



# IMPACT OF PHYSICO-CHEMICAL PARAMETERS ON THE BIODIVERSITY AND DISTRIBUTION OF MACRO-INVERTEBRATES AT SELECTED AREAS ALONG THE SHORE CALABAR RIVER, NIGERIA

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## ABSTRACT

Spatio-temporal studies were conducted on the impact of physico-chemical parameters on the biodiversity and distribution of macro-invertebrates at selected areas along the shores of Calabar River, Nigeria. Results revealed the distribution of 3601 macro-invertebrates fauna, which consisted of 13 species, belonging to 3 phyla which were represented by Arthropoda, Mollusca and Annelida. *Tympanotonus fuscatus* was the most abundant macro-invertebrate species, having a numerical abundance of 1564 (43.43%) while the least abundant species was *Potadoma moerchii*, which had a total abundance of 3 (0.08%). Macro-invertebrates were more abundant at Adiabo beach. Phylum Mollusca was the most abundant, having a numerical abundance of 2810 (78.03%), while phylum Annelida was least represented, having a numerical abundance of 19 (0.52%). Mean temperature, salinity, pH, DO, BOD and conductivity were  $27.064 \pm 1.222^{\circ}\text{C}$ ,  $0.032 \pm 0.014^{\circ}\text{C}$ ,  $6.315 \pm 0.120$ ,  $4.583 \pm 0.982$  mg/L,  $3.071 \pm 1.831$  mg/L and  $32.055 \pm 11.753$   $\mu\text{S}/\text{cm}$ , respectively. Mean water temperature, salinity, pH, DO, and conductivity varied insignificantly between the three sampling stations ( $p > 0.05$ ), while the BOD varied significantly across the sampling stations ( $p < 0.05$ ). Calabar River is unpolluted and healthy. The abundance of macro-invertebrates was influenced by water quality parameters, as shown by their strength of the various relationships. Although the study revealed that Calabar River is not polluted, it is mandatory that the Government enforces policies and laws regarding the anthropogenic discharges of energies and waste into the river system, in order to sustain its current healthy status. Government should set-up a monitoring team to continually monitor the ecological status of the River so as to ensure sustenance of fishery resources within the River system.

**KEYWORDS:** Physico-chemical parameters, biodiversity, macro-invertebrates, Calabar River, Nigeria

## INTRODUCTION

Macro-invertebrates are organisms that can be seen with naked eyes and can be retained by a mesh or sieve with pore size of 0.2 to 0.5 mm, consisting of diverse array of animals the various groups of crustaceans, flat worms, eel worms and segmented round worms, molluscs (snails and bivalves) (Winterbourn, 1999). These organisms are commonly used for biological monitoring of aquatic ecosystems worldwide (Jimoh *et al.*, 2011), because they are found in most habitats. Macro-invertebrates have generally limited mobility and are quite easy to collect by way of well-established sampling techniques.

Macro-invertebrates explain most of the ecosystem functioning and biodiversity in both lotic and lentic water bodies because they serve as important contributors in detritus processing, animal-microbial interaction and energy transfer to the consumers at higher trophic levels (Allen, 1995; Wallace and Webster, 1996). Benthic macro invertebrates are used largely in assessments of the aquatic ecosystems (Giller and Malmsqvist, 1998). Furthermore, they equally assist in the breakdown of organic matter and cycling of nutrients, prevent blooms in some areas and at times may become food for predators (eg fish) (Hynes, 1970; Jimoh *et al.*, 2011; Uwem *et al.*, 2011).

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One of the common resources for all life forms on the planet is water. About 2/3 of the earth surface is covered with water (Smith, 1974). Water is critical for sustainable livelihoods and it is impossible for a single life to exist without water. There is an entwining relationship between water quality of streams/ivers and macro-invertebrate diversity. This is because water is an important and essential substance in protoplasm and is the basis of life. In addition, water also forms a single worldwide resource distribution on land, sea and atmosphere and unified by hydrological cycle without which life would not be maintained. However, it is argued that the physical and chemical condition of many streams and rivers in tropical countries is deteriorating as a result of human population explosions, changes in land use, intensified agricultural practices and increased industrialization, all of which cause changes to natural flow regimes directly or indirectly (Pringle *et al.*, 2000; Wishart *et al.*, 2000; Ekanem *et al.*, 2018; Job, 2019). The quality of water therefore determines how abundant organisms will be in it. This means that the influence of physical and chemical parameters of a

Increase in temperature lowers the solubility of oxygen, resulting in low values (Ugwumba, 2010). Natural differences in pH and alkalinity may be important determinants of macro-invertebrate community structure in small water bodies (SWBs). Highly acidic water generally results in impoverishment of fauna, while low acidities reflect better buffering and higher productivity (Busulwa and Bailey, 2004). Acidification alters community structure by chronically damaging tissues of invertebrates, particularly of species that easily lose sodium ions when pH is reduced (Shieh and Yang, 2000). Secondly, it alters algal communities upon which some invertebrates depend on for food and shelter, alters predation on invertebrates by decimating numbers of other crustaceans, fish and amphibians and by altering the bio-availability of some other potential stressors, such as heavy metals. Such effects may reduce invertebrate species diversity, increase abundance of tolerant species and change community composition (Shieh and Yang, 2000).

From available literature, studies on the effect of physico-chemical parameters on macro-invertebrate diversity include those of Howiell & Wilhm (1984), Harrison & Hynes (1988), Hart (1999), Efitre *et al.* (2001), Amakye (2001), Narita *et al.* (2003), Idowu & Ugwumba (2005), Sharma *et al.* (2020), Okorafor *et al.* (2021), Sharma *et al.* (2013), Andem *et al.* (2013), Rashid & Pandit (2014), Ngodhe *et al.* (2014) and Andem *et al.* (2015). None of these literature reports on the impact of physico-chemical parameters on the biodiversity and distribution of macro-invertebrates along the shoreline of the Calabar River system at designated locations used for this study.

river must be friendly so as to permit the growth, development, diversity and abundance of aquatic organisms. The structure and function of aquatic organisms reflect physical and chemical conditions and change with increased human influence (Karlson *et al.*, 2002; Herraman, 1999). Aquatic macro-invertebrates have the ability to live under different levels of physico-chemical conditions and to occupy different substrata. The main physico-chemical factors that affect aquatic environments are temperature, dissolved oxygen, pH, nutrients and specific conductivity (Hannien *et al.*, 2000; Boney, 1989). Temperature is an ecologically significant parameter that is known to influence the structure of aquatic communities (Giller and Malmsqvist, 1998). Temperature has critical effects on the distribution of species (Rostgaard and Jacobsen, 2005) and density (Hogy and William, 1996) through combined influence of dissolved oxygen and metabolic activity. Temperature and dissolved oxygen levels are known to generally fluctuate and aid in the structuring of benthic communities, which varies from species to species (Shieh and Yang, 2000). It also regulates the amount of dissolved oxygen in water (Kalf, 2002).

