Recent Benthic Foraminifera in Surficial Sediment off Kodiyakarai, Palk Bay, Tamilnadu, East Coast of India

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Abstract

Various hydrographic parameters such as temperature, salinity, oxygen content as well as bathymetry and substrate condition affect the distribution of foraminifera. However, it has not been convincingly shown that these are the sole factors influencing the distribution of foraminiferal populations in the shelf environment. Recent benthic foraminifera in surficial sediment off Kodiyakarai, Palk Bay, Tamilnadu, east coast of India has been studied. In total, 48 species belonging to 14 families and 22 genus were identified. The following species are widely distributed in the offshore samples, namely *Ammonia beccarii*, *A. dentata*, *A. tepida*, *Asterorotalia trispinosa*, *Spiroloculina communis*, *Quinqueloculina elongatum*, *Q. lamarckiana*, *Q. seminulum*, *Triloculina trigonula*, *Elphidium crispum*, *Parallina hispidula*, and *Assilina ammonoides*. The environmental parameters mainly sediment texture and salinity appear to govern the abundance distribution of foraminifera in this region. Live/ dead ratio in benthic population ranges between 0.7 and 4.39 %. It suggests a low rate of sedimentation in this region.

Keywords: Benthic Foraminifera, Environment, Off Kodiyakarai, Palk Bay

Introduction

Palk Bay is one among the five major sediment sinks of India. The study area off Kodiyakarai is located in Palk Bay of Tamilnadu (Fig.1). The area is influenced by major drainage patterns of the River Cauvery, which transports large amounts of terrigenous sediments into shelf, producing coastal shoal. This part of the area is also located in a Sethusamudram canal project where intensive downslope sediment transport processes are observed. The study area is endangered with high siltation (Loveson *et al.*, 1990; Gandhi, 1999; Jena *et al.*, 2001; Mohan *et al.*, 2000; Santhidevi and Rajamanickam, 2009; Kumar, *et al.*, 2000; Sundararajan and Natesan, 2010). Foraminifera are sensitive even to subtle changes in ambient environmental conditions and, therefore, have emerged as potential tools for assessing any climatic/environmental changes. The east coast of India has prolific presence of foraminifera and a number of studies have been published on foraminiferal characteristics from this region particularly on taxonomy and distribution. However, literature is sparse and scattered in the present study area off Kodiyakarai and, therefore, it is most appropriate to study the foraminiferal distribution its relationship with modern environmental conditions.

Fig.1: Location map of study area.

Study Area

Palk Bay, named after Sir Robert Palk (1717-1798), the then Governor of Madras Presidency (1755-1763), is situated in the southeast coast of India encompassing the sea between Point Calimere (Kodiyakarai) near Vedaranyam in the north and the northern shores of Mandapam to Dhanushkodi in the south. It is situated between Latitude 9° 55' - 10° 45' N and Longitude 78° 58' - 79° 55' E. The Palk Bay itself is about 110 km long and is surrounded on the northern and western sides by the coastline of the State of Tamilnadu in the mainland of India. Palk Bay and Gulf of Mannar to its south are connected by a narrow passage called Pamban Strait, which is about 1.2 km wide and 3 to 5 m deep that separates the Island of Rameswaram from the mainland. The region between Nagapattinam and Adirampattinam 18 strandlines are identified. They vary in length from 100 to few Km. They are aligned EW, NW and SW, NNE - SSW and SW-NE (Fig. 2). The hydrographic parameter of the Palk bay is shown in the Table-1.

Fig.2: Geomorphological map of the study area.

Table-1: Hydrographic parameters of Palk Bay.

S.No.	Parameters	Range
1	Temperature	35oC
2	Salinity	34.3 ppt
3	PH	8.72
4	DO	3.5ml/l
5	Gross and Net primary production	0.67mgC/l/day
6	Rainfall	909.7
7	Tides and currents	0.41 msl

Methodology

Surface sediment and water samples were collected at 7 locations off Kodiyakarai from water depths between 1.0 and 10 m. Sediment samples were collected using grab sampler deploying both mechanized and country boats in the month of May, 2011. Sediment samples immediately after collection were preserved in a 10% neutralized formaldehyde solutions, neatly labeled for further sample processing, analysis and foraminiferal separation (Walton, 1952). Calcium Carbonate was determined by volumetric method (Hutchinson and McClelland, 1947). Organic carbon content is determined by the Walkey–Black method (1947), adopted and modified from Jackson (1958). For identification, classification of Loeblich and Tappan (1988) has been followed in the present work. Scanning electron micrographs of different views of all the foraminiferal species were obtained using a JOEL JSM 6530 model.

