BENTHIC FUNGAL AND MOLLUSCAN ASSEMBLAGES OF A TROPICAL MANGROVE SWAMP: IMPACT OF SEDIMENT CHARACTERISTICS ON BIODIVERSITY AND ECOSYSTEM FUNCTION.

R.E UWADIAE and J. EBONNE

Benthic Ecology Unit, Department of Marine Sciences, University of Lagos, Akoka, Lagos, Nigeria. E-mail: eferoland@yahoo.com; ruwadiae@unilag.edu.com. Tel: +2347059497190.

ABSTRACT: This study examines the fungal species composition and density, taxonomic composition as well as functional feeding groups of benthic molluscan community in a tropical mangrove swamp at six study stations (1 – 6). The study area was predominantly muddy (70.7 – 83.6 %) with high organic content (34 – 62 %). In the fungal community *Aspergillus* recorded the highest frequency of occurrence, followed by *Penicillium* and *Fusarium,* these three genera were isolated in the six study stations while *Trichoderma* and yeast cells were recorded in low frequencies and restricted to few study stations. The molluscan community recorded a total of 2 classes (Gastropoda and Bivalvia), 5 families, 5 genera and 5 species from a total density of 3240 ind/m^2. Gastropod species; *Pachymelania aurita* and *Typanotonus fuscatus* var *radula* were widely distributed, while bivalve species; *Aloidis trigona* and *Anadara senilis* were recorded only in three stations, except *Gryphae gasar* which occurred in four stations. There was no molluscan species found in stations 5 and 6. Analysis of the functional feeding composition of the molluscan community revealed that, of the two functional groups recorded, deposit feeding represented by *T. fuscatus* var *radula* was the most abundant FFG, it accounted for 51.54% of the total molluscan population, while the filter feeders constituted 48.46 %. Grain size and organic content of sediment had strong effects on community indices and population densities of molluscs. The low diversity of fungal and molluscan species observed in this study may be attributed to the sedimentary condition of the mangrove swamp.

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Key words: fungi, molluscs, environmental conditions, tropical mangrove swamp

INTRODUCTION

Mangrove ecosystems are detritus based, so the majority of primary production enters detrital food webs (McNaughton *et al*., 1989; Cebrian, 1999), therefore, the roles of organic matter decomposers such as fungi is paramount to the health and functioning of mangrove ecosystems (Loreau *et al*., 2002; Hooper *et al*., 2005), and their patterns of biodiversity (Hutchinson 1959; Wilson 1992). It has remained a primary aim of the aquatic ecologist to understand the dynamics of the flux of matter as it goes from photosynthetic plant tissue to all other trophic levels (Strickland, 1972). In oceans and coastal waters, decomposition of organic matter and nutrient regeneration are predominantly the result of metabolic activities of living organisms. Decomposition of organic matter is the only source of energy for the heterotrophic benthic population. Together with the production of organic matter especially that due to photosynthesis and the transformation of organic matter, decomposition of organic matter and nutrient regeneration (remineralization) constitute the fundament of an ecosystem.

Microbial synthesis transforms dead organic matter and CO_2 into microbial cell protein (Parsons and Strickland, 1961). This process includes transfer into cell synthesis and thus into the food chain as well an appreciable number of elements, such as N, P, S, Fe, Co and some trace metals. A specific feature of microbial decomposers is their ability to metabolize and include into the ecosystem's energy budget, energy from sources and concentrations which are barely, or not at all, accessible to other organisms (Hyde, 1988). Among these sources are *in situ* concentrations of dissolved organic matter (sugars, amino acids, fatty acids, humic acid), dead particulate organic material, cellulose, chitin and hydrocarbons. Decomposition of organic substances in anaerobic habitats is accomplished almost exclusively by microbial populations. Microflora components also oxidize the low molecular weight products of anaerobic decomposition, such as fatty acids and alcohols, and reduced mineral substances (e.g. methane, hydrogen, hydrogen sulphide, ammonia), using oxidation energy for biosynthesis. In this way, microbial populations constitute functional bridge between biological processes in the water and its reduced sediment in addition to promoting mobilization of energy resources {contained in organic sediments, and including these resources into the biological production process. Microbial populations are also fundamental producers of external metabolites, which constitute the biochemically active portion of dissolved organic matter in water (Parsons and Strickland, 1961).

Among the microbial populations, fungi play crucial roles in organic matter decomposition and ecosystem function (Christensen, 1989). Fungi constitute one of the dominant groups involved in carbon-nitrogen cycling, primarily in the degradation of organic matter. Critical stages in lignin decomposition are almost exclusively carried out by fungi, and the breakdown of complex biomolecules such as cellulose and tannins in sediments is due mostly to fungal enzymatic activity. Fungi mediate plant health and promote growth via mycorrhizal and parasitic associations. They provide food for a wide range of invertebrates including benthic macrofaunal communities (Shaw, 1992).

Owning to the roles of fungal communities in the aquatic ecosystem in particular in the sedimentary environment, their relative diversity could influence nutrient cycling and energy flow dynamics in aquatic environment. Fungal diversity appears to impart stability on litter breakdown (Dang *et al.* 2005). In addition, there is evidence to suggest that fungal taxa diversity can alter other key fungal processes such as fungal biomass production (Duarte *et al*., 2006) and fungal conditioning of leaf litter for benthic macroinvertebrate consumption (Lecerf *et al.* 2005).

The location of mangroves at the sea-land interface makes the ecosystem vulnerable to disturbance from both regions. Contamination and unstable nature of mangrove sediment are major threats to mangroves throughout the tropics (Garrity and Levings, 1993). Deposition of sediment arising from inflow of run-off into the University of Lagos mangrove swamp and continuous tidal flushing engender instability in the sediment. Hyde (1989) reported that the presence of hydrocarbons reduced the diversity and numbers of saprotrophic fungi on intertidal mangrove wood. The presence of mangrove mud reduces aeration and slows down the activity of micro-organisms such as fungi (Scherrer and Miller, 1989). The reduction in activity also slows down mineralization of organic matter, which causes deficiency of nutrients essential for the growth of the benthic macroinvertebrates.

Destruction of mangrove forests which is major feature of the study area decreases the amount of substrates available for colonization, thus reducing the number of species of benthic fungi and invertebrates.

Several studies have examined the effects of microbial consumer diversity (Ba¨rlocher and Corkum, 2003; Dang *et al*., 2005; Duarte *et al*., 2006; Lecerf *et al*., 2005) on invertebrates (Jonsson and Malmqvist, 2000; Boyero *et al*., 2007), and invertebrate diversity has been linked with accelerated litter decomposition (Jonsson and Malmqvist, 2000) and complementarity of fine particulate organic matter (FPOM) retention (Cardinale *et al*., 2002), however, recent evidence suggests that species richness effects on ecosystem functioning are strongly influenced by species evenness. For example, as species evenness increases among sites, the number of invertebrate species required to maintain litter breakdown rates may increase (Dangles and Malmqvist, 2004; Boyero *et al*., 2007; McKie *et al*., 2008).

