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STATISTICAL STUDIES AND ECOLOGY OF *BENTHIC FORAMINIFERA* FROM TAMILNADU COAST, INDIA

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INTRODUCTION

The foraminiferans are the most diverse phylum of mieofauna . Foraminifera are found in all marine environments. they may be planktic or benthic in mode of life. It has been estimated that the total number of foraminiferans species might be approximately 4000 living species of foraminifera. The present paper deals with the distribution and diversity of marine foraminiferans all over Tamilnadu Coast. Foraminiferal distribution has been reported by many workers. Foraminiferans were the most abundant group of meiofauna at the sampling sites. The number species per station ranged from 11 to 32.

MATERIAL AND METHODS

The sediment samples were collected from intertidal areas of Tamil Nadu coast during 2006 to 2007. Twelve stations were chosen for the present stady from Chennai- 1 Pondicherry-2, Cuddalore-3, Karaikal-4, Nagapattinam-5, Thondi-6, Thiruchendur-7, Tuticorin-8, Mandapam-9, Pamban -10, Rameswaram-11 and Kanyakumari along the Tamil Nadu Coast. Sediment samples were collected with a plastic cover (3 cm internal diameter) up to a depth of 15 cm. Sampling was made during low tide, mostly near the mid tide level. The samples were vertically subdivided into slices of 0-2, 2-4, 4-6, 6-10 and 10-15 cm depth . Meiobenthos was extracted from sediments by decanting with tap water and washing through a 500 mm sieve suspended above a 45--m sieve (McIntyre,1969). Animals were stored in 5% formaldehyde solution and coloured with Rose Bengal (0.1 g in 100 ml distilled water).

Fig. 1. Map showing the study area

HISTORY AND DISTRIBUTION OF FOR AMINIFERANS

The recent reviews of Bhalla *et al.* (2007) and Khare *et al.* (2007) on foraminiferal studies in near shore regions of western and eastern coasts of India reveal that most of the studies are related to taxonomic and ecological aspects and palaeoenvironmental interpretations. A few studies have been undertaken along the eastern coast of India on applied aspects of Foraminifera. Taxonomic and ecological studies on foraminifera from west coast of India were carried out by some

researchers. Bhalla & Nigam (1979) and Bhalla & Gaur (1987) worked on foram diversity of Calangute and Colva beach sands respectively. Bhalla & Raghav (1980) studied the ecologyof Foraminifera of Malabar coast and suggested that salinity is the chief governing factor. Raj & Chamyal (1998) studied the ecology of foraminifera of Mahi valley of Gujrat. Shareef & Venkatachalapathi (1988) reported 40 and 41 species of foraminifera from bhatkal and Devgad islands, respectively. Nigam (2005) addressed the question as to how environmental issues can be solved through Foraminifera. Some studies were carried out on taxonomy and ecology of Foraminifera from beaches and estuaries of east coast of India. Foraminiferal diversity in relation to different ecological condition was reported by Bhalla (1968) from Vishakhapatnam beach sands. Hamsa (1973) and Kathal & Bhalla (1998) from palk Bay and Gulf of Mannar, Narappa *et al.* (1981) from Godavari river system, and Kathal *et al.* (2000) from Kanyakumari, and Satyanarayana *et al.* (2007) from Nagapattinam. Very scanty literature is available on Foraminifera of Lakshadweep (Gupta 1973; Rao *et al.*, 1987; Saraswati 2007). To utilize these marine protists efficiently, adequate Knowledge of their diversity and distribution pattern in modern environment is of utmost importance. Therefore, a study of intertidal forams was undertaken comparing the east and west- coast and the sensitivity of forams to monsoons. This paper presents the scanning electron photomicrographs of inter tidal forams along the Indian coast, so as to benefit researchers in diverse areas who use Foraminifera.

