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Distribution of Benthic Foraminifera with Reference to Sediment Characters from off the Coast of Manapad, South East Coast of India

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Abstract In order to assess the distribution of foraminifera with reference to sediment characters from the inner shelf sediments of Gulf of Mannar, off Manapad to Tiruchendur, the following objectives were taken up i. to inventory the foraminifera fauna and to observe their quantitative composition ii. to ascertain the distribution of living and total (living + dead) population of the fauna and iii. to correlate the temporal and spatial distribution of the fauna with observed substrate characteristics. For the study, 54 sediment samples were collected once in four months for a year, representing summer, pre-monsoon and winter/post monsoon, from the study area. A total of 99 species were identified, belonging to the suborders Textulariina, Miliolina, Lagenina and Rotaliina. The following six species were found to be abundant viz. *Ammonia beccarii, Ammonia tepida, Asterorotalia inflata, Noninoides boueanum, Quinqueloculina seminulum* and *Spiroloculina communis*. Spatially, the population, in general, increased with the depth and was found to be higher along the deeper part of the collection (stations 8, 9 and 10) and minimum population was found to occur in near shore stations (stations 1 and 18). The living population was found to be maximum during summer (May) and minimum during pre-monsoonal period (September). The species distribution revealed that the foraminiferal population has a positive correlation with depth, calcium carbonate and organic matter content of the substrate. In general, the higher values of $CaCO_3$ found in stations 7 to 13, support higher foraminiferal population in the area. The population was also found to be maximum when the organic matter percentage was between 1.90 and 2.00 % along with other amiable environmental parameters. The congenial substrate for the population abundance was siltysand.

Keywords: *benthic foraminifera, spatial, temporal distribution, sediment characters, Manapad, Tiruchendur, Gulf of Mannar*

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1. Introduction

The present study was carried out from off the coast of Manapad to Tiruchendur (Figure 1), that lies between N 8°22’ to N 8°27’latitudes and E 78°4’ to E 78°10’ longitude (Table 1) and forms a part of Survey of India’s toposheet no. 58 L/3. The area has a raised beach with a sand bar parallel to the coastline, that lies north of Kulashekarapattinam. The samples were collected from 18 stations, once in four months for a period of one year and thus the total samples amounted to 54.

The main objectives of the study comprise

i. to inventory the foraminifera fauna and to observe their quantitative composition
ii. to ascertain the distribution of living and total (living + dead) population of the fauna and
iii. to correlate the temporal and spatial distribution of the fauna with observed substrate characteristics.

