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BIOLOGICAL SIGNIFICANCE AS AN INDICATOR OF ORGANIC POLLUTION IN THE UPPER REGION OF QUA IBOE RIVER, NIGER DELTA, NIGERIA

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Abstract

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The pollution status of Qua Iboe River, Niger Delta, Nigeria, was studied between January 2020 and June 2021 at five sampling locations based on human activities. The indices used were PPI and HFBI for organic pollution. The identified phytoplankton comprised 44 taxa belonging to 5 taxonomic groups, 14 genera of pollution indicators out of 33 genera of the total population, among which Bacillariophyceae accounted for 48.25%, followed by Chlorophyceae (28.87%), and the least was Euglenophyceae with 3.16%. The macroinvertebrates identified comprised 25 taxa, 3 phyla, and 22 families of pollution indicators. Among them, phyla arthropoda accounted for 83.9%, while Mollusca was the lowest accounted for 6.6 %. The HFBI values ranged from 3.94 to 5.98, while PPI score ranged between 17 and 25.The values of HFBI obtained in locations 2, 3, and 5 reflected significant level of organic pollution, while the values of PPI obtained between locations 2 and 5 revealed higher level of organic pollution, which was unsafe for the sustenance of aquatic life; mostly intolerant species. The occurrence of pollution indicator species further proved that the river water was polluted owing to anthropogenic activities. The activities of humans within the watershed should be of concern to the relevant authorities; regulation of these activities should be enforced to minimize the situation of water deterioration and for regaining the natural water quality to support aquatic life and health and make it fit for domestic usage.

Key words: organic pollution, indices, anthropogenic activities, Qua Iboe River, Nigeria.

Introduction

Aquatic ecosystems are built up with many forms of pollutants from point and non-point sources; ranging from polycyclic aromatic hydrocarbons, polychlorinated biphenyl dioxins, potentially toxic elements, pesticides, herbicides, fertilizers, animal waste from feedlots, and other organic contaminants (Jonah et al., 2023a,b). Other forms of pollutants in aquatic ecosystems are untreated sewage, pharmaceutical waste, and thermal effluent (Cunningham et al., 2005).Aquatic pollution occurs when pollutants (substances that cause undesirable effects) are introduced into the water body, altering the water quality. In Niger delta, this is one of the major environmental issues that are yet to be given much attention. Accumulation of pollutants beyond the carrying capacity of water is a serious environmental threat not only to water bodies but also to the bio-resources, including planktons and macroinvertebrates (McCabe, 2010; George et al., 2020).

However, water pollution is considered as an indicator of increase in human population, urbanization, agricultural activities, poor sanitation, poor waste management, industrial revolution, and sand dredging activities (Koehnken et al., 2020; Jonah et al., 2020a, b; Anyanwu et al., 2021;Ukoha-Onuoha et al., 2022; Jonah, Archibong, 2022). A large number of surface waters in Niger delta, especially the rivers and streams, have been polluted due to municipal waste discharge (Ayandiran et al., 2018; Ukoha-Onuoha et al., 2022; Akpan et al., 2023; Jacob et al., 2024); thus, their capacity to support aquatic organisms and carry out other functions of aquatic ecosystems are diminished (Beier et al., 2017). In the past, monitoring of aquatic pollution was focused more on the contents of physical and chemical variables while less attention was given to the application of biological components as an indicator of aquatic pollution. Biological indicator is an important tool, and it has been applied in the evaluation of pollution status of inland water bodies (Çiçek, Yamuç, 2017; Singh, Sharma, 2018; Mahmoud, Riad, 2020; Jonah, Archibong, 2022). Studies (Jafari, Gunale, 2006; Kutama et al., 2014; Arimoro et al., 2015; Anyanwu et al., 2019; Jonah, Akpan, 2021) affirmed that monitoring of phytoplankton and macroinvertebrates provide historic ecological conditions, due their vulnerability to natural and anthropogenic changes in the aquatic ecosystem.

The non-pollution tolerant species are more vulnerable to unfavorable water conditions, leaving behind the pollution-tolerance species (George et al., 2020). The use of the invertebrate is based on the two assumptions, either the water is not affected by pollutants which could support abundance of pollutant-sensitive taxa, or the water is affected by having less or non-pollutant-sensitive taxa with the predominance of pollution-resistant species. The insect taxa such as Trichopterans, Plecoepterans, and Ephemeropterans, etc., are recognized to be pollution sensitive, and strictly inhabiting unclean water bodies (Jonah, Akpan, 2024). However, some species in the families like Ceratopogonidae, Chironomidae, and Thaumaleidae are well known for pollution tolerance, hence often considered as indicators in organic pollution of water (Oku et al., 2014). Palmer (1969) listed certain genus of algae, such as Oscillatoria, Microcystis, Closterium, Micractinium, Pandorina, Euglenaria, Melosira, Synedrosphenia, and Cyclotella, as biological indicators of organic pollution. The proportion of these genuses in a water body expresses the health status of such aquatic ecosystems. Several studies regarding biological significance as indicators of organic pollution have been documented, but few have been reported from the upper segment of Qua Iboe River. The Qua Iboe River is one of the major tropical rainforest rivers in Niger Delta that traverses over 100 communities from its origin, covering three Local Government Areas in Abia State and ten in Akwa Ibom State. The river is subjected to various anthropogenic pressures, which might hamper the ecological integrity. The intense agricultural activities within the catchment area are a source of concern due to the consistent application of pesticides, insecticides, fertilizers, and other synthetic organic compounds widely used in agriculture, which are highly toxic to water. These substances might get into the adjoining water bodies and subsequently Qua Iboe River through surface run-off.

