Original Research Article

Ecological Approach of Plankton Responses to Water Quality Variables of 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 ± SE) 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 limit. A total of 23 phytoplankton species belonging to five families, totalling a numerical abundance of 368 phytoplankton were observed. *Bacillariophyceae* was the most abundant phytoplankton family (63.81%), *Chlorophyceae* (17.41%). *Dinophyceae* (7.87%), *Cryptophyceae* (9.77%), the least abundant was *Zygnemophyceae* accounting for (1.08%). A total of 20 zooplankton species belonging to five phyla, totalling a numerical abundance of 140 Zooplankton individuals 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 distributed than zooplankton during the study period. Shannon Weiner and Margalef's diversity index shows that the River is in a healthy condition and the equitability level was low across all the stations, indicating uneven 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 allochthonously 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 are also an ecologically important groups of aquatic organisms that occupy a wide range of habitats. Major constituents of zooplankton community include Copepods, Chaetognaths, Amphipods, Euphausiids, Pteropods, Holoplankton, as well as larval stages of meroplankton. Zooplankton are 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 species of zooplankton 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]. Zooplanktons make up 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]. Planktons generally form the base and the starting point of every aquatic food chain. They sustain the aquatic eco-system and control primary productivity in the aquatic eco-system. This is the reason they are generally called Pastures of the Sea. No Planktonic report is available for Idundu River, and as a result, was of great significance to carry out this Planktonic study, as it will serve as the Planktonic Community baseline of 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 lies 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 mean annual rainfall of about 2000mm [22]. Air temperatures generally range from 22^{0}C in the wet season to 35^{0}C in the dry season, with 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, Avecinia 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 co-ordinates 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° 20′45.9″E and Latitude 05°00′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° 23′49.5″ E and Latitude 05°05′ 66.0″ N. This station has very few Nypa palm 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° 29′46.8″E and Latitude 05° 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 includes 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 2019. 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]. Plankton samples were collected using plankton net with mesh size of 55mm. The water samples were stored in plastic bottles and fixed with 4% formalin in the field immediately before it was taken to the Oceanography laboratory, University of Calabar for identification and analysis. Key guides provided by [23,24,20 and 25], were used for identification of the plankton specimen. Microsoft excel (2007) was used for Data analysis, while version 3 of PAST Software Design was used to determine the Diversity index of the plankton community and Principal Components Analysis (PCA) to determine the pattern of distribution of plankton groups related to physical and chemical parameters.

