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Population fluctuation and vertical distribution of meiofauna in a tropical mudflat at Mandovi estuary, west coast of India

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A study was conducted to observe the meiofaunal community structure and its temporal and spatial fluctuation and a profile of vertical distribution of a mudflat in relation to sediment temperature, grain size, organic carbon and sedimentary chlorophyll *a*. The sampling was carried out for three seasons viz. Pre-monsoon (summer), monsoon and post-monsoon. The faunal density (no/10 cm^2) ranged between 945-2063/10 cm^2 and 704-1549/10 cm^2 at stations 1 and 2 respectively. The fauna was dominated by nematodes, turbellarians and harpacticoid copepods. The fauna fluctuated seasonally. A vertical zonation in the distribution of fauna was significantly correlated with interstitial water, chlorophyll *a* and sediment organic carbon. It is suggested that meiofauna in mudflats serve as food for the higher trophic levels.

The mud flats are specialized intertidal ecosystems between sea and estuaries. Materials are brought to and removed from mud flats largely as a function of water movements and the pattern of water movement is the determinant of the direction and thrust of nutrients flux in these complex systems. High rate of production in mud flats including saltmarsh is well documented[1,2]. It is generally believed that high production in mudflats is a function of high nutrient availability. The fine particles of mudflats tend to adsorb more nutrient particles because of larger interstices. The mudflats are covered with water at high tide and act as sink for the nutrients which come along with water from the adjoining areas. Meiofauna is reported to be rich in estuarine mudflat[2].

Very little information available from Indian coast on the meiofauna of mudflats[3,4]. This somewhat meager data suggests that there is a need for more information on meiofaunal community of tropical mudflats and their temporal changes, whether stochastic, seasonal or long-term to understand their trophic relation in the benthic ecosystem. This study was undertaken to provide answers to the basic question on what are different types of meiofaunal metazoans and their spatio-temporal variation in the mudflat of Mandovi estuary in Goa, west coast of India.

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Materials and Methods

The intertidal mudflat of the Mandovi estuary (Fig. 1) is the transformation of gentle sloping of near-shore bank of Mandovi, which is filled with silt, clay, and detritus brought by river water from the upper reaches including mangrove swamps. The mudflat extends more than 4 km and gets inundated by incoming seawater of high tide. The marshy, muddy bottom, vegetated with mangroves make it highly productive with respect to benthic production, thus invites high number of economically important species of avian fauna and fishes for feeding purpose. The entire mudflat consist of loose muddy soil bordered by mangrove aforestation.

