

Seasonality in meiofaunal distribution on a tropical beach at Balramgari, northeast coast of India

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Maximum density of meiofauna was recorded during the southwest monsoon season (June to September). The major part of the faunal group consisted of cladocerans (47%) followed by nematodes (15%) and harpacticoids (14%). None of the faunal group showed any significant difference with tide level during different seasons. Cladoceran was the only group exhibited seasonality in their abundance with the depth of the sediment. Dispersion of turbellarians, ostracods and lamellibranchs was regular; random in isopods and patchy or contagious in nematodes, harpacticoids and cladocerans. A significant correlation was observed between nematoda, turbellaria, amphipoda and cladocera with salinity, pH, chlorophyll-*a* and POC respectively. Mean grain size of the sediment was highly correlated with the abundance of cladocerans and harpacticoids.

The study of seasonal patterns of meiofauna provides valuable information on the productivity of a beach. A comparative study of meio and macrofauna based on production or energy flow values is an ecologically important aspect in understanding the trophic relationship. Intertidal habitats in temperate and subtropical zones are subjected to distinct seasonality in the distribution of benthic fauna. Dispersion of meiofauna inhabiting the intertidal zone is not uniform and distinct variations in faunal pattern attributed to spatial and temporal variations, changes in sediment granulometry¹ and abundances of microbial food organisms²⁻⁴ have been observed. The present account deals with the study of the distribution and abundance of meiofauna of a tropical beach in relation to environmental factors. The beach serves as a breeding ground for the horseshoe crab *Tachypleus gigas* (Müller).

Materials and Methods

Balramgari beach is a flat exposed sandy strip along the northeast coast of India (Fig. 1). Climatically, the study area experiences 3 distinct seasons i.e. northeast monsoon (October to January), fair season (February to May) and southwest monsoon (June to September). The tides (60-90 cm) in the region are of a mixed type with a strong semidiurnal influence. During neap tide the intertidal area extends up to 8 km of an almost continuous stretch, horizontally. Much of the area is subjected to active erosion and silt deposition⁵.

The interruption of estuarine flow from Burhabalanga river, and sand bar formation at the mouth of the estuary, the beach profile and sediment characteristics of the beach change considerably during different seasons. The sediment is primarily composed of medium to fine sand, silt and clay. The area is particularly affected by large salinity fluctuations arising from the freshwater flow of river Burhabalanga.

Sampling (October 1988 to September 1989) was done along a transect perpendicular to the shore and extending seaward, through 8 stations, at a distance of 5 m between each station. Monthly

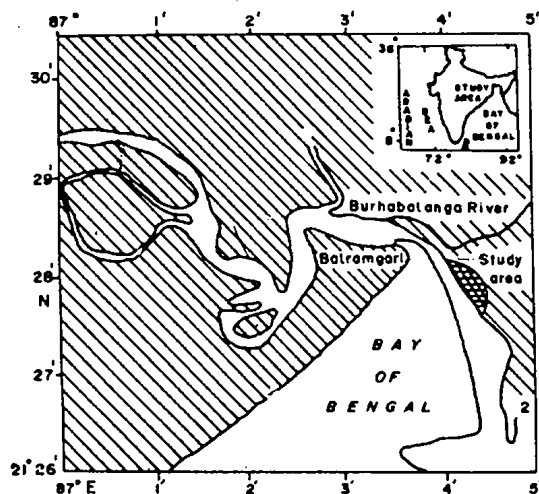


Fig. 1—Map showing the study area (hatched zone)

observations and collections of meiofaunal samples were carried out during fall spring tides of full and new moons. At each station sediment temperature was recorded and pH measured using portable pH meter (Philips 4016). Salinity, chlorophyll-*a* and particulate organic carbon (POC) analyses were done following the methods described by Parsons *et al.*⁶. Sand samples were collected during each observation for particle size analysis done by a modified graphic method⁷.

Meiofauna were collected in 3 replicates with a plexiglass core tube (4.5 cm diam. and 20 cm length) thrust into undisturbed beach sand, to a depth of 15 cm. Sediment in the core was further subsampled at 5 cm intervals, and preserved in 5% formalin with Rose Bengal for further processing in the laboratory.

Meiofauna were extracted by passing the sediment through a set of 2 sieves, the upper one with a mesh size of 0.5 mm and the lower one

with a mesh size of 0.062 mm. All the fauna retained on the lower screen were considered meiofauna and used for counts. Identification and enumeration of each taxon was done using Sedgwick rafter cell.