Foraminiferans Diversity

A total of 37 species of foraminiferans as belonging to 21 families were recorded in the present study. The list is follows :

Check list of Foraminiferans of Tamilnadu

FORAMINIFERANS													
Family: Ameridae													
1.	*America* sp.	-	-	-	+	-	-	+	-	-	-	+	-
Family: Soritidae													
2	*Amphisorus* sp.	+	-	-	-	+	-	+	+	+	+	+	+
Family: Bolivinidae													
3	*Bolivina abbreviata*	+	+	+	+	-	+	+	+	+	+	-	-
Family: Cibicidae													
4	*Cibicides lobotulus*	+	+	+	-	-	+	-	-	-	-	-	-
5	*C. refulegens*	-	-	-	-	-	-	-	-	-	-	-	+
Family: Cyclamminidae													
6	*Cyclammina* sp.	-	-	-	-	-	+	-	+	-	-	-	-
Family: Discorbidae													
7	*Discorbis* sp.	+	+	+	+	-	+	+	+	+	+	+	-
8	*Rotalia pulchella*	+	+	+	+	+	-	+	-	-	-	-	-
9	*R. translucens*	-	+	+	-	+	-	-	-	-	-	-	-
Family: Elphidiidae													
10	*Elphidium* sp.	+	+	+	-	-	-	-	+	-	+	-	+
Family: Eponididae													
11	*Eponides repandus*	+	+	+	+	+	+	+	+	+	+	+	+

Family: Candeinidae													
12	*Globigerina* sp.	+	+	+	-	-	-	+	-	+	-	+	+
13	*Globigerinita* sp.	-	+	+	-	-	-	-	-	-	-	-	-
Family: Vaginulinidae													
14	*Legena* sp.	+	+	+	-	+	-	+	-	-	+	-	-
Family: Neoconorbinidae													
15	*Neoconorbina* sp.	-	-	-	-	+	-	-	+	-	-	+	+
Family: Nonionidae													
16	*Nonion depressulum*	-	+	+	-	-	-	+	+	-	-	-	-
Family: Heterolepidae													
17	*Oridosalis umbonatus*	-	-	-	+	+	-	-	-	-	-	-	-
Family: Planulinidae													
18	*Planulina* sp.	-	-	-	-	-	-	-	+	-	-	-	-
19	*Planorbullina* sp.	-	-	-	-	-	-	-	+	-	-	-	-
Family: Hauerinidae													
20	*Quinqueloculina bradyana*	+	+	+	+	+	+	+	+	+	+	+	+
21	*Q. laevigata*	+	+	+	-	-	-	+	-	-	-	-	-
22	*Q. agglutianans*	+	+	+	-	-	+	-	-	-	-	-	-
23	*Q. oblanga*	+	+	+	-	-	+	-	-	-	-	-	-
24	*Q. lamarkiana*	-	-	-	-	-	+	-	-	-	-	-	-
Family: Rosalinidae													
25	*Rosalina agglutinans*	+	+	+	+	+	+	+	+	+	+	+	+
26	*R. floridana*	-	+	-	-	-	-	+	-	-	+	-	-
27	*R. globularis*	+	+	+	+	+	+	+	+	+	+	+	+
28	*R. vilardeboana*	+	-	+	-	-	-	-	+	-	-	-	-
29	*R. bradyi*	+	+	+	+	+	+	+	+	+	+	+	+
Family: Rotaliidae													
30	*Ammonia beccarii*	-	+	+	+	-	+	+	+	+	+	+	+
Family: Spirillinidae													
31	*Spirillina lateseptata*	-	-	-	-	-	-	+	+	-	+	-	+
32	*S. limbata*	+	+	+	+	+	+	+	+	+	+	+	+
Family: Nubeculariidae													
33	*Spiroloculina antillarum*	-	+	-	-	-	-	-	-	-	-	-	-

Family: Textulariidae													
34	*Textularia cuneiformis*	+	-	-	-	-	-	-	-	-	+	-	-
35	*T. candiana*	-	-	-	-	-	-	-	-	-	-	-	+
36	*T. agglutinans*	-	+	-	+	-	-	-	+	-	+	-	+
Family: Miliolidae													
37	*Triloculina* sp.	+	+	+	+	+	+	+	+	+	+	+	+

