

## MACROINVERTEBRATE BIOMASS AND NUTRIENT CHARACTERISTICS OF SEDIMENT OF A PERTURBED URBAN LAGOON IN NIGERIA.

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### ABSTRACT

The macroinvertebrate biomass and nutrient characteristics of a perturbed urban lagoon in Southwest Nigeria were investigated by a monthly sample collection and analysis for six months. A generally low macroinvertebrate biomass was observed in this study. Of the total 7,782.3 gm<sup>-2</sup> recorded, mollusca contributed 7,715 gm<sup>-2</sup> and accounted for 99.1 % of the total macroinvertebrate biomass. The gastropod *Pachymelania aurita* was the most abundant taxa, the species recorded a biomass of 2700.25 gm<sup>-2</sup> and accounted for 35 % of molluscan biomass. This was followed by *Tympanotonus fuscatus* another gastropod which accounted for 22 % (biomass 1697.3 gm<sup>-2</sup>) of molluscan biomass. Annelida recorded a biomass of 67.31 gm<sup>-2</sup> from the single genus *Nereis* collected from the study area and accounted for 0.9% of the total benthic macroinvertebrate biomass. There was high variability in values of sediment protein and lipid among study stations during sampling months. Whereas protein fluctuated between 0.13 and 1.74%, lipid varied from 0.01 to 0.21%. Relatively higher values of protein were recorded in this study. The poor nutrient content of sediment and low macroinvertebrate biomass observed in this study are likely the resultant effects of sediment disturbance arising from sand mining activities in the study area.

**Keywords:** Sediment disturbance, macrofauna, food availability in sediment.

### INTRODUCTION

The stability and productivity of aquatic systems have been seriously jeopardized due to pollution and ecological alterations arising from human activities (Alongi and Christoffersen, 1992; Uwadiae *et al.*, 2009). Assessment and evaluation of the degree of alteration in aquatic ecosystems arising from anthropogenic activities have being a major challenge to aquatic scientists. In recent times, biological assessment which is the use of biological responses to evaluate changes in an ecosystem has been widely accepted as the most reliable method of assessing the impact of anthropogenic influences on the aquatic ecosystem (Hart and Fuller, 1979).

Iyagbe Lagoon like most of the lagoons in Lagos State is a hotspot for human activities notably fishing and sand mining. The unscrupulous manner in which artisanal sand mining is carried out in the Lagos Lagoons has attracted the attention of the Lagos State Government who at various occasions has issued directives to stop this practice. Sand mining activities in the aquatic systems constitutes a major disturbance to the bottom sediment. Percival and Frid (2000) as well as Pearson and Rosenberg (1978) reports that disturbance is a key factor regulating the structure and

functioning of natural communities. In sedimentary habitats, physical disturbance modifies sediment structure and seriously damage infauna and epifauna (Bigot *et al.*, 2006; Brugnoli *et al.*, 2007). As invertebrates show a high degree of selectivity for a sediment structure, physical disturbance may also indirectly shift the structure and functioning of benthic communities. Disturbance causes a partial or total removal of dominant species creating unoccupied space for further colonization and may thus alter the community structure (Fabiano and Danovaro, 1994). Strong levels of physical disturbance favours the dominance of opportunistic fast growing species and mobile epifauna (Kotta and Pärnoja, 2000; Dunn *et al.*, 2017).

Benthic organisms constitute an important part of the aquatic food chain, especially as food for fish, and because of their abundance and position as “middlemen” in the aquatic food chain, benthos play critical roles in the natural flow of energy and nutrients. Most benthic fauna exhibit limited mobility and so they are less able to escape anthropogenic influences that diminish water quality. Therefore, benthos can give reliable information on water quality. Their long life cycles allow studies conducted by aquatic ecologists to determine any decline in

environmental quality (Pearson and Rosenberg, 1978; Danulat *et al.*, 2002).

