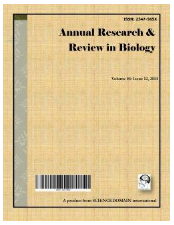

Annual Research & Review in Biology
7(3): 171-184, 2015, Article no.ARRB.2015.120
ISSN: 2347-565X

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Bioecology of Sediment-Polychaete in Estuarine Subtidal Habitat on Bonny River, Nigeria

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Author's contribution

The sole author designed, analyzed and interpreted and prepared the manuscript.

Article Information

DOI: 10.9734/ARRB/2015/18321
Editor(s):
(1) George Perry, Dean and Professor of Biology, University of Texas at San Antonio, USA.
Reviewers:
(1) Fatik Baran Mandal, Bankura Christian college, India.
(2) Anonymous, University of Tartu, Estonia.
Complete Peer review History: http://www.sciencedomain.org/review-history.php?iid=975&id=32&aid=9697

Original Research Article

Received 15th April 2015
Accepted 5th May 2015
Published 11th June 2015

ABSTRACT

Midchannel subtidal Polychaete Fauna were collected at the Bonny-estuary and analysed for their composition and abundance in relation to biotic and abiotic factors that are associated with life history strategies through a twelve-month cycle. The diversity index of Shannon-Weiner (0.637 to 2.252) showed that monthly diversity ranges from low to moderate, while the diversity index of Margalef (0.558 to 2.667) showed a moderate to high species diversity. Two Polychaete associations were identified -the generalists made up of 12 species with frequent occurrences and the specialists made up of 13 species with single month occurrences. The species turnover among the specialists with single month occurrences seems to be governed by environmental processes. In contrast, the generalists with the ability to recur throughout the sampling period seem to be less restricted by the prevailing environmental conditions. A positive correlation was observed between Polychaete abundance and silt/clay ($p>0.05$ $r = 0.5429$) and organic matter ($p>0.05$ $r = 0.8857$), which shows that both organic matter and silt/clay were important in promoting the abundance and diversity of the Polychaete fauna in the study area. The study provides evidence that variation in occurrence of the Polychaetes operates on a range of scales with differing responses to abiotic variables. This should be considered in environmental impact assessments and monitoring studies to fully account for observed distribution.

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Keywords: Estuarine; polychaetes; Bonny River; abundance; diversity; sediment.

1. INTRODUCTION

Polychaetes are bristle-bearing segmented worms belonging to phylum Annelida, class Polychaeta. Polychaete communities are key components in the functioning of coastal and marine ecosystems [1,2]. Being the most dominant groups in benthic infaunal communities, they contribute about 80% to the total macrobenthic community and their diet includes microbial (bacteria, microalgae, protists and fungi), meiobial and organic substance [2,3]. Polychaetes form an important component in the marine food chain, especially for bottom fish and some mammals, as they form an important source of food for demersal fish [2,4,5]; and are tools for biomonitoring program as organic pollution indicators to check the health of the marine environment [2,6-8]. Despite the role and function of Polychaetes in the marine environment, only a handful of reports [9-12] exist on the Polychaetes of Bonny River.

To this end, this study is aimed at describing the temporal variation of diversity and association of Polychaetes along the Bonny-Midchannel Estuarine Sediment of the Bonny River in order to understand the biotic and abiotic changes associated with life history strategies. This study assumes that the dynamic nature of estuarine benthos can be ordered through the simple processes of immigration and extinction. Immigration of a species into a habitat and extinction of species already present will cause a change in the composition and arrangement of the species. The rates of immigration and extinction result in predictable or observable changes in temporal diversity effected through the types and number of *Polychaete* species within a defined physico-chemical setting. These measurable components provide a quantitative expression of the temporal nature of the diversity and association measured in this study.

2. STUDY AREA

The study area is located within the mouth of the Bonny River Estuary as shown in Fig. 1. NEDECO [13] provides a description of the width at the mouth of the estuary to be approximately 3000 meters. The tides as published by the Nigerian Port Authority [14] which are semi–diurnal reach a maximum height of 2.4 m and 1.8 meters during spring and neap tides respectively. At the mouth of the river are the communities of Bonny on the eastern wing and Peterside on the western side. Closely located within the Bonny and Finima towns are the oil and gas facilities belonging to Shell Petroleum Development Company, Nigerian National Petroleum Corporation and close to Finima is Mobil Producing Nigeria Unlimited. The River is described to have insignificant freshwater discharge [13] and therefore salinities at the mouth remain at 20 parts per thousand throughout the year.

3. FIELD PROCEDURES

Samples at the river mouth were collected from twenty locations - upper, mid and lower areas as shown in Fig. 1. The stations were chosen through the length of the shoreline corresponding to the Mean Low Water (MLW) mark. The stations were spread across a distance of seven kilometers (7 km) which included the shorelines of Bonny Town, the Shell Terminal, Nigerian National Liquefied Gas, the Bonny Natural Gas Liquid Plant (Mobil) with the last sample point terminating at the mouth of Finima River. At each location, three random samples were taken with a 0.023 m^2 Ekman grab. All samples from the sites were composited. All the locations were sampled approximately between two to three months over a 12 month period by using waypoints loaded into a GPS to collect samples from the same location as closely as possible. The grab samples were washed with water in a 45μ nitex bags, and preserved in 10% buffered formalin. Rose Bengal stain was added. Each preserved samples were hand sorted. All Polychaetes were sorted, identified with stereo and compound microscope and categorized into families and generic groups. *Polychaete* literature from Kierkegaard [15], Day [16] and Fauchald [17] were used in the course of this study.

