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THE MEIOFAUNA AND MACROFAUNA OF DIGHA BEACH, WEST BENGAL, INDIA

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(With 4 Figures and 7 Tables)

INTRODUCTION

The distribution and ecology of fauna inhabiting the intertidal sediments of sea shore beaches have been intensively investigated in different parts of the world and the literature on the subject is too vast to be reviewed here. Hitherto, nothing is known of the meiofauna and macrofauna of the Digha beach located on West Bengal coast. Hence, the present investigation was undertaken to make a preliminary survey of the composition, density and distribution of the fauna in the beach. This paper presents the results of qualitative and quantitative investigations carried out on the beach for a period of 2 years from July 1978 to June 1980.

AREA INVESTIGATED

The Digha beach is situated close to the Gangetic mouths on the east coast of India facing the Bay of Bengal at latitude 21°36′ N and longitude 87°30′E. Here, the sea is quite shallow with very little wave action on the beach and an extensive area about 250 m of the intertidal zone is exposed during low water spring tides. The beach slope is very low upto the low water mark. The shore was subjected to considerable erosion in the recent past and the bank is presently protected with the construction of a sloping sea-wall. Three distinct seasons, summer from March to June with high temperature, monsoon from July to October with heavy rainfall and winter from November to February with low temperature, are experienced in this region.

METHODS

All the investigations on the sand flat were carried out during low tide. An intertidal transect was established on the beach with 6 sampling stations (A-F), each 40 m apart between MLWS and MHWS (Fig. 1). Beach profiles were recorded following the method of Emery (1961). For granulometric analyses, samples of the sediment were

collected from the top 10 cm, seived, different fractions weighed and cumulative curves ploted. Temperature of the sediment was recorded with a centigrade thermometer at depths of 1, 5, 10 and 15 cm below the surface. Salinity and oxygen determinations were made by Knudsen's and Winkler's methods, respectively. Particulate organic matter of the sediment was assessed with visual obsevation based on personal experience.

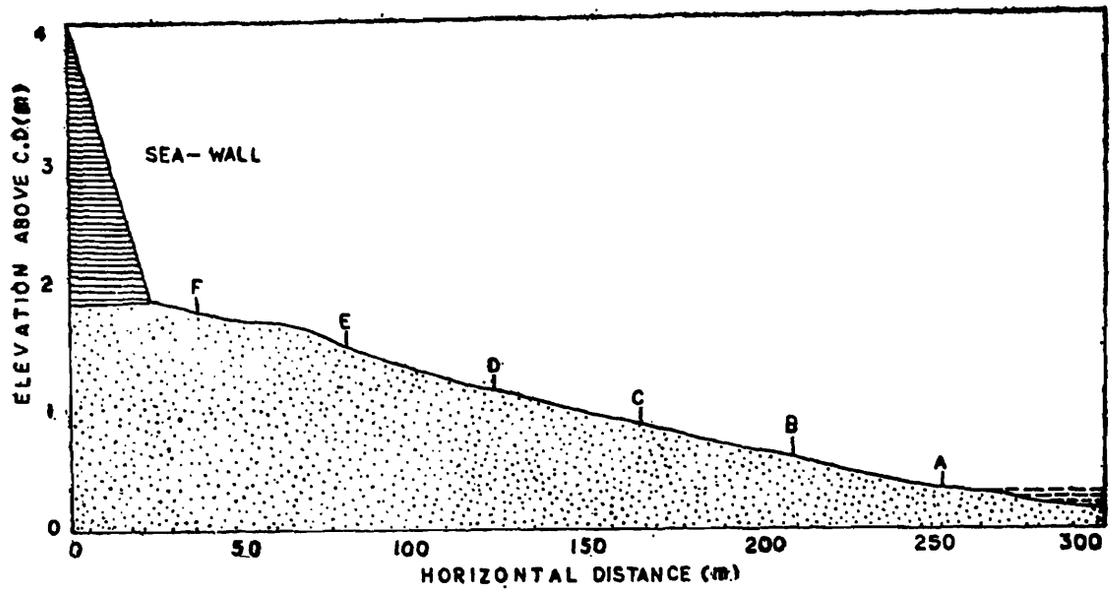

Fig. 1. Selected beach profile on Digha beach (18 August 1978), showing the position of 6 sampling stations (A-F) along the intertidal transect.

For quantitative study, the beach was sampled thrice in a year during summer, monsoon and winter periods to study the seasonal distribution of the fauna. Samples for meiofauna were collected using a hand operated matallic corer 30 cm in length and 20 cm^2 in internal cross sectional area. The core was cut into 5 cm segments to collect data on the vertical distribution of fauna. Meiofauna from these samples was extracted by means of decanting and sieving. The fauna passing through 1.0 mm sieve was collected, identified and counted. The meiofaunal densities are expressed as the number of individuals per 10 cm^2.

The macrofauna was collected using a square metallic frame 25×25×5 cm in dimensions. The quadrat was pushed into the sediment and the enclosed deposit dug out. This was repeated at the same spot to get another 5cm segment of the sediment below the first one to study the vertical distribution of fauna to a depth of 10 cm. All the fauna retained on a 1.0 mm sieve was collected. Faunal densities are given as the number of animals per m^2. As bulk of the meiofauna and macrofauna were confined to the top 10 cm of the sediment, the data presented here are limited to that depth.

RESULTS

The Envirorment

Beach profile : The beach slope was uniformly very low and the sand flat was nearly stable without any significant changes during the period of study. A selected beach profile recorded is shown in Fig. 1.