The sampling schedule of the present study was designed so that comparison of tide level, months, season and depths with respect to mean meiofaunal density could be made using 2 types of analysis of variance⁸. Relationships of meiofaunal density with environmental characteristics were examined using Pearson's correlation coefficient⁹. Dispersion patterns^{10,11} of meiofauna taxa at each station, were calculated according to Morisita's Index (Id).

Results

The meiofauna comprised 8 major groups (Table 1). The abundance of each faunal group encountered in different seasons in relation to

Table 1—Mean (\pm SD) abundance (no. 10 cm⁻²) of meiofauna (sediment depth: 0-5; 5-10 and 10-15 cm) at low, mid and high intertidal regions

Faunal group	Tide level (cm)	Northeast monsoon			Fair season			Southwest monsoon			Total faunal composition (%)
		0-5	5-10	10-15	0-5	5-10	10-15	0-5	5-10	10-15	
Nematoda	Low	156 \pm 98	69 \pm 16	54 \pm 45	28 \pm 27	55 \pm 9	74 \pm 74	127 \pm 63	23 \pm 14	44 \pm 31	5.9
	Mid	213 \pm 21	59 \pm 16	110 \pm 121	91 \pm 53	37 \pm 20	45 \pm 9	61 \pm 40	31 \pm 8	19 \pm 18	5.9
	High	122 \pm 55	85 \pm 31	28 \pm 8	56 \pm 19	32 \pm 11	65 \pm 40	63 \pm 43	44 \pm 35	29 \pm 21	4.0
Harpacticoida	Low	14 \pm 6	31 \pm 14	20 \pm 4	18 \pm 12	21 \pm 18	20 \pm 11	184 \pm 145	126 \pm 111	142 \pm 149	4.9
	Mid	39 \pm 11	14 \pm 7	9 \pm 3	23 \pm 22	33 \pm 8	34 \pm 12	127 \pm 134	119 \pm 139	177 \pm 206	4.9
	High	27 \pm 0	19 \pm 6	27 \pm 2	27 \pm 29	24 \pm 18	61 \pm 50	137 \pm 181	57 \pm 28	165 \pm 138	4.3
Turbellaria	Low	33 \pm 9	22 \pm 6	16 \pm 3	18 \pm 7	12 \pm 5	21 \pm 20	38 \pm 17	16 \pm 10	19 \pm 6	1.5
	Mid	12 \pm 9	12 \pm 7	23 \pm 6	11 \pm 5	11 \pm 3	9 \pm 3	26 \pm 20	12 \pm 5	76 \pm 86	1.4
	High	33 \pm 2	11 \pm 4	12 \pm 6	6 \pm 0	12 \pm 8	12 \pm 3	24 \pm 0	8 \pm 1	12 \pm 0	0.9
Ostracoda	Low	8 \pm 1	11 \pm 3	43 \pm 3	15 \pm 0	7 \pm 8	22 \pm 4	41 \pm 15	65 \pm 52	22 \pm 7	1.8
	Mid	11 \pm 4	10 \pm 4	14 \pm 1	18 \pm 0	22 \pm 0	12 \pm 0	20 \pm 9	35 \pm 18	37 \pm 2	1.4
	High	17 \pm 4	6 \pm 0	14 \pm 5	33 \pm 0	11 \pm 11	9 \pm 4	35 \pm 4	14 \pm 7	38 \pm 2	1.3
Lamellibranchiata	Low	93 \pm 39	25 \pm 1	24 \pm 6	12 \pm 5	7 \pm 8	12 \pm 0	13 \pm 1	14 \pm 5	7 \pm 1	1.6
	Mid	35 \pm 14	38 \pm 8	53 \pm 22	27 \pm 25	20 \pm 20	23 \pm 3	9 \pm 3	8 \pm 1	12 \pm 0	1.7
	High	15 \pm 0	0	11 \pm 1	8 \pm 3	30 \pm 0	7 \pm 1	0	0	18 \pm 12	1.3
Amphipoda	Low	11 \pm 1	12 \pm 5	12 \pm 6	6 \pm 0	14 \pm 4	6 \pm 0	52 \pm 7	58 \pm 21	65 \pm 52	1.8
	Mid	12 \pm 1	36 \pm 0	12 \pm 3	10 \pm 2	12 \pm 0	0	62 \pm 34	50 \pm 26	89 \pm 70	1.3
	High	9 \pm 3	6 \pm 0	21 \pm 15	0	6 \pm 0	9 \pm 3	60 \pm 7	29 \pm 17	68 \pm 54	0.8
Isopoda	Low	0	0	0	12 \pm 0	0	0	12 \pm 0	0	12 \pm 0	0.8
	Mid	12 \pm 0	6 \pm 0	9 \pm 3	0	12 \pm 6	6 \pm 0	0	0	12 \pm 0	0.8
	High	0	0	0	12 \pm 0	6 \pm 0	72 \pm 0	12 \pm 0	0	0	0.5
Cladocera	Low	12 \pm 3	113 \pm 97	45 \pm 33	32 \pm 0	38 \pm 0	44 \pm 0	609 \pm 285	608 \pm 266	692 \pm 552	18.4
	Mid	62 \pm 4	42 \pm 24	32 \pm 8	24 \pm 0	24 \pm 0	36 \pm 0	545 \pm 265	593 \pm 324	742 \pm 529	17.2
	High	108 \pm 0	78 \pm 30	96 \pm 0	81 \pm 0	45 \pm 0	81 \pm 0	398 \pm 135	550 \pm 264	571 \pm 387	15.7

