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ARTICLE

Distribution Pattern of Macrozoobenthos in Relation to Salinity of Hugli-Matla Estuaries in India

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Abstract Distribution pattern of 58 macrozoobenthic species comprising of polychaetes (10 species) and molluscs (48 species) collected for a period of 2 years from seven selected sites of Hugli estuary and one site of Matla estuary was analyzed in relation to salinity gradients. Out of these 58 species, 21 macrozoobenthic species responded strongly to high salinity (18–33.5‰), 15 species showed salinity tolerance range of 5.1–9.5‰ and 17 species were confined to freshwater sector of Hugli estuary. The remaining five species showed wider range of tolerance to salinity (0.5–33.5‰). The variation in spatio-temporal distribution of macrozoobenthos in the Hugli-Matla estuaries is regulated by the fluctuating salinity along with associated substrate condition and anthropogenic stresses of the sites in the estuaries.

Keywords Polychaete · Mollusc · Spatio temporal distribution · Salinity tolerance

Introduction

The variable nature of salinity in estuaries is due to their open to both fresh- and salt water inflow, which plays an important role in the distribution pattern, particularly of benthic invertebrate species. But it is not well known whether invertebrate community response is driven primarily by the direct effect of seasonal salinity stress or by the variation in substratum condition of the estuarine habitat. Attempts to understand the effect of these factors on macrobenthic invertebrate populations in Hugli-Matla estuary, though hampered by variation in climatic conditions and the intensity of human activities at these sites, are made to determine the relationships between disturbance and diversity. Environmental data, including water and sediment salinity, were collected for a period of 2 years along with population and diversity data of two important macrobenthic groups viz., polychaetes and molluscs, mainly comprised of infaunal and epibenthic elements respectively.

Among the macrobenthic invertebrates, polychaetes and molluscs are abundantly represented groups in the estuaries. The distribution pattern of these two macrozoobenthic groups are investigated seasonally from seven sites along the tidal stretches of Hugli estuary and fortnightly from one site of Matla estuary to understand the impact of salinity and salinity fluctuation on the abundance and diversity of these organisms.

There has been considerable works on hydrology and biodiversity in the Hugli-Matla estuaries (Choudhury et al. 1980; Bhunia and Choudhury 1981; Nandi and Choudhury 1983; Mandal and Misra 1985; Nandi and Das 2003; Roy et al. 2008), but none of these works have considered in detail the effects of salinity in the distribution pattern of benthic community.

Material and Methods

Study Areas

The Hugli estuary is one of the major distributaries of Ganga-Bhagirathi river system that opens into the Bay of

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Bengal at Sagar Island of the Indian Sundarban. It stretches 290 km in length and can be divided into three zones viz.: Zone I extending from Nabadwip to Kolkata; Zone II from Kolkata to Diamond Harbour, and Zone III stretching across the entire Sundarban (Dutta et al. 1973). Ray (1981) divides the estuary between Kakdwip and Falta as brackishwater zone and upstream of Kolkata as the freshwater zone and the area between these two zones possesses transitional characteristics. In this investigation, seven sites (latitude 23° 43′N to 21°31′N and longitude 87° 2′6E to 88°15′E) covering saline to freshwater zones were selected along the Hugli estuary, (Fig. 1), while one site at Canning Town (latitude 22°17.84′N and longitude 88°40.7′E), in the Indian Sundarban was selected in the Matla estuary for more frequent temporal sampling.

