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HUMAN-INDUCED IMPACT ON THE DISTRIBUTION AND DIVERSITY OF BENTHIC MACROINVERTEBRATES AND FISH FAUNA IN THE TROPICAL IKANG RIVER, NIGERIA

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ABSTRACT

South-eastern Nigeria's tropical water ecosystems typically consist of mangrove swamps and riparian forests, both of which have become endangered in the last six decades. The purpose of this research was to determine the extent of human-induced impact and activities on the effect of water quality on the distribution and diversity of benthic macroinvertebrates and fish fauna in the Tropical River (Ikang). The river's surface water, benthic macroinvertebrates, and fish fauna were sampled and identified to create a database of reference information. Twelve (12) species of benthic macroinvertebrates from two (2) phyla were identified. Station 1 had the highest benthic macroinvertebrate abundance of 58 (35.65%), while Station 3 had the lowest abundance of 52 (31.70%). *Uca tangeri* was the most abundant benthic macroinvertebrate with a percentage abundance of 28 (17.07%), while *Dinocras* sp., *Macromia* sp., and *Gomphus* sp. were the least abundant benthic macroinvertebrates with a percentage abundance of 3.66%. In addition, seven (7) fish species from six (6) families were identified. During the study, the family *Claroteidae* was the most abundant, while the family *Carangidae* was the least abundant. The temperature of the river had a positive correlation with the families *Carangidae* and *Mugilidae*, a negative correlation with the family *Clupeidae*, and no correlation with the family *Claroteidae*. Total dissolved solids (TDS) correlated positively with the families *Carangidae*, *Mugilidae*, and *Clariidae*, while conductivity correlated positively only with the family *Sciaenidae* and negatively with the families *Carangidae*, *Mugilidae* and *Clariidae*. The abundance and diversity of benthic macroinvertebrates and fish fauna were generally influenced by the physical and chemical characteristics of the water, the availability of food, and the extent of human impacts and activities. In order to ensure sustainable water quality and biodiversity conservation in our environment, it is necessary to manage the river and the surrounding ecosystem appropriately.

How to Cite

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INTRODUCTION

Physical, chemical, and biological properties that affect species composition, diversity, stability, production, and physiological conditions of indigenous populations are referred to as water quality criteria (Oyediran et al., 2017). The conservation of biological diversity is vital to human survival and well-being because wide species of plants, animals, and other organisms provide food, medicine, industrial raw materials, pest control, flood control, and natural waste recycling (Ekpo et al., 2011). According to Khan and Ishaq (2012), biodiversity is the variety of organisms in the world's biota. Cunningham et al. (2005) categorized biodiversity essential to ecological systems into three types: genetic biodiversity, which measures the variety of different versions of the same genes within individual species; species diversity, which measures biodiversity as the number of different kinds of organisms within individual communities or ecosystems; and ecological diversity, which measures biodiversity as the variety of ecosystems.

Over the past 60 years, environmental pollution from oil exploration, drilling, refining, and transportation of crude and other finished products, toxic contaminants (point and nonpoint sources), and hydrological system modification (damming and dredging) has endangered the mangrove swamps and riparian forests of south-eastern Nigeria's tropical water ecosystems (Amaeze and Onyema, 2014). The tropics are losing the most biological diversity due to rapid population growth, widespread poverty, rising demand for fuelwood, interspecies competition, overexploitation of species, habitat destruction, and lack of sustainable farming and forestry practices (Ayotunde and Ada, 2013), as well as climate change (Ekpo and Nzegblue, 2012). In the last 50 years, hundreds to thousands of the earth's species have been lost due to different human activities from habitat destruction for urbanization purposes to excessive loss of biodiversity (fauna and flora). Explosive human growth increased the demand for the consumption of biodiversity resources and services (Ekpo et al., 2011). Planktonic, pelagic, and benthic organisms live in aquatic environments. Benthic macroinvertebrates and vertebrate fauna in tropical waters have shown that a quantitative collection of key species from natural aquatic habitats can help estimate ecological parameters like species richness or evenness in diversity (Odo et al., 2007). The physical and chemical properties of the water and immediate substrate of occupation determine the emergence and distribution of macroinvertebrates and vertebrates (areas of water bottom occupied by the macroinvertebrate and fish). Aquatic species are greatly affected by water quality parameters like temperature, pH, dissolved oxygen, and nutrients. They affect species composition, distribution, diversity, stability, production, and physiological conditions of organisms (Sharma et al., 2013). Humans are the main cause of new changes in any ecosystem, and their effects can be small, subtle, big, or catastrophic (Karr, 2005). Plants, animals, and humans may suffer from these effects. Rural and urban communities use inland freshwaters like the Tropical River (Ikang) for domestic purposes. Many harmful activities to the river's inhabitants (fauna and flora) are done daily without a detailed investigation of their environmental effects. Several sections of the river are heavily dredged for sand, causing turbidity and waste discharge. This research study aims to investigate the degree of human impact and activities on the physicochemical parameters, distribution and biodiversity of benthic macroinvertebrate and fish fauna of the Ikang River.

