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# Variation in Abundance and Diversity of Macrobenthic fauna of Ekerekana and Okochiri Creeks in the upper Bonny Estuary, Nigeria

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**Abstract**

The Ekerekana and Okochiri Creeks in the upper Bonny Estuary is prone to effluent discharges from industries located in the area. This study aimed to assess the macrobenthos of the creeks and the adjoining river with respect to diversity and abundance. Twenty three stations grouped into six zones were sampled in September 2014 (wet season) and February 2015 (dry season) to reflect spatial and seasonal fluctuations. Fourty six samples were collected during the dry and wet season periods. Samples were collected using an Ekman grab, washed through 0.5mm mesh sieve and preserved in 5% formalin before sorting and identification in the laboratory, using appropriate keys. A total of 250 organisms were recorded across the zones examined. Zone B had the highest percentage abundance (42%) while zone A had 25 % and zone C, 18 %. Others were zone E (11 %) and zone F (4 %). Zone D was almost defaunate (<1%) with regards to macrobenthic fauna and showed least diversity indices and highest dominance indicating a deteriorated condition. Polychaetes and crustaceans were the two groups recorded with such worms as *Nereis* sp, *Nephtys* sp, *Capitella capitata, Notomastus tenius and Cossura* sp. showing higher abundance but the dominant polychaete family was the Nereidae. There were significant difference ($p<0.001$) in the density of some genera (*Captella capitata*, *Scoloplos* sp, *Cossura* sp and *Uca tangeri*) between zones. The significant difference in the abundance of *Capitella capitata,* an acclaimed pollution indicator between zone A and other zones suggest pollution prone aquatic system traceable to anthropogenic activities in the study area. Cluster analysis after fourth root transformation of benthic abundance data also showed differences in similarity between zones. The differences between zones could be due to spatial scale of impact regarding anthropogenic activities in the study area. In conclusion, the abundance and diversity of the macrobenthic fauna of the Ekerekana/Okochiri Creeks and the adjoining creeks was generally poor. The poor benthic community structure of the study area suggests a declining aquatic system with more implications for environmental monitoring programmes.

Keywords: Abundance, Diversity, MacroBenthos, Ekerekana and Okochiri Creeks

## Introduction

The ultimate sink for virtually every class of environmental pollutant is the seabed (Salomons *et al.*, 1987) and it habours macrobenthic epifauna and infauna. The vast majority of these benthos are sedentary or very slow moving and therefore, susceptible to a variety of pollutant and disturbances. The introduction of industrial and urban sewage to the marine environment causes changes to the structure of benthic communities. The analysis of these changes constitutes an important tool in interpreting and evaluating the effects of contaminants in a particular ecosystem both in space and time (Heip, 1992). Marine benthic communities are considered to exhibit the greatest potential for integrating conditions in a site (Bilyard, 1987). The subtidal zone is considered the most appropriate habitat for the development of benthic monitoring programmes (Pagola-cart *et al*., 2002). Attributes of benthic community structure, species composition, quantitative parameters, trophic groups and the sets of species (indicators) may therefore, reflect the quality of the marine environment (Belan, 2003). The ability of the benthic communities to reveal spatial and temporal changes make them the target for most environmental monitoring programmes developed either to detect signs of habitat change or to assess the effectiveness of restoration plans (Warwick, 1993; Jan *et al*., 1994). The sediment in which the benthic organisms live is continuously modified by the introduction of new chemicals. The habitats and sediment communities are now being characterized by quantitative and qualitative parameters (Belan, 2003). Contaminated sediments are a major source of pollution in estuaries because it acts as a sink for an array of organic and inorganic contaminants. The Bonny Estuary is one of the richest estuaries in the Niger Delta aquatic ecosystem, with a network of creeks/tributaries linking various habitats of highly economic and ecological importance. The estuary is open with abundant composition of flora and fauna of unique biodiversity (Wilcox, 1980). These ecosystems are often the site where many pollution problems exist (Saiz-Salinas and Gonzlez-Oreja, 2000, Ekweozor *et al.,* 2004) and where pollution loading caused significant changes in abundance and species composition. A number of studies have been carried out on the benthic communities of the upper Bonny estuary (Ekweozor, 1996; Umesi and Daka, 2004; Ikomah *et al*., 2005; Moslen *et al.,* 2006; Daka *et al*., 2007; Daka and Moslen, 2013; Miebaka and Daka, 2013; Moslen and Daka, 2014; Moslen *et al*., 2015,). The Ekerekana and Okochiri Creeks receive industrial effluents and domestic wastes from nearby industries and squatter settlements which are capable of altering the benthic community structure. This study aimed to assess the abundance and diversity of macrobenthic fauna of the creeks and the adjoining river.

