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Tropical Climate Ecology and Water Quality Interactions: Evaluating Physico-Chemical Influences on Benthic Macroinvertebrate Assemblages in the Great Kwa River, Calabar

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Abstract
This study investigates how tropical climate-driven water quality variations influence benthic macroinvertebrate assemblages in the Great Kwa River, Calabar. Twenty physicochemical parameters were measured across three stations from October 2024 to March 2025, these include temperature (27.16–27.2 °C), pH (5.97–6.03), dissolved oxygen (7.33–46.6 mg/L), turbidity (11.75–22.13 NTU), conductivity (15.0–95.6 mg/L), BOD (6.27–7.05 mg/L), nutrients such as nitrate (4.99–7.30 mg/L), nitrite (0.06–2.08 mg/L), ammonia (0.26–0.50 mg/L), and phosphorus (2.44–19.31 mg/L); other parameters including chromium, iron, and manganese, showed no significant variation ($p < 0.05$). A total of 184 macroinvertebrates, representing 3 phyla, 6 classes, 11 orders, and 19 species, were recorded. Gastropoda (33.15%) was dominant, followed by Insecta (25%) and Crustacea (20.65%), while Annelids were the least represented. Station 2 showed the highest taxa richness (17 taxa; 78 individuals), compared with Stations 1 (15 taxa; 57 individuals) and 3 (15 taxa; 49 individuals). Diversity indices revealed the lowest richness at Station 1 (Margalef's index 3.51) and the highest at Station 2 (3.74). The observed physico-chemical conditions and faunal patterns, particularly at Stations 1 and 2, suggest substantial organic pollution linked to anthropogenic activities. Regular monitoring and stricter pollution control measures are recommended to safeguard tropical aquatic biodiversity and ecosystems.

Keywords: Benthic macroinvertebrates**, p**hysico-chemical parameters**, t**ropical river ecology**, w**ater quality**, b**ioindicators

Introduction

Benthic macroinvertebrates are aquatic organisms without backbones that inhabit or burrow into bottom sediments and are visible without magnification. They play crucial ecological roles in mineralization, sediment mixing, nutrient cycling, and oxygen flux, thereby sustaining aquatic ecosystem functioning (George *et al*., 2009). Their distributions are strongly influenced by physico-chemical factors such as substrate type, depth, nutrient load, stability, and dissolved oxygen (Sharma *et al*., 2013). Because of their differential sensitivity to environmental stressors, macroinvertebrates are widely recognized as reliable bioindicators for evaluating water quality, eutrophication, and pollution (Barbosa *et al*., 2001; Adakole & Annune, 2003; Arimoro *et al*., 2007).

In tropical regions, aquatic ecosystems are increasingly threatened by climate change, population growth, and unregulated urban expansion, which alter riparian vegetation, increase nutrient and pollutant loading, and reduce habitat heterogeneity (Xu *et al*., 2013; Zhang *et al*., 2013). These pressures often degrade water quality and diminish sensitive taxa, leading to shifts in macroinvertebrate community structure (Tchakonté *et al*., 2014). Recent studies highlight that tropical rivers, due to their climatic variability and high ecological productivity, are particularly vulnerable to such disturbances (Alade *et al*., 2021; Dalu *et al*., 2022).

Macroinvertebrate responses, including shifts in abundance, diversity, and species richness, offer integrative insights into both short- and long-term ecological stress, capturing intermittent discharges and sub-lethal contaminant effects that may be undetectable by physico-chemical monitoring alone (Suozzo, 2006; USEPA, 2005). Thus, combining physico-chemical assessments with macroinvertebrate bioassessment provides a more comprehensive understanding of river health, especially under tropical climatic conditions where seasonal variability can drive rapid ecological changes (Kaaya *et al*., 2021; Kaboré *et al*., 2023).

The Great Kwa River in Calabar, South-South Nigeria, is a vital tropical freshwater system that supports biodiversity and local livelihoods but is increasingly impacted by domestic effluents, land-use change, and other anthropogenic pressures. Understanding how physico-chemical dynamics affect macroinvertebrate assemblages in this river is therefore critical for tropical freshwater ecology, biodiversity conservation, and sustainable water management. This study uniquely integrates tropical climate dynamics, water quality variability, and macroinvertebrate assemblages to assess the Great Kwa River ecosystem health. Assessing the influence of selected physico-chemical parameters on the composition, distribution, and abundance of benthic macroinvertebrates across three stations (Esuk Atu, Obufa Esuk, and Anantigha) of the Great Kwa River.

