

# Substrate Characteristics and Benthic Foraminiferal Distribution from the Gulf of Mannar, Off Tiruchendur, Southeast Coast of Tamilnadu, India

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**Abstract** To document the relationship between the substrate characteristics and benthic foraminiferal occurrence in the inner shelf of Gulf of Mannar, off Tiruchendur, sediment samples were collected and studied from 27 stations along three traverses, having depths ranging from 1.5 to 18.5 metres. Surface sediments were collected during May and October in the year 2016 representing summer and pre monsoon respectively and thus the total samples amounted to 54. The traverses are made between south off Veerapandianpatinam and off Alanthalai. During the study 105 foraminiferal species belonging to 40 genera, 29 families, 15 super families and 4 sub orders have been recorded. Among them, 5 have been identified as widespread and abundantly occurring living species since they are found in all the samples collected and studied. The distribution and diversity of foraminiferal fauna are correlated with the substrate characteristics. Their living and total population (living + dead) is relatively higher in the summer (May) than in pre monsoon (October). It has been observed that the living foraminiferal population shows an increase with respect to depth. Silty sand substrate, higher concentration of CaCO<sub>3</sub> (< 25%) and moderate organic matter (1.0 – 2.3%) in the substrate are the congenial ecological condition favouring abundance of the living foraminiferal population in the inner shelf off Tiruchendur coast.

**Keywords:** substrate characteristics, ecology, recent benthic foraminifera, gulf off Tiruchendur

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## 1. Introduction

Benthic foraminifera are quite abundant and widespread in marine and brackish environments and are endowed with a broad ecological adaptability. Their occurrence is controlled by number of physical, chemical and biological factors. Benthic foraminifera are recognized as exceptional bio-indicators because of their good preservation in marine sediments, diversity and abundance and their sensitivity to rapidly changing environmental conditions. Numerous investigations have been carried out on the ecology and distribution of benthic foraminifera from different areas of the east coast of Tamilnadu [1-11].

## 2. Materials and Methods

The present study focuses on the spatial and temporal distribution of the recent benthic foraminifera from the

inner shelf sediments off Tiruchendur, southeast coast of Tamil Nadu, India. The study area extending between Alanthalai in the south to off the coast of Veerapandianpatinam in the north (long. 78°30' to 78°40' E and lat. 8°25' to 8°45' N), is a coastal stretch comprising of a flat and narrow beach. In this study, an attempt is made to decipher the distribution and diversity of the foraminiferal fauna of the shelf region with respect to the observed environmental parameters. The shelf sediments were collected from 27 stations along three traverses (Figure 1) once in the month of May and the other in October 2016, representing summer and pre-monsoon seasons respectively. The sediment samples were collected carefully using Van Veen grab sampler, from depths varying between 1.5 and 18.5 m. For the study of foraminiferal fauna, a unit volume of 50 ml wet sediment from each sample was preserved in 10% formaldehyde solution and a small quantity of sodium carbonate was added to maintain the alkaline condition [12]. The remaining sample from each station was preserved in a polythene bag for further study. The respective depths of

the water column at each sampling site were recorded and indexed. The sample collection was followed by systematic laboratory studies. In order to assess the living and dead population of foraminifera Walton's Rose Bengal technique [14] was adopted. Foraminiferal tests were separated by CCL4 floatation technique [15]. Identification of Foraminifera and their classification was made following the nomenclature proposed by Leoblich & Tappan [13]. Sand – silt – clay ratio of the substrate was determined following the Pipette method of Krumbein and Pettijohn [16] and Trefethon's [17] textural nomenclature was followed to assign the sediments type. Organic matter was estimated through Chromic acid method of Walkley and Black as enumerated by Jackson [18]. Rapid titration method of Piper [19] was adopted to determine calcium carbonate content.