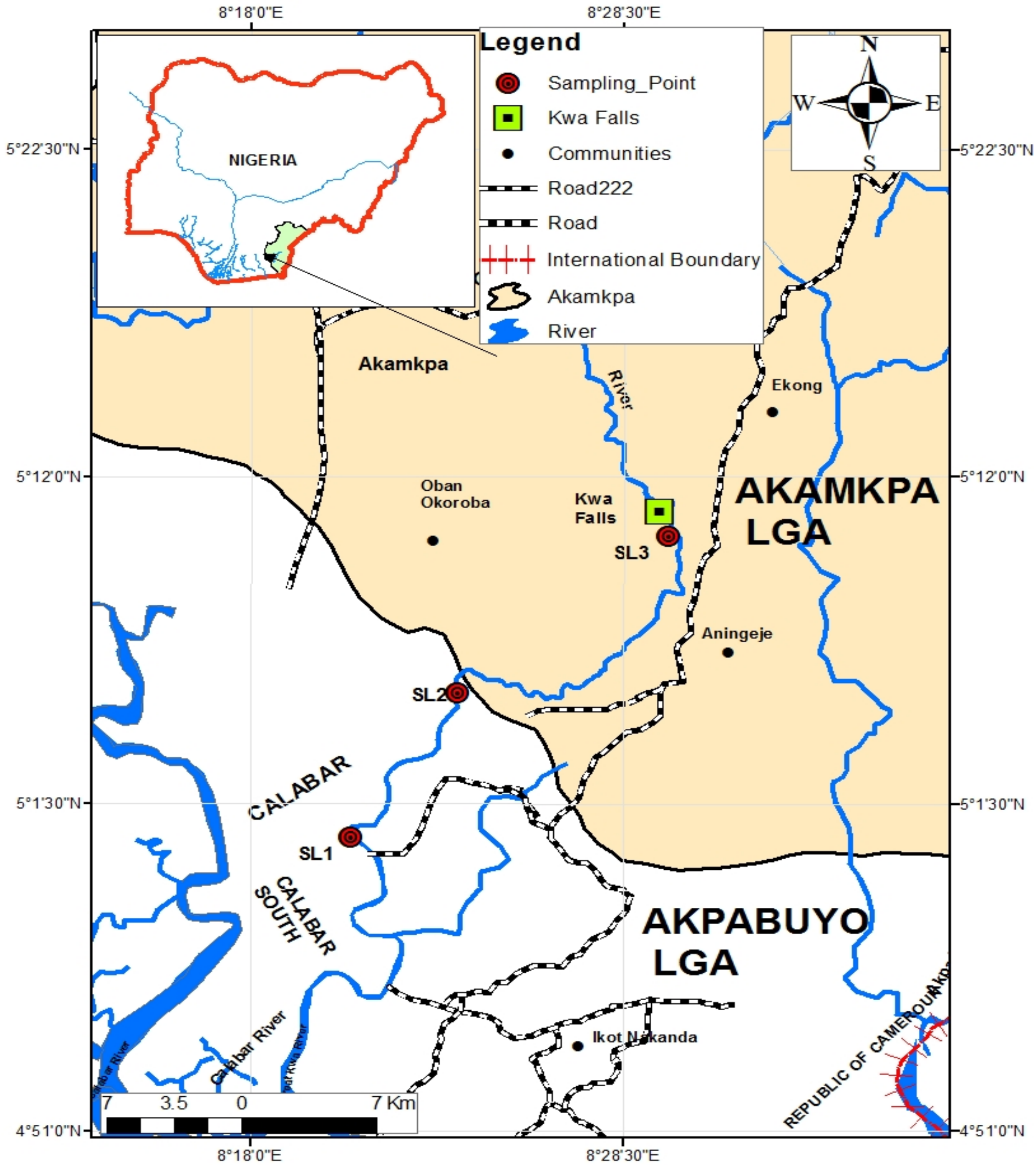

Fig.1. Map of Idundu River Showing the Sampling Stations.

3. RESULTS

3.1 Water Parameters

The results showing the Mean and Ranges of Water parameters measured is represented in Table 1 and monthly variations of water parameters is presented in Figure 2. The pH value of Idundu River ranged from 6.12 to 6.74, with a mean and standard deviation of 6.526±0.104, with Ernest Beach (station 3) having the highest pH value of 6.740, while the least pH value was observed in Idundu Beach (station 1), having a pH value of 6.123. Through-out the study, 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. The pH values through-out the study was within the NESREA acceptable limit. The temperature value of Idundu River ranged from 26.0^0C to 26.5^0C, with a mean and standard deviation of $26.24±0.106^0$C, with Ernest Beach (station 3) having the highest temperature value of 26.47^0C, while the least temperature value was observed in Idundu Beach (station 1), having a temperature value of 26.0^0C. Throughout the study, in terms of spatial variation of temperature, the lowest temperature value was observed in station 1 (Idundu Beach) during December (25.6^0C), while the highest temperature value was observed in station 3 (Ernest Beach) during November (26.8^0C) (Fig 2). The spatial distribution of temperature across the stations did not vary significantly across the sampling stations at $P>0.05$. The temperature values through-out the study was within the NESREA acceptable limit. The Dissolved Oxygen value of Idundu River ranged from 1.36 mg/l to 1.62 mg/l, with a mean and standard deviation of 1.474±0.135 mg/l, with Ernest Beach (station 3) having the highest Dissolved Oxygen value of 1.626 mg/l, while the least Dissolved Oxygen value was observed in Idundu Beach (station 1), having a Dissolved Oxygen value of 1.366 mg/l. Through-out the study, 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. The Dissolved Oxygen values throughout the study were within the NESREA acceptable limit. The Nitrate value of Idundu River ranged from 0.024 mg/l to 0.031 mg/l, with a mean and standard deviation of 0.026±0.001 mg/l, with Idundu Beach (station 1), having 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) having the 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. The Nitrate values throughout the study were within the NESREA acceptable limit. The phosphate value of Idundu River ranged from 0.014 mg/l to 0.017 mg/l, with a mean and 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) having the 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 $P>0.05$. The Phosphate values throughout the study were within the NESREA acceptable limit.