More so, sand mining and indiscriminate disposal of domestic wastes are another illicit activity within the Qua Iboe River, which could have a direct or indirect consequence on the aquatic system. The intensive and massive road construction (urbanization) around the Qua Iboe River is also of concern due to the impacts associated with such activities. Municipal runoff and effluent discharged into the river may have a long-term effect on plankton and macroinvertebrates. Therefore, the objective of this study was to evaluate the levels of organic pollution of the upper region of Qua Iboe River, Niger Delta, Nigeria using PPI and HFBI.

Material and methods

Description of the study area

The studied sections of Qua Iboe River were between Obot Akara and Ukanafun Local Government Area, lying between Latitude 04°53' and 05°9'North and Longitude 07°39' to 07°47' East. The locations with their respective geo-coordinates are presented in Table 1.The area is characterized by long wet season (March–October) and short dry season (November–February), with a mean annual rainfall of 2,200 mm (Jonah, Archibong, 2022). The area experience significant seasonal variations, with temperatures ranging from 22 °C during dry months to 35 °C during wet months. The river flows in southeastern direction towards the Atlantic Ocean from Ikwuano Local Government Area of Abia State into Usaka community in Akwa Ibom State. The river receives waste from point and non-point sources. The river water serves as a source for irrigation, industrial use, and domestic use.

Sampling locations

For the purpose of this study, five sampling locations were selected from the stretch of the river (Fig. 1), which criteria were based on the level of perturbation by anthropogenic activities and geo-morphological aspect of the area. The anthropogenic activities observed during the study period in location one was bathing, laundry, and farming. The location is further characterized by slow water current, higher penetration of sunlight intensity; substrate is sandy and muddy at the right-hand side of the river. In location two, the observed human activities were extensive farming, intense sand dredging, bathing, laundry, sand loading, stone mining, and other domestic activities. The river receives waste from nearby communities, markets, municipal run-off, direct dumping, and from road construction. The substratum is muddy and sandy, while some sections are stony. The third location is characterized by high level of anthropogenic activities ranging from extensive farming, sand dredging, bathing, laundry, and sand loading, while the substratum is sandy. In location four, farming at the wetland behind the river, fishing, and laundry were observed. Macrophytes were abundant at the bank of this location, where the substrate is sandy and muddy. The study location 5 is characterized by slow water current and sandy substrate, while the edge is muddy. Human activities found were intense sand dredging, farming, bathing, and laundry, and the river at this point receives waste from nearby community through runoff.

Sample collection and analysis

The samples were collected monthly for 18 months between January 2020 and June 2021.The phytoplankton was collected by towing 55µm-mesh size of plankton net in the water column for 10 minutes (Jonah, Ubong, 2019; Jonah et al., 2024). The net was towed horizontally against the water current in each sampling location. The sample on the towing net was filtered into 1 L sampling bottle and fixed with two drops of 4% formalin solution before taking to the laboratory for analysis. In the laboratory, the samples were kept for 30 minutes for the phytoplankton to settle at the base of the bottles. The settled samples were further filtered into 100 mL of sampling bottles, from which a sub-sample (1 mL) was taken and transferred into Sedgewick Rafter counting chamber fitted on a microscope for enumeration. The counting and enumeration were done using compound microscope at various magnifications, while identification to genus level was carried out with the aid of standard keys of Botes (2003) and Burchardt (2014).Three replicate observations were made, and the average count was recorded. The phytoplankton enumerated was expressed as individual per mL of sample.

Aquatic macroinvertebrates were collected using a standard D-frame hand net, 0.5 mm mesh size, and Van Veen grab sampler (0.05 m^2). The use of hand net was achieved by putting into the water facing the flow direction of the river, and the water was disturbed by kicking. The procedure was repeated in three replicates in each sampling station. The use of VanVeen grab sampler was achieved by locking the opening and subjecting the device vertically into the river bottom, where the device gets