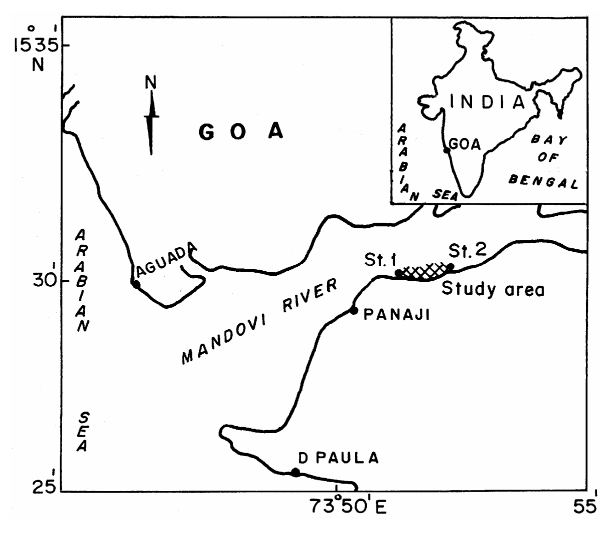

Fig. 1 — Mandovi estuary along Goa coast

Sediment samples for environmental parameters and meiofauna were collected from two stations (Fig. 1) with the help of a hand core of 4.5 cm inner diameter and 10 cm length situated approximately 800 m apart in the estuary. The stations were selected based on their proximity to mangroves station 1(lat 15° 29.45"N, long 73°51.40" E) was closer than station 2 (lat 15°30"N, long 73°52.30"E). Samples for horizontal and vertical distribution were collected during pre-monsoon (Feb-May 1999), monsoon (June-Sept 1999) and postmonsoon (Oct 1999-Jan 2000) seasons. Monthly sampling was carried out wherein three replicate cores were collected at low tide by inserting the 10 cm length core into the sediment from each station. The core sediments were sub-sectioned at 1 cm interval for the study of vertical distribution of meiofauna, grain size analysis, organic carbon content and chlorophyll *a*. Sediment samples for meiofauna were treated with 5% formalin mixed with rose bengal solution. Sediment temperature was recorded with the help of a centigrade thermometer. Interstitial water was collected for the estimation of salinity and dissolved oxygen. In the laboratory, meiofauna were sorted with the help of two sieves, the upper one of 0.5 mm mesh and the lower one of 0.062 mm mesh size. The animals retained on the finer mesh screen were considered as meiofauna[5]. The counting was done under microscope and dry weight biomass were obtained by multiplying a factor of 0.00045 with total number of taxa recorded on each sampling date and station[6].

For the estimation of salinity, method of Strickland & Parsons[7] was followed. Oxygen concentration was estimated using an oxygen meter. The percent interstitial water of the sediment was measured regularly. Wet sediment from the fraction of core was weighed on a watchglass, dried at 100°C to constant weight and re-weighed. Wet weight minus dry weight was interpreted as a rough estimate of the weight of interstitial water from which the percent interstitial water was calculated[8]. Organic content of the sediment was determined by chromic acid oxidation[9]. Sedimentary pigment determination was made to obtain estimates of chlorophyll *a* in the sediment[10], and sand silt and clay fractions of the sediment were analysed[11].

Simple correlation coefficient (r) was used to find the relation between different environmental parameters and meiofaunal density. The data on meiofaunal density obtained in the present study was subjected to ANOVA analysis to understand whether there exists any significant difference in the meiofaunal densities with depth.

Results

Environmental parameters

The physico-chemical parameters are illustrated in Fig. 2. Sediment temperature was observed to vary from a low of 26°C in monsoon to 30°C in premonsoon (summer) in the mudflat area of the estuary. This variation is due to the heavy precipitation of rain water which decreases the water temperatures and also due to the cloudy nature of atmosphere which does not allow much of heating to take place. The variation in salinity of the interstitial water was from 18 in August to 35 psu in May. The dissolved oxygen content varied from 3.5 to 4.5 ml/l. The oxygen content was highest during the monsoon period. The dissolved oxygen content showed an inverse relation with temperature and salinity, as expected.

The sediment was predominantly loose mud and had silt as most dominant constituent with sand and clay in different proportion at the two stations (Table 1). Observations taken in three seasons showed little