Grain size : The substrate on the beach was more or less unifom in character. It was mostly composed of fine silicious sand, with a considerable percentage of fine material as clay, silt, etc. which generally increased with depth in sediment. Selected cumulative curves showing granulometric characteristics at the 6 intertidal stations are shown in Fig. 2.

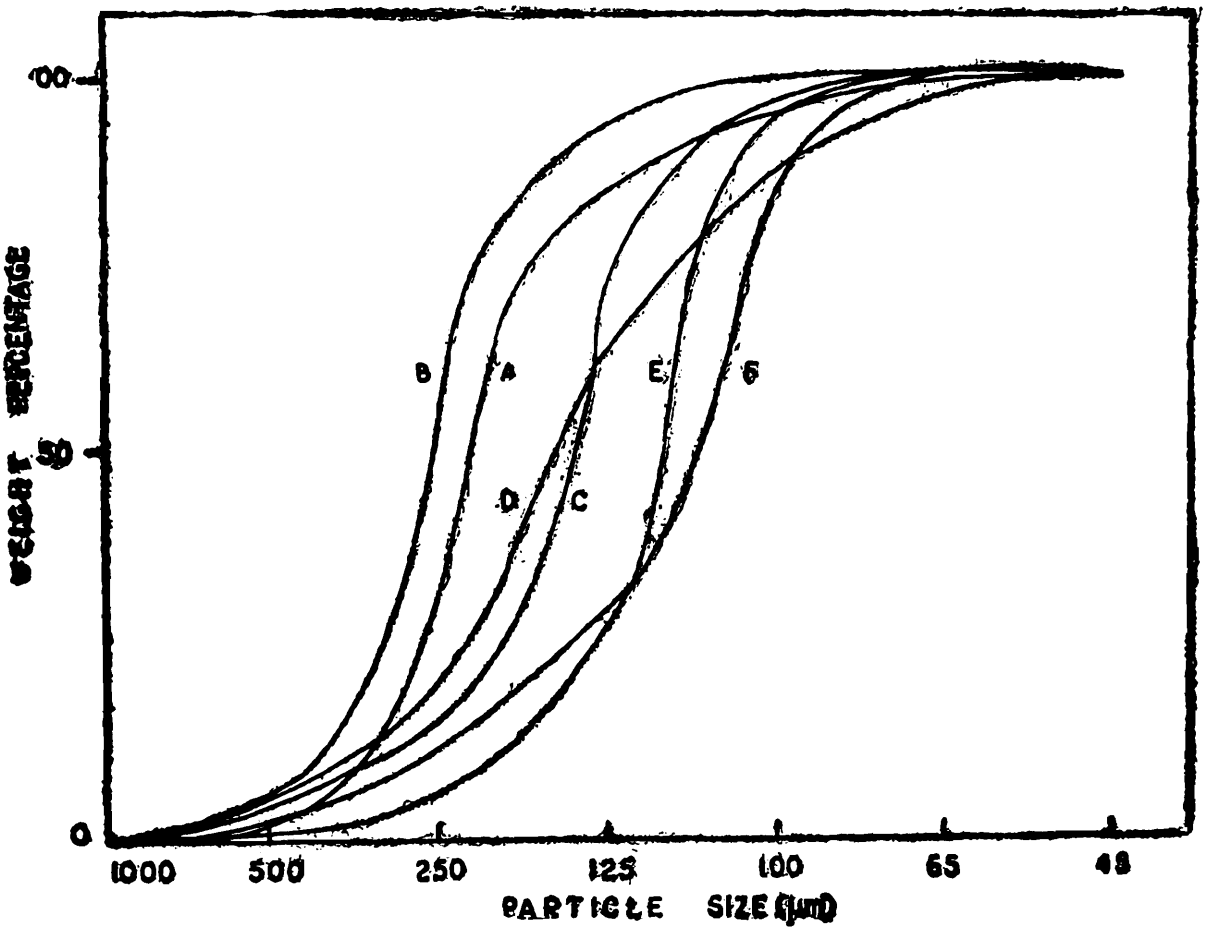

Fig. 2. Selected cumulative curves of sediment particle size for the 6 intertidal stations A-F.

Water content : The beach was fully saturated upto station D and the water table was very close to the surface. The degree of water permeability and desiccation in the beach were low due to the fineness of sediment.

Temperature : Temperature of ambient sea water varied between 20°C and 34°C. The beach values were very close to that of the sea

water, particularly on the lower shore. Temperature at higher tidal levels varied by 1—3°C depending on the prevailing climatic conditions. The upper 5 cm of sediment was usually subjected to diurnal variations in temperature, while the lower layers remained relatively unaffected.

Salinity : Salinity of sea water in the area varied between 22 and 34‰. The beach values upto station D were nearly the same as that of the ambient sea water. Salinity of interstitial water was lower by 2—12‰ near high water mark probably due to the steep elevation of adjacent land beyond the sea-wall that resulted in ground water seepage into the beach.

Oxygen : The concentration of dissolved oxygen in the beach generally decreased from low water level to high water level and particularly with depth in sediment. Oxygen values recorded to a depth of 10 cm ranged from 4.6 ml/L to 2.4 ml/L.

Organic matter : The beach sands were sufficiently rich in organic detritus due to the relatively sheltered condition of the sand flat that permits settlement of organic detritus. Apparently, it is concentrated more on the lower shore than at the higher tidal levels.

The Meiofauna

Composition : Nematodes, copepods, turbellariarians and polychaetes, constituted the major groups of meiofauna in this beach. Gastrotrichs, oligochaetes, ostracods, isopods, amphipods and halacarids, occurred in small numbers. The larval forms of annelids, crustaceans, insects and molluscs, were also present. Ciliates also occurred in the habitat in small numbers, but they were not included in the present study. The percentage abundance of the meiofauna groups encountered is shown in Fig. 3A. Numerically, Nematoda were the most abundant group followed by Copepoda. All the three ecological types of meiofauna, i.e. epipelic forms crawling on the surface of sediment, the endopelic forms burrowing into the substrate and the mesopelic forms truly interstitial in habit, were represented in the fauna. Bulk of the meiofauna in the beach, however, appeared to be of the burrowing type.

