Response of Benthic Macroinvertebrate Community to Salinity Gradient in a Sandwiched Coastal Lagoon

Roland Efe Uwadiae

Benthic Ecology Unit, Department of Marine Sciences, University of Lagos, Akoka, Lagos. Nigeria.
Email: eferoland@yahoo.com. **Tel:** +2348063145723.

Abstract: Salinity has been implicated as a major factor affecting the biotic composition of estuarine ecosystems. To investigate the response of benthic macroinvertebrate community to salinity gradient in a sandwiched lagoon in Nigeria, three replicate Van Veen grab ($0.1m^2$) samples of benthic macroinvertebrates were collected at 8 different locations covering the whole length of the lagoon for 24 months (Sept., 2004 - Aug., 2006). In a total of 576 samples, there were 17,712 specimens belonging to 45 species. Molluscs constituted the highest percentage (98.43%) of the animal population, followed by Annelida (1.16%), Arthropoda (0.32%), Nermertina (0.04%), Chordata and Porifera (0.02%) respectively, and Echinodermata (0.005%). There were strong similarities in the values obtained for monthly fauna abundance, species richness, diversity and evenness for wet and dry seasons, indicating no strong seasonal influence. However, the benthic macroinvertebrate abundance and distribution suggested strong influence by the salinity gradient. The values of benthic macroinvertebrate abundance were higher in locations with mean salinity range >0.34ppt while low abundance occurred in areas with mean salinity range <0.09ppt. The highest number (33) of species was observed in station 7 which had the highest mean salinity (3.44ppt). Physico-chemical parameters such as total dissolved solids (TDS), Total organic content of sediment (TOC), percentage sand and mud in sediment were also investigated in the respective stations. Salinity, conductivity and total dissolved solids showed increasing graduation in concentration downstream. There was significant difference (ANOVA, P<0.05) in all the parameters investigated at the study stations. The salinity at the upstream stations 1 to 6 were similar (DMRT, P<0.05) and significantly lower than those at downstream stations (7 and 8) which were also similar (DMRT, P<0.05). Index of similarity was higher between stations within close proximity and subsequently falling in the same salinity range. [Report and Opinion. 2009; 1(4):45-55]. (ISSN: 1553-9873)

Key words: benthic macroinvertebrate; salinity gradient; sandwiched lagoon**.**

1. Introduction

Estuaries are characterized by the presence of a longitudinal gradient in salinity with which other gradients in physico-chemical parameters, such as conductivity and concentration of total dissolved solids are associated (Nybakken, 1988; Tait and Dipper, 1998; Catsro and Huber, 2005). In estuarine lagoons, these environmental parameters may fluctuate at any point according to displacements of the longitudinal gradient induced by factors such as tides and river discharge (Rejean and Julian, 1993).These fluctuations in abiotic conditions may cause major physiological problems for animals (Beadle, 1972; Odiete, 1999).

Studies on pattern of salinity variation in estuaries have demonstrated that fluctuations may have major effects on growth, reproduction and ultimately survival because osmotic and thermal stresses cause changes in basal metabolic rate, which reduces surplus energy available for other activities. These observations have led to the widely accepted concept that estuarine ecosystems are variable (or unstable) environments (Nybakken, 1988; Tait and Dipper, 1998; Catsro and Huber, 2005). This concept has played a fundamental role in estuarine ecology and constitutes one of the principal assumptions of several hypotheses that explain a whole range of observations. For example, fluctuation in salinity may constitute a major factor controlling the distribution of estuarine animals (Rejean and Julian, 1993). Burrowing in the sediment has been reported as an adaptation to reduce tidal salinity fluctuations.

Environmental variability may be responsible for the lower diversity of estuarine organisms compared to marine and limnitic environments, few species being adapted to tolerate rapid changes in abiotic conditions (Miller et al., 1985). Estuarine communities may be mainly 'physically controlled' in opposition to the 'biologically accommodated' communities found in areas where physical conditions are constant and uniform for long periods of time (Rejean and Julian, 1993). These hypotheses including others assume that estuarine animals are subjected to fluctuations in environmental conditions. The mechanism that generates environmental variability for animals in estuaries may be reduced to two components (Rejean and Julian, 1993; Agard et al., 1993). The first component corresponds to the presence of longitudinal and vertical gradients in physico-chemical parameters. The second component is dynamic: environmental variability resulting from the movement of animals against the spatial gradients. The speed and direction of this movement determine the rate and the direction of changes in abiotic conditions an individual experiences.

Most of the information available on the nature of environmental variability experienced by estuarine animals comes from studies of benthic organisms. This stems from the fact that these animals are affected by the periodic longitudinal displacement of the horizontal gradient in physico-chemical conditions caused by tides and river discharge. Sessile animals are exposed to the whole range of fluctuations observed at one geographic point in the estuary, unless adaptations such as living in interstitial waters or in a shell reduce the range of fluctuations experienced by an individual (Odiete, 1999).

Benthological studies in Nigeria including Ajao and Fagade (1991), Brown (2000) and Edokpayi et al. (2004), have centered majorly on general species composition and distribution, not much has been documented on the role of some tidal related variables such as salinity in determining benthic macroinvertebrates population, distribution, diversity and community structure. This has made it difficult to explain the roles of these variables in spatiotemporal interpretation of the observed pattern of distribution of benthic invertebrates in coastal hydro ecosystems. This present paper examines the relationship between pattern in benthic macroinvertebrates characteristics and the salinity gradient in Epe lagoon.