The large numbers of species possess a wide range of responses to stressors originating from agricultural, domestic and industrial sources. Many benthic macro-invertebrates are long-lived, allowing detection of past disturbance events such as oil spills and dumping of wastes (Hynes, 1970). Also, many benthic organisms are sensitive to pollutants and the presence or absence of certain feeding groups (such as scrapers and filterers) may indicate a disturbance in the food supply to the benthic animals in the aquatic system and the possible effects of stress

Biotic and abiotic conditions of sediments have been widely used as monitoring tools in the aquatic environment. They are used as health status indicators as well as sentinel parameters, serving significant purposes in toxicity testing of effluents to ensure receiving water standards, or to ensure that standards are maintained during and after the life cycle of a project (Pearson and Rosenberg, 1978; Danulat *et al.*, 2002; Don-Pedro *et al.*, 2004). Benthic macrofauna, are animals that are larger than 0.5 millimeter and live on rocks, logs, sediment, debris and aquatic plants during some period in their life cycle. Benthic macrofauna include vast array of aquatic organisms. These animals are widespread in their distribution and can live on all bottom types, even on man-made objects. The distribution of benthic organisms depends on variable environmental factors, including physical (e.g. currents, waves, tides, and temperature), chemical (e.g. salinity, pH, DO) and biological parameters (e.g. microalgae availability) in addition to substrate type (Hynes, 1970). According to Oyeneke (1988b), of all the environmental factors affecting benthic organisms in their habitat, characteristics of substrate are of cardinal importance. Sediment inhabitability by an organismic assemblage as well as the community composition depends on the porosity of the sediment, internal water and oxygen

circulations in interstitial spaces as well as food availability (Hyland *et al.*, 2005). That benthic assemblage is constrained by sediment granulometry and chemistry has been well documented (Hyland *et al.*, 2005).

Although a number of studies (such as Oyeneke, 1988 a;b; Uwadiae, 2010; 2014; 2016; 2017) have been carried out on the benthic macroinvertebrates community of the Lagos Lagoon system, not much has been done in Iyagbe Lagoon. The aims of the this paper are to investigate the biomass of benthic macroinvertebrate and nutrient composition of sediment in Iyagbe Lagoon with a view to determining the level of impact in the face of the environmental degradation prevalent in the lagoon

### Study Area

This study area, Iyagbe Lagoon (Fig. 1) is located in Lagos State, South-West, Nigeria. The Lagoon is a two-arm lagoon located between Latitude 6° 23'N and Longitude 3° 06' E and comprised of the Porto-Novo Creek as one arm and Badagry Creek as another arm. The depth of the lagoon in the area used for this study ranged from 0.74 to 1.74 m. The lagoon experiences a rainfall distribution pattern which tends to regulate the salinity and water level. The existence of littoral mangrove vegetation at the fringes of the lagoon and the mass of water hyacinth on the surface of the lagoon constitute major sources of detrital input into the lagoon. A major feature of the lagoon is wide spread human activities, notable among which is sand mining, involving majorly the manual use of baskets and buckets. Across the length and breadth of the lagoon are sand mining spots, where the bottom sediment is unscrupulously removed. The activities of the miners are continuous in such a way that no room is provided for repopulation of the sediment.