Horizontal distribution : The mean values of the meiofauna population densities recorded during the period are given in Table 1. The results did not indicate any appreciable variation in their spatial distribution within the beach and the fauna occupied almost the same horizontal levels all through the year. Maximum densities of the meiofauna (about 76%) occurred on the lower shore, showing a general decrease towards higher tidal levels. Of the total fauna collected at the

TBBLE 1. Mean population densities (nos./10 cm^2) of meiofauna in the upper 10 cm of the sediment at the six intertidal stations, A-F.

Group	Depth (cm.)	Stations					
		A	B	C	D	E	F
Nematoda	0-5	236	412	318	104	82	54
	6-10	140	186	134	76	60	76
Copepoda	0-5	152	264	160	82	32	42
	6-10	38	72	56	50	44	18
Nauplii	0-5	68	96	42	18	3	4
	6-10	22	18	28	6	2	0
Turbellaria	0-5	86	168	124	56	28	4
	6-10	28	64	78	32	30	12
Polychaeta	0-5	54	108	66	18	14	2
	6-10	18	34	30	26	16	18
Ostracoda	0-5	28	36	14	1	0	0
	6-10	1	2	0	0	0	0
Others	0-5	37	52	66	28	40	26
	6-10	18	14	21	18	12	14
Total meiofauna	0-5	661	1136	790	307	199	132
	6-10	265	390	347	208	164	138
	Totals	926	1526	1137	515	363	270

6 intertidal stations, 19.54% occurred at station A, 32.21% at station B, 24% at station C, 10.87% at station D, 7.66% at station E and 5.69% at station F. Maximum numbers of the nematodes, copepods, nauplii, turbellarians and polychaetes, were recorded on the lower shore, although their distribution extended to all levels of the intertidal zone. The ostracods were mostly confined to the lower shore, while the oligochaetes were more numerous on the upper shore. Isopods and amphipods occurred at all levels on the beach.

The horizontal distribution of the meiofauna species identified, is shown in Table 2. Although there was some amount of overlapping in their distribution, many of these species showed their occurrence limited to certain levels of the beach, apparently depending on their environmental preferences. The turbellarian *Macrostomum* sp. was collected only at station A. The nematodes *Halalaimus* sp. and *Viscosia cobbi*, the ostracod *Polycope* sp. and the copepod *Neocyclops* sp. have a wider distribution on the lower shore, while the gastrotrich *Chaetonotus* sp. and the nematode *Desmodora* sp. occured all

TABLE 2. Horizontal distribution of meiofauna species on Digha beach.

Species	Stations					
	A	B	C	D	E	F
Macrostomum sp.	+					
Halalaimus sp.	+	+	+			
Viscosia cobbi Filipjev	+	+	+			
Polycope sp.	+	+	+			
Neocyclops sp.	+	+	+	+		
Chaetonotus sp.	+	+	+	+	+	
Desmodora sp.	+	+	+	+	+	
Sphaerolaimus pacificus Allgen		+				
Araeolaimus elegans de Man		+				
Exogone sp.		+				
Tisbe furcata Baird		+				
Enhydrosoma sp.		+				
Monocelis lineata (O. F. Muller)		+	+			
Halalaimus filicollis Timm		+	+			
Hesionides sp.		+	+			
Potamodrilus sp.		+	+			
Harpacticus gracilis Claus		+	+			
Hesionides gohari Hartmann-Schroder		+	+	+		
Stenhelia sp.			+			
Southerniella simplex Allgen			+	+		
Microlaimus sp.			+	+		
Richtersia sp.			+	+		
Nannopus palustris Brady			+	+		
Paramesochra sp.			+	+	+	
Minona sp.				+		
Halectinosoma sp.				+		
Kliopsyllus sp.				+		
Dichromadora sp.				+	+	+
Enchytraeus sp.				+	+	+
Halicephalobus limuli Timm					+	+
Enchytraeus barkudensis Stephenson						+

along the beach. The nematodes *Sphaerolaimus pacificus* and *Araeolaimus elegans*, the polychaete *Exogone* sp. and the copepods *Tisbe furcata* and *Enhydrosoma* sp. werc collected only at station B. The turbellarian *Monocelis lineata*, the nematode *Halalaimus filicollis*, the polychaetes *Hesionides gohari* and *Hesionides* sp., the oligochaete *Potamodrilus* sp. and the copepod *Harpacticus gracilis* occurred at stations B and C. The nematodes *Southerniella simplex*, *Microlaimus* sp. and *Richtersia* sp. and the copepods *Stenhelia* sp., *Nannopus palustris* and *Paramesochra* sp. were common at stations C and D. The turbellarian *Minona* sp., the copepods *Halectinosoma* sp. and *Kliopsyllus* sp. were collected only at

station D. The nematode *Dichromadora* sp. and the oligochaete *Enchytraeus* sp. were found at all the 3 stations D, E and F. Two brackish water species, the nematode *Halicephalobus limuli* and the oligochaete *Enchytraeus barkudensis* occurred towards the high water mark.