### 3. Results and Discussion

#### 3.1. Living Population

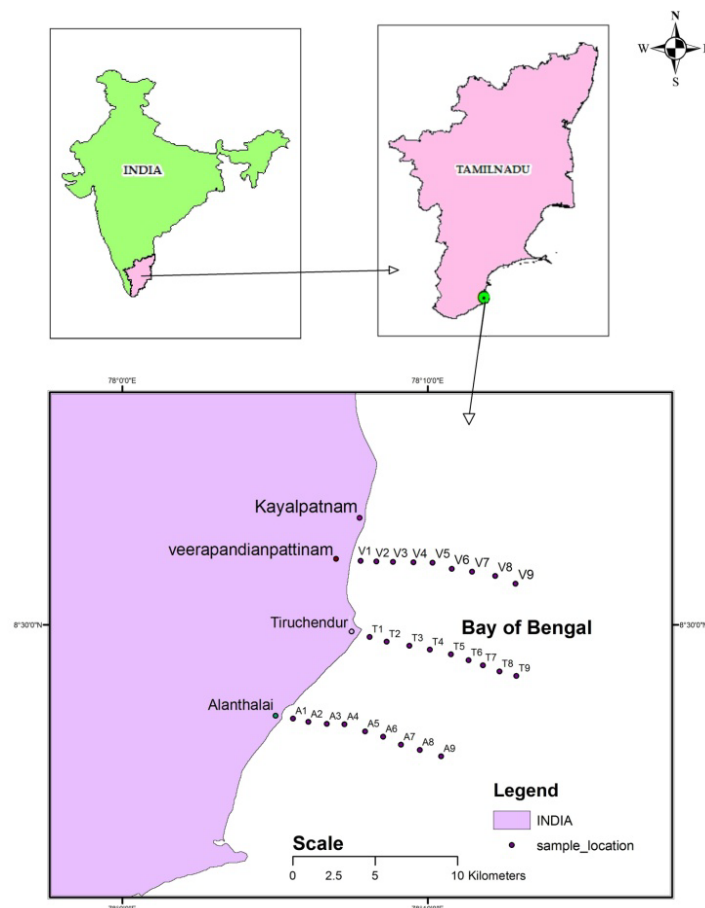
In the study area, living forms of the foraminifera are found in all the 54 samples collected and studied. The size of the living population varies between 4744 and 5867 specimens per 50ml of wet sediment, higher numbers being found in stations T9 and A9 in May and lower counts in station A1 in October. In general, the size of the living population is large only in deeper locations, where the sediment fines are comparatively higher and the population is thin in shallow depths where the percentage

of sand in the substrate is relatively higher. The living population is found to be higher during summer when  $\text{CaCO}_3$  concentration in the substrate goes up.

#### 3.2. Substrate Characteristics

A positive correlation between  $\text{CaCO}_3$  content and foraminiferal population was observed in Tuticorin - Kovalam stretch [20] and in Gulf of Mannar [21]. In the present study, calcium carbonate content is generally moderate and varies between 20.6% (A1, October) and 25.8 % (T9, A8 and A9, May). Seasonal mean value is found to be higher (24.2%) during May and lower (23.1%) during October. Higher percentages of  $\text{CaCO}_3$  are recorded in the samples collected from the deeper segments of all the traverses. Hence it can be inferred that  $\text{CaCO}_3$  content is a controlling factor for the foraminiferal abundance (Figure 2a and Figure 3a).

Venkata Rao and Subba Rao [22]. stated that high sedimentation, greater input, slow decay and humid condition may be considered to be the reason for the high values of organic matter. In the study area, organic matter content is low to moderate, varying between 1.32 % (V1 October) and 2.27% (A9 May). Higher seasonal mean value is higher (1.918 %) during May and lower (1.771%) in October. It has been generally observed that there is poor content of organic matter in the sandy sediments and a fairly higher content in fine grained sediments. Thus, organic matter is one of the factors influencing the population and diversity of foraminifera (Figure 3a and Figure 3b)



**Figure 1.** Map showing Sampling Locations in the inner Shelf off Tiruchendur, Southeast Coast of Tamilnadu

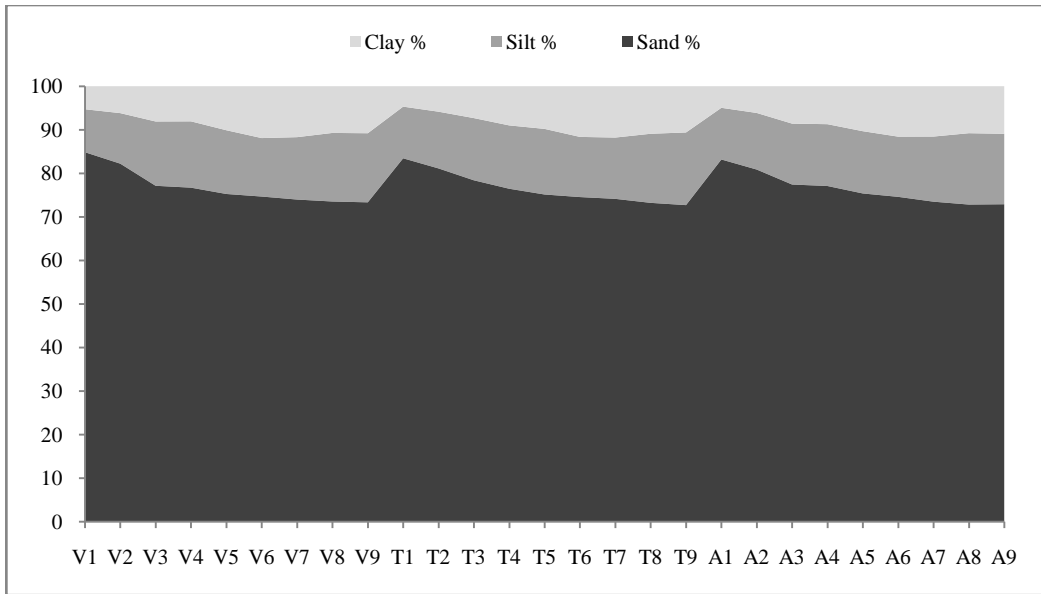


Figure 2. Relative abundance of Sand-Silt-Clay from the inner shelf off Tiruchendur (May, 2016)