Detrital materials constitute a major fraction of food available to benthic molluscs (Uwadiae *et al*., 2009), which is made available to them by the activities of microbial decomposers, hence they depend on high diversity of microbial decomposers such as fungi for abundant and rich supply of food. Low abundance and species diversity of benthic communities have been linked with poor food supplies associated with impoverished fungal populations (Ba¨rlocher and Corkum, 2003; Dang *et al*., 2005; Duarte *et al*., 2006).

Global declines in biodiversity and shifts in species composition have motivated research that links biodiversity and ecosystem functioning (Schulze and Mooney, 1993; Kinzig *et al*., 2002; Loreau et al., 2002; Hooper *et al*., 2005), Biodiversity ecosystem function (B–EF) studies have expanded into detritus based ecosystems to better understand the importance of biodiversity on the ecosystem processes of decomposition and nutrient cycling. Some publications have reviewed the effects of disturbances on mangrove plants and fauna in other parts of the world (Kongsangchai, 1984; Dicks and Westwood, 1987; Garrity and Levings, 1993). In Nigeria, information on benthic communities of mangrove ecosystems is scarce. This present study examines the community structure and taxonomic composition of benthic fungal and molluscs communities of the University of Lagos mangrove swamp. The hypothesis being tested here is that the degraded environmental conditions in the mangrove ecosystem impacted negatively on benthic fungal and molluscan communities.

MATERIALS AND METHODS

Description of Study area

The study area (fig. 1) is located in the mangrove swamp of the University of Lagos bordering the Lagos lagoon system. The swamp is brackish (salinity 0.1-25‰) and is located on the North-western part of the Lagos lagoon. The tidal fluctuations of the lagoon flush the surrounding mangrove swamp at high tides and water enters the swamp through the creeks from the lagoon. The area is a depositional coastal environment where fine sediments (often with high organic content) collect in areas protected from high energy wave action. The study area is characterized by the presence of three mangrove plants namely: red mangrove (*Rhizophora racemosa*), white mangrove (*Langucularia racemosa*) and the black mangrove (*Avicennia africana*). The brackish water ferm (*Acrostichum aeurum*) and halophytic grass (*Paspalum orbicularia*) were also found at the site. Other macroflora common in the area include; *Dalbergia ecastophulum, Drepanocarpus lunatus, Orrmocarpum verrucosum, Hibiscus tiliaceus, Acrostichum aureum, Paspalum vaginatum, Eragrostis linearis, Cyperus articulates and Phoenix reclinata* (Egonmwan, 2008). Crabs, *Cardisoma armatum, Sesarma huzardii*, *Uca tangeri, Clinanarius* sp. and fishes; *Periophthlamus* spp have been reported in the study area. The study area is shallow with a dept of between 0.5 and 0.76m (Egonmwan, 2008).

Field Studies

In situ measurements and collection of samples

In situ measurements of surface water temperature (^{0}C), pH, and electrical conductivity (µScm-1) were carried out using battery operated Horiba U10 model. Transparency was determined using a 20 cm diameter Secchi disk painted black and white. Water samples for the determination of dissolved oxygen (DO) and biochemical oxygen demand (BOD) were collected in transparent and amber coloured 250ml reagent bottles. The samples were treated on the field according to the procedures described in APHA (1985) and taken to the laboratory for further analysis.

Benthic samples were collected using a van Veen grab at six locations distributed within the mangrove swamp. Three grab hauls were taken from each site and the collected materials washed through a 0.5mm mesh sieve. The residue in the sieve for each station was preserved in 10% formalin solution and kept in labelled plastic containers for further laboratory analysis. Sediment samples were collected with van Veen grab, by removing the topmost 1 – 5 cm of a successful haul at each study station. The samples were kept in properly labeled polythene bags while samples for fungal analysis were placed in sterilized Aluminum foil and properly rapped to avoid contamination.

Laboratory studies

Environmental parameters

Dissolved oxygen, BOD and COD were determined according to the methods described in APHA (1985). In the laboratory, macroinvertebrate samples were washed to remove the fixative and sorted under a dissecting microscope.

For granulometric analysis, sediment samples were dry-sieved through the Wentworth series of screens with mesh openings from 1.0 mm to 63 µm. Samples were separated into sand and mud fractions (Buchanan and Kain, 1971). Organic content of the sediment was determined using the loss of weight on ignition method following Crisp (1971).

Culture, Isolation and identification of fungal taxa

Soil dilution plate method (Waksman, 1922) was employed in the isolation of fungi from the sediment. The sediment samples were mixed with sterile distilled water and a series of dilutions were made. From the dilutions, 0.5ml volumes were pippeted onto Sabouraud Dextrose Agar (SDA)and incubated at 26°C for three days (Plates 1 and 2).

Occurrence of fungal growth was recorded and examined under the microscope for description and consequent identification. The following references were adopted as syllabi for the morphological identification of the genera and species of fungi during this study; Raper & Thom (1949) and Gilman (1945).

