Factors Affecting Macrobenthic Invertebrates Distribution in Badagry Creek, South Western Nigeria

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Authors’ contributions

This work was carried out in collaboration between both authors. Author OAO performed the statistical analysis, interpreted the analysed result, managed the literature searches and wrote the final manuscript. Author CAE designed the study and wrote the first draft of the manuscript. Both authors read and approved the final manuscript.

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ABSTRACT

The aim of the paper is to identify macroinvertebrates distribution in response to induced stressors and physico-chemical parameters of water and sediment. The species composition of macrobenthic invertebrates as well as the physico-chemical characteristics of Badagry creek was investigated monthly. Six sampling stations selected based on different levels of human activities along the creeks stretch and samples were collected monthly from September 2006 to February 2007. The fluctuations of some of the physical and chemical parameters such as pH, dissolved oxygen, BOD and total organic carbon appeared to have been influenced by activities along the study stretch. Analysis of variance (ANOVA) for all parameters showed no significant differences (P > 0.05) in the parameters but Post hoc tests analysis using Duncan showed that there was a significant difference (P = 0.05) in the mean total of some of the parameters. pH, clay, sand and gravel were significantly correlated with other parameters while canonical correspondence analysis

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(CCA) model showed that the environmental variables correlated with significant part of the variations in the individual species abundance and it revealed that dominant species were found to be significantly correlated with dissolved oxygen, total dissolved solids, sand and pH.

Keywords: Badagry creek; environmental variables; macrobenthic invertebrates; sediment.

1. INTRODUCTION

Estuaries are amongst the most productive world natural habitats structured by a complex gradient of abiotic factors that regulates fauna composition, distribution and abundance [1].

Macroinvertebrates play a key role and are in part responsible for the high productivity in estuarine environments [2-5] and the common factors that determine the community composition and structure of macroinvertebrates fauna are the aquatic bottom sediment characteristics, predator exposure and food availability.

Over-time the benthic invertebrates become dominated by resilient communities that can tolerate stressful environmental conditions in the bottom sediment [1]. Once established, these resilient communities usually alter their environment through physical sediment alteration, enhancing sediment-water fluxes, increasing available area for solute exchange by reworking and bioturbation [6-9] in addition to promoting community succession, species settlement and populations persistence [10-12,9,1].

Given scanty literature on the abundance and composition of macrobenthic invertebrates of Badagry lagoon, the study aims to assess the physical, chemical and macrobenthic invertebrate characteristics of the Badagry creek perturbed by various human-induced stressors such as port related activities along the creek and waste discharges from point and non-point sources of surrounding settlements. This would help understand ecological role of benthic invertebrates in the aquatic ecosystem and establish that their relevance is essential to the proper functioning and health of the aquatic ecosystem.

2. MATERIALS AND METHODS

2.1 Study Area

Badagry creek is one of the major water bodies which pass through the Lagos port and it is highly polluted by anthropogenic activities such as dredging and fishing in the creek and its bank. It is situated on Latitude: 6° 24’ 54.07” N Longitude: 2° 52’ 52.75” E and lies between Badagry and Ajumo east of Lekki town in Nigeria. The Creek approximately equidistant from the entrances of Lagos and Cotonou harbours (Fig. 1). The creek empties into the Atlantic Ocean through the Lagos harbour and it surrounds an Island inhabited by a community of people.

The water is generally brownish in colour which may be due to the tidal influxes and domestic effluent discharges from surrounding community, dominated by floating debris principally polythene bags and heaps of domestic debris seen also along the water boundary. Artisanal fishing is the major occupation of the locals in addition to occasional bottom sediment mining in the creek which may result in the physical sediment disturbance and subsequently, the benthic community structure.

