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Attributes of the Subtidal Macrobenthos of Azuabie Creek in the upper Bonny Estuary, Niger Delta, Nigeria

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Abstract: The objective of the study was to describe the abundance, distribution and diversity of macro benthic assemblages in Azuabie creek, upper Bonny estuary of the Niger Delta, Nigeria. Benthic samples were collected from ten sampling stations, seven (St. 1, 2, 6, 7, 8, 9 and 10, respectively) along the main creek and three (St. 3, 4 and 5, respectively) along a creeklet that empties into the main creek between April, 2006 and March, 2007. This ensured a total coverage of the entire creek along its salinity gradient. Polychaetes constitute 96% of the macrobenthos and were observed in more than 90% of the stations examined while fish were the least making up less than 1% of the organisms; other taxawere oligochaetes (2%), crustaceans (1%) and bivalvia (1%). In all, 37 species constituting 34 genera were observed, with the polychaetes having 29 species in 26 genera. *Streblospio* sp., and *Boccardia* sp., had higher densities at station 6 and 5, respectively during the dry season but *Nephtys* spp. and *Nereis* spp. had higher densities at station 1and lower densities at Sts. 5 and 6. Although, minimal variation was observed across periods, mean species richness was highest (3.92) in the month of October but species were most evenly distributed at station 10 across all sites studied. Species diversity also showed minimal variations (1.27-1.64) across periods but remarkable variation (0.00-2.12) between stations. Cluster analysis of the organisms separated station 3 from others due to its azoic nature; St 7, 8 and 10, respectively fell in the same group, while the others showed no clear pattern. The observed distribution/pattern of macro-invertebrate assemblage are strongly related to salinity gradient, sediment composition/characteristics and anthropogenic influence in the study area.

Keywords: Azuabie creek, density, distribution, diversity, infauna, invertebrates, upper bonny estuary

INTRODUCTION

Estuaries are rich productive zones with high biodiversity and the benthic community is an integral part of this diverse community. The estuaries are often exposed to such factors as chemical contaminants that are capable of altering the benthic community structure and pattern in rivers and creeks. These ecosystems are often the site where many pollution problems exist and where pollution loading caused significant changes in abundance and species composition (Saiz-Salinas and Gonzlez-Oreja, 2000). Estuaries provide an ideal system in which to study impacts on ecosystem functioning as tools and techniques needed to measure processes are well developed and have been studied extensively (Biles *et al*., 2002). The estuarine faunal composition varies, over spatial scales from meters to kilometers and temporal scales of days to years (Morrisey *et al*., 1992a, b). Such variations in diversity and abundance of benthos in estuarine systems have often been correlated with environmental variables (e.g., salinity, (Sanders *et al*., 1965) tidal level, (Warwick and Uncles, 1980) sediment characteristics, (Gray, 1974; Chapman and Tolhurst, 2004) density of sea grass plants, (Bostrom and Bonsdorff, 1997) biotic interactions, (Wilson, 1991) perturbations, (Belan, 2003)). This means that the estuarine community structure can change as a continuum on various spatial and temporal scales in relation to both natural and anthropogenic gradients (Pearson and Rosenberg, 1978; Rakocinski *et al*., 1997).

In shallow water systems, such as coastal lagoons, the benthic compartment plays a crucial role in determining the functioning of the system, controlling the main ecological processes and changes in its structure could affect the whole system (Snelgrove *et al*., 1997; Weslawski *et al*., 2004; Tenore *et al*., 2006). The introduction of industrial and urban sewage to the marine environment cause 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 ability of the benthic communities to reveal spatial and temporal changes make them the target for most environmental monitoring programmers developed either to detect

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signs of habitat change or to assess the effectiveness of restoration plans (Warwick, 1993; Jan *et al*., 1994).

Studies of benthic communities are essential for monitoring biodiversity and the environment, not only in order to preserve them, but also for the species of commercial interest that they support (Desroy *et al*., 2002). Such monitoring should be a long-term program in order to identify trends of environmental degradation, but the high cost of sampling leads to a compromise between its spatial and temporal extent and frequency (Currie and Small, 2005). Daka *et al*. (2007) reported that the Azuabie creek in the upper Bonny estuary is more contaminated than the adjacent Obufe creek. Daka and Moslen (2013) gave a detailed description of the sediment quality profile of the Azuabie creek along its entire stretch. This study examines the subtidal macrobenthic fauna of Azuabie creek system (including a small creeklet that empties into it). It describes the spatial and seasonal dynamics of the abundance and diversity of the benthic assemblages of the study area. The observed patterns were discussed in relation to environmental variables within the system.

MATERIALS AND METHODS

Study area: The Azuabie Creek located on the eastern part of Port Harcourt is part of the upper Bonny estuary of the Niger Delta (Fig. 1). The creek originates southerly from the Okpoka River and continues northwards to the Oginigba area. It meanders further inland from where it is joined by a fresh water drainage

