Proc. Indian Acad. Sci. (Anim. Sci.), Vol. 92, Number 1, January 1983, pp. 73–85.

Studies on the meiofauna of Sagar Island

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MS received 24 July 1982; revised 16 October 1982

Abstract. Mean number of total meiofauna individuals in the intertidal estuarine sediments around the island ranged from 1/10 cm^2 to 517/10 cm^2. Nematodes and copepods were the dominant taxa comprising over 80% of the total fauna. Higher meiofaunal densities occurred over the lower shore. The fauna was concentrated mostly in top 4 cm of sediment, showing little submergence towards higher tidal levels. No diurnal and seasonal vertical migrations of meiofauna were observed. Two small seasonal peaks of meiofaunal abundance were noted. Total population values were highest in summer and lowest during monsoon. Nematodes reached their maximum in winter and copepods in summer. Variations in salinity appeared to be responsible for the seasonal pattern. The present meiofaunal densities are considerably lower than those recorded in other areas. The highly fluctuating hydrographical conditions and the fine sediment with silt-clay fraction, poor drainage, low oxygen content, etc., are considered responsible for the paucity of meiofauna in this area.

Keywords. Meiofauna; composition; density; Sagar Island.

1. Introduction

The interest in a study of the distribution and ecology of meiofauna in sediments of fluctuating salinity has been steadily increasing in recent years. Compared to marine habitats, the distribution of estuarine meiofauna has been investigated only in a few geographically isolated areas of the world (Coull 1973). Very little is known about it in the Indian waters, the studies of McIntyre (1968), Patnaik (1971), Damodaran (1974), Sarma and Ganapati (1975) and Sarma and Rao (1980) being notable in this regard. Hitherto, nothing is known of the meiofauna inhabiting the Gangetic estuarine system, the largest of its kind on the Indian coast. Hence, the present investigation was undertaken to make a preliminary survey of the composition, density and distribution of meiofauna within the intertidal deposits around Sagar Island, located at the Gangetic mouths. This paper deals with the results of the study carried out for 2 years from April 1978 to March 1980.

2. Material and methods

2.1 *Area investigated*

Sagar Island, the western most part of Sunderbans in the Bay of Bengal, is situated 96 km south of Calcutta, between latitudes 21°37′ and 21°52′ N and longitudes 88°03′ and 88°11′E. The island is somewhat triangular in outline, about 30 km in length, 16 km in maximum width and 380 sq km in area. It is flanked by two rivers, Hooghly on the west and Baratala on the east. On the southern side, it faces the open sea. It is a flat delta with many tidal creeks and muddy shores on either side and fine sandy beaches on the southern side. The soil is mostly of river borne silt, sometimes with overlying sand. Three seasons are well experienced in this region, the summer from March to June with high temperature, the monsoon from July to October with heavy rainfall and the winter from November to February with low temperature. The annual cycle of water temperature, salinity and plankton in the Hooghly estuarine system was given by Saha *et al* (1975). After a preliminary survey of the coast around the island, 6 areas were selected for the present investigation (figure 1), of which the site at Gangasagar (station 6) was chosen for a detailed study of the fauna.

Gangasagar is located about half-way on the south coast. Here, the sea is shallow and the beach is moderately a sheltered one, with an extensively wide stretch of intertidal sand flat exposed at low tide. A horizontal distance of about 240 m was exposed during low water spring tides. The other 5 subsidiary areas located on river bank are in the vicinity of Radhakrishnapur, Mandirtala, Kachuberia, Kaylapara and Chemaguri. In these places, extensive mud-flats of varying width are exposed at low tide. The sediment is of uniformly soft mud, with high organic content.

