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Ecological Impact Assessment and Limnological Characterization in the Intertidal Region of Calabar River Using Benthic Macroinvertebrates as Bioindicator Organisms

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ABSTRACT
A study on ecological impact assessment and limnological characterization of Calabar River using benthic macroinvertebrates as bioindicators organisms was conducted from August, 2012 to January, 2013. Surface water and benthic samples were collected from two different stations along the intertidal region of the river. The mean value of surface water temperature was 28.0±0.71 ˚C; pH, 8.20±0.35; dissolved oxygen, 4.30±0.4 mg/L; biochemical oxygen demand, 2.30±0.26 mg/L; conductivity, 281.8±89.5 mg/L; There were significant differences ($p < 0.05$) in the mean values of conductivity in the sampling stations. Three phyla of benthic macroinvertebrates were encountered in the River. The first Phylum, Arthropoda was represented by five genera and four species. The second Phylum, Annelida was represented by only one genus, *Capitella* (Polychaeta). The third Phylum, Mollusca was represented by seven species of gastropods. *Pachymelania fusca* dominated the benthic macroinvertebrate with a total relative abundance of 50.0% by number while *Hemigrapsus species* and *Capitella species* were the least abundant, 0.13% by number. All the benthic macroinvertebrate fauna recorded were pollution-tolerant and clean water species. This could influence the distribution and abundance of benthic macroinvertebrates in the intertidal region of Calabar River and that the river could also be under pollutional stress because the benthic macroinvertebrate observed were pollution-tolerant and clean water species.

Keywords: Ecological, Limnological, Benthic macroinvertebrates, Calabar River.

1. Introduction

In different parts of Nigeria, rivers are used for disposal of refuse, human sewage, and waste waters from residential areas, abattoirs and industries [1]. Storm water runoffs and discharge of sewage into rivers are two common sources of nutrients in aquatic ecosystem that results in their pollution [2, 3]. Rapid industrialization has direct and indirect adverse effects on our environment [4]. This has led to an increase in generation of industrial effluents which when discharged untreated, would result in water, sediment and soil pollution [5]. Environmental degradation, deterioration and underdevelopment are top public issues both at national and international levels [6]. Anthropogenic discharges in aquatic ecosystems, reduces light penetration and transparency and these have adverse effect on the primary productivity and hence benthos community [7]. In some advanced countries, general monitoring of water quality is done on a regular basis [8, 9]. Thus, abnormal changes in the water quality can easily be detected and appropriate measures taken before the outbreak of epidemics [5].

Several health stressors significantly deplete the biodiversity of aquatic ecosystems. Biodiversity loss and its effects are predicted to be greater for aquatic ecosystems than for terrestrial ecosystems [10]. Pollutants are conserved in sediments over long periods of time according to the chemical persistence, physico-chemical and biochemical characteristics of the substrata [11]. Macroinvertebrate organisms form an integral part of an aquatic environment and are of ecological and economic importance as they maintain various levels of interaction between the community and the environment [12]. Unlike other biotic measures, benthos reflects conditions at a specific location.

Benthic macroinvertebrates are useful biological indicators, which provide a precise understanding of changing aquatic conditions than chemical and microbiological data, which presents rather short term fluctuation[13, 14]. Benthic macroinvertebrate play an important role in aquatic community which includes mineralization, mixing of sediments and flux of oxygen into sediment, cycling of organic matter and are useful in assessing the quality of water[15]. The presence or absence and abundance of benthic macroinvertebrate have been shown to be a good indicator of both chronic and episodic impact of human disturbance to river condition and other aquatic environment[16]. In recent years, environment concerns relating to the health and vitality of aquatic ecosystem have become emerging issues in Nigeria. In assessing the health of aquatic environment, bioassessment has become a reliable method for measuring human influence on aquatic ecosystems, complementing traditional, physical and chemical methods[3]. Species diversity is the most frequently used parameter in biology to assess environmental health[17, 18]. It is a measure of variability among the species of a community as well as availability of various ecological niches for various individuals of species to occupy in an ecosystem. Biological assessment supports physico-chemical water analysis, providing a more robust measure of aquatic conditions. Although physico-chemical parameters represent water quality and limnological characterization at the time of sampling, biological assessment determines long-term water quality trends[16]. Several studies have been carried out on physico-chemical parameters and macrobenthos as bioindicators of pollution in Nigerian rivers[19, 20, 21, 22, 15]. The purpose of this paper is to present a general account of the water quality and benthic macroinvertebrate species composition and diversity within the river. The impact described here must be considered preliminary, as this is a preliminary investigation, owing to limitations on the scope and depth of parameters used as criteria.

