The Effects of Marginal Mangrove Reclamation and Bridge Construction on Subtidal Benthic Fauna of Okpoka Creek, Upper Bonny Estuary, Niger Delta

[1]Anyanwu, H. C., [1,2*]Daka, E. R. & [1]Moslen, M.
[1]Department of Animal and Environmental Biology
Rivers State University, Nkpolu-Oroworukwo,
Port Harcourt, Nigeria
[2]Institute of Pollution Studies
Rivers State University, Nkpolu-Oroworukwo,
Port Harcourt, Nigeria
*daka.erema@ust.edu.ng

Abstract
The mangrove around Okrika including the area bordering the Okpoka Creek a tributary of the Bonny Estuary has been reclaimed while the opposite area remains vegetated. We present here the impact of the reclamation and bridge construction on the macroinvetebrate communities of the Okpoka Creek. Three sample sites were located on either side of the Okpoka creek, one close to the piers of a bridge under construction, one upstream and another downstream of the bridge location. Sediment samples were collected with an Ekman grab in five replicates, and processed for benthic organisms. Composite samples were also collected for sediment particle size analysis. Faunal data were square root transformed before ANOVA. Cluster Analysis was used to aggregate the locations. The sediment on the landward side had significantly higher sand while the vegetated side had significantly higher silt/clay particles. Overall, there were significantly higher mean number of species ($p=0.04$) and total abundance ($p<0.001$) at the vegetated side of the creek. The mean values of Nereis ($p<0.001$), Nephthys ($p<0.001$), and Polydora ($p=0.036$) were also significantly higher at the vegetated side, while no significant difference between sides was observed for Capitella ($p=0.328$) and Glycera ($p=0.071$). The output of the Cluster analysis generally showed the locations on the landward side clustered together but with slight monthly modifications whereby the bridge location on the vegetated side tended to cluster with the landward locations. This suggests that reclamation had a significant impact on the subtidal benthos in Okpoka Creek, but bridge construction might be having similar impacts.

Keywords: *Mangrove Reclamation; Bridge; Okpoka Creek; Benthos; Sediment*

Introduction

Land reclamation is the process of creating new land from materials dredged from ocean, river, or lake beds. It is a process used for a number of things from creating new islands to reclaiming eroded land, and from repairing degraded land to restoring wildlife habitats. Dredging is an excavation activity or operation usually carried out at least partly underwater, in shallow seas or fresh water areas with the purpose of gathering up bottom sediments and disposing of them at a different location. It is mostly a coastal activity referring to the actual removal of sand from lakes, streams, and rivers. The process of dredging creates spoils (excess material such as sand, clay or rocks from streambed), which are deposited on the designated site for land reclamation or other purposes such as repairing degraded land to restoring wildlife habitats (Tamunobereton-ari *et al*., 2012). The material may also be used for flood or erosion control. Dredging can create disturbance in aquatic ecosystems, often

with adverse impacts.
River crossings by bridges play important roles in road construction. Bridges may alter the form and function of river geomorphology, floodplain ecosystem, habitat and movement of aquatic organisms (Singleton, 2001). Bridge construction is necessary for land transport system to cross water ways, but construction activities also have a potential to cause environmental impacts (Seiyaboh *et al*., 2013). The close association of benthic vertebrates to the sediments suggest the possibility of their use as indications of disturbances originated by the erosion effects under the bridges (Bletter and Marchese, 2005). The distribution and abundance of invertebrates are not only affected by water quality, but also by current velocity and sediments grain size (Minshall and Minshall, 1978). Bletter and Marchese (2005) carried out a study on the effects of bridge construction on the benthic invertebrate structure in the Parana River Delta discovered that sites with silt- clayed sediments, mainly upstream from the bridges, showed higher species richness, diversity and benthic biomass than the sites with sandy sediments, under and downstream from the bridges.

The mangrove around Okrika Island in Rivers State was sand-filled over three decades ago. This reclamation included the area bordering the Okpoka Creek a tributary of the Bonny Estuary at ATC while the opposite area remains vegetated. A bridge is recently being constructed across the creek. We present here the impact of the reclamation and bridge construction on the sediment characteristics and macroinvetebrate communities of the Okpoka Creek in the upper Bonny Estuary, Niger Delta, Nigeria.

Material and Methods

Study Sites

The mangrove around Okrika town in Rivers State was sand-filled a few decades ago; this included the area bordering the Okpoka Creek a tributary of the Bonny Estuary while the opposite area remains vegetated. Three sample sites were located on either side of the Okpoka creek, one close to the piers of a bridge under construction, one upstream and another downstream of the bridge (Fig. 1).

