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Studies on Zooplankton Community and Physicochemical Parameters of Cross River Estuary, South-South, Nigeria

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Abstract

The zooplankton community and some physicochemical parameters were studied for six (6) months in the Cross-River estuary to determine their abundance. To achieve this, Water samples for physicochemical parameters were collected monthly from three stations within the study area using twenty liters (20 L) plastic bucket, filtered through 55µm plankton net, preserved in four percent (4%) formaldehyde and were stained with 3 mL Lugol's iodine in the laboratory prior to analysis. The samples were analyzed microscopically following standard scientific procedures. Data obtained from this study was analyzed using Analysis of variance (ANOVA) descriptive statistics and regression analysis. Total of 5,303 individuals made up 17 species belonging to 3 families was recorded. Rotifers had the highest species composition of 41.06%, followed by Copepods and Ciliates with 29.41% and 23.53% respectively. There was no significant relationship ($P<0.05$) in zooplankton composition across the stations and between seasons. Significant positive relationship occurred between the zooplankton abundance and temperature ($r = 0.619$), DO ($r = 0.572$), salinity ($r = 0.481$), Silicate ($r = 0.462$) and ammonium ($r = 0.475$). For a proper management of our water bodies, further studies on the relationships between the zooplankton community and the environmental factors is required.

Keywords: Zooplankton, Rotifers, Copepods, Ciliates, Cross River Estuary

Introduction

Changes in physicochemical properties resulting from deterioration of water quality brings about changes in species composition and diversity of the zooplankton community [1]. Water salinity due to natural and anthropogenic processes decreases species diversity and abundance [2].

The zooplankton community serve as bio indicators of eutrophication as they respond faster to environmental changes [3, 4]. Zooplankton abundance and species diversity can determine the health of an ecosystem. Eutrophication is indirectly caused by anthropogenic inputs as well as industrialization from where chemicals enter the aquatic ecosystem [5]. Due to these various sources [2] including natural inputs, urbanized estuaries are open to pollution [3].

Zooplankton are categorized by size and developmental stages of which some change into fishes, worms, crustaceans and insects. Pteropods, chaetognaths, larvaceans, siphonophores and copepods remain plankton throughout their life cycle, copepods feed on phytoplankton as well as other zooplankton smaller in size [6]. Zooplankton composition, distribution and abundance are affected by the interactions between several biological and environmental factors [7, 6, 4]. Larger zooplankton species occupy the cooler regions of the aquatic ecosystem [8] as their metabolic rates are controlled by temperature [9]. Nutrients like nitrogen and phosphorus affects algae, protozoa and bacteria which serve as prey of zooplankton, indirectly affecting zooplankton themselves [6].

Several researchers have carried out different studies on planktons, for instance [10] worked on tidal influence on nutrients status and phytoplankton population of Okpoka Creek, upper Bonny estuary, Nigeria. Their findings showed a total of 158 species of phytoplankton identified. Diatoms dominated the phytoplankton (62.9%). Diversity indices of diatoms were 1.5 ± 0.03 (Margalef) and 0.8 ± 0.01 (Shannon). Their work was mainly targeted at tidal influence on phytoplankton and no aspect of zooplankton was studied. However, [9] studied plankton responses to water quality variables of a tropical Idundu river in Nigeria. Their findings revealed a total of 368 individuals of phytoplankton and 140 individuals of zooplankton species. Shannon Wiener and Margalef's diversity index showed that the river was in a healthy state and the equitability level was high across all the stations, indicating even plankton distribution. According to [4] who carried out a systematic study on the influence of high tide on zooplankton population in Cross River estuary. Their findings showed a total of of 17 species of zooplankton belonging to 3 families. Copepod was observed to be most abundant, constituting 82.09% of the total density. Total densities ranged from 1 – 2,506 cells/ mL in the rainy season and 1 – 418 cells/mL in the dry season. High tide was said to be responsible for the low number of zooplankton species observed, though no relationship was investigated between the zooplankton species and the physical environmental factors. It is on this background, that the present study, was ardent on identifying the zooplankton species in the Cross-River system in order to evaluate the relationships between zooplankton abundance and some physical environmental factors.