## MATERIALS AND METHODS

### *Description of the study area*

The Calabar River originates from the Oban Hills in the Cross River National Park and is located between latitude 80 15°E and 80 30°E and longitude 40 45°N and 50°E and it has an estimated length of 56 km and is about 2.8 km wide at the mouth where it empties into the Cross River Estuary (Okorafor *et al.*, 2012).

This region has a rainy season from April until October, with peaks in June and September. Annual rainfall averages 1,830 millimeters and average temperature range from 24°C (75°F) in August to 30°C (86°F) in February. Relative humidity is high, between 80% and 100%. The Cross River basin has 223 streams with a total length of 516 kilometers drainage is poor, so the basin is subject to flooding, gully erosion and landslides, while the dry season experiences occasional down pours. The shorelines are lined with dark mud plates usually exposed during low tides. The water at the shore being brackish is rich in macro-invertebrates and debris (Okorafor *et al.*, 2012; Ada & Job, 2020).

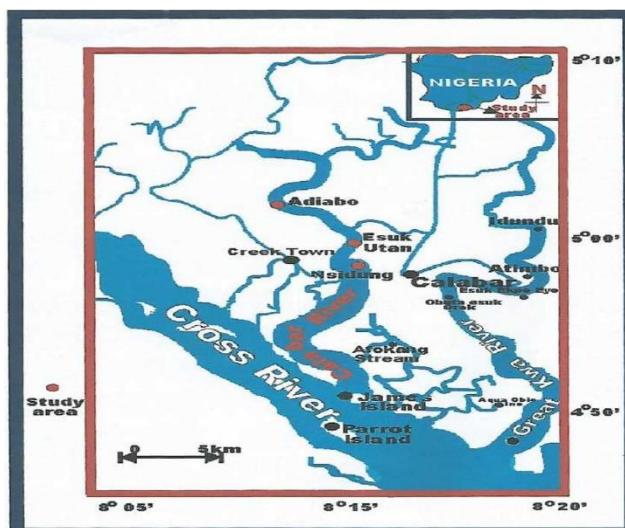
The banks of this study area are surrounded by lush evergreen forest vegetation with different species of trees, shrubs and grasses (Job *et al.*, 2011).

The region has traditionally been limited to small scale farming, aquaculture and artisanal fisheries, mainly for shrimps. However, Calabar is growing, due in part to the Calabar Free Trade Zone, thus causing growing numbers of houses and factories to be built in the fresh water and mangrove swamps of the Calabar River. Three sampling stations are randomly selected for this study. These were Adiabo, Nsidung and Esuk Utan Beaches (Table 1).

**Table 1:** The sampling stations and their GPS readings

Stations	GPS Readings
Station 1: Ahiabo beach	N05°5'23.42" E008°14'52.58"
Station 2: Esuk Utan	N05°1'0.00" E008°20'0.00"
Station 3: Nsidung beach	N05°57'32.6" E008°18'55.7"

Source: Field Data (2018)

**Fig. 1:** Map of Calabar River showing sampling stations

### Collection of samples

Samples were collected twice between 0700 and 1200 hrs on each sampling daily for three months (August-October, 2018) and pooled into a single monthly sample for each of the months. Triplicate samples were collected at each sampling station during each visit and mean and standard error recorded after analysis. Water samples were collected into three plastic sampling bottles measuring one litre each. The bottles were immersed into the river 10 cm below the water surface, filled to capacity and properly corked, according to Ngodhe *et al.*, (2014), Ada & Job, 2018; Ekanem *et al.* (2018).

For the collection of macro-invertebrates from the river banks, nets of mesh sizes 0.1mm, 0.2mm and 0.5mm, held downstream was used. Also, some of the macro-invertebrates were collected by hand-picking, at the intertidal regions during low tide. Samples were stored in plastic bottles preserved in 10% for analysis.

### Analysis of physico-chemical parameters

For the parameters, temperature was measured *insitu* with mercury-in-glass thermometer; pH was similarly measured with a pocket pH meter; salinity was measured *insitu* with a hydrometer, dissolved oxygen (DO) was measured with a dissolved oxygen meter (hand-held) and biochemical oxygen demand (BOD) was determined using dissolved oxygen meter after incubating for five days at 20°C in BOD bottle.

The difference between the DO of first day and DO of fifth day gave the BOD, i.e.  $DO_1 - DO_5 = BOD$  (Alabaster & Lloyd, 1980).

### Laboratory studies

#### Identification of macro-invertebrates

The macro-invertebrates were poured into a white enamel tray, stained with Rose Bengal solution and sorted using forceps into different species and phyla. Rose Bengal solution enhances the benthic organisms to be clearly seen even with unaided eyes (Narita *et al.*, 2003; Hart, 1999). A hand magnifying glass was used to observe the finer details of the macro-organisms.

### Statistical analysis

Data were presented in Tables with mean values and standard deviations of each of the physico-chemical parameters calculated. Analysis of variance (ANOVA) was used to test for statistical differences between the means of the physical and chemical parameters of the three sampling stations.

## RESULTS

The respective readings of the physico-chemical parameters of the surface water are presented in Table 2. The summary of the mean physico-chemical parameters of water from Calabar River throughout the study is shown in Table 1.

At Adiabo beach, the temperature ranged from 27.00 – 28.10°C, having a mean and standard deviation of  $27.633 \pm 0.568^\circ\text{C}$ , while the salinity values ranged from 0.02 – 0.03‰, with a mean and standard deviation of  $0.023 \pm 0.005^\circ\text{‰}$ . The pH of water ranged from 6.24 – 6.32, with a mean and standard deviation of  $6.283 \pm 0.040$ , while dissolved oxygen (DO) ranged from 4.00 – 6.22mg/l, with a mean and standard deviation of  $5.373 \pm 1.200\text{mg/l}$ . The biochemical oxygen demand (BOD) ranged from 0.03 – 1.53, with a mean and standard deviation of  $0.850 \pm 0.759\text{mg/L}$ , while conductivity ranged from 18.90 – 30.40 $\mu\text{s/cm}$ , with a mean and standard deviation of  $25.466 \pm 5.921\mu\text{s/cm}$  (Table 2).

At Esuk Atu, the temperature ranged from 24.50 – 27.55°C, having a mean and standard deviation of  $26.016 \pm 1.525^\circ\text{C}$ , while the salinity values ranged from 0.02 – 0.04 ‰, with a mean and standard deviation of  $0.030 \pm 0.010^\circ\text{‰}$ . The pH of water ranged from 6.09 – 6.41, with a mean and standard deviation of  $6.243 \pm 0.160$ , while the DO ranged from 3.28 – 4.80, with a mean and standard deviation of  $4.126 \pm 0.774\text{mg/l}$ . The BOD ranged from 2.90 – 4.66, with a mean and standard deviation of  $3.786 \pm 0.880\text{mg/l}$ , while conductivity ranged from 23.10 – 48.60 $\mu\text{s/cm}$ , with a mean and standard deviation of  $34.200 \pm 13.066\mu\text{s/cm}$  (Table 2).