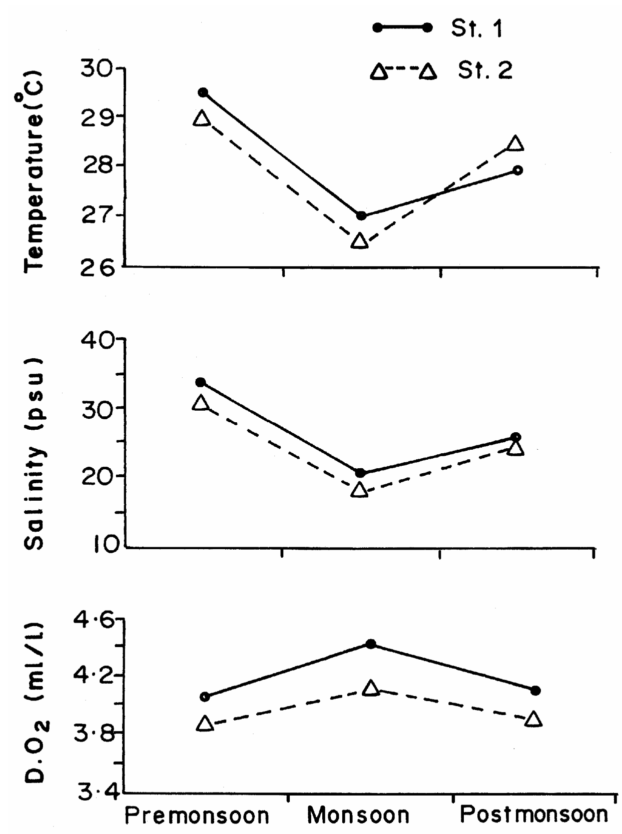

Fig. 2 — Environmental parameters at the study stations

variation in sand, silt and clay. The average value of sand, silt and clay at station 1 was 11.06, 73.57 and 15.36% respectively while at station 2 the values for the same are 14.06, 75.63 and 10.3%, respectively.

The sedimentary chlorophyll *a*, organic carbon and interstitial water are illustrated in Fig. 3. Sediment chlorophyll provides information on the primary productivity in the sediment and is considered to be an important parameter in the shallow estuarine area. Chlorophyll *a* content varied from 2.6 to 18.6 and 2.2 to 17.4 µg/g at stations 1 and 2. The chlorophyll *a* values showed a clear seasonal pattern. The values were significantly higher during the pre and post-monsoon (Nov-Dec) period and lowest during monsoon period (July-Aug) ($p \leq 0.01$). Similarly the organic carbon of the sediment ranged from 1.60 to 2.92% and 1.25 to 3.82% at stations 1 and 2 respectively. The percent of interstitial water of the 5 cm core sediment varied between 40.5 and 47.6% at st 1 and 31.6 and 38.6% at st 2. No significant differences were seen in the interstitial water content due to seasonal variation.

Vertical distribution of environmental parameters

A well defined vertical profile was recorded in the interstitial water, sediment organic carbon and chlorophyll *a* concentration (Table 2). The interstitial water content showed a decreasing trend from surface to a depth of 5 cm in the sediment. A difference of over 50% in the organic carbon values was seen in the top (0-2 cms) and bottom (2-5 cms) layer. Chlorophyll *a* followed the same trend of decrease with increasing depth. Average maximum value of 16.6 µg/g was recorded at the surface and lower value of 2.2 µg/g was recorded at a depth of 5 cm.

Abundance and composition of meiofauna

Total number of meiofauna varied from 945 to 2063 no/10 cm^2 at station 1 and 704 to 1549 no/10 cm^2 at station 2 in the mudflat area sampled (Table 3). The total biomass fluctuated between 0.42 and 0.92 mg/10 cm^2 at station 1 and 0.31 to 0.69 mg/10cm^2 at

Table 1 — Sedimentary properties at stations 1 and 2 during 1999

Season	Sand (%)		Silt (%)		Clay (%)	
	St 1	St 2	St 1	St 2	St 1	St 2
Pre-monsoon	11.28	13.28	87.42	77.62	1.30	9.23
Monsoon	12.28	17.64	70.74	66.93	16.98	158.54
Post-monsoon	9.62	11.40	62.57	82.44	27.81	6.24

Table 2 — Vertical profile of chlorophyll *a*, organic carbon and interstitial water at stations 1 and 2

[Values are average of three seasons ± SD]

	Core depth (cm)				
	0-1 cm	1-2 cm	2-3 cm	3-4 cm	4-5 cm
Station 1					
Chlorophyll a (µg/g.sed)	15.2±1.5	8.7±1.07	5.5±0.8	3.2±0.6	2.2±0.3
Organic carbon (%)	3.4±0.3	2.40±0.2	1.92±0.2	1.64±0.2	0.92±0.1
Interstitial water (%)	48±5	45±6	42±6	38±6	36±4
Station 2					
Chlorophyll ā (µg/g.sed)	16.6±2.6	10.8±1.9	6.62±1.2	4.5±0.6	2.2±0.8
Organic carbon (%)	3.2±0.3	2.50±0.4	1.6±0.3	1.6±0.2	1.2±0.1
Interstitial water (%)	38±7	36±6	31±8	25±5	24±6