2. Materials and Methods

2.1 Description of Study Area

The Calabar River in Cross River State, Nigeria flows from the north part of the city of Calabar, joining the larger Cross River of about 8 kilometres to the south with the longitude of $8^0$18’0E and latitude of $4^0$58’3N (Figure 1). The river at Calabar forms a natural harbour deep enough for vessels with a draft of 6 metres[23]. The Calabar River drains part of the Oban Hills in the Cross River National Park[24]. The geology of the river basin includes the Pre-Cambrian Oban Massif, Cretaceous sediments of the Calabar flank and the recent Niger Delta sedimentary basin[25]. The basin is about 43 kilometres wide and 62 kilometres long, with an area of 1,514 square kilometres[25]. At one time it was entirely covered by tropical rainforest[26]. The region has a rainy season from April until October, during which 80% of the annual rainfalls, with peak of the rainfall in June and September. Annual rainfall averages 1,830 millimetres. Average temperatures range from 24 °C (75 °F) in August to 30 °C (86 °F) in February. Relative humidity is high, between 80% and 100% [25]. The basin has 223 streams with a total length of 516 kilometres. This is a small number given the size of the basin [25]. Drainage is poor, so the basin is subject to flooding, gully erosion and landslides. A 2010 study said that flooding had increased in recent years [25].

2.2. Sampling Stations

Two sampling stations (1-2) were chosen along the intertidal region of the river. The co-ordinates of the sampling stations were also taken using Geographic Positioning System (GPS) and approximate distances of the stations were calculated.

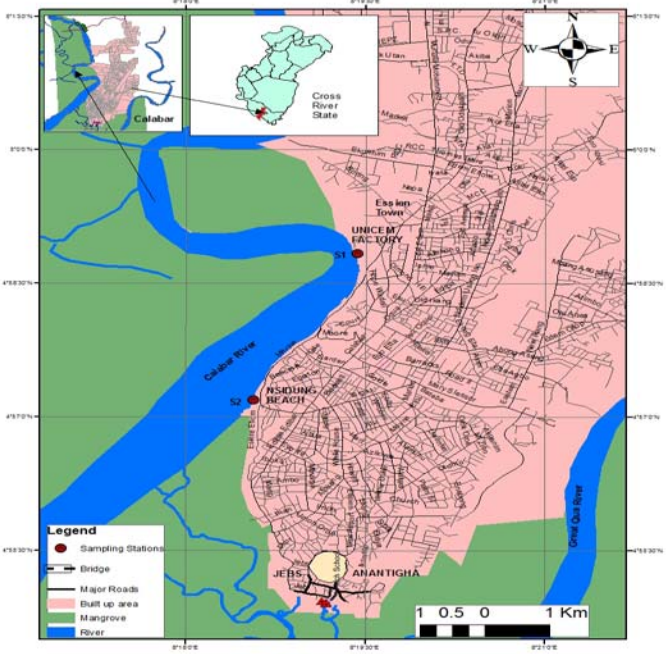

Fig 1: Map of Calabar River Showing Sampling Stations

2.2.1 Station 1

This station is assumed to be the upstream, Fishing activities is very minimal in this station. This station is located at United Cement Company of Nigeria (UNICEM) between Latitude: N 4^0 58’ 988”; Longitude: E 8^0 16’ 872”) at 24 feet altitude.

2.2.2 Station 2

This is a commercial station with a large market located at the River side, domestic wastes from human households is being emptied into the River. This is a landing site for fishermen and distribution to other sectors. The station is located at Nsidung Beach between Latitude: N 4^0 57’ 326’’; Longitude: E 8^0 18’ 557’’ at 26 feet altitude.

2.3. Physico-chemical parameters

Samples were collected monthly from the August, 2012 to January, 2013 at two different stations usually between 8:00 am and 12:00 moon. The physico-chemical parameters investigated in each case were surface water temperature, pH, dissolved oxygen (DO), biochemical oxygen demand (BOD), and conductivity, all from surface water.

2.3.1. Surface water temperature

At each sampling station, temperatures of the river were measured with a mercury-in-glass thermometer which was inserted at a depth of about 2cm from surface for 5 minutes. The readings was expressed in degrees Celsius (˚C).

2.3.2 pH

The pH was measured with a Pocket-Sized pH meter, Model (pH-1). The glass probe of the meter was dipped into the water sample and the pH read as recommended by APHA, AWWA and WEF[27].

