The Impact of Makeshift Oil Refineries on the Macro-Invertebrates of the Nun River Estuary, Niger Delta, Nigeria

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ABSTRACT

Sampling was done in six sampling stations for one year (August, 2014- July, 2015) to investigate the impacts of makeshift oil refineries on the macro-invertebrates of the Nun River estuary in the Niger Delta region of Nigeria after over 3 years of chronic pollution of this estuary by the makeshift refinery activities. There was also a massive destruction of the benthic and mangrove associated macrofauna of the Nun River estuary and its tributaries. 18 species of benthic macro- invertebrates distributed among 15 genera and 9 families were recorded during the study. A total of 2, 942 individual organisms were collected in which 41 belonged to the Class Polychaeta, 684 belonged to the Class Decapoda (subphylum crustacea), and 2, 217 belonged to the Class Gastropoda. The class Gastropoda, made up of 1 family and 2 species had the highest percentage composition (75.36%) and are the most dominant species of the area, followed by the class Decapoda (23.25%), and Class Polychaeta (1.39%), respectively. About 12 organisms (which were present during the baseline study) were absent during the current study. The biodiversity of the estuary is low. The alteration of the physico- chemical parameters as well as the direct contact with the spilled crude oils which resulted from the makeshift oil refinery activities is responsible for the massive destruction of the macro zoobenthos in the area.

INTRODUCTION

Benthic organisms (or benthos) are organisms that inhabit the bottom of the rivers, streams or seas, whether in the intertidal region or below tidal marks (Tait 1982; Josiah 1997). They fall into two major categories, namely, the animal called zoobenthos and the plant component known as the phytobenthos (Holmes and McIntyre 1984). The zoobenthos which are essentially invertebrates are further distinguished into three groups: macro-benthos, meio-benthos and micro-benthos, according to the size of the organisms. The macro-benthic invertebrates (or macro- zoobenthos) are described as bottom dwelling animals that are big enough to be retained by a sieve with a mesh size of 1.0mm (Holmes and McIntyre, 1984; Day 1981 and 1982). Most macrobenthic organisms have intermediate planktonic larval phases, a few swim freely during a short breeding season before settling permanently on rocks, sediments, or mangroves to become adults. The most abundant macro-zoobenthos are often polychaetes, molluscs (both bivalves and gastropods), nematodes, isopods, ceridian and panaeid shrimps, crabs and echinoderms (Gijo, 2011). The intertidal macro- zoobenthos have been recognized to be economically important. For instance, benthic molluscs are important sources of calcium and protein in human diets and these are often found in the mangrove environment (Sasekumar, 1984; Josiah, 1997; Gijo, 2011). Also, the shells of the gastropod molluscs such as *T. fuscatus* and *P. fusca* are used extensively in some localities in building and construction works. Zoobenthos also serve as food to various species of birds and fishes like *Fundulus heterodontus* and *Aplocheilichthyes spilauचना* which feed on mangrove invertebrates such as molluscs, crustaceans and

polychaetes (Sasekumar, 1984; Josiah, 1997; Gijo, 2011).

A baseline ecological survey of the macro-invertebrates of the Nun River estuary was conducted from September, 2009 to July, 2010. Shortly after the research, makeshift oil refineries were established in the estuary and this resulted in frequent oil spills from 2011 till date, which seriously polluted the area. These events necessitated the current research.

The aim of this project was to investigate the impacts of makeshift oil refining activities on the mangrove ecosystem and on the macro- invertebrates of the Nun River Estuary in Brass Local Government area, Bayelsa State, Nigeria. The specific objective of this research is:

To determine the impacts of the crude oil spillages associated with the makeshift oil refining activities on the benthos of the area.

MATERIALS AND METHODS

Description of Study Area

The study area is the Nun River Estuary, which is situated around Akassa kingdom in Brass Local Government Area of Bayelsa State, Nigeria. Several creeks, inlets, and canals are connected to this estuary, which serve as navigational routes and drainages in the area. It is also connected to other estuaries through these channels. The Brass river estuary is situated towards the east while the Sangana river estuary is situated towards the west of the Nun River estuary. The Atlantic Ocean is connected to the Nun River estuary from the south.

Figure 1: Map of the Niger Delta, Nigeria

http://1.bp.blogspot.com/_DeabNDTNx68/SVPr7EKXy6I/AAAAAAABAAIY/162HX8mmP-4/s1600/NigerDelta.gif

Makeshift oil refineries (Kpo fire) are established in the area. Indigenous technologies used to distil locally made gin (ogogoro or kaikai) are employed to refine the crude oil into various petroleum products. Metal pipes and drums welded together are used- in which crude oil is boiled and the resultant fumes are collected, cooled and condensed in tanks to be used locally for lighting, energy or transport.

