Spatial variation in sediment characteristics and macrofaunal diversity in the intertidal zones of Elechi Creek, upper Bonny estuary

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ABSTRACT

Estuarine ecosystem is unique; it sustains and provides essential ecological services for mankind. Species distribution, abundance and diversity of benthos and their relationships to environmental conditions are very essential to understand the functioning and structure of an estuarine ecosystem. The benthic macrofauna and physico-chemical parameters in Elechi Creek were studied over a period of three months (August to October, 2015). Three stations were established along the creek based on the human activities going on in the area and proximity to saline water. In this study, spatial variation in sediment characteristics, distribution of macrobenthos, species richness and related environmental parameters were explored at the three intertidal levels in the three stations sampled. Three (3) replicates of sediment samples and five (5) replicates of benthic samples were collected in each of the three intertidal levels in each station. A total of forty five (45) benthic samples were collected in each month. A total of 27 sediment samples were analyzed for each month to determine monthly variation in organic carbon content, organic matter, sediment texture, salinity and conductivity. Physico-chemical parameters of surface water were measured in-situ. Univariate and Multivariate statistical analyses were employed to help understand the diversity and distribution of benthic macrofauna, water quality and benthic characteristics at the three stations. Twenty seven (27) species of benthos with highest abundance in the middle intertidal level were identified from 135 samples. There was no significant variation of diversity indices between stations and levels of the intertidal zones (p<0.05). This is probably because of the relative uniformity in the prevailing environmental conditions and anthropogenic activities in the creek. In conclusion, the overall differences observed in the abundance, diversity and species richness in Low, Middle and High intertidal levels may be due to the slight variations in the physico-chemistry and sediment quality of the various levels of the intertidal zone. The dominance of polychaetes in the area can be attributed to their high level of pollution-tolerance. Bray-Curtis cluster analysis revealed that the percentage similarities between samples were very high in the creek.

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1. INTRODUCTION

Distribution, diversity, and abundance of benthic organisms inhabiting intertidal environments have been associated with variations of several factors, such as depth, tidal height, time of exposure and type of sediment [1, 2]. Anthropogenic and industrial activities reduce the water quality of the estuary [3], thus affecting the biodiversity in the area. The patterns of infaunal benthos communities in an estuary may be influenced by a combination of natural abiotic factors (e.g sediment type, salinity etc) or by anthropogenic influences such as dumping and industrial wastes [4, 5]. Estuarine benthic assemblages are highly sensitive to pollution. At the same time, they are sensitive to chemical and/or physical changes induced by tides or floods [6]. Benthos is particularly sensitive to any type of substrate [7], but in coastal areas and estuaries, the salinity becomes the most important conditioning factor. Pollution can be another significant variable affecting highly populated and industrialized

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areas [8], increasing in low-energy sectors. Benthic communities may fluctuate in a cyclic pattern over time, because of the characteristics of the life cycle of the species, as well as of the influence of temporal fluctuations of abiotic factors, such as environmental temperature or salinity [9]. Species distribution, abundance and diversity of mangrove benthic macroinvertebrate fauna and the relationships to environmental conditions are important parts of understanding the structure and function of mangrove ecosystems [10]. Studies on the intertidal ecology are important as marine ecosystem degradation is rapidly increasing due to the impact of pollution and global warming on marine ecosystems functioning. This study presents the a comparative analysis of macrofauna diversity in the various intertidal zones of Elechi creek, upper Bonny estuary, Nigeria

2. MATERIALS AND METHODS

2.1 Study area

The study area is Elechi creek which is part of the upper Bonny estuary in the South East of Niger Delta, Nigeria. The study area was divided into three stations: Station 1, 2 and 3 (Fig. 1). These sites were chosen on the basis of their locations for industries and different anthropogenic activities along the entire creek.

Station 1 (latitude 4°46'4.18"N to 4°46'5.07"N and longitude 6°59'14.39"E to 6°59'14.99"E) is located by Elechi Creek entrance, where the creek branches off from Bonny River. There is minimal human interference except for transportation activities.

Station 2 (latitude 4°46'47.34"N to 4°46'48.69"N and longitude 6°58'24.54"E to 6°58'22.95"E) is situated midstream of the creek by Eagle Island water front. It is close to a petroleum tank farm and defecation from human inhabitants is common.

