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Microbial Population Dynamics as a Function of Sediment Salinity Gradients in the Qua Iboe Estuary Mangrove Swamp (Nigeria)*

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Abstract: In this investigation the extent to which sediment salinity gradients can be used to predict the sensitivity of microbial populations in mangrove ecosystem was investigated. The microbial groups monitored were heterotrophic bacteria, coliform bacteria, actinomycetes, fungi and yeasts. Pearson's Product-Moment Correlation (r) analyses were done on Log_{10} - transformed estimates of population densities. The values obtained from the intertidal (epipellic) and subtidal (benthic) sediments were less than the critical value of 0.707 ($n = 8$, $p = 0.05$). This indicates that salinity was less closely related to the microbial population densities. A positive but insignificant relationship was found for fungi ($r = 0.03$) in intertidal sediment. The total heterotrophic bacteria ($r = -0.69$), coliforms ($r = -0.54$), actinomycetes ($r = -0.43$) and yeasts ($r = -0.56$) were negatively affected by salinity in epipellic sediment. But in the benthic sediment, total heterotrophic bacteria ($r = 0.55$) and unexpectedly, the fungi ($r = 0.58$) and actinomycetes ($r = 0.29$) exhibited positive but insignificant correlations while coliform and yeast counts in the benthic sediments were negatively influenced by salinity. However the coefficient of determinations (R^2) revealed that total heterotrophic bacteria (48.06%) and yeasts (31.18%) were more extensively distributed in the intertidal sediments than coliforms (29.38%), actinomycetes (18.68%) and fungi (0.09%). In contrast, the fungi (33.48%) demonstrated a wider distribution in benthic sediment. This may be ascribed to their existence, mostly as dormant, but culturable spores in the anoxic bottom sediment. The weak relationship exhibited by coliforms further confirms their usefulness as indicator of faecal contamination in estuarine ecosystem.

Key words: Microbial population, salinity, mangrove swamp

INTRODUCTION

Mangroves are facultative halophytes, meaning they have the ability to grow in either fresh or salt water depending on which is available. However despite the fact that mangroves are able to grow in fresh water, they are largely confined to estuaries and upland fringe areas that are at least periodically flooded by brackish or salt water (Filmore and Snedaker, 1993). As facultative halophytes, mangroves not only tolerate, but thrive under saline conditions. They accomplish this either by preventing salts from entering their tissues or by being able to excrete salts that are taken in (Tomlinson, 1986). In addition to excluding salts, mangroves also have the ability to exclude sulphides from their tissues. This sometimes results in elevated pore water concentrations of sulphides in localities where poor flushing of the mangrove area is common (Carlson and Yabro, 1987). The net effect is the creation of mixohaline fluvial biotope, in a brackish estuarine environment (Essien and Ubom, 2003).

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Tidal mud flats (intertidal or epipellic sediment) with high salt content are found in the mouth of estuaries inundated by tropical tide waters (Ukpong, 1991; Essien and Ubom, 2003; Essien *et al.*, 2005). Several studies have attempted to correlate salinity to the productivity of mangrove ecosystem (Good, 1972; Lugo and Snedaker, 1974; Ukpong, 1991; Essien *et al.*, 2005). Walsh (1974) however reported that such correlations often fail to identify directly the differences in primary production of macrophytes in mangroves due to overlapping responses of species to salinity. Very recently Essien *et al.* (2005) have established a salinity gradient effect on the productivity of microalgae in the tidal mud flats of the Estuary. The present investigation focuses on understanding the microbial ecology of a tropical estuarine ecosystem through the evaluation of the relationships between the densities of different microbial groups and salinity gradients in the mangrove swamp sediments of the Qua Iboe Estuary. The study specifically determines the extent to which sediment salinity gradients can be used to predict the sensitivity of microbial populations in mangrove ecosystem.

MATERIALS AND METHODS

Study Area

The study area is a mesotidal brackish estuary of the Qua Iboe River (7°30-8°20W, 4°30- 5°30N) located within the Niger Delta region of Nigeria (Fig. 1). The Qua Iboe Estuary with her creeks and tributaries comprise a rich collection of fluvial biotopes dominated by vast areas of mangrove swamp forest. During the course of this investigation the ecosystem experience a third tier oil spillage which occurred on 22nd November, 2003 from a leakage in the facility of an oil company located close to the estuarine environment.