2.3.3 Dissolved oxygen (DO) and Biochemical oxygen demand (BOD)

Dissolved oxygen was measured *in situ* with a Dissolved Oxygen meter, Model (DO-5509), water surface were also taken for Biochemical oxygen demand and were incubated for five days with the temperature of 20 ^{0}C. DO of First day minus DO of fifth day give us the BOD, i.e. DO_1- DO_5= BOD.

2.3.4 Conductivity

Water sample were taken from the River to the Chemistry Laboratory, University of Calabar for Analysis. In the laboratory, Conductivity was measured for each sampling station using an Extech meter model ExStik EC400. The electrode of the meter was immersed in the water samples collected; the Conductivity was read off[28].

2.4. Collection of benthic macroinvertebrate

Benthic samples were collected from two sampling stations of the study area (Figure1) using a van Veen grab. For each sampling station, 3 or 4 hauls were made by sending the grab down into the bottom. The sediment collected were poured into polythene bags, labelled and brought to the laboratory for analysis. The sediments were passed through 3 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 and sorted using forceps. They were sorted out into different groups and preserved in 4% phosphate buffered formalin. They were identified under a stereoscope microscope using identification guides[29, 30, 31] and the numbers were counted.

2.5 Determination of biological parameters
2.5.1. Diversity index

The percentage occurrence and relative numerical abundance of benthic macroinvertebrates were calculated using biotic indices such as Margalef's index and Shannon and Weaver's index to estimate abundance and diversity of species.

Margalef's index (d): is a measure of species richness[32] and is expressed as:

$$d = \frac{S-1}{\text{In} N} \quad \text{..................... ....} (1)$$

Where;
S is the number of species in samples.
N is the number of individuals in the samples.
Shannon and Weaver's index (H): is a measure of species abundance and evenness[33] and is expressed as:

$$H \quad = \quad H{=}\sum \frac{Ni}{N} \quad \log_2 \frac{Ni}{N} \quad \text{....................................} (2)$$

Where;
N is the total number of individual in the sample
Ni is the total number of individuals of species *ith* in the sample
Species equitability or evenness (E)[34] is determined by the equation:

$$E = \frac{H}{\text{In}\ S} \quad \text{..} (3)$$

Where;
H is the Shannon and Weavers index.
S is the Number of species in samples.

2.6 Statistical analysis

Analysis of variance (ANOVA) was used to test for significant differences between the means of the physico-chemical parameters of the two sampling stations[15]. Pearson correlation coefficient (r) was used to know the relationship between physico-chemical parameters with the abundance of benthic macroinvertebrates.

3. Results
3.1 Physico-chemical parameters

A summary of the physico-chemical parameters of the surface water in the intertidal region of Calabar River is shown in Table 1. Water temperature ranged between 27.3-28.7 °C with mean and standard error values of 27.5±0.35 and 28.5±0.32 for upstream and downstream stations respectively. Water temperature did not differ significantly between the stations ($P>0.05$). pH was alkaline throughout the study. The values were within the range 7.57 - 8.9 with mean and standard error values of 7.9±0.17 and 8.4±0.15 for the upstream and downstream stations accordingly. Also, pH variation did not show significant difference between stations ($P>0.05$). Dissolved oxygen values were within the range 2.9- 5.1mg/L with mean and standard error values of 4.4±0.07 and 4.2±0.06 for upstream and downstream station respectively. Dissolved oxygen did not show significant difference between the stations ($P >0.05$). Biochemical oxygen demand was generally low during the study period. The values ranged between 1.9-2.8 mg/L. The mean and standard error values were 2.5 ± 0.13 and 2.13±0.11 for upstream and downstream station respectively. Biochemical oxygen demand did not show significant difference between the stations ($P>0.05$). Conductivity values ranged between 212.3-367.0 µS/cm, with the mean and standard error value were 218.5±44.7 and 345.0±44.3 for upstream and downstream station respectively. Conductivity was found to be significantly different across all stations ($P<0.05$).

Table 1: Mean Variations and F-values of the Analysis of Variance (ANOVA) of Physico-chemical parameters measured at two stations in the intertidal region of Calabar River.

