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PLANKTON DYNAMICS AS POLLUTION INDICATOR IN THE COASTAL WATERS OF ONDO STATE, NIGERIA

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ABSTRACT: *The dynamics of planktons in the coastal waters of Ondo State, Nigeria were investigated from April, 2014 to March, 2016. Samples were collected monthly using plankton net of 55 µm-mesh size, preserved in 4% formalin, examined with Olympus microscope and identified using standard guides. Zooplankton was more abundant in the environment in this study with NOI of 55.54% and 53.25% in the wet and dry seasons respectively. A total of twenty-three species of phytoplanktons belonging to two taxonomic groups were recorded. Diatom (65.22%) represented by five phyla consisting of Ochrophyta (7species), Heterokontophyta (6species) and Bacillariophyta (2species) while Dinoflagellates (34.78%) were represented by phylum Dinoflagellata (4species) and Myzozoa (4species). The zooplankton assemblage was composed of twenty-seven species including phylum Arthropoda (10), Rotifera (6), Chordata (3), Chaetognatha (2), Echinodermata (2), Ciliophora (1), Cnidarian (1), Granolereticulosa (1), and Mollusca (1). In wet-season, Fish-eggs (4.69%) (most abundant) Brachionus quadridentatus (3.79%); Coscinodiscus sp (3.67%); Biddulphia mobiliensis (3.31%) and Odonata nymph (3.01%) with Foraminifera (0.60%, the least) while the composition of the dry-season had a descending trend of Asterionellopsis sp (3.25%)>Cerataulina sp and Pseudo-nitzschia sp (3.02%)>Chaetognatha adult (2.86%)>Brachionus falcatus; Ceratium hirundinella sp and Coscinodiscus sp (2.70%)>Gyrodinium spp (2.62%) to Protoceratium reticulatum (0.48%). The Number of Individuals ranged from 26.25±6.86 (Dry-season) to 38.85±16.33 (Wet-Season) while Number of the most abundant species (Nmax) and average number of species (S) (which exhibited seasonal variation at P<0.05) ranged from 2.92±0.87 (Dry-Season) to 3.92±1.18 (Wet-Season) and from 18.10±3.14 (Dry-season) to 20.38±5.72 (Wet-Season) respectively. The Margalef's Diversity Index and Shannon-Wiener Index which showed no seasonal variation ranged from 5.25±0.70 to 5.35±1.28 and 2.80±0.18 to 2.86±0.29 respectively, while Simpsons-Reciprocal Index ranged from 32.25±12.74 (Wet-Season) to 40.10±15.84 (Dry-season) and exhibited seasonal variation at P<0.05. The abundance and diversity of planktons in this study is an indicator of eutrophic ecosystem that is possibly unstressed.*

KEYWORDS: Brackish-water; Planktons; Eutrophic; Diversity Index, Abundance, composition, Nigeria.

INTRODUCTION

The term plankton refers to any small biota (usually microscopic) living in the water adrift in the water column and incapable of maintaining its position and at the mercy of currents. In the aquatic ecosystem, the phytoplankton is the foundation of the food web, in providing a nutritional base for zooplankton and subsequently to other invertebrates, shell fish and finfish

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(Emmanuel and Onyema, 2007). The productivity of any water body is determined by the amount of plankton it contains as they are the major primary and secondary producers. The distribution, abundance and diversity reflect the physico-chemical conditions of aquatic ecosystem in general and its nutrient statue in particular (Ezekiel *et al.*, 2011).

Planktons are of great importance in bio-monitoring of pollution (Davies *et al*., 2009). The distributions, abundance, species diversity, species composition of the phytoplankton are used to assess the biological integrity of the water body (Townsend *et al*., 2000, Ezekiel *et al.*, 2011). Pollution affects the composition and distribution of planktons since they do not have control over their movements thus they cannot escape pollution in the environment. Fachrul and Syach (2006) showed that as pollution increases over time, the plankton abundance and diversity decrease. The waters become dominated by fewer, more pollution-tolerant species. This loss of diversity can affect aquatic food webs, resulting in repercussions for other species, as well as fishing industries (Fachrul and Syach, 2006).

