Original Research Article

Ecological Approach of Plankton Responses to Water Quality Variables of a Tropical River, South-eastern Nigeria: A Bio-indicator-Based Community Assessment of Idundu River.

ABSTRACT

In the present study, the water quality variables of the Idundu River were assessed by evaluating the Plankton community. Three sampling stations: station 1 (minimal fishing), station 2 (artisanal fishing area/ cluster of human settlements) and station 3 (fisheries landing area, dredging) representing regions along the stretch of the watershed with considerable economic importance and anthropogenic activity, were selected within the period of six (6) months. The study determines plankton distribution, diversity and some water quality variables of Idundu River, and how it influence plankton abundance. The results of this study reveal that water quality variables (mean ± SD) of the River were pH (6.526 ± 0.104), surface water temperature (26.224 ± 0.106^{o}C), dissolved oxygen (1.474 ± 0.135 mg/l), nitrate (0.026 ± 0.001 mg/l) and phosphate (0.015 ± 0.000 mg/l). All the water quality variables assessed were within the acceptable range. A total of 23 phytoplankton species belonging to five families, totalling a numerical abundance of 368 cell/L individuals were observed. Bacillariophyceae was the most abundant phytoplankton family (63.81%), followed by Chlorophyceae (17.41%), Dinophyceae (7.87%), Cryptophyceae (9.77%), and the least abundant was Zygnemophyceae accounting for (1.08%). A total of 20 zooplankton species belonging to five phyla, totalling a numerical abundance of 140cell/L of Zooplankton were observed. Rotifera was the most abundant zooplankton phylum (35.69%), Arthropoda (30.62%), Ciliophora (17.79%) and Annelida (12.15%); the least abundant was Nemata (2.85%). Principal component analysis (PCA) for planktonic organisms showed that phytoplankton were more homogenously distributed tan zooplankton during the study period. Shannon Wiener and Margalef's diversity index showed that the River is in a healthy condition and the equitability level was high across all the stations, indicating even planktonic distribution.

Keywords: Ecological, Water Quality Variables, Distribution, Idundu River, Principal component analysis (PCA).

1. INTRODUCTION

Phytoplankton communities are major producers of organic carbon in large rivers, a food source for plankton consumers and many of them represents the primary oxygen source in many low-gradient rivers [1]. Phytoplankton as the lowest members of the most aquatic food chain is usually very numerous in numbers and of diverse shapes and they constitute the starting point of energy transfer. It is however highly sensitive to allochthonous materials that imposed changes as a result of oil pollution and municipal waste disposal [2, 3]. Thus, the spatiotemporal distribution of the species, relative abundance and composition are an expression of the environmental health and quality of the existing water body [4]. Zooplanktons is also an important groups of aquatic organisms that occupy a wide range of habitats. Major constituents of zooplankton community in estuarine environment includes; Copepods, Chaetognaths, Amphipods, Euphausiids, Pteropods, Holoplankton, as well as larval stages of meroplankton. Zooplankton is one of the most important biotic components which influence the functionality of an aquatic ecosystem such as energy flow, food chain, food web and cycling of matter [5,6]. Copepods are known to be the major link between phytoplankton and first level carnivores while arrow worms are the common carnivores in Zooplankton [7]. Most zooplankton species are Cosmopolitan in distribution [8]. Zooplankton mostly grazes on phytoplankton and for this they are most abundant in shallow areas where primary productivity is high due to high availability of light [9]. Zooplankton distribution is also related to their ability to adapt to the prevailing factors in the environments [7]. Zooplanktons are useful indicator of future fisheries health because they are a food source of organisms at higher trophic levels [10]. The biomass, abundance and species diversity of zooplankton are used to determine the conditions of aquatic environment [11]. Zooplankton organisms are identified as important component of aquatic ecosystems [12, 13]. They help in regulating algal microbial productivity through grazing and in the transfer of primary productivity to fish and other consumers [14]. Zooplankton represents an invaluable source of protein amino acids, lipids, fatty acids, minerals and enzymes and are therefore an inexpensive ingredient to replace fishmeal for cultured fish [15,16]. There are obvious relationships between changes in plankton communities and water environmental factors. Hence, plankton may serve as a bio-indicator to monitor estuarine environment for both pollution or as a modelling for fish population dynamics [17,18]. Environmental disturbances induce changes to the structure and function of biological systems [19]. As a result, ecologists over the years have attempted to judge the degree and severity of pollution by analysing changes in biological systems [20,21]. Plankton generally form the base and the starting point of every aquatic food chain. They sustain the aquatic ecosystem and control primary productivity in the aquatic ecosystem. No Planktonic report is available in Idundu River and it's very important this study is carryout to provide baseline information of plankton organisms in the river through which subsequent studies can rely on. Planktonic community plays a vital role in the primary productivity of the aquatic ecosystem. The importance of the study of the distribution, composition and diversity of various planktonic groups cannot be over emphasized, as it reveals the well-being and the nature of the environment. These planktonic communities are hugely affected by several perturbations due to various human activities. As a result, this study will reveal the nature and pollution status of the study area. This study aimed at assessing Environmental factors on the distribution and diversity of planktonic community in Idundu River.

2. MATERIALS AND METHODS

2.1 Study Area

Idundu River is located at latitude $4^0 53' 57''$N and Longitude $8^0 34' 29''$E Southeast of Nigeria (Figure 1). The climate is characterized by a long wet season from April to October and a dry season from

November to March with a mean annual rainfall of about 2000mm [22]. Air temperature generally range from 22^0C in the wet season to 35^0C in the dry season, with a relative humidity generally above 60% at all seasons [22]. Vegetation is basically of Tropical rainforest close to mangrove belt. Mangrove species such as *Rhizophora cemosa, Avicennia africana* are present, but are very few. *Nypa fruticans* is prevalent in the study area. The main activities of the people living in the study area include fishing, farming and sand dredging.