Sediment Sampling

Monthly sampling was carried out between June 2003 and February 2004 at 3 sampling locations designated Iwo-okpom, Mkpanak and Ukpenekang. During sampling the top intertidal sediment (the epipellic sediment) was carefully scooped using a short core sampler. Subtidal (benthic) sediment samples were obtained with the aid of a Shipek grab sampler. The samples were carefully transferred into clean plastic containers. Both samples were transported to the laboratory for analysis. A total of 72 samples, comprising 24 sample each of water, epipellic and benthic sediments were collected and analysed within 12 h of collections.

Determining the Physicochemical Properties of Sediment

Sediment samples from the various sampling locations were separated and mixed to obtain composite samples from the three locations. The pH, organic carbon, total nitrogen, nutritive salts (CO_3^{2-}, $C1^-$, NO_3^-, SO_4^{2-} and NH_4^+) the exchangeable bases (Ca, Mg, K and Na) and exchange acidity (EA) were analysed using standard procedures described in APHA (1998, 1995 and 1985) and by Radojevic and Bashkin (1999). Effective cation exchange capacity (ECEC) of sediment was obtained by summation of total exchangeable bases and exchange acidity. The % base saturation was extrapolated as follows:

$$\frac{\text{TEB}}{\text{ECEC}}.100$$

Where

TEB = Total Exchangeable Base
ECEC= Effective Cation Exchange Capacity

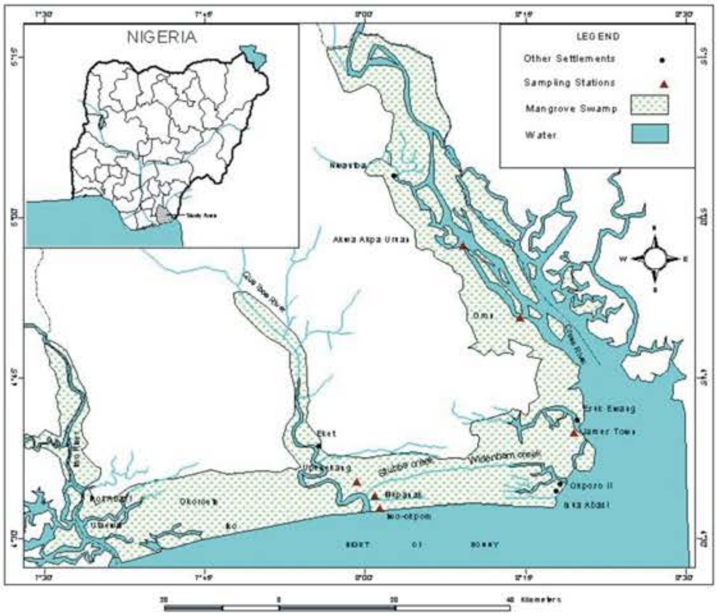

Fig. 1: Mangrove ecosystems of the Southeastern coast of Nigeria showing the sampling stations at Qua Iboe Estuary. Insert: the location of the study area in the Niger Delta region of Nigeria

Determining the Salinity Levels of Sediments

The sediment samples were air dried before analysis. Percentage salinity for each sample was determined from silver thiourea (AgTu) extracts and $AgNO_3$(0.1M) titration using potassium chromate as indicator and calculated as total water-soluble salts (chlorides + sulphates) (Ukpong, 1991; Radojevic and Bashkin, 1999; Essien *et al*., 2005).

Enumeration of Microorganisms

Sediment samples for microbial densities analysis were collected aseptically, stored in 14 packed plastic cooler and transported to the laboratory where they were analysed within 8 h of collection. Supernatant solution of the sediment samples were prepared with a known volume of filtered sterile seawater and vigorously shaken for 1 min (using a vortex shaker) to dislodge biota. This method disrupted the flocculent material and randomly distributed the protists. The different microbial groups in sediments were enumerated by the spread and pour plate techniques (Harrigan and McCance, 1990, Kelly and Post, 1978) using diluents prepared with quarter strength Ringer's solution.

The counts of total heterotrophic (THB) and coliform (TCC) bacteria were enumerated on nutrient agar (NA) and MacConkey agar (MA), respectively. The NA medium was amended with cycloheximide (100 μg mL^{-1}) and benomyl (50 μg mL^{-1}) in order to prevent fungal growth. The actinomycetes were estimated using acidified - nutrient agar (Ac-NA). The pH of Ac-NA was adjusted to 5.5 with lactic acid to arrest the growth of non-filamentous bacteria (Essien and Udosen, 2000). The Total Heterotrophic Fungi (THF) count was enumerated on Sabouraud dextrose agar (SDA) supplemented with 0.5 mg streptomycin L^{-1} to inhibit bacterial contaminants; while estimates of the number of yeasts (YEC) present were obtained by plating the various diluents on streptomycin (0.5 mg L^{-1}) fortified tomato juice agar (TJA) (Martini *et al* ., 1980).

