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Distribution Patterns of Inner Shelf Benthic Foraminifera and Their Relationship to Climatic Conditions in Northeastern Tamil Nadu, India

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Abstract: The present study, involving investigations of recent foraminifera from the sediments of the inner shelf off Nagapattinam on the southeast coast of India, was undertaken to document the composition, distribution, and ecology of the foraminifera and their relationship to the climatic conditions of the study area. Thirty sediment samples were collected from depths ranging from 3.4 to 30.8 m during the fieldwork conducted in July 2001 and various ecological parameters were determined. Sediment samples from the sediment-water interface yielded 151 benthic foraminifera species and varieties belonging to 82 genera, 42 families, 21 superfamilies, and 5 suborders, which have been described and illustrated in this study. The spatial and temporal variations of total ("live" + dead) foraminifera populations were analysed. The study shows significant total populations in the collected samples. This was attributed to higher temperatures resulting in higher salinities during this period. Both species and genus diversity increase with increasing depth. In the context of the Indian Ocean tsunami, the pronounced changes in the nearshore continental region will certainly provide a different picture, and the present results would provide a reliable database for comparative post-tsunami studies. The results show a clear relationship between foraminifera and local climatic conditions.

Keywords: Lake irrigation; River linking scheme.

Introduction

India has a coastline of 7,516 km, of which 5,422 km is mainland. In the islands of Lakshadweep and Andaman and Nicobar Islands, the coastline is 132 km and 1,962 km, respectively. The state of Tamil Nadu, located in the southern part of India, has nearly 1,000 km of coastline with a variety of habitats such as rocks, coral reefs, mangroves, salt marshes, sand dunes, etc. Nagapattinam is one of the most famous ancient fishing ports in India, mainly because of the production of valuable, high quality chunks as well as marine products. The study area is very close to the central part of the Cauvery basin. The tributaries of the Cauvery River empty into the sea near the study area. Aside from these features, new development work such as the construction of jetties to transport oil and natural gas from shore to land has been initiated (Hilbrecht, 1992). Numerous micropaleontologists have studied the taxonomy, distribution, and ecology of recent foraminifera and their response to trace metal concentrations on the east and west coasts of India (Pitchainmani et al., 2021).

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However, no work had been done in the study area prior to this project. In recent years, many large and small industrial plants have been developed along the coastal zone and marine life has taken the burden of the many effluents entering the coastal zone. This study will serve as a baseline study for future changes in the distribution and population of foraminifera and their response to sediment conditions

Study Area

The area studied is off the coast of Nagapattinam in the Bay of Bengal. The physical and chemical properties and circulation of the surface waters of the Bay of Bengal are highly influenced by the meteorological conditions associated with the monsoon system. The study area is generally influenced by the southwest and northeast monsoons. In summer, the land temperature rises up to 45°C. The area experiences two phases of rainfall: one during the southwest monsoon (June to September) in the form of occasional showers and the second phase during the northeast monsoon (October to December), when cyclones normally occur almost every year, causing heavy rainfall. The total annual rainfall varies between 1,100 and 1,250 mm, of which the northeast monsoon accounts for about 50-60% and the southwest monsoon for about 30-40%. The coolest month is January with an average temperature of 25°C, while the hottest month is May with an average temperature of 37°C. Varadachari and Sharma (1967), based on the analysis of streamlines from observations of various ships, suggested the presence of a seasonally varying current due to the influence of the west-flowing North Equatorial Current and the east-flowing Indian Monsoon Current in summer.

Methodology

The fieldwork was conducted in the month of July. Figure 1 shows the study area and sampling locations. Sediment and water samples were collected in three

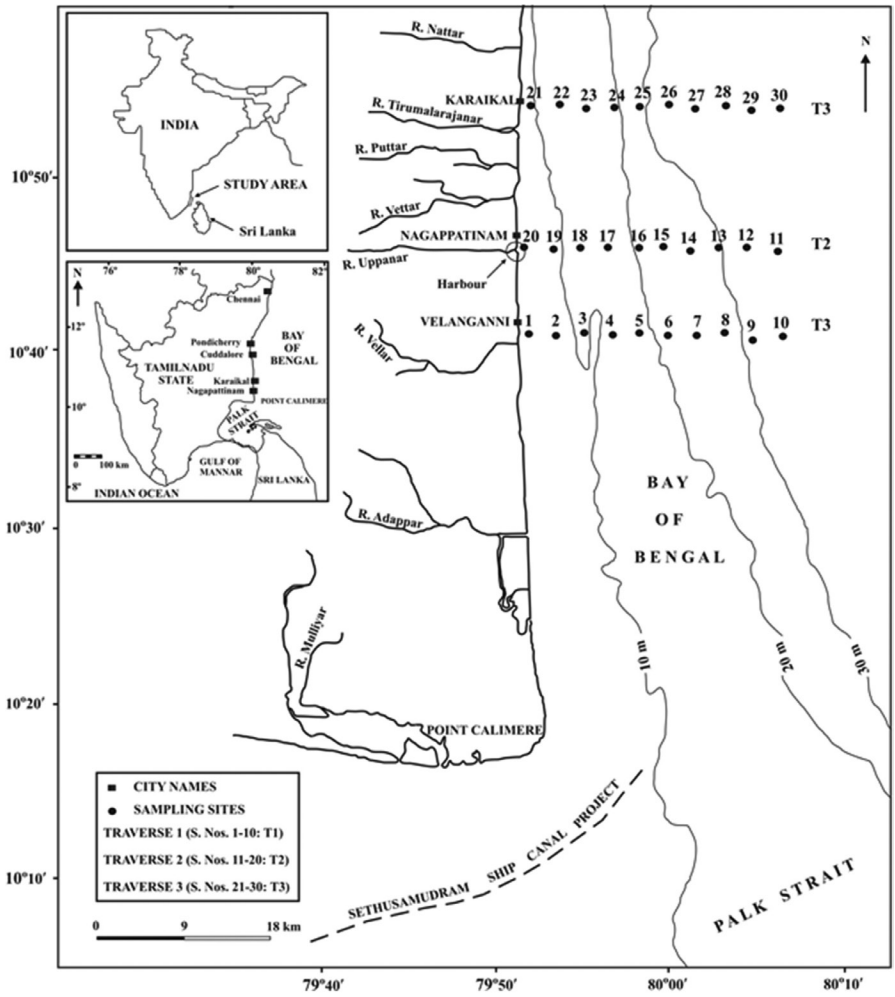


Figure 1: Geographical and sampling locations of the study area.

traverses at latitudes 10° 45', 10° 48', and 10° 51'. At each traverse, 10 samples were collected at one-minute intervals. A total of 30 samples were collected. Table 1 shows the sampling locations with their respective depths. Sediment samples were collected at all sites for foraminifera studies. A global positioning system (GPS) was used to locate the sampling sites in the offshore region. An echo sounder (Koden) was used to determine the depth of the sampling sites. A Petersen grab was used to collect the surface samples. Sampling was done in an easterly direction, starting from the shoreline near the fishing harbour. A unit volume of 100 ml wet sediment sample from the uppermost 1 cm of the substrate was immediately preserved in a 10% neutralized formaldehyde solution. A small amount of sodium carbonate was added to maintain the alkaline medium. Soil water samples were also collected at each station.

Table 1: Geographic locations of sampling stations with depth

Sample No.	*Latitude*	*Longitude*	*Depth (M)*
1	10°45' 30"	79°51' 30"	6.1
2	10°45' 30"	79°52' 30"	8.7
3	10°45' 30"	79°53' 30"	10.5
4	10°45' 30"	79°54' 30"	11.7
5	10°45' 30"	79°55' 31"	12.4
6	10°45' 30"	79°56' 30"	16.8
7	10°45' 30"	79°57' 30"	20.3
8	10°45' 30"	79°58' 30"	22.5
9	10°45' 30"	79°59' 30"	25.6
10	10°45' 30"	80°00' 30"	27.3
11	10°48' 30"	79°59' 30"	29.1
12	10°48' 30"	79°58' 30"	28.5
13	10°48' 30"	79°57' 30"	25.4
14	10°48' 30"	79°56' 30"	21.3
15	10°48' 30"	79°55' 30"	16.2
16	10°48' 30"	79°54' 30"	15.3
17	10°48' 30"	79°53' 30"	13.8
18	10°48' 30"	79°52' 30"	11.5
19	10°48' 30"	79°51' 30"	9.7
20	10°48' 30"	80°00' 30"	6.8
21	10°51' 30"	79°51' 30"	3.4
22	10°51' 30"	79°52' 31"	10.5
23	10°51' 30"	79°53' 31"	12.8
24	10°51' 30"	79°54' 31"	14.2
25	10°51' 30"	79°55' 31"	14.6
26	10°51' 30"	79°56' 30"	18.8
27	10°51' 30"	79°57' 31"	22.6
28	10°51' 30"	79°58' 30"	26.2
29	10°51' 30"	79°59.' 30"	29.2
30	10°51' 30"	80°00' 30"	30.8