4. DATA MINING AND STATISTICAL ANALYSES

A variety of diversity indices have been used in benthic ecology to assess the community structure of benthic communities. In the present study, the calculation of two diversity and Evenness indices were carried out using Shannon Wiener diversity (H’), Margalef diversity index (Da) and Pielou Evenness (J’). Shannon-Wiener index is used as a quantitative measure reflecting the number of different types of species existing in a dataset, and concurrently takes into account the even distribution of the individuals among those types. The two indices rely on different concepts to measure diversity. The Shannon-Wiener Index relies heavily on uncertainty. This means that the more diverse the area, the lower the probability of correctly guessing the species of a random organism from the area. This is in contrast to Simpson's index which measures the dominance in the area. This means the more diverse the area, the lower the probability of obtaining two organisms from the area which are both of the same species.

H = -SUM [(pi) × In (pi)]
SUM = summation pi = proportion of total sample represented by species.
Da = (S - 1)/log lo base e N

Where

Da = Margalef index,
S = the number of species and
N = the total number of individuals.

Evenness = E = H/Ln(S)

Where

H' is Shannon Weiner diversity and *S* is the total number of species in a sample, across all samples in dataset.

Pielou's or species evenness (E) refers to the closeness in number of each species in an environment. If E is close to 1.0, this means that equitability is higher (all species in the community are represented by a similar number of individuals).

An analysis of variance to fit means which test equality was performed with multiple comparison tests on means, with means comparison circles and outlier box plots overlaid on each group. The box plots summarize the distribution of points at each factor level. Each multiple comparison test is represented by a comparison circles plot which is a visual representation of group mean comparisons. The diamond plot represents the confidence interval for each group. Overlap marks for each diamond are computed as group mean shown as the horizontal line inside each diamond. Overlap marks in one diamond that are closer to the mean of another diamond than that diamond's overlap marks indicate that those two groups are not different at the 95% confidence level. *Polychaete* associations were analyzed with average linkage clustering statistics. The strength of the linear relationships between each pair of response variables (sediment and abundance) was evaluated using JMP SAS Correlations Table. The Principal component analysis was also used to derive the independent linear combinations (principal components) of the set of measured variables between sediment and abundance that capture as much of the variability as possible.

5. RESULTS

5.1 Composition and Abundance

Table 1 shows the *Polychaete* fauna collected within the period of study. A total of 213 individuals consisting of 25 *Polychaete* species, 17 genera and belonging to 14 families were recorded from the study area. The dominant *Polychaete* family, in terms of abundance, was Lumbrineridae which had 7 genera followed in decreasing order by Capitellidae (3), Glyceridae (2), Cirratullidae (2), Orbinidae (2), Paraonidae (1), Spionidae (1), Cossuridae(1), Onuphidae (1), Sternaspidae (1), Nepthydae (1), Sigalionidae (1), Longosmatidae (1) and Phyllodocidae (1). Five genera were the most abundant, with Lumbrieneris being the most abundant in the study area with 6 species, followed by *Scoloplos, Notomastus* and *Glycera* with 2 species each. The species abundance showed that *Diopatra neapolitana* and *Chaetozone setosa* were the most numerous with 41 and 33 individuals respectively followed in decreasing order by other species numbering between 1 and 19 individuals such as *Cossura longocirrata* (19), *Scoloplos (scoloplos) armiger* (16), *Sternpsis scutata* (15), *Aglaophamus malmgreni* (14), *Notomastus aberans* (10), *Lumbrineriopsis paradoxa* (8), *Lumbrineris coccinea* (7), *Lumbrineris fragilis* (6), *Tharyx dorsobranchialis* (6), *Scoloplos (leodamas) johnstonei* (5), *Ninoe lagosiana* (5),. *Paracapitella pettiboneae* (4), *Lumbrineris aberrans* (4), *Aricidea simplex* (3), *Malacoceros indicus* (3), *Glycera tridactyla* (3), *Notomastus latericeus* (2), *Glycera prashadi* (2), *Sigalion opalinus* (2), *Heterospio longissima* (2), *Eteone picta* (1), *Lumbrineris tetraura* (1) and *Lumbrineris latreilli* (1).

