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Full Length Research Paper

Environmental Characteristics and Community Structure of Benthic Macroinvertebrate of Epe Lagoon, Nigeria

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Abstract

This paper investigates the environmental characteristics and community structure of benthic macroinvertebrate community of Epe Lagoon, Nigeria, from 2004 to 2006. Ranges of environmental variables studied demonstrated wide fluctuations within the period of study. Seasonal and hydroclimatic changes as well as anthropogenic activities were the overriding factors that affected values of environmental variables investigated. Analysis of benthic community structure of the lagoon reveals a community dominated by molluscs. Molluscs constituted over 92 % of the total benthic macroinvertebrate population. Annelida ranked second in terms of number of specimens represented and constituted 1.3 % of the total benthic macrofauna enumerated, this was followed by Arthropoda which accounted for 0.4 % of the total benthic macrofauna count. Other benthic phyla collected and their relative contribution to benthic macroinvertebrate population include; Nemertina (0.06 %), Chordata (0.006 %), Echinodermata (0.006 %) and Porifera (0.02 %). A major feature of the community observed in the lagoon is the occurrence of brackish and freshwater species.

Keywords: Physical-chemical characteristics, benthic macrofauna, Epe Lagoon.

Introduction

The coastal area of south-western Nigeria situated at approximately an angle of 45^o to the prevailing south-west wind is a meandering network of lagoons (Hill and Webb, 1958). This area stretches from Benin Republic in the west to the Niger delta in the east and consists of eight major lagoons, namely; Yewa, Ologe, Mahin, Lagos, Epe, Lekki, Iyagbe and Kuramo Lagoons (Nwankwo, 1998). These lagoons open to the sea only through the Lagos Harbor which is part of the Lagos Lagoon, with the entire lagoon system experiencing different levels of semi-diurnal tidal influences (Webb, 1958a; FAO, 1969; Olaniyan, 1969). Fresh and brackish water conditions have been recorded in these lagoons as a result of freshwater runoffs from land and inflow of rivers and other water bodies as well as tidal incursion into these lagoons.

Lagos state is within a low lying coastal zone of the south-western Nigeria sedimentary basin (Nwilo and Onuoha, 1993), this low lying position tends to influence the flow of other water towards the lagoons. Network of interwoven rivers, estuaries, and creeks linked to the lagoons are major conduits for pollutants from the inland. Being a central receptacle of water bodies draining a large area of agricultural and industrial lands, the lagoons has been described as a sink to large amounts of aquatic pollutants resulting in severe consequences for the biota. Loss of biodiversity, introduction of exotic species and complete decimation of economically important species are some of the deleterious observations made by earlier workers (Nwankwo, 1998; Nwankwo and Akinsoji, 1992). Mostly affected in the aquatic biota are the benthos which are in close association with the aquatic sediment which serves ultimately as recipient of most aquatic pollutants (Oyenekan, 1988).

Although several studies (Webb, 1958a, b; Brown and Oyenekan, 1983, 1998; Ajao and Fagade, 1991; Brown, 1998, 2000; Chukwu and Nwankwo, 2004) on the environmental characteristics and benthic macroinvertebrate community structure of most of the aquatic systems in south-western Nigeria have been carried out, information on the environmental features and benthic macroinvertebrate community structure of Epe lagoon is scanty. Epe Lagoon is an important aquatic system in Lagos state. The dearth of information on the benthic macrofauna assemblage, community structure, abundance and distribution has made it difficult in the assessment of environmental status of the lagoon. This paper therefore, is aimed at providing information on the environmental characteristics and community structure of the benthic macroinbertebrate community of the lagoon.

Materials and Methods

Description of Epe Lagoon

Epe Lagoon (Fig. 1) is situated between latitudes 3050' – 4010'N and longitudes 5030' – 5040'E. The lagoon lies within the rainforest belt of southern Nigeria which experiences two major seasons, the rainy season concentrated between May and November, and dry season occurring between December and April. Annual rainfall ranged from 6 to 330 mm during the study period. Riparian vegetation at the bank of the lagoon consists mainly of grasses and secondary rainforest. Land use in the study area includes agriculture, human activities in the study stretch include sand mining, artisanal fisheries and transportation of people and goods using Motorized Boats. A major feature of the lagoon is the overwhelming preponderance of floating vegetation of water hyacinth, a phenomenon that has been linked to pollution (Nwankwo and Onitiri, 1992). The study area is a rural setting with most of the population concentrated along the bank of the lagoon. Wastes of various types are dumped into the lagoon. Also, most inhabitants of the shore communities do not have toilet facilities hence defecation and release of other human wastes into the lagoon are common features in the study stretch.