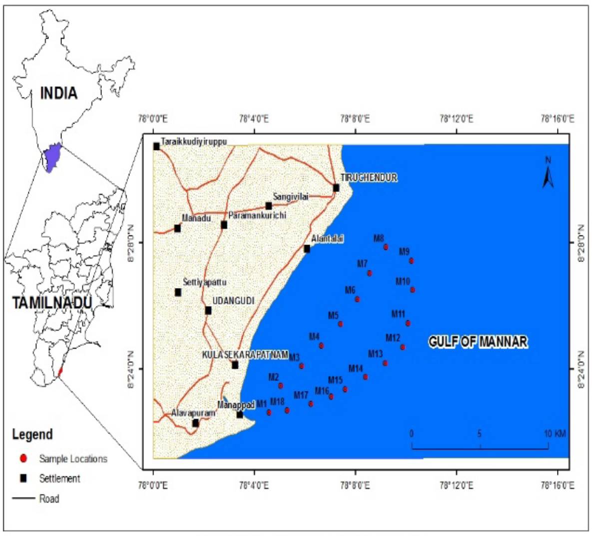

Figure 1. Study area map showing sample locations

Table 1. Geographic locations of sample stations

Station no:	Latitude	Longitude
M1	8°22'35.02"N	78° 4'34.94"E
M2	8°23'27.53"N	78° 5'2.51"E
M3	8°24'04.36"N	78° 5'53.45"E
M4	8°24'44.77"N	78° 6'39.97"E
M5	8°25'25.79"N	78° 7'24.99"E
M6	8°26'14.07"N	78° 8'05.34"E
M7	8°27'02.31"N	78° 8'33.21"E
M8	8°27'51.10"N	78° 9'13.88"E
M9	8°27'28.42"N	78°10'12.61"E
M10	8°26'30.48"N	78°10'16.69"E
M11	8°25'28.72"N	78°10'05.30"E
M12	8°24'42.90"N	78° 9'51.52"E
M13	8°24'11.93"N	78° 9'10.09"E
M14	8°23'44.41"N	78° 8'23.95"E
M15	8°23'21.79"N	78° 7'36.34"E
M16	8°23'08.46"N	78° 7'02.57"E
M17	8°22'53.61"N	78° 6'13.42"E
M18	8°22'41.30"N	78° 5'19.82"E

2. Materials and Methodology

The samples were collected using motor launch and mud grab by taking necessary precautions in the months of May 2016, September 2016 and January 2017. A unit volume of 100 ml of wet sediment was preserved in 10 % formaldehyde solution for foraminiferal study.

The remaining sediment samples were preserved in polythene covers and labeled for laboratory work. To distinguish living from dead foraminifera, Walton's Rose Bengal staining technique [26] was adopted. The foraminifera separated from the sediment were classified and their population (living and dead) was analyzed quantitatively. Krumbein and Pettijohn's pipette method [7] was followed to find out sand-silt-clay ratio of the substrate and the sediment types were recognized by Trefethen's textural nomenclature [24]. Calcium carbonate content of the sediment was determined using rapid titration method of Piper [19]. Organic matter content in the sediments was estimated using chromic acid method of Walkley and Black as detailed out by Jackson [5].

3. Results and Discussion

Post et. al. [20] after their detailed work in Gulf of Papua, suggested that the distribution of benthic foraminifera strongly correlate to changes in water depth, percent carbonate mud, percent gravel, organic carbon flux, temperature and salinity. Enge et.al. [2] detected that species composition of calcareous foraminifera vary strongly between depths. During the study on recent benthic foraminifera with respect to environmental variables from the shoreface and inner shelf off Valencia (Western Mediterranean), Lopez-Belzunce M. et. al. [13] found that depth, energy conditions, type of substrate (bioclastic), organic matter and presence of seagrass are the main factors influencing the distribution of dead foraminiferal assemblages. They inferred that the highest proportions of bioclastic sands with high organic matter and carbonate content correspond to samples with the highest numbers of living foraminifera. Recently, Martins M.V.A. et. al. [17] pointed out that bathymetry, sediment characteristics and the supply of organic matter clearly controls the distribution pattern of living foraminiferal assemblages in the continental shelf of the Campos Basin. Martins M.V.A et. al. [15] made a detailed study on the density and diversity of living and dead foraminifera in the Aveiro continental shelf and found higher density and diversity of living species in the middle continental shelf due to the substrate stability, reduced deposition of fine sedimentary particles and availability of organic matter. Hence, in the present study, relationship between the distribution of living and total foraminiferal population was analysed with respect to substrate characteristics like sediment type, calcium carbonate and organic matter.

Foraminiferal study of the samples collected led to the recognition of 99 benthic foraminiferal species belonging to 47 genera, 33 families, 17 super families of the suborders Textulariina, Miliolina, Lagenina and Rotaliina, following the classification of Loeblich and Tappan [12].

3.1. Living Population

Living foraminifera was found to be present in all the samples collected and studied. The living population size varied from 80 (Station 1 of September) to 394 specimens (Station 9 of May) per 100 ml of wet sediment. Spatially, maximum population was found in the farthest stations from the shore (stations 8, 9 and 10) and minimum population was found to occur in near shore stations (stations 1 and 18). The living population was found to be maximum (4099 specimens) during summer (May) and minimum (3442 specimens) during pre-monsoonal period (September). Seasonal variations of living population are given in Figure 2.