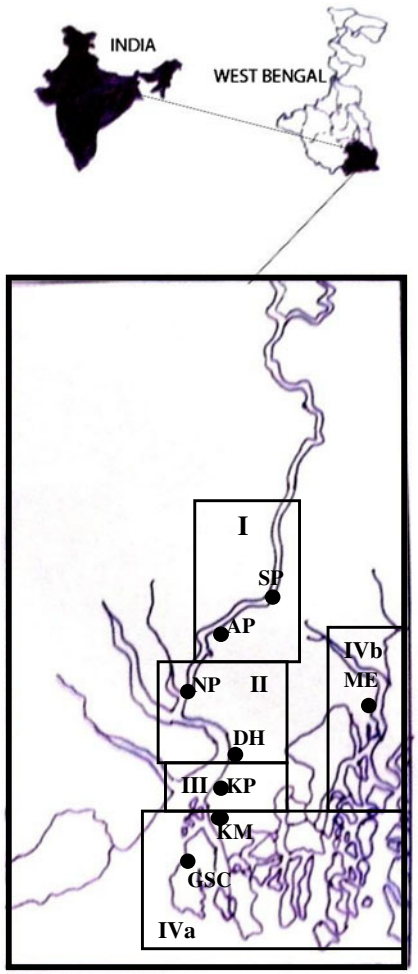

Fig. 1 Map of the Hugli-Matla estuarine region of West Bengal, India, showing salinity zones and selected study sites. Salinity zones: I = Freshwater zone of Hugli estuary, II = Low saline zone of Hugli estuary, III = Moderate saline zone of Hugli estuary, IVa = High saline zone of Hugli estuary, IVb = High saline zone of Matla estuary. Acronym of the selected sites: GSC = Ganga Sagar Creek, KM = Kakdwip Mudflat, KP = Kulpi, DH = Diamond Harbour, NP = Nurpur, AP = Achipur, SP = Shibpur, ME = Matla Estuary

Sampling Procedure

Seasonal sampling was conducted from seven intertidal locations viz., GSC and KM under high saline zone, KP under moderate saline, DH and NP under low saline, and AP and SP under freshwater zone along Hugli estuary; while fortnightly samplings comprising of six replicates were made in one high saline location at Canning viz., Matla Estuary (ME), using box type sampler of 0.225 m^2 area (Paul and Nandi 2003) at low tide during April 2004–March 2006. In the present investigation the months from March to June were considered as hot premonsoon season with occasional rain, July to October as wet monsoon season with maximum rainfall and November to February as cold and dry postmonsoon season with negligible rain. The salinity of water and soil (supernatant of 1:5 air dried soil–water mixture) was estimated using a Refractometer (RF10) and also according to APHA (1998).

Data Analysis

Cluster analysis was performed on the basis of species distribution through SPSS10 software to determine whether the eight sites cluster corresponding to the lines of salinity zones.

Results

The characteristic features and salinity conditions showed considerable variations from site to site (Table 1).

Water Salinity

Salinity of water of eight sites in the Hugli-Matla showed existence of a gradient from premonsoon to monsoon season with the maximum values in GSC situated in high saline zone to minimum at SP and AP of freshwater zone (Fig. 2). Salinity of water along the Hugli estuary fluctuated from 0.0‰ (SP) to 32.0‰ (GSC).

Sediment Salinity

Sediment salinity in the Hugli estuary ranged from 0.0 to 3.8‰ (Fig. 3), which was highest in GSC and nil at NP, AP and SP sites.

Salinity Fluctuation

Monthly variations in water and sediment salinity in the Matla estuary (Fig. 4) showed considerable variations in water salinity with the maximum value of 27.7‰ (May, 2004; premonsoon) to minimum of 3.5‰ (October, 2005;

Table 1 Characteristic features and salinity conditions of the selected sites in the Hugli-Matla estuaries

Parameter	GSC	KM	KP	DH	NP	AP	SP	ME
Water Salinity	18–33.5	5–22.8	0–9.5	0–5.1	0–2.2	0–0.7	0–0.1	3.5–27.9
(‰) Mean/SD	23.63±5.61	10.75±4.01	5.06±2.23	3.11±0.74	1.2±0.58	0.08±0.07	0.03±0.04	14.21±7.87
Soil Salinity	0.5–4.0	0.05–2.5	0.0–1.0	0–0.5	0	0	0	0.2–2.8
(‰)Mean/SD	2.2±0.77	1.24±0.53	0.73±0.09	0.07±0.03	–	–	–	1.01±0.62
Soil condition	Muddy	Sandy	Silty	Silty	Silty	Silty	Silty	Silty
Vegetation cover (%)	60	10	7	45	15	20	30	45
Salinity condition	High saline	High saline	Medium saline	Low saline	Low saline	Fresh water	Fresh water	High saline
Disturbance status	FUD	CD	LD	MD	HD	MD	UD	LD
Distance from sea (km)	0	25	73	80	115	123	160	105

For sites as shown under Fig. 1.

FUD fully undisturbed, *CD* critically disturbed, *LD* less disturbed, Md moderately disturbed, *HD* highly disturbed, *UD* undisturbed

Monsoon), while salinity of sediments ranged at minimum from 0.2 to 2.8‰. Sediment salinity was highest in March and minimum in November, influenced by rain and freshwater flow into the system.

Diversity of Species

A total of 58 macrozoobenthic species belonging to Polychaeta (10 species) and Mollusca (48 species) were recorded in the Hugli and Matla estuaries (Table 2). The occurrence and distribution data amongst the saline sites revealed that GSC had the highest diversity of 38 species, followed by ME (32 species) and KM (23 species) mainly in the high saline sites, while highest diversity of species was recorded in SP (20 species), followed by AP (17 species) and NP (8 species) in freshwater zone. The diversity of species has revealed differential composition in relation to salinity regime.