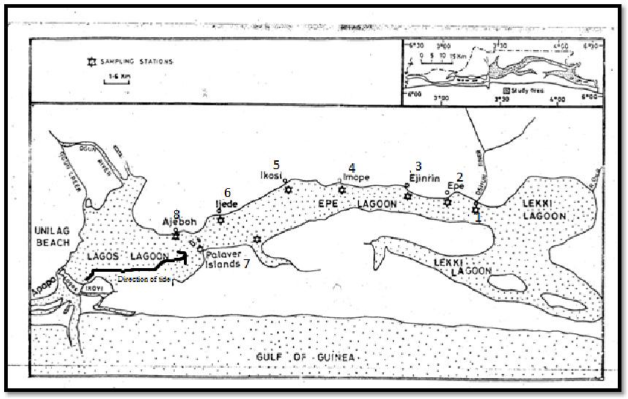

Fig. 1. Epe Lagoon showing study stations

Collection and Processing of Samples

Water and sediment samples

250ml transparent and amber coloured reagent bottles were used for the collection of water samples used for the analysis of Dissolved oxygen (DO) and Biochemical oxygen Demand (BOD) ,while water samples used for the determination of other physico-chemical parameters were collected in one litre plastic bottles. Sediment samples from each sampling point were collected using Van veen grab of size $0.1m^2$. The top 5cm layer of each haul was carefully scooped and placed in labeled polythene bags and transported to the laboratory, where samples were preserved in the deep freezer before analysis. Laboratory sample handling and analyses were carried out according to procedures described in Holme and Mclntyre (1971), and APHA (1998).

Benthic Macrofauna

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 in labeled plastic containers for onward transportation to the laboratory.

In the laboratory, preserved benthic samples were washed with tap water to remove the preservative and any remaining sediment to facilitate sorting. The animals were sorted on a white tray into taxonomic groups (Phyla, Class, Families, and Species) and identification was carried out using suitable texts including; Buchanan (1954); Edmunds (1978), Yankson and Kendall (2001). The number of species and individuals for each station were counted and recorded. Classification of species into fresh and brackish water species was based on salinity of study area of the occurrence of the species and information from literature.

Results

Environmental Characteristics

The summary of environmental features of Epe Lagoon is presented in Table 1. Physical attributes of water and sediment were typical of tropical conditions. Air temperature in the area varied between 24 and 37 ^oC, while water temperature fluctuated between 23 and 43 ^oC. The depth of the lagoon ranged between 0.7 and 4.7 m. Hydrogen ion concentration varied from 6.10 to 8.90. Total organic content (TOC) of sediment ranged between 1.01 and 10.45%. Sand fractions in sediment fluctuated between 54.4 and 93.6%, while mud particles varied from 5.8 to 44.6%.

Nutrient levels (Phosphate and nitrate) in water were higher in the wet season than the dry season and varied from 0.12 to 6.50 mg/L and 0.15 to 6.80 mg/L respectively. The values of heavy metals studied were also higher in the wet season except copper in sediment which recorded the highest value in the dry season. The values of copper and zinc in water varied from 0.02 to 0.97 mg/L, and from 0.00 to 0.097 mg/L respectively. Higher values of the heavy metals were observed in sediment, copper ranged between 0.01 to 5.21 mg/kg, while zinc varied from 3.45 to 68.30 mg/kg.

Other chemical attributes of the lagoon investigated recorded highest values in the dry season except Dissolved oxygen (DO) in water. A range of 0.01 – 19.72 ‰ for water salinity , Total dissolved solids (TDS) ranged between 18 and 15,200 mg/L, conductivity varied from 150 – 33252 μScm^{-1}, DO 2.4 – 15.0 mg/L, Biological oxygen demand (BOD) 4.0 – 114.4mg/L, while Chemical oxygen demand (COD) recorded a range of 69.6 – 557 mg/L.

Table 1: Summary of environmental features of Epe Lagoon.

Parameter/Unit	Range	Season with the highest value.
Water		
Depth (m)	0.7 - 4.7	
Air temperature (^oC)	24 – 37	Dry season
Water temperature (^oC)	23 – 43	Dry season
Salinity (‰)	0.00 – 19.72	Dry season
Total dissolved solids (TDS) (mg/L)	30 – 15400	Dry season
Conductivity (μScm^{-1})	150 – 33252	Dry season
Hydrogen ion concentration (pH)	6.10 – 8.90	Wet season
Dissolved oxygen(DO) (mg/L)	2.4 – 15.0	Wet Season
Biological oxygen demand (BOD_5) (mg/L)	4.0 – 114.4	Dry Season
Chemical oxygen demand (COD) (mg/L)	69.6 – 557	Dry Season
Phosphate-phosphorus (PO4-P) (mg/L)	0.12 – 6.50	Wet Season
Nitrate-Nitrogen (NO_3-N) /mg/L	0.15 – 6.80	Wet Season
Copper (Cu) (mg/L)	0.02 – 0.97	Wet season
Zinc (Zn) (mg/L)	0.00 – 0.092	Wet season
Sediment		
Copper (mg/kg)	0.01 – 5.21	Dry season
Zinc (mg/kg)	3.45 – 68.30	Wet season
Total organic content (TOC) (%)	1.01 – 10.45	Wet season
Sand (%)	54.4 – 94.2	Wet season
Mud (%)	5.8 – 44.6	Wet season

