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# Stochastic evaluation of benthic biocoenosis as pollution assessment tool in a perturbed aquatic ecosystem

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## Abstract

To analyse the extent of disturbances and determine the state of health of aquatic systems, the integration of several biological effects at different levels of biological organization has been used. One of the most valuable methods of biological effect measurements is the use of ecological surveys at community and population levels. In this study, the distributional evaluation of benthic biocoenosis was undertaken to determine site-specific differences in community assemblage in relation to environmental status of the study sites. Three study locations (Okobaba, Iddo and Tin Can Island) in the western side of the Lagos Lagoon with highest concentrations of human activities were selected. These sites represent areas directly affected by major anthropogenic discharge into the Lagos Lagoon. Samples were collected for six consecutive months (March and August 2014). There was great variation in parameters investigated among the study sites. The concentrations of dissolved oxygen in surface water varied from 3.0- 4.5 mg/L. Chlorophyll a in surface water fluctuated from 0.12- 2.01 mg/L whereas, in sediment values varied from 0.14-1.32 mg/g. Biomass of microphytobenthos (MPB) varied from 1.4-13.2 g. Of the total 841 MPB cells collected the highest population was recorded in Okobaba. Twelve MPB taxa were recorded in the study area. The most important species in terms of numerical abundance was *Oscillatoria* sp. This organism occurred in all the study stations and recorded a total of 113 cells in the study stretch. A major feature of the population distribution of the MPB taxa in this study is the occurrence of higher number of cells at Okobaba. The number of individuals and the distribution of BMF taxa varied greatly from one study location to another. Of the total 801 individuals collected, 398 were recorded at Okobaba, 316 occurred at Tin Can Island and 18 at Iddo. Unlike the case of MPB organisms, a fewer number of BMF taxa were recorded in the study area. The most important MBF taxon in terms of numerical abundance was *Pachymelania aurita*. This organism occurred in all the study sites and recorded a total of 162 individuals thereby constituting 20% of the total MBF population collected. The benthic community observed in this study was characterized by low number of individuals and the species of MPB and MBF recorded are known opportunistic species common in stressed environments.

**Keywords: benthic, biocoenosis, pollution, lagoon, ecosystem**

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## INTRODUCTION

In order to analyse the extent of disturbances and to quantify the state of health of aquatic systems, the integration of several biological effects at different levels of biological organisation has been suggested by several authors (Rosenberg and Resh, 1993). Biological effect measurements incorporate three main approaches: (i) biomarker studies at molecular, cellular and tissue level; (ii) bioassay studies at whole organism level; and (iii) ecological surveys at community and population level (Rosenberg and Resh, 1993). In the coastal environment, ecological processes interact across land and sea to create complex dynamic spatial patterns in physical, chemical, biological, and socioeconomic attributes. The biological components (e.g., species composition and distribution) of coastal ecosystems provide the environmental template on which the impact of human activities can be assessed. The differences in the degree of impact results in ecosystem heterogeneity and this means that some places will be more productive, more diverse, more stable, more commercially valuable, more susceptible to climate change, or more resilient than other areas (Walter, 2002). The widespread recognition that coastal environments are spatially heterogeneous and are being adversely impacted by multiple stressors, many of which are directly related to human activity, has reinforced the need for coordinated efforts to effectively monitor, assess, and judiciously manage ecosystems within a spatial framework (Rosenberg and Resh, 1993; Walter, 2002).

Benthic organisms with little or no mobility have been widely used in aquatic environmental impact assessment and monitoring (Rosenberg and Resh, 1993). As a matter of fact, they are sensitive sensors of physical and chemical changes undergone by aquatic systems in general and benthic systems in particular (Bolam *et al*., 2002). They are closely associated with the floor of aquatic systems, hence can hardly avoid deteriorated conditions of water or sediment. Furthermore, they have relatively long-life cycles and exhibit different stress tolerance (Beukema *et al*., 1999). According to their response to stress, species can be divided into sensitive species (able to only survive within a narrow range of environmental conditions and disappear from polluted areas); tolerant species (being not sensitive to a particular stress and/or pollution); opportunistic species (able to quickly exploit new recourses or ecological niches as they become available, characterized by early reproduction, high reproduction rates, rapid development, small body size, and an uncertain adult survival rate), and indifferent species (without real affinity for any particular community and showing no response to pollution) (Babcock *et al*. 1999).

In addition, benthic bioceonosis are known to be bioindicators of the ecological state of water bodies (Bremner *et al*., 2003). Bioindication of aquatic systems based on the species composition and quantitative characteristics of benthic biocoenosis has long been recognised. It is particularly important to consider changes in their assemblage, distributional, morphological, floristic, quantitative and production characteristics for assessing the quality of any water body and for predicting such negative phenomena as defaunation, algal blooms and red tides (Beukema *et al*., 1999; Bremner *et al*., 2003).

Most academic literature reports on the Lagos Lagoon system centre on the rising concentration of pollutants and the degraded ecological health of the lagoon. These reports (including Ajao and Fagade, 1991; Brown and Oyenekan, 1998; Uwadiae, 2014; 2016;2017) relied majorly on chemical measurements in drawing inferences about the environmental status of the lagoon. This, to most ecologists does not present the full picture of environmental conditions especially as it relates to pollution conditions of the lagoon. In this present study, the distributional evaluation of benthic biocoenosis was undertaken to determine site specific differences in community assemblage in relation to environmental variables.