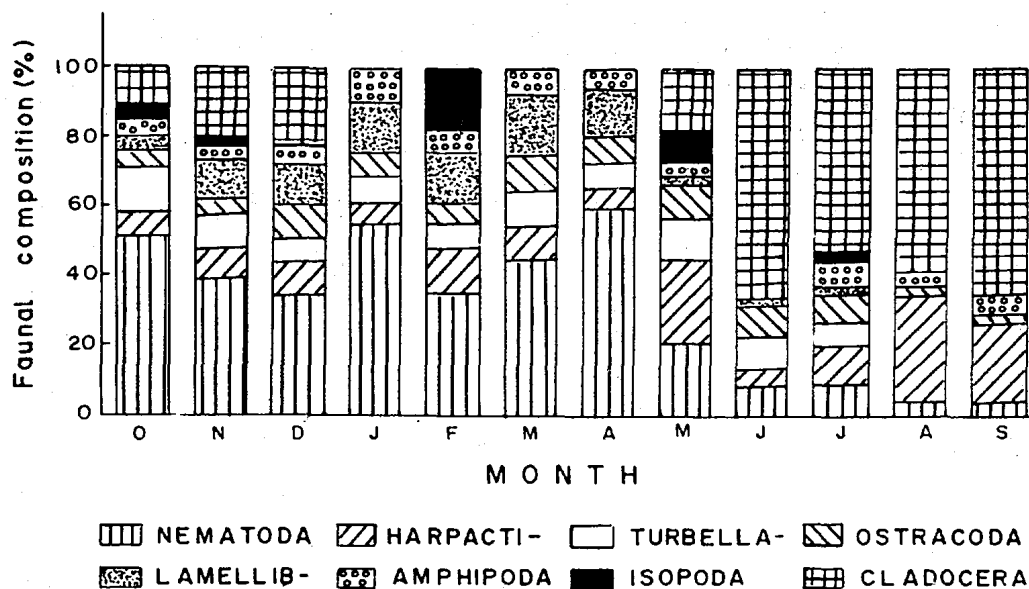


Fig. 2—Percentage of different groups collected during different months

depth and tide are also presented in Table 1. In general, the variations in the abundance of total meiofauna were highest during the southwest monsoon at all tide levels. Most abundant group was cladocerans (47.70%) followed by nematodes (15.71%) and harpacticoids (14.12%). Cladocerans showed a clear seasonality in their occurrence and minimum abundance was recorded during the northeast monsoon (Oct.-Jan.) and fair seasons (Feb.-May). Their density, however, increased in southwest monsoon season (June to Sept.) (Fig. 2). Similarly, nematodes were found in higher densities during northeast monsoon and fair seasons whereas, harpacticoids, though present throughout the year, had their highest densities during the southwest monsoon (Fig. 2). The abundances of turbellarians, ostracods, lamellibranchs, amphipods and isopods did not show any marked seasonal variation.

Analyses of variance were performed on the data for mean meiofauna number during three seasons with three depths of the sediment (0-5; 5-10 and 10-15 cm) and three tide levels (low, mid and high). Nematodes, harpacticoids and cladocerans showed significant difference in their abundance with tide level only during the fair and the southwest monsoon season. Except the cladocerans ($P < 0.05$) no other faunal group showed any significant variation in relation to depth. The abundances of other faunal groups did not show much of a variation with the tide level and depth of the sediment.