2.2 *Techniques of study*

All the field observations and collections were made during low tide. Environmental parameters of the beach were studied only at Gangasagar. An intertidal transect

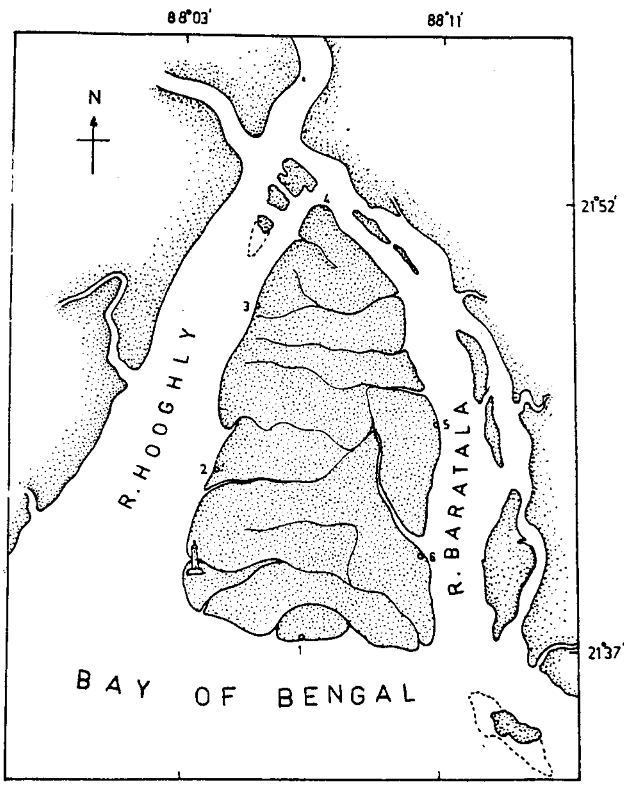

Figure 1. Sagar Island, showing the study areas 1-6. **1.** Gangasagar; **2.** Radhakrishnapur; **3.** Mandirtala; **4.** Kachuberia; **5.** Kaylapara; **6.** Chemaguri.

was established on the beach with 4 sampling stations, A-D, between MLWS and MHWS (figure 2). Beach profiles were obtained by using the survey technique of Emery (1961). For granulometric analyses, core samples of the sediment were collected from the top (10 cm) at 4 stations along the transect. The amount of capillary water present at different levels of the beach was determined by weighing the wet sand samples and reweighing the same to constant weight after they were completely dehydrated. The temperature of adjacent sea water was recorded in knee deep water with a sensitive centigrade thermometer and that of the intertidal sediment by inserting the thermometer to depths of 1, 5, 10, 15 and 20 cm below surface at all the 4 stations. Pore water samples were collected with a hypodermic syringe following the method of Johnson (1967). Salinity determinations were made by Knudsen's method, while Winkler's method was used in estimating the amount of dissolved oxygen. Particulate organic matter of the sediment was approximately determined by the loss in weight on ignition.

For a quantitative study, regular monthly sampling was conducted at Gangasagar during lowest spring tides. Due to difficulties in sampling and sieving, collections at the 5 muddy areas were made only at one point on the traverse between low and midwater levels. Sediment samples were taken using a hand-operated metallic corer, 30 cm in length and 20 cm^2 in internal cross sectional area. The corer was longitudinally cut into two halves and hinged on one side, so that it could be easily opened without disturbing the sediment core. The core samples were cut into 2 cm thick segments to ascertain the vertical distribution of meiofauna and anaesthetized with a solution of $MgCl_2$ isotonic with sea water. Animals were extracted from these samples by decanting and sieving method. The fauna passing through a 1 mm sieve and retained on a 45 μm sieve are considered as meiofauna in the present investigation. Faunal densities are expressed as the number of individuals per 10 cm^2 and each value represents the mean of two cores.