Methodology

The Great Kwa River is one of the major tributaries of the Cross River Estuary. It originates from the Oban Hills in Aningheje, Cross River State, Nigeria, and flows southwards to discharge into the Cross River Estuary around latitude 4°45′N and longitude 8°20′E (Akpan, 2000). The lower reaches of the river drain the eastern coast of Calabar Municipality, the capital of Cross River State. The study was conducted from October 2024 to March 2025. Three sampling stations, ~2 km apart, were selected: Obufa Esuk (fishing), Esuk Atu (domestic use), and Anantigha (industrial discharge) (Figure 1). The ecology of the river is increasingly under threat from anthropogenic activities, including farming, fishing, and sand mining.
The region experiences a tropical climate characterized by a long wet season and a relatively short dry season. The cool dry season extends from October to February, followed by a hot dry season from March to April, and a rainy season from May to September. Temperatures remain relatively stable throughout the year, with mean annual values ranging between 25°C and 28°C.

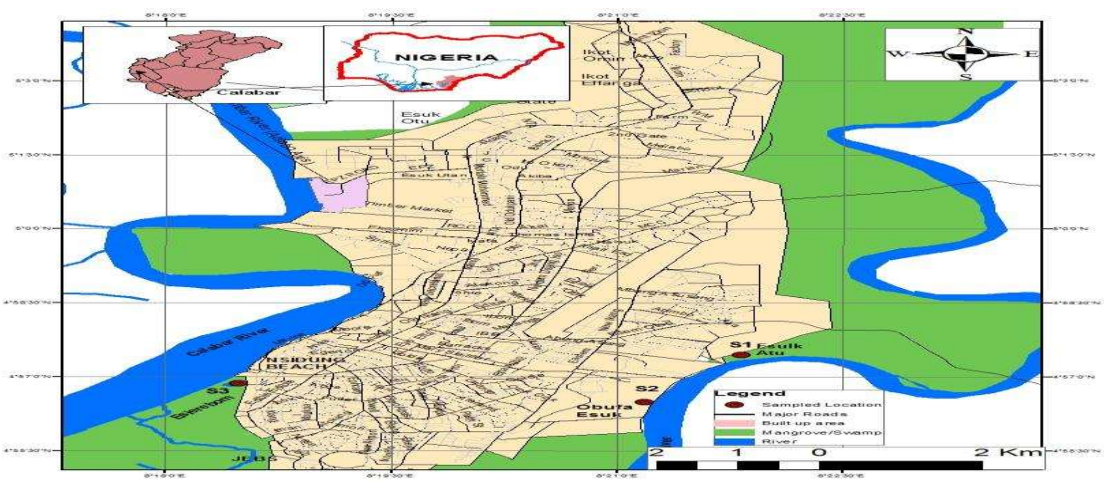

Figure 1. Map of the study area

Sample Collection

Collection of Benthic Macroinvertebrates

Benthic macroinvertebrates were collected using the kick sampling technique as described by Lenat *et al.* (1994). This method involved vigorously disturbing the substratum and emergent vegetation upstream by kicking, allowing the current to wash dislodged organisms into a downstream metal hand net with a mesh size of 0.05 µm (Lenat *et al.,* 1994).

Additionally, a scoop net of the same mesh size (0.05 µm) was used to collect organisms directly from the water column. The net was dipped and swept through the water, after which the captured macroinvertebrates were transferred into clean plastic containers and preserved with 10% formalin. Identification and taxonomic grouping were carried out using standard identification keys and manuals, including those provided by the Environmental Protection Agency (EPA) and the Natural Resources Management Board, Australia (NRM, 2010).

