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PHYSICO–CHEMICAL PARAMETERS AND BENTHIC MACRO-INVERTEBRATE COMMUNITIES OF CALABAR RIVER, NIGERIA

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ABSTRACT

A study was conducted to assess the influence of physicochemical parameters on the abundance and distribution of benthic macro–invertebrates in Calabar River (latitude 04^0 55' 55" to 05^0 02' 50"N; longitude 008^0 16' 35" to 008^0 18' 13.8" E). Five sampling stations labeled stations 1, 2, 3, 4 and 5 respectively, were chosen along the river course. Physicochemical parameters were measured using their respective meters while macro–invertebrates were collected using a Van Veen grab and identified under microscope. Diversity indices; Margaleaf's (d), Shannon's (H) and Pielou's (E) were calculated using their respective formulae. All physico–chemical parameters differed significantly across sampling stations with the exception of temperature and pH. Temperature was lowest (27.52^0C) at station one and highest (30.30^0C) at station five while the lowest and the highest average pH were 6.0 at station one, and 6.40 at station three respectively. The lowest DO value (3.10 mg/l) was recorded at station five while stations three and four had the highest value (3.95 mg/l). Lowest and highest BOD were 1.05 mg/l at station one and 2.05 mg/l at station three respectively. TSS was lowest (10.60 mg/l) at station four, and highest (29.05 mg/l) station five while TDS was lowest (19.70 mg/l) in station one and highest (40.80 mg/l) at station five. 5866 macro–invertebrates belonging to different taxa were identified. Species abundance and diversity indices were generally low, indicating stress in the environment.

Keywords: Macro–invertebrates, Physicochemical parameters, Calabar River, Diversity indices, Correlation.

INTRODUCTION

Macro-invertebrates are organisms without backbones, which are visible to the eye without the aid of a hand lens or microscope. They can be found in both terrestrial and aquatic environment. Aquatic macro-invertebrates live on, under and around rocks and sediment in the bottom of lakes, rivers and streams (Idowu and Ugwumba, 2005). The freshwater benthic macro-invertebrates include the immature and adult stages of different types of invertebrates such as flies, beetles (adult and immature), mayflies, caddis flies, stoneflies, dragonflies, aquatic worms, snails, and numerous other organisms that inhabit the bottom layer of water bodies (Roseberg and Resh, 1998). They are extremely important in the food–chain of aquatic environment as they play important roles in the processing and cycling of nutrients and are a major food for fish and other aquatic organisms (Idowu and Ugwumba, 2005).

Several ecological factors influence the abundance and distribution of benthic macro-invertebrates. These factors include: substrate types, water velocity, discharge, riparian vegetation and the level of pollution in the ecosystem among others (Giller and Malmqvist, 1998). All these factors tend to influence the physico–chemical parameters which trigger some responses from the macrobenthic invertebrates and so determine their abundance and distribution in the ecosystem. Ramesh *et al*. (2016) observed that changes in physico-chemical parameters of ecosystems have a substantial impact on the distribution, periodicity and quantitative and qualitative composition of biota. Hence this study assessed the influence of physico–chemical parameters on abundance and distribution of macrobenthic invertebrates in Calabar River, Nigeria.

MATERIALS AND METHODS

The Study Area

The Calabar River in Cross River State, Nigeria is located between latitude 04^0 55′ 55″ to 05^0 02′ 50″N and longitude 008^0 16′ 35″ to 008^0 18′ 13.8″ E. It flows from the north through the city of Calabar, joining the larger Cross River at about 8km to the south (FIG. 1). The Calabar River drains part of the Oban Hills in the Cross River National Park. The geology of the river basin includes the pre-Cambrian Oban Massif, Cretaceous sediment of the Calabar Flank and the recent Niger Delta sedimentary basin which is about 43km wide and 62km long, with an area of 1,514 square kilometers (Eze and Effiong, 2010) and it is entirely covered by tropical rainforest (Effiong, 2011).