Abundance of foraminiferans

The foraminiferan density ranged from 24 to 285 ind. 10 cm^{-2}, 72 to 220 ind. 10 cm^{-2}, 65 to 345 ind. 10 cm^{-2}, 20 to 210 ind. 10 cm^{-2}, 40 to 210 ind. 10 cm^{-2}, 90 to 190 ind. 10 cm^{-2}, 90 to 235 ind. 10 cm^{-2}, 15 to 140 ind. 10 cm^{-2}, 110 to 160 ind. 10 cm^{-2}, 90 to 240 ind. 10 cm^{-2}, 85 to 190 ind. 10 cm^{-2}, and 50 to 150 ind. 10 cm^{-2}, at stations 1-12 respectively during 2006.

Whereas during 2007, it was observed 24-151 no/10 cm^2, 90-175 no/10 cm^2,45-180 no/10 cm^2, 50-330 no/10 cm^2,5-90 no/10 cm^2,80-395 no/10 cm^2,120-495 no/10 cm^2, 20-70 no/10 cm^2, 90-155 no/10 cm^2, 90-290 no/10 cm^2, 40-180 no/10 cm^2 and 60-150 no/10 cm^2 at stations 1-12 respectively.

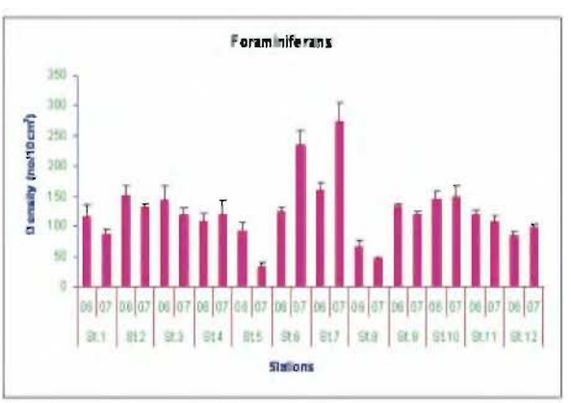


Fig. 2. MDS for foraminiferans of Tamil Nadu coast during 2006 and 2007.

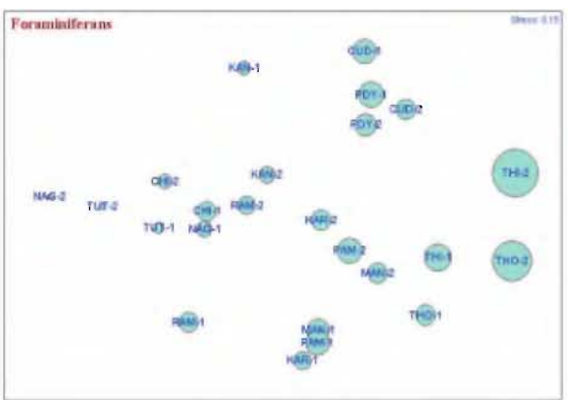


Fig. 3. MDS for foraminiferans of Tamil Nadu coast during 2006 and 2007.

Fig. 3. **CHI**-Chennai; **PDY**-Puducherry; **CUD**-Cuddalore; **KAR**-Karaikal; **NAG**-Nagapattinam; **THO**-Thondi; **THI**-Thiruchendur; **TUT**-Tuticorin; **MAN**-Manddapam; **PAM**-Pamban; **RAM**-Rameswaram; **KAN**-Kanyakumari; **1**-2006: **2**-2007

The mean density of foraminiferans ranged between 67 no/10 cm^2 and 160 no/10 cm^2 during 2006 and 32 no/10 cm^2 and 275 no/10 cm^2 during 2007. Highest densities of foraminifera were recorded at station 7 during 2006 and 2007 (Figs. 2 & 3), while lowest density was observed at stations 8 and 5 respectively during 2006 and 2007.