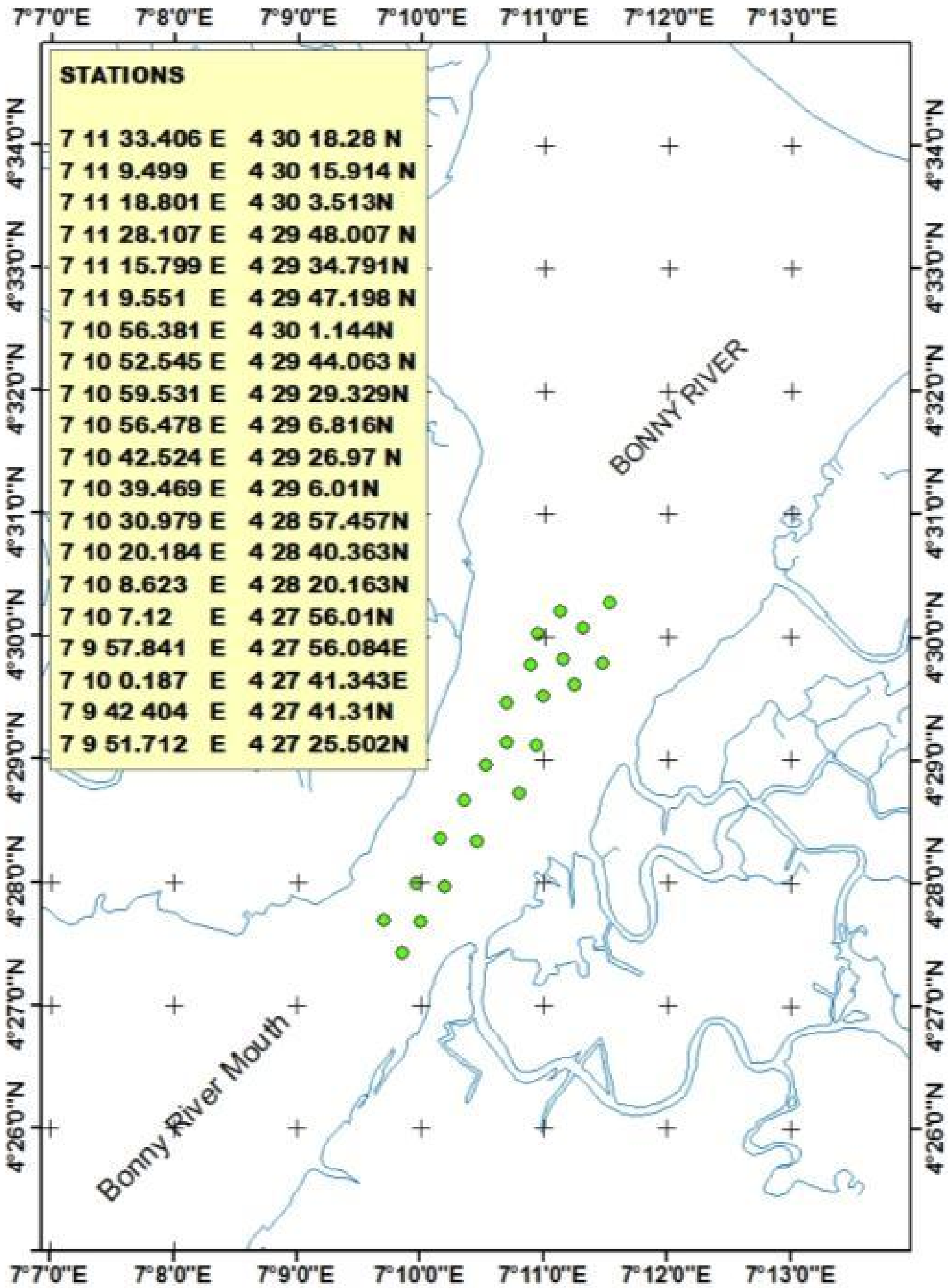


Fig. 1. Sampling stations at the Midchannel of Bonny River Estuary

The mean abundance of Polychaetes from the study area ranged from 0.24 to 3.60. In addition, the mean value of the month of October 2012 was significantly different from the others. Fig. 2 shows the species abundance between months. Values were lowest in the month of June 2012 and highest in the month of October 2012. Fig. 3 shows the number of individuals between months with numbers highest in the months of October 2012 and lowest in the month of June 2012.

Table 1. Abundance of *Polychaete* Fauna Recorded in the Polyhaline Region of the Bonny Midchannel from June 2012 to June 2013

Species	June_2012	August_2012	October_2012	February_2013	April_2013	June_2013	Total
Notomastus aberans Day			6			4	10
Notomastus latericeus Sars			2				2
Paracapitella pettiboneae Carrasco and Gallardo			4				4
Lumbrineris aberrans Day				3	1		4
Lumbrineriopsis paradoxa Saint-Joseph		5			3		8
Lumbrineris fragilis Müller			4	1	1		6
Lumbrineris coccinea Renier					7		7
Lumbrineris latreilli Audouin and Milne Edwards				1			1
Lumbrineris tetraura Schmarda		1					1
Ninoe lagosiana Augener				2		3	5
Aglaophamus malmgreni Théel	2				5	7	14
Scoloplos (scoloplos) armiger Müller		3	13				16
Scoloplos (leodamas) johnstonei Day			5				5
Glycera tridactyla Schmarda			3				3
Glycera prashadi Fauvel						2	2
Tharyx dorsobranchialis Kirkegaard				6			6
Chaetozone setosa Malmgren		6	11		16		33
Malacoceros indicus Fauvel			3				3
Sigalion opalinus Intes and Le Loeuff		2					2
Diopatra neapolitana Delle Chiaje		10	23		6	2	41
Sternpsis scutata Ranzani		2		7		6	15
Heterospio longissima Ehlers			2				2
Aricidea simplex Day			2		1		3
Cossura longocirrata Webster and Benedict	4		12	2		1	19
Eteone picta Quatrefages					1		1
Total	6	29	90	22	41	25	213
Mean	0.24	1.16	3.60	0.88	1.64	1.00	
Standard Deviation	0.88	2.46	5.63	1.88	3.60	1.98	
Coefficient of Variation	3.66	2.12	1.57	2.13	2.20	1.98	

In Figs. 4 and 5, the species diversity values for Shannon Weiner and Margalef indices are shown. The study area had low to moderate Shannon-Weiner diversity (0.637 to 2.252). The highest Shannon-Weiner diversity value occurred in the month of October 2012, followed in decreasing order by June 2013, April 2013, February 2013 and August 2012, with lowest diversity in June 2012. The Margalef index had values ranging from 0.558 to 2.667. The highest value was observed in October 2012 and April 2013 and the lowest value in the month of June 2012. In a non-polluted environment, the Shannon diversity and Margalef richness are higher and in the range of 2.5 to 3.5. However, in the present study, all the months for Shannon Weiner and Margalef had values below 2.5 indicating low diversity in the study area. However, the Pileou Evenness (E) (Fig. 6) values indicated low evenness with values in decreasing order as follows: 0.553, 0.552, 0.500, 0.478, 0.474 and 0.355 for the months of June 2013, February 2013, October 2012, August 2012, April 2013 and June 2012 respectively.