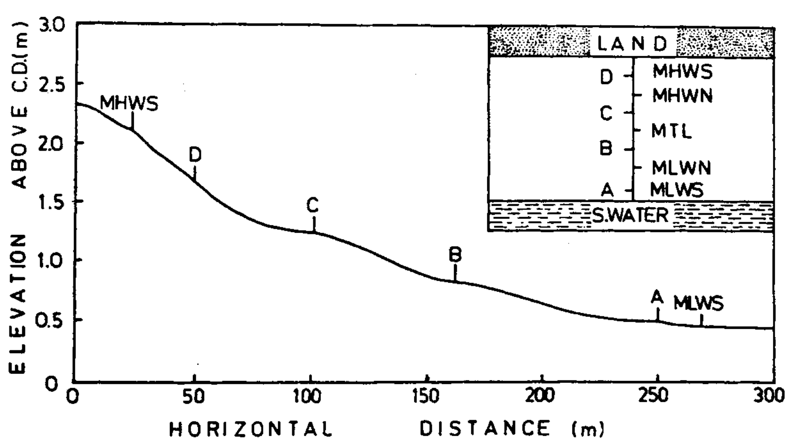

Figure 2. Selected beach profile at Gangasagar (18 November 1979), showing the position of sampling stations A-D along the intertidal transect.

3. Results

3.1 *The environment*

The beach slope at Gangasagar was uniformly very low and a typical profile recorded is shown in figure 2. The sand was largely fine in texture with a considerable percentage of silt or clay, which generally increased with depth in the sediment (figure 3). The beach was fully saturated nearly up to station C, resulting in a relatively permanent ground water table close to the surface. Temperature values of the intertidal sediment followed the usual pattern of summer maximum and winter minimum, with variations mostly occurring in the upper 5 cm of the sediment towards higher tidal levels (figure 4). The salinity values of interstitial water in the beach were generally the same as that of the adjacent sea water (figure 5). The concentration of dissolved oxygen in the beach showed a distinct decrease with distance from low water level and particularly with depth in the sediment. The beach sands were sufficiently rich in organic detritus.

3.2 *Composition of meiofauna*

Free-living nematodes and harpacticoid copepods constituted the major groups of meiofauna in this area. Turbellarians, polychaetes, oligochaetes, ostracods, isopods, amphipods, cumaceans and halacarids occurred in small numbers. Hydrozoans and nemerteans were rare. The larval forms of polychaetes, crustaceans, molluscs and insects were present. The mean annual density and percentage abundance of the diverse groups of meiofauna at the most frequently sampled station B during the period of study are given in table 1. True interstitial forms were rare, while the burrowing ones predominated in the habitat.

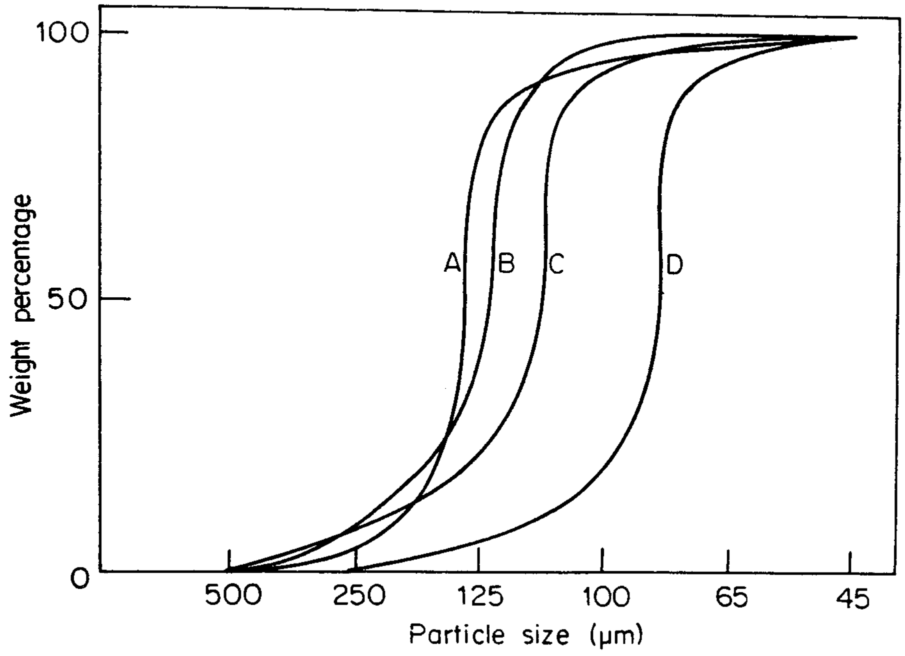

Figure 3. Representative cumulative curves of sediment particle size for the 4 intertidal stations A-D.