Species composition of foraminiferans

A total of 37 species belonging to 24 genera were identified. The number species per station ranged between 13 to 24. The foraminiferans were dominated by *Rosalina globularis* (0.63-3.39%), *Quinqueloculina bradyana* (0.5-3.38%), *Eponides repandus* (0.67-2.26%), *Rosalina agglutinans* (0.37-2.08%) and *Triloculina* sp. (0.27-1.51%) There was only seven species, which occurred in all the 12

stations. These are *Eponides repandus, Quinqueloculina bradyana, Rosalina globularis, Rosalina agglutinans, Rosalina bradyi, Spirillina limbata and Triloculina* sp. (Table 1). The species such as *America* sp., *Cibicides lobotulus, C. refulegens, Cyclammina* sp., *Rotalia pulchella, Elphidium* sp., *Globigerinita* sp., *Neoconorbina* sp., *Nonion depressulum, Oridosalis umbonatus, Planulina* sp., *Planorbullina* sp., *Q. laevigata, Q. agglutianans, Q. oblanga, Q. lamarkiana, Spirillina lateseptata, Spiroloculina antillarum, Textularia cuneiformis, T. candiana* and *T. agglutinans* were observed occasionally.

Family composition of foraminiferans

A total of 21 families of foraminiferans were recorded. These were in order of their importance: Rosalinidae (1.89-6.23%), Hauerinidae (0.75-3.69%), Eponididae (0.67-2.26%), Rotaliidae (0.34-2.26%) and Spirillinidae (0.3-2.38). Only 5 families could be characterized as very common at all the 12 stations. These are Eponididae, Hauerinidae, Rotaliidae, Spirillinidae and Miliolidae.

The families such as Soritidae, Cibicidae, Cyclamminidae, Elphididae, Vaginulinidae, Neoconorbinidae, Nonionidae , Heterolepidae and planulinidae were occurred sporadically.

Diversity indices of foraminiferans

The diversity indices were lowest at stations 9 (Mandapam) and 11 (Rameswaram), which can be considered as indications of the stress at these sites. At station 11 is situated very close to Rameswaram temple. At stations 1, 2 and 3 had higher values of diversity indices although it had very high density of foraminiferans. It must be also be stated the sediment here was fine sand. (Table-2)

Table 2. Shannon-Winner diversity index (H') and evenness of foraminiferans species at various stations of Tamil Nadu coast during 2006 and 2007.

Stations	S	N	D	J'	H'(log2)	1-Lambda'
1	20	116	3.997	0.9498	4.105	0.9402
2	24	152	4.578	0.9655	4.427	0.9547
3	22	144	4.226	0.9408	4.195	0.941
4	14	107	2.782	0.9743	3.71	0.9272
5	13	92	2.654	0.9489	3.512	0.9071
6	15	124	2.904	0.9558	3.734	0.9216
7	19	160	3.547	0.9416	4	0.9265
8	20	67	4.519	0.9616	4.156	0.9498
9	12	135	2.242	0.9577	3.433	0.9053
10	17	146	3.211	0.9158	3.743	0.91
11	13	119	2.511	0.9693	3.587	0.919
12	16	85	3.376	0.9622	3.849	0.9345

No significations difference between the meiofauna and stations could be demonstrated by the ANOVA test at the $p>0.05$ level (Table 23).

Table 3. One-way ANOVA of all species of foraminiferans and different stations.

Factor	SS	Df	Ms	F(cal)		P(F<=F(cal)	F(0.05)
A (Between Groups)	246.40	11	22.40	1.002	N.S. (P>0.05)	0.443	1.811
R(A) (Within Groups)	9654.81	432	22.35				
AR (Total)	9901.21	443					

The *k*-dominance curves for the foraminiferans species and stations show that in terms of dominance and diverse are similar (Fig. 4) The *k*-dominance curves were significant different from the stations. At stations 9 and 11 are the most highly dominated. Probably because at stations 11 situated very close to Rameswaram temple, which was highly disturbing by tourist.Whereas stations 2 and 3 are the more diverse. It must be also be stated that sediment here was fine sand. Thus the foraminiferal population and diversity are highest in very fine grained sediments, while density secrease coarser grained sediments. These findings also support the results of Shannon- Wiener diversity index (H') and MDS analysis. The differences between the other stations are less amenable interpretation as the curves cross (Fig. 4)

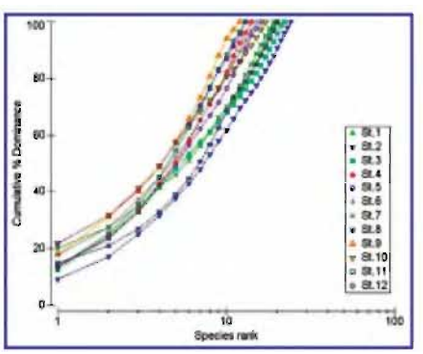


Fig. 4. Average k-dominance curves derived from foraminiferans species at all the 12 stations of Tamil Nadu coast.