At Nsidung beach, the temperature ranged from 27.00 – 28.61°C, having a mean and standard deviation of  $27.543 \pm 0.923^\circ\text{C}$ , while the salinity values ranged from 0.02 – 0.06 ‰, with a mean and

standard deviation of  $0.043 \pm 0.020^\circ\text{‰}$ . The pH of water ranged from 6.34 – 6.48, with a mean and standard deviation of  $6.420 \pm 0.072$ , while the DO ranged from 3.55 – 4.80, with a mean and standard deviation of  $4.250 \pm 0.638\text{mg/L}$ . The BOD ranged from 3.88 – 5.29, with a mean and standard deviation of  $4.576 \pm 0.705\text{mg/L}$ , while conductivity ranged from 23.30 – 53.80 $\mu\text{s/cm}$ , with a mean and standard deviation of  $36.500 \pm 15.657\mu\text{s/cm}$  (Table 2).

Throughout the study, the mean temperature ranged from 24.50 – 28.61°C, having a mean and standard deviation of  $27.064 \pm 1.222^\circ\text{C}$ , while the salinity values ranged from 0.02 – 0.06 ‰, with a mean and standard deviation of  $0.032 \pm 0.014^\circ\text{‰}$ . The pH of water ranged from 6.09 – 6.48, with a mean and standard deviation of  $6.315 \pm 0.120$ , while the DO ranged from 3.28 – 6.22mg/l, with a mean and standard deviation of  $4.583 \pm 0.982\text{mg/L}$ . The BOD ranged from 0.03 – 5.29mg/l, with a mean and standard deviation of  $3.071 \pm 1.831\text{mg/L}$ , while conductivity ranged from 18.90 – 53.80 $\mu\text{s/cm}$ , with a mean and standard deviation of  $32.055 \pm 11.753\mu\text{s/cm}$  (Table 2).

The distribution of the physico-chemical parameters of the surface water across the sampling stations of Calabar River as shown in Table 2 revealed the mean water temperature, salinity, pH, DO, and conductivity to have varied insignificantly between the three sampling stations ( $p > 0.05$ ), while the BOD varied significantly across the sampling stations ( $p < 0.05$ ). All studied water parameters of the selected areas in the Calabar River were within the WHO acceptable limit (Table 1).

**Table 2: Physico-chemical parameters of the surface water of the selected areas in the Calabar River, Nigeria, during the period of study**

Water parameters	Months	Adiabo beach	Esuk Utan	Nsidung beach
Temperature	August	27.0	26	27.0
	September	27.8	24.5	27.02
	October	28.1	27.55	28.61
Salinity	August	0.02	0.02	0.02
	September	0.02	0.03	0.05
	October	0.03	0.04	0.06
pH	August	6.29	6.41	6.44
	September	6.32	6.23	6.48
	October	6.24	6.09	6.34
DO	August	4.0	4.80	4.40
	September	5.90	4.30	4.80
	October	6.22	3.28	3.55
BOD	August	0.03	3.80	4.56
	September	0.99	2.90	3.88
	October	1.53	4.66	5.29
Conductivity	August	30.4	30.9	32.4
	September	27.1	23.1	23.3
	October	18.9	48.6	53.8

**Table 3: Mean, Ranges and Standard Deviation of Physico-chemical Parameters of surface water of the Calabar River, Nigeria, during the Study**

Water Physico-chemical Parameters	S1 Adiabo beach	S2 Esuk Atu	S3 Nsidung beach	Mean	WHO Limit
Temperature (°C)	27.633 ± 0.568 <sup>a</sup> (27.00 – 28.10)	26.016 ± 1.525 <sup>a</sup> (24.50 – 27.55)	27.543 ± 0.923 <sup>a</sup> (27.00 – 28.61)	27.064 ± 1.222 (24.50 – 28.61)	20 – 40
Salinity (‰)	0.023 ± 0.005 <sup>a</sup> (0.02 – 0.03)	0.030 ± 0.010 <sup>a</sup> (0.02 – 0.04)	0.043 ± 0.020 <sup>a</sup> (0.02 – 0.06)	0.032 ± 0.014 (0.02 – 0.06)	-
pH	6.283 ± 0.040 <sup>a</sup> (6.24 – 6.32)	6.243 ± 0.160 <sup>a</sup> (6.09 – 6.41)	6.420 ± 0.072 <sup>a</sup> (6.34 – 6.48)	6.315 ± 0.120 (6.09 – 6.48)	6.0 – 8.5
Dissolved Oxygen (DO) mg/L	5.373 ± 1.200 <sup>a</sup> (4.00 – 6.22)	4.126 ± 0.774 <sup>a</sup> (3.28 – 4.80)	4.250 ± 0.638 <sup>a</sup> (3.55 – 4.80)	4.583 ± 0.982 (3.23 – 6.22)	>4
Biochemical Oxygen Demand (BOD) mg/L	0.850 ± 0.759 <sup>a</sup> (0.03 – 1.53)	3.786 ± 0.880 <sup>b</sup> (2.90 – 4.66)	4.576 ± 0.705 <sup>c</sup> (3.88 – 5.29)	3.071 ± 1.831 (0.03 – 5.29)	<10
Conductivity (µs/cm)	25.466 ± 5.921 <sup>a</sup> (18.90 – 30.40)	34.200 ± 13.066 <sup>a</sup> (23.10 – 48.60)	36.500 ± 15.657 <sup>a</sup> (23.30 – 53.80)	32.055 ± 11.753 (18.90 – 53.80)	400

Values are in Mean ± Standard deviation, Ranges in Parenthesis (), \*Means with Different Superscript are Significantly Different (P<0.05)



### Macro-invertebrates Abundance

The species composition of the abundance and distribution of macro-invertebrates in the different areas of the Calabar River, Nigeria, during the period of study is presented in Table 4a. Total of three thousand six hundred and one (3601) macro-invertebrates fauna were encountered which comprised 13.7(36.30%) at Adiabo beach, 110(30.57%) Esuk Atu and 1193(33.13%) at Nsidung beach. The three phyla observed were Arthropoda, Mollusca and Annelida. Arthropods identified were *Hyperiodrilus africanus*, *Chironomus antracinus*, *Spirostreptus assiniensis*, *Callinectes amnicola*, *Macrobrachium vollenhovenii*, *Oxidus sp* and *Uca tangeri*. The most abundant Arthropod was *Uca tangeri* which had 424 individuals (11.77% abundance), while the least abundant Arthropod was *Chironomus antracinus*, having 16 individuals (0.44% abundance). Phylum Mollusca were represented by *Potadoma moerchii*, *Tympanotonus fuscatus*,