According to Suzuki *et al*, (2002) there are only few records on the plankton and productivity of Nigerian creeks. Furthermore, there are few published works on planktons in South-western Nigeria which include: Onyema and Ojo, (2008) in the Agboyi creek Lagos state, Nigeria; Olaniyan (2013) in Owena reservoir, Ondo state, Nigeria; Anago *et al.*, (2013) in Awba Reservoir, Ibadan Nigeria among others. Consequent upon this, there is a need for information on the dynamics of planktons in the coastal waters of Ondo state especially in relation to the water quality changes caused by seasonal dynamics and anthropogenic activities. The study is important because it will contribute to the knowledge of phycological information in Nigeria.

MATERIALS AND METHODS

Study area:

The study was carried out in the coastal towns of Ayetoro (06°06'N 04°46'E), Idiogba (06°05'N 04°47'E), Bijimi (06°04'N 04°49'E), and Asumogha (06°03'N 04°39'E) in Ilaje Local Government Area of Ondo State from April, 2014 to March, 2016. The study area is at the extreme southern part of Ondo State in Nigeria. The area is positioned within the equatorial evergreen swamp forest with two major seasons; the dry season and the wet season. The environment experiences consistently high temperatures (about 32°C) all year round (Bayode *et al.*, 2011).

The study area was purposely selected based on earlier information for extensive fishing activities in the towns, accessibility and possible anthropogenic inputs from activities of oil exploration, transportation, farming practice, domestic and cottage industrial discharges into creeks and streams which finally emptied into Atlantic Ocean in the southern part. This area is noted for sea foods which are consumed within and outside the state.

Collection of water samples for the determination of planktons

The plankton samples were collected monthly from April 2014 to March 2016 using sampling net of 55 μm-mesh size net tied to the boat horizontally along the water course and towed at low speed for 10 minutes at each sampling station according to the methods of Anene (2003). All samples were collected between 11:00 hrs and 14:00 hrs so as to minimize the variations of zooplankton distribution that could occur due to diurnal migrations (Bainbridge, 1972).The

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resultant concentrated plankton samples were later transferred to 250ml sampling bottles, fixed and preserved in 4% formalin according to the method of Boney (1983) and Anene (2003). The samples collected were transported in ice to the laboratory and kept refrigerated prior to analysis.

Laboratory Analysis

Samples were homogenized by inverting the containers few times. With a wide-mouthed pipette, 1ml of the plankton subsample was withdrawn in triplicate from the field samples, placed on a glass slide with a cover slip placed over the mount and observed under microscope Olympus model at different magnifications ranging from ×50 to ×400. Planktons identification was done with the aid of keys, description and illustration as given by United Nations Educational, Scientific and Cultural Organization (UNESCO, 1978), Dutta (1979), APHA (1998), Waife and Frid, (2001), Perry 2001, National Institute of Oceanography (N.I.O) (2004), Yamaguchi and Gould (2007). Counts were made in triplicates and their averages expressed as either cells/ml (phytoplankton) or organisms/ml (zooplankton) of water.

Statistical analysis: Data were subjected to the following Diversity indices: Margalef's diversity index (Margalef, 1968); Shannon-Wiener index (Shannon and Wiener (1963): Simpson's Index (Ogbeibu, 2005); Simpson's Diversity Index (Ogbeibu, 2005); Simpson's Reciprocal Index (Ogbeibu, 2005); Pielou's Equitability Index (Pielou, 1966); Menhinick's index (Ogbeibu, 2005); Berger- Parker Diversity Index (Ogbeibu, 2005); Berger- Parker Dominance Index (Ogbeibu, 2005); and Number of Occurrence Index (NOI). Also, Multi-Variate Analysis of Variance (MANOVA) and Duncan multiple range test was used to evaluate the significant difference in the values of different parameters. A probability level of less than 0.05 was considered significant. Standard deviations were also estimated. Descriptive analysis was also used to present tables and figures.

