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Salinity Induced Longitudinal Zonation of Polychaete Fauna on the Bonny River Estuary

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Author's contribution

The sole author designed, analyzed and interpreted and prepared the manuscript.

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ABSTRACT

The longitudinal zonation of polychaetes was studied across 13 stations on the Bonny River estuary. A total of eighty-eight (88) species of polychaetes, from 68 genera, belonging to 31 families, were identified. Based on salinity values, three major salinity zones were identified: The alpha-Polyhaline – beta-Polyhaline and Mesohaline. The dendrogram shows four polychaete associations which correlated with salinity variation. The first group comprises of species which occurred in a very narrow salinity range (0.9-2.0 gL^{-1}) and are referred to as the true marine or the alpha-polyhaline inhabitants. The second were group of species that colonize the transition zone where salinity oscillates from alpha to beta-polyhaline (0.9-5.3 gL^{-1}). The third group comprises of species that are specific to the beta-polyhaline which has a constant salinity of 5.3 gL^{-1}. The fourth association was the euryhaline group which composed of species that occurred at all the stations from salinity variation of 0.9 to 15.4 gL^{-1}. The study observed that some genera with more than one species have ecological divergence along the salinity gradient. The three species of the genus Aricidea namely (*Aricidea* sp.; *Aricidea simplex*; and *Aricidea* (*Acrima*) *assimillis*) occur over the range with *Aricidea* sp. occurring at the alpha-polyhaline, Aricidea simplex occurring at both the alpha and beta polyhaline zone while *Aricidea (Acrima) assimillis)* occur strictly at the beta-polyhaline zone. Similarly the *Lumbrineris aberrans* and *Lumbrineris fragilis* occur only in the alpha-

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polyhaline while their sympatric species *Lumbrineris latreilli* and *Lumbrineris tetraura* occur in both the alpha and beta polyhaline zones. Similarly the salinity preferences for *Eteone siphonodonta* were the alpha-polyhaline zone while *Eteone picta* were in the beta-polyhaline zone only. The *Scoloplos* spp group was observed to be spaced with *Scoloplos dayi*, occurring in the alpha-polyhaline zone while two species, *Scoloplos (Scoloplos) armiger* and *Scoloplos* (*Leodamas) johnstonei* occur in both the alpha and beta polyhaline zones. The *Notomastus* spp group have two species *Notomastus* sp. which occur in salinity gradient of alpha and beta polyhaline zones while *Notomastus aberrans* were observed to occur in the alpha-beta polyhaline and mesohaline zones. Similar salinity spacing preferences in the Notomastus genus were observed for *Glycera prashadi* and *Glycera tridactyla.* Two species namely *Phyllodoce mucosa* and *Phyllodoce tubicola* were spaced between salinity gradients of alpha-polyhaline and beta-polyhaline respectively. This divergence suggests that other biotic and abiotic factors other than salinity may be responsible for the zonation. Therefore understanding observed polychaete distribution along the salinity gradient need additional studies that consider nonlinear abiotic and biotic variables.

Keywords: Polychaetes; zonation; bonny river; salinity; gradient.

1. INTRODUCTION

Salinity, one of the most tangible characteristics of an estuarine and marine ecosystem, has often been considered as a major factor in ecological zonation. A few studies have described and classified the estuarine ecosystems of Niger Delta along a salinity scale [1,2]. Many of these estuaries, such as Bonny River and its coastal zones, are characterized by gradients in chemical (salinity) features. However, many studies that have provided information about the distribution of biological communities have been restricted to small parts of these gradients and are mainly focused on the marine or brackish part of the estuary without attention to tidal freshwater areas [3-10].

Benthic macrofauna, such as polychaetes, have been identified as a suitable ecological group for monitoring and detecting the effects of stress and pollution [11-14]. Community structure of estuarine macrobenthos has been used as an indication of water and sediment quality [15-18]. The unique ecological value of the Bonny River as an environment with a mix of multifaceted activities of socioeconomic and industrial value makes the current survey of polychaete zonation invaluable to the ecological assessment and auditing of the health of various sections of the estuary. The present study therefore uses the presence-absence of polychaetes along the Bonny River estuary, including the tidal freshwater section to understand the species distribution imposed by a salinity gradient.