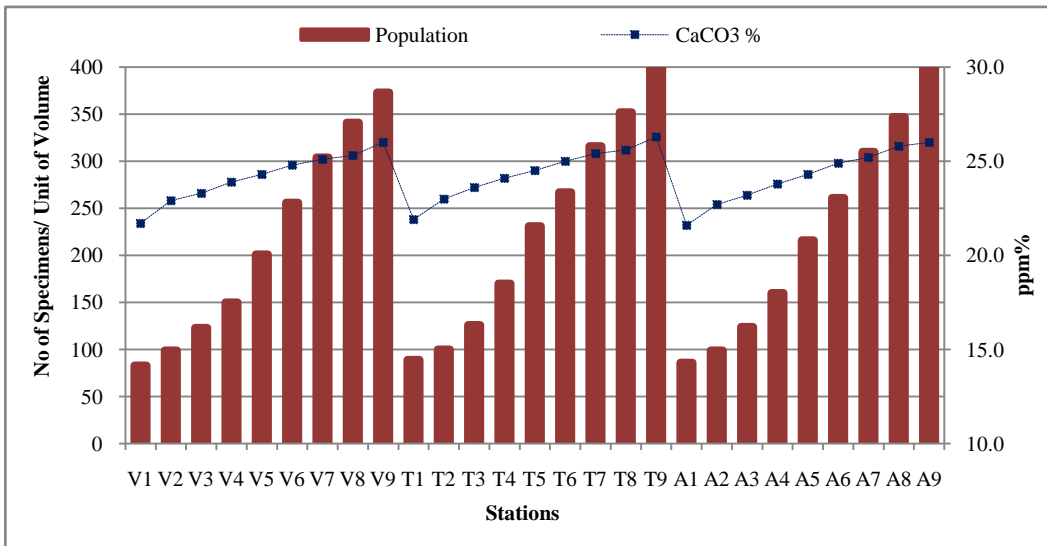


Figure 2a. Living Population VS Calcium Carbonate from the inner shelf off Tiruchendur (May, 2016)

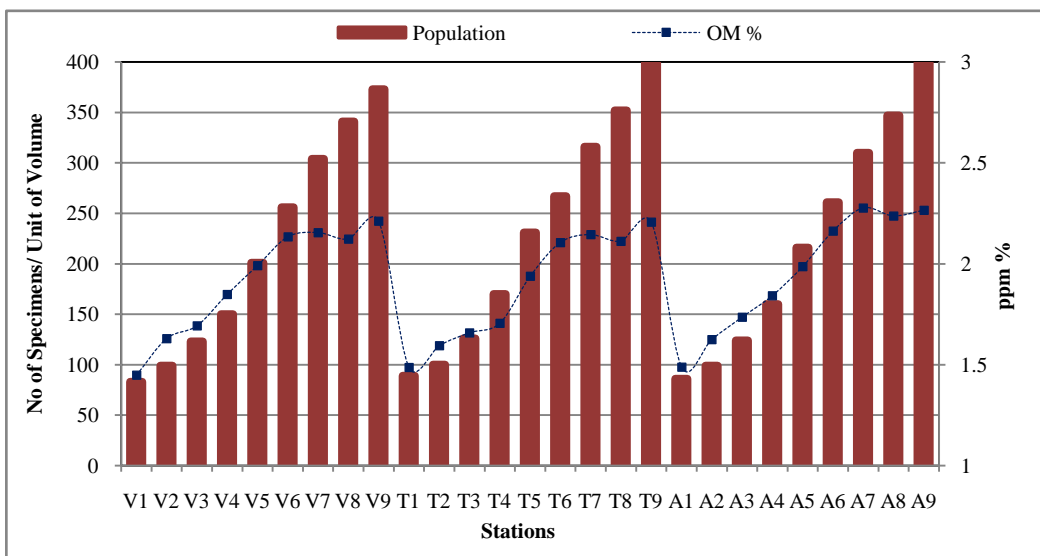


Figure 2b. Living Population VS organic matter from the inner shelf off Tiruchendur (May, 2016)