RESULTS

Plankton Composition and Abundance

The composition of planktons of the coastal waters of Ondo state with reference to the type/group is presented in figure 1. The figure reveals that zooplankton was more abundant in the environment throughout the study with NOI of 55.54% and 53.25% in the wet and dry seasons respectively. Also, the composition of planktons in terms of phylum in the coastal waters of Ondo state is presented in figure 2. The figure shows that the phylum Arthropoda (18.10% in dry season and 19.55% in wet season) was the most abundant in the environment throughout the study period. Also, phylum Onchrophyta (15.16% in dry season and 15.34% in wet season) was the second most abundant phylum throughout the study while the phylum Rotifera (13.96%) and Heterokontophyta (13.81%) had the third highest abundance in the wet and dry season respectively. Furthermore, phylum Heterokontophyta (11.55%) and Chordata (9.81%) were the next on the hierarchy in the wet season and were represented by Rotifera (12.54%) and Dinoflagellata (8.41%) in the dry season while the least represented phylum was Granoloreticulosa (0.60% in the wet season) and Cnidaria (1.27% in the dry season).

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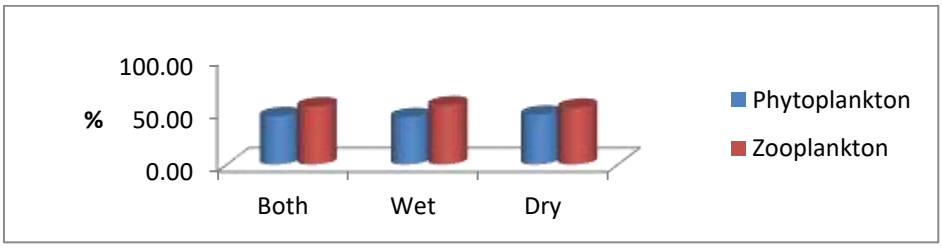

Figure 1: Composition of Planktons in the Coastal waters of Ondo State

Table 1 presents the composition and abundance of phytoplanktons in this study. The table shows that twenty three (23) species of phytoplanktons including fifteen (15) diatoms (7 Onchrophyta, 6 Heterokontophyta and 2 Bacillariophyta) and eight (8) dinoflagellates (4 dinoflagellata and 4 myzozoa) were recorded in this study. Moreover, in the dry season, *Asterionellopsis sp* (6.96%) had the highest and was followed by *Pseudo-nitzschia sp* and *Cerataulina sp* (6.45%); *Ceratium hirundinella sp* and *Coscinodiscus sp* (5.77%); *Gyrodinium sp* (5.60%); *Thalassiora sp* (5.43%) to *Protoceratium reticulatum* (1.02%) while in the wet season, *Coscinodiscus sp* (8.25%) > *Biddulphia mobiliensis* (7.44%) > *Ditylum brightwelli* (5.95%) > *Thalassiora sp* and *Dinphysis rotundata* (5.55%) > *Odontella sp* (5.28%) to *Bacterastrum sp* and *Unidentified Coscinodiscus spp* (1.62%) was the trend of abundance. The table further reveals that the overall trend of abundance was *Coscinodiscus sp* (7.15%) > *Asterionellopsis sp* (5.87%) > *Cerataulina sp*, *Biddulphia mobiliensis* and *Pseudo-nitzschia sp* (5.72%) > *Ditylum brightwelli* (5.57%) > *Thalassiora sp* (5.50%) to *Protoceratium reticulatum* and *Unidentified Coscinodiscus spp* (2.18%)

Table 2 presents the composition and abundance of zooplanktons in this study. The table shows that twenty seven (27) species of zooplanktons (including ten (10) members of the phylum Arthropoda, 6 Rotifera, 3 Chordata, 2 Chaetognatha, 2 Echinodermata, 1 Ciliophora, 1 Cnidaria, 1 Granolereticulosa, and 1 Mollusca) were recorded in this study. The table further shows that zooplanktons recorded in the dry season had the following composition in descending order of abundance: *Chaetognatha adult* (5.37%) > *Brachionus falcatus* (5.07%) > Fish embryo (4.77%) > *Codonellopsis spp* (4.47%) > Fish eggs and Copepods eggs (4.32%) to Odonata nymphs and Chaetognatha juvenile (2.09%) while in the wet season, Fish eggs (8.45%) had the highest abundance and was followed (in descending order) by *Brachionus quadridentatus* (6.83%), Odonata nymphs (5.42%), Fish embryo (5.09%), *Asplanchna brightwelli* (4.98%) with Foraminefera (1.08%) being the least abundant zooplankton. Furthermore, the overall trend of abundance was Fish eggs (6.71%) > *Brachionus quadridentatus* (5.65%) > Fish embryo (4.96%) > *Asplanchna brightwelli* (4.58%) > *Filinia opoienses* (4.27%) to Foraminefera, *Siphonophora* and *Echinoderm post-larvae* (2.26%) as shown in table 2.