Collection and Determination of Physico-chemical Parameters

Physico-chemical parameters were assessed monthly at each of the three sampling stations over a period of three months (August–October 2015). Water samples were collected in clean, labelled plastic bottles between 07:00 and 08:00 hours. The following parameters were analyzed:

In situ measurements of water quality parameters: water quality parameters were conducted at the sampling sites using standard portable meters. Water temperature and pH were determined using a Hanna Instruments portable pH/Temperature Meter (HI98127, pHep®4, USA). Dissolved oxygen (DO) was measured with a YSI Pro20 Dissolved Oxygen Meter (YSI Inc., USA), while alkalinity was assessed using a Hach Digital Titrator (Model 16900, Hach Company, USA). Turbidity was determined with a Hach 2100Q Portable Turbidimeter (Hach Company, USA), and electrical conductivity (EC) was measured using a Hanna Instruments Conductivity Meter (HI99300, Italy). Biochemical oxygen demand (BOD) was estimated with a Hach HQ40d Multiparameter Meter fitted with a BOD probe (Hach Company, USA). Total hardness was analyzed using a LaMotte Water Hardness Test Kit (Model 3609, LaMotte Company, USA), while salinity was determined using YSI Pro30 Salinity/Conductivity Meter (YSI Inc., USA).

Laboratory analyses: nitrate, nitrite, ammonia, phosphorus, calcium, phosphate, magnesium, chromium, potassium, iron, chloride, and manganese concentrations were determined using a UV–visible spectrophotometer (HACH DR/5000) following standard methods for water and wastewater analysis.

Statistical Analysis: Invertebrate fauna diversity was assessed using Margalef's Species Richness Index (d), Shannon–Wiener Diversity Index (H′), and the Equitability (Evenness) Index (E).

Margalef's Species Richness Index (d): This index measures species richness and is expressed as:

$$d = \frac{S-1}{\ln N} \quad \text{……………………….. eqtn 1}$$

Where:

d = Species richness index

S = Total number of species recorded

N = Total number of individuals in the population

Shannon–Wiener Diversity Index (H′): This index reflects both species richness and the evenness of distribution. It is calculated as:

$$H = \frac{N \ln N - \sum f_i \log f_i}{N} \quad \text{……………………………. eqtn2}$$

Where:

H′ = Shannon–Wiener diversity index
f_i = Number of individuals of the i^{th} species
N = Total number of individuals in the population
ln = Natural logarithm

Equitability (Evenness) Index (E): This index measures how evenly individuals are distributed among the species present (Ogbeibu, 2005, Jimmy *et al*., 2022) and is expressed as:

$$E = \frac{H}{\ln s} \quad \text{……………………………. eqtn3}$$

Where:

E = Equitability index
H′ = Shannon–Wiener diversity index
S = Number of species in the population

Results

Physico-Chemical Characteristics of the Great Kwa River

The mean values of water temperature across the three sampling stations were similar: Station 1 (27.16 ± 0.93 °C), Station 2 (27.16 ± 0.95 °C), and Station 3 (27.20 ± 1.07 °C). Statistical analysis revealed no significant differences in temperature among the stations ($p > 0.05$). Similarly, pH values showed no significant variation, with mean values of 6.03 ± 0.12 at Station 1, 5.97 ± 0.33 at Station 2, and 6.02 ± 0.13 at Station 3. The highest mean dissolved oxygen (DO) concentration was recorded at Station 3 (46.6 ± 24.16 mg/L), whereas Stations 1 and 2 had lower but comparable values. Mean alkalinity values were similar across stations, ranging from 7.75 ± 0.32 mg/L at Station 1 to 7.89 ± 0.35 mg/L at Station 2, and 7.76 ± 0.15 mg/L at Station 3 (Table 1).

Turbidity varied across stations, with mean values of 11.75 ± 5.55 NTU (Station 1), 22.13 ± 14.32 NTU (Station 2), and 15.70 ± 9.63 NTU (Station 3). Conductivity was highest at Station 3 (95.6 ± 49.20 mg/L), while Stations 1 and 2 recorded much lower values (15.18 ± 1.51 mg/L and 15.00 ± 0.76 mg/L, respectively).

Biochemical Oxygen Demand (BOD) values ranged from 6.27 ± 0.90 mg/L at Station 2 to 7.05 ± 0.20 mg/L at Station 1. Water hardness was also comparable across sites: Station 1 (22.8 ± 5.60 mg/L), Station 2 (17.1 ± 0.00 mg/L), and Station 3 (28.5 ± 11.40 mg/L), with no significant differences observed ($p > 0.05$).