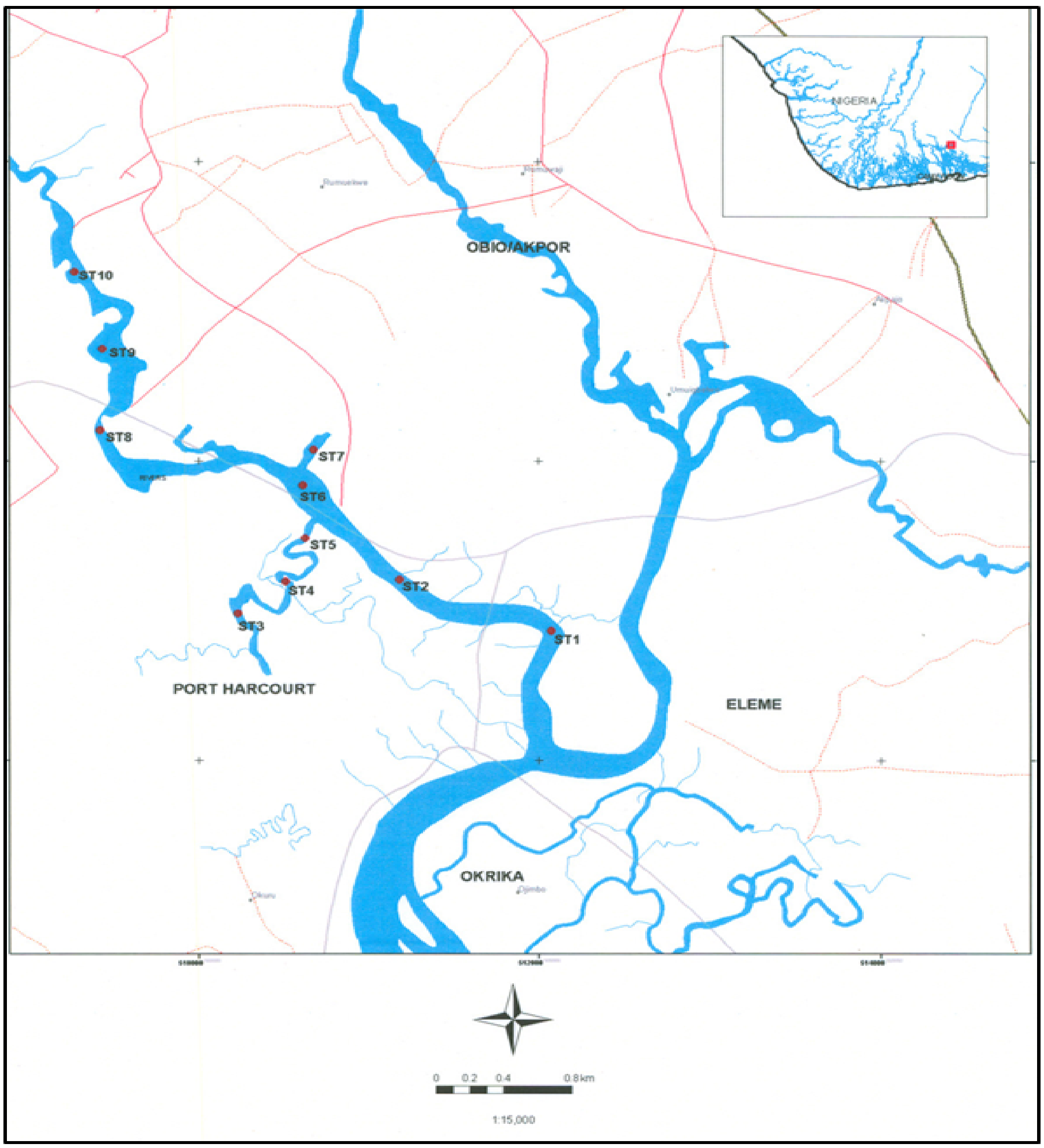


Fig. 1: Map showing sampling sites in the study area. Inset: The Niger Delta showing the study area

meandering far inland (Daka *et al*., 2007). The Azuabie creek has a creeklet (Okolo-Azuabie) that empties into it. This creeklet receives industrial effluent from the Trans-Amadi Industrial Layout drains, especially, that from the Rivers Vegetable Oil Company (RIVOC). The major vegetation along this creek is the mangrove forest, mainly of *Rhizophora* sp., *Nypa fruticans* and *Avicennia* sp. A coastal settlement (Azuabie Town) is also found along the Azuabie creek from where numerous domestic wastes are generated and dumped along the creek. A major abattoir and some other companies are located upstream of the Azuabie creek. The Azuabie Creek is open to different kinds of human activities, which ultimately translate into the discharge of various kinds of wastes into this environment. The regular discharge of wastes into his creek is capable of partitioning the macro-benthic community structure of the creek. A reconnaissance survey was carried out in February 2006, during which 10 sampling stations were established for monthly sampling. Sampling sites were adequately spread to cover the entire creek including a major creek-let (Okolo-Azuabie). Two stations (st. 1 and 2) were located downstream (more saline end) of the creek while stations 3, 4 and 5 were located along the creeklet, stations 6 and 7 (midstream) and stations 8, 9 and 10 were located upstream (less saline end) of the creek (Fig. 1).

Sample collection and analysis: Samples were collected for a period of one year from April 2006 to March 2007. Sediment samples were collected with an Ekman grab (15 by 15 cm) and emptied into a 15 L plastic bucket. The benthos/sediment samples were collected randomly from five different spots (five replicates) per station for analysis. 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 brackish water mixture, stained in Rose Bengal to facilitate sorting in the laboratory. Laboratory analyses of infauna were carried out shortly after field sampling. Aliquots of the sample were transferred on to a white surgical tray with water for sorting. The detrital sediment samples were then sorted using a pair of forceps and a hand lens. The macro-infanuna found were collected and preserved in small bottles containing 70% ethanol. The contents were later identified to the lowest possible taxonomic level using appropriate keys (Day *et al*., 1989; Fauchald, 1977). 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) 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):

$$H' = - \Sigma pi \times (\log_2 pi)$$
$$J = H'/\log_2 Si$$
$$d = (S - I) /\log_2 N$$
$$\lambda = \Sigma (pi)^2$$

Both multivariate and univariate statistical analysis was applied to the data obtained. A 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 used to test for differences between locations and time for polychaete families and benthic community indices (H, J, d and λ). Bonferroni test was used for pair-wise comparison among levels of time and location. Data were transformed as appropriate before statistical analysis. The computer package MINITAB R.14 was used for the ANOVA.

RESULTS

Abundance, distribution and density: A total of 37 species from 34 genera were observed, with the polychaetes having 29 species in 26 genera (Table 1). Polychaetes were the most abundant constituting 96% while fish were the least making up less than 1% of the organisms. Other taxa recorded are oligochaetes (2%), crustaceans (1%) and bivalves (1%). A total of 13,040 organisms were counted during the study period. This suggests that the abundance of organisms in the study area was generally low. It was also observed that more organisms were found during the dry season period than the rainy season period.

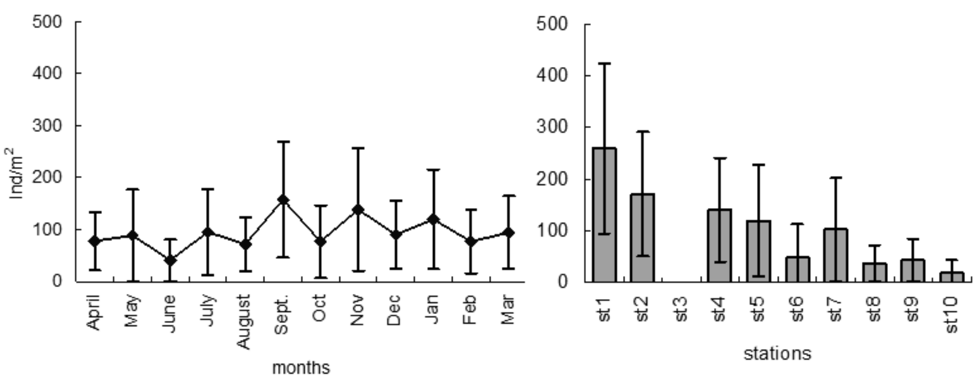
Nereis spp. were one of the organisms observed during the study. The mean density of *Nereis* spp. varied across stations and periods with more of the organisms observed at station 1 during the dry season. The mean density of the organism varied from 0-276 ind/m^2 (Fig. 2a) with statistical analysis showing significant difference in locations, time and also significant interaction between location and time ($p<0.001$) (Table 2). *Nephtys hystricis* and *Nephtys hombergi* were the two species of Nephtidae found during the study with mean densities showing spatial and seasonal variation (Fig. 2b and c). Higher densities of these species were observed during the dry season particularly at locations 1 and 2. These organisms were observed at all stations except station 3 and station 10 for the latter species. The mean density of the former ranged from 0-245 ind/m^2 while that of the latter varied from 0-149 ind/m^2 with ANOVA results showing significant difference between locations, time and location interaction time for both organisms (Table 2). For *Nephtys hystricis*, stations 1 and 2 were significantly different from stations 3-10 while stations 4 and 5 varied significantly with stations 6-10 and st. 7 significantly different from st. 10. The abundance of *N. hystricis* in the months of May, June, August, November and January were significantly different from that in the month of February while abundance in the month of April was also significantly different from those in February and March.