Molluscan community

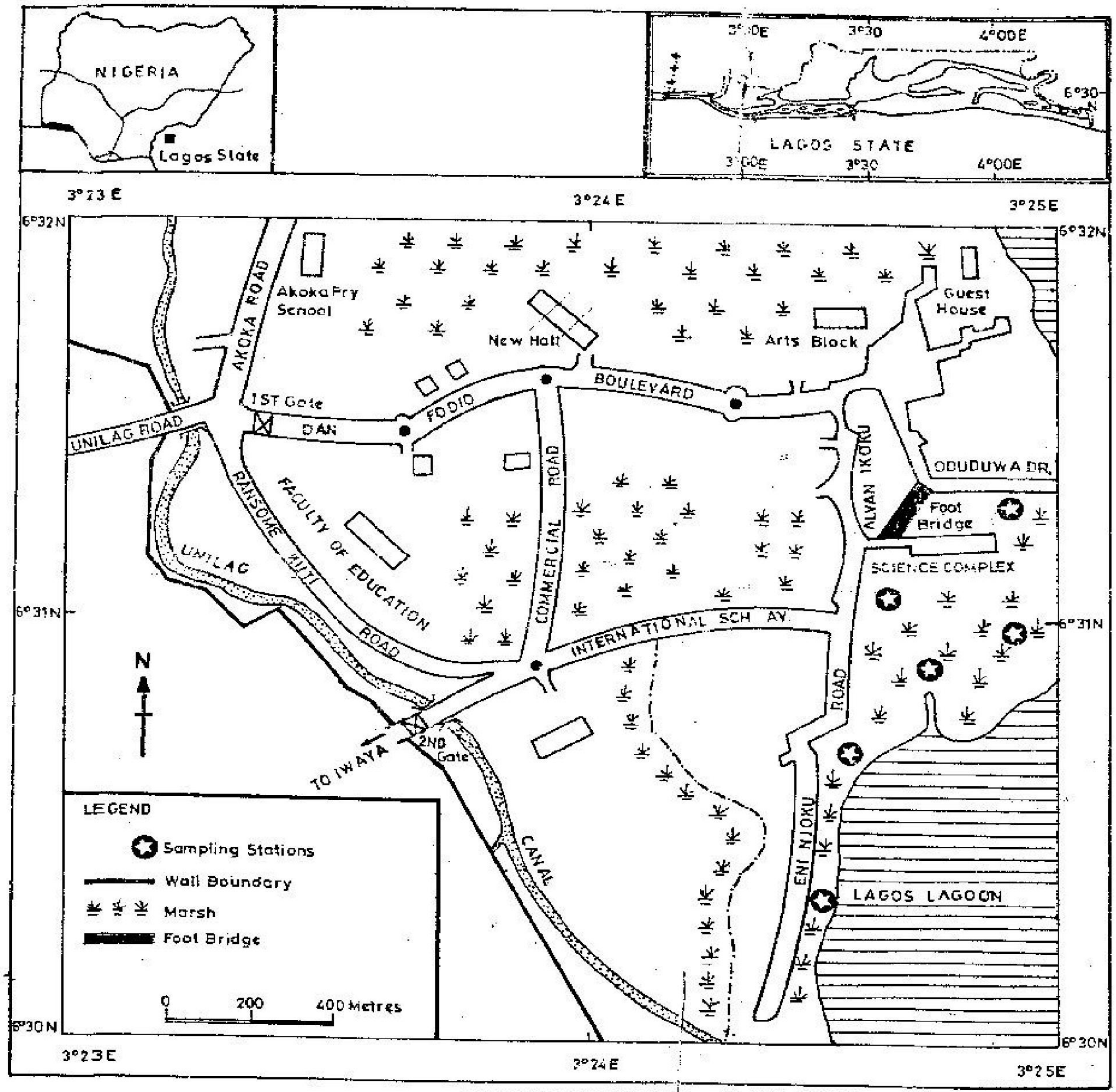
Specimens of macroinvertebrates were identified to the lowest possible taxonomic level using the available keys of Edmunds (1978), and Yankson and Kendal (2001). Numbers of individuals expressed as population density (untransformed data of individuals per m^2) in each study site and month were recorded. Density of the community at each site was the sum of population densities of each species. For all collections over the study period ($n = 6$) at each site, the grand mean density of each species was calculated as the mean of population densities of that particular species.

Community structure in the study area was characterized in terms of species richness, species diversity and evenness. Species richness was determined using Margalef's index. Species diversity and evenness were expressed using the Shannon-Wiener index (H') and the Pielou index (J') (Pielou 1966), respectively.

The allocation of each taxon to functional feeding group (FFG) depended mainly on the works of Yoloye (1994) and Cummins *et al*. (2003).

Statistical analysis

The relationships between biotic and environmental parameters were determined using Spearman rank correlations (Sokal and Rohlf, 1981). Environmental parameters included sediment grain size (sand and mud) and organic content; the biotic parameters included population densities of each species, and indices of species diversity and evenness. All statistical calculations were carried out using SPSS10.



Source : Map of Unilag Campus / Field Work, 2008.

Fig. 1. Map of the study area showing the sampled stations

Plate 1. *Aspergillius* sp.growing on SDA in a petri dish.

Plate 2. *Penicillium* sp. growing on SDA in a petri dish.

RESULTS

Environmental parameters of water

The surface water temperature varied between 26^0 and 29.5^0C and mean ± SE water temperature in the mangrove swamp was 29.03 ± 0.9^0C. A range of 1.7 – 14.0‰ was recorded for salinity indicating a brackish water environment. Low values were observed during the onset of the rains in March and April while higher values occurred in the dry months (November to February). The pH range (6.2 – 7.7) indicated weak acidic and low alkaline environment. The BOD of water varied from 4 to 60mg/l and mean ± SE, 30.7±7.8 mg/l was observed, suggesting a high organic content of water and severe pollution in the study area. Mean ± SE DO levels of 5.0 ± 0.3mg/l was recorded in the study area. Water transparency recorded mean ±SE value of 4.1±1.2 m.

Physical and granulometric characteristics of sediment

A summary of physical and granulometric attributes of the sediment in the study area is presented in table 1. The study area was predominantly muddy with high organic content. Low percentage sand in sediment samples was recorded throughout the study period. Total organic content of sediment was consistently high except in the month of April (Fig. 2). A significant positive correlation occurred between organic content and mud (Spearman's r = 0.78, p = 0.5).

Table 1. Physical and granulometric attributes of study area

Sampling station	Description	% sand		% mud		% TOC	
		Max	Min	Max	Min	Max	Min
1	Blackish grey with decomposing plant debris.	27	21.3	77.5	73	44	34
2	Blackish grey with decomposing organic matter.	28.9	22.3	74.6	71.1	47	40
3	Blackish and muddy	23.2	19	80	76.6	62	45
4	Blackish and muddy	28.3	16.2	83.6	70.7	55	41
5	Blackish grey with decomposing organic matter.	27.3	20.1	79.7	72	52	46
6	Blackish grey with decomposing organic matter.	26.3	21.2	78.3	73.4	51	44