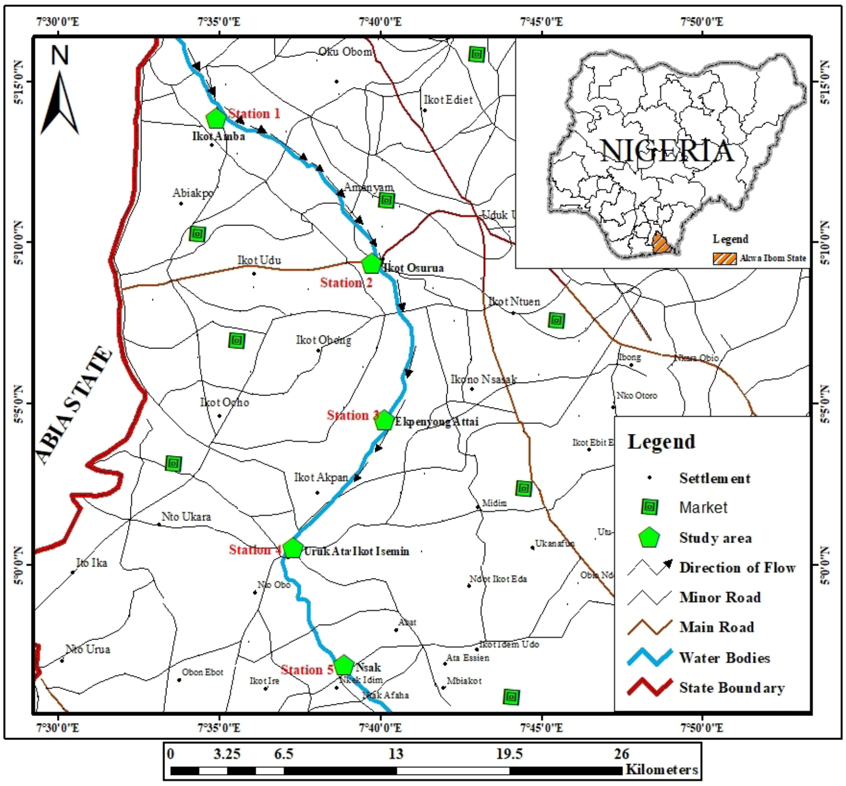

Fig. 1. A map showing the stretch of Qua Iboe River and sampling locations.

Table 1.Geo-coordinates and sampling locations of the upper segment of Qua Iboe River.

Locations	Co-coordinates
I - Ikot Anba in Obot Akara L.G.A.	Latitude 5° 9'22.4; Longitude 7° 39'44.5
II - Ikot Osurua in Ikot Ekpene L.G.A.	Latitude 5° 4'29.6; Longitude 7° 40'7.32
III - Ekpenyong Attai 1 in Essien Udim L.G.A.	Latitude 4° 57'14.7; Longitude 7° 39'2.6
IV - Uruk Ata Ikot Isemin in EtimEkpo L.G.A.	Latitude 4° 54'57.2; Longitude 7° 42'52.1
V - Nkek Idim in Ukanafun L.G. A.	Latitude 4° 53'18.4; Longitude 7°47'23.8

unlocked, grabbing the sediments when getting in contact with. The grabbed sediments were sieved with a mesh size net of 2, 1, and 0.5 mm,to remove the clay particles. The macroinvertebrates retained on the screen of the sieve were sorted and stored in a glass bottle, labeled and preserved in buffered 4% formaldehyde. Macroinvertebrates collected were identified to lowest taxonomic level based on the identification guide of Ward, Whipple (1959), Macan, (1959), Willoughby (1976), Pennak (1978), and Umar et al. (2013), and counted according to taxonomic groups and location.

Data analysis

The sample data obtained were summarized with Microsoft Excel, while test for significant difference (P<0.05) between the study sites was carried out using one-way ANOVA. Significant variations were isolated using Least Significant Difference (LSD) test, while the relative abundance (%) was calculated using equation 1.

$$RA\ (\%) = n/N \times 100, \qquad (1)$$

where n = the total number of individuals; N = the total number of individuals in from the entire groups. The relative abundance is the percentage abundance of a particular species over the total abundance of phytoplankton and macroinvertebrates recorded.

Determination of organic pollution status of the river

Organic pollution status of the river was determined using PPI and HFBI.

PPI: This index has been considered as an effective gauge to evaluate the level of organic pollution in aquatic ecosystems, and it has been used extensively by many researchers including Cicek, Yamuc, (2017), Ghaderpoori (2018), Kar et al. (2018), Vishal, Meeta, (2020), Yusuf (2020), and Inyang et al. (2022).The index is best on the occurrence of pollution-resistant species in the sampled water locations, which pollution tolerant score was assigned by Palmer (1969). When summation of index scores in each sampling location is between 0 and 10, it reflects lack of organic pollution; from 11 to 15, indicating moderate organic pollution, and 16 to 20, indicating probable high organic pollution, while scores >20 entailed higher organic pollution (Palmer, 1969).

HFBI: This index has been employed by researchers including Jonah, Akpan (2021) to evaluate the level of organic pollution in aquatic systems. The HFBI is calculated by multiplying the number of individual species (xi) from each family obtained in each location by the pollution tolerance score assigned to each species (ti).The aggregate number is then divided by the total number of species (n), and the obtained value is then compared with the water quality rating based on HFBI for organic pollution given in Table 2.

Results and discussion

Result of phytoplankton composition: A summary of numerical and relative abundant of phytoplankton species obtained are presented in Table 3. A total of 44 taxa comprising of 6,605 individual species belonging to 5 taxonomic groups (Cyanobacteria, Chlorophyceae, Dinophyceae, Euglenophyceae, and Bacillariophyceae), 14 genera of pollution indicators out of 33 genera of the total population were recorded.