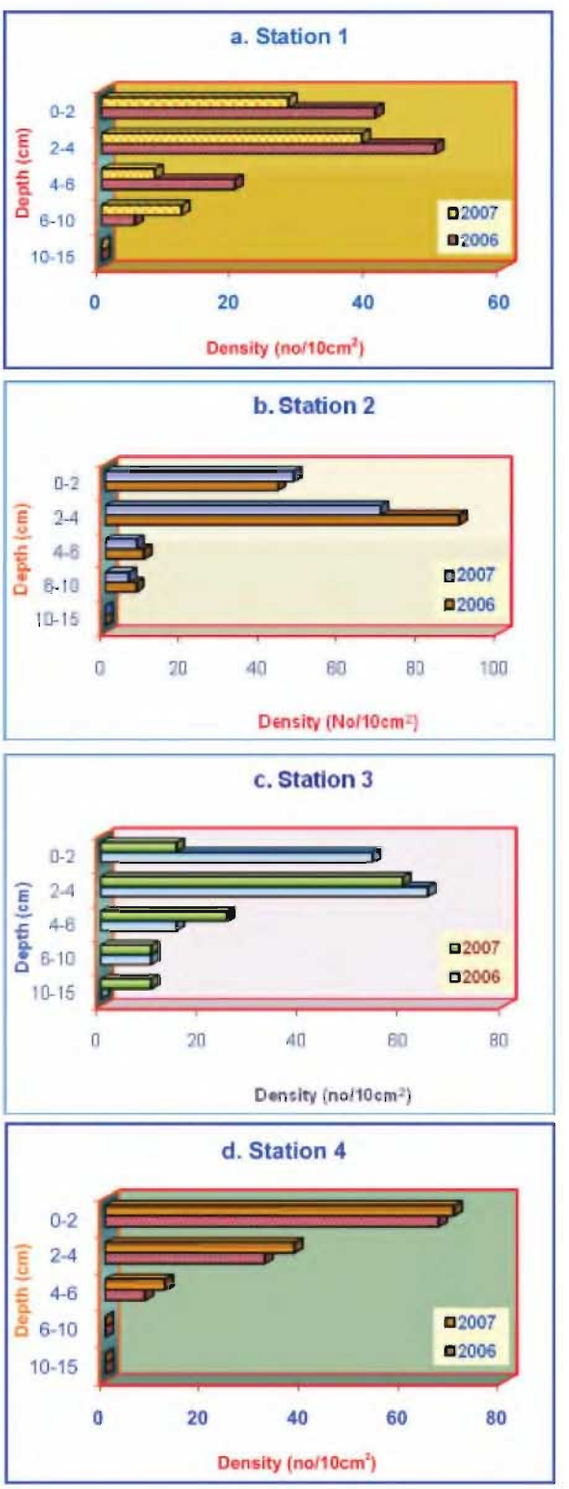
Vartical distribution of foraminiferans

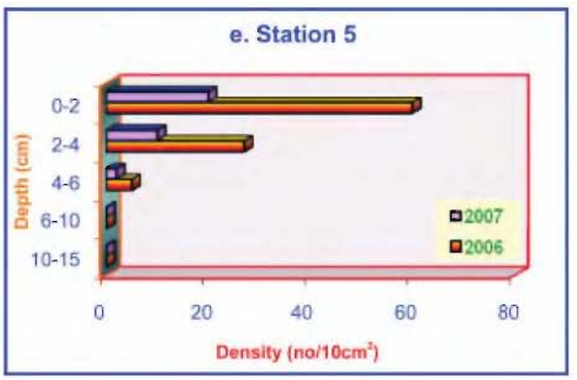
The upper layers of 0-2 cm (20-120 ind. 10 cm^{-2}; 4-11% of the total meiofauna at this interval) and 2-4 cm interval (10-70 ind. 10 cm^{-2}; 3-10% of the total meiofauna at this interval) show a high abundance of foraminiferans in muddy sediments (Fig. 30d, e, f, g,h, j & k) Whereas in sandy sediment, the maximum value of 90 ind. 10 cm^{-2} (9% of the total abundance) was recorded at 2-4 cm interval (Fig. 31a, b, c & 1)).