STATIONS	Station one	Station two	Mean Values	Analysis of Variance	
Physico-chemical parameters	**Mean values**	**Mean values**		**Cal F-Value (P<0.05;P>0.05)**	**Tab F-Value (P<0.05:P>0.05)**
Surface water temperature (^{0}C)	27.5±0.35 (27.3.-28)	28.5±0.32 (28-28.7)	28.0±0.71	1.20[a]	3.80
PH	7.9±0.17 (7.57-8.2)	8.4±0.15 (8.2-8.9)	8.2±0.35	0.90[a]	3.08
Dissolved Oxygen (mg/L)	4.4±0.07 (3.8-4.8)	4.2±0.06 (2.9-5.1)	4.3±0.14	2.30[a]	5.18
Biochemical oxygen demand (mg/L)	2.5±0.13 (2.3-2.8)	2.13±0.11 (1.9-2.4)	2.3±0.26	1.9[a]	4.20
Conductivity (µS/cm)	218.5±44.7 (212.3-222.8)	345.0±44.3 (330.0-367.0)	218.8±89.5	7.50[ab]	5.50

Values are Mean±SE (Minimum-Maximum values in parenthesis) Different superscript letters in a row show significant difference at ($P <0.05$) and the similar superscript letters in a row show not significant at ($P >0.05$).

3.2 Correlation coefficient of physico-chemical parameters of surface water between abundance of benthic macroinvertebrates in the intertidal region of Calabar River.

A summary of the relationship between physico-chemical parameters of surface water and abundance of benthic macroinvertebrates is shown in Table 2. The result shows that they were strong correlation between the physico-chemical parameters and the abundance of benthic macroinvertebrates along the shores of Calabar River.

Table 2: Correlation coefficient (r) between the means of the physico-chemical parameters of surface water and benthic macroinvertebrates in the intertidal region of Calabar River

Benthic macroinvertebrates species / Physiochemical Parameter	Surface water temperature	pH	Dissolved Oxygen (mg/L)	Biochemical Oxygen Demand (mg/L)	Conductivity (µS/cm)
Uca tangeri	0.98*	0.97	-0.95	-0.93	0.98
Hemigrapsus species	0.98	0.97	0.96*	0.95	0.98
Penaeus notialis	0.97	0.99	-0.91	-0.91	0.99
Macrobrachium vollenhovenii	0.95	0.92	0.91	-0.93	-0.95
Macrobrachium felicium	0.91	0.93	0.95	-0.96	-0.97
Macromia species	0.78	0.80	0.90*	-0.85	0.81*
Capitella species	0.90*	0.70	-0.80	-0.83	0.90*
Diplodonta diaphana	0.81	0.87	-0.83	-0.90	0.81
Melanoides tuberculata	0.82	0.91	-0.85	-0.83	0.90
Pachymelania fusca	0.90	0.97	-0.92	-0.91	0.95
Pachymelania byronsis	0.80	0.81	-0.93	-0.89	0.83
Pachymelania aurita	0.71	0.79	-0.80	-0.83	0.76
Neritina rubricata	0.91*	0.96*	-0.93	-0.95	0.89
Thais callifera	0.61	0.73	-0.70	-0.80	-0.81

*Correlation is significant at $P < 0.05$.

Dissolved oxygen show a negative relationship with *Uca tangeri*, *Penaeus notialis, Capitella species*, *Diplodonta diaphana*, *Melanoides tuberculata*, *Pachymelania fusca, Pachymelania byronsis*, *Pachymelania aurita*, *Neritina rubricata* and *Thais callifera* respectively (r = -0.95, -0.94, -0.80, -0.83, -0.85, -0.92, -0.93, -0.80, -0.93, -0.79, $p < 0.05$). Biochemical oxygen demand also show negative relationship with *Uca tangeri*, *Penaeus notialis, Macrobrachium vollenhovenii, Macrobrachium felicium, Macromia species*, *Capitella species*, *Diplodonta diaphana*, *Melanoides tuberculata*, *Pachymelania fusca*, *Pachymelania byronsis*, *Pachymelania aurita, Neritina rubricata* and *Thais callifera* respectively (r = -0.95, -0.94, -0.80, -0.83, -0.85, -0.92, -0.93, -0.80, -0.93, -0.79, $p<0.05$). Conductivity show negative relationship with *Macrobrachium vollenhovenii*, *Macrobrachium felicium*, *Macromia species* and *Thais callifera* respectively (r = -0.95, -0.97, -0.81, -0.81, $P<0.05$).