Vertical distribution : The quantitative data collected on the vertical distribution of meiofauna in the beach indicated that all through the year the total fauna was confined to the top 10 cm of sediment. There was a steady decrease in number with depth. Some meiofaunal submergence was noticed at higher locations on the beach probably due to reduced water saturation in the upper layers. Nematodes were more numerous in the upper 5 cm, although they could penetrate upto 20 cm in the sediment. Copepods and nauplii were confined to the upper 10 cm. The ostracods were largely epipelic, crawling on the surface layers of the sediment, while the oligochaetes penetrated to greater depths at higher tidal levels. Other groups of animals mostly occurred within the top 10 cm of sediment.

Seasonal districution : The seasonal abundance of meiofauna recorded at station B, where bulk of the fauna was represented during the period of study, is indicated in Table 3. Densities of total populations during different seasons of the year indicated only minor fluctuations in their numbers. But, distinct seasonal changes occurred for some groups of the meiofauna, particularly the nematodes, copepods and polychaetes. Maximum densities of the nematodes were recorded during winter months associated with lowest temperatures in the habitat, while their minimum numbers occurred in summer months. Maximum densities of the copepods, nauplii and polychaetes occurred in summer months associated with highest temperatures. Thus, there appears to be an inverse relationship in the seasonal abundance of

TABLE 3. Seasonal abundance (nos./10^2) of meiofauna at station B during 1978-80.

Months	Nematoda	Copepoda	Nauplii	Turbellaria	Polychaeta	Ostracoda	Others	Total meiofauna
1978, August	168	86	20	74	44	26	18	436
December	310	142	44	80	38	14	14	692
1979, April	96	184	83	56	76	36	24	555
August	220	106	37	124	42	18	16	563
1980, Jan.	272	112	38	92	50	22	8	594
May	134	225	62	110	94	28	27	680

nematodes and other groups of animals in general. The minor groups of animals that occurred in small numbers did not indicate any clear pattern in their seasonal distribution.

The Macrofauna

Composition : The macrofauna of the beach was dominated by the deposit and filter feeders. Burrowing sea anemones, annelids, crustaceans and molluscs comprised the major constituents of the macrofauna (Fig. 3B). Among these groups, the polychaetes, decapods, bivalves and gastropods occurred in considerable abundance. The oligochaetes, shrimps, isopods, amphipods and cumaceans were collected in small numbers. Qualitatively, out of the 44 species listed in Table 5, 10 (22.72%) are polychaetes, 6 (13.63%) are decapods, 10 (22.72%) are gastropods and 6 (13.63%) are bivalves.

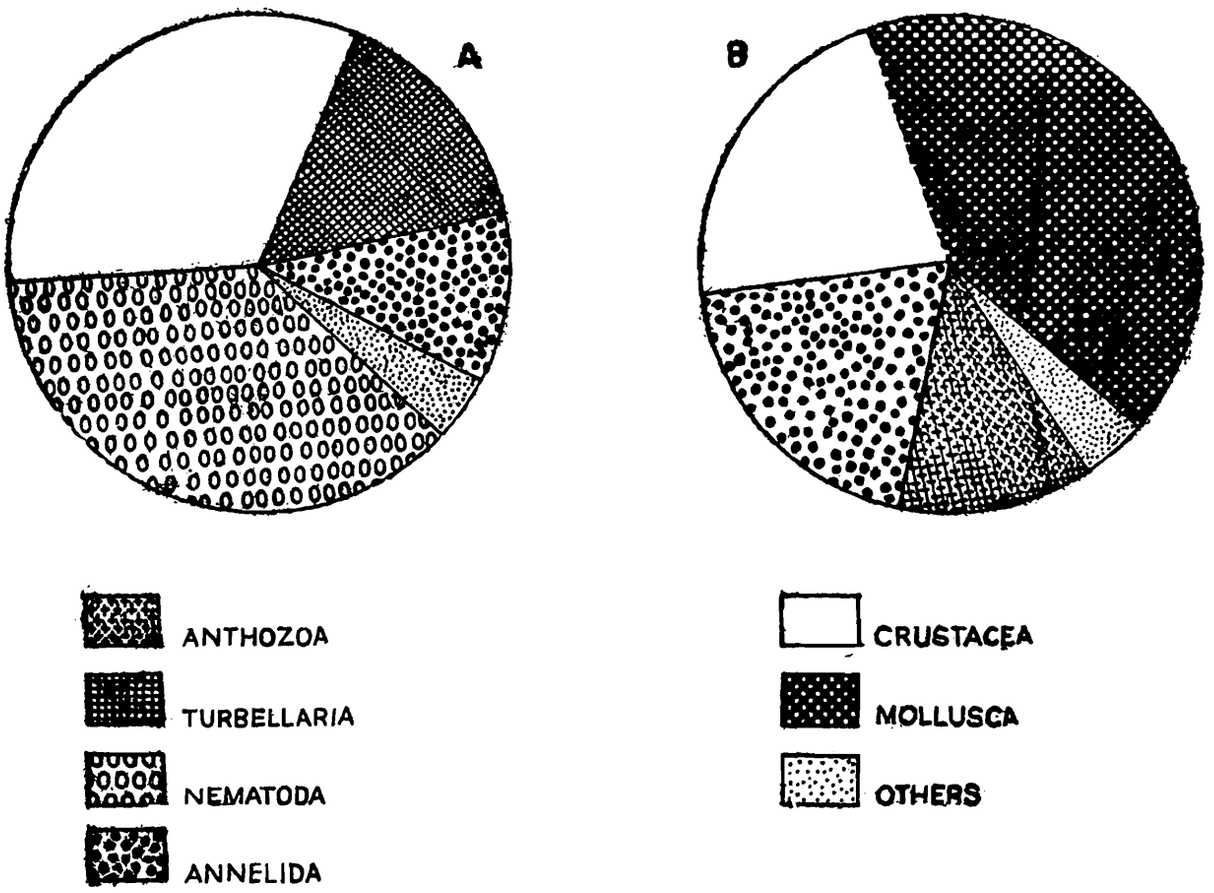

Fig. 3. Circle diagrams Illustrating the percentage composition of the diverse groups of meiofauna (A) and macrofauna (B).