## Materials and Methods

### *Study Site*

The Ekerekana and Okochiri Creeks and the adjoining river are located on the northern flank of the Bonny River Estuary. The creeks are tidal in nature and receive domestic wastes and industrial effluents from nearby settlements and industries. The two creeks are linked by a narrow channel and have fringing mangrove as the main vegetation. Human activities along the creek include sand mining/dredging, fishing, navigation by speed boat/vessels, transportation of people and petroleum products and recreational activities. These activities can influence the natural balance of the aquatic ecosystem and consequently its biota, particularly benthic community structure. For purposes of this study, samples were collected from twenty three points which were grouped into zones (Fig. 1) for adequate coverage of the study area. ST 1, 2, 3 (zone A), ST 4, 5, 6, 7, 8, 9, 10, 11, 12 (zone B), ST. 13, 14, 15 (zone C), ST 16, 17 (zone D), ST 18, 19, 20 (zone E) and ST 21, 22, 23 (zone F). The key criteria considered in the sampling stations and zones were the presence of anthropogenic activities and interplay with hydrodynamic conditions of the study area. Stations in zones A were closest to the direct discharge point of effluent water from the Port Harcourt refinery on the Ekerekana creek while stations in zone B on the same creek were further away from the point source and had additional wastes input from domestic activities due to wastes dump sites and peer latrines located in the area. Hydrodynamically, stations in zone C connects between Ekerekana and Okochiri creeks with influence of dredging activities while the stations in zone D receive industrial effluents from a fertilizer company in the area. Stations in zone E had influence of domestic waste inputs and dredging activities while stations in zone F were located close to the petroleum refinery loading jetty on the adjoining creek.

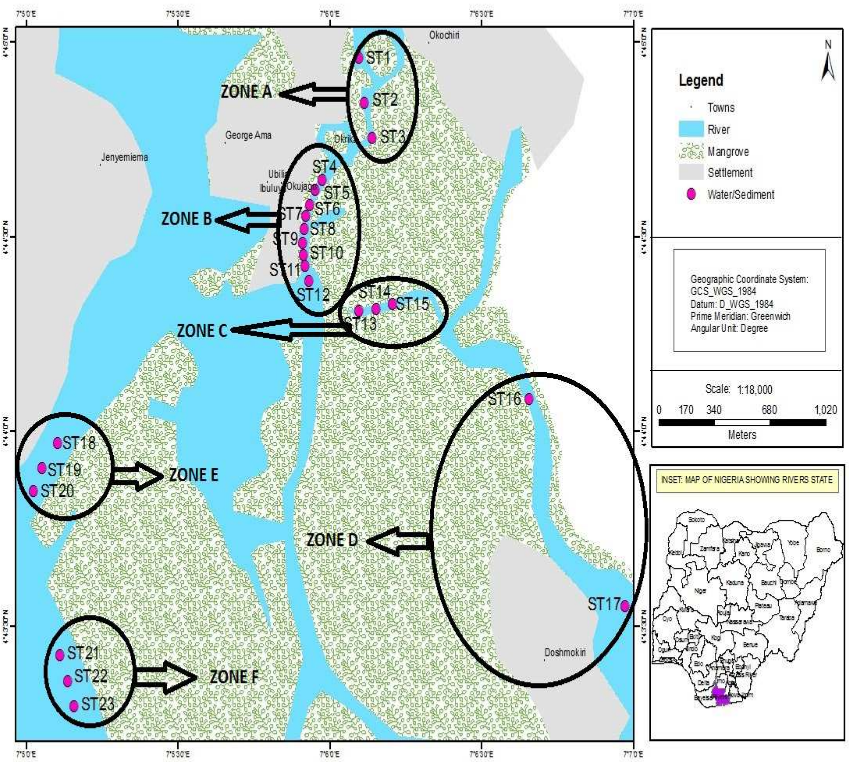


Fig. 1: Map showing study sites

### *Sample Collection and Analysis*

Sediment samples were collected with an Ekman grab (15 x 15 cm) and emptied into a 15 litre plastic bucket. The sediment samples were washed through a 0.5 mm sieve to obtain the macro-fauna. The material retained by the sieve was placed in a container and preserved with 5% formalin water mixture, stained in Rose Bengal to facilitate sorting in the laboratory. During sorting in the laboratory, aliquots of the sample were transferred on to a white surgical tray with water. The detrital sediment samples were then sorted using a pair of forceps and a hand lens. The macro-infauna found were collected and preserved in small bottles containing 70% ethanol. The contents were later identified to the lowest possible taxonomic level under the microscope. Only the heads of organisms were counted, since the individuals were sometimes fragmented.