Station 3 (Latitude N 4°47'37.42"N to 4°47'38.29"N and longitude 6°58'19.75"E to 6°58'20.10"E) is situated by the Agip base landing jetty close to the Rivers State University of Science and Technology, Nkpulu-Oworukwo. It is close to an abattoir and waste dump sites.

2.2 Sample collection and analysis

Studies on the spatial variation of benthic macrofauna diversity in the intertidal zones, water qualities and sediment characteristics were carried between the months of August and October 2015.
Collection of water samples for DO and BOD was done according to standard procedures [11]. DO and BOD were determined using Winkler method. Other physico-chemical parameters were measured in-situ using multiple meter (Extech Do700).

Samples for sediment particle size analysis (gain size) and total organic carbon analysis were collected at the intertidal zone from the upper 15cm layer at the study stations and wrapped in a well labelled foil paper. Three (3) samples were collected randomly from each zone (Low tide, Mid tide and High tide) in each of the study stations. This was repeated in the three sampling stations totalling twenty seven (27) sediment samples. The samples were packed in cool-boxes containing ice block and transported to the laboratory for further treatment and analysis. The organic carbon was determined using the method of Walkley and Black [12], while particle size analysis of sediment was determined according to Bouyoucos [13].

Five (5) replicate samples of benthos were collected along a transect from each zone (Low tide, Mid tide and High tide) in each of the study station [14]. This was repeated in the three sampling stations totalling forty five (45) sediment samples. The samples were collected with a quadrat of 25 cm x 25 cm up to a depth of 15cm using a hand trowel [15]. The three stations are sampled on the same day.

Each sample was washed using 0.5 mm mesh net and the residue in the sieve was then emptied into a labeled plastic container and preserved with 10% formalin solution to which Rose Bengal (dye) had been added. The dye at a strength of 0.1% selectivity was meant to stain all the living organisms in the sample as to facilitate the sorting of organisms from the sample [16-18]. The preserved samples were transported to be laboratory for subsequent analysis.

Standard procedures were observed in sorting and identification and counting of the samples. The organisms were identified taxonomically to the possible lowest levels using appropriate keys as previously described [19-21]. The identified organisms were grouped and reserved for further analysis.

2.3 Statistical analysis

Biodiversity indices such as species diversity, richness and evenness were calculated following standard formulae [22-24]. Two-way Analysis of Variance (ANOVA) without replication was applied to sediment particle data while two-way ANOVA with replicate was used for biological indices. Where ANOVA result showed a significant difference, Tukey test were performed for mean separation. Product moment correlation was calculated to determine relationships between water physicochemical parameters and biological variables. Minitab 17 and Biodiversity Pro were used to carry out the statistical analysis.

3. RESULTS

3.1 Species abundance and composition in the intertidal zones

A total of 27 taxa were recorded from the three stations. Three invertebrate phyla (Annelida, Arthropoda and Mollusca) and one vertebrate phylum (Pisces) were recorded in the benthic samples. The molluscs were made up of bivalves and Gastropods. The bivalves are represented by 3 families and 4 species with 5.19% abundance while the gastropods were represented by 3 families and 5 species with 5.87% abundance. The phylum Arthropoda had 1 class the malacostraca (crustacean) with 6 families and 9 species with 19.85% abundance. Phylum Annelida represented by the class oligochaeta and polychaeta. The class Oligochaeta had one 1 representative family (Naididae: Ophidonais serpentina) with 0.18% abundance. The polychaeta has 7 families and 7 genera with 68.87% abundance. The phylum pisces is represented by 1 family with 1 species (Bostrychus africanus ) with 0.03% abundance (Fig. 2).

The number of benthic fauna found in Elechi Creek varied from station to station; and also varied within the station from one intertidal level to another as shown in Fig.3. The population pattern is the same over the study period. Station 3 had the highest number of organism.

