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(Research Article)

Zooplankton and benthic fauna composition of Isaka-bundu mangrove swamp, Niger delta, Nigeria: A polluted tidal mangrove tropical creek

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Abstract

The study was aimed at examining the impact of untreated discharges from artisanal refineries (illegal bunkering), loading and other related activities on the composition, abundance, distribution, and diversity of zooplankton and macrobenthic fauna from four creek channels of the Isaka-Bundu waterfront in Rivers State, a polluted tidal mangrove wetland. Zooplankton and benthic fauna samples were collected monthly from each of the sampling stations for six months (July to December 2021 using standard sampling methods. Margalef (D), Shannon Wienner (H), and Evenness indices were tools used to determine the species richness and diversity respectively using the SPSS statistical package. This study shows that illegal refining activities and other discharges from industrial and human wastes had an unfavourable impact on the zooplankton and macro-benthic fauna community in Isaka-Bundu waterfronts. The effects are reflected in the spatial variations in the composition with more agitation, especially in station 2 in zooplankton and station 3 in macrobenthic fauna, which has a lower number of species and abundance. The majority of indicator species is a validation of this study, the community structure is an insight into the adverse effects of individual and cumulative activities. More impact was observed on the benthos and benthic fauna and this could be due to their exceptional features and location in the aquatic environment. While therefore, this is an indication that creeks are polluted and regular monitoring should be carried out to report the special degradation level of this creek.

Keywords: Zooplankton; Macrobenthic; Illegal refinery; Polluted tidal mangrove

1. Introduction

The aquatic environment in the Niger Delta is exposed to different kinds of industrial, sewage treatment plants, and drainages from urban and agricultural effluent and waste discharges [1]. The discharges from most municipal and industrial sewage and the drainage of agricultural and urban areas also dispose of their waste in the aquatic environments [2]. These have caused great damage to the aquatic environment and its environment, and the pollutants have led to an imbalance in the composition of plankton [3];[4]. These anthropogenetic activities have posed a risk to the availability of nutrients for living organisms which depend on many Physico-chemicals in addition to biological factors thereby causing an imbalance in the population and distribution of zooplankton, and benthic fauna communities, damage to the resources that depend on them for existence [5]. The composition of zooplankton and benthic fauna has direct relevance to the trophic levels of plankton feeders, such as marketable fish species [6].

The health of the aquatic ecosystem depends on the plankton colonies, as they play a crucial role as part of the food chain [7]; [8]. However, zooplankton and benthic fauna communities are micro and macro-organisms that live at different trophic levels, and the health of the aquatic ecosystem depends on the plankton colonies as they play an

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essential role as part of the food chain [9]; [10]. These discharges, especially those from factories, contain heavy inorganic metals [11]; [12].

The quantity of plankton in every water body affects its productivity because they are the main primary and secondary producers. The food chain that supports commercial fishing is supported by plankton populations [13]. Phytoplankton communities, according to [14] are important producers of organic carbon in big rivers, a source of food for planktonic consumers, and possibly the main supply of oxygen in many low-gradient rivers. The biomonitoring of pollution relies heavily on phytoplankton [15]. To evaluate the biological integrity of the water body, one uses the distribution, abundance, species diversity, and species composition of the phytoplankton [16]. They also reflect the level of nutrients in the surrounding environment [17].

These organisms cannot escape pollution because they have little control over their movements, which makes them an excellent indicator of environmental pollution [18]; [19]. According to [20], pollution has an impact on the distribution of plankton, standing crops, and chlorophyll content. These contaminants have the potential to seriously harm aquatic life and can lead to an unbalanced composition of planktons [21]. Anthropogenic activities like those stated above may cause an imbalance in the population and distribution of planktons, which could harm the fishing resources that depend on them [22]. Since plankton feeders like commercial fish are directly impacted by any factor that alters plankton composition [23].

The study area is bordered by interconnecting creeks that have been urbanized and industrialized due to the search for natural resources like crude oil, gas, and other natural resources. The quality of the creek may be harmed by effluents from human waste, pipeline leaks, unintentional discharges, refinery discharges, and sabotage (illegal bunkering) loading activities. To build an independent database for future research in this study area and to identify the special and distribution pattern of the zooplankton, benthos, and benthic fauna, assemblage, this information is essential. The purpose of this study was to evaluate the distribution of the distinctive zooplankton, benthos, and benthic fauna in the Isaka-Bundu mangrove swamp.