## MATERIALS AND METHODS

### Study Location

Three study locations (Okobaba, Iddo and Tin Can Island) in the western side of the Lagos Lagoon with highest concentrations of human activities (Fig. 1) were selected for this study. The study sites represent areas directly affected by major anthropogenic discharge into the Lagos Lagoon. Generally, the study area was characterized by surface oil films on the water surface indicating chronically or intermittently accidental spills or seepage. The sediments in this area were very fine, muddy or dark in appearance and rich in organic compounds. Careful examination of surface undisturbed sediment samples reveals a grey-green layer of easily resuspended substances. Below the sediment surface were black patches which indicate evidence of local deoxidization (Danovaro *et al*, 1993; Fabiano and Danovaro, 1994; Buscail *et al*., 1995). Station 1 was at Okobaba **(**$6^o34'24''$N and $3^o31'52''$E), this part of the lagoon is known for the deposition of wood waste which is indiscriminately released into the lagoon. Station 2 was located at the Iddo **(**$6^o47'36''$N and $3^o27'29''$E) area of the lagoon, which is a sewage dump site. Station 3 was at the Tin Can Island Port slightly adjacent the Lagos Harbour ($6^o52'19''$N and $3^o43'41''$E), pollutants here include oil and related products from shipping and associated human activities (Uwadiae, 2016).

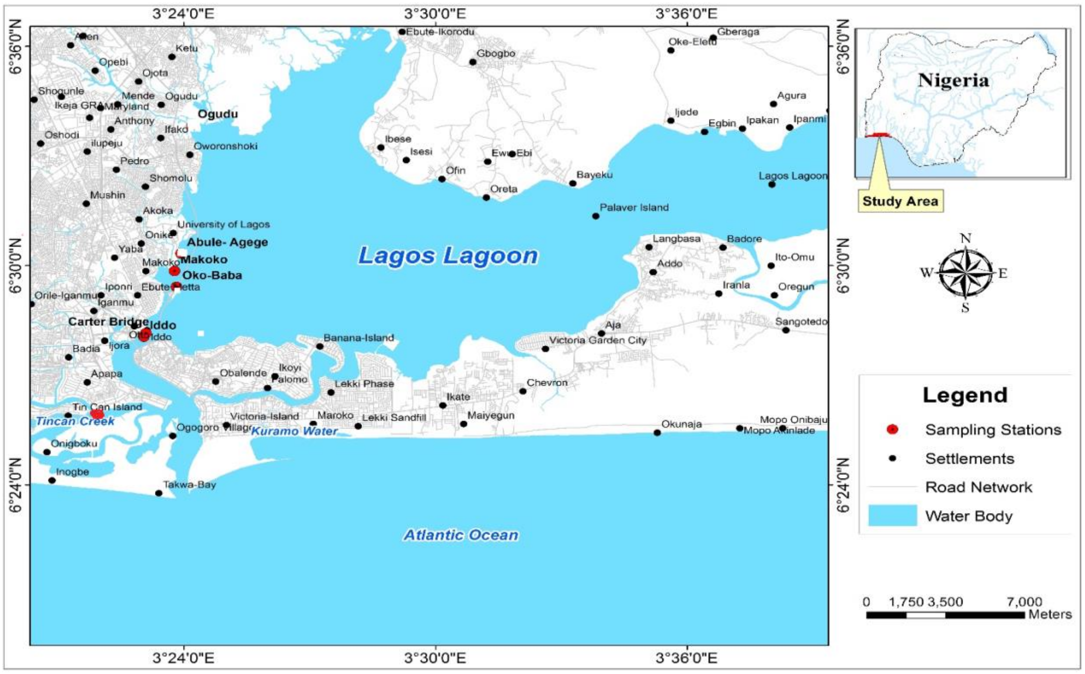



Fig. 1. Lagos Lagoon showing the study stations.

**Collection of samples**

**Water**

Water samples for the analysis of Dissolved Oxygen (DO) was collected with 250 ml prewashed reagent bottles and fixed with 1ml each of Winkler's solutions A and B (APHA 1985). Chlorophyll-*a* (Chl a) was collected using a phytoplankton net dragged along the surface of the water for 5 minutes when the boat was in a slightly reduced motion. The samples were carefully emptied into a properly labeled phytoplankton sample container and transported to the laboratory in a cooler.

**Sediment**

Sediment samples were collected using locally fabricated van Veen grab of size 0.1 $m^2$ from each sampling point. The top 5 cm layer of each haul was collected and placed in a labelled polythene bag. The samples were preserved in the deep freezer before analysis in the laboratory.

**Microphytobenthos (MPB)**

Micrphytobenthos samples were collected from the surface layer of the sediment-water interface by scooping the upper few centimetres of the sediment after successful deployment and retrieval of van Veen grab of 0.1 $m^2$ in area. The collected samples were then placed in washed transparent plastic containers and pre-filtered water from the sampling station added and the sample gently stirred to allow the water to properly mix with the collected sediment. The samples were then transported to the laboratory for further processing.

**Benthic macrofauna (BMF) samples**

Three grab hauls were taken from each station, using 0.1 $m^2$ van Veen grab from an anchored boat with an out-board engine. The collected material was washed through a 0.5 mm mesh sieve in the field. The residue in the sieve was preserved in 10% formalin solution and kept in labelled plastic containers for further analyses in the laboratory.

### Laboratory Analyses

### Environmental Variables

Total organic matter (TOM) in water and sediment samples was analysed according to methods described in Buchanan and Longbottom (1970), and Buchanan (1984). Dissolved oxygen in surface water samples was determined according to the methods described in APHA (1985). Chlorophyll samples were filtered through Whatman glass-fibre filter and extracted with acetone in the dark and under refrigeration (Holm-Hansen, 1978; Whitney and Darley, 1979; Wright *et al*., 1991; Daemen, 1986). Chlorophyll-*a* was determined fluorometrically.