2.2 Sampling Stations

Three sampling stations (1-3) were chosen along the shoreline of the River. The coordinates and appropriate distances of each station were taken and calculated using Geographic Positioning System (GPS).

Station 1 is at Idundu beach located at Longitude $08^o\ 20'45.9''$E and Latitude $05^o00'28.3''$N. This station is the control point and is dominated with Nypa palm and very few other Mangroves trees. Very minimal human activities were observed such as minimal fishing activities, washing and bathing. Station 2 is at Ifeta beach located at Longitude $008^o\ 23'49.5''$ E and Latitude $05^o05'\ 66.0''$ N. This station has very few Nypa palms along its shores with grasses and shrubs dominating. The human activities such as intensive dredging, washing and bathing were observed. Station 3 is at Ernest beach located at Longitude $008^o\ 29'46.8''$E and Latitude $05^o\ 10'06.1''$N. Vegetation in this station is mainly dominated by trees, grasses and shrubs with no Nypa palm along its shores. The human activities include intensive and industrial dredging, washing and bathing.

2.3 Samples Collection

Water temperature, pH, dissolve oxygen (DO), Nitrate and phosphate of the river were measured *in situ* from October 2016 to March 2017 and sampling was done on monthly basis. Temperature was measured using a mercury glass thermometer. pH was measured using Jenway pH meter. DO, Nitrate and Phosphate were determined by methods described by [23]. Both phytoplankton and zooplankton samples were collected by filtering 100litres of water fetched with rubber bucket through 55µm mesh standard plankton hydrobios net. Both phytoplankton and zooplankton were preserved in 4% buffered formalin solution and stored in 500ml plastic bottles before transporting them to Fisheries and Aquaculture Laboratory, University of Calabar for identification and analysis. Key guides provided by [23, 24, 20 and 25], were used for identification of the plankton specimens.

2.4 Statistical Analysis

Data obtained were subjected to descriptive statistic for mean, standard deviation and range values, Analysis of Variance (ANOVA) was used to test the significant difference between the physico-chemical parameters in each sampling stations. Effect with probability of P=.05 was considered significant. Principal Component Analysis was only used to summarize the major pattern of distribution in relation to sampling stations of planktonic community using predictive analytical software (PASW). PAST Software Design **(Version 3)** was used to determine the Diversity indices of the plankton community. Graph pad and Microsoft excel 2013 was used graphical illustrations.

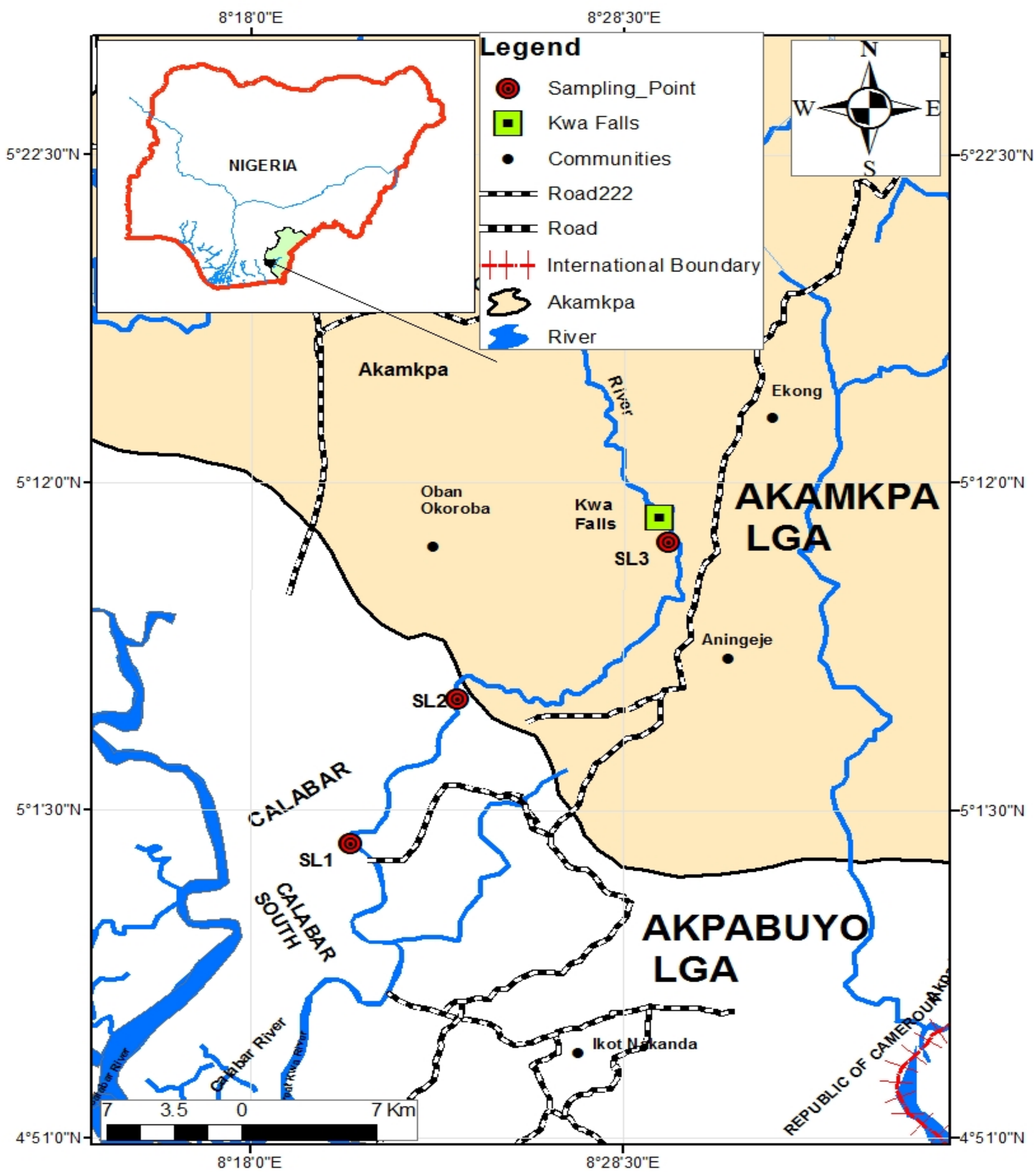

Fig.1. Map of Idundu River Showing the Sampling Stations.