2. Materials and methods

2.1. Description of the study area

The Isaka-Bundu ama axis of the Bonny Estuary mangrove swamp is a tidal soft-bottom ecosystem that is often exposed to a wide range of mudflats. It is a tributary of the upper Bonny Estuary in the Niger Delta, Nigeria. The sampling stations were at least 1,000 meters apart along the tributary of the upper Bonny Estuary. The sampling stations were geo-referenced and selected specifically to cover study areas of the creek receiving effluents and wastes from different anthropogenic activities of the area; Station 1: (4°45'11.0"N: 7°01'02.2"E, Bundu waterfront), Station 2: (4°45'06.3"N:7°00'12.3" E, Ibeto waterfront), Station 3: (4°44'13.9"N:7°00'14.8 "E, Isaka waterfront), and Station 4: (4°45'23.8"N 7°00'10.5"E - Dockyard waterfront) as shown in (Figure 1). This 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 effluence from Illegal refining sits, artisanal channelization, domestic dumps, bunkering activities, sand dredging, and runoffs and is visible on the shorelines by residents for artisanal fishing, while various water-related activities such as commercial water transportation, industrial/manufacturing activities and oil and gas logistics operations are equally deployed either within or on the shores of this section of Bonny River. The vegetation present in the area is the red mangrove *Rhizophora mangles* and white mangrove *Laguncularia racemose.* Some of the dominant fish families in this ecosystem include the Lutjanidae, Clupeidae, Cichlidae, and the Claroteidae, but the most abundant are the Claroteidae (silver catfish) and Cichlidae (tilapias). Whereas the tidal mudflats species include gobies, mudskippers, periwinkles, and crabs, only to mention a few.

2.2. Samples and sampling techniques

2.2.1. Plankton composite

The 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 (5 X, 10 X, and 40 X). Direct plankton counts were done using the drop count method. Taxonomic identification was carried out as far as possible, to identify organisms to the highest practicable level.