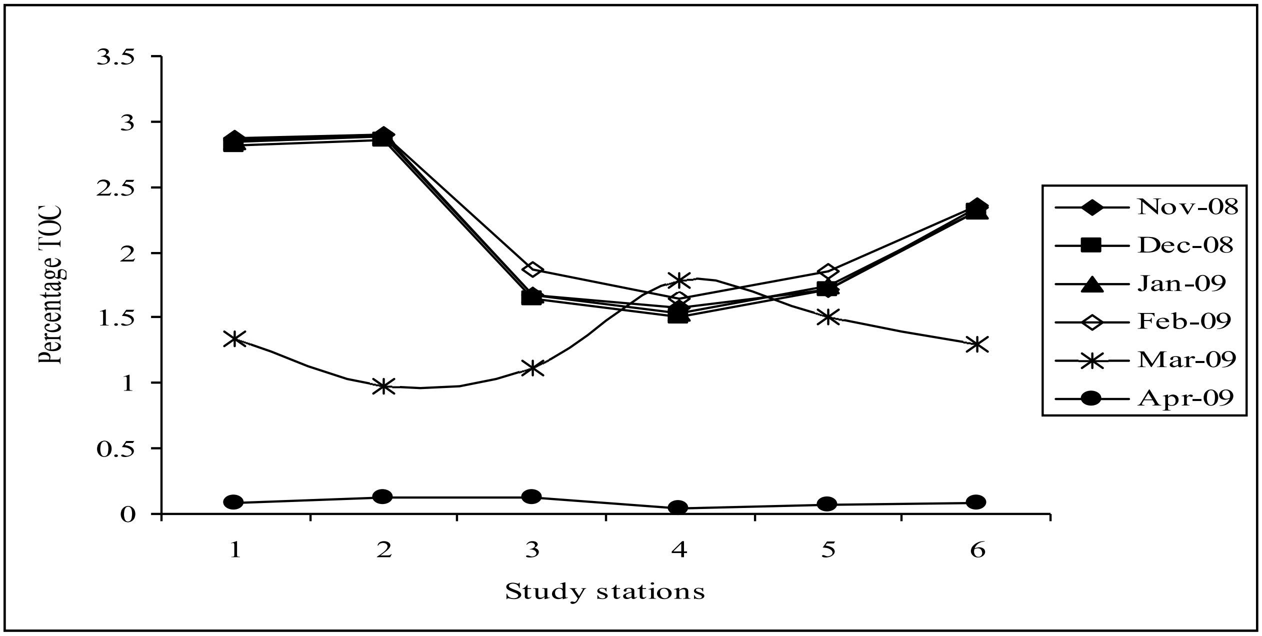


Fig. 2. Spatiotemporal variations in percentage TOC in sediment

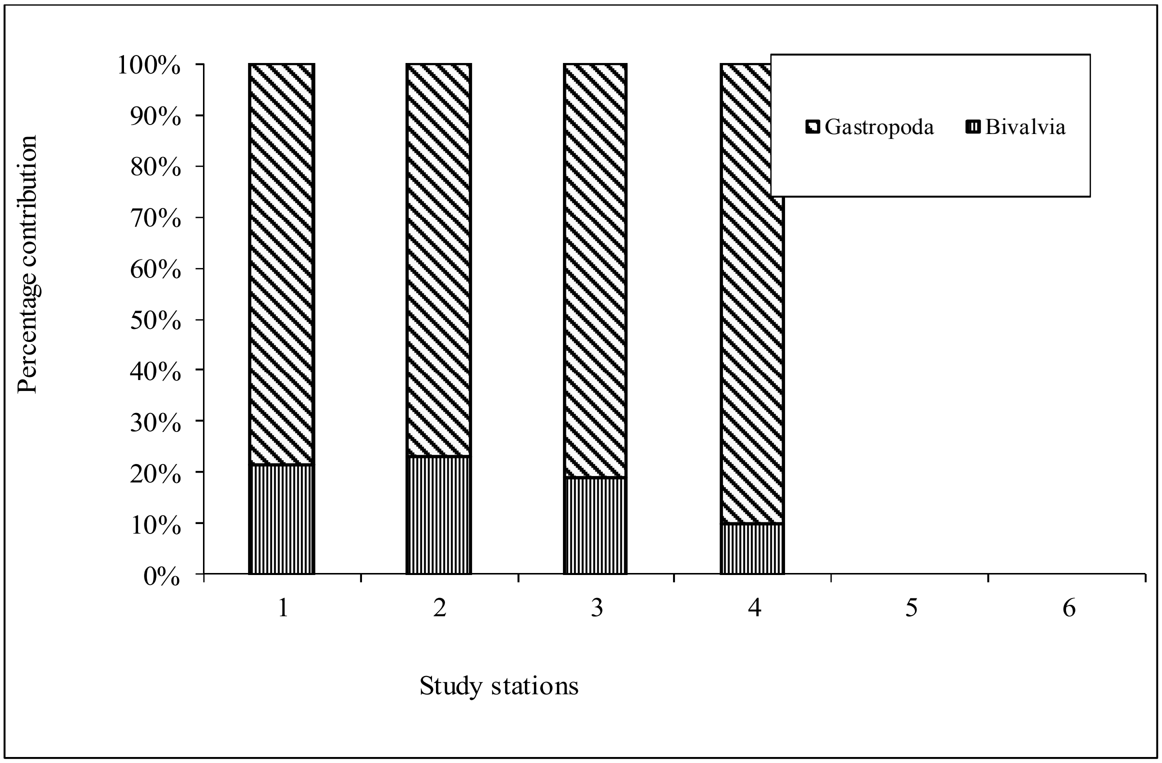


Fig. 3. Percentage contributions of the two classes of Molluscs at the study stations.