Sample Collection and Analysis

Sediment samples were collected monthly with an Ekman grab (15 cm by 15 cm) at each of the stations for a period of three months from January to March 2017 (covering the dry season period). Grab samples were also collected for physicochemical analysis of the sediment. These were transported to the laboratory in ice-cooled boxes. The sediment samples were air-dried and the Bouyoucos hydrometer method was used for the particle size analysis.

Five replicate benthos samples were collected with a grab, sieved through a 0.5mm mesh size net and the debris emptied into a plastic container. The samples were immediately preserved with 5% formaldehyde-water mixture and stained with eosin to aid sorting. In the laboratory, the organisms were sorted and preserved in 75% ethanol before identification to the lowest possible taxonomic level using appropriate Keys (Day 1967; Fauchald, 1977); individuals of each taxonomic group were counted and recorded.

Data Analysis

A number of statistics were used as measures of the attributes of community structure of the benthos samples. These include measures of species richness (Margalef, d) diversity (Shannon-Weiner H'), equitability (Pielou, J') and dominance (Simpson λ). The formulae for the calculation of the various indices are as follows (Pielou, 1975, Heip *et al*., 1988, Magurran, 1991):

Margalef index: $d = (S-1) / \log N$
Shannon-Weiner Index: $H' = - \Sigma_i \, p_i \log(p_i)$
Pielou Evenness: $J' = H'/H'_{max} = H' / \log S$
Simpson Index $\lambda = \Sigma pi^2$

Analysis of Variance (ANOVA) was used to test for significant differences in the sediment particle size, as well as total abundance and abundance of individual species (square root transformed) with shore and location as fixed effect factors. Cluster analyses were also performed based on Bray-Curtis Similarities after fourth root transformations of the abundance data. These analyses were computed using MINITAB and Plymouth Routines of Multivariate Experimental Research (PRIMER) software.