### Micrphytobenthos (MPB)

Micrphytobenthos samples were exposed to light for an approximate period of 24 hrs to enhance the migration of the organisms to the surface water above the sediment. The water was then decanted into a clean container and fixed with 4% formaldehyde. The decanted subsamples were examined under the microscope and MPB cells identified, counted and recorded for each sampling station throughout the study period with the aid of different identification guides (Round, 1971; Parsons *et al*, 1984). Confirmation was made using internet-based global authoritative taxonomic information "the Integrated Taxonomic Information System (ITIS) of North America and the world" (Encyclopedia of life (2017). The number of cells and species belonging to the different groups were recorded.

### Benthic macrofauna samples

Preserved macroinvertebrate samples were washed with tap water to remove the preservative and remaining sediment particles in order to facilitate easy sorting. The animals were sorted on a white tray and the identity of individual specimen confirmed using suitable texts such as Edmunds (1978) and Yankson and Kendall (2001). The number of species and individuals for each station were counted and recorded.

### Statistical analysis

Data on environmental parameters and biotic variables were subjected to statistical analyses to determine the mean, minimum and maximum values. The extent of deviation from the mean was also computed using standard deviation. Relationships between and among environmental parameters and biotic variables were determined using Spearman Rank Correlations (Sokal and Rohlf, 1995). All statistical analyses were performed with SPSS 10.

## RESULTS

### Environmental variables

Summary of environmental variables at the study sites is presented in Table 1. Overall trends in variables investigated did not depict any discernable pattern for study sites. The concentrations of dissolved oxygen in surface water varied between 3.0 and 4.5 mg/L. Total organic matter varied from 51 to 69% in surface water and, between 97 and 100% in sediments, while Chl a fluctuated between 0.12 and 2.01 mg/L in surface water and from 0.14 to 1.32 mg/g in sediment. Mean and standard deviation values of Chl a in water for the study stations were 0.75±0.50 for Okobaba, 0.82±0.6 for Iddo and 0.84±0.36 for Tin Can Island, while in sediment, 0.55±0.29 for Okobaba, 0.92±0.15 for Iddo and 0.74±0.39 for Tin Can Island were observed. Biomass of MPB also varied at sampling locations with highest value (13.2 g) occurring at Tin Can Island and the lowest value (1.4 g) observed at Okobaba. The highest mean biomass value of MPB was recorded at Iddo.

### Microphytobenthos community

The summary of the abundance and distribution of collected taxa from the study area is presented in Table 2. All the taxa displayed highly variable number of individuals across the stations (Fig. 2). Of the total 841 cells collected, 369 were recorded in Okobaba (44%), 256 occurred in Tin Can Island (33%) and 216 in Iddo (23%) as shown in Fig. 3. A total twelve MPB taxa (Table 2) were recorded in the study area. The most important species in terms of numerical abundance was *Oscillatoria* sp (Fig. 4). This organism occurred in all the study stations and recorded a total of 113 cells in the study stretch. It was represented by 46 cells in Iddo, 34 cells in Tin Can Island and 33 in Okobaba. *Coscinodiscus centrales* was another MPB species of numerical importance in the area of study. It was represented by 102 cells distributed in the three stations as follows; 62 in Okobaba, 39 in Tin Can Island and one cell in Iddo. *Synedra crystellina* was also important numerically ninety-eight cells of the species were observed in the three study locations, 52 were found in Okobaba, 19 occurred at Tin Can Island and 17 at Iddo. *Navicula bicapitata* had its highest (62) representation at Okobaba and lowest (9) number of cells at Iddo. Another important contributor to the microphytobenthic population was *Nitzchia* sp which recorded 79 individual cells represented by 41, 29 and 9 cells at Okobaba, Tin Can Island and Iddo respectively. *Cyclotella* sp was also an important component of MPB population in the area investigated. *Gyrosigma balticum* was represented by 64 cells in the area. Its highest population (26) occurred at Okobaba and the least number of cells was observed at Iddo. *Lyngba limmetica* had its highest (48) representation at Iddo and lowest (2) at Okobaba. This organism recorded a total of 57 cells in the study stretch. Other MPB taxa encountered during this investigation were *Phacus pavula* (A total of 51 cells; highest population at Iddo and lowest at Okobaba), *Pluerosigma* sp (A total of 44 cells, highest population at Okobaba and Iddo), *Synedra ulna* (A total population of 41 cells, highest population at Tincan Island and lowest at Iddo) and *Paralia sulcata* (A total of 23 cells, highest population at Okobaba). The organism was not recorded at Iddo. A major feature of the population distribution of the MPB taxa recorded in this study is the occurrence of higher number of cells of most of the organisms at Okobaba (Figure 4).