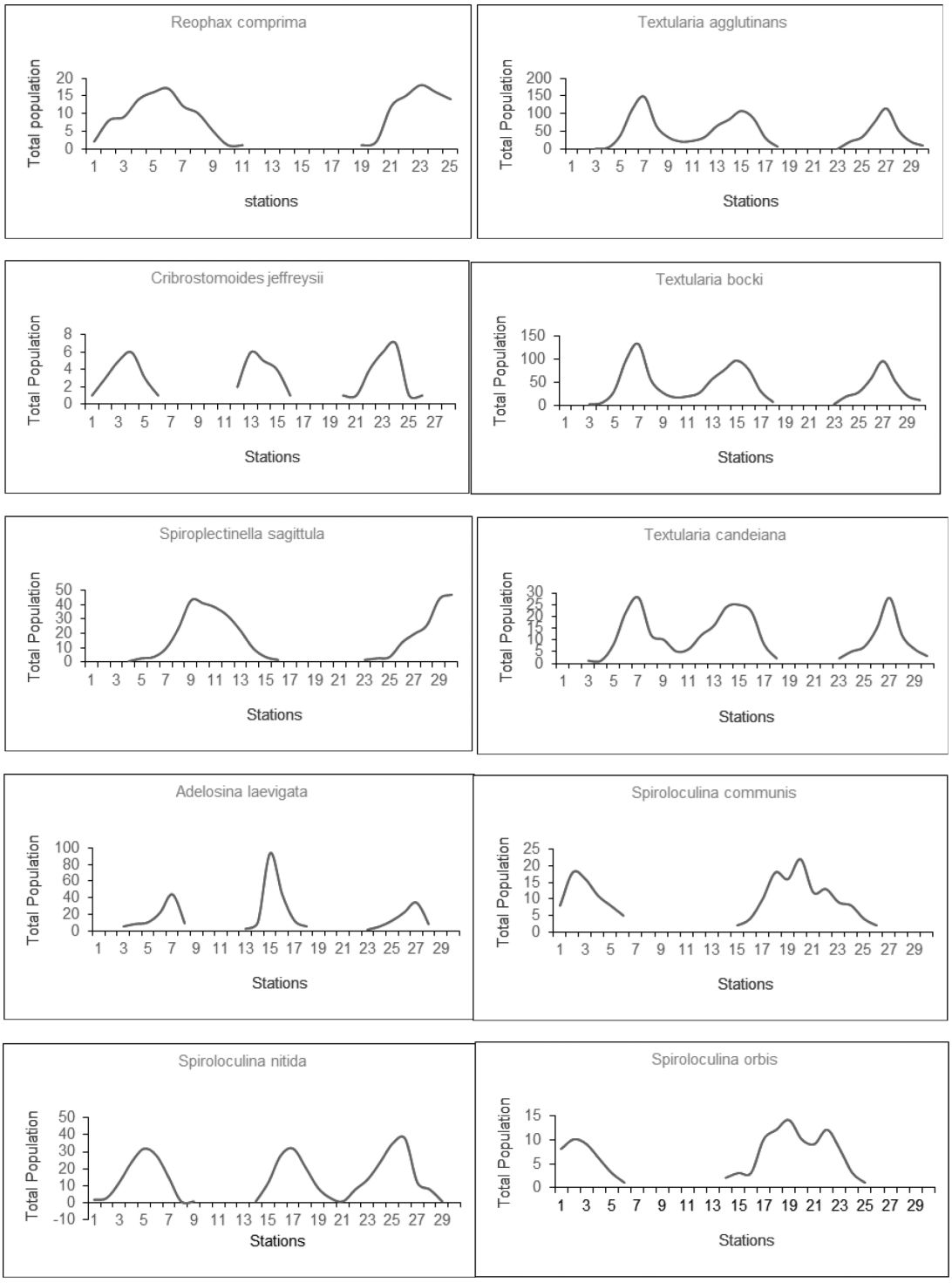
In the present study, sediment samples were preserved in neutralised formalin according to the method given by Walton (1952). The preserved samples were washed over a 230 mesh (0.063 mm) ASTM sieve to remove silt and clay. The sieve containing the residues was placed in a dish containing an aqueous solution of rose bengal (1 g rose bengal dye in 1 litre distilled water) for approximately 4-6 hours, making sure that the residues on the sieve were completely covered by the solution. The material on the sieve was then washed thoroughly to remove excess stain and dried. The foraminifera samples were then separated from the residue by flotation with carbon tetrachloride (Cushman, 1959). As a control, after flotation, the residue was again examined under a binocular stereomicroscope for foraminifera that may have escaped flotation. They were picked out manually using a Windsor Newton sable hair brush '00'. The specimens thus obtained were distributed on a collection tray and the different genera and species were determined. The live and dead populations were counted. If the population was very large, it was divided to obtain a population that could be studied further. Selected specimens of each species were mounted on micropaleontological slides by family, genus, and species and coated with a thin layer of tragacanth gum. Before the gum dried, each specimen was oriented into the desired position for further examination. The hypotypes were mounted on double-sided tape that was glued to brass pins. The hypotypes were mounted on brass stubs (1 cm diameter) with carbon double-sided tape and plated with platinum for approximately 3 to 4 minutes using the JEOL-JFC -1600 Auto Fine Coater to make the surface of the foraminifera specimens conductive for scanning. To obtain meaningful images, photomicrographs of different views of all foraminifera species present were taken using a scanning electron microscope (JEOL JSM -6360).

Results and Discussion

The study of foraminifera began with an examination of their taxonomy. Although the purely descriptive phase of foraminiferal studies is gradually giving way to ecological studies, it is nevertheless felt that to be of greatest value they should have a sound taxonomic

basis. The widely used classification proposed by Loeblich and Tappan (1987) was followed in the present study.

A total of 143 species and varieties of foraminifera were identified, belonging to 82 genera, 42 families, 21 superfamilies, and 5 suborders. Of these, 21 are arenaceous, agglutinated taxa (suborder Textulariina), 55 are calcareous, imperforate, porcelain forms (suborder Miliolina), 10 belong to suborder LAGENINA, and 57 are calcareous, perforate species of suborder Rotaliina (Figure 2).



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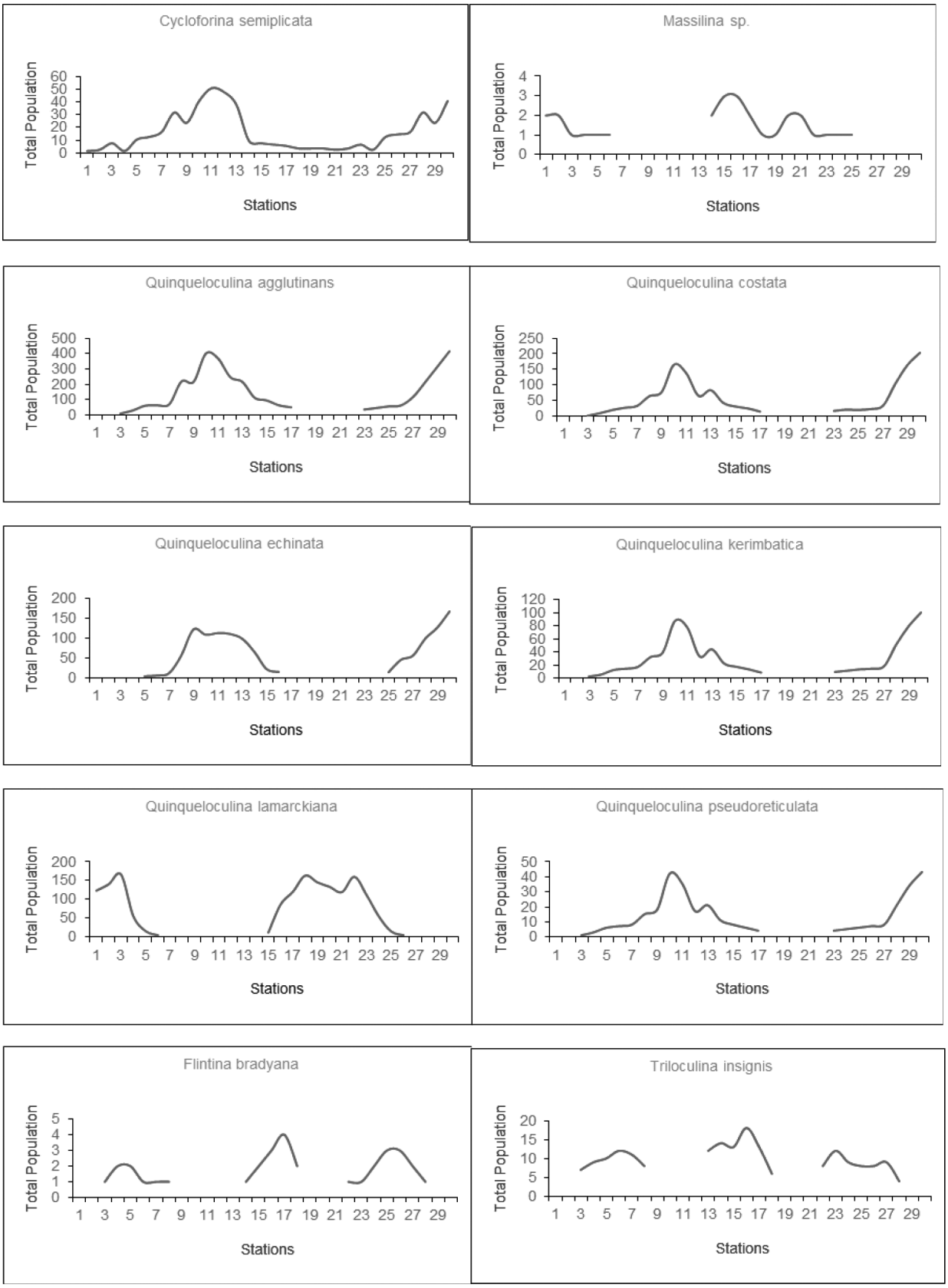
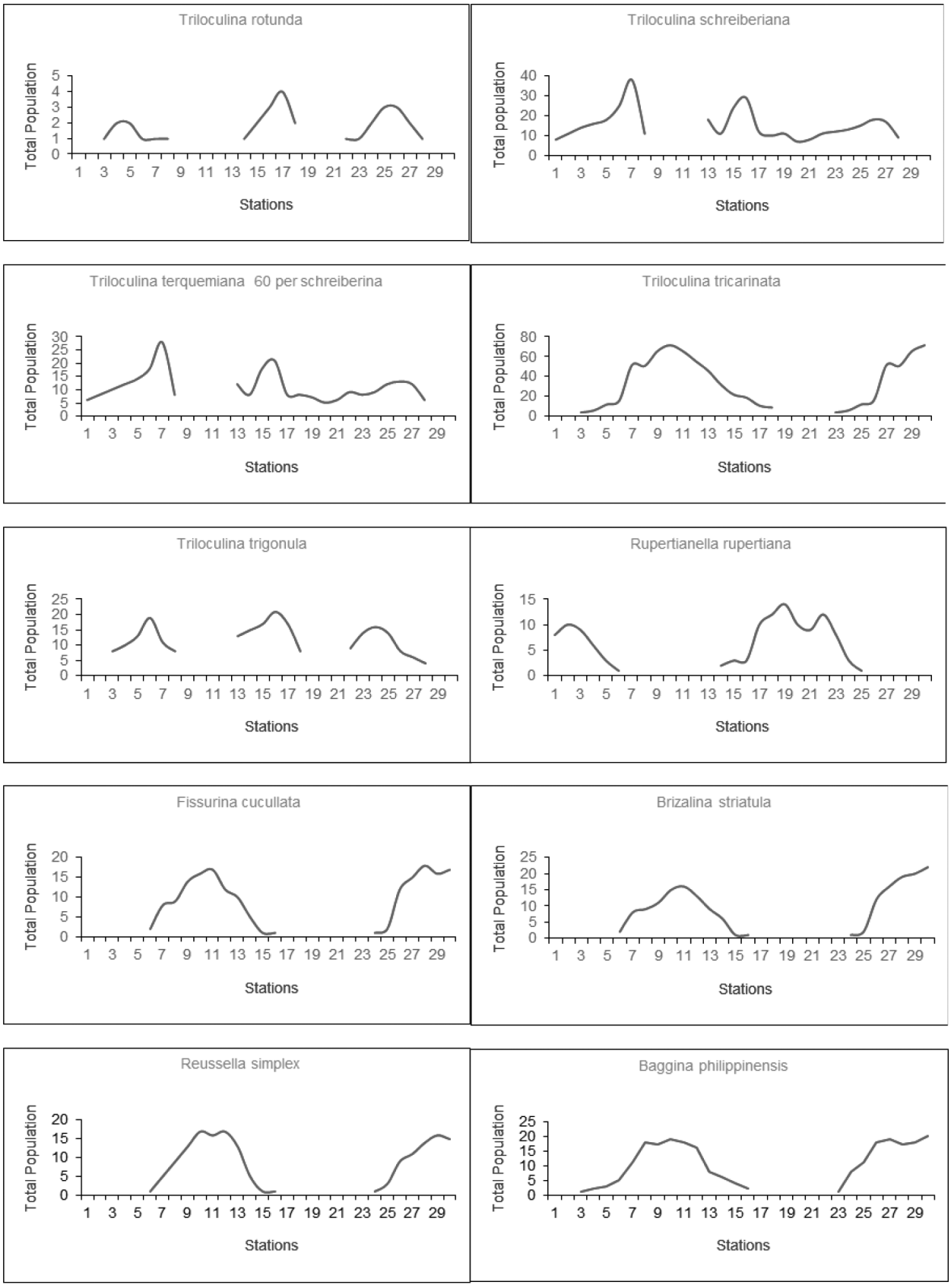
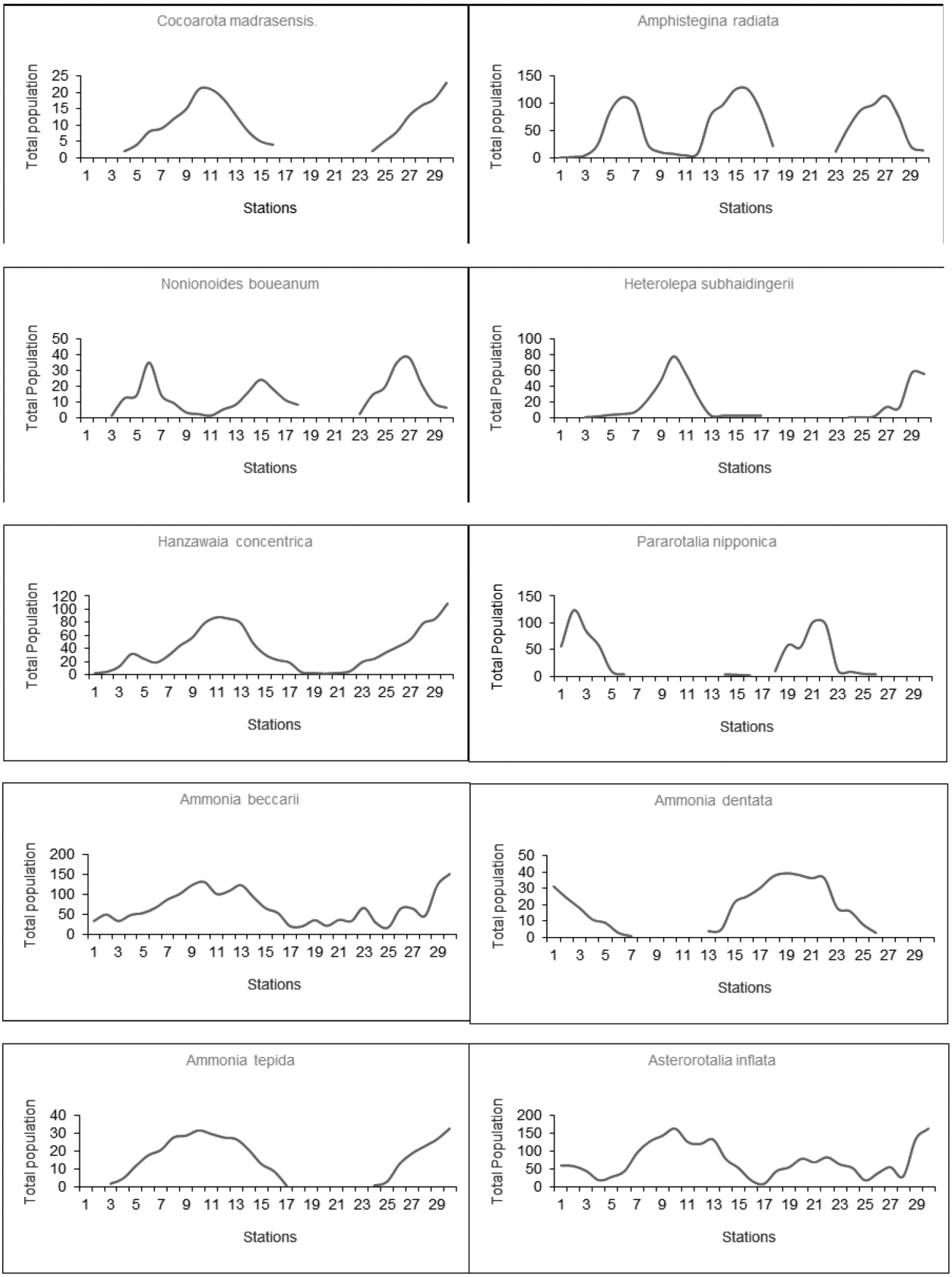