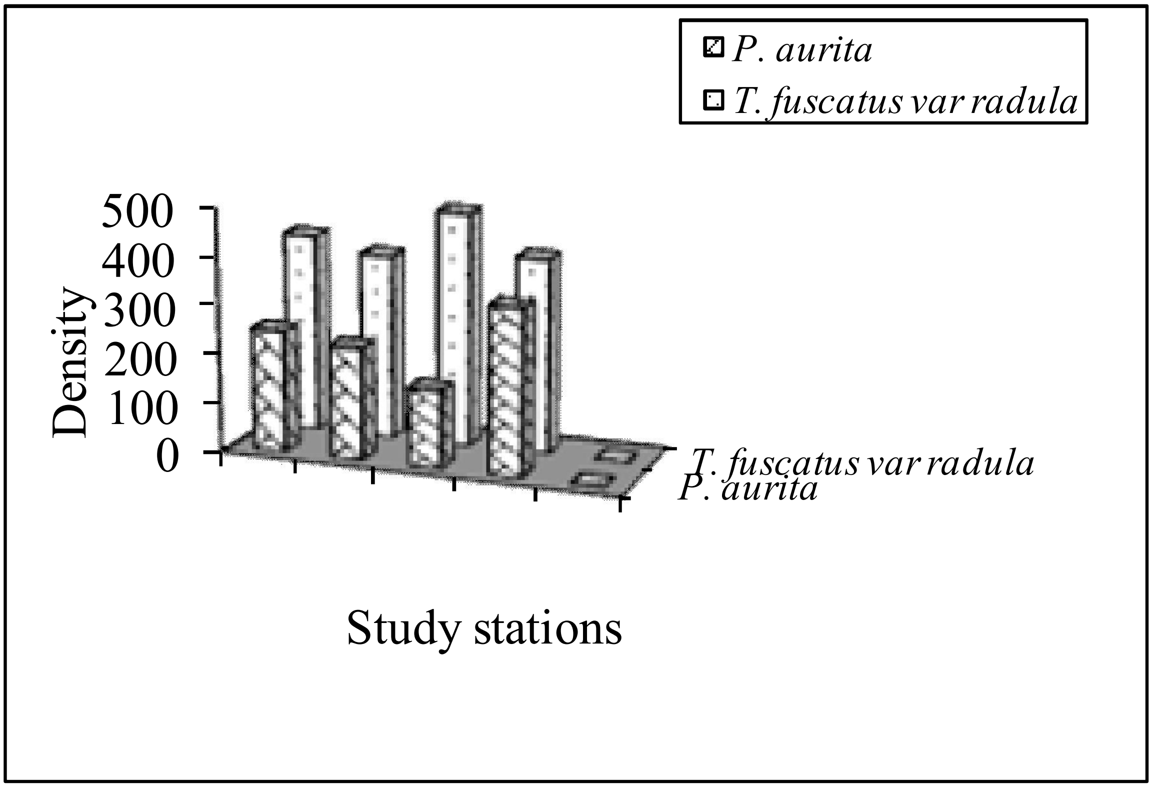


Fig. 4. Spatial variations in the densities of gastropod species.

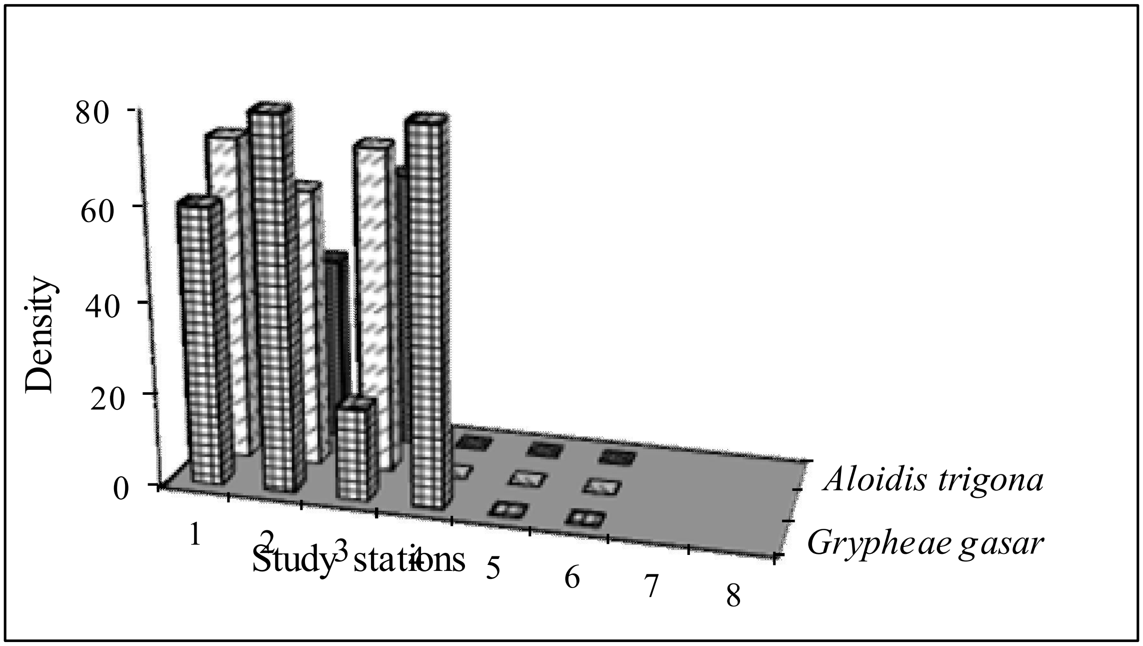


Fig. 5. Spatial variations in densities of bivalve species.

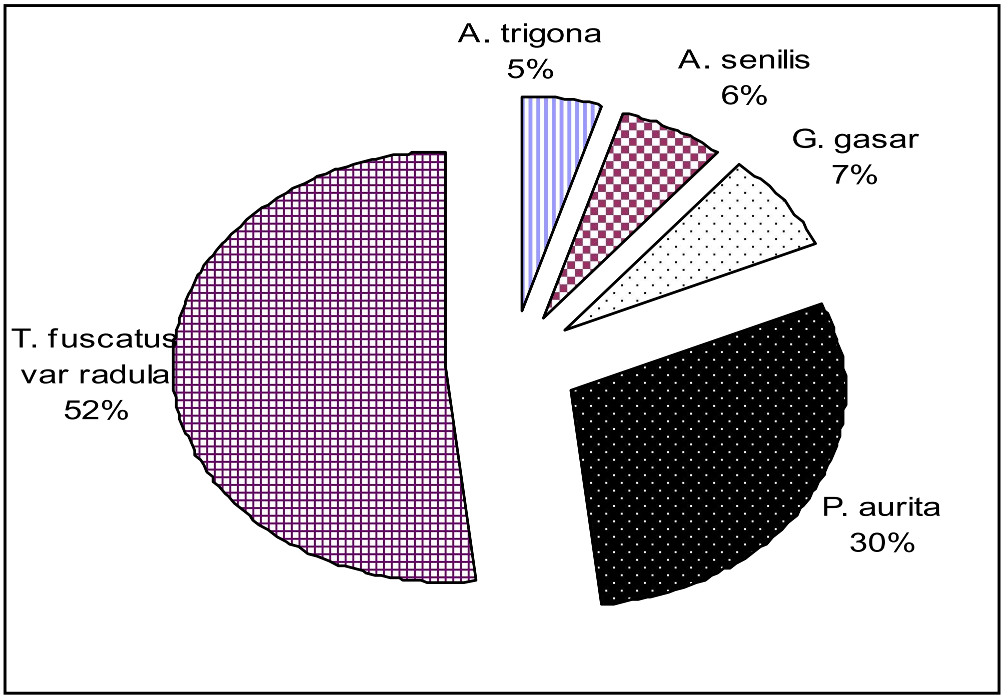


Fig. 6. Percentage species contribution in the stdy area.