2. Materials and Methods

2.1. Description of Study Area

Epe lagoon (fig. 1) lies between latitudes $3^{0}50'$ – $4^{0}10'$N and longitudes $5^{0}30'$ – $5^{0}40'$E. It has a surface area of about 243km^{2}, and is sandwiched between two other lagoons, the Lekki lagoon (freshwater) in the east and Lagos lagoon (brackish water) in the west. It is situated in the rain forest region of Nigeria which experiences long period of rainy season and short dry period. The lagoon experiences lowland fresh water input during the rains.

The vegetation of the area consists primarily of Raphia palms (*Raphia sudanica*) and oil palms (*Elaeis guineensis*), coconut palms (*Cocos nucifera*) which are widespread in the surrounding villages. Swards of floating aquatic macrophytes occur on the periphery and occasionally at mid points in the lagoon. Notable among these plants are water hyacinth (*Eichhornia crassipes*), water lettus (*Pistia stratiotes, Ipomea aquatica, Salvinia nymphellula, Lemna* sp.*, and Hydrocharis marsus-renae.*

Within the study area the lagoon water tends towards fresh in the wet season but assume a higher salinity status in the dry season. Seawater incursion in the study area is considerably low as fresh water input from streams and land runoff is comparably stronger. The salinity gradient observed in the lagoon is a reflection of its sandwiched position. Human activities in the area include fishing, sand mining and boat traffic. Eight study stations (Fig. 1) were selected based on accessibility for this study.

2.2. Field Investigation

Water, sediment and benthic macroinvertebrate samples were collected monthly in all the eight stations from Sept., 2004 to August, 2006. Samples were collected between 0900 and 1500h on each occasion.

Water samples for chemical analyses were collected in pre-washed 1litre plastic bottles. Sediment samples were collected using a Van Veen grab (0.1m^{2}). The sediment samples collected at each station were placed in labeled polyethylene bags for analysis in the laboratory. The samples were stored in the refrigerator prior to analysis. Three grab hauls for benthic samples were also taken from each station and the collected materials washed through a 0.5mm mesh sieve. The residue in the sieve was preserved in 10% formalin solution and kept in labeled plastic containers for further laboratory analysis.

2.3. Laboratory Investigations

The conductivity and TDS of the water samples were measured in the laboratory using a Portable combined Total Dissolved Solids, Electrical conductivity, Temperature meter, HM Digital COM – 100. The salinity of the water samples were measured using a portable salinity meter, Hiener instrument, Model HI991301. Sediment grain size analysis was performed using the direct method for separating sediment into grain size fractions. Air dried samples were passed through a graded series of standard sieves. Griffin SIH – 310-V sieving outfit was used. The fractions of sand and mud obtained were recorded in percentages. The TOC of the sediment was estimated by loss of weight on ignition in muffle furnace at 555^{0}C as employed by Oyenekan (1988).

Preserved benthic samples were washed with tap water to remove the preservative and any remaining sediment for easy sorting. The animals were sorted into different taxonomic groups using suitable identification manuals including Yankson and Kendall (2001). The number of species and individuals for each station were counted and recorded.

2.4 Data Analysis

All statistical analyses were performed with the Statistical Package for Social Sciences (SPSS). One-Way analysis of variance (ANOVA) was used to determine the significance difference (P=0.05) that exist at the study stations for each physico-chemical parameter. When significant variations are detected, a *post hoc test* using Duncan New Multiple Range Test (DMRT) was performed to determine the locations of significant differences. Simple linear regression model was used to determine the relationship between benthic macroinvertebrates' metrics (Y) and salinity (X).

Margalef's index of taxa richness (d), Shannon-Weiner's index (H) of general diversity and Equitability index (E) were used to determine taxa richness, species diversity and evenness respectively. Sorenson's index (Stephen, 2000) of similarity was calculated to compare overlap of species between each pair of study stations using the formula

$2C / A + B$

Where;

A = number of species in sample A.

B = number of species in sample B.

C = number of species common to both samples.

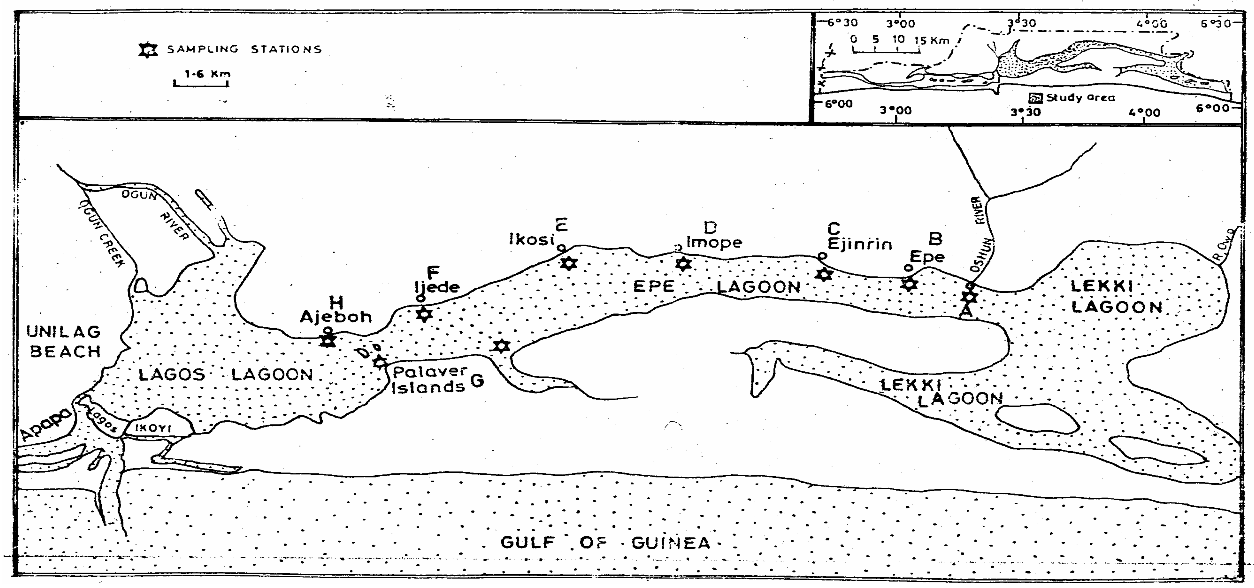

Figure 1. Map Showing Lagos, Epe and Lekki Lagoons as well as the Sampling Stations