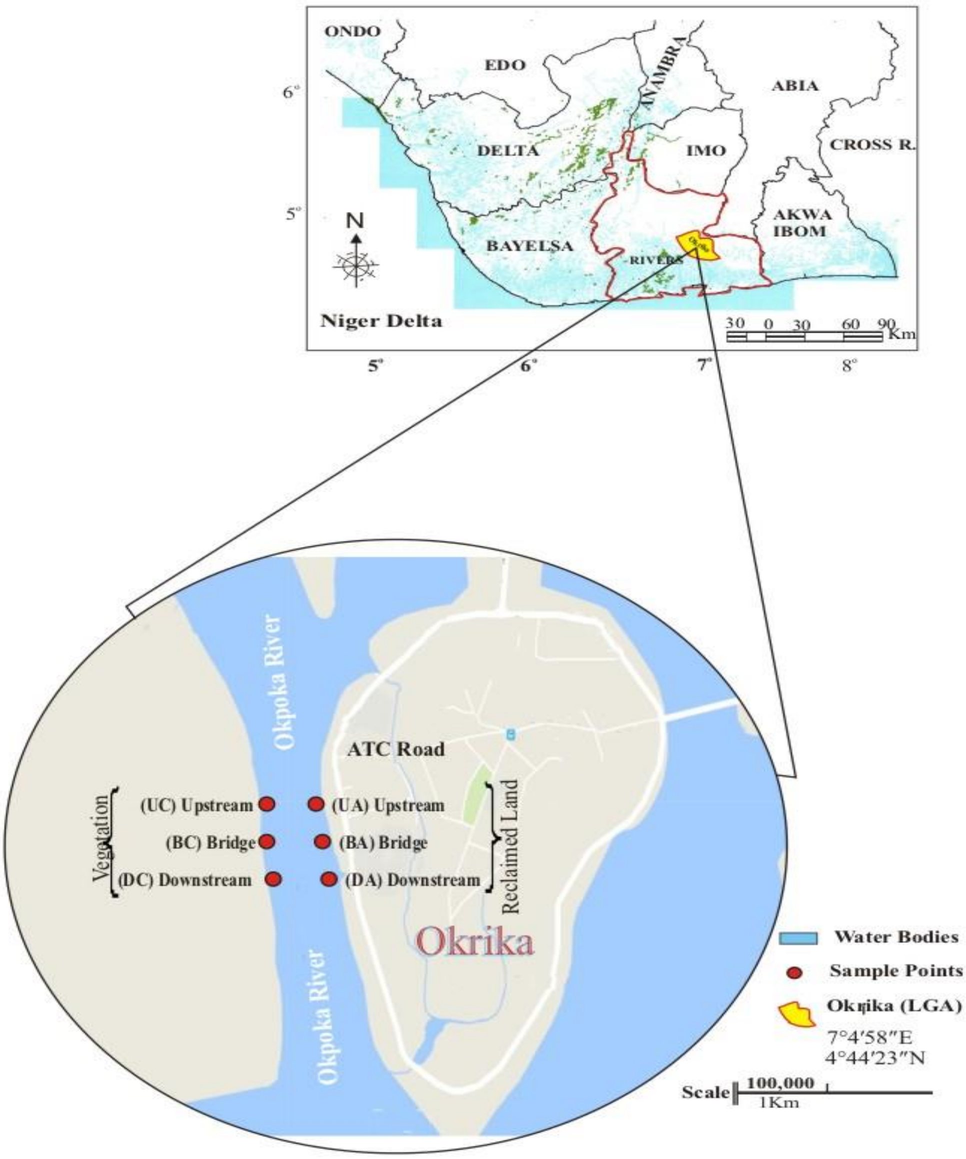


Fig 1: Map of the Niger Delta showing the Study Area

Results and Discussion

Table 1 is a presentation of the mean values of particle size distribution of sediment from Okpoka Creek. The particle size distributions of the sediment showed a significantly higher proportion of sand particles (p=0.022) at the landward shore with mean values of 62.5% to 87.9% compared to 53.6% to 61.6% at the vegetated shore. On the other hand, the percentage silt was significantly higher (p=0.05) at the vegetated shore (mean 12.2% to 18.6%) then the reclaimed shore (mean 3.4% to 15.6%). Similarly, clay particles were significantly higher (p=0.031) at the vegetated shore (mean 22.5% to 27.7%) compared to the reclaimed shore (mean 8.7% to 21.9%). With respect to location (bridge, upstream and downstream), no significant difference was obtained for any of the sediment particle fractions (% sand p=0.210; % silt p=0.118; % clay, p=0.145). Seiyaboh *et al*. (2013) reported from their study of bridge construction across the Nun River at Tombia, Bayelsa State of Nigeria, that the distribution of particle of size fractions shows a high proportion of sand particles at the bridge station; indicative of higher energy environment. This was not obvious in this study as the effect of reclamation on sediment particle tended to override that of the bridge.

A checklist of the benthic macrofauna identified during the study is presented in Table 2. Four phyla – Annelida (12 Polychaeta), Mollusca (1 Bivalve, 2 Gastropods and 1 Cephalopod), Arthropoda (subphylum Crustacea with 2 Amphipods and 1 Decapod) and (1 Holothuroid) were observed in the samples over the study period. Thus out of the twenty genera, polychaetes accounted for 60%. Similar faunal composition has been reported from previous studies in the upper Bonny Estuary by George *et al* (2009) in their study on the Okpoka creek. Moslen and Daka (2014) in Azuabie Creek, Hart and Zabbey (2005) from the Woji creek, and Onwumere (2016) from the Elechi creek. The mean number of species was higher on the vegetated area in comparison with the reclaimed area (Fig 2). Analysis of variance showed a significant difference in the number of species between shores (p=0.04) but there was no significant difference between locations (Table 3).

The total abundance of benthic invertebrates was 32 (± 6) individuals/0.05/m^2 in the reclaimed area and 116 (±20) individuals/0.05/m^2 in the vegetated area (Fig. 2); with ANOVA showing a significant difference between shores p<0.001, Table 3). There was a significant difference in the abundance values between locations (p=0.04), and Tukey tests indicated that upstream > downstream; upstream =bridge, and bridge=downstream. The abundance profiles of the most dominant fauna are presented in Fig. 3. The mean abundance of *Glycera* was similar in the vegetated and reclaimed areas and there was no significant difference between shores (p=0.071) or locations (p=0.304). However, the other species (*Polydora, Capitella, Nephtys and Nereis*) had higher densities at the vegetated area. *Polydora* had significantly different values between shores (0.036), but no significant difference between locations (p=0.248, Table 3). For *Capitella*, there was no significant difference in mean abundance between shores (p=0.328), but there were significant differences between locations (p<0.001), with Tukey tests (p<0.05) indicating downstream>upstream=bridge There were significant differences in the mean abundance of *Nephtys* between shores (p<0.001) and locations (p<0.001); Tukey tests showed bridge>downstream=upstream *Nereis* also had significantly different mean densities between shores (p<0.001) and locations (p=0.004), with mean separations between locations being downstream=bridge >upstream.