Taxonomic composition and community structure

Overall benthic macrofauna species composition in Epe Lagoon is shown in Table 2 while the summary of the community structure is depicted in Table 3. A total of 17711 specimens of benthic macrofauna comprising seven phyla (Mollusca, Annelida, Arthropoda, Nemertina, Chordata, Porifera and Echinodermata), 10 classes, 27 families and 44 species was recorded. The phylum Mollusca ranked first in abundance with 17415 specimens comprising 2 classes, 7 families and 12 species constituting 98.20 % of the total benthic macrofauna. Twelve molluscan species (Fig. 2) made up of six gastropod species belonging to three families (Neritidae, Melaniidae, Potamididae) and six bivalve species belonging to four families (Tellinidae, Avcidae, Osteridae and Aloididae)) were identified. The dominant species observed among the gastropod was *P. aurita*, which recorded 7852 specimens and constituted 44.33 % of the benthic macrofauna population, the species ranked highest in abundance among the species of molluscs collected. Other gastropods recorded in large numbers include *Neritina kuramoensis* (1329 specimens; 7.5 %) and *N. glabarata* (1111 specimens; 6.25 %). Among the bivalves collected from the study stretch, *Macoma cumana* dominated in terms of number of specimens. Of the total number (5548) of specimens of bivalves recorded, *M. cumana* contributed 5117 specimens, thereby constituting 29 % of the total benthic macrofauna population. Another major representative in the bivalve group was *Aloidis trigona* which recorded 244 specimens. Annellida ranked second in terms of number of specimens represented with 229 specimens comprising 2 classes, 5 families and 11 species (Fig. 3), it contributed 1.3 % of the total benthic macrofauna enumerated. Among the members of this phylum, the family Nereidae contributed 142 individuals while Capitellidae contributed 51 specimens. Major species collected include, *Nereis lamillosa* (45 specimens; 0.25 %), *Capitella capitata* (43 specimens; 0.24 %), *N. succinea* (38 specimens; 0.21 %) and *N. diversicolor* (37 specimens; 0.20 %). Other annelids recorded include; Naididae (17specimens) and Lumbrineridae (11 specimens). A total of 67 individual of arthropods made up of 2 classes, 10 families and 16 species (Fig. 4) were encountered in this study. Arthropods accounted for 0.4 % of the total benthic macrofauna count. The class crustacean contributed 38 individuals while insecta contributed 28 individuals. Nemertina had nine (9) individuals represented, consisting of *Nemertea* sp (5 individuals) and *Cerebratulus* sp (4 individuals). They accounted for 0.06 % of the total benthic macrofauna.

The phylum chordata was represented by a single individual of *Brachiostoma nigeriense* belonging to the class Leptocaridia. It accoutered for 0.006 % of the total benthic macrofauna. Echinodermata was represented by a single individual of *Cuccumaria* sp. belonging to the class Holothuriodea. The phylum accounted for 0.006% of the total benthic macrofauna. For the phylum porifera**,** two species (*Tetilla monodi* and *Adocia cinerae*) each represented by single and two individuals respectively were recorded and together they accounted for 0.02 % of the total population of benthic macrofauna.

The community of benthic macroinvertebrates recorded can be grouped into freshwater and brackish water species. Of the 44 species collected, 14 species were freshwater species which constituted 31.8 % of the total benthic species collected, while brackish water species comprised 68.2 % of the total species with 30 species represented (Table 2). Freshwater group was represented by 82 individuals therefore constituted approximately 0.5% of benthic macroinvertebrate population, while brackish water comprised 99.5 % of the total population.