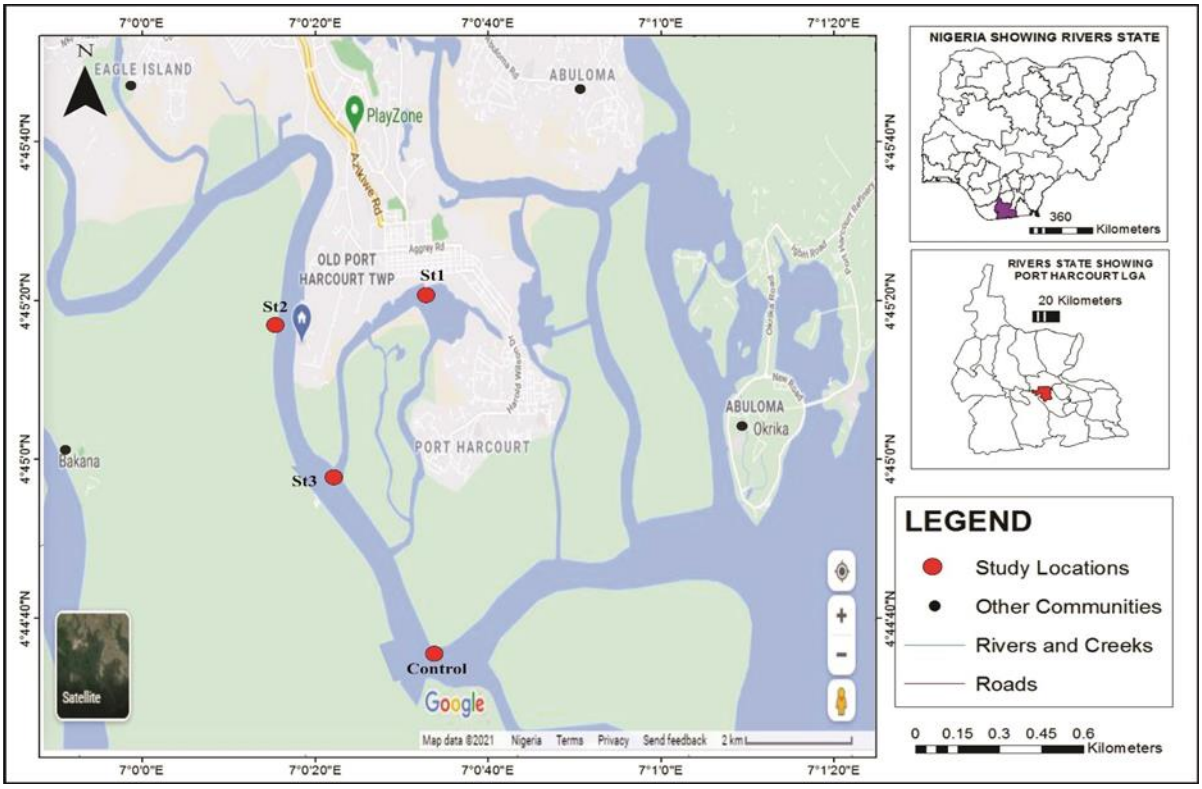

Figure 1 Map showing study areas

2.2.2. Determination of species abundance/dominance Index (SIMPSON)

Species abundance/Density was determined using Simpson's dominance index using the equation:

$$C= \sum \left(\frac{n_i}{N}\right)^2$$

Where;

n_i = the no. of individuals in the species
N = the total no. of individuals.

2.2.3. Determination of species diversity indices (d), and productivity

This is also known as the species diversity/richness index. The species richness (Margalef, 1951) [24] was given by the equation.

$$d = \frac{S - 1}{\text{In N}}$$

Where d = Margalef richness index or species diversity index
S = Number of species in the population
N = Total number of individuals in a species.

2.2.4. Benthos and Benthic Fauna

A quantitative sampling was carried out for benthic fauna for each station using the Ekman Grab (0.0225m^2) and poured through a sieve of 1mm x 1mm mesh size [25], and washed through a sieve of fine mesh size made of silk material, to wash off formalin and 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 [26], and labelled with the name of the sample, location, and date of collection. Laboratory analysis was carried out 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 highest practicable level using the lowest possible taxonomic level reliable identification keys and texts.

3. Results and discussion

3.1. Zooplankton Species Composition, Relative Abundance Distribution, and Diversity.

Table 1 Variation and distribution of zooplankton species at the various stations

Phylum	Zooplankton species	Control	Station 1	Station 2	Station 3	Total number of species
Protozoa	*Lagynophoya confera*	3	5	3	0	11
	Frontoria leucas	2	2	0	3	7
	Tintinnopsis sinerisis	3	3	5	2	13
	Lembadion magnum	1	1	0	0	2
	Askenasia fourei	4	7	2	1	14
	Quairulella Sp.	2	4	0	2	6
	Pseudodileptus Sp	1	2	0	0	3
	Coleps ociospitus	2	4	0	2	8
Total		28	10	10	8	56
	Brochionus urceus	3	2	5	2	12
Rotifera	*Brochionus pliiatilis*	2	3	1	2	8
	Brochiamus Ureceolaris	1	0	0	3	4
	Brochiomis rubens	2	3	3	0	8
Total		8	8	9	7	32
Copepoda	*Copepod*	4	6	6	2	18
	Faracydops funbriatus	2	4	1	1	8
	Cyclops copepodd	2	4	0	2	8
	Thermacyclops with Egg	1	0	1	1	3
	Macrocyclops albidus	2	3	0	2	7
	Acanthrocycloops vernalis	3	3	1	4	11
	Calanoid cotepo	2	3	2	1	8
Total		16	23	11	13	63
Nematoda	*Monhystera*	2	5	1	2	10
	Alainus	2	4	0	2	8
	Tripyla	1	2	0	2	5
	Maspfera Sp	4	5	2	8	19
Total		9	16	3	14	42
Porifera	*Anheteromeyenia rycleric*	3	5	1	3	12
	Radiospongilla Crateriforms	2	3	1	1	7
	Total	5	8	2	4	19

The distribution, abundance, and diversity of zooplankton species are represented in Table 1 and graphically in Figure 2. The Zooplankton in the study area belonged to phyla namely; Porifera, Nematoda, Copepoda, Rotifera, and Protozoa. The most frequent phylum was Copepoda (30%) with a total number of 63 species while Porifera recorded the lowest frequency of occurrence (9%). With a total of 19 species. There were significant differences in the number of species across the stations as compared to the control which recorded the highest number of 66 species while the least number of species was observed in station 2 with 35 species.