2. STUDY AREA

The Bonny estuary is located on the immediate eastern flank of the Niger Delta between longitudes 7°00' and 7°15'E and latitudes 4°25' and 5°50'N of southern Nigeria. The strategic location of the estuary serves as an entrance point to Port-Harcourt, Onne and Okirika ports in Rivers State. Immediately east of the estuary is the Bonny barrier island. The mouth of the estuary is jointly shared by the Cawthorne Channel and the New Calabar River. The width of the estuary's mouth is 13.5 km and drains a total area of 621,351 km^2. It has an estimated area of 206 km^2 and extends 7km offshore. The tidal regime of the Bonny River estuary has a range of 0.8 m at neap tide and 2.4 m during spring tides [19]. This tidal regime extends up to 66km inland where it meets with the New Calabar River at Aluu in a tidal freshwater habitat. The Bonny River System is known to have the largest tidal volume of all river systems in the Delta. There is generally a net flux of tidal water up the river which disperses into various creeks and channels [19]. The Bonny River is one of the most environmentally stressed rivers in the Niger Delta due to shipping activities associated with four port complexes (Port Harcourt, Onne, Okrika and Bonny) and other boat landings, such as Buguma, which service oil and gas production. Several oil fields are located in and around the Bonny estuary including Orubiri field on Primrose Creek; Onne fields on Ogu creek; Bomu, Bodo and Bonny fields on the eastern part of the Bonny estuary. Also located within the river system are the Nigerian National Petroleum Corporation (NNPC), Petroleum Refinery Plant near Okrika, NAFCON fertilizer plant on Ogu creek, the Bonny Crude Tank Farm, the LNG plant of NNPC and NGL plant of Exxon-Mobil located at the mouth of Bonny River. Several dredging activities go on periodically to keep the channels open for the numerous continuous shipping logistics.

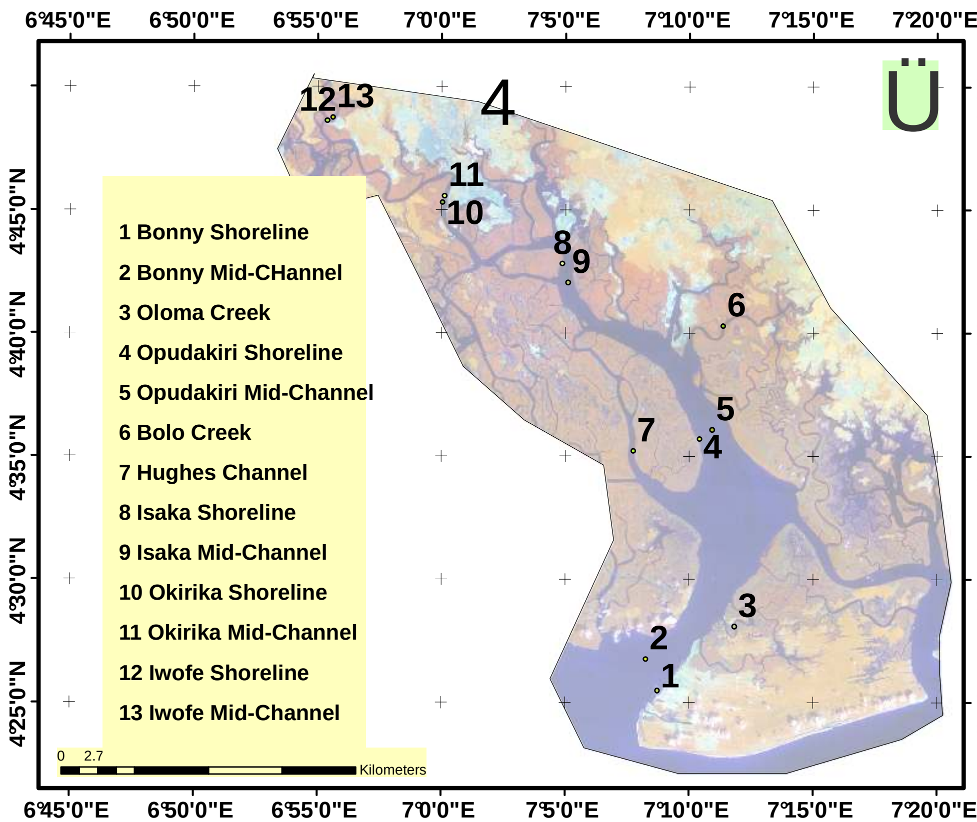

Fig. 1. Sampling stations along the Bonny River estuary

3. METHODOLOGY

The stations were sampled as in Onwuteaka [10,20,21]. Samples were collected from twelve locations (defined by the salinity values in Table 1.0) along Bonny River between June 2012 and June 2013. At each location, three random samples were taken using a 0.023 m^2 Ekman grab. All samples at each site were combined into a composite sample. The grab samples were washed with water in 45 µ nitex bags and preserved in 10% buffered formalin. Approximately 3 to 4 drops of 1g 100 mL^{-1} of Rose Bengal solution was added. Each preserved sample was hand sorted. All polychaetes were sorted, identified with stereo (Olympus s2 series) and Brunnel (DN-117M) digital compound microscopes and categorized into families and genera. Polychaete species were identified to the lowest taxonomic level using the keys of Kierkegaard [22], Day [23] and Fauchald [24]. At each station, salinity values were measured with a Science first Refractometer (0-100 gL^{-1}) and classified according to the Venice System for the Classification of Marine Waters [25]. Due to large variations that exist at some stations, a consistent delineation of broad zones, according to the Venice system, was adopted. These recognize the following zones, namely Mesohaline (0 – 5 gL^{-1}), Hypo-Mesohaline (5 – 10 gL^{-1}), Hyper-Mesohaline (10 – 18 gL^{-1}) and β–Polyhaline (25 – 35 gL^{-1}). Based on these broad zones, stations are categorized into two groups with respect to the range of salinity obtained.