Five sampling stations with an approximate distance of 4.5 km from one another were chosen along the river course: Ikot Okon Abasi, Tinapa, Unicem, Marina resort and Nsidung beach which were labeled stations 1, 2, 3, 4 and 5 respectively. Station 1 is upstream with clean water and little human activities going on there while stations 2 and 4 are tourist sites with some human activities. Stations 3 and 5

receive a lot of effluents and other wastes as a result of industrial and commercial activities there.

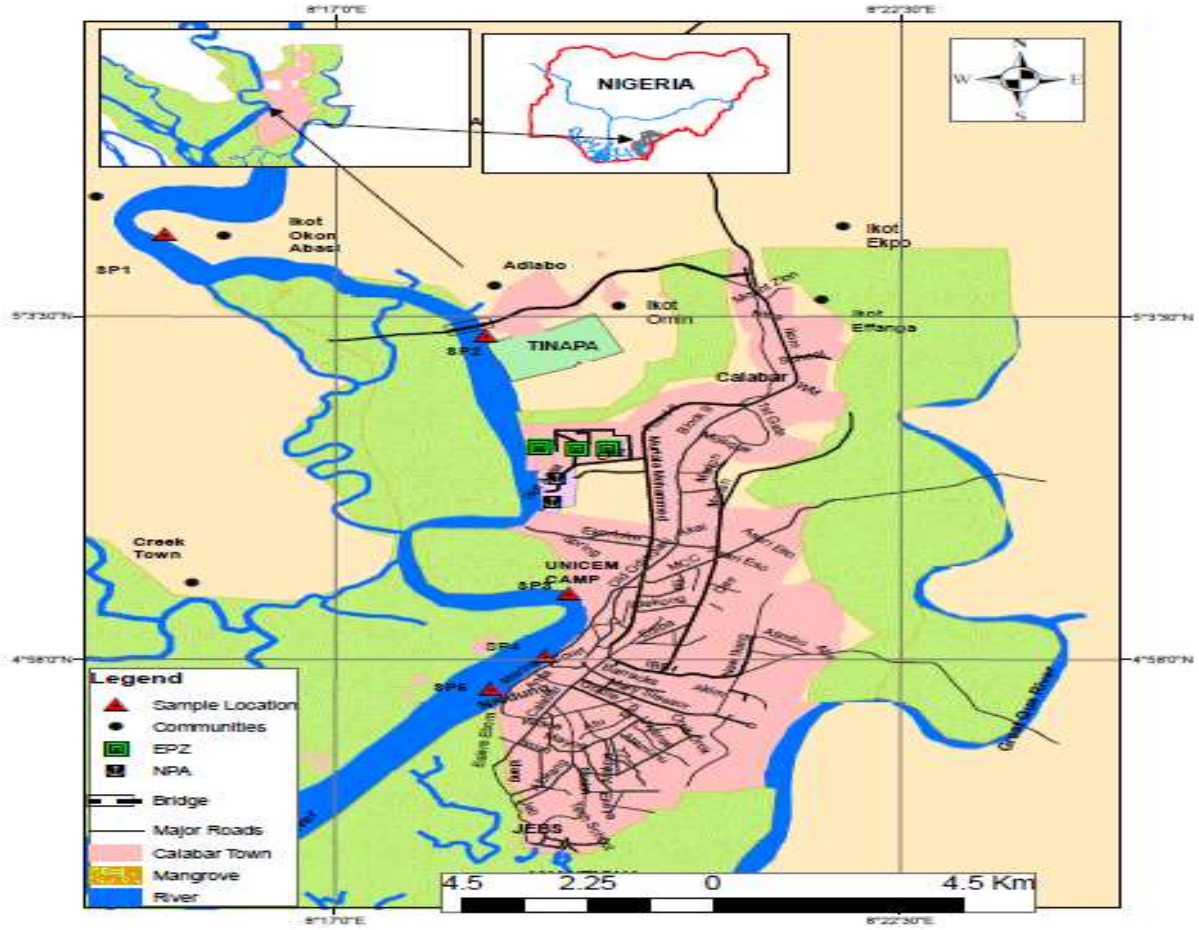

FIG. 1: Map of Study Area showing Calabar River and Sampling Stations

Measurement of Physico-chemical Parameters

Water samples were collected monthly between February and July 2018 from the five sampling stations. The Physico-chemical parameters investigated in each case were Surface Water Temperature, pH, Dissolved Oxygen (DO), Biochemical Oxygen Demand (BOD), Total Dissolved Solids (TDS) and Total Suspended Solids (TSS).

Temperature was measured using a mercury-in-glass thermometer which was inserted to a depth of about 2 cm from the surface for three minutes and the readings were expressed in degrees Celsius (^{0}C). The water pH was measured with a pocket-size pH metre, Model (pH-1) whose glass probe was dipped into the water sample and the pH was read as recommended by APHA, AWWA, WEF (1995). Dissolved oxygen was measured *in situ* with a dissolved oxygen meter, model (DO-5509), surface water was also taken for studies on Biochemical Oxygen Demand and was incubated for five days and the BOD was calculated as DO of Day one minus DO of Day five, i.e. DO_1–DO_5= BOD. Total dissolved solids and total suspended solids were measured using an Extech meter, model Exstik EC 400. The electrode of the meter was immersed in the water samples collected, the total dissolved solids and total suspended solids were read.

Collection of Benthic Macro-invertebrates

Benthic-macro-invertebrates samples were collected monthly from the five sampling stations of the study area during the study period. A Van Veen grab was used for each sampling station, 3 or 4 hauls were made by sending the grab down into the bottom of the river at random locations. The sediment collected were poured into a labeled white plastic can of about 