3. Results

3.1. Physico-chemical Conditions

Table 1 summarizes the physico-chemical conditions at the study stations. Salinity, conductivity and TDS values were higher at the downstream stations and each had elevated values in the dry than in the wet season. There was significant difference (ANOVA, $P<0.05$) in these parameters at the study stations. The salinity at the upstream stations 1 to 6 were similar (DMRT, $P<0.05$) and significantly lower than those at downstream stations (7 and 8) which had similar (DMRT, $P<0.05$) salinity. The study area was predominantly sand intermixed with varying proportions of mud in the stations sampled. The highest value of sand fraction (93.6%) recorded occurred in station 5, while the least (54.4%) was recorded in station 3. The highest amount (44.6%) of mud in sediment was recorded at station 3.

3.2. Benthic Macroinvertebrates

3.2.1. Abundance and Diversity

Table 2 shows the summary of the benthic macroinvertebrates' metrics at the study stations in Epe lagoon. The total population density of sampling stations ranged from 87indm^{-2} (station 3) to a maximum density of 3855indm^{-2} (station 8). The remaining six stations recorded densities >1000indm^{-2}. Abundance of macrobenthic invertebrates were mainly determined by molluscs (98.23% of the total population), especially the gastropod *Pachymelania aurita* (44.33% of the total population) and the bivalve *Macoma cumana* (28.89% of the total population). Trend in macrobenthic invertebrates' characteristics in the lagoon was closely linked with salinity during the study period (Figure 2).

Of the 45 species observed, 35.6% were Arthropods, 27% Molluscs, 22.2% Annelids, 4.44% Nemertina and Porifera respectively, and 2.2% Chordate and Ehinodermata respectively. Molluscs were present in all the study stations, *P. aurita* and *M. cumana* had the widest distribution with representations in all the stations. Benthic macroinvertebrates' species richness, abundance, and diversity showed positive correlations with salinity (Table 3). To a less extent the percentage sand in sediment showed a positive correlation with species richness (r=0.64), diversity (r=0.046) and Margalef's index of species richness(r=0.083).

The mean number of species per sampling station remained relatively constant in the upstream and downstream stations, but clearly declined in the middle area. The same pattern was shown by the diversity index. Upstream stations recorded majorly freshwater species, while in downstream stations brackish and marine species were observed. Monthly diversity and species richness indices recorded at the study stations were significantly different (ANOVA, $P<0.05$). Similarity (DMRT, $P>0.05$) existed among the study stations except in station 3 which was significantly lower. Regressions between abundance, species richness, diversity, Margalef's index of species richness and salinity were significant ($P<0.05$), indicating that salinity of water a very good predictor of the trend in benthic macroinvertebrates characteristics in the lagoon (Table 3, Figure 3). The relations between total abundance, total species richness and average salinity at the study stations are shown in figure 4.

Table 1: Summary of Values of Physico-chemical Characteristics of Water and Sediment at the Study Stations (Sept. 2004 – Aug. 2006)

Parameter	**1**			**2**			**3**			**4**			**5**			**6**			**7**			**8**			
	Max	Min	Mean SD	Max	Min	Mean ± SD	Max	Min	Mean ± SD	Max	Min	Mean ± SD	Max	Min	Mean ± SD	Max	Min	Mean ± SD	Max	Min	Mean ± SD	Max	Min	Mean ± SD	F-VALUE
Water																									
Salinity(ppt)	0.35	0.00	0.06k± 0.08	0.24	0.00	0.07k± 0.08	0.28	0.00	0.09k± 0.08	1.77	0.01	0.34k± 0.69	3.62	0.01	0.39k± 0.74	8.37	0.01	1.70± 2.25	19.30	0.06	3.44m± 5.78	19.72	0.04	3.19 m± 5.29	5.893*
TDS (mg/L)	350	70	173r± 86.23	340	80	172r± 67.23	1860	30	267r± 453.75	1270	70	398r± 437.39	1400	71	448r± 475.48	6852	82	1388t± 1501.71	10932	77	1883t± 2587.57	15200	75	2067 t± 3591.728	5.290*
Conductivity (µS/cm)	799	165	481n± 185.67	710	225	547n± 156.26	710	230	548n± 165.29	3100	150	971n± 808.90	3220	211	1103n± 960.51	13352	229	2923p± 3777.63	29200	252	4098p± 6281.90	33253	162	4410 p± 7266.33	4.674*
Sediment																									
Sand (%)	92.2	79	83.8 ± 16.27	87.4	61.4	82.3 ± 4.29	89.4	54.4	78.0g ± 9.98	85.4	65.4	81.0g ± 3.36	93.6	71.4	78.5 ± 5.41	92.2	73.6	81.0g ± 4.77	89	65.8	81.0g ± 6.08	92.4	73.5	80.5 g± 5.00	5.376
Mud (%)	21	7.8	13.5 ± 3.74	28.6	11.4	17.3h ± 4.21	44.6	9.4	20.7h ± 9.22	27.6	14.6	18.7h ± 2.66	28.6	6.5	20.6h ± 6.38	26	7.8	18.6h ± 4.11	29	11	19.2h ± 5.06	26.5	7.6	18.7 h± 5.32	4.128
TOC (%)	8.61	2.11	5.91f ± 1.98	8.22	2.10	5.35f ± 1.90	10.45	3.51	6.18f ± 1.93	7.50	1.01	3.64e ± 1.64	7.30	1.02	3.63e ± 1.60	7.50	1.01	3.81e ± 1.73	6.00	1.01	4.14e ± 1.44	6.30	1.01	3.75e ± 1.80	9.089