MATERIALS AND METHODS

Description of the study area

The Ikang River is a tropical river in Bakassi Local Government Area of Cross River State, Nigeria. It is situated between latitude 04º 46.5’ 41.77” N and longitude 008º 33’ 8.65” E (Figure 1). The river serves as a link between Cameroon, Chad, and Equatorial Guinea. The river is surrounded by a dense swamp of trees. The river has a number of beaches, including Flying Boat Beach, Market Beach, Mkparawa Beach and Iyio Beach. Fishing, boat transportation, washing, bathing, sand dredging, buying, and selling, and other human activities take place along the river. Fishing, commercial business, and farming are the most common occupations.

Sampling stations

Three stations (1–3) were chosen along the river's shoreline.

Station One (S1)

This station is known as Flying Boat Beach, and it serves as the control site due to the limited activities taking place. The coordinates are 040° 47' 41.207" N and 0080° 32' 08.145" E, with a height of 9 m above sea level. The only obvious activity on this beach is boating.

Station Two (S2)

This station is known as Market Beach, and it serves as the first discharge point for all major trading, including abattoirs, landing sites for fishermen, farm products, lumbering, and firewood sales. The coordinates are 040º 47' 20.029" N and 0080º 32' 1.125" E, with an elevation of 8 m. The beach market is an archive of activities with a heavy load of pollution such as abandoned boats, plastic paper bags, broken glass, planks, public defecation, etc.

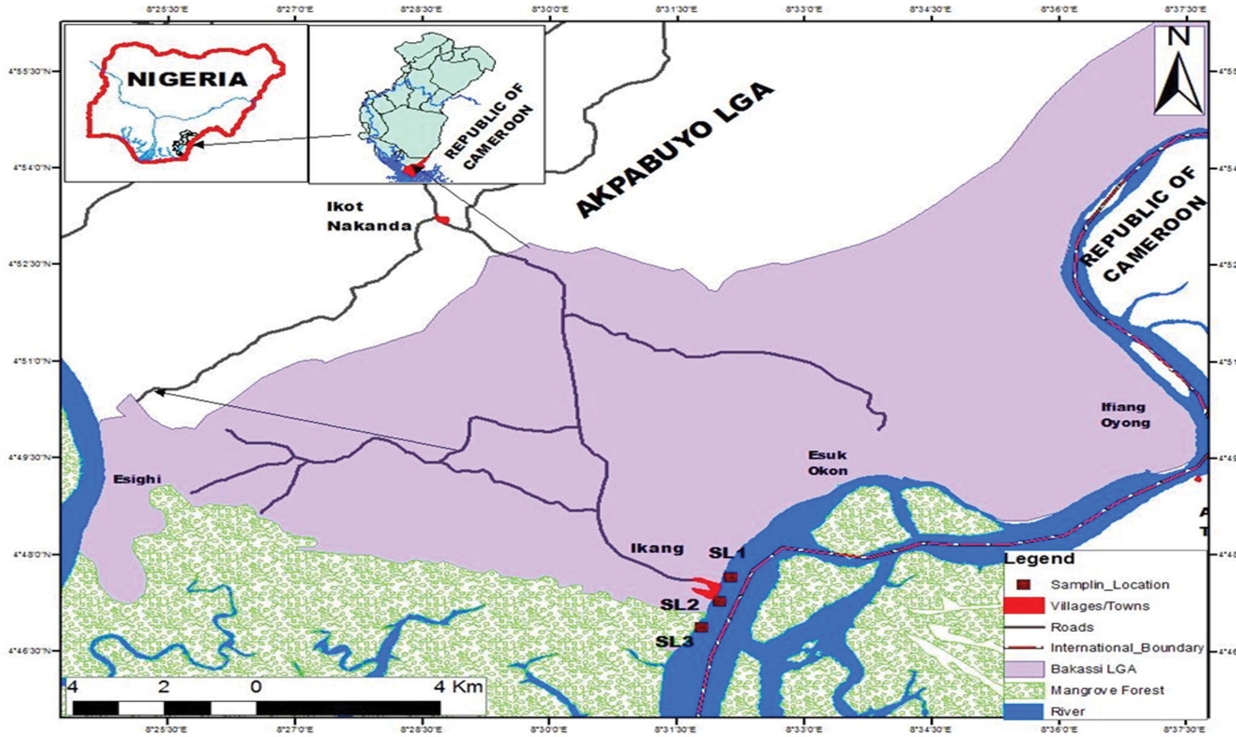

Fig 1. Map of study area with sampling stations

Station Three (S3)

This station is known as Mkparawa Beach and is the second discharge point. The coordinates are 040° 46' 56.027"N and 0080° 48.479" E, with an elevation of 8 m. The beach is the largest and busiest of the stations chosen, serving as a landing and departure point for both travellers and traders. Activities near the station include intensive farming, fishing, boat transportation, laundry, and swimming.