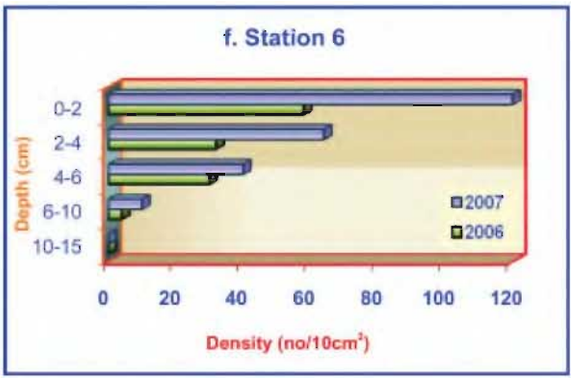
From 4-6 cm interval in sandy sediments, a minimum of 8 ind. 10cm^{-2} and maximum of 45 ind. 10 cm^{-2} was recorded, whereas in muddy dediments range between 2-85 ind. 10 cm^{-2} was recorded.

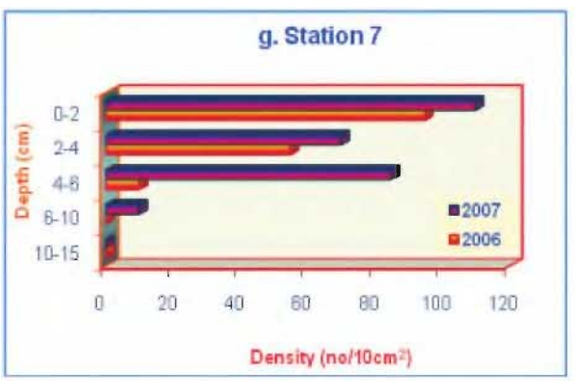
The other depth intervals of sandy sediments had 4-12 ind. 10 cm^{-2} and 0-15 ind. 10 cm^{-2} at 6-10 cm and 10-15 cm intervals respectively . In muddy sediments, it's range from 0 to 10 ind.10 cm^{-2} at 6-10 cm interval. However, it was totally absent in 10-15 cm depth interval in muddy sediments.

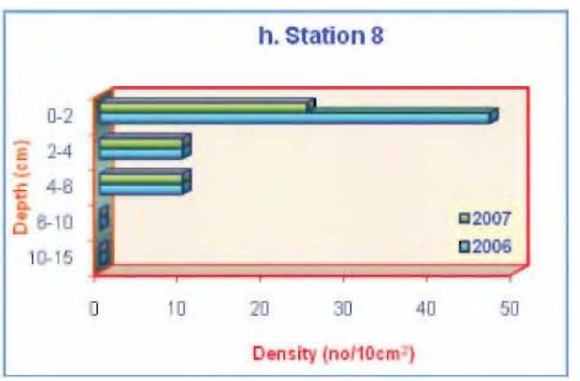
Fig. 5. Vertical distribution of foraminiferans of Tamil Nadu coast at stations 1-12