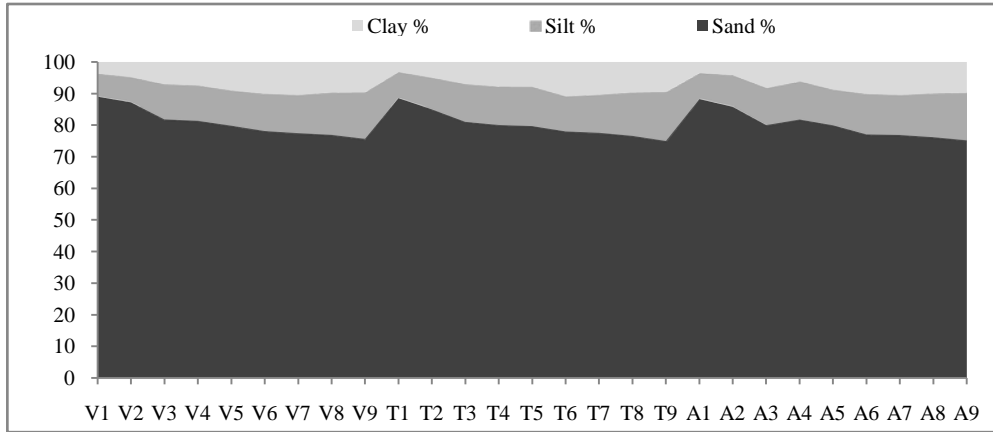


Figure 3. Relative abundance of Sand-Silt-Clay from the inner shelf off Tiruchendur (October, 2016)

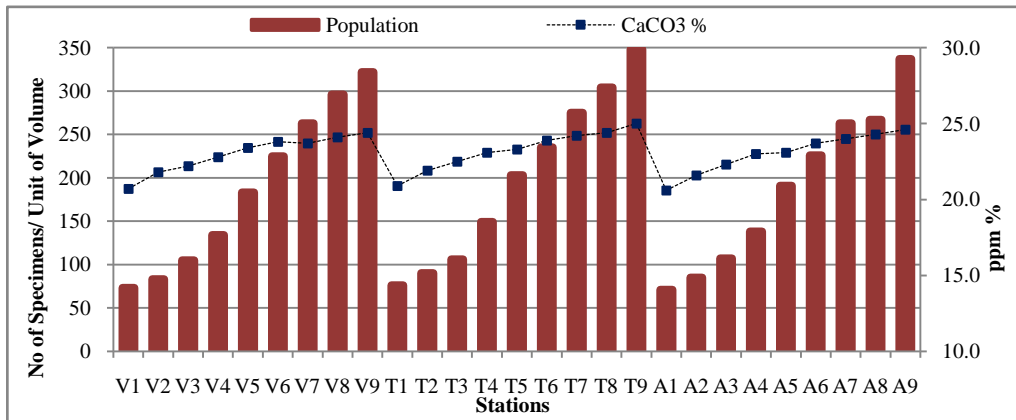


Figure 3a. Living Population VS Calcium Carbonate from the inner shelf off Tiruchendur (October, 2016)

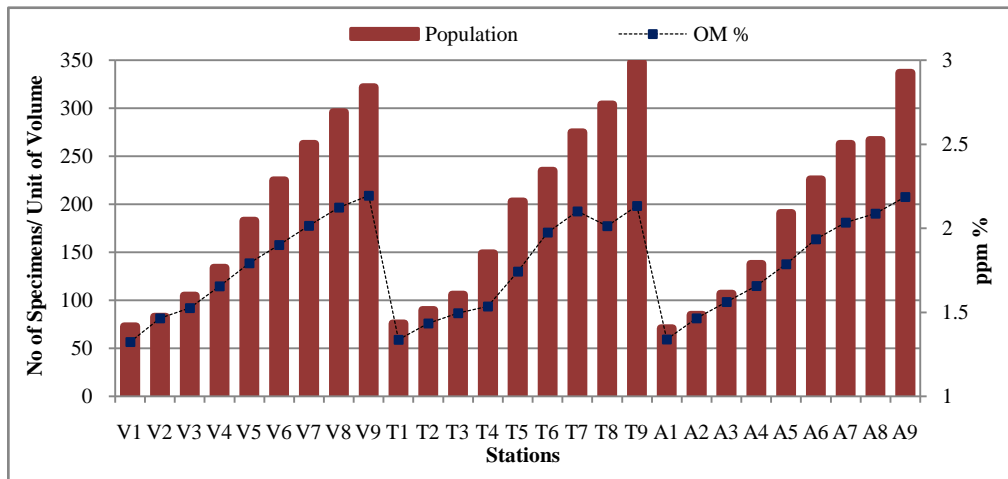


Figure 3b. Living Population VS organic matter from the inner shelf off Tiruchendur (October, 2016)