Inoculated NA and MA plates were incubated at 37°C for 24 h and the Ac-NA at room temperature (28±2°C) for 7 days. While the SDA and TJA plates were incubated at 28±2°C for 5 days before enumeration. In all the cases, counts were recorded as numbers of Colony Forming Unit (CFU) per gram of wet weight of sediment.

Data Analysis

All statistical calculations were performed with the Analyse - it + General 1.71 statistical software®. To determine significant relations in sensitivity between salinity and microbial populations, Pearson's Product-Moment Correlation analyses were done on Log_{10} - transformed estimates of population densities (Log_{10} cfu/g) at $p<0.05$. The coefficient of determinations (R^2) was also calculated to measure the extent of distribution (Pearson and Hartley, 1958) exhibited by the different microbial groups in response to salinity gradients in sediment.

RESULTS AND DISCUSSION

The physicochemical properties of the intertidal (epipellic) and subtidal (benthic) sediment from the Qua Iboe Estuary mangrove swamp are presented in Table 1-4. The properties varied seasonally. The relative standard deviation values for salinity revealed much more variable salinity levels during the dry season than the wet session and in benthic sediment than epipellic sediment. The salinity levels ranged from 3.05% in July 2003 to 3.71% in June 2003 with a mean of 3.43% in the epipellic sediment during the wet season. The dry season values for the intertidal sediment ranged from 5.32% recorded in January 2004 to 5.44% in December 2003 with a mean of 5.37%. Lower levels of salinity were obtained from the benthic sediments of the mangrove ecosystem. The values ranged from 2.56% in June 2003 to 2.79% in August 2003 with a mean of 2.66% during the wet season and from 5.60% in December 2003 to 6.25% in January 2004 with a mean of 5.48% during the dry season. The higher salts content of the intertidal sediment may be ascribed partly to the finer particulate composition or grain size distribution of the epipellic sediment (Prahl and Carpenter, 1983) and the salt-excretory habit of mangrove trees (Tomlinson, 1986).

Figure 2 depicts higher salts level during the dry season than the wet season. The results also show that the salinity was higher in the epipellic sediment than in benthic sediment during the wet season. The corresponding loads of the various groups of microorganisms in the epipellic and benthic sediment of the mangrove ecosystem are shown in Table 5 while their sensitivity to sediment gradients are shown in Fig. 3 and 4. The linear correlation between salinity levels and microbal densities in the mangrove sediments showed that there was no significant relation ($p>0.05$) between salinity gradients and microbial loads. The strong seasonal variation in sediment salinity may be ascribed to influence of increase freshwater imputs e.g., rainfall and run-off from upland areas (Ukpong,1991; Essien *et al* ., 2005). The increase in salinity levels during the dry season corresponded with the remarkable increase in the concentrations of SO_4^{2-} and Cl^- in the epipellic and benthic sediments. In an earlier study, Essien and Antai (2005) reported a positive correlation between oil content and the levels of salinity and nutritive salts in estuarine beach soil. In a similar research, the mixohaline nature of the epipellic sediment of the Qua Iboe Estuary mangrove swamp has also been reported (Essien and Ubom, 2003). The variation in sediment salinity would certainly influence the existence and distribution of microphytes including the protists, in the estuarine mangrove swamp.

As depicted in the Pearson's Linear plots in Fig. 3, a positive but insignificant relationship was established between mycological count ($r = 0.03$) and salinity of intertidal sediment, while heterotrophic bacteria ($r = -0.69$), coliform ($r = -0.54$), yeasts ($r = -0.56$) and actinomycetes ($r = -0.43$) were negatively affected by increase in the salinity level of epipellic sediment. This implies that fungi can survive better in the mixohaline sediment than reduced benthic sediment.

Table 1: Physicochemical properties of epipellic sediment from the Qua Iboe Estuary mangrove swamp during the wet season