The density of *Nephtys hombergi* at st. 1 was significantly different from those of st. 3-10 while those of st. 2 differed significantly with those of st. 3, 6, 7, 8, 9 and 10, respectively. Also the density at st. 3 differed significantly with those of st. 4-7 while that at st. 4 varied significantly with the density of the organism at st. 8-10 and that in st. 6 and 7 differed significantly with the density at st. 10. The density of *Nephtys hystricis* at st. 1 in the month of June had significant

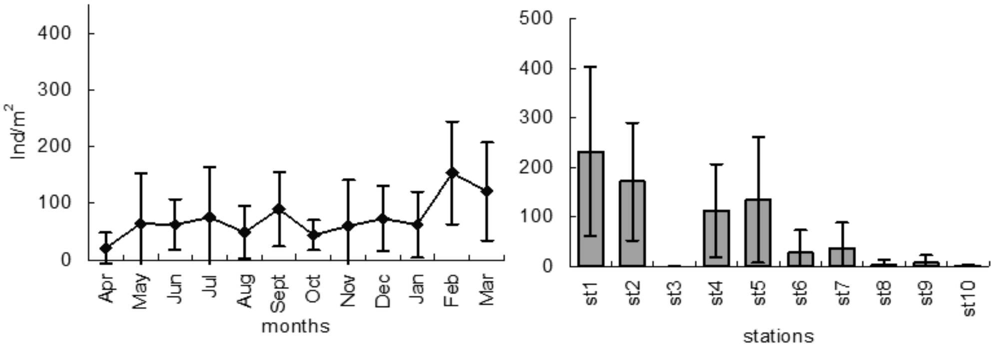
Table 1: Checklist of benthic macro fauna of Azuabie creek during the study

TAXA		St. 1	St. 2	St. 3	St. 4	St. 5	St. 6	St. 7	St. 8	St. 9	St. 10
Polychaeta	Species										
Nereidae	*Nereis* spp	+	+	-	+	+	+	+	+	+	+
Nephtidae	*Nephtys hystricis*	+	+	-	+	+	+	+	+	+	+
	Nephtys hombergi	+	+	-	+	+	+	+	+	+	-
Pisionidae	*Pision* sp.	+	+	-	-	+	-	-	-	+	+
Onuphidae	*Nothria* sp.	+	+	-	+	-	+	-	-	-	-
	Onuphis sp.	+	+	-	+	-	+	-	-	-	-
Nephtidae	*Nephtys* sp.	+	+	-	+	+	+	+	+		
Capitellidae	*Notomastus latriceous*	+	+	-	+	+	+	+	-	+	-
	Capitella capitata	-	+	-	+	+	+	+	+	-	-
	Notomastus tenius	+	+	-	+	+	+	+	+	+	-
	Capitella capitata	-	+	-	+	+	+	+	+	-	-
Spionidae	*Polydorella* sp.	+	+	-	+	+	+	+	+	+	+
	Streblospio sp.	+	+	-	+	+	+	+	+	+	+
	Boccardia sp.	+	+	-	+	+	+	+	-	-	+
	Polydora sp.	+	+	-	+	+	+	+	+	-	-
Nerididae	*Hedistae* sp.	+	+	-	+	+	-	-	-	-	-
Glyceridae	*Glycera* sp.	+	+	-	+	+	-	+	-	-	-
Owenidae	*Owenia* sp.	+	+	-	-	-	-	-	-	-	-
Orbiniidae	*Scoloplos uniramus*	+	+	-	+	+	+	+	+	+	-
	Orbinia sp.	+	+	-	+	-	-	-	-	-	-
	Perkinsiana riwo	+	+	-	+	+	-	+	-	-	-
	Fabricia filamentosa	+	+	-	+	+	+	+	+	-	-
Lumbrineridae	*Lumbrineris* sp.	+	+	-	+	+	+	+	+	+	+
	Spirobis sp.	+	+	-	+	+	-	-	-	-	-
	Sclerobregma sp.	+	-	-	-	+	-	-	-	-	-
	Sclerocheilus	+	-	-	-	-	-	-	-	-	-
Pilargiidae	*Sigambra bassi*	+	+	-	+	+	-	-	-	-	-
	Paralacydonia sp.	-	-	-	-	+	-	-	-	-	-
	Sphaerodoridium sp.	-	-	-	-	-	+	-	-	-	+
	Aphrodita sp.	+	-	-	-	-	-	-	-	-	-
Oligochaeta											
	Aeolosoma sp.	-	-	-	-	-	-	-	+	+	+
	Tubifex sp.	-	-	-	-	-	-	-	+	+	+
	Enchytraeous sp.	-	-	-	-	-	-	-	-	+	+
	Stylaria sp.	-	-	-	-	-	-	-	+	+	+
Bivalvia											
	Lucina subfragilis	+	+	-	+	+	+	+	+	-	-
Crustacea											
	Macrobrachium sp.	+	+	-	+	+	-	+	-	-	-
Fish											
Anguilidae	*Anguila anguila*	+	-	-	-	+	-	-	-	-	-

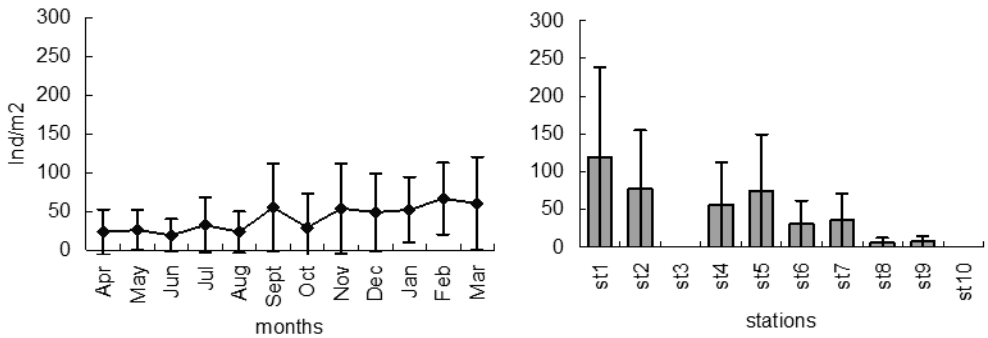
+: Present; -: Absent



(a) *Nereis* spp.