Table 2. Composition of benthic macoinvertebrates. * = Freshwater species; ** = Brackish water species

Phylum	Class	Family	Species
Annelida	Polychaeta	Capitellidae	***Capitella capitata* Fabricius, 1780.
			***Capitella hermaphrodita* Boletzky and Dolile,1967.
			**Heteromastus filiformis* (Laparède, 1864.
			**Notomastus hemipodus*Hartman, 1945
		Lumbrineridae	**Lumbrinerides cingulata* Ehlers, 1897
			**Lumbrineriopsis paradoxa* Saint-Joseph, 1888
		Nereidae	***Nereis lamellose* Linnaeus, 1758.
			***Nereis succinea* Leuckart, 1847.
			***Nereis diversicolor* MÜller, 1776.
	Oligochaeta	Lumbriculidae	**Lumbriculus variegatus* Müller, 1774.
		Naididae	**Nais eliguis* Müller, 1774.
Arthropoda	Crustacean	Gammaridae	**Gammarus fasciatus* Say, 1818
		Corophidae	***Corophium volutator* Pallas, 1766
		Penaeidae	***Penaeus notialis* Pérez Farfante, 1967
			***Palaemonetes vulgaris* Say, 1818
		Ocypodidae	***Ocypoda cursor*
			***Ocypoda* Africana
			***Uca tangeri* Eydoux, 1835.
		Sesarmidae	***Sersama huzardi*(Desmarest, 1825.
		Clibanaridae	***Clibanarius africanus,* Aurivillus,1898
			***Clibanarius senegalenses* Chevreux & Bouvier, 1898
			***Clibanarius chapini* Schmitt, 1926.
	Insecta	Chironomidae	**Chironomus plumosus* Linnaeus, 1785.
		Gomphidae	**Gomphus vulgatissimus* Linnaeus 1758.
		Libellulidae	**Libellula vibrans*Fabricius, 1793.
		Baetoidae	**Baetis muticus* Linnaeus, 1758.
		Tenthredinidae	**Kaliofenusa ulmi*
Chordata	Leptocaridia	Branchiostomidae	***Branchiostoma nigeriense* Webb, 1955
Echinodermata	Holothuroidea	Cucumariidae	***Cucumaria conicospermium* Stepanov, 2001
Mollusca	Gastropoda	Neritidae	***Neritina glabarata* Sowerby, 1849.
			***Neritina kuramoensis*Yoloye&Adegoke, 1977
		Melaniidae	***Pachymelania aurita* Muller, 1776.
			***Pachymelania* fusca *quadriseriata*Gray, 1831.
		Potamididae	***Tympanotonus fuscatus* Linnaeus, 1758.
			***Tympanotonus fuscatus* var radula Linnaeus, 1758.

	Bivalvia	Tellinidae	***Macoma cumana* O.G. Costa, 1829.
			***Tellina nymphalis* Lamarck, 1818.
		Avcidae	***Mytilus edulis* Linnaeus, 1758
			***Mytilus perna* Linnaeus, 1758
		Ostreidae	***Graphae gasar* Dautzenberg
		Aloididae	***Aloidis trigona*. Hinds
Nermertina	Hoplonemertea	Otonemeridae	**Lineus longissimus* Gunnerus, 1770.
			**Lineus ruber* Müller, 1774
Porifera	Demospongiae	Chalinidae	***Tetilla monodii* Burton, 1929

Table 3: Summary of benthic macrofauna community structure in Epe lagoon.

Phylum	Number of individual(s)	Classes	Families	Species	Percentage Composition
Annelida	207	2	5	13	1.16
Arthropoda	57	2	11	15	0.32
Chordata	4	1	1	1	0.02
Echinodermata	1	1	1	1	0.005
Mollusca	17433	2	7	12	98.43
Nermertina	6	1	1	2	0.04
Porifera	3	1	1	2	0.02
Total	17,711	10	27	44	