Parameters	Jun. 2003	Jul. 2003	Aug. 2003	Sep. 2003	Mean	SD	RSD (%)
Temperature (°C)	30.14	29.47	29.75	29.93	29.82	0.28	0.95
pH	6.37	6.27	6.48	6.32	6.36	0.09	0.14
Total organic carbon (%)	12.91	14.08	13.18	11.19	12.84	1.21	9.41
Available phosphorus (mg kg^{-1})	6.78	5.78	5.71	5.29	5.89	0.63	10.72
Total nitrogen (%)	0.68	0.59	0.47	0.38	0.53	0.13	24.89
Exchangeable Ca (mg kg^{-1})	6.17	6.21	6.40	6.31	6.27	0.10	1.65
Mg (mg kg^{-1})	2.44	2.73	2.66	2.68	2.63	0.13	4.89
Na (mg kg^{-1})	10.13	10.14	10.16	10.31	10.19	0.08	0.83
K (mg kg^{-1})	0.12	0.13	0.14	0.16	0.14	0.02	12.42
Nutritive salts (mg kg^{-1})							
CO_3^{-2}	99.91	96.25	92.25	93.62	95.68	3.16	3.30
$C1^{-}$	113.46	148.17	148.51	125.37	133.88	17.39	12.99
SO_4^{-2}	46.71	37.59	33.48	31.32	37.28	6.81	18.26
NO_3^{-}	33.22	32.40	32.49	31.26	32.34	0.81	2.50
NH_4^{+}	162.59	203.40	196.89	145.39	177.07	27.69	15.64
Salinity (%)	3.71	3.05	3.33	3.64	3.43	0.30	8.85
THC (mg kg^{-1})	21.11	43.33	84.14	41.80	47.59	26.39	55.44
Exchange Acidity (EA) (mg kg^{-1})	4.48	3.87	4.07	4.08	4.13	0.26	6.19
Cation Exchange Capacity (CEC)	23.35	23.14	23.43	23.54	23.37	0.17	72.34
Base Saturation (%)	80.80	83.27	83.27	82.62	82.35	1.07	1.30
Particle size distribution (%)							
Sand	63.13	1.51	1.31	63.07	32.26	35.62	110.42
Silt	10.07	8.74	9.65	10.13	9.65	0.64	6.65
Clay	26.80	86.21	87.27	26.80	56.77	34.60	60.96

Table 2: Physicochemical properties of epipellic sediment from the Qua Iboe Estuary mangrove swamp during the dry season

Parameters	Nov. 2003	Dec. 2003	Jan. 2004	Feb. 2004	Mean	SD	RSD(%)
Temperature (°C)	29.29	28.61	28.65	29.38	28.98	0.41	1.41
pH	6.37	6.54	6.37	6.48	6.44	0.08	1.31
Total organic carbon (%)	10.67	10.46	9.99	9.59	10.18	0.48	4.76
Available phosphorus (mg kg^{-1})	5.05	4.95	5.71	5.48	5.30	0.36	6.77
Total nitrogen (%)	0.23	0.26	0.22	0.26	0.24	0.02	8.50
Exchangeable Ca (mg kg^{-1})	6.20	6.05	7.09	6.89	6.56	0.51	7.77
Mg (mg kg^{-1})	3.08	3.08	3.64	3.23	3126.0	0.26	8.12
Na (mg kg^{-1})	9.99	9.26	9.49	9.56	9.58	0.30	3.18
K (mg kg^{-1})	0.23	0.21	0.22	0.30	0.24	0.04	17.01
Nutritive salts (mg kg^{-1})							
CO_3^{2-}	77.50	77.60	95.59	97.96	87.16	11.14	12.78
$C1^{-}$	84.67	158.32	124.31	106.55	118.46	31.13	26.28
SO_4^{2-}	32.99	46.68	54.95	52.22	46.71	9.77	20.92
NO_3^{-}	16.29	15.45	15.58	13.73	15.26	1.09	7.12
NH_4^{+}	89.70	80.22	69.29	64.94	76.04	11.15	14.66
Salinity (%)	5.41	5.44	5.22	5.41	5.37	0.10	1.88
Total hydrocarbon content (mg kg^{-1})	48.19	179.90	135.21	102.55	15.21	53.59	46.51
Exchange Acidity (EA) (mg kg^{-1})	4.71	5.35	3.99	3.86	4.48	0.69	15.44
Effective Cation Exchange Capacity (ECEC)	24.21	23.95	24.43	20.49	23.27	1.86	8.01
Base Saturation (%)	80.57	77.65	83.51	80.06	62.45	36.34	58.19
Particle size distribution (%)							
Sand	54.85	54.98	54.38	54.95	54.79	0.28	0.51
Silt	9.63	10.18	10.25	10.57	10.16	0.39	3.84
Clay	35.36	34.83	33.12	34.49	34.45	0.96	2.78

In benthic sediment, (Fig. 4) the total heterotrophic bacteria ($r = 0.55$), actinomycetes ($r = 0.29$) and fungi ($r = 0.58$) exhibited positive insignificant relationships with salinity levels, while the yeasts ($r = -0.10$) and coliform ($r = -0.09$) counts exhibited negative but insignificant correlation with salinity levels in the subtidal sediment. However the coefficient of determination (R^2) derived from the analyses revealed a more remarkable relation between salinity and heterotrophic bacteria (48.06%) and yeasts (31.18%) in the epipellic sediment. This implies that the two groups of microorganism are more widely