## Data analysis

The software package Plymouth Routine in Multivariate Ecological Research (PRIMER 6) was used to analyze biological properties which includes the following; Abundance (N), number of Species (S), Shannon-Wiener diversity index (H'), Pielou evenness index (J), Margalef richness index (d) and Simpson domination index (λ): H' = - Σpi x (log2 pi); J = H'/log2 Si; d = (S - I) /log2 N; λ = Σ (pi)2. Both multivariate and univariate statistical analyses were applied to the data obtained. Multivariate technique was by classification using cluster analysis. Clustering was by hierarchical method using group average linkage of Bray-Curtis similarities, after 4th root transformation. Analysis of variance using the General Linear Model was applied to test for differences between zones and also between seasons. Tukey test was used for pair-wise comparison among levels of time and zones. The computer package MINITAB R.16 was used for the ANOVA.

## Results

A total of 250 organisms were recorded during the study. The density of macrobenthic fauna (Table 1) varied across the zones examined. During the wet season *Nereis* sp had the highest density (20 ± 8.40 Ind/$m^2$) at zone B while *Nephtys* sp followed closely with a density of 17 ± 8.11 Ind/$m^2$ at the same zone. There was no significant difference ($p>0.05$) between locations and also between periods in terms of the abundance of *Nereis* sp and *Nephtys* sp. During the dry season *Capitella capitata* had the highest density (19 ± 11.81 Ind/$m^2$) at zone A and showed significant difference ($p<0.01$) between zones while *Nereis* sp followed closely with a density of 17 ± 7.88 Ind/$m^2$ which was not significantly different ($p>0.05$) between zones and periods. Other worms found in this study had lower abundance but some had densities that were significantly different between zones including *Cossura* sp ($p<0.001$), *Scoloplos* sp ($p<0.001$) and *Orbinia* sp ($p<0.05$). Seasonally significant difference ($p<0.05$) was also observed in the abundance of *Orbinia* sp. Crustaceans found in this study made up less than 1% of the macrobenthic fauna and included *Uca tangeri* and *Palaemonetis* sp. The density of *Uca tangeri* was significantly different ($p<0.001$) between zones while those of *Palaemonetis* sp did not show significant difference ($p>0.05$) both in space and time. Macrobenthic community indices show that species richness, evenness and diversity were lowest at zone D while species dominance was highest at the same zone due to the defaunate nature of the zone. Macrobenthic species were however, richer and most diverse at zone B but most evenly distributed at zone F (Fig. 2). Cluster analysis indicated that zone D was most dissimilar with other zones (10% similarity) while zones B and C were most similar with about 70% similarity in terms of benthic abundance (Fig. 3).

Table 1: Density of Macrobenthos (Mean ± Standard Error - SE) and ANOVA output.