Table 3 — Total average density (no/10cm^2) and biomass (mg/10 cm^2) of meiofauna at station 1 and 2

Season	Station 1		Station 2	
	Density	Biomass	Density	Biomass
Pre-monsoon	1969 ± 109	0.88 ± 0.545	1525 ± 103.5	0.68 ± 0.235
Monsoon	985 ± 42.5	0.435 ± 0.2	765 ± 60	0.34 ± 0.165
Post-monsoon	1462 ± 92	0.65 ± 0.62	1378 ± 85	0.615 ± 0.325

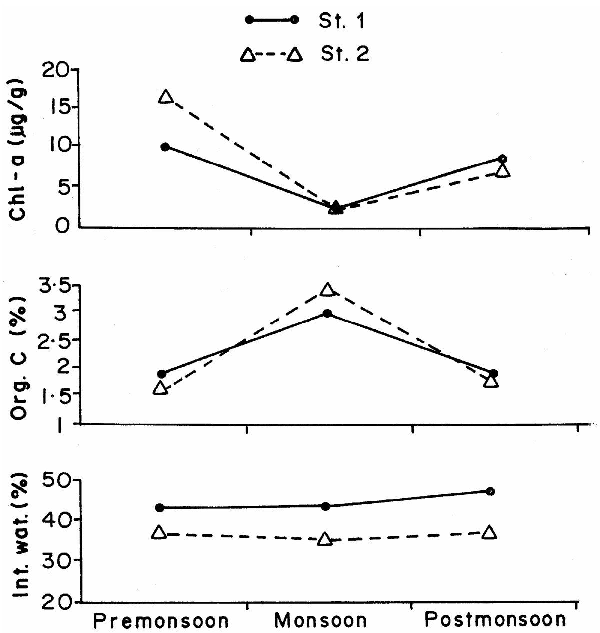

Fig. 3 — Seasonal variation in chlorophyll *a*, organic carbon and interstitial water

station 2. The fauna in general was similar both quantitatively and qualitatively in the estuary. The faunal density was lowest during the monsoon period and increased during the pre and post-monsoon period at both the stations.

Three major groups were represented in the present study. Nematodes were the most abundant group with a density of 589 to 1457 no/10 cm^2 at station 1 and 452-1144 no/10 cm^2 at st.2. They contributed 65 and 66% at stations 1 and 2, respectively. Turbellaria was the second most abundant group with density of 259-336 no/10 cm^2 and 193-329 no/10 cm^2 at st 1 and 2, respectively. They contributed 21 and 22% at stations 1 and 2. Harpacticoid copepod remained the third major group and contributed 7 and 9% at stations 1 and 2, respectively. Other taxa (tardigrada, gastrotricha, foraminifera, oligochaeta and crustacean nauplii) occurred in limited number and collectively averaged between 4 and 6% of the total fauna. Temporal variation in different stations has been illustrated in Fig. 4.

Vertical distribution of fauna

On an average over 65% of the total fauna was restricted to the top 0-2 cm layers and there was a consistent decrease in the number with increasing depth in the sediment. This trend was observed in three seasons (Table 4). Vertical distribution of major groups is given in Figs 5 and 6. The faunal density