Materials and Methods

Study area

The Cross-River Estuary is eutrophic in nature and is characterized by extensive mangrove islands. It is located between latitude 4°30'N and 5°15'N and longitude 8°00'E and 8°30'E, with the Calabar River, the Great Kwa River and the

Akpa Yafe as its major tributaries [3] (Fig. 1). Mangrove systems are particularly rich in bacteria due to the high content of organic substrate of the area [11] and serve as breeding nursery grounds for important fish and shellfish species [12]. Nutrient cycles and food web of the mangrove communities are strongly influenced by the adjoining water bodies [13]. The important ecological roles played by estuaries are due to the high productivity associated with their nutrient rich waters [3]. According to [21], the Calabar city and the current developments associated with the Export Processing Zone (EPZ) of Nigeria presents a potential source of pollution as discharge of lubricating oils and other hydrocarbon into the River will increase.

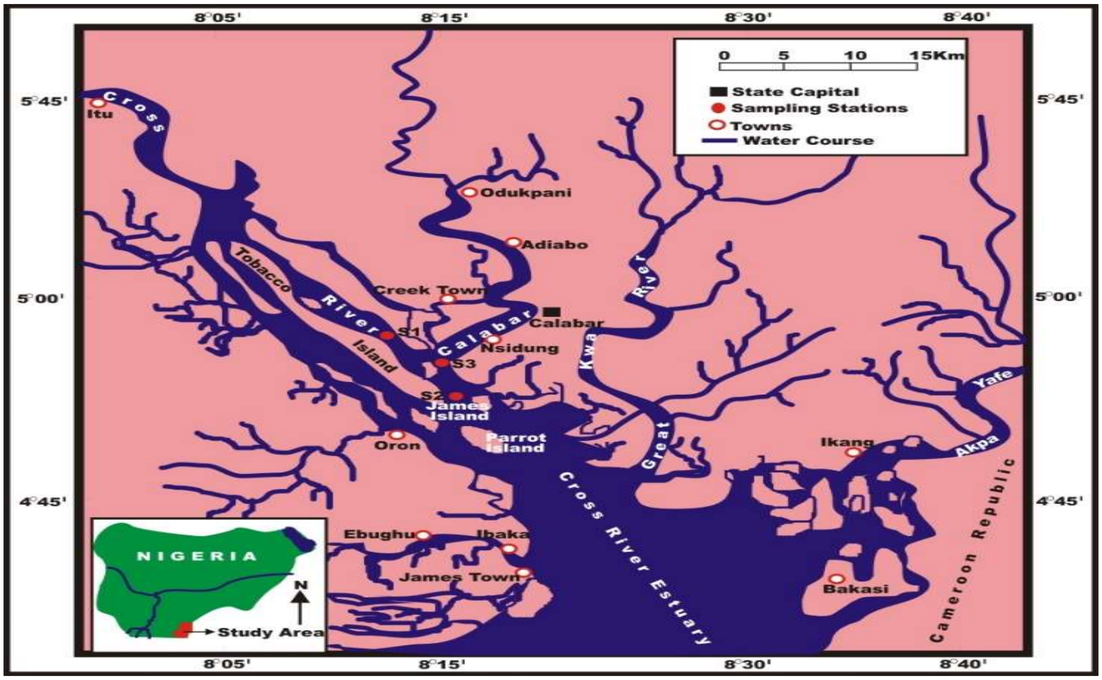

Fig. 1: **Map of Cross River Estuary showing the Sampling Stations**
Source: [4]

Sampling stations
Three sampling stations were chosen along the shoreline of the river using the Global Positioning System (GPS). The coordinates are presented in Table 1.