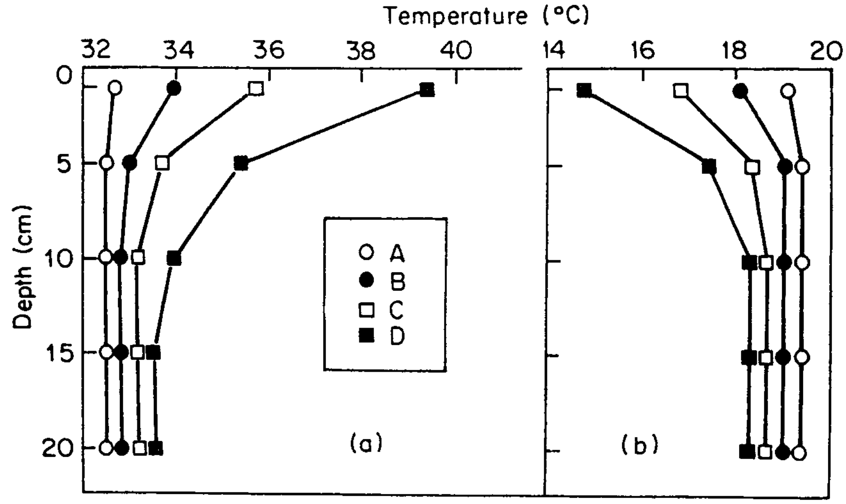

Figure 4. Temperature gradients in the sediment at the 4 intertidal stations. a —Summer (14 May 1979); b—Winter (28 December 1979).

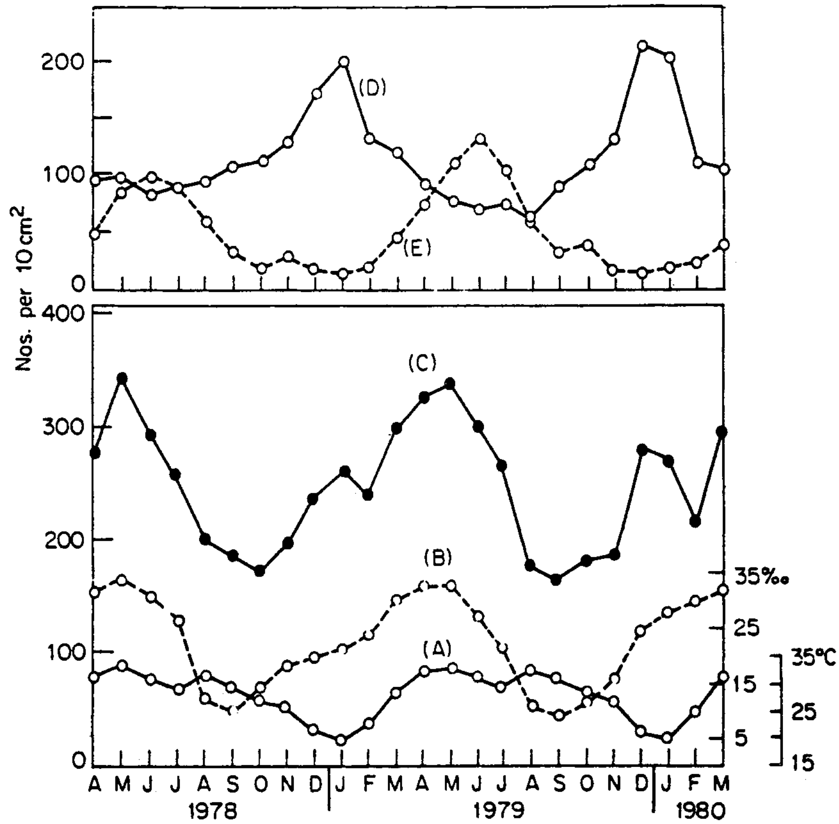

Figure 5. Comparison of seasonal changes in temperature and salinity of sea water with the meiofaunal abundance at station B. A—Temperature; B—Salinity; C—Total meiofauna; D—Nematoda; E—Copepoda.