Cluster Analysis

A clustering through SPSS 10 software for eight brackishwater wetland sites of coastal West Bengal reflects differential affinities between macrozoobenthic assemblages and the sites surveyed. The cluster analysis (Fig. 5) shows three prominent clusters and two intermediate clusters. The first primary cluster denotes the highest similarity between freshwater sites AP and SP. The second prominent cluster is formed between low saline sites DH and NP evidently due to similar habitat condition, salinity and substratum conditions. Third cluster shows the similarity between high saline zone of Hugli (GSC) and Matla (ME) estuaries apparently due to similar saline condition. The first intermediate cluster denotes the affinities between low (DH and NP) and moderate saline sites (KP) exhibiting habitat similarities. The second intermediate cluster shows some similarity of KM with the other high saline sites of Hugli-Matla estuaries.

Distribution of Species

Neither polychaete and molluscan species were evenly distributed in the selected stretch of Hugli estuarine system (Table 2). Only five species viz., *Dendronereis estuarina* and *Namalycastis fauveli* of Polychaeta and *Neritina (Dostia)*

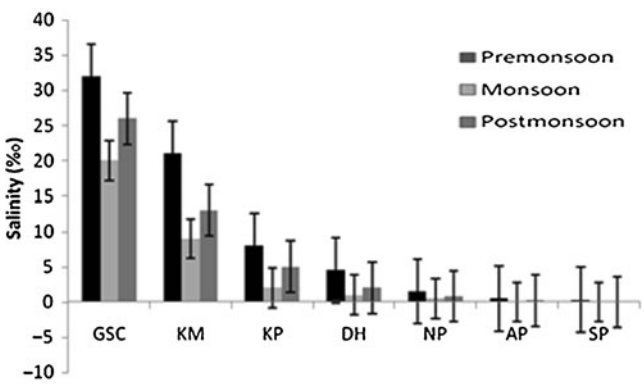

Fig. 2 Seasonal fluctuations of water salinity in Hugli estuaries, acronym as above

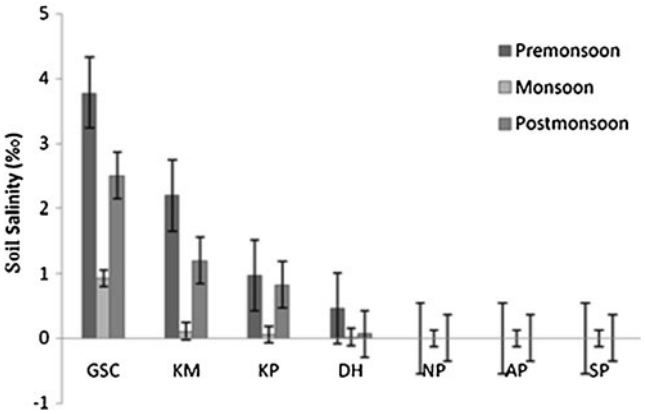

Fig. 3 Seasonal fluctuations of sediment salinity in the selected sites of Hugli estuaries, acronym as above