Nutrient concentrations varied among stations. Nitrate concentrations were 5.18 ± 0.89 mg/L (Station 1), 4.99 ± 0.69 mg/L (Station 2), and 7.30 ± 1.12 mg/L (Station 3). Nitrite concentrations ranged from 0.06 ± 0.00 mg/L (Station 1) to 2.08 ± 2.06 mg/L (Station 2), with Station 3 recording 0.07 ± 0.00 mg/L. Ammonia levels were low across all stations: 0.26 ± 0.13 mg/L (Station 1), 0.32 ± 0.15 mg/L (Station 2), and 0.50 ± 0.18 mg/L (Station 3). The highest mean phosphorus concentration was observed at Station 1 (19.31 ± 11.16 mg/L), followed by Station 2 (7.00 ± 0.75 mg/L) and Station 3 (2.44 ± 0.96 mg/L). Among the major ions, calcium concentrations were similar across stations, ranging from 2.85 ± 0.60 mg/L (Station 3) to 3.17 ± 0.43 mg/L (Station 2). Magnesium concentrations were highest at Station 3 (25.1 ± 10.31 mg/L), compared to Station 1 (14.08 ± 0.56

mg/L) and Station 2 (13.93 ± 0.43 mg/L). Trace metal concentrations showed low variability. Chromium levels ranged between 0.023 ± 0.00 mg/L (Station 1) and 0.062 ± 0.006 mg/L (Station 3), with no significant differences among stations ($p > 0.05$). Potassium was highest at Station 2 (12.78 ± 7.61 mg/L), followed by Station 1 (10.9 ± 6.21 mg/L) and lowest at Station 3 (3.41 ± 0.21 mg/L). Iron concentrations were relatively uniform: 1.58 ± 0.53 mg/L (Station 1), 1.40 ± 0.19 mg/L (Station 2), and 1.57 ± 0.22 mg/L (Station 3).
Chloride concentrations varied from 10.2 ± 5.38 mg/L at Station 3 to 20.1 ± 10.67 mg/L at Station 1. Manganese concentrations were lowest at Station 2 (0.87 ± 0.43 mg/L) and highest at Station 3 (1.37 ± 0.68 mg/L), with Station 1 recording an intermediate value of 1.07 ± 0.55 mg/L. Overall, differences in most parameters across stations were not statistically significant ($p > 0.05$) (Table 1).

Table 1. Mean (±SD) values of physicochemical parameters across three sampling stations of the Great Kwa River.

Parameter	Esuk Atu (S1)	Obufa Esuk (S2)	Anantigha (S3)	Sig. (p-value)
Temperature (°C)	27.16 ± 0.93^{a}	27.16 ± 0.95^{a}	27.20 ± 1.07^{a}	0.98
pH	6.03 ± 0.12^{a}	5.97 ± 0.33^{a}	6.02 ± 0.13^{a}	0.97
Dissolved Oxygen (mg/L)	7.33 ± 0.66^{a}	7.33 ± 0.33^{a}	46.60 ± 24.16^{b}	0.15
Alkalinity (mg/L)	7.75 ± 0.32^{a}	7.89 ± 0.35^{a}	7.76 ± 0.15^{a}	0.87
Turbidity (NTU)	11.74 ± 5.55^{a}	22.13 ± 14.32^{a}	15.70 ± 9.63^{a}	0.78
Conductivity (µS/cm)	15.18 ± 1.51^{a}	15.00 ± 0.76^{a}	95.60 ± 49.20^{b}	0.14
BOD (mg/L)	7.05 ± 0.20^{a}	6.27 ± 0.90^{a}	6.95 ± 0.54^{a}	0.64
Hardness (mg/L)	22.80 ± 5.60^{a}	17.10 ± 0.00^{a}	28.50 ± 11.40^{a}	0.57
Nitrate (mg/L)	5.18 ± 0.89^{a}	4.99 ± 0.69^{a}	7.30 ± 1.12^{a}	0.22
Nitrite (mg/L)	0.06 ± 0.06^{a}	2.08 ± 2.06^{b}	0.07 ± 0.00^{a}	0.42
Ammonia (mg/L)	0.26 ± 0.13^{a}	0.32 ± 0.15^{a}	0.50 ± 0.18^{a}	0.58
Phosphorus (mg/L)	19.31 ± 11.16^{a}	7.00 ± 0.75^{b}	2.44 ± 0.96^{c}	0.24
Calcium (mg/L)	3.02 ± 0.56^{a}	3.17 ± 0.43^{a}	2.85 ± 0.60^{a}	0.90
Phosphate (mg/L)	20.41 ± 10.71^{a}	7.79 ± 1.32^{b}	2.84 ± 1.36^{c}	0.20
Magnesium (mg/L)	14.08 ± 0.56^{a}	13.93 ± 0.43^{a}	25.10 ± 10.31^{b}	0.37
Chromium (mg/L)	0.023 ± 0.00^{a}	0.038 ± 0.14^{a}	0.062 ± 0.006^{b}	0.06
Potassium (mg/L)	10.90 ± 6.21^{a}	12.78 ± 7.61^{a}	3.41 ± 0.21^{b}	0.50
Iron (mg/L)	1.58 ± 0.53^{a}	1.40 ± 0.19^{a}	1.57 ± 0.22^{a}	0.92
Chloride (mg/L)	20.10 ± 10.67^{a}	13.30 ± 6.74^{a}	10.20 ± 5.38^{a}	0.68
Manganese (mg/L)	1.07 ± 0.55^{a}	0.87 ± 0.43^{a}	1.37 ± 0.68^{a}	0.82