| Taxa (Ind./m2) | PERIOD | ZONE A | ZONE B | ZONE C | ZONE D | ZONE E | ZONE F | Location (F-values | Time (F-values) |
|---|---|---|---|---|---|---|---|---|---|
| **Polychaeta** | | | | | | | | | |
| | WET | 5 ± 1.16 | 20 ± 8.40 | 7 ± 3.52 | 1 ± 0.50 | 1 ± 0.33 | 0 ± 0.33 | 2.20$^{ns}$ | 0.00$^{ns}$ |
| *Nereis* sp. | DRY | 10 ± 2.61 | 17 ± 7.88 | 7 ± 2.41 | 0 ± 0.00 | 0 ± 0.33 | 1 ± 0.58 | | |
| | WET | 1 ± 0.58 | 17 ± 8.11 | 13 ± 6.37 | 0 ± 0.00 | 2 ± 0.33 | 0 ± 0.00 | 1.70$^{ns}$ | 1.72$^{ns}$ |
| *Nephtys* sp. | DRY | 4 ± 0.67 | 8 ± 2.98 | 1 ± 1.00 | 0 ± 0.00 | 1 ± 0.33 | 0 ± 0.33 | | |
| | WET | 9 ± 6.12 | 2 ± 0.52 | 4 ± 1.53 | 0 ± 0.00 | 0 ± 0.33 | 0 ± 0.00 | 4.70** | 0.75$^{ns}$ |
| *Capitella capitata* | DRY | 19 ± 11.81 | 3 ± 1.42 | 1 ± 1.33 | 0 ± 0.00 | 1 ± 0.67 | 0 ± 0.00 | | |
| | WET | 2 ± 1.53 | 1 ± 0.24 | 4 ± 2.08 | 0 ± 0.00 | 1 ± 0.33 | 1 ± 0.33 | 2.16$^{ns}$ | 0.37$^{ns}$ |
| *Notomastus tenius* | DRY | 5 ± 3.18 | 3 ± 0.71 | 1 ± 0.67 | 0 ± 0.00 | 0 ± 0.00 | 1 ± 0.33 | | |
| | WET | 0 ± 0.00 | 0 ± 0.12 | 0 ± 0.33 | 0 ± 0.00 | 0 ± 0.00 | 0 ± 0.00 | 0.58$^{ns}$ | 0.33$^{ns}$ |
| *Apistobranchus* sp. | DRY | 0 ± 0.00 | 0 ± 0.14 | 0 ± 0.00 | 0 ± 0.00 | 0 ± 0.00 | 0 ± 0.00 | | |
| | WET | 1 ± 0.67 | 1 ± 0.26 | 1 ± 0.67 | 0 ± 0.00 | 0 ± 0.00 | 0 ± 0.00 | 1.80$^{ns}$ | 0.90$^{ns}$ |
| *Notomastus hemipodus* | DRY | 1± 0.88 | 2 ± 0.79 | 0 ± 0.00 | 0 ± 0.00 | 0 ± 0.33 | 0 ± 0.00 | | |
| | WET | 0 ± 0.00 | 1 ± 0.88 | 1 ± 0.33 | 0 ± 0.00 | 0 ± 0.33 | 0 ± 0.00 | 0.94$^{ns}$ | 0.84$^{ns}$ |
| *Pision* sp. | DRY | 0 ± 0.00 | 1 ± 0.55 | 0 ± 0.00 | 0 ± 0.00 | 0 ± 0.33 | 0 ± 0.00 | | |
| | WET | 0 ± 0.00 | 0 ± 0.11 | 0 ± 0.00 | 0 ± 0.00 | 7 ± 2.08 | 0 ± 0.00 | 14.13*** | 3.09$^{ns}$ |
| *Cossura* sp. | DRY | 0 ± 0.00 | 2 ± 1.11 | 1 ± 0.00 | 0 ± 0.00 | 8 ± 1.73 | 0 ± 0.00 | | |
| | WET | 0 ± 0.00 | 0 ± 0.00 | 0 ± 0.00 | 0 ± 0.00 | 1 ± 0.67 | 0 ± 0.00 | 6.20*** | 1.31$^{ns}$ |
| *Scoloplos* sp. | DRY | 0 ± 0.00 | 0 ± 0.24 | 0 ± 0.33 | 0 ± 0.00 | 1 ± 0.67 | 0 ± 0.00 | | |
| | WET | 0 ± 0.00 | 0 ± 0.11 | 0 ± 0.00 | 0 ± 0.00 | 0 ± 0.00 | 0 ± 0.00 | 0.29$^{ns}$ | 0.92$^{ns}$ |