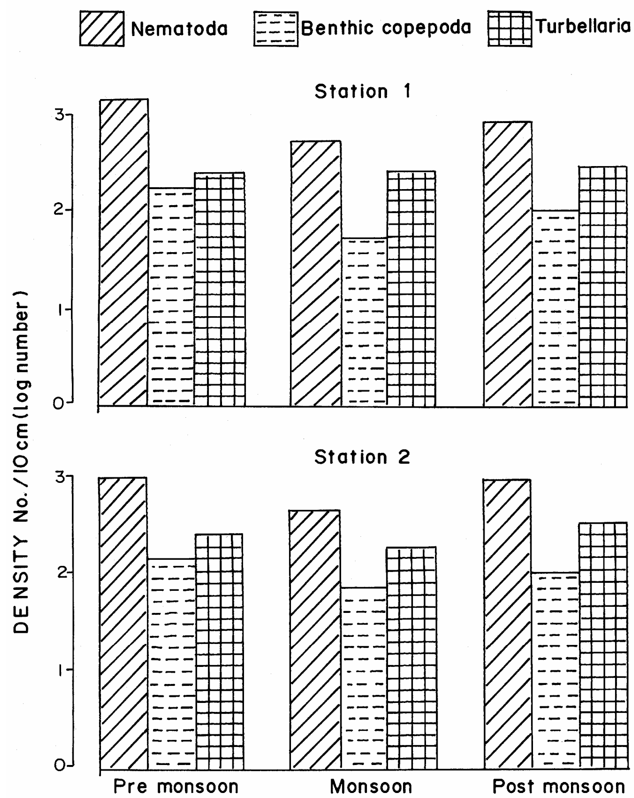

Fig. 4 — Distribution of major taxa at study stations 1 and 2

decreased with increasing depth in the sediment. There was consistency in the vertical profile of meiofauna and the pattern of vertical distribution and its variation was similar at both the stations. Out of a total number of 4416 only about 2% were present at the 4-5 cm layer and the remaining in the top layer.

Majority of nematodes (< 75%) were found in the 0-3 cm layer of sediment and there was a significant difference ($p \leq 0.01$) in the total number observed between 0-1 and 4-5 cm depth. Turbellarians were restricted in the top 4 cm layer with 55% population restricted to 0-1 cm layer. Benthic copepods are sensitive to oxygen tension and 90-100% occurred in the top 3 cm layer.

Discussion

The hydrographical features observed in the present study area follow the seasonal cycle[12]. The low temperature was due to the heavy precipitation, which decreases the water temperature, and also due to the cloudy nature of atmosphere, which does not allow much of heating to take place. The intense precipitation and land runoff during monsoon brings about large changes in the hydrographical features whereas during post and pre-monsoon seasons the estuary remains well mixed.