Table 1. Summary of environmental variables investigated at the study locations

| Parameter | Sampling Sites | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | Okobaba | | | Iddo | | | Tin Can Island | | |
| | Min | Max | Mean ±SD | Min | Max | Mean ±SD | Min | Max | Mean ±SD |
| Total organic matter in water **(%)** | 60.0 | 67.0 | 64±0.54 | 51 | 69.0 | 57±0.67 | 65 | 66.00 | 61±0.81 |
| Total organic matter in sediment **(%)** | 97.0 | 98.0 | 97±0.56 | 99.0 | 100 | 99±0.34 | 97 | 99.00 | 98±0.92 |
| Dissolved oxygen (DO) mg/L | 3.40 | 4.5 | 3.83±0.42 | 3.00 | 4.00 | 3.42 ±34 | 3.1 | 4.30 | 3.4 ±0.50 |
| Chlorophyll a in water (mg/L) | 0.32 | 92.0 | 0.75±0.50 | 0.46 | 2.01 | 0.82±0.60 | 0.12 | 1.13 | 0.84±0.36 |
| Chlorophyll *a* in sediment (mg/g) | 0.14 | 0.91 | 0.55±0.29 | 0.76 | 1.21 | 0.92±0.15 | 0.35 | 1.32 | 0.74±0.39 |
| Biomass of MPB in sediment (g) | 1.40 | 9.10 | 5.33±2.99 | 7.6 | 12.1 | 9.15±1.53 | 3.5 | 13.20 | 7.75±4.00 |

Table 2. Summary of MPB taxa populations at the study locations

| MPB Taxa | Study locations | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | Okobaba | | | Iddo | | | Tin Can Island | | |
| | Min | Max | Mean ±SD | Min | Max | Mean ±SD | Min | Max | Mean ±SD |
| Bacillariophyceae | | | | | | | | | |
| *Navicula bicapitata* | 2.0 | 25 | 10.3±8.0 | 0.0 | 3.0 | 1.5±1.6 | 2.0 | 8.0 | 4.0±3.3 |
| *Nitzchia* sp | 1.0 | 15 | 7.0±5.2 | 3.0 | 6.0 | 1.5±2.5 | 2.0 | 8.0 | 4.8±3.3 |
| *Cyclotella* sp | 3.0 | 13 | 5.8±4.8 | 3.0 | 5.0 | 1.7±2.1 | 2.0 | 10 | 4.8±3.8 |
| *Synedra ulna* | 3.0 | 7.0 | 2.5±3.0 | 2.0 | 5.0 | 1.7±2.1 | 1.0 | 5.0 | 2.7±2.1 |
| *Gyrosigma balticum* | 1.0 | 9.0 | 4.3±3.7 | 2.0 | 7.0 | 2.3±3.0 | 2.0 | 9.0 | 4.0±3.2 |
| *Pluerosigma* sp | 2.0 | 9.0 | 3.2±3.4 | 5.0 | 9.0 | 3.2±3.7 | 1.0 | 5.0 | 1.0±2.0 |
| *Coscinodiscus centrales* | 2.0 | 23 | 10.3±9.3 | 0.0 | 1.0 | 0.17±0.4 | 3.0 | 14 | 6.5±5.0 |
| *Paralia sulcata* | 1.0 | 8.0 | 2.7±3.2 | - | - | - | 0.0 | 7.0 | 1.2±2.8 |
| Cyanophyceae | | | | | | | | | |
| *Lyngba limmetica* | 0.0 | 2.0 | 0.33±0.81 | 4.0 | 14 | 7.2±4.9 | 2.0 | 7.0 | 2.0±2.8 |
| *Oscillatoria* sp | 1.0 | 13 | 5.5±5.5 | 2.0 | 18 | 7.7±6.5 | 2.0 | 10 | 5.7±2.7 |
| Euglenophyceae | | | | | | | | | |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| *Phacus pavula* | 1.0 | 5.0 | 1.0±2.0 | 2.0 | 15 | 6.3±5.2 | 1.0 | 3.0 | 1.2±1.5 |
| *Synedra crystellina* | 2.0 | 18 | 8.7±6.1 | 2.0 | 7.0 | 6.2±2.7 | 1.0 | 10 | 4.8±4.4 |