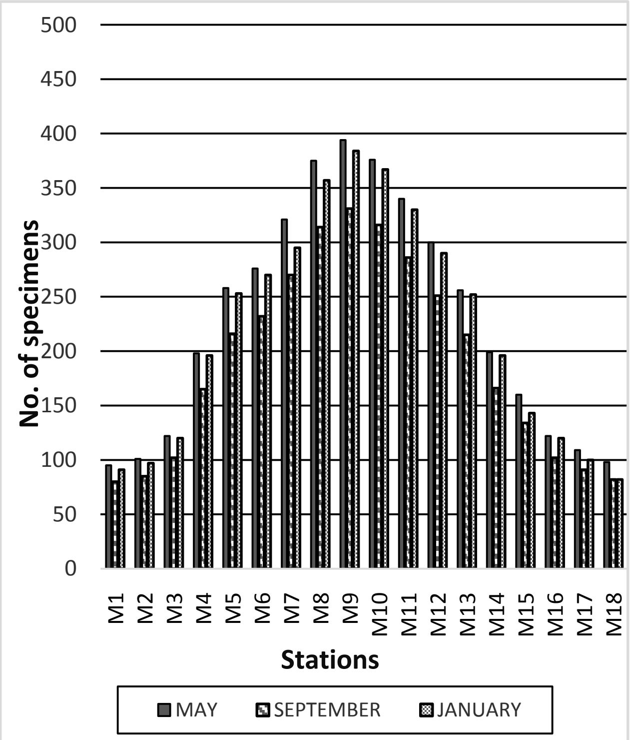

Figure 2. Seasonal variations of living population

3.2. Total Population

The total (living + dead) population size ranged from 286 (Station 1 of September) to 1190 specimens (Station 9 of May) per 100 ml of wet sediment. Temporally, the lowest population (11090 specimens) was observed during pre-monsoon and in the stations nearest to the shore, while the maximum (13212 specimens) was noticed during summer and spatially, at the stations farthest from the shore.

Among the 99 benthic foraminiferal species observed in the study area, the following 6 benthic foraminiferal species were found to be abundant as their population was more than 150 specimens per 100 ml of wet sediment in the study area viz. *Ammonia beccarii, Ammonia tepida, Asterorotalia inflata, Noninoides boueanum, Quinqueloculina seminulum* and *Spiroloculina communis*. The living and total population sizes of these abundant species are given in Table 3 to 8.

3.3. Sand-silt-clay Ratio

The correlation between texture of sediment and foraminiferal population was understood from several studies. Reddy and Reddy [21] suggested that higher foraminiferal count is related to the presence of silt dominated clay. V. Kumar et. al. [9] found that fines of the substrate has positive effect on the foraminiferal population in Thamirabarani river estuary. V. Kumar and K. Sivakumar [10] found siltysand substrate to be favorable for the abundance of foraminiferal species. After their study on the ecological and pollution aspects of benthic foraminifera from the Palk Bay, off Rameswaram, Kumar et al. [11] deduced that the siltysand type substrate favors higher foraminiferal population. Mendes et al. [18] from their study observed that the type of substrate controls the type foraminiferal assemblage. According to them, *Eggerella scaber, Planorbullina mediterranensis* and *Cribrononion gerthi* shows highest number of tests in sediments dominated by sandysilt while *Bulimina aculeate, Epistominella vitrea* and *Cassidulina laevigata* displays highest number of tests in samples characterized by sandy silty clay.

Of the twelve sediment types suggested by Trefethen [24], only sand and siltysand types were present in the study area (Table 2). The favorable substrate for the foraminiferal abundance was found to be siltysand. The data related to sand silt clay percentages in the trilinear diagram for all 54 samples are summarized in the following Table 2.