3.2 Spatial variation of species diversity indices and sediment characteristics

Table 1 shows the variation in diversity indices in the intertidal zones of stations. In Station 1, Simpson Index species richness (D) ranged from 0.668-0.7295 and was highest at Middle intertidal and lowest at Low intertidal. Shannon diversity (H’) varied between the zones ranging from 1.751 to 1.817 and Margalef diversity ranged from 2.024 to 3.181. In station 2, Shannon diversity (H’) varied between the zones ranging from 1.232 to 1.898 and Margalef diversity ranged from 1.779 to 2.444. Simpson Index species richness (D) ranged from 0.4851-0.7663 and was highest at High intertidal and lowest at Low intertidal. While in station 3, Shannon diversity (H’) varied between the zones ranging from 1.349 to 1.578 and Margalef diversity ranged from 1.678 to 1.955. Simpson Index species richness (D) ranged from 0.6422-0.6754 and was highest at High intertidal and lowest at Middle intertidal.
Table 2 shows the spatial variation of sediment characteristics. It was observed that station three had very high organic carbon content because of presence of hard substrata made up of decaying wood materials. Salinity was highest at the station (Station 1) closest to the sea while the station (Station 3) had the least salinity because of dilution from urban runoffs. Elechi creek is predominantly sandy (Fig.4). Table 3 shows the Analysis of variance (ANOVA) showing the effect of station and levels on the various diversity indices. ANOVA of the effect of station and levels on the various diversity indices showed no significant difference.
Table 1. Benthic fauna species diversity indices in the intertidal levels.

<table>
<thead>
<tr>
<th>Sediment Parameters</th>
<th>Station 1</th>
<th>Station 2</th>
<th>Station 3</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Low</td>
<td>Mid</td>
<td>High</td>
</tr>
<tr>
<td>Taxa_Species</td>
<td>15</td>
<td>20</td>
<td>11</td>
</tr>
<tr>
<td>Individuals</td>
<td>175</td>
<td>393</td>
<td>140</td>
</tr>
<tr>
<td>Simpson_1-D</td>
<td>0.67</td>
<td>0.73</td>
<td>0.72</td>
</tr>
<tr>
<td>Shannon_H</td>
<td>1.78</td>
<td>1.82</td>
<td>1.75</td>
</tr>
<tr>
<td>Evenness_e^H/S</td>
<td>0.39</td>
<td>0.31</td>
<td>0.52</td>
</tr>
<tr>
<td>Margalef</td>
<td>2.71</td>
<td>3.18</td>
<td>2.02</td>
</tr>
</tbody>
</table>

Table 2. Sediment Characteristics in the intertidal levels.

<table>
<thead>
<tr>
<th>Sediment Parameters</th>
<th>Station 1</th>
<th>Station 2</th>
<th>Station 3</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Low</td>
<td>Mid</td>
<td>High</td>
</tr>
<tr>
<td>Organic Carbon</td>
<td>0.27</td>
<td>0.26</td>
<td>0.25</td>
</tr>
<tr>
<td>Salinity</td>
<td>12.97</td>
<td>12.7</td>
<td>12.5</td>
</tr>
<tr>
<td>Conductivity</td>
<td>21.6</td>
<td>17.5</td>
<td>7.53</td>
</tr>
<tr>
<td>% Clay</td>
<td>27.33</td>
<td>8.33</td>
<td>14</td>
</tr>
<tr>
<td>% Silt</td>
<td>18.67</td>
<td>13.67</td>
<td>7.67</td>
</tr>
<tr>
<td>% Sand</td>
<td>54</td>
<td>78</td>
<td>78.33</td>
</tr>
</tbody>
</table>

Figure 4. Spatial variation of mean grain size in the various levels of the intertidal zone.

3.3 Cluster analysis

The hierarchical clustering routine produces a ‘dendrogram’ showing how data points (rows) can be clustered. The % similarity of taxa between samples is high. The cluster analysis using Bray-Curtis Analysis single link showed two major joins revealing how the taxa composition in the sites resemble each other (Fig. 5).

Table 3. Multi-way Analysis of Variance of diversity indices values of the three stations and three intertidal levels in Elechi Creek.

<table>
<thead>
<tr>
<th>Source</th>
<th>Margalef</th>
<th>Evenness</th>
<th>Shannon</th>
<th>P-Value</th>
<th>Abundance</th>
<th>Taxa Composition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Station</td>
<td>0.089</td>
<td>0.577</td>
<td>0.355</td>
<td>0.926</td>
<td>0.625</td>
<td>0.227</td>
</tr>
<tr>
<td>Level</td>
<td>0.288</td>
<td>0.146</td>
<td>0.782</td>
<td>0.419</td>
<td>0.606</td>
<td>0.360</td>
</tr>
<tr>
<td>Station*Level</td>
<td>0.291</td>
<td>0.332</td>
<td>0.771</td>
<td>0.857</td>
<td>0.488</td>
<td>0.350</td>
</tr>
</tbody>
</table>
4. DISCUSSION