Horizontal distribution : The total number of macrofauna recorded in the upper 10 cm of sediment at the 6 intertidal stations are represented in Table 4. Maximum densities of the fauna occurred in the middle beach, with a general decrease towards the low and high water

marks. Of the total fauna collected, 1.62% occurred at station A, 5.86% at station B, 9.78% at station C, 80.82% at station D, 1.10% at station E and 0.82% at station F. The high faunal density at station D was largely due to the molluscan beds comprising the populations of *Donax* and *Odostomia*. The macrofauna was also consideably patchy in its distribution on the beach.

TABLE 4. Seasonal abundance of macrofauna (nos./m^2) in the upper 10 cm of the sediment at the 6 intertidal stations, A-F.

Month	A	B	C	D	E	F	Total
1978, August	136	1,044	1,732	15,416	216	192	18736
December	264	1,132	1,936	13,612	212	124	17280
1979, April	720	1,704	3,640	18,204	408	228	24904
August	364	1,396	1,276	15,820	112	176	19144
1980, January	172	948	1,080	18,136	96	108	20540
May	408	1,260	2,824	22,040	364	216	27112

The macrofauna species of this sand flat showed more or less a distinct zonal distribution along the intertidal transect with little overlapping in their occurrence (Table 5). The lowest zone of the beach at the proximity of station A is associated with the occurrence of the burrowing gastropods *Tonna dolium*, *Pyrene zebra* ane *P. versicolor*, the bivalve *Siliqua radiata*, the sea-pen *Virgularia* sp. and rarely the brachipod *Lingula anatina*, the king-crab *Carcinoscorpius rotundicauda* and the brittle-star *Ophiactis modesta*. Nearer to station B, large populations of the polychaete *Onuphis* sp. become conspicuous with their emerging heads during receding tide and withdrawing completely into the sediment on being exposed. *Prionospio krusadensis* and *Nerine cirratulus* are the other polychaetes occurring in this area and they along with *Onuphis* constitute the polychaete zone of the beach. Smaller numbers of the gastropods *Oliva gibbosa* and *Bursa spinosa* and the bivalves *Meretrix meretrix* and *Mactra luzonica* are also encountered in this zone. However, station B is mainly characterized by the presence of the giant sea-anemone *Paracondylactis* sp. associated with atleast another two anemone species (undetermined). The siphons of the deep-burrowing bivalve *Sanguinolaria acuminata* occur scattered at this station, the animal lying 35-40 cm below the surface. Three species of the hermit crabs *Diogenes avarus*, *D. rectimanus* and *D. investigatoris*, are also common in this zone. The starfishes *Astropecten indicus* and *A. euryacanthus* were collected from this area lying on the sand surface along with the sea urchin *Temnopleurus toreumaticius*. However, these echinoderms appear to be regular inhabitants of the sub-littoral region.

TABLE 5. Horizontal distribution of macrofauna species on Digha beach.

Species	Stations					
	A	B	C	D	E	F
Tonna dolium (Linnaeus)	+					
Pyrene zebra (Gray)	+					
Pyrene versicolar (Sowerby)	+					
Siliqua radiata (Linnaeus)	+					
Virgularia sp.	+					
Lingula anatina Linnaeus	+					
Carcinoscorpius rotundicauda (Latreille)	+					
Ophiactis modesta Brook	+					
Onuphis sp.	+	+				
Prionospio krusadensis Fauvel	+	+				
Nerine cirratulus Delle Chiaje	+	+				
Oliva gibbosa (Born)	+	+				
Bursa spinosa (Lamarck)	+	+				
Meretrix meretrix Linnaeus	+	+				
Mactra luzonica Deshayes	+	+				
Paracondylactis sp.		+				
Sanguinolaria acuminata (Deshayes)		+				
Diogenes avarus Heller		+				
Diogenes rectimanus Miers		+				
Diogenes investigatoris Alcock		+				
Astropecten indicus Doderlein		+				
Astropecten euryacanthus Lutken		+				
Temnopleurus toreumaticus Agassiz		+				
Cavernularia sp.		+	+			
Onuphis emerita Aud. & M. Edwards		+	+			
Scolelepis squamata (Muller)		+	+			
Scolaricia sp.		+	+			
Hemipodus sp.		+	+			
Nephtys sp.		+	+			
Macropthalmus transversus (Latr.)		+	+			
Polinices didyma Roeding		+	+			
Natica tigrina (Roeding)		+	+			
Natica sp.		+	+			
Nudibranch (undetermined)		+	+			
Thorsonia investigatoris (Kochler & Vaney)		+	+			
Diopatra cuprea cuprea Bosc			+			
Isopod (undetermined)			+	+		
Amphipod (undetermined)			+	+		
Cumacean (undetermined)			+	+		
Odostomia antelia Melville ?			+	+		
Donax incarnatus Gmelin			+	+		
Glycera alba Rathke			+	+	+	+
Dotilla blanfordi Alcock					+	+
Ocypode macrocera H. M. Edwards						+