A total number of 212 Individuals were recorded during the sample period. The highest number of taxa (25) was recorded in the control while the lowest (15) was observed in the station during the sampling periods. Copepods were recorded with the highest total number of *Copepod* recorded in stations 2 and 3 while the least species observed were *Thermacyclops with Egg* in station 1.

The relative abundance as shown in Table 1, revealed that the Phylum Copepoda recorded the highest numerical abundance with a total of 63 zooplankton individuals, and a relative abundance of 30%, followed by Protozoa with 56 individuals and a relative abundance of 26%, Nematoda, with 42 individuals and relative abundance of 20%, Rotifera with 32 individuals and relative abundance of 15% while Porifera was the least with 19 individuals and a relative abundance of 9% from an abundance of a total 212 individuals (100%) of the zooplanktons in the various Phylum (figure 2). The analysis of variance between the three stations and the control revealed a significant difference in the relative abundance of the zooplankton community.

Table 2 Diversity Indices of zooplankton species at the various stations

Diversity Indices	Control	Station 1	Station 2	Station 3
Number of Taxa	25	23	15	21
Number of Individuals	66	65	35	46
Species richness (d) (Margalef's Index)	5.936	4.979	3.938	5.166
Species diversity (H) (Shannon-Wiener Index)	3.137	3.059	2.481	2.885
Species evenness (Pielou Evenness Index)	0.974	0.975	0.916	0.948
Species dominance (Simpson's Index)	0.046	0.05	0.1	0.068

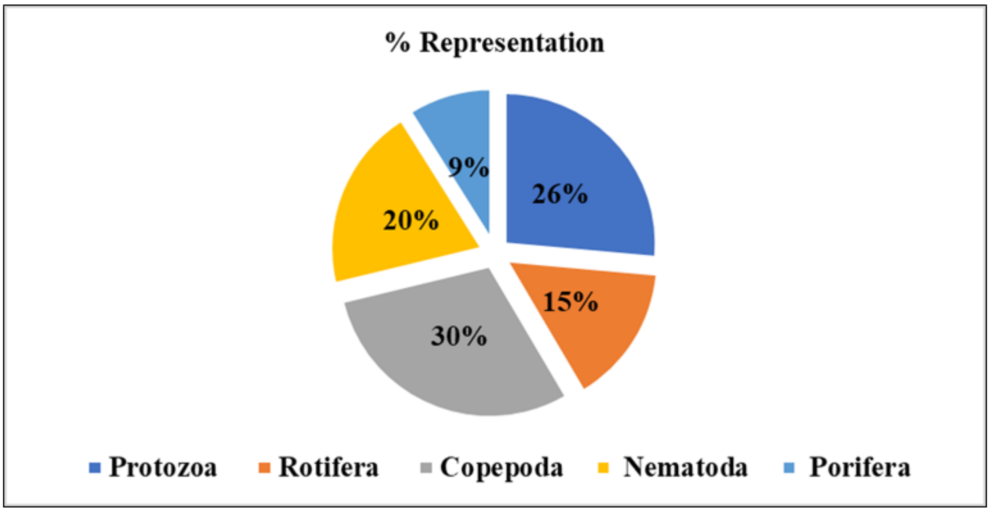

Figure 2 Percentage representation of the zooplankton fauna

Diversity values varied across the stations with changes in zooplankton composition as seen in table 2. The low diversity of the zooplankton population in station 2 could be attributed to poor light penetration into the turbid water, which reduced the photosynthetic depth as a result of the high level of turbidity from other anthropogenic activities on this sample station [27]. They also reported that the abundance and diversity of zooplankton species as in the study could be attributed to the scouring action of flood water on the substratum. This agrees with [28] who reported that the water flowing into the other areas later increases significantly and hence leads to an increased velocity of seaward flow which may affect the production of planktons. [29] stated that during tidal propagation upstream, more energy dissipates, and therefore the production level decreases as seen in station 2. According to [30], the number of species in the zooplankton assemblages and the degree of evenness are closely related to diversity. The higher abundance of species in the control can be associated with stability in the environmental parameters and nutrient availability [31]. The low abundance of species in station 2 could be likened to the collapse of the phytoplankton community [32]. These values recorded in the diversity were similar to the Shannon-Wiener diversity (H) range of 2.48-3.137 reported for the Lower Bonny Estuary by [33] but higher than the values for a closely linked Sombrero River, which ranged between 0.922 and 1.573 (H) [34]. This minimal variation in the species evenness is probably due to the uniformity and stability of chemical and physical conditions of the environment [27].