Note: Values sharing the same superscript letters within a row are not significantly different (Tukey's HSD, $p < 0.05$).

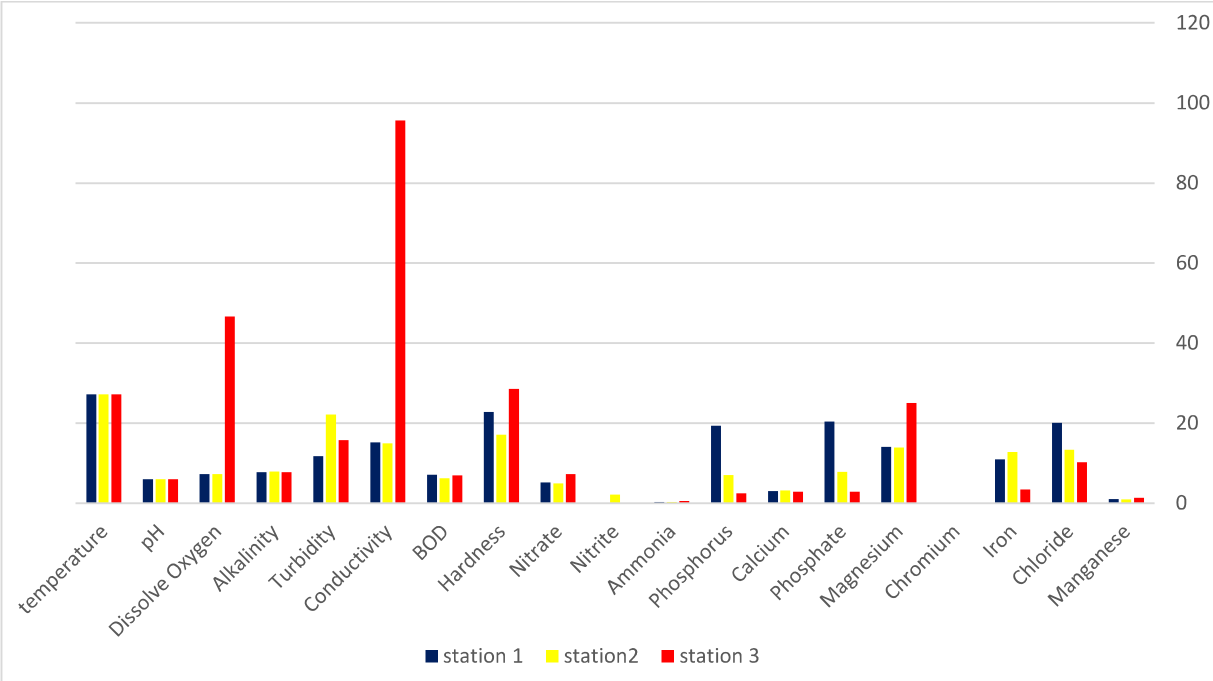

Figure 2: Water sample physicochemical parameters mean value variation of the three sample stations.