2.2 Sample Collection

Monthly sampling from September 2006 to February 2007 at depth ranged between 0.71 – 1.35 m was carried out for water, sediment and benthic samples collected between 0900h and 1200 h. Bottom water samples were collected with a water sampler and the temperature was measured using a mercury-in-glass thermometer (°C). Another one liter sample was collected in pre-washed polythene containers at each station and analysed in the Department of Chemistry laboratory, University of Lagos, for pH, total dissolved solid and conductivity using methods as described by [13]. At the time of sampling, separate water samples were collected in 250 ml glass bottles at each study stations for dissolved oxygen and biochemical oxygen demand estimation using the iodometric Winkler’s method [13]. Dissolved oxygen was measured at day zero of collection while biochemical oxygen demand was measured at day five after collection. Benthic samples were collected by taking three grab bites using a 0.1 m² van Veen grab at each study station and washed through a 0.5 mm mesh sieve in the field. The retained material was preserved in 5% formalin and kept
in labeled jars for further sorting and analysis in the laboratory according to methods described by earlier researchers [14,15]. The identification manuals used were as listed in [16] to the species level. Sub-sediment samples were collected from each station for the determination of total organic carbon content and particle size characteristics following the method of Walkley-Black chromic acid wet oxidation. 2 g of soil sample at each study location was weighed into a 250 mL conical flask and 10 mL of 1 N K₂Cr₂O₇ was added. Flask was swirled gently to disperse the soil in the solution. 20 mL of concentrated H₂SO₄ was added, swirled immediately until the soil and the reagent are mixed. A 200°C thermometer was inserted while swirling the flask and the contents on a hot plate for about 30 secs after which it was set aside to cool slowly on an asbestos sheet in a fume cupboard. Two blanks (without soil) were run in the same way to standardize the FeSO₄ solution. When cooled after 20–30 minutes, the solution was diluted to 200 mL with deionized water and titrated with FeSO₄ using 3-4 drops "ferroin" indicator. As the end point was approached, the solution takes on a greenish colour and then changes to a dark green. At this point, the ferrous sulphate was added drop-by-drop until the colour changes sharply from blue-green to reddish-grey.

The percentage of carbon is determined from the equation below:

\[
\text{Organic Carbon (\%) = Organic carbon (\%) =} \frac{3(1-T/S)}{W}
\]

Where:

\[
N = \text{Normality of } K_2Cr_2O_7 \text{ solution}
\]

\[
T = \text{Volume of } FeSO_4 \text{ used in sample titration (mL)}
\]

\[
S = \text{Volume of } FeSO_4 \text{ used in blank titration (mL)}
\]

\[
ODW = \text{Oven-dry sample weight (g)}
\]
2.3 Statistical Analysis

Hierarchical cluster analysis (Bray-Curtis dendrogram) was used to test for significant differences in the spatial density and number of macrobenthic invertebrate species among the study stations in Lagos lagoon. Macrobenthic abundance data was reported per unit area.

*Density= (nr.of Individual)/ (0.1 m² ) (grab area)*

Pearson correlation coefficient (rs) analysis was used to test for significant relationship among physico-chemical characteristics (sediment and water) recorded in Badagry creek, null hypothesis assuming equality of abundance in all six stations were tested using Chi-square (χ²) and spatial differences in the environmental variables between the study sites were tested using analysis of variance (ANOVA) using statistical package SPSS 23.0 for windows while canonical correspondence analysis (CCA) using only seven most abundant species which together contributed more than 80% were analysed with paleontological statistics (PAST version 3.14) software to explain the relationship between physico-chemical properties and species composition of the creek. The spatial a similarity of the benthic fauna among the study stations was investigated applying cluster analysis based on the Bray-Curtis similarity index of species abundance [17]. A hierarchical agglomerative dendogram was produced using similarity matrix (unweighted pair group average, UPGMA) to give a graphical representation of community relationships [18]. Routine univariate analysis of diversity indices were estimated for the Margalef’s species richness index (d), the Shannon-Wiener diversity index (H©) and Evenness was also calculated.

3. RESULTS AND DISCUSSION

3.1 Environmental Variables

The summary of the spatial variations in the physical and chemical condition of the water and sediment at the study sites is presented in Table 1. Comparison of spatial variations using Analysis of variance (ANOVA) for all parameters showed no significant differences (P > 0.05) in the parameters but Post hoc tests analysis using Duncan showed that there was significant difference (P = 0.05) in the mean depth, dissolved oxygen, total dissolved solids, and conductivity at the stations but showed no biochemical oxygen demand, total organic carbon and pH at the stations shown in Table 1.

Statistical analysis of relationship between physicochemical parameters using Pearson correlation (Table 2) showed that pH was significantly and negatively correlated with sand and gravel sediment characteristics, clay was significantly and negatively correlated with sand, silt and gravel sediment characteristics, sand was significantly and negatively correlated with silt but significantly positively correlated with gravel. Gravel was significantly and negatively correlated with silt.