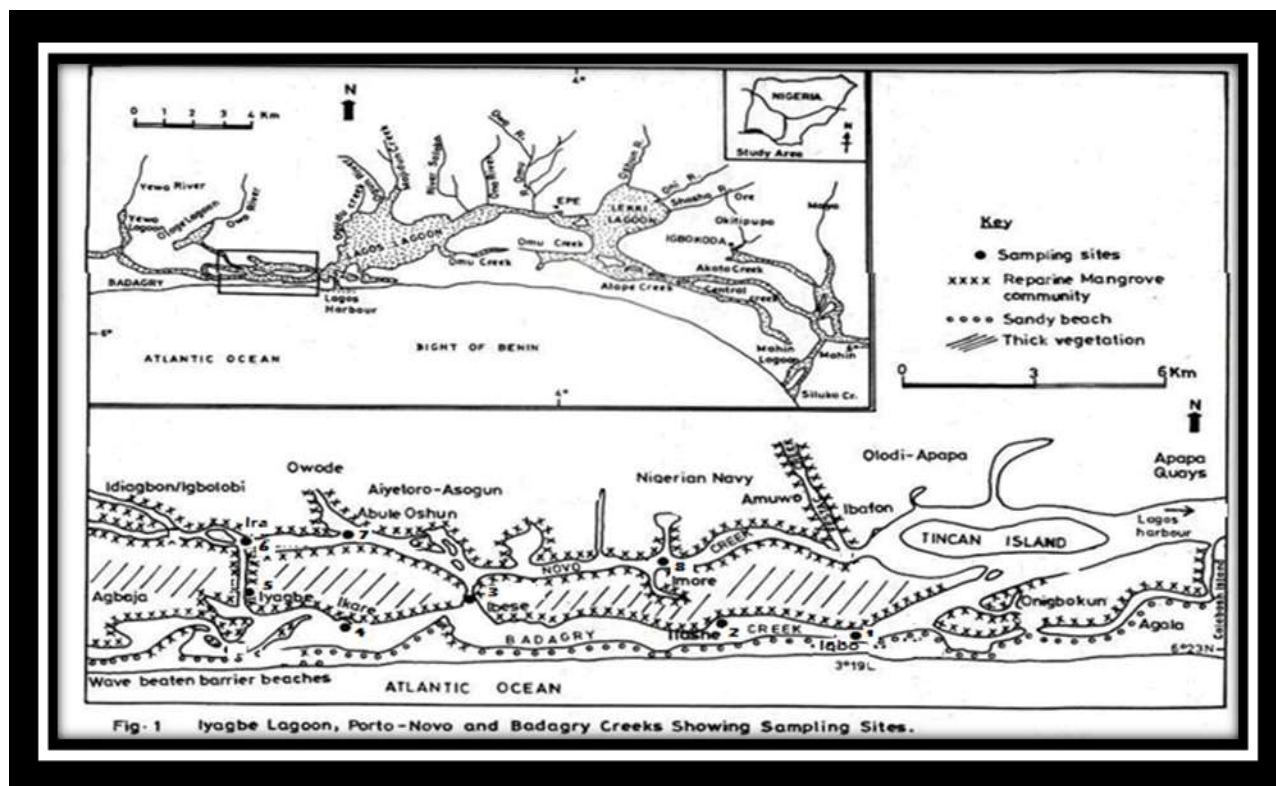


Fig. 1. Map of study area showing sampling stations

## MATERIALS AND METHODS

### Collection of samples and Sampling protocol

Sampling for environmental parameters and benthic macrofauna were carried out in eight study stations between 10:00 and 15:00 hrs on each sampling day at monthly intervals between November, 2013 and May, 2014. Water samples for the analyses Phosphate-phosphorus (PO<sub>4</sub>-P) and Nitrate-Nitrogen (NO<sub>3</sub>-N) were collected using prewashed and properly labelled reagent bottles according to methods described in APHA (1985). Sediment samples for the determination of nutrient parameters were collected using van Veen grab of size 0.1m<sup>2</sup> from each sampling location. The top 5 cm layer of each haul was collected and placed in a labeled polythene bag. The samples were preserved in the deep freezer before analysis in the laboratory.

Samples of benthic macrofauna were taken in three replicates with a van Veen grab of 0.1 m<sup>2</sup> in area. Samples were washed through a sieve of 0.5 mm mesh size and organisms retained in the sieved were collected in labelled sample containers and preserved with 10 % formaldehyde solution *in situ*.

### Laboratory analyses

In the laboratory analyses of nutrient in sediment involved the determination of percentage composition of protein and lipids according to the methods described in Bligh and Dyer (1954). After sonication in deionized water, total lipids were extracted by direct elution with chloroform-methanol.

Protein analyses of three replicates were conducted following extraction with NaOH (0.5M, 4h) and were determined according to Rice (1982) to compensate for phenol interference and expressed as bovine serum albumin (BSA) equivalents. Analyses of PO<sub>4</sub>-P and NO<sub>3</sub>-N were carried out according to the methods described in APHA (1985).

