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Research Article

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Biological Assessment of Anthropogenic Impacts in Buguma Creek, Rivers State, Nigeria

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ABSTRACT

The objective of this research was to assess the anthropogenic impact on plankton and macrobenthic fauna composition, abundance, distribution, and diversity of four communities in Buguma creek. The Phytoplankton, zooplankton, and benthic fauna samples were collected quantitatively monthly from each of the four sampling stations between January and June 2020 using standard sampling methods. Margalef (D), Shannon Wienner (H), and Evenness indices were used to determine species richness and diversity respectively using the PAST statistical package. This study revealed that artisanal refinery activities, sand mining/dredging, and discharge of industrial, domestic, human, and animal wastes have adversely affected the aquatic biota (plankton and macrobenthic fauna) in Buguma creek. The effects of these activities have remarkable spatial manifestations; with the more perturbed especially station 2, having a lower number of species and abundance. The preponderance of indicator species is a confirmation while the community structure gave an insight into the negative impact of these activities individually and cumulatively. The brunt of these activities rests more on the macrobenthic fauna; probably due to their unique characteristics and position in the aquatic environment. The result indicated that Buguma creek had been polluted seriously to a large extent.

Keywords: Aquatic biota, Bioindicator, Anthropogenic, Artisanal refinery, Diversity

ABSTRAK

Penelitian ini bertujuan untuk mengkaji dampak antropogenik terhadap komposisi plankton dan fauna makrobentos, kelimpahan, distribusi, dan keanekaragaman empat komunitas di sungai Buguma. Sampel Fitoplankton, zooplankton, dan fauna bentik dikumpulkan secara kuantitatif setiap bulan dari masing-masing empat stasiun pengambilan sampel antara Januari dan Juni 2020 menggunakan metode pengambilan sampel standar. Indeks Margalef (D), Shannon Wienner (H), dan Evennes digunakan untuk menentukan masing-masing kelimpahan dan keragaman spesies menggunakan paket statistik PAST. Studi ini mengungkapkan bahwa kegiatan kilang artisanal, penambangan/pengerukan pasir, dan pembuangan limbah industri, domestik, manusia, dan hewan telah berdampak buruk terhadap biota air (plankton dan fauna makrobentik) di sungai Buguma. Efek dari aktivitas ini memiliki manifestasi spasial yang luar biasa; dengan semakin terganggu terutama stasiun 2, memiliki jumlah spesies dan kelimpahan yang lebih rendah. Predominan spesies indikator adalah konfirmasi sementara struktur komunitas memberikan wawasan tentang dampak negatif dari kegiatan ini secara individu dan kumulatif. Beban terbesar dari aktivitas ini lebih banyak bertumpu pada fauna makrobentos; mungkin karena karakteristik dan posisinya yang unik di lingkungan perairan. Hasil ini mengindikasikan bahwa Sungai Buguma telah tercemar secara serius.

Kata kunci: Biota perairan, Bioindikator, Antropogenik, Artisanal refinery, Keanekaragaman

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1. Introduction

Rivers and creeks are among the most productive ecosystems as well as important biodiversity systems on the earth. They provide a conducive environment that supports a wide range of flora and fauna. Globally, water bodies are getting adversely affected as a result of various anthropogenic activities (Anyanwu and Umeham, 2020; Mallin and Cahoon 2020; Kinuthia et al., 2020; Davies et al., 2021). This has affected the ecosystem services accruable from such water bodies. In recent times, it has become more challenging to maintain the quality of the aquatic ecosystem (Palaniappan et al., 2010). Discharges from municipal and industrial sources, sewage, effluents, and runoffs from agricultural activities are discharged into the aquatic environment (Anju et al., 2010). Studies have shown that the quality of an aquatic environment can be determined through the assessment of its biological communities and the application of bioassessment to determine the ecological effects of pollution has been well documented (Davies and Nwose, 2019; Aliu et al., 2020; Santos and Ferreira, 2020; Anyanwu et al., 2021a, b, c).

Nigeria has a wide range of water bodies that is capable of sustaining different types of aquatic organisms such as plankton, nekton, benthic organisms, other aquatic invertebrates, and vertebrates (Atobatele and Ugwumba, 2008). Planktons are one of the indispensable biological communities in lotic ecosystems (Komala et al., 2013; Sharma, 2018). Planktons (phytoplankton and zooplankton) are microscopic, non-motile, or weak swimming organisms that float in the water column or drift with it; thereby making them prone to changes in the water (Suthers and Rissik, 2009; Afroz et al., 2014). The cheapest and easiest method of assessing the quality of water in developing countries is to monitor planktons regularly (Ovie et al., 2011). Phytoplankton and zooplankton communities are the first and second lower trophic levels, and the health of the aquatic ecosystem depends on the plankton colonies as plankton play an essential role as part of the food chain (Van Donk et al., 2011; Cavan and Hill, 2022).