3.2. Benthos and Benthic Fauna

The most occurring taxonomic group is the Polychaeta with 3 species, while all other groups had 1 species each. Tables 3 and 4 show the distribution and variation of species among the different taxonomic groups and indicate that the highest numbers of 41 species were gotten in the control and the least in Stations 3 which had 23 species.

Table 3 Checklist of benthos and benthic fauna found in the sediment

Class	Species	Control	Station 1	Station 2	Station 3
Polychaeta	*Nephthys caeca*	+	+	-	+
	Nereis diversicolor	+	-	+	+
	Notomatus latericeus	+	+	+	+
Pisces	*Gobionellas sp (Larva)*	+	-	+	+
Bivalvia	*Crassostrea gasar (Larva)*	+	+	+	+
Insecta	*Chironomus larva*	+	+	+	+
Gastropoda	*Tympanotonus fuscatus*	+	+	+	+
Crustacea	*Alpheops monody*	+	+	+	+

Key: - (Absent) + (Present)

Table 4 Total abundance of benthos and benthic fauna found in the sediment

Class	Species	Control	Station 1	Station 2	Station 3	Total
Polychaeta	*Nephthys caeca*	5	5	0	3	13
	Nereis diversicolor	6	0	4	5	15
	Notomatus latericeus	7	5	6	3	21
Pisces	*Gobionellas sp* (Larva)	6	3	5	2	16
Bivalvia	*Crassostrea gasar* (Larva)	4	6	3	2	15
Insecta	*Chironomus larva*	3	3	7	4	17
Gastropoda	*Tympanotonus fuscatus*	6	5	6	3	20
Crustacea	*Alpheops monody*	2	3	2	1	8
Total		39	30	33	23	121

In terms of class abundance, Polychaeta dominated the benthic community with 39% (49 individuals) of the total number of individuals enumerated. This was followed by Gastropoda (16%) (20 individuals) and Insecta 14% (17 individuals) respectively. Others such as Crustacea, Bivalvia, and Pisces contributed 6%, 12%, and 13% (8, 15, and 16 individuals) each of the total macro-fauna of the study area. The benthos and benthic fauna community of the study area were represented by individuals from 4 different phyla and six (6) major macro-faunal groups (classes) namely; Arthropoda (Crustacea and Insecta), Annelida (Polychaeta), Mollusca (Gastropoda and Bivalvia) and Chordata (Pisces). A total of eight (8) species were recorded in the study of which 3 species accounting for 39% are polychaetes and others such as Pisces (13%), Bivalvia (12%), Insecta (14%), Gastropoda (16%) and Crustacea (6%) were represented by 1 species each (Figure 4).