3.3 *Horizontal distribution*

The entire intertidal transect was sampled to a depth of 30 cm thrice in a year during summer (May), monsoon (September) and winter (January) to study the horizontal and vertical distribution pattern of the meiofaunal populations against fluctuating temperature and salinity regime in the habitat. No remarkable variations were detected during these periods in their spatial distribution within the beach, indicating that the fauna occupied the same horizontal and vertical levels in the sediment throughout the year. The mean values of population densities at different levels based on the six complete transects are presented in table 2. As the core samples collected 10 cm below the sediment surface did not contain any animals, the present data are limited to that depth. Distribution of the total population indicated that bulk of the meiofauna was concentrated on the lower half of the beach, showing a general decrease towards high water level. Of the total fauna collected at the 4 intertidal stations, 28.81% of them occurred at station A, 43.74% at station B, 19.15% at station C and 8.30% at station D. The density and diversity of meiofaunal groups showed a distinct decrease towards higher tidal levels.

3.4 *Vertical distribution*

No distinct seasonal or diurnal vertical migrations of the meiofauna were observed during the study period and the total populations were close to the surface throughout the year (table 2). Of the total fauna collected at the 4 intertidal stations, 63.93% of them occurred in the upper 2 cm of the sediment, 25.30% between 2-4 cm, 7.02% between 4-6 cm, 3.03% between 6-8 cm and 0.72% between 8-10 cm depth. Between low and half-tide levels, the fauna occurred mostly in the top 4 cm, while it was found at 2-6 cm below the surface towards higher tidal levels. Thus, little meiofaunal submergence occurred towards higher levels due to reduced water content in the upper layers of the sediment.

3.5 *Seasonal distribution*

Quantitative studies on meiofaunal population density during different months of the year were carried out at station B and the results are presented in table 3. The

Table 1. Composition of meiofauna (nos./10 cm^2) at station B during April 1978 to March 1980.

Group	Maximum	Minimum	Mean	Percentage
Turbellaria	17	0	6.50	2.65
Nematoda	218	66	117.17	47.84
Polychaeta	21	0	9.42	3.85
Oligochaeta	7	0	1.75	0.71
Ostracoda	11	3	6.79	2.77
Copepoda	134	16	51.87	21.18
Nauplii	97	0	33.96	13.87
Isopoda	11	0	3.37	1.38
Amphipoda	5	0	2.04	0.83
Others	21	5	12.04	4.83
Total meiofauna	342	160	244.91	

Table 2. Mean population densities (nos./10cm^2) of meiofauna in the upper 10 cm of the sediment at the 4 intertidal stations, A-D.

Meiofauna group	Depth (cm)	A	B	C	D
Turbellaria	0-2	7	11	5	0
	2-4	1	2	2	1
	4-6	0	0	0	0
	6-8	0	0	0	0
	8-10	0	0	0	0
Nematoda	0-2	124	192	47	14
	2-4	37	64	78	36
	4-6	13	19	21	27
	6-8	7	11	14	6
	8-10	2	3	3	1
Polychaeta	0-2	16	21	2	0
	2-4	2	4	5	1
	4-6	0	0	0	0
	6-8	0	0	0	0
	8-10	0	0	0	0
Oligochaeta	0-2	1	2	4	3
	2-4	0	2	6	7
	4-6	0	0	1	2
	6-8	0	0	0	0
	8-10	0	0	0	0
Ostracoda	0-2	9	13	4	0
	2-4	0	0	1	0
	4-6	0	0	0	0
	6-8	0	0	0	0
	8-10	0	0	0	0
Copepoda	0-2	69	93	18	0
	2-4	7	11	9	0
	4-6	0	0	0	0
	6-8	0	0	0	0
	8-10	0	0	0	0
Nauplii	0-2	38	57	5	0
	2-4	3	8	2	0
	4-6	0	0	0	0
	6-8	0	0	0	0
	8-10	0	0	0	0
Isopoda	0-2	3	5	1	0
	2-4	1	2	2	1
	4-6	0	0	0	0
	6-8	0	0	0	0
	8-10	0	0	0	0
Amphipoda	0-2	2	3	1	0
	2-4	1	1	1	0
	4-6	0	0	0	0
	6-8	0	0	0	0
	8-10	0	0	0	0
Others	0-2	12	15	3	1
	2-4	5	7	5	3
	4-6	1	2	1	1
	6-8	0	0	0	0
	8-10	0	0	0	0
Total meiofauna	0-2	281	412	90	18
	2-4	57	101	110	49
	4-6	14	21	23	30
	6-8	7	11	14	6
	8-10	2	3	3	1
	Totals	361	548	240	104