Table 1: Sampling Stations and Coordinates

Stations	Coordinates	
	Latitude	Longitude
Station 1 (Tobacco Island)	$4^{0}54^{I}56.52^{II}$N	$8^{0}14^{I}28.52^{II}$ E
Station 2 (James Island)	$4^{0}54^{I}16.44^{II}$ N	$8^{0}15^{I}56.96^{II}$ E
Station 3 (Nsidung)	$4^{0}52^{I}48.96^{II}$ N	$8^{0}15^{I}48.95^{II}$ E

Source: [4]

Sample collection and preservation
Water samples for the analysis of physicochemical parameters were collected in triplicate once every month into one liter (1 L) sterile sampling bottles following the method described by [14] and [15]. For zooplankton samples, 20 liters of water was filtered through a 55µm plankton net, transferred into a 20 mL sterile container and fixed with 4% formalin. The samples were transported to the laboratory in an ice-cold chest for analysis [4].

Physicochemical parameters
Physicochemical parameters were analyzed in-situ (temperature °C) and ex-situ (pH, DO (mg/L), Salinity (mg/L), Nitrate (mg/L) and phosphate (mg/L)) during each sampling occasion.
Temperature was measured using a mercury-in-glass thermometer. pH was measured using a pH meter (Model – PHS-3C). Dissolved oxygen (DO) was determined with the aid of a DO meter (Model – JPB-607). For salinity, conductivity was measured using the conductivity meter (Model – DDS-307) and the values were then converted to salinity using the formula; Salinity = $0.65 \times conductivity/1000$. The Cadmium reduction method was used to determine nitrate concentration which was measured with a spectrophotometer at 540 nm.

The Molybdenum blue method was used to measure for silicate and phosphate, the absorbance of the resultant color was read with a spectrophotometer at 810nm and 885nm respectively. For amonium, the Direct Nesslerization method was and the extinction was measured spectrophotometrically at 425 nm.

Species identification and counting
A homogenate of the sample fixed with 4% formalin was put in a 1 mL plankton counting chamber and allowed to settle after covering it with a glass slide. Examination and photomicrographs were done at different magnifications of 80, 100 and 200X using the X10 magnification lens. Identification was done using different taxonomic keys [16, 17, 18].

Biological variables determination
The biological variables, relative abundance, species composition, richness and diversity were estimated as follows:

Relative abundance
Relative abundance was computed, using equation 1[19]

$$(\%Ra)\ \%Ra = n\ (100)/N \quad (1)$$

Where n = total number of individuals in each taxonomic group.
N = total number of individuals in the entire taxonomic group.

Species composition (%SC)
This was computed, using equation 2[19].

$$\%SC = n/N \times 100 \quad (2)$$

Where n = total number of species in each taxonomic group.
N = total number of species in the entire taxonomic group.

Species richness
Species richness was computed, using equation 3 [20]

$$d = S - 1/(N) \quad (3)$$

Where; d is Margalef's index
S is total number of species
In is natural logarithm (log)
N is total number of individuals

Species diversity
This was computed, using equation 4.
Simpson's Diversity Index (D)

$$D = \sum ni\ (ni - 1)\ /\ N\ (N - 1) \quad (4)$$

Where ni is the number of individuals of each species.
N is the total number of individuals for all species

Statistical analysis
Statistical analysis was done using Microsoft Excel (2020). Significant relationships between seasons and stations were determined by ANOVA. Descriptive statistics provided the means and standard deviations of the physicochemical parameters while the significant correlations between zooplankton species and physicochemical parameters were determined by the correlation coefficients (r) using regression analysis.

Results and Discussion

Zooplankton composition and abundance
The distribution and abundance of Zooplankton across the 3 sampling stations of Cross River Estuary is shown in Table 2.

A total of 5,303 individuals made up by 17 species of zooplankton belonging to 3 families were identified during this study and arranged in their order of species abundance. The families were Rotifera represented by 8 species, Copepoda represented by 5 species and Cilliophora represented by 4 species. Copepods were the most abundant, as 4,353 individuals in this research were observed, constituting 82.09% of the total zooplankton population followed by Rotifers which was represented by 531 individuals with relative abundance of 10.01%. Cilliates were the least represented group with 419 individuals constituting only 7.90% of the total population the result is similar to the findings [4] who observed Copepod to be the most abundant group constituting 82.09% of the total density, [19] recorded more of copepods also 20(45.45%), [22] recorded Copepod to be highest (54.89%), and [23] results of findings followed the same trend with Copepod being the most dominant in their observations. However, the present finding's result differs from the result of a similar research carried out by [9] who recorded Rotifera to be the most abundant zooplankton phylum (35.69%).