20 cm^3 in volume and taken to the laboratory for analysis. In the laboratory, the sediment were passed through three sieved of 2 mm, 1 mm and 0.5 mm mesh sizes to collect the benthos. The benthos were poured into a white enamel tray, stained with Rose Benger solution to highlight the hidden features and sorted using forceps. They were sorted out into different taxa and preserved in 4% formalin. They were then identified under a stereoscope microscope using identification guides of Pennak (1978) and EPA (1998) and counted. In case of stony substrate, stones were lifted to remove the animals that are hidden in between and a sweep net of mesh size 0.5 – 1 mm was used to collect flying macro-invertebrates.

Diversity Indices

The occurrence and relative numerical abundance of benthic-macro-invertebrates were calculated using biotic indices;

Margalef's index and Shannon's index to estimate abundance and diversity of species.

Margalef's index (d): is a measure of species richness (Margalef, 1949) and is expressed as;

$$d = \frac{S-1}{N}$$

Where: S = The number of species in samples

N = The number of individuals in samples

Shannon's diversity index (H): is a measure of the species abundance and evenness (Shannon and Weaver, 1946) and is expressed as:

$$H = \sum_{i=1}^{s} -(Pi * \ln Pi)$$

where: H = the Shannon diversity index

P_i = fraction of the entire population made up of species i

S = numbers of species encountered

$\sum$ = sum from species 1 to species S

Species equitability or evenness (E) (Pielou, 1996) is a measure of diversity that quantifies how equal the community is numerically. The index E is a constraint between 0 and 1. The more frequent the variation in communities among the species, the higher the values of E. It was determined by using the equation:

$$E = \frac{H}{\ln(S-1)}{\ln(N)}$$

Where; H = Shannon's diversity index

S = Number of species in the sample

N = Total Number of Individuals in the Sample

Statistical Analysis

Analysis of variance (ANOVA) was used to find out whether there's a significant difference among the physico–chemical parameters from the different sampling stations and correlation analysis was done to determine the relationship between macro–invertebrates' abundance and the physico–chemical parameters.