Table 3: Composition and Relative Abundance of Benthic macroinvertebrates encountered in the intertidal region of Calabar River during the Study Period (Aug-Jan, 2013)

Species Composition	**STATIONS**					
	STATION ONE (UNICEM)		**STATION TWO (NSIDUNG BEACH)**		**TOTAL**	
TAXA	**NO**	**%**	**NO**	**%**	**NO**	**%**
ARTHROPODA						
Crustacean						
Decapoda						
Uca tangeri	14	87.5	15	1.92	29	3.64
Hemigrapsus species	0		1	0.13	1	0.13
Penaeus notialis	0		4	0.51	4	0.50
Macrobrachium vollenhovenii	0		5	0.64	5	0.63
Macrobrachium felicinum	0		1	0.13	1	0.13
Odonata						
Macromia species	2	12.5	8	1.03	10	1.26
ANNELIDS						
Polychaeta						
Capitella species	0		1	0.13	1	0.13
MOLLUSCA						
Gastropoda						
Diplodonta diaphana	0		25	3.21	25	3.14
Melanoides tuberculata	0		266	34.1	266	33.42
Pachymelania fusca	0		398	51.0	398	50.0
Pachymelania byronensis	0		13	1.67	13	1.63
Pachymelania aurita	0		33	4.23	33	4.15
Neritina rubricata	0		8	1.03	8	1.01
Thais callifera	0		2	0.26	2	0.25
Total Number of Taxa	**2**	**100**	**14**	**100**	**14**	**100**
Total Number of Individual	**16**	**2.01**	**780**	**97.99**	**796**	**100**

3.3 Benthic macroinvertebrate composition, abundance and distribution

Summary of the relative abundance of the various macroinvertebrates taxa encountered at the different sampling stations is presented in Table 3 while the illustration in Figure 6 shows the percentage composition of macroinvertebrate phyla in the intertidal region of Calabar River. Fourteen genera were identified belonging to three phyla from a total of 796 individuals collected from all the stations. Nsidung station accounted for the highest abundance (97.99%) by number while the Unicem station accounted for the lowest abundance (2.01%) by number. The

highest number of taxa (14) was also recorded in Nsidung stations while the lowest number (2) was recorded in Unicem station. Mollusca had the highest percentage composition (94%) by number (Table 3), followed by Arthropods (6%) then Annelids had the least (0.13%) by number (Table 3). The gastropod *Pachymelania fusca* had the highest percentage composition of 50% while *Thais callifera* had the lowest composition of 0.25% (Table 3). Other species of gastropods collected from Nsidung station includes; *Diplodonta diaphana* (3.14%), *Melanoides tuberculata* (33.42%), *Pachymelania byronensis* (1.63%), *Pachymelania aurita* (4.15%) and *Neritina rubricata* (1.01) (Table 3). These gastropods were not encountered in the Unicem station.

3.4 Diversity indices of benthic macroinvertebrates in the intertidal region of Calabar River

A summary of the diversity and dominance indices calculated for the two stations is shown in Table 4. Taxa richness calculated as Margalef's index (d) was least in Unicem station (0.360) which is the upstream station while Nsidung Beach station accounted for the highest diversity (1.950). The pattern was similar for Shannon diversity index (H). Equitability was least in Nsidung beach station (0.213) and highest in Unicem station (0.236). The two stations had more or less equal dominance and diversity levels with insignificantly different indices values.

Table 4: Diversity indices of benthic macroinvertebrates in the intertidal region of Calabar River

STATIONS	STATION ONE (UNICEM)	STATION TWO (NSIDUNG BEACH)	TOTAL
Margalef's diversity (d)	0.360[a]	1.950[a]	2.310[a]
Shannon wiener (H)	0.164[a]	0.562[a]	0.726[a]
Equitability (E)	0.236[a]	0.213[a]	0.449[a]

Similar superscript letters in a row indicates insignificant differences in the indices values (P >0.05).

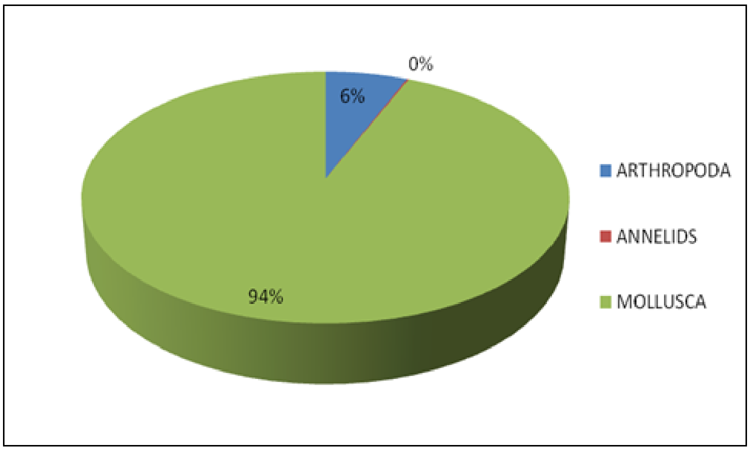

Fig 2: Percentage composition of benthic macroinvertebrate phyla in the intertidal region of Calabar River.

