscinodiscus sp	19.05	8	17.65	6	15.38	4
Biddulphia mobiliensis sp	9.52	4	5.88	2	7.69	2
Fish embryo	4.76	2	5.88	2	7.69	2
Biddulphia aurita sp	7.14	3	8.82	3	3.85	1
Skeletonema costatum	9.52	4	11.76	4	3.85	1
Ditylum brightwelli	0	0	5.88	2	7.69	2
Odontella sp	0	0	11.76	4	0.00	0
Ceratium hirundinella sp	0	0	2.94	1	0.00	0
Thalassiora sp	0	0	11.76	4	0.00	0
Rhizosolenia	2.38	1	2.94	1	0.00	0
Pseudo-nitzschia	7.14	3	8.82	3	0.00	0
Brachionus falcatus	4.76	2	0.00	0	7.69	2
Brachionus quadridentatus	11.9	5	0.00	0	11.54	3
Lepadella patella	4.76	2	0.00	0	7.69	2
Asplanchna brightwelli	4.76	2	0.00	0	3.85	1
Filinia oponienses	4.76	2	0.00	0	3.85	1
Odonata nymphs	4.76	2	0.00	0	11.54	3

Table 4. Biodiversity indices of plankton and primary productivity in coastal waters of Ondo State

Biodiversity index	Olotu	Ayetoro	Bijimi
Shannon-Wiener (H')	2.50^{b}	2.36^{a}	2.47^{ab}
Margalef's Index (*d*)	8.02^{b}	7.18^{a}	8.48^{c}
Pielou's measure of Evenness (J)	0.66^{a}	0.64^{a}	0.69^{a}
Number of species (S)	14.00^{a}	13.00^{a}	12.00^{a}
Primary productivity	133.91 ± 9.79^{a}	132.19 ± 13.48^{a}	134.48 ± 15.27^{a}

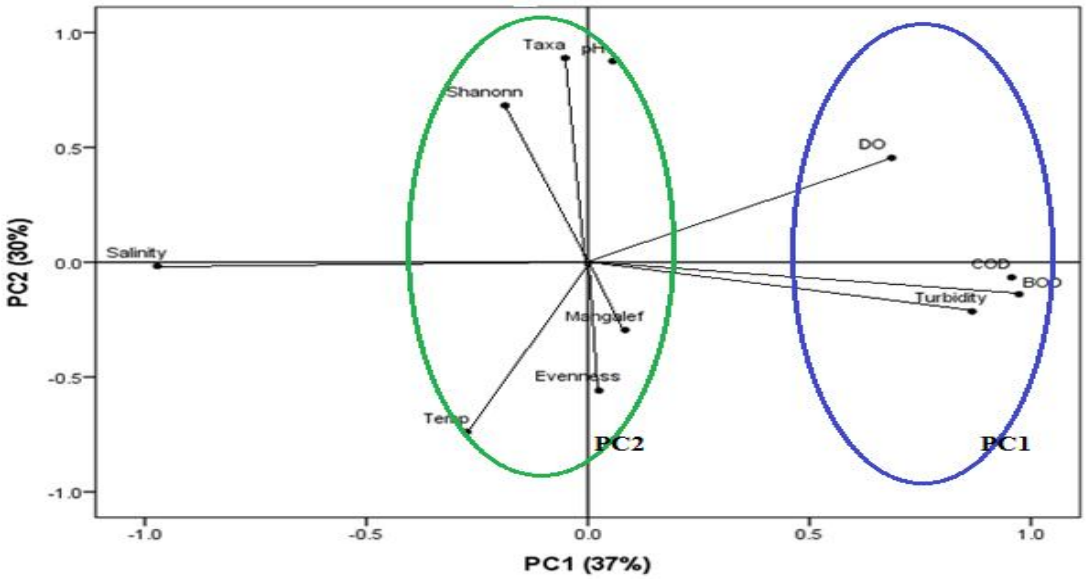

Fig. 1. Relationship between plankton and water quality of the coastal waters of Ondo State Nigeria

Table 5. Principal components analysis of plankton and physicochemical properties of the coastal waters of Ondo State, Nigeria

	Component	
	PC1	**PC2**
Shannon Wiener Index	-0.201	0.679
Margalef's Diversity Index	0.09	-0.293
Evenness Index	0.037	-0.558
Species (Taxa)	-0.069	0.888
Temperature	-0.258	-0.744
Turbidity	0.871	-0.197
pH	0.038	0.877
DO	0.676	0.468
BOD	0.976	-0.12
Salinity	-0.971	-0.036
COD	0.957	-0.046
%Variance	38	30
Eigen value	4.15	3.24

4. DISCUSSION

Temperature which is the most important physical variable affecting the metabolic rate of living organisms in the aquatic environment was within the optimal water temperatures of 18ºC – 38ºC, for optimum production and growth of planktons and fish in water bodies [24]. The result was also similar to previous findings [12, 25,26,27] in the Coastal waters of Ondo State. The water pH and turbidity values were significantly different across the stations and could be associated with the presence of suspended particles due to sewage discharges, acid runoffs and other human-mediated activities such as dredging and other activities in and around the study area. Moreover, the pH was in consonance with the report of Onyema and Ojo [28], Nkwoji et al. [29]; Abowei [30] and Ajibare [25] in the Niger Delta region.