(b) *Neptys hystricis*



(c) *Nephtys hombergi*

Fig. 2: Spatial and temporal variations in mean densities of *Nereis* spp., *Nephtys hystricis* and *Nephtys hombergi* in the study area Error bars represent standard error; n = 50 for months, 60 for stations

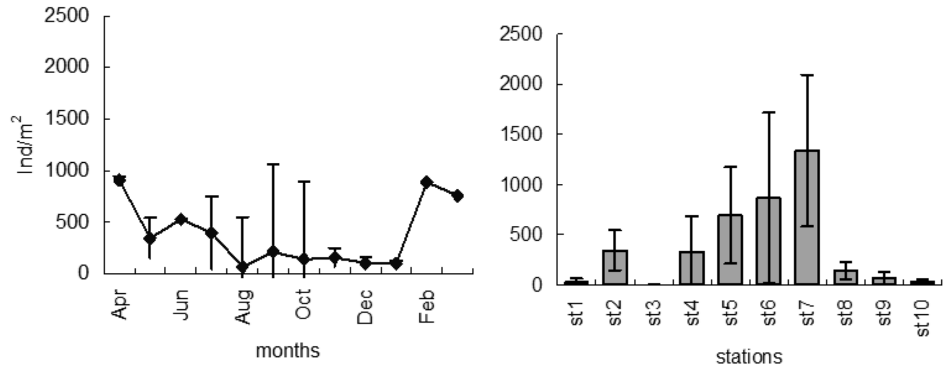
Table 2: Summary of ANOVA tables for benthic organisms in the study area

	F-values		
Parameters	Location	Time	Location*time
Nereis spp	43.16***	3.51***	1.73***
Nephtys hystricis	32.26***	4.11***	1.76***
Nephtys hombergi	58.86***	4.97***	2.17***
Notomastus latriceous	12.78***	1.19	1.29*
Notomastus tenius	18.80***	1.44	1.48**
Polydorella sp.	18.16***	15.17***	3.73***
Streblospio sp.	88.41***	19.24***	6.57***
Polydora sp.	10.02***	3.35***	2.38***
Boccardia sp.	107.45***	54.43***	18.41***
Capitella capitata	17.22***	7.63***	2.38***
Lubrineris sp.	4.93***	4.14***	1.27
Glycera convoluta	13.21***	0.93	0.89
Aeolosoma sp.	46.68***	1.71	0.95
Tubifex sp.	109.19***	1.11	1.13
Enchytreaus sp.	23.87***	0.24	0.39
Stylaria sp.	17.90***	2.69**	1.87***

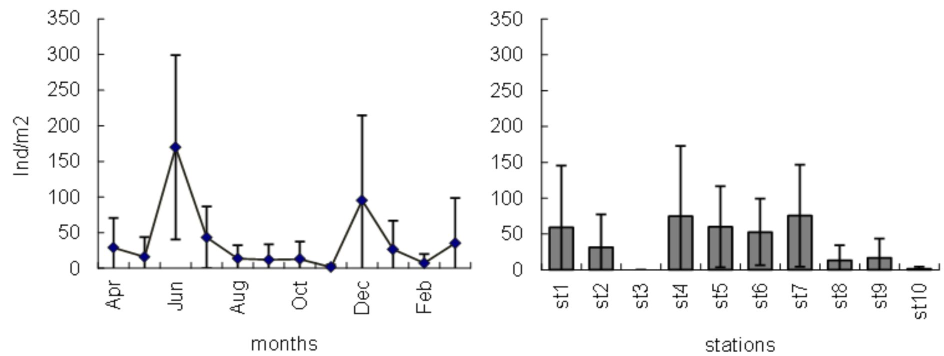
***: $p \leq 0.001$; **: $p \leq 0.01$; *: $p \leq 0.05$

interactions with values at st. 4 (July), st. 6 (April, may, June, July, August, September, October, November, December, February and March), st. 7 (May, June, August, September, October, December, January and February) and st. 8, 9, 10 (all months). For the other species of *Nephtys*, significant interaction was observed between st. 1 in the month of September and st 8. (May, June, July, August, September, October, November March), st. 9 (April, may, June, July, August, December and February) and st. 10 (All months).

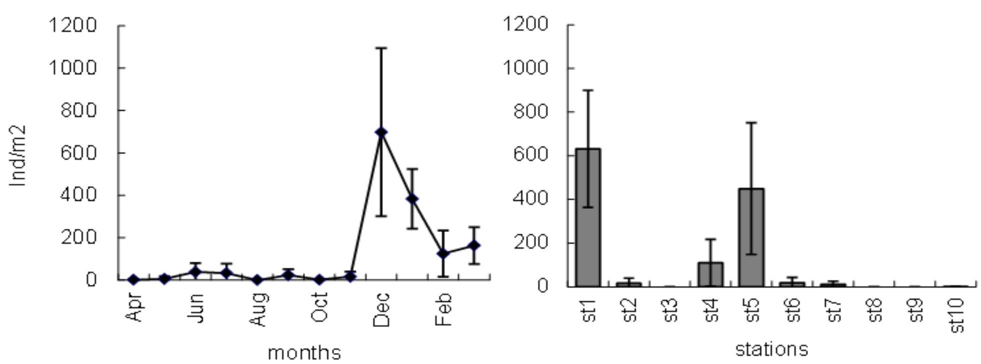
The spionid, *Streblospio* sp., was one of the most abundant animals found during the study with mean density varying across sites and periods (Fig. 3a). It was found in all months of the study in all stations except at station 3. Maximum mean density observed was 1336 ind/m^2 at station 6 in the month of February. Locations periods varied significantly and significant interaction was also observed between location and time (Table 2). The interaction occurred between location 2 in April and all sites in all months except in April and May (st. 5), February and March (st. 6) and February and March (st. 7). The density of the Spionid (*Polydorella* sp.) also showed spatial and temporal variations during the study (Fig. 3b). The organism was found in all stations during the study except at station 3 with mean density varying from 0-169 ind/m^2. Analysis of variance gave a statistically significant difference between locations, time and also a significant interaction between location and time. The density of *Boccardia* sp., was generally high and varied across stations and periods (Fig. 4c) but the organism was not found at stations 3, 8 and 9. The mean density of the organism ranged from 0-697 ind/m^2 with statistically significant differences and interaction found in locations, time and location and time, respectively (Table 2). The interaction occurred