3.2 Faunistic Composition

A total of 31 invertebrate taxa were collected in the Badagry creek during the study period. Table 3 lists the taxonomic categories of the macrobenthic invertebrates, the number of taxa recognised within each category with distribution and abundance per square meter (m²) at the six study stations. All families were represented by one taxon each except for Arenicolidae, Potamididae, Arcidae, Mytilidae and Mactridae that had two taxa each. Although two taxa of Mytilidae were identified, Branchyodontes puniceus accounted for 76 specimens while Mytilus perna recorded 13 specimens at station 6 only. Since the same sampling effort was used at the study stations, null hypothesis assuming equality of abundance in all six stations was tested using Chi-square (χ²) analysis (Table 3). These analyses were sub-divided to locate similarities and differences among stations. However, taxa represented by a combined total of <50 individuals at each station or those recorded only at one station were not included in these analyses.

The monthly variations in abundance and spatial distribution of the dominant taxon (Nereis indica, Neritina glabrata, Tympanolonus fuscatus, T. fuscatus var radula, Pahymelania aurita, Crassostrea gasar and Mactra glabrata) were investigated. Generally, the abundance of each taxon at the study stations was higher in the dry months than the wet months (Fig. 2) with exceptions at stations 1 and 4. Spatially, the distribution pattern of the dominant taxa families had the Potamididae as the most occurring species and the Nereidae as the least present species (Fig. 3).
Table 1. Spatial variations in the mean concentration (Mean ± SE*) of physico-chemical variables of Badagry creek water and sediment samples (Sept. 2006 – Feb. 2007)

| Parameters          | Stations | Depth (m) | Dissolved oxygen (mg/l) | Biochemical oxygen demand (mg/l) | Total dissolved solid (mg/l) | Conductivity (mS/cm) | Total organic carbon (%) | Ph     |
|---------------------|----------|-----------|-------------------------|----------------------------------|-------------------------------|----------------------|---------------------------|--------|
|                     | 1        | 1.34± 0.30* | 5.167±0.89sm            | 0.87±0.15*                       | 0.66±0.15*                   | 1.34±0.30*           | 1.11±0.49*                | 7.30± 0.39* |
|                     | 2        | 0.47± 0.22* | 5.04±0.96sm             | 0.88±0.20*                       | 0.23±0.11*                   | 0.47±0.22*           | 0.72±0.05*                | 7.18± 0.20* |
|                     | 3        | 3.48± 1.75* | 4.25±0.35s              | 0.97±0.28*                       | 1.74±0.87c                   | 3.48±1.75*           | 0.87±0.23*                | 7.48± 0.29* |
|                     | 4        | 3.34± 1.49c | 4.16±0.31s              | 0.82±0.18s                       | 1.44±0.42c                   | 3.34±1.50c           | 0.62±0.11s                | 7.35± 0.25s |
|                     | 5        | 3.28±1.77c  | 6.30±1.36sm             | 0.95±0.22s                       | 0.59±0.03s                   | 3.28±1.77c           | 0.95±0.36s                | 5.85± 1.19s |
|                     | 6        | 3.22±1.89c  | 7.17±0.63s              | 0.82±0.18s                       | 0.59±0.03s                   | 3.22±1.89c           | 0.49± 0.13s               | 7.02± 0.23s |

Means with the same superscript letter in a column are not significantly different (P >0.05) when subjected to Duncan multiple range, DMRT (ANOVA post hoc)

*SE = Standard error

Table 2. Pearson correlation coefficient (r) matrix of physicochemical characteristics of Badagry creek water and sediment samples (Sept. 2006 – Feb. 2007)

| Water temperature | Dissolved oxygen | pH | Clay | Sand | Gravel | Silt | TOC |
|-------------------|------------------|----|------|------|--------|------|-----|
| Water temperature | 1                | .290 | .022 | .045 | -.148  | -.278 | .369 |
| Dissolved oxygen  |                  | 1   | .266 | .381 | -.063  | -.033 | .040 |
| pH                |                  |     | 1    | .416 | -.490  | -.890 | -.877 |
| clay              |                  |     |      | .381 | 1      | .890  | .416 |
| sand              |                  |     |      |      | 1      | -.117 | -.107 |
| gravel            |                  |     |      |      |        | -.033 | .212 |
| silt              |                  |     |      |      |        |       | .049 |
| toc               |                  |     |      |      |        |        | .034 |