Macroinvertebrate Community Structure across Sampling Stations

The macroinvertebrate community of the Great Kwa River comprised 184 individuals belonging to 19 taxa across the three stations. Obufa Esuk (S2) recorded the highest abundance (78 individuals, 17 taxa), followed by Esuk Atu (S1) with 57 individuals (15 taxa), while Anantigha (S3) had the lowest abundance (49 individuals, 15 taxa) (Table 2). The percentage distribution and abundance of the macroinvertebrate classes in the different stations is shown in Table 3 and Figure 3. Across phyla, Arthropoda (Insecta and Crustacea) contributed the largest share of species, with insect larvae such as Diptera (blackflies, craneflies, horsefly maggots) and Coleoptera (water beetles) well represented. The decapods, especially crayfish (Palaemonidae) were particularly dominant (33 individuals; 17.93% of total). Within Annelida, earthworms (Lumbriculidae) were moderately abundant (19 individuals; 10.32%), while leeches (Haemopis sp.) were also widely distributed across stations (17 individuals; 9.23%). The Mollusca (Gastropoda) group was important, with *Tympanotonus fuscatus* (periwinkle) emerging as one of the most abundant single taxa (30 individuals; 16.30%), distributed across all stations.

Community distribution varied slightly among stations, at Esuk Atu (S1), periwinkles (*T. fuscatus*) and crayfish were dominant, each contributing ~19% of the assemblage. At Obufa Esuk (S2), crayfish were markedly abundant (23.07%) alongside periwinkles (11.53%). At Anantigha (S3), periwinkles (20.40%) were most dominant, while insect groups such as mayflies (*Ephemeroptera*) and caddisflies (*Trichoptera*) were relatively more common than in other stations.

Table 2. Species composition, distribution and abundance of macroinvertebrates across the three sampling stations of the Great Kwa River.

Phylum / Class	Taxa	Common Name	Esuk Atu (S1) No. (%)	Obufa Esuk (S2) No. (%)	Anantigha (S3) No. (%)	Total No. (%)
Arthropoda						
Insecta	Diptera: Simuliidae sp.	Blackfly	2 (3.50)	2 (2.56)	3 (6.12)	7 (3.80)
	Arthericidae sp.	Cranefly	1 (1.75)	1 (1.28)	–	2 (1.08)
	Tabanidae sp.	Horsefly maggot	2 (3.50)	2 (2.56)	–	4 (2.17)
	Coleoptera: Psephenidae sp.	Water penny	2 (3.50)	1 (1.28)	–	3 (1.63)
	Cybister sp.	Water beetle	4 (7.01)	5 (6.41)	1 (2.04)	10 (5.43)
	Hydrophilidae sp.	Scavenger beetle	1 (1.75)	3 (3.84)	–	4 (2.17)
	Odonata: Libellulidae	Dragonfly larva	–	3 (3.84)	2 (4.08)	5 (2.71)
	Trichoptera: Leptoceridae	Caddisfly	–	–	3 (6.12)	3 (1.73)
	Ephemeroptera: Ephemeridae sp.	Burrowing mayfly	1 (1.75)	–	4 (8.16)	5 (2.71)
	Plecoptera: Neoparis sp.	Stonefly	–	1 (1.28)	2 (4.08)	3 (1.63)
Crustacea (Malacostraca)	Decapoda: Palaemonidae	Crayfish	11 (19.29)	18 (23.07)	4 (8.16)	33 (17.93)
	Callinectes amnicola	Crab	1 (1.75)	3 (3.84)	1 (2.04)	5 (2.71)
Annelida						
Hirudinea: Haemopis sp.	Leeches	4 (7.01)	8 (10.25)	5 (10.20)	17 (9.23)	
Polychaeta: Capitella sp.	Bristle worm	–	2 (2.56)	1 (2.04)	3 (1.63)	
Oligochaeta: Lumbriculidae	Earthworm	7 (12.28)	6 (7.69)	6 (12.24)	19 (10.32)	

Mollusca						
Gastropoda: Tympanotonus fuscatus	Periwinkle	11 (19.29)	9 (11.53)	10 (20.40)	30 (16.30)	
	Lymnaea sp.	Snail	1 (1.75)	4 (5.12)	2 (4.08)	7 (3.80)
	Pachymelaria fusca	Periwinkle	5 (8.77)	6 (7.69)	3 (6.12)	14 (7.60)
	Neritina sp.	Snail	4 (7.01)	4 (5.12)	2 (4.08)	10 (5.43)
	Total Number of Taxa		**15**	**17**	**15**	**19**
	Total Number of Individuals		**57 (100)**	**78 (100)**	**49 (100)**	**184 (100)**