4. Discussion

The number of recorded macrobenthic population was relatively low because of some ecological imbalance arising from alterations of some important factors governing the abundance and distribution of the benthic communities. Similar result was also reported by[35] in Stream communities such factors include water quality, immediate substrates for occupation and food availability. According to Brinkhurst[36] cited by Yakub and Ugwumba[37], the bigger the size of a lotic water body the poorer the macroinvertebrate richness. In addition, high human activity around the sampling stations which released wastes into the river could also be a possible explanation, similar observation was also made by Ogbeibu and Egborge[38] in bodies in the Okomu forest reserve (sanctuary) in southern Nigeria and he reported that high biodiversity is expected in ecosystems devoid of significant anthropogenic impacts. Results from the present study shows that the most abundant macroinvertebrate fauna throughout the study period was *Pachymelania fusca*; could be attributed to the fact that this gastropod were transported by water current and were tolerant of the prevalent water condition. The distribution and abundance of benthic macroinvertebrates as the results showed were, probably affected by the physico-chemical qualities such as dissolved oxygen, biochemical oxygen demand and Conductivity of the water. These parameters correlated significantly with some species of the benthos including *Hemigrapsus species*, *Macromia species* and *Capitella species*. However, the presence of these indicator species suggests organic pollution from anthropogenic source. A similar finding was also reported by Okorafor *et al*.[39]. The low species diversity observed in this study could partly be due to some physico-chemical conditions like fast flow of water and low dissolved oxygen[40] probably resulting in disruption of reproductive cycle and food chain[41, 42, 39]. All physico-chemical parameters analyzed with the exceptions of conductivity did not show significant difference between stations. The mean temperature values (28.0±0.71 ^{0}C) for surface water recorded during the sampling period were within the stipulated range of 25-30 °C[43]. The pH values (8.2±0.35) recorded falls within the recommended range (6.5-9) as suitable for aquatic life[44]. Dissolved oxygen is probably the most universal applied water quality criterion. The observed dissolved oxygen (4.3±0.14mg/L) concentrations during the study period were lower than

Federal Ministry of Environment permissible range of 5.0mg/L. International Joint Commission (IJC)[45] recommended that dissolved oxygen concentration above 4 mg/L is good while below 4mg/L is detrimental to the aquatic life. This was not surprising considering the high levels of conductivity contents of the effluent from Nsidung station. The depletion of dissolved oxygen at this station could also be due to enormous amount of organic loads which required high levels of oxygen for chemical oxidation, decomposition or break down. Similar findings were reported by Arimoro *et al.*[46]; Ohimain *et al.*[47]. The biochemical oxygen demand (2.3±0.26 mg/L) was very low during this study. Water with biochemical oxygen demand less than 4 mg/L are termed reasonably clean and unpolluted, while water with level greater than 10 mg/L are considered polluted since they contain large amount of degradable organic materials[48]. Low biochemical oxygen demand recorded in this study could also explain low level of dissolved oxygen recorded in the reservoir station indicated deteriorating water quality and probably resulted from the death and decay of aquatic macrophyte, increased active organic decomposition in the bottom sediment and the absence of flow-induced turbulence which normally enhances oxygen dissolution in water, this was also observed by Ohimain *et al.*[47]. The conductivity along the intertidal region of the River during the study period falls within the medium level 50-600µS/cm reported by FMENV[49]. Boyd[28] affirmed that natural water normally has conductivity ranges from 20-1500 µS/cm. Adebisi, 1989 observed a range of 13- 31 µS/cm in upper Ogun River. Higher conductivity observed in this study could be due to increase in amount of organic material of the river. High conductivity recorded in this study also could explain low biochemical oxygen demand also recorded in this study, this was also observed by Atobatele *et al.* [50].

4. Conclusion

I. The physico-chemical parameter like dissolved oxygen in the intertidal region Calabar River water were not within suitable range for aquatic organisms and drinking water.
II. All the benthic macroinvertebrate fauna recorded were pollution-tolerant and clean water species.
III. Gastropods were the most abundant taxonomic group in terms of numerical abundance, with *Pachymelania fusca* being the most abundant.
IV. Physico-chemical parameters influenced the distribution and abundance of benthic macroinvertebrates in the intertidal region of Calabar River.