3. RESULTS

3.1 Water Parameters

The Mean and Ranges of Water sample measured in each parameter is represented in Table 1 while Figure 2 shows monthly variations of them. The pH value of Idundu River ranged from 6.12 to 6.74, with a mean value and a standard deviation of 6.526±0.104, with Ernest Beach (station 3) showing the highest pH value of 6.740, while the least pH value was observed in Idundu Beach (station 1), with a pH value of 6.123. Through-out the study period in terms of spatial variation of pH, the lowest pH value was observed in station 1(Idundu Beach) during October (6.10), while the highest pH value was observed in station 2 (Ifeta Beach) during December (6.88) (Fig 2). The spatial distribution of pH across the stations varied significantly across the sampling stations at P=.05 (Tab 1). The pH values through-out the study period were within the NESREA acceptable range (Tab 1). The temperature value of Idundu River ranged from 26.0^{0}C to 26.5^{0}C, with a mean and a standard deviation of 26.24±0.106^{0}C, with Ernest Beach (station 3) with a highest temperature value of 26.47^{0}C, while the least temperature value was observed in Idundu Beach (station 1), with a temperature value of 26.0^{0}C. Throughout the study, in terms of spatial variation of temperature, the lowest temperature value was observed in station 1 (Idundu Beach) during December (25.6^{0}C), while the highest temperature value was observed in station 3 (Ernest Beach) during November (26.8^{0}C) (Fig 2). The spatial distribution of temperature across the stations did not vary significantly across the sampling stations at P>0.05 (Tab 1). The temperature values through-out the study was within the NESREA acceptable range. The Dissolved Oxygen value of Idundu River ranged from 1.36 mg/l to 1.62 mg/l, with a mean and a standard deviation of 1.474±0.135 mg/l, with Ernest Beach (station 3) with a highest Dissolved Oxygen value of 1.626 mg/l, while the least Dissolved Oxygen value was observed in Idundu Beach (station 1), with a Dissolved Oxygen value of 1.366 mg/l. Through-out the study period in terms of spatial variation of Dissolved Oxygen, the lowest Dissolved Oxygen value was observed in station 1(Idundu Beach) during November (1.32 mg/l), while the highest Dissolved Oxygen value was observed in station 3 (Ernest Beach) during November (1.70 mg/l) (Fig 2). The spatial distribution of Dissolved Oxygen across the stations varied significantly across the sampling stations at P=.05 (Tab 1). The Dissolved Oxygen values throughout the study were within the NESREA acceptable range. The Nitrate value of Idundu River ranged from 0.024 mg/l to 0.031 mg/l, with a mean and a standard deviation of 0.026±0.001 mg/l, with Idundu Beach (station 1), with the highest Nitrate value of 0.031 mg/l, while the least Nitrate value was observed in Ifeta Beach (station 2) and Ernest Beach (station 3) with a Nitrate value of 0.024 mg/l. Throughout the study, in terms of spatial variation of Nitrate, the lowest Nitrate value was observed in station 3 (Ernest Beach) during October (0.023 mg/l), while the highest Nitrate value was observed in station 1 (Idundu Beach) during March (0.032 mg/l) (Fig 2). The spatial distribution of Nitrate across the stations varied significantly across the sampling stations at P=.05 (Tab 1). The Nitrate values throughout the study were within the NESREA acceptable range. The phosphate value of Idundu River ranged from 0.014 mg/l to 0.017 mg/l, with a mean and a standard deviation of 0.015±0.000 mg/l, with Ernest Beach (station 3), having the highest Phosphate value of 0.017 mg/l, while the least phosphate value was observed in Idundu Beach (station 1) and Ifeta Beach (station 2) with a Phosphate value of 0.014 mg/l.

Throughout the study, in terms of spatial variation of phosphate, the lowest phosphate value was observed in station 2 (Ifeta Beach) during October (0.012 mg/l), while the highest Phosphate value was observed in station 3 (Ernest Beach) during February and March (0.018 mg/l) (Fig 2). The spatial distribution of phosphate across the stations did not vary significantly across the sampling stations at $P>0.05$(Tab 1). The Phosphate values throughout the study were within the NESREA acceptable range.

Table 1. Mean, Range and F-value of Physico-chemical Parameters Measured in Idundu River.

Parameters	Station 1	Station 2	Station 3	Mean ± S.D	F- Value	P-Value	P-test	NESREA Permissible Limit
pH	6.123	6.72	6.74	6.526 ± 0.104 (6.12-6.74)	46.85	0.0018	P<0.05	6.0-9.0
Surface Water Temperature (^{o}C	26.00	26.27	26.47	26.244 ± 0.106 (26.00-26.46)	2.00	0.2140	P>0.05	20 – 40 ^{o}C
Dissolved Oxygen (mg/l)	1.37	1.43	1.63	1.474 ± 0.135 (1.36-1,62)	9.00	0.0441	P<0.05	50
Nitrate (mg/l)	0.031	0.024	0.024	0.026 ± 0.001 (0.024-0.031)	57.57	0.0268	P<0.05	10
Phosphate (mg/l)	0.014	0.014	0.017	0.015 ± 0.000 (0.014-0.017)	3.38	0.0568	P>0.05	50

S1: Idundu Beach, S2: Ifeta Beach, S3: Ernest Beach, S D: Standard Deviations, F: Calculated values, NESREA: National Environmental Standards and Regulations Enforcement Agency.