The composition of plankton has a direct impact on the trophic levels of plankton feeders, such as commercial fish (Abo-Taleb, 2019). Phytoplankton is widespread in the aquatic ecosystem; they play a major ecological role in human use of water; though are relatively unnoticed except in bloom conditions (Anyinkeng et al., 2016). They are bioindicators and primary producers; providing for carbon fixation, oxygen, and food production (Yusuf, 2020). The assessment of the effects of anthropogenic impacts on phytoplankton communities is important in understanding the effects of environmental parameters (Znachor et al., 2020). Zooplanktons are microscopic, essential components of aquatic food webs that respond quickly to environmental change (Brito et al., 2011; Primo et al., 2015). Their composition, abundance, and distribution vary with spatiotemporal variations of water quality parameters due to their short life span and fast regeneration (Rajagopal et al., 2010; Anyanwu et al., 2013). Benthic macroinvertebrates have often been used to assess the water quality and ecological health of aquatic ecosystems (Dallas, 2021). The consistent and extensive use of macroinvertebrates in biological assessments is based on their wide distribution, sensitivity to organic pollutants, cheapness, and ease of sampling (Leslie and Lamp, 2017). They are suitable for the evaluation of specific pollutants in the aquatic environment because of their slow mobility, extended life period, quick response to environmental changes, and tolerance (Duc et al., 2015). The brackish water environment is being endangered by discharges of untreated wastes and industrial effluents (Jonah et al., 2020a).

The Niger Delta region has a network of lotic water bodies and tributaries, of which the rivers are the major source of potable water for many towns and villages (Tolulope, 2004). The area surrounding the creek has been urbanized and industrialized due to the quest for crude oil, gas, and other natural resources. The effluents discharged from human wastes, pipeline leakage, accidental discharges, discharges from artisanal or illegal refineries, and sabotage (illegal bunkering) loading activities may be detrimental to the quality of the creek and aquatic biota. The objective of this study is to assess the impacts of anthropogenic activities in Buguma Creeks, Rivers State using aquatic biota.

2. Materials and methods

2.1. Study Area

The study was conducted along the Buguma creek in the Asari-Toru Local Government Area of Rivers State, Southeast of the Niger Delta (Figure 1). The Creek is part of the Sombreiro Estuary, one of the 21 estuaries in the Niger Delta geomorphic unit of Nigeria's extensive (853 km) coastline (Zabbey et al., 2021). The creek system consists of the main channel and associated feeder creeks linking different neighbouring communities. The tidal influence is frequent and vigorous. Pollutants such as effluents from Illegal refining sites, artisanal channelization, domestic wastes, and

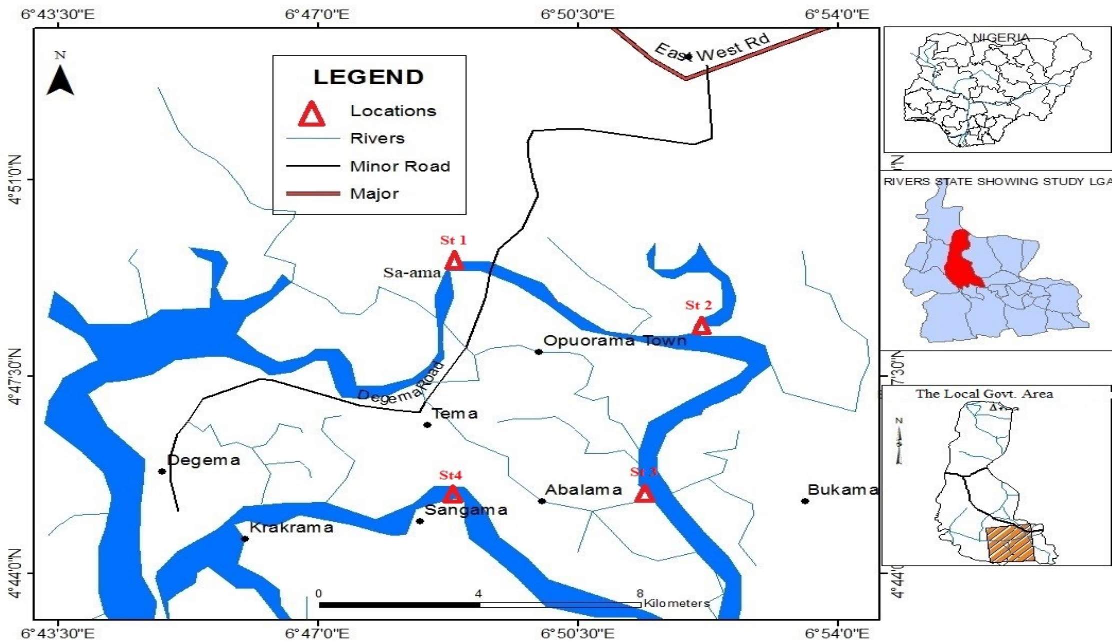

Figure 1. Map showing the study area

human waste disposal, bunkering activities, sand dredging, and deliberate clearing of mangroves in the community jetties around the creeks are common in the environment. The samples were collected in four stations along the creek.