| *Sphaerodoropsis* sp. | DRY | 0 ± 0.00 | 0 ± 0.00 | 0 ± 0.00 | 0 ± 0.00 | 0 ± 0.00 | 0 ± 0.00 | | |
| | WET | 0 ± 0.00 | 1 ± 0.56 | 0 ± 0.00 | 0 ± 0.00 | 0 ± 0.33 | 1 ± 0.67 | 1.95$^{ns}$ | 1.12$^{ns}$ |
| *Eunice* sp. | DRY | 0 ± 0.00 | 2 ± 0.64 | 0 ± 0.00 | 0 ± 0.00 | 1 ± 0.58 | 0 ± 0.33 | | |
| | WET | 0 ± 0.00 | 0 ± 0.22 | 0 ± 0.33 | 0 ± 0.00 | 0 ± 0.33 | 2 ± 0.88 | 1.65$^{ns}$ | 1.65$^{ns}$ |
| *Glycera convolute* | DRY | 0 ± 0.33 | 1± 0.39 | 0 ± 0.00 | 0 ± 0.00 | 1 ± 1.00 | 1 ± 0.58 | | |
| | WET | 0 ± 0.00 | 3 ± 1.58 | 0 ± 0.00 | 0 ± 0.00 | 0 ± 0.00 | 0 ± 0.00 | 1.61$^{ns}$ | 0.13$^{ns}$ |
| *Perinereis* sp. | DRY | 0 ± 0.00 | 2 ± 1.23 | 2 ± 1.67 | 0 ± 0.00 | 0 ± 0.00 | 0 ± 0.00 | | |
| | WET | 0 ± 0.33 | 3 ± 1.40 | 0 ± 0.00 | 0 ± 0.00 | 0 ± 0.00 | 0 ± 0.00 | 1.48$^{ns}$ | 0.58$^{ns}$ |
| *Hediste* sp. | DRY | 0 ± 0.00 | 1 ± 0.48 | 1 ± 1.00 | 0 ± 0.00 | 1 ± 0.33 | 0 ± 0.00 | | |
| *Orbinia* sp. | WET | 0 ± 0.00 | 0 ± 0.00 | 0 ± 0.00 | 0 ± 0.00 | 1 ± 0.33 | 0 ± 0.00 | 2.47* | 4.05* |
| | DRY | 0 ± 0.00 | 1 ± 0.43 | 0 ± 0.00 | 0 ± 0.00 | 2 ± 0.88 | 0 ± 0.00 | | |
| | WET | 0 ± 0.00 | 0 ± 0.11 | 0 ± 0.00 | 0 ± 0.00 | 0 ± 0.00 | 0 ± 0.00 | 0.29$^{ns}$ | 0.92$^{ns}$ |
| *Eumida* sp. | DRY | 0 ± 0.00 | 0 ± 0.00 | 0 ± 00 | 0 ± 0.00 | 0 ± 0.00 | 0 ± 0.00 | | |
| *Aricidea* sp. | DRY | 0 ± 0.00 | 1 ± 0.32 | 0 ± 00 | 0 ± 0.00 | 0 ± 0.33 | 0 ± 0.00 | nr | nr |
| *Ophiodromus* sp. | DRY | 0 ± 0.00 | 0 ± 0.11 | 0 ± 0.00 | 0 ± 0.00 | 0 ± 0.00 | 0 ± 0.00 | nr | nr |
| *Notomastus latricious* | DRY | 0 ± 0.33 | 1 | 0 ± 0.00 | 0 ± 0.00 | 0 | 0 ± 0.33 | nr | nr |
| **Crustacea** | | | | | | | | | |
| | WET | 0 ± 0.00 | 0 ± 0.00 | 0 ± 0.00 | 0 ± 0.00 | 0 ± 0.00 | 0 ± 0.33 | 6.88*** | 0.57$^{ns}$ |
| *Uca tangeri* | DRY | 0 ± 0.00 | 0 ± 0.00 | 0 ± 0.00 | 0 ± 0.00 | 0 ± 0.00 | 1 ± 0.33 | | |
| | WET | 0 ± 0.00 | 0 ± 0.00 | 0 ± 0.00 | 0 ± 0.00 | 0 ± 0.00 | 1 ± 0.33 | 1.97$^{ns}$ | 0.60$^{ns}$ |
| *Palaemonetis* sp. | DRY | 0 ± 0.00 | 0 ± 0.11 | 1 ± 0.67 | 0 ± 0.00 | 0 ± 0.00 | 0 ± 0.33 | | |