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

Parameters	Station 1	Station 2	Station 3	Mean ± S.E	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.E: Standard Error, F: Calculated values, NESREA: National Environmental Standards and Regulations Enforcement Agency.

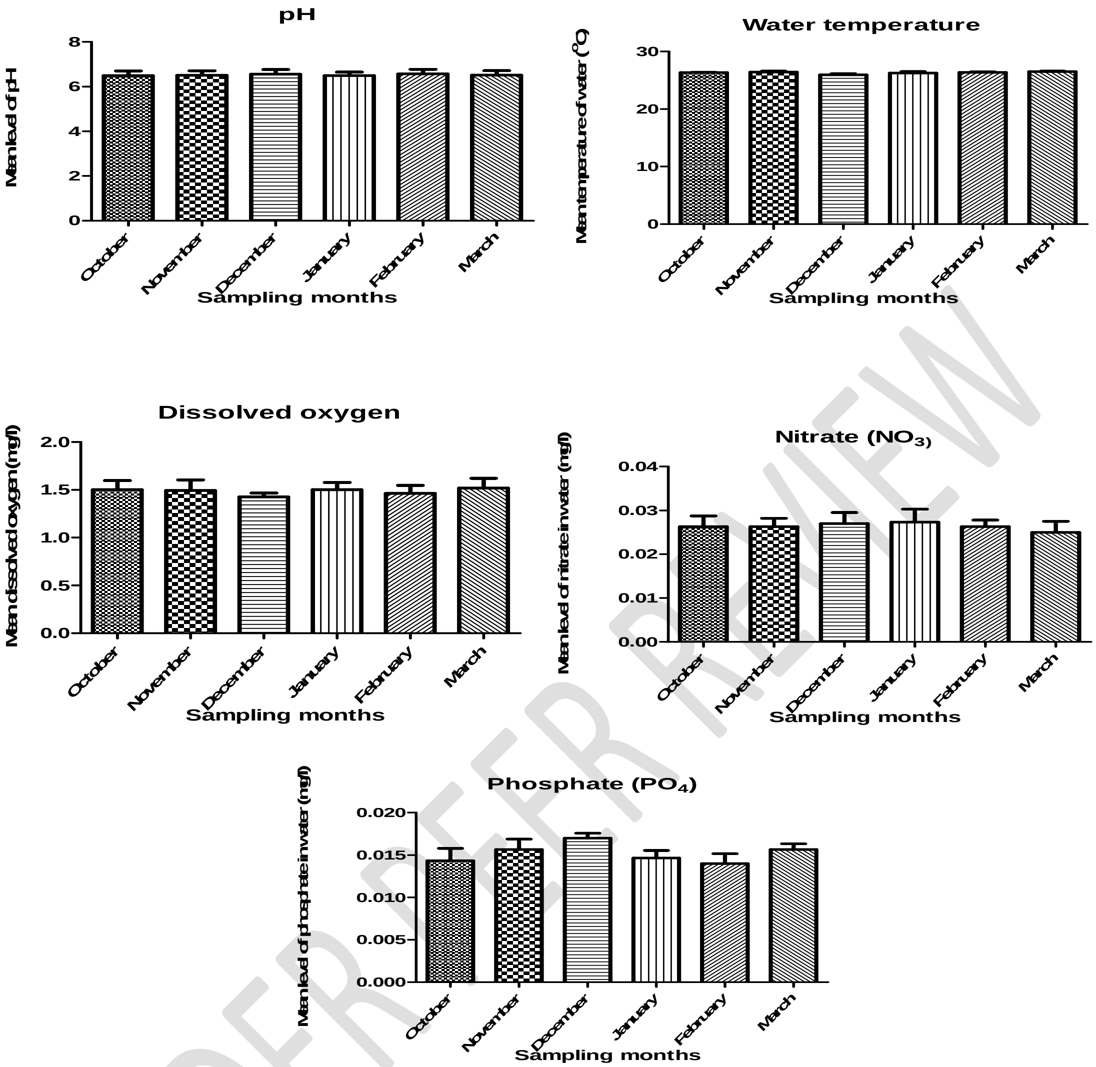

Fig.2. Monthly variations of water parameters in Idundu River.