Station 1 (N04º 48'14.8" and E006º 50'17.9") located in Sa-ama. It is heavily littered with wastes and covered with artisanal oil refining sheen. An abandoned bunkering site was within view. Other activities include the disposal of refuse and human wastes and fishing.

Station 2 (N04º 48'14.2"and E006º 50'17.1") located in Opuro-Ama community, about 600 metres downstream of station 1. It is a highly populated coastal settlement. Activities observed include sand dredging activities, illegal bunkering discharges, domestic, human, animal, and plastic waste disposal, and discharges of runoff laden with petroleum product residues.

Station 3 (N04º48'13.2" and E006º 50'16.9") located in Abala-ama community, about 500 metres downstream of station 2. It is a fishing settlement. Activities observed include discharge of illegally refined oil effluent, dredging and domestic and industrial waste disposal, runoffs from the market, lairage, boat maintenance, fabrication activities, etc.

Station 4 (N04º 770'57.0"and E006º 83'91.9") located in the Sanga-ama community is the control or reference site, about 900 meters downstream of station 3. It is a fishing settlement with lesser activities observed around the creek except for local fishing vessels.

2.2. Sample Collection

The plankton and macrobenthic fauna samples were collected monthly from each of the four sampling stations between January and June 2020.

Plankton Composite

Phytoplankton and zooplankton composite samples were collected quantitatively by filtering 50litres of water through a 55µm mesh size Hydrobios plankton net. All samples (concentrated to 100ml) collected for phytoplankton analysis were preserved in Lugol's iodine, while samples collected for Zooplankton were preserved in 4% buffered formaldehyde in a sample bottle. In the laboratory, the Zooplankton and Phytoplankton samples were thoroughly examined and counted using an Olympus® binocular microscope with a calibrated eyepiece at different magnifications (5x, 10x, and 40x). Direct plankton counts were done using the drop count method. Taxonomic identification was carried out as far as possible, to identify organisms to the lowest practicable level. Identification work was done using appropriate keys. List and numbers of plankton were compiled.

Macrobenthic Fauna

A quantitative sampling was carried out for benthic fauna for each station using the Ekman Grab (0.0225 m^2) and poured through a sieve of 1 mm x 1 mm mesh size and washed through a sieve of fine mesh size made of silk material, to wash off excess silt or mud. All samples were preserved in wide-mouthed plastic containers by adding some quantities of 40% formaldehyde and stained with Rose Bengal solution. Benthic samples were then transferred to a shallow white tray with water for sorting. Sorting was done using forceps and a hand lens. The macro-benthic fauna was sorted into separate vials, preserved in 70% ethanol (APHA, 2005), and labeled with the name of the sample, location, and date of collection. Laboratory analysis was carried out by using the binocular dissecting microscope for sorting, dissection of relevant taxonomic parts, and preparation of slides. The taxonomic identification was carried out as far as possible; to identify organisms to the lowest practicable level using reliable identification keys and texts List and numbers of plankton and macrobenthic fauna were compiled.

Data Analysis

Margalef (D), Shannon-Weiner (H), and Pielou's Evenness (J) indices were used to determine species richness and diversity respectively using the PAST statistical package (Hammer et al., 2001). One-way ANOVA was used to ascertain if there were significant differences in the biodiversity indices among the stations. The source of significant difference at $p<0.05$ was determined with Tukey pairwise posthoc test. All procedures followed the basic COVID-19 protocol while working on this research in the laboratory.

3. Results and Discussion

3.1. Phytoplankton Species Composition, Abundance, Distribution, and Diversity

The study recorded a total abundance of 1948 phytoplankton individuals in the 4 stations (Table 1). Total composition of 58 species from 5 taxonomic groups was recorded. The highest abundance (611 individuals, 31.4%) was recorded in the control (station 4) while the lowest (302 individuals, 15.5%) was recorded in station 2. The dominant and most abundant group was Baccilariophyta with 44 species and 1535 individuals (78.8%). The highest abundance (483 individuals) was recorded in the control (station 4) while the lowest (270 individuals) was recorded in station 2. The Cyanophyta had an abundance of 142 individuals (7.3%) from 3 species. The highest abundance (62 individuals) was recorded in station 1 while the lowest (6 individuals) was recorded in station 2. Chlorophyta had 121 individuals (6.2%) from 5 species. The highest abundance (36 individuals) was recorded in station 1 while the lowest (13 individuals) was recorded in station 2. Pyrrophyta had an abundance of 102 individuals (5.2%) from 4 species. The highest abundance (36 individuals) was recorded in the control (station 4) while the lowest (6 individuals) was recorded in station 1. The lowest abundance (48 individuals, 2.5%) was recorded among the Chrysophyta. The highest abundance (28 individuals) was recorded in station 3 and none was recorded in 2. *Coscinodus granii* (Baccilariophyta) was the most abundant species with 65 individuals (3.3%).