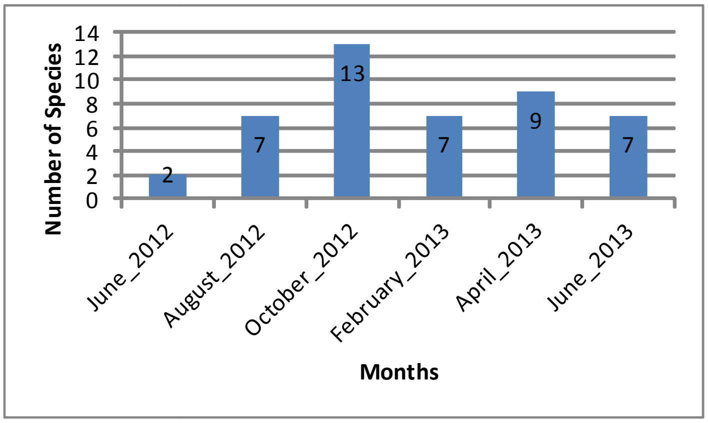


Fig. 2. Species abundance between months

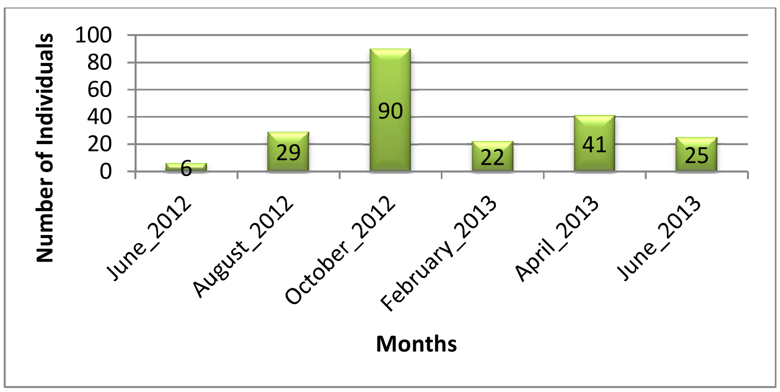


Fig. 3. Number of individuals between months

The one way analysis of variance of *Polychaete* abundance is shown in Fig. 7. The graphical means diamond plot shows the abundance for each month with the X axis scaled proportional to the sample size of each month. The boxplots which compare the different months on a numeric response show that the months clearly differ with variability highest in the months of October 2012 and the least in the month of June 2012.

5.2 Species Association

The association of *Polychaete* species during the period under study is shown by the dendogram in Fig. 8. The average linkage shows the hierarchical cluster of 25 species grouped into two major associations of one group of generalist species and one group of an "assemblage of drifters". The first association is a group of generalist species made up of twelve species namely *Notomastus aberans*, *Lumbrineris aberrans, Lumbrineriopsis paradoxa, Lumbrineris fragilis, Ninoe lagosiana*, *Aglaophamus malmgreni, Scoloplos (scoloplos) armiger, Chaetozone setosa, Diopatra neapolitana, Sternpsis scutata, Aricidea simplex,* and *Cossura longocirrata.* This association is characterized by species that co-occurred at least two to four times out of the six sampling months. These generalists are those that seem to disperse and recur successfully throughout the year. In this group, the co-occurrence is evidence of their ability at successful temporal recruitment and spatial dispersal in both wet and dry seasons. The second association comprises of thirteen species namely *Notomastus latericeus, Paracapitella pettiboneae, Lumbrineris coccinea, Lumbrineris latreilli, Lumbrineris tetraura, Scoloplos (leodamas) johnstonei, Glycera tridactyla, Glycera prashadi, Tharyx dorsobranchialis, Malacoceros indicus, Sigalion opalinus, Heterospio longissima* and *Eteone picta*. The second association is an assemblage of "drifters" which can be termed specialists due to the fact of their single month occurrence which is indicative evidence of an environmental effect on temporal recruitment.