Table 3: Physicochemical properties of benthic sediment from the Qua Iboe Estuary mangrove swamp during the wet season

Parameters	Jun. 2004	Jul. 2004	Aug. 2004	Sep. 2004	Mean	SD	RSD (%)
Temperature (°C)	27.84	27.33	27.21	27.18	27.39	0.31	1.12
pH	7.75	7.27	7.93	7.71	7.67	0.28	3.65
Total organic carbon (%)	4.75	5.30	5.10	4.29	4.86	0.44	9.11
Av. P. (mg kg^{-1})	2.24	1.57	1.31	1.92	1.76	0.41	23.07
Total nitrogen (%)	0.26	0.27	0.21	0.24	0.25	0.03	10.80
Exchangeable Ca (mg kg^{-1})	7.43	7.18	6.77	6.44	6.96	0.44	6.29
Mg (mg kg^{-1})	3.35	3.65	3.71	3.85	3.64	0.21	5.79
Na (mg kg^{-1})	10.18	10.16	9.16	10.51	10.00	0.58	5.84
K (mg kg^{-1})	0.14	0.15	0.20	0.19	0.17	0.03	17.32
Nutritive Salts(mg kg^{-1})							
CO_3^{2-}	71.15	55.66	53.61	51.58	58.00	8.92	15.39
Cl^-	7.95	3.85	3.59	3.78	4.79	2.11	43.98
SO_4^{2-}	23.06	19.06	17.76	18.39	19.57	2.39	12.20
NO_3^-	35.55	34.89	28.88	34.52	33.46	3.08	9.21
NH_4^+	43.55	14.14	10.28	13.85	20.46	15.49	75.76
Salinity (%)	2.56	2.58	2.79	2.69	2.66	0.11	4.02
Total hydrocarbon content (mg kg^{-1})	14.33	15.59	17.16	15.26	15.59	1.18	7.56
Exchange Acidity (EA) (mg kg^{-1})	2.94	3.04	2.65	3.37	3.00	0.29	9.89
Effective Cation Exchange Capacity ECEC)	24.05	24.19	22.49	24.35	23.77	0.86	3.63
Base saturation (%)	87.87	87.63	88.30	86.31	87.53	0.86	0.98
Particle size distribution (%)							
Sand	81.21	60.23	60.14	60.20	65.45	10.51	16.06
Silt	5.54	10.18	10.38	10.21	9.08	2.36	25.99
Clay	13.02	26.23	29.24	29.49	24.50	7.79	31.81

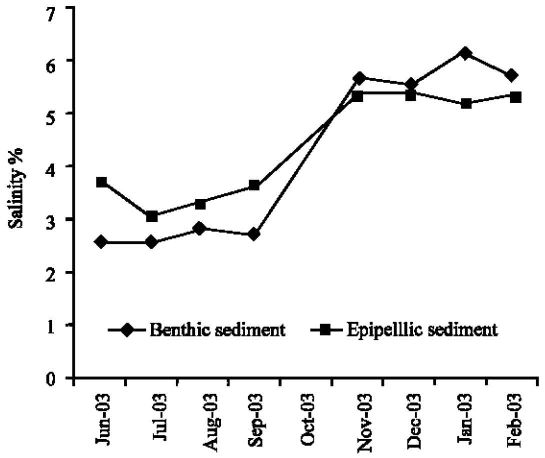

Fig. 2: Monthly variation in salinity levels in epipellic and benthic sediments of the Qua Iboe Estuary mangrove swamp

distributed (Pearson and Hartley, 1958) in the tidal mud flats. On the other hand, the distribution of the actinomycetes (18.68%), fungi (0.09%) and coliforms (29.38%) were more seriously hindered by salinity in the epipellic sediment.