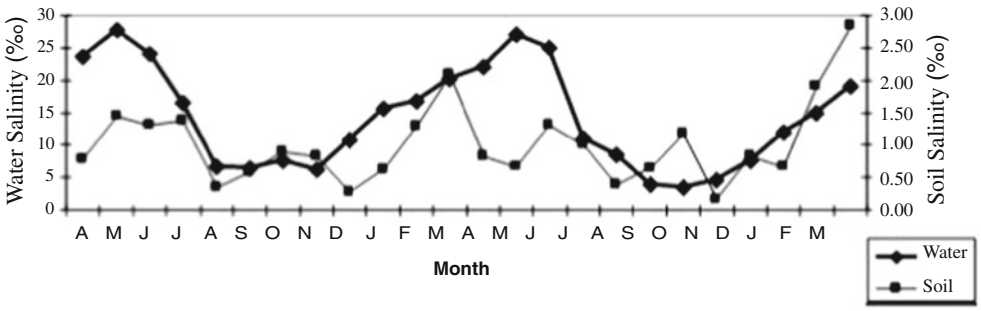

Fig. 4 Monthly fluctuation of water and soil salinity at Matla Estuary, Canning

violacea, *Stenothyra deltae* and *Natica tigrina* of Mollusca occurred both in estuarine and freshwater zone. Among the total 58 macrobenthic species, 3 species representing Polychaeta, 13 species belonging to Gastropoda and 1 species of Bivalvia were restricted in freshwater stretch at AP and SP throughout the year. Similarly members of the polychaete families viz., Tahelsapiidae, Lumbrineridae and Glyceridae showed their exclusive presence in the high saline region of the Hugli-Matla estuaries. Likewise, among the molluscs, species of the families viz., Assimineidae, Potamididae, Ranellidae, Muricidae, Nasssariidae, Ellobidae, Arcidae, Tellinidae, Semelidae and Donacidae were constricted only to high saline condition of the estuaries. So far as polychaetes are concerned, the species belonging to Nephtyidae family were recorded mainly from the freshwater zone, whereas the molluscan macrobenthic species belonging to the families Thiaridae, Planorbidae, Lymnaidae, Bithyniidae and Viviparidae were encountered in the freshwater sites.

Seasonal Abundance of Species

From the population abundance of macrozoobenthic species (0–2489 m^{-2}) at ME (Table 3) it is evident that nine species (*Talehsapia annandalei*, *Dendronereis arborifera*, *Cerithidea cingulata*, *Cerithidea alata, Telescopium telescopium*, *Stenothyra deltae*, *Assiminea brevicula*, *Assiminea beddomeana* and *Gangetia miliacea*) were apparently ecologically important species. Month-wise population data revealed that the polychaete species *Dendronereis arborifera* and *Talehsepia annandalei* though noticed in premonsoon and postmonsoon season were completely absent in monsoon season when salinity of the river declined drastically.

Among the gastropod mollusc species *Cerithidea cingulata* exhibited its presence only in the monsoonal months at ME when salinity was much lower. On the other hand, *Cerithidea alata* was quite abundant at ME throughout the year. *Telescopium telescopium* and *Gangetia miliacea* were mostly abundant in premonsoon to early monsoon in this site when salinity remained higher. The gastropod species *Stenothyra deltae* was encountered only in postmonsoon season in this site when salinity varied from 3.5 to 18.0‰ in water presumably indicating its requirement of suitable range of salinity along with other habitat ecological factors which needs further specific study. *Assiminea brevicula* preferred mostly moderate salinity and was recorded only in late monsoon to postmonsoon months when salinity values were near freshwater condition. *Neritina violacea* was almost common in occurrence excepting the period when salinity decreased to near freshwater condition.

The bivalve species *Donax incarnatus* and *Pelecyora trigona*, which inhabit inside the sediment, were found to be confined to high salinity period in summer (premonsoon). *Theora opalina* was abundant, mainly by juvenile forms, only in postmonsoon (622 m^{-2}) season when salinity was recorded 15.0–18.0‰. The sudden appearance of juveniles of this bivalve species at ME and the usual occurrence of adult forms at GSC and KM of Hugli estuary (18–33.5‰) need further exploration to ascertain its precise habitat condition, difference in salinity tolerance range of juveniles and adults and seasonality in migration, if any.

Tolerance to Salinity

Out of a total of 32 macrozoobenthic polychaete and mollusc species of ME, 9 species were common in the estuary, representing 75% of total numbers. Abundance of these commonly occurring macrozoobenthic species were compared according to their range of salinity tolerance (Table 3 and Fig. 6). The result revealed that the polychaete *Dendronereis arborifera* showed narrower range of salinity (8–19‰ of water and 0–2.5‰ of soil) tolerance than *Talehsapia annandalei* (9–27.9‰ of water and 0–2.5‰ of soil). Amongst the molluscan species, viz., *Cerithidea cingulata*, *Telescopium telescopium*, *Stenothyra deltae*, *Assiminea brevicula* and *Gangetia miliacea* exhibited wider range of salinity tolerance, whereas *Thiara (Mainwaringia) paludomoidea* and *Assiminea beddomeana* had comparatively narrower range of water salinity tolerance.