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% abundance. The abundance and 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.

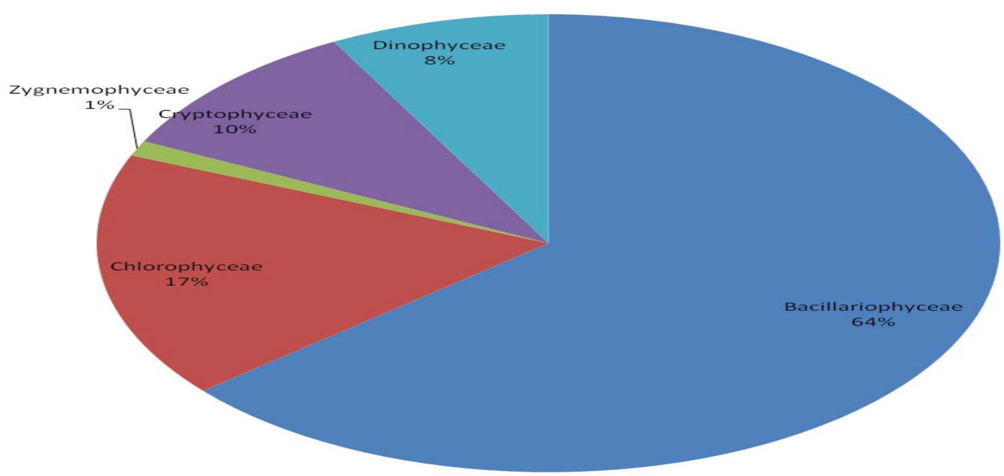

Fig.3. Percentage composition of phytoplankton families of Idundu river.

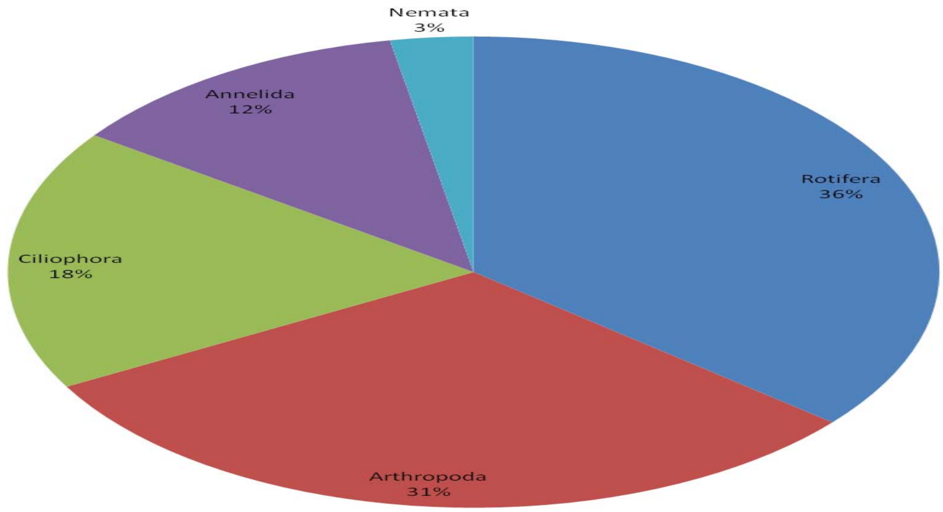

Fig.4. Percentage composition of Zooplankton Phyla of Idundu River.