In contrast, the fungi, despite being obligate aerobes exhibited a wider distribution (33.48%) in response to salinity gradients in benthic sediment. This may be ascribed to their existence mostly as dormant culturable spores in the bottom sediment (Given and Dickinson, 1975). The distribution of actinomycetes (8.25%), yeasts (1.00%) and coliform bacteria (0.78%) in response to salinity gradients

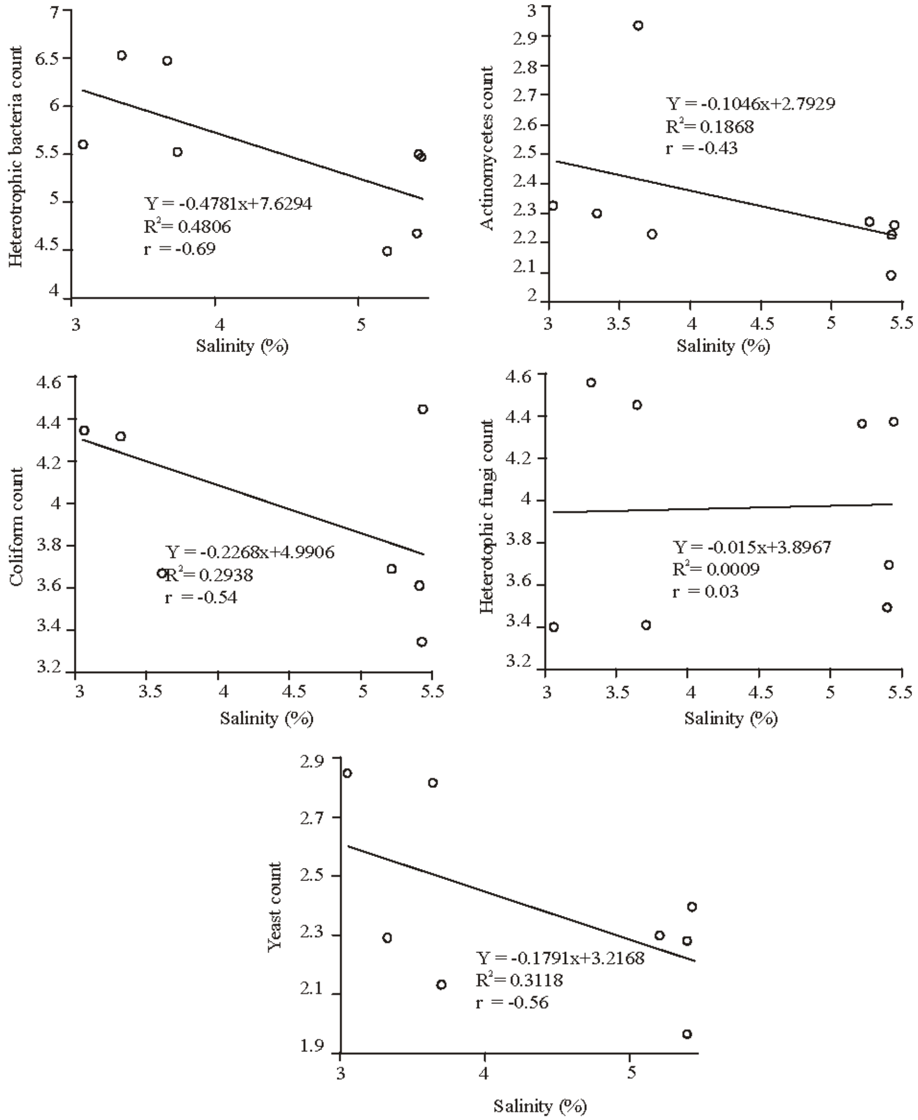

Fig. 3: Relationships between salinity and densities ($\log_{10}$CFU/g) of different groups of microorganisms in the epipellic sediments of the Qua Iboe Estuary mangrove swamp

were comparatively low in the subtidal sediment. While the distribution of heterotrophic bacteria (30.52%) was slightly lower, 17.54% less than its status (48.06%) in the mixohaline epipellic sediments. Other factors apart from the low level of oxygen or anoxic nature of the bottom sediment (Freckman *et al*., 1997) may have contributed to their poor distribution in the bottom sediments. The effect of salinity on the dissociation, bioavailability and toxicity of heavy metals in bottom sediment have been reported by Depledge (1990) and Dorigan and Harrison (1987). Polycyclic Aromatic Hydrocarbons (PAH) are known to accumulate and persist more in the bottom sediment (Law, 2000). Other chemical pollutants e.g., organochlorine and radionuclide are readily detected in the benthic sediment. Their co-interaction may exert complex influence on the effect of salinity on benthic microorganisms.