The phytoplankton biodiversity assessment parameters - number of taxa (species), number of individuals and indices (Shannon-Wiener diversity index, Margalef's species richness index, and Pielou's Evenness index) are shown in Table 2. The indices varied spatially across the stations. The analysis of variance (ANOVA) revealed significant differences in all the biodiversity indices evaluated except Margalef's Index. The number of taxa (species) ranged between 52 (station 2) and 58 (station 4). The control (station 4) and station 1 were significantly higher than station 2. The abundance ranged between 302 individuals (station 2) and 611 individuals (station 4). The control (station 4) and station 1 were also significantly higher than station 2. On the other hand, the Shannon-Wiener diversity index ranged between 3.756 (station 2) and 3.961 (station 4). Stations 4 (control) and 3 were significantly higher than station 2. Margalef's species richness index ranged between 8.744 (station 3) and 8.931 (station 2). There was no significant difference among the stations. Pielou's Evenness index ranged between 0.8227 (station 2) and 0.9128 (station 3). Stations 3 and 4 (control) were significantly higher than station 2.

3.2. Zooplankton Species Composition, Abundance, Distribution, and Diversity

The study recorded a total abundance of 990 zooplankton individuals in the 4 stations (Table 3). The total composition of 21 species from 4 taxonomic groups was recorded. The highest abundance (338 individuals, 34.1%) was recorded in station 4 (control) while the lowest values (186 individuals, 18.8%) were recorded in stations 2 and 3. The dominant and most prevalent group was Copepoda with 7 species and an abundance of 363 individuals (36.7%). The highest abundance (126 individuals) was recorded in station 1 while the lowest (66 individuals) was recorded in station 2. The protozoa had an abundance of 328 individuals (33.1%) from 8 species. The highest abundance (168 individuals) was recorded in station 4 (control) while the lowest (40 individuals) was recorded in station 2. Rotifera had an abundance of 183 individuals (18.5%) from 4 species. The highest abundance (48 individuals) were recorded in stations 4 (control) and 2 while the lowest (43 individuals) was recorded in station 3. Porifera had an abundance of 116 individuals (11.7%) from 2 species. The highest abundance

Table 1. Composition, abundance, and distribution of phytoplankton species in Buguma Creek

Taxonomic Group	Taxa	Station 1	Station 2	Station 3	Station 4 (Control)	Total
Baccilariophyta	*Coscinodiscus wailisii*	14	2	9	18	43
	Coscinodiscus granii	17	17	7	24	65
	Coscinodiscus centralis	24	0	0	19	43
	Coscinodiscus asteromphalus	9	0	5	10	24
	Coscinodiscus janischii	8	4	18	8	38
	Bacillinia paradoxa	4	4	9	11	28
	Navicula amphibola	21	6	0	19	46
	Navicula amrupta	13	0	8	14	35
	Nitzschia paradoxa	8	6	10	13	37
	Thalassiosira eccentrica	8	24	6	10	48
	Thalassiosira oestrupii	15	6	0	17	38
	Tabellaria floculisa	8	2	1	12	23
	Tabellaria fenestrate	7	1	6	14	28
	Cyclotella meneghiniana	5	6	2	9	22
	Cyclotella stylorum	9	6	6	10	31
	Cyclotella striata	11	5	5	15	36
	Melosira nummuloides	10	8	2	8	28
	Melosira varian	9	8	8	7	32
	Pleurosigma elongatum	5	6	7	7	25
	Pleurosigma strigosum	14	7	11	11	43
	Diploneis litoralis	10	4	8	10	32
	Diploneis elliptica	14	9	11	12	46
	Paralia sulcata	9	12	7	16	44
	Fragilaria foma	5	0	8	8	21
	Fragilaria paradora	9	4	9	7	29
	Gyrosigma attenuatum	11	8	8	6	33
	Cocconeis diminuta	9	6	6	6	27
	Achnauthes prominula	7	8	5	9	29
	Chactoceros	15	6	7	10	38
	Chactoceros compressus	5	6	6	7	24
	Pinnularia heniiptera	9	5	9	10	33
	Pinnularia braunii	8	3	13	8	32
	Pinnularia mesolepth	10	10	8	10	38
	Suirrella sulcata	7	9	9	8	33
	Suirrella fastuasa	13	8	10	10	41
	Amphiphora	5	6	14	6	31
	Entonioneis sulcata	11	6	12	10	39
	Rhizosoleuia longiseta	13	7	12	13	45
	Actinocyclus octonarius	9	7	8	10	34
	Nitzschia sigmisidea	5	7	12	11	35
	Odontella aurita	10	7	13	8	38
	Triceratium broeckii	10	8	10	11	39
	Bacteriastrum hyalinum	4	1	10	8	23
	Gyrosigma acuminatum	17	5	3	13	38
Cyanophyta	*Oscillatoria tenius*	20	2	6	18	46
	Oscillatoria priceps	30	1	2	23	56
	Gloeotrichia echimicha	12	3	6	19	40
Chrysophyta	*Dinoloryin cylindrueum*	4	0	18	8	30
	Dinoloryin divergen	2	0	10	6	18
Chlorophyta	*Planklosphaeria gelatinosa*	10	2	9	3	24
	Chlamydominas	6	5	10	5	26
	Errerella bornhemlensis	7	2	12	1	22
	Pediastrum simplex	5	1	13	5	24
	Microthmnion	8	3	10	4	25
Pyrrophyta	*Cryptomonas reflexa*	0	2	13	7	22
	Procentrum gracile	3	3	9	6	21
	Procentrum lima	1	3	13	8	25
	Procentrum rhathymum	2	5	12	15	34
	Total	**554**	**302**	**481**	**611**	**1948**