Key: * = significant (p<0.05); ** = significant (p<0.01); *** = significant (p<0.001); ns = not significant; nr = no result

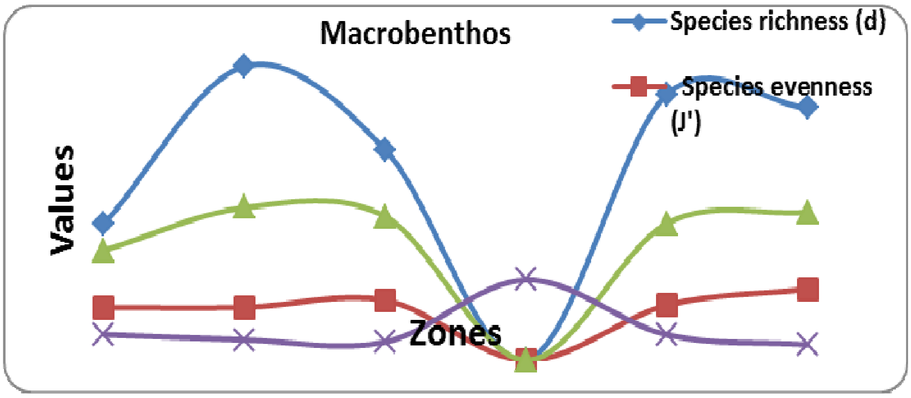


Fig. 2: Univariate diversity indices for macrobenthos across zones

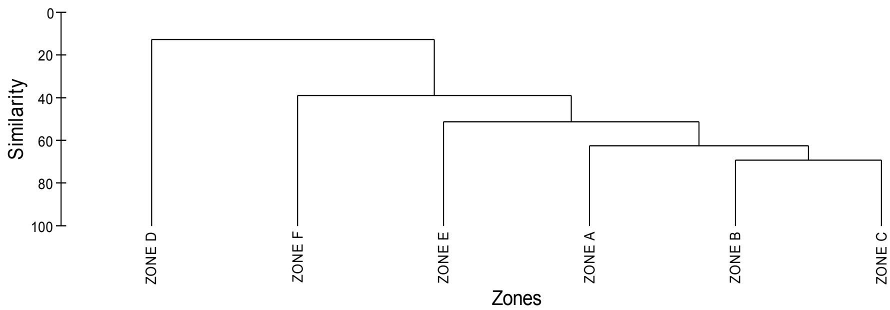


Fig. 3: Cluster Analysis of Macrobenthic fauna based on zones

## Discussion

A total of 250 individuals were recorded in this study. This number is 120 individuals less than that recorded by Onwuteaka (2015) in a study of polychaete diversity and association in the Bonny Estuary. The low total benthic fauna observed in this study also corroborates the findings of Anaero-Nweke (2013) who reported that benthic organism distribution and abundance amongst the sampling stations in Ekerekana area were very poor with a total of six species from the family Nereidae. The result of this study adds to the knowledge of macrobenthos of the creeks by indicating poor abundance status compared to Ebere (2002) who recorded 436 – 4878 Ind/$m^2$ in a benthic study of the area but indicated marginal improvement in the abundance and diversity of benthic fauna compared to Anaero-Nweke (2013) who recorded only six species of the Nereidae in the study area. Several other studies have also reported negative effect of effluent discharge on the abundance and diversity of benthic communities in the Niger Delta (Ekweozor, 1996; Umesi and Daka, 2004; Ikomah *et al*., 2005; Wake, 2005; Dean, 2008; Moslen and Daka, 2014). Zone B had the highest percentage abundance (42%) of individuals while zone A had 25 % and zone C 18 %. Others were zone E (11 %), zone F (4 %) and zone D had < 1% of the total fauna. The observed spatial or zonal differences may be attributable to the different anthropogenic activities (industrial effluents discharge, domestic waste dumps, dredging and loading of petroleum products) and environmental differences particular to each zone along the creek while temporal influence on the abundance and diversity of the organisms was found to be generally insignificant. Impairment of water quality due to such anthropogenic activities and also substrate composition could account for the differences observed. Polychaetes and crustaceans were the two groups recorded with such worms as *Nereis* sp., *Nephtys* sp., *Capitella capitata, Notomastus tenius and Cossura* sp. showing higher abundance but the dominant polychaete family was the Nereidae. This agrees with the finding of George *et al*. (2009) who also recorded higher abundance of the polychaetes than other phyla in a benthic study of the Okpoka River in the Bonny Estuary. The reduced abundance of the crustaceans may also be related to the anthropogenic activities in the study area as observed by Ajao and Fagade (1989) that the bivalves, *Aloidis trigona* (Hinds) and the gastropod, *Neritina glabrata* were virtually absent from the western industrialized parts of Lagos lagoon which received a complex mixture of domestic and industrial wastes. Univariate diversity indices differed across zones with evenness and diversity generally low, again suggesting that general habitat quality was low. This is related to the anthropogenic activities in the area particularly the release of industrial effluent into the Ekerekana and Okochiri creeks (Ikomah *et al*., 2005).The findings of this study agrees with that of Onwuteaka (2015) who record poor to moderate diversity of polychaets of the Bonny Estuary but at variance with George *et al.* (2010) who observed that benthic diversity along the Okpoka River was high compared to the low diversity obtained in this study. The implication is that the direct discharge of industrial effluent could affect the benthic community structure and diversity of Ekerekana and Okochiri Creeks relative to the farther away Okpoka River. Zone D had the least diversity indices and the highest dominance indicating a deteriorated condition. There was significant difference ($p<0.01$) in the abundance of *Capitella capitata* between zones. Other genera that showed significant difference ($p<0.001$) between zones were *Cossura* sp., *Scoloplos* sp. and *Uca tangeri*. The actual difference in the density of *Capitella capitata* occurred between zone A and other zones while that of *Uca tangeri* occurred between zone F and other zones. *Capitella capitata* survives in pollution ridden sites and zone A in this study is the closest to the industrial effluent discharge point. On the other hand, the actual difference in the density of the Cossuridae occurred between zone E (adjoining river) and other zones. Only the genus *Orbinia* sp exhibited significant difference ($p<0.05$) both in space and time but did not show between which zones actual difference occurred. Cluster analysis showed that zones B and C were most similar in benthic abundance while zones D and F stood out clearly as the most dissimilar zones. Zone F was close to the refinery loading jetty with spills of petroleum products while zone D was on the Okochiri Creek under the influence of industrial effluent discharge. Spatial scale of impact with regards to anthropogenic activities in the study area could affect benthic community structure as seen in the varying degrees of similarity observed in the cluster analysis. Onwuteaka (2015) however, noted that the 'specialist-generalist' observed in the association analysis of his study may not always reflect impacts.