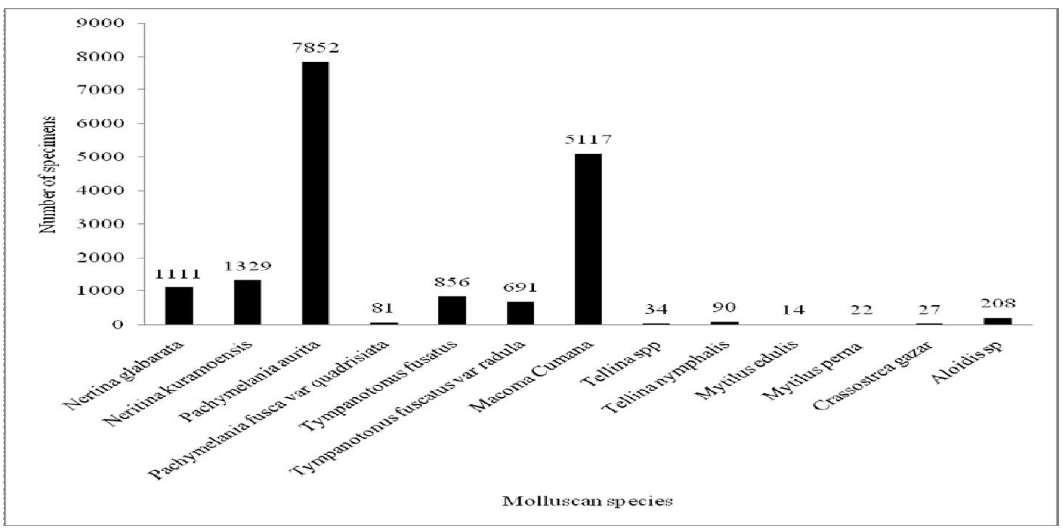

Fig. 2. Representative species of mollusca and number of specimens collected

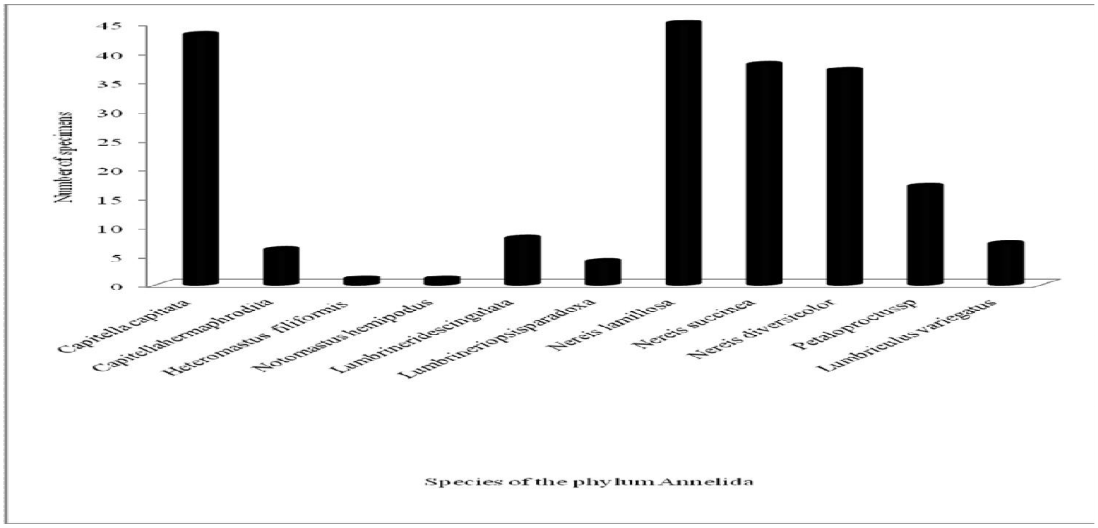

Fig. 3. Representative species of annelida and the number of specimens collected

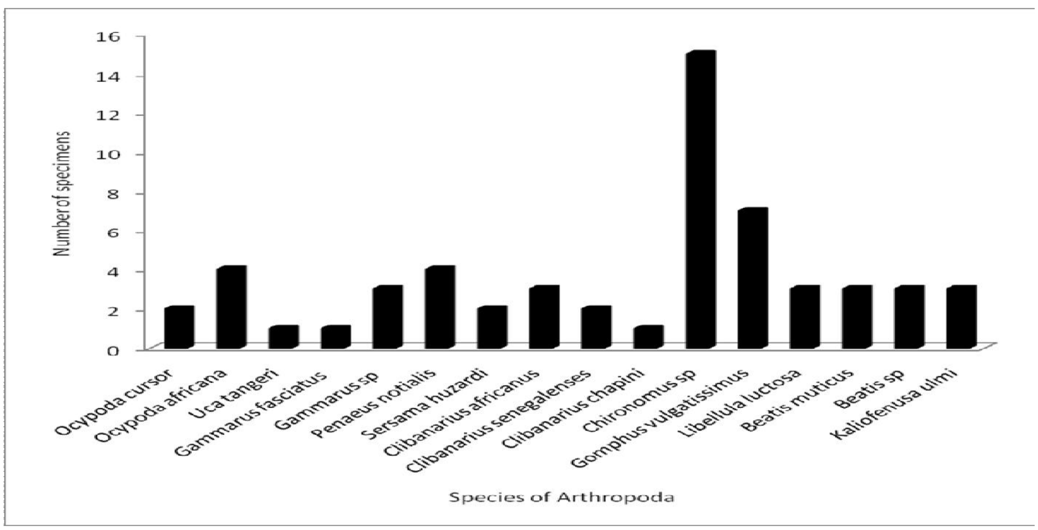

Fig. 4. Representative species of arthropoda and the number of specimens collected

Discussion

The range of values of environmental variables studied demonstrated large fluctuations within the period of study, these variations were majorly influenced by seasonal and hydroclimatic changes as well as anthropogenic activities. This observation corroborates the reports of earlier workers (Webb, 1958a,b; Hill and Webb, 1958; Sandison and Hill, 1966; Olaniyan, 1969; Ajao, 1996; Ajao *et al*. 1996; Nwankwo, 1998) in south-west Nigerian Lagoons.