N= 24 (no. samples); lower case alphabets indicate no significance ($P>0.05$: Duncan Multiple Range Test) *significance ($P<0.05$)

3.2.2. Change Along the Estuarine Gradient

The values of similarity between study stations during sampling months as computed using Sorensen index are presented in table 4. The following ranges were recorded between stations; 0 – 1 (I versus 2), 0 – 0.67 (2 Versus 3), 0 – 0.90 (3 versus 4), 0.22 – 0.94 (4 Versus 5), 0.40 – 0.92 (5 versus 6), 0.33 – 1.00 (6 versus 7), 0.40 – 1.00 (7 versus 2), 0 –0. 67 (8 versus 1), 0 – 0.86 (8 versus 2) and 0.22 – 1.00 (8 versus 5). It was observed that greater fauna similarity existed between stations close to each other. It was clear that especially towards the oligohaline zone, the benthic community abruptly changed. The similarity pattern observed shows a more or less gradual and continual change in assemblage along the estuarine gradient. The rate of change in the benthic coenocline of the lagoon was mainly determined by differences in salinity.

3.2.3. Community Structure

Community structure analysis shows that the 3 most upstream stations situated in freshwater zone (oligohaline zone) was characterized by a very impoverished benthic fauna population with only one taxon (*M. cumana*) dominating. The species recorded here were mainly arthropods, including; *Gammarus fasciatus*, *Gomphus vulgatissimus*, *Libellula luctosa* and *Beatis muticus*. The mid and downstream stations (4, 5, 6, 7, and 8) comprised brackish water species which are able to survive in mesohaline waters. In station 7 organisms able to survive in low polyhaline conditions were also observed. The total number of observed species as well as the mean number of species per sampling station were clearly higher for the brackish water species and stations than those of freshwater.

The dominance of molluscs was the major feature of brackish water species community. Characteristic species of this group were *M. cumana*, *Aloides trigona*, *Neritina glabarata*, *Tellina nymphalis*, *P. aurita*, *N. kuramoensis*, *Tympanotonus fusatus*, *T. fuscatus var radula*. *Pachymelania aurita contributed* most to the total population of the brackish water part. With a mean density of 982indm^{-2}, the organism penetrated the lagoon up to the freshwater part, but here few individuals were observed. *Macoma cumana* was another very common species, that also had a wide distribution. Its highest density (13470 indm $^{-2}$) occurred at station 8, but was poorly represented in stations 6 and 7. In this group arthropods were represented by the crabs; *Ocypoda cursor*, *O. africana*, *Uca tangeri*, *Penaeus notialis*, *Clibanarius africana*, *C. senegalensis*, *C. chapini* and *Sersema huzardi* which occurred only in station 7.

Table 2: Summary of the Benthic Macroinvertebrates' Metrics at the Study Stations in Epe Lagoon (Sept. 2004 – Aug. 2006). Lower case alphabets indicate no significant difference (P>0.05) *DMRT (P<0.05)

	Stations							
Metric	1 (Mouth of Oshun River)	2 (Epe jetty)	3 (Ejirin)	4 (Imope)	5 (Ikosi)	6 (Egbin Power station)	7 (Palava Island)	8 (Ajebo)
Number of samples	72	72	72	72	72	72	72	72
Number of taxa	23	23m	11	12j	18k	12m	32k	18j
Number of individuals	191h	1045h	87h	3312i	3611i	3120i	2489i	3855i
Margalef's Index of species richness (*d*)	4.37d	3.30c	2.46c	1.60d	2.32d	1.37c	4.09	2.18d
Shannon-wiener diversity index (H')	1.06f	0.34f	0.77	0.61g	0.60g	0.62f	0.60	0.66g
Evenness (E)	0.33a	0.10a	0.31	0.24a	0.19a	0.25a	0.20a	0.22a

Table 3. Regressions Between Benthic Macroinvertebrates' Metrics and Salinity. *significant (P>0.05)

	Model	r	df	F	P
Abundance	Y= 87.864 + 3.8166X	0.128	191	3.173	0.05*
Species richness	Y= 4.355 + 0.125X	0.146	191	4.003	0.05*
Shannon-Wiener	Y= 0.395 + 0.0275X	0.312	191	20.527	0.05*
Margalef	Y= 1.718 + 0.065X	0.176	191	6.044	0.05*