The assemblage of benthic macroinvertebrates

Benthic macroinvertebrate sampling was conducted monthly for six (6) months between February and July 2022. To avoid bias, measurements of 10 m by 10 m were marked out at each station prior to sampling. Within the designated area, macroinvertebrates were sampled using a sweeping net, a hand trowel, and a hand-picking technique. The sweeping net was used to collect aquatic insects, while the hand trowel and hand-picking method were used to collect sediment samples, which were then placed in labelled polyethylene bags and transported to the laboratory for sorting and analysis. In the laboratory, to collect macrobenthos, sediments were passed through three (3) sieves with mesh sizes of 2 mm, 1 mm, and 0.5 mm. The macrobenthos was emptied or poured into a white enamel tray, stained with Rose Bengal solution, and sorted with forceps. The assortment was done into groups and preserved in 4% formalin, while identification was done with the help of appropriate guides (Voshell, 2002; Nesemann et al., 2007).

Procedure for collecting fish samples

Fish samples were collected from the river with the assistance of local artisanal fishermen once a month for six (6) months using various types of traditional fishing gear such as cast nets (10 - 15 mm mesh size), drift nets (5 mm mesh size), gill nets (5 mm mesh size), local traps, hook and line. Throughout the study period, a consistent fishing effort of two fishermen per sampling station for six hours per day was maintained (Andem et al., 2016). Various fish species were collected and placed in an iced cooler before being transported to the laboratory, where they were identified and preserved in 10% formalin for further examination. The fish were identified using the following key guides: Dailey (2003) and Idodo-Umeh (2006). Each fish species was counted and recorded after identification.

Physicochemical parameters

Water samples were measured monthly between February and July 2022 at three different sampling stations, usually between 6:00 a.m. and 10:00 a.m. Surface water temperature, pH, dissolved oxygen (DO), conductivity, salinity and total dissolved solids (TDS) were all investigated in each case.

Temperatures in the river were measured at each sampling station using a mercury-in-glass thermometer inserted about 2 cm below the surface for 5 minutes. The temperature was given in degrees Celsius (°C). The pH was determined using a Pocket-Sized pH Meter, model pH-1.

The meter's glass probe was dipped into the water sample and the pH was read as recommended by APHA, AWWA, and WEF (1995). Dissolved oxygen (DO) was measured in situ using a Dissolved Oxygen Meter, model DO-5509. The salinity of the river water was measured in situ with a salinometer. The probe was inserted at a depth of 2 cm for about 3 minutes, and the water salinity was read to the nearest mg/L. TDS were measured in situ with an Extech Meter, model ExStik EC400. The meter electrodes for each parameter were immersed in the river water for 3 minutes at a depth of about 2 cm, and the total dissolved solid was read to the nearest mg/L.

Determination of biological parameters

Individual macroinvertebrate species and fish fauna were identified, sorted, and counted. The sum of each individual macroinvertebrate and fish fauna from each sampling station for the six (6) sampling months was added together to determine the total abundance of each species in each station.

Relative abundance (%)

The relative abundance (%) of macroinvertebrate species and fish fauna from the river was calculated as follows:

$$\% RA = n (100)/N$$

where:

n = the total number of individuals in each macroinvertebrate and fish fauna taxonomic group,

N = the total number of individuals in the entire macroinvertebrates and fish fauna taxonomic group.

Ecological diversity indices

The occurrence and relative numerical abundance of benthic macroinvertebrates and fish fauna were calculated using biotic indices such as Margalef's index, Equitability and Shannon and Weiner's index to determine the abundance and diversity of species.

Margalef's index (d) is a measure of species richness

$$d = \frac{S-1}{In\,(N)}$$

(Margalef, 1949) and is expressed as:

where:

S = the number of species in samples,

N = the total number of individuals in a sample,

In is the natural logarithm.

Shannon and Weiner's index (H) is a measure of species abundance and evenness. It was calculated according to

$$H = \sum \frac{Ni}{N} \log_2 \frac{Ni}{N}$$

Shannon and Weiner (1949) as follows:

where:

N = the total number of individuals in the sample,

Ni = the total number of individuals of species in the sample.

Species equitability or evenness (E) was calculated according to Pielou (1966) using the equation:

$$E = \frac{H}{In\,S}$$

where:

H = Shannon and Wiener's index,

S = the number of species in samples.

Statistical analysis

The data obtained were analyzed using predictive analytical software (PASW, version 25, IBM Corp., Armonk, New York, USA). The values were expressed as the mean standard error (mean ± SE). A two-way Analysis of Variance (ANOVA) was used to test differences in mean values with a significance level of 5% (p<0.05) to reject the null hypothesis. The Pearson correlation coefficient (r) was employed to establish linear relationships between physicochemical parameters, benthic macroinvertebrates, and fish fauna abundance in the Tropical River (Ikang). The Paleontological Statistical (PAST) software was used to assess other biotic indices such as Dominance, Simpson index and Menhinick index of fish fauna abundance and benthic macroinvertebrate abundance.