Table 1 shows the zones in relation to their salinity variation as described by Powell and Onwuteaka [2]. Eleven stations (Bonny Shoreline, Bonny Midchannel, Hughes Shoreline, Oloma Midchannel, Opudakiri Midchannel, Opudakiri Shoreline, Bolo Creek Shoreline, Okirika Shoreline, Okirika Midchannel, Isaka Shoreline and Isaka Midchannel) have a constant salinity/conductivity (β-Polyhaline - β-Polyhaline), while the salinities of Iwofe shoreline and Iwofe midchannel is constantly Mesohaline.

Table 1. Stations, salinity classes and salinity ranges of the study area [2]

Station	Salinity class	Salinity range (gL^{-1})
Bonny shoreline	Alpha-Polyhaline	27 – 28
Bonny midchannel	Alpha-Polyhaline	27– 28
Hughes shoreline	Beta-Polyhaline - Alpha-Polyhaline	24 – 27
Oloma midchannel	Alpha-Polyhaline	28 – 30
Opudakiri midchannel	Alpha-Polyhaline	25 – 28
Opudakiri shoreline	Alpha-Polyhaline	25 – 28
Bolo creek shoreline	Beta-Polyhaline - Alpha-Polyhaline	24 – 27
Okirika shoreline	Beta-Polyhaline	20 – 24
Okirika midchannel	Beta-Polyhaline	20 – 24
Isaka shoreline	Beta-Polyhaline	20 – 23
Isaka midchannel	Beta-Polyhaline	20 – 23
Iwofe shoreline	Mesohaline	5 – 12
Iwofe midchannel	Mesohaline	5 - 12

4. RESULTS

4.1 Composition and Zonation

Table 2 shows the occurrence distribution of polychaete fauna along the longitudinal gradient from the mouth of the estuary at the Bonny to the upper estuary at Iwofe station. The Polychaete fauna comprise a total of eighty-eight (88) polychaete species belonging to thirty (30) families. Between salinity zones 9 families out of the 30 families were observed to occur in both alpha-polyhaline and beta-polyhaline. These were the Capitellidae, Eunicidae, Lumbrinereidae, Nereidae, Onuphidae, Pectinariidae, Sigalionidae, Sternapsidae, and Terebellidae. Six families were also observed to occur in all the salinity zones (alpa-polyhaline; beta-polyhaline and mesohaline) from the lower estuary at Bonny station to the upper estuary at Iwofe station. These were the Capitellidae, Glyceridae, Nephtydae, Nereidae, Orbiniidae and Pilargidae.

In Fig. 2 is shown the occurrence of Polychaete family and species in the different salinity zones. In the alpha-polyhaline zone the number of families range from 11 (at Opudakiri and Hughes channel stations) to 21 (at Bolo creek station) while the number of species occurrence range from the lowest of 17 at Hughes channel station to 35 at Bolo creek station. The abundance of families, in order of decreasing number, within the Alpa-Polyhaline salinity were Bolo Creek (21), Opudakiri Shoreline (19), Bonny Shoreline (19), Oloma Creek (18), Bonny Midchannel (14), Opudakiri Midchannel (11), and Hughes Channel (11). Similarly the occurrence frequency of species in decreasing order shows Bolo Creek Station with the highest number at 35 species; Bonny Shoreline, 34 species; Oloma Station, 29 species; Bonny Midchannel, 24 species; Opudakiri Shoreline, 24 species; Opudakiri Midchannel, 18 species; and Hughes Shoreline with 17 species.

Within the stations experiencing only beta-polyhaline conditions the number of families range from the lowest of 4 at Okirika station to 8 at Isaka. Similarly the number of species occurrence range from 4 at Okirika to 13 at Isaka station, Okirika (11), Isaka Shoreline (6) and Isaka Midchannel (4). The abundance of families, in order of decreasing number, within the Beta-Polyhaline salinity were Isaka shoreline (8), Isaka midchannel station (11), Okirika shoreline (6) and Okirika midcahnnel station (4). Similarly the occurrence frequency of species in decreasing order shows Okirika Shoreline with 13 species; Okirika Midchannel, 12 species; Isaka Shoreline, 7 species; Iwofe Shoreline, 6 species; Isaka Midchannel, 4 species and Iwofe Midchannel, 2 species. At the mesohaline stations, the range in the number of families was between 2 and 4 while the number of species occurrences range from 2 to 6 between the two Iwofe stations.