The makeshift (local) oil refineries or Kpo fire have been in operation since 2011 and abated gradually early 2015. The study area was chosen because, in spite of the heavy aquatic pollution that the estuary has been subjected to, no research has been conducted in the area to ascertain the impacts on the macro benthic intertidal invertebrates.

Designation of Sampling Stations

Six sampling stations were chosen. The randomized block experimental design was used during the research. Two Six sampling stations were chosen. The randomized block experimental design was used during the research. Two of the sampling stations (stations 1 and 3) were established exactly on the makeshift oil refinery camps, which were designated the "highly impacted zones" and Station 2 was established in an area that is adjacent to station 1, which was designated as "partially impacted zone". The remaining sampling stations (stations 4, 5, and 6) were the three sampling stations (Stations 1, 2, and 3), that were sampled during the base line study, respectively. The experimental design that was used during study was the randomized block design.

Field Sampling

This research was conducted for one year; from August, 2014 to July, 2015. A reconnaissance survey of the area was conducted prior to the main study. Benthos, water and soil were sampled once a month from the six sampling stations along a transect running from the low intertidal level (LTL) through the mid intertidal level (MTL) to the high intertidal level (HTL).

Sampling of intertidal benthic macro invertebrates

Different sampling methods were used in the collection of faunal samples. These methods included the use of quadrats, Visual counts (Okon, 2005), collections (Hanley, 1993; Okon, 2005), and burrow counts (Mc Guinness, 1992, 1993). Sampling of the macro invertebrates of the area was done monthly with a quadrat of size 0.5m² (50cm x 50cm) at the ebb of the spring tide in each of the stations. The benthos covered by the quadrat was excavated with the aid of a spade to the depth of about 20cm, digging below 20cm will produce a strong smell and only few animals are found beyond that depth (Sesarkuma, 1984). Prior to the excavation, all juvenile crabs, and gastropod molluscs

crawling within the quadrat were hand- picked and put into a labeled wide mouthed bottle containing 10% formalin and 0.1% of the vital stain, Rose Bengal (Mason and Yevich 1967; Frigelos and Zenetos 1988). The excavated samples were kneaded and then washed with several runs of water through a 1mm mesh sieve (Holland et al., 1977). Where the substratum was sticky and muddy, it was broken up in small bits and macro fauna sorted out by hand picking. After washing, the mangrove residue, the macrofauna retained in the sieve were transferred into the bottle containing Rose-Bengal in formalin (10%).

Sorting and Identification of Benthos

The preserved zoobenthic samples were examined in the laboratory and the infauna present were isolated. Initially, each sample was washed to remove the formaldehyde which would otherwise cause a choking smell and discomfort. The samples were then placed on a white surgical tray and pink stained animals were removed with a pair of forceps and were preserved in 50% alcohol. By means of an illuminating dissecting microscope the infauna were sorted and identified to the lowest possible taxonomic level using the keys of Day (1967).

The number of species in each sample and station were recorded. Some components of the macro fauna notably, the polychaetes, oligacheates and crustaceans were fragmented during the process of washing, hence only heads were counted (Ankar and Jansson, 1973; Gijo, 2011).

For the calculation of density, the formula that was used was:

$$= \frac{\text{Total number of animals}}{\text{Total Area of quadrat}}$$

The density of the major macrofauna was estimated by counting the number of organisms present in each sample, and values were approximated to the nearest whole number.

The percentage frequency of occurrence was calculated with the formula:

$$= \frac{\text{Number of occurrence of species in sample thrown}}{\text{Total Number of throws}} \times \frac{100}{1}$$

PAST (a statistical package) was used to calculate the dominance, evenness, and the Shannon- Weaver's, Simpson's, and Margalef's diversity indices.

RESULTS

The checklist of the intertidal benthic macro invertebrates is presented in Table 1. A total 18 species

As the margalef values show (Table 2) species richness was highest at station 4 and lowest at stations 1 and 3. Community diversity (Shannon- Weaver) was in the sequence: 4>2>6>5>1=3. The species are more

Table 1: A Checklist of benthic macro invertebrates collected from the Nun River Estuary