RESULTS AND DISCUSSION

Physical and chemical variables

The surface water temperature (SWT) values of the river at each of the three designated sampling stations are presented in Table 1. At Station 1, the temperature of 27.33 °C was measured, which increased to 28 °C at Station 2 and remained constant at 28 °C at Station 3. During the study, their respective means and standard deviations were 27.78 and 0.38 degrees Celsius. All temperature readings from sampling stations remained within the National Environmental Standards and Regulations Enforcement Agency (NESREA) permissible ranges of 25 to 30 and 20 to 40 degrees Celsius, respectively. At p<0.05, the SWT (°C) spatial variation across the three sampling stations shows significant difference (Table 1). During the study, the temperature range at the three sampling stations was between 27.33 and 28.00 degrees Celsius, which was consistent with Okeke and Adinna's (2013) earlier work in the Otamiri River which reported a mean temperature of 27.40 degrees Celsius. In his study on the comparative limnology of the Unizik and Amansea Streams in Awka, Okoye (2016) found that uniform climatic regions and regular tidal motions ensure complete water mixing. During the study period, the values of dissolved oxygen obtained from the three sampling stations varied, as shown in Table 1. The lowest value was recorded at Station 1 (3.63 ± 0.69 mg/L) and the highest value was recorded at Station 3 (5.00 ± 0.69 mg/L). There are statistically significant differences in DO between sampling stations (p<0.05), the DO concentration was lower at Station 1 and higher at Station 3. NESREA acceptable limits for DO concentration at Stations 2 and 3 were met. World Health Organization (WHO) recommends that dissolved oxygen concentrations above 4 mg/L are beneficial, whereas values below 4 mg/L are lethal to aquatic life. The range of DO concentration in the study was from 3.63 mg/L to 5.00 mg/L, with a mean DO concentration of 4.34 ± 0.69 mg/L, which meets the universal standard recommended for aquatic life (Kansas Department of Health and Environment, KDHE, 2011). According to Okeke and Adinna (2013), dissolved oxygen ranges between 2.1 - 6.8 mg/L during the rainy season and between 2.7 - 9.1 mg/L during the dry season. Table 1 presents the pH values measured in the river, as reported by the researchers. Throughout the study, the river's pH was slightly acidic (5.58 - 5.80). The highest pH was measured at Station 1 (5.80), while the lowest was measured at Station 3. (5.68). The pH value differs significantly between sampling stations at $p<0.05$. Variations in pH values were dependent and exhibited a consistent pattern of variation across all stations. The pH levels at each station were within the NESREA allowable ranges. The value indicates that the stations are pollutant-free and safe for aquatic life. A similar report on a slightly alkaline pH value was reported by Andem et al. (2012) in a case study of the Ona River in Apata, Ibadan. Also, studies by Ogidiaka et al. (2012), Ogunwenmo and Osuala (2004) on the estuarine creek and artificial pond in Lagos, and studies on the Ogunpa River at Ibadan and Okorafor et al. (2013) in the Calabar River reported similar values as the present study.

The river's values for total dissolved solids (TDS) are shown in Table 1. During the study, the TDS values across the three sampling stations were 124.05 mg/L, 102.34 mg/L and 97.60 mg/L, respectively, the mean and standard deviation (mean ± SD) of the TDS was 108.00 ± 14.10 mg/L. The TDS values at each of the three sampling stations decreased from Station 1 to Station 3, possibly because of the river's fluctuating tidal influences. While the TDS values ranged from 97.60 to 124.05 mg/L, the NESREA determined that all values were within acceptable limits. Table 1 displays the conductivity results from the three sampling stations along the river.

The results show Station 1 has 173.43 µs/cm and Stations 2 and 3 have 144.47 µs/cm and 137.37 µs/cm, respectively. Table 1 displays the mean, standard deviation, and range of conductivity values across the three sampling stations. The conductivity level was highest at Station 1 (173.43 µs/cm) and lowest at Station 3 (137.37 µs/cm). The conductivity varies significantly between the three sampling locations ($p<0.05$). The conductivity level was within the acceptable limit of the NESREA. The salinity result across the three sampling stations is presented in Table 1. The range of salinity values was between 0.10 and 0.19 ppt, with a mean and standard deviation (mean ±SD) of 0.13 ± 0.05 ppt. The salinity varies significantly between the three sampling stations ($p<0.05$). The lower salinity in this study, compared to the results of Okorafor et al. (2014) and Adjarho et al. (2013), may be attributable to differences in physicochemical parameters between study stations, as well as the level of human activities due to the actual waste discharge into the river.

Relationship between the physicochemical parameters and benthic macroinvertebrate species

There was a significant positive relationship between the physicochemical parameters and abundance of benthic macroinvertebrate species like *Gomphus species*, *Callinectes amnicola*, *Notonectes species*, *Naboandelus species*, *Thais califera* (r = 0.95; r = 0.99; r =0.87; r = 0.87) and the pH of the water. Also, there was a negative relationship between benthic macroinvertebrate species such as *Tympanotomus fuscatus*, *Penaeus notialis*, *Gerris lacustris* and *Dinocras species* with water pH consequently resulting in the reduction of their population with distribution, while *Macromia species* showed no relationship with the pH of the river.

Furthermore, there was a positive relationship between the SWT of the river and *Thais califera* (r = 0.87), while benthic macroinvertebrates such as *Dinocras species* and *Macromia species* (r = -0.87; r = 0.89) showed a negative relationship with the SWT of the river, reflected in their dwindling numbers and distribution.

Table 1. Mean, standard deviation, range and analysis of variance of physicochemical parameters measured in the Ikang River

Parameters	S1	S2	S3	Mean ± SD	Range	*P* – Values	Inferences	NESREA Permissible Limit
pH	5.80	5.74	5.68	5.74 ± 0.06	5.58 – 5.80	0.003	P<0.05(S)	6.0 - 9.0
Temperature (°C)	27.33	28.00	28.00	27.78 ± 0.38	27.33 – 28.00	0.000002	P<0.05(S)	20 - 40°C
Conductivity (µs/cm)	173.43	144.47	137.37	151.76 ± 19.11	137.37 – 173.43	0.0002	P<0.05(S)	50 - 600
Dissolved oxygen (mg/L)	3.63	4.40	5.00	4.34 ± 0.69	3.63 – 5.00	0.029	P<0.05(S)	50
Salinity (ppt)	0.19	0.10	0.11	0.13 ± 0.05	0.10 – 0.19	0.032	P<0.05(S)	-
Total dissolved solids (mg/L)	124.05	102.34	97.60	108.00 ± 14.10	97.60 -124.05	0.0002	P<0.05(S)	500

Where: S1 = Flying Boat Beach, S2 = Market Beach, S3 = Mkparawa Beach, SD = Standard Deviation, *P* = Probability, NESREA = National Environmental Standards and Regulations Enforcement Agency

Macromia species and *Dinocras species* (r = 0.94; r = 0.76) both displayed a positive relationship with the water conductivity, total dissolved solids (TDS) and salinity of the river, while *Notonectes species* and *Naboandelus species* displayed no relationship with any of the physicochemical parameters except pH. This is in agreement with earlier reports of Edokpayi and Nkwoji (2007) where the relationship between water quality parameters and the composition of benthic macroinvertebrates of the Otamiri River displayed both direct and inverse relationships with some parameters (Table 2).

Abundance, composition and distribution of benthic macroinvertebrates

In Table 3, a total of 164 macroinvertebrate specimens from two phyla (Arthropoda and Mollusca) and 12 species from two distinct classes (Insecta and Crustacea) are presented. *Dinocras species*, *Macromia species*, *Gomphus species*, *Gerris lacustris*, *Notonectes species*, *Callinectes amnicola*, *Uca tangeri*, and *Penaeus notialis* represented the phylum Arthropoda, while *Tympanotomus fuscatus*, *Pachymelania fusca*, and *Thais califera* represented the phylum Mollusca. Arthropoda was the most abundant phylum, with a relative abundance of 68.21%, whereas Mollusca was the least abundant, with a relative abundance of 31.71%. The highest number of species was recorded at Stations 1 and 3, but Station 1 had the highest abundance of benthic macroinvertebrate species at 58 (35.65%), whereas Station 3 had the lowest abundance at 52 (31.70%). Station 2 recorded the fewest species, but a higher abundance percentage of 54 (32.90%). During the study, *Uca tangeri* was the most abundant benthic macroinvertebrate, with an abundance of 28 (17.07%) across all three sampling stations. The least abundant species of benthic macroinvertebrates were *Dinocras species*, *Macromia species*, and *Gomphus species*, all of which had an abundance of 6 (3.66%) and were observed at all three sampling stations, except for *Dinocras species* which was conspicuously absent (Table 3). Obot et al. (2014) reported eighteen (18) species of macroinvertebrates, Teferi et al. (2013) reported forty-two (42) species of macroinvertebrates, Keke (2017) reported forty-one (41) species, Akaahan (2014) reported twenty-one (21) species of benthic macroinvertebrates, and Okorafor et al. (2013) reported ten (10) species of macroinvertebrates. The present study recorded 164 macroinvertebrate individuals throughout the study period, which was less than Adjarho et al. (2013) who reported 1,317 individuals; Akaahan (2014) who reported 4,451 individuals; Keke (2017) who reported 676 individuals; and Andem et al. (2015) who reported 289 individuals. The dominant macroinvertebrate species in the present study was *Uca tangeri*, which was not the case in other reference studies, such as Adjarho et al. (2013) who reported Chironomus species as the most dominant species, and Andem et al. (2013) who identified *Pachymelania fusca* as the dominant species. Arthropoda was reported as the dominant phylum in this study, which is consistent with the findings of Okorafor et al. (2013) who also reported Arthropoda as the most abundant phylum in their study but contradicts the findings of Andem et al. (2015).

Table 2. Relationship between the physicochemical parameters and benthic macroinvertebrate species of the Ikang River

Macroinvertebrate/Parameters	PH	SWT (°C)	Conductivity (µ/cm)	DO (mg/L)	Salinity (ppt)	TDS (mg/L)
Dinocras sp.	-0.87	-0.87	0.76	-0.56	0.91	**0.97***
Macromia sp.	0.02	-0.87	**0.94***	-0.99	0.81	**0.94***
Gomphus sp.	**0.95***	0.50	0.03	0.50	0.60	0.50
Gerris lacustris	**0.97***	-0.69	0.55	-0.31	0.76	0.56
Notonectes sp.	0.87	0.02	0.19	-0.44	-0.10	0.17
Naboandelus sp.	0.87	0.05	0.19	-0.44	-0.10	0.17
Callinectes amnicola	**0.99***	0.50	-0.33	0.07	-0.59	-0.35
Uca tangeri	-0.19	0.76	-0.86	0.97	-0.69	-0.86
Penaeus notialis	**0.99***	-0.50	0.33	-0.07	0.59	0.35
Tympanotomus fuscatus	-0.94	-0.76	0.62	-0.39	0.82	0.64
Pachymelania fusca	0.50	-0.50	0.65	-0.83	0.41	0.64
Thais califera	0.87	0.87	-0.76	0.56	-0.91	-0.77

* Correlation is significant at $p<0.05$ (SWT = Surface water temperature, DO = Dissolved oxygen, TDS = Total dissolved solid, PPT = Part per thousand)

Table 3. Relative abundance and composition of benthic macroinvertebrate species of the Ikang River

Taxa	S1	%	S2	%	S3	%	Total	%
Arthropoda								
Insecta								
Plecoptera								
Dinocras sp.	4	6.90	0	0.00	2	3.85	6	3.66
Macromia sp.	3	5.17	2	3.70	1	1.92	6	3.66
Gomphus sp.	2	3.45	2	3.70	2	3.85	6	3.66
Hemiptera								
Gerris lacustris	6	10.34	2	3.70	5	9.62	13	7.93
Notonecta sp.	4	6.90	6	11.11	2	3.85	12	7.32
Naboandelus sp.	3	5.17	4	7.41	2	3.85	9	5.49
Crustacean								
Decapoda								
Callinectes amnicola	7	12.07	10	18.52	7	13.46	24	14.63
Uca tangeri	8	13.79	9	16.67	11	21.15	28	17.07
Penaeus notialis	3	5.17	2	3.70	3	5.77	8	4.88
Mollusca								
Gastropoda								
Tympanotomus fuscatus	8	13.79	5	9.26	7	13.46	20	12.20
Pachymelania fusca	7	12.07	7	12.96	6	11.54	20	12.20
Thais califera	3	5.17	5	9.26	4	7.69	12	7.32
Total number of individuals	**58**	**100**	**54**	**100**	**52**	**100**	**164**	**100**
Total number of species	**12**		**11**		**12**		**12**	

Where: S1 = Flying Boat Beach, S2 = Market Beach, S3 = Mkparawa Beach

All these discrepancies in numerical abundance, species dominance, and most abundant phylum and species between the present study and other related studies could be attributed to differences in the study area, duration, pollution status, and other anthropogenic factors or river activities. This study revealed two (2) benthic macroinvertebrate phylum, namely Arthropoda and Mollusca, which was similar to the findings of Andem et al. (2013) and Okorafor et al. (2014). According to Kripa et al. (2013), benthic macroinvertebrates are excellent bio-monitoring materials due to their limited migration, suitability for evaluating specific environmental impact assessments, sensitivity to pollution, and incorporation of both the short and long-term effects of environmental stressors.

Species composition, abundance and diversity of fish fauna

A total of 416 species of fish fauna belonging to six (6) families and seven (7) species were recorded as presented in Table 4. Both Stations 1 and 3 recorded the highest number of species, but Station 1 had the highest percentage abundance (53.84%) of fish species compared to the other sampling stations studied. Station 2 recorded the lowest percentage abundance (14.66%) of fish species. The family *Claroteidae* was the most abundant species (20.91%) in this study, occurring at all three sampling stations, while the family *Carangidae* had the lowest abundance (3.82%).

Table 4. Relative abundance and composition of the fish fauna of the Ikang River

Taxonomic	Stations							
	S1	%	S2	%	S3	%	Total	%
Carangidae								
Caranx latus	10	4.46	10	16.39	5	3.82	25	6.00
Clupeidae								
Ilisha Africana	45	20.08	-	-	40	30.53	85	20.43
Ethmalosa fimbriata	55	24.55	-	-	20	15.27	75	18.02
Clariidae								
Clarias gariepinus	24	10.71	10	16.39	8	6.11	42	10.10
Claroteidae								
Chrysichthys nigrodigitatus	48	21.43	6	9.84	33	25.19	87	20.91
Mugilidae								
Mugil cephalus	32	14.29	26	42.62	10	7.63	68	16.35
Sciaenidae								
Pseudotolithus elongatus	10	4.46	9	14.75	15	11.45	34	8.17
Number of species (S)	7	100	5	100	7	100	7	100
Total number of individuals (N)	224		61		131		416	
ANOVA		**F**	**FCrit**	**P-Value**	**Inference**			
		24.14	7.71	0.008	P<0.05 (S)			

Where: S1 = Flying Boat Beach, S2 = Market Beach, S3 = Mkparawa Beach

Correlation between physicochemical parameters and fish fauna

The correlation between physicochemical parameters and the abundance of fish fauna is presented in Table 5. There was a positive relationship between fish fauna families such as *Carangidae* and *Mugilidae* (r = 0.99; r = 0.99) with SWT, while the family *Sciaenidae* (r = -0.95) displayed a negative relationship with SWT, and *Clupeidae* and *Claroteidae* showed no relationship with the surface water temperature of the river. Also the family *Clupeidae* and *Clariidae* showed a positive relationship with pH and salinity, while *Clariidae* showed a positive relationship with total dissolved solids.

Table 5. The correlation coefficient between physicochemical parameters and fish fauna of the Ikang River

Physicochemical parameters / Fish fauna	SWT (°C)	pH	DO (mg/L)	Salinity (ppt)	Cond (µS/cm)	TDS (mg/L)
Carangidae	**0.99***	0.50	-0.73	-0.32	-0.93	**0.91***
Clupeidae	0.05	0.80	0.76	0.98	-0.25	0.32
Clariidae	0.72	**0.99***	0.11	0.57	-0.84	0.88
Claroteidae	0.00	0.77	0.79	**0.99***	-0.20	0.27
Mugilidae	**0.99***	0.71	-0.53	-0.06	-1.00	**0.99***
Sciaenidae	-0.95	-0.36	**0.83***	0.46	**0.87***	-0.83

* Correlation is significant at p<0.05

Total dissolved solids showed a positive relationship with *Carangidae*, *Mugilidae* (r = 0.91; r = 0.99) and *Clariidae* (r = 0.88), while the conductivity of the water exhibited a positive relationship only with *Sciaenidae* (r = 0.87) and negative relationship with *Mugilidae*, *Clariidae* and *Carangidae* (r = -1.00; r = -0.84 and r = -0.93). Dissolved oxygen only exhibited a positive relationship with *Sciaenidae* (r = 0.83) but no form of relationship was seen with *Clariidae*.

Diversity indices of benthic macroinvertebrate

A summary of the diversity and dominance indices of benthic macroinvertebrates calculated during the study for the three sampling stations is presented in Table 6. The Shannon index (H) recorded at Stations 1, 2 and 3 was 2.389, 2.242 and 2.282, respectively, which suggests that the sampling stations in the Tropical River are a polyvalent community. Station 1 had the highest diversity index as calculated by Shannon-Wiener (H), which reflects the even distribution of organisms encountered in the station. This corresponds with the recommendation of Magurran (2004) that the Shannon-Weiner diversity index ranges between 1.5 and 3.5 and is rarely greater than 4 for an ideal ecosystem. This represents a characteristic of species diversity for an average site which is supported by similar values obtained using the same size of sampling units in the FLONA of São Francisco de Paula (Narvaes et al., 2005), which arrived at a Shannon index value of 2.22. The benthic macroinvertebrate comparisons of the three sampling stations clearly show that the three sampling stations enjoy almost equal levels of abundance, which can be attributed to nutrient availability and the presence of suitable habitats. The high evenness and low dominance index justify this situation, since the higher the evenness, the higher the diversity, and the lower the dominance index, the higher the diversity (Victor and Ogbeibu, 1989). In the present study, the Shannon-Wiener and Menhinick index both had the highest levels in Station 1, indicating a high diversity of benthic macroinvertebrates in the station. The Simpson index (D) indicated dominance at all three sampling stations but exhibited the greatest dominance at Station 1. The same was for the equitability index (E) whose value proves that all the species were equally abundant at all three sampling stations. The three stations had low diversity levels with Shannon, Simpson, Menhinick, Margalef and equitability index values all varying insignificantly between sampling stations (p>0.05) but the dominance index varied significantly between sampling stations (p<0.05) in Table 6. The lowest dominance index was recorded at Station 1, while the lowest Simpson's index was observed at Station 2, indicating that Stations 1 and 2 were richer in species. The value for the equitability index at all three sampling stations was close to 1, suggesting that the benthic macroinvertebrates were evenly distributed.

Diversity indices of fish fauna

The Shannon index (H) recorded from Stations 1-3 illustrates a low diversity index since the values presented in Table 7 were below 1.50, which was assumed as the lowest point range for the Shannon index analysis. The dominance indices show if there is dominance by one or a few species in the sampled area. In species dominance, the Simpson index presented high dominance in Station 1 with the value of 0.801, while the equitability (E) index showed no significant difference (p>0.05) with low uniformity in all three sampling stations. Species richness according to the Menhinick index exhibited moderate to high levels of diversity at the three sampling stations, with the respective index values > 1, as presented in Table 7. Also, Margalef's index (d) at the three-sampling stations suggests a high level of diversity in species as their values are either close to 1 or >1 (Table 7). The dominance (D) index indicated a significant difference at p<0.05.

Table 6. Diversity indices of benthic macroinvertebrates of the Ikang River

Stations	S1	S2	S3	Total	*P* –Values	Inference
Taxa	12	11	12	12		
Individuals	58	54	52	164		
Dominance (D)	0.099	0.119	0.119	0.107	**0.031***	P<0.05(S)
Shannon index (H)	2.389	2.242	2.282	2.350	0.627	P>0.05(NS)
Simpson index (D)	0.901	0.881	0.881	0.893	0.126	P>0.05(NS)
Menhinick	1.576	1.497	1.664	0.937	0.508	P>0.05(NS)
Margalef (d)	2.709	2.507	2.784	2.157	0.317	P>0.05(NS)
Equitability (E)	0.962	0.935	0.918	0.946	0.140	P>0.05(NS)

* indicates a significant difference at a probability level of 5% (S1 = Flying boat Beach, S2 = Market Beach, S3 = Mkparawa Beach, *P* = Probability, S = Significant, NS = Not significant)

Table 7. Diversity indices of fish species of the Ikang River

Stations						
Biotic indices	**S1**	**S2**	**S3**	**Total**	***P* -Values**	**Inference**
Margalef's index (d)	1.109	0.973	1.231	1.016	7.709	P>0.05(NS)
Shannon-Wiener (H)	0.778	0.636	0.755	0.798	4.754	P>0.05(NS)
Equitability (E)	0.399	0.396	0.388	0.409	7.735	P>0.05(NS)
Dominance (D)	0.096	0.123	0.121	0.115	**0.037***	P<0.05(S)
Simpson index (D)	0.801	0.731	0.741	0.793	0.134	P>0.05(NS)
Menhinick	1.576	1.497	1.664	0.937	0.607	P>0.05(NS)

* indicates significant difference at a probability level of 5%, (S1 = Flying boat Beach, S2 = Market Beach, S3 = Mkparawa Beach, *P* = Probability, S = Significant, NS = Not Significant)

A total of 416 fish fauna including seven (7) species and six (6) families were recorded at the three sampling stations during the study. This is similar to the observations of Ojo (2013) who reported an estimated 21 species and 12 families from the Osse/Ovia River, Okomu National Park Nigeria. Also, Odo (2004) reported an estimated 52 fish species belonging to 17 families from the Anambra River, including 171, 236, and 169 individual captures at Ogurugu, Otuocha, and Nsugbe stations, respectively. Obiyor et al. (2017) recorded a total of 129 fish belonging to 5 species and 4 families of fish fauna in the Otamiri River in Imo State, Nigeria. Four (4) families were reported by Ogidiaka et al. (2012) in the Ogunpa River in Ibadan, and 10 families were reported by Adjarho et al. (2013) in the Ona River, Ibadan. Furthermore, the family *Claroteidae* is the most abundant species (20.91%) in this study, a result recorded by Obiyor et al. (2017) on the Otamiri River, which was dominated by the family *Claroteidae* with an abundance of 36.25%.

CONCLUSION

The physical and chemical characteristics of water, the availability of food, and other anthropogenic factors all have an impact on the abundance and diversity of benthic macroinvertebrates and fish fauna. Dredging, sand mining, bridge construction, and waste discharge into the river are likely to cause stress on aquatic life, particularly at Station 2 where some species were conspicuously absent during the study period, resulting in a reduction in benthic macroinvertebrate and fish fauna diversity and abundance. Adequate management practices for both the river and its surrounding ecosystem are required to ensure water quality and sustainable biodiversity.

UTJECAJ ČOVJEKA NA DISTRIBUCIJU I RAZNOLIKOST BENTOSKIH MAKROBESKRALJEŠNJAKA I RIBA U TROPSKOJ RIJECI IKANG, NIGERIJA

SAŽETAK

Tropski vodeni ekosustavi jugoistočne Nigerije obično se sastoje od močvara mangrova i obalnih šuma, a ugroženima su postale posljednjih šest desetljeća. Cilj ovog istraživanja bilo je utvrditi opseg i aktivnosti utjecaja čovjeka na kakvoću vode, te na distribuciju i raznolikost bentoskih makrobeskralježnjaka i riba u tropskoj rijeci Ikang. Uzorkovani su riječna voda, bentoski makrobeskralješnjaci i fauna riba, te su identificirani kako bi se stvorila baza referentnih podataka. Identificirano je dvanaest (12) vrsta bentoskih makrobeskralježnjaka iz dvije (2) skupine. Postaja 1 imala je najveću brojnost bentoskih makrobeskralježnjaka od 58 (35,65%), dok je postaja 3 imala najnižu brojnost od 52 (31,70%). *Uca tangeri* bio je najzastupljeniji bentoski makrobeskralješnjak s postotkom brojnosti od 28 (17,07%), dok su *Dinocras* sp., *Macromia* sp. i *Gomphus* sp. bili su najmanje zastupljeni bentoski makrobeskralježnjaci s postotkom zastupljenosti od 3,66%. Osim toga, identificirano je sedam (7) vrsta riba iz šest (6) porodica. Tijekom istraživanja najzastupljenija je bila porodica *Claroteidae*, dok je porodica *Carangidae* bila najmanje zastupljena. Temperatura rijeke imala je pozitivnu korelaciju s prodicama *Carangidae* i *Mugilidae*, negativnu s porodicom *Clupeidae*, dok nikakvu s porodicom *Claroteidae*. Ukupne otopljene čvrste tvari (TDS) pozitivno su korelirale s porodicama *Carangidae*, *Mugilidae* i *Clariidae*, dok je vodljivost pozitivno korelirala samo s prodicom *Sciaenidae*, a negativno s prodicama *Carangidae*, *Mugilidae* i *Clariidae*. Na brojnost i raznolikost bentoskih makrobeskralješnjaka i riblje faune općenito su utjecale fizikalne i kemijske karakteristike vode, dostupnost hrane te opseg ljudskih utjecaja i aktivnosti. Kako bismo osigurali održivu kvalitetu vode i očuvanje bioraznolikosti u ovom okolišu, potrebno je primjereno upravljati rijekom i okolnim ekosustavom.

Ključne riječi: ribe, brojnost, bioraznolikost, fizikalno-kemijski parametri, održivo gospodarenje

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