Table 1: Mean (± SD) of physicochemical variable of sediment from the Okpoka Creek

Parameter	Reclaimed (land)			Vegetated			ANOVA			
							Shore		Location	
	Bridge	Upstream	Downstream	Bridge	Upstream	Downstream	F (1,12)	p-Value	F (2,12)	p-Value
Sand (%)	72.8 ±15.7	87.9 ±1.9	62.5 ±20.1	60.2 ±7.1	61.6 ±15.7	53.6 ±5.7	6.94	0.022	2.55	0.120
Silt (%)	7.9 ±6.3	3.4 ±1.5	15.56 ±11.1	12.2 ±4.8	15.9 ±4.3	18.6 ±6.4	4.74	0.050	2.57	0.118
Clay (%)	19.4 ±9.8	8.7 ±1.2	21.9 ±10.2	27.5 ±2.4	22.5 ±13.4	27.7 ±2.0	5.94	0.031	2.28	0.145

Table 2: Checklist of benthic invertebrates recorded from the study area

Taxa	Family	Species	Reclaimed (Land)			Vegetated		
			Br	Ups	Dsr	Br	Ups	Dsr
ANNELIDA								
Polychaeta	Nereidae	*Nereis* spp	+	+	+	+	+	+
"	Nepthydae	*Nephtys* spp	+	+	+	+	+	+
"	Capitellidae	*Capitella* spp	+	+	+	+	+	+
"	Glyceridae	*Glycera* spp	+	+	+	+	+	+
"	Spionidae	*Polydora* spp	+	+	+	+	+	+
"	Eunicidae	*Lumbrinereis* spp	+	+	+	+	+	+
"	Cirratulidae	*Cirriformia* spp	+	+	+	+	-	+
"	Turbellaria	*Golfringia* spp	-	-	+	-	-	
"	Paraonidae	*Aricidea* spp	-	+	-	-	-	-
"	Orbinidae	*Orbinia* spp	-	+	+	+	+	-
"	Cosuridae	Cosura spp	-	-	+	+	+	+
"	Arenicolidae	*Arenicola* spp	-	-	+	-	-	-
MOLLUSCA								
Bivalvia	Lucinidae	*Loripes rhyzoecus*	-	+	+	+	+	+
Gastropoda	Potamididae	*Tympanotonus fuscatus*	-	+	-	-	-	-
"	Melaniidae	*Parchymeliana aurita*	-	+	-	-	-	-
Cephalopoda	Octopodidae	Unidentified	-	-	-	-	+	-
CRUSTACEA								
Amphipoda	Gammaridae	*Gammarus* spp	-	+	-	-	-	-
"	Alpheidae	*Alpheus* spp	-	+	-	-	-	-
Decapoda	Pennidae	*Penaeus* spp	+	+	+	+	+	+
ECHINODERMATA								
Holothuroidea		Unidentified	_	+	-	-	-	-

Br = Bridge; Ups = Upstream; Dsr = Downstream

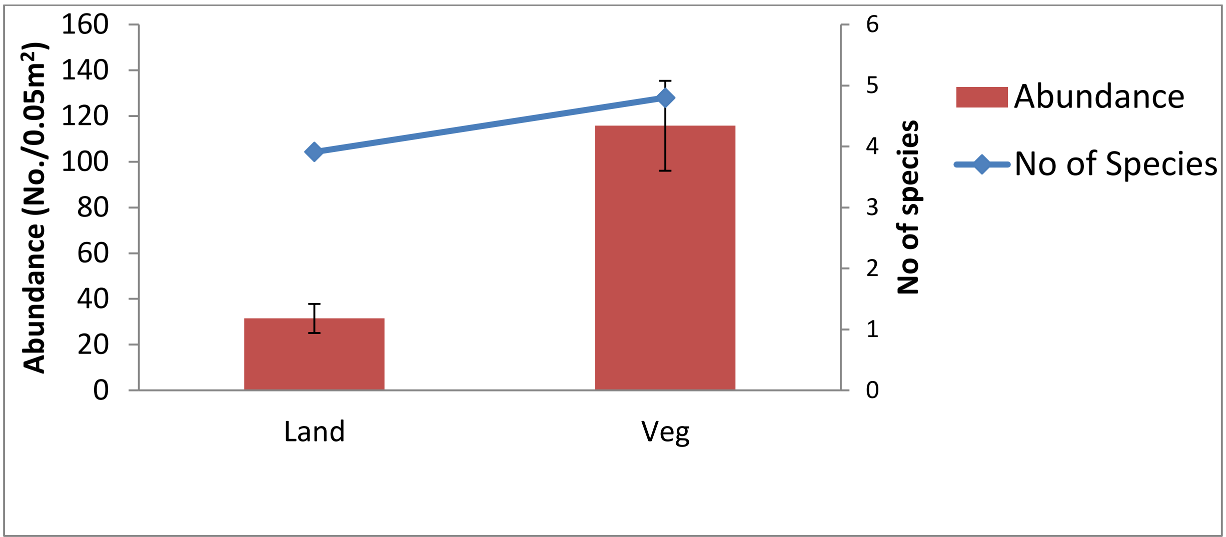


Fig 2: Mean (± SE) total abundance and number of species in the reclaimed (land) and vegetated sections of Okpoka Creek