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 Weiner 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 Weiner 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 low, 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 Weiner 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 Weiner 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 Figure 5 and 6. Phytoplankton taxa such as *Zygnemophyceae*, *Dinophyceae* and *Chlorophyceae* recorded high positive loading of 0.97, 0.97 and 0.91in the first component while in 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 in the first component, while in the second component high positive loading of 0.84 was recorded for *Ciliophora*. However, factor analysis for planktonic community was able to show the most distributed taxa among the planktonic community suggesting that phytoplankton were most distributed than zooplankton during the study period.

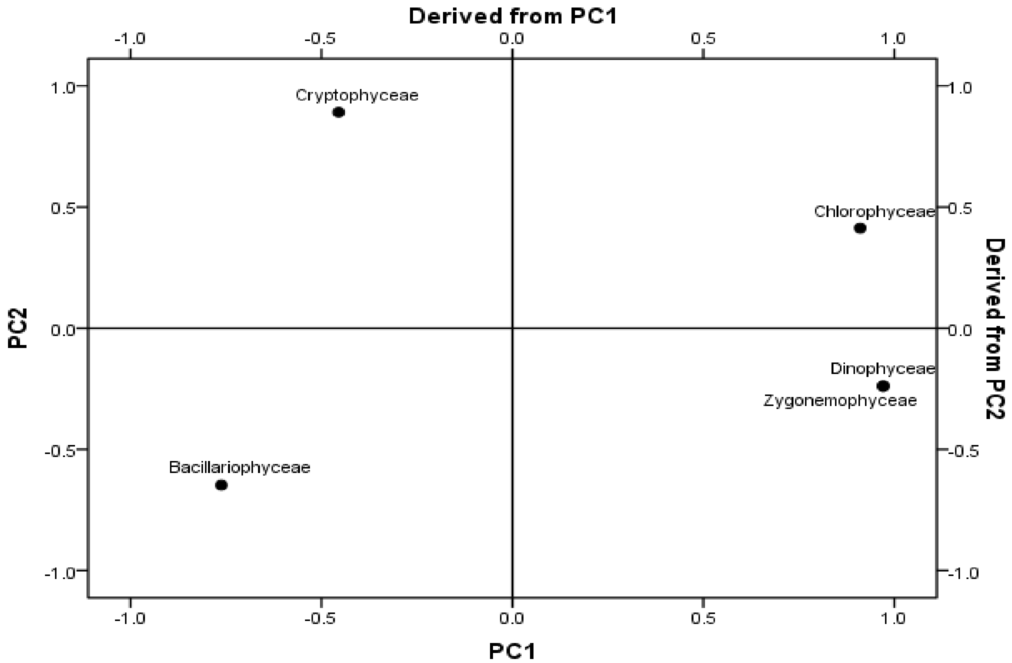

Fig.5. Principal Component Analysis (PCA) Plot of Phytoplankton.