*Pachymelania fusca*, *Haliotis tuberculata* and *Pachymelania byronensis*. The most abundant Mollusca was *Tympanotonus fuscatus* which had 1564 fauna (43.43% abundance), while the least abundant Mollusca species was *Potadoma moerchii*, having 3 fauna (0.08% abundance). Phylum Annelida was represented by *Glossiphonia complanata*, having an abundance of 19 (0.52% abundance) (Table 4a). Throughout the study, *Tympanotonus fuscatus* was the most abundant Macro-invertebrate species, having a numerical abundance of 1564 (43.43% abundance), while the least abundant Macro-invertebrate species was *Potadoma moerchii*, having a numerical abundance of 3 (0.08% abundance) (Fig 2). Station 1 (Adiabo beach) and station 2 (Esuk Utan) had a total of twelve (12) macro-invertebrates species each, while a total of thirteen (13) macro-invertebrates species were identified in station 3 (Nsidung beach) during the study (Table 4a). Selected examples of the macro-invertebrates are shown in Plates 1-4.



Plate 1: *Uca tangeri* (Eydoux 1835)



Plate 2: *Oxidus wikiwand* (Koch 1857)



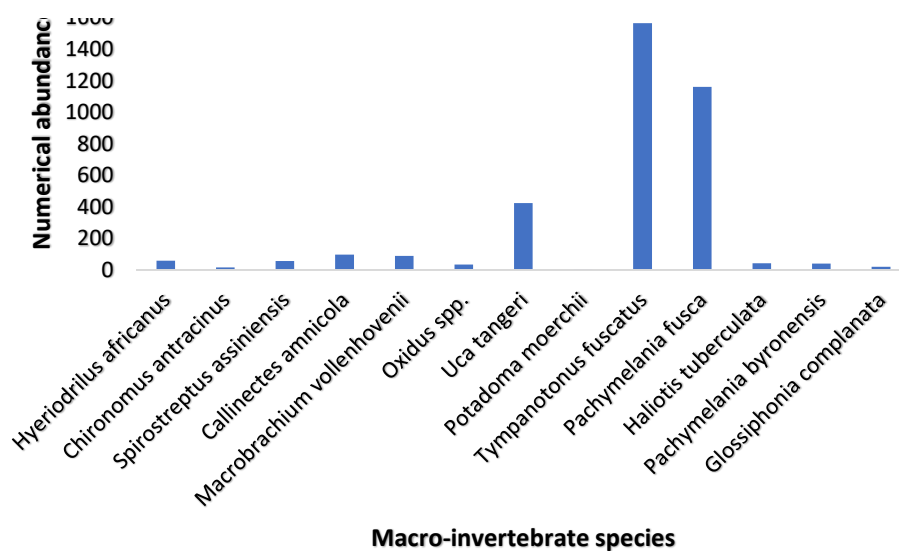
Plate 3: *Pachymelania fusca* (Gmelin, 1790)



Plate 4: *Pachymelania fuscatus* (Muller, 1774)

**Table 4a: Abundance of Macro-invertebrates in each of the three sampling stations of Calabar River, Nigeria during the period of study**

S/N	Macro-invertebrate Species	S1	%	S2	%	S3	%	Total	%	Marginal total
<b>Arthropoda</b>										
1	<i>Hyriodrilus africanus</i>	18	1.37	27	2.45	13	1.08	58	1.61	
2	<i>Chironomus antracinus</i>	8	0.61	5	0.45	3	0.25	16	0.44	
3	<i>Spirostreptus assiniensis</i>	18	1.37	15	1.36	24	2.01	57	1.58	
4	<i>Callinectes amnicola</i>	41	3.13	23	2.08	32	2.68	96	2.66	
5	<i>Macrobrachium vollenhovenii</i>	23	1.76	27	2.45	38	3.18	88	2.44	
6	<i>Oxidus wikiwand</i>	16	1.22	13	1.18	4	0.33	33	0.91	
7	<i>Uca tangeri</i>	128	9.79	194	17.62	102	8.55	424	11.77	
<b>Mollusca</b>										
8	<i>Potadoma moerchii</i>	-	-	-	-	3	0.25	3	0.08	
9	<i>Tympanotonus fuscatus</i>	622	47.59	438	39.78	504	42.24	1564	43.43	
10	<i>Pachymelania fusca</i>	398	30.45	324	29.42	437	36.63	1159	32.18	
11	<i>Haliotis tuberculata</i>	21	1.60	13	1.18	9	0.75	43	1.19	
12	<i>Pachymelania byronensis</i>	11	0.84	13	1.18	17	1.42	41	1.13	
<b>Annelida</b>										
13	<i>Glossiphonia complanata</i>	3	0.22	9	0.82	7	0.58	19	0.52	
<b>Total Abundance</b>		<b>1307</b>	<b>99.9</b>	<b>1101</b>	<b>100</b>	<b>1193</b>	<b>99.9</b>	<b>3601</b>	<b>99.9</b>	<b>3601</b>
		<b>(36.30%)</b>	<b>~100</b>	<b>(30.57%)</b>		<b>(33.13%)</b>				

**Fig. 2: Numerical Abundance of Macro-invertebrates**

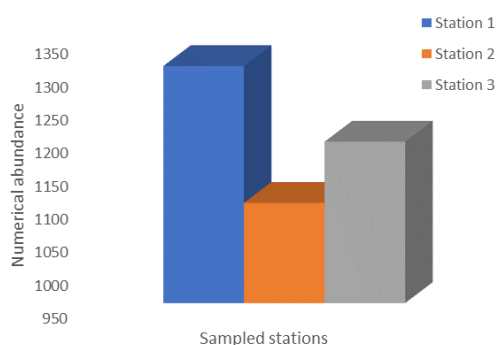


Fig. 2a: Station-by-station numerical abundance of the macrobenthos

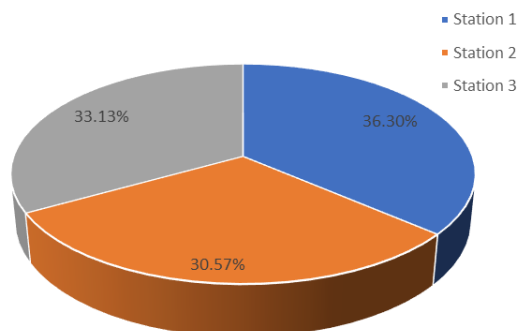


Fig. 2b: Station-by-station percentage abundance of the macrobenthos

**Table 4b: The numerical abundance and relative abundance of the macro-invertebrate phyla**

Phyla	Numerical Abundance	Relative abundance %
Arthropoda	772	21.43
Mollusca	2810	78.03
Annelida	19	0.52
Total Abundance	3601	99.9~100