(a) *Streblospio* sp.,



(b) *Polydorella* sp.,

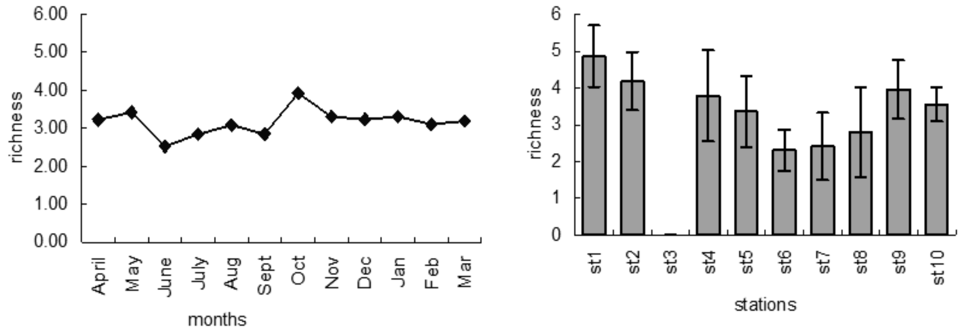


(c) *Boccardia* spp.

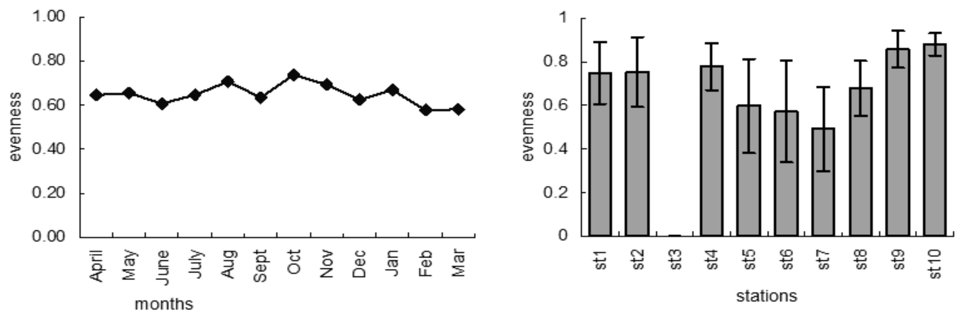
Fig. 3: Variations in mean density of *Polydorella* sp., *Streblospio* sp. and *Boccardia* sp., Error bars represent standard error; n = 50 for months, 60 for stations

between station 1 in the months of December, January, February and March and all stations in all months of the study. Among the spionids, *Polydora* sp., had the lowest abundance, it was in all stations except at stations 3, 9 and 10 but mean density varied from 0-136 ind/m^2 all through the study period with location and time showing significant differences, location also interacted significantly with time ($p<0.001$).

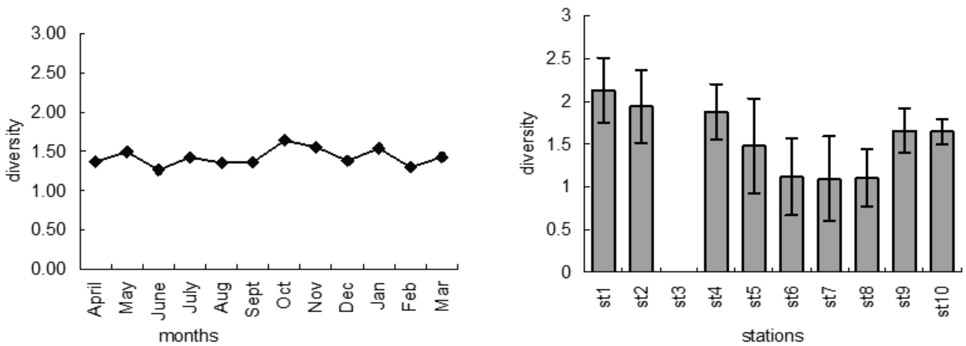
Two species of *Notomastus* were found during the study. *Notomastus latriceous* and *Notomastus tenius*. Mean density of the former varied from 0-72 ind/m^2 while that of the latter ranged from 0-96 ind/m^2. More than 70% of *Notomastus latriceous* were found at stations 1 and 2 while *Notomastus tenius* was also observed at stations 1 and 2 in all months of the study except in May and June. ANOVA for both organisms showed significant difference between locations ($p<0.001$) but none between time and also a significant interaction between location and time ($p<0.05$) (Table 2). Another species of Capitellidae found in six stations



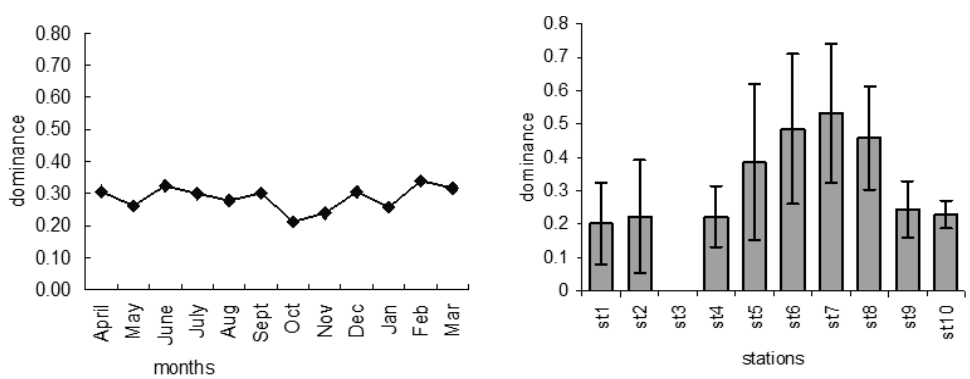
(a) Species richness



(b) Species evenness



(c) Species diversity



(d) Species dominance

Fig. 4: Variation in species diversity and dominance (mean±S.E.) in the study area

(2, 4, 5, 6, 7 and 8, respectively) of the study area was *Capitella capitata*. The mean maximum density recorded was 144 ind/m^2 at station 7 in the month of March. Locations and time varied and also interacted significantly ($p<0.001$) (Table 2). The significant interactions occurred between locations 1, 3, 5, 6 and all months of the study ($p<0.05$) and also between station 4 and all months except September while station 7 also had interactions with all months except December but station 2 did not interact significantly with the month of November. The density of *Glycera convolute* varied across stations with much of the organism found at stations 1 and 2. The maximum density (56 ind/m^2) was found at stations 1 but none of the organism was found beyond station 7 upstream of the creek suggesting the affinity of the organism for the more saline end of the creek. There was no significance difference in periods but locations varied significantly ($p<0.001$) (Table 2). The numerical density of *Lumbrineris* sp., varied spatially during the study, with analysis of variance giving statistically significant difference both in space and time ($p<0.001$) (Table 2). The mean density (232 ind/m^2) of *Scoloplos uniramus* was highest at station 7 in the month of May with location and time also showing statistically significant variation but no significant interaction.