RESULTS

Surface Water Temperature

The mean surface water temperature of the various stations during the study ranged from 27.52 to 30.30 ^{0}C with the overall mean value of 29.11 ± 0.99 ^{0}C (Table 1). The lowest average surface water temperature value (27.52^{0}C) was recorded at Station 1 (Ikot Okon Abasi), while the highest temperature level (30.30 ^{0}C) was recorded in Nsidung Beach. Among the five sampling stations, surface water temperature showed no significant difference (P>0.05) (Table 1) during the study period.

1

Water pH

The mean pH of the various stations at the time of the study ranged from 6.00 to 6.35 with an overall mean of 6.22 ± 0.13 (Table 1). The lowest average pH (6.0) was recorded in station one (Ikot Okon Abas), and the highest (6.40) was in station three (United cement). The pH for the five sampling stations during the study period did not vary significantly (P>0.05).

2

Dissolved Oxygen (DO)

The average dissolved oxygen concentration ranged from 3.10 to 3.95mg/l with an overall mean of 3.74 ± 0.31 mg/l (Table 1). The lowest DO value (3.10 mg/l) was recorded in station five (Nsidung Beach), while stations three and four had the highest value (3.95 mg/l). There was a significant difference (P<0.05) in DO among the five sampling stations during the study period.

Biological Oxygen Demand (BOD)

The average Biological Oxygen Demand (BOD) ranged from 1.05 to 2.05 mg/l with a mean of 1.50 ± 0.35 mg/l (Table 1). The lowest BOD (1.05 mg/l) was recorded at station one (Ikot Okon Abasi), while the highest BOD (2.05 mg/l) recorded was in station three (UNICEM). Within the five sampling stations, the spatial variations in BOD showed a significant difference (P<0.05) (Table 1).

3

Total Suspended Solids (TSS)

The average concentrations of Total Suspended Solids ranged from 10.60 – 29.05 mg/l with an overall mean value of 18.39 ± 6.18 mg/l (Table 1). The lowest average TSS value (10.60 mg/l) was rerecorded at Marina Beach, while the highest value (29.05 mg/l) was recorded in Nsidung Beach. The spatial variations of TSS among the stations sampled were significantly different (P< 0.05).

Total Dissolved Solids (TDS)

The average levels of TDS ranged from 19.70-40.80 mg/l with overall mean value of 27.24 ± 7.59 (Table 1). The lowest TDS mean value (19.70 mg/l) was recorded in station one (Ikot Okon Abasi), while the highest value (40.80 mg/l) was recorded in station five (Nsidung Beach. Among the five sampling stations, the spatial variation of TDS showed significant difference (P< 0.05).

Table 1: Mean Values of Physico-Chemical Parameters of Calabar River from February to July, 2018 and their Comparison with NESREA Permissible Limits

Parameters	S1	S2	S3	S4	S5	Mean ± S. E.	P–test	Inference	NESREA limits	Permissible
Surface Water temperature (^{0}C)	27.52	28.59	29.32	29.83	30.30	29.11±0.99	P>0.05	Not significant	20-40	
pH	6.00	6.15	6.40	6.20	6.35	6.22±0.13	P>0.05	Not significant	6.0–9.0	
Dissolved Oxygen (DO) mg/l	3.80	3.90	3.95	3.95	3.10	3.74± 0.31	P<0.05	Significant	5.0	
Biochemical Oxygen Demand (BOD)mg/l	1.05	1.60	2.05	0.95	1.85	1.50±0.35	P<0.05	Significant	50	
Total suspended solids (mg/l)	17.70	20.00	14.60	10.60	29.05	18.39±6.18	P<0.05	Significant	>10	
Total Dissolved Solids (mg/l)	19.70	20.55	26.60	28.55	40.80	27.24±7.59	P<0.05	Significant	500	

Where:

SE = Standard Error

NESREA = National Environmental Standard and Regulations Enforcement Agency

Benthic Macro-Invertebrates Composition and Abundance

Fourteen genera were identified belonging to three phyla from the total 5866 individuals collected. Arthropoda was represented by Crustacea and Insecta which accounted for 63.2% and 3.6% of the total collection respectively. Mollusca was represented by Gastropoda which made up 33.1% and Annelida was represented by Clitellata which contributed 0.3%.