Table 3: Percentage Composition of Macro-Invertebrate Classes in The Sampling Stations

Class	Station 1	Station 2	Station 3	Total
Gastropoda	34.42	37.70	27.86	33.15
Insecta	28.26	39.13	32.60	25
Malacostraca	31.57	55.26	13.15	20.65
Oligochaeta	36.84	31.57	31.57	10.32
Hirudinea	23.52	47.05	29.41	9.23
Polychaeta	-	66.66	33.33	1.63

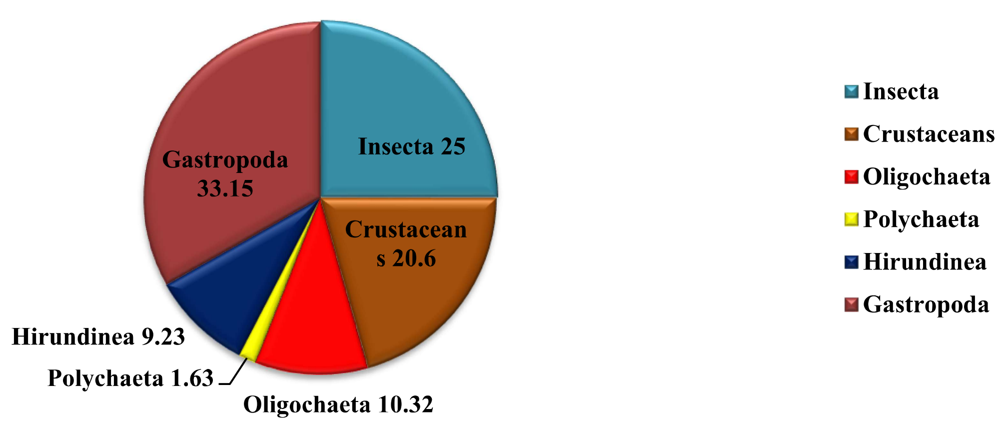

Figure 3: Percentage distribution of invertebrate classes.

Diversity Patterns of Benthic Macroinvertebrates across Stations

The diversity indices of benthic macroinvertebrates across the three study stations (Table 4) revealed noticeable spatial variation in species richness, diversity, and evenness. Taxa richness, as measured by Margalef's index, was lowest at Esuk Atu (S1: 3.51) but peaked at Obufa Esuk (S2: 3.74), with Anantigha (S3: 3.61) occupying an intermediate position. This indicates that Obufa Esuk supported a relatively wider range of taxa compared to the other two stations.

The Shannon–Wiener diversity index (H′), which accounts for both richness and abundance distribution, followed a similar trend. Station 2 (1.35) exhibited the highest diversity, suggesting a more complex and balanced community structure, whereas Station 3 (1.08) had the lowest, reflecting reduced species heterogeneity. Station 1 (1.23) showed moderate diversity.

Equitability (E), which measures the evenness of species distribution, varied among stations. The lowest evenness was observed in Station 3 (0.388), implying dominance by a few taxa. In contrast, Station 2 (0.477) had the highest evenness, closely followed by Station 1 (0.453), suggesting a more balanced distribution of individuals among species at these locations.

The results demonstrate that Obufa Esuk (S2) maintained comparatively higher richness, diversity, and evenness, indicating a healthier and more stable benthic macroinvertebrate community. In contrast, Anantigha (S3) appeared more stressed or disturbed, given its lower diversity and evenness values.

Table 4. Diversity indices of benthic macroinvertebrates at three stations on the Great Kwa River (pooled monthly samples).

Index	Esuk Atu (S1)	Obufa Esuk (S2)	Anantigha (S3)	Total
Margalef's richness, *d*	3.51	3.74	3.61	3.45
Shannon-Wiener, *H′* (ln)	1.229	1.350	1.084	1.139
Evenness, *E* (= *H′*/ln*S*)	0.453	0.477	0.388	0.387

Total = index calculated on the combined assemblage across all stations.

Discussion

Rivers are dynamic ecosystems whose ecological health depends on the interplay between physico-chemical conditions and the biological communities they support (Wetzel, 2001; Allan & Castillo, 2007). Benthic macroinvertebrates are widely applied as bioindicators due to their varying sensitivity to pollution and habitat alteration (Dudgeon, 2008).