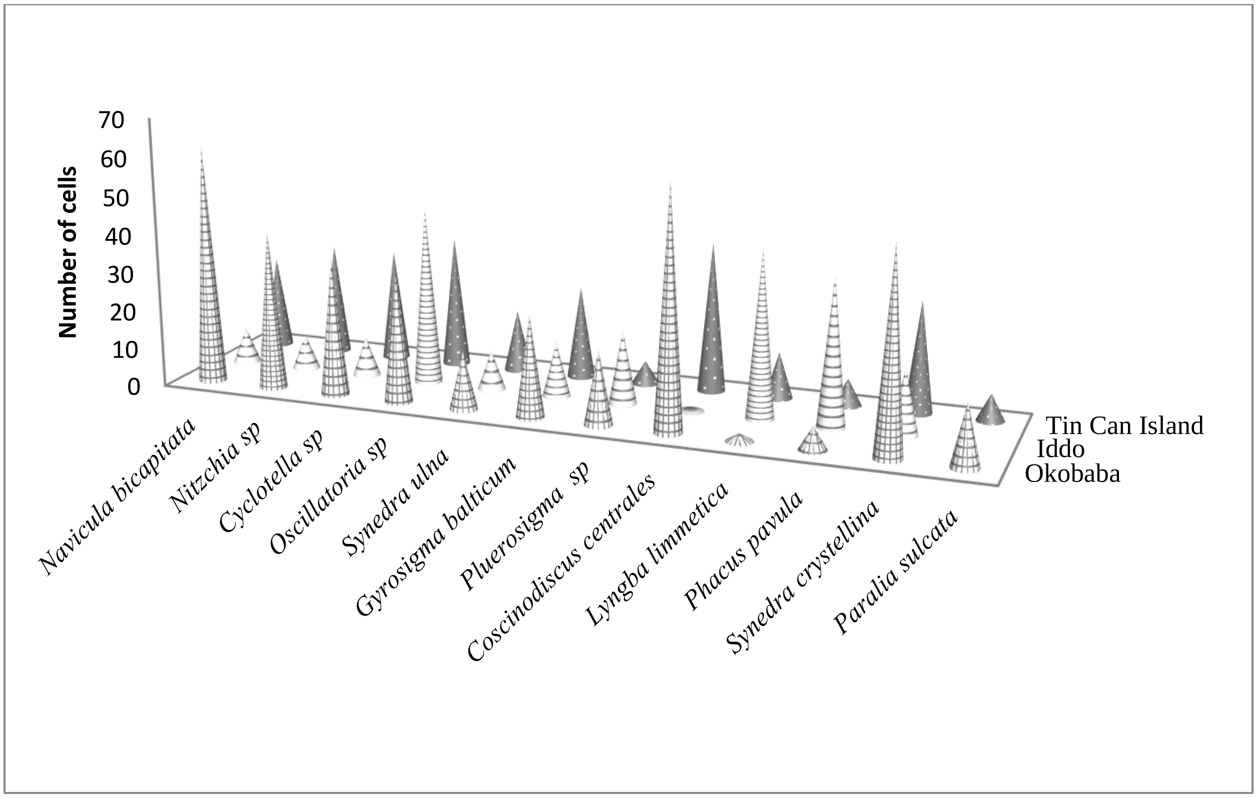
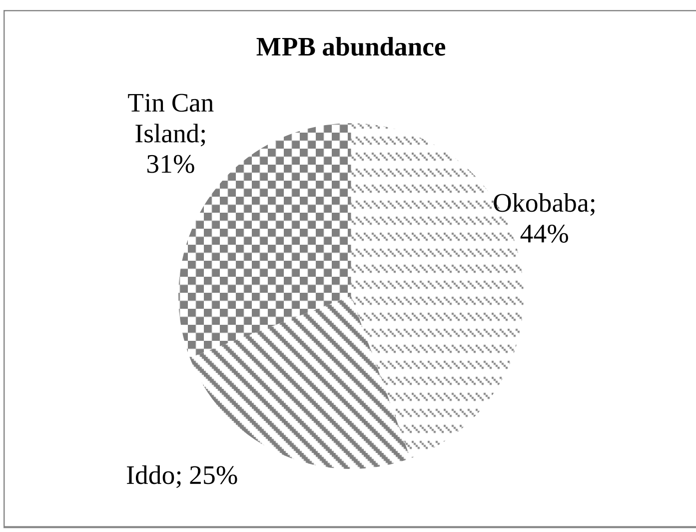



Fig. 2. Abundance and distribution of MPB taxa at the study locations




Fig, 3. Representation of MPB population in the study area

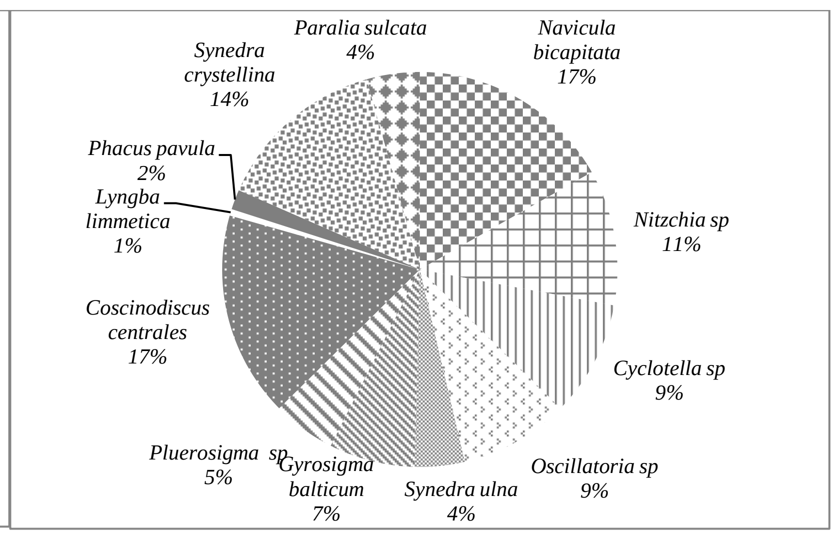



Fig. 4. Relative contribution of the different taxa to the overall MPB population

**Benthic macrofauna community**

The summary of the abundance and distribution of BMF taxa collected from the study area is presented in Table 3. The number of individuals and the distribution of BMF taxa recorded during this study varied greatly from one study location to another (Fig. 5). Of the total 801 individuals collected, 398 (50% of the population) were recorded at Okobaba, 316(39% of the population) occurred at Tin Can Island and 18 (11% of the population) at Iddo (Fig. 6). Unlike the case with MPB organisms, a fewer number (11) of BMF taxa (Table 3) were recorded in the study area. The most important MBF taxon in terms of numerical abundance was *Pachymelania aurita* (Fig. 7). This organism occurred in all the study stations and recorded a total of 162 individuals thereby constituting 20% of the total MBF population collected. The organism was represented by 92 individuals at Okbaba, 51 individuals at Tin Can Island and 19 individuals at Iddo (Fig.). Next to *P. aurita* in terms of numerical significance was the bivalve, *Tellina nymphalis*. This species was represented by 99 individuals, which constituted 12% of the entire BMF population. The highest population (43) of the organism was recorded at Tin Can Island, while 41 individuals occurred at Okobaba, and 15 at Iddo. *Tympanotonus fuscatus* was also significantly recorded in this study. The organism constituted 11% of the entire BMF population. This gastropod occurred in the following order: 51 individuals at Okobaba, 27 at Tin Can Island and 13 at Iddo. Also of significant representation are two species of polychaete Annelid: *Nereis succinea* and *N. diversicolor.* The two organisms were closely related in terms of the number of individuals represented in the study stretch. Both organisms recorded their highest occurrences at Tin Can Island and lowest numbers of at Iddo. *Nereis succinea* accounted for 11% (84 individuals) while, *N. diversicolor* recorded 82 individuals which accounted for 10% of the BMF population. *Neritina senegalensis,* a gastropod was represented by 79 individuals constituting about 10% of the total BMF count. Its highest (42) congregation individuals were recorded at Okobaba while the lowest was found at Tin Can Island. The organism was represented at Iddo by two individuals. The bivalve *Macoma cumana* had 74 individual representation constituting approximately 9% of the total BMF population. Its highest (37) representation occurred at Okobaba and lowest (9) was recorded at Iddo. Other BMF taxa encountered in this study were *Nereis* sp. (60 individuals), *Tympanotonus fuscatus* var *radula* (51 individuals) and *N. lamellose* (20 individuals).