Table 2. Diversity Indices of phytoplankton species in Buguma Creek

Diversity Indices	Station 1	Station 2	Station 3	Station 4 (Control)
Number of Taxa (species)	57^{a}	52^{b}	55^{ab}	58^{a}
Number of Individuals	554^{a}	302^{b}	481^{ab}	611^{a}
Species richness (d) (Margalef's Index)	8.865	8.931	8.744	8.885
Species diversity (H) (Shannon-Wiener Index)	3.898^{ab}	3.756^{b}	3.916^{a}	3.961^{a}
Species evenness (Pielou's Evenness Index)	0.8653^{ab}	0.8227^{b}	0.9128^{a}	0.9054^{a}

a, b, = Values with different superscripts across the rows are significantly different at p<0.05

Table 3. Composition, abundance and distribution of zooplankton species in Buguma Creek

Group	Taxa (species)	Station 1	Station 2	Station 3	Station 4 (Control)	Total
Protozoa	*Lagynophoya confera*	6	13	3	30	52
	Frontoria leucas	5	4	7	22	38
	Tintinnopsis sinerisis	7	16	9	23	55
	Lembadion magnum	2	3	2	21	28
	Askenasia fourei	9	15	3	24	51
	Quairulella Sp.	5	3	9	17	34
	Pseudodileptus Sp	8	4	3	15	30
	Coleps ociospitus	18	2	4	16	40
Rotifera	*Brochionus urceus*	9	17	9	12	47
	Brochionus pliiatilis	15	14	2	10	41
	Brochiamus Ureceolaris	10	10	19	13	52
	Brochiomis rubens	10	7	13	13	43
Copepoda	*Copepod nauplii*	28	16	13	14	71
	Faracydops funbriatus	12	7	9	14	42
	Cyclopoid copepod	21	6	8	13	48
	Thermacyclops sp.	20	10	12	11	53
	Macrocyclops albidus	13	11	15	13	52
	Acanthrocyclops vernalis	15	7	9	15	46
	Calanoid cotepo	17	9	13	12	51
Porifera	*Anheteromeyenia rycleric*	26	10	11	18	65
	Radiospongilla Crateriforms	24	2	13	12	51
	Total	**280**	**186**	**186**	**338**	**990**

(50 individuals) was recorded in station 1 while the lowest (12 individuals) was recorded in station 2. Copepod nauplii (Copepoda) were the most abundant with 71 individuals (7.2%).

The zooplankton biodiversity assessment parameters - number of taxa (species), number of individuals and indices (Shannon-Wiener diversity index, Margalef's species richness index, and Pielou's Evenness index) are shown in Table 4. The indices varied spatially across the stations. The analysis of variance (ANOVA) revealed significant differences in all the biodiversity indices evaluated except for some species (taxa). The number of taxa (species) was 21 in all the stations. The abundance ranged between 186 individuals (stations 2 and 3) and 338 individuals (station 4). Stations 4 (control) and 1 were also significantly higher than stations 2 and 3. On the other hand, the Shannon-Wiener diversity index ranged between 2.887 (station 2) and 3.000 (station 4). Station 4 (control) was significantly higher than the other stations. Margalef's species richness index ranged between 3.435 (station 4) and 3.827 (stations 2 and 3). Stations 2 and 3 were significantly higher than station 4 (control). Pielou's Evenness index ranged between 0.8538 (station 2) and 0.9562 (station 4). Station 4 (control) was significantly higher than station 2.