It is evident that 21 macrozoobenthic species viz., *Dendronereis arborifera*, *Talehsapia annandalei*, *Lumbrineris* sp., *Glycera* sp., *Neritina (Vittina) smithi*, *Nerita (Amphinerita) articulata*, *Littoraria (Palustrina) melanostoma*,

Table 2 Occurrence of macrozoobenthic species recorded in Hugli and Matla estuaries

Sl. No.	Groups and species	GSC	KM	KP	DH	NP	AP	SP	ME
ANNELIDA									
POLYCHAETA									
Family NEREIDIDAE									
1.	*Dendronereis arborifera* Pefers	+	–	–	–	–	–	–	+
2.	*Dendronereis estuarina* Southern	+	–	–	–	–	+	+	+
3.	*Namalycastis fauveli* Rao	+	+	+	+	+	+	+	+
4.	*Neanthes meggitti* (Monro)	–	–	–	–	–	–	+	–
5.	*Neanthes* sp.	+	–	–	+	–	–	–	+
Family NEPHTYIDAE									
6.	*Nephtys oligobranchia* Southern	–	–	–	–	+	+	+	–
7.	*Nephtys polybranchia* Southern	–	–	–	–	–	–	+	–
Family TALEHSAPIIDAE									
8.	*Talehsapia annandalei* Fauvel	+	+	–	–	–	–	–	+
Family LUMBRINERIDAE									
9.	*Lumbrineris* sp.	+	+	–	–	–	–	–	+
Family GLYCERIDAE									
10.	*Glycera* sp.	+	–	–	–	–	–	–	+
MOLLUSCA									
GASTROPODA									
Family NERITIDAE									
11.	*Neritina (Dostia) violacea* (Gmelin)	+	–	+	+	+	+	+	+
12.	*Neritina(Vittina) smithi* Wood	+	–	–	–	–	–	–	–
13.	*Nerita (Amphinerita) articulata* Gould	+	+	–	–	–	–	–	–
14.	*Septeria lineata* (Lamarck)	–	–	–	–	–	+	+	–
Family LITTORINIDAE									
15.	*Littoraria (Palustrina) melanostoma* (Gray)	+	+	–	–	–	–	–	–
16.	*Littoraria (Littorinopsis) scabra scabra* (Linnaeus)	+	+	–	+	–	–	–	+
17.	*Littoraria (Littoraria) undulata* Gray	–	–	–	+	–	–	–	+
Family STENOTHYRIDAE									
18.	*Stenothyra deltae* (Benson)	+	+	+	+	+	–	+	+
19.	*Stenothyra blanfordiana* Nevill	–	+	–	–	–	–	–	+
20.	*Gangetia miliacea* (Nevill)	+	+	+	–	–	–	–	+
Family ASSIMINEIDAE									
21.	*Assiminea beddomeana* Nevill	+	+	+	–	–	–	–	+
22.	*Assiminea brevicula* (Pfeiffer)	+	+	+	–	–	–	–	+
23.	*Assiminea francesiae* (Wood)	–	–	–	–	+	+	+	–
Family THIARIDAE									
24.	*Thiara (Mainwaringia) paludomoidea* Nevill	–	+	+	–	–	–	–	+
25.	*Thiara scabra* (Müler)	–	–	–	–	–	+	+	–
26.	*Tarebia lineata* (Gray)	–	–	–	–	–	+	+	–
27.	*Tarebia granifera* (Lamarck)	–	–	–	–	–	+	–	–
Family PLANORBIDAE									
28.	*Gyraulus convexiusculus* (Hutton)	–	–	–	–	–	+	+	–
29.	*Gyraulus labiatus* (Benson)	–	–	–	–	–	+	+	–
30.	*Indoplanorbis exustus* (Deshayes)	–	–	–	–	–	+	+	–
31.	*Brotia costula* (Rafinesque)	–	–	–	–	+	+	+	–
Family LYMNAEIDAE									
32.	*Lymnaea acuminata* (Lamarck)	–	–	–	–	–	+	+	–
33.	*Lymnaea luteola* (Lamarck)	–	–	–	–	–	+	+	–

Table 2 (continued)