*Correlation is significant at 0.05 level (2 – tailed).
**Correlation is significant at 0.01 level (2 – tailed)
Table 3: Taxa distribution, total number and chi-square ($\chi^2$)* test analysis of macroinvertebrates in the study stretch (Sept. 2006 – Feb. 2007)

| Station 1 No of taxa | Station 2 No of taxa | Station 3 No of taxa | Station 4 No of taxa | Station 5 No of taxa | Station 6 No of taxa | Overall |
|----------------------|----------------------|----------------------|----------------------|----------------------|----------------------|---------|
| ANNELIDA             |                      |                      |                      |                      |                      |         |
| Polycheata           |                      |                      |                      |                      |                      |         |
| Nereidae             | 60                   | 130                  |                      |                      |                      |         |
| Capitellidae         | 10                   | 10                   | 10                   | 10                   | 10                   |         |
| Nephtyidae           |                      |                      |                      |                      |                      |         |
| Arenicolidae         | 10                   |                      | 10                   |                      | 20                   |         |
| Malaididae           |                      |                      |                      |                      | 10                   |         |
| MOLLUSCA             |                      |                      |                      |                      |                      |         |
| Gastropoda           |                      |                      |                      |                      |                      | 20      |
| Nassaridida          | 20                   |                      |                      |                      |                      |         |
| Neritidida           | 100                  | 220                  | 20                   | 80                   | 230                  | 710     |
| Littorinida          | 20                   |                      |                      |                      |                      | 30      |
| Melanidida           | 780a                 | 1290b                | 420c                 | 360d                 | 500e                 | 3860    |
| Potamididae          | 1760a                | 360b                 | 840c                 | 950d                 | 1880e                | 6130    |
| Naticidae            |                      |                      | 10                   |                      | 10                   |         |
| Galeolidida          | 10                   |                      |                      |                      |                      |         |
| Turritellidae        | 10                   |                      |                      |                      |                      |         |
| Bivalvia             |                      |                      |                      |                      |                      |         |
| Pharellidae          | 1                    |                      |                      |                      |                      |         |
| Arcidida             |                      |                      | 2                    | 60                   | 2                    | 910     |
| Mytilidae            |                      |                      | 10                   | 2                    | 890                  |         |
| Ostreidae            | 570a                 | 180b                 | 1000c                |                      | 250e                 | 2630    |
| Veneridae            | 10                   | 10                   | 630d                 | 1                    |                      |         |
| Pinnaidae            |                      |                      | 10                   | 80                   |                      |         |
| Macrididae           | 60a                  | 170b                 | 90c                  | 100c                 | 240d                 | 1090    |
| Aiolidae             |                      |                      |                      | 10                   | 10                   |         |
| Cardididae           |                      |                      | 10                   |                      | 10                   |         |
| Donacidae            |                      |                      | 60                   | 60                   |                      |         |
| ARTHROPODA           |                      |                      |                      |                      |                      |         |
| Crustacea            |                      |                      |                      |                      |                      |         |
| Palinuridae          | 40                   |                      |                      |                      |                      | 40      |
| Sesarmidae           | 20                   | 10                   | 40                   |                      |                      | 70      |
| Penaeid              | 50                   | 10                   |                      |                      |                      | 60      |
| Total                | 14                   | 3500                 | 2390                 | 9                    | 2430                 | 16380   |

* chi-square ($\chi^2$) test with same letter are not different at 5% level of significance
An agglomerative dendrogram of the taxa abundance using the unweighted pair group average (UPGMA) cluster analysis revealed one group at a Bray-Curtis similarity (Fig. 4). Station 2 is the station far away from the other clusters.

The first and second axes in the CCA triplot represent the most important environmental gradient along which the macrobenthic species are distributed. The direction of each environmental vector represents the maximum
rate of change for that particular environmental variable and its length indicates the relative importance of the ordination [19,20]. The significance of the primary CCA axes was estimated by a Monte Carlo permutation test (100 permutations) of the eigen values [21].

The environmental variables in the CCA are water temperature, depth, dissolved oxygen (DO), conductivity, biochemical oxygen demand (BOD), and total organic carbon (TOC) shown as radiating lines and the relative importance showed that T. fuscatus are positively correlated with the water temperature and biochemical oxygen demand at station 3, the other taxa – Pachymelania aurita, Nereis indica, Neritina glabrata, Mactra glabrata are negatively correlated with depth and total organic carbon (TOC) (Fig. 5). There is no relative relationship between the Crassostrea gasar and T. fuscatus var. radula and the environmental variables as revealed in the CCA ordination.