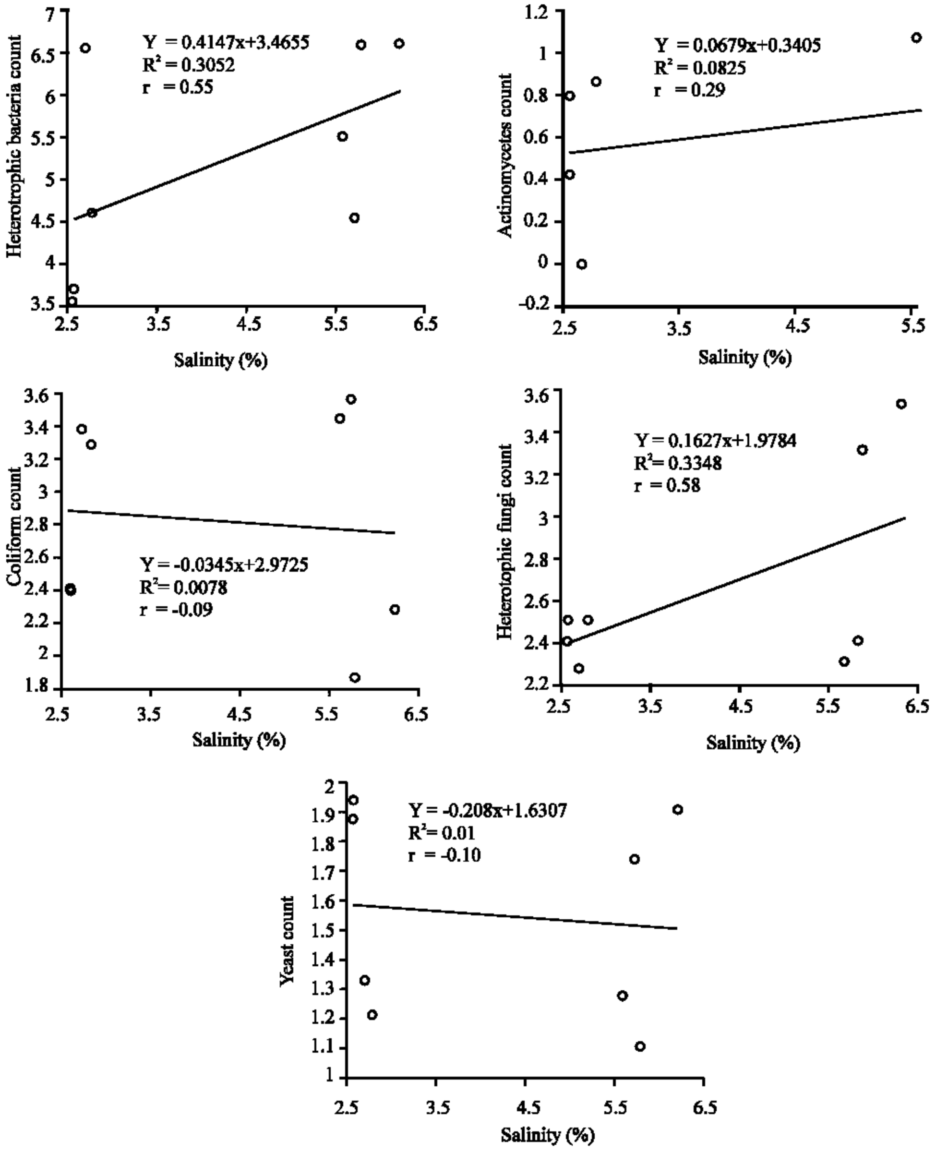

Fig. 4: Relationships between salinity and densities ($\log_{10}$CFU/g) of different groups of microorganisms in the benthic sediments of the Qua Iboe Estuary mangrove swamp

Table 4: Physicochemical properties of benthic sediment from the Qua Iboe Estuary mangrove swamp during the dry season

Parameters	Nov. 2003	Dec. 2003	Jan. 2004	Feb. 2004	Mean	SD	RSD (%)
Temperature (°C)	27.38	28.31	28.02	28.22	27.98	0.42	1.50
pH	7.23	7.15	7.47	7.19	7.26	0.14	1.98
Total organic carbon (%)	5.39	5.45	5.55	6.36	5.69	0.45	7.97
Av. P. (mg kg^{-1})	4.80	4.98	4.73	5.15	4.92	0.19	3.84
Total nitrogen (%)	0.38	0.27	0.31	0.27	0.31	0.05	16.87
Exchangeable Ca (mg kg^{-1})	6.47	6.28	6.21	6.20	6.29	0.13	1.99
Mg (mg kg^{-1})	4.34	3.58	3.76	3.49	3.79	0.38	10.07
Na (mg kg^{-1})	8.84	10.55	9.47	9.62	9.62	0.71	7.34