Copepod is an important group of zooplankton and are present in marine and freshwater bodies. In terms of species composition, Rotifers were the highest having a species composition of 47.06%. Copepods had a species composition of 29.41% and was followed by ciliates with 23.53% species composition (Fig. 2). The distribution of Zooplankton varied across sampling stations, with station 3 having the highest abundance of 2787 Cells/L, while station 2 had the least Zooplankton abundance of 970 Cells/L.

The ecological diversity index varied across the sampling stations. The Shannon Wiener index accounted for the lowest species abundance in Station 3 (0.1436) while Station 1 accounted for the highest species abundance (0.5818). The pattern was similar in the Margalef Index (d). The most dominant zooplankton species was *Copepod nauplii* (4262 individuals), followed by *Keratella tropica* (438 individuals) and *Tintinopsis sp.* (403 individuals). The least dominant species were *Vorticella sp.*, *Arcella discoides*, *Polyarthra encryptera* and *Bryocamptus birstenii* with 3 individuals each. They were followed by *Notholca acuminate* (2 individuals) then *Ectocyclops sp.* and *Thermcyclops sp.* each represented by a lone individual.

Table 2: Spatial Distribution of Zooplankton Species within the Sampled Stations

S/N	Family	Stations 1	2	3	Total
	Rotifera				
1	*Branchionus calyciflorus*	1	0	48	49
2	*Filinia opolemais*	56	0	0	56
3	*Hexarthra sp.*	48	1	0	49
4	*Keratella tropica*	138	146	54	338
5	*Lecane luna*	0	0	29	29
6	*Lepadella apsida*	4	1	0	5
7	*Notholca acuminate*	2	0	0	2
8	*Polyarthra encryptera*	0	0	3	3
	Copepoda				
9	*Bryocamptus birstenii*	3	0	0	3
10	*Copepod nauplii*	927	758	2577	4262
11	*Cyclops sp.*	14	0	72	86
12	*Ectocyclops sp.*	0	1	0	1
13	*Thermycyclops sp.*	0	0	1	1
	Cilliophora				
14	*Arcella discoides*	2	0	1	3
15	*Flavella Ehrenbergii*	8	2	0	10
16	*Tintinopsis sp.*	341	60	2	403
17	*Vorticella sp.*	2	1	0	3
	Total	1546	970	2787	5303
	No. of Species	13	8	9	
	Margalef's Index (D)	1.6341	1.0178	1.0085	
	Simpson's Index of Diversity (D).	0.5818	0.3632	0.1436	