Bacillariophyceae was represented by 20 species, followed by Chlorophyceae (12 species), Cyanobacteria (7 species), Dinophyceae (3 species), and Euglenophyceae (2 species). The sampling location 1 had 41 taxa and 1,584 individual phytoplankton, contributing 23.98% of the total population. Location 2 was 39 taxa with 1,193 individuals, contributing 18.06% of the total population. However, 36 taxa were obtained in sampling location 3, comprising of 1,124 individuals (17.02%); location 4 was recorded with 44 taxa and 1,329 individuals (20.12%), while location 5 had 43 taxa with 1,375 individuals accounting for 20.82% of total population. The Bacillariophyceae was the most abundant group recorded with 3,187 individual cells/L, accounting for 48.25% of the total population, followed by Chlorophyceae (1,907 cells/L; 28.87%), Cyanobacteria (1,004 cells/L; 15.2%), Dinophyceae (298 cells/L; 4.52%), and Euglenophyceae (209 cells/L; 3.16%).

The Cyanobacteria was more in location 3 (293 individuals), while few were obtained in location 1 (25 individuals). The maximum number of Chlorophyceae was obtained in location 1 (622 individuals), while the least were recorded in locations 2 and 3 (268 and 262 individuals). A higher number of Dinophyceae was obtained in location 1 (117), while the minimum number was in location 5 (23 individuals). Euglenophyceae was high in location 4 (71 individuals), while the lowest was in location 3 (7 individu-

Table 2. Water quality rating based on HFBI.

Index values	Water status	Level of organic pollution
0.00 –3.75	Excellent	No apparent organic pollution
3.76–4.25	Very good	Possible slight organic pollution
4.26–5.00	Good	Some organic pollution probably
5.01–5.75	Fair	Fairly significant organic pollution
5.76–6.50	Fairly poor	Significant organic pollution
6.51–7.25	Poor	Very significant organic pollution
7.26–10.00	Very poor	Severe organic pollution

Note: Jonah, Akpan (2021).

Table 3. Composition of phytoplankton species identified from the upper segment of Qua Iboe River water during the study period.

Phytoplankton Taxonomic Groups	Number of Species	Studied locations					Total (cells/L)	R.A (%)
		1	2	3	4	5		
Cyanobacteria	7	25.000[a]	279[b]	293[c]	201[d]	206[d]	1,004	15.2
Chlorophyceae	12	622.000[a]	268[b]	262[b]	434[c]	321[d]	1,907	28.87
Dinophyceae	3	117.000[a]	44[b]	0[c]	114[a]	23[d]	298	4.52
Euglenophyceae	2	42.000[a]	45[a]	7[b]	71[c]	44[a]	209	3.16
Bacillariophyceae	20	778.000[a]	557[b]	562[b]	509[c]	781[a]	3,187	48.25
No. of individuals	**44**	**1,584**	**1,193**	**1,124**	**1,329**	**1,375**	**6,605**	**100**
Number of species (N)		**41**	**39**	**36**	**44**	**43**	**44**	
Relative abundance (RA)		**23.98**	**18.06**	**17.02**	**20.12**	**20.82**	**100**	

Note: Values with different superscripts along the same row are significantly different (P<0.05).

Table 4. Palmer pollution index of algal in upper segment of Qua Iboe River during the study period.

Genus	PPI score	Studied locations				
		1	2	3	4	5
Cyanobacteria						
Johanseninema constrictum	-	+	+	+	+	+
Dolichospermum spiroides	-	+	+	+	+	+
Microcystis wesenbergii	1	-	1	1	1	1
Oscillatoria tenuis	5	-	5	5	5	5
Nostoc punctiforme	-	+	+	+	+	+
Woronichinia naegeliana	-	+	+	+	+	+
Rivularia sphaerica	-	+	+	+	+	+
Chlorophyceae						
Cladophora glomerata	-	+	+	+	+	+
Closterium moniliferum	1	1	1	1	1	1
Closterium kuetzingii	1	1	1	1	1	1
Cosmarium biretum	-	+	+	+	+	+
Cosmarium connatum	-	+	+	+	+	+
Mougeotia scalaris	-	+	+	+	+	+
Micractinium pusillum	1	1	1	1	1	1
Pandorina morum	1	1	1	1	1	1
Monactinus simplex	-	+	+	+	+	+
Planktophaeria gelatinosa	-	+	-	-	+	-
Scenedesmus quadricauda	4	4	4	4	4	4
Spirogyra grossii	-	+	-	-	+	+
Dinophyceae						
Tripos platycornis	-	+	+	-	+	+
Ceratium trichoceros	-	+	+	-	+	+
Ceratium pulchellum	-	+	+	-	+	+
Euglenophyceae						
Euglenaria caudate	1	1	1	-	1	1
Phacus longicauda	2	2	2	2	2	2
Bacillariophyceae						
Asterionella formosa	-	+	+	+	+	+
Aulacoseira granulata	-	+	+	+	+	+
Bacillaria paxillifer	-	+	+	+	+	+
Biddulphia sp.	-	+	+	+	+	+
Chaetoceros sp.	-	+	+	+	+	+
Coscinodiscus subtilis	-	+	-	-	+	+
Coscinodiscus concinnus	-	+	-	-	+	+
Cyclotella sp.	1	1	1	1	1	1
Diatomella balfouriana	-	+	+	+	+	+
Fragilaria capucina	-	+	+	+	+	+
Fragilaria construens	-	+	+	+	+	+
Melosira varians	1	1	1	1	1	1
Melosira moniliformis	1	1	1	1	1	1
Navicula sp.	3	3	3	3	3	3
Pinnularia borealis	-	+	+	+	+	+
Pinnularia major	-	+	+	+	+	+
Pleurosigma sp.	-	+	-	+	+	+
Surirella calcarata	-	+	+	+	+	+
Synedrosphenia crytallina	2	-	2	2	2	2
Tabellaria fenestrate	-	+	+	+	+	+
Index values	Σ=25	Σ=17	Σ=25	Σ=24	Σ=25	Σ=25