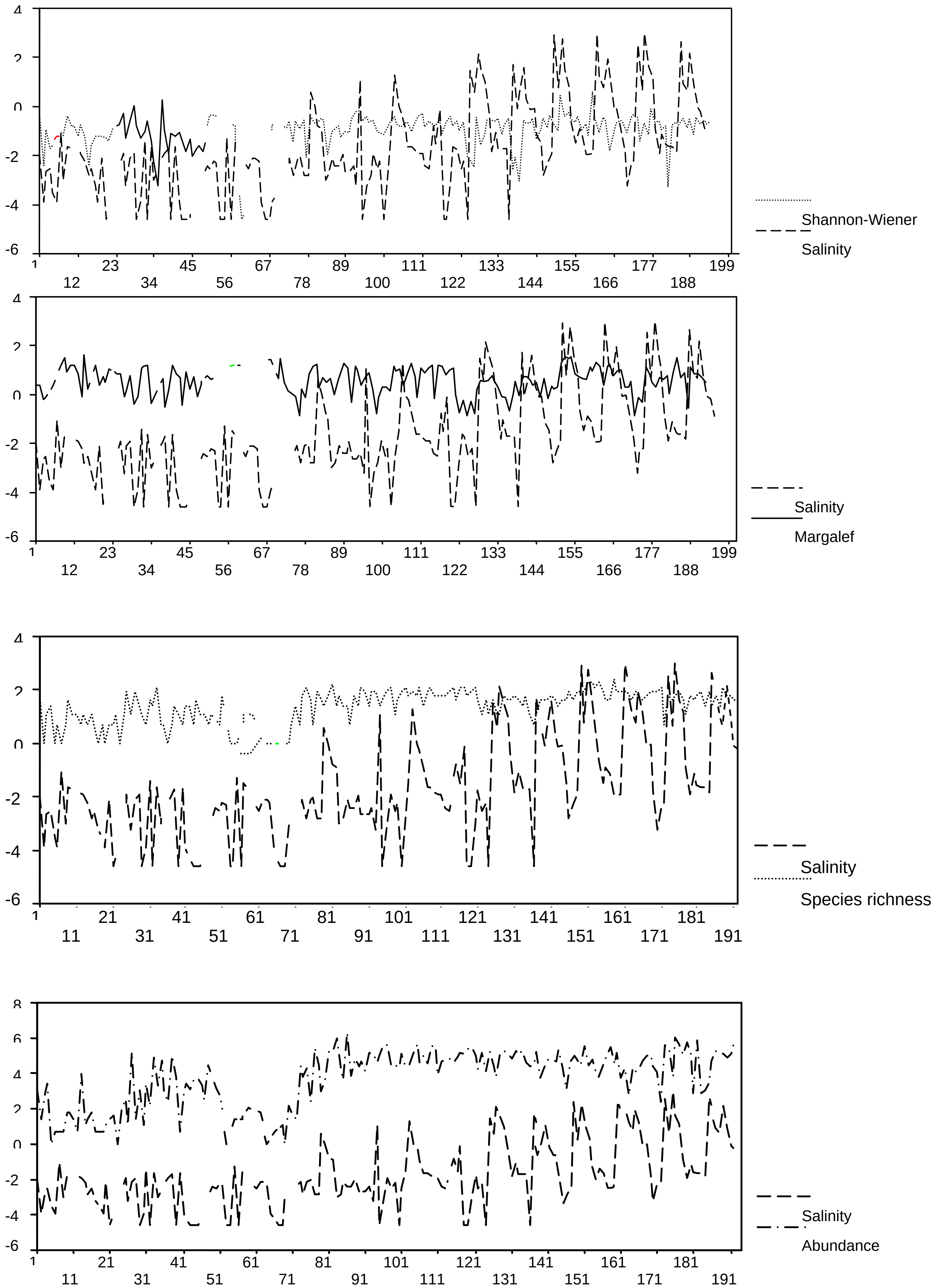

Figure 2. Sequence Charts Showing the Links Between Macrobenthic Invertebrates' Metrics and Salinity.

Several species were common to both freshwater and brackish water groups, but were very low in abundance, notably *Heteromastus filiformis, Nereis diversicolor, N. succinea, N. lamellosa* and *Chironomus plumosus*. Some species like *Notomastus hemipodus, Lumbrinerides cingulata* and *Lumbrineriopsis paradoxa* were also common in both the freshwater and brackish part, but were less abundant than the species mentioned above. Polyhaline species notably; *Brachiostoma nigeriense, Cucumaria conicospermium, Adocia cinerea* and *Tetilla monodii* were recorded only in station 7.

It can be concluded from the results recorded in this study that the stations were separated in groups closely linked with the salinity gradient of the lagoon. However, since many dominant species were common in both the fresh and brackish water parts, the distinguished groups are likely to be variants of one community type, rather than that of a clear distinction into two totally different benthic communities.