3.3. Macrobenthic Fauna Species Composition, Abundance, Distribution, and Diversity

A total abundance of 939 macrobenthic individuals was recorded in the 4 stations (Table 5). The total composition of 11 species from 6 taxonomic groups was recorded. All the species recorded are tolerant and very tolerant. The highest abundance (261 individuals, 27.8%) was recorded in station 4 (control) while the lowest value (199 individuals, 21.2%) was recorded in station 2. The dominant group was Polychaeta with 3 species and an abundance of 314 individuals (33.4%). The highest abundance (105 individuals) was recorded in station (control) while the lowest (60 individuals) was recorded in station 2. The Nematoda had an abundance of 259 individuals (27.6%) from 4 species. The highest abundance (97 individuals) was recorded in station 1 while the lowest (24 individuals) was recorded in station 2. The nematode occurred in large numbers after Polychaeta in all the stations except station 2. Gastropoda had an abundance of 111 individuals (11.8%) from 1 species. The highest abundance (32 individuals) was recorded in stations 1 and 2 while the lowest (22 individuals) was recorded in stations 3. Insecta had an abundance of 110 individuals (11.7) from 1 species. The highest abundance (43 individuals) was recorded in stations 2 while the lowest (22 individuals) was recorded in stations 1 and 3. Bivalvia had an abundance of 86 individuals (9.2) from 1 species. The highest abundance (27 individuals) was recorded in station 4 (control) while the lowest (14 individuals) was recorded in station 3. The lowest abundance (59 individuals, 0.6%) was recorded among the crustaceans from 1 species. The highest abundance (21 individuals) was recorded in station 4 (control) while the lowest (6 individuals) was recorded in station 3. *Notomastus latericeus* (Polychaeta) was the most abundant species with 125 individuals (1.3%).

The macrobenthic fauna biodiversity assessment parameters - number of taxa (species), number of individuals, and indices (Shannon-Wiener diversity index, Margalef's species richness index, and Pielou's Evenness index) are shown in Table 6. The indices varied spatially across the stations as in the case of the plankton. The analysis of variance (ANOVA) revealed significant differences in all the biodiversity indices except the number of species (taxa) and individuals (abundance). The number of taxa (species) was 11 in all the stations. The abundance ranged between 199 individuals (station 2) and 261 individuals (station 4). There was no significant difference among the stations. On the other hand, the Shannon-Wiener diversity index ranged between 2.148 (station 2) and 2.372 (station 1). Station 1 was significantly higher than station 2. Margalef's species richness index ranged between 1.797 (station 4) and 1.889 (stations 2 and 3). Stations 2 and 3 were significantly higher than station 4 (control). Pielou's Evenness index ranged between 7792 (station 2) and 0.9748 (station 1). Station 1 was significantly higher than station 2.

Table 4. Diversity Indices of zooplankton species in Buguma Creek

Diversity Indices	Station 1	Station 2	Station 3	Station 4 (Control)
Number of Taxa	21	21	21	21
Number of Individuals	280^{a}	186^{b}	186^{b}	338^{a}
Species richness (d) (Margalef's Index)	3.549^{ab}	3.827^{a}	3.827^{a}	3.435^{b}
Species diversity (H) (Shannon-Wiener Index)	2.896^{b}	2.887^{b}	2.895^{b}	3.000^{a}
Species evenness (Pielou Evenness Index)	0.8621^{ab}	0.8538^{b}	0.8613^{ab}	0.9562^{a}

a, b, = Values with different superscripts across the rows are significantly different at $p<0.05$

Table 5. Composition, abundance and distribution of macrobenthic fauna in Buguma Creek

Taxonomic Group	Species	Station 1	Station 2	Station 3	Station 4 (Control)	Total	PS
Polychaeta	*Nephthys caeca*	26	7	17	30	80	VT
	Nereis diversicolor	16	21	36	36	109	VT
	Notomastus latericeus	29	32	25	39	125	VT
Bivalvia	*Crassostrea gasar* (Larva)	24	21	14	27	86	VT
Insecta	*Chironomus larva*	22	43	22	23	110	VT
Gastropoda	*Tympanotonus fuscatus*	32	32	22	25	111	VT
Crustacea	*Alpheops monody*	13	19	6	21	59	T
Nematoda	*Monhystera* sp	24	4	21	15	64	T
	Alainus sp	27	10	19	9	65	T
	Tripyla sp	22	4	14	19	59	T
	Maspfera sp	24	6	24	17	71	T
Total		**259**	**199**	**220**	**261**	**939**	

Key: PS = Pollution status, T = Tolerant, VT = Very tolerant

Table 6. Diversity Indices of macrobenthic fauna species in Buguma Creek

Diversity Indices	Station 1	Station 2	Station 3	Station 4 (Control)
Number of Taxa	11	11	11	11
Number of Individuals	259	199	220	261
Species richness (d) (Margalef's Index)	1.800^{ab}	1.889^{a}	1.854^{a}	1.797^{b}
Species diversity (H) (Shannon-Wiener Index)	2.372^{a}	2.148^{b}	2.328^{ab}	2.331^{ab}
Species evenness (Pielou Evenness Index)	0.9748^{a}	0.7792^{b}	0.9325^{ab}	0.9353^{ab}

a, b, = Values with different superscripts across the rows are significantly different at $p<0.05$

Aquatic biota has been used to assess the environmental health of water bodies globally (Takarina et al., 2019; Arias et al., 2022). They interact with the environment and often show impacts that are not captured by the traditional physicochemical water quality assessments and are considered necessary indicators of the health of the aquatic ecosystem (Forio and Goethals, 2020; Lopes Costa et al., 2020; Davies and Efekemo, 2022). The Niger Delta region has been plagued with some anthropogenic activities. The most common is the extensive exploration and exploitation of crude oil which has resulted in the release of industrial wastes and spilled oil into the water bodies (Nzeako et al., 2015) including in Buguma Creek. Related activities like artisanal refining activities (Nwankwoala et al., 2017; Sibe et al., 2019; Ikezam et al., 2021) and sand mining and dredging have contributed to the pollution stress in the region (Nzeako et al 2015; Anyanwu et al., 2021a, b, c). These activities and more have adversely affected the aquatic biota in the area.