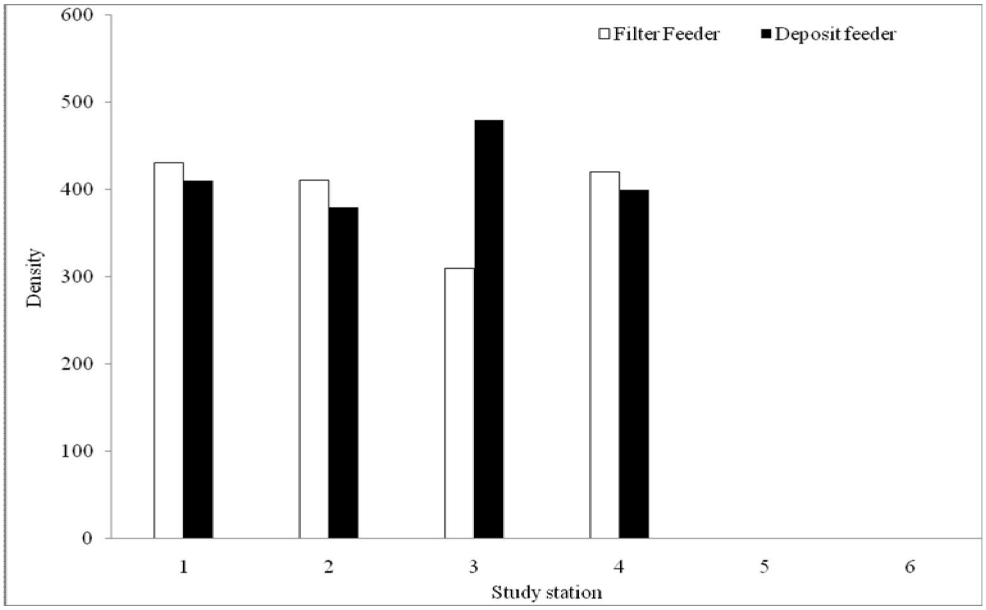


Fig. 7. Spatial variations in density of the FFGs.

Table 2. Frequency of occurrence of fungi in the sediment of University of Lagos mangrove swamp.

Taxa	Study station					
	1	2	3	4	5	6
Mitosporic fungi						
Aspergillus wentii	-	1	1	2	2	1
Aspergilius niger	2	2	1	3	2	3
Aspergillus flavus	4	2	1	1	3	1
Aspergillus fumigatus	1	2	3	-	-	1
Penicillium spp	4	4	3	6	3	5
Fusarium spp	2	4	4	6	3	2
Rhizopus spp	-	1	2	3	1	1
Trichoderma spp	-	-	-	-	2	1
Yeast cells	1	1	-	1	-	-

Table 3. Composition, Density (ind /m^2) and relative abundance (%) of each species at the study stations

	Study stations					
Taxa	1 Mean ± SE %	2 Mean ± SE %	3 Mean ± SE %	4 Mean ± SE %	5 Mean ± SE %	6 Mean ± SE %
Melaniidae						
Pachymelania aurita	41.70±13.4 30	38.3±I2.8 29	26.7±8.80 20	56.7±20.4 41	-	-
Aloididae					-	-
Aloidis trigona	8.0±4.20 6	6.7±3.30 5	10.0±5.2 8	-		
Arcidae						
Anadara senilis	11.7±5.4 8	10.0±5.2 8	11.7±5.4 9	-	-	-
Potamididae						
Tympanonus fuscatus var *radula*	68.3±24.4 49	63.3±21.3 48	80.0±2.57 61	66.6±23.0 49	-	-
Ostreidae						
Grypheae gasar	10.0±3.7 7	13.3±4.2 10	3.33±1-08 3	13-33±1.7 10	-	-

Table 4. Summary of biotic parameters of molluscan community at study station.

	Study stations					
	1	2	3	4	5	6
Number of samples	6	6	6	6	6	6
Number of Taxa	5	4	5	4	--	--
Number of Individual	84	79	79	82	--	--
Margalef's Index (D)	2.08	1.58	2.10	1.57	--	--
Shannon wieners index (H)	1.92	1.89	1.89	1.91	--	--
Evenness	1.00	0.99	0.99	0.99	--	--

Table 5. Seasonal changes in species richness, diversity and evenness of benthic macrofauna

Sampling month	Margalef's index	Shannon-Weiner index	Evenness index
December	2.08	1.92	1
January	1.58	1.89	0.99
February	2.1	1.89	0.99
March	1.57	1.91	0.99
April	1.42	1.87	0.98
May	1.4	1.90	0.99

Table 6. Faunal composition and functional feeding groups

Taxa	Functional feeding groups
Bivalva	
Aloididae	FF
Arcidae	FF
Ostreidae	FF
Gastropoda	
Melaniidae	FF
Potamididae	DF

Table 7. Spearman's correlations between biotic and environmental parameters in the study area; +: positive correlation; -: negative correlation; ns: no significant correlation; .p >O.05; *: significant correlation; p <O.05.

Biotic parameters	Environmental parameters		
	Sand	Mud	Organic content
Community index			
Shannon-Wiener H	+*	-ns	-*
Equitability	+ns	-ns	+ns
Population density			
Pachymelania aurita	+ns	-ns	-*
Aloidis trigona	-ns	+ns	-*
Anadara senilis	-ns	+ns	-*
Tympanotonus fuscatus var *radula*	-ns	+ns	+ns
Grypheae gasar	+ns	-ns	-ns

Fungal Community

Nine (9) aquatic fungal taxa were recorded in this study (Table 3). *Aspergillus* recorded the highest number (4) of species in the study stretch and was isolated from all the stations used for this study. *Penicillium* had a total frequency of occurrence of 25 and occurred in all the stations sampled. *Fusarium* was isolated 21 times and was observed in all the stations. *Rhizopus* occurred in all the station s except in station 1, while *Trichoderma* and yeast cells were only recorded in few stations.

In all the stations used for this investigation, stations 2 and 6 recorded the highest number of isolates while the least number of taxa was observed in station 1.

Taxonomic composition and abundance of benthic molluscs

Composition, Density (ind m^{-2}) and relative abundance (%) of each species at the study stations are presented in table 2.Two classes (Fig 3); Gastropoda and Bivalvia, 5 families, 5 genera and 5 species all belonging to the phylum mollusca were recorded in this study. Gastropod species (*Pachymelania aurita* and *Tympanotonus fuscatus* var *radula*) were widely distributed and occurred in stations 1-4 (Fig. 4), while bivalve species (*Aloidis trigona* and *Anadara senilis)* were recorded only in three stations (1-3), except *Gryphae gasar* which occurred in four stations (Fig. 5). There was no benthic macrofauna species found in stations 5 and 6. Of the overall benthic macrofauna density of 3240 ind/m^2 recorded in the study area, gastropoda constituted 2650 ind/m^2 (81.79%), while bivalvia recorded total density of 590 ind/m^2 accounting for 18.21% of the overall density. The density of gastropod was highest (740 ind/m^2) in station 4 and the lowest (610 ind/m^2) value observed in station 2, while the highest value for the bivalvia was 180 ind/m^2 in stations 1 and 2 and the lowest was 80 ind/m^2 in station 4.The total density of benthic macrofauna at the stations (1-4) where animals were recorded ranged between 790 ind/m^2 (observed in stations 2and 3) and 840 in station 1. The most dominant species *T. fuscatus* var *radula* comprised 51.45% of the total benthic macroinvertebrate population (Fig. 6).