The area between stations B and C is inhabited by the sea-pansy *Cavernularia* sp. and the polychaetes *Onuphis emerita*, *Scolelepis squamata*, *Scolaricia* sp., *Hemipodus* sp. and *Nephthys* sp. This zone is also characterised by the decapod crab *Macrophthalmus transversus*, the burrowing gastropods *Polynices didyma*, the crawling gastropods *Natica tigrina*, *Natica* sp. and a nudibranch (undetermined). A small sea-cucumber *Thorsonia investigatoris* was also collected in this area. The holothurian lies buried under the sand surface, with both the oral and anal openings at the surface, giving the appearance of widely broadened 'U'. Some specimens were also collected on the surface indicating that they were washed on to the beach from the sublittoral region. Large colonies of the tube-dwelling polychaete *Diopatra cuprea cuprea* occurred at station C, showing preference for a fine and stable substratum. The juveniles of anemones also occurred in abundance (9,000/m^2 to 12,000/m^2) in a wide belt at station C, although the adults were encountered only in the vicinity of station B. It may be that these juveniles migrate to lower levels with increasing size and thus avoid a longer exposure. Stations C and D support small populations of isopods, amphipods, shrimps and cumaceans (undetermined), forming a crustacean zone. The high-water polychaete *Glycera alba* makes its appearance here with their increasing numbers towards higher tidal levels.

The vicinity of station D was mainly characterised by the molluscan beds comprising the bivalve *Donax incarnatus* and the small gastropod *Odostomia antelia* ?, giving a honey-comb appearance to the whole sand surface in this area. Maximum counts of these bivalves were

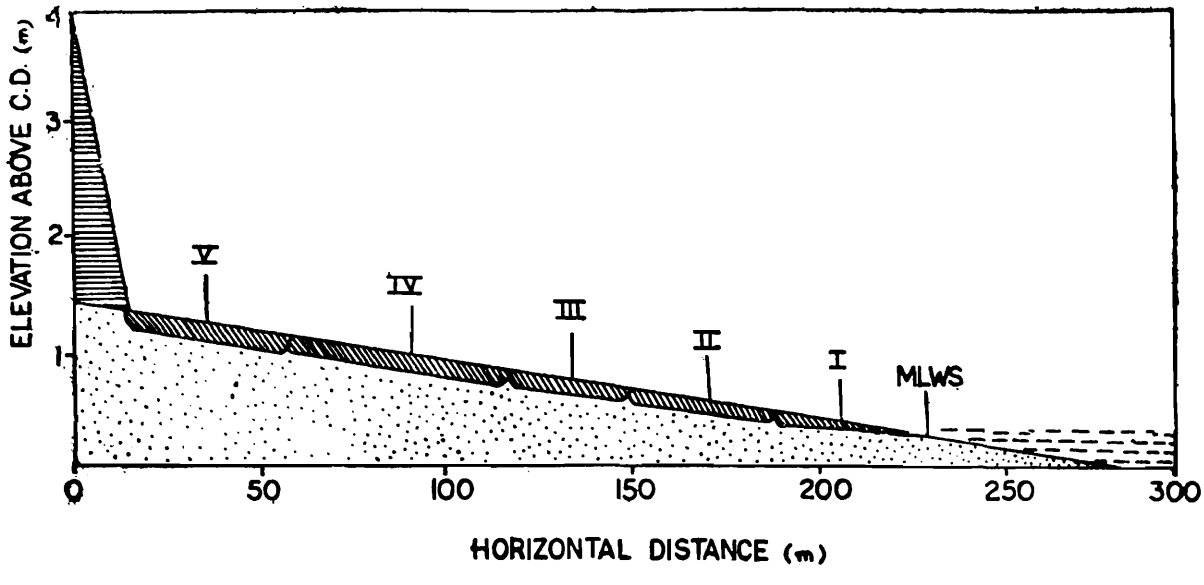

Fig. 4. Diagrammatic representation of zonation of macrofauna in the Digha beach. I. Polychaete zone. II. Anemone zone, III. Crustacean zone, IV. Bivalve zone, V. Decapod zone.

obtained between 2 cm and 6 cm depths below the surface. These animals largely colonized fine sands rich in organic detritus and high in water content. A very interesting associatlon was observed between the bivalve and the gastropod. One to three of these gastropods were usually found attached to some of these bivalves close to the hinged portion of shell. Our observations showed that the *Donax-Odostomia* populations were a regular feature of this zone stretching over 40 m in width. A quantitative study of these two molluscs from 4 sub-stations established 10 m apart showed that they tended to maintain more or less a constant numerical ratio between them at all the levels (Table 6). Further investigations on this association are likely to yield interesting results. *D. incarnatus* was the commonest bivalve species encountered on this beach.

TABLE 6. Quantitative distribution of *Donax-Odostomia* populations (nos./m^2) in the mid-water zone during monsoon, winter and summer. Sub-stations I-IV are 10 m apart.

Sub-station	Species	Ausust 1979	January 1980	May 1980
I	*Donax*	10080	1280	432
(Towards LWM)	*Odostomia*	2880	336	128
	Ratio	3.5:1	3.8:1	3.7:1
II	*Donax*	3276	12940	1440
	Odostomia	840	3080	400
	Ratio	3.9:1	4.2:1	3.6:1
III	*Donax*	544	6188	3360
	Odostomia	160	1820	960
	Ratio	3.4:1	3.4:1	3.5:1
IV	*Donax*	820	732	16420
(Towards HWM)	*Odostomia*	232	196	4480
	Ratio	3.5:1	3.7:1	3.6:1

Among the macrofauna encountered at stations E and F, the most conspicuous were the polychaete *Glycera alba* and the small decapod crab *Dotilla blanfordi*. This zone was readily recognised from a distance by the continuous blanket of pellets formed as a result of the constant activity of these crabs. Random counts show that the population density of this crab varied between 96/m^2 and 160/m^2. The ghost-crab *Ocypode macrocera* occasionally occurred living in burrows in the vicinity of high water mark. Laterally, this crab was more common below sand dunes on Digha beach beyond the sea-wall. The construction of sea-wall seems to have affected its natural habitat in the area investigated.