4.2 Salinity Species Clusters

Fig 3 shows the dendogram cluster of the 88 species of polychaetes separated into four associations namely alpha-polyhaline, alpha-beta-polyhaline beta-polyhaline and alpha-beta-polyhaline-mesohaline variants. The first group belonging to the alpha-polyhaline association include a total of 29(32%) species such as *Ancistrosyllis cingulate, Aricidea sp., Ceratonereis (Composetia) costae, Dasychone* *serratibranchis, Decamastus nudus, Eteone picta, Eurythoe pervecarnuculata, Gyptis incise, Hediste diversicolor, Heterospio longissima, Laonice cirrata, Levinsenia gracilis, Lumbrineris aberrans, Lumbrineris fragilis, Lysidice collaris, Lumbrineriopsis paradoxa, Melinna palmate, Melinna sp., Nephthys sp., Nicomache sp., Paraonis fulgens, Paraonis pygoenigmatica, Paraonis sp., Phyllodoce mucosa, Scoloplos dayi, Simplisetia erythraeensis, Sphaerodoropsis sp., Stygocapitella sp., and Travisia sp..* The second association represented by species that occur in alpha and beta polyhaline include a total of 27(30%) species such as *Aglaophamus malmgreni, Aricidea simplex, Cossura longocirrata, Euclymene oerstedi, Glycera africana, Glycera prashadi, Harmothoe sp., Isolda whydahaensis, Loimia medusa, Loimia sp., Lumbrineris coccinea, Lumbrineris latreilli, Lumbrineris tetraura, Malacoceros indicus, Maldane sarsi, Namalycastis sp., Notomastus latericeus, Notomastus sp., Oxydromus fasciatus, Paracapitella pettiboneae, Polydora sp., Prinospio sp., Sabillides sp., Scoloplos (Leodamas) johnstonei, Scoloplos (Scoloplos) armiger, Sigalion opalinum and Sternapsis scutata.*

The third association represented by species that occur only in the beta polyhaline zone include a total of 21(23.9%) species such as *Alikuhnia longicirrus, Aricidea (acrima) assimills, Cabira incerta, Capitella capitata, Eteone siphonodonta, Glycinde kameruniana, Heterospio reducta, Irana heterobranchiata, Levinsenia acutibranchiata, Nephthys assimilis, Nicomache mossambica, Oxydromus berrisfordi, Paraleiocapitella sp., Pectinaria korenii, Pectinaria (Lagis) neapolitana, Petaloproctus terricolus, Phyllodoce tubicola, Pista sp., Poecilochaetus tropicus, Prionospio dubia,* and *Tauberia sp.*

The fourth association represented by species that occur in the alpha, beta polyhaline and the mesohaline zones include a total of 8(7%) species such as *Diopatra neapolitana, Glycera tridactyla, Heteromastus sp., Neanthes sp., Ninoe lagosiana, Notomastus aberrans, Sigambra tentaculata and Tharynx dorsobranchialis.*

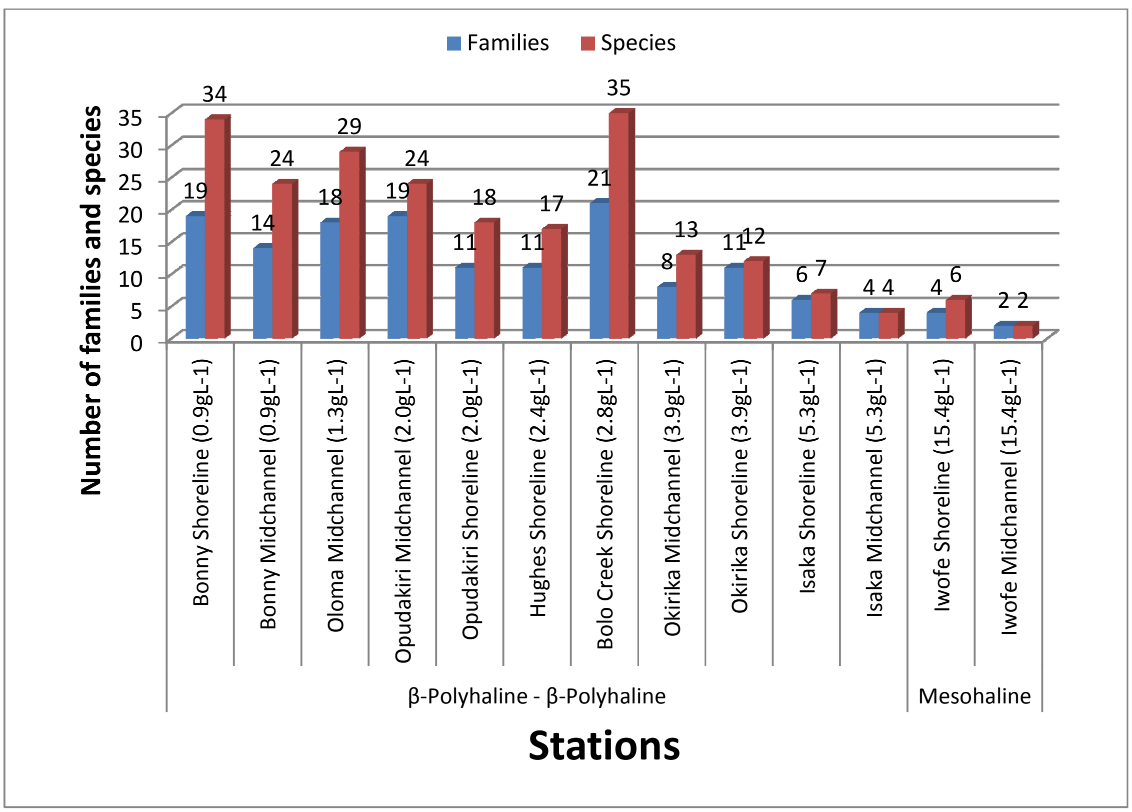

Fig. 2. Abundance of polychaete families and species along the longitudinal gradient of the Bonny River