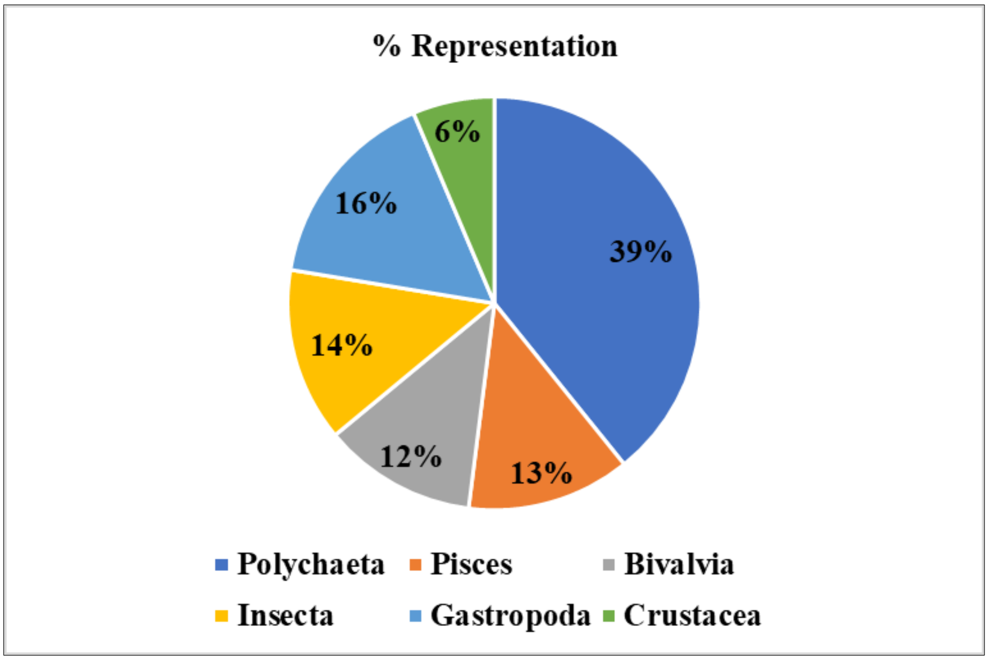

Figure 3 Percentage distribution of the benthos and benthic fauna

3.3. Total abundance of Benthos and Benthic Fauna Found in The Sediment

The eight (8) species of benthos and benthic fauna community were found in the study area which cut across four phyla, six classes, and eight genera. The composition of benthic macro-fauna in terms of representative phyla in the study area is closely related to the five phyla observed by [35]; [36] in the Andoni flats and Eagle Island (both in the Niger Delta) respectively. This phylum is indicative of good ecological similarities. It is equally related to the three phyla (Arthropoda, Annelida, and Mollusca) reported by [37] in the Sombreiro River, the only missing phyla being Chordata. They recorded six classes of benthic macro-fauna in this study area. The 8 species observed in this study are analogous to the 9 species recorded by [38] in the Ikpoba River but lower than the 28 species reported by [37]. [39] reported 30 species, while [35] also recorded 30 species. The differences in species composition and abundance may be attributed to several ecological factors including differences in the different habitat locations and periods of investigation, water quality, and substrate for occupation and food availability [40].

Polychaetes dominated the benthic community of the sampled stations with three species and were near evenly distributed across the four stations. Meanwhile, all other classes of benthos had only one representative. Similarly, the dominance of Polychaeta recorded in this study agrees with the report of [41];[42] and could also be attributable to the similarity in the study areas and their high level of pollution tolerance [43]. The very low number of species and individual members enumerated in this study could be a reflection of the quantity of sampling time or an indication of sediment pollution.

The differences in species composition and abundance in the benthos and benthic fauna may be attributed to several environmental factors including differences in the different habitat locations and period of investigation, water quality, and substrate for occupation and food availability. Although, the dominance of Polychaeta as shown in this study is similar and agrees with most research from the Niger Delta creeks [37]. [44]; [39] who attribute this to the high level of pollution tolerance while the low number of species and individual members enumerated in this study is indicative of gradual sediment pollution.

4. Conclusion

In conclusion, anthropogenic activity around the study area has a direct impact on the aquatic environment with more adverse impacts on the distribution and abundance of the distribution, abundance, and diversity of zooplankton, benthos, and benthic faunas. This study shows that the effluents from unintentional discharges, refinery discharges, and sabotage (illegal bunkering) loading activities have adversely affected the aquatic biota (zooplankton and macrobenthic fauna) in the Isaka-Bundu mangrove swamp. The effects have a notable spatial with more agitation especially in stations 2 in zooplankton and stations 3 in macrobenthic fauna, having a lower number of species and abundance. The majority of indicator species is a validation while the community structure is an insight into the adverse effect of individual and cumulative activities. More impact was observed on the benthos and benthic fauna and this could be due to their exceptional features and location in the aquatic environment.

Compliance with ethical standards

Acknowledgments

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Disclosure of conflict of interest

All of the authors declare that they have both participated in the design, execution, and analysis of the paper and that they have approved the final version. Additionally, there are no conflicts of interest in connection with this paper, and the material described is not under publication or consideration for publication elsewhere.

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