Vertical distribution : All through the year, bulk of the macrofauna on this beach was found to be confined to the upper 10 cm of the sediment. Again, it was the top 5 cm of the sediment that supported majority of these organisms. The fauna in general also showed an increasing submergence from low water mark to the high water mark. Bulk of the fauna occurred in the upper 1-2 cm of the sediment near LWM, between 2-4 cm towards MWM and between 3-5 cm towards the HWM.

Seasonal distribution : The seasonal abundance of macrofauna recorded at the 6 intertidal stations is shown in table 4. Maximum counts of the fauna were obtained during summer months of the year. Increase in the number of *Donax-Odostomia* populations and the polychaetes during summer appeared to be mainly responsible for the increased seasonal abundance of the total fauna in this area. During the 2 years of study, the peak periods nearly remained the same, although their population densities slightly varied. Interesting seasonal dynamics in the horizontal distribution of *Donax-Odostomia* populations were observed. The populations tended to migrate towards the lower shore during monsoon and gradually return to the upper beach during summer (Table 6). No distinct seasonal variations in the horizontal distribution of other macrofauna species were observed during the period. The sub-littoral molluscs and echinoderms were, however, more common on the lower beach during summer months, probably due to wave action created by strong breeze during the season that washes these animals ashore.

DISCUSSION

The Meiofauna

The present authors earlier studied the composition, density and distribution of meiofauna on a fine intertidal sand flat at Gangasagar on Sagar Island located at the Gangetic mouths (Rao and Misra, 1983). Due to the geographical proximity and the resemblance in the nature of substratum, both Gangasagar and Digha beaches shared many features in common, although the former is estuarine and the latter is marine. These two extensive sand flats with fine sediment showed close resemblance in the distribution of their meiofauna as well. Associated with fine substratum, the meiofauna in this area is predominatly of the burrowing type, and the major groups of fauna as usual consisted of nematodes, copepods, turbellarians and polychaetes. The meiofauna of Digha beach is, however, largely marine in character and has more number of interstitial species due to its comparatively coarser sediment.

Characteristic of flat extensive beaches, the horizontal distribtion of meiofauna on Digha beach is also remarkably wide, with the maximum concentration of fauna on the lower shore. The density and diversity of the fauna, in general, decreased towards the higher tidal levels. Many of the meiofauna species showed distinct preference to different levels of the beach, but the factors limiting distributions of of these species to a particular level are not completely understood due to nearly uniform conditions of temperature, salinity, grain size, water content, etc. through a greater part of the sand flat. The greater availabilability of oxygen and organic matter on the lower shore may, however, favour their colonization. Correlated with the greater fluctuating conditions at higher tidal levels, only the more tolerant species seemed to occupy those levels. This is reflected in the occurrence of brackish water species as the oligochaete *Enchytraeus barkudensis* and the nematode *Halicephalobus limuli* towards the high water mark, where lower salinities were experienced due to seepage of ground water into the beach. This freshwater seepage into the beach seems to have created estuarine conditions in the marine habitat as reported at Kames Bay (Smith, 1955). The restriction of meiofauna to the upper sediment in fine sandy beaches due to reduced oxygen tension in lower layers, is well known.

Seasonal changes in the population density of meiofauna are known to be related with their reproductive activity stimulated by fluctuations in temperature and salinity in the habitat, attaining their maximum development during summar. The present data, however, did not indicate distinct seasonal peaks in the total population of the meiofauna. This appears to be due to the seasonal variation in the abundance of the major groups as nematodes, copepods and polychaetes favouring different periods for their multiplication. The inverse relationship in the seasonal abundance of nematodes and some other groups of animals is also suggestive of the effects of predation, competition, etc. between them.

Probably due to its proximity to the Gangetic mouths, like the Gangasagar beach, the Digha beach also suppored a considerable amount of clay and silt in it. Compared with the world situations, the density and diversity of meiofauna in this beach are relatively poor, apparently due to the fine nature of sediment that inhibits the development of true interstitial populations. This may also explain the absence of typical interstitial macrodasyoid gastrotrichs, archiannelids, tradigrades, kinorhynchs and molluscs in this sand flat. Thus, as elsewhere, the quality of the substratum seemed to be most important ecological factor influencing the composition, density and distribution of meiofauna on Digha beach.

THE MACROFAUNA

The density and diversity of macrofauna on Digha beach proved to be sufficiently rich, apparently due to the relatively sheltered sand flat rich in organic detritus. Due to the fine nature of the substratum, the majority of the species colonising the beach are deposit and filter feeders. The abundant occurrence of *Donax-Odostomia* populations in the middle beach is probably related with the abundant supply of detritus on the beach. Fine intertidal deposits are also known to support rich populations of micro-organisms forming food for the bivalves. But, with the available data, it is difficult to explain the differences in density of macrofauna at other horizontal levels on the beach, However, the patchy distribution of macrofauna in the beach seems to be due to their environmental preferences and tolerances of the component species (McIntyre 1969). Like the meiofauna, the vertical distribution of macrofauna also seems to be restricted to the upper 10 cm of sediment due to reduced oxygen content in layers. The macrofauna also showed some submergence in the beach towards higher tidal levels, apparently seeking optimum conditions of water saturation in the habitat.