Diversity Indices of planktons

Table 3 shows the diversity indices of planktons as recorded in this study. The table shows that Number of Individuals ranged from 26.25±6.86 (in Dry season) to 38.85±16.33 (in the wet season). Also Table 2 shows that there was significant difference ($P<0.05$) between the two seasons. Furthermore, the overall Number of Individuals was 32.55±13.97 and was not significantly different ($P>0.05$) from both dry and wet seasons.

Number of individuals of the most abundant species (Nmax) analyzed from the study area ranged from 2.92±0.87 (Dry season) to 3.92±1.18 (Wet Season). There was significant

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difference (P<0.05) between the dry and wet seasons in the study area. The average number of species (S) of planktons which ranged from 18.10±3.14 in dry season to 20.38±5.72 in wet season showed seasonal variation at P<0.05. The Margalef's Diversity Index and Shannon-Wiener Index which showed no seasonal variation at P>0.05 ranged from 5.25±0.70 to 5.35±1.28 and 2.80±0.18 to 2.86±0.29 respectively, while Simpsons Reciprocal Index ranged from 32.25±12.74 (Wet) to 40.10±15.84 (dry) and exhibited seasonal variation at P<0.05

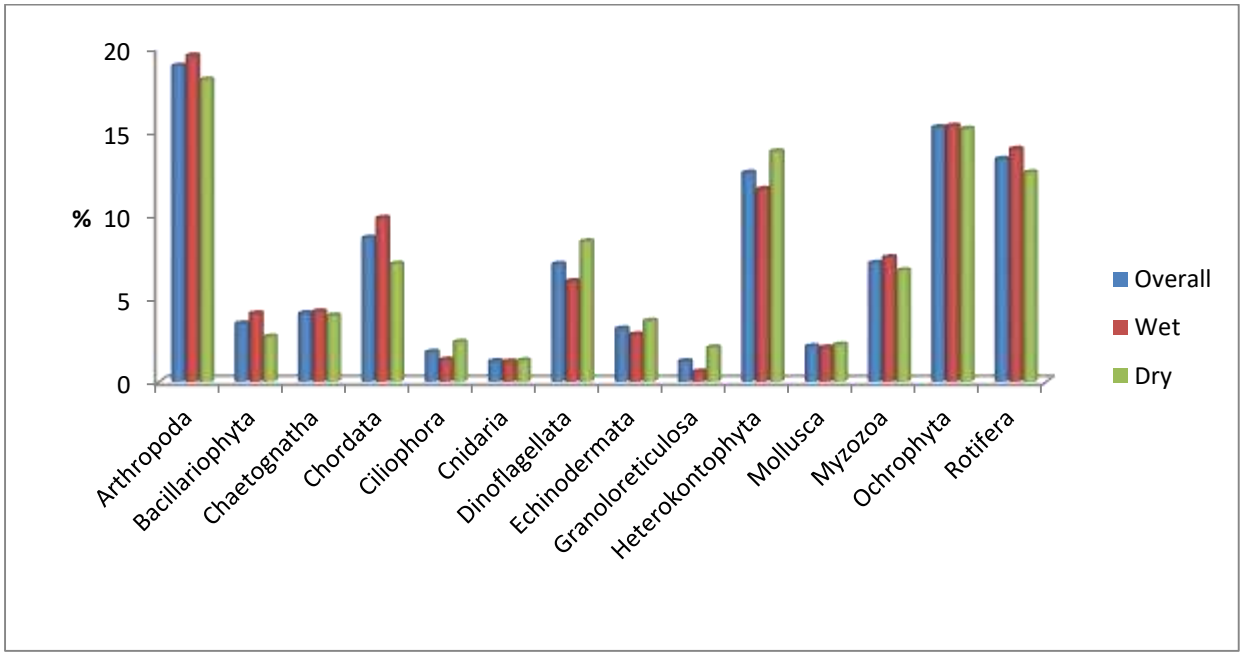

Figure 2: Composition of Planktons (Phylum) in the Coastal waters of Ondo State

Table 1: The Composition and Abundance of Phytoplanktons in the coastal waters of Ondo State