Table 3. Summary of the abundance and distribution of BMF taxa from the three study stations

| Name of species | Okobaba | | | Iddo | | | Tin Can Island | | |
|---|---|---|---|---|---|---|---|---|---|
| | Min | Max | Mean ±SD | Min | Max | Mean ±SD | Min | Max | Mean ±SD |
| *Pachyrnelania aurita* | 2 | 28 | 15.33±8.30 | 3 | 7 | 3.1±2.80 | 5 | 12 | 8.5±2.40 |
| *Tympanotomus fuscatus* | 2 | 14 | 8.33±4.10 | 2 | 4 | 2.1±1.80 | 1 | 8 | 4.5±3.30 |
| *Tympanotomus fuscatus var radula* | 1 | 15 | 4.7±5.80 | 0 | 4 | 0.7±1.60 | 1 | 7 | 3.2±3.10 |
| *Neritina senegalensis* | 6 | 13 | 7±4.38 | 0 | 2 | 0.33±0.80 | 1 | 17 | 5.8±6.80 |
| *Macoma Cumana* | 2 | 12 | 5±3.60 | 1 | 5 | 1.33±1.20 | 1 | 8 | 4.5±3.30 |
| *Tellina nymphalis* | 1 | 3 | 1.1±1.50 | 0 | 1 | 0.17±0.41 | 0 | 1 | 0.17±0.40 |
| *Aloides trigina* | 3 | 14 | 6.8±6.60 | 5 | 10 | 2.5±4.18 | 3 | 12 | 7.2±3.30 |
| *Nereis diversicolor* | 3 | 10 | 6.5±2.70 | 4 | 7 | 1.83±2.90 | 1 | 12 | 5.3±3.70 |
| *Nereis succinea* | 2 | 8 | 4.7±2.30 | 0 | 1 | 0.17±0.41 | 3 | 19 | 9.2±5.50 |
| *Nereis* sp. | 1 | 12 | 6.5±3.70 | 4 | 7 | 1.83±2.90 | 4 | 6 | 1.7±2.70 |
| *Nereis lamellose* | 0 | 2 | 0.33±0.80 | 0 | 2 | 0.33±0.80 | 3 | 13 | 2.7±5.20 |