5. References

1. Fagade SO, Adebisi AA, Ugwumba OA. Conservation of aquatic resources through aquaculture. National Resources Conservation Council 1993; 176-182.
2. Sudhira HS, Kumar VS. Monitoring of lake water quality in Mysore city. In: International symposium on restoration of Lakes and Wetlands: Ramachandra TV, Rajasekara MC and Ahalya N (Eds.), Banalore, India: Centre for Ecological Sciences, Indian Institute of Science, 2000, 1-10.
3. Adeyemo OK. Consequences of pollution and degradation of Nigerian aquatic environment on fisheries resources. The Environmentalist 2003; 23(4):297-306.
4. Nasrullah RN, Hamida B, Mudassar I, Durrani MI. Pollution load in industrial effluent and ground water of Gadoon Amazai Industrial Estate (GAIE) SSWABI, NWFP. Journal of agricultural and biological science 2006; 1(3):18-24.
5. Wakama RJ, Uzairu A, Kagbu JA. Impact assessment of effluent discharge on physico-chemical parameters and some heavy metal concentrations in surface water of River Challawa Kano Nigeria. African journal of pure and applied chemistry 2008; 2(10):6-13.
6. Ekweozor I, Agbozu IE. Surface water pollution studies of environment on fisheries resources. The environmentalist 2001; 23(4):297-306.
7. Odiete WO. Environmental physiology of animals and pollution. Diversified Resources Limited Lagos Nigeria 1999, 32.
8. Neal C, Robson AJ. Summary of river water quality data collection within the Land-ocean interaction study Core data for Eastern UK Rivers draining to the North Sea. Science of the total environment 1997; (251/252):585-665.
9. United States Environmental Protection Agency (USEPA). Biological indicators of watershed health, 2000, 85.
10. Sala OE, Chapin IS, Armesto JJ, Berlow E, Bloomfield J, Dirzo R *et al.* Global biodiversity scenarios for the year 2100. Science 2000; 287:1770–1774.
11. Adeyemo OK, Adedokun OA, Yusuf RK, Adeleye EA. Seasonal changes in physico-chemical parameters and nutrient load of river sediments in Ibadan city Nigeria. Global nest journal 2008; 10(3):326-336.
12. Anderson NH, Sedell JR. Detritus processing by macroinvertebrates in some ecosystems. Annual review entomology 1979; 24:357-377.
13. Ravera O. Utility and limits of biological and chemical monitoring of aquatic environment. Annali di Chimica 1998; 88:909-913.
14. Ravera O. Ecological monitoring for water body management. Proceedings of international workshop on information for sustainable water management 2000; 157-167.
15. Chukwu LO, Nwankwo DI. The Impact of land based pollution on the hydrochemistry and macro benthic community of a tropical West African creek. Diffuse Pollution Conference Dublin. *E*CSA4: Persistent polluants, 2003, 65.
16. Rosenberg DM, Resh, VII. Fresh water biomonitoring and benthic macro invertebrates, New York Chapman and Hall, 1998, 488.
17. Mason CF. Biology of fresh water pollution. Longman Scientific and Technical, New York, USA, 1992, 350.
18. Ogbeibu AE. Biostatistics A practical approach to research Data handling. Mindex Publishing Company Limited. Nigeria 2005, 153-162.
19. Monda DP, Galat DL, Finger SE. Evaluating ammonia toxicity in sewage effluents to stream macroinvertebrates a multilevel approach. Archives of environmental contamination and toxicology 1995; 28:378-384.
20. Matagi SV. The effect of pollution on benthic macroinvertebrates in a Ugandan stream. Archiv fur hydrobiologie 1996; 137:537-549.
21. Edopkayi CA, Osimen EC. Hydrobiological studies on Ibiekuma River at Ekpoma Southern Nigeria After impoundment the fauna characteristics. African journal of science and technology 2001; 12:72-81.
22. Tyokumbur J, Okorie TG, Ugwumba OA. In Limnological assessment of the effects of effluents on fauna in Awba stream and Reservoir Ibadan Nigeria. The