The texture of substrate material has a profound influence on the distribution and abundance of the benthic organisms owing to the tendency of the clay particles to bind the organic matter [23]. Fine grained bottom sediments (silt+clay) serve as favourable substrate for microorganisms [20]. In the study area, the percentage of sand in the substrate is generally high in near shore sediments and it decreases away from the shore. During May the first two samples near the shore and the first 4 samples in October of all the traverses represent sandy substrate. Most of the remaining samples are silty sand and considered to be the favourable substrate for higher population. Temporally, the average sediment fine (silt

+clay) percentage is higher (23.36 %) during May while it is lower (19.79 %) during October. It has been observed that the percentage of sediment fines has a positive correlation with foraminiferal population.

Among the total of 105 species recognised, five species namely *Ammonia beccarii*, *A. tepida*, *Asterorotalia inflata*, *Nonionoides boueanum* and *Quinqueloculina seminulum* are considered to be widespread and abundantly occurring and found as living in all the samples collected and studied. The substrate environmental conditions which have yielded the maximum number of living specimens of these five species during May and October (Table 1 and Table 2) are described here below.

**Table 1. Counts of Living and Total Population of Abundant and Widespread Foraminifera off Tiruchendur Coast (May, 2016) Per Unit of Volume of Sediment**

S.No	<i>Ammonia beccarii</i>		<i>Ammonia tepida</i>		<i>Asterorotalia inflata</i>		<i>Nonionides boueanum</i>		<i>Quinqueloculina seminulum</i>		Average	
	Living	Total	Living	Total	Living	Total	Living	Total	Living	Total	Living	Total
V1	11	32	9	28	7	23	6	21	8	27	8.2	26.2
V2	12	39	10	32	8	26	8	27	8	24	9.2	29.6
V3	13	42	12	36	9	29	11	33	8	25	10.6	33.0
V4	14	44	12	40	11	35	8	27	11	35	11.2	36.2
V5	14	46	12	43	12	40	6	21	13	44	11.4	38.8
V6	18	59	13	42	17	53	12	40	16	52	15.2	49.2
V7	23	73	15	48	15	50	14	46	18	56	17.0	54.6
V8	25	81	19	59	17	57	14	45	16	53	18.2	59.0
V9	27	84	21	71	18	57	12	40	20	60	19.6	65.4
T1	12	35	9	28	6	21	6	20	7	22	8.0	25.2
T2	10	28	9	28	7	22	6	22	9	32	8.2	26.4
T3	13	42	12	36	9	29	11	33	8	25	10.6	35.0
T4	14	46	12	43	12	40	6	21	13	44	11.4	38.8
T5	17	55	15	48	13	42	7	23	14	41	13.2	41.8
T6	20	65	17	55	14	46	7	22	16	48	14.8	47.2
T7	22	67	17	54	16	52	12	38	18	55	17.0	53.2
T8	26	79	20	63	15	49	15	47	21	63	19.4	60.2
T9	30	94	20	66	17	56	15	48	22	68	20.8	66.4
A1	12	34	9	28	7	22	6	21	8	25	8.4	26.0
A2	11	34	10	30	8	24	7	25	9	28	9.0	28.2
A3	13	42	12	36	9	29	11	33	8	25	10.6	33.0
A4	14	45	12	42	12	38	7	24	12	40	11.4	37.8
A5	16	51	14	46	13	41	7	22	14	43	12.8	40.6
A6	19	62	15	49	16	50	10	31	16	50	15.2	48.4
A7	23	70	16	51	16	51	13	42	18	56	17.2	54.0
A8	26	80	20	61	16	53	15	46	19	58	19.2	59.6
A9	29	89	22	69	18	57	16	51	21	64	21.2	66.0
Total	484	1518	374	1232	338	1092	268	869	371	1163	369.4	1176.8

**Table 2. Counts of Living and Total Population of Abundant and Widespread Foraminifera off Tiruchendur Coast (October, 2016) Per Unit of Volume of Sediment**