Two factors namely; freshwater discharge from rivers and tidal seawater incursion, influence the physical, chemical and biological characteristics of the coastal lagoons in south-west Nigeria (Webb, 1958a,b; Nwankwo, 1998). During the rainy season, a large volume of freshwater enters the lagoons from drainage channels, creeks and rivers from the adjoining inland resulting in a dilution effect on the lagoons. On the other hand, during the dry season when there is reduction in the freshwater inflow into the lagoons there is a decrease in the volume of water and consequently increase in salinity of the lagoon water. The salinity of the lagoons is further increased by the incursion of tidal seawater especially for the lagoons with direct connection with the sea (Webb, 1958a; Hill and Webb, 1958; Sandison and Hill, 1966; Olaniyan, 1969; Nwankwo, 1996), like the Lagos lagoon which is connected to the sea through the Lagos harbor. According to Nwankwo and Akinsoji (1989), there is an existence of environmental gradient linked with rainfall pattern in Lagos lagoon. Foremost of these environmental factors showing gradient is salinity which according to Solarin (1998) is the most variable factor in the Lagos lagoon ranging from 0.5 to $28.5^{o}/_{oo}$, and showing high variations between the rainy and dry seasons.

Air and water temperatures as recorded in this present study were relatively higher in the dry seasons than in the wet seasons corroborating the reports of Nwankwo and Akinsoji (1989) and Nwankwo and Onitiri (1992). Nwankwo (1993) observed that though an obvious gradient existed in temperature, hydrogen-ion concentration (pH), salinity, transparency and cation values, with higher values in the dry season than wet season, there are no clear pattern shown by dissolve oxygen (DO) in the south-western coastal waters. The report also showed that nutrient levels, PO_4-P and NO_3-N were significantly higher (P‹ 0.05) in the wet season than dry season, and also showed that there was an inverse relationship between the PO_4-P levels and salinity such that nutrient levels dropped with increasing salinity. According to the same report, a range of 7.0~7.2 for pH, 0.01~0.5 $^o/_{oo}$ for salinity, 6.40~7.40 mg/L for DO, 26.8 – 30 ^{o}C for temperature and 20~65mg/L for Total Suspended Solids (TSS) were observed in Epe lagoon, while that of the Lagos lagoon were; 7.2~7.6 for pH, 0.2~5.8 $^o/_{oo}$ for salinity, 6.40~7.20 mg/L for DO, 27~30 ^{o}C for temperature and 15~35 mg/L for TSS. Kusemiju (1975), reported a range of 21.3~31.9 ^{o}C for temperature, 0.04~0.30$^o/_{oo}$ for salinity, 6.8~8.3 for pH and 0.51~0.98 m for transparency. The above values recorded compares favourably with those observed in this study (Table 1).

In this study, values of nutrients (NO_3 and PO_4-P) and heavy metals in water were higher in the wet season. Total organic content and heavy metals in sediment were also higher in the wet season. Higher values of these of parameters during the rains may be attributed to increased amount of runoffs discharging into the lagoon during this period. A number of rivers acting as conduit for the release of nutrients and heavy metals into the lagoon transverses rural settlements and farm lands which have no proper waste disposal systems and as such large proportions of the wastes along the terrain are deposited in the lagoon.

A number of factors have been implicated as responsible for the high variability of environmental conditions in coastal lagoons. Nixon (1982) observed that, coastal lagoons have peculiar functional and structural attributes due to their position between the land and sea. They generally show large temporal and spatial variation in hydrochemical characteristics (Yanez – Arancibia *et al*. 1994; Cushing and Walsh, 1980). In addition coastal lagoons are particularly sensitive to anthropogenic impacts as a result of their shallowness, which reduces their capacity to accommodate wastes owing to limited circulation and flushing.