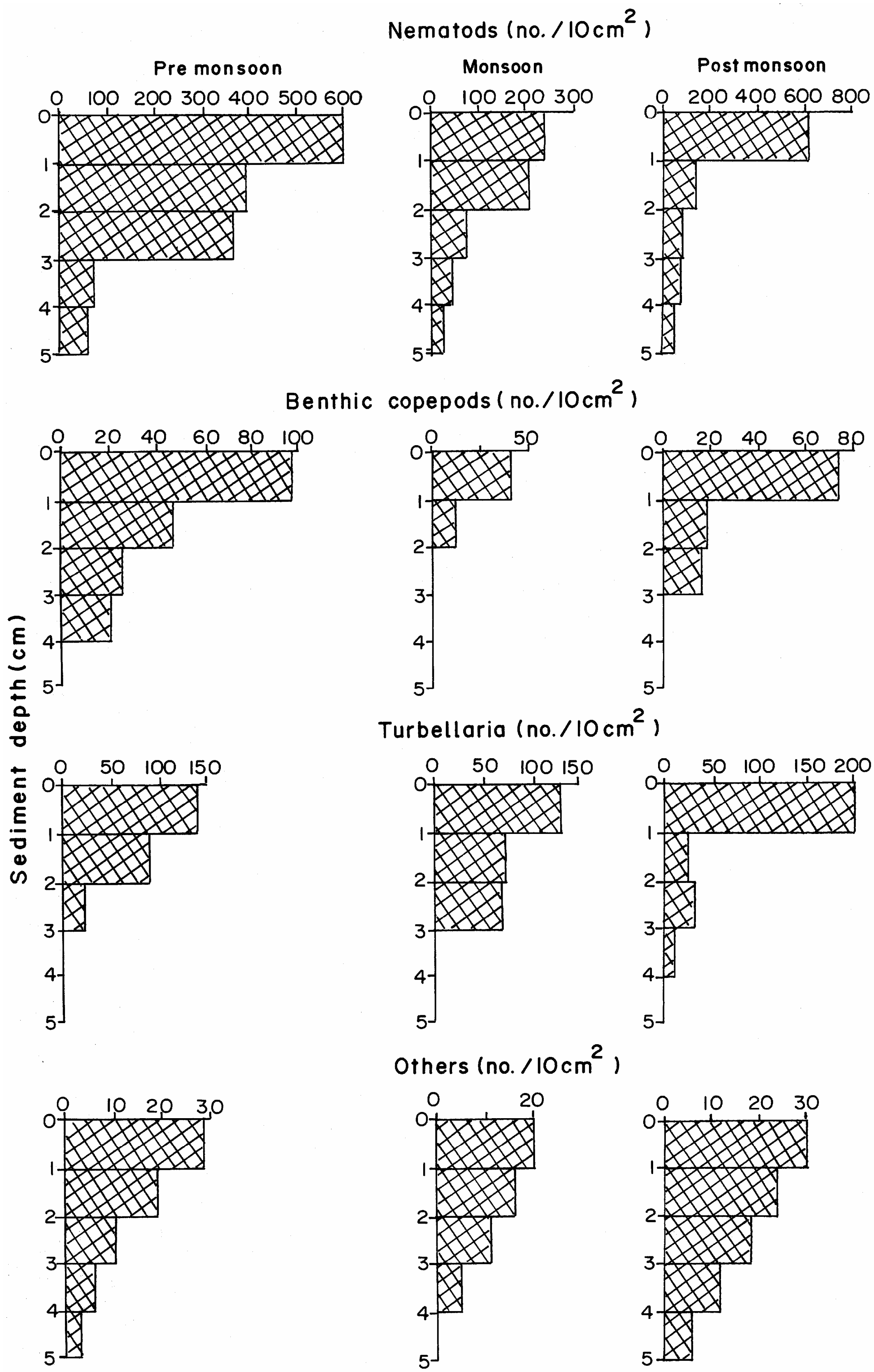

Fig. 5 — Vertical distribution of major meiofaunal taxa at station 1 during different seasons