S.No	<i>Ammonia beccarii</i>		<i>Ammonia tepida</i>		<i>Asterorotalia inflata</i>		<i>Nonionides boueanum</i>		<i>Quinqueloculina seminulum</i>		Average	
	Living	Total	Living	Total	Living	Total	Living	Total	Living	Total	Living	Total
V1	9	26	7	23	6	18	5	17	6	22	6.0	21.2
V2	9	31	8	26	6	21	6	22	6	19	7.0	23.8
V3	10	33	9	29	7	24	8	26	6	20	8.0	26.4
V4	11	35	9	32	9	28	6	23	9	28	8.8	29.2
V5	11	37	9	35	9	32	6	22	11	35	9.2	32.2
V6	15	46	10	34	14	43	9	32	13	42	12.3	39.4
V7	18	58	12	39	12	40	11	37	15	45	13.6	35.8
V8	20	65	15	48	14	46	11	37	13	43	14.6	47.8
V9	22	68	17	57	15	46	9	32	16	48	15.8	50.2
T1	9	28	7	23	5	17	5	16	6	18	6.4	20.4
T2	8	23	9	29	6	18	6	19	7	26	7.2	23.0
T3	10	34	9	35	7	24	8	25	6	22	8.0	28.0
T4	11	37	12	39	9	31	6	20	10	34	9.6	32.2
T5	14	44	14	44	10	34	6	22	11	33	11.0	35.4
T6	16	52	14	43	11	37	7	20	13	39	12.2	38.2
T7	18	54	16	51	13	41	9	31	15	44	14.2	44.2
T8	21	64	16	51	12	40	12	38	17	51	15.6	48.8
T9	25	76	16	53	14	45	12	39	18	55	17.0	53.6
A1	9	27	7	23	5	18	5	16	6	20	6.4	20.8
A2	9	27	8	25	6	19	6	20	7	23	7.2	22.8
A3	10	34	9	29	7	24	9	27	7	20	8.4	26.8
A4	11	34	9	33	9	30	6	19	9	32	8.8	31.4
A5	11	37	11	37	10	33	5	18	11	35	9.6	32.6
A6	13	41	12	39	13	40	8	25	13	40	11.8	37.0
A7	18	57	13	41	13	41	10	34	15	45	13.8	43.6
A8	20	65	16	49	13	43	12	37	15	47	15.2	48.2
A9	23	72	17	55	14	46	12	39	17	51	16.6	52.6
Total	381	1205	311	1022	269	879	215	713	298	937	294.3	910.2

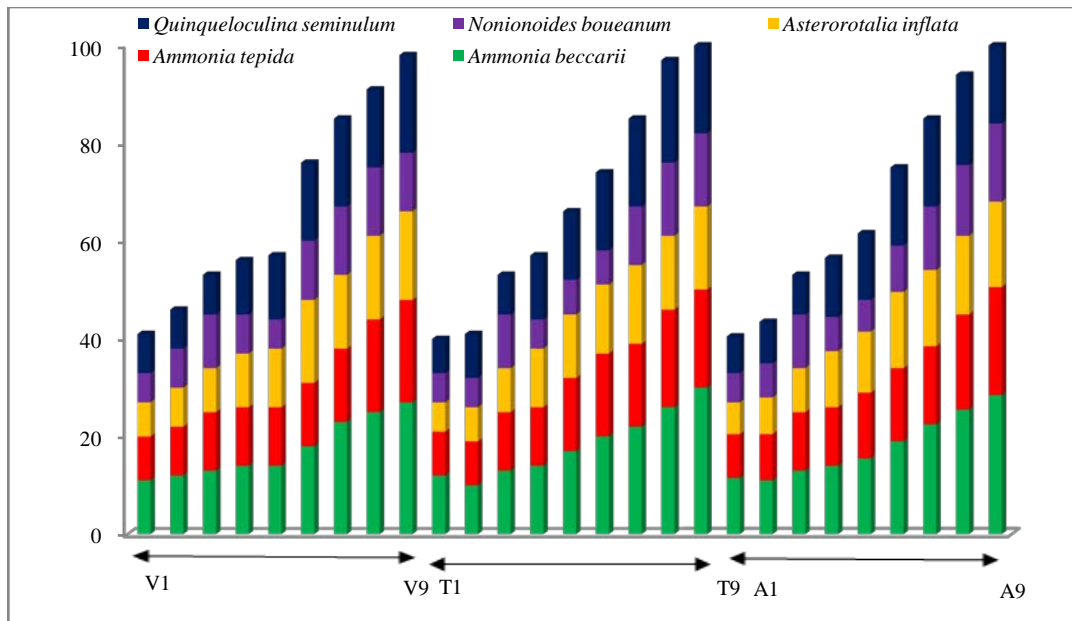


Figure 4. Distribution of Abundant and Widespread (Living + Dead) Foraminiferal Species, from the inner shelf off Tiruchendur (May, 2016)