Table 2. Soil texture of samples

Month	Sand	Siltysand
May 2016	1,18	2,3,4,5,6,7,8,9,10,11,12, 13,14,15,16,17
September 2016	1,2,17,18	3,4,5,6,7,8,9,10,11,12,13, 14,15,16
January 2017	1,2,3,17,18	4,5,6,7,8,9,10,11,12,13,14,15,16

3.4. Calcium Carbonate

Jayaraju and Reddy [6] observed a positive correlation between $CaCO_3$ and foraminiferal population in the Tuticorin and Kovalam stretch. Manivannan et. al. [14] suggested $CaCO_3$ as an important controlling factor for foraminiferal population in the Gulf of Mannar. V. Kumar et. al. [8] found an increase in living population size with increasing $CaCO_3$ content in the Palk Bay, off Rameshwaram. S.M. Hussain et. al. [4] found that higher $CaCO_3$ in beach sands of Kovalam favors maximum distribution of foraminifera. Suresh Gandhi et. al. [23] spotted out calcium carbonate as the major controlling factor for the thriving of foraminiferal fauna in and around the region of Manalmelkudi Spit, Palk Strait.

In the present study area, $CaCO_3$ varied between 20.5% (station 1, September) to 25.81% (station 12, May). Station wise mean percentage of $CaCO_3$ was obsreved to be the maximum in station 12 and it was also higher in stations 13 and 14. Temporally, the mean value was highest (24.77%) during May, and the lowest (22.87%) for September and was positively correlated with the foraminiferal abundance. Spatially, the higher values of $CaCO_3$ were found in stations 7 to 14 which supported higher foraminiferal population size in the area.

3.5. Organic Matter

The preservation of organic matter depends greatly on the sediment texture. Sediment fines are less permeable and thus preserve more organic matter. Venkata Rao and Subba Rao [25] found lower organic matter content in sandy sediments and higher content in the fine sediments of Suddagedda river estuary. Kumar et al. [11] after a detailed study on the foraminiferal population and sediment parameters from the Palk Bay, off Rameswaram have stated that the organic matter of the area is low due to low sedimentation rate. The living foraminiferal population has inverse relationship with organic matter content. Eric Armynot et al. [3] confirmed that foraminifera density is low and species richness is high in sediments with a low organic matter content (<2%) and foraminifera density is high and species richness at an intermediate value in sediments with very high organic matter content. M.V.A. Martins et. al. [16] revealed that opportunistic species populate in areas where the substrate is composed of fine-grained sediments enriched in organic matter. Arslan M. et. al. [1] after studying Askar boat harbor samples of Eastern Bahrain concluded that higher organic matter content supports dominance of Ammonia, Glabratellina, and Murrayinella in sediments and an impotence in the population of Miliolid.

In the area under study, organic matter content was maximum (2.364%) in station 9 of May and minimum (0.653%) in Station 2, September. Seasonally, mean value of organic matter content was the highest (1.99%) in May and the lowest (1.45%) in September. Spatially, the mean organic matter content was found to be higher (>1.98%) between stations 6 and 13 and favored higher population, when the other parameters were congenial.

3.6. Distribution of abundant Foraminifera

Solai A. et. al. [22] suggested that the distribution of foraminifera from off Tuticorin and Tiruchendur is controlled by bathymetry and the nature of the substrate. According to Lopez-Belzunce M. et. al. [13], the environmental variables like bathymetry, substrate grain size composition on the inner shelf and shoreface influence the dead foraminifera distribution and for the living assemblages, the main variables affecting are bioclastic sand substrate, the carbonate proportion and the organic matter content. This was observed to be synonymous with the present study. The relation between substrate characteristics, depth and abundant foraminiferal population for different seasons is shown in Figure 3.