## Conclusions

The abundance and diversity of macrobenthos in Ekerekana, Okochiri Creeks and the adjoining river area were generally poor. This is evident by the poor abundance, composition and diversity of benthic fauna of the study area. Zone D on the Okochiri Creek was almost defaunate compared to other zones in the study area. The presence of *Capittella capitata,* a world acclaimed pollution indicator also suggest contamination prone aquatic system. The generally low diversity and species evenness is also an indication of a poor habitat with deteriorating water and sediment quality. The implication of the findings of this study is that direct discharge of domestic wastes into creeks should be discouraged while industrial wastes should be properly treated before released into the aquatic environment. Contrary to this, may cause severe alterations leading to an ecological imbalance that affects biotic compositions of the aquatic ecosystem.

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## References

Ajao, E. A. and Fagade, S. O. (1989). A study of sediment and communities in Lagos lagoon, Nigeria. Oil and Chem. Pollut., (7):85 – 117.

Anaero-Nweke,G. N. (2013).Impact of oil refinery effluent on the water quality: case study of Ekerikana creek in Nigeria. A Thesis Submitted to the Department of Environmental Science of the Kwame Nkrumah University of Science and Technology, Ghana.

Belan, T.A 2003. Benthos Abundance Pattern and Species Composition in Conditions of Pollution in Amursky Bay (the Peter the Great Bay, the Sea of Japan). *Mar.Pollut. Bull*., 46, (9), 1111-9.
Belan T.A. 2003. Marine Environmental Quality Assessment using Polychaete Taxocene Characteristics in Vancouver Harbour. *Mar. Environ .Res.*, 57, 89-101.

Bilyard, G.R. 1987. The value of benthic Infauna in marine pollution monitoring studies. *Mar. Pollut. Bull*., 18, 581 - 585.

Daka, E.R., M. Moslen, C.A. Ekeh and I.K.E. Ekweozor, 2007. Sediment quality status of two creeks in the upper Bonny estuary, Niger Delta, in relation to urban/ industrial activities. *Bull. Environ. Contam. Toxicol*., 78, 151-521.

Daka, E.R. and Moslen, M. (2013). Spatial and temporal variation of physicochemical parameters of sediment from Azuabie creek of the upper Bonny estuary, Niger Delta. *Research Journal of Environmental and Earth Sciences*, 5(4), 291-228

Dean, H.K. (2008). The use of polychaetes (Annelida) as indicator species of marine pollution. *Rev. Biol. Trop. (Int. J. Trop. Biol.*, 56(4), 11-38.

Ebere, N. The impact of oil refinery effluent on the distribution, abundance and community structure of macrobentghos in Okrika Creek. P.hD. Thesis, RSUST, Port Harcourt. Pp.47 – 180.