Table 3. Seasonal abundance (nos./10 cm²) in the monthly composition of meiofauna at station B during April 1978 to March 1980.

Months	Turbellaria	Nematoda	Polychaeta	Oligochaeta	Ostracoda	Copepoda	Nauplii	Isopoda	Amphipoda	Others	Total meiofauna
1978 April	13	94	16	2	6	47	74	4	2	13	271
May	17	98	21	0	9	82	93	7	4	11	342
June	9	82	17	0	11	96	51	5	4	9	284
July	2	87	18	1	8	87	37	4	2	7	253
August	0	93	12	4	6	58	14	2	1	10	200
September	5	107	14	3	4	31	4	0	0	11	179
October	1	114	11	5	7	19	0	0	2	5	164
November	12	127	2	1	6	27	2	2	3	12	194
December	3	172	0	0	10	18	6	3	0	18	230
1979 January	0	201	2	0	7	16	11	2	1	14	254
February	7	134	5	2	6	21	36	0	3	18	232
March	11	120	13	1	9	43	81	4	2	11	295
April	14	93	18	0	4	76	97	6	4	15	327
May	12	81	17	2	6	112	74	11	4	17	336
June	3	74	11	1	6	134	42	7	5	13	296
July	3	78	13	0	9	107	27	5	1	19	262
August	2	66	6	3	4	65	18	1	0	10	175
September	0	92	9	7	3	36	5	0	2	6	160
1979 October	2	106	4	4	8	41	2	3	1	7	178
November	7	135	0	1	7	20	0	4	0	9	183
December	9	218	1	1	5	17	14	0	0	12	277
1980 January	5	211	2	2	6	24	9	2	2	8	271
February	8	115	5	0	9	27	35	3	3	13	218
March	11	114	9	2	7	41	83	6	3	21	297
Mean	6.50	117.17	9.42	1.75	6.79	51.87	33.96	3.37	2.04	12.04	244.91

seasonal fluctuations indicated two small peaks of meiofaunal abundance in a year, a major one during summer and a minor one in winter. Lowest densities of total populations were recorded during and immediately after the monsoon months. As more than 80% of the total fauna comprised of nematodes and copepods, fluctuations in total meiofauna numbers mostly depended on the abundance of these two groups. The maximum copepod production during summer months was mainly responsible for the major peak in meiofauna numbers, while the nematode increase in winter for the minor peak. The nematodes formed a relatively constant proportion in meiofauna population with little seasonal fluctuation in their numbers, while the monsoon months were the poorest for copepod production. The other groups of meiofauna did not indicate any distinct pattern in their seasonal abundance. During the 2 years of study, the peak periods and the low levels of abundance nearly remained the same for major meiofaunal groups.

3.6 *Meiofauna of the muddy beaches*

The mean density values of meiofauna individuals in the fine intertidal estuarine muds recorded at the 5 subsidiary study areas are presented in table 4. The vertical distribution of meiofauna at all these sites conformed to the usual pattern, bulk of the total fauna being confined to the upper 1 cm of the sediment. Free-living nematodes formed the dominant element, averaging about 80% of the total meiofauna numbers. Copepods were the next abundant group. Abundance of meiofauna individuals and poverty of species appeared to prevail in these areas. Further, the density and diversity of meiofauna in these muds indicated a general decrease from sea towards the upper reaches of the estuarine system. As no regular monthly sampling was carried out at these areas, nothing can be said about the seasonal abundance of meiofauna.