Table 2. Distribution of polychaete families and species across the salinity zones and salinity variation

Family	Species	Alpha-polyhaline				Beta-polyhaline							Mesohaline		Total station
		Bonny shoreline (0.9 gL^{-1})	Bonny midchannel (0.9 gL^{-1})	Oloma midchannel (2.0gL^{-1})	Opudakiri midchannel (1.3 gL^{-1})	Opudakiri shoreline (1.3 gL^{-1})	Hughes shoreline (2.8 gL^{-1})	Bolo creek shoreline (2.4 gL^{-1})	Okirika shoreline (3.9 gL^{-1})	Okirika midchannel (3.9 gL^{-1})	Isaka shoreline (5.3 gL^{-1})	Isaka midchannel (5.3 gL^{-1})	Iwofe shoreline (15.4 gL^{-1})	Iwofe midchannel (15.4 gL^{-1})	
Ampharetidae	*Isolda whydahaensis* Augener, 1918	*				*	*	*							4
Ampharetidae	*Melinna palmata* Grube, 1870	*			*										2
Ampharetidae	*Irana heterobranchiata* Wesenberg-Lund, 1949						*								1
Ampharetidae	*Sabellides* sp. Milne Edwards in Lamarck, 1838				*					*					2
Ampharetidae	*Melinna* sp. Malmgren, 1866				*										1
Amphinomidae	*Eurythoe parvecarunculata* Horst, 1857				*										1
Capitellidae	*Notomastus aberans* Day, 1957	*	*	*	*	*			*	*			*	*	9
Capitellidae	*Notomastus latericeus* Sars, 1851	*	*					*							3
Capitellidae	*Notomastus* sp. Sars, 1850				*				*	*					3
Capitellidae	*Paracapitella pettiboneae* Carrasco and Gallardo, 1987	*	*	*				*							4
Capitellidae	*Heteromastus* sp. Eisig, 1887			*	*	*	*			*	*				6
Capitellidae	*Paraleiocapitella* sp. Thomassin, 1970						*								1
Capitellidae	*Decamastus nudus* Thomassin, 1970			*											1
Capitellidae	*Capitella capitata* Czerniavsky, 1881							*							1
Cirratulidae	*Tharyx dorsobranchialis* Kirkegaard, 1959	*			*		*	*		*	*				6
Cirratulidae	*Chaetozone setosa* Malmgren, 1867		*	*	*	*									4
Cossuridae	*Cossura longocirrata* Webser and Benedict, 1887	*	*	*		*		*							5
Eunicidae	*Lysidice collaris* Grube, 1870	*							*						2
Glyceridae	*Glycera tridactyla* Schmarda, 1861	*	*	*	*			*	*	*	*	*	*	*	11
Glyceridae	*Glycera prashadi* Fauvel, 1932	*	*	*		*		*							5
Glyceridae	*Glycera africana* Arwidsson, 1899			*		*									2
Goniadidae	*Glycinde kameruniana* Augener, 1918	*						*							2

Family	Species	Alpha-polyhaline				Beta-polyhaline							Mesohaline		Total station
		Bonny shoreline (0.9 gL^{-1})	Bonny midchannel (0.9 gL^{-1})	Oloma midchannel (2.0 gL^{-1})	Opudakiri midchannel (1.3 gL^{-1})	Opudakiri shoreline (1.3 gL^{-1}	Hughes shoreline (2.8 gL^{-1})	Bolo creek shoreline (2.4 gL^{-1})	Okirika shoreline (3.9 gL^{-1})	Okirika midchannel (3.9 gL^{-1})	Isaka shoreline (5.3 gL^{-1})	Isaka midchannel (5.3 gL^{-1})	Iwofe shoreline (15.4 gL^{-1})	Iwofe midchannel (15.4 gL^{-1})	
Hesionidae	*Gyptis incisa* Böggemann, 2009	*					*								2
Hesionidae	*Oxydromus fasciatus* Grube, 1855			*											1
Hesionidae	*Alikuhnia longicirrus* Alikuhni, 1949							*							1
Hesionidae	*Oxydromus berrisfordi* Day, 1967							*							1
Longosomatidae	*Heterospio longissima* Ehlers, 1874		*	*											2
Longosomatidae	*Heterospio reducta Laubier,* Picard and Ramos, 1973							*							1
Lumbrineridae	*Lumbrineris heteropoda difficilis* Day, 1962	*		*											2
Lumbrineridae	*Lumbrineris aberrans* Day, 1963	*	*												2
Lumbrineridae	*Lumbrineriopsis paradoxa* Saint Joseph, 1888	*	*												2
Lumbrineridae	*Lumbrineris coccinea* Renier, 1804	*	*		*					*		*			5
Lumbrineridae	*Lumbrineris latreilli* Audouin and Milne-Edwards, 1834	*	*					*							3
Lumbrineridae	*Lumbrineris tetraura* Schmarda, 1861	*	*	*		*	*			*					6
Lumbrineridae	*Lumbrineris fragilis* Müller, 1776		*												1
Lumbrineridae	*Ninoe lagosiana* Augener, 1918	*	*	*		*	*	*	*		*				8
Maldanidae	*Nicomache* sp. Malmgren, 1865				*										1
Maldanidae	*Nicomache mossambica* Day, 1951							*							1
Maldanidae	*Euclymene oerstedi* Claparede, 1863			*		*	*	*							4
Maldanidae	*Petaloproctus terricolus* Quatrefages, 1866							*							1
Maldanidae	*Maldane sarsi* Malmgren, 1865	*					*	*							3
Nephtyidae	*Aglaophamus malmgreni* Théel, 1879	*	*	*											3
Nephtyidae	*Aglaophamus lyrochaeta* Fauvel, 1902	*		*		*									3
Nephtyidae	*Nephthys assimilis* Örsted, 1843	*						*					*		3