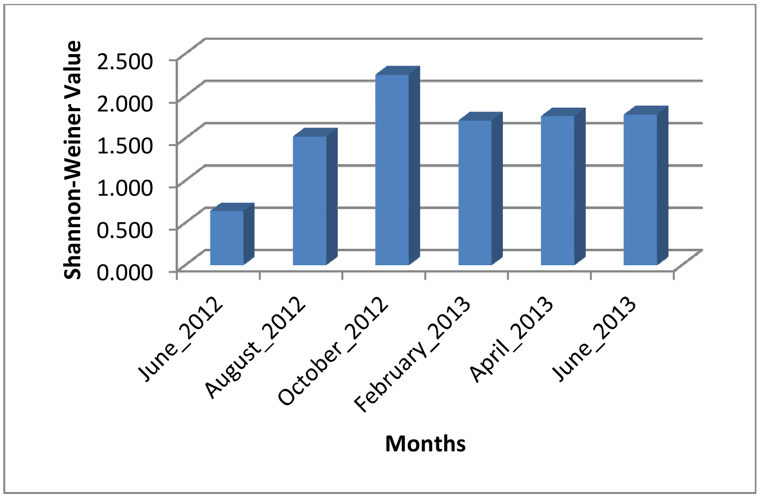


Fig. 4. Shannon Weiner diversity index for the study period

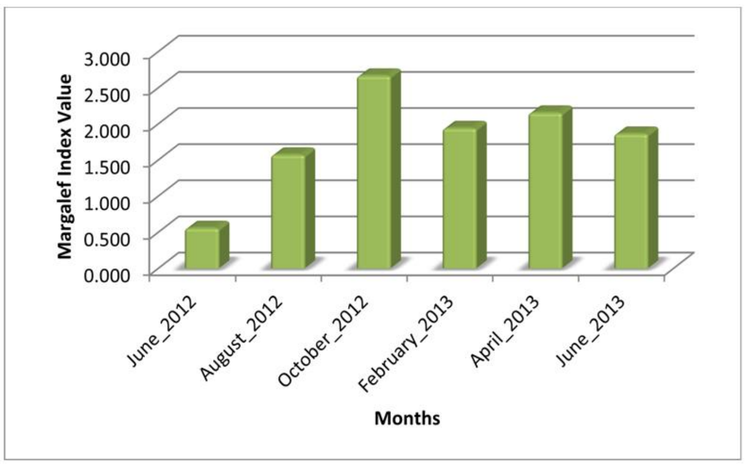


Fig. 5. Margalef index for the study period

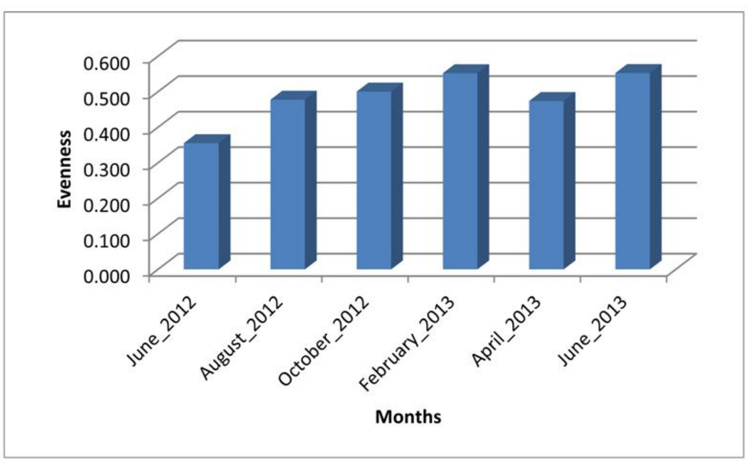


Fig. 6. Pieleou evenness index of the study period

5.3 Sediment *Polychaete* Interaction

Figs. 9 to 12 show the graph that illustrates the relationship between *Polychaete* abundance and physical variables of sand, silt/clay and organic matter respectively. Fig. 9 shows a negative correlation trend between *Polychaete* abundance and sand, implying that high value of sand is equivalent to low value of *Polychaete* abundance and low value of sand is equivalent to high Polychaete abundance, having a correlation statistics value of -0.3042 and -0.3980 for Pairwise and Spearman's coefficient respectively. Fig. 10 shows a moderate positive correlation between *Polychaete* abundance and silt/clay, implying that in most cases, high value of silt/Clay produced high value of *Polychaete* abundance and low value of sand produced low *Polychaete* abundance. The relationship between abundance and silt/clay had a correlation statistics value of 0.3042 and 0.3980 for Pairwise and Spearman's Rho respectively. Fig. 11 shows a positive correlation trend between *Polychaete* abundance and organic matter which implies that the abundance of *Polychaete* increased as the value of organic matter increased, with a correlation statistics value of 0.7297 and 0.6136 for Pairwise and Spearman's Rho respectively. Fig. 12 shows the Principal Component analysis showing the eigenvalue plots, the score and the loading plots. The bar chart of the eigenvalues provides the variation accounted for each principal component indicating that the first two components which were organic matter and silt/clay accounted for 93.4% of the total variation. The Loading Plot shows that all the sediment variables are not correlated positively with the first component as shown by their positive and negative extent in the first component 1 dimension. In agreement with the scatterplot matrix spearman rank correlation, organic matter is the principal component of influence on abundance of the Polychaetes.

6. DISCUSSION

The study introduces a new *Polychaete* family – the Longomastidae - in addition to the thirty four families reported by Onwuteaka [9]. The abundance of the *Polychaete* species was strongly correlated with organic matter and followed by silt and clay which agrees with the abundance of surface and subsurface deposit feeders such as *Notomastus aberans, Lumbrineris aberrans, Lumbrineriopsis paradoxa, Lumbrineris fragilis, Ninoe lagosiana, Aglaophamus malmgreni, Scoloplos (scoloplos) armiger, Sternpsis scutata, Aricidea simplex and Cossura longocirrata.* This is in agreement with studies which show that a strong correlation with the organic matter and silt clay content is dominated by deposit-feeder organisms [18-21].

This is also supported by the findings of Amar and Datesh [2], which showed high *Polychaete* abundance in relation to high organic content in sediment in one of the study areas along the Indian coast, of which the deposit feeders were the dominant ones. This indicates that the Polychaetes in the study area (Bonny Midchannel) can withstand high organic carbon and can be indicators of the organic content of an area. Furthermore, the organic content of the area represents an important direct or indirect food source for the Polychaetes and it enhances their rate of metabolism [2,22,23].

The pattern of succession in the composition of the *Polychaete* community shows a group of twelve repeater species with a group of thirteen species in asynchronous single month occurrences. The easily measured parameters of sediment parameters and the indices of diversity which correlate with abundance provide only the empirical evidence of succession but do not provide mechanistic explanations for the characteristic temporal patterns. Many successional models such as the inhibition, tolerance and facilitation models [24] have been proposed to explain the temporal patterns of successions in soft bottom communities.

Basically, the differences in the three models indicate that if the abundance of an early species in the succession sequence is enhanced, only the facilitation model would predict an increase in the immigration rates or survival of other species. The inhibition model would predict a strong decrease, whereas the tolerance model would predict a slight decrease or no change. The facilitation model is plausibly the model that seems to fit the occurrence of the single month specialists which were continuously lost and added to the habitat in a pattern that concurs with Mangum et al. [25] Whitlatch [26] Woodin [27] who observed that the mere tolerance of species to physical and chemical conditions often does not provide sufficient explanation for the observed distribution pattern.