Sl. No.	Groups and species	GSC	KM	KP	DH	NP	AP	SP	ME
Family BITHYNIIDAE									
34.	*Bithynia (Digoniostoma) cerameopoma* (Benson)	–	–	–	–	–	+	+	–
Family VIVIPARIDAE									
35.	*Bellamya bengalensis* (Lamarck)	–	–	–	–	+	+	+	–
Family: POTAMIDIDAE									
36.	*Cerithidea (Cerithidea) obtusa* (Lamarck)	+	+	–	–	–	–	–	+
37.	*Cerithidea (Cerithideopsilla) cingulata* (Gmelin)	+	+	+	–	–	–	–	+
38.	*Cerithidea (Cerithidea) alata* (Philippi)	+	+	+	–	–	–	–	+
39.	*Telescopium (T.) telescopium* (Linnaeus)	+	+	+	+	–	–	–	+
Family: NATICIDAE									
40.	*Natica tigrina* (Roeding)	+	–	–	+	+	–	–	+
Family: RANELLIDAE									
41.	*Gyrineum natator* (Roeding)	+	–	–	–	–	–	–	–
Family MURICIDAE									
42.	*Thais blanfordi* (Nevill)	+	–	–	–	–	–	–	+
43.	*Thais lacera* (Born)	+	–	–	–	–	–	–	–
Family: NASSARIIDAE									
44.	*Nassarius stolatus* (Gmelin)	+	+	–	–	–	–	–	+
45.	*Nassarius foveolata* (Reeve)	+	–	–	–	–	–	–	–
Family: ELLOBIIDAE									
46.	*Auricula* sp.	+	+	–	–	–	–	–	–
47.	*Pythia plicata* (Ferussac)	+	+	–	+	–	–	–	–
Family ONCHIDIIDAE									
48.	*Onchidium tenerum* (Stoliczka)	+	–	–	+	–	–	–	+
49.	*Onchidium tigrina* Stoliczka	+	–	–	+	–	–	–	+
BIVALVIA									
Family ARCIDAE									
50.	*Anadara granosa* (Linnaeus)	+	–	–	–	–	–	–	+
Family: TELLINIDAE									
51.	*Strigilla splendida* (Anton)	+	+	–	–	–	–	–	–
52.	*Macoma birmanica* (Philippi)	+	–	–	–	–	–	–	+
Family: SEMELIDAE									
53.	*Theora opalina* (Hinds)	+	+	–	–	–	–	–	+
Family: DONACIDAE									
54.	*Donax incarnatus* Gmelin	+	–	–	–	–	–	–	+
Family CORBICULIDAE									
55.	*Corbicula striatella* Deshayes	–	–	–	–	–	–	+	–
56.	*Polymesoda (Geloina) bengalensis* (Lamarck)	+	–	–	–	–	–	–	+
Family: VENERIDAE									
57.	*Meretrix meretrix* (Linnaeus)	+	+	–	+	–	–	–	+
58.	*Pelecyora trigona* Reeve	+	+	+	–	–	–	–	+
	Total (58 species)	38	23	11	12	8	17	20	32

Note: Acronym of sites as above

Stenothyra blanfordiana, *Cerithidea (Cerithidea) obtusa*, *Gyrineum natator*, *Thais blanfordi*, *Thais lacera*, *Nassarius stolatus, Nassarius foveolata*, *Auricula* sp., *Anadara granosa*, *Strigilla splendida*, *Macoma birmanica*, *Theora opalina* and *Donax incarnatus* responded strongly to high saline condition and were restricted to Ganga Sagar Creek

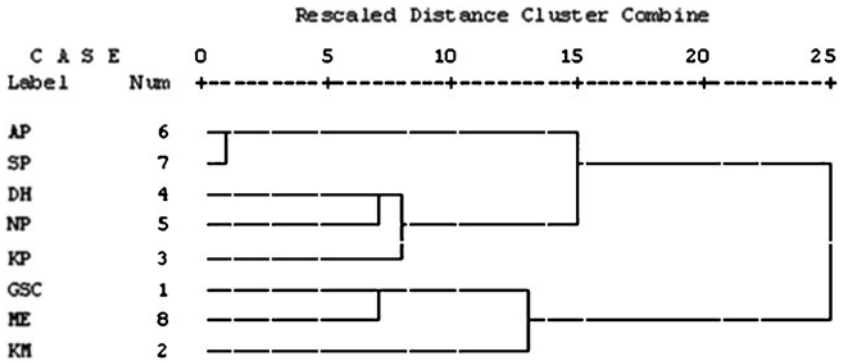

Fig. 5 Dendrogram showing similarity values among the eight selected brackishwater wetlands of West Bengal