Family	Species	Alpha-Polyhaline					Beta-Polyhaline						Mesohaline		Total station
		Bonny shoreline (0.9 gL^{-1})	Bonny midchannel (0.9 gL^{-1})	Oloma midchannel (2.0 gL^{-1})	Opudakiri midchannel (1.3 gL^{-1})	Opudakiri shoreline (1.3 gL^{-1})	Hughes shoreline (2.8 gL^{-1})	Bolo creek shoreline (2.4 gL^{-1})	Okirika shoreline (3.9 gL^{-1})	Okirika midchannel (3.9 gL^{-1})	Isaka shoreline (5.3 gL^{-1})	Isaka midchannel (5.3 gL^{-1})	Iwofe shoreline (15.4 gL^{-1})	Iwofe midchannel (15.4 gL^{-1})	
Nephtyidae	*Nephthys* sp. Cuvier, 1817						*								1
Nereididae	*Ceratonereis (Composetia) costae* Grube 1840	*													1
Nereididae	*Simplisetia erythraeensis* Fauvel, 1918	*													1
Nereididae	*Hediste diversicolor* Müller, 1776			*											1
Nereididae	*Namalycastis* sp. Hartman, 1959								*						1
Nereididae	*Neanthes* sp. Kinberg, 1865												*		1
Onuphidae	*Diopatra neapolitana,* Delle Chiaje, 1841	*	*	*	*	*	*	*	*	*		*			10
Orbiniidae	*Scoloplos (Scoloplos) armiger* Müller, 1776	*	*	*		*		*					*		6
Orbiniidae	*Scoloplos (Leodamas) johnstonei* Day, 1934	*	*	*				*							4
Orbiniidae	*Scoloplos dayi* Pettibone, 1957			*											1
Paraonidae	*Aricidea simplex* Day, 1963	*	*	*				*							4
Paraonidae	*Aricidea (Acrima) assimills* Tebble, 1959							*	*						2
Paraonidae	*Aricidea sp.* Webster, 1879				*		*								2
Paraonidae	*Paraonis pygoenigmatica* Jones, 1968	*													1
Paraonidae	*Paraonis* sp. Cerruti, 1909				*										1
Paraonidae	*Paraonis fulgens* Levinsen, 1883					*									1
Paraonidae	*Levinsenia gracilis* Tauber, 1879			*											1
Paraonidae	*Levinsenia acutibranchiata* Strelzov, 1973							*							1
Paraonidae	*Tauberia* sp. Strelzov, 1973						*								1
Parergodrilidae	*Stygocapitella* sp. Knöllner, 1934					*									1
Pectinariidae	*Pectinaria korenii* Malmgren, 1866						*	*	*	*					4
Pectinariidae	*Pectinaria (Lagis) neapolitana* Claparède, 1869							*							1
Phyllodocidae	*Phyllodoce mucosa* Örsted, 1843			*				*							2
Phyllodocidae	*Phyllodoce tubicola* Day, 1963							*							1