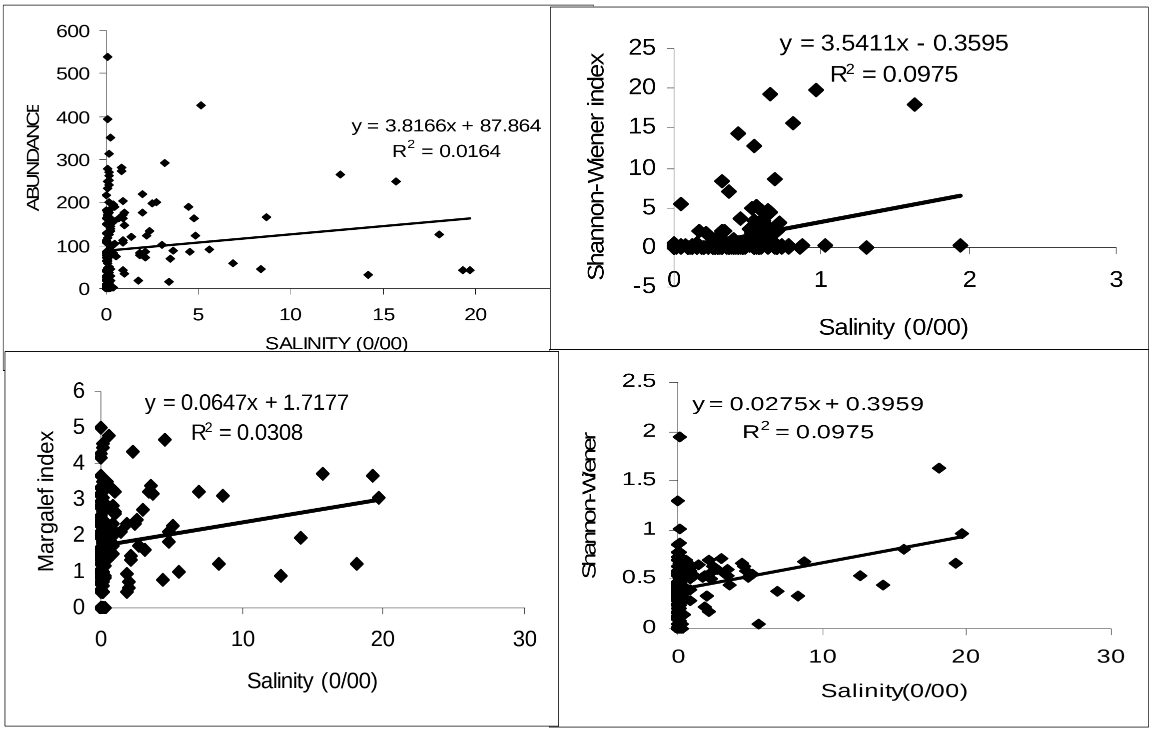

Figure 3. Relationships Between Macrobenthic Invertebrates' Metrics and Salinity.

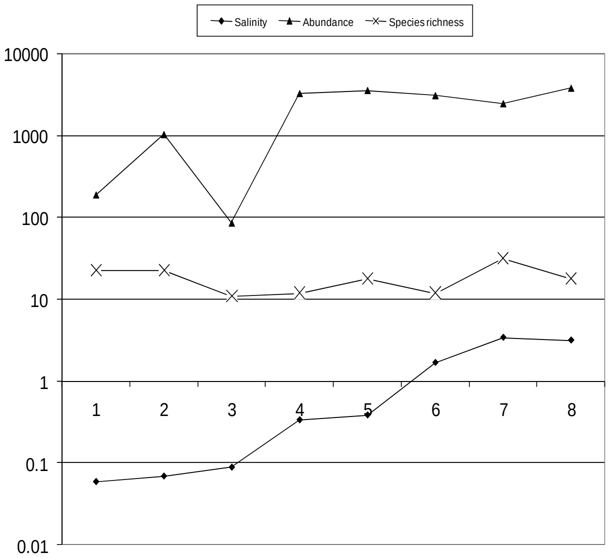

Figure 4. Variations in Mean Species Richness, Abundance and Salinity in the Study Stations

Discussion

Tidal incursion through the Lagos harbour as well as freshwater input from run offs and river inflow are the major factors controlling the salinity of lagoons of south-western Nigeria (Nwankwo, 1998). Epe lagoon sandwiched between two lagoons, the Lagos and Lekki lagoons is weakly influenced by tidal water input through the Lagos lagoon. Higher salinities values occur in study stations (5 to 8) close to the Lagos lagoon than those (1 to 4) close to Lekki lagoon and the discharge points of Oshun and Oni rivers.

This study is one of the first on a sandwiched lagoon in South-Western Nigeria investigating the benthic macroinvertebrates along an estuarine gradient. Previous studies (Sandison and Hill, 1966; Brown, 2000; Edokpayi et al., 2004) on the benthic macroinvertebrates in South-Western Nigeria aquatic systems dealt only with the marine and brackish part of the Lagos estuarine system, and never emphasized or reported a gradient along the study stretch. However, in these studies benthic communities, besides those described here were recorded. The differences are due mainly to salinity variations. Sandison and Hill (1966) described the epifauna *Balanus pallidus* Darwin, *Graphea gazar* Dautzenburg, *Mercierella enigmatica* Linneaus and *Hydroides uncinata* L. and their distribution in relation to seasonal salinity changes. They reported that the two salinity regimes in the Lagos lagoon affected the distribution of the benthos. Salinity has also been reported to affect the life cycles of *Ballanus pallidus* (Sandison, 1966) and *Tympanotonus fuscatus* var *radula* (Egonmwan and Odiete, 1983). The community types described in this study are both freshwater species *(e.g.* insect larvae) and marine/brackish water species *(e.g. Brachiostoma nigeriense).* The sizes of the brackish water species recorded in this study were smaller than those encountered in the Lagos lagoon (Ajao and Fagade, 1990).

Estuaries and the nearby coastal zones are characterized by steep gradients in chemical, physical and biological features. In the North-American estuaries the oligohaline and freshwater tidal parts are characterized by relatively low species richness, with Oligochaeta and chironomids, and to a less extent amphipods and molluscs as the dominating species (Simpson et al., 1986; Odum et al, 1988). Reduction of species diversity with fluctuations in salinity results from osmotic stress experienced by organisms (Tait and Dipper, 1988; Odiete, 1999). External salinities changes usually produce corresponding changes in the concentration of internal fluid by passage of water into or out of the body (osmotic adjustment) to preserve the osmotic equilibrium and these changes are often accompanied by alteration in the proportions of the constituent ions of the internal fluids (Tait and Dipper, 1988; Odiete, 1999). By these limits which often differ for different species, departure from the normal concentration and composition of the internal medium cause metabolic disturbances and eventual death. This constraint imposed by wide salinity fluctuations in estuarine ecosystems accounts to a large extent for the low biodiversity of estuaries. Only species that can survive wide fluctuations in salinity can thrive in the estuaries. This study observed the occurrence of *P. aurita* and *M. cumana* in all the study stations with poor populations in the stations 1 to 3. These two species have been reported as truly euryhaline organisms (Egonmwan, 2007). This may have accounted for their wide distribution in the study area