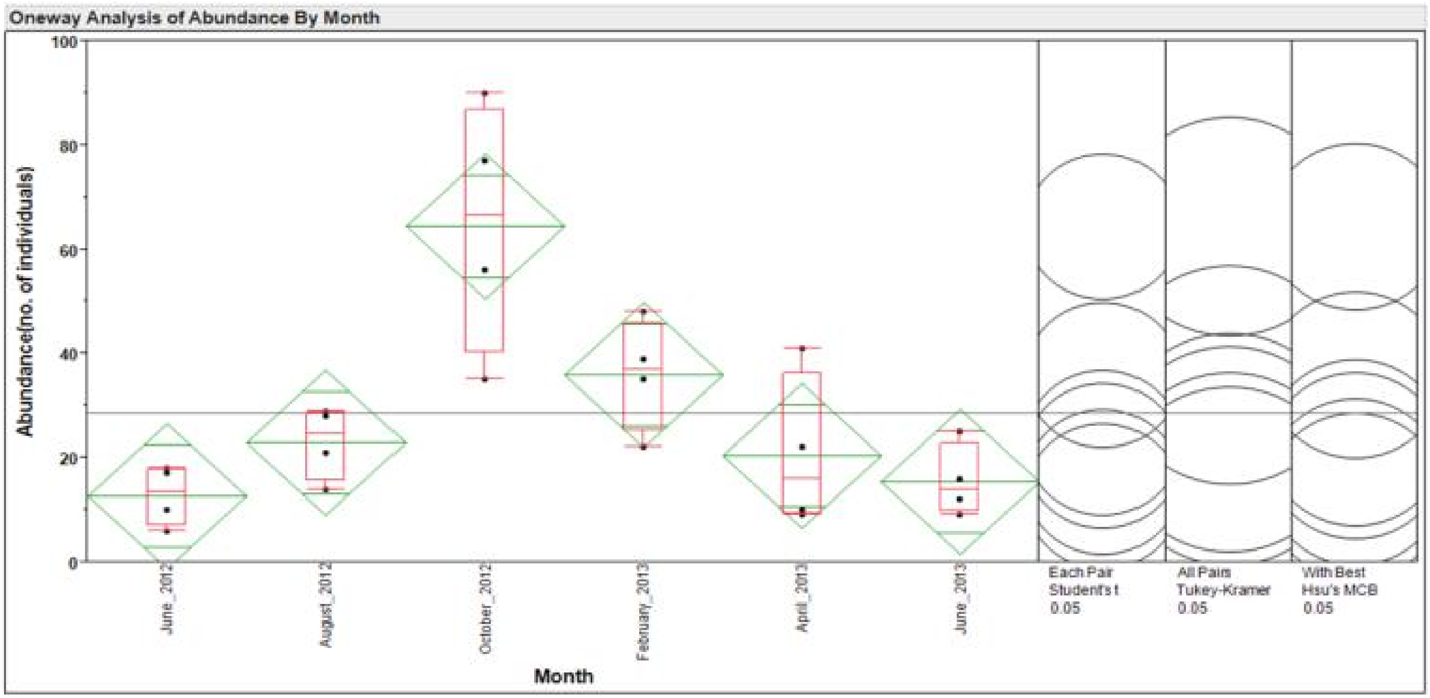


Fig. 7. One way analysis of *Polychaete* abundance by month

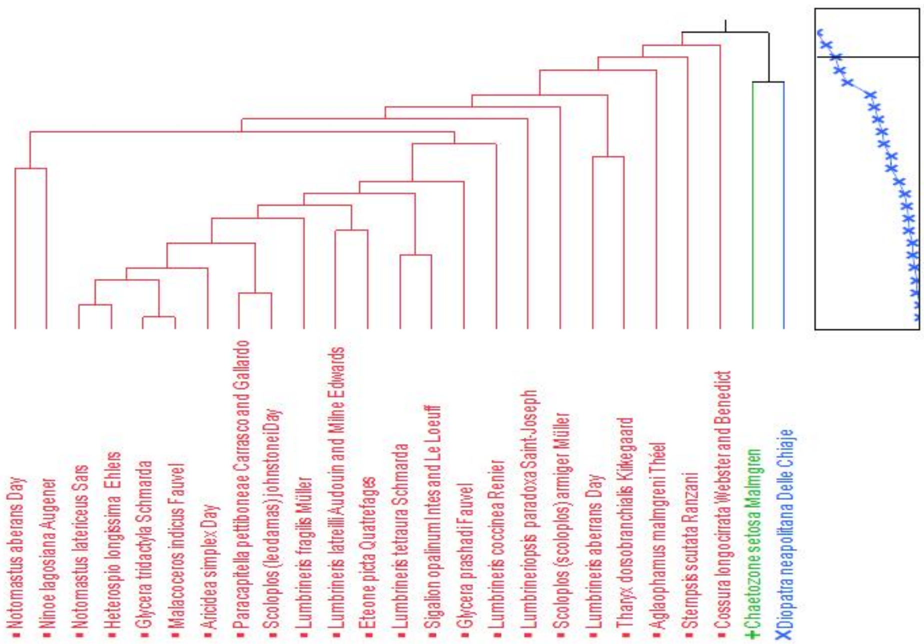
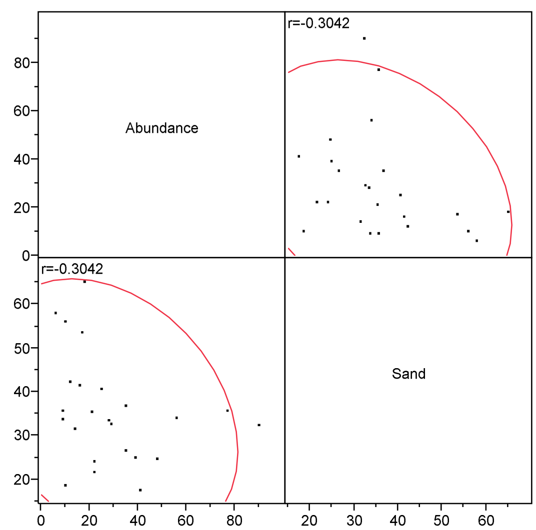


Fig. 8. Dendrogram of *Polychaete* species assemblage in Bonny Midchannel during the study