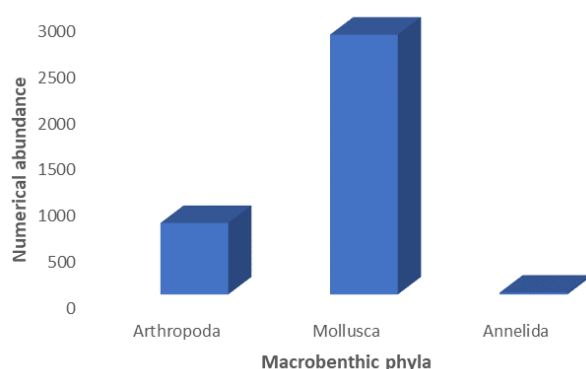


Fig 3a: Relative Abundance of the macro-invertebrate phyla

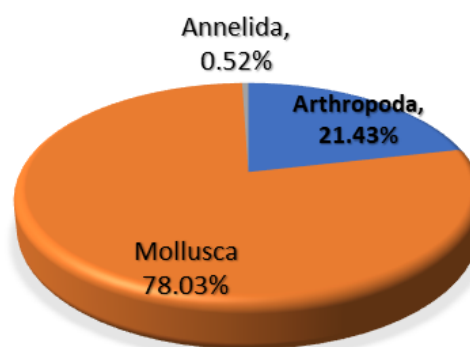


Fig 3b: Percentage Abundance of the macro-invertebrate phyla

#### Diversity Indices of Macro-invertebrates

The summary of the ecological diversity indices of macro-invertebrate in the study area of the Calabar River, Nigeria, and shown in Table 3. The Shannon Weiner diversity index at in Adiabo beach, Esuk Utan and Nsidung beach were 1.446, 1.575 and 1.454 respectively. The highest Shannon Weiner diversity index value was observed at Esuk Utan (1.575), while the least Shannon Weiner diversity index value was observed at Adiabo beach (1.446). The Margalef diversity index at Adiabo beach, Esuk Utan and Nsidung beach were 1.533, 1.571 and 1.694 respectively. The highest Margalef diversity index was observed at Nsidung beach (1.694), while the least Margalef diversity index was observed at Adiabo beach (1.533).

The equitability indices at Adiabo beach, Esuk Utan and Nsidung beach were 0.582, 0.633 and 0.566 respectively. The highest equitability diversity index was observed at Esuk Utan (0.633), while the least equitability index was observed at Nsidung beach (0.566) (Table 5). Statistically, there were no significant differences in the Shannon Weiner, Margalef and Equitability diversity indices between the three sampling stations at  $p > 0.05$ .

The summary of the numerical abundance and relative abundance of macro-invertebrate phyla is presented in Table 4. Phylum Mollusca was the most abundant, having a numerical abundance of 2810 (78.03% abundance), while phylum Annelida was least represented, having a numerical abundance of 19 (0.52% abundance).



Arthropoda had an abundance of 772 (21.43% abundance). These are depicted in Figures 3a and b above.

#### Distribution pattern of the macroinvertebrates

The distribution of the macro-invertebrates was in the following order: Mollusca > Arthropoda > Annelida (Table 4b, Figures 3a and b)

**Table 5:** Diversity Indices of Benthic Macro-invertebrates of Calabar River during the study period

Stations	S1	S2	S3	Significant value	Inference
Shannon Index	1.446	1.575	1.454	0.429	Not Significant
Margalef's Index	1.533	1.571	1.694	0.527	Not Significant
Equitability	0.582	0.633	0.566	0.07	Not Significant
<b>Taxa</b>	<b>12</b>	<b>12</b>	<b>13</b>		
<b>Individual</b>	<b>1307</b>	<b>1101</b>	<b>1193</b>		

Where S1 = Adiabo beach; S2 = Esuk Utan and S3 = Nsidung beach

#### Correlational relationship between the abundance of macro-invertebrates and water quality parameters

The summary of the relationship between the numerical abundance of macro-invertebrates and water quality parameters is shown in Table 6. Phylum Arthropoda had a strong negative significant relationship with temperature ( $r = -0.89$ ) and pH ( $r = -0.92$ ) at  $p < 0.05$ . Mollusca had a strong positive significant relationship with temperature ( $r = 0.96$ ) and

DO ( $r = 0.80$ ) at  $p < 0.05$ . Phylum Annelida had a strong negative significant relationship with temperature ( $r = -0.78$ ) and DO ( $r = -0.92$ ) at  $p < 0.05$ . Mollusca had a strong positive significant relationship with temperature ( $r = 0.96$ ) and DO ( $r = 0.80$ ) at  $p < 0.05$ . Phylum Annelida had a strong negative significant relationship with temperature ( $r = -0.78$ ) and DO ( $r = -0.97$ ) ( $p < 0.05$ ), but had a strong positive significant relationship with BOD ( $r = 0.86$ ) and conductivity ( $r = 0.86$ ) ( $p < 0.05$ ) (Table 6).

**Table 6:** Relationship between the numerical abundance of macro-invertebrates and water quality parameters of Calabar River, Nigeria

Physico-chemical parameters	Arthropoda	Mollusca	Annelida
Temperature	-0.89	0.96	-0.78
Salinity	-0.56	-0.13	0.52
pH	-0.92	0.42	-0.02
DO	-0.19	0.80	-0.97
BOD	-0.09	-0.60	0.86
Conductivity	-0.09	-0.60	0.86

**Correlation (r) Ratings:** 0.70 – 0.99 Strong relationship, 0.50 – 0.69 Slightly strong relationship, 0.10 – 0.49 Weak relationship, and 0.00 – 0.09 No relationship

#### DISCUSSION

Macro-invertebrates are organisms that exhibit limited mobility and quite easy to collect by way of well-established sampling techniques (Elias *et al.*, 2004). Macro-invertebrate community of organisms integrate the impact of different stressors and this provides a broad measure of their aggregate impact. Since many of them are sensitive to pollution and integrate short term and long term effect on environmental stressors, they are mostly used in Bio-monitoring (Kripa *et al.*, 2013). Benthic macro-invertebrates play roles in aquatic ecosystem which includes sediment mixture, depletion of oxygen into sediment, mineralization and organic matter cycling and these are useful in

assessing the quality of water (Eseneowo and Ugwumba, 2010).

The study reveals that the abundance of macro-invertebrates varied across sampling stations, with Adiabo beach (control station) having the highest abundance of macro-invertebrates. Similar findings were reported by Woke *et al.* (2007b) in Elechi Creek, Lagos, Nigeria. The variations in the distribution of macro biotic organisms could be as a result of differences in the local environmental conditions (Salveit and Snook, 2001), as well as the difference in the level of human activities across the sampling stations, since they are pollution indicators (Ada & Job, 2020 and Job *et al.*, 2011).