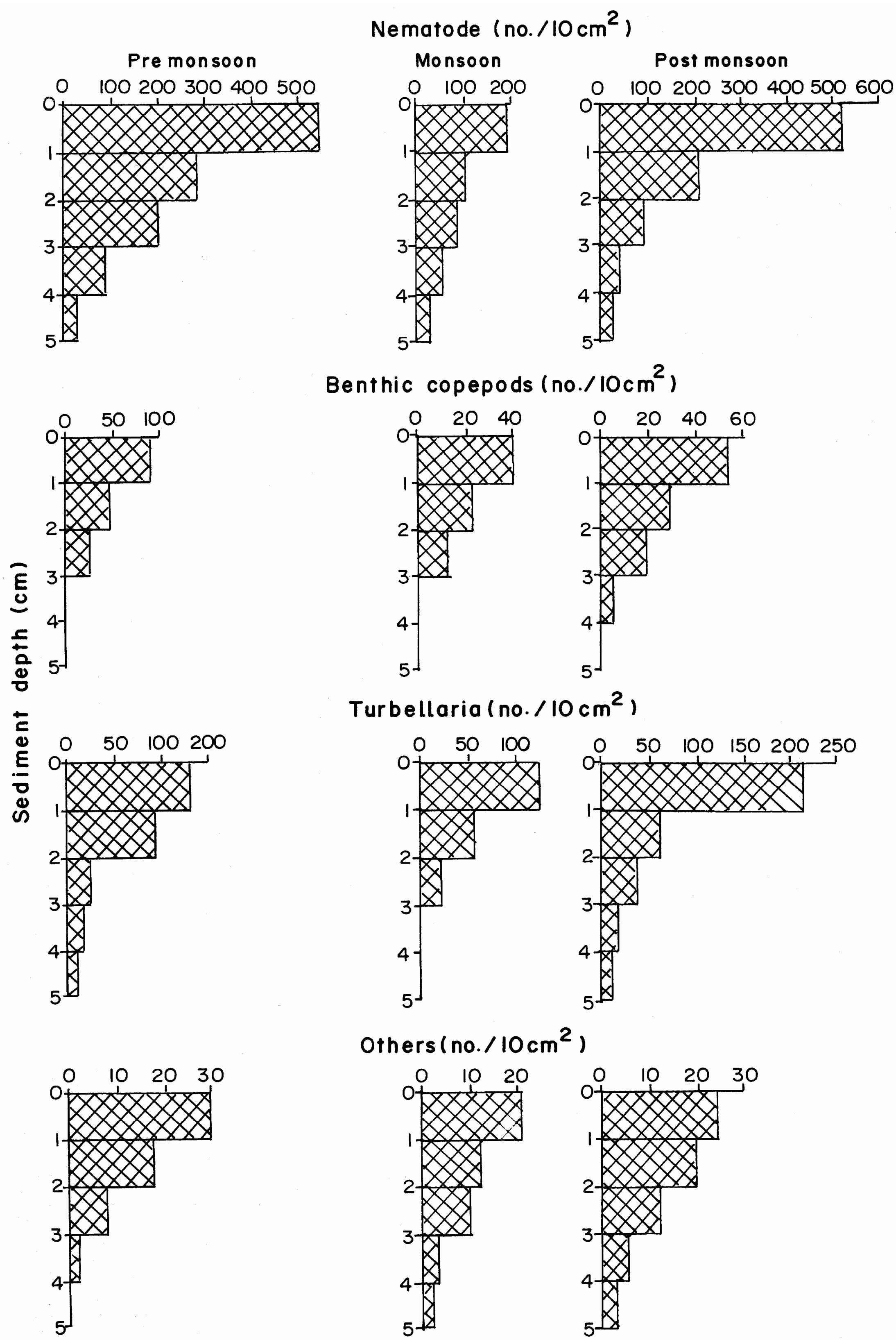

Fig. 6 — Vertical distribution of major meiofaunal taxa at station 2 during different seasons

Table 4 — Vertical distribution of meiofauna (no/10cm^2) at stations 1and 2

Season	Core depth (cm)				
	0-1	1-2	2-3	3-4	4-5
			Station 1		
Pre-monsoon (April- May)	873	532	393	121	50
Monsoon (July- Aug)	438	314	167	43	23
Post-monsoon (Nov-Dec)	920	240	194	66	42
			Station 2		
Pre-monsoon (April- May)	795	380	255	96	20
Monsoon (July- August)	381	187	119	53	25
Post-monsoon (Nov-Dec)	813	325	163	51	25

Temporal distribution of meiofauna

The meiofauna of the present study area showed considerable fluctuation in the total density, which coincided with parallel changes in some environmental parameters. These fluctuations in meiofauna were to a large extent affected by variations in the density of nematodes, which constituted more than 65% of the total meiofauna. Similar results on the temporal variation have been reported from estuarine muddy substratum of the Indian coast[1,13] and fluctuations were correlated with the density of the most dominant group, namely nematoda.

The total density observed in the present study was similar to those reported from other shallow regions of the Indian coast[14,15]. High to very high density of meiofauna in the fine sandy substratum of beach has also been reported[16]. Benthic fauna of the mud banks of the Kerela coast reported much higher density than observed in the present study. Similarly high meiofaunal density (4094 no/10cm^2) in the muddy substratum of mangrove swamp area on east coast of India have also been reported[13].

Temporal changes were more discernible and observed in different dominant groups. Higher density in pre and post-monsoon followed by low density in monsoon was the feature of this study. The dominance of nematodes followed by turbellaria and harpacticoid copepodes are the general feature of meiofauna reported from different geographical regions[8,17,18]. In most of the studies nematodes are the dominant group and temporal variations are mainly due to the variations occurred in this group.

Vertical distribution of meiofauna

On an average over 50% of the density of all taxa occurred in the 0-2 layer and progressively decreased with increasing depth in the sediment (Fig. 7).

