Inner Shelf Substrate Characteristics and Their Impacts on the Distribution of Recent Benthic Foraminifera from the Southern Part of Gulf of Mannar, Southeast Coast of India

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Received October 09, 2020; Revised November 10, 2020; Accepted November 17, 2020

Abstract The present study elaborates the relationship between sediment characteristics and benthic foraminiferal population distribution from off the coast of Theresapuram, Sippikulam, Mookaiyur and Valinokkam representing the southern part of Gulf of Mannar, Southeast coast of India. A systematic collection of sediment and bottom water samples were made at 28 sampling stations, keeping seven samples each, along the four traverses. The samples were collected for three seasons, representing pre-monsoon (October), post-monsoon/winter (January) and summer (April) and thus the collections amounted to a total of 84 samples. The benthic foraminiferal studies from the sediments collected have led to the recognition of 124 benthic foraminiferal species belonging to 59 genera, 39 families and 21 superfamilies of 5 suborders. Among the 124 species, Ammonia beccarii, A. tepida, Asterotalia inflata, Elphidium advenum, Noninoides boueannum, and Quinqueloculina seminulum are considered to be abundant and widespread in the present study area. It has been observed that the maximum population is observed during summer (April) with 2335 specimens and the minimum with 1934 specimens during monsoon (October). Spatially, the middle segment (stations 3-5) of all traverses of all the collections encounter with relatively higher population. Impact of spatial and seasonal variation in substrate characteristics on the benthic foraminiferal population revealed that the calcium carbonate content shows a positive correlation with the fauna of the study area and the organic matter content has somewhat inverse relationship with the population abundance. In the present study, organic matter content is not an effective factor that controls the population abundance, but along with other parameters plays a supporting role. Out of 12 possible sediment types of Trefethen’s classification, the sediments in the study area fall only in three types’ viz., sand, siltsand and claysand. The most favourable substrate for higher benthic foraminiferal population seems to be siltsand. In general, the benthic foraminiferal population of the present study is directly proportional to the calcium carbonate content of the sediments along with lower organic matter (0.7 -0.93%) and the accommodative substrate for higher reproduction is silty sand.

Keywords: benthic foraminifera, innershelf, Gulf of Mannar, substrate characteristics, Theresapuram, Sippikulam, Mookaiyur and Valinokkam

Cite This Article: Rethikala K.R, V. Kumar, and B. Satish, “Inner Shelf Substrate Characteristics and Their Impacts on the Distribution of Recent Benthic Foraminifera from the Southern Part of Gulf of Mannar, Southeast Coast of India.” Applied Ecology and Environmental Sciences, vol. 9, no. 1 (2021): 30-41. doi: 10.12691/aees-9-1-4.

1. Introduction

The coastal area environment is highly dynamic with many cyclic and random processes owing to a variety of resources and habitats. Further, the marine ecosystems are one of the most productive ecosystems on earth. The ecological systems of the sea can achieve great complexity, as in the “upwelling” areas where ocean water rises to the surface. In the recent days due to industrial developments and anthropogenic activities a number of problems have aroused and the marine ecosystem has been highly disturbed. In order to understand the changes and the effect of marine coastal ecosystem there is a need to study the micro level changes in the coastal marine environment. Though there are many tools/ indicators have been developed to study the environmental modifications, foraminifera have taken a leading role.

Foraminifera generally vary between 10 μm and less than 1 mm in size and are the most abundant and diverse group of eukaryotes found in the marine realm. They are
distributed from the tropics to the polar region and from the intertidal (< 100m) to the bathyal zone (5000m) in marine habitats.

In order to assess the environmental impact on foraminifera from the inner shelf sediments of Gulf of Mannar, off the coast of Theresapuram, Sippikulam, Mookaiyur and Valinokkam the following objectives are taken up,

i. to inventory the benthic foraminiferal fauna and to observe their morphological variation and quantitative composition,

ii. to ascertain the distribution of living population of the fauna

iii. to discover the effect of environmental parameters on the seasonal and spatial distribution of the foraminiferal fauna.

The study area falls on the southeast coast of India. It covers an area from off the coast of Theresapuram in the south to off the coast of Valinokkam in the north constraining to the southern portion of Gulf of Mannar. It is located geographically between 78° 09' E - 78° 30' E longitudes and 8° 49' N - 9° 05' N latitudes, comprising survey of India toposheet numbers 58 K/3, 4 and 58 O/3, 4 (Figure 1). The Tropical climate prevails in this area throughout the year. The monthly average annual temperature varies from 27°C to 33 °C with the maximum and minimum in April/May and January respectively. This area comes under the spell of both Southwest (June to September) and Northeast monsoon (October to December). Northeast monsoon contributes about 50-60 percent of mean annual rainfall which varies from 762 mm to 1270 mm.

2. Materials and Methods

2.1. Field Work

For the present study, sediment samples from 28 stations varying in depths from less than 1 to 10 m were collected. These samples were obtained from 4 traverses from off-coast of Sippikulam, Theresapuram, Valinokkam and Mookaiyur, keeping 7 stations for a traverse. The samples have been made for three different seasons: Monsoon (October 2016), Monsoon, winter (January 2017) and summer (April 2017) and thus the samples amounted to a total of 84 samples. The samples were collected using Petersen mud grab. A unit volume (100 ml) wet sediment from the top 1 cm layer was taken using a plastic tube from all the samples.