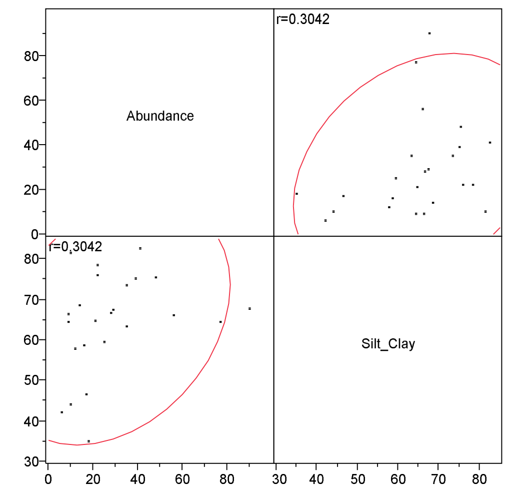
Pairwise correlations

Variable	by variable	Correlation	Count	Lower 95%	Upper 95%	Signif Prob
Sand	Abundance	-0.3042	24	-0.6303	0.1131	0.1484

Nonparametric: Spearman's ρ

Variable	by variable	Spearman ρ	Prob>|ρ|
Sand	Abundance	-0.3980	0.0541

Fig. 9. Correlation Statistics between Abundance and Sand



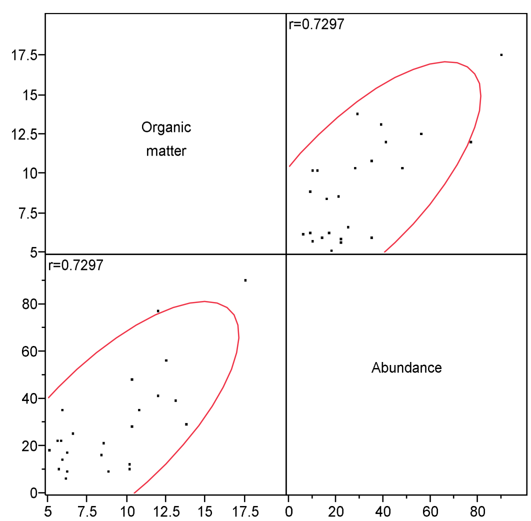
Pairwise correlations

Variable	by variable	Correlation	Count	Lower 95%	Upper 95%	Signif Prob
Silt_Clay	Abundance	0.3042	24	-0.1131	0.6303	0.1484

Nonparametric: Spearman's ρ

Variable	by variable	Spearman ρ	Prob>|ρ|
Silt_Clay	Abundance	0.3980	0.0541

Fig. 10. Correlation statistics between abundance and silt/clay



Pairwise correlations

Variable	by variable	Correlation	Count	Lower 95%	Upper 95%	Signif Prob
Abundance	Organic matter	0.7297	24	0.4625	0.8754	<.0001*

Nonparametric: Spearman's ρ

Variable	by Variable	Spearman ρ	Prob>|ρ|
Abundance	Organic matter	0.6136	0.0014*

Fig. 11. Correlation statistics between abundance and organic matter

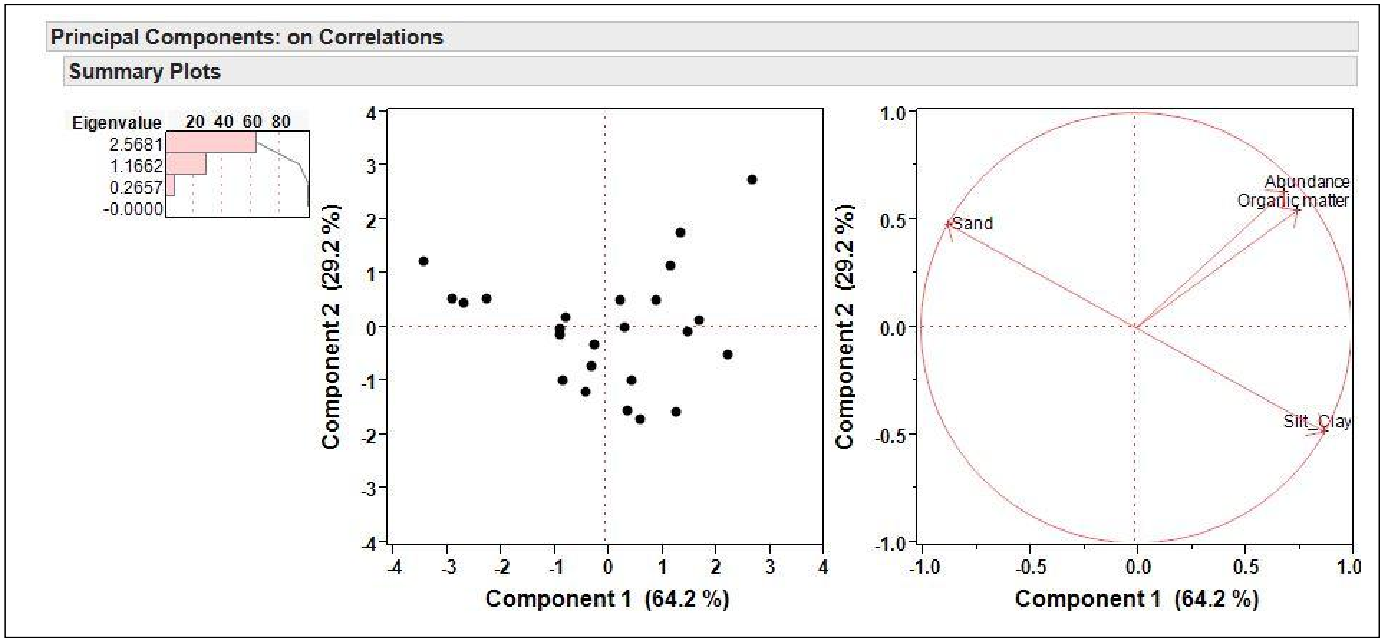


Fig. 12. Principal component analysis of organic matter, sand and silt/clay

7. CONCLUSION

This study therefore provides a basis for further evaluation of the processes affecting the immigration and survival of larvae and juveniles of Polychaetes in order to fully explain the mechanism of soft-bottom benthic succession. This requirement is important as facilitation or inhibition to succession may be due to immigration rates and not survival. It may also be due to the interaction of larvae and juveniles with small scale alterations of the local environment caused by either the tubes or feeding activities of the deposit feeders [28,29].