Notes: Palmer (1969); PPI – Palmer pollution index; + – Present; - – Absent.

als). Bacillariophyceae was high in locations 1 (778 individuals) and 5 (781 individuals) with the lowest in location 4 (509 individuals). The most abundant species recorded across the locations was *Mougeotia scalaris* (229 cells/L), followed by *Pandorina morum* (216 cells/L), *Coscinodiscus subtilis* (214 cells/L), *Cladophora glomerata* (207 cells/L), and *Bacillaria paxillifer* (204 cells/L), with the relative abundance of 3.46, 3.27, 3.24, 3.13, and 3.08%, respectively, while the lowest was *Euglenaria caudata* (39 cells/L), accounting for 0.59 % of total population. Following the numerical values of water quality classification regarding organic pollution by Palmer (1969), the pollution scores obtained ranged from 17 to 25 as shown in Table 4.

Location 1 was recorded with 11 pollution indicator species with the lowest pollution index score (17); location 2 was recorded with 14 population indicator species, having an index score of 25; location 3 was recorded with 13 population indicator species, with an index score of 24, while locations 4 and 5 were recorded with 14 pollution indicator species, with an index score of 25, respectively. The highest pollution index score (25) was recorded in locations 2, 4, and 5.

***Result of macroinvertebrates composition*:** The composition of macroinvertebrates and their taxonomic groups obtained is shown in Table 5. A total number of 25 taxa comprising of a total number of 1,294 individual species belonging to 3 phyla, 4 classes, 12 orders, and 22 families of macroinvertebrates were identified. Among the phyla, Arthropoda had the highest number (1,087) of individual species, with relative abundance of 83.9%, followed by Annelida (123), with relative abundance of 9.5%, Mollusca had the least number of individual species (84), with relative abundance of 6.6%, respectively.

The class Insecta had the highest number of individuals (1,005), with relative abundance of 77.6%, followed by Clitellata (123; 9.5%), Gastropoda (84; 6.6%), and Crustacean (82; 6.3%). Odonata was the highest occurring order of macroinvertebrates with 264 individuals (20.4%), while the lowest was Trichoptera, with 38 individuals accounting for 2.9% of the total population. The Hemiptera was represented by 4 families (Gerridae, Notonectidae, Corixidae, and Veliidae); Diptera was presented by three families (Chironomidae, Simuliidae, and Tabanidae); Odonata (Macromiidae and Gomphidae), Ephemeroptera (Ephemerellidae and Baetidae), Coleoptera (Dytiscidae and Hydrophilidae), Decapoda (Palaemonidae and Potamonautidae), and Architaenioglossa (Ampullariidae and Thiaridae) were represented by two families each; while Trichoptera (Philopotamidae), Plecoptera (Perlidae), Polychaeta (Capitellidae), Oligochaeta (Tubificidae), and Hygrophila (Planorbidae) were represented by one family each.

Among the studied locations, the highest number of macroinvertebrates (380) was recorded in location 1, followed by location 4 (306), while location 5 had the least number of individuals (195). Arthropoda was high in location 1, with 374 individuals, followed by location 4 (287), while the lowest was obtained in location 5 (135), Annelida was observed to be high in location 3 (55), followed by location 5 (33), and the lowest was recorded in location 4 (3). The highest number of Mollusca (27) was obtained in location 5, followed by location 3 (18), and the lowest of 6 was recorded in location 1. Highest number of Insecta was recorded in location 1 (361), while the location 5 had the lowest (117). Crustacean was recorded as the highest in

Table 5. Summary of composition and relative abundance of macroinvertebrates from the upper segment of Qua Iboe River.