The broom worms (*Perkinsiana riwo* and *Fabriciafila mentosa*) were found almost at the same stations (1, 2, 4, 5 and 7, respectively). The mean monthly density of the organisms varied across stations with the former having a mean maximum density of 64 ind/m^2 and the latter 136 ind/m^2 at station 5 in the month of December. There were significant differences ($p<0.001$) between locations for both organisms but no significant difference between periods for the density of *Perkinsiana riwo.* Significant interaction also occurred between location and time for both organisms. For *Perkinsiana riwo*, the interaction occurred as follows station 1<April = May = June = October = December = March, station 2<April = May = June = July = November, station 4<April = May = June = July = August = September = October = November = December = March, station 5<April = June = July = August = December and station 3 interacted with all months of the study. For *Fabricia filamentosa*, the interaction occurred as follows; station 1-3 < all months, station 4<April = May = June = July = August = September = October = November = December = March and station 5<April = May = June = July = August = September = October = November = December. The numerical density of *Orbinia* sp., was very low, the maximum observed was 24 ind/m^2 at station 1 in September and October but spatial differences were noticeable. The density of *Spirobis* sp., was lower than that of *Orbinia* sp. and was observed in only four stations. The maximum density observed was 8 ind/m^2 and ANOVA showed statistically significant difference between stations ($p<0.05$). *Sigambra bassi* was one of the organisms with the least abundance, the animal was found only at four stations (1, 2, 4 and 5) during the dry seasons. The average maximum density recorded was 24 ind/m^2 but ANOVA result showed a significance difference between locations and periods ($p<0.05$) but no significant interaction between location and time. Onuphidae was also observed during the study. Wide variations were noticed in the density of *Onuphis* sp., both in space and time with more of the organism found at station 1. There were also significant differences ($p<0.05$) between locations and also between periods. There was also a significant interaction between location and time. The numerical density of *Hedistes* sp., was very low across all stations during the study period. The maximum density recorded was 32 ind/m^2 at station 5 in the month of October however, locations were observed to vary significantly while periods showed no variation. Among the very rare polychaetes found during the study are *Owenia* sp., *Aphrodita* sp., *Sphaerodoridium* sp., *Paralacydinia* sp., *Sclerocheilus* sp. and *Sclerobregma* sp. These organisms were found either once or twice throughout the entire study period and their mean maximum density was not more than 40 ind/m^2.

The Oligochaetes were the second most abundant group of organisms found during the study. These animals were only seen at stations st. 8, 9, 10, upstream (less saline end) of the Azuabie Creek. They include *Aeolosoma* sp., *Tubifex* sp., *Echytreous* sp. and *Stylaria* sp. The mean densities of *Aeolosoma* sp. and *Tubifex* sp., ranged from 0-88 and 0-96 ind/m^2 (Table 3) and values showed statistically significant difference between stations but non between time (Table 2). Mean maximum density recorded for *Enchytreous* sp. and *Stylaria* sp., was 32 ind/m^2 at station 10. ANOVA result also indicated significant differences ($p<0.001$) in location and time ($p<0.05$) for both organisms and also a significant interaction ($p<0.001$) between location and time was observed for values of the latter. Other polychaetes that were not Identified (UI) were also recorded during the study. Maximum density of this unidentified organism was 24 ind/m^2.

Benthic community indices and multivariate patterns: There were variations in the diversity patterns and benthic community characteristics of the study area. Species richness (d) varied across stations and was observed to be highest (4.86) at station 1 during the dry season while station 2 followed closely (Fig. 4). Though minimal variation was observed across periods, mean species richness was highest (3.92) in the month of October during the study. Macrobenthic species were most evenly distributed at station 10 followed by station 9 across all sites studied. Mean maximum values of evenness (j’) were 0.88 and 0.85 for stations 10 and 9 respectively (Fig. 4). The variations across periods were minimal with mean

Table 3: Density of oligochaetes in the study area

	Density (Ind/m^2)									
Species	St1	St2	St3	St4	St5	St6	St7	St8	St9	S10
Aeolosoma sp.	0	0	0	0	0	0	0	24	40	88
Tubifex sp.	0	0	0	0	0	0	0	16	48	96
Stylaria sp.	0	0	0	0	0	0	0	8	8	32
Enchytraous sp.	0	0	0	0	0	0	0	0	8	32

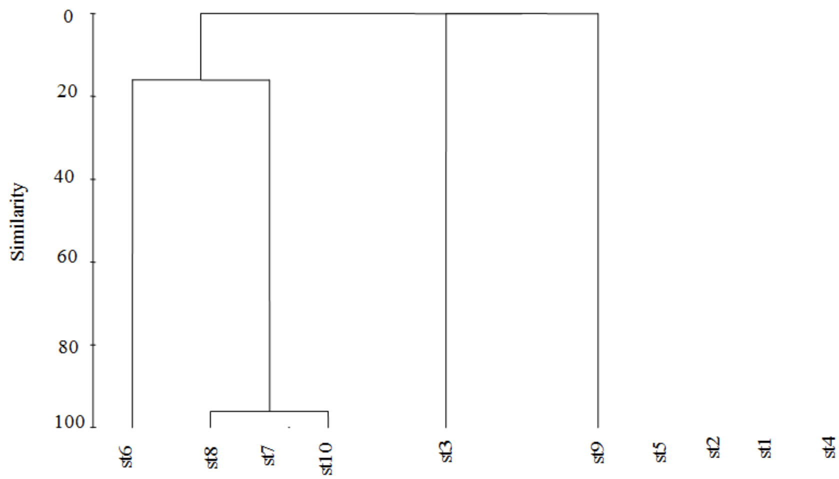


Fig. 5: Overall cluster analysis of benthic macrofuana based on stations

Table 4: Summary of ANOVA tables for benthos diversity indices

	F-values	
Parameters	Location	Time
Species richness (d)	2.10*	33.78***
Species evenness (j')	1.96*	38.35*
Species dominance (λ)	1.60	14.29***

***: p≤0.001; **: p≤0.01; *: p≤0.05

lowest value (0.58) noticed during the dry season months of February and March while the mean highest value (0.74) was observed in October. Species diversity also showed minimal variations across periods but the reverse was seen across stations. The lowest value (1.27) was observed in the month of June while the highest value (1.64) was noticed in October suggesting seasonal differences in benthic species diversity (Fig. 4).