Furthermore, the presence of more macro-invertebrates in Adiabo beach could be due to the less human activities observed in the station compared to the other 2 stations, thereby allowing for healthy water quality which makes macro-invertebrates thrive more. The study reveals a total of 13 macro-invertebrate species over the 3 months sampling period, which is lower than the 78, 14, 19 and 36 macro-invertebrate species reported respectively by Arimoro and Ikomi (2007), Woke *et al.* (2007a), Woke *et al.* (2007b) and Arimoro *et al.* (2007b) during their studies. Also, 3601 macro-invertebrate individuals were recorded during the study, which is by far higher than the 1859 macro-invertebrate individuals reported by Odo *et al.* (2007). The differences in the number of species and numerical abundance recorded during this study with that of the other reported findings could be as a result of the difference in study area, duration of study, period of study, geographical area, environmental parameters and level of human activities among the different studies. The low abundance of macro-invertebrates species in the present study corroborated with the report of Chukwu and Nwankwo, (2003). This could be attributed to the stress imposed by effluents from land-based sources as well as substrates instability (Chukwu and Nwankwo, 2003), or to conversion from natural habitat and the frequent human perturbation through nutrient input from urine and faeces and trampling of sediment by man and livestock (Griffith *et al.*, 2005).

Phylum Mollusca is the most dominant during the study, and this corroborated with the findings of Woke *et al.* (2007a), who also reported Mollusca as the most abundant phylum during their study, but differed with the report of Chukwu and Nwankwo (2003), who reported phylum Annelida as the most dominant phylum. In terms of species abundance, the present study revealed *Tympanotonus fuscatus* as the most abundant species, which differed with the findings of Okorafor *et al.* (2012) and Adjarko *et al.* (2013) who reported *Litopaenaeus varinamei* and *Chironomus* species as the most abundant macro-invertebrate species. The difference in the findings between the two studies could again be due to the variation in study season, geographical area, soil type, environmental parameters and pollution level between the two studies.

Ecological diversity indices like Shannon weinner and Margalef indices revealed that macro-invertebrates were more diverse at Esuk Utan and Nsidung beach due to their high diversity indices. Also, Equitability indices revealed that Esuk Utan had a more even distribution of its macro-invertebrates than the two sampling stations. The low abundance in species of macro-invertebrates during the study could be an indication of a possible environmental stress and pollution due to anthropogenic activities within the stations.

Domestic sewage and other organic-rich industrial effluents, as well as waste from agricultural and forestry products, are the main sources of aquatic pollution in Africa. Organic pollution affects the aquatic organisms by lowering the available dissolved oxygen in the water (Saad *et al.*, 1994). The study revealed that the physico-chemical parameters varied across the different stations. This variation could be due to the difference in the level of human activities and discharges into the waters of the different sampling stations. The water temperature, salinity, pH, DO and conductivity varied insignificantly across sampling stations, while BOD varied significantly across sampling stations. This indicates that the level of human activities might have varied between the 3 sampling stations, so that it was able to create a significant difference in BOD levels of the water.

The water quality parameters varied across the sampling stations, with the control station (Adiabo beach) having the most stabilized water quality. This indicates that the intensity of human activity within the River and energy discharges into the River influenced the water quality of the River. The pH value recorded in the present study was lower, while the DO value was higher than that reported by Andem *et al.* (2012, 2013) and Atobatele and Ugwumba (2008). The conductivity value of this study was lower than that reported by Atobatele and Ugwumba (2008). The mean salinity value recorded during the study was lower than that reported by Andem *et al.* (2012), while the BOD value recorded during the study was higher than that reported by Andem *et al.* (2013). The differences in the values of the physico-chemical parameters with that of other compared findings, could be due to the differences in study area, study period, geo-graphical area and level of human activities between the different study areas. The mean temperature, salinity, pH, DO, BOD and conductivity values of the present study were all within the acceptable limit of WHO, denoting that Calabar River is still healthy.

The study revealed that the abundance of different macro-invertebrates species are influenced by water quality. Arthropod had a strong negative significant relationship with temperature and pH, denoting that an increase in the water temperature and pH led to a decrease in the abundance of Arthropoda. Mollusca had a strong positive significant relationship with temperature and DO, indicating that an increase in the temperature and DO led to a corresponding increase in the abundance of Mollusca. The Annelids had a strong negative significant relationship with temperature, but had a strong positive significant relationship with BOD and conductivity, this denotes that increase in the temperature and DO led to a decrease in the abundance of Annelids abundance, while an increase in the BOD and conductivity led to a corresponding increase in the abundance of Annelids.

## CONCLUSION

The abundance of macro-invertebrates varied across sampling stations. Macro-invertebrates were more abundant in the control stations (Adiabo beach). A total of three thousand six hundred and one (3601) macro-invertebrate individuals, which were made up of thirteen species (13), and belonging to three (3) Phylum were observed throughout the period of study. Macro-invertebrates were represented by Phylum Arthropoda, Mollusca and Annelida. Phylum Arthropoda were represented by *Hyperiodrilus africanus*, *Chironomus antracinus*, *Spirostreptus assiniensis*, *Callinectes amnicola*, *Macrobrachium vollenhovenii*, *Oxidus* sp. and *Uca tangeri* species. The most abundant Arthropod was *Uca tangeri* which had 424 individuals (11.77% abundance), while the least abundant Arthropod was *Chironomus antracinus*, having 16 individuals (0.44% abundance). Phylum Mollusca were represented by *Potadoma moerchii*, *Tympanotonus fuscatus*, *Pachymelania fusca*, *Hilolitis tuberculata* and *Pachymelania byronensis*. The most abundant Mollusca was *Tympanotonus fuscatus* which had 1564 individuals (43.43% abundance), while the least abundant Mollusca species was *Potadoma moerchii*, having 3 individuals (0.08% abundance). Phylum Annelida was represented by *Glossiphonia complanata*, having an abundance of 19 (0.52% abundance). Throughout the study, *Tympanotonus fuscatus* was the most abundant Macro-invertebrates species, having a numerical abundance of 1564 (43.43% abundance), while the least abundant Macro-invertebrates species was *Potadoma moerchii*, having a numerical abundance of 3 (0.08% abundance). Stations one (Adiabo beach) and station two (Esuk Utan) had a total of twelve (12) macro-invertebrates species each, while a total of thirteen (13) macro-invertebrates species were identified at station three (Nsidung beach) throughout the study. Adiabo, Esuk Utan and Nsidung beach had a numerical abundance of 1307, 1101 and 1193 individuals of macro-invertebrates, respectively. Phylum Mollusca was the most abundant, having a numerical abundance of 2810

(78.03% abundance), while phylum Annelida was least represented, having a numerical abundance of 19 (0.52% abundance). Arthropoda had an abundance of 772 (21.43% abundance). Ecological diversity indices like Shannon weinner and Margalef indices revealed that macro-invertebrates were more diverse at Esuk Utan and Nsidung beach due to their high diversity indices. Also, Equitability indices revealed that Esuk Utan had a more even distribution of its macro-invertebrates than the two other sampling stations.