Preserved macro-invertebrate samples were washed with tap water to remove the preservative and sediment particles and the animals were sorted on a white tray and the identity of individual organism confirmed using Edmunds (1978) and Yankson and Kendall (2001). The number of species and individuals for each station were enumerated and recorded.

The biomass of all sorted organisms was determined by wet method (Holme and McIntyre, 1971). This involves direct weighing of all the sorted animals of each phylum. The organisms were allowed to dry for one minute after puncturing the shells with a fine needle and the mantle cavity water sucked up with filter paper (in the case of molluscs) and all the animals were drained on a fine sieve until liquid is no longer noticeable. The organisms were then weighed using an electronic scale of 0.001g sensitivity and values approximated to the nearest weight in gramme (g) and converted to gm<sup>-2</sup>.

**RESULTS**

**Spatial and temporal dynamics in nutrients**

Table 1 shows the summary of values of nutrient parameters investigated in the study area. There was high variability in values of sediment protein and lipid among study stations and sampling months (Figs 2 -3). Whereas protein fluctuated between 0.13 and 1.74%, lipid varied from 0.01 to

0.21%. Relatively higher values of protein against lipids were recorded in this study. Although there were no strong seasonal influences on the values recorded for both parameters, relatively higher concentrations occurred in months noted for higher rainfall. Spatially analysis of values observed did not demonstrate any particular trend.

Mean phosphate-phosphorus concentration in water varied between 0.88 mg/L observed in station 2 and 2.13 mg/L recorded in station 4. Overall maximum value of PO<sub>4</sub>-P (6.5 mg/L) was recorded in the month of May in station 8, while corresponding minimum (0.12 mg/L) was detected in station 5 in the month of February. This pattern relates closely with the trend recorded for NO<sub>3</sub>-N. Mean value of this parameter fluctuated between 1.33 mg/L in station 3 and 2.66 mg/L in station 8. Overall maximum value (6.01 mg/L) of NO<sub>3</sub>-N was recorded in the month of May in station 7, while corresponding minimum (0.15 mg/L) was measured also in station 7 in the month of February.

**Table 1. Summary of nutrient parameters investigated in the study area.**

Sampling Stations		Parameters			
		Protein (%)	Lipid (%)	PO <sub>4</sub> -P (mg/L)	NO <sub>3</sub> -N (mg/L)
1	Max	1.44	0.2	4.0	5.4
	Min	0.63	0.01	0.24	0.6
	Mean	0.9	0.7	1.5	2.11
2	Max	1.50	0.21	1.95	3.28
	Min	0.6	0.01	0.5	0.8
	Mean	0.9	0.71	0.88	2.12
3	Max	0.96	0.13	5.0	3.3
	Min	0.38	0.02	0.36	0.3
	Mean	0.75	0.5	1.5	1.33
4	Max	0.96	0.13	4.9	3.2
	Min	0.4	0.02	0.32	2.21
	Mean	0.8	0.6	2.13	1.56
5	Max	0.71	0.1	5.6	2.25
	Min	0.13	0.01	0.12	0.85
	Mean	0.52	0.33	2.02	1.90
6	Max	0.73	0.11	4.8	3.14
	Min	0.16	0.01	0.21	0.53
	Mean	0.52	0.34	1.59	2.14
7	Max	1.74	0.20	6.2	6.01
	Min	0.2	0.07	0.4	0.15
	Mean	1.1	0.84	1.9	2.09
8	Max	1.72	0.20	6.5	6.6
	Min	0.22	0.07	0.23	0.4
	Mean	1.1	0.83	1.69	2.66