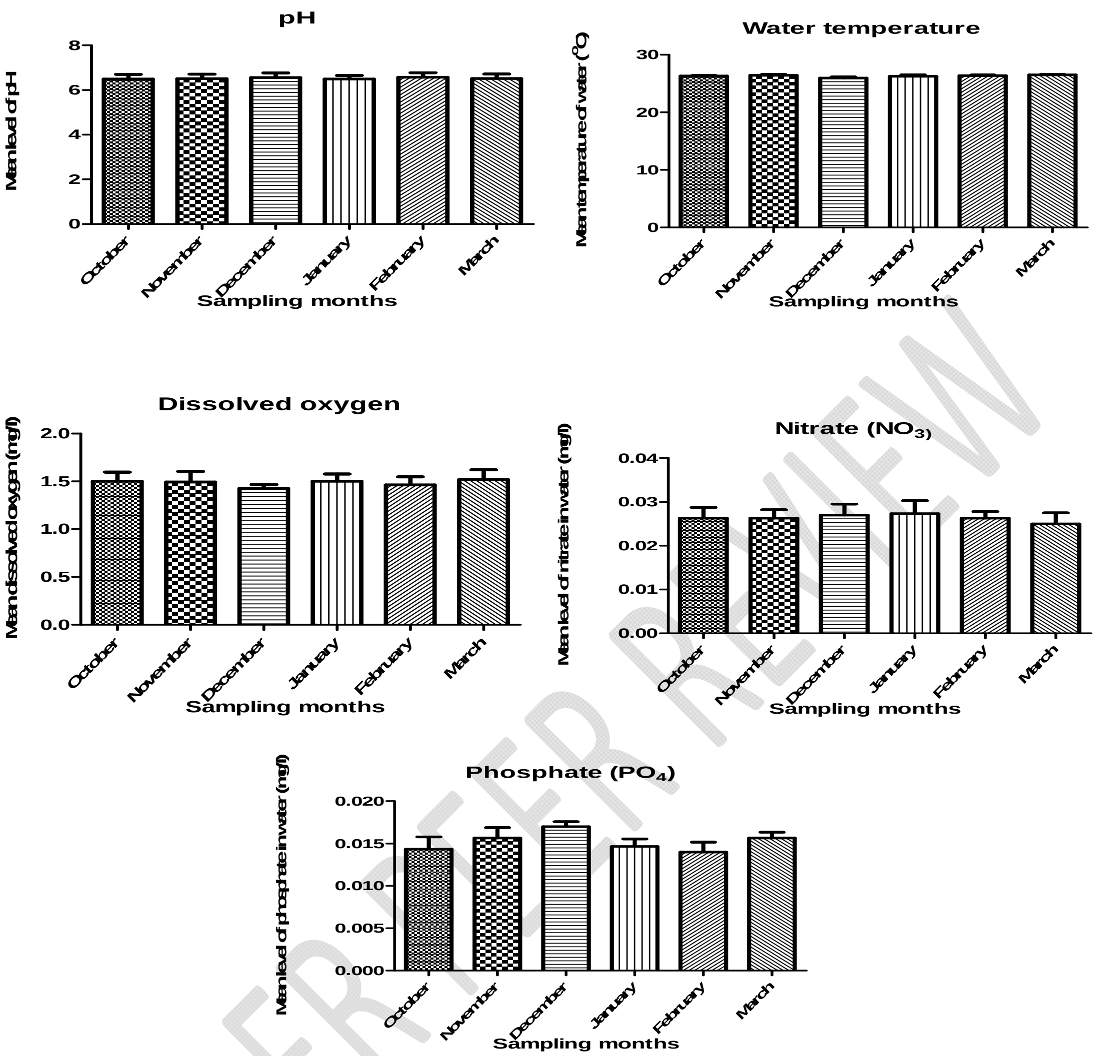

Fig.2. Monthly variations of water parameters in Idundu River.

3.2 Plankton species composition and abundance

The composition, abundance and distribution of Phytoplankton across the 3 sampling stations of Idundu River is shown in Figure 3 and 4. A total of 23 phytoplankton Species belonging to 5 families were observed. The phytoplankton families represented were: Bacillariophyceae, Chlorophyceae, Zygnemophyceae, Cryptophyceae and Dinophyceae. Bacillariophyceae was the most abundant phytoplankton family, with a relative abundance of 63.81%, followed by Chlorophyceae which had 17.41% abundance. Dinophyceae and Cryptophyceae had 7.87% and 9.77% abundance respectively. The least abundant phytoplankton family was Zygnemophyceae, which had just 1.08%. The distribution of phytoplankton varied across sampling stations, with Ernest Beach (station 3) having the highest abundance of 128 individuals, while Idundu Beach (station 1) had the least phytoplankton abundance of 115 individuals. A total of 20 Zooplankton Species belonging to 5

Phylum. The Zooplankton Phylum represented was: Rotifera, Arthropoda, Ciliophora, Annelida and Nemata, Rotifera was the most abundant, with a relative abundance of 35.69%, followed by Arthropoda which had 30.62%. Ciliophora and Annelida had 17.79% and 12.15% abundance respectively. The least abundant was Nemata, which had just 2.85% abundance. The distribution of Zooplankton varied across sampling stations, with Idundu Beach (station 1) having the highest abundance of 55 individuals, while Ernest Beach (station 3) had the least of 32 individuals.