and Kakdwip Mudflat of Hugli estuary exhibiting salinity range of 18–33.5‰. Fifteen species viz., *Neanthes* sp., *Littoraria scabra scabra*, *Littoraria undulata*, *Gangetia miliacea*, *Assiminea beddomeana*, *Assiminea brevicula*, *Thiara paludomoidea*, *Cerithidea cingulata*, *Cerithidea alata*, *Telescopium telescopium*, *Pythia plicata*, *Onchidium tenerum*, *Onchidium tigrina*, *Meretrix meretrix* and *Pelecyora trigona* were found to extend up to KP or DH, about 80 km away from Bay of Bengal, representing salinity range from high saline condition of 18–33.5‰ to moderate saline condition of 5.1–9.5‰ in summer (premonsoon). Seventeen species belonging to Polychaeta and Mollusca viz., *Nephtys oligobranchia*, *Neanthes meggitti*, *Nephtys polybranchia*, *Septeria lineata*, *Assiminea francesiae*, *Thiara scabra*, *Tarebia lineata*, *Tarebia granifera*, *Gyraulus convexiusculus*, *Gyraulus labiatus*, *Indoplanorbis exustus*, *Brotia costula*, *Lymnaea accuminata*, *Lymnaea luteola*, *Bithynia (Digoniostoma) cerameopoma*, *Bellamya bengalensis* and *Corbicula striatella* were confined to freshwater zone of Hugli estuary. The remaining five species viz., *Dendronereis estuarina*, *Namalycastis fauveli*, *Neritina (Dostia) violacea*, *Stenothyra deltae* and *Natica tigrina* showed wider range of salinity tolerance from freshwater to high saline zone.

The polychaete viz., *Dendronereis arborifera* and *Glycera* sp., and molluscan species viz. *Neritina (Vittina) smithi*, *Gyrineum natator*, *Nassarius foveolata*, *Thais blanfordi*, *Thais lacera*, *Anadara granosa*, *Macoma birmanica* and *Donax incarnatus* are considered herein as high saline species, occurring only in GSC and ME.

The impact of salinity on the population of nine important macrozoobenthic species (Table 4) in the Hugli-Matla estuaries (0–178 m^{-2}) showed their preference of very high salinity as their density decreases corresponding to low salinity excepting *Stenothyra deltae*. The polychaete species *Dendronereis arborifera* and *Talehsapia annandalei* were constricted to high salinity conditions of water and sediment, while *Dendronereis estuarina* and *Namalycastis fauveli* showed a wide range of salinity tolerance.

The gastropod species viz., *Neritina smithi*, *Natica tigrina*, *Gyrineum natator*, *Nassarius stolatus*, *Thias lacera*, *Thias blanfordi* and the bivalve species viz., *Anadara granosa* and *Donax incarnates* preferred high saline zone. The genus *Neritina* differed considerably in their tolerance to salinity. *Neritina violacea* had highly wide range (0–33.5‰) of salinity tolerance whereas *Neritina smithi* was restricted to salinity values of 18–33.5‰ in GSC. The distribution of other molluscan macrobenthic species viz., *Cerithidea cingulata*, *Cerithidea alata*, *Telescopium telescopium*, *Stenothyra deltae*, *Gangetia miliacea*, *Assiminea beddomeana*, *Assiminea brevicula*, *Thiara paludomoidea*, and *Pelecyora tigrina* were found at high to low saline zones.

Table 3 Season wise mean population density (no. m^{-2}) of ecologically important macrobenthic species of Matla Estuary

Species	Pre-monsoon	Monsoon	Post-monsoon
Cc	27.31±38.63	120.37±75.95	61.11±81.19
Ca	155.09±170.88	537.96±569.61	174.07±130.95
Tte	31.48±39.28	1.85±2.62	0.00±0.00
Sd	2.78±3.93	1.85±2.62	13.89±14.40
Abr	8.33±11.79	3.70±5.24	76.85±103.45
Abe	7.41±0.00	0.00±0.00	57.41±0.00
Nv	6.48±7.64	12.96±15.27	9.57±2.55
Gm	44.44±62.85	3.70±5.24	1.85±2.62
Ls	11.11±14.18	27.78±42.07	0.00±0.00
Pt	33.33±66.67	0.00±0.00	0.00±0.00
To	0.00±0.00	0.00±0.00	622.22±1244.44
Nf	1.85±2.62	0.00±0.00	1.85±2.62
Ta	17.59±11.79	0.00±0.00	5.56±7.86
Da	22.22±44.44	0.00±0.00	33.33±42.55
Lsp	5.56±7.09	1.85±3.70	18.52±24.57

Cc Cerithidea cingulata, *Ca Cerithidea alata*, *Tte Telescopium telescopium*, *Sd Stenothyra deltae*, *Abr Assiminea brevicula*, *Abe Assiminea beddomeana*, *Nv Neritina violacea*, *Gm Gangetia miliacea*, *Ls Littoraria scabra*, *Pt Pelecyora trigona*, *To Theora opalina*, *Nf Namalycastis fauveli*, *Ta Talehsepia annandalei*, *Da Dendronereis arborifera*, *L sp. Lumbrineris* sp.