Phylum	Family	Type of Organism	Plankton	Dry Season	Wet Season	Overall
Bacillariophyta	Probosciaceae	Diatom	*Proboscia alata*	2.89	4.47	3.77
Bacillariophyta	Skeletonemaceae	Diatom	*Skeletonema costatum*	2.89	4.74	3.92
Heterokontophyta	Chaetocerotaceae	Diatom	*Bacterastrum sp*	4.92	1.62	3.09
Heterokontophyta	Lithodesmiaceae	Diatom	*Ditylum brightwelli*	5.09	5.95	5.57
Heterokontophyta	Naviculaceae	Diatom	*Navicula spp*	2.89	2.44	2.64
Heterokontophyta	Eupodiscaceae	Diatom	*Odontella sp*	4.75	5.28	5.05
Heterokontophyta	Bacillariaceae	Diatom	*Pseudo-nitzschia sp*	6.45	5.14	5.72
Heterokontophyta	Thalassiosiraceae	Diatom	*Thalassiora sp*	5.43	5.55	5.5
Ochrophyta	Fragilariaceae	Diatom	*Asterionellopsis sp*	6.96	5.01	5.87
Ochrophyta	Biddulphiaceae	Diatom	*Biddulphia aurita*	4.07	5.14	4.67
Ochrophyta	Biddulphiaceae	Diatom	*Biddulphia mobiliensis*	3.57	7.44	5.72
Ochrophyta	Hemiaulaceae	Diatom	*Cerataulina sp*	6.45	5.14	5.72
Ochrophyta	Coscinodiscaceae	Diatom	*Coscinodiscus sp*	5.77	8.25	7.15
Ochrophyta	Rhizosoleniaceae	Diatom	*Rhizosolenia sp*	2.72	1.89	2.26
Ochrophyta	Coscinodiscaceae	Diatom	*Unidentified Coscinodiscus spp*	2.89	1.62	2.18
Dinoflagellata	Ceratiaceae	Dinoflagellate	*Ceratium hirundinella sp*	5.77	4.6	5.12
Dinoflagellata	Ceratiaceae	Dinoflagellate	*Ceratium spp*	4.75	3.38	3.99

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Dinoflagellata	Brachidiniaceae	Dinoflagellate	*Karenia sp*	4.24	3.11	3.61
Dinoflagellata	Noctilucacaee	Dinoflagellate	*Noctiluca scintillans*	3.23	2.44	2.79
Myzozoa	Dinophysiaceae	Dinoflagellate	*Dinphysis rotundata*	4.75	5.55	5.2
Myzozoa	Gymnodiniaceae	Dinoflagellate	*Gymnodinium sp*	2.89	4.06	3.54
Myzozoa	Gymnodiniaceae	Dinoflagellate	*Gyrodinium sp*	5.6	4.06	4.74
Myzozoa	Gynyaulaceceae	Dinoflagellate	*Protoceratium reticulatum*	1.02	3.11	2.18

Table 2: Composition and Abundance of Zooplanktons in the Coastal Waters of Ondo State