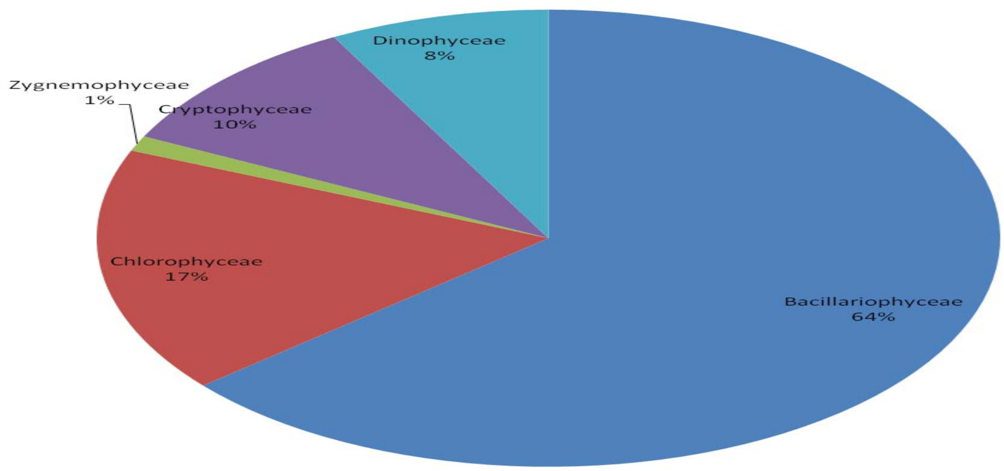

Fig.3. Relative proportion of phytoplankton families of Idundu River.

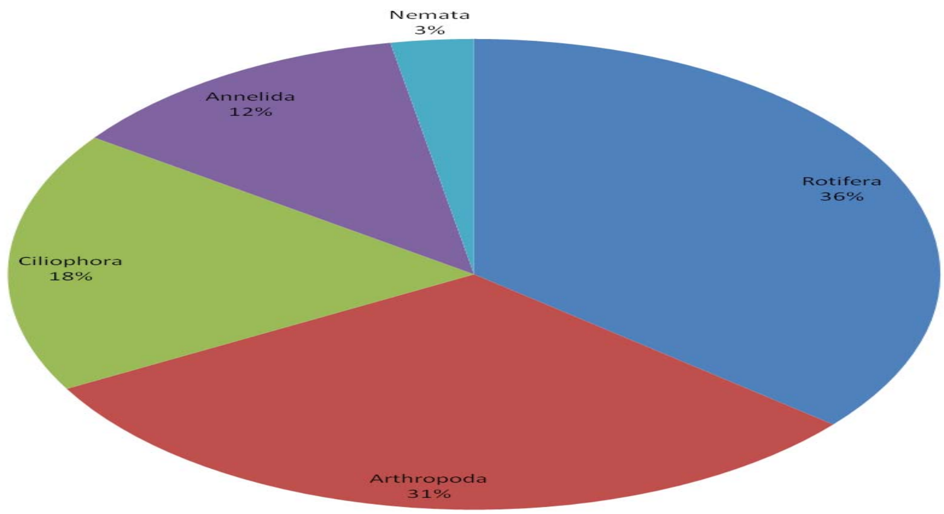

Fig.4. Relative proportion of Zooplankton Phyla of Idundu River.

3.3 Planktonic Diversity

The diversity index of plankton community in Idundu River is shown in Table 2 and 3. For phytoplankton, the ecological diversity index varied across the sampling stations. The Shannon Wiener diversity index for Idundu, Ifeta and Ernest Beach were: 2.864, 2.772 and 2.675 respectively. The Margalef index for Idundu, Ifeta and Ernest Beach were: 4.215, 4.142 and 3.916 respectively. The equitability index values for Idundu, Ifeta and Ernest Beach were: 0.9406, 0.9104 and 0.8929 respectively. However, the Shannon Weiner and Equitability index did not vary significantly across the sampling stations, but the Margalef index varied significantly across the stations. For Zooplankton, the ecological diversity index varied across the sampling stations. The Shannon Wiener diversity index for Idundu, Ifeta and Ernest Beach were: 2.524, 2.690 and 2.488 respectively. The Margalef index for Idundu, Ifeta and Ernest Beach were: 3.494, 4.069 and 4.004 respectively. The equitability index values were generally very high and its values for Idundu, Ifeta and Ernest Beach were: 0.932, 0.9495 and 0.9187 respectively. However, the Shannon Weiner and Equitability index did not vary significantly across the sampling stations, but the Margalef index varied significantly across the stations.

Table 2. Ecological Diversity Index of Phytoplankton from Idundu River.

Ecological Indices	*S1*	*S2*	*S3*	*F- Value*	*P-test*	*Inference*
Shannon Wiener Index	2.864	2.772	2.675	1.764	P>0.05	Diff nt Sig
Equitability Index	0.940	0.910	0.892	3.532	P>0.05	Diff nt Sig
Margalef Index	4.215	4.142	3.916	12.81	P<0.05	Diff Sig

S1: Idundu Beach; S2: Ifeta Beach; S3: Ernest Beach

Table 3. Ecological Diversity Index of Zooplankton from Idundu River.

Ecological Indices	*S1*	*S2*	*S3*	*F- Value*	*P-test*	*Inference*
Shannon Wiener Index	2.524	2.690	2.488	0.954	P>0.05	Diff nt Sig
Equitability Index	0.932	0.949	0.918	3.412	P>0.05	Diff nt Sig
Margalef Index	3.494	4.069	4.004	9.398	P<0.05	Diff Sig

S1: Idundu Beach; S2: Ifeta Beach; S3: Ernest Beach

3.4 Principal Component Analysis (PCA)

The Principal Component Analysis (PCA) is shown in Figures 5 and 6. Phytoplankton taxa such as Zygnemophyceae, Dinophyceae and Chlorophyceae recorded high positive loading of 0.97, 0.97 and 0.91 respectively for the first component while in the second component high positive loading of 0.89 was recorded for Cryptophyceae. For Zooplankton, Arthropoda, Annelida and Nemata recorded positive loading of 0.26, 0.26 and 0.26 respectively for the first component, while in the second component high positive loading of 0.84 was recorded for Ciliophora. However, principal component analysis for planktonic community was able to show the most major distributed family among the planktonic groups suggesting that phytoplankton were more homogenously distributed than zooplankton during the study period.