The salinity of this study reveals a brackish environment with no significant difference across the stations. This supports the distribution, abundance, growth and diversity of planktons and aquatic organisms that requires stable salinity for survival. The DO concentrations obtained across the stations supports the

relationship between BOD and COD. High DO and Low BOD values are mainly due to higher algal productivity, along with increased solubility of oxygen at low temperatures [25] as observed in this study. The observed COD were higher when compared to BOD, signifying that the study area was highly affected by organic matter which comes from dead and decayed plant and animals in the ecosystem. These also clearly indicates that the areas receive high amount of sea wage waste containing high level of organic matter that supports the growth of planktons with adverse effect on aquatic ecosystem.

The composition, species richness, abundance and diversity indices revealed 18 different species across the stations which ranged from 12 to 14 per station. This shows that the study area was relatively rich in the assemblage of plankton. The Pielou's measure of evenness showed that the three stations had low dominance of a single-species because the values were closer to one (1) than zero (0). The Shannon-Weiner index (H') also suggests a generally high diversity and similarity among the plankton communities in the study area and this is buttressed by the non-variation of the indices across the stations. However, the differences in the level of anthropogenic activities/pollution in the communities may be responsible for the slight variation obtained in the Margalef's diversity as it was also observed by Olawusi-Peters and Ajibare [31] who worked on the species richness and abundance of the coastal waters of Ondo State.

The percentage composition/Number of Occurrence Index (%) of plankton's families at the three different stations showed that Coscinodiscaceae (*Coscinodiscus sp*) dominated the plankton groups, followed by Skeletonemataceae (*Skeletonema costatum)*, Biddulphiales (*Biddulphia mobiliensis* and *Biddulphia aurita*), Lepadellidae (*Brachionus quadridentatus*), Osteichthyes (Fish embryo), Bacillariaceae (*Pseudo-nitzschia*), and the least represented family was Ceratiaceae (*Ceratium hirundinella sp*). The dominance of family Coscinodiscaceae across the stations was similar to the findings of Varadharajan and Soundarapandian, [32]. Diatoms were dominant in the plankton collection and could be as a result of their ability to tolerate wide geographical and climatic conditions [33]. In addition, diatoms are considered euryhaline and eurythermal species as they grow and are widely distributed under marine conditions [34]. The trend of dominance in plankton composition across the stations followed the order Bijimi<Ayetoro<Olotu. The high diversity and population of plankton in Olotu could be adduced to high tidal influx, organic production and nutrient availability in the area.

According to Adirondack Ecologists [35], the species abundance and composition of phytoplankton have significant effects on both the water quality and clarity of aquatic ecosystems. The eighteen species and fifteen families of phytoplankton caught in this study revealed the area to be an area of high primary productivity, where the rate of photosynthesis is relatively high. This is in line with the report of Offem et al*.,* [2] who stated that phytoplankton carry out most of the primary productivity that takes place in the marine/brackish environment even though other marine plants (e.g. algae) contribute to primary productivity. This research also compares favorably with the reports of Balogun and Ajani [33] who worked on the coastal waters of Lagos state and tidal creeks of south-west Nigeria.

The analysis of the relationship between plankton and physicochemical properties reveals that BOD, COD, salinity, turbidity and DO were highly correlated and had 38% influence on the entire aquatic ecosystem. Similarly, diversity indices (Shannon-Wiener Index, Margalef's Index and Evenness Index) correlated significantly with pH and Temperature to have 30% influence on the health of the waterbody. This shows that the composition, distribution and diversity of plankton are influenced by the physicochemical parameters of the aquatic ecosystem.

5. CONCLUSION

This study revealed that the physicochemical parameters fall within acceptable range and it directly influences the occurrence, growth, diversity and distribution of plankton in the study area. The composition of plankton indicates suitability of the environment as habitat and breeding ground for diverse aquatic species. The study also revealed that BOD, COD, salinity, turbidity, DO, pH and temperature were major determinant of the composition, abundance and diversity of plankton. The variation in the plankton groups reflects the locational dynamics and the impact of human activities or/and pollution on the water quality. Thus, proper and continuous monitoring of the coastal waters of Ondo State is recommended in order to safeguard the entire ecosystem from collapse as

well as contribute to the survival and growth of aquatic organisms.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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