Cycloforina semiplicata
Massilina sp.
Quinqueloculina agglutinans
Quinqueloculina costata
Quinqueloculina echinata
Quinqueloculina kerimbatica
Quinqueloculina lamarckiana
Quinqueloculina pseudoreticulata
Flintina bradyana
Triloculina insignis
Total Population
Stations

(*Contd.*)


Triloculina rotunda
Total Population
Stations
Triloculina schreiberiana
Total population
Stations
Triloculina terquemiana 60 per schreiberina
Total Population
Stations
Triloculina tricarinata
Total Population
Stations
Triloculina trigonula
Total Population
Stations
Rupertianella rupertiana
Total Population
Stations
Fissurina cucullata
Total Population
Stations
Brizalina striatula
Total Population
Stations
Reussella simplex
Total Population
Stations
Baggina philippinensis
Total Population
Stations

(*Contd.*)


Cocoarota madrasensis.
Total population
Stations
Amphistegina radiata
Total population
Stations
Nonionoides boueanum
Total Population
Stations
Heterolepa subhaidingerii
Total Population
Stations
Hanzawaia concentrica
Total Population
Stations
Pararotalia nipponica
Total Population
Stations
Ammonia beccarii
Total population
Stations
Ammonia dentata
Total population
Stations
Ammonia tepida
Total population
Stations
Asterorotalia inflata
Total Population
Stations

(*Contd.*)

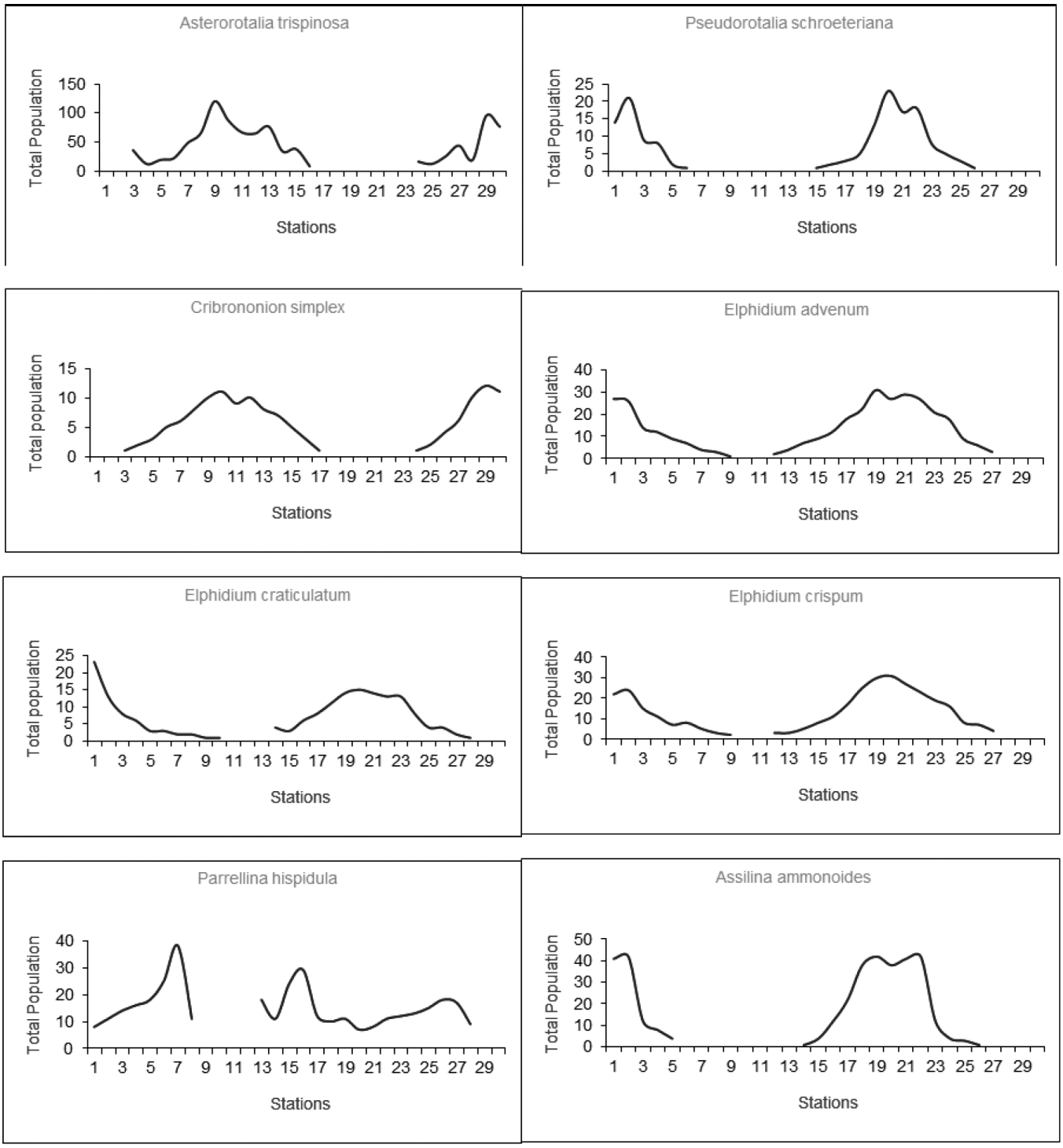


Figure 2: Spatial distribution of total populations of widespread and abundant species.