Throughout the study, the mean temperature, salinity, pH, DO, BOD and conductivity were  $27.064 \pm 1.222$  °C,  $0.032 \pm 0.014$  ‰,  $6.315 \pm 0.120$ ,  $4.583 \pm 0.982$  mg/L,  $3.071 \pm 1.831$  mg/L and  $32.055 \pm 11.753$  µs/cm, respectively. The mean water temperature, salinity, pH, DO, and conductivity varied insignificantly among the 3 sampling stations ( $p > 0.05$ ), while the BOD varied significantly across the sampling stations ( $p < 0.05$ ). Based on the results of the study, the physico-chemical indices of Calabar River suggest a healthy and uncontaminated water body. The abundance of macro-invertebrates is influenced by water quality parameters, as shown by the strength of various relationships.

In conclusion, the study revealed that macro-invertebrates are not evenly distributed, varying across sampling stations. Macro-invertebrates were more abundant at the control station (Adiabo beach). The physico-chemical parameters of water varied across sampling stations. Also, water physico-chemical parameters had influence on the abundance and distribution of macro-invertebrates as a result of their relationship strength ( $r$ ).

Although the study revealed that Calabar River is not polluted, it is important that the Government enforces policies and laws regarding the discharges of energies and waste into the River system by man, and also keep a watchful eyes on the level of activities around this river in order to sustain the health status of the River. Government should fund similar studies regularly, so as to continually monitor the health status of the River system, so as to ensure sustenance of fishery resources which provide cheap protein source for humans within the River environment.

## REFERENCES

- Adjarho, U. B., Esenowo. I. K. and Ugwumba, A. A. A., 2013. Physico-Chemical Parameters and Macroinvertebrates fauna of Ona River at Oluvole Estate, Ibadan. Nigev and Research Journal of Environmental and Earth Sciences, 5(1 1). 671-676.
- Alabaster, J. S. and Lloyd, R., 1980. Water quality criteria for freshwater Fish. Food and Agricultural Organization of the United Nations. Butterworths London. 297p.
- Allen, J.D., 1995. Stream Ecology: structure and function of running waters. London: Kluwer Academic Publishers. 368p.
- Amakye, J.S., 2001. Some observations on Macro-invertebrate benthos of Lake Volta at Yeji Area (Stratum VII) thirty years after impoundment. West African Journal of Applied Ecology, 2(1): 91-102

- Andem, A. B., Okorafor, K. A., Eyo, V. O. and Ekpo. P. B., 2013. Ecological Impact Assessment and Limnological Characterization in the Intertidal Region of Calabar River using benthic macroinvertebrates as bioindicator organisms. *International Journal of Fisheries and Aquatic Studies*. 1(2):8-14.
- Andem, A. B., Udofia, U., Okorafor, K. A., Okete, J. A., Ugwumba, A. A., 2012. A Study on Some Physical and Chemical Characteristics of Ona River. Apata, Ibadan South-west, Oyo State, Nigeria. *European Journal of Zoological Research*. 1 (2):37-46.
- Andem, B. A., Kalu, O. and Ekanem, S., 2015. Factor Analysis and Physico-chemical Characteristics of Calabar River, Southern Nigeria. *International Journal of Science and Technology Research*, 4 (1): 25-28.
- Arimoro, F. O., Ikomi, R. B. and Efemuna, E., 2007. Macro-invertebrate Community Patterns and Diversity in Relation to Water Quality Status of River Ase, Niger Delta. *Journal of Fisheries and Aquatic Science*, 2 (5), 337-344.
- Arimoro, F. O. and Ikomi, R. B., 2007. Response of Macro-Invertebrate Communities to Abattoir Wastes and Other Anthropogenic Activities in a Municipal Stream in the Niger Delta, Nigeria. *The Environmentalist*. 3(4):23-25.
- Atobatele, O. E. and Ugwumba, O. A., 2008. Seasonal variation in the physico-chemistry of a small tropical reservoir in Aiba Reservoir, Iwo, Osun, Nigeria. *African Journal of Biotechnology*. 7 (12): 1962-1971.
- Batzer, D.P. and Wissinger, S.A., 1996. Ecology of insects communities in nontidal wetlands. *Annual Review of Entomology*, 41:75-100.
- Boney, A.D., 1989. *Phytoplankton*. London: Chapman and Hall, p.118.
- Busulwa, H. S. and Baily, R.G., 2004. Aspects of the Physiochemical Environment of the Rwenzori Rivers, Uganda. *Africa Journal of Ecology*, 42 (1):87-92.
- Chukwu, L.O. and Nwankwo, D.I., 2003. The Impact of Land Based Pollution on the Hydrochemistry and Macro-benthic Community of a Tropical West African Creek. *Diffuse Pollution Conference Dublin. ECSA4: Persistent Pollutants*. Pp. 65.
- Efitre, J., Chapman, L.J. and Makanga, B., 2001. Inshore Benthic Macroinvertebrate of Lake. *Article in African Zoology*, 36(2): 205-216.
- Ekanem, A. P.; Job, B. E. and Essien, A. E., 2018. Influence of some physic-chemical parameters on the Spatio-temporal abundance and diversity of phytoplankton in the Great Kwa River, Southeast Nigeria. *European Academic Research*, 4:1774-1796.
- Elias, R., Vallavinor. E. A., Seagliola, M. and Isla, F. I., 2004. Macrobenthic distribution patterns at a savage disposal site in the inner shelf off Mardel plata (SW Atlantic). *Journal of Coastal Research* 20:1176-1182.
- Eseneowo, 1. K and Ugwumba. A. A., 2010. Composition and Abundance of Macrobenthos in Majidun River Ikorodu Lagos State Nigeria. *Research Journal of Biological Science*, 5(8):556-560.
- Giller, P.S. and Malmsqvist, B., 1998. *The biology of streams and rivers*. New York: Oxford University Press.
- Griffith, M.B., Hill, B., McCormick, H., Kaufmann, R, Herlihy, T. and Selle, A.R., 2005. Comparative application of indices of biotic integrity based on periphyton, macro invertebrates and fish to Southern Rocky mountain streams. *Ecological Indices*, 5:117-136.
- Hannien, J., Vuorinen, H., Kirkkala, T., and Lehti L., 2000. Trends and Gradients in Nutrients Concentration and Loading in the Archipelago Sea, Northern Baltic, *Shelf Science*, 50:153 – 171.
- Harrison, A.D. and Hynes, H.B.N., 1988. Benthic fauna of Ethiopian mountain streams and rivers. *Hydrobiology*, 1:1-36
- Hart, A. L., 1999. Temporal distribution of benthic fauna in a mangrove forest of the bonny estuary, Nigeria. *Journal of Science and Environmental Management*, 3:65-70.
- Herraman, J., 1999. Freshwater biodiversity and ecosystem functions; ideas and the case river eman. in: Friberg, N. and Carl, J.D. (Eds), *Biodiversity in Benthic Ecology*. Proceeding of Nordic Benthological Meeting, Silkeborg, Denmark. Technical Report, 266:11-28.