The physico-chemical profile of the river reflected relatively stable conditions typical of tropical rivers, with minimal variation in temperature between stations. This uniformity is expected in southern Nigeria's tropical climate, where seasonal thermal fluctuations are small, thereby supporting year-round biological activity (Dudgeon, 2008). The slightly acidic pH (5.9–6.1) observed across sites reflects findings from other rainforest rivers influenced by organic matter decomposition and leaching (Ogbeibu & Oribhabor, 2002). While these values are within the tolerance limits for many aquatic organisms, more pH-sensitive taxa may be constrained in their distribution.

Dissolved oxygen (DO) varied across stations, with particularly high values at Station 3. Although anomalously high DO readings (>40 mg/L) may reflect analytical error, oxygen enrichment in flowing tropical rivers is often linked to turbulence and photosynthetic activity (Allan & Castillo, 2007). Conductivity and nutrient concentrations also varied spatially, with higher ion levels at Station 3, possibly linked to runoff, erosion, or anthropogenic inputs. Phosphorus levels were elevated at Station 1, suggesting inputs from domestic or agricultural sources along the riverbanks. Similar patterns of nutrient enrichment driving ecological change have been reported in the Warri River (Arimoro & Ikomi, 2009). While most trace metals were low, slightly elevated chromium at Station 3 indicates potential anthropogenic influence. Such enrichment, even at low levels, can affect benthic fauna due to the bio-accumulative nature of metals (Reynolds, 2006).

The macroinvertebrate assemblages revealed moderate richness, comprising 184 individuals across 19 taxa. Arthropods, especially decapods (Palaemonidae crayfish) and insect larvae (Diptera, Coleoptera, Odonata), were dominant. This mirrors findings from Niger Delta rivers where decapods and insects formed the bulk of benthic fauna (Ogbeibu & Oribhabor, 2002). Gastropods such as *Tympanotonus fuscatus* were also abundant, consistent with their wide distribution and tolerance of varied conditions. Conversely, more sensitive groups such as Ephemeroptera, Trichoptera, and Plecoptera (EPT taxa) were less represented, indicating environmental conditions that may not fully support sensitive assemblages. This agrees with Dudgeon (2008), who noted that tropical rivers generally support fewer EPT taxa compared to temperate systems.

Spatial differences were evident: Obufa Esuk (S2) recorded the highest taxa richness and abundance, while Anantigha (S3) had the lowest. Diversity indices confirmed this, with Margalef's index and Shannon–Wiener values peaking at S2 (3.74 and 1.35, respectively), followed by moderate values at S1, and lowest values at S3. Evenness followed the same trend, with S3 showing higher dominance of a few tolerant taxa. This pattern suggests that S2 provides relatively stable ecological conditions, while S3 may be more disturbed, despite higher conductivity and nutrient levels. The mismatch between nutrient enrichment and diversity at S3 suggests that excess inputs may be linked to habitat degradation, suppressing sensitive taxa rather than enhancing productivity.

These findings align with Arimoro & Ikomi (2009), who reported that nutrient enrichment in the Warri River favored tolerant macroinvertebrates at the expense of sensitive groups. Similarly, Ogbeibu & Oribhabor (2002) observed gastropod and decapod dominance in impacted Niger Delta river. In contrast, temperate rivers often report higher representation of EPT taxa, highlighting how both biogeographic differences and anthropogenic pressures shape macroinvertebrate assemblages (Allan & Castillo, 2007). The relatively high diversity at S2 despite moderate disturbance supports the intermediate disturbance hypothesis (Connell, 1978), which predicts that biodiversity is maximized under intermediate stress conditions that prevent dominance but do not eliminate sensitive taxa.

This study contributes baseline ecological data for the Great Kwa River, where such detailed benthic assessments are scarce. By integrating physicochemical conditions with macroinvertebrate structure, the study provides a holistic picture of river health. The dominance of gastropods and decapods, coupled with low EPT representation, underscores both resilience and vulnerability of tropical rivers to human pressures. Consistent with previous studies (Ogbeibu & Oribhabor, 2002; Arimoro & Ikomi, 2009), the results highlight how local anthropogenic activities and tropical climate dynamics strongly modulate aquatic community composition. The novelty of this work lies in establishing clear ecological linkages between water chemistry and benthic assemblages in a Nigerian estuarine tributary, providing a foundation for biomonitoring and conservation in the Cross River catchment.

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