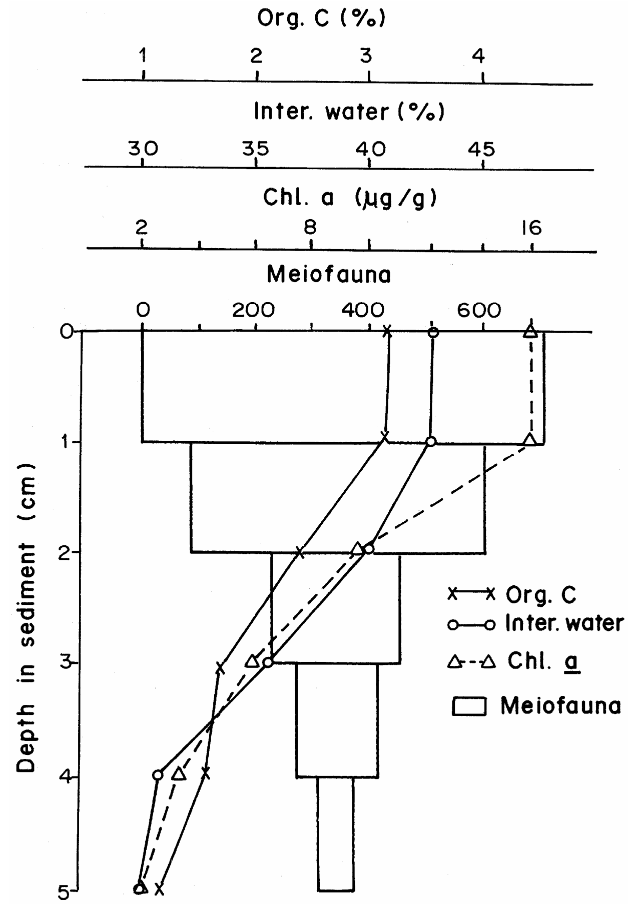

Fig. 7 — Vertical distribution of meiofauna, Chlorophyll *a*, interstitial water and organic carbon in the sediment

Significant vertical decrease in densities as observed in the present study have also been reported earlier[1,2,5,19,20]. Nematodes were the only group present in the entire core and dominated the fauna. A number of nematode species are known to withstand near anaerobic condition in the sediment[21] and this may explain the regular occurrence of this group in the

Table 5 — Macrofaunal density (no/m^2) at stations 1 and 2

	Station 1	Station 2
Pre-monsoon	392	335
Monsoon	112	128
Post-monsoon	206	245

deeper layers of the present study. Among other groups copepodes and turbellarians have also shown vertical reduction in the density. A significant decrease in the turbellarians with increasing depth and positive correlation with oxygen concentration was also observed[22]. The difference in the meiofauna taxa is also due to the clumped distribution of the meiofauna[23].

Generally those parameters which control macrofauna are also responsible for the distribution and abundance of meiofauna. Food availability, and oxygen are considered important factors responsible for the vertical distribution of meiofauna[24,25] Significant vertical decrease in the meiofaunal density was positively correlated with sediment chlorophyll *a* ($r=0.82$ $p\leq0.01$) interstitial water ($r=0.77$; $p\leq 0.01$) and organic carbon ($r=0.73$; $p\leq0.01$) (Fig. 7). These factors can prove limiting in shallow areas such as mud flats and mangrove swamps[25,26] as they form important sources of food and energy supply.

Trophic relation

There has been much debate on the ultimate fate of meiobenthos in the ecosystem. The present study area is a part of an estuarine mudflat and according to Coull[27] the pathways from estuarine meiofauna could be linked to macrofauna, nektonic forms and nutrient regeneration. The abundance of meiofauna in mud flat areas is regulated by macrobenthic predation. High macrofaunal abundance was recorded at two stations in which polychaetes and crustaceans were most dominant groups (Table 5). It is because majority of meiofauna in mud flat occur in the top few centimeters of sediment where they are easily accessible to predators including fishes[28]. The nematodes seem to play the role of conveyer belt and therefore the meiofauna of mud flat could be considered important as food for higher trophic levels.

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