A comparison of the dispersion of different

meiofaunal groups at each station was tested by applying Morisita's Index ($I\delta$). Ostracods, turbellarians and lamellibranchs at Stations II, III and VIII respectively, showed a regular dispersion while the dispersion of other groups was patchy or contagious. The isopods showed a random dispersion (Table 2).

During the southwest monsoon season, sediment temperature, salinity, pH, POC and chl-*a* values were low whereas, mean grain size values were higher during the same season (Table 3). Meiofauna correlated with different environmental parameters by applying Pearson's correlation coefficient (Table 4) showed that, except the nematodes, all groups were negatively correlated with the salinity but the relationship between mean density of nematodes, turbellarians and ostracods with salinity was positive and significant ($P < 0.05$). A significant negative correlation was also found between the abundance of some of the faunal groups with pH. The only exception was turbellarians. Similarly, chlorophyll *a* also showed a significant negative correlation with the abundances of harpacticoids, ostracods, lamellibranchs and amphipods except nematodes, isopods and cladocerans which showed a positive correlation ($P < 0.05$). The abundance of cladocerans was positively correlated with POC whereas, nematodes, harpacticoids, lamellibranchs and isopods showed a negative correlation with POC.

The abundance of nematodes, harpacticoids, amphipods and cladocerans showed a significant relationship with mean grain size of the sediment

Table 2—Morisita's Index (I_d) of dispersion of meiofauna at each station

Group	Stations							
	I	II	III	IV	V	VI	VII	VIII
Nematoda	3.03	2.00	2.54	1.96	3.35	3.92	2.51	1.57
Harpacticoida	3.49	2.40	3.56	3.56	3.86	2.55	3.84	2.96
Turbellaria	1.37	1.45	0.95†*	1.21†	1.87	4.08	2.55	1.03†
Ostracoda	2.20	0.10*	1.25	1.49	1.25†	1.23	1.20	1.25
Lamellibranchiata	2.35	1.68	5.03	1.56†	2.33	2.86	1.24†	0.12*†
Amphipoda	3.33	2.77	2.84	2.63	2.77	1.25	5.47	2.62
Isopoda	0.50*†	0.66*†	—	0.90*†	1.86†	0.50*†	2.17	0.14*†
Cladocera	2.76†	3.17	3.10	3.13	2.12	1.85	2.04	2.38

*Regular dispersion

†Not significant ($P > 0.05$)Table 3—Hydrological parameters (\pm SD) at Balramgari

Parameters	Northeast monsoon (Oct.-Jan.)	Fair season (Feb.-May)	Southwest monsoon (June-Sept.)
Temp. ($^{\circ}$ C)	31.6 \pm 5.32	30.5 \pm 2.14	28.5 \pm 5.32
Sal. ($\times 10^{-3}$)	22.0 \pm 2.65	22.4 \pm 0.81	17.2 \pm 3.54
pH	7.6 \pm 0	7.5 \pm 1.08	7.5 \pm 0.7
Chl- <i>a</i> (mg. m^{-3})	1.8 \pm 1.42	1.8 \pm 0.32	0.8 \pm 0.70
POC (mg. m^{-3})	1256 \pm 319	1287 \pm 537	2318 \pm 801
Grain size (ϕ)	2.31 \pm 0.01	2.29 \pm 0.07	2.66 \pm 0.14

and definite pattern in their occurrence observed (Fig. 3). The abundances of harpacticoids, amphipods and cladocerans were greater in sediment of finer sand whereas nematodes was relatively low in finer sand. The abundance of ostracods, lamellibranchs, turbellarians and isopods was not consistent with the grain size of the sediment.

Discussion

The Balramgari beach is directly exposed to wave action and the profile of the beach is extremely variable⁵. The sediment is poorly sorted and comprised high silt/clay content (unpublished data). During the southwest monsoon, the magnitude of the river discharge increases and the direction of the longshore currents is from north to south¹². The river flow obstructs the sediment transport leading to significant deposition of the finer sediment in the study area and provides a suitable environment for meiofauna.

The meiobenthic community of the present study is a temporal and spatial mosaic and follows a trend of different levels of succession. Most of the meiofaunal groups are closely related with the season, grain size, and depth of the sediment. These faunal groups are mainly distributed

within the top 5 cm of sediment. Meiofauna have been reported to occur to a depth of 50 cm in beach sediment and can attain a high density in the upper 20 cm on high energy sandy beaches¹³. Such meiofaunal distribution leads to clumped or contagious dispersion which reiterates the fact that meiofauna are patchy in distribution¹⁴.