4.1 Species abundance and composition in the intertidal zones

Several factors have been proposed to regulate infaunal densities in mangrove sediments: physical forces, competition with epifauna, predation by epifauna, poor quality of food and chemical defense by mangroves [25]. These factors could also account for the differences in spatial distribution and species composition found along the transect. The middle intertidal zone recorded the highest abundance and species composition in Elechi creek. A total of twenty seven taxa belonging to twenty one families, six classes, and five phyla in her study of Andoni flats of Niger Delta. Umeozor [27] recorded twenty three species in the Bonny River; while Sikoki and Zabbey [28] identified fourteen species representing eleven families of macro invertebrates in Imo River.

This report varied from previous findings [29-30]. Hart [29] reported forty-three species from mangrove swamp of Port Harcourt area of the Niger Delta while George et al. [30] in their study of Okpoka Creek, reported nineteen species belonging to twelve families, six classes and four phyla. The high number reported by Hart [29] may be due to lesser impact of anthropogenic activity at that time while few taxa recorded [30] may be due to heavy pollution of Okpoka Creek which is evident in the dominance of polychaetes. The dominance of polychaetes in the area can be attributed to their high level of pollution- tolerance. This assertion is in agreement with previous observations [31, 32].

This study showed that invertebrate phyla (99.97%) dominated the benthic community. The invertebrate phyla were made up of bivalves (5.19% abundance), gastropods (5.87% abundance), arthropoda (19.85% abundance), oligochaeta (0.18% abundance) and polychaeta (68.87% abundance). These findings are in agreement with previous reports on the species composition of benthic community in the Niger Delta. George et al. [30] reported dominance of Polychaeta (82.8%), Bivalvia (4.6%), Crustacea (4.5%), and Oligochaeta (3.9%), Gastropoda (2.1%) and Insecta (2.0%). Ombu [33] in his report, Polychaeta was the highest in species richness with 68.78% followed by Oligochaetes and Crustacea with 6.5% each. Zabbey [17] also had similar results for Woji creek in the upper reaches of Bonny River. The report by Hart [29] was different. He reported the predominance of crustaceans, polychaetes, and gastropods, while Nwadiaro [34] recorded a dominance of crustaceans and insects followed by molluscs and annelids in a lower Niger Delta river.

4.2 Spatial variation of species richness, evenness, abundance, composition, dominance and diversity within the intertidal zones of Elechi Creek

Analysis of variance (ANOVA) for the indices of
Margalef, Evenness, Shannon and Simpson, Abundance and Taxa composition between different levels and sampling stations indicated no significant differences (p>0.05). This is similar to the report of [35] in their study of higher macrobenthic infaunal taxa of mangrove mud flats at Khamir Port. In their study, analysis of variance for the indices of Shannon and Simpson between different season and sampling stations indicated no significant differences (p < 0.05).

Species richness at the mouth of the Elechi Creek (Station 1) was relatively higher than other stations (although not statistically significant). This is similar to the report of Snowden and [36], although their study was conducted over a higher range of salinities. Whereby the decline in species richness from the mouth inwards was attributed to the reduction in stenohaline species. The decreased substrate diversity in the progression from the sand of the lower reaches to the mud of the middle reaches could also lead to lower abundance values [37-38]. There were significant differences in the proportions of sediment particle size (parentage clay, silt and sand) at the different stations. This is presumed to have contributed to the spatial differences observed. However, no significant correlations were found between Margalef richness index and any of the sediment particle fractions when all data were combined; some correlations were significant when considered on a site by site basis.

CONCLUSION

Elechi Creek was predominantly sandy. The temperature was fairly uniform across the creek with low salinity gradient. The dissolved oxygen and biological oxygen demand in the creek was high enough to support aquatic life. The dominance of polychaetes in the area can be attributed to their high level of pollution-tolerance. There was no significant variation of diversity indices across stations and levels of the intertidal zones (p>0.05). This is probably because of the relative uniformity in the prevailing environmental conditions in the creek. This also suggests that the effect of anthropogenic activities on benthic community in the creek is fairly uniform. The overall differences observed in the abundance, diversity and species richness in Low, Middle and High intertidal levels may be due to the slight variations in the physico-chemical and sediment quality of the various levels of the intertidal zone. Bray-Curtis cluster analysis revealed that the percentage similarities between samples were very high.

REFERENCES