Ekweozor, I.K.E. (1996). The Impact of Chronic discharges of petroleum hydrocarbons on the littoral macrofauna of Elechi Creek, Nigeria. *Niger Delta Biologia*, 1 (1),55-66.

Ekweozor, I. K. E, Daka, E. R, Ebere, Bob-Manuel, K. N. O., (2004). An estuary under stress: The case study of 18 years chronic hydrocarbon pollution of Bonny Estuary, Nigeria.. *Journal of Nigerian Environmental Society,* 2(1),12-15.

George, A.D.I., Abowei J.F.N., and Alfred-Ockiya J.F. (2010).The Distribution, Abundance and Seasonality of Benthic Macro Invertebrate in Okpoka Creek Sediments, Niger Delta, Nigeria. *Research Journal of Applied Sciences Engineering and Technology*, 2(1), 11-18

Heip, C. 1992. Benthic Studies: Summary and Conclusions. *Mar. Ecol. Prog .Ser*., 19, 265- 269.

Ikoma, F. B. , Ekweozor, I. K. E., Daka, E. R. and Dambo, W. B. (2005).The impact of fertilizer plant effluents on the littoral benthos of an estuarine creek in the Niger Delta, Nigeria. *African journal of Environmental Pollution and Health*, 4(2), 62 – 71.

Jan, R. Q.; Dai, C. F. and Chang, K.H. 1994. Monitoring of hard substrate communities. In: kramer, K. J. M. (Ed.) *Biomonitoring of Coastal Waters and Eestuaries*. CRC Press, Bocar Raton pp. 310 - 385.

Miebaka, C. A. and Daka, E. R. (2013). Dynamics of Zooplankton of Azuabie Creek in the Upper Bonny Estuary of the Niger Delta. *International Journal of Fisheries and Aquatic Sciences*, 2(2), 29-37.

Moslen, M., Daka, E.R., Ekeh, C.A. and Ekweozor, I.K.E. (2006). Physicochemical properties of two estuarine creeks in the Niger Delta in relation to urban/industrial activities. *Niger Delta Biologia*, 5(2), 115-122.

Moslen, M. and Daka E.R. (2014). Attributes of the subtidal macrobenthos of Azuabie Creek in the upper Bonny Estuary, Niger Delta, Nigeria. *Res. J. Environ. Earth Sci.,* 6, 143-155.

Moslen, M., Miebaka, C. A. and Daka, E. R. (2015). The Menace of solid wastes in some creeks around Port Harcourt: The way forward. *Journal of Nigerian Environmental Society,* 9(1), 86-91

Moslen, M. and Daka E. R. (2016). Spatio-Temporal Differences of Physicochemical Variables in Relation to Industrial Effluent Discharges into Ekerekana and Okochiri creeks, Bonny Estuary of the Niger Delta, Nigeria. *Journal of Nigerian Environmental Society,* 10(1)

Onwuteaka, J. (2015). The Temporal Abundance and Distribution of Polychaete Fauna along the Shoreline of Bonny River in Nigeria. *Journal of Environmental Science, Toxicology and Food Technology* . 9, (2 Ver. I), 39-45.

Pagola, Carte, S.; Urkiaga-Alberdi, J.; Bustamante, M.; and Saiz-Salinas, J.I (2002). Concordance degrees in macrocrozoobenthic monitoring porgrammes using different sampling methods and taxonomic resolution levels. *Mar. pollut. Bull*., 44, 63-70.

Saiz-Salinas, J. I. and Gonzalez-Oreja, J. A. (2000). Stress in estuarine communities: lessons from the highly-impacted Bilbao Estuary (Spain). *J. Aqua. Ecos. Stress and Recovery*., 7, 43 – 55.

Salomons, W and De-Groot, A.J. (1987). Pollution history of trace metals in sediments as it affects Rhine River. In: *Environmental Biogeo-Chemistry and Geomicrobiology*. Krumbein, W.E. (ed). Ann Arbor. Sci. Publ. 1, pp 140-164.

Umesi, N. and Daka E. R. (2004).Effects of abattoir run-off on benthic populations in atidal creek in the upper Bonny estuary. *Journal of Environmental Management and Education*, 1(2), 158-170.

Wake, H., (2005). Oil refineries: a review of their ecological impacts on the aquatic environment. *Estuar. Coast Shelf Sci.*, 62, 13-140.

Warwick, R.M. 1993. Envirommental impact studies on marine communities: pragmatic consideration. *Aust. J. Ecol*., 18, 63 - 80.