TAXON	No of Families	No of Species	% Composition	Total No of organisms
PHYLUM: ANNELIDA	2	3	1.39	41
CLASS: POLYCHAETA				
FAMILY: CAPITELLIDAE				
<i>Capitella sp.</i>				
FAMILY: NEREIDAE	No of Families	No of Species	% Composition	Total No of species
<i>Nereis sp</i>				
<i>Nereis diversicolor</i>				
PHYLUM: ARTHROPODA				
SUBPHYLUM: CRUSTACEA	7	15	23.25	684
CLASS: DECAPODA				
FAMILY: GRASPSIDAE				
<i>Sesarma huzardi</i>				
<i>Sesarma elegans</i>	No of Families	No of Species	% Composition	Total No of species
<i>Sesarma alberti</i>				
<i>Sesarma angolense</i>				
<i>Pachygrapsus sp.</i>				
<i>Goniopsis pelli.</i>	No of Families	No of Species	% Composition	Total No of species
FAMILY: PORTUNIDAE				
<i>Callinectes amnicola</i>				
FAMILY: OCYPODAE				
<i>Ocypode africana</i>	No of Families	No of Species	% Composition	Total No of species
<i>Uca tangeri</i>				
FAMILY: GECARDINIDAE				
<i>Cardisoma armatum</i>				
FAMILY: ALPHEIDAE	No of Families	No of Species	% Composition	Total No of species
<i>Alpheus pontederiae</i>				
FAMILY: DIOGENIDAE				
<i>Clibanarius cooki</i>				
FAMILY: BALANIDAE	No of Families	No of Species	% Composition	Total No of species
<i>Balanus sp.</i>				
PHYLUM: MOLLUSCA				
CLASS: GASTROPODA	1	2	75.36	2217
FAMILY:				
POTAMIDIDAE				
<i>Pachymelania fusca</i>				
<i>Tympanotonous fuscatus</i>	Total No of Families	Total No of Species	Total No of individual species	
	10	18	2942

Figure 2: Percentage composition of each class of benthic macro invertebrates of the Nun River Estuary during the current study

Figure 3: Percentage composition of each class of benthic macro invertebrates of the Nun River Estuary during the baseline study in 2009-2010

Table 2: Diversity indices across the stations

Diversity indices	STN 1	STN2	STN3	STN4	STN5	STN6
No. of Taxa	0	36	1	76	17	82
No. of Individuals	0	58	1	328	28	2522
Dominance	0	0.033	1	0.037	0.074	0.070
Simpson	0	0.967	0	0.963	0.926	0.930
Shannon	0	3.499	0	3.789	2.713	3.002
Evenness	0	0.919	1	0.582	0.887	0.245
Margalef	0	8.62	0	12.95	4.802	10.34

Table 3: Monthly diversity indices (August, 2014- July, 2015)

Month	No. of Taxa	No. of individual	Dominance	Simpson	Shannon	Evenness	Margalef
Aug	12	188	0.518	0.482	1.339	0.182	3.819
Sep	12	217	0.488	0.512	1.441	0.184	4.089
Oct	10	227	0.520	0.480	1.263	0.208	2.949
Nov	11	231	0.588	0.412	1.118	0.170	3.124
Dec	9	286	0.573	0.427	1.086	0.174	2.829
Jan	7	285	0.754	0.246	0.664	0.162	1.946
Feb	11	205	0.520	0.480	1.345	0.213	3.185
Mar	10	243	0.585	0.415	1.15	0.186	2.913
Apr	13	373	0.672	0.328	0.946	0.117	3.546
May	11	144	0.475	0.525	1.371	0.281	2.616
Jun	10	203	0.451	0.549	1.417	0.295	2.447
Jul	12	332	0.594	0.406	1.048	0.15	3.101

DISCUSSION

The data obtained during this study indicated that the makeshift oil refining activities had a tremendous impact on the benthos. The impact of the illegal oil refineries affected both the density and distribution of the biota. 30 species of benthic macro invertebrates were identified during the baseline study, whereas, only 18 species were recorded in the current study. About 12 species were absent during the current study. The species that were absent include *Marphysa* sp., *Marphysa sanguinae*, *Notomastus latericeus*, *Lumbrinereis* sp., *Marianida pinniger*, *Lillyalla* sp., *Mandippi* sp., *Littorina anguilifera*, *Neritina owenensis*, *Pachymelania aurita*, *Pachymelania bryonensis*, and *Crassostrea gasar*. The organisms that were recorded during the baseline study belonged to 15 families; unlike those of the current study that had just 10 families. Also, the total of number of individual organisms were higher in the baseline study than the current study. 3,052 individual organisms were collected during the baseline study while only 2, 942 individual organisms were obtained during the current study. The 3,052 individual organisms were collected from only 3 sampling stations and the samples were collected for only 6 months out of one year; unlike the current study that had up to 6 sampling stations and the samples were collected for 12 months.

The number of species that were collected in the current study are also fewer than those recorded by other researchers in the Niger Delta. For instance, Josiah (1997) recorded 23 species; Zabbey (2002) recorded 30 species; Hart (1994) recorded 43 species; Mansi (1997) recorded 44 species and Zabbey (2011) recorded 65 species of macro-zoobenthos (18 species of epifauna and 47 species of infauna). However, Woke (2004) recorded just 14 species, fewer than those recorded in the current study.