Many benthic organisms rely upon stable salinity regimes to survive and propagate. *Terebelid* polychaetes and *sipunculids* were found to be adversely affected by salinity fluctuations (Ferraris *et al.*, 1994). The growth and development of the marine polychaete *Arenicola cristata* and the gastropod *Ilyanassa obsolata* were both found to be impacted by periodic reductions in ambient salinity (Richmond and Woodin, 1999). Populations of the soft clam *Mulinia lateralis* perished and the amphipod *Ampelisca abdita* emigrated from the area during a three week exposure to freshwater discharges which lowered salinities in the St. Lucie Estuary from 18-30 ppt to 0.5-5.0 ppt (Haunert and Startzman, 1985). Richmond and Woodin (1999) reported that the growth of the hard clam, *Mercenaria mercenaria*, was inhibited at salinities less than 20 ppt and mortality of adults and juveniles increased when exposed to salinities less than 15 ppt for greater than 12 days. Development and survival of some grapsid crabs was found to be related to salinity stability (Spivak, 1999), and the behavior of newly recruited xanthid crab larvae has been found to be very sensitive to salinity gradients (Forward, 1989). Larvae of two species of xanthid crabs were shown to ascend or descend in the water column dependent upon salinity. Sudden decreases in salinity may cause these crab larvae to sink at a rate which causes them to prematurely settle on inappropriate bottom habitats, resulting in increased mortality (Forward, 1989).
Death and/or impairment have been documented in many species exposed to salinities outside their ideal ranges (Odiete, 1999). Organisms may potentially

Table 4: Values of Sorensen Index of Similarity Between Study Stations During the Sampling Months.

Compared stations	2004				2005												2006							
	SEPT.	OCT.	NOV.	DEC.	JAN.	FEB.	MAR.	APRIL	MAY	JUNE	JULY	AUG.	SEPT.	OCT.	NOV.	DEC.	JAN.	FEB.	MAR.	APRIL	MAY	JUNE	JULY	AUG.
1 and 2	0.31	0.8	0.8	0.5	0	1	0.33	0.67	0.77	0.4	0.66	0	0	0.33	0.5	0	0	0.33	0.5	0.29	0.4	0.67	0.66	0.57
2 and 3	0	0.22	0.62	0	0	0	0.33	0	0.6	0	0.4	0	0	0.4	0	0	0	0.4	0	0.25	0	0.67	0.33	0.33
3 and 4	0	0.77	0.73	0	0.3	0	0	0	0.5	0	0.44	0	0	0.25	0	0.4	0	0.3	0	0.4	0.25	0.57	0.9	0.44
4 and 5	0.86	0.75	0.75	0.22	0.93	0.91	0.55	0.83	0.94	0.75	0.92	0.7	0.8	0.62	0.5	0.8	0.94	0.93	0.67	0.67	0.93	0.8	0.83	0.93
5 and 6	0.86	0.67	0.6	0.4	0.77	0.67	0.4	0.91	0.77	1	0.92	0.77	0.8	0.83	0.55	0.5	0.67	0.77	0.8	0.62	0.86	0.8	0.73	0.78
6 and 7	0.55	0.6	0.8	0.4	0.5	0.6	0.46	0.63	0.4	0.67	1	0.6	0.75	0.5	0.5	0.5	0.33	0.5	0.4	0.67	0.62	0.8	0.6	0.5
7 and 8	0.62	0.29	0.46	0.44	0.77	0.83	0.63	0.71	0.53	0.57	1	0.9	0.73	0.56	0.62	0.31	0.62	0.77	0.44	0.8	0.62	0.91	0.73	0.4
8 and 1	0.29	0.2	0.33	0	0.29	0	0	0.44	0.6	0.29	0	0.33	0.4	0.4	0.36	0.22	0	0.5	0.67	0.2	0.5	0.4	0	0.44
8 and 2	0.53	0.22	0.67	0	0.44	0	0.36	0.55	0.77	0.33	0.22	0.4	0.22	0.73	0.67	0.44	0.4	0.8	0.86	0.77	0.67	0.4	0.29	0.22
8 and 5	0.63	0.4	0.33	0.22	0.86	0.56	0.62	0.62	0.77	0.75	1	0.77	0.67	0.77	0.5	0.31	0.62	0.86	0.67	0.88	0.86	1	0.83	0.77

avoid the low salinity area, and thus delay settling in nursery habitats (and therefore may be exposed to enhanced risk of predation), or they may die or suffer reduced fitness due to exposure to deleterious salinity levels. Low salinity exposure may cause eggs or larvae to settle prematurely in inappropriate habitats, leading to reduced fitness or death (Forward, 1989).

The observed species distribution in this study follows the classical concepts of species response to salinity gradients (Ferraris et al., 1994). Every estuary has its own physical and therefore ecological characteristics (Meire et al, 1991; Warwick et al., 1991). For instance, how far a marine species is able to penetrate into an estuary largely depends on the amount and variability of the freshwater discharge, relative to the tidal inflow of sea water. The oligohaline zone, which is both a physical and a biological buffer, is in estuaries characterized by the lowest species richness. This is true of the study area as few numbers (12 to 24) of species and individuals (87 to 1045) were recorded in oligohaline and mesohaline areas, while 33 species and number of individuals >2000 were recorded in station 7 with a relatively higher salinity condition.