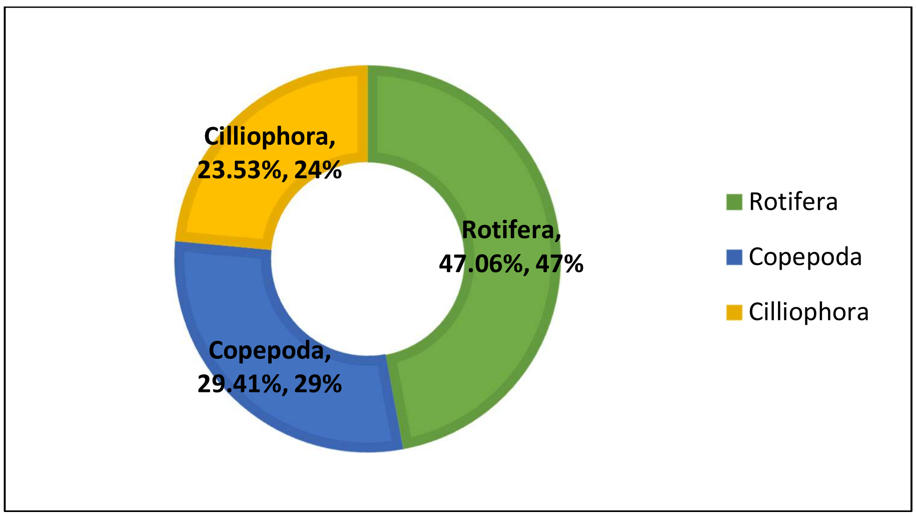

Fig. 2. Composition of Identified Zooplankton Species

Copepod nauphii are primary marine aquatic animals. This result is in line with findings of [24], who opined that Copepod nauphii dominate most aquatic ecosystem because of their resistance and adaptability to changing environment and ability to withstand changing environmental stress. They display varying morphological diversity, occupying an enormous range of habitat in the aquatic realm from freshwater to hyper saline shallow pool, cave of deep sea and environmentally notorious for cryptic speciation. The juvenile copepods are a chief part of the diet of young fish. They are ubiquitous abundant and productive in marine water [6,4]. The size and species of zooplankton in turn are often reflective of the types of fish present on any given river system and the extent of which the fish community utilizes the zooplankton as food. In addition to their impact on fish, the amount and types of algae (phytoplankton) in the river are heavily dependent upon the predatory effectiveness of the zooplanktons at any given time and their average size since zooplankton feed on algae

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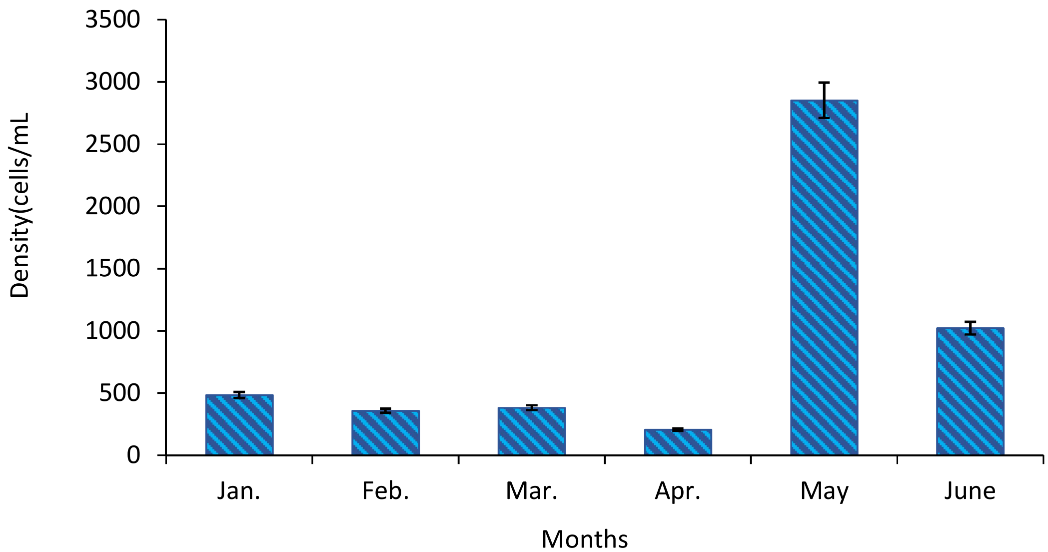

Station I recorded the highest number of species with Rotifers topping the list. Rotifers are known to prefer freshwater [25], but most species such as *Branchionus* and *Keratella sp.* are salt tolerant species, this could be the reason behind the increase in their numerical and species abundance during the rainy season due to dilution of the estuary by rainfall and the inflow of water from the connecting rivers. Copepods are macrozooplankton feeding on phytoplankton, detritus and occasionally on other zooplankton smaller in size, hence, their high abundance [6,4].

The present study recorded higher abundance of zooplankton individuals and species in the wet season than in the dry season which is in contrast with the reports of [3, 23], where high abundance of zooplankton was recorded during the dry season. This might be due to high tide, increased rainfall and the sampling technic employed [4]. Richness determined in this study was lower than that reported by [26] who reported 28 zooplankton species and Calanoida as the most dominant Zooplankton Order, and also lower than the findings made by [9] who reported a total of 20 zooplankton species belonging to five phyla. However, the number of species observed in this study is similar in numerical value to that reported by [27, 28] who both reported 16 ad 17 species 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, sampling stations, level of human activities, variation in environmental disturbances 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 [9]. Zooplankton composition decreased with increased salinity during the sampled months and seasons which might have led to loss of sensitive species [25].