Distribution of Benthic Foraminifera

Given the relatively large number of benthic foraminifera species found in the sediments of the study area, an attempt was made to determine the distribution and taxonomy of the foraminifera that are either widespread or common/permanent. Arbitrarily, those species occurring in at least 60% of the stations, i.e., 18 of the 30 stations, were classified as widespread and common/ permanent. The distributions (July 2001) of "live" (pink Bengal stained) and total ("live" + dead) foraminifera in actual numbers per unit volume (25g sediment) are shown in Table 2.

Table 2: Distribution of living (stained) and total (living + dead) in foraminiferal actual numbers

Sl.No.	*Station Numbers*	*1*		*2*		*3*		*4*		*5*		*6*		*7*		*8*		*9*		*10*	
	Name of Species	*L*	*T*	*L*	*T*	*L*	*T*	*L*	*T*	*L*	*T*	*L*	*T*	*L*	*T*	*L*	*T*	*L*	*T*	*L*	*T*
1	Reophax comprima											0	2	1	8	1	9	3	14	1	16
2	Reophax pilulifer																	0	2	0	1
3	Reophax scorpiurus																	1	2	1	1
4	Cribrostomoides jeffreysii					0	1	0	3	0	5	0	6	0	3	0	1				
5	Haplophragmoides sp																	0	1	0	1
6	Ammoscalaria runiana															0	1	0	1	0	1
7	Ammoscalaria tenuimargo																	0	2	0	1
8	Ammobaculites exiguus					0	1	0	1	0	1										
9	Spiroplectinella sagittula							0	1	0	3	0	4	1	10	4	24	4	43	3	41
10	Nouria polymorphinoides																	0	1	0	2
11	Trochammina inflata																	1	14	1	12
12	Eggerella australis							0	1	0	3	1	4								
13	Bigenerina nodosaria													0	1	0	3	0	1	0	8
14	Textularia agglutinans					0	2	0	5	4	38	10	112	12	148	5	66	3	34	2	22
15	Textularia bocki					0	1	0	4	3	29	8	98	10	132	4	55	2	26	1	16
16	Textularia candeiana					0	1	0	1	2	8	2	22	3	28	1	12	3	10	2	5
17	*Textularia conica*															1	1	0	1	0	1
18	*Textularia dupla*																	0	1	0	1
19	*Textularia earlandi*																	0	2	0	1
20	Textularia porrecta									0	1	0	1	1	2	2	8	2	7	2	9
21	*Karrerotextularia* cf. *albatrossi*									0	1	0	1	0	1	0	2	1	3	1	4
22	Subfischerina galapagosensis									0	1			0	2	0	2	0	3	0	2
23	Vertebralina striata							0	1			0	2	1	4	1	3	1	4	2	5
24	Edentostomina cultrata	0	2	0	3	0	2	0	2	0	2	0	1								
25	Edentostomina milletti	0	3	0	5	0	4	0	3	0	1	0	1								
26	Adelosina laevigata					0	5	0	8	2	10	4	22	6	44	0	9				
27	Spiroloculina aequa																	0	1	0	1
28	Spiroloculina affixa																	0	1	1	1
29	Spiroloculina communis	0	8	1	18	2	16	2	11	0	8	0	5								
30	Spiroloculina corrugata	0	1	0	1																

(*Contd.*)

Table 2: (*Contd.*)

Sl.No.	*Station Numbers*	*1*		*2*		*3*		*4*		*5*		*6*		*7*		*8*		*9*		*10*	
	Name of Species	*L*	*T*	*L*	*T*	*L*	*T*	*L*	*T*	*L*	*T*	*L*	*T*	*L*	*T*	*L*	*T*	*L*	*T*	*L*	*T*
31	Spiroloculina costifera	0	1	0	2																
32	Spiroloculina depressa	0	3	0	4	0	3	0	2	0	4	0	3								
33	Spiroloculina henbesti							0	1			0	1	1	3	1	2	1	3	2	4
34	Spiroloculina nitida	0	2	0	3	2	12	3	24	5	32	4	28	1	15	0	1	0	1		
35	Spiroloculina orbis	1	8	1	10	1	9	0	6	0	3	0	1								
36	Cycloforina semiplicata	0	2	0	3	1	8	0	2	1	11	1	13	2	17	3	32	2	24	4	41
37	*Massilina* sp.1	0	2	0	2	0	1	0	1	0	1	0	1								
38	*Massilina* sp.2	0	2					0	1												
39	Quinqueloculina agglutinans					1	12	6	32	10	62	8	65	9	72	35	218	22	216	51	397
40	Quinqueloculina bicostata	1	8	2	7	1	9	0	4	0	3										
41	Quinqueloculina costata					1	3	2	11	3	21	3	28	3	34	10	65	8	78	28	165
42	Quinqueloculina cristata																	0	1	0	2
43	Quinqueloculina echinata									0	4	0	6	1	12	2	56	2	121	12	108
44	Quinqueloculina elegans					0	1	0	1	0	3	0	2								
45	Quinqueloculina kerimbatica					1	2	2	5	2	12	1	14	1	17	5	32	4	39	14	88
46	Quinqueloculina lamarckiana	14	124	11	141	28	167	6	56	2	16	0	5								
47	*Quinqueloculina* cf. *mosharrafai*					0	1	0	1	0	3	0	2								
48	Quinqueloculina polygona					0	1	0	2	0	3	0	2								
49	Quinqueloculina pseudoreticulata					1	1	1	3	1	6	1	7	1	8	2	15	2	18	5	42
50	*Quinqueloculina tropicalis*					0	1	0	1	0	3	1	4	0	1						
51	*Quinqueloculina* sp.1									0	1	0	2	0	1	0	3	0	2	0	1
52	*Quinqueloculina* sp.2									0	2	0	1	0	1	0	2	0	1	0	1
53	*Quinqueloculina* sp.3							0	1									0	2	0	2
54	*Quinqueloculina* sp.4							0	1	0	2	0	1					0	1	0	1
55	Flintina bradyana					0	1	0	2	0	2	0	1	0	1	0	1				
56	*Miliolinella circularis*					0	3	1	5	1	3	1	3								
57	Miliolinella elongata					1	1			1	2										
58	*Neopateoris* sp.1									0	1							0	1	0	1
59	Parahauerinoides complanatiformis									1	3	0	2	1	3	1	7	0	1	1	5
60	Pyrgo laevis					0	1	0	1			0	1	1	3	1	2	1	3	2	4

61	Triloculina insignis					1	7	1	9	1	10	2	12	1	11	1	8				
62	Triloculina rotunda					0	1	0	2	0	2	0	1	0	1	0	1				
63	Triloculina schreiberiana	0	8	1	11	1	14	2	16	2	18	2	25	3	38	2	11				
64	Triloculina striatotrigonula	0	5	0	7	0	1														
65	Triloculina terquemiana	0	6	1	8	1	10	2	12	2	14	2	18	2	28	1	8				
66	Triloculina tricarinata					0	4	0	6	1	12	2	16	7	52	6	51	11	66	11	72
67	Triloculina trigonula					1	8	1	10	1	13	2	19	1	11	1	8				
68	Articulina pacifica																	0	1	0	2
69	Parrina bradyi																	0	1	0	1
70	Rupertianella rupertiana	1	8	1	10	1	9	0	6	0	3	0	1								
71	Sorites marginalis coast															0	1	0	2	0	1
72	Nodosaria catesbyi																	1	4	1	10
73	Pyramidulina catesbyi																	0	1	0	2
74	Lenticulina limbosa																	0	1	0	1
75	Lenticulina macrodiscus																	0	1	0	1
76	Lagena interrupta																	0	4	1	3
77	Lagena setigera																	0	1	1	8
78	Lagena striata																	0	1	0	1
79	*Lagena sulcata* var. *spicata*																	0	1	0	2
80	*Lagena* sp.1																	0	1	0	1
81	Favulina hexagona																	0	1	0	1
82	Oolina laevigata																	0	1	0	1
83	Fissurina cucullata											0	2	1	8	1	9	1	14	1	16
84	Fissurina laevigata																			0	1
85	Glandulina laevigata																			0	1
86	*Tappanella* sp.																				
87	Globorotalia tumida															0	1	0	3	0	3
88	Neogloboquadrina dutertrei															0	2	0	3	0	7
89	Pulleniatina obliquiloculata															0	1	0	1	0	2
90	Globigerina bulloides															0	1	0	3	0	2
91	Globigerinella aequilateralis															0	2	0	1	0	3
92	Globigerinoides ruber															2	31	1	14	2	21
93	Globigerinoides sacculifer													0	3	0	15	1	14	2	15

(*Contd*.)