Mean maximum value (2.12) of species diversity was observed at station 1 while the lowest (0.00) was at station 3, which also indicates spatial differences. However, species dominance showed the opposite of richness and diversity in terms of spatial trend. Dominance was highest (0.53) at stations 7, followed by values at stations 6 (0.48) and 8 (0.45) indicating spatial variations (Fig. 4). Across periods, species dominance values ranged from 0.21 in October to 0.34 in February, which also suggests minimal temporal variations in the study area. ANOVA for species richness and evenness showed significant differences in time and also across locations studied ($p<0.05$) (Table 4). There was a significant difference ($p<0.001$) in species dominance across stations while species diversity did not differ significantly in space and time (Table 4). Overall cluster analysis of macrofauna based on stations suggests that stations 1, 2 and 4 are similar, also, stations 7, 8 and 10 are similar, while station 3 is clearly different because of it azoic nature (Fig. 5).

DISCUSSION

Abundance and distribution: The macro-benthic abundance and composition of the Azuabie creek were generally low. Some important factors governing the abundance and distribution of macro-invertebrate benthic communities include water quality, immediate substrates for occupation and food availability (Dance and Hynes, 1980). Ecological imbalance arising from any severe alterations of these factors may affect the macro-benthos. Therefore, it appears that the low macro-benthic invertebrate community abundance, composition and diversity may have been greatly affected by land base pollutant washed into the creek, as well as instability possibly arising from frequent dredging of the creek. Five different groups (Polychaeta, Oligochaeta, Crustacea, Bivalvia and Fish) of organisms were identified during this study. Polychaetes were the most dominant making up about 96% of the entire taxa found, with oligochaetes having just 2% as the next major taxa observed. Polychaetes contributed 29 species in 26 genera with mean monthly maximum density reaching 3992 ind/m^2 for an organism (*Streblospio* sp.). The maximum infaunal density value observed in the Azuabie creek during this study is within the range those previously reported. Ebere (2002) recorded 436-4878 ind/m^2 with polychaetes contributing 78%, Ekweozor (1991) recorded 2590-4110 ind/m^2 in the Bonny estuary while Je *et al*. (2003) recorded infaunal density ranging from 262-1,788 ind/m^2 in the Vancouver harbour and Belan (2003) recorded between 194-846 ind/m^2 in the same area. In comparison with the downstream stations (more saline end of creek), there was a significant reduction in macro-benthic, abundance and diversity in upstream stations (less saline end of creek) of the creek. Similar observations were made by Ajao (1989), that the bivalve, *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. The distribution and abundance of specific taxa could be used in assessing the levels of impact in the study area. Of the five taxa recorded in this study, two (98%) were annelids, dominated by the polychaetes in terms of species richness and diversity. The presence of polychaetes, *Streblospio* sp., *Nephtys* sp., *Nereis* spp., *Boccardia* sp., *Polydorella* sp. and *Polydora* sp., in high density within the creek may be indicative of organic enrichment. These organisms were observed in areas were higher organic carbon and hydrocarbon have been found in the Azuabie Creek (Daka *et al*., 2007; Daka and Moslen, 2013). Brown and Oyenekan (1998) suggested that *Polydoraciliate* could be as opportunistic as *Capitella capitata*, a universal indicator of organic pollution. In this study, *Capitella cpitata* was mostly found at polluted sites particularly at station 7 where both organic and hydrocarbon concentration were found to be higher compared to other stations (Daka *et al*., 2007; Daka and Moslen, 2013). Diversity indices also suggest a deteriorated habitat at st. 7 where reduced evenness and higher dominance were recorded. Snelgrove and Butman (1994) suggested that sediment particle size, together with a complex of factors that covary, would be the mechanism responsible for the control of the composition of benthic communities in relation to trophic groups and species distribution. Furthermore, the establishment and performance of benthic populations are determined by physiological requirements of the organism and by their capacity to use available food suppliers (Roth and Wilson, 1998). The boundary in the species composition between stations 1 and 2 is not clear because the environmental features of both stations are more homogenous (Daka *et al*., 2007) but major biological distinction was observed between stations 1, 2 and stations 8, 9 and 10 which are separated by salinity gradient and turbidity. Daka and Moslen (2013) concluded that physicochemical variables of sediment in Azuabie Creek were influenced by pollution sources and these would affect the benthic community structure in the estuarine creek. The spatial differences in the composition of the benthic communities along estuarine gradients have also been related mainly to changes in salinity, depth, sediment grain size and organic content (Day *et al*., 1989). Giberto *et al*. (2004) found in the Rio de la Plata system that depth, salinity and % clay showed the strongest correlation with the observed faunal patterns and also that beta diversity varied between dominant taxonomic groups due to changes in salinity. In this study, most of the stations downstream of the creek were clearly related to depth, salinity and sediment type in terms of their faunal compositions. The high variability in mean density of the organisms could imply environmental differences along the study area. *Nereis* and *Nephtys* were among the common species found during the study. Mean monthly maximum densities for both organisms reached 352 and 488 ind/m^2 with most of the animals found at stations 1, 2 and 4 downstream of the study site. *Nephtys* sp., is commonly found in low salinity areas (<15 psu), (Giberto *et al*., 2004) and this conforms with salinity ranges found at the downstream section (more saline end) of the Azuabie creek as reported in previous studies (Daka *et al*., 2007). Giberto *et al*. (2004) also reported that bottom type salinity and the presence of a turbidity front are considered the main physical variables in restructuring benthic communities in an Argentina-Uruguay estuary. Two species of Onuphidae were found during the study, they are *Nothria* sp. and *Onuphis* sp. The mean maximum density of the former is 24 ind/m^2 while that for the latter is 48 ind/m^2 implying their poor abundance in the area. It is important to state that these organisms were mostly found in tubes made of sand and other sediment debris at the more saline end of the creek indicating that they have affinity for saline environments. The capitellid polychaetes were also observed in the Azuabie creek, present among them were *Notomastus latricious*, *Tenius* and *Capitella capitata*. These organisms are also known to be good indicator of polluted sites especially *Capitella capitata*, a world acclaimed pollution indicator. Average maximum densities recorded for these annelids are 72, 96 and 144 ind/m^2, respectively. Though, *Notomastus latricious* and *Notomastus tenius* were seen up to station 7 towards the less saline end of creek, they were more abundant at stations 1 and 2 where higher salinity and conductivity have been reported in the creek (Daka *et al*., 2007). Contrarily, *Capitella capitata* were not found at stations 1 and 2 but 4, 6 and 7. Stations 6 and 7 corresponds to areas where elevated levels of organic carbon and hydrocarbon pollution have been reported (Daka *et al*., 2007).