The most abundant species was *Penaeus notalis* with a total of 41.9%. The species was more abundant in Nsidung Beach with 47.7% individuals and least abundant in Marina Beach with 24.4% individuals. The least abundant species was *Tubifex tubifex* which had 0.3% of total collections. A summary of the relative abundance of the various benthic macro-invertebrates taxa collected along Calabar River between February and July, 2018 is presented in Table 2.

Diversity Indices of Benthic Macro-Invertebrates

Taxa richness calculated as Margaleaf's index (d) was highest at Marina Beach (0.021) and least at Nsidung Beach (0.007) which is the downstream. Shannon's diversity index was highest at Ikot Okon Abasi (1.159) and least at Marina Beach (0.2187). Equitability was highest at Marina Beach (0.829) and lowest at UNICEM (0.2914). A summary of the diversity indices calculated for the five stations is shown in Table 3.

Correlation between Physico-chemical Parameters of Water and Benthic Macro-Invertebrates Abundance

The relationship between physico-chemical parameters of surface water and abundance of benthic macro-invertebrates is shown in Table 4. The classes Crustacea and Clitellata had strong negative correlation (– 0.71 and – 0.71) with surface water temperature while Insecta and Gastropoda had strong positive relationship (0.55 and 0.63) with temperature. Crustacea and Gastropoda had negative correlation with pH while Insecta and Clitellata had positive correlation, though all the relationships are weak (< 0.5). All macro-invertebrate classes had positive correlation with dissolved oxygen (DO), with Gastropoda and Crustacean having strong (>0.5) relationships while Insecta and Clitellata had weak (<0.5) relationships. There was a negative correlation between all macro-invertebrate classes and biochemical oxygen demand (BOD) while all classes had positive relationship with total suspended solids (TSS) and total dissolved solids (TDS) except for Insecta and TSS whose relationship was negative during this study

Table 2: Composition and Relative Abundance of Benthic Macro-invertebrates of Calabar River between February and July 2018

PHYLUM	CLASS	ORDER	FAMILY	SPECIES	S_1 (%)	S_2 (%)	S_3 (%)	S_4 (%)	S_5 (%)	Total (%)
ARTHROPODA	CRUSTACEA	DECAPODA	Palaenomidae	*Macrobrachium vellenhovenii*	87 (9.0)	102 (8.5)	87 (6.5)	68 (11.4)	140 (7.9)	484 (8.3)
			Penaeidae	*Peneaus notalis*	295 (30.6)	472 (39.5)	701 (52.2)	146 (24.4)	841 (47.7)	2,455 ((41.9)
			Ocypodidae	*Uca tangeri*	73 (7.6)	92 (7.7)	102 (7.6)	66 (11.0)	113 (6.4)	446 (7.6)
			Portunidae	*Callinates amnicola*	58 (6.0)	64 (5.4)	59 (4.4)	43 (7.2)	90 (5.1)	314 (5.4)
	INSECTA	EPHEMEROPTERA	Heptageniidae	*Stenonema species*	12 (1.2)	11 (0.9)	9 (0.7)	11 (1.8)	8 (0.5)	51 (0.9)
		TRICHOPTERA	Limnephilidae	*Pycnopsyche species*	12 (1.2)	10 (0.8)	5 (0.4)	13 (2.2)	4 (0.2)	44 (0.8)
		ODONATA	Corduliidae	*Macromia species*	16 (1.7)	16 (1.3)	11 (0.8)	18 (3.0)	7 (0.4)	68 (1.2)
		ODONATA	Libellulidae	*Crocothemis erythra*	11(1.1)	8 (0.7)	7 (0.5)	10 (1.7)	3 (0.2)	39 (0.7)
MOLLUSCA	GASTROPODA	NEOTAENIOGLOSSA	Thiaridae	*Pachymelania fusca*	89 (9.2)	95 (7.9)	105 (7.8)	61 (10.2)	127 (7.2)	477 (8.1)
		NEOTAENIOGLOSSA	Potamididae	*Tympanotomus fuscatus*	68 (7.0)	58 (4.9)	79 (5.9)	51 (8.5)	125 (7.1)	381 (6.5)
		CYCLONERITIMOPHA	Neritidae	*Neritina afra*	116 (12.0)	134 (11.2)	71 (5.3)	42 (7.0)	72 (4.1)	435 (7.4)
		SORBEOCONCHA	Thiaridae	*Melanoides tubercula*	63 (6.5)	70 (5.9)	58 (4.3)	31 (5.2)	126 (7.1)	348 (5.9)
		SORBEOCONCHA	Thiaridae	*Pachymalenia byronensis*	57 (5.9)	59 (4.9)	4.9 (3.6)	35 (5.8)	106 (6.0)	306 (5.2)
ANNELIDA	CLITELLATA	OLIGOCHAETA	Tubificidae	*Tubifex tubifex*	8 (0.8)	4 (0.3)	1 (0.07)	4 (0.7)	1 (0.06)	18 (0.3)
Total No of Individuals					965	1,195	1,344	599	1,763	5866