2.2. Laboratory Work

Walton’s [1] Rose Bengal staining technique is followed to distinguish between living and dead foraminifera. The foraminiferal tests were then separated from the residue by flotation method using carbon tetrachloride [2]. As a check, the residue after flotation was re-examined under a binocular stereo-microscope for the presence of any foraminiferal tests left unconcentrated. They were handpicked using 'OO' Windsor Newton sable hairbrush.

The faunal specimens separated from the dyed sediments were quantitatively and qualitatively examined. The ratio relative abundance between sand, silt and clay of the substrate was determined using Krumbein and Pettijohn’s [3] pipette method. The sediment types were then recognized based on Trefethon’s [4] textural nomenclature. Calcium carbonate content of the sediments was determined using rapid titration method of Piper [5]. Chromic acid method of [6] was followed for the estimation of organic matter content in the sediments.

3. Results

3.1. Foraminifera

The foraminiferal studies from the sediments collected from the present study area led the recognition of 124 foraminiferal species belonging to 59 genera, 39 families, and 21 super-families of the suborders Spirillina, Textulariina, Rotaliina, Lagenina and Miliolina. (Table 1). Among these 124 living species, six are found to be
widespread and abundant in the research area. They are *Ammonia beccarii*, *A. tepida*, *Asterotalia inflata*, *Elpidium advenum*, *Noninoides boueanum* and *Quinqueloculina seminulum*. The population size both living and total (living + dead) in each of the stations during different seasons have been found out (Figure 2).

| TAXONOMY CHART- Benthic foraminiferal species from the southern part of Gulf of Mannar |
|-------------------------------|-------------------|-------------------|-----------------|-------------------|
| SUBORDER | SUPER FAMILY | FAMILY | SUB FAMILY | GENUS | SPECIES |
| AMMODISCACEA | AMMODISCIDAE | AMMODISCINAE | Ammodiscus | A. tenuis |
| LITUOLACEA | LITUOLIDAE | AMMOMARGINULININAE | Ammobaculites | A. dilatatus |
| Rhabdamminidae | Rhabdammininae | Rhabdammina | R. scabra |
| TROCHAMMINACEA | TROCHAMMINIDAE | TROCHAMMININAE | T. advena |
| TEXTULARIACEA | TEXTULARIIDAE | TEXTULARIINAE | T. inflata |
| SPIRILLININA | SPIRILLINIDAE | | | |
| CORNUSPIRACEA | FISCHERINIDAE | NODOBECULARILLINAE | Vertebrina | V. striata |
| S. angulata |
| S. antilarum |
| S. communis |
| S. costifera |
| HAUERININAE | HAUERINIDAE | | H. bradyi |
| TUBINELLINAE | TUBINELLIDAE | | H. fragilissima |
| MILIOLACEA | MILIOLINAE | | |
| MILIOLINA | MILIOLINAE | | |
| ALVEOLINACEA | PENEROPLIDAE | | |
| SORITACEA | SORITIDAE | SORITINAE | | |
| NODOSARIACEA | NODOSARIIDAE | NODOSARIINAE | | |
| SUBORDER | SUPER FAMILY | FAMILY | SUB FAMILY | GENUS | SPECIES |
|----------|--------------|--------|------------|-------|---------|
| LAGENINA | LEGENIDAE    | Lagena |            | L. laevis |         |
|          |              |        |            | L. setigera |         |
|          |              |        |            | L. striata |         |
|          |              |        | Procerolagena | P. gracillima |         |
|          | POLYMORPHINIDAE | POLYMORPHINAE |        | Globulina | G. gibba |
|          |              |        |            | Guttulina | G. ovata |
|          | ELLIPSOLAGENIDAE | ELLIPSOLAGENINAE |        | Oolina | O. globosa |
|          |              |        |            |            | O. ovoidea |
|          |              |        |            | Fissurina | F. laevigata |
|          |              |        |            |            | F. margina |
|          | ACERVULINICAE | ACERVULINIDAE |        | Acervulina | A. inhaerens |
|          | BOLIVINACEA | BOLIVINIDAE |        | Bolivina | B. donizzi |
|          |              |        |            | B. nobilis |         |
|          |              |        |            | B. pseudoplicata |         |
|          |              |        | Brizalina | B. striatula |         |
|          | SIPHONINOIDEA | SIPHONINIDEA |        | Siphonina | S. pulchera |
|          | LOXOSTOMATACEA | LOXOSTOMATIDEA |        | Rectolinna | R. glabra |
|          |              |        |            | R. raphanus |         |
|          |              |        | Buluminina | B. marginata |         |
|          | BULUMINACEA | BULUMINIDAE |        | Buliminella | B. milleti |
|          |              |        | UVigerina | U. proboscidea |         |
|          |              |        |             | Chrysalidinella | C. dimorpha |
|          |              |        | Reussella | R. spinulosa |         |
|          | FURSENKOINACEA | FURSENKOINIDAE |        | Fursenkoaina | F. compressa |
|          |              |        | Sigmavigulina | S. tortuosa |         |
|          | DISCORBACEA | BAGGINIDAE | BAGGINIAE | Cancris | C. auriculus |
|          |              |        |            | C. oblonga |         |
|          | EPONOIDIDAE | EPONOIDINAE | Poroeponoides | P. lateralis |         |
|          | HELENINIDAE | HELENINAE | Helinia | H. perlucida |         |
|          | ROSALINIDAE | ROSALINAE | Rosalina | R. globularis |         |
|          |              |        |            | C. dispars |         |
|          |              |        |            | C. lobatus |         |
|          |              |        |            | