DOI: 10.1515/cjf-2016-0024

CODEN RIBAEG ISSN 1330-061X (print), 1848-0586 (online)

DE GRUYTER OPEN

ENVIRONMENTAL VARIABLES AND ECOLOGICAL DISTRIBUTION OF ICHTHYOFAUNA ASSEMBLAGES IN THE CALABAR RIVER, NIGERIA: PRESENT AND FUTURE PROSPECTS

Andem Bassey Andem*, Sunday Ben Ekanem, Esien Ene Oku

University of Calabar, Department of Zoology and Environmental Biology, Cross River State, Nigeria

*Corresponding Author, Email: a.b.andem@unical.edu.ng

ARTICLE INFO

Received: 1 July 2016
Received in revised form: 1 September 2016
Accepted: 3 September 2016
Available online: 4 October 2016

ABSTRACT

Studies on environmental variables and ecological distribution of ichthyofauna assemblages were conducted in the Calabar River. Surface water and ichthyofauna were sampled in order to provide baseline or reference data on the Calabar River at present as regard its future prospects. Seasonal variation shows significant differences in surface water temperature, pH, DO, BOD, conductivity, TDS and TSS between sampling stations and insignificant differences in heavy metals such as cadmium, chromium, iron and copper between sampling stations. Twenty six species of fish fauna were identified belonging to twenty two families. Mugilidae, Clariidae, Cichlidae, Gobiidae and Sciaenidae were the most abundant for both wet and dry season, while Clupeidae, Bathyclupeidae, Carangidae and Sphyraenidae were low in the wet season but high in the dry season. Chromium, copper, surface water temperature, DO correlate significantly with the presence of *E. fimbriata, B. soporator, M. sebae, C. gariepinus, M. loennbergii*, *C. guentheri* and *P. babarus*. The overall values of biotic diversity indices ranged from 0.0504-0.0745 for Simpson's Index, 2.770-3.095 for Shannon Index, 2.821-3.105 for Margalef's Index and 0.8606-0.9498 for equitability. However, the presence of certain fish fauna in polluted and non-polluted parts of the river indicates that they could be used as potential bioindicators in assessment and biomonitoring of the river. The methods used in identifying fish diversity proved their applicability for future studies.

Keywords:
Ecological distribution
Ichthyofauna
Biotic indices
Pollution

How to Cite

Andem, A. B., Ekanem, S. B., Oku, E. E. (2016): Environmental variables and ecological distribution of ichthyofauna assemblages in the southeastern coastal region of the Calabar River, Nigeria. Croatian Journal of Fisheries, 74, 159-171. DOI: 10.1515/cjf-2016-0024.

INTRODUCTION

Freshwater ecosystems in tropical Africa are rich in fauna and flora species and they are very complex, especially species. In Nigeria, these fishes are widely spread all over the fresh water bodies; this is based on their morphology and life history, and attributed to their different features and habitats in which they are embedded (Mims et al., 2010). The ecology of rivers in tropical Africa is dominated by flow seasonality with profound consequences for fishes and zoobenthos during the wet season (Dudgeon, 2000). Thus, fluctuations and changes in discharge patterns affect the abundance, species composition and viability of living aquatic resources resident in the river. Also, along the river gradient, the variations in geo-morphological characteristics of the river as well as environmental variables (both biotic and abiotic) are the major factors that govern fish communities both in terms of species richness and distribution of individual species (Orrego et al., 2009; Alexandre et al., 2010; Kimmel and Argent, 2010).

Moreover, different aquatic environments favour particular traits of fish species making them develop different strategies that enable different fish species to cope with a range of ecological challenges (Mims et al., 2010). However, any river system under normal conditions is characterized by constant increase of fish species (Orrego et al., 2009). In a fluvial ecosystem, species composition is influenced by some parameters such as altitude, gradient, current velocity and temperature. However, the downstream, functional structure of the river changes as a result of some physical factors such as flow regime, temperature, food availability and river morphological conditions (Orrego et al., 2009). Generally, fishes show high adaptability to their habitat environment, whereas their morphological and ecological characteristics change correspondingly (He et al., 2010). The range of distribution of fish species from the source (upstream) to the discharge point (downstream) is determined by the ecological requirements of each fish species (Ferreira and Petrere, 2009). Most fish in the river system cannot live their whole lives in one habitat, especially when requirements for reproduction and feeding at different life stages cannot be met in the same place; fishes therefore have to move between places to survive (Baran and Jutagate, 2010). Different classes of fish in Nigeria can complete their life cycle only if they can gain access to different riverine environment. There are two types of riverine environment which different fishes spawn on; obligatory species spawn only in the river corridor, while non-obligatory or facultative riverine species realize their life history strategy in both lotic and lenthic waters (Penczak, 2002).

Ita (1993) in his study reported that there are about 511 species of fish in Nigerian water bodies of which about 34% are restricted to Exclusive Economic Zone (EEZ), while approximately 44% are freshwater fishes inhabiting waters of very low salinities (below 1 part per thousand (ppt) or conductivity of 1000 µS/cm). The presence of *Potamotrygeon garouensis* in the waters of northern Nigeria (Reed et al., 2000; Obasohan and Oronsaye, 2006) and the River Ase in Delta State of Nigeria (Idodo-Umeh, 1987) is of scientific interest because *Potamotrygeon garouensis* is a ray of the family Dasyatidae. These species which occur in both brackish and freshwaters are unique and so require protection. The majority of Carangidae were marine water fish, while Characidae were mostly fresh water fish, except the two species of Myletes, *M. guile* and *M. nurse,* which are brackish (Obasohan and Oronsaye, 2006). Among Carangidae, only *Trachinotus goreensis*, a marine species, has been reported in these freshwaters (Kusemiju and Olaniyan, 1997) and Oguta Lake (Nwadiaro, 1984). These species appear restricted in distribution and therefore need to be protected. Mudskipper *Periophthalmus sp.* (family Periopthalmidae) is a fish of great biological and evolutionary significance. The continued existence of this fish is seriously threatened by pollution arising from oil spills and reclamation exercises, especially in the mangroves and Lagos Lagoon

Table 1. List of endangered freshwater fishes in Nigeria

Family	Species	Distribution
Albulidae	*Albula vulpes*	Warri River
Amphillidae	*Phractura clauseri*	Ogun River
Carangidae	*Trachinotus goreensis*	Niger/Benue
Centropomidae	*Lates niloticus*	Widespread
Cromerridae	*Cromeria nilotica*	Niger/Benue
Gymnaichiidae	*Gymnanchus niloticus*	Widespread
Hepsetidae	*Hepsetus odoe*	Widespread
Lepidosireniidae	*Protopterus annectens*	Fair Distribution
Lutjanidae	*Lutjanus spp*	Cross River
Mastacembelidae	*Mmastacembelus loennbergii*	Fair Distribution
Malapteruriidae	*Mmalapterurus electricus*	Widespread
Nanidae	*Polycentropsis abbreviate*	Fair Distribution
Ophiocephalidae	*Paraophiocephalus africana*	Oguta Lake
Osteoglossidae	*Heterotis niloticus*	Widespread
Pantodoltidae	*Pabtodon putcholzi*	Fair Distribution
Phracholaemidae	*Phracholeamus ansorgei*	Fair Distribution
Synbranchidae	*Synbranchus afer*	Ethiope River
Trigonidae	*Trigon margrarita*	Epe Lagoon
Estuarine and marine migratory species		
Pristidae	*Pristis perrottetis*	Niger/Benue
Trigonidae	*Potamotryon garouensis*	Niger/Benue
Monodactylidae	*Monodactylus sebae*	Niger/Benue

beaches. Welman (2003) identified 181 fish species from the major river systems in Nigeria which included estuarine and marine fishes present in the rivers. Banks et al. (1965) identified and described about 139 fish species in the River Niger within the proposed Kainji Reservoir Basin. Reed et al. (2000) investigated and reported about 160 fish species in the northern region of Nigeria. Many fish species have been identified in Kainji Lake and other freshwater bodies leading to the description and identification of fish species in Nigeria (Ita, 1978). One of the recent investigations into the fish diversity of the major rivers of Nigeria (Ita, 1993; Obasohan and Oronsaye, 2006) recorded 239 fish species. There are at least 18 freshwater species in Nigeria which are endangered (Table 1). A drastic decline has recently been observed among larger species such as *Gymnarchus niloticus. Lates niloticus, Heterobranchus bidorsalis* and *Protopterus annectus* (Ita, 1993; Obasohan and Oronsaye, 2006).

The importance of this study is to complement available information in the baseline data and help in the exploitation of fishery, execution of fisheries policies and programmes, especially in the artisanal sector. This will ensure effective management as well as biodiversity conservation. This study was aimed at evaluating some environmental variables and ecological distribution, diversity and abundance of ichthyofauna assemblages of the Calabar River in Nigeria.

MATERIALS AND METHODS

Description of study area

The Calabar River flows from the northern part of the city of Calabar joining the southern at about 8 km. This river forms a natural harbour deep enough for vessels with a draft of 6 m. The river drains from the part of Oban hills in the Cross River National Park (Cross River National Park, 2010) with the longitude of $8^0 18'$E and latitude of $4^0 58'3$N (Fig. 1.) (Andem et al., 2013). The basin of the river is about 43 km wide and 62 km long, with an area of 1,514 km^2 (Eze and Effiong, 2010). The region has a wet season between April and October with about 80% of the annual rainfall, with the peak of rainfall between June and September. The river has an annual rainfall average of about 1,830 mm, average temperature range from 24^0C (75^0F) in August to 30^0C (86^0F) in February. Relative humidity is high and it ranges between 80% and 100% (Eze and Effiong, 2010). The river basin has about 223 streams with a total length of 516 km; this is a small number given the size of the basin. The drainage system in Calabar is poor so the basin is subjected to gully erosion, flooding and landslides; in fact, a 2010 study said that flood had increased in recent years (Eze and Effiong, 2010).

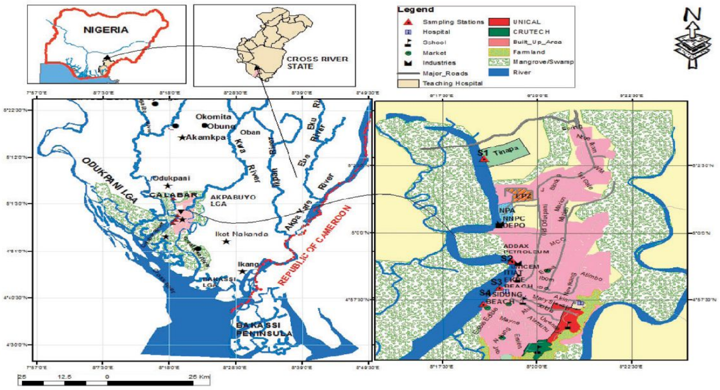

Fig 1. Map of study area showing different sampling stations

Sampling stations

Four stations (1-4) were chosen along the shoreline of the river. Co-ordinates of each station were digitized using Arc Geographic Information System (GIS) software.

Station One (S1)

It is coastal water which flows behind Africa's first ever free trade zone which is also a tourist destination with a serene environment; it is an upstream station which serves as a control point. This station is assumed to be unpolluted since the wastes which flow into the river from this point are minimal. The water channels are clean, very little activity occurs at the river banks and fishing activities are restricted for security reasons. The station is located at Tinapa Resort Beach between latitude: N 5^0 02' 820", longitude: E 8^0 19' 16" at 23 feet altitude.

Station Two (S2)

Station 2 is the first discharge point; it receives effluents from shipping activities, off-loading of finished petroleum product from ship to pipelines; fishing activity is minimal and some of the industrial wastes are also drained into the river. This station is located at Addax Petroleum Company between latitude: N 4^0 58' 988", longitude: E 8^0 16' 872" at 24 feet altitude.

Station Three (S3)

This station is the second discharge point; it consists of linear settlement across the river bank where fishing activities predominate; ships and boats also anchor along this beach. The Station is located at Itiat Ekpe Beach between latitude: N 4^0 32' 124", longitude: E 8^0 16' 872 " at 42 feet altitude.

Station Four (S4)

This station is a commercial station with a large market located at the bank of the river. Anthropogenic wastes from this station also empty into the river. This is a landing site for fishermen and a big fish market. This station is located at Nsidung Beach between latitude: N 4⁰ 57' 326", longitude: E 8⁰ 18' 557" at 26 feet altitude.

Physico-chemical parameters

Samples were collected monthly between January and December 2013 at four different stations, usually between 7:00 a.m and 10:00 a.m. The physico-chemical parameters investigated in each case were surface water temperature, pH, dissolved oxygen (DO), biochemical oxygen demand (BOD), conductivity, total dissolved solids (TDS), total suspended solids (TSS) and heavy metals, all from surface waters. In each sampling station, surface water temperature of the river was measured with a mercury-in-glass thermometer which was inserted into the water at a depth of 2 cm from the surface for 3 minutes. The readings were expressed in degrees Celsius (°C). The pH was measured *in situ* using pocket pH meter (pH 1 model). The probe of the meter was dipped into the water sample and the pH read as recommended by APHA, AWWA, WEF (1995). Dissolved oxygen was measured *in situ* with DO meter (Model DO−5509) and the water sample was taken to the Postgraduate Laboratory, Department of Zoology and Environmental Biology and incubated for five days at 20°C; after five days the reading was taken. The first day DO minus the fifth day DO (DO_1- DO_5) gave BOD. In the laboratory, conductivity, TDS and TSS were measured using Hannah Instrument (Bench meter 211 model). A different probe of the meter for each parameter was immersed in the water samples collected; parameters such as conductivity, TDS and TSS were read off as recommended by APHA, AWWA, WEF (1995). Heavy metals were determined by digesting 250 ml of water samples with 10 ml analytical grade nitric acid to acidify it; the solution was evaporated on a crucible to approximately 25 ml then filtered into a standard flask and diluted with distilled water (Farombi et al., 2007). The mixture was gently heated in a water bath until the acid became bleached. The digested water samples were analyzed for lead (Pb), copper (Cu), iron (Fe), chromium (Cr) and cadmium (Cd) using Perkin Elmer's AAnalyst 200 version 6.0 Atomic Absorption Spectrometer (AAS).

Fish sampling procedure

The gears and methods used were in accordance with the recommendation of Gullard (1980); reliable sampling involves a combination of two or more gears. In each sampling period, fishing was carried out during high tide and low tide, both during the day and night. Sampling was done once a month for twelve months (January-December 2013). The gears consisted of cast net (10-15 mm mesh size), drift net (5 mm mesh size), gill net (5 mm mesh size), local traps, hook and line. A uniform fishing effort of 2 fishermen in each sampling station for six hours per day was maintained throughout the study period. Fish were collected and put into an iced cooler and transported to the laboratory where they were identified and preserved in 10% formalin for further examination. The fishes were identified using the following key guides: FAO, (2001), Idoho-Umeh (2003) and Adesulu and Sydenham (2007); after identification each fish species was counted and recorded accordingly.

Statistical analysis

Data obtained were subjected to descriptive statistics for mean, standard error and range values. Analysis of variance (ANOVA) was used to test the significant difference between seasonal variations of physico-chemical parameters and fish fauna of the Calabar River. Effects with a probability of $p<0.05$ were considered significant. Biotic indices such as Simpson's index, Margalef's index, Shannon-Wiener index were used to estimate species dominance, abundance, richness and evenness using PAST (Paleontological Statistics) software. Microsoft Excel 2013 (Microsoft Corporation 1985-2013) was used for graphical illustrations. Two-tailed correlation coefficient (r) was used to determine the relationships existing between the physico-chemical parameters of water and abundance of fish fauna of the Calabar River (Ogbeibu, 2005).

RESULTS

Physico-chemical parameters

Summary of the data obtained on mean variation, range and F-value of physico-chemical parameters studied between January and December 2013 is presented in Table 2. Seasonal mean, standard error values and analysis of variance on physico-chemical parameters measured in the Calabar River are shown in Table 3.

During the study period, surface water temperature ranged from 25.92 to 27.92°C with the mean value of 26.97 ± 0.84°C (Table 2). Within four sampling stations, spatial variations of surface water temperature showed insignificant difference at $p>0.05$ (Table 2). Mean surface water temperatures obtained in the wet season and dry season were 27.33 ± 1.11°C and 26.71 ± 0.70°C (Table 3), respectively. Seasonal variation between the wet and dry

Table 2. Mean, range and F-value of physico-chemical parameters measured in the Calabar River

Physico-chemical parameters	Range	Mean ±S.E	F-value	*P*-Probability	Inferences	NESREA Permissible limit
Water Temperature (^{0}C)	25.92 – 27.92	26.97 ± 0.84	4.92	P>0.05(NS)	H_0 accepted	20-40^{0}C
pH	7.20 – 7.69	7.44 ± 0.25	0.015	P>0.05(NS)	H_0 accepted	6.0-9.0
Dissolved Oxygen (mg/L)	3.07 – 3.79	3.35 ± 0.33	23.90	P>0.05(NS)	H_0 accepted	5.0
Biological Oxygen Demand (mg/L)	1.53 – 1.99	1.82 ± 0.21	1.56	P>0.05(NS)	H_0 accepted	50
Conductivity (µS/cm)	237.14 – 290.67	254.31 ± 24.56	12.92	P<0.05(S)	H_0 rejected	50-600
Total Dissolved Solid (mg/L)	414.63 – 700.14	528.63 ± 124.69	2.16	P<0.05(S)	H_0 rejected	500
Total Suspended Solid (mg/L)	1093.77 – 1376.06	1205.35 ± 125.57	2.35	P<0.05(S)	H_0 rejected	>10
Lead (mg/L)	0.00 – 0.01	0.01 ± 0.001	2.59	P<0.05(S)	H_0 rejected	0.05
Cadmium (mg/L)	0.00 – 0.02	0.02 ± 0.001	2.32	P>0.05(NS)	H_0 accepted	0.01
Chromium (mg/L)	0.01 – 0.02	0.02 ± 0.001	14.40	P>0.05(NS)	H_0 accepted	1.0
Iron (mg/L)	1.31 – 3.23	2.59 ± 0.89	18.39	P<0.05(S)	H_0 rejected	0.05
Copper (mg/L)	0.06 – 0.29	0.19 ± 0.11	10.77	P<0.05(S)	H_0 rejected	0.1

S.E = Standard Error, F = Tabulated values, NESREA = National Environmental Standards and Regulations Enforcement Agency, (NS) = Not Significant, (S) = Significant, H_0= Null Hypothesis

season showed insignificant difference at p>0.05 (Table 3). pH ranged from 7.20 to 7.69 with a mean of 7.44 ± 0.25 (Table 2). Within the four sampling stations, spatial variations of pH were significantly different (p>0.05). Mean values of pH obtained in the wet season and dry season were 7.33 ± 0.27 and 7.55 ± 0.39 (Table 3), respectively. Seasonal variation between the wet and dry season showed insignificant difference at p>0.05 (Table 3). The values of dissolved oxygen recorded ranged from 3.07 to 3.79 mg/L with a mean of 3.35 ± 0.33 mg/L (Table 2). Within the four sampling stations, spatial variations of dissolved oxygen showed insignificant difference (p>0.05). Mean values of dissolved oxygen obtained in the wet and dry seasons were 3.66 ± 0.51 mg/L and 3.03 ± 0.30 mg/L, respectively (Table 3). Seasonal variation between the wet and dry season showed significant difference at p<0.05 (Table 3). Biological oxygen demand (BOD) ranged from 1.53 to 2.80 mg/L with a mean of 2.73 ± 0.21 mg/L (Table 2). The spatial variations of BOD within the sampling stations showed insignificant difference at p>0.05 (Table 2). Mean BOD concentrations obtained in the wet and dry seasons were 2.00 ± 0.39 mg/L and 2.63 ± 0.16 mg/L, respectively (Table 3). Seasonal variation between the wet and dry season showed insignificant difference at p>0.05 (Table 3). The values of conductivity recorded ranged from 237.14 to 290.67 µS/cm with the mean value of 254.31 ± 24.56 µS/cm (Table 2).

Within the four sampling stations, spatial variations of conductivity showed significant difference (p<0.05). Mean values of conductivity obtained in the dry and wet seasons were 250.87 ± 34.15 µS/cm and 257.74 ± 16.40 µS/cm (Table 3), respectively. Seasonal variation between the wet and dry season showed insignificant difference at p>0.05 (Table 3). The levels of TDS ranged from 414.63 to 700.14 mg/L with the mean value of 528.63±124.56 mg/L (Table 2.). Within the four sampling stations, spatial variations of total dissolved solid shows significant difference (p<0.05). Mean total dissolved solids obtained in the wet and dry seasons were 522.83 ± 177.21 mg/L and 534.43 ± 72.26 mg/L, respectively (Table 3). Seasonal variation between the wet and dry season showed insignificant difference at p>0.05 (Table 3). The concentrations of TSS ranged from 1093.77 to 1376.06 mg/L with the mean value of 1205.35±125.57 mg/L (Table 2). Within the four sampling stations, spatial variations of TSS were significantly different (p<0.05). Mean total dissolved solids obtained in the wet and dry seasons were 1191.80±117.23 mg/L and 1223.91±120.38 mg/L, respectively (Table 3). Seasonal variation between the wet and dry season was not significantly different at p>0.05 (Table 3). The level of lead (Pb) ranged from 0.00 to 0.01 mg/L with the mean value of 0.01 ± 0.00 mg/L (Table 2). Within the four sampling stations, spatial variations of Pb showed significant difference (p<0.05). Mean values of Pb obtained in the wet

Table 3. Seasonal mean variation, standard error and F-values of physico-chemical parameters measured in the Calabar River for the wet and dry season

Physico-chemical parameters	Wet Season Mean±S.E	Dry Season Mean ± S.E	F-value	*P*-Probability	Inferences
Surface water temperature (^{0}C)	27.33±1.11	26.71±0.70	1.88	P>0.05(NS)	H_0 accepted
pH	7.33±0.27	7.55±0.39	1.03	P>0.05(NS)	H_0 accepted
Dissolved oxygen (mg/L)	3.66±0.51	3.03±0.30	18.02	P<0.05(S)	H_0 rejected
Biological oxygen demand (mg/L)	2.00±0.39	2.63±0.16	4.24	P>0.05(NS)	H_0 accepted
Conductivity (µS/cm)	257.74±16.40	250.87±34.15	0.41	P>0.05(NS)	H_0 accepted
Total dissolved solids (mg/L)	522.83±177.21	534.43±72.26	2.19	P>0.05(NS)	H_0 accepted
Total suspended solids (mg/L)	1191.80±117.23	1223.91±120.38	4.41	P>0.05(NS)	H_0 accepted
Lead (mg/L)	0.01±0.01	0.01±0.01	0.00	P>0.05(NS)	H_0 accepted
Cadmium (mg/L)	0.00±0.00	0.00±0.00	0.23	P>0.05(NS)	H_0 accepted
Chromium (mg/L)	0.02±0.01	0.01±0.00	0.00	P>0.05(NS)	H_0 accepted
Iron (mg/L)	1.67±0.74	3.48±1.17	16.76	P<0.05(S)	H_0 rejected
Copper (mg/L)	0.22±0.15	0.17±0.08	0.96	P>0.05(NS)	H_0 accepted

S.E = Standard Error, F = Tabulated values, (NS) = Not Significant, (S) = Significant, H0= Null Hypothesis

and dry seasons were 0.01 ± 0.01 mg/L and 0.01 ± 0.00 mg/L, respectively (Table 3). Seasonal variation between the wet and dry season showed insignificantly different at p>0.05 (Table 3). Within the four sampling stations, spatial variations of cadmium showed insignificant difference (p>0.05). Mean values of cadmium (Cd) obtained in the wet and dry seasons were also not detected (Table 3). Seasonal variation between the wet and dry season also showed insignificant difference at p>0.05 (Table 3). The chromium (Cr) level ranged from 0.01 to 0.02 mg/L with the mean value of 0.02 ± 0.00 mg/L (Table 2). Within the four sampling stations, spatial variations in the levels of Cr showed insignificant difference at p>0.05 during the study period. Mean Cr levels obtained in the wet and dry season were 0.02 ± 0.01 mg/L and 0.01 ± 0.00 mg/L (Table 3), respectively. Seasonal variation between the wet and dry season also showed insignificant difference at p>0.05 (Table 3). The levels of iron (Fe) ranged from 1.31 to 3.23 mg/L with the mean value of 2.59 ± 0.89 mg/L (Table 2). Within the four sampling stations, spatial variations of Fe showed significant difference at p<0.05. Mean iron levels obtained in the wet and dry season were 1.67 ± 0.74 mg/L and 3.48 ± 1.17 mg/L (Table 3). Seasonal variation between the wet and dry season showed significant difference at p<0.05 (Table 3). The copper (Cu) level ranged from 0.06 to 0.29 mg/L with the mean value of 0.19 ± 0.11 mg/L (Table 2). Within the four sampling stations, spatial variations of copper showed significant difference (p<0.05). Mean Cu levels obtained in the wet and dry seasons were 0.22 ± 0.15 mg/L and 0.17 ± 0.08 mg/L (Table 3), respectively. Seasonal variation between the wet and dry season showed insignificant difference at p>0.05 (Table 3).

Ichthyofauna composition and abundance

The relative abundance of various fish fauna taxa encountered at four different sampling stations is presented in Table 4, while the illustration in Fig. 2 shows the percentage composition of fish fauna phyla of the Calabar River. Twenty six (26) species were identified belonging to twenty two (22) families from the total of 17464 individuals collected across the stations. Clupeidae was the most abundant fish family with 13.61%, followed by Cichlidae with 10.12%, and Osteoglossidae was the least fish family with 0.59%. Among the stations, *Mugil cephalus* was abundant only in Station 1 (13.40%), while *Clarias gariepinus* was the most abundant in Station 2 (11.60%) and *Orechromis niloticus* was the most abundant in Station 3 (8.50%) and Station 4 (7.90%). *Heterotis niloticus* was the least abundant (1.50%); this species occurred only in Station 4. Mugilidae, Clariidae, Cichlidae, Gobiidae and Sciaenidae had the most abundant distribution for both wet and dry seasons, while Clupeidae, Bathyclupeidae, Carangidae and Sphyraenidae were low in the wet season but high in the dry season. There was no significant difference between the two seasons (p>0.05).

Table 4. Composition, absolute and relative abundance of fish fauna encountered in the Calabar River

STATIONS/TAXA	S1	%	S2	%	S3	%	S4	%	Total	%
CLAROTEIDAE										
Chrysichthys nigrodigitatus	198	8.7	181	6.2	253	5.1	345	4.9	997	5.7
BATHYCLUPEIDAE										
Bathygobis soporator	7	0.3	11	0.01	53	1.1	75	1.1	147	0.8
CYNOGLOSSIDAE										
Cynoglossus senegalensis	54	2.4	121	4.1	182	3.7	279	3.9	646	3.7
CARANGIDAE										
Caranx hippos	11	0.5	67	2.3	141	2.9	117	1.7	342	1.9
Caranx latus	7	0.3	32	1.1	54	1.1	75	1.2	170	0.9
CLUPEIDAE										
Ilisha africana	102	4.5	179	6.2	192	3.9	216	3.1	703	4.0
Ethmalosa fimbriata	187	8.3	191	6.5	300	6.1	325	4.6	1024	5.9
Pellonula sp.	95	4.2	66	2.3	178	3.6	300	4.3	649	3.7
CLARIIDAE										
Clarias gariepinus	245	10.8	338	11.6	304	6.1	460	6.6	1375	7.9
CICHLIDAE										
Orechromis niloticus	168	7.4	247	8.5	421	8.5	553	7.9	1413	8.1
Chromidotilapia sp.	18	0.8	27	0.9	98	1.9	208	2.9	355	2.0
CITHANNIDAE										
Citharinus citherus	114	5.0	158	5.4	241	4.9	312	4.5	840	4.8
ELOPIDAE										
Elop lacerta	2	0.1	23	0.8	45	0.9	33	0.6	105	0.6
ELEOTIDAE										
Eleotris daganensis	11	0.5	41	1.4	79	1.6	108	1.5	242	1.4
PERIOPHTHALMIDAE										
Periophthalmus sp.	94	4.1	133	4.6	419	8.5	598	8.5	1261	7.2
HEPSETIDAE										
Hepstus odoe	27	1.2	33	1.1	151	3.1	233	3.3	449	2.6
OSTEOGLOSSIDAE										
Heterotis niloticus	0	0	0	0	0	0	103	1.5	103	0.6
MASTACEMBLIDAE										
Mastacemoelus loennbergii	8	0.4	53	1.8	49	18.6	106	1.5	237	1.4
MONDACTYLIDAE										
Monodactylus sebae	20	0.9	25	0.9	96	1.9	163	2.3	308	1.7
MORMYRIDAE										
Gnathonemus senegalensis	148	6.5	169	8.7	264	5.3	350	4.9	952	5.5
MUGILIDAE										
Mugil cephalus	304	13.4	213	7.9	373	7.5	445	6.3	1363	7.8
MOCHOKIDAE										
Synodontis eupterus	7	0.3	49	1.7	137	2.8	282	4.0	480	2.8
POLYNEMIDAE										
Polydactyl us quadrafilis	143	6.3	172	5.9	265	5.4	395	5.6	993	5.7
SCIAENIDAE										
Pseudolithus elongatus	186	8.2	205	7.0	373	7.5	475	6.8	1262	7.2
SCHILBEIDAE										
Schilbe mystus	68	2.9	122	4.2	178	3.6	254	3.6	633	3.6
SPHYRAENIDAE										
Sphyraena barracuda	48	2.1	67	2.3	104	38.9	209	2.9	471	2.7
Total number of species	**25**		**25**		**25**		**26**		**101**	
Total number of individuals	**2272**	**100**	**2923**	**100**	**4950**	**100**	**7019**	**100**	**17464**	**100**

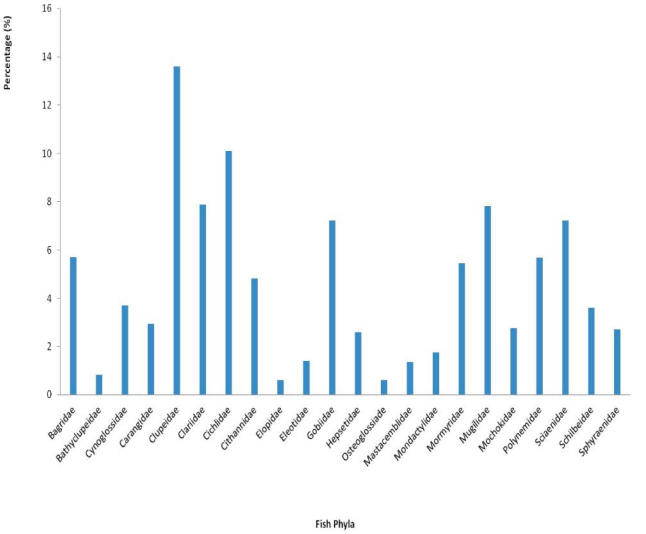

Fig 2. Composition of fish families in the Calabar River (Nigeria) during the study period

Diversity indices of ichthyofauna

Summary of the diversity and dominance indices calculated during the study for the four sampling stations is presented in Table 5. Species richness calculated as Margalef's index (d) was least in Station 3 (2.821), which is the second downstream station, while Station 1 accounted for the highest diversity (3.105). Shannon diversity index (H) in Station 1 accounted for the lowest diversity (2.770), while Station 4 accounted for the highest diversity (3.095). Equitability was least in Station 1 (0.8606) and highest in Station 4 (0.9498). The four stations had low dominance levels with no significant difference in index values (p>0.05).

Correlation between physico-chemical parameters and ichthyofauna assemblages

Correlation co-efficient (r) values for physico-chemical parameters and fish fauna abundance are presented in Table 6. *Clarias gariepinus*, *Mastacemoelus loennbergii* significantly correlated positively with surface water temperature (r =0.96; r =0.97), *Bathygobis soparator*, *Orechromis niloticus*, *Chromidotilapia sp*., *Citharinus citherus*, *Periophthalmus sp*., *Hepstus odoe*, *Monodactylus sebae*, *Synodontis eupterus*, *Pseudodolithus elongatus*, *Sphyraena barracuda* significantly correlated positively with DO (r = 0.98; r = 0.96; r = 0.99; r = 0.96; r = 0.98; r = 0.99; r = 0.98; r = 0.98; r = 0.99 and r = 0.97), respectively. *Chrysichthyes nigrodigitatus*, *Heterotis niloticus* and *Sphyraena barracuda* significantly correlated positively with conductivity (r = 0.96; r = 0.99 and r = 0.96), *Bathygobis soparator* significantly correlated positively with chromium (r = 0.96) and *Mugil cephalus* significantly correlated positively with copper (r = 0.96) at p < 0.05.

DISCUSSION

Physico-chemical parameters

The most common physical assessment of water quality is the temperature. In fact, no other single factor has such an intense influence and direct, as well as indirect, effect on biota of an ecosystem like temperature (Fauzia and Khan, 2013). During the study, the result showed that the mean surface water temperature fell within the normal temperature which ranged from 20-40^{0}C as recommended by the National Environmental Standards and Regulations Enforcement Agency, indicating that the river is thermally unpolluted. Andem et al. (2013) reported similar temperature

Table 5. Diversity indices of fish fauna of the Calabar River

Biotic Indices/Stations	S1	S2	S3	S4
Simpson's Index (D)	0.0745	0.0607	0.0537	0.0504
Shannon Index (H)	2.770	2.954	3.043	3.095
Margalef's Index (d)	3.105	3.007	2.821	2.823
Equitability (E)	0.8606	0.9178	0.9454	0.9498
Taxa	**25**	**25**	**25**	**26**
Individual	**2272**	**2923**	**4950**	**7619**

S1 (Station one) = Tinapa Resort Beach, S2 (Station two) = Addax Petroleum Company, S3 (Station three) = Itiat Ekpe Beach, S4 (Station four) = Nsidung Beach in the intertidal region of the Calabar River; this could be attributed to the fact that only degraded organic and inorganic matter contained in the effluents was discharged into the river. Similar result was also observed by Yakub (2010) who reported surface water temperature in the lower Ogun River; this resulted from the fact that degraded organic matter contained in the effluent was discharged into the river. The spatial variations in the physico-chemical parameters indicate the influence of season on the physico-chemical hydrology of the Calabar River. Adebisi (1981), cited by Grover and Chrzanowski (2006), reported that the rainfall pattern is an important climatic factor governing the physico-chemical dynamics of water bodies. The pH of the water was mostly alkaline throughout the course of the study. The result of this study shows that the pH range was within the recommended range (6.0-9.0), as

Table 6. Correlation co-efficient (r) between some environmental variables and ichthyofauna abundance of the Calabar River

Physico-chemical Parameter/ Fish fauna	Surface water temp(^{0}C)	pH	DO	BOD	Conductivity µS/cm	TDS	TSS	Lead	Cadmium	Chromium	Iron	Copper
Chrysichthyes nigrodigitatus	0.67	-0.51	1.00	0.65	**0.96***	0.85	0.93	-0.43	0.00	0.86	-0.82	0.86
Bathygobis soparator	0.69	-0.25	**0.98***	0.50	0.85	0.67	0.79	-0.16	0.00	**0.96***	-0.63	0.90
Cynoglossus senegalensis	0.87	-0.17	0.94	0.31	0.86	0.63	0.74	-0.09	0.00	0.86	-0.65	0.73
Caranx hippos	0.64	0.30	0.71	0.03	0.45	0.16	0.33	0.40	0.00	0.90	-0.13	0.71
Caranx latus	0.86	-0.04	0.91	0.23	0.79	0.53	0.65	0.04	0.00	0.89	-0.54	0.73
Ilisha africana	0.92	0.25	0.72	-0.10	0.59	0.27	0.40	0.31	0.00	0.74	-0.33	0.50
Ethmalosa fimbriata	0.62	-0.19	0.94	0.49	0.77	0.59	0.73	-0.08	0.00	0.99	-0.53	0.93
Pellonula sp.	0.65	-0.50	1.00	0.66	0.95	0.84	0.93	-0.42	0.00	0.87	-0.81	0.88
Clarias gariepinus	**0.96***	-0.23	0.81	0.18	0.86	0.66	0.71	-0.20	0.00	0.58	-0.75	0.43
Orechromis niloticus	0.79	-0.18	**0.96***	0.39	0.84	0.63	0.75	-0.09	0.00	0.93	-0.62	0.83
Chromidotilapia sp.	0.76	-0.41	**0.99***	0.54	0.95	0.80	0.89	-0.33	0.00	0.86	-0.80	0.81
Citharinus citherus	0.80	-0.17	**0.96***	0.38	0.85	0.63	0.75	-0.09	0.00	0.92	-0.62	0.81
Elop lacerta	0.61	0.43	0.60	-0.09	0.33	0.02	0.20	0.52	0.00	0.84	0.00	0.62
Eleotris daganensis	0.83	-0.08	0.93	0.29	0.80	0.55	0.68	0.01	0.00	0.92	-0.56	0.78
Periophthalmus sp.	0.71	-0.26	**0.98***	0.49	0.86	0.68	0.80	-0.17	0.00	0.95	-0.65	0.88
Hepstus odoe	0.70	-0.31	**0.99***	0.54	0.88	0.72	0.83	-0.22	0.00	0.94	-0.68	0.89
Heterotis niloticus	0.75	-0.61	0.88	0.56	**0.99***	0.92	0.93	-0.58	0.00	0.58	-0.96	0.57
Mastacemoelus loennbergii	**0.97***	-0.13	0.84	0.15	0.84	0.60	0.67	-0.09	0.00	0.68	-0.68	0.51
Monodactylus sebae	0.78	-0.25	**0.98***	0.44	0.88	0.69	0.80	-0.16	0.00	0.92	-0.67	0.83
Gnathonemus senegalensis	0.75	-0.29	0.99	0.49	0.89	0.71	0.82	-0.20	0.00	0.92	-0.69	0.85
Mugil cephalus	0.38	-0.57	0.93	0.82	0.85	0.81	0.90	-0.48	0.00	0.88	-0.72	**0.96***
Synodontis eupterus	0.81	-0.32	**0.98***	0.46	0.93	0.75	0.84	-0.24	0.00	0.86	-0.75	0.78
Polydactylus quadrafilus	0.79	-0.34	**0.99***	0.49	0.93	0.75	0.85	-0.26	0.00	0.88	-0.75	0.81
Pseudolithus elongatus	0.71	-0.27	**0.98***	0.50	0.86	0.68	0.80	-0.17	0.00	0.95	-0.65	0.89
Schilbe mystus	0.86	-0.16	0.94	0.32	0.85	0.63	0.74	-0.08	0.00	0.88	-0.64	0.75
Sphyraena barracuda	0.82	-0.41	**0.97***	0.49	**0.96***	0.81	0.88	-0.35	0.00	0.80	-0.83	0.74

*Correlation is significant at $p<0.05$

suitable for aquatic life (NESREA, 2011). Similar alkaline pH condition was reported in the intertidal region of the Calabar River (Andem et al., 2013). The spatial variation in pH was significant. This is an indication that various anthropogenic disturbances significantly alter the pH along the river. The dissolved oxygen concentration in the Calabar River was low and below the acceptable limit (5.0 mg/L) for fish survival by the National Environmental Standards and Regulations Enforcement Agency. High organic content from human faeces and domestic wastes from the intertidal region of the Calabar River may be responsible for low dissolved oxygen. Similar reports on organic pollution with marked reduction in dissolved oxygen level include that of Andem et al. (2013) in the intertidal region of the Calabar River caused by organic rich effluent from domestic and agricultural activities, and Lawson (2011) in the Lagos Lagoon caused by human sewage and municipal waste discharge.

The higher level of dissolved oxygen in the dry season might be attributed to possible increase in photosynthetic activities of the river, while lower dissolved oxygen in the wet season could be explained by the decrease in photoperiod, photosynthetic activities and increase in turbulence and turbidity of the river, and also by some chemical, biological oxidation processes, as well as increase in organic load from the river runoff. Similar observation was also made by Mane (2002) in the Manar River near Degloor District, India. The mean BOD was less than 4 mg/L, which is suitable for aquatic life as recommended by the National Environmental Standards and Regulations Enforcement Agency. Since the BOD range in the present study did not exceed the limit (4.0 mg/L), it does not pose a threat to the aquatic life. Higher BOD of 5.0 mg/L recorded in Station 4 might be attributed to the different organic waste from human sewage and waste water from residential areas discharged into the river which brings Station 4 into the brink of pollution. The higher BOD level in the wet season could be the effect of runoff water from heavy rainfall which carries wastes and deposit in the river, while lower values in the dry season could be due to reduction in the amount of runoff water discharge into the river (Abowei and Sikoki, 2005; Andem et al., 2012). Conductivity level below 50 µS/cm is expected to be low; between 50-600 µS/cm fall within the medium class, while above 600 µS/cm fall in the high class according to the National Environmental Standards and Regulations Enforcement Agency. In this study, conductivity range between 237.14 µS/cm-290.67 µS/cm, which falls within the medium class, indicated moderate pollution (NESREA, 2011). In the past two decades, research done on the physico-chemistry in many Nigerian inland water bodies showed that conductivity levels were less than 500 µS/cm during the dry season and less than 100 µS/cm during the wet season (Egborge, 1992). Similar findings were also observed by Andem et al. (2012) in the Ona River. The conductivity of this study followed a similar trend, increasing in the wet season and decreasing in the dry season. Similar work by Oben (2000) showed increase in conductivity level in the wet season, which could be attributed to more mineralization of organic matter and the concentration of ions could result to evaporation, while the decrease in conductivity values during the dry season may be a result of decomposition of allochthonous organic materials discharged into the river. Similar findings were recorded by Okayi (2003) in the River Benue. The author also suggested that the increase in conductivity values during the rainy season may be due to dilution by rainwater. He also reported that in the wet season allochthonous materials brought in by streams draining from catchments area and then discharged into the reservoir may play a major role in their limnology. Low conductivity levels recorded for the dry season may be a result of utilized allochthonous materials by the phytoplanktonic organisms of the river. High conductivity values have been reported to be indicative of an increase in the amount of polluting particles (Oben, 2000). Range of TDS and TSS obtained in this study were high and beyond acceptable limit for drinking water and survival of aquatic life as recommended by the National Environmental Standards and Regulations Enforcement Agency. High levels of total dissolved solids and total suspended solids observed in this study could be a result of regular discharge of wastes from domestic and industrial sources. The continuous deposition of these wastes into the river could impede the free flow of the river. Long term deposition of materials in the river could also result in flooding, particularly during heavy rainfall, which could have both economic and ecological implications (Andem et al., 2012). Metal concentrations in the environment are controlled by various processes such as particulate surface adsorption and micronutrient cycle (Lawson, 2011). The concentrations of some heavy metals in water such as lead, chromium and copper in this study were below permissible limit for drinking water and survival of aquatic life by the National Environmental Standards and Regulations Enforcement Agency, except for cadmium and iron which were above the recommended standard. This could be a result of anthropogenic wastes from household and dump sites containing these materials (such as batteries and insecticides found in dump sites around the river) and because of its closeness to a highly industrialized area. Heavy metal detected was higher during the dry season than rainy season; this may be due to dilution from heavy rainfalls during the rainy season. Similar findings were also made by Kar et al. (2008) from the River Ganga.

Ichthyofauna assemblages

The results indicate that fish fauna diversity of the Calabar River was generally very high. The relative fish abundance compare favourably with similar reports on streams in southern Nigeria (Imefon, 2012). However, Udoidiong and King (2000) investigate the relative abundance of fish fauna in two second-order streams of Akwa Ibom State and these are as follows: authors reported that the Esedeke have 25 fish species belonging to 23 genera representing 16 families and the Iba-Oku have 18 fish species belonging to 17 genera representing 13 families. Similar findings were observed by Onuoha et al. (2010); authors recorded 26 fish species belonging to 20 families during their study in the Ntak Inyang Stream. The aforementioned studies are very similar to the present study which recorded 26 species belonging to 26 genera representing 22 families. Sikoki et al. (2008) investigated the fish fauna of the Onu-Iyi ukwu stream in southeastern Nigeria. In their study, they recorded 17 fish species belonging to 15 genera and 11 families. The results of the present study are different from that of Udoidiong and King (2000). This could be due to differences in the research period and sampling frequency. In this study, Mugilidae, Clariidae, Gobiidae, Sciaenidae, Clupeidae and Cichlidae were the most abundant and dominant groups. Studies indicated that the major causes of declining fish catches from the river are increased fishing pressure and habitat destruction (Emmanuel and Onyema, 2007). However, distribution and abundance of fish in tropical water bodies have been variously attributed to several factors, particularly depth (Idodo-Umeh, 2003). The dominance of the members of the family Cichlidae in the Calabar River, attributed to the fact that they reproduce very fast, means that they are prolific breeders and this confirms that they were under uncontrolled conditions. Similar observation was made by Obasohan and Oronsaye (2006) in Ikpoba Reservoir in Edo State. A higher abundance of the fish species during the dry season than in the rainy season could be attributed to the fact that the water level was low which causes fishes to concentrate more in the environment. Ayoola and Kuton (2009) recorded higher abundance of fish species at low levels of water in the Lagos Lagoon during the dry season. Higher Shannon-Weiner index (H) and Margalef's index (d) were recorded in the river. The low value of dominant fish species could be caused by flood which might lead to migration of some fish in the river. Flood on aquatic ecosystem has been known to have a negative effect on the distribution of the resident organism (Ogbeibu and Oribhabor, 2002). The distribution and abundance of fish fauna, as the results show, were also affected by the physico-chemical qualities such as surface water temperature, DO, conductivity, high concentration of chromium and copper in the water. These parameters positively correlated significantly with fish species including *Clarias gariepinus, Mastacemoelus loennbergii, Bathygobis soparator*, *Orechromis niloticus*, *Chromidotilapia sp*., *Citharinus citherus*, *Periophthalmus sp*., *Hepsetus odoe*, *Monodactylus sebae*, *Synodontis eupterus*, *Pseudodolithus elongatus*, *Sphyraena barracuda*, *Chrysichthyes nigrodigitatus*, *Heterotis niloticus* and *Mugil cephalus*. This is an indication of the ability of organisms to survive and migrate to more favourable conditions or die under unfavourable environmental conditions as was also reported by Tejerina-Garro and De Merrona (2010). Similar trends in the correlation between effect of water quality and the distribution of fish fauna have been reported by Othman et al. (2001). The weak correlation between some of the fish fauna and water quality parameters could be attributed to the variation in mesh size and gear use by fishermen, which might have greatly influenced the species composition and abundance in this study.

CONCLUSION

Ecological relevance of the measured physico-chemical parameters was assessed by comparing the degree of correlation of fish fauna diversity. The result revealed that the fish fauna showed fairly good relation with physico-chemical attributes and the value of data obtained reflected the conditions existing in the river in terms of the quality and quantity of the biota. Considering the temperature, pH and dissolved oxygen content of the water, it can be said the river is moderately unpolluted. However, the level of conductivity, biological oxygen demand and total dissolved solids are an indication of pollution of the river in spite of the factors. In this study, fish fauna diversity across the sampling stations remains high, suggesting that the water quality of the Calabar River is good and supports diverse, well stable and balanced fish assemblages of the river. It also provides a healthy environment for growth and survival of biological communities, but this does not mean that the river is free from pollution. The ichthyofauna assemblage such as abundance and composition was high. This could be due to a low water level and depth of the river. The presence of certain fish fauna in polluted and non-polluted parts of the river indicates that they could be used as potential bioindicators in assessment and biomonitoring of the river. The methods used in identifying fish diversity in the river proved their applicability for future studies in other regions of the country and the world at large.

Sažetak

VARIJABILNOST OKOLIŠNIH PARAMETARA I EKOLOŠKA DISTRIBUCIJA IHTIOFAUNE U JUGOISTOČNOM PRIOBALNOM PODRUČJU RIJEKE KALABAR, NIGERIJA

Studije o varijabilnosti okoliša i ekološkoj distribuciji ihtiofaune provedene su u rijeci Kalabar. Uzorkovane su površinske vode i ihtiofauna s ciljem da se dobiju osnovni podaci o postojećem stanju rijeke Kalabar, te buduća stanja rijeke. Sezonske varijacije pokazuju značajne razlike u temperaturi površinske vode, pH-u, DO-u, BPK-u, vodljivosti, TDS-u i TSS-u između uzorkovanih postaja, te neznatne razlike u sadržaju teških metala poput kadmija, kroma, željeza i bakra. Identificirano je dvadeset i šest ribljih vrsta koje spadaju u dvadeset dvije obitelji. Mugilidae, Clariidae, Cichlidae, Gobiidae i Sciaenidae su bile najviše zastupljene i za vrijeme kišne i suhe sezone, dok su Clupeidae, Bathyclupeidae, Carangidae i Sphyraenidae bile manje zastupljene u kišnoj sezoni, ali visoko zastupljene u suhoj sezoni. Krom, bakar, površinska temperatura vode i DO značajno su korelirali s prisutnošću vrsta *E. fimbriata, B. soporator, M. sebae, C. gariepinus, M. loennbergii, C. guentheri* i *P. babarus*. Ukupna vrijednost biotičkih indeksa raznolikosti se kretala u rasponu od 0,0504-0,0745 za Simpsonov indeks, 2,770-3,095 za Shannonov indeks, 2,821-3,105 za Margalef indeks i 0,8606-0,9498 za nepristranost. Međutim, prisutnost određenih ribljih vrsta u zagađenim i nezagađenim dijelovima rijeke ukazuje na to da bi se mogle koristiti kao mogući bioindikatori u procjeni i biomonitoringu rijeke. Metode koje se koriste u određivanju raznolikosti riba potvrdile su da se mogu primjenjivati i u budućim istraživanjima.

Ključne riječi: ekološka distribucija, ihtiofauna, biotički indeks, zagađenje

REFERENCES

Abowei, J. F. N., Sikoki, F. D. (2005): Water Pollution: Management and Control. Double Trust Publishers, Port Harcourt, Nigeria, pp. 254.

Adebisi, A. A. (1981): The Physical and Chemical Hydrology of a Tropical Seasonal River, Upper Ogun River. Hydrobiologia, 79, 157-165.

Adesulu, E. A., Sydenham, D. H. (2007): The Freshwater Fishes and Fisheries of Nigeria. Macmillan Nigeria Publishers Limited, Yaba, Lagos, pp. 33-397.

Alexandre, C.V., Esteves, K. E, de Moura e Mello, M. A. (2010): Analysis of Fish Communities along a Rural–Urban Gradient in a Neotropical Stream (Piracicaba River Basin, São Paulo, Brazil). Hydrobiologia, 641, 97–114.

Andem, A. B., Okorafor, K. A., Eyo, V. O., 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.

APHA/AWWA and WEF. (1995): Standard Methods for the Examination of Water and Waste Water. 20th Edition. Washington DC, pp. 1132-1145.

Ayoola, S. O., Kuton, M. P. (2009): Seasonal Variations in Fish Abundance and Physico-chemical Parameters of Lagos Lagoon Nigeria. African Journal of Environmental Science and Technology, 3, 5, 149-156.

Banks, J.W., Holden, M. J., Mc-Connel, R.M. (1965): Fishery Report. In: White E (Ed). The First Scientific Report of the Kainji Biological Research Team. University of Ile-Ife, Nigeria, pp. 88

Baran, E., Jutagate, T. (2010): Would Barriers to Migration have the same Effect on all Fish species? In: Dugan, P. and Barlow, C. (eds.) Dams as Barriers to Fish Migration in the Mekong, and Possibilities for Mitigation, MRC Technical Paper, Mekong River Commission, Vientiane, p. 35-42.

Cross River National Park (CRNP) (2010): Important Bird Areas Factsheet. Oban Division. Bird Life International, p. 9.

Dudgeon, D. (2000): The Ecology of Tropical Asian Rivers and Streams in Relation to Biodiversity Conservation. Annual Review of Ecology and Systematic, 31, 239-263.

Egborge, A.B.M. (1992): Problems of Aquatic Resources Conservation. A Case Study of Nigerian Fishes. In Proceedings of the National Conference on Aquatic Resources, Calabar. 11-14th May, 1992, pp. 27.

Emmanuel, B. E., Onyema, I. C. (2007): The plankton and Fishes of Tropical Creek in South western Nigeria. Tropical Journal of Fisheries and Aquatic Sciences, 7, 105-114.

Eze, E. B., Effiong, J. (2010): Morphometric Parameters of the Calabar River Basin: Implication for Hydrologic Processes. Journal of Geography and Geology, 2 (1), 1916-1920.

Farombi, E. O., Adelowo, O. A and Ajimoko, Y. R. (2007): Biomakers of Oxidative Stress and Heavy metal levels as Indicators of Environmental Pollution in African catfish (*Clarias gariepinus*) from Nigerian Ogun River. International Journal of Environmental Resources and Public Health, 4, 2, 158-165

Fauzia, I., Khan, A. (2013): Diversity Pattern of Macro-zoobenthos and their Relation with Qualitative Characteristics of River Yamuna in Doon Valley Uttarakhand. American-Eurasian Journal of Toxicological Sciences, 5, 1, 20-29.

Ferreira, F. C., Petrere, M. (2009): The Fish Zonation of the Itanhae River Basin in the Atlantic Forest of Southeast Brazil. Hydrobiologia, 636, 11-34

Food and Agriculture Organization (FAO) (2001): Methods of Collection and Analysing Size and Age Data for Fish Stock Assessment. FAO Fish Circular, 736, 1-100

Grover, J. P., Chrzanowski, T. H. (2006): Seasonal Dynamics of Phytoplankton in Two Warm Temperate Reservoir Association of Taxonomic Composition with Temperature. Journal of Plankton Research, 28, 1, 1-17.

Gullard, J. A. (1980): General Concept of sampling fish. Fisheries Department, FAO. Rome, pp. 7-12.

He, Y., Wang, J., Lek-Ang, S., Lek, S. (2010): Predicting Assemblages and Species Richness of Endemic Fish in the Upper Yangtze River. Science of the Total Environment, 408, 4211-4220.

Idodo-Umeh, G. (1987): Studies on the fish community of River Ase, Bendel State with special Emphasis on the Food and Feeding Habits of Citharinidae, Bagridae, Schilbidae and Mokochidae, PhD Thesis, University of Benin, Benin City. p. 412.

Idodo-Umeh, G. (2003): Fresh Water Fishes of Nigeria Taxonomy, Ecological Notes, Diet and Utilization. Idodo Umeh Publishers Limited, p. 7-221.

Imefon, U. U. (2013): Taxonomic Composition, Diversity and Abundance of the Ichthyofaunal Assemblage of Iba-Oku Stream, Ikpa River, Nigeria. International Journal of Zoological Research, 8, 2, 71-80.

Ita, E.O. (1978): An Analysis of Fish Distribution in Kainji Lake, Nigeria. Hydrobiology, 58, 3, 235-244.

Ita, E.O. (1993): Inland Fishery Resources of Nigeria. F.A.O. CIFA Occasional Paper No. 20, pp. 120.

Kar, D., Sur, P., Mandal, S. K., Saha, T., Kole, R. K. (2008): Assessment of Heavy metal pollution in surface water from River Ganga in West Bengal. International Journal of Environmental Science and Technology, 5, 1, 119-124.

Kimmel, W.G., Argent, D. G. (2010): Stream Fish Community Responses to a Gradient of Specific Conductance. Water Air and Soil Pollution, 206, 49–56.

Kusemiju, K., Olaniyan, C.I.O. (1997): The Food and Feeding Habits of the Catfish: *Chrysichthys walker* (Gunther), *Chrysichthys filamentosus* (Boulenger) and *Chrysichthys nigrodigitatus* (Lacepedae) in the Lekki Lagoon, Nigerian Journal of Fish Biology, 10, 105-112.

Lawson, E. O. (2011): Physico-chemical Parameters and Heavy Metal Content of Water from the Mangrove Swamps of Lagos Lagoon, Lagos, Nigeria. Advances in Biological Research, 5, 1, 8-21.

Mane, M. E. (2002): The Study of Hydrobiology of Manar River Near Degloor District, Nanded. Ph.D. Thesis, S.R.T.M. University, Nanded, Maharashtra India, pp. 198.

Mims, M.C., Olden, J. D., Shattuck, Z. R., Poff, N. L. (2010): Life History Trait Diversity of Native Freshwater Fishes in North America. Ecology of Freshwater Fish, 19, 390–400.

National Environmental Standards and Regulations Enforcement Agency (NESREA) (2011): National Environmental (Surface and Groundwater Quality), p. 693-727.

Nwadiaro, C. S. (1984): The Longitudinal Distribution of Macro-invertebrates and Fish in a lower Niger Delta River (River Sombrerio) in Nigeria. Hydrobiology Bulletin, 18, 13-40.

Obasohan, E. E., Oronsaye, J. A. (2006): Biodiversity and Sustainability of Freshwater Fishes of Nigeria, FISON Proceeding, pp. 230-237.

Oben, B. O. (2000): Limnological Assessment of the Impact of Agricultural and Domestic Effluents in Three Manmade Lakes in Ibadan, Nigeria. PhD Thesis, University of Ibadan, Ibadan, pp. 176

Ogbeibu, A. E. (2005): Biostatistics: A Practical Approach to Research Data Handling. Mindex Publishing Company Ltd. Nigeria, p.p 153 -162.

Ogbeibu, A. E., Oribhabor, B. J. (2002): Ecological Impact of River Impoundment Using Benthic Macro-invertebrates as Indicator. Water Research, 36, 2427-2436.

Okayi, R. G. (2003): Effect of Effluent Discharge on Water Quality, Distribution and Abundance of Plankton and Fish Species of River Benue. Ph.D Thesis. University of Ibadan, Ibadan, pp. 198.

Onuoha, G. C., Ekpo, I. E., Chude, L. a., Isangedighi, I. A. (2010): Composite Preliminary Ichthyofaunal Survey of Ntak Inyang Stream, Ikpa River, Nigeria. Nigeria Journal of Agricultural and Food Environment, 6, 83-89.

Orrego, R., Adams, S.M., Barra, R., Chiang, G., Gavilan, J. F. (2009): Patterns of Fish Community Composition along a River Affected by Agricultural and Urban Disturbance in South-central Chile. Hydrobiologia, 620, 35-46.

Othman, M. R., Samat, A., Hoo, L. S. (2001): Effect of Water Quality to Fish Abundance and Chlorophyll a (Selected Aquatic Organisms) in Labu River System, Malaysia. Journal of Biological Science, 1, 1178-1182.

Penczak, T. (2002): Threatened Obligatory Riverine Fishes in Human Modified Polish Rivers. Ecology of Fresh Water Fish, 9, 109-117.

Reed, W., Burschard, J., Hopson, A.J., Jenness, J., Yaro, I. (2000): Fish and Fisheries of Northern Nigeria. Ministry of Agriculture, Northern Nigeria, pp. 226.

Sikoki, F.D., Zabbey, N., Anyanwu, I. N. (2008): Fish Assemblages of Onu-Iyi-Ukwu Stream in Southeastern Nigeria. Tropical Freshwater Biology, 17, 41-51.

Tejerina-Garro, F. L., De Merrona, B. (2010): Flow Seasonality and Fish Assemblage in Tropical River, French Guiana, South America. Neo-tropical Ichthyology, 8, 1-16.

Udoidiong, O. M., King, R. P. (2000): Ichthyofauna Assemblages of Some Nigerian Rainforest streams. Journal Aquatic Science, 15, 1-8.

Welman, J. B. (2003): Preliminary Survey of the Fresh Water Fisheries of Nigeria. Government Printer, Lagos, Nigeria, pp. 88.

Yakub, A. S. (2010): Physico-chemical Parameters, Macro-invertebrates and Fish fauna of lower Ogun River at Ishasi-Olofin, Ogun State. Ph.D Thesis, Department of Zoology, University of Ibadan, Ibadan, pp. 162.