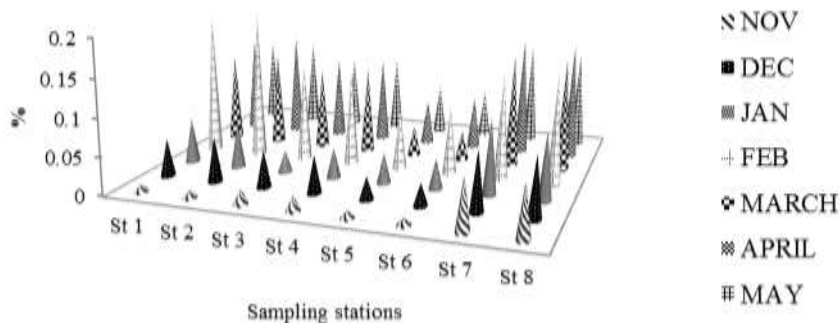


Fig. 2. Spatial and temporal variations in percentage concentration of lipids in sediment

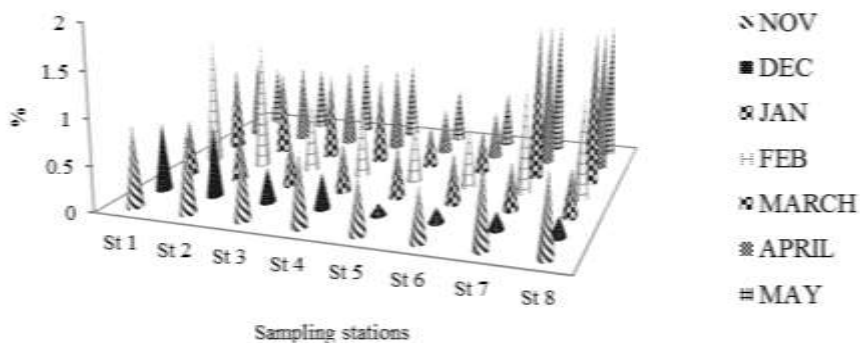


Fig. 3. Spatial and temporal variations in percentage concentration of protein in sediment

**Benthic macrofauna biomass**

Changes in benthic macrofauna biomass in sediment during period of study are shown in Fig. 4. A total benthic macrofauna biomass of 7782.3 gm<sup>-2</sup> was recorded in this study. Whereas a range of 623 – 1450 gm<sup>-2</sup> was observed at the spatial scale with the lowest and highest values recorded in stations 4 and 3 respectively, total biomass at the temporal scale fluctuated between 977 gm<sup>-2</sup> in November and 1540 gm<sup>-2</sup> in May. Total benthic macrofauna biomass recorded for other sampling stations were; 940 gm<sup>-2</sup> in station 4, 911 gm<sup>-2</sup> in station 2, 700 gm<sup>-2</sup> in station 5, 670 gm<sup>-2</sup> in station 6, 1180 gm<sup>-2</sup> in station 7 and 1310 gm<sup>-2</sup> in station 8. Total monthly values recorded were; 1144 gm<sup>-2</sup> in November, 1040 gm<sup>-2</sup> in December, 1242.0 gm<sup>-2</sup> in January, 980 gm<sup>-2</sup> in February and 101 gm<sup>-2</sup> in March.

Of the total biomass of 7782.3 gm<sup>-2</sup> observed in the study area, mollusc contributed 7715 gm<sup>-2</sup>. At the spatial scale, molluscan biomass varied between 6.18 gm<sup>-2</sup> recorded in station 4 and 142.8 gm<sup>-2</sup> in station 3. Molluscan biomass in other stations sampled were; 938 gm<sup>-2</sup> in station 1, 903 gm<sup>-2</sup> in station 2, 690