Table 3: Summary of ANOVA of benthic organisms in the study area

Taxa	**Shore (df 1, 76)**			**Location (df 2, 76)**		
	MS	**F**	**p-Value**	**MS**	**F**	**p-Value**
No of Species	1.191	4.37	0.040	0.036	0.13	0.877
Total Abundance	420.7	33.91	<0.001	41.54	3.35	0.040
Polydora spp	4.452	4.54	0.036	1.393	1.42	0.248
Glycera spp	7.525	3.36	0.071	2.703	1.21	0.304
Capitalla spp	2.967	0.97	0.328	23.32	7.60	0.001
Nephtys spp	119.3	48.4	<0.001	39.54	16.03	<0.001
Nereis spp	235.3	32.0	<0.001	43.17	5.87	0.004

Sediment particle size, together with a complex of factors (e.g. salinity, depth, organic matter) that covary, would be the mechanism responsible for the control of the composition of benthic communities in relation to tropic groups and species distribution (Day *et al*, 1989; Snelgrove and Butman 1994). In this study, the significantly higher silt/clay fractions in the vegetated are led to significantly higher total abundance of infauana as well as the densities of *Polydora* spp, *Nephtys* spp and *Nereis* spp.

The Shannon-Weiner Diversity (H) and Simpsons Dominance indices were higher in the vegetated area, while Margalef species richness and Pielou evenness measure were higher on the reclaimed (land) area (Fig. 4). However, none of these indices had significant difference between shores or locations (Table 4). The result of the cluster analysis of the macrofauna based on Bray-Curtis similarity is presented in Fig. 5. Although no clear patterns could be deduced from the cluster in March, distinct groupings were found in January and February. Three Clusters (upstream, downstream and bridge) were found in January. However, in February two groups clustering along shore areas were observed with the reclaimed landward stations being clearly delineated from the vegetated stations. This implies that reclamation was a major forcing factor in the abundance and distribution of fauana in the Okpoka creek, but the piers of the bridge also had an influence in the faunal aggregations.