Macroinvertebrates taxonomic Groups	**Number of species**	**Studied locations**					**Total**	**R.A (%)**
		1	**2**	**3**	**4**	**5**		
Insecta	17	361[a]	135[b]	128[b]	264[c]	117[d]	1,005	77.6
Crustacean	2	13[a]	12[a]	16[a]	23[b]	18[a]	82	6.3
Clitellata	2	0[a]	32[b]	55[c]	3[d]	33[b]	123	9.5
Gastropoda	4	6[a]	17[b]	18[b]	16[b]	27[c]	84	6.6
No. of individuals	**25**	**380**	**196**	**217**	**306**	**195**	**1,294**	**100**
Number of species(N)		**19**	**20**	**20**	**23**	**21**	**25**	
Relative abundance (RA)		**23.98**	**18.06**	**17.02**	**20.12**	**20.82**	**100**	

Note: Values with different superscripts along the same row are significantly different (*P*< 0.05).

Table 6. HFBI values of water quality from the upper segment of Qua Iboe River, Niger Delta, Nigeria.

Classes	**Family**	**Species**	**Station 1**			**Station 2**			**Station 3**			**Station 4**			**Station 5**		
			xi	**Ti**	**xi**	**xi**	**Ti**	**xi**	**xi**	**ti**	**xi**	**xi**	**Ti**	**xi**	**xi**	**ti**	**xi**
Insecta	Chironomidae	*Chironomus* sp. larvae	0	8	0	8	8	64	6	8	48	0	8	0	16	8	128
	Simuliidae	*Simulium* sp. larvae	0	6	0	8	6	50	10	6	60	0	6	0	4	6	24
	Tabanidae	*Tabanus* sp. larvae	4	6	24	15	6	90	23	6	138	2	6	12	11	6	66
	Macromiidae	*Macromia magnifica*	29	3	87	22	3	66	16	3	48	36	3	108	16	3	48
	Macromiidae	*Macromia splendens*	14	3	42	18	3	21	25	3	75	16	3	48	15	3	45
	Gomphidae	*Progomphus* sp. Larvae	14	3	42	4	3	12	12	3	36	20	3	60	7	3	21
	Ephemerellidae	*Ephemerella mucronata*	53	4	212	0	4	0	0	4	0	26	4	104	0	4	0
	Baetidae	*Baetis bicaudatus*	30	4	120	0	4	0	0	4	0	28	4	112	0	4	0
	Baetidae	*Callibaetis pictus*	33	7	231	0	7	0	0	7	0	31	7	217	14	7	98
	Gerridae	*Aquarius remigis*	16	4	64	12	4	48	1	4	4	10	4	40	9	4	36
	Notonectidae	*Notonecta glauca*	19	5	95	11	5	55	17	5	85	24	5	120	1	5	5
	Corixidae	*Hesperocorixa castanea*	18	5	90	16	5	21	6	5	30	11	5	55	4	5	20
	Veliidae	*Velia caprai*	14	5	70	9	5	45	1	5	5	9	5	45	10	5	50
	Dytiscidae	*Cybistertri punctatus*	21	5	105	8	5	40	9	5	45	17	5	85	6	5	30
	Hydrophilidae	*Hydrophilus triangularis*	25	5	125	4	5	20	2	5	10	23	5	115	4	5	20
	Philopotamoidae	*Trichoptera* larvae	30	1	30	0	1	0	0	1	0	8	1	8	0	1	0
	Perlidae	*Plecoptera* larvae	41	1	41	0	1	0	0	1	0	3	1	3	0	1	0
Crustacea	Palaemonidae	*Palaemon malcolmsonii*	5	6	30	5	6	30	15	6	90	7	6	42	7	6	42
	Potamonautidae	*Sudanonautes africanus*	8	6	48	7	6	42	1	6	6	16	6	96	11	6	66
Clitellata	Capitellidae	*Capitella capitata*	0	8	0	19	8	152	31	8	248	2	8	16	18	8	144
	Tubificidae	*Tubifex tubifex*	0	10	0	13	10	130	24	10	240	1	10	10	15	10	150
Gastropoda	Planorbidae	*Planorbis carinatus*	0	6	0	8	6	48	4	6	24	7	6	42	10	6	60
	Planorbidae	*Bulinus africanus*	0	6	0	6	6	36	6	6	36	2	6	12	5	6	30
	Ampullariidae	*Pomacea maculate*	2	7	14	2	7	14	6	7	42	6	7	42	6	7	42
	Thiaridae	*Pachymelania aurita*	4	7	28	1	7	7	2	7	14	1	7	7	6	7	42
Total			**380**		**1,498**	**196**		**1,141**	**217**		**1,284**	**306**		**1,399**	**195**		**1,167**
HFBI Value				**3.94**			**5.82**			**5.92**			**4.57**			**5.98**	
Remark			**Very Good**			**Fairly Poor**			**Fairly Poor**			**Good**			**Fairly Poor**		

location 4 (23) and least was in location 2 (12), Clitellata was high in location 3 (55), while location 3 had the least number (3) and completely absent in station 1. Gastropoda had highest occurrence of macroinvertebrates in location 5 (27), while the lowest (6) was in location 1. Going by the modified HFBI, the pollution score values obtained ranged from 3.94 to 5.98, with the highest values in location 5 (5.98), followed by location 3 (5.92), while the lowest value was in location 1 (3.94) as presented in Table 6.