Due to fluctuations in biotic and abiotic factors of the environment, seasonal changes in population density of macrofauna are known to occur from season to season and from year to year. Maximum counts in the present study were obtained during summer months, probably related with higher temperature and salinity, as well as an undisturbed substratum during the period. While studying the zonation on a muddy flat, Brady (1943) showed that the distribution of fauna varied with season, occupying different tidal levels during different seasons. The seasonal dynamics exhibited by the *Donax-Odostomia* populations on Digha beach are apparently similar to the above pattern of distribution. The distinct downward migration of these populations during monsoon was probably to avoid low interstitial salinities at higher tidal levels resulting from heavy rainfall. Ansell *et al* (1972) also studied the population dyanamics of *Donax incarnatus* on two sandy beaches in South West India.

The zonal distribution of macrofauna in stable sandy beaches has been well documented in several tropical and sub-tropical situations (Pearse *et al.* 1942, Colman and Segrove 1955, Gauld and Bauchanan 1956, Ganapati and Rao 1962, McIntyre 1968, Gopalakrishnan 1970, Trevallion *et al* 1970, Philip 1974). According to the universal scheme of zonation for sandy shores proposed by Dahl, in tropics the ghost-carbs (Ocypodidae) inhabit the upper littoral zone, the isopods (Cirolanidae) in the mid-

littoral zone and the anomuran crab (Hippidae) in the lower littoral zone. The present study indicated distinct zonation for some dominant species, these indicator organisms occupying almost the same ecological niches reported in other tropical regions. Five broad zones could be recognized on Digha beach based on the animal distribution (Fig. 4), although the density of these indicator organisms used in defining these zones was quite variable. They are *viz.*, (i) the polychaete zone reqresented by *Onuphis* sp., *Prionospio krusadensis* and *Nerine cirratulus*, (ii) the anemone zone with *Paracondylactis* sp. and 2 other anemones, (iii) the crustacean zone with shrimps, isopods and amphipods, (iv) the bivalve zone with *Donax incarnatus* and (v) the decapod zone with *Dotilla blandfordi*. These zones are also quite broad probably due to the extensively wide stretch of the sand flat. The pattern of zonation observed on Digha beach is in agreement with Dahl's universal scheme of zonation in so far as the crustacean zone is concerned. Higher on the beach the *Ocypode* zone is replaced by another crab *Dotilla blanfordi*. Lower down the beach the hippid crabs are absent and this zone is characterised by the polychaetes and a little above by anemones. Hippid crabs are characteristic of exposed and wave washed tropical beaches and their absence at Digha is due to the sheltered nature of the sand flat. Gauld and Buchanan (1956) suggested adding a *Donax* zone to Dahl's scheme and our observations at Digha lend support to this view. Deviations from Dahl's scheme were observed by previous workers (Colman and Segrove, 1955 ; Gauld and Buchanan, 1956 and Ganapati and Rao, 1962) and hence more work is probably necessary before we can decide on the number of zones to be recognised on sand beaches and the characteristic species on their ecological equivalents.

Comparison of Macrofauna and Meiofauna

The macrofauna and meiofauna on Digha beach largely exhibited a similar pattern in their spatial and temporal distribution, apparently due to the identical environmental parameters affecting them. Compared with the densities of intertidal fauna recorded in different world situations, the Digha beach supported considrably rich populations of the macrofauna than the meiofauna. With the available data it is, however, difficult to explain this variation in their abundance. The numerical relationship between these two size categories of the fauna collected in an area is known to be of considerable ecological significance (McIntyre 1969). The mean population densities and their ratios recorded at different horizontal levels on Digha beach are presented in Table 7. The data nearly showed an inverse relationship in their occurrence.

At levels where the macrofauna was rich, the meiofauna numbers were remarkably low. As suggested by McIntyre, this was probably due to the macrofauna affecting the density of meiofauna by predation, competition and physical disturbance of environment.

TABLE 7. Compaarison of mean values of macrofauna and meiofauna at different intertidal stations on Digha (numbers per m^2)

Stations	A	B	C	D	E	F
Macrofauna	344	1248	2081	17205	235	174
Meiofauna	66100	113600	79000	30700	19900	13200
Ratio (approx.)	1:192	1:91	1:38	1:1.8	1:85	1:76

SUMMARY

1. The paper presents the results of a preliminary investigation on the composition, density and distribution of meiofauna and macrofauna in the Digha beach made during 1978-80. The meiofauna is largely of the burrowing type, with a small percentage of interstitial species. Nematodes, copepods, turbellarians and polychaetes formed the major groups. The macrofauna largely comprised of the deposit and filter feeders. Anemones, annelids crustaceans and molluscs, constituted the major groups.
2. Greater number of meiofauna species and individuals were found on the lower shore, with their densities in the beach ranging from 132/10 cm^2 to 1136/10 cm^2. Richest macrofauna occurred on the middle beach due to the presence of molluscan beds composed of *Donax-Odostomia* populations. Total number of macrofauna individuals ranged from 96/m^2 to 22040/m^2.
3. Many meiofauna species occurred at different horizontal levels on the beach, without indicating a clear dominance. There was a distinct zonation of macrofauna in the beach, each zone being dominated by a group of organisms. Five broad zones could be recognised on the beach. The pattern of zonation on Digha beach is in close agreement with the universal scheme of zonation of sandy shores proposed by Dahl.
4. All through the year, bulk of the sand-living community was restricted to the upper 10 cm of sediment, with a higher concentration of the fauna in the top 5 cm. No seasonal vertical migrations of the fauna were observed.

5. The seasonal and annual dynamics in the population density of the beach fauna are described. The summer months, in general, appeared to be more favourable for their multiplication, while the monsoon months yielded their minimum numbers. The *Donax-Odostomia* populations tended to migrate downwards during monsoon and upwards during summer.

6. A comparison of the macrofauna and meiofauna encountered at different horizontal levels on the beach is suggestive of an inverse relationship in their numerical abundance.

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