Family	Species	Alpha-Polyhaline					Beta-Polyhaline						Mesohaline		Total station
		Bonny shoreline (0.9 gL^{-1})	Bonny midchannel (0.9 gL^{-1})	Oloma midchannel (2.0 gL^{-1})	Opudakiri midchannel (1.3 gL^{-1})	Opudakiri shoreline (1.3 gL^{-1}	Hughes shoreline (2.8 gL^{-1})	Bolo Creek shoreline (2.4 gL^{-1})	Okirika shoreline (3.9 gL^{-1})	Okirika midchannel (3.9 gL^{-1})	Isaka shoreline (5.3 gL^{-1})	Isaka midchannel (5.3 gL^{-1})	Iwofe shoreline (15.4 gL^{-1})	Iwofe midchannel (15.4 gL^{-1})	
Phyllodocidae	*Eteone siphonodonta* Claparède, 1868							*							1
Phyllodocidae	*Eteone picta* Quatrefages, 1866		*			*									2
Pilargidae	*Ancistrosyllis cingulata* Korscheit, 1893					*									1
Pilargidae	*Sigambra tentaculata* Treadwell, 1941	*				*							*		3
Pilargidae	*Cabira incerta* Webster							*							1
Poecilochaetidae	*Poecilochaetus tropicus* Okuda, 1937							*							1
Polynoinae	*Harmothoe* sp. Kinberg, 1856										*				1
Sabellidae	*Dasychone serratibranchis* Ehlers, 1907	*		*											2
Scalibregmatidae	*Travisia sp.* Johnston, 1840					*									1
Sigalionidae	*Sigalion opalinum* Intes and Le Loeuff, 1975		*	*				*	*						4
Sphaerodoridae	*Sphaerodoropsis sp.* Hartman and Fauchald, 1971					*									1
Spionidae	*Prionospio dubia* Day, 1961							*							1
Spionidae	*Prinospio* sp. Malmgren, 1867										*				1
Spionidae	*Malacoceros indicus* Fauvel, 1928	*	*		*	*				*		*			6
Spionidae	*Laonice cirrata* Sars, 1851			*											1
Spionidae	*Polydora* sp. Bosc, 1802				*						*				2
Sternaspidae	*Sternapsis scutata* Ranzani, 1817	*	*		*	*	*	*	*						7
Terebellidae	*Loimia medusa* Savingy, 1818			*		*									2
Terebellidae	*Loimia* sp. Malmgren, 1866					*			*						2
Terebellidae	*Pista* sp. Malmgren, 1866						*								1
	Total Number of Polychaete per station	34	24	29	18	24	17	35	13	12	7	4	6	2	225

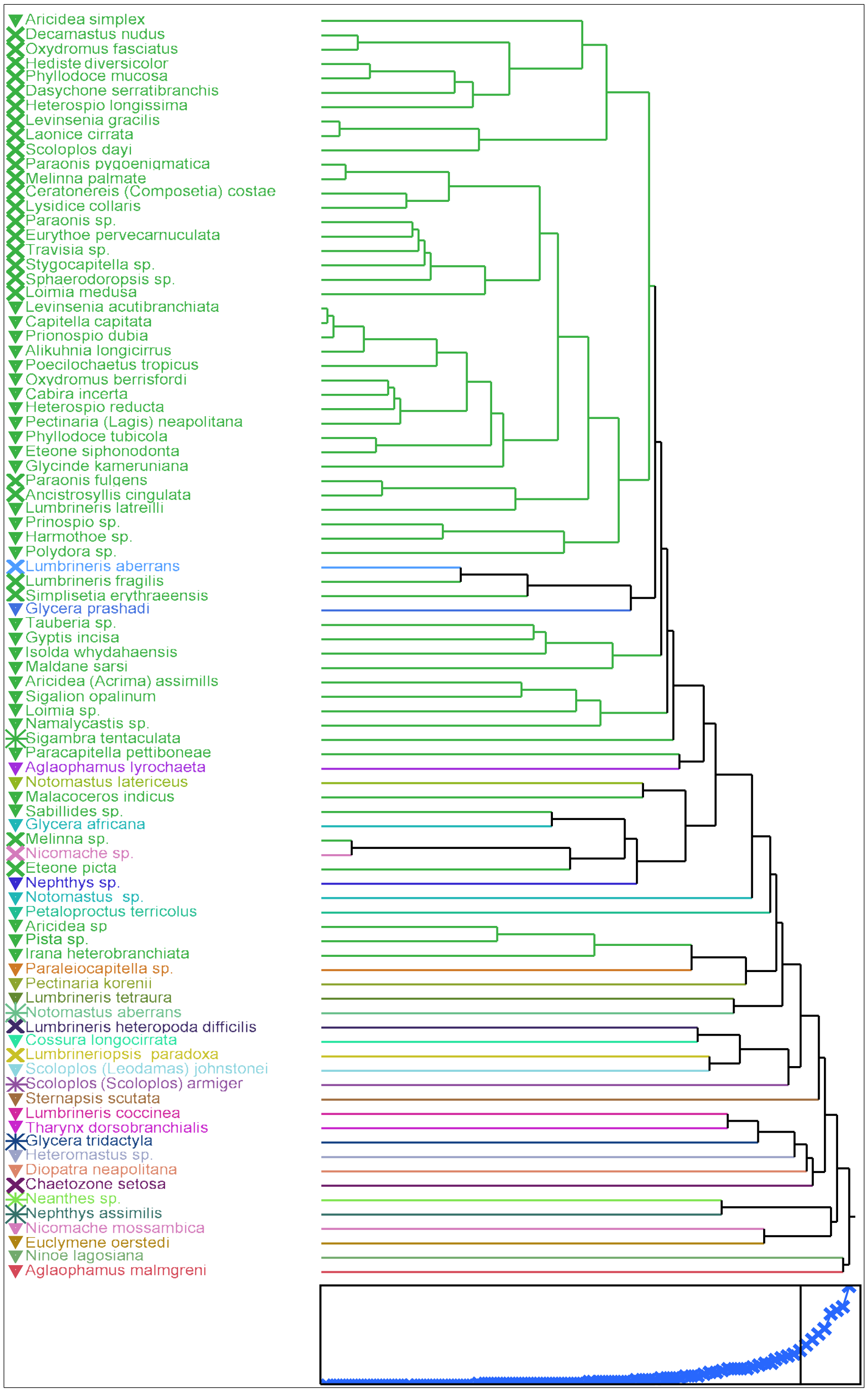

Fig. 3. Dendrogram of polychaete associations across the salinity variation of Bonny River