Discussion

Biological communities of aquatic ecosystems are regarded as detectors of pollution (Nwonumara, 2018; Yusuf, 2020). As reported by researchers (Hamid et al., 2021; Nwonumara et al., 2022; Jonah et al., 2022; Jacob et al., 2023; Jonah, Akpan, 2024; Ekpo et al., 2025), changes in water quality are corresponding with the drastic decline in aquatic biota, including phytoplankton and macroinvertebrates. In this study, most species of phytoplankton, such as *Johanseninema constrictum*, *Dolichospermum spiroides*, *Oscillatoria tenuis*, *Microcystis wesenbergii, Pandorina morum, Closterium* sp*., Micractinium pusillum, Scenedesmus quadricauda, Monactinus simplex, Mougeotia scalaris, Euglenaria caudata, Phacus longicauda*, *Synedrosphenia crystallina, Navicula* sp*., Melosira* sp. and *Cyclotella* species, are pollution indicators mostly from locations 2, 3 and 5 as listed by Palmer (1980). These could be associated with the higher-level organic pollutants in the water body exacerbated by human activities like agricultural and indiscriminate disposal/dumping of wastes into the water body (Kutama et al., 2014; Vishal, Meeta, 2020). The abundance of Baccillariophyceae is consistent with the findings of Esenowo et al. (2018) in Ikpa River, Jonah et al. (2020b) in Ikpe Ikot Nkon River, and Jonah, Archibong (2022) in water bodies from this region; this could be ascribed to the diplontic nature of life cycle exhibited by species belonging to this group (Jonah, Etteokon, 2020) and the capacity to adapt to negative changes in nutrient concentrations and other pollutants in the water body (Vishal, Meeta, 2020; Yusuf, 2020). Dinophyceae was represented by 3 species, while Euglenophyceae was represented by 2 species; the low abundance and dominance of these groups could be suggested to the impact of sand dredging activities, although the two species of Euglenophyceae recorded (*Euglenaria caudata* and *Phacus longicauda*) were included by Palmer (1969) as indicators of organic pollution. Yusuf (2020) affirms that the presence of *Euglenaria* in any water body shows the pollution load associated with anthropogenic activities. However, following the numerical values for water pollution classification of Palmer (1969), the study revealed that locations 2 to 5 were highly polluted organically, while location 1 was probably highly organically polluted. The values recorded are in line with the findings of Vishal, Meeta (2020) in Urban Pond and Jonah, Archibong (2022) in waters from North-West zone of Akwa Ibom State. Salem et al. (2017) affirmed that, when values of Palmer indices range from 10 to 15, it indicates moderate organic pollution, while values from 15 to 20 indicate moderate to high pollution, and values above 20 indicate higher organic pollution.

The PPI values recorded between locations 2 and 5 may be ascribed to the high anthropogenic activities, such as intense farming, demotic waste discharge, laundering, bathing and sand mining/dredging, as observed during the study period, which contributed to the pollution load in the water bodies. High organic load in the water body was associated with intense farming activities, industrial discharge of untreated water, municipal runoff, and exoneration of waste from domestic activities (Jonah et al., 2020a).The low values recorded in location 1 may suggest lesser human activities and absence of sand mining.

The present water quality influences the abundance and distribution of macroinvertebrates obtained in this study. The study revealed that Arthropada was the most abundant group, followed by Annelida and Mollusca, respectively. Similar trends were reported by Avoaja et al. (2007), Okorafor et al. (2014), and Jonah et al. (2020c). These discrepancies in the abundance of groups could be due to the differences in the characteristics of their morphological characteristics, adaptation to different substrate types, level of predator's duration, and adaptation to changes in water quality characteristics (Azrina et al., 2006; Mesa et al., 2013; George et al., 2020). The study also revealed that Insecta was the most dominant class; this could be attributed to the favorable water quality, presence of aquatic plants at the locations, coupled with their ubiquitous nature, and the fact that insects do not show habitat restriction (Arimoro, Ikomi, 2009; Jonah et al., 2020b). The findings agreed with the assertion and reports of Udebuana et al. (2015) in Okhuo River, Hamid et al. (2021) in stream and Bate, George (2021) in Hadejia-Nguru Wetlands, Nigeria.

Higher macroinvertebrate species were recorded in locations 1 and 4, while the lowest was in locations 2, 3, and 5. The observed variability in numbers could be attributed to the level of human activities in each location. According to George et al. (2020) and Jonah et al. (2020c), the number of macroinvertebrates obtained in environment reflects the stability of such location. The higher number of species recorded in locations 1 and 4 could be linked to low impacts of anthropogenic activities like sand dredging and intensive agricultural activities that could lead to removal of aquatic macrophytes and other riparian vegetations. Submerged macrophyte communities play a crucial role for animals and lower plants in aquatic ecosystems, by providing habitat complexity, shelter, breeding area as well as being substrata for periphyton and sites of abundant food production for many aquatic insects (Rennie, Jackson, 2005; Ali et al., 2007; Jonah et al. (2020d).This agrees with the report of Andem et al. (2012) for Ona River, where they recorded high macroinvertebrates in an area devoid of anthropogenic impacts. Sand dredging led to instability of benthic organisms and their life cycle (Edokpayi, Nkwoji, 2007). According to Koehnken et al. (2020), sand excavation affects macroinvertebrates drift, species abundance, and community structures, while Gubbay (2003) reported that, when the environment of a river has been altered because of sand dredging and excavation, the biota is also altered because they tend to adapt to the prevailing conditions.