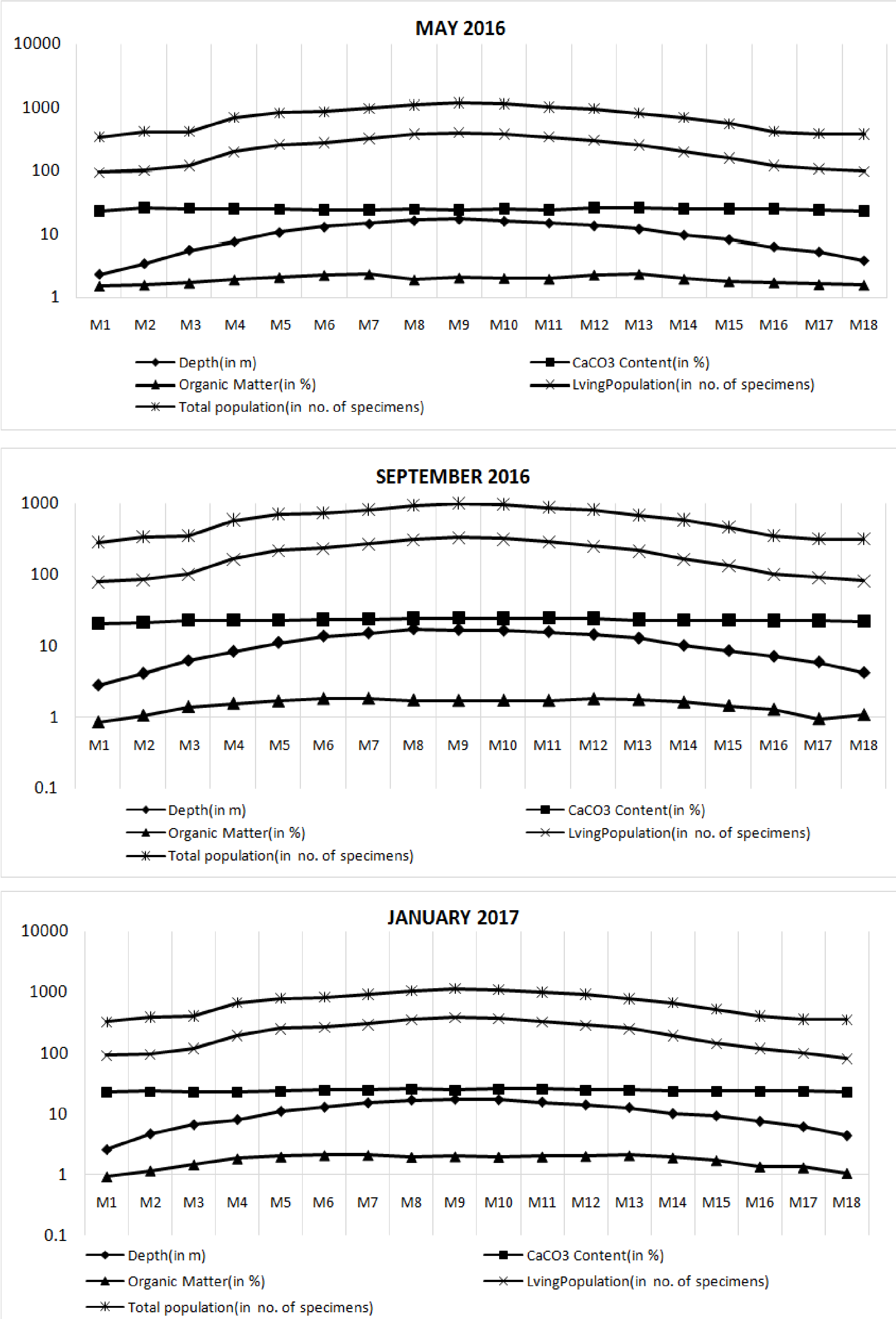

Figure 3. Correlation between sediment parameters and population for May2016, September 2016 and January 2017

Table 3. Occurrence of living and total population of Ammonia beccarii in actual numbers per unit volume