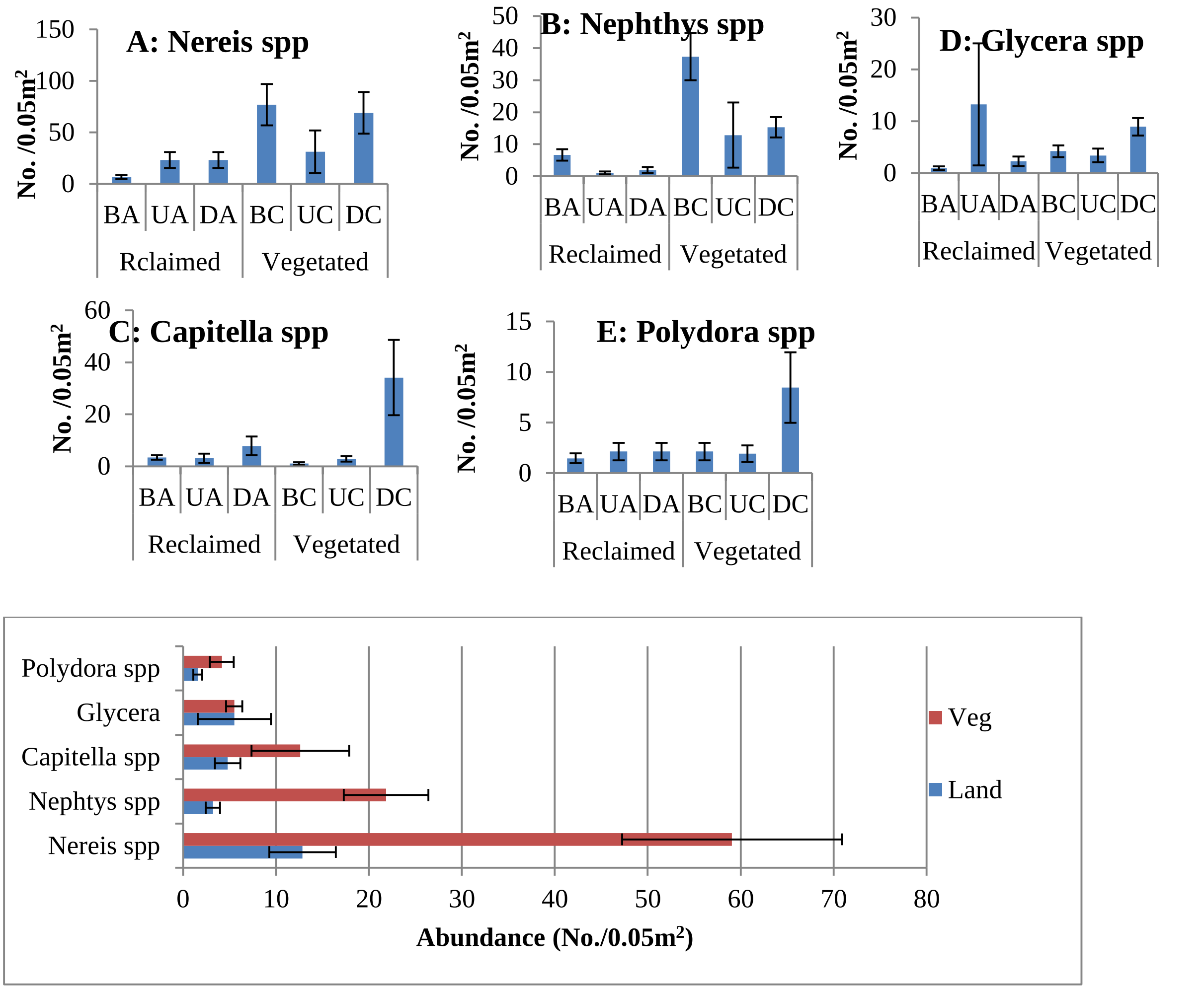


Fig. 3: Abundance (mean ± SE) of major benthic fauna in the reclaimed (land) and vegetated sections of Okpoka Creek (BA, BC = Bridge; UA, UC = Upstream; DA, DC = Downstream)

Table 4: Summary of ANOVA of benthic community indices

Index	Shore (df 1, 76)			Location (df 2, 76)		
	MS	**F**	**p-Value**	**MS**	**F**	**p-Value**
Margalef Richness (d)	0.0284	0.09	0.763	0.471	1.52	0.226
Shannon Weiner Diversity (H)	0.130	0.62	0.433	0.126	0.60	0.549
Pielou Evenness (J)	0.012	0.16	0.694	0.054	0.70	0.499
Simpson Dominance (λ)	0.006	0.15	0.703	0.062	1.51	0.228