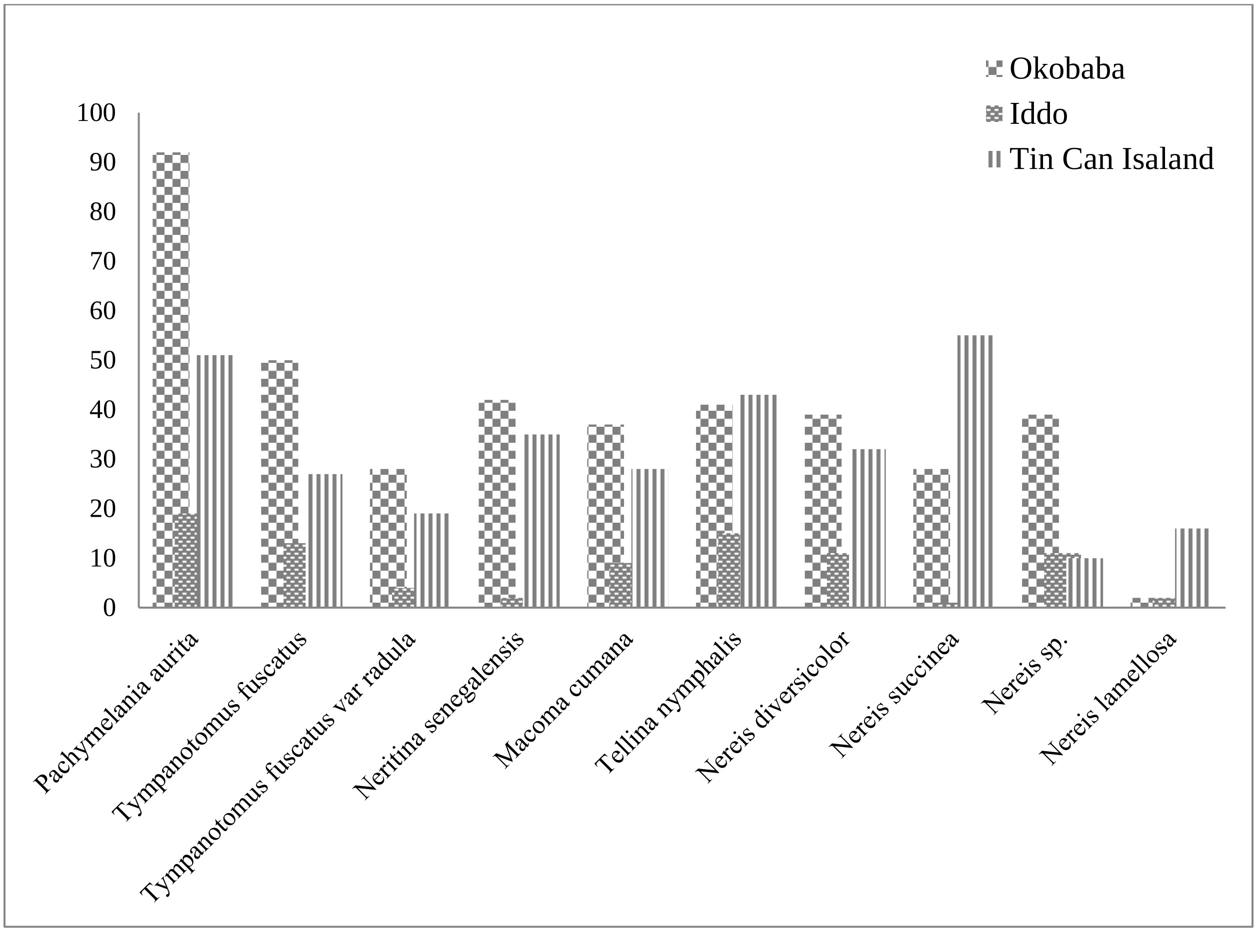



Fig. 5. Abundance and distribution of MBF taxa at the study locations

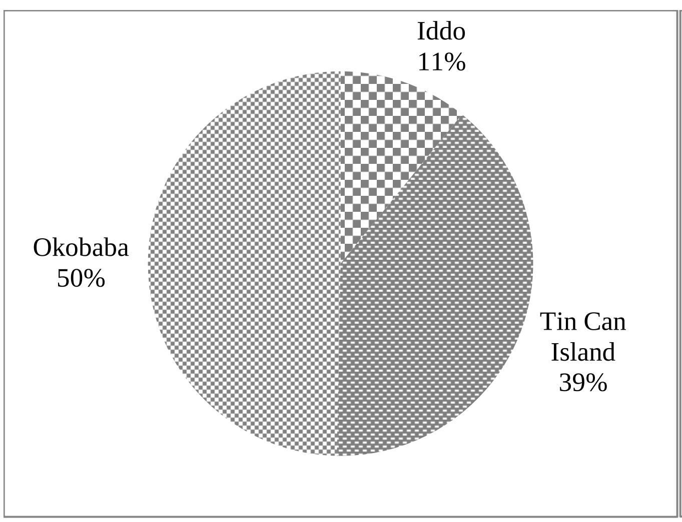



Fig. 6. Representation of BMF population in the study area

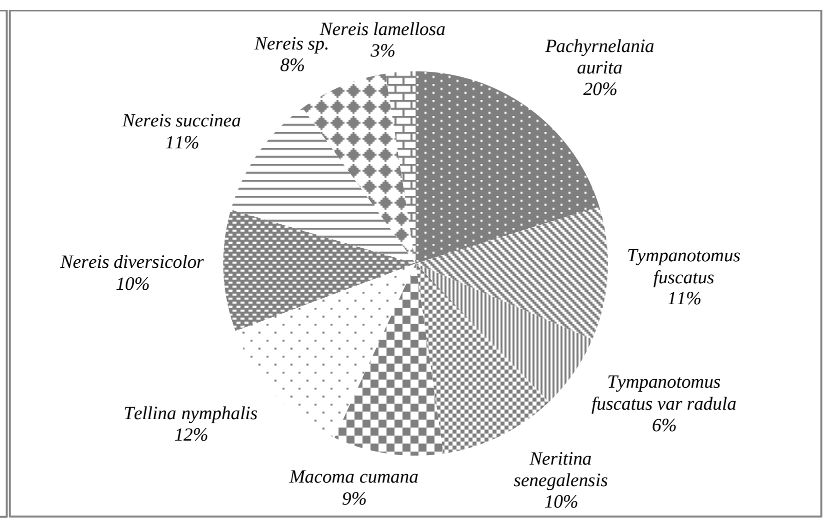



Fig. 7. Relative contribution of the different taxa to the overall BMF population

**Relationship between variables investigated**

Correlation analyses between variables investigated showed that, there was significant correlation between number of individuals of BMF and Chl a in sediment (*rs* = -1.00; *p*< 0.01), Chl a in water (*rs* = 0.667; *p*< 0.01) and numbers of individuals of MPB (*rs* = -1.00; *p*< 0.01). The analyses also indicated that, a significant positive relationship was established between number of individuals of MPB and benthic macrofauna (*rs* = 0.665; *p* > 0.001), Chl a in sediment (*rs*= 1.00; *p*> 0.001) and Chl a in water (*rs*= 0.667; *p*>0.001). Whereas TOM correlated positively with values observed for numbers of individuals of MPB (*rs* = 0.35; *p* > 0.001), it related negatively with values recorded for BMF (*rs* = - 0.55; *p* > 0.001).