More so, the intensity of agricultural activities could lead to the higher content of organic pollutant that favor the abundance of pollution tolerant in a species (Mckey, King, 2006). Zhang et al. (2019) in related study reported that the diversities of the macroinvertebrate assemblages were regulated by total phosphorus contents in the water, which acted as the major environmental factor. The Chironomidae, Simuliidae, Tabanidae, and Tabanidae are known to be inhabited mildly to polluted water with anoxia condition (Edegbene et al., 2015; Adebayo et al., 2019; Anyanwu et al., 2019), and they were in abundant in locations 2, 3, and 5. The occurrence of these groups could beascribed to their efficacy of tolerating wide ecological changes. On the other hand, pollution-sensitive groups such as Ephemeroptera, Plecoptera, and Trichoptera were conspicuously absent in these locations, rather inhabiting locations 1 and 4, indicating severe pollution and multiple environmental stressors in locations 2, 3, and 5 due to intense anthropogenic activities. Adeogun, Fafioye (2011) in a related study reported that the absence of Ephemeroptera, Plecoptera, and Trichoptera was associated with higher levels of organic pollution due to agricultural activities around the water body.

The abundance of Odonata *Macromia magnifica* and *Progomphus* larvae in locations 1 and 4 could be attributed to food availability and abundance of macrophytes (Popoola, Otalekor, 2011), while in locations 2, 3, and 5, it could be attributed to their ability to withstand moderate to severely polluted water body. Arimoro et al. (2015) pointed out that Odonata generally preferred aquatic vegetation as refuge and again the canopy cover. Clitellata (Annelid) has been found to be widely colonized and preferred to have highly organically polluted environment; hence they have been used as indicators of environmental degradation (Peckarsky et al., 1990; Masese et al., 2009; Chanazah et al., 2018).The two species, *Capitella capitata* and *Tubifex tubifex*, of this group were absent in location 1 and abundance in locations 2, 3, and 5; suggesting favorable habitat, food availability, decaying organic matter, and the fact that they can survive in polluted water bodies (Quinn, Hickey, 1990; Jonah et al., 2020b). Gastropoda was recorded in all the locations, with the highest in location 5, and the lowest in location 1. Species *Planorbis carinatus and Pomacea maculata* were the highest occurring species; the occurrence of these species and others, such as *Balinus africana and Pachymelania aurita*, can be traced to their tolerance to some levels of organic pollution and favorable substrate quality (Esenowo, Ugwumba, 2010; Jonah et al., 2022).

Going by the classification of water quality based on modified HFBI, the values obtained in locations 1 and 4 reflect good water quality with less organic pollution (possible slight organic pollution and some organic pollution probably), while the values in locations 2, 3, and 5 reflect poor water quality with significant organic pollution. The poor water quality recorded in the aforementioned locations suggests the accumulation of organic pollutants in the water body arising from human indiscriminate dumping of refuse materials and agricultural and sand mining/dredging activities observed during the study period. Jonah, Akpan (2021) in a similar study, reported higher values of this index attributed to consistent discharge of organic wastes and other considerable amounts of industrial and municipal effluents being added to the water body. The index revealed that the water quality in locations 2, 3, and 5 had poor water quality, indicating significant organic pollution.

Conclusion

The deterioration of aquatic ecosystems by organic pollutants is a global concern. Pollutants from point and non-point sources into the water pose a serious negative impact on the water quality and the inhabitant organisms. River water is considered a significant source of life for myriad species of aquatic biota; for the safety of these organisms and the entire ecosystem, constant monitoring should be considered as priority. The present investigation revealed that the river is under a serious threat of organic pollutants exacerbated by anthropogenic activities. The data obtained for PPl and HFBI indicated the levels of deterioration of water in the studied locations, owing to anthropogenic activities, especially in locations 2, 3, and 5. Variability in phytoplankton and macroinvertebrates composition was obtained across the locations, and the domination of Bacillariophyceae and Arthropoda, respectively, and other tolerant species is an indication of increasing environmental degradation. This study indicates the need of continuous monitoring of the water body using water indices and pollution indicator organisms, as this will provide further vital information on the ecological status, biological composition, and suitability of water for human consumption in Nigeria, and will help to develop measures to mitigate water pollution and prevent loss of biodiversity. Also, the activities of humans within the watershed should be of concern to the relevant authorities; regulation of these activities should be enforced to minimize the situation of water deterioration and for regaining the natural water quality to support aquatic life and health and make it suitable for domestic usage.

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