4. Discussion

In many of the world beaches studied, the nematodes formed a relatively stable and dominant element of the meiofauna due to their ability to withstand fluctuating conditions in the habitat, while copepods were generally second in overall abundance (McIntyre 1968, 1969; Harris 1972; Coull 1973; Martinez 1975; Platt 1977; Dye and Furstenberg 1978; Moore 1979). The present investigation also

Table 4. Mean numbers of meiofauna individuals per 10 cm^2 at the 5 muddy areas 2 - 6 on Sagar Island (vide figure 1) during March 1979 and 1980.

Areas	2	3	4	5	6
Nematoda	306	228	65	249	412
Copepoda	32	18	3	12	23
Ostracoda	21	16	0	5	14
Turbellaria	13	14	2	7	17
Polychaeta	14	8	2	11	21
Isopoda	11	3	0	0	7
Amphipoda	3	0	0	1	2
Others	13	17	4	13	21
Totals	413	304	76	298	517

indicated a nearly similar composition, the nematodes predominating in all the areas studied on the island, the finer muddy sediments supporting slightly higher populations over the sandy ones. Compared to the mud deposits, the copepods are well represented in sandy areas (McIntyre 1969). The numerical abundance of the remaining smaller groups of meiofauna reported from different global regions varied from area to area, making their comparison difficult. The blocking of intertices in these fine sands with silt-clay fraction has practically eliminated many of the truly interstitial species and groups characteristic of the habitat. As bulk of the beach sands fall under 160 μm in mean particle size, the meiofauna of this area is to be considered mostly of the burrowing type, excepting the nematodes capable of sliding even in very small spaces (McIntyre and Murison 1973; McLachlan *et al* 1977; Dye and Furstenberg 1978; Moore 1979).

Due to the presence of a high percentage of water saturation through most part of the extensively wide intertidal zone at Gangasagar, the horizontal distribution of meiofauna was also correspondingly great. Further, as recorded in the present study, the concentration of meiofauna at lower levels of flat and sheltered beaches is also known in certain other areas (Smidt 1951; Harris 1972a; Martinez 1975; Dye and Furstenberg 1978; Moore 1979). Animals tolerant to higher temperatures, lower values of water saturation and oxygen tension, appeared to occupy higher tidal levels and this was particularly observed with nematodes, oligochaetes and halacarids. The superficial concentration of meiofauna in fine and poorly drained beaches due to reduced oxygen tensions in the lower layers of the sediment is known in several world situations, particularly in estuarine environments (Perkins 1958; Fenchel and Jansson 1966; Fenchel 1969; Jansson 1969; Coull 1973; Platt 1977; McLachlan 1978; Moore 1979). The concentration of meiofauna in the top 1 cm of the fine sediment in muddy beaches due to lack of oxygen in the lower layers is also well known (Rees 1940; Barnett 1968; McIntyre 1968). Pronounced seasonal changes in the vertical distribution of meiofauna populations due to fluctuations in temperature were observed on the European coasts, where surface concentrations occurred during summer and deep distributions in winter (Renaud-Debyser 1963; Schmidt 1969; Harris 1972b; McIntyre and Murison 1973). As no such seasonal variations in the vertical distribution of meiofauna were observed in the present study, it appears that the seasonal pattern is characteristic only of the temperate areas where freezing temperatures are experienced in the superficial layers of the sediment during winter. The absence of any distinct diurnal vertical migrations of meiofauna in the sand flat might be due to the waterlogged nature of the sediment as reported by Dye (1978).