Table 2: (*Contd.*)

Sl.No.	*Station Numbers*	*1*		*2*		*3*		*4*		*5*		*6*		*7*		*8*		*9*		*10*	
	Name of Species	*L*	*T*	*L*	*T*	*L*	*T*	*L*	*T*	*L*	*T*	*L*	*T*	*L*	*T*	*L*	*T*	*L*	*T*	*L*	*T*
94	Orbulina universa															0	1	0	1	1	4
95	Bolivina hadai															0	1	0	2	0	3
96	Bolivina persiensis															0	1	1	11	0	14
97	Brizalina striatula											0	2	1	8	1	9	1	11	1	15
98	Loxostomina durrandii																	0	1	0	1
99	Loxostomina limbata															0	1	0	1	0	2
100	Sagrinella lobata															1	5	0	1	1	6
101	Saidovina karreriana																	0	1	0	2
102	Globobulimina ovata															0	1			0	1
103	Siphogenerina virgula											0	1	1	8	1	9	2	18	2	19
104	Neouvigerina interrupta															0	1	1	4	0	3
105	Uvigerina senticosa															0	1	0	10	1	11
106	Reussella atlantica															0	1	1	5	1	6
107	Reussella simplex											0	1	1	5	1	9	1	13	1	17
108	Pavonina flabelliformis																	0	1	0	2
109	Fursenkoina pontoni																	0	2	0	1
110	Sigmavirgulina tortuosa															0	1	1	1	1	1
111	Baggina philippinensis					0	1	0	2	0	3	1	5	1	11	2	18	2	17	2	19
112	Cancris auriculus									1	0	2	7	1	9	0	6	0	1	0	1
113	Cancris oblanga															0	1	0	1	0	2
114	Eponides cribrorepandus					0	2	0	1	0	3	0	1								
115	Eponides repandus					0	5	1	7	0	5	0	5								
116	Helenina anderseni																	0	1	0	1
117	Rosalina globularis											0	3	1	4	0	1	0	3	1	2
118	Rosalina macropora											0	2	0	3	0	1	0	2	1	1
119	Discorbinella bertheloti									1	1	0	1	1	1	0	2	0	1	1	7
120	Cibicides lobatulus	0	1	0	1	0	3	0	3												
121	Cocoarota madrasensis.							0	2	0	4	0	8	0	9	1	12	1	15	1	21

122	Cymbaloporetta bradyi																	0	1	0	1
123	Planorbullinella larvata																	0	1	0	1
124	Amphistegina radiata	0	1	0	2	0	5	3	25	5	86	10	112	7	98	4	25	2	11	0	8
125	Nonionella stella																	0	1	0	1
126	Nonionellina labradorica																	0	2	0	3
127	Nonionoides boueanum					0	1	2	12	3	14	2	35	2	14	1	9	0	3	0	2
128	Nonionoides elongatum											4	40	3	22	2	14	1	4	0	4
129	*Nonionoides grateloupi*																	0	1	0	2
130	Heterolepa praecincta							0	1	0	2	0	3	0	4	1	12	2	23	4	35
131	Heterolepa subhaidingerii					0	1	0	2	0	4	0	5	0	8	1	24	2	47	6	78
132	Hanzawaia concentrica	0	2	0	4	1	12	2	31	2	24	1	18	2	28	3	44	5	56	7	78
133	Pararotalia calcar									0	1	0	4								
134	Pararotalia nipponica	5	56	21	124	4	84	4	57	1	9	0	3								
135	Ammonia beccarii	2	34	2	50	1	34	2	49	2	54	5	67	12	88	13	102	10	124	21	132
136	Ammonia dentata	2	31	1	24	3	18	1	11	0	9	0	3	0	1						
137	Ammonia tepida					0	2	0	5	1	12	2	18	3	21	4	28	4	29	5	32
138	Asterorotalia inflata	2	60	2	58	2	44	1	18	2	28	3	44	15	96	13	128	12	144	25	164
139	Asterorotalia trispinosa					2	36	1	12	2	19	2	22	7	48	8	66	6	121	13	88
140	Pseudorotalia schroeteriana	1	14	2	21	1	9	1	8	0	2	0	1								
141	Cribrononion simplex					0	1	0	2	1	3	2	5	2	6	1	8	1	10	2	11
142	Elphidium advenum	4	27	2	26	1	14	2	12	1	9	0	7	0	4	0	3	0	1		
143	Elphidium craticulatum	2	23	1	13	5	8	1	6	1	3	0	3	0	2	1	2	0	1	0	1
144	Elphidium crispum	3	22	2	24	1	15	2	11	1	7	0	8	0	5	0	3	0	2		
145	Elphidium discoidale															0	1	0	2	1	7
146	Elphidium discoidale multiloculatum																	0	1	1	5
147	Elphidiumincertum							0	4	0	6	1	8	2	13						
148	Elphidium norvangi	4	48	2	27	1	15	0	9	0	6	0	2								
149	*Elphidium* sp.	0	1	0	1																
150	Parrellina hispidula	0	8	1	11	1	14	2	16	2	18	2	25	3	38	2	11				
151	Assilina ammonoides	5	41	6	42	2	12	1	8	0	4										
	TOTAL	47	562	60	663	70	660	55	579	71	722	92	1037	136	1277	154	1344	134	1535	255	2007

(*Contd.*)

Table 2: (*Contd.*)

Sl.No.	Station Numbers	11		12		13		14		15		16		17		18		19		20	
	Name of Species	L	T	L	T	L	T	L	T	L	T	L	T	L	T	L	T	L	T	L	T
1	Reophax comprima	1	17	1	12	1	10	1	5	0	1	0	1								
2	Reophax pilulifer	0	2	0	4	1	2														
3	Reophax scorpiurus var.testacea	0	2	0	1	0	2	0	1												
4	Cribrostomoides jeffreysii							0	2	0	6	0	5	0	4	0	1				
5	Haplophragmoides sp	0	2	0	2																
6	Ammoscalaria runiana	0	2	0	1																
7	Ammoscalaria tenuimargo	0	2	0	1																
8	Ammobaculites exiguus											0	2	0	1	0	1	0	1	0	1
9	Spiroplectinella sagittula	3	38	3	32	2	22	1	10	0	4	0	2								
10	Nouria polymorphinoides	0	1	0	2																
11	Trochammina inflata	0	1	0	1																
12	Eggerella australis							0	1	0	1	0	2								
13	Bigenerina nodosaria	0	3	0	1	0	2	0	1												
14	Textularia agglutinans	2	24	3	35	4	66	8	84	10	108	5	88	3	32	0	8				
15	Textularia bocki	1	18	2	26	3	55	7	75	9	96	4	77	3	29	0	6				
16	Textularia candeiana	2	6	1	12	1	16	2	24	2	25	1	22	1	8	0	2				
17	Textularia conica	0	1	0	1	0	2														
18	Textularia dupla	0	2	0	1																
19	Textularia earlandi	0	1	0	1																
20	Textularia porrecta	2	8	2	8	2	7	1	5	0	2										
21	*Karrerotextularia* cf. *albatrossi*	0	3	0	3	0	2	0	1	0	1	`1									
22	Subfischerina galapagosensis	0	3	0	2	0	1			0	2	0	1								
23	Vertebralina striata	2	6	1	4	1	3	0	2	0	1	0	1								
24	Edentostomina cultrata													0	1	0	3	0	4	0	5
25	Edentostomina milletti													0	1	0	2	0	5	0	4
26	Adelosina laevigata					0	2	2	10	4	94	6	44	3	12	0	5				
27	Spiroloculina aequa	0	1	0	1																
28	Spiroloculina affixa	0	1	0	1																
29	Spiroloculina communis									0	2	0	4	0	10	1	18	1	16	1	22
30	Spiroloculina corrugata									0	1	0	1			0	3				

31	Spiroloculina costifera															0	7			0	2
32	*Spiroloculina depressa*											0	1	0	1	0	3	0	4	0	5
33	Spiroloculina henbesti	2	5	1	3	1	3			0	1	0	1								
34	Spiroloculina nitida							0	1	2	12	3	28	4	32	2	21	1	9	0	3
35	Spiroloculina orbis							0	2	1	3	1	3	1	10	1	12	1	14	1	10
36	Cycloforina semiplicata	5	51	5	48	4	38	1	10	1	8	0	7	0	6	0	4	0	4	0	4
37	*Massilina* sp.1							0	2	0	3	0	3	0	2	0	1	0	1	0	2
38	*Massilina* sp.2	0	1	0	1											0	1				
39	Quinqueloculina agglutinans	52	366	34	246	22	215	9	114	8	96	7	65	3	52						
40	*Quinqueloculina bicostata*									0	2	0	5	1	7	2	9	2	9	1	8
41	Quinqueloculina costata	26	138	10	66	8	84	3	44	2	32	2	26	1	16						
42	Quinqueloculina cristata	0	1	0	1	0	1														
43	Quinqueloculina echinata	11	112	9	110	8	98	5	65	1	22	0	15								
44	Quinqueloculina elegans							0	2	0	2	0	2								
45	Quinqueloculina kerimbatica	13	78	5	33	4	44	1	22	1	17	1	13	1	8						
46	Quinqueloculina lamarckiana									0	12	5	87	8	121	15	164	14	146	12	134
47	*Quinqueloculina* cf. *mosharrafai*							0	2	0	2	0	2								
48	Quinqueloculina polygona							0	3	0	2	0	1								
49	Quinqueloculina pseudoreticulata	4	35	2	17	2	21	1	11	1	8	1	6	1	4						
50	Quinqueloculina tropicalis							0	3	1	2	0	1	0	1					0	1
51	*Quinqueloculina* sp.1	0	1	0	1					0	1	0	1	0	1						
52	*Quinqueloculina* sp.2	0	3																		
53	*Quinqueloculina* sp.3					0	2									0	1				
54	*Quinqueloculina* sp.4	0	1																		
55	Flintina bradyana							0	1	0	2	0	3	0	4	0	2				
56	Miliolinella circularis							0	4	0	3	0	3	1	3						
57	Miliolinella elongata													1	2			1	1		
58	*Neopateoris* sp.1													0	1	0	2	0	1		
59	Parahauerinoides complanatiformis	1	9	2	14					0	3	0	3	0	3						
60	Pyrgo laevis	2	5	1	3	1	3			0	1	0	1								
61	*Triloculina insignis*					1	12	1	14	1	13	2	18	1	13	0	6				
62	*Triloculina rotunda*							0	1	0	2	0	3	0	4	0	2				
63	*Triloculina schreiberiana*					2	18	2	11	2	24	3	29	1	12	1	10	1	11	0	7

(*Contd.*)

Table 2: (*Contd.*)

Sl.No.	Station Numbers	11		12		13		14		15		16		17		18		19		20	
	Name of Species	L	T	L	T	L	T	L	T	L	T	L	T	L	T	L	T	L	T	L	T
64	*Triloculina striatotrigonula*															0	2	0	2	0	8
65	*Triloculina terquemiana*					2	12	1	8	1	18	2	21	1	8	1	8	1	7	0	5
66	*Triloculina tricarinata*	10	66	9	56	6	46	5	32	2	22	2	19	1	11	1	9				
67	*Triloculina trigonula*					1	13	1	15	1	17	2	21	1	17	0	8				
68	*Articulina pacifica*	0	1	0	1																
69	*Parrina bradyi*	0	2	0	2																
70	*Rupertianella rupertiana*							0	2	1	3	1	3	1	10	1	12	1	14	1	10
71	*Sorites marginalis coast*	0	2	0	1																
72	*Nodosaria catesbyi*	0	2	0	1																
73	*Pyramidulina catesbyi*	1	3	0	2																
74	*Lenticulina limbosa*	0	2	0	1																
75	*Lenticulina macrodiscus*	0	1	0	1																
76	*Lagena interrupta*	0	2	0	1																
77	*Lagena setigera*	0	1																		
78	*Lagena striata*	0	2	0	1																
79	*Lagena sulcata* var. *spicata*	0	1	0	2																
80	*Lagena* sp.1	1	3	0	2																
81	*Favulina hexagona*	0	1	0	2																
82	*Oolina laevigata*	0	1	0	1	0	1														
83	*Fissurina cucullata*	1	17	1	12	1	10	1	5	0	1	0	1								
84	*Fissurina laevigata*	1	3	1	2	0	1														
85	*Glandulina laevigata*	0	1	0	1	0	2														
86	*Tappanella* sp.	0	1	0	1																
87	*Globorotalia tumida*	0	4	0	3	0	2														
88	*Neogloboquadrina dutertrei*	0	6	0	7	0	4														
89	*Pulleniatina obliquiloculata*	0	1	0	2	0	1														
90	*Globigerina bulloides*	2	14	0	2	2	5	0	1												
91	*Globigerinella aequilateralis*	2	9	0	4	1	8	0	1												
92	*Globigerinoides ruber*	0	1	5	29	2	14														
93	*Globigerinoides sacculifer*	1	12	2	16	1	8	0	5												