The total phytoplankton abundance (1948 individuals) recorded was very low compared to 9276 individuals recorded in Asarama estuary, Adoni land in Rivers State (Dirisu et al., 2019) and slightly lower than 3050 individuals recorded in Makoko creek, Lagos (Adejumobi et al., 2019). Though the number of taxa (species) recorded in the Asarama estuary was lower (52 species), the taxonomic groups were higher (8) while only 3 taxonomic groups were recorded in Makoko creek. The dominant taxonomic group was Baccilariophyta (78.8% abundance). The same trend (65.22%) was reported in some coastal towns in Ondo State, Nigeria (Ajibare et al., 2019), and 84% was recorded in the Asarama estuary in Rivers State (Dirisu et al 2019). However, Cyanophyta (80%) was the dominant group in Makoko creek (Adejumobi et al., 2019). Baccilariophyta (diatoms) have been extensively used as bioindicators of anthropogenic impacts in lotic ecosystems (Beyene et al., 2009; Krajenbrink et al., 2019; Shibabaw et al., 2021). The highest abundance recorded in station 4 (control) could be a result of minimal anthropogenic activities in the station while the lowest recorded in station 2 could be attributed to massive anthropogenic activities there, which included artisanal refinery, sand mining/ dredging, and discharge of large quantity of human, animal and domestic wastes (Nzeako et al., 2015; Wokoma et al., 2020; Davies et al., 2022; Anyanwu et al., 2021a, b, c). The presence of *Coscinodiscus species, Fragilaria species, Navicula species, Pleurosigma spp,* and *Oscillatoria* species in high numbers is an indication that the river is enriched with organic pollutants (Nwonumara, 2018). The most abundant species - *Coscinodus granii* (Baccilariophyta) is a pollution indicator and could have been more but Shabaan (2001) reported that planktonic diatoms are sensitive to petroleum products, especially *C. granii.*

The total zooplankton abundance (990 individuals) was lower than 1,299 individuals recorded in Asarama estuary, Adoni land, Rivers State (Dirisu et al., 2019) and slightly lower than 1,067 individuals recorded in Uta Ewa Estuary, Akwa Ibom State (Jonah et al., 2020b) and 1055 individuals recorded in Makoko creek (Adejumobi et al., 2019). The number of species was higher than 15 taxa recorded by Dirisu et al., (2019) and 17 individuals recorded by Adejumobi et al., (2019) but lower than 30 individuals recorded by Jonah et al (2020b). The number of taxonomic groups (4) is the same as Jonah et al. (2020b) but higher than the 3 recorded by Adejumobi et al. (2019) and Dirisu et al. (2019). The dominant group was Copepoda (36.7%); Adejumobi et al. (2019) and Dirisu et al., (2019) also recorded a similar trend with high percentages of 90.9% and 99% respectively. As in the case of phytoplankton, the highest abundance recorded in station 4 (control) could be a result of minimal anthropogenic activities in the station while the lowest recorded in station 2 could be attributed to massive anthropogenic activities there like artisanal refinery, sand mining/dredging and discharge of large quantity of human, animal and domestic wastes (Nzeako et al., 2015; Anyanwu and Mbekee, 2020; Wokoma et al., 2020; Anyanwu et al., 2021b; Hastuti et al., 2018). The abundance of Copepod nauplii (Copepoda) and the complete absence of Cladocera is an indication of disturbance. When microzooplankton (copepod nauplii) dominate over larger ones (Cladocerans and adult Copepods), it is an indication of anthropogenic pollution (Arias et al., 2022).

The macrobenthic fauna abundance (939 individuals) was higher than 284 individuals recorded in a brackish water system in Akwa Ibom State by Jonah et al (2020a). However, the number of species and taxonomic groups were lower than 18 species and 7 taxonomic groups respectively recorded by Jonah et al (2020a). All the species recorded are tolerant and very tolerant species (Chessman, 2003) which could be attributed to anthropogenic impacts because the sensitive species have been eliminated. These species often colonize perturbed environments (Marchese et al., 2008). Tolerant species thrive in unstable environments because of their capacity to deal with disturbances (Mariantika and Retnaningdyah, 2014; Okere et al., 2020) and tend to be more abundant (Kucuk, 2008).