The intertidal meiofauna of Balramgari are similar to those reported from Indian coast¹⁵. However, the incidence of cladocerans was unusual and not reported, so far. The cladocerans are basically planktonic and thrive well in limnetic marine environments¹⁶. Some of the species of Macrothricidae and Chydoridae are known to be benthic and occur within the surface layer of beach sediments¹⁷. The occurrence of cladocerans in relatively higher densities than the other meiofaunal groups during southwest monsoon season raised a question about their distributional relationship with other groups. There is no information available on the occurrence of freshwater or marine cladocerans in estuarine beach sediment. In the present study, all the specimens of cladocerans (mostly *Diaphanosoma excism*¹⁸) were identified purely as freshwater forms. However, a definite pattern in the occurrence of cladocerans was observed on the Balramgari beach during June to September with a highest density in September. The abundance of cladocerans on the beach showed clear temporal and spatial variation. Density of cladocerans was maximum at low tide level and minimum at high tide level during fair and southwest monsoon. Occurrence of these cladocerans on the estuarine beach could be due to land runoff because the discharge of the river Burhabalanga is also reported to be high during southwest monsoon season.

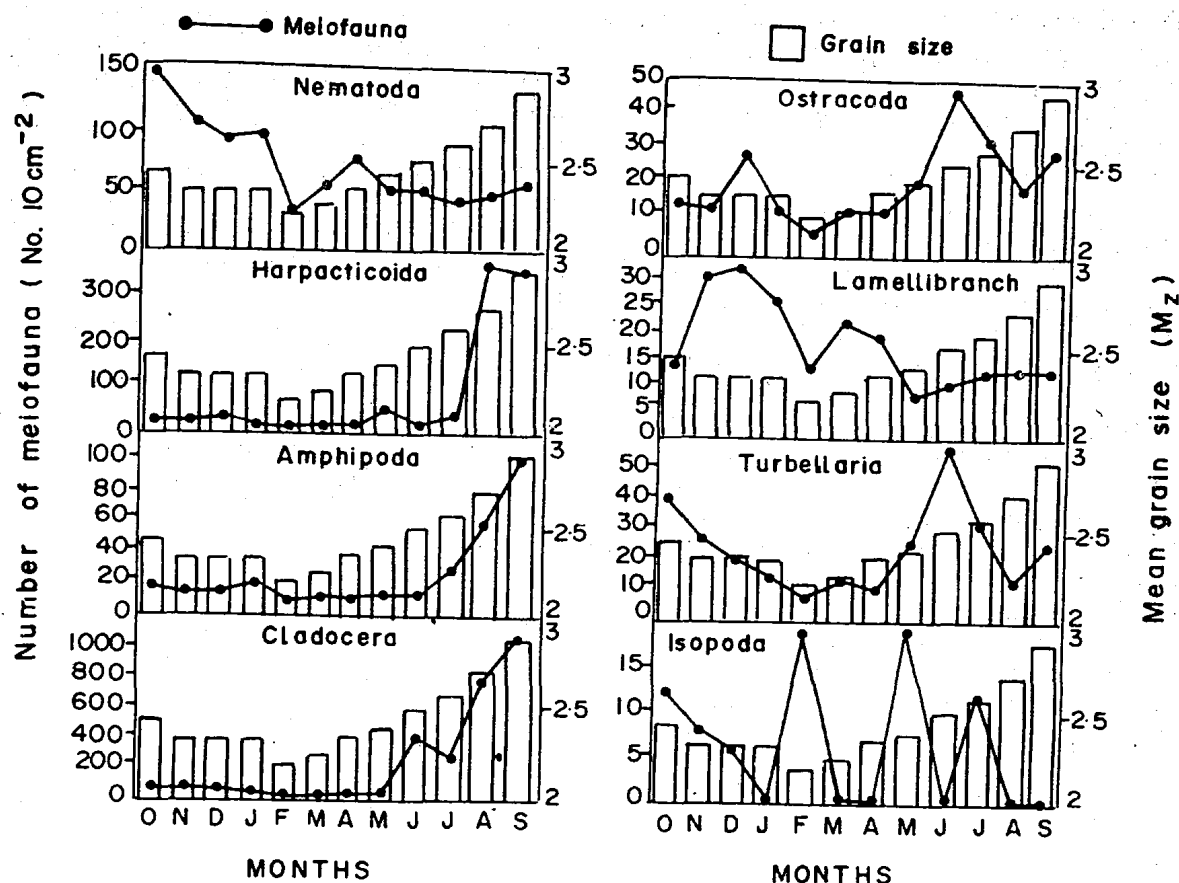


Fig. 3—Density of meiofauna in relation to mean grain size (M_z) of the sediment of the study area