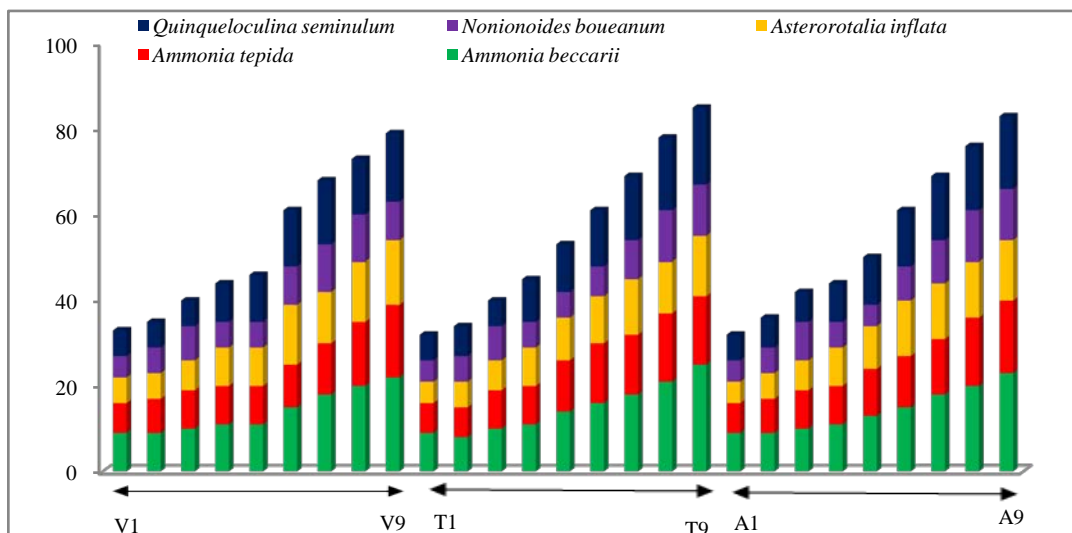


Figure 5. Distribution of Abundant and Widespread (Living+Dead) Foraminiferal Species from the inner shelf off Tiruchendur (Oct., 2016)

### 3.3. Ammonia Beccarii (Linne, 1767)

*Ammonia beccarii* was frequently recorded in the East China Sea and Okinawa Trough [24]. It has been repeatedly investigated with regard to various aspects such as geographic distribution ecology, biology, life-cycles, morphology, structure and environmental applications [25] [26] [27] from all over world. It is an abundant species recorded in entire stretch of east coast of Tamilnadu [1,2,4,5,6,7,21,23]. In the present study, this species occurs in living condition in 54 samples collected and studied. Spatially, maximum population is noticed in stations, away from the shore and was poorly represented in stations nearer to the shore. The total population has been found to be 484 specimens for May and 381 for October. In the area under study, higher population (>15 specimens) has been observed in 24 stations of which 14 are in May and 10 in October. The living population of this species is found mostly in silty sand substrate. The optimum ecological conditions for this fauna comprise of CaCO<sub>3</sub> > 23% and Organic

matter 1.0 to 2.3%. In general, the population increases with increasing CaCO<sub>3</sub> content of the substrate and depth. Kasilingam et al [10] observed that the most abundant species was observed to be *A. beccarii* in the central coast of Tamilnadu between Kottaipattinam and Kodiyakkarai.

### 3.4. Ammonia Tepida (Cushman, 1926)

This species had also been frequently reported from the Bohai Sea [28] the Yellow Sea [29]. and from Palk Bay [2]. It is a common species in continental shelf sediments and in water depth of 3 to 40.m. In the present area, this species occurs in living condition in all the 54 samples. Spatially, the higher population is recorded in stations away from the shore and is poorly represented in stations nearer to the coast. The total number of specimens recorded for May is 374 whereas it is only 311 for October. In the study area, the higher living population (>15 specimens) is found in 9 stations during May and in October. Favorable substrate for this species is silty sand.



The optimum ecology conditions for this fauna in the study area are  $\text{CaCO}_3 > 25\%$  and Organic matter 1.0 to 2.3%. In general, the population increases with increasing  $\text{CaCO}_3$  content of the substrate and depth.

### 3.5. *Asterorotalia Inflata* (Millett, 1940)

This species occurs in living condition in all the 54 samples collected and studied. Spatially maximum population is observed in stations away from the shore and poorly represented in near shore stations such as V1, T1, and A1. Seasonally, the total living population size is 338 specimens for May and 269 for October. In the study area, the higher living population (>15 specimens) is recorded in 9 stations, all in May. Silty sand substrate,  $\text{CaCO}_3 > 25\%$  and organic matter 1.0 to 2.3% constitute the favourable niche for this species. In general, population increases with increasing  $\text{CaCO}_3$  content.