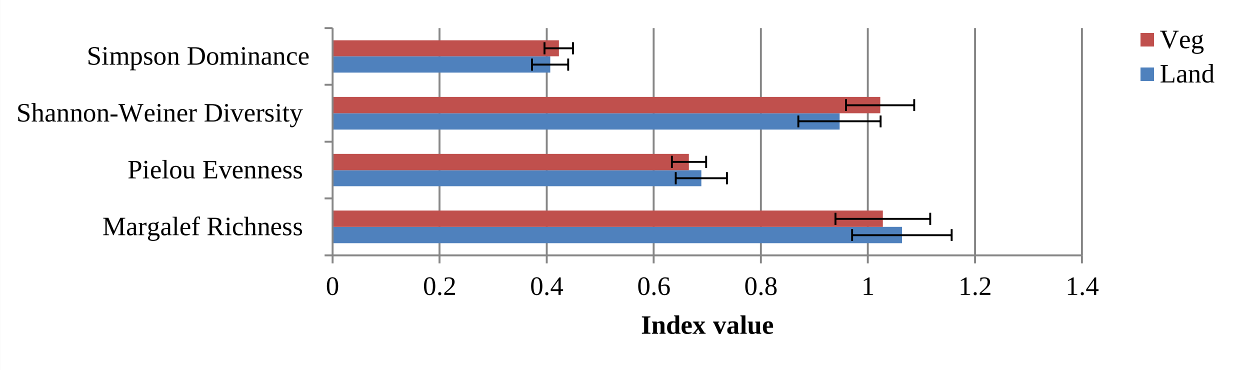
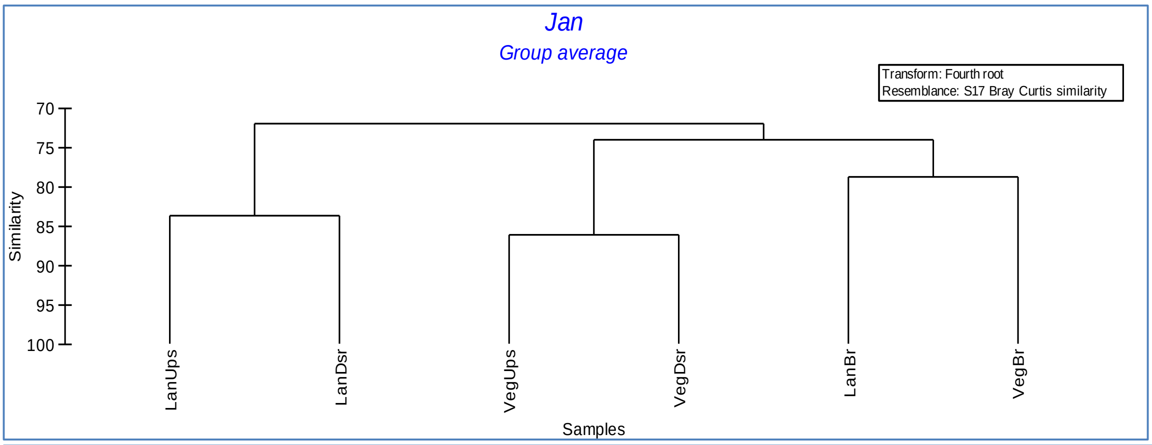
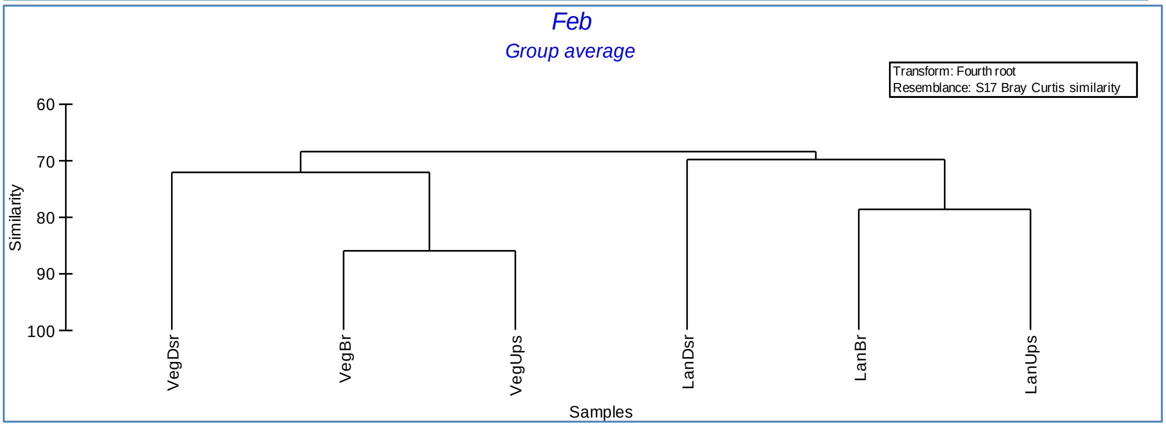


Fig 4: (mean ± SE) of faunal indices in the reclaimed (land) and vegetated sections of Okpoka Creek





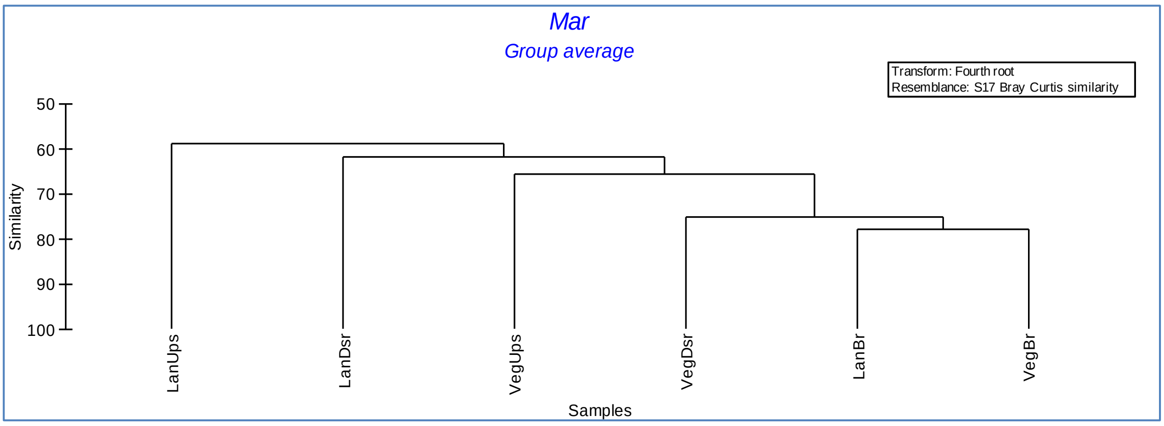


Fig. 5 Cluster of fauna based on Bray-Curtis Similarities of benthic fauna in the reclaimed (land) and vegetated sections of Okpoka Creek

Conclusion

Sediment particle size distribution has been significantly influenced more by the reclamation than the bridge construction. Similarly, the composition and abundance of benthic macrofauna was more significantly affected by reclamation than the bridge construction. Nevertheless, Cluster analysis outputs suggest that bridge construction also had an impact on the benthic fauna.