The results also show that the class Gastropoda, made up of 1 family and 2 species had the highest percentage composition (75.36%) and are the most dominant species of the area, followed by the class Decapoda (22.5%), Class Polychaeta (1.39%), and Class Bivalvia (0.57%), respectively (Table 1 and Figure

2). In the baseline study, the percentage composition of the Class Gastropoda was 64.1% (against 75.36% in the current study), followed by the Class Decapoda (Crustacea) which had a percentage composition of 15.37% (against 22.5% in the current study), and then Class Bivalvia which had a percentage composition of 11.99% (against 0.57% in the current study), and Class Polychaeta, which had a percentage composition of 8.55% (against 1.39% in the current study)- figure 3. Various results from studies on benthic macro invertebrates in the Niger Delta showed remarkable variation of dominant groups. According to Woke (2004) organisms of the Classes Gastropoda and Insecta were dominant in his study in terms of species composition and number of families. Conversely, Akani (1994), Mansi (1997), and Zabbey (2002) all reported that the polychaetes were the most dominant benthos. Also, Ewa-Oboho and Oladimej (1999) reported that Polychaetes and crustaceans dominated by species and number (31.2%, 55.6%) and (20.8%, 28.9%), respectively, followed by molluscs (16.9%). In addition, Zabbey (2002) reported that the Class Oligochaeta was the second most dominant benthos in terms of species composition and number of families followed by the Class Crustacea. Snowden and Ekweozor (1990) also reported that the polychaetes and the fiddler crab (*Uca tangeri*) were the most abundant.

Among all the organisms, *Pachymelania fusca* of the class Gastropoda was the most abundant, having about 2, 213 individual organisms out of the 2, 942 organisms that were collected during the study. *Pachymelania fusca* occurred only at the **Mid** and **High** intertidal zones of sampling station 6, unlike the baseline study in which the organism occurred in large numbers in at the low, mid and high intertidal zones of station 1 (current station 4) and the low and mid intertidal zones of stations 2 (current station 5) and 3 (current station 6). Decapod crustaceans had the highest number of families (7) and species (15) with the family Grapsidae being the most dominant. The polychaetes consisted of about 3 species from 2 families with the family Nereidae being the most abundant.

The results also indicated that the benthic macrofauna of stations 1 and 3 (the illegal oil refinery camps) were completely destroyed, except for station 3 that had just one species of *Sesarma huzardi*. Station 1 had THC, pH, temperature, and salinity of 1881.79 mg/l, 5.54, 28.83°C, and 7.87‰, respectively. Similarly, Station 3 had THC, pH, temperature, and salinity of 1907.89 mg/l, 5.47, 28.73°C, and 7.92‰, respectively. The high THC in the illegal oil refinery camps coupled with the acidic pH (5.47 and 5.54) and low DO may have caused the elimination of the macrofauna in these stations. The intertidal benthic macro invertebrates of station 2 were also very few, compared to stations 4, 5, and 6. Station 2 had THC, pH, temperature, and salinity of 1810.43 mg/l, 5.47, 28.68°C, and 7.9‰, respectively. In a related study, Ekweozor, et al., (1989) undertook a baseline survey of the intertidal macrofauna of the Bonny Estuary and found that Port Harcourt and Okrika sites located in the central portion of the estuary had very low polychaete and total faunal densities with Okrika having a particularly lower number of species in comparison with the other sites, with *Capitella capitata* being dominant. These low faunal densities were ascribed to pollution of soil (Spies and Davies, 1979; Dauvin, 1982; McLusky, 1982). Levels of total oil and grease in the sediment at the Okrika site were found to: range from 0.13- 0.58 g/100 g-1 at the least oiled and most oiled stations respectively, values which Ekweozor, et al., (1989) pointed out, far exceeded background levels found in other areas.

CONCLUSIONS

The study revealed that the persistent environmental pollution (specifically, oil spillages) that were caused by the makeshift oil refining activities have adversely affected the macro zoobenthos of the area, with overall negative effects on the sustainability in the Nun river estuary and the Niger Delta environment as a whole. Therefore, it is reasonable to conclude that the makeshift oil refineries and related activities that were condoned in Akassa kingdom, around the River Nun estuary, are detrimental to the environment.

RECOMMENDATIONS

The results of this study have shown the imminent problems that arise from the pollution of the water and sediments of the Nun River estuary. Based on the findings of this research, it is, therefore, recommended that:

1. Makeshift oil refineries should be discouraged or, if they will be allowed to operate, proper measures should be put in place to prevent environmental pollution.
2. Oil pollution in the estuary and other water bodies receiving effluents should be constantly

monitored and properly controlled in order to forestall cumulative effects of pollution in the river.

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