Table 3: Diversity Indices of Benthic Macro-Invertebrates of Calabar River between February and July, 2018

Biotic indices	S1	S2	S3	S4	S5	Total
Margaleaf's Index (d)	0.013	0.010	0.0097	0.021	0.007	0.002
Shannon's Index (H)	1.159	0.8828	0.7689	0.2187	0.8597	0.8686
Equitibility (E)	0.4391	0.3345	0.2914	0.829	0.3258	0.3291
No. of Species	14	14	14	14	14	14
Individual	965	1195	1344	599	1763	5866

Table 4: Correlation between Physico-chemical Parameters and Macro-invertebrates Abundance During the Study Period

	SWT	pH	DO	BOD	TSS	TDS	CRUSTACEAN	INSECTA	GASTROPODA	CLITELLATA
SWT	1									
pH	-0.05	1								
DO	0.08	0.05	1							
BOD	0.06	0.64	0.97	1						
TSS	-0.69	-0.27	0.16	0.01	1					
TDS	-0.95	-0.15	-0.21	-0.25	0.8	1				
CRUSTACEAN	-0.71	-0.46	0.64	-0.55	0.67	0.87	1			
INSECTA	0.55	0.48	0.25	-0.04	-0.11	0.35	0.03	1		
GASTROPODA	0.63	-0.27	0.81	-0.75	0.2	0.66	0.66	0.62	1	
CLITELLATA	-0.71	0.27	0.44	-0.37	0.32	0.72	0.57	0.68	0.77	1

DISCUSSION

Physico–chemical Parameters of Calabar River

The mean temperature obtained during the study lies within the National Environmental Standards Regulation and Enforcement Agency (NESREA, 2011) acceptable temperature range (20-40 ^{0}C). This is an indication that the temperature of Calabar River is fit for organisms' survival as when the temperature becomes higher or lower than the recommended value organisms die off or migrate to a more favourable environment. Andem *et al*., (2013) also reported the temperature values that lie within the same range in Calabar River during both the wet and dry seasons in their studies on ecological assessment and limnological characterization in the intertidal region of Calabar River using benthic macro-invertebrates as bioindicator organisms.

The mean pH values obtained during the study were within the NESREA recommended range for aquatic life while the mean dissolved oxygen (DO) concentration in Calabar River during the study was below acceptable limit for organisms' survival and the BOD was less than 4mg/L which is suitable for aquatic life as recommended by NESREA. Similar pH values but higher DO values above the NESREA limits were observed by Abowei (2010) in his studies on physico–chemical parameters of Nkoro River, Niger–Delta, Nigeria.