gm<sup>-2</sup> in station 5, 670 gm<sup>-2</sup> in station 6, 117 gm<sup>-2</sup> in station 7 and 130.5 gm<sup>-2</sup> in station 8. Monthly values of biomass recorded for molluscs fluctuated between 826 gm<sup>-2</sup> in April and 152.8 gm<sup>-2</sup> in May. Values for other sampling months were; 114 gm<sup>-2</sup> in November, 103.6 in December, 1222 gm<sup>-2</sup> in January, 971 g in February and 992 gm<sup>-2</sup> in March (Fig. 4). Mollusca accounted for 99.1 % of the total macro-invertebrate biomass. The gastropod *Pachymelania aurita* was the most abundant with a biomass of 2700.25 gm<sup>-2</sup> and accounted for 35 % of molluscan biomass, this was followed by *Tympanotonus fuscatus* another gastropod which accounted for 22 % (biomass 1697.3 gm<sup>-2</sup>) of mollusc population. Other gastropod species recorded include; *T. fuscatus* var *radula* (8 %; 617 gm<sup>-2</sup>) and *Neritina glabarata* (0.5%; 38.38 gm<sup>-2</sup>). Among the bivalve species *Macoma cumana* constituting 20 % with a biomass of 1435 gm<sup>-2</sup> dominated in abundance while *Tellina nymphalis* (12 %; 925.8 gm<sup>2</sup>) and *Aloides* sp (3 %; 233.45 gm<sup>-2</sup>) were also important contributors.

Annelida recorded a biomass of 67.31 gm<sup>-2</sup> from the single genus *Nereis* collected from the study

area and accounted for 0.9% of the total benthic macroinvertebrate biomass. Annelida biomass varied between 5.4 gm<sup>-2</sup> recorded in stations 5 and 8, and 19 gm<sup>-2</sup> in station 3. Biomass values in other stations were; 6.3 gm<sup>-2</sup> in station 1, 8.1 gm<sup>-2</sup> in station 2, 10 gm<sup>-2</sup> in station 4, 7.3 gm<sup>-2</sup> in station 6 and 6.3 gm<sup>-2</sup> in station 7. Monthly biomass values varied between 3.8

gm<sup>-2</sup> in November, and 19.6 gm<sup>-2</sup> in January. Values for other sampling months were; 6.4 gm<sup>-2</sup> in December, 5.7 gm<sup>-2</sup> in February, 14.2 gm<sup>-2</sup> in March, 8.5 gm<sup>-2</sup> in April and 9.1 gm<sup>-2</sup> in May (Fig. 5). Spatial and temporal variations in total biomass of benthic macrofauna during this study are shown in Fig. 6.