Acknowledgements:

We appreciate the assistance of Dr (Mrs) C. Miebaka (laboratory), Hanson Uyi (sampling and laboratory), and Nathan Nario (fieldwork).

References

Bletter, M. C.M. & Marchese, M. R. (2005)..Effects of Bridge Construction on the Benthic Invertebrates Structure in Parana River Delta. *Interciencia*, 30(2), 60-66.

Daka, E.R., & Moslen, M. (2013). Spatial and temporal variation of physico-chemical parameters of sediment from Azuabie Creek of the Upper Bonny Estuary, Niger Delta. *Research Journal of Environmental and Earth Sciences 5*(4), 219-228.

Day J.H. (1967). *Monograph of the polychates of Southern Africa. Part I Errantia*. The British Museum (Natural History), London, 420pp.

Day Jr. J.W; Hall, C.A.S; Kemp, W.M. & Yanez-Arancibia, A. 1989. *Estuarine Ecology*. John Wiley and Sons, New York. pp. 554 - 558.

Fauchald, K. (1977). *The polychaete worms. Definitions and keys to the genera*. Natural History Museum of Los Angeles country in conjunction with the Allan Hancock Foundation University of Southern California.

Griggs, G. (1975). An investigation of bottom sediments in a polluted marine environment in upper Saromkos Gulf, Greece. Report of the Environmental Pollution Control Project, Athens, Greece.

Hart, A. I. & Zabbey, N. (2005). Physico-chemical and benthic fauna of Woji Creek in the Lower Niger Delta, Nigeria. *Environmental Ecology*, 23(2): 361-368

Heip, C., Herman,, P.M.J. & Soetaert, K. (1998). Data processing, evaluation and analysis. In: Higgis, R.P. and Thiel, H. (eds), *Introduction to the study of meiofauna*. Smithsonian Institution, Washington DC, pp. 197-231.

Magurran, A.E. (1991). Ecological diversity and its measurement. Chapman and Hall, London.

Minshall, G.W. & Minshall, J.W. (1978). Further evidence on the role of chemical factors in determining the distribution of benthic invertebrate in the river, Duddon. *Archives of Hydrobiology*,. 83:324-355.

Moslen, M., Daka, E.R., Ekeh, C.A., & Ekweozor, I.K.E. (2005). Physicochemical properties of two estuarine creeks in the Niger Delta in relation to urban/industrial activities. *Niger Delta Biologia*, *5*(2), 104-111

Moslen, M. & Daka, E.R. (2014). Attributes of the Subtidal Macrobenthos of Azuabie Creek in the upper Bonny Estuary,Niger Delta, Nigeria. *Research Journal of Environmental and Earth Sciences* 6(3): 143-155.

Onwumere, D.C (2016). Spatial Variation of Physico-chemical Parameters and Intertidal Macrobenthos along Elechi Creek, Upper Bonny Estuary, Niger Delta. MSc Thesis, Rivers State University, Port Harcourt, Nigeria.

Pielou, E.C. (1975). *Ecological diversity*. Wiley, New York.

Seiyaboh, Inyang, I.R.. & Gijo, A.H. (2013). .Environmental impact of Tombia Bridge construction Across Nun-River in central Niger Delta, Nigeria. *The International Journal of Engineering and Science*, 2(11), 32-41.

Singleton G.H. (2001)**.** Marine Aggregate Dredging in the U.K: A Review. Journal of the Society for Underwater Technology 25**:** 3–14.

Snelgrove, V.R. & Butman, C.A. (1994) Animal Sediment Relationships Revisited – Cause Versus Effect. *Oceanography and Marine Biology*, 32, 111-177.

Tamunobereton-ari, I, Omubo-Pepple, V.B., & Briggs-Kamara, M.A. (2012). Dredging For Reclamation of Mangrove Swamp at Ogu, in Ogu/Bolo Local Government Area of Rivers State, Nigeria: The Impact on Biodiversity and the Environment. *Trends in Advanced Science and Engineering,* 3(2), 57-63.