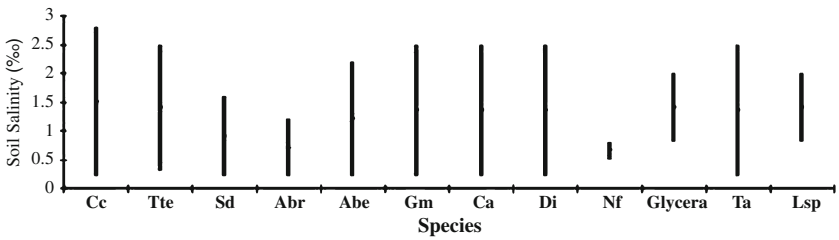

Fig. 6 Sediment salinity tolerance range of some common macrozoobenthic species found in the Matla estuary, acronym as above, Di = *Donax incarnatus*

Discussion

Several workers have assigned various reasons for variation in diversity, distribution and abundance of macrozoobenthic species (Verschuren et al. 2000; Josefson and Hansen 2004; Teske and Wooldridge 2004). One of the major cues for variation in spatio-temporal distribution of macrozoobenthos, both epibenthos and infauna, has been assigned to salinity (Teske and Wooldridge 2004; Velasco et al. 2006), specifically, their ability to tolerate salinity (McLusky et al. 1982; McLusky 1986). One can find variations with respect to salinity, even among the members of the same genus in population and distribution pattern (Greenwood and Wood 2003; Kefford et al. 2007a, b).

The clustering of sites indicates the role of substratum and water salinity in the distribution of benthic animals. However, the present study leads to confer that even though the salinity plays a prominent role in spatial distribution of species, while, other factors such as soil condition and vegetation cover also contribute to the distribution and abundance of species, besides the impact of anthropogenic disturbance at different sites.

The study supports the findings of previous work by Teske and Wooldridge (2004), in that the polychaete species *Dendronereis arborifera* inhabits mostly in the hypersaline zone. Like-wise, the polychaete, *Talehsapia annandalei*, and molluscs viz., *Nerita (Amphinerita) articulata*, *Littoraria (Palustrina) melanostoma*, *Cerithidea (Cerithidea) obtusa*, *Nassarius stolatus*, *Auricula* sp., *Strigilla splendida* and *Theora opalina* are true estuarine species occurring in the salinity range of 18–33.5‰ (Teske and Wooldridge 2004). Temporal distribution of macrozoobenthic species in the Matla Estuary (Table 3) shows patchiness in relation to salinity. The relatively higher sediment salinity reduces the decomposition rate (Bandopadhyay and Burman 2006) of organic matter which may affect the feeding habit of benthic organisms. Desai and Krishnankutty (1967) found that the salinity and substratum quality played dominant roles in quantitative distribution of benthos in backwaters as observed in this study.

Besides anthropogenic stresses of the habitats, the lower salinity in low saline sites (0.5–5‰ in Diamond Harbour, Nurpur and Achipur in the central section) also imposes stress to both marine elements and freshwater organisms, leading to lowering of diversity of species. The higher diversity of species in the high saline Ganga Sagar Creek and in Shibpur among the freshwater sites indicates preponderance of marine elements and freshwater species respectively. The higher diversity in Shibpur freshwater site is due to its more consistent fresh condition than the DH and NP sites, meaning that species intolerant of brackish conditions are more likely to be found there. Overall, the pattern of diversity reflects the existence of obligate euhaline species (those species requiring salt and intolerant of prolonged fresh conditions) in Ganga Sagar Creek and species intolerant of higher salinities in Shibpur site, with little evidence of variation in salinity driving diversity. Thus, it is evident that the benthic community increases in diversity with the increase in salinity in the estuarine sector and also increases in the freshwater sector represented by freshwater species, though population varies from site to site.

Table 4 Salinity zone-wise average population density (nos. m^{-2}) of some important macrozoobenthic species in Hugli-Matla estuary in premonsoon season

Group and species	Hugli estuary				Matla estuary
	VH	H	M	L	VH
Polychaeta					
Namalycastis fauveli	3	2	2	1	4
Mollusca					
Neritina violacea	8	4	2	1	7
Stenothyra deltae	4	2	3	2	6
Assiminea beddomeana	9	3	1	0	8
Assiminea brevicula	19	8	1	0	17
Cerithidea cingulata	70	39	12	0	55
Cerithidea alata	138	22	1	0	34
Telescopium telescopium	178	4	1	0	4
Pelecyora trigona	69	2	0	0	33

N. B. No decimal figure was used in the table as the specimen was not present in fraction

VH very high (30 above); *H* high (15–30); *M* moderate (5–15); *L* low (0.5–5.0)

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