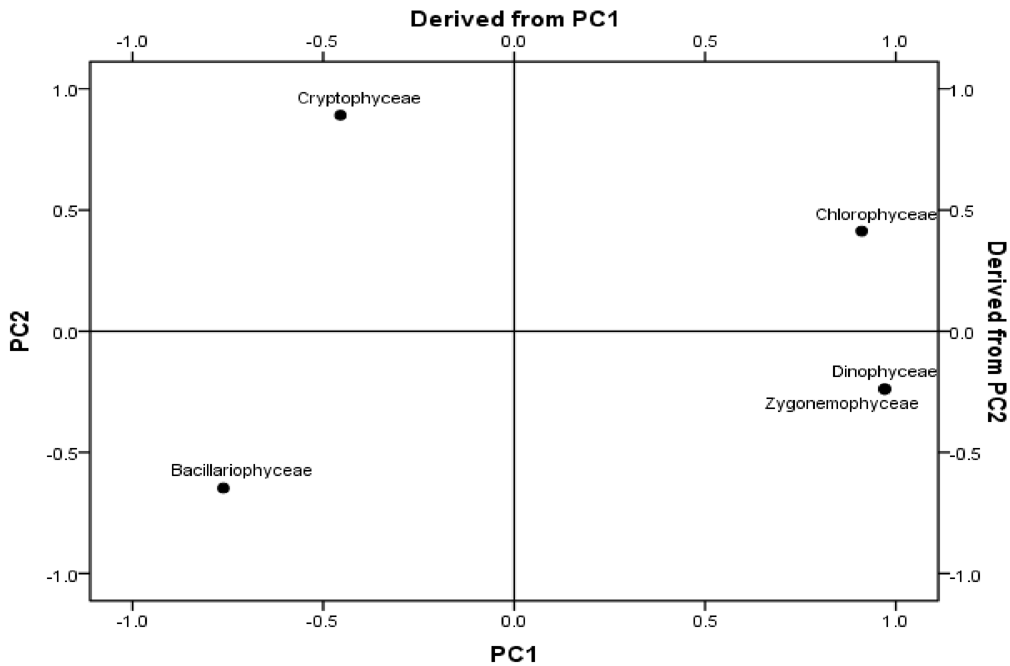

Fig.5. Principal Component Analysis (PCA) Plot of Phytoplankton.

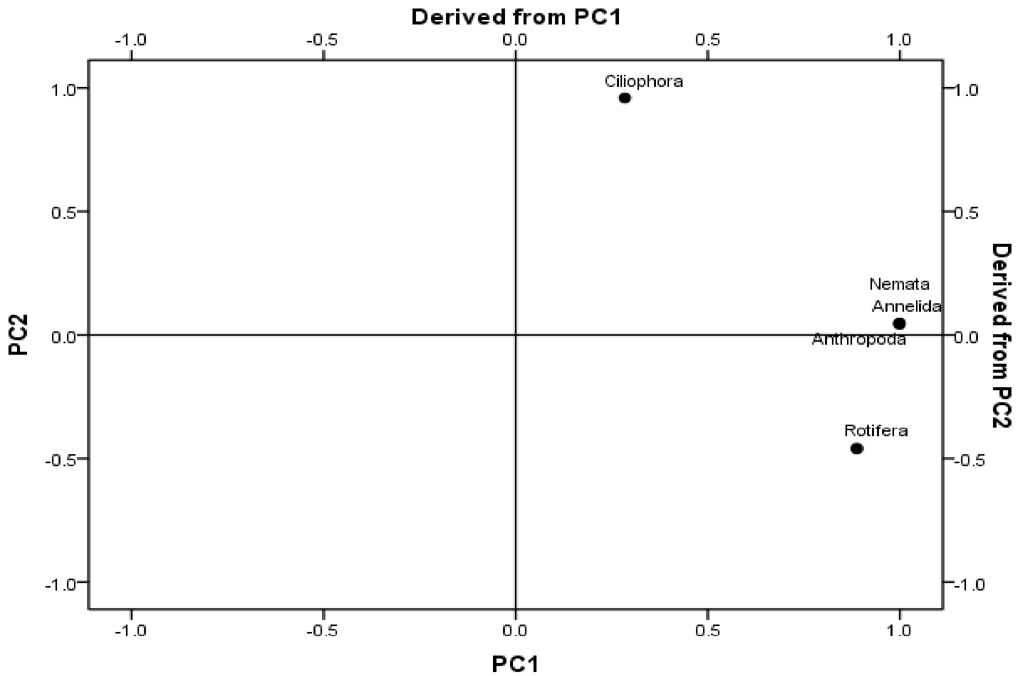

Fig.6. Principal Component Analysis (PCA) Plot of Zooplankton.

3.5 Correlation between Plankton abundance and Water Parameters

The correlation between Phytoplankton, Zooplankton and Water Parameters is presented in Table 4 and 5. Bacillariophyceae significantly correlate positively with pH (r = 0.99;), temperature (r = 0.94) and DO (r = 0.76), and Nitrate (r = -0.99) at P=.05. Chlorophyceae also shows a good relationship and correlate signicantly with Nitrate (r = 0.92), pH (r = -0.94), temperature (r = -0.99), DO (r = -0.90) and Phosphate (r = -0.78) at P=.05. Zygnemophyceae significantly correlate negatively with phosphate (r = - 0.75). Dinophyceae had strong negative relationship with temperature (r = -0.82) and DO (r = -0.97). Rotifera correlate significantly with Nitrate (r = 0.90), pH (r = -0.92), temperature (r = -0.99), DO (r = -0.92) and phosphate (r = -0.81) at P= .05 while Arthropoda, Annelida and Nemata significantly correlate negatively with temperature (r = -0.82) and DO (r = -0.97).