Little information is available on the seasonal abundance of intertidal meiofauna and peaks are usually noted when observations are made over a full year or more (McIntyre 1969). The observed pattern of two distinct maxima in the present study, a major one in summer and a minor one during winter, is not universal. Correlated with an increase in sea water temperature, one major peak was usually recorded during or immediately after summer, while variations occurred with the other peak (Smidt 1951; Ganapati and Rao 1962; Govindankutty and Nair 1966; Muus 1967; Fenchel 1967; Schmidt 1969; Harris 1972b; McIntyre and Murison 1973; Dye and Furstenberg 1978). However, the meiofaunal densities recorded in the present investigation conform with the earlier studies on Indian coast, which indicated peak numbers of meiofauna during summer, reduced numbers during monsoon and gradual recovery during winter (Ganapati and Rao 1962; Govindankutty and Nair 1966; Panikkar and Rajan 1970; Damodaran 1974). A similar observation was also made for the population of macrobenthos in a tidal creek on Sagar Island (Bhunia and Choudhury 1981). Lower salinities experienced during monsoon months appear to be unfavourable for the population increase and the seasonal abundance of meiofauna seems to depend mostly on changes in the hydrobiological conditions (figure 5). Low temperature and salinity conditions in the habitat were associated with nematode increase, while their higher values favoured copepods. The hydrographic cycle is probably related with their reproductive activity.

The quantitative data available on meiofauna of the fine intertidal estuarine sediments are presented in table 5, which indicate that the densities of meiofauna populations recorded on Sagar Island are considerably lower than those of the other areas. The present values approach only those of Smidt (1951) from mud wadden on Danish North Sea coast and Dye and Furstenberg (1978) from muddy sand in Swartkops estuary, South Africa. Estuaries are generally considered highly productive systems with greater meiofauna densities than those of non-estuaries (Coull 1973) and thus, the paucity of meiofauna in sediments of this area obviously needs an explanation. The turbid suspension characteristic in waters of this region is inhospitable for animal life. Further, the highly fluctuating hydrographical conditions and the sediment characteristics as fine grain size, presence of silt-clay fraction, poor drainage, high organic matter, low oxygen content, presence of H_2S, etc appear by no means ideal for the meiofauna to flourish in this estuarine environment.

The Hooghly estuarine system is a positive type with varying salinites experienced upstream up to about 296 km from the river mouth (Saha *et al* 1975). It is known that the number of species and individuals of meiofauna steadily decreases from high saline to less saline areas in an estuarine system (Capstick 1959; Gunter 1961; Coull 1973). Further, Sanders *et al* (1965) reported a pronounced reduction in the number of species in a gradient estuary, a reduction that is not evident in a fluctuating estuary. But as already stated, the present study indicated a distinct decrease in the number of meiofauna species and individuals from areas near the mouth towards

Table 5. Maximum densities (nos./10 cm^2) of meiofauna recorded in fine intertidal estuarine sediments.

Locality	Nematoda	Copepoda	Ostracoda	Total meiofauna	Reference
Bristol Channel, Britain	10,440	500	790	11,820	Rees 1940
Mud wadden, Denmark	367	389	12	768	Smidt 1951
Whitstable, Britain	5,200	486	742	5,807	Perkins 1958
Blyth estuary, Britain	2,830	—	—	—	Capstick 1959
Salt marsh, Massachusetts	2,130	—	—	—	Weiser and Kanwisher 1961
Salt marsh, Georgia	16,300	—	—	—	Teal and Wieser 1966
Muddy beach, S. India	3,240	490	63	3,815	McIntyre 1968
Sandy beach, S. India	1,150	448	0	1,960	McIntyre 1968
Sandy beach, S. Africa	955	208	—	1,146	Dye and Furstenberg 1978
Muddy sand, S. Africa	329	13	—	345	Dye and Furstenberg 1978
Sandy beach, Sagar Island	218	134	11	342	Present study
Muddy beach, Sagar Island	412	32	21	517	Present study

locations at the upper reaches. Thus, the gross distribution of meiofauna in general appears to be the same in both the fluctuating and gradient estuaries, except that the pattern is more pronounced in the latter. However, as the species composition of meiofauna has not been well worked out in the present investigation, these observations could only be of a tentative nature.

Acknowledgements

The authors would like to express their sincere gratitude to Dr T N Ananthakrishnan, former Director, Zoological Survey of India, Calcutta, for the initiative, interest and encouragement during the course of this work. The authors are also grateful to the S D Marine Biological Research Institute, Sagar Island, for the laboratory facilities provided during their stay on the island.

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