Table 4—Pearson's correlation of coefficient between groups and different hydrological parameters

Group	Temp.	Sal.	pH	Chl- <i>a</i>	POC	Mean grain size
Nematoda	-0.387	0.005*	-0.101	0.185	-0.168	-0.220
Harpacticoida	0.351	-0.242	-0.599	-0.315	-0.005*	-0.006*
Turbellaria	0.498	-0.006*	-0.004*	0.432	0.331	0.315
Ostracoda	0.322	-0.003*	0.440	-0.340	0.504	0.539
Lamellibranchiata	-0.554	-0.499	0.271	-0.295	-0.477	-0.477
Amphipoda	0.445	-0.232	0.269	-0.006**	0.759	0.906
Isopoda	0.007*	-0.204	-0.187	0.182	-0.567	-0.312
Cladocera	0.499	-0.203	0.004	0.400	0.796**	0.935**

*Significance $P < 0.05$

**Significance $P < 0.01$

Further, to confirm the presence of freshwater cladocerans in the Burhabalanga river, an attempt was made to collect the cladoceran by a horizontal tow of a zooplankton net at the river mouth, close to the study area. Surprisingly, no cladoceran specimens were recorded in the zooplankton sample during the study period. The sediment also was found to be completely devoid of resting

cladocerans eggs. This indicates that the cladocerans are not true inhabitants of the estuarine beach¹⁶, their occurrence is accidental, and possibly due to land runoff.

The temperature of the interstitial waters showed a narrow range of variation whereas, a wide fluctuation in salinity occurred was mainly due to the southwest monsoon flow of the

river Burhabalanga. In the present study, no taxa showed significant correlation with the temperature except for isopods. However, temperature was reported to be an important limiting factor in controlling the distribution of nematodes in mangrove sediment².

Nematodes occurred at all depths and tide levels during different seasons and constituted 15.17% of the total meiofauna group. Nematodes were reported to occur to a depth of 60 cm in the intertidal sediments¹³. Their density, however, decreased with increasing depth. The distribution of nematodes was significantly affected by the changes in the salinity. At a lower salinity (southwest monsoon) a low density of nematodes was recorded. An increase in salinity (northeast monsoon) coincided with an increase in nematode density. A strong positive correlation between the abundance of harpacticoids with season was found in the present investigation. In the reduced salinities during August to September, the density of harpacticoids was relatively high. This corroborates earlier findings¹⁹. Except for turbellarians, no other group showed any significant correlation with pH.

It is rather difficult to ascertain the influence of a single environmental factor independently and other factors in the control of the abundance of meiofauna. However, laboratory studies²⁰ have revealed that the abundance of meiofauna is highly correlated with the different grades of sands than any other factors. The availability of food is also an important limiting factor in controlling meiofaunal abundance. These animals feed actively on diatoms, bacteria, protozoans, detritus and dissolved organic carbon²¹. Maximum density of meiofauna occur during the southwest monsoon season in coincidence with high POC values in the sediments (2318 mg. m⁻³). This shows that the availability of food is one of the important factors controlling the meiofauna density on a particular beach¹⁴. Alongi²² and Harkantra & Parulekar²³ reported a significant correlation in the distribution of meiofauna with chl-*a*. However, in the present study chl-*a* was not found to play any significant role in controlling meiofaunal abundance except in amphipods (Tables 3, 4).

Sediment characteristics of a beach have been considered as an important factor in controlling the distribution and abundance of meiofauna²³. In the present investigation, the mean grain size is between 2.18 and 2.86 phi. It is clearly evident that during the southwest monsoon the density of meiofauna was high and was influenced significantly by the grain size of the sediments. Second-

dly, during this season, the organic input to the beach also increased considerably due to land runoff which could have contributed to the high meiofaunal density²⁴. Impoverished meiofauna however, has been reported from sandy beaches during the southwest monsoon along the west coast of India²⁵. During the southwest monsoon, the cladocerans were the main contributors (65.55%) and increased the total density of meiofauna, considerably. Harris¹⁹ however, did not find any significant correlation between meiofauna and sediment grain size.

The significant interaction between hydrological features and the occurrence of meiofauna indicates that conditions during the different seasons affect the meiofauna densities at different depths. This is probably controlled chiefly by salinity and mean grain size of the sediments.

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