Species richness, diversity and evenness

Variations in species richness, diversity,evenness and other biotic parameters and presented in table 3, while seasonal vriations in species richness, diversity and evenness are depicted in table 4. Species richness was highest (2.10) in station 3 and the lowest(1.57) in station 4, while highest diversity value (1.91) was observed in station 1 and the lowest value (1.89) in stations 2 and 3. Evenness was highest (1.00) in station 1. Seasonal analysis (Table 4) of species richness, diveristy and evenness indicates that the month of December recorded the highest values for the three parameters.

Structure of functional feeding groups

Analysis of the functional feeding composition of the assemblage revealed that of the two FFGs (Table 5) recorded, deposit feeder (*T. fuscatus* var *radula*) was the most abundant FFG, it accounted for 51.54% of the total benthic macoinvertebrate population, while the filter feeders constituted 48.46 %. Filter feeders represented by the gastropod *P. aurita*, which accounted for 30.25% of the observed population, and the three bivalve molluscs (*A. trigona, A. senilis* and *G. gasar*) were recorded in this study.

The two functional groups were recorded in all the study stations except in stations 5 and 6. Density of filter feeders was greater than that of the deposit feeders in stations 1, 2, and 4, while in station 3 greater density of the DF was observed (Fig. 7).

Relationships among biotic and environmental parameters

The relationships among biotic and environmental parameters are depicted in table 6. In the overall, organic content of sediment had strong effects on community indices and population densities. Sand and mud content were relatively unimportant. Species diversity (H') and the population densities of *P.aurita, A. trigona, A.senilis, and G. grasar* decreased significantly with increasing organic content. The population density of the dominant species *T. fuscatus* var *radula* and evenness showed a reverse trend, increasing with organic content. Percentage sand in sediment was observed to have influenced the species diversity in the study area, increased in sand in sediment appeared to have favoured species diversity.

DISCUSSION

Environmental parameters

The salinity of the mangrove swamp is consistent with other estuarine ecosystems in south west Nigeria and indicated the extent of tidal incursion of saline water from the Lagos lagoon. In the rainy months, lower salinity values were observed owing to the diluting effect of the rains.

The low dissolved oxygen concentration recorded in this study agrees with values reported for some polluted water bodies in south west Nigeria (Nwankwo and Akinsoji, 1989; Ogbeibu and Victor, 1989). The dissolved oxygen values revealed anoxic conditions which can be deleterious to most aquatic fauna. In line with the classifications of Vowels and Connel (1980), unpolluted water (BOD < 1.0mgL-1), moderately polluted (BOD between 2-9mgL-1) and heavily polluted (BOD > 10mgL-1) the study area can be described as heavily polluted. The low DO and high BOD values observed may be the resultant effect of biochemical oxidation of the heavy organic load in the water.

The black colour and a foul smell of the sediment when unearthed indicate the presence of hydrogen sulphide (McKee, *et al*., 1988). This is the result of the activities of anaerobic bacteria on the organic content of the sediment.

The TOC of sediment recorded in this study was high when compared to those (highest mean value = 6.88%) observed by Uwadiae *et al.* (2009) for Epe lagoon and those (0.030 – 0.340 %) reported by Shazra *et al.* (2008) for a mangrove ecosystem in Maldives. Castro and Huber (2005) recognized the high organic matter content of near shore environments such as the present study area. A number of factors may have influenced the TOC of sediment in the study area including input from anthropogenic origin through drainage channels which drain the University of Lagos and organic debris from decaying mangrove roots, stems and leaves. The mud content of sediment recorded in this study agreed with the report (6 to 60% silt/clay content) of Hsieh (1995) for a subtropical mangrove swamp, these high values are expected since mangrove swamp are known to develop on protected coasts where muddy sediment accumulate (Castro and Huber, 2005). High fraction of mud in sediment of mangrove swamps may be related to the high organic content which is thought to induce sedimentation.

Fungal community

Mangroves are considered to be biodiversity ‘hotspots’ for aquatic fungi with over 625 fungal species recorded from mangrove habitats (Shearer *et al*. 2007). Hyde (1988) listed 120 fungal species from 29 mangrove forests around the world including 87 Ascomycetes, 31 Deuteromycetes and 2 Basidiomycetes.

Reasons for the great diversity include; factors such as a diverse number of substrates and a range of environments in terms of salinity and immersion (Sasekumer and Chong, 1988), the detritus (leaf litter, woody litter, animal remains), marsh vegetation and imported substances constitute a major source of organic matter. Mangroves support abundant benthic fungal communities through high rates of decomposition (Hsieh, 1995).

The ecology of fungi is structured by responses to the abiotic environment and interactions with other biota (Jones, 2000).

The number of species of fungi recorded in this study is low when compared with those recorded for similar tropical ecosystems (Hyde, 1988). The occurrence of *Aspergillus* spp as the dominant taxa recorded in this study agrees with the report of Klich (2002), and *Aspergillus* noted to be ubiquitous in tropical and subtropical environments (Klich, 2002). The prevailing abiotic conditions of sediment in the study area may have favoured the proliferation of the fungal taxa recorded. According to Sasekumer and Chong (1988), highest populations of *A. flavus* were associated with soils containing higher organic matter. The authors also observed that edaphic factors such as organic matter content, nitrate and extractable phosphorus correlated with the density of *Aspergillus*, *Fusarium* spp., and total fungi. Sediments with high organic matter have a greater moisture-holding capacity than those with a lower organic matter content (Alongi and Christoffersen, 1992).

Sediments serve as seed bank for resting spores of aquatic fungal species. In the upper sediment layers, heterotrophic fungal activity has been suggested (Flegler *et al*., 1974). Oxygen, if present, is restricted to the uppermost layer of sediments. Fungi are generally thought to be aerophilic, and few species can withstand or remain active under anoxic conditions (Scupham *et al*. 2006). Czeczuga *et al* (1987) found a negative correlation between BOD and fungal species richness.

Sediment fungal diversity varies according to specific ecosystems, the particular estuarine conditions appear to select for distinct fungal communities. The low number of species recorded in this study may be due the muddy nature of the sediment in the study area. Hyde & Goh (1998) and Tsui *et al*. (2001a, b) suggested that pollution of the aquatic environment and instability in sedimentary conditions could influence fungal diversity. In the current study, pollution as evidenced in the low DO, high BOD, muddy sediment and high TOC values may have affected the diversity observed.