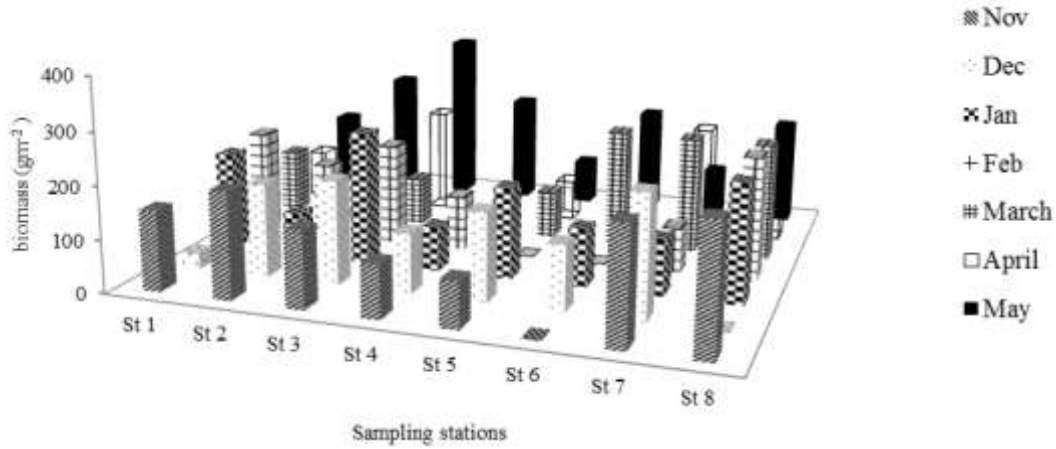


Fig. 4. Spatial and temporal variations in biomass of benthic molluscs

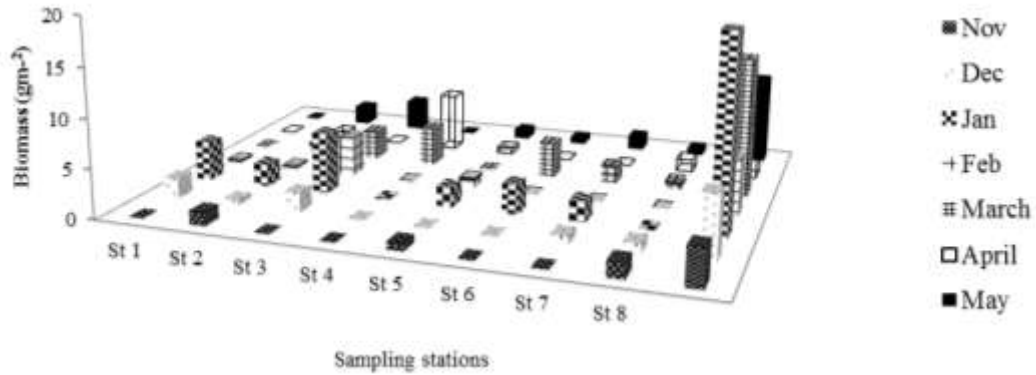


Fig. 5. Spatial and temporal variations in biomass of benthic annelids

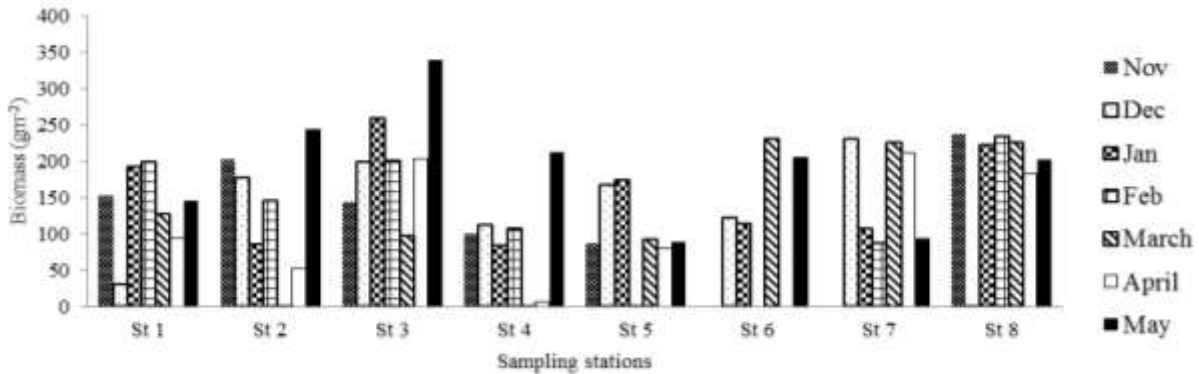


Fig. 6. Spatial and temporal variations in total biomass of benthic macrofauna

## DISCUSSION

The values recorded for nutrient variables did not show any discernable trend. Generally, values of nutrient variables recorded in this study were low and compared favourably with the record observed for phosphate (0.24 -2.43 $\mu$ M) and maximum 2.4  $\mu$ M for nitrate in a stressed pond by Cardozo *et al.*, (2011), and the observations of Percival and Frid (2000) for protein and lipid in sediment. The low concentration of nutrients in the overlying water and sediment observed in this present study may be due ostensibly to the degraded environmental conditions occasioned by the wide spread sand mining activities. According to (Percival and Frid, 2000) the availability of nutrients in the aquatic system is in part determined through sediment-water fluxes of nutrients. This, microbially mediated benthic remineralisation of organic compounds is recognized as a significant pathway by which inorganic nutrients are regenerated and released to the overlying waters (McCaffey *et al.*, 1980).

The magnitude of this recycling and release pathway can be a controlling factor for pelagic primary productivity, supplying a potentially significant proportion, up to 80%, of the nutrient requirements of primary producers (Nixon *et al.* 1976; Pastuszak *et al.*, 1996). Studies have shown that where physical disruption to the sediment occurs, fluxes from gradient controlled molecular diffusion, the mechanism which occurs in undisturbed sediments are altered (McCaffey *et al.*, 1980). Nutrient cycling processes are reliant on specific oxidation boundaries within the sediment (McCaffey *et al.*, 1980). The nature of aquatic sediments usually only allows for the uppermost layer of the sediment to exhibit oxidising conditions, underlain by a reduced sediment environment (Bagander and Niemisto, 1978).