Physicochemical parameters

Various physicochemical parameters of Nigerian waters have been studied [4] in Cross River Estuary and [21] in Calabar River.

Zooplankton are highly responsive to nutrient levels, temperatures, pollution, food that are not nutritious, levels of light and increases in predation [6]. The mean values for physicochemical parameters were recorded as follows, temperature ranged from 29 °C in June to 30.67°C in March. pH was between 5.83 in January and 7.29 in April, DO ranged between 3.70 mg/L in May and 7.43 mg/l in January, Salinity ranged from 0.05ppm in June to 11.35 ppm in February. Nitrate was between 0.06 mg/L in May and 0.72 mg/L in June, Silicate was within the range of 1.41 mg/L in June and 4.85 mg/L in January. Mean concentrations for Ammonium was from 0.21 mg/L in May to 5.58 mg/L in March while Phosphates ranged between 0.01 mg/L in March and 2.02 mg/L in January (Table 3, Fig. 4).This result varies from the result of water quality parameters recorded by [9] for Idundu River, variables (mean ± SD) of the River were pH (6.526 ± 0.104), surface water temperature (26.224 ± 0.106˚C), dissolved oxygen (1.474 ± 0.135 mg/L, nitrate (0.026 ± 0.001 mg/L and phosphate (0.015 ± 0.000 mg/L. Although the water quality parameters of the current studies had slight variations with that of [9], some differed slightly from the acceptable range prescribed by World Health Organization (WHO) and Federal Ministry of Environment (FMEnv.).

TABLE 3: Mean Values of Physicochemical Parameters (January – June 2017)

Parameters	Months					
	January	February	March	April	May	June
TEMPERATURE (^{o}C)	30.33±0.59	31.17±1.04	30.67±0.58	30.00±1.00	29.33±0.58	29.00±0.00
pH	5.83±0.16	6.64±0.02	7.16±0.14	7.29±0.38	6.28±0.13	6.17±0.25
DO (mg/L)	7.43±0.80	5.13±0.85	5.33±0.85	4.67±0.31	3.70±0.56	5.13±0.35
SALINITY (mg/L)	3.19±0.70	11.35±0.46	7.75±0.38	3.87±0.45	1.89±1.58	0.05±0.01
NITRATE (mg/L)	0.14±0.04	0.11±0.11	0.44±0.33	0.37±0.02	0.06±0.08	0.72±0.07
SILICATE (mg/L)	4.85±0.34	4.28±0.26	3.25±0.52	2.69±0.19	2.28±0.15	1.41±0.19
AMMONIUM(mg/L)	0.42±0.11	3.23±0.35	5.58±0.28	1.32±0.25	0.21±0.16	0.48±0.06
PHOSPHATE (mg/L)	2.02±0.01	1.04±0.01	0.01±0.01	0.02±0.01	0.19±0.27	0.04±0.01

Values are in Mean ± standard deviation

The water parameter values like the pH (5.83 – 7.29) in this study was found to be slightly acidic, but fell within WHO and FMEnv stipulated standards for drinking water quality of 6.5 - 8.5 mg/L acceptable range, indicating a healthy environment for plankton growth and production. If the surface water pH shifts too far either way from the acceptable range (6.5-8.5), highly mobile aquatic organism tends to migrate to safer environments while the life of sedentary organisms are susceptible to loss. Dissolved Oxygen content in the present study fluctuated from 3.70 mg/L to 7.43 mg/L.. The WHO permissible limit for DO is 5.00mg/l -7.00mg/l [29]. The nitrate contents of water in this study ranged from 0.06 mg/L and 0.44 mg/L which is within the United Nations Environment Programme (UNEP) permissible limit

. Excessive concentrations of nitrate in lakes, streams and rivers greater than about 5 mg/L can cause excessive growth of algae and other plants. Phosphate level range between 0.01 mg/L and 2.02 mg/L which is within the stipulated range of 0.00mg/l - 5.0 mg/L for portable water. Ammonia level, silicate mg/L, salinity mg/L and temperature (°C) did not pose any serious impact on the water quality. It also further confirmed that water parameters influence the abundance and distribution of Zooplankton.