Analysis of the community structure of benthic macroinvertebrate of Epe Lagoon reveals two major features. Viz; The dominance of molluscs and the occurrence of freshwater and brackish water species. The dominance of molluscs in the lagoons of south-west Nigeria has been observed by earlier workers (Webb, 1958a, b; Brown, 1998; Brown and Oyenekan, 1998; Ajao and Fagade, 1991; Brown, 2000). The characteristic occurrence of fresh and brackish water species in the lagoon is occasioned by its sandwiched location which resulted in the establishment of a gradient in salinity with upstream stations having freshwater condition and downstream stations exhibiting brackish water conditions. The role of salinity in the distribution of benthic macroinvertebrates of Epe has been extensively reported. Uwadiae (2009), investigated the response of benthic macroinvertebrate community to salinity gradient in Epe Lagoon, and reported that salinity was the major determinant of the distributional patterns observed in the benthic macroinvertebrate community. In the same vain, Uwadiae (2013) related the observed spatial patterns in distribution and diversity of benthic molluscs in Epe Lagoon to salinity variations.

Ecological interest in West African Lagoons has grown over the years in view of the fluctuations in salinity and the effects this has on the distribution of flora and fauna. Lagos Harbour is the only natural break in a continuous barrier beach extending from the Volta River in Ghana to the Niger in Nigeria. On the falling tide, water flows from the lagoons in to the harbor through Badagry Creek, Five Cowry Creek and beneath Crater Bridge. With rising tide the direction of the currents is reversed. The influx of salt water from sea gives rise to brackish conditions in the lagoons and encourages the growth of estuarine species (Hill and Web, 1958). As the water in the Lagos Harbour and lagoons is derived from partly from the sea entering the harbor on the rising tide and partly from rivers entering the lagoons, the salinity shows both a diurnal fluctuation due to tidal effects and much greater seasonal changes caused by the influx of freshwater during the rainy periods (Hill and Web, 1958). Only the downstream part of Epe Lagoon is affected (weakly) by tidal salt water input, hence resulting in brackish conditions. The upstream portion of the lagoon receiving freshwater inflows demonstrated characteristic of freshwater environment. These variations were majorly responsible for the type of assemblage recorded in this present study.

The population of Epe and neighboring villages has increased through expanding commercial activities due to its closeness to metropolitan Lagos. Consequently, there is an increasing abuse of the lagoon as it is now used for sewage and refuse disposal. The general degradation of the environment arising from human activities and the prevalence of water hyacinth has reached high enough levels to constitute hindrance to boat traffic and fishing, altered water quality and may pose serious management problems. If human activities and the growth of water hyacinth in the lagoon continue unchecked, one would expect a modification in biotic community structure and dynamics in response to changes in spatial complexity of the vegetative structure, shading effects of dense canopies, amount and location of plant biomass, densities of vegetation patches, plant detritus deposition rate, growth rates, dissolved oxygen levels and rates of evapotranspiration (Bryan, 1993). Therefore, there is need to put in place sensitization and monitoring programmes in place in order to curtail human activities in the area.

References

Ajao, E.A. (1996). Review of the state of pollution of the Lagos lagoon. NIOMR Tech. Paper No. 106. 19pp.

Ajao, E.A. and Fagade, S.O. (1991). Study of the sediments and communities in Lagos Lagoon, Nigeria. *Oil and Chemical Pollution*. Elsevier Science Publishers Ltd., England. 75 – 117.

Ajao, E.A., Oyewo, E. and Unyimadu, J.P. (1996). A Review of the Pollution of Coastal Waters in Nigeria. NIOMR. Tech Paper. No. 107. 20pp.

American Public Health Association (1998). *Standard Methods for the Examination of Water and Waste Water*. 20^{th} Ed. APHA New York. 1270pp.

Brown, C.A. (1998). Distribution and population dynamics of an estuarine population of *Aloidis trigona* Hinds (Bivalvia). *Acta. Hydrobiol.* **40**(4): 227 – 237.

Brown, C.A. (2000). The diversity and density of macrobenthic fauna in the western part of the Lagos lagoon, Lagos, South-west, Nigeria. Ph.D. Thesis, University of Lagos. 346pp

Brown, C.A. and Oyenekan, J.A. (1998). Temporal variability in the structure of benthic macrofauna communities of the Lagos lagoon and harbour, Nigeria. *Pol. Arch. Hydrobiol.* **45**(1): 45 – 54.

Bryan, C.F. (1993). Roles of the exotic water hyacinth in the distribution and resets of macroinvertebrates in the Atchafalaya River Swamp. ASLO and SWS Annual general meeting Abstracts,USA. ASLO-SWS 1993.

Buchanan, J.B. (1954). Marine molluscs of Gold Coast, West Africa. *J. West Africa Sci. Ass.,* **7**: 30 – 45.

Chadwick, M.J. and Obeid, M. (1966). A comparative study of the growth of Eichhornia crassipes (Mart.) Solms and Pistia stratiotes L. in water culture. *Journal of Ecology*. **54**:563-576

Chukwu, L.O. and Nwankwo, D.I. (2004). The impact of land based pollutants on the hydrochemistry and macrobenthic community of a tropical West African Creek. *Ekologia (*Asia). **2**(1): 1-9.