Living																		
Month	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	Total
May	13	11	15	16	19	22	24	29	34	30	28	26	20	16	16	15	14	12	360
September	11	9	13	13	16	18	20	24	29	25	24	22	17	13	13	13	12	10	302
January	13	11	15	16	18	21	23	27	33	29	27	25	19	16	15	15	14	12	349
Mean	12	10	14	15	18	20	23	27	32	28	26	24	19	15	15	14	13	11	337
Total (living + dead)																			
Month	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	Total
May	35	28	42	46	55	64	67	78	93	83	80	72	59	46	44	42	39	32	1004
September	29	24	35	39	46	54	56	66	78	70	67	60	50	39	37	35	32	26	844
January	34	27	41	44	54	62	65	76	90	80	78	69	57	44	42	41	37	30	971
Mean	33	26	39	43	52	60	63	73	87	78	75	67	55	43	41	39	36	29	940

Table 4. Occurrence of living and total population of *Ammonia tepida* in actual numbers per unit volume

Living																		
Month	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	Total
May	10	10	13	14	17	19	19	23	22	24	21	17	15	14	14	13	12	10	286
September	8	8	11	12	14	16	16	19	18	20	18	14	13	12	11	11	10	8	240
January	9	9	13	14	17	18	18	22	21	23	20	17	15	14	13	13	12	9	277
Mean	9	9	12	13	16	18	18	21	20	22	20	16	14	13	13	12	11	9	268
Total (living + dead)																			
Month	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	Total
May	28	28	36	43	48	55	53	63	65	70	59	48	42	43	40	36	32	28	816
September	24	24	30	36	40	46	45	53	55	59	50	40	35	36	33	30	27	24	686
January	27	27	35	42	46	54	51	61	63	67	57	46	41	42	38	35	30	27	789
Mean	26	26	34	40	45	52	50	59	61	65	55	45	39	40	37	34	30	26	764

Table 5. Occurrence of living and total population of *Asterorotalia inflata* in actual numbers per unit volume

Living																		
Month	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	Total
May	8	8	10	14	15	16	17	17	19	20	19	17	19	14	12	10	9	8	253
September	7	7	8	12	13	13	15	15	16	17	16	14	16	12	10	8	8	7	212
January	7	7	9	14	15	16	17	17	18	19	18	17	18	14	12	9	8	7	242
Mean	7	7	9	13	14	15	16	16	18	19	18	16	18	13	11	9	8	7	236
Total (living + dead)																			
Month	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	Total
May	23	22	29	40	42	46	52	49	56	57	57	50	53	40	35	29	26	23	727
September	19	18	24	34	35	39	43	41	47	48	48	42	45	34	29	24	22	19	611
January	22	21	28	39	41	44	50	47	55	55	55	48	51	39	34	28	25	22	704
Mean	21	20	27	38	39	43	48	46	53	53	53	47	50	38	32	27	24	21	681

Table 6. Occurrence of living and total population of *Nonionoides boueanum* in actual numbers per unit volume

Living																		
Month	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	Total
May	7	7	12	7	8	8	14	17	17	14	16	16	14	7	10	12	10	7	201
September	6	6	10	6	7	7	11	14	14	12	13	13	12	6	8	10	8	6	169
January	6	6	12	6	7	7	14	16	17	14	16	16	14	6	9	12	9	6	193
Mean	6	6	11	6	7	7	13	15	16	13	15	15	13	6	9	11	9	6	188
Total (living + dead)																			
Month	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	Total
May	20	22	33	21	23	22	38	47	48	40	45	46	40	21	27	33	27	21	573
September	17	18	28	18	19	18	32	39	40	34	38	39	34	18	23	28	22	18	482
January	19	21	32	20	22	21	37	45	46	39	43	44	39	20	26	32	25	20	551
Mean	19	20	31	20	21	20	36	44	45	38	42	43	38	20	25	31	25	20	535