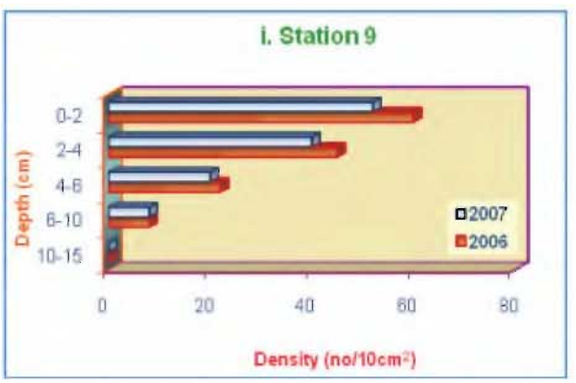


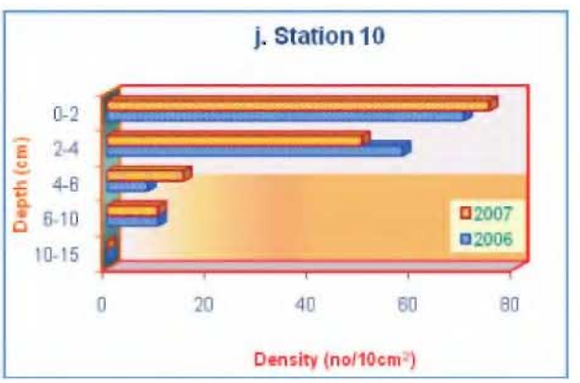

e. Station 5
Depth (cm)
0-2
2-4
4-6
6-10
10-15
2007
2006
0
20
40
60
80
Density (no/10cm²)

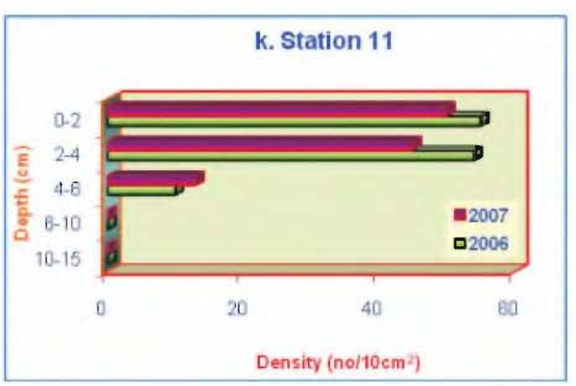

f. Station 6
Depth (cm)
0-2
2-4
4-6
6-10
10-15
2007
2006
0
20
40
60
80
100
120
Density (no/10cm²)

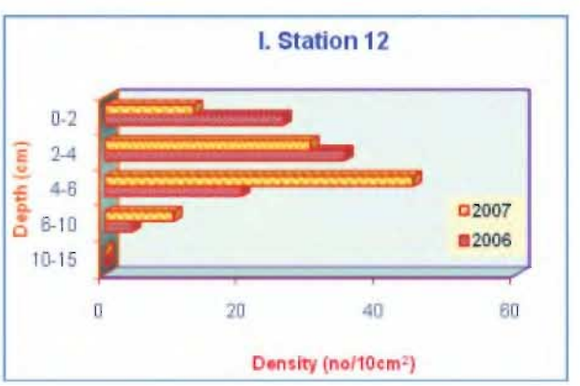

g. Station 7
Depth (cm)
0-2
2-4
4-6
6-10
10-15
2007
2006
0
20
40
60
80
100
120
Density (no/10cm²)


h. Station 8
Depth (cm)
0-2
2-4
4-6
6-10
10-15
2007
2006
0
10
20
30
40
50
Density (no/10cm²)


i. Station 9
Depth (cm)
0-2
2-4
4-6
6-10
10-15
2007
2006
0
20
40
60
80
Density (no/10cm²)


j. Station 10
Depth (cm)
0-2
2-4
4-6
6-10
10-15
2007
2006
0
20
40
60
80
Density (no/10cm²)


k. Station 11
Depth (cm)
0-2
2-4
4-6
6-10
10-15
2007
2006
0
20
40
60
80
Density (no/10cm²)


l. Station 12
Depth (cm)
0-2
2-4
4-6
6-10
10-15
2007
2006
0
20
40
60
Density (no/10cm²)

Foraminiferans were most important among meiofauna, probably because all sampling sites situated in the marine environment had fine sand. Similar observation was made by Varshney *et al.* (1984) and Nigam and Chaturvedi (2000). It is well known that foraminiferans occur mostly under high saline conditions with few species penetrating into the estuarine conditions (Gooday, 1988).

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