Table 4. Correlation between water parameters and Phytoplankton from Idundu River.

Parameters against Phytoplankton Family	pH	Temperature	DO	Nitrate	Phosphate
Bacillariophyceae	**0.99***	**0.94***	**0.76***	**-0.99***	0.59
Chlorophyceae	**-0.94***	**-0.99***	**-0.90**	**0.92***	-0.78
Zygnemophyceae	0.15	-0.24	-0.57	-0.18	**-0.75***

Cryptophyceae	-0.29	0.10	0.45	0.32	0.65
Dinophyceae	-0.52	-0.82	-0.97*	0.50	-1.00

**Correlation is significant at P=.05*

Table 5. Correlation between water parameters and Zooplankton from Idundu River.

Parameters against Zooplankton Family	pH	Temperature	DO	Nitrate	Phosphate
Rotifera	**-0.92***	**-0.99***	**-0.92***	**0.90***	-0.81
Arthropoda	-0.52	**-0.82***	**-0.97***	0.50	-1.00
Ciliophora	0.62	0.26	-0.09	-0.65	-0.32
Annelida	-0.52	-0.82	-0.97	0.50	-1.00
Nemata	-0.52	-0.82	-0.97	0.50	-1.00

**Correlation is significant at P=.05s*

4. DISCUSSION

A total of 23 phytoplankton species, from 5 families, totalling 368 cells/L individuals with Bacillariophyceae being the most abundant family in this study which is lower than reported by [26] that recorded 41 phytoplankton species and Cyanophyceae as the most dominant phytoplankton family, as well as the 42 phytoplankton species and Chlorophyceae dominance reported by [27]. However, the number of species observed in this study is higher than that reported by [28] who reported 19 phytoplankton species. Also, the 368 phytoplankton individuals reported in this study is by far lower than the 1288 cells/L of phytoplankton individuals reported by [27]. These discrepancies in the numerical abundance, most abundant and number of phytoplankton species observed between the present study and the other aforementioned reports could be due to the difference in study area, study duration, study period, water quality and level of human activities in the different studies [29]. These variation could be due to difference in the intensity of environmental disturbances such temperature, turbidity, dissolved oxygen etc which could induce changes to the structure and function of biological systems during the different studies [19,30] and due to the relationships between changes in plankton communities and water environmental factors which differs for each study area [17,31]. The differences in the most abundant of phytoplankton family between the present study and that reported by [27] who reported Chlorophyceae as the most abundant phytoplankton family as opposed to the Bacillariophyceae observed in this study, could be due to low level of nutrients introduced into Idundu River such that eutrophication did not occur [32,33]. [28] reported the occurrence of Chlorophyceae, Bacillariophyceae and Dinophyceae Families during their study, and these families were also fully represented in this study as well. Plankton is highly sensitive to allochthonous materials that imposed changes in the environment as a result of oil pollution and municipal waste disposal [2,3and16]. Spatio-temporal distribution of the plankton, relative abundance and composition are an expression of the environmental health and quality of the existing water body [4]. The distribution of phytoplankton varied across sampling stations, and these variations could be due to difference in the levels of human activities in the different sampling stations. A total of 20 Zooplankton species, from 5 phyla, totalling 140 cells/L individuals as recorded during this study, with Rotifera being the most abundant phylum. Abundance determined in this study was lower than that reported by [34] who reported 28 zooplankton species and Calanoida as the most dominant Zooplankton Order. However, the number of species observed in this study is higher than that reported by [26, 28], who both reported 16 ad 17species of zooplankton, respectively. These discrepancies in the most abundant and number of Zooplankton species observed between the present study and the other aforementioned reports could be due to the difference in study area, study duration, study period, water quality and level of human activities in the different studies. It could as well be due to the fact that the nature of species occurring, diversity, biomass and season of maximum abundance of zooplanktonic organisms differ in water bodies [35, 18]. These variations could also be due to difference in the intensity of environmental disturbances such water current, turbidity, temperature and dissolved oxygen which could induce changes in the structure and function of biological systems during the different studies [19], and due to the relationships between changes in plankton communities and water environmental factors which differs for each study area [17]. [28], reported that the occurrence of Rotifera and as the most abundant Zooplankton Phylum during their study corroborated with the observation of this study which also had Rotifera represented as the most abundant Phylum. The distribution of Zooplankton varied across sampling stations, and these variations could be due to difference in the levels of human activities measured at different sampling stations using different environmental variables. The low abundance of Zooplankton in this study could be due to the fact that most zooplankton migrates upward from deeper strata as darkness approaches and return to the deeper areas at dawn [36-38]. The Shannon Wiener, Margalef and Equitability diversity index of Plankton across all the 3 sampling stations indicated a good and healthy Plankton ecosystem. Also, the high evenness values of the 3 stations indicate differences in the level of inputs of various anthropogenic wastes, leading to an uneven distribution of planktonic species. Throughout the study and across the different sampling stations, the pH values were generally alkaline, and this is corroborated with the report of [39]. Also, statistically the analysis of variance of pH values varied significantly across the 3 sampling stations at P=.05. This indicates that the different level of activities in the different sampling stations influenced the parameters significantly. The mean pH value recorded in this study is lower than that reported by [40, 39]. This variation in pH value between the different studies could be due to difference in level of activities in the study areas, study duration and study period. The pH values were generally within the NESREA acceptable range, and as such deemed unpolluted. Temperature is another parameter that has huge influence the distribution of several flora and fauna. One of the most important environmental parameters that have direct or indirect significant effects on biota is surface water temperature [41]. The temperature values across the different sampling station varied, although the variation was not significant at $P>0.05$. The mean temperature recorded for this study was also lower than that reported by [40, 39]. This variation in temperature value between the different studies could be due to difference in level of activities in the study areas, study duration and study season. The temperature values were generally within the NESREA acceptable range, and as such the River could be deemed unpolluted. Dissolved oxygen (DO) is probably the most important abiotic parameters because aquatic organism cannot survive without dissolved oxygen. The dissolved oxygen values varied significantly across the different sampling stations at $P=.05$. This indicates that the level of activities in the different sampling stations has influenced the DO value significantly. This is because some activities may have increased the nitrate and phosphate thereby reducing the DO values in some sampling stations. The mean DO values during the study were generally low, and were lower than the values reported by [40, 39]. This discrepancy could be due to the different levels of the introduction of organic matter into the different study areas. It could also be due to the difference in study duration and season of study. The DO values were generally within the NESREA acceptable range, and as such the River could be deemed unpolluted. Nutrients like nitrate and phosphate are very important for plankton, because the use nutrients to photosynthesize as well as growth and reproduction. When the nutrient level is too high, it leads to eutrophication, thereby leading to reduction of DO and subsequent pollution of the River [42] The nitrate and phosphate value varied across sampling stations, although only nitrate varied significantly at P=.05. This indicates that the different levels of introduction of organic substances like effluent, sewage, waste water into the different stations influenced the levels of nutrient in the 3 stations. The Nitrate and phosphate values reported in this study were lower than that reported by [17]. On the other hand, the nitrate value of this study was higher and phosphate values of the present study were lower than that reported by [30, 43]. This variation could be due to the variations in organic matter introduction in the different study areas. The nitrate and phosphate values of this study were within the acceptable range of NESREA, which indicates a healthy environment for Planktonic productivity. Various physico-chemical parameters affect the distribution and abundance of plankton. Bacillariophyceae had a strong positive relationship with pH, temperature and DO. This indicates that an increase in the pH, temperature and DO will lead to a corresponding increase in the abundance of Bacillariophyceae. On the contrary, Bacillariophyceae had a strong negative relationship with Nitrate. This indicates that increase in the nitrate will lead to the decrease in Bacillariophyceae abundance. Chlorophyceae had a strong positive relationship with Nitrate, indicating that an increase in nitrate concentration will lead to an increase the abundance of Chlorophyceae. On the other way round, Chlorophyceae had a strong negative relationship with pH, temperature, DO and Phosphate. This means that increase in pH, temperature, DO and Phosphate will lead to a decrease in the abundance of Chlorophyceae. Zygnemophyceae had a strong negative relationship with phosphate, which means that as the phosphate increases, the Zygnemophyceae decreases in abundance. Dinophyceae had strong negative relationship with temperature and DO, which illustrates that as the temperature and DO increases, the Dinophyceae decreases in abundance. Phylum Rotifera had a strong positive relationship with Nitrate, and this indicates that increase in Nitrate will lead to a corresponding increase in Rotifera. On the other hand, Rotifera had a strong negative relationship with pH, temperature, DO and phosphate. Indicating that an increase in pH, temperature, DO and phosphate will lead to a decrease in Rotifera abundance. Arthropoda, Annelida and Nemata had a strong negative relationship with temperature and DO. This indicates that as the temperature and DO increase, the Arthropoda, Annelida and Nemata abundance decreases.Some rivers receive water from drainages or channels with respect to their sizes, therefore vulnerable to changes in the quality of water [13]. Principal component analysis (PCA) of the planktonic community study in Idundu River shows differences in the most important families between phytoplankton and zooplankton. Zygnemophyceae, Dinophyceae, Chlorophyceae and Cryptophyceae recorded high positive loading in the first and second component, this is because the ecological success of this species which could be as a result of large scale tolerance to different environmental, ecological and climatic conditions such as temperature and relative humidity [21, 44]. Arthropoda, Annelida, Nemata and Ciliophora recorded high positive loading for Zooplankton, this result could be attributed to the influence of internal load of suspended material on the quantity and quality of food. Similar observations were also made by [45] in the Broa tropical Reservoir, Brazil.