- Howick, G. L. and Wilhm, J., 1984. Zooplankton and Benthic Macro invertebrates in Lake Carl Black-Well. Proceeding of Oklahoma Academy of Science, 64: 63-65.
- Hynes, H.B.N., 1970. The ecology of running waters. Liverpool: Liverpool University Press. 284p.
- Idowu, E.O. and Ugwumba, A.A., 2005. Physical, Chemical and Benthic Faunal characteristic of a Southern Nigerian Reservoir, Article in African Zoology, 5: 15-25.
- Jimoh, A.A., Clarke, E. O., Whenu, O.O. and Adeoye, H.B., 2011. Food and feeding habits of the African river prawn (*macrobrachium vollenhovenii*) in Epe Lagoon. South west Nigeria. International Journal of Fisheries and Aquaculture, 3(1):10-15.
- Job, B. E., 2019. Assessment of phytoplankton species composition, abundance and diversity within the Itu bridge-end area of the lower Cross River System, Nigeria. International Journal of Fisheries and Aquatic Studies, 7(4):398-405.
- Kalff, J., 2002. Limnology: Inland water ecosystems. New Jersey: Prentice Hall Inc. 308p.
- Karlson, K., Rosenberg, R. and Bonsdorff, E., 2002. Temporal and Spatial large scale effect of eutrophication and oxygen deficiency on benthic fauna in Scandinavian and Baltic waters. A Review of Oceanography. Marine Biology, 40: 427 – 489.
- Kripa, P. K., Prusanth, K. M., Sreejesh, K. K. and Thomes, T. P., 2013. Aquatic Macroinvertebrates as Bioindicators of stream water quality. A case study in Koratty. Kerala. India. Research Journal of Research of Recent Sciences, 2:217-222.
- Narita, T., Hossain, M. and Sekiguchi, H., 2003. Seasonal and Inter Annual variation in biomass and abundance of Megabenthos in Ise Bay. Central Japan Benthos Research, 58(1): 75-85.
- Ngodhe, S.O., Phillip, O.R., and Alfred, A., 2014. Impact of water quality on species diversity and richness of macro invertebrates. Journal of Ecology and the Natural Environment. P, 34.
- Odo, G. E., Inyang, N. M., Ezenwaji, H. M. G. and Nwani, C. D., 2007. Macroinvertebrate Fauna of a Nigerian Freshwater Ecosystem. Animal Research International, 4 (1): 611-616.
- Okorafor, K. A., Andem, A. B., Okete, J. A. and Ettah, S. E., 2012. The composition, distribution and abundance of macro invertebrates in the shores of the great Kwa River, Cross River State, South-East, Nigeria. European Journal of Zoological Research, 1(2):31-36.
- Pringle, C. M., Scatena, F. N., Paaby-Hansen, P. and Nunez-Ferrera, M., 2000. River conservation in Latin America and the Caribbean. In: Boon, P. J., Davies, B. R. and Petts, G. E. (Eds.). Global perspectives on river conservation: science, policy and practice. Chichester: John Wiley and sons, Ltd. 406p.
- Rashid Rafia, and Pandit K. Ashok, 2014. Review on Macro invertebrates as indicators of pollution. Journal of Ecology and Natural Environment 6(4): 140-144.
- Rostgaard S. and Jacobsen, D., 2005. Respiration rate of stream insects measured insitu along a large altitude range. Hydrobiologia 459: 79-98.
- Saad, M. A., Amuzu, A. T., Biney, C., Calamari, D., Imevbore, A. M., Nazve, H. and Ochumba, P. B., 1994. Domestic and industrial organic loads. In: Review of pollution in the African aquatic environment CIFA Technical paper FAO/UN. 25: 23 -27.
- Salveit, O. M. and Snook, C. U., 2001. Effect of Hoods versus low flows on invertebrates in New Zealand gravel - Bed River. Fresh Water Biology, 51:2207-2227.
- Sharma, S., Joshi, V., Kurde, S. and Singh, M. S., 2010. Biodiversity and Abundance of Benthic macroinvertebrate Communities. Researcher, 2 (10): 57-67.
- Sharma, S., Sudha, D. and Dave, V., 2013. Macro-invertebrate Community Diversity in relation to water quality. Discovery Publication: 3 (9): 40 - 46.
- Shieh, S.A. and Yang, P. S., 2000. Community structure and functional organization of aquatic insects in an agricultural mountain of Taiwan. Zoological Studies, 39:191-202.
- Shubhanath, B., 2002. Physico-chemical and microbial analysis of water and soil samples in proposed coal mine area at latehar. Baroni 2017 and AGU 1995.
- Smith, R. L. (1974). Ecology and field biology. Second edition. New York: Harper and Row, Publishers, Incorporated.



- Uwem, G. U., Ekanem, P. A. and George, E., 2011. Food and feeding habits of *Ophiocephallus obscura* (African snake head) in the Cross River estuary, Cross River state, Nigeria. *International Journal of Fisheries and Aquaculture*, 3(13): 231-238.
- Wallace, J. B. and Webster, J. R., 1996. The role of macroinvertebrate in stream ecosystem function. *Annual Reviews Entomology*, 41:115-139.
- Winterbourn, M. J., 1999. New Zealand stream ecosystems really different? *N. Z. J. Mar. Freshwater Res.* 15:321-328.
- Wishart, M.J., Davies, B.R., Boon, P. J. and Pringle, C.M., 2000. Global disparities in river conservation: "First World" values and "third world" realities. In: Boon, P.J., B.R. Davies and G.E. Petts, (Eds.). *Global Perspectives on River Conservation: Science, Policy and Practice*. Chichester: John Wiley and sons, Ltd., 353-369.
- Woke, G. N., Aleleye, A. and Wokoma, I. P., 2007a. Composition and Abundance of Benthic Macro-invertebrates of NTA-WOGBA Stream, Port Harcourt, Nigeria *Global Journal of Pure and Applied Sciences*, 13(3), 353-357.
- Woke, G. N., Aleleye, A. and Wokoma, I. P., 2007b. Effect of Organic Waste Pollution on the Macro-benthic Organisms of Elechi Creek Port Harcourt, Nigeria *African Journal of Applied Zoology and Environmental Biology*, 9, 26-30.