The dominant group was Polychaeta. This group has been reported to be an indicator of organic pollution in the aquatic environment. Al-Farraj Saleh (2012) reported the dominance of Polychaeta (*Capitella capitita*, *Notomastus latericeus,* and *Heteromastides similis*) in a station (Half-moon) impacted by sewage effluent and *Capitella capitita*, *Heteromastides similis and Cirratulus ciratus* in another station (Manifa) impacted by oil spills in Saudi Arabia. The study attributed these alterations of the faunal composition to the large-scale discharge of organic wastes and oil pollution in the stations. The Nematoda occurred in large numbers after Polychaeta in all the stations except station 2. Nematoda has also been used as an indicator of organic pollution in the aquatic environment. Generally, nematodes are tolerant to diverse environmental conditions (Barbuto and Zullini, 2005; Nzeako et al., 2015). The highest abundance recorded in station 4 (control) and the lowest recorded in station 2 could be attributed to the same factors observed in the planktons. The most abundant species - *Notomastus latericeus* is an indicator of organic pollution as reported by Al-Farraj Saleh (2012).

Biodiversity indices can reveal salient and important information about the structure of a river (Türkmen and Kazanci, 2010). Generally, in an aquatic community undergoing perturbation, species diversity and richness decrease and enabling the proliferation of some tolerant species (Ngodhe et al., 2014; Arias et al., 2022). The number of taxa (species) and abundance of phytoplankton recorded in station 4 (control) was significantly higher than in stations 1 and 2. The low number of taxa and individuals recorded in station 2 could be attributed to the effect of anthropogenic activities (Arimoro and Oganah, 2010; Okonkwo et al., 2021) while station 3 showed signs of recovery after the impacts. Sensitive species tend to disappear when the aquatic environment is disturbed and recovers quickly downstream of the impact source while tolerant ones tend to flourish because of their capacity to survive stress associated with the impacts (Arimoro and Oganah, 2010). On the other hand, the Shannon-Wiener diversity index for station 4 (control) was significantly higher than stations 1 and 2. The index was < 3 in station 2; indicating environmental perturbation. When the values are > 3.0, it is an indication of a stable and balanced habitat (Shah and Pandit, 2013).

Margalef's species richness index was high; though station 2 with the lowest abundance had the highest value and station 3 with higher abundance had the lowest. The reason for this trend is that the index has no limit and is determined by the number of species and taxonomic composition rather than the number of individuals (Türkmen and Kazanci 2010; Meng et al. 2020). This trend was also reported by Anyanwu et al (2021c) where the most perturbed stations had higher Margalef index values. The Pielou's Evenness index for stations 3 and 4 (control) were significantly higher than station 2. The evenness values were generally high in all the stations with values closer to one (1), especially in stations 3 and 4 (control). When the evenness values are closer to 1, it means that the individuals are distributed equally (Okere et al., 2020) and no species or group of species are dominating. The lowest value recorded in station 2 could be a result of uneven distribution caused by anthropogenic impacts.

The number of zooplankton taxa (species) was the same while the abundance was lowest in stations 2 and 3; attributable to anthropogenic impacts (Arimoro and Oganah, 2010). Shannon-Wiener diversity index was < 3 in all the stations except station 4 (control); indicating instability as a result of anthropogenic impacts (Shah and Pandit, 2013). Stations 2 and 3 had higher Margalef's species richness index with their lowest abundance as observed in the phytoplankton and can be attributed to the same reason (Türkmen and Kazanci 2010; Meng et al. 2020). The evenness index was high though station 2 had the lowest as observed in the phytoplankton due to anthropogenic impacts.

The number of macrobenthic fauna taxa (species) was the same in all the stations and station 2 had the lowest abundance attributable to anthropogenic impacts (Arimoro and Oganah, 2010). The Shannon-Wiener diversity index and Margalef's species richness index were <3 in all the stations especially in station 2. Margalef and Shannon-Wiener indices > 3 is an indication of good water quality that can support macroinvertebrate fauna while poor water quality is usually associated with indices <3 (Akindele et al., 2018). The evenness index was also the lowest in station 2; indicating a high level of perturbation. Benthic invertebrates always bear the brunt of most devastation in the aquatic environment because of their life cycle length, sedentary habits, and exposure to pollutants through food or by body contact with polluted sediment or water (Duc et al., 2015; Arias et al., 2022).

4. Conclusion

In conclusion, every anthropogenic activity has an impact on the aquatic environment but some have more adverse impacts than others. This study has shown that artisanal refinery activities, sand mining/dredging, and discharge of industrial, domestic, human, and animal wastes have adversely affected the aquatic biota (plankton and macrobenthic fauna) in Buguma creek. The effects of these activities have remarkable spatial manifestations; with the more perturbed especially station 2, having a lower number of species and abundance. The preponderance of indicator species is a confirmation while the community structure gave an insight into the negative impact of these activities individually and cumulatively. The brunt of these activities rests more on the macrobenthic fauna; probably due to their unique characteristics and position in the aquatic environment.

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Author Contributions

This manuscript covers research conducted by both authors. The main concept and methodology were generated and academically supervised by both authors. All the authors contributed to writing the manuscript, reading, and approving the final manuscript.

Competing Interests

The authors declared no potential competing interest with respect to the research, authorship, and/or publication of this article.

Authors' Statement of Originality

The authors declare that this article is original research conducted by both and has not been published in any other journal

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