## DISCUSSION

### Environmental variables

Environmental quality of the study area seems to be generally controlled by the TOM content. The high TOM in water and sediment which was relatively higher at Iddo and Tin Can Island, is typical of the anthropogenically perturbed Lagos Lagoon system as observed in Uwadiae (2009). According to Mayer (1989), Fichez (1991) and Hyland *et al*. (2005), the yellow or brown color commonly associated with water bodies is often the result of the decomposition of organic matter. The most abundant sources of this material include decaying vegetation, algae, and microscopic organisms. These substances are produced mostly on land and during runoff are flushed into the water (which is a major occurrence at the study stations) where complex biological processes occur. These compounds are known to aid in transporting and solubilizing many trace elements and are important in determining the overall health status of the aquatic system (Danovaro *et al*., 1993). Furthermore, organic substances interact with both organic and inorganic pollutants. In addition to organic matter from natural sources, increasing amounts are entering the Lagos Lagoon, as a direct and (or) indirect result of man's activities. Leading sources of this material are industrial and domestic waste, agriculture, urban runoff, mining, and watercraft as well as foaming detergents in water supplies (Fichez, 1991). Organic load in water have resulted in the accumulation of toxic chemicals and have been linked to nutrient-induced algae blooms, which deplete the dissolved oxygen. Because of the myriad of sources from both pollution and natural processes, organic matter is present in almost all surface and ground waters and directly influences the water quality (Fabiano and Danovaro, 1994). For instance, the depleted level of dissolved oxygen observed at the study locations may be associated with high oxygen required or the biological degradation of the organic load in the water.

### Benthic Communities

The pattern observed in the abundance of benthic biocoenosis also emphasizes the cardinal influence of TOM. The generally higher abundance of benthos recorded at Okobaba where a relatively lower values of TOM were observed is supportive of the above claim. It has been noted that, changes in species diversity, abundance and biomass of benthic community take place along a gradient in space in relation to organic matter enrichment (Cahoon and Cooke, 1992; Cahoon, 1999; Cahoon *et al*., 1999, Hyland *et al*., 2005). This underscores the importance of organic matter in the distribution, growth and species diversity of benthic community. Although spatial variability in benthic biocoenosis may reflects the effects of many factors including substrate characteristics, light flux patterns, nutrient availability, physical disturbance, and grazing, among others (Light and Beardall, 1998). In this present study, a critical examination of the trend established in abundance of taxa recorded and the correlation analysis indicate that the TOM content of the study area was an important factor responsible for observed patterns.

The results of this study demonstrate that TOM correlated positively with values observed for numbers of individuals of MPB (*rs* = 0.35; *p* > 0.001), but negatively with values recorded for BMF (*rs* = -0.55; *p* > 0.001). The low diversity and population of benthic community recorded in this study is a general reflection of the environmental conditions in sampled locations. Although TOM hold the largest amounts of food resource for deposit feeding organisms (Calow, 1975), it limited the abundance of benthos. Induced sedimentation resulting from high organic matter can smother benthic molluscs both at their adult and planktonic stages. Increased turbidities may increase the formation of pseudofeces and decrease the amount of water that is pumped (Dillon, 2000). According to Hyland *et al* (2005), the concentration of organic matter in sediment above 3.5% act as reducing factor for benthic abundance, biomass and species diversity. Spatial and temporal changes in sedimentary organic matter (OM) in the aquatic environments is known to affect spatial distribution, metabolism and dynamics of all benthic components, from bacteria to macrofauna (Danovaro *et al*., 1993; Buscail *et al*., 1995; Duineveld *et al*., 1997). In this study, the correlation between number of individuals of benthos and organic matter corroborates this assertion. Organic matter is essentially rich in nutrients and when present in aquatic systems in appropriate proportions stimulate growth and productivity of biota. Most benthic fauna prefers organic matter in form of fresh algal materials as food (Grant and Hargrave, 1987; Dillon, 2000).

The impact of high TOM on the abundance of benthic organisms has been reported by a number of workers. Uwadiae (2009) observed low populations of the benthic gastropod *P. aurita* in areas with the highest TOM content in Epe Lagoon. In the same vein, Cahoon *et al*. (1999) observed that, muddy sediments with high organic matter supported lower Chl *a* level than sediments with some sand content. The study also noted that muddier sediments have lower sediment chlorophyll *a* concentration than sandier sediments in several estuarine ecosystems. There are several factors that may account for this pattern, including reduced interstitial space volumes, nutrient fluxes, and light penetration in muddier sediments, any combination of which might support lower microalgal biomass (Newell and Field, 1983). Although, there are also circumstances, such as reduced grazing pressure or nutrient enrichment, that can support high benthic microalgal biomass in substrates with high organic load, this may not be the same for macrofauna. Animals in sediments with high organic load are subjected to suffocating conditions, hence, find it difficult to survive. Thus, location-specific factors can mask or alter a relationship between sediment composition and benthic microalgal biomass.

The benthic community observed in this study was characterized by low taxonomic diversity and number of individuals. Most species of MPB and MBF recorded here have been reported in stressed environments. For example, the mollusc *P. aurita* is well known for its ubiquitous status in the Lagos Lagoon, it has been reported even in severely stressed conditions (Uwadiae, 2013). Molluscs are known to tolerate stressed conditions owning to their ability to adapt to relatively high turbidities and anaerobic conditions prevalent in most estuaries by the closure of their shells during such unfavorable conditions (Hart and Fuller, 1979; Constable, 1999).

## CONCLUSION

The association we found between lower benthic microalgal biomass and high TOM in study locations also suggests a potentially significant relationship between anthropogenic impacts and estuarine ecology. Land disturbing activities are known to cause elevated loading of sediments, particularly introduction of organic waste from sundry sources into receiving waters, causing accumulation of organic matter in estuaries (Riaux-Gobin *et al.*, 1987; Ajao and Fagade, 1991). Anthropogenic waste loading may, therefore, reduce the total microalgal and macrofauna biomass, as well as alter the taxonomic composition of benthic communities in estuarine ecosystems.

## Conflict of interest

Authors have no conflict of interest to declare.

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