The mean values of total suspended solids (TSS) and total dissolved solids (TDS) were within the NESREA acceptable limit. Nnamani *et al*. (2015) obtained similar results in their analysis of physico–chemical parameters of water from Isu and Calabar Rivers.

Macro-invertebrates Composition and Abundance

The Crustacean dominance of the total macro–invertebrates abundance with about 63% despite having only four species could be attributed to the Crustacean adaptation for survival in different kinds of environment which enable them to colonize and occupy a variety of niches. Besides having specialized features, Crustaceans also blend in to their environment using colours which make it difficult for predators to access them and some of the females brood eggs or brood young in a ventral brood chamber (marsupium) (George *et al*., 2010). This result is in a sharp contrast to what was obtained by Ene *et al*. (2013) in their study on arthropods community of mangrove swamp of Great Kwa River, Southern Nigeria. They found the most abundant class to be Insecta (71.2%) while Crustacea constituted 18%.

Margaleaf's index (d) or taxa richness range from 0.007 in station five (Nsidung Beach) to 0.021 in station four (Marina Beach) while Shannon's diversity index (H) range from 0.2187 in station four (Marina Beach) to 1.159 in station one (Ikot Okon Abasi) and Pielou's evenness index (E) range from 0.2914 in station three (UNICEM) to 0.8291 in station four (Marina Beach). This suggests that there are other variables influencing the environmental quality in Calabar River besides the parameters measured in this study. George *et al*. (2017) reported that low diversity index is an indication of stress in the environment and high diversity index is a reflection of a stress free environment while Latha and Thanga (2010) showed that species diversity and distribution is clearly related to water quality and the more contaminated water is, the less the diversity index will be.

Correlation Between Macro-Invertebrates Abundance and Physico-chemical Parameters

A correlation is a mutual relationship or a connection between two or more variables, though a positive correlation between two variables does not imply that one causes the other. Classes Insecta and Gastropoda had strong positive relationships with temperature. All classes had positive relationship with Dissolved Oxygen (DO) and negative relationship with Biochemical oxygen demand (BOD). Gastropoda and Crustacea had strong positive relationship with Total dissolved solids (TDS) and only Crustacea had strong positive relationship with Total suspended solids while all classes relationship with pH were weak. These could be explained by the fact that lower acidity generally leads to reduced biodiversity and species composition while low dissolved oxygen (DO) content is harmful to aquatic organisms since DO is needed for aerobic respiration. Amusat *et al*., (2019) in their study on the impact of physicochemical parameters on benthic macro-invertebrates assemblage of Erelu Reservoir in Oyo Town, Nigeria, found out that temperature and TDS had inverse correlation with all orders of benthic macro-invertebrates examined while Yap *et a*l. (2006) observed a negative correlation between density and distribution of macro-invertebrates with DO and pH, and positive correlation with BOD and TSS.

CONCLUSION

The mean values of all the physicochemical parameters measured during the period of this study were within the acceptable limits for surface and ground water quality except for dissolved oxygen (DO) level while all the parameters differed significantly across sampling stations with the exception of temperature and pH.

Five thousand eight hundred and sixty six macro–invertebrate individuals were collected and identified during the study period, belonging to 14 species, 14 genera, 12 families, eight orders, four classes and three phyla. The class Crustacea dominated the macro–invertebrate composition and Clitellata was the least. Species abundance and diversity indices were generally low, indicating some sort of stress in the environment. Seeing that most of the measured parameters in this study were within the NESREA limits, these indices suggest that there are other factors influencing the environmental quality in Calabar River.

A correlation analysis between physicochemical parameters of Calabar River and macro–invertebrate abundance showed that all classes had positive relationship with Dissolved Oxygen (DO) and negative relationship with Biochemical oxygen demand (BOD). Gastropoda and Crustacea had strong positive relationship with Total dissolved solids (TDS) and only Crustacea had strong positive relationship with Total suspended solids while all classes relationship with pH were weak and classes Insecta and Gastropoda had strong positive relationships with temperature.

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