Tan and Lim (1984) demonstrated that, the diversity and the number of individuals of fungi were lower in a more polluted site. Similar results were reported from Au and Hodgkiss (1992a) in Hong Kong. They compared the fungi found on leaf baits in polluted and unpolluted streams located geographically close together. The species richness and conidial production was higher in the unpolluted stream. In the same study, Au and Hodgkiss (1992b) found that the decomposition of leaf baits seemed to be suppressed in the polluted stream.

Molluscan community

Benthic malacofuna in mangrove swamps has not been extensively studied in Nigeria, therefore, comparative analysis of the assemblage, community structure and taxonomic composition of benthic macrofauna recorded in this study with those of other Nigeria mangrove ecosystems may be difficult. The low benthic mollusc density and number of species recorded here depict an impoverished community. Environmental variables in the mangrove swamp indicate degraded ecosystem that could sustain only opportunistic species. According to Uwadiae *et al*. (2009), most aquatic molluscs (Eckman, 1983) prefers sediments with little silt, and greater densities of occur in stations with low TOC (<10%), high sand (>60%) and low mud (<30%) contents. The authors observed that induced sedimentation resulting from high organic matter content 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 during respiratory and feeding activities (Hart and Fuller, 1979).

According to Peres (1982), the coastal subsoil/sediment is a rather dark environment, where there are no photo-autotrophic algae to produce the energy required for the system hence, fauna composition is rather poor. Due to the high water retaining ability of mud its infauna is always poor, due principally to low oxygen content of interstitial water and the very fine silt or clay particles which may clog respiratory or food collecting mechanisms.

The dominance and large scale distribution of the gastropod *Tympanotonus fuscatus* var *radula* in the study area corroborates the observation of Egonmwan (1988) and further strengthens the argument that the animal can withstand some degree of perturbations (Don-Pedro *et al*., 2004; Jamabo and Chinda, 2010).

Impact of sediment characteristics on fungal and molluscan assemblages

Oyenekan (1988b) observed that, of all the environmental factors affecting benthic organisms in their habitat, substrate of occupation is of cardinal importance. The sediment inhabitability by an organismic assemblage as well as the assemblage composition depends on the porosity of the sediment, i.e. internal water and oxygen circulations in interstitial spaces (Kinne, 1982). That benthic assemblage is constrained by sediment granulometry and chemistry has been well documented (Castro and Huber, 2005, Hyland *et al*., 2005). Ajao, (1990) and Uwadiae *et al.*, 2009) reported that molluscs, *P. aurita* in particular is associated with sediments ranging from medium to fine sand with little silt but not with muddy sediment like the situation observed in the study area. This may have accounted for the poor representation of the organism in the study area. Hart and Fuller (1979) reported that very few benthic 0rganisms are able to survive in muddy sediments, this is because mud smoothers benthic organisms by blocking their respiratory organs.

The diversity and population density of benthic molluscs of the mangrove swamp were significantly impacted by the high TOC of sediment (Table 2). Total organic content provides a measure of how much organic matter occurs in sediments. Hyland *et al.* (2005) observed that although organic matter in sediments is an important source of food for benthic organisms, an overabundance can cause reductions in species richness, abundance, and biomass due to oxygen depletion and buildup of toxic by-products (ammonia and sulphide) associated with the breakdown of these materials. Moreover, high organic content of sediment is often accompanied by other chemical stressors co-varying with sediment particle size. Hyland *et al.* (2000) found that extreme concentrations of TOC can have adverse effects on benthic communities. The authors reported that, TOC levels below 0.5 mg/g (0.05%) and above 30 mg/g (3.0%) could impact negatively on the abundance and biomass of benthic communities.

In the views of Castro and Huber (2005), large amount of leaves and other dead plant material accumulate in the mangrove forest. Although considerable amount are eaten and some exported to other ecosystems, much of the detritus is broken down by fungi and bacteria. This makes the mud in mangrove swamps black and oxygen deficient and toxic substances released by the leaves make life on muddy bottoms in mangrove forests less abundant than on similar ecosystems elsewhere.

In addition, runoff and tides continuously occur within the mangrove swamp, bringing in large quantities of materials, but broader tidal fluctuations may cause these materials to be resuspended. High levels of resuspended material input to mangrove can significantly alter benthic assemblages. Wood and Armitage (1997) identified four ways in which resuspended materials can affect benthic organisms: (1) by altering substrate composition and changing the suitability of the substrate for some taxa (Hynes, 1970; Waters, 1995); (2) by increasing drift as a result of sediment deposition or substrate instability (Culp *et al.*, 1986; Rosenberg and Wiens, 1978); (3) deposition on respiration structures affecting oxygen uptake or low oxygen concentrations associated with fine sediment deposits (Waters, 1995); and (4) by affecting feeding activities by reducing the food value of periphyton (Graham, 1990) and reducing the density of prey items (Peckarsky, 1984).

The characteristic of sediment observed in the study area may have also influenced the functional composition of molluscan communities. The guilds structure in an aquatic system reflects the overall health of the water body. Typically, polluted water bodies show a decline in Coarse Particulate Organic matter (CPOM) and Fine Particulate organic matter (FPOM), shredders and collectors dependent on allochthonous inputs, and a rise in scrapers and collectors dependent on autotrophic energy inputs. The diversity of functional feeding groups groups (FFG) is influenced by the characteristics of the available habitats, proving that different FFG explore different alimentary resources (Benke, 1993). A habitat can supply protection or impede the settlement of macroinvertebrates in an environment, thus favouring the occurrence of certain functional feeding groups

In general terms, it was possible to relate the dominance of deposit feeders with the environmental characteristic of the study area. Deposit feeders had the highest population constituting 51.54% of the total molluscan community. Deposit feeders are thought to live in a trophically more stable environment, with resource limitation. Two arguments supported the apparent constancy and resource limitation of deposit-feeding populations. First, deposit feeders are more abundant in fine-grained sediments, which contained more organic matter than the coarser-grained sediments, which are more usually dominated by suspension feeders (Sanders, 1958). Second, deposit feeders are found to digest and assimilate microbial organisms from the sediment with much greater efficiency than the more refractory particulate organic matter (Lopez and Levinton, 1987).

The occurrence of these deposit feeders in higher proportions might be related to the organic content of sediment in the study area. The studied stations present typical characteristics such as influence of the riparian vegetation and high content of TOC and mud in sediment.

The two functional feeding groups (FF and DF) observed in this study are generalist feeders that can survive the sedimentary conditions of the study area. Since they rely on wide range of food items, they are better adapted to life in the mangrove swamp.

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