### 3.6. *Nonionoides Boueanum* (d' Orbigny, 1846)

This species was originally described from the Miocene of Vienna Basin d' Orbigny [30] From the Indian waters, there are various reports of their occurrence as shallow water species, in a depth range of 25 to 100m. This species occurs in the living condition in all the 54 samples. As in other species maximum population is recorded in the farthest stations of all the traverses and poorly represented in stations nearer to the shore. Total living population is found to be maximum (268 specimens) in May and less (215 specimens) in October. The higher living population of this species (>15 specimens) is found only in A9 station during May. Silty sand substrate,  $\text{CaCO}_3 > 25\%$  and organic matter 1.0 to 2.3% are the most favourable ecological conditions for this species. In general, the population increases with increasing  $\text{CaCO}_3$  content of the substrate and depth.  $\text{CaCO}_3$  content of the substrate and depth.

### 3.7. *Quinqueloculina Seminulum* (Linne, 1767)

This species is widely distributed and abundant in inner shelf sediments of Tamilnadu coast. In the study area, this species occurs in living condition in all the 54 samples. As in the other species, this is also exhibiting maximum population in the last two to three seaward stations of the traverses and poorly represented in the first two near shore stations. Seasonally, the total population is found to be maximum (371 specimens) during May and a lesser number (298 specimens) during October. The higher living population of this species (>15 specimens) is found in 12 stations during May and 8 in October. Silty sand

substrate,  $\text{CaCO}_3 > 21\%$  and organic matter 1.0 to 2.3 are the favourable conditions for this species. There is an increase in its population with respect to increase in depth and  $\text{CaCO}_3$  content.

## 4. Distribution and Ecology of Abundant Foraminifera

As outlined in the previous section, spatially the living population of all the foraminiferal species is found to be concentrated to a greater extent in the last three stations of all the traverses (Figure 4 and Figure 5) and in both the collections. It is observed that if the Calcium carbonate exceeds 25% the living population is found to be higher. Similarly when the organic matter ranges between 1.0 and 2.3% there is higher counts of living population. Temporally, the monsoon condition and bay depressions supported by freshwater ingress account for a decline in living population noticed in October. The favorable substrate for the fauna is silty sand type. The substrate environmental conditions which have yielded the maximum number of living specimens of these five species during May and October. (Table 3 and Table 4) are described here below.

## 5. Summary and Conclusion

Investigations pertaining to the benthic foraminifera in the Gulf of Mannar, off Tiruchendur in Southeast Coast of Tamilnadu have revealed the presence of 105 benthic foraminiferal species belonging to 40 genera, 29 families, 15 super families and 4 sub orders. Five widespread and abundantly occurring species have also been recognized viz. *Ammonia beccarii*, *A. tepida*, *Asterorotalia inflata*, *Nonionoides boueanum* and *Quinqueloculina seminulum*. The substrate characteristics such as  $\text{CaCO}_3$  content, organic matter and sediment type have been evaluated. The distribution and ecology of the foraminifera, in general and five abundant and widespread fauna in particular of the study area have been described. Silty sand substrate and higher concentration of  $\text{CaCO}_3 (>25\%)$  with organic matter (1.0 - 2.3%) of the substrate have been found to provide a favourable ecological niche for the abundance of the living foraminiferal population in the study area. The foraminiferal population shows an increase with respect to depth. The summer month of May rather than October appears to be more favourable for foraminiferal abundance.

**Table 3. Abundantly Occurring Foraminiferal Species and Ecological Parameters Tiruchendur Coast. (May, 2016)**

Parameters	<i>Ammonia beccarii</i> (Linne)	<i>A.tepida</i> (Cushman)	<i>Asterorotalia inflata</i> (Millett)	<i>Nonionoides boueanum</i> (d' Orbigny)	<i>Quinqueloculina Seminulum</i> (Linne)
Substrate	Silty sand	Silty sand	Silty sand	Silty sand	Silty sand
CaCO <sub>3</sub>	>25%	>23%	>25%	>23%	>23%
Organic Matter	1.1 – 2.3 %	1.1 – 2.3 %	1.1 – 2.3 %	1.1 – 2.3 %	1.1 – 2.3 %
Maximum living Specimens	484	374	338	268	371

**Table 4. Abundantly Occurring Foraminiferal Species and Ecological Parameters Tiruchendur Coast. (October, 2016)**

Parameters	<i>Ammonia beccarii</i> (Linne)	<i>A.tepida</i> (Cushman)	<i>Asterorotalia inflata</i> (Millett)	<i>Nonionoides boueanum</i> (d' Orbigny)	<i>Quinqueloculina Seminulum</i> (Linne)
Substrate	Silty sand	Silty sand	Silty sand	Silty sand	Silty sand
CaCO <sub>3</sub>	>21%	>18%	>18%	>21%	>21%
Organic Matter	1.0 – 1.4 %	1.0 – 1.4 %	1.0 – 1.4 %	1.0 – 1.4 %	1.0 – 1.4 %
Maximum living Specimens	381	311	269	215	298

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