Fig. 4. The Group Average Agglomerate Dendrogram of Bray-Curtis similarity of Macrobenthic faunal abundance data between the six study stations using the unweighted pair group average (UPGMA) algorithms

Fig. 5. Canonical correspondence analysis (CCA) ordination plot for the abundance of macrobenthic dominant taxon environment triplot
Table 4. Diversity indices of the dominant macrobenthic invertebrate taxon during the study period Sept. 2006 – Feb 2007

| Indices       | Station 1 | Station 2 | Station 3 | Station 4 | Station 5 | Station 6 |
|--------------|-----------|-----------|-----------|-----------|-----------|-----------|
| Individuals  | 382       | 235       | 210       | 123       | 340       | 209       |
| Dominance_D  | 0.2939    | 0.3477    | 0.3138    | 0.2298    | 0.2165    | 0.1941    |
| Simpson_1-D  | 0.7061    | 0.6523    | 0.6862    | 0.7702    | 0.7835    | 0.8059    |
| Shannon_H    | 1.455     | 1.385     | 1.365     | 1.595     | 1.701     | 1.736     |
| Evenness_e^H/S| 0.6118    | 0.666     | 0.6526    | 0.821     | 0.7832    | 0.8106    |
| Equitability_J| 0.7475    | 0.7731    | 0.7618    | 0.8899    | 0.8744    | 0.8921    |

4. DISCUSSION

The chemistry of aquatic environment generally depends on the physical and geological features of the environment and some of the parameters evaluated in this study is to ascertain that the physical and chemical parameters estimated within the range of those reported for similar brackish water [22,23,24,25] in Nigeria. Conductivity and total dissolved solids fluctuated during the wet and dry months and the elevated values of these parameters in the months of the dry periods are said to be due to evaporation while the low levels of these parameters observed in the wet months are a reflection of dilution by rainfall [26]. Thirty-one invertebrate taxa recorded in this creek is low in number compared to most tropical creeks but similar to those reported for some perturbed water bodies of similar environmental conditions [27-30] and each of the higher taxonomic group recorded with the exception of five families Potamididae, Arenicolidae, Arcidae, Mactridae and Mytilidae) were represented by one taxon only. The Shannon Wiener diversity during the period of study is low which suggests that the Badagry creek is a system controlled mainly by anthropogenic influences [31,32]. Only few species are capable of tolerating the environmental stress of frequent anthropogenic input through surface run off or direct/indirect discharges of various pollutants which probably explains the poor fauna diversity and low abundance of benthic invertebrates recorded during the study period (Table 4).

The dominance of mollusc species in the brackish water bodies of the coastal Lagos state of Nigeria has been documented [33,31] and the faunal dynamics of macrobenthos generally follows patterns characterised by high variability in abundance and dominance pattern over time [34]. In the Badagry creek, the recorded spatial and monthly variability in addition to the station similarities suggests that a few dominant macrobenthic species which were distributed throughout the study area controlled the community structure and similar trend was reported for Kaita lagoon in Ghana [17]. The individual discriminating taxon notably the oyster, Crassostrea gasar, and the periwinkle, T. fuscatus var. radula and Pachymelania aurita were responsible for the spatial variability.

The distribution pattern of the dominant taxa families appeared to have a different density distribution among faunal groups it seems a normal phenomenon while the dominant species appears to be redistributed in response to fluctuations in environmental variables. This observation is in consonance with data reported by other researchers who observed that a number of environmental variables (e.g. organic matter content, pH, temperature, depth, dissolved oxygen, salinity and nutrient concentration) are correlated with the abundance, density and diversity of macrobenthic organisms in coastal waters [34,30].

As indicated by the CCA ordination, the environmental variables are correlated with significant part of the variations in the individual species abundance. Dominant species were found to be significantly correlated with the environmental variables with the exception of the Crassostrea gasar and T. fuscatus var. radula which show no relative relationship with the environmental variables. T. fuscatus var. radula has been reported to inhabit shallow mangrove mudflats and usually co-exists with species such as T.fuscatus and Pachymelania species in the Nigerian brackish water. The relationship of the periwinkles – T. fuscatus with water depth at the Badagry creek supports earlier reports [33,30] of these species preference for shallow waters. Other specific correlation includes Mactra...
**glabrata** with sand sediment characteristics and this correlates with the reports of [17] for Kaita lagoon.

### 5. CONCLUSION

Changes in community structure and distribution of macrobenthic organisms are influenced largely by a suite of environmental variables and anthropogenic impacts causing the observed species to respond differently. These changes were associated with the reduction in biodiversity, alteration in macrobenthic fauna abundance in the study area and analysis in this study suggests that these changes are in response to chemical parameters. Therefore, the continual influence of pollution in the study area would affect the macrobenthic fauna production which would in turn, affect the production of commercially important demersal fish which for most of their life take their food predominantly from the benthic communities.

### COMPETING INTERESTS

Authors have declared that no competing interests exist.

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