Zoologist 2002; 1(2):59-69.
23. Encyclopaedia Britannica. Description of Calabar River, 2011.
24. Cross River National Park (CRNP). Important Bird Areas factsheet. Oban Division. Bird Life International, 2010.
25. Eze EB, Effiong J. Morphometric Parameters of the Calabar River Basin Implication for Hydrologic Processes. Journal of Geography and Geology 2010; 2(1):69-78.
26. Effiong J. Changing Pattern of Land Use in the Calabar River Catchment South-eastern Nigeria. Journal of Sustainable Development 2011; 4(1):3-9.
27. AWWA, WEF. Standard methods for the examination of water and Wastewater. Edn 16, Amer Public Health Assn Washington DC, 1995, 1041-1195.
28. Boyd CE. Water Quality in warm water fish ponds. Craftmaster and Printers Inc. Auburn, Alabama 1979, 359.
29. Pennak E. A field guide to African fresh water snails. West African species, WHO snail identification centre Danish bilharziasis laboratory 1978, 5-15.
30. Edmunds J. Sea shells and other molluscs found on West African coast and estuaries, Ghana Universities Press, 1978, 87.
31. Environmental Protection Agency (EPA). Lake and Reservoir Bioassessment and Biocriteria. Technical Guidance Document 1998; 841(B):98-007.
32. Margalef DI. Diversidad de species en las comunidales naturals. Publication institute biological application Barcelona 1949; 9:5-27.
33. Shannon CE, Weaver W. The Mathematical theory of communication. University of Illinois, Press-Urbana, 1949, 125.
34. Pielou EC. The measurement of diversity in different type of biological collections. Journal of theoretical biology 1966; 13:131-144.
35. Dance KW, Hynes HB. Some effects of agricultural land use on stream insects communities. Environmental pollution service 1980; 22:19-28.
36. Brinkhurst RO. Organic pollution In Pollution, causes, effect and control (Edn). Harrison RR. The Royal Society of Chemistry, London, 1970, 103.
37. Yakub AS, Ugwumba AAA. A study on the macroinvertebrate fauna of lower Ogun River at Ishasi South west Nigeria. The Zoologist 2009; 7:65-74.
38. Ogbeibu AE, Egborge AB. Hydrobiological studies of water bodies in the Okomu forest reserve (sanctuary) in southern Nigeria. Tropical freshwater biology 1995; 4:1-27.
39. Okorafor KA, Andem AB, Okete JA, Ettah SE. The Composition, Distribution and Abundance of Macroinvertebrates in the Shores of Great Kwa River, Cross River State, South-east Nigeria. European journal of zoological research 2012; 1(2):31-36.
40. Emere MC, Nasiru EC. Macroinvertebrates as indicators of the water quality of an urbanized stream Kaduna Nigeria. Journal of nature and science 2009; 7(1):7-9.
41. Adakole JA, Annune PA. Benthic macroinvertebrates as indicators of environmental quality of an urban stream Zaria Northern Nigeria. Journal of aquatic science 2003; 18(2):85–92.
42. Andem AB, Udofia U, Okorafor KA, Okete JA, Ugwumba AAA. A study on some physical and chemical characteristics of Ona River Apata Ibadan South-west, Oyo State Nigeria. European Journal of Zoological Research 2012; 1(2):37-46.
43. World Health Organization (WHO). Guideline for drinking water quality. Edn 3, Vol. 1, Recommendation. World Health Organization, Geneva 1999, 30-113.
44. Adeniji HA. Limnological characteristics of man-made lakes in Nigeria. In The Proceedings of the National Conference of Two Decades of Research on Lake Kainji. Nigerian Institute of Freshwater Fishery Research 1989; 224–232
45. International Joint Commission (IJC). New and Revised Specific Water Quality Objectives. Great Lakes Water Quality Board Report 1977, 11-18.
46. Arimoro FO, Ikomi RB, Iwegbue CM. Ecology and abundance of oligochaetes as indicators of organic pollution in an urban stream in southern Nigeria Pakistan. Journal of biological science 2007; 10:446-453.
47. Ogbeibu AE, Oribhabor BJ. Ecological impact of river impoundment using benthic macroinvertebrates as indicators. Water Research 2002; 36:2427-2436.
48. Ohimain EI, Imoobe OT, Dorcas DS. Changes in water physico-chemical properties following the dredging of an oil well access canal in the Niger Delta. World journal of agricultural sciences 2008; 4(6):752-758.
49. Federal Ministry of Environment (FMENV). Guidelines and standards for environmental pollution control in Nigeria, Decree 58 of 1988, 1999, 238.
50. Atobatele OE, Morenikeji OA, Ugwumba OA. Spatial variation in physical and chemical parameters of benthic macroinvertebrate fauna of River Ogunpa Ibadan. The Zoologist 2005; 3:58-67.