94	*Orbulina universa*	1	3	1	3	1	4														
95	*Bolivina hadai*	0	2	0	5	0	3														
96	*Bolivina persiensis*	0	1	0	2																
97	*Brizalina striatula*	1	16	1	13	1	9	1	6	0	1	0	1								
98	*Loxostomina durrandii*	0	1	0	2																
99	*Loxostomina limbata*	0	4	0	3																
100	*Sagrinella lobata*	1	7	1	6																
101	*Saidovina karreriana*	0	3																		
102	*Globobulimina ovata*	0	1	0	2																
103	*Siphogenerina virgula*	3	21	2	18	0	8														
104	*Neouvigerina interrupta*	0	1																		
105	*Uvigerina senticosa*	0	2	0	1																
106	*Reussella atlantica*	0	2	0	1																
107	*Reussella simplex*	1	16	1	17	1	13	0	5	0	1	0	1								
108	*Pavonina flabelliformis*	0	1	0	2																
109	*Fursenkoina pontoni*	0	1	0	2	0	1														
110	*Sigmavirgulina tortuosa*	0	1	1	1																
111	*Baggina philippinensis*	2	18	2	16	1	8	1	6	0	4	0	2								
112	*Cancris auriculus*	0	2	0	4	1	8	1	7	2	9										
113	*Cancris oblanga*	1	6	0	1																
114	*Eponides cribrorepandus*					0	1	0	4	0	2	0	2	0	2	0	3				
115	*Eponides repandus*					0	2	0	3	0	5	0	5	0	5	1	7				
116	*Helenina anderseni*	0	1																		
117	*Rosalina globularis*	1	3	1	2	1	3	1	3	1	2	1	4								
118	*Rosalina macropora*	0	2	1	1	1	2	0	1												
119	*Discorbinella bertheloti*	3	12	2	8	0	1	0	1												
120	*Cibicides lobatulus*											0	3	0	1	0	1	0	2	3	0
121	Cocoarota madrasensis.	2	9	0	4	1	8	0	1												
122	Cymbaloporetta bradyi	0	1	5	29	2	14														
123	Planorbullinella larvata	1	12	2	16	1	8	0	5												
124	Amphistegina radiata	1	3	1	3	1	4														
125	Nonionella stella	0	2	0	5	0	3														
126	Nonionellina labradorica	0	1	0	2																

(*Contd.*)

Table 2: (*Contd.*)

Sl.No.	Station Numbers	11		12		13		14		15		16		17		18		19		20	
	Name of Species	L	T	L	T	L	T	L	T	L	T	L	T	L	T	L	T	L	T	L	T
127	Nonionoides boueanum	1	16	1	13	1	9	1	6	0	1	0	1								
128	Nonionoides elongatum	0	1	0	2																
129	Nonionoides grateloupi	0	4	0	3																
130	Heterolepa praecincta	1	7	1	6																
131	Heterolepa subhaidingerii	0	3																		
132	Hanzawaia concentrica	0	1	0	2																
133	Pararotalia calcar	3	21	2	18	0	8														
134	Pararotalia nipponica	0	1																		
135	Ammonia beccarii	0	2	0	1																
136	Ammonia dentata	0	2	0	1																
137	Ammonia tepida	1	16	1	17	1	13	0	5	0	1	0	1								
138	Asterorotalia inflata	0	1	0	2																
139	Asterorotalia trispinosa	0	1	0	2	0	1														
140	Pseudorotalia schroeteriana	0	1	1	1																
141	Cribrononion simplex	2	18	2	16	1	8	1	6	0	4	0	2								
142	Elphidium advenum	0	2	0	4	1	8	1	7	2	9										
143	Elphidium craticulatum	1	6	0	1																
144	Elphidium crispum					0	1	0	4	0	2	0	2	0	2	0	3				
145	Elphidium discoidale					0	2	0	3	0	5	0	5	0	5	1	7				
146	Elphidium discoidale multiloculatum	0	1																		
147	Elphidiumincertum	1	3	1	2	1	3	1	3	1	2	1	4								
148	Elphidium norvangi	0	2	1	1	1	2	0	1												
149	*Elphidium* sp.	3	12	2	8	0	1	0	1												
150	Parrellina hispidula											0	3	0	1	0	1	0	2	3	0
151	Assilina ammonoides	5	41	6	42	2	12	1	8	0	4										
	TOTAL	179	1385	133	1117	102	1014	61	681	57	730	52	690	41	485	31	393	28	295	26	269

Table 2: (*Contd.*)

Sl.No.	*Station Numbers*	*21*		*22*		*23*		*24*		*25*		*26*		*27*		*28*		*29*		*30*	
	Name of Species	*L*	*T*	*L*	*T*	*L*	*T*	*L*	*T*	*L*	*T*	*L*	*T*	*L*	*T*	*L*	*T*	*L*	*T*	*L*	*T*
1	Reophax comprima							0	1	1	2	3	12	3	15	4	18	4	16	3	14
2	Reophax pilulifer															0	2	0	1	0	2
3	Reophax scorpiurus															0	1	0	2	0	1
4	Cribrostomoides jeffreysii			0	1	0	1	0	4	0	6	0	7	0	1	0	1				
5	Haplophragmoides sp															0	2	0	1	0	1
6	Ammoscalaria runiana															0	1	0	2	0	1
7	Ammoscalaria tenuimargo																	0	1	0	1
8	Ammobaculites exiguus			0	1	0	1	0	1	0	1										
9	Spiroplectinella sagittula					0	2	0	3	0	4	1	14	2	20	3	26	4	44	5	47
10	Nouria polymorphinoides																	0	1	1	1
11	Trochammina inflata															2	12	2	18	1	9
12	Eggerella australis					0	1	0	2	0	4	0	5								
13	Bigenerina nodosaria													0	1	0	1	0	5	0	8
14	Textularia agglutinans					0	2	2	22	3	35	8	76	12	115	5	53	3	22	2	11
15	Textularia bocki					0	1	2	18	3	27	6	56	9	95	5	51	2	19	2	10
16	Textularia candeiana					0	2	2	5	1	7	2	15	3	28	1	12	1	6	1	3
17	*Textularia conica*															0	2	0	1	0	1
18	*Textularia dupla*																	0	1	0	1
19	*Textularia earlandi*																	0	1	0	2
20	Textularia porrecta									0	1	0	3	1	5	2	8	2	9	2	8
21	*Karrerotextularia* cf. *albatrossi*									0	1	0	1	0	1	0	2	1	3	1	4
22	Subfischerina galapagosensis									0	1			0	3	0	3	1	3	1	2
23	Vertebralina striata													0	1	0	2	1	3	2	4
24	Edentostomina cultrata	0	3	0	2	0	1	0	1	0	1	0	1								
25	Edentostomina milletti	0	3	0	3	0	1	0	2	0	1	0	1								
26	Adelosina laevigata					0	1	0	5	1	12	2	22	4	34	0	8				
27	Spiroloculina aequa																	0	1	0	2
28	Spiroloculina affixa																	0	2	0	1
29	Spiroloculina communis	1	12	1	13	1	9	0	8	0	4	0	2								
30	Spiroloculina corrugata	0	2	0	1																

(*Contd.*)

Table 2: (*Contd.*)

Sl.No.	*Station Numbers*	*21*		*22*		*23*		*24*		*25*		*26*		*27*		*28*		*29*		*30*	
	Name of Species	*L*	*T*	*L*	*T*	*L*	*T*	*L*	*T*	*L*	*T*	*L*	*T*	*L*	*T*	*L*	*T*	*L*	*T*	*L*	*T*
31	Spiroloculina costifera	0	1	0	5	0	1														
32	Spiroloculina depressa	0	4	0	5	0	4	0	2	0	1	0	1								
33	Spiroloculina henbesti											0	1	0	1	0	2	1	3	2	4
34	Spiroloculina nitida	0	1	0	8	1	14	2	24	3	35	4	38	2	12	0	8	0	1		
35	Spiroloculina orbis	1	9	1	12	0	8	0	3	0	1										
36	Cycloforina semiplicata	0	3	0	4	1	7	0	3	1	13	2	15	3	17	3	32	2	24	4	41
37	*Massilina* sp.1	0	2	0	1	0	1	0	1	0	1										
38	*Massilina* sp.2	0	2	0	1	0	2	0	3	0	1										
39	Quinqueloculina agglutinans					2	38	7	48	8	58	9	64	11	118	22	213	28	312	32	412
40	Quinqueloculina bicostata	1	9	1	6	0	4	0	1												
41	Quinqueloculina costata					2	18	2	22	3	21	3	24	4	35	10	105	14	165	17	203
42	Quinqueloculina cristata															0	1	0	1	0	1
43	Quinqueloculina echinata									0	14	2	45	6	56	11	98	14	126	17	166
44	Quinqueloculina elegans							0	1	0	2	0	1							0	2
45	Quinqueloculina kerimbatica					2	9	1	11	2	13	2	14	2	18	5	52	7	80	8	101
46	Quinqueloculina lamarckiana	12	120	14	161	10	112	6	55	1	15	0	5								
47	*Quinqueloculina* cf. *mosharrafai*							0	1	0	2	0	1								
48	Quinqueloculina polygona							0	1	0	1	0	2								
49	Quinqueloculina pseudoreticulata					1	4	1	5	1	6	1	7	1	8	2	21	3	34	4	43
50	Quinqueloculina tropicalis	0	1					0	1	1	2	1	3	0	2						
51	*Quinqueloculina* sp.1					0	1	0	1	0	1							0	1	0	1
52	*Quinqueloculina* sp.2																	0	3	0	2
53	*Quinqueloculina* sp.3															0	1	0	1	0	1
54	*Quinqueloculina* sp.4																	0	1	0	2
55	Flintina bradyana			0	1	0	1	0	2	0	3	0	3	0	2	0	1				
56	Miliolinella circularis					1	3	0	4	3	2	0	1								
57	Miliolinella elongata			1	1	1	2	1	2	1	2										
58	*Neopateoris* sp.1																				
59	Parahauerinoides complanatiformis					0	3	1	3	1	2					0	1	1	8	1	9