Cushing, D.H. and Walsh, J.J. (1976). The Ecology of the Seas. Blackwell Scientific Publications, London. 467pp.

Drake, J.A. and Mooney, H.A. (1989). Biological invasions: A Global Perspective. Scope 37. John Wiley and Sons, Chichester, New York, U.S.A.

Edmunds, J. (1978). Sea shells and molluscs found on West African Coasts and Estuaries, Ghana University Press, Accra. 146pp.

F.A.O. (1969). Fisheries survey in the Western and Mid-Western Regions of Nigeria. FAO/SI: 74/NIR 6. 142pp.

Hill, M.B. and Webb, J.E. (1958). The ecology of Lagos Lagoon II. The topography and physical features of the Lagos harbour and Lagos lagoon. *Philosophical Transaction of Royal Society, London.* **241**: 307 – 417.

Holme, N. A. and Mclntyre, A. D. (1971). Methods for the study of marine benthos. IBP Handbook No. 16. International Biological Programme, London, Oxford and Edinburgh. Blackwell Scientific Publications. 334pp.

Nwilo, P. and Onouha, A. (1993). Environmental impacts of human activities on the coastal areas of Nigeria. In: coastal of western Africa, ed. by Awosika, L. F. and Muyoon O. American Society of Engineers.

Nwankwo, D.I. (1993). Cyanobacteria bloom species in coastal waters of South-Western Nigeria. *Archiv Hydrobiologie Supplement.***90**:553-542.

Nwankwo, D.I. (1996). Phytoplankton diversity and succession in Lagos lagoon, Nigeria. *Archiv Fur Hydrobiologie***.** **135**(4):529-542

Nwankwo, D.I. (1998). Seasonal changes in phytoplankton population and diversity in Epe lagoon, Nigeria. *Acta Hydrobiologia*. **40**(2): 82 – 92.

Nwankwo, D.I. and Akinsoji, A. (1989). The benthic algal community of a sawdust deposition site in Lagos lagoon. *Internat. J. Ecol. Env.* **15**: 197 – 204.

Nwankwo, D.I. and Onitiri (1992). Periphyton (Aufuschs) community on submerged aquatic macrophytes in Epe Lagoon, Nigeria. *J. Agric. Sci. Tech.,* **3**: 153 – 141.

Olaniyan, C.I.O. (1969). The seasonal variation in the hydrology and total plankton of the lagoons of South-West Nigeria. *Journal of Science*. **3**(2): 101 – 119.

Oyenekan, J.A. (1983). The polycheates of the Lagos lagoon and harbour. *Nigeria. Journal of Science and Technology*. **1**(2): 181-185.

Oyenekan, J.A. (1988). Benthic macrofaunal communities of Lagos Lagoon, Nigeria. *Nigerian Journal of Sciences*. **21**: 45 – 51.

Sandison, E.E. and Hill, M.B. (1966). The distribution of B*alanus pallidus strusburi* (Darwin), *Gryphaea gasar* (Adanson) Dautzenbergi, *Mercierella engmatica* farvel and *Hydroides uncinata* (Philippi) in relation to salinity in Lagos harbour and adjacent creeks. *Journal of Animal Ecology*. **38**: 235 – 258.

Uwadiae, R. E. ()2009). Response of benthic macroinvertebrate community to salinity gradient in a sandwiched coastal lagoon. Report and Opinion. **1**(4):45-55.

Uwadiae, R. E. (2013). Spatial Patterns in Diversity and Distribution of Benthic Molluscs in a Weak Tidal Tropical Lagoon. International Journal of Marine Science **3**(14): 111-120

Webb, I.E. (1958b). The life history of *Branchiostoma nigeriense* Webb. *Philosophical Transaction Royal Society London.* **Ser. B**: 335 – 354.

Webb, J.E. (1958a). The Ecology of Lagos lagoon. I: The lagoons of the Guinea Coast *Philosophical Transaction Royal Society London*. **Ser. B**. 241 – 283.

Yanez-arancibia, A.; Lara Dominguez, A.L. and Pauly, D. (1994). Coastal lagoons and fish habitats. **In**: Kjerfve, B. (Ed.). *Coastal lagoon processes.* Elsevier Oceanographic Series 60, Amsterdam, pp. 363 – 376.

Yankson, K. and Kendall, M. (2001). A Student's guide to the seashore of West Africa. Marine Biodiversity Capacity Building in the West African Sub-region. Darwin Initiative Report 1, Ref. 162/7/451. 305pp.