Phylum	Family	Plankton	Dry Season	Wet Season	Overall
Arthropoda	Acartiidae	*Acartia spp*	4.17	4.01	4.08
Arthropoda		*Cirripede larva*	3.13	4.01	3.64
Arthropoda		*Cirripede naupli*	3.58	4.33	4.02
Arthropoda		*Copepod eggs*	4.32	3.79	4.02
Arthropoda		*Copepod naupli*	2.98	4.01	3.58
Arthropoda		*Decapod larvae*	4.17	1.19	2.45
Arthropoda		*Decapod megalopa*	2.68	3.25	3.01
Arthropoda	Lepadidae	*Lepa nauplii*	3.43	1.63	2.38
Arthropoda		*Odonata nymphs*	2.09	5.42	4.02
Arthropoda		*Ostracoda*	3.43	3.58	3.51
Chaetognatha		*Chaetognatha adult*	5.37	3.25	4.14
Chaetognatha		*Chaetognatha juvenile*	2.09	4.33	3.39
Chordata		*Fish eggs*	4.32	8.45	6.71
Chordata		*Fish embryo*	4.77	5.09	4.96
Chordata		*Fish larvae*	4.17	4.12	4.14
Ciliophora	Codonellopsidae	*Codonellopsis spp*	4.47	2.38	3.26
Cnidaria		*Siphonophora*	2.38	2.17	2.26
Echinodermata		*Echinoderm larvae*	3.28	3.79	3.58
Echinodermata		*Echinoderm post-larvae*	3.58	1.3	2.26
Granoloreticulosa		*Foraminifera*	3.87	1.08	2.26
Mollusca		*Cephalopoda larvae*	4.17	3.68	3.89
Rotifera	Asplanchnidae	*Asplanchna brightwelli*	4.02	4.98	4.58
Rotifera	Brachionidae	*Brachionus falcatus*	5.07	3.25	4.02
Rotifera	Brachionidae	*Brachionus quadridentatus*	4.02	6.83	5.65
Rotifera	Trochosphaeridae	*Filinia opoienses*	4.17	4.33	4.27
Rotifera	Lepadelliae	*Lepadella patella*	3.13	2.28	2.63
Rotifera		*Rotifer eggs*	3.13	3.47	3.32

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Table 3: Seasonal Variation of Diversity Indices of Planktons in the Coastal Waters of Ondo State

Index	Dry Season	Wet Season	Overall
N	26.25[a]	38.85[b]	32.55[ab]
Nmax	2.92[a]	3.92[b]	3.42[ab]
Taxa (S)	18.10[a]	20.38[b]	19.24[ab]
Margalef's Diversity (d)	5.25[a]	5.35[a]	5.30[a]
Shannon-Wiener (H')	2.80[a]	2.86[a]	2.83[a]
Simpson's Index	0.93[a]	0.93[a]	0.93[a]
Pielou's Equitability (J)	0.97[a]	0.96[a]	0.97[a]
Berger-Parker Dominance (D)	0.12[a]	0.11[a]	0.11[a]
Berger Parker Diversity	9.53[a]	10.80[a]	10.17[a]
Menhinick's Index (M)	3.55[a]	3.34[a]	3.44[a]
Simpson's Index of Diversity	0.97[a]	0.96[a]	0.97[a]
Simpson's Reciprocal Index	40.10[b]	32.25[a]	36.18[ab]

Mean in the same column with homogenous superscript are not significantly different ($p>0.05$)

DISCUSSION

The diversity and quantity of planktons recorded in the study area is a good indicator of an ecosystem that is possibly not stressed (Emmanuel and Onyema, 2007). Arthropods were the most abundant phylum observed during the study. However, Fish egg, *Branchionus quadridentatus*, Fish embryo, *Asplanchna brightwelli* and *Filinia oponienses* were the most abundant zooplankton in terms of species while *Coscinodiscus sp, Asterionellopsis sp, Biddulphia mobiliensis, Cerataulina sp* and *Pseudo-nitzschia sp* were the most abundant phytoplankton in this study. This observation agrees with the observations of Onyema *et al*, (2003), Emmanuel and Onyema, (2007), Onyema and Ojo, (2008) and Anago *et al.*, (2013). The dominance of the phylum Arthropoda and Rotifera was not unexpected as both phyla have been reported by Akin-Oriola (2003), Onyema *et al*, (2003) and Mustapha and Omotosho (2006) as the most dominant zooplankton group in aquatic ecosystems.