60	Pyrgo laevis											0	1	0	1	0	2	1	3	2	4
61	Triloculina insignis			1	8	1	12	0	9	0	8	1	8	1	9	0	4				
62	Triloculina rotunda			0	1	0	1	0	2	0	3	0	3	0	2	0	1				
63	Triloculina schreiberiana	0	8	0	11	1	12	1	13	1	15	2	18	2	17	0	9				
64	Triloculina striatotrigonula	0	7	0	1																
65	Triloculina terquemiana	0	6	0	9	1	8	1	9	1	12	2	13	2	12	0	6				
66	Triloculina tricarinata					0	4	0	6	1	12	2	16	7	52	6	51	11	66	11	72
67	Triloculina trigonula			1	9	1	14	1	16	1	14	1	8	1	6	0	4				
68	Articulina pacifica																	0	1	0	1
69	Parrina bradyi													0	1	0	3	0	2	0	3
70	Rupertianella rupertiana	1	9	1	12	0	8	0	3	0	1										
71	Sorites marginalis coast							0	1	0	1			0	1	0	1	0	2	0	1
72	Nodosaria catesbyi															1	2	1	3	0	1
73	Pyramidulina catesbyi															0	1	0	1	0	2
74	Lenticulina limbosa															0	1	0	2	0	1
75	Lenticulina macrodiscus															0	2	0	3	0	2
76	Lagena interrupta																	0	2	0	1
77	Lagena setigera																	0	1	0	2
78	Lagena striata																	0	2	0	1
79	*Lagena sulcata* var. *spicata*															0	1	0	2	0	1
80	*Lagena* sp.1																	0	3	0	2
81	Favulina hexagona															0	1	0	2	0	1
82	Oolina laevigata															0	1	0	1	0	3
83	Fissurina cucullata							0	1	1	2	1	12	1	15	1	18	1	16	1	17
84	Fissurina laevigata															0	1	1	2	0	1
85	Glandulina laevigata															0	1	0	2	0	1
86	*Tappanella* sp.																	0	1	0	1
87	Globorotalia tumida					0	1	0	3	0	4	0	5	1	6	2	7	1	6	8	21
88	Neogloboquadrina dutertrei															0	2	0	7	1	5
89	Pulleniatina obliquiloculata											0	1	0	2	0	1				
90	Globigerina bulloides											0	2	0	1	1	7	2	7	1	6
91	Globigerinella aequilateralis													0	1	0	4	1	3	1	2
92	Globigerinoides ruber													0	2	3	12	8	17	6	18

(*Contd.*)

Table 2: (*Contd.*)

Sl.No.	*Station Numbers*	*21*		*22*		*23*		*24*		*25*		*26*		*27*		*28*		*29*		*30*	
	Name of Species	*L*	*T*	*L*	*T*	*L*	*T*	*L*	*T*	*L*	*T*	*L*	*T*	*L*	*T*	*L*	*T*	*L*	*T*	*L*	*T*
93	Globigerinoides sacculifer													0	1	2	14	3	18	2	16
94	Orbulina universa																	1	1	1	1
95	Bolivina hadai													0	1	0	4	0	2	0	1
96	Bolivina persiensis															1	4	2	12	3	14
97	Brizalina striatula							0	1	1	2	1	12	1	16	1	19	2	20	2	22
98	Loxostomina durrandii																	0	1	0	2
99	Loxostomina limbata																	0	1	0	1
100	Sagrinella lobata																	1	7	1	8
101	Saidovina karreriana																	0	1	0	2
102	Globobulimina ovata																	0	2	0	4
103	Siphogenerina virgula									0	2	0	4	0	5	1	9	2	14	3	22
104	Neouvigerina interrupta																	0	1	0	2
105	Uvigerina senticosa																	0	1	0	12
106	Reussella atlantica																	1	5	2	12
107	Reussella simplex							0	1	1	3	1	9	1	11	1	14	1	16	1	15
108	Pavonina flabelliformis																			0	1
109	Fursenkoina pontoni																	0	2	1	4
110	Sigmavirgulina tortuosa																	0	1	0	2
111	Baggina philippinensis					0	1	4	8	1	11	2	18	2	19	2	17	1	18	2	20
112	Cancris auriculus																	0	1	0	2
113	Cancris oblanga																	0	2	0	1
114	Eponides cribrorepandus			0	2	0	1	0	3	0	1										
115	Eponides repandus			0	2	0	4	0	2	0	3										
116	Helenina anderseni																	0	1	0	2
117	Rosalina globularis									1	8	0	4	0	1	0	2	0	1	1	4
118	Rosalina macropora									1	4	0	2	0	1	0	1	0	1	0	1
119	Discorbinella bertheloti															0	1	2	8	1	6
120	Cibicides lobatulus	2	0	3	5	0	1	0	1	0	1										
121	Cocoarota madrasensis.							0	2	0	5	0	8	1	13	1	16	1	18	2	23
122	Cymbaloporetta bradyi															0	3	0	4	0	2

123	Planorbullinella larvata															0	3	0	4	0	2
124	Amphistegina radiata					1	12	5	55	8	88	7	98	9	114	8	78	3	22	2	14
125	Nonionella stella															0	1	0	2	0	3
126	Nonionellina labradorica															0	2	0	4	0	8
127	Nonionoides boueanum					0	2	1	14	2	19	3	35	3	38	2	21	1	9	0	6
128	Nonionoides elongatum									2	22	3	42	5	48	2	16	1	11	0	4
129	Nonionoides grateloupi																	0	3	1	4
130	Heterolepa praecincta									0	1	0	1	1	7	2	9	5	35	4	27
131	Heterolepa subhaidingerii							0	1	0	1	0	2	1	14	2	13	12	57	5	56
132	Hanzawaia concentrica	0	2	0	5	1	19	2	24	3	34	4	43	5	54	7	78	9	85	10	108
133	Pararotalia calcar					0	1			0	1										
134	Pararotalia nipponica	5	102	3	98	1	10	0	8	0	4	0	3								
135	Ammonia beccarii	2	37	2	34	10	67	2	29	3	18	2	65	4	65	2	47	13	124	10	152
136	Ammonia dentata	6	36	5	36	3	18	1	16	1	8	0	3								
137	Ammonia tepida							0	1	0	3	1	13	2	19	3	23	3	27	4	33
138	Asterorotalia inflata	6	69	7	83	8	63	4	53	2	18	3	38	3	55	1	29	11	135	10	164
139	Asterorotalia trispinosa							1	16	1	12	3	25	3	44	1	19	8	96	8	77
140	Pseudorotalia schroeteriana	1	17	2	18	1	8	0	5	0	3	0	1								
141	Cribrononion simplex							0	1	0	2	1	4	2	6	2	10	3	12	2	11
142	Elphidium advenum	4	29	4	27	3	21	2	18	1	9	0	6	0	3						
143	Elphidium craticulatum	2	14	2	13	1	13	1	8	1	4	0	4	0	2	0	1				
144	Elphidium crispum	3	27	3	23	2	19	2	16	1	8	0	7	0	4						
145	Elphidium discoidale													4	18	5	27	4	28	5	38
146	Elphidium discoidale multiloculatum													3	7	2	13	2	15	2	22
147	Elphidiumincertum																				
148	Elphidium norvangi	3	29	2	21	1	18	0	9	0	4										
149	*Elphidium* sp.							0	1	0	1	0	2								
150	Parrellina hispidula	0	8	0	11	1	12	1	13	1	15	2	18	2	17	0	9				
151	Assilina ammonoides	5	41	6	42	2	12	0	4	0	3	0	1								
	TOTAL	55	613	60	697	61	616	56	639	70	693	88	995	130	1299	137	1386	210	1907	222	2223

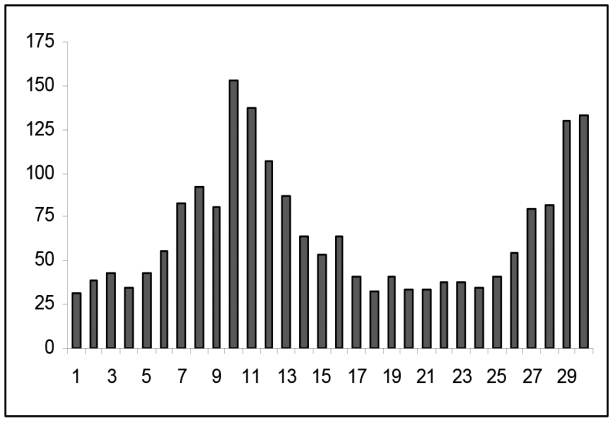


Figure 3a: Station wise species diversity pattern.

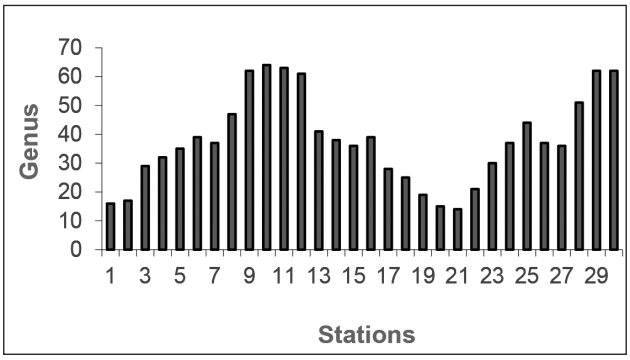


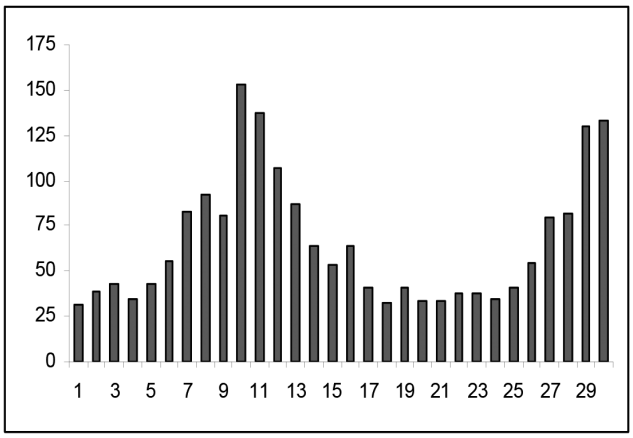
Figure 3b: Station wise diversity pattern of Genera.