However, alteration of the redox status by direct physical disruption by sand mining affects the microbial activity within the sediments. The relatively higher values of protein compared to lipid corroborates the observations of (Pastuszak *et al.*, 1996). The author reported that the concentration of protein in sediment is highly influenced by the amount of organic matter and bacterial densities. Plants-animal residues and the microbial population are known to be the major sources of proteins in the sediments. Therefore the generally low values of nutrient observed in this study may be due to poor organic matter content of sediment, since removal of sedimentary materials through sand mining

completely removes organic matter and sediment particles from the bottom.

The total benthic biomass per unit area (7,782.3  $\text{gm}^{-2}$ ) recorded in this study is low when compared to results recorded elsewhere. For example, an average biomass of 36.4  $\text{gm}^{-2}$  macrofauna was recorded for one sampling event by Masłowski (2001). The low biomass observed in this study may be due to the destructive sand mining activities in the lagoon. Sand mining is a major threat to the benthic community in particular and the aquatic system in general. The continuous removal of the bottom sediment decimates benthic community, alters the original content and configuration of the sediment. The resuspension of materials during sand mining activities in the overlying water reduces the transparency of water thereby reducing the penetration of light in the aquatic system. Generally the disturbances generated by sand mining activities create serious environmental challenge for the adults and juveniles of benthic macroinvertebrates.

The result observed did not depict any definite pattern therefore influence of any localized factor cannot be suspected. Of the total benthic macrofauna biomass recorded, mollusca contributed 7,715  $\text{gm}^{-2}$  (99.1%) while annelida recorded 0.0673  $\text{gm}^{-2}$  (0.9%). The taxa represented in these two phyla are mainly opportunistic. The dominance of molluscs in perturbed areas of the Lagos Lagoon system has been previously reported by Uwadiae (2016). The general habitat alteration associated with sand mining and other anthropogenic activities in the study area made it difficult for the deposit feeding and tube dwelling macroinvertebrates to survive. Most molluscs recorded in this study are filter feeders; this may be a major adaptive attribute enhancing their survival. The low benthic mollusc biomass and number of species recorded here depict an impoverished community. Direct physical damage occurs to the benthic community from the activities of sand miners, this can cause a shift in the assemblage of benthic organisms. Such a shift can potentially cause concomitant impacts to the nutrient dynamics of the system as the natural reworking of organic matter and release of nutrients through burrowing activity is altered.

Environmental conditions in the study indicate degraded ecosystem that could sustain only opportunistic species (Uwadiae, 2016; 2017). According to Ajao (1990) and Uwadiae *et al.* (2009),

most soft bottom molluscs (Alongi and Christoffersen, 1992) prefer sediments with proportionate mixture of sand, silt and clay. High turbidities during sand mining resulting in resuspension of materials may increase the formation of pseudofeces and reduce the amount of water that is pumped during respiratory and feeding activities (Hart and Fuller, 1979). The dominance and large scale preponderance of the gastropods *Tympanotonus fuscatus* var *radula* and *Pachymelania aurita* in the study area aligns with the observations of Egonmwan (1988) and further strengthens the argument that these species can withstand some degree of perturbations (Uwadiae, 2017).

### CONCLUSION AND FURTHER RESEARCH NEEDS

The results obtained in this study indicate that the benthic community of Iyagbe Lagoon is seriously perturbed due ostensibly to sediment disturbance through human activities such the wide spread sand mining prevalent in the lagoon. Further research on the impact of sediment disturbance and sand mining on macroinvertebrate communities is required in Iyagbe Lagoon, to understand the full ecological implications of the problem. The research should focus on the inter play of factors for better understanding of the critical factors responsible for observed patterns.

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