5. DISCUSSION

The study shows evidence that polychaete occurrence and distribution can be explained by variation in salinity values following the classical concept of species response to salinity gradients [26-29]. The cluster statistics provide evidence of groups occurring from extreme marine conditions through a transition zone to borderline estuarine conditions. The first cluster group can be described as the true marine or the alpha-polyhaline inhabitants. These are species whose occurrences were in very narrow salinity values (0.9-2.0 gL^{-1}). Their strict salinity preference classify them as stenohaline forms since they can tolerate exposure to a limited salinity range thereby occupying only a limited portion of the entire range of salinity regime available within the estuary. The second association whose occurrences were in salinity variation of 0.9-5.3 gL^{-1} was able to colonize the transition zone where salinity oscillates from alpha to beta polyhaline. The third group comprises of species found strictly in the beta-polyhaline zone where salinity variation is consistently at 5.3 gL^{-1}. The fourth association was those that can be termed euryhaline occurring at all the stations from salinity variation of 0.9 gL^{-1} to 15.4 gL^{-1}. These patterns are in agreement with the other studies of tropical estuaries where salinity exerts influence on community structure along a gradient [30-38] with higher species occurrence at the mouth of the river as in this study.

The study also provides evidence of certain resident polychaete species such as in the genera *Aricidea, Eteone, Lumbrinereis, Notomastus* and Phyllodoce which have more than one species that are partially or fully segregated along the salinity gradient. The three species of the genus Aricidea namely (*Aricidea sp.; Aricidea simplex; Aricidea (Acrima) assimillis)* occur over the range with *Aricidea sp.* occurring at the alpha-polyhaline, *Aricidea simplex* occurring at both the alpha and beta polyhaline zone while *Aricidea (Acrima) assimillis)* occur strictly at the beta-polyhaline zone. Similarly the *Lumbrineris aberrans* and *Lumbrineris fragilis* occur only in the alpha-polyhaline while their sympatric species *Lumbrineris latreilli and Lumbrineris tetraura occur in both the* alpha and beta polyhaline zones. Similarly the Salinity preferences for *Eteone siphonodonta* were the alpha-polyhaline zone while *Eteone picta* were in the beta-polyhaline zone only. The Scoloplos spp group was observed to be spaced with *Scoloplos dayi*, occurring in the alpha-polyhaline zone while two species, *Scoloplos (Scoloplos) armiger* and *Scoloplos (Leodamas) johnstonei* occur in both the alpha and beta polyhaline zones. The Notomastus group has two species *Notomastus sp.* which occur in salinity gradient of alpha and beta polyhaline zones while *Notomastus aberrans* were observed to occur in the alpha-beta polyhaline and mesohaline zones. Similar salinity spacing preferences in the Notomastus spp group were observed for the *Glycera prashadi* and *Glycera tridactyla*. Two species namely *Phyllodoce mucosa* and *Phyllodoce tubicola* were spaced between salinity gradients of alpha-polyhaline and beta-polyhaline respectively. The patterns observed suggest a capacity for hyper- and hypo-osmotic regulation in all species examined as is seen a few documented polychaete species such as *Glycera dibranchiata*, *Neanthes succinea, Nereis diversicolor*, *Nereis liminicola* and *Nereis succinea* [39-46]. On the Bonny river the evidence is shown by the greater presence of polychaetes towards the mouth of the Bonny River where the zone with salinity variation 0.9 gL^{-1} - 2.8 gL^{-1} was observed to consist of over 81% of the species. They also suggest ecological divergence between similar species at different salinity gradients whose observed patterns are plausibly due to physiological and behavioral responses. Both responses are influenced by non-linear biotic and abiotic variables which control the dynamics of change in occurrence and distributions [47-49]. Ultimately the results together with the critical salinity concept agrees with Deaton and Greenberg [50] who showed that the complexity of processes in estuaries promotes ambiguity of conventional zoning using one factor such as salinity. To be able to explain natural environmental perturbations versus anthropogenic stress within the Bonny river salinity gradient, further investigations into the interaction modes of biotic/abiotic processes are necessary to improve the accuracy of the occurrence of polychaete biota along gradients of non-linear biological, chemical and physical processes.

6. CONCLUSION

The present study shows the strong relationship between polychaetes and salinity along a longitudinal gradient on Bonny River. Within this gradient are critical salinity ranges which define the characteristic composition and distribution of polychaete fauna within and between stations. This has important implications for understanding how to interpret polychaete communities found in certain sections of the river during anthropogenic impacts assessment and evaluation. The study also provides a good opportunity to test the correspondence between the diversity of the salinity gradient and the distribution of species as the physiology and distribution of polychaetes in saline estuarine habitats in the tropics has yet to be adequately described.

COMPETING INTERESTS

Author has declared that no competing interests exist.

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