The occurrence of marine species like Decapod larvae/megalopa, Cirripede larva/naupli, cephalopoda larvae, Chaaetognatha juvenile, fish egg/embryo, Odonata nymphs and rotifer eggs indicated that these species live and reproduce from nearly freshwater to hyperhaline waters or conditions. Thus, the developmental stages of zooplanktons of known lagoon and marine species in this study pointed to the suitability of the shallow tidal creek as a nursery and feeding ground for a variety of aquatic organisms (Emmanuel and Onyema, 2007). This supports the view of Layman *et al.*, (2004) that some marine species periodically enter estuarine areas to feed and juveniles of others species utilize these areas as nursery grounds.

The high population density and biomass of zooplankton in this study could be traced to the high population of the phytoplankton food source which was highly abundant within the area during the different seasons because an increase in primary production (phytoplankton) tends to be followed by an increase in zooplankton number and biomass. The most abundant phytoplankton phylum throughout the study period was the Onchrophyta (diatom). This agrees with the observations of Ugwumba and Ugwumba (1993) and Anago *et al.*, (2013) that algae dominated the Awba reservoir, Ibadan as well as Onyema *et al*, (2003) in Lagos lagoon. Algae,

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(*Microcystis*) have also been reported to dominate the phytoplankton group in Lake George, Uganda (Burgis *et al*., 1973) and Lake Asejire, Nigeria (Egborge, 1979) while *Anabeana*, a filamentous form of blue-green algae was reported to dominate phytoplankton in Lake Rudolf, Kenya and diatoms in Lake Albert (Fish, 1955 as reported by Anago *et al.*, (2013).

The abundance of species like *Brachionus quadridentatus* is an indication that the study area is eutrophic and maybe due to the presence of high levels of organic matter in the environment (Anago *et al.*, 2013). The low genera abundance of cladocerans and copepods has also been documented in other water bodies such as Lake Cubhu in South Africa (Martin and Cyrus, 1994), the Ogun and Ona rivers (Akin-Oriola, 2003) and Lagos lagoon (Emmanuel and Onyema, 2007; Onyema and Ojo, 2008).

The results obtained in this study may also be affected by the water bodies connected to the creeks, such as adjoining waters from the ocean, which may contribute to the species composition and abundance. Also, the non-seasonal variation in the abundance and species diversity of the planktons may probably be due to the high tolerance of these plankton species to higher variations in salinity as earlier stated by Onyema *et al*, (2003) Nwankwo, (2004) and Onyema and Ojo, (2008).

Holden and Reed (1978) found that diversity indices were ecological tools for assessing pollution while Ismael and Dorgham (2003) echoed Margalef (1968) that plankton diversity ranges between 1 and 3 in eutrophic lakes. Hence, applying this criterion to the diversity observed in this study, it could be assumed that, the study area is eutrophic. Diversity indices have also been proposed by Mihnea (1985) on the ground that diversity values decrease as productivity increases. Similar views have been expressed with reference to pollution (Holden and Reed 1978) that the severity of pollution is inversely proportional to species diversity. Therefore the high values of Shannon-Wiener Index (H') and Margalef's diversity index (*d*) reflect high productivity while Equitability/Evenness and Berger-Parker dominance Index showed high evenness among the species observed in this study. Also, the number of species and individuals reflect good abundance of planktons in the study area. Thus, the high diversity and evenness values recorded in this study shows that the anthropogenic activities in the study area are within the level that still sustains the ecosystem.

CONCLUSION

Based on the findings of this research, there was no seasonal variation in abundance and diversity of plankton biotypes of the coastal waters of Ondo state in the Niger Delta region of Nigeria eventhough there was relatively higher mean plankton abundances and diversities in the wet season. Also, most of the phytoplankton and zooplankton species identified were diatoms and arthropods respectively, there was no high single-species dominance as the evenness index and the dominance index was high and low respectively. This study therefore reveals that the plankton community as well as the biodiversity of the coastal waters of Ondo State is sufficient enough for food production in the environment. The study area can be classified as an eutrophic environment (i.e. having high amount of nutrients and planktons).

Furthermore, in order to sustain the quality and productivity of the study area, immediate actions need to be taken to reduce the increasing levels of anthropogenic activities which have

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resulted in the reduction of the water quality and fisheries sustainability of most aquatic ecosystem.

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