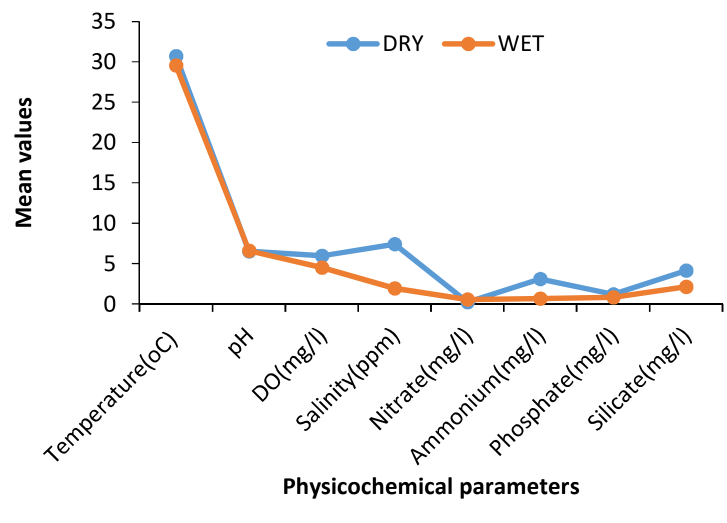

Fig. 4: Mean Values of Physicochemical Parameters during the Two Seasons

Correlation between zooplankton abundance and water parameters

The correlations between zooplankton and water parameters are presented in Table 4. There was a positive correlation (P<0.05) between zooplankton abundance and temperature (r = 0.619), DO (r = 0.572) and a weak relationship between zooplankton abundance and salinity (r = 0.481), Silicate (r = 0.462) and ammonium (r = 0.475). Nutrients like nitrogen and phosphorus affects algae, protozoa and bacteria which serve as prey to zooplankton, indirectly affecting zooplankton survival [6].

Table 4: Correlation coefficient between the physico-chemical parameters of Cross River Estuary and Zooplankton

Physicochemical Parameters	Values
Temperature (oC)	**0.619**
Dissolved Oxygen (DO)	**0.572**
Salinity (mg/L)	0.481
Silicate (mg/L)	0.462
Ammonium (mg/L)	0.475

Note: Bold r-value indicates slightly strong positive relationship. Slightly strong relationship 0.50 – 0.74; Weak relationship 0.10 – 0.49; No relationship 0.00 – 0.09

Conclusion

The Cross River estuary has come under some level of threat from anthropogenic activities, and the biodiversity are the worst hit. In this study, a total of 5,303 individuals made up by 17 species of zooplankton belonging to 3 families were identified. The families were Rotifera represented by 8 species, Copepoda represented by 5 species and Cilliophora represented by 4 species. Copepods were the most abundant, as 4,353 individuals in this research were observed, constituting 82.09% of the total zooplankton population followed by Rotifers which was represented by 531 individuals with relative abundance of 10.01%. Cilliates were the least represented group with 419 individuals constituting only 7.90% of the total population. Competition for food by other aquatic animals such as the fish in the estuary could be responsible for the low abundance of zooplankton species observed among other families except for the Copepoda, other factors include; the discharge of ballast water into the Calabar Port which introduces some invasive species into the aquatic water body, and the release of some pollutants into the water body. The physicochemical parameters observed were all within normal and acceptable range for tropical water bodies and for planktons to live, procreate, and grow. This study recommends that monitoring programs that are essential to capture the natural variability of plankton in coastal waters be intensified. Concerted environmental surveillance on the Cross River Estuary is encouraged to reduce the inflow of pollutants from industries and human activities within the shorelines into the Cross River Estuary. Aquatic scientists should continue to conduct further researches on different aspects of the ecology of plankton in Cross River Estuary as well as other tributaries in order to link the gap in knowledge of the abiotic and biotic properties of this estuary

Declaration of conflicting interests

The authors declared no potential conflicts of interest.

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