Acknowledgement:
The author wishes to acknowledge the assistance of Mr Emubaiye Number during the sampling trips, and to thank the University of Lagos for the award of a graduate fellowship.

Correspondence to:
Roland Efe Uwadiae
Benthic Ecology unit,
Department of Marine Sciences,
University of Lagos, Akoka, Lagos. Nigeria.
Email: eferoland@yahoo.com.
Tel: +2348063145723.

References

Agard JBR, Gobin J and Warwick RM. Analysis of marine macrobenthic community structure in relation to pollution, natural oil seepage and seasonal disturbance in a tropical environment (Trinidad, West Indies). Marine Eiology Progress Series.1993: 92: 233-243.

Ajao EA and Fagade SO. Production and population dynamics of *Pachymelania aurita* MÜLLER. Arch Hydrobiologia. 1990:120: 97 - 109.

BeadIe LC. Physiological problems for animal life in estuaries. ln: Bames, R. S. K., Green, J. (eds.) The estuarine environment. Applied Science Publishers, London. 1972:51-60

Brown CA. 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. 2000: 346pp.

Castro P and Huber ME. Marine Biology. McGraw Hill Higher Education, New York. 2005. 452pp.

Chindah AC. Response of Periphyton Community to Salinity Gradient in Tropical Estuary, Niger Delta. Polish Journal of Ecology. 2004: 1: 83–89

Edokpayi CA, Lawal MO, Okwok NA and Ogunwemo CA. Physico-chemical and macrobenthic faunal characteristics of the Kuramo water, Lagos, South- Western Nigeria. African Journal of Aquatic Sciences. 2004: 29(2): 235 – 241.

Egonmwan RI. Reproductive Cycle of the Mangrove Prosobranch, *Pachymelania fusca* (Gmelin, 1971) var. *quadirseriata* (Gray) (Gastropoda: Melaniidae) in Lagos, Nigeria. Pakistan Journal of Biological Sciences. 2007: 10(4):649-653.

Egonmwan RI and Odiete WO. The seasonal gonadal changes, spawning and early development of *Tymponotonus fuscatus* var *radula* L. (Prosobranchia: Potamididae). Journal of Molluscan Studies. 1983: 12A:43-46.

Ferraris JD, Fauchald K and Kensley B. Physiological responses to fluctuations in temperature or salinity in invertebrates. Adaptations of *Alpheus viridari*, *Terebellides parva* and *Golfinigia cylindrata* to the mangrove habitat. Marine Biology. 1994: 120:397-406.

Forward R. Behavioral responses of crustacean larvae to rates of salinity change. The Biological Bulletin. 1989: 176(3): 221 - 229.

Haunert DE and Startzman JR. Short term effects of a freshwater discharge on the biota of the St. Lucie estuary, Florida. South Florida Water Management District Resource Planning Department, Environmental Sciences Division. Technical Publication, West Palm Beach, Florida. 1985: 85-101

Meire PM, Seys JJ, Ysebaert TJ and Coosen J. A comparison of the macrobenthic distribution and community structure between two estuaries in SW Netherlands. In: M. Elliot and J.P. Ducrotoy, Eds. Estuaries and Coasts: Spatial and Temporal Intercomparisons. Olsen & Olsen, Fredensborg, Denmark. 1991: 221-230.

Miller JM, Crowder LB, Moser ML. Migration and utilization of estuarine nurseries by juvenile fishes: an evolutionary perspective. Contributions in Marine Science. 1985: 27: 338-352

Montague CL and Ley JA. A possible effect of salinity fluctuation on abundance and associated fauna in northeastern Florida Bay. Estuaries. 1993:16(4): 703-717

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

Nybakken JW. Marine Biology. An ecological Approach. Harper and Row Publishers, New York. 1988: 514pp.

Odiete WO. Environmental Physiology of Animals and Pollution. Diversified Resources Ltd., Lagos. 1999: 261.

Odum WE, Rozas LP and Mcivor CC. A comparison of fish and invertebrate community composition in tidal freshwater and oligohaline marsh systems. In: D.D. Hook, Ed. Ecology of wetlands. 1988: 1: 561-569.

Oyenekan JA. Macrobenthic invertebrates communities of Lagos Lagoon, Nigeria. Nigerian Journal of Sciences. 1988: 21: 45 – 51.

Rejean L and Julian JD. Nature of environmental variability experienced by benthic and pelagic animals in the St. Lawrence Estuary, Canada. Marine Ecolog Progress Series. 1993: 94: 129 – 139.
.
Richmond C and Woodin S. Effect of salinity reduction on oxygen consumption by larval estuarine invertebrates. Marine Biology. 1999: 134: 259-267.

Sandison EE. The effect of salinity fluctuation on the life of *Balanus pallidus strusburi* (Darwin) in Lagos Harbour, Nigeria. Journal of Animal Ecology. 1966: 35: 365 – 378.

Sandison EE and Hill MB. 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. 1966: 38: 235 – 258.

Spivak E. Effects of reduced salinity on juvenile growth of two co-occurring congeneric grapsid crabs. Marine Biology. 1999: 227(66)1-9.

Stephen W. Statistical ecology in practice. A guide to analyzing environmental and ecological field data. Pearson Education Limited, Harlow. 2000: 414.

Tait RV and Dipper FA. Elements of marine ecology. Butterworth-Heinemann, Oxford. 1998: 459pp.

Warwick RM, Goss-Custard JD, Kirby R, George CL, Pope ND and Rowden AA. Static and dynamic environmental factors determining the community structure of estuarine macrobenthos in SW Britain: Why is the Severn estuary different? Journal of Animal Ecology**.** 1991: 28: 329-345.

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

6/21/2009