Table 4: Continued

Parameters	Nov. 2003	Dec. 2003	Jan. 2004	Feb. 2004	Mean	SD	RSD(%)
K (mg kg^{-1})	0.56	0.18	0.19	0.34	0.32	0.18	55.89
Nutritive salts (mg kg^{-1})							
CO_3^{2-}	49.19	54.56	55.85	56.08	53.92	3.22	5.98
Cl^{-}	5.45	5.57	5.57	5.55	5.54	0.06	1.04
SO_4^{2-}	17.13	18.71	19.09	19.70	18.66	1.10	5.88
NO_3^{-}	11.85	8.04	8.04	7.57	8.88	1.99	22.49
NH_4^{+}	9.29	10.89	10.88	9.98	10.26	0.77	7.55
Salinity(%)	5.72	5.60	6.25	5.79	5.84	0.28	4.87
Total hydrocarbon content (mg kg^{-1})	37.05	82.01	196.14	208.41	130.90	84.58	64.61
Exchange Acidity (EA) (mg kg^{-1})	2.71	3.15	2.52	2.61	2.75	0.28	10.17
Effective Cation Exchange Capacity (ECEC)	22.92	22.73	21.81	21.06	22.13	0.86	3.89
Base Saturation (%)	88.16	85.93	88.39	87.60	87.52	1.11	1.27
Particle size distribution (%)							
Sand	69.95	69.42	69.42	67.88	69.17	0.89	1.29
Silt	9.53	9.67	9.67	9.72	9.65	0.08	0.85
Clay	20.52	20.91	20.91	22.07	21.10	0.67	3.18

Table 5: Mean densities (Log$_{10}$cfu/g of wet sediment) of the different groups of microorganisms in epipellic and benthic sediment of the Qua Iboe Estuary mangrove swamp

	Benthic sediment		Epipellic sediment	
Microbial properties	Wet season	Dry season	Wet season	Dry season
Total heterotrophic bacteria	5.95	6.33	6.25	5.21
Actinomycetes count	0.64	0.99	2.56	2.22
Total coliform count	3.09	3.24	4.28	4.00
Total hetertrophic fungi	2.45	3.17	4.34	4.13
Yeasts count	1.69	1.62	2.70	2.30

CONCLUSIONS

Estuaries provide an interface between fresh and salt waters; they have strong gradients in many physical and chemical variables including salinity, pH, dissolved oxygen nutrients and amount and composition of particles. Unlike freshwater where pH is the controlling factor, in estuaries salinity is the controlling factor for the partitioning of contaminants between sediments and overlying or interstitial waters and both are the key variables to control the levels of other attributes, the bioavailability and the toxicity of pollutants bound to sediments (Riba *et al*., 2003). The results of the present study have reveal that the linear correlation coefficient (r) values between salinity and microbial densities in the epipellic and benthic sediments of the Qua Iboe Estuary mangrove swamp were less than the critical value of 0.707 ($n = 8$, $p>0.05$) (Pearson and Hartley, 1958). This indicates that there was no tendency of the microbial densities being governed by the salinity values as a function of their existence and distribution in the brackish estuarine sediments. This was expected, especially when the microorganisms are of autochthonous origin (Reinheimer, 1992). It implies that the coliforms, were the mostly affected group because they are allochthonous, originating from the human and animal intestine and hardly adapts to the changing brackish condition of the mangrove sediment. It confirms the usefulness of coliforms as indicator of fresh faecal contamination in an estuary. On the other hand, fungi exist mostly as spores in aqueous environment and most yeasts are osmotolerant (Ramos *et al*., 1999). The high sensitivity of yeasts to salinity, observed in this study was not expected. This may be attributed to factors other than salt stress. Frequent fluctuations in salinity levels might be a factor. The growth of fungal vegetative cells has also been demonstrated to be more sensitive to matric than osmotic stress (Magan, 1998; Ramos *et al*., 1999). They survives osmotic stress by the accumulation of compatible solutes particularly polyols (Ramos *et al*., 1999). This is a process that requires stable physiological conditions. These conditions are not obtainable in a dynamic estuarine environment. Therefore the existence of the strict aerobes as dormant, resistant (but culturable) spores might have contributed to their presence in the bottom sediment.

Although the effect of salinity on the autochthonous microbial populations was not remarkable, the study has provided inside into establishing habitat characterization based on salinity gradients, especially the revelation of the high sensitivity of indicator bacteria (coliforms) to fluctuating salinity levels. In a similar investigation on the productivity and distribution of epipellic microalgae along salinity gradient, Essien *et al*. (2005) observed that no microalgae species was found to occur on the highest value of sediment salinity and there were overlapping range of occurrences and ecological optima for most species along the gradient. Therefore, its variable influence on the different microbial groups, as well as its effect on the diversity and distribution of protists is not doubtful.

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