The spioniid polychaetes polydorella sp. and *Streblospio* sp., were found in 90% of the sites studied while *Boccardia* sp., had only 60% distribution across study sites. *Streblospio* sp., was the most abundant of the spionidae with mean monthly maximum density of

3992 ind/m^2 but *Baccardia* had average monthly maximum density of 3952 ind/m^2 during the dry season while that of *Polydorella* sp., reached a maximum of 560 ind/m^2 during the rainy season. Polychaetes shell borers mostly are *Boccardia*, *Polydora* and *Dipolydora* species of the family spionidae, belonging to the Polydora-group of species, often referred to as polyrids (Read, 2004). *Glyceara convoluta* of the family Glyceridae was found in five stations of the study area with higher abundance observed at stations 1 and 2 downstream of the study creek (more saline end of the creek). None of the organisms was found beyond station 7 upstream of the study area suggesting the limited distribution of the organisms to higher salinity environment, the organism was not significantly affected by seasonal variations. *Scoloplos uniramus* was also sparsely distributed in the Azuabie creek with average maximum density reaching 232 ind/m^2 at station 7 with high organic pollution. These finding is in agreement with that reported by Venturini and Tomassi (2004) who has also found that *Scoloplos* sp., are found in organically enriched sediments. Another Orbinidae found during the study was *Orbinia* sp., this was however, numerically less than *Scoloplos* sp., but well restricted to the more saline end of the creek at station 1.

The broom-shaped polychaetes *Perkinsiana riwo* and *Fabricia filamentosa* were found in about 50% of the stations studied. Though their abundance was generally low, mean maximum densities for both organisms reached 64 and 136 ind/m^2, respectively. Most of the organisms were found at stations 1, 2 4 and 5 with highest densities occurring during the dry season, suggesting their affinity for saline environments. Significant differences in stations affected both organisms probably due to environmental differences but the effect of season was only significant on *Fabricia filamentosa*. *Lumbrineris* sp., was found in all stations of the study area except at station 3 which was azoic all through the study period. The wide distribution of this organism across study stations also suggests its ability to survive in moderately saline and less saline environments but the distribution of this organism was significantly influenced by space and time. Oligochaets also had limited distribution in the creek. The high abundance of oligochaetes at stations 9 and 10 suggest their affinity for less saline environments. The types found here (stations 9 and 10) include *Aeolosoma* sp., *Tubifex* sp., *Enchytraous* sp. and *Stylaria* sp., with *Tubifex* as the most abundant having a mean maximum density of 96 ind/m^2. Significance differences in space which affected these organisms are mainly due to environmental differences but seasonal differences appeared to have insignificant effects on the oligochaetes.

Benthic community indices and multivariate patterns: It is well known that highly stressed marine benthic communities are characterized by low level of species richness and diversity, abundance and biomass and dominant by tolerant species (Dauer, 1997; Warwick, 1988). The most striking feature of the study area is the overall low diversity of macro-benthic invertebrates. The margalef's species richness (d) was highest in station 4 and lowest in station 3 while station 1 had higher species richness than station 2. Temporal variations were also observed with higher values observed during the dry season. The species diversity measured by Shannon wenner diversity index (H) almost followed the same trend with generally higher values observed at stations 1 and 2. The evenness index (J) in the study stations ranged from 0 at station 3 to 0.97 in station 10. The mean values of species evenness show moderate temporal variations with peak in October, in all stations studied. The low diversity indices in the entire study area may be a further indication of the impact of perturbation stress on the macro-invertebrate benthic communities while the reduced values of species richness and general diversity of fauna at upstream stations may also indicate pollution and environmental differences. This corroborates the findings of Daka and Moslen (2013) that pollution in the Azuabie Creek influence physicochemical attributes which in turn affect the benthic community structure in the area. However, the higher diversity at downstream stations (less saline end) could be a reflection of its substratum heterogeneity and stability. The presence of polychaetes such as *Streblospio* and *Capitella capitata* within the creek also indicates the increasing level of organically related pollution.

Cluster Analysis of species abundance allowed us to distinguish different groups based on sampling sites. Most conspicuous is station 3 standing differently from all other stations in all months of the study. Generally stations 1 and 2 were observed to have very close similarity as they mostly grouped together. Sites 1 and 2 were also observed to have similarity with site 4 as these were closely grouped especially, in the months of August October and December. Station 7 also stood out differently but was seen to be close to stations 8 and 10 in some months during the study. Thus, the groups of sites observed in this study had actual differences in species composition. The lowest Bray-Curtis similarity (0%) was between stations 3 (azoic) and all other stations in the study area. This may be explained by the differences in natural environmental factors (depth and sediment pollution). In a similar work done in an estuary in Brazil, the classification and ordination analysis separated sampling stations into two main groups corresponding to inner (Area 1) and outer (Area 2) stations based on sediment contamination (Giberto *et al*., 2004). Belan (2003) also used PCA techniques to detect four groups of stations based on sediment contamination in Vancouver harbour. This also corresponded with the MDS and cluster analysis, which also detected four groups of organisms in that study. He showed that Port Moody appear to be more contaminated than other sites. In contrast, no clear pattern in ordination was observed in a PCA and MDS analysis in a work on the impact of dredged material disposal on benthic assemblage (Cruz-Motta and Collins, 2004). In this study two major distributions of macro-benthic organisms were observed apparently based on salinity differences, sediment characteristics influenced by pollution in the Azuabie creek.

CONCLUSION

The benthic community structure of the Azuabie creek is mainly influenced by the pollution induced factors and environmental differences such as salinity differences and sediment characteristics. Oligochaets and other pollution tolerant polychaetes dominate the less saline end of the creek (st. 6. 7, 8, 9 and 10, respectively) while other polychaetes dominated the more saline end of the creek (st. 1 and 2).

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