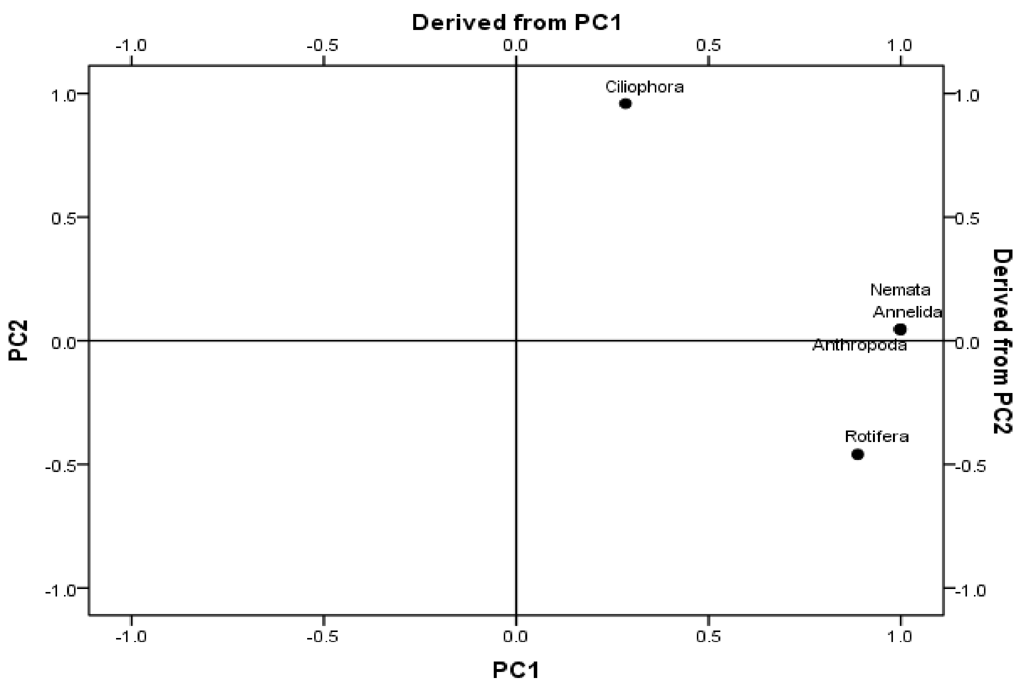

Fig.6. Principal Component Analysis (PCA) Plot of Zooplankton.

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* had a strong positive relationship with pH (r = 0.99), temperature (r = 0.94) and DO (r = 0.76), and strong negative relationship with Nitrate (r = -0.99). *Chlorophyceae* had a strong positive relationship with Nitrate (r = 0.99) and a strong negative relationship with pH (r = -0.94), temperature (r = -0.99), DO (r = -0.90) and Phosphate (r = -0.78). *Zygnemophyceae* had a strong negative relationship with phosphate (r = - 0.75). *Dinophyceae* had strong negative relationship with temperature (r = -0.82) and DO (r = -0.97). Rotifera had a strong positive relationship with Nitrate (r = 0.90), and had a strong negative relationship with pH (r = -0.92), temperature (r = -0.99), DO (r = -0.92) and phosphate (r = -0.81) while Arthropoda, Annelida and Nemata had a strong negative relationship 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

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

Parameters against Zooplankton Family	pH	Temperature	DO	Nitrate	Phosphate
Rotifer	-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

4. DISCUSSION

A total of 23 phytoplankton species, from 5 families, totalling 368 individuals, with *Bacillariophyceae* being the most abundant family in this study is far lower than report by [26] who 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 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 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 allochthonously 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 individuals was recorded during this study, with Rotifera being the most abundant phylum. This report was lower that reported by [34] who reported 28 zooplankton species and Calanoida as the most dominant Zooplankton Phylum. However, the number of species observed in this study is higher than that reported by [26,28], who both reported 16 Zooplankton species, 17 Zooplankton species. 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 variation could also be due to difference in the intensity of environmental disturbances which could induce changes to 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 the occurrence of Rotifera and as the most abundant Zooplankton Phylum during their study, and this corroborated with the observation of this study which also had Rotifera represented and also 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 in the different sampling stations. 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 Weiner, Margalef and Equitability diversity index of Planktons across all the 3 sampling stations indicated a good and healthy Plankton ecosystem. Also, the low 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 corroborated with the report of [39]. Also, the pH values varied across the different sampling stations, and the difference 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=.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 is 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 BOD levels 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 is deemed unpolluted. Nutrients like nitrate and phosphate are very important to planktons, because the use nutrients to photosynthesize. 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 affects 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 species 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 [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 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 in the 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 water parameters. The ecological diversity index like; Shannon Weiner, Margalef and equitability index were assessed, and generally described a conducive and healthy aquatic environment, although the equitability values were low, thus confirming that the distribution of Plankton was not evenly distributed. The water 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. Plankton community is very paramount, as it forms the base of the aquatic food chain, and initiates primary productivity. This is the reason they are called pastures of the sea. To this effect, it is highly important that our Plankton community and population are sustained. 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 water parameters, by controlling and enforcing against careless discharges in the River. This will help ensure a healthy planktonic abundance and a sustainable eco-system at large.

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