5. CONCLUSION

The distribution of Plankton varied across different sampling stations and between different study areas and Bacillariophyceae was the most dominant phytoplankton family, while the most dominant Zooplankton Phylum was Rotifera. The distribution of Planktons was highly influenced by the different levels of human activities such as intensive industrial dredging, fishing and bathing in different sampling stations. The plankton abundance was strongly influenced by the physico-chemical parameters like; pH, DO, temperature, nitrate and phosphate, which either showed a strong positive or strong negative relationship between the plankton and the physical-chemical parameters. The ecological diversity indices like; Shannon Wiener, Margalef and equitability index were assessed, and generally described a conducive and healthy aquatic environment, although the equitability values were high thus confirming that the distribution of Plankton was evenly distributed. The physical-chemical parameters varied across the sampling stations, with pH, DO and nitrate varying significantly across the stations across the sampling stations. The temperature and phosphate did not vary significantly across stations. The water parameter values were all within the NESREA acceptable range, indicating a healthy environment for maximum plankton growth and production. The study also revealed the variation in the distribution of Planktons and water parameters across stations. It also further confirmed that water parameters affect the abundance and distribution of Plankton. The River is not polluted, since the parameters were all within the NESREA standard. However, in this present study, principal component analysis reveal that association was more evident in phytoplankton than zooplankton, this could attribute to the fact that water column and water temperature of the River was stable which provide conducive environment for competitive equality among the opportunistic species leading to the increase of the dominance species. It is already known that Planktons are affected by water quality of their environment, in order to maintain a healthy aquatic ecosystem, it is important that the Government ensures healthy physical-chemical parameters, by controlling and enforcing against careless discharges in the River.

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