Table 7. Occurrence of living and total population of *Quinqueloculina seminulum* in actual numbers per unit volume

Living																			
Month	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	Total
May	8	10	9	15	12	14	20	23	25	22	18	20	18	15	12	9	9	9	268
September	7	8	8	13	10	12	17	20	21	18	15	17	15	13	10	8	7	8	225
January	7	9	8	15	12	14	19	23	24	21	18	19	18	15	12	8	8	8	258
Mean	7	9	8	14	11	13	18	22	23	20	17	19	17	14	11	8	8	8	250
Total (living + dead)																			
Month	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	Total
May	22	32	25	44	32	48	55	63	70	60	53	56	52	44	35	25	24	27	765
September	18	27	21	37	27	40	46	53	59	50	45	47	44	37	29	21	20	23	643
January	21	30	24	42	30	46	53	61	67	58	51	55	50	42	34	24	23	26	737
Mean	20	30	23	41	30	45	51	59	65	56	50	53	49	41	32	23	22	25	715

Table 8. Occurrence of living and total population of *Spiroloculina communis* in actual numbers per unit volume

Living																			
Month	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	Total
May	5	3	6	7	10	10	14	15	16	12	14	10	8	7	7	6	6	4	159
September	4	3	5	6	8	8	12	12	13	10	12	8	7	6	5	5	5	3	134
January	5	3	6	6	9	9	14	15	16	12	14	9	7	6	6	6	5	4	152
Mean	5	3	6	6	9	9	14	14	15	11	13	9	7	6	6	6	5	4	148
Total (living + dead)																			
Month	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	Total
May	13	10	16	19	28	27	40	43	46	33	37	27	22	19	18	16	15	12	439
September	11	8	13	16	24	23	33	36	39	28	31	23	18	16	15	13	12	10	368
January	13	9	16	18	27	26	38	41	44	32	36	26	21	18	17	16	14	12	424
Mean	12	9	15	18	26	25	37	40	43	31	35	25	20	18	16	15	14	11	410

From the above tables, ecological study of the abundant and wide spread foraminiferal species revealed the following:

- Among the six abundant and wide spread fauna viz. *Ammonia beccarii, Ammonia tepida, Asterorotalia inflata, Noionoides boueanum, Quinqueloculina seminulum* and *Spiroloculina communis* prefered the environmental conditions that prevailed during April (summer) for higher reproduction in the present area.
- In the study area, wherever the environmental conditions were uncongenial (stations 1and 18) and wherever the substrate was sandy, the population and species diversity were also less and hence resulted in the lower predominance of abundant species.
- Samples collected in deeper segment viz. samples 7 to 13 accounted for higher population and was positively correlated with higher $CaCO_3$ and moderate organic matter content of the substrate.
- The less population encountered during September was mainly because of the bay depression and monsoon rain and the resultant modifications of the substrate characters.
- The accommodative substrate that favored the population abundance was siltysand.

4. Conclusion

Spatially, the living population of all the species of foraminifera was found to be more concentrated in the deeper part of the collections (station 9 and closely followed by stations 8 & 10). The living as well as total (living + dead) population size were less in all the near shore stations because of the wave agitation. The monsoon weather and bay depressions supported by fresh water influence accounted for the minimum population noticed in September.

Temporally, the mean value of $CaCO_3$ was the highest (24.77%) during May, and the lowest (22.87%) for September and was positively correlated with the foraminiferal abundance. In general, the higher values of $CaCO_3$ found in stations 7 to 13, supported higher foraminiferal population in the area. The population was found to be maximum when the organic matter percentage was between 1.90 and 2.00 % along with other amiable environmental parameters. In the present area, the population was more in the siltysand type of substrate, which is always associated with comparatively deeper waters.

The congenial environments for the abundance of living population in general, wide spread and abundant foraminifera in particular of the study area are higher $CaCO_3$ content (> 23.0%) and optimum (1.9 – 2.0 %) organic content of the substrate.

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