The following 44 benthic foraminiferal species have been observed to be widespread and abundant/ persistent during the collection: *Cribrostomoides jeffreysii, Spiroplectinella sagittula, Textularia agglutinans, T. bocki, T. candeiana, Adelosina laevigata, Spiroloculina communis, S. nitida, S. orbis, Cycloforina semiplicata, Quinqueloculina agglutinans, Q. costata, Q. echinata, Q. kerimbatica, Q. lamarckiana, Q. pseudoreticulata, Flintina bradyana, Triloculina insignis, T. rotunda, T. schreiberiana, T. terquemiana, T. tricarinata, T. trigonula, Rupertianella rupertiana, Fissurina cucullata, Baggina philippinensis, Cocoarota madrasensis, Amphistegina radiata, Nonionoides boueanum, Heterolepa subhaidingerii, Hanzawaia concentrica, Pararotalia nipponica, Ammonia beccarii, A. dentata, A. tepida, Asterorotalia inflata, A. trispinosa, Pseudorotalia schroeteriana, Cribrononion simplex, Elphidium advenum, E. craticulatum, E. crispum, Parrellina hispidula* and *Assilina ammonoides.* Among these, *Textularia agglutinans*, *T. bocki* and *Asterorotalia inflata* consistently exhibit a distinct preference for substrates with relatively higher mud content in calmer, deeper waters off Nagapattinam.

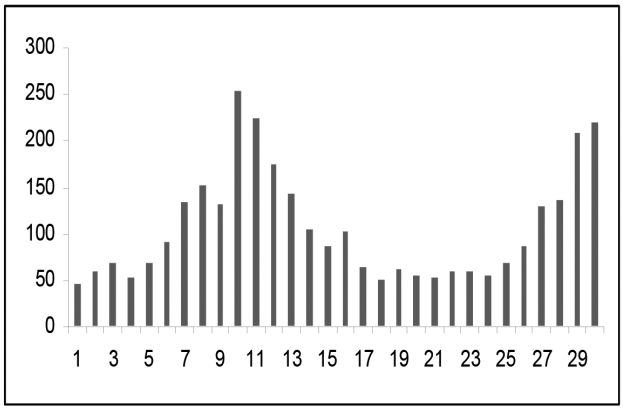
The "live" (pink Bengal stained) and total ("live" + dead) benthic foraminifera populations in the study area during collection are moderately high. This may be due to the fact that the southeast coast of India and its offshore region are very hot; maximum temperatures of over 40°C are usually recorded in May, and even in June and July they are above 36° C, sometimes reaching "highs" of 38°C or more. During this time, evaporation is highest in this part of the bay, resulting in relatively high salinity, often around 35‰. These factors are thought to be responsible for the higher foraminifera populations during this period. Similar observations have been made by several researchers (Ragothaman, 1974; Ragothaman and Kumar, 1985; Ragothaman and Manivannan, 1985; Kumar, 1988; Rajeshwara Rao, 1998) as far as the Bay of Bengal is concerned. This is also confirmed by relatively higher populations of ostracods in summer in the Gulf of Mannar (Hussain, 1992), Palk Bay (Sridhar, 1996) and off Mahabalipuram (Minikumari, 1998). The spatial distribution curves representing the total populations of the widespread and common species are shown in Figures 3 a, b, c and d. The spatial variations in the faunal diversity (at specific and genus-specific levels) show a high number of species and a high diversity of genera in the study area (Figure 4a, b). From the distribution curves for species and genera, relatively higher diversity values coincide with greater depths (Ragothaman and Kumar, 1985). More than 60 genera were found at stations 9, 10, 11, 12, 29, and 30, while more than 40 genera were recorded at stations 8, 13, and 27. It is evident from the curves that high species and genus diversity generally coincide with stations where the depth of the water column is greatest.

Distribution of Planktic Foraminiferal Taxa

Of the nine planktonic foraminifera species found in bottom sediments off Nagapattinam, only five taxa—*Globorotalia tumida, Neogloboquadrina dutertrei, Globigerina aequilateralis, Globigerinoides ruber*, and *G. sacculifer*—were detected. Among these, *Globigerinoides ruber* and *G. sacculifer* are significant in terms of their populations. In general, they were observed to be abundant in deeper water, in the outer inner shelf stations. This is consistent with the observations of Mathieu (1986) and Levy et al. (1995), who noted a general increase in the relative proportions of planktonic species from the coast towards the outer shelf. Be and Hamlin (1967) conducted extensive studies of planktonic foraminifera and discussed their ecology in detail. Vincent and Berger (1981) enumerated species typical of tropical and subtropical latitudes. Similar observations were made by Hatta et al. (1996) in their



(a)



(b)

Figure 4a and b: Spatial and temporal distribution of living population.

studies in the western Pacific and Hilbrecht (1997), they noted that subtropical populations of *Neogloboquadrina dutertrei* prefer temperatures between 15 and 22° C and salinity between 35 and 26.5‰. Off Nagapattinam, the abundance of species such as *Globorotalia tumida, Neogloboquadrina dutertrei, Globigerina aequilateralis, Globigerinoides ruber*, and *G. sacculifer*, as well as the occurrence of *Globigerina bulloides* in stations of relatively great depth and the secondary occurrence of *Pulleniatina obliquiloculata*, are consistent with previous studies (op. cit).

Living and Total Populations

Living Populations

In the study area, living foraminifera were observed in all 30 samples collected and examined. The size of the living population varied from 47 to 255 specimens per 25 g sediment sample. The spatial and temporal distribution of the live population is shown in Figure. 5. It can be seen that the live population is low to moderate in most samples. The population size of 1-50 specimens is found in only one station, 51-100 in 16 stations, 101-250 in 12 stations, 255 in one station of the study area. In general, the living population is high in the outer stations of the study area. In the present area, the fauna is very low in the two sampling stations near the coast. The living population is > 100 specimens per unit volume of sediment in all samples, while it is < 50 specimens per unit volume in the nearshore station. The live population value of each station ranges from 26 to 255, and these values are particularly high in the outer stations of the study area. The highest live population size reached in any season is found at station 10.

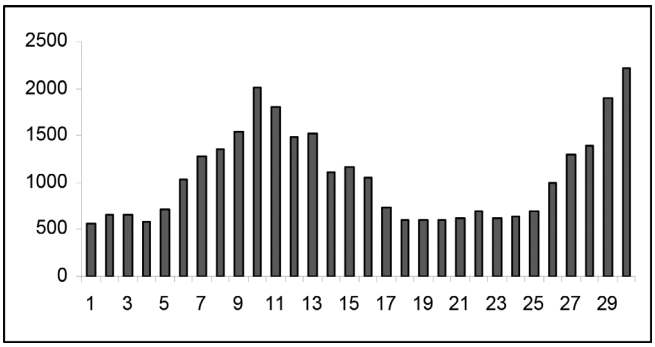


Figure 5: Spatial and temporal distribution of total population.

Total Populations

Total (live + dead) population size ranges from 562 to 2223 specimens per 25 g of sediment of the study area, with the maximum at station 30 and minimum at station 1. The spatial and temporal distribution of the total population is shown in Figure 5. It can be seen that the total population is relatively moderate to high in most samples. The population size range of 500 - 1000 specimens is found in 15 stations of the coastal and nearshore stations, 1001 - 2000 in 13 stations and >2000 in two of the outer stations of the study area.

Climate Studies and Their Implications for Formaminifera

The Bay of Bengal and its hinterland exhibit a wide range of climatic characteristics. Because the area is primarily influenced by the monsoon, Landsberg et al. (1966) proposed a climate classification based on rainfall and, in particular, the length of the dry and wet seasons. Tropical and subtropical cyclones provide gale force winds and heavy rainfall over the northern Indian Ocean and surrounding areas. Over the bay, storms and depressions are usually observed from June to November. According to Rao (1981), tropical cyclones are associated with very heavy rainfall and

gale force winds during the post-monsoon transition period, especially in coastal areas. Carpenter (1856) was the first to suggest that temperature may play an important role in the morphological variations of the foraminifera sample. Rhumbler (1911) pointed out that the same species (e.g., *Trilovulina tricarinata* and some Astrorhiziidae) may be represented by larger specimens in cold water than in warm. In general, the study area is influenced by the southwest and northeast monsoons. In summer, land temperatures rise to as high as 45°C. The area experiences two phases of rainfall, one during the southwest monsoon (June to September) in the form of occasional showers and the second phase during the northeast monsoon (October to December), when cyclones normally occur almost every year, causing heavy rainfall. The total annual rainfall varies between 1,100 and 1,250 mm, of which the northeast monsoon accounts for about 50-60% and the southwest monsoon for about 30-40%. The coolest month is January with an average temperature of 25°C and the hottest month is May with an average temperature of 37°C.

Conclusions

Prior to the start of the present study in July, studies of foraminifera near or off Nagapattinam were limited to either the beach sands or the littoral zone. Very little information was available on the foraminifera populations. Therefore, an attempt was made to study the distribution of the inner shelf foraminiferal fauna in this part of the southeastern coast of India off Nagapattinam. This resulted in the following findings.

A total of 151 benthic foraminifera species and varieties belonging to 82 genera, 42 families, 21 superfamilies and 5 suborders were described and illustrated. It is found that the number of living populations is low to moderate. In general, the number of living populations is high in the outstations of the study area. In the present area, the fauna is present in very low abundance in the nearshore stations. The distribution of Forminifera is controlled by various environmental factors and energy conditions. From the spatial and temporal distribution of total populations, it is evident that total populations are relatively moderate to high in most samples.

In the present study of shelf sediments off Nagapattinam, benthic foraminifera are sensitive to climatic conditions, especially temperature, pH, salinity, and subsurface properties. The morphological characteristics of some species of foraminifera show that the morphological variations of foraminifera are due to climatic conditions, especially temperature. The species *Trilovulina tricarinata* were found to be larger specimens in cold water than in warm water. The distribution pattern and the total percentage of living and non-living foraminers clearly shows the suitable and influenceable climatic conditions.

In light of the catastrophic Indian Ocean tsunami of December 26, 2004 and the significant changes in the nearshore continental region, the results of this research project would provide a reliable data base for comparative post-tsunami studies.

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