Results and Discussion

In the present study, 48 species belonging to 14 families and 22 genera were identified. The foraminiferal taxa belong to five Suborders such as TEXTULARIINA, MILIOLINA, LEGENINA, GLOBIGERININA and ROTALIINA. The total distribution of foraminifera is shown in Table-2. The genus *Ammonia*, *Asterorotalia*, *Elphidium*, *Pararotalia* predominate in the assemblages. The fine grained beach sediment contains less abundance of foraminifera.

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Habitat	pH	Oxygen	Diatoms and other plants	Size	Salinity (parts per thousand)				
					0	9	18	27	36
Stagnant water	?	Deficiency	Deficiency	Small	Ammonastuta				
					Bathysiphon				
					Haplophragmoides Trochammina				
					Ammobaculites				
Open water		Excess	Excess	Normal	Streblus				
					Elphidium				
					Deficiency				
					Deficiency				

Fig.3: Assemblage and ecologic factors (adapted in part from data by Lowman, 1949).

Distribution of Foraminiferal Species

The Fig. 4 shows the pattern distribution of living foraminiferal species in the offshore region. The distribution of total living foraminiferal species is very less up to the depth of 5.5 m, whereas it is slightly increased at depths between 5.5 and 8.5 m. Due to the tidal fluctuation, and changing substrate, the diversity is also varied according to depths (Hayward, 1981). Sediment samples from the near shore region and inner shelf (maximum depth of ~30 m) yielded a high species diversity (Renata Szarek, *et al.*, (2006). The near shore region was typified by species *Quinqueloculina lamarckiana*, *Ammonia beccarii*, *Pararotalia nipponica* and *Elphidium crispum*, all of which have been recorded from shallow waters worldwide (Murray, 1991; Nisha and Singh, 2012). Few tests of *A. dentata* with long, slender spines were observed, but only in the relatively deeper water sediment samples. A similar observation was also made by earlier workers (*e.g.* Ragothaman, 1974; Rajeshwara Rao, 1998; Nisha and Singh, 2012). *A. dentata* with short, blunt spines are more common in the near shore waters. The species *Asterorotalia trispinosa* is dominated in all the samples. Smaller sized foraminifera observed in some sampling locations may be due to the fine sediment texture.

Live/Dead Ratio

Live/dead ratio in benthic foraminiferal assemblages ranges between 0.7 and 4.39. It suggests a low rate of sedimentation in this region. The low rate of sedimentation prevailing in this part is in agreement with the findings of Paropkari (1979), Setty and Nigam (1982) and Paropkari *et al.*, (1993) who reported low organic matter in the places of low sedimentation rate. The organic matter is also found to be low in this area. According to Demaison and Moore (1980), relatively higher values of organic matter content in the vicinity of the coast is related to high input of terrigenous matter.

Fig.4: Distribution of living foraminifera in percentage.

Ecology of Foraminifera

The distribution and abundance of living foraminifera are controlled by a number of natural factors which include temperature, salinity, water depth, nutrients, sediment substrate, dissolved oxygen content, organic matter etc. The results of ecological parameters and living/dead species are shown in Table-3. Kodiyakarai is found to be highly favourable for the foraminifera; probably because of protected environment due to the impact of long shore current. In spite of lesser water depth and more protective in nature, it may also be ascribed to the wider undisturbed contact with open sea.

Temperature

The present study does not show much variation in temperature at different depths in the offshore stations (29°C to 30°C). This is due to the fact that the stations are located in the nearshore environment within the depth of 15 m. From the overall distribution of the foraminifera in the present area, it may be observed that the temperature condition is within the tolerance for the thriving of foraminifera fauna throughout the year.

Salinity

Each benthic foraminifera species, has a specific limit of its tolerance to salinity besides other factors. In all sampling locations, the salinity does not show much variation due to mixing of water and due to bay nature of the coast (Table-2). But up to 1.5 m depth, is slightly decreased. Salinity increased at the depths of 5.5 and 8.5m and species diversity also increased accordingly.

Table-3: Distribution of ecological parameters, textural parameters, living, dead foraminifera off Kodiyakarai.

Distance	Depth in m	Calcium Carbonate	Organic matter	Salinity	Substrate	Standard Deviation	Mean	Skewness	Kurtosis	pH	Dead %	Living %
0.5	1.5	0.47	0.33	34.5	Silty Sand	0.501	2.518	0.028	1.075	6.500	99.29	0.71
1.5	3	2.46	0.09	34.2	Silty sand	0.398	2.091	-0.110	1.080	7.000	98.740	1.26
3	5.5	3.33	0.33	35.67	Fine Sand	0.492	2.559	-0.195	1.205	7.000	87.77	2.23
4.2	6.7	19.47	0.28	35.85	Fine Sand	0.457	2.406	0.114	1.112	7.500	98.310	3.60
5.5	7.5	7.7	0.09	35.2	Fine Sand	0.564	2.012	0.098	1.042	7.500	95.77	4.22
6	8	7.22	0.05	35.44	Fine Sand	0.409	2.575	0.087	0.875	7.500	95.72	4.08
6.5	8.5	8.14	0.14	35.3	Fine Sand	0.539	2.536	-0.036	1.083	7.500	95.77	4.23
Average		6.97	0.19	35.31		0.480	2.385	-0.002	1.0676	7.214	95.91	2.90

Water Depth

The effect of water depth is difficult to assess because other ecological factors vary with depth, like temperature, light intensity, pressure, oxygen etc. (Boltovskoy and Wright, 1976). For the present study, samples were collected from 0 to 15 m depth. The number of foraminiferal species is increased from 5.5 m depth may be due to the tidal fluctuation and shadow zone environment; the lesser number of species is observed up to the depth of 3.0 m.

Sand-Silt-Clay Ratio

The textural attributes of sediment samples are either silty sand or clayey sand. Silty sand is predominant in deeper stations. The living foraminiferal populations are more abundant in silty sands.

Organic matter

The scatter plot of organic matter vs living species ($R = 0.377$) shows positive correlation (Fig.5). Furthermore, the trend of organic matter vs carbonate content (Fig. 6) suggests that the drifting of sediment from the inner shelf regions due to littoral drift activities played a role in the contribution of carbonate shells. The percentage abundance of living species indicates a rise in the deeper station at Kodiyakarai and this may be due to oxygenated conditions prevailed at the location.

Calcium Carbonate

A lower amount of carbonate content at shallower depths in all the stations is noticed (Table-2). The scatter plot of carbonate content vs living species (Fig.7) shows the negative correlation ($R = -0.16$). It suggests that a weak relationship is maintained between carbonate content and living/dead species.

Fig. 5: Scatter plot of organic matter and living species.

Fig. 6: Scatter plot of organic matter vs calcium carbonate.

Fig. 7: Scatter plot of calcium carbonate vs living species.

Discussion

In total, 44 foraminiferal species belonging to 23 genus, 15 families, have been identified from 7 sediment samples collected off Kodiyakarai, Palk Strait (Plate- I to III). The majority of benthic foraminifera is reported to be dead, whereas live species are rarely reported. Out of the forty four species, ten species are abundant namely *Ammonia beccarri*, *Elphidium macellum*, *E.incertum*, *E.crispum*, *Asterorotalia inflata*, *A.trispinosa*, *Nonionoides boveanum*, *Bolivina nobilus*, *Quinqueloculina elongatum* while others are in common and rare category. Due to wave shadow conditions and clayey substratum the *N. boveanum* and *A.trispinosa* occur frequently. The depth wise distribution of living specimens shows that the first three depths up to 3.0 m record < 10 specimens. In spite of the presence of protective environment in Kodiyakarai the absence of more families may be attributed to clayey substrate.

Kodiyakarai records higher species diversity in spite of less depth and more protective environment in nature, and it may be ascribed to the continued connection with open sea with finer substratum and less turbid condition. The sizes of the foraminifera at these sampling locations are generally very small.

The low organic matter in Kodiyakarai in all the depths and particularly in deeper depths (8.5 m) is observed. Here the drifting currents move in anticlockwise direction and further the monsoonal currents enter from the channel with full strength. It is found to be a zone of unstable substratum having a number of minor channels conduit the fast moving currents and that hinder the settling of organic carbon. Moreover, it is observed that, with sheltered environment allowing the deposition of only fine sediments, pushed aside to the calm environment. The low energy

condition is also accounted by the positive skewness prevailing in this region. It is supported by the earlier studies by Mohan *et al.*, 2000.

The organic matter maintains a positive correlation ($R = 0.377$) with distribution pattern of living species, in Kodiyakarai. It is rather difficult to assess the biomass contributed to the sediments from the living species, because abundance estimate was made on total specimen counts. The species are seen to be abnormally small in size. The small size (0.12 -0.10 mm) suggests a lack of normal environment for healthy growth. Since, there is no free mixing of wave action, surface productivity must have been low and settling of biomass must have been predominantly less. Moreover, since, there is lack of oxygenated conditions, humus accumulation also must have been low (Dwivedi, *et al.*, 1975). Above all, the living benthic foraminifera must have consumed whatever little organic matter available in the substratum for survival (Murray, 1991; Fontainer *et al.*, 2002). Such activities have also been assumed to have given rise to low organic matter in this area, in spite of more number of living species, miniature in size.

The carbonate content is higher in 8 m water depths compared to less than 8m depths. When the sediments are checked visually, a higher order of broken shells is noticed in that depth. Carbonate does not indicate any good correlation with living species. The carbonate shells have also been the product originated elsewhere, probably the drifted shell debris. It may also be due to the existing strong currents leading to non-deposition of terrigenous material and or to a limited terrigenous supply (Mohan and Rajamanickam, 1994).

The silty nature of samples at Kodiyakarai indicates the prevalence of calm environment allowing the drifted suspended load to get settled. It is supported by Ramasamy *et al.*, (1998) who had calculated the accretion of sediments and the extent of land building activity in the Vedaranyam offshore area due to littoral currents seems to be happening at the rate of 29 meters/year. The sorting character at Kodiyakarai station looked displays poor sorting, though it establishes a protected calm environment. It may be presumed that the returning currents from spit through Sethubavachattiram would have disturbed the seabed before leaving the channel. Moreover, the broken shell remains as reflected from the high carbonate values may also give rise to poor sorting. The complete positive skewness of Kodiyakarai may be attributable to the low energy condition of deposition or otherwise the dominant influence of dune/ ridge sediments as noticed around the Vedaranyam ridge.

The dead specimens are more in all the sampling locations in Koddiyakarai. Only at these stations, the finest fractions of the sediment load seem to be brought by the currents. The nature of substratum also supplements this inference with the presence of silty sand at Kodiyakarai at all the depths. A larger deposit of dead specimens is normally expected at the point of outlet because of the interference of the incoming currents and the configuration of the coastline which directs the currents to pass out by the sides of the spit limb in the north by Vedaranyam spit.

Conclusions

In total, 48 species belonging to 14 families and 22 genera were identified. Study suggests that fine sediments in Kodiyakarai are much favorable for thriving of foraminiferal species. *Asterorotalia trispinosa* is the most dominated species in this region followed by *A. beccarii* and *E. crispum*. The low salinity condition, less organic matter content and fine sediment texture are the major factors controlling foraminiferal distribution in Kodiyakarai region.

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Table-2: Distribution of foraminifera off Kodiyakarai (in numbers).

S/No	Species	Beach	K1		K2		K3		K4		K5		K6		K7	
		Depth	1.5 m		3.0 m		5.5m		6.7m		7.5m		8.0 m		8.5 m	
			L	T	L	T	L	T	L	T	L	T	L	T	L	T
1	<i>Ammobaculites exiguus</i>									2		2				
2	<i>Textularia agglutinans</i>	2		3		2										
3	<i>Textularia bocki</i>					2		1								
4	<i>T. porrecta</i>	1		2		1		1								
5	<i>Spiroloculina communis</i>			4		3		2	0	4	0	4	0	2		7
6	<i>S. nobilis</i>	1		1												
7	<i>S. depressa</i>			6		4		3		2		1				
8	<i>S.indica</i>	2		2		1										
9	<i>Spiroloculina orbis</i>					2				6				4		3
10	<i>Quinqueloculina cultrata</i>															
11	<i>Q.costata</i>															
12	<i>Q. lamarckiana</i>	2								4				6		
13	<i>Q.seminulum</i>			2				1								
14	<i>Q.strigillata</i>							2				1				
15	<i>Q.tropicalis</i>					3				5	1	4	2	6	2	7
16	<i>Miliolinella circularis</i>					2				3				4		
17	<i>M.pyrgoformis</i>	1		3				4				4		4		
18	<i>Legina perlucida</i>													2		2
19	<i>Bolivina durandi</i>									2		3	1	3	1	3
20	<i>B. lobata</i>															
21	<i>B.spathulata</i>							1						2		2
22	<i>B.ordinaria</i>									2		1		2		2
23	<i>Loxostomina limbata</i>			2						1						
24	<i>Reusella simplex</i>											2		3		3
25	<i>Shiphovigerina virgula</i>													1		1
26	<i>Triloculina tricarinata</i>	1		2												
27	<i>T. trigonula</i>			2				4				6		6		2
28	<i>Globigerina bulloides</i>									2		2		2		2
29	<i>Eponides repandus</i>			2				2		2						
30	<i>Cibicides lobatulus</i>											4				
31	<i>Amphistegina radiata</i>	2				6		4				4	1	3		
32	<i>Nonion elangatum</i>						2			3	1	8	2	6	2	6
33	<i>N.scaphum</i>									1		4		4		4
34	<i>Nonionellina labradorica</i>							1						2		2
35	<i>Nonionoides boueanum</i>									3		8		7	2	8

36	<i>Pararotalia calcar</i>	2			1		1	6	2	12	1	13	2	22	2	12
37	<i>P. nipponica</i>	4	1	13		16		12	2	14	3	12	2	22		18
38	<i>Ammonia beccarii</i>	14	1	28	2	32	3	32	5	30	4	46	5	57	2	43
39	<i>A. dentata</i>	1		18		6		12	1	14	2	3	2	22	2	34
40	<i>A. tepida</i>	2		4		3		6	1	6	1	9	2	14	2	14
41	<i>Asterorotalia trispinosa</i>	14		156	1	202	2	224	3	258	6	324	4	387	4	298
42	<i>Elphidium ?</i>	1		6		8		10	1	12	1	14	1	16		
43	<i>E. crispum</i>	1		21		18		17		14	2	26	2	22	2	22
44	<i>E. discoideale</i>							4				6		2		
45	<i>E. delicatulum</i>			1				3				2		1		
46	<i>E. norvangi</i>			1		2						6		1		
47	<i>Assilina ammonoides</i>	2		3				4				1		2		2
48	<i>Parallilna hispidula</i>					4		2		2		1				
	TOTAL	53	2	282	4	317	8	358	15	404	22	521	26	637	21	497
	Total Number of Individuals	17	2	22	3	21	5	25	7	24	10	29	12	31	10	23
	Living/ Dead Ratio		0.7		1.26		2.23		3.71		4.22		4.39		4.22	
	Dead Species %			99.29		98.7		97.8		96.31		95.77		95.92		95.8
	Living Species %		0.71		1.26		2.23		3.6		4.22		4.08		4.23	

PLATE-I

Ammobaculites exiguus (AV)

Textularia agglutinans (SV)

Textularia bocki (SV)

spiroloculina communis(SV)

S.depressa (SV)

S.orbis (SV)

T.Porrecta(SV)

Q.costata (SV)

Q. lamarckiana (SV)

Spiroloculina nobilis (SV)

T. tricarinata (SV)

T. trigonula (SV)

PLATE-II

G. bulloides(AV)

Cibicides lobatulus(DV)

Amphistegina radiata (DV)

Nonionella labradica(SV)

Nonionoides boueanum (SV)

Pararotalia calcar(VV)

Pararotalia nipponica (AV)

Ammonia beccarii(DV)

Ammonia dentate(VV)

Ammonia tepida(DV)

Asterorotalia trispinosa(DV)

Elphidium norvangi (DV)

PLATE-III

E. crispum(DV)

E. discoidale(DV)

E. delicatulum(DV)

Assilina ammonoides (DV)

Parallina hispidula(DV)

Q. seminulum(SV)

Q. cultrata (SV)

Q. strigillata(SV)

N. elongatum(SV)

Nonion scaphum (DV)

Eponides repandus (DV)

Bolivina durrandii(SV)

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