COMPETING INTERESTS

Author has declared that no competing interests exist.

REFERENCES

1. Lu L. The relationship between soft bottom macrobenthic communities and environmental variables in Singaporean waters. Marine Pollution Bulletin. 2005;51: 1034-1040.
2. Amar SM, Dattesh VD. Distribution and abundance of macrobenthic Polychaetes along the South Indian coast –Bulletin of the National Institute of Oceanography. 2011;178(1-4):423-436.
3. Shou L, Huang Y, Zeng J, Gao A, Liao Y, and Chen Q. Seasonal changes of macrobenthos distribution and diversity in Zhoushan sea area. Aquatic Ecosystem Health and Management. 2009;12(1): 110–115.
4. Herman PMJ, Middelburg JJ, Widdows J, Lucas CH, Heip CHR. Stable isotopes as trophic tracers: Combining field sampling and manipulative labelling of food resources for macrobenthos. Marine Ecology Progress Series. 2000;204:79–92.
5. Parulekar AH, Harkantra SN, Ansari ZA. Benthic production and the assessment of demersal fishery resources of the Indian sea. Indian Journal of Marine Sciences. 1982;11:107-114.
6. Jayaraj KA, Jayalakshmi KV, Saraladevi K. Influence of environmental properties on Macrobenthos in the northwest Indian shelf. Environmental Monitoring and Assessment. 2007;127:459–475.
7. Warwick RM, Ruswahyuni. Comparative study of the structure of some tropical and temperate marine soft bottom macrobenthic communities. Marine Biology. 1987;95:641-649.
8. Remani KN, Devi KS, Venugopal P, Unnithan RV. Indicator organisms of pollution in Cochin backwaters. Mahasagar. 1983;16(2):199-207.
9. Onwuteaka J. The Temporal Abundance and Distribution of *Polychaete* fauna along the Shoreline of Bonny River in Nigeria. IOSR Journal of Environmental Science, Toxicology and Food Technology. 2014; 9(2 Ver. I):39-45.
10. Chinasa U, Emmanuel U, Raymond A, George IU, Emmanuel O. Comparative assessment of the relative abundance and diversity of near-shore and offshore communities of benthic macro-invertebrates off the bonny estuary, Nigeria. 2013;14(2):617-625.
11. Woke GN, Aleleye-Wokoma IP. Composition and Abundance of Benthic Macro-invertebrates of Nta-Wogba Steam, PH Nigeria. 2006;13(3). 2007;353-357.
12. Snowden RJ, Ekweozor I. Littoral infauna of a West African estuary: an oil pollution baseline survey. Marine Biology. 1990;105:51-57.
13. NEDECO the waters of the Niger Delta. Report of an investigation by NEDECO (Netherlands Engineering consultants). The Hague. 1961;210-228.
14. NPA Nigerian port Authority. Tide table of Bonny River; 2014.
15. Kierkegaard JB. Bathyal benthic Polychaetes from the N.E. Atlantic Ocean, S.W. of British Isles, J. Mar. Biol. Ass. U.K. 1983;63:593-608.
16. Day JA. Monograph of the Polychaeta of Southern Africa. London: British Museum Natural History Publication 656; 1967.
17. Fauchald K. National History Museum, Los Angeles County, Sci. Ser.1977;28:190.
18. Rakocinski CF. Evaluating macrobenthic process indicators in relation to organic enrichment and hypoxia. Ecological Indicators. 2012;13:1-12.
19. Rakocinski CF, Brown SS, Gaston GR. Heard RW, Walker WW, Summers JK. Species-abundance-biomass responses by estuarine macrobenthos to sediment chemical contamination. Journal of Aquatic Stress Recovery. 2000;7:201-214.
20. Gaston GR, Rakocinski CF, Brown SS. and Cleveland CM. Trophic function in estuaries: Response of macrobenthos to

natural and contaminant gradients. Marine Freshwater Research.1998;49:833-846.
21. Diaz RJ, Rosenberg R. Marine benthic hypoxia: A review of its ecological effects and the behavioural responses of benthic macrofauna. Oceanography Marine Biology Annual Review. 1995;33:245-303.
22. Meksumpun C, Meksumpun S. *Polychaete*-Sediment relations in Rayong, Thailand. Environmental Pollution. 1999;105:447-456.
23. Gray JS. The ecology of marine sediments. An introduction to the structure and function of benthic communities. In: Cambridge Studies in Modern Biology. Cambridge University Press. 1981;185.
24. Connell JH, Slayer RO. Succession in natural communities and their role in community stability and organization. American Naturalist.1977;111:1119-1144.
25. Mangum CP, Dykens JA, Henry RP, Polites G. The excretion of NH,' and its ouabain sensitivity in aquatic annelids and molluscs. J Exp Zool. 1978;203:151-157.
26. Whitlatch RB. Seasonal changes in the community structure of the macrobenthos inhabiting the intertidal sand and mudflats of Barnstable Harbour, Massachusetts. Biological Bulletin Marine Biological Laboratory, Woods Hole. 1977;152:275-294.
27. Woodin SA. *Polychaete* abundance patterns in a marine soft-sediment environment: The importance of biological interactions. Ecological Monographs. 1974; 44:171-187.
28. Woodin SA. Disturbance and community structure in a shallow water sand flat. Ecology.1981;62:1052-1066.
29. Woodin SA. Refuges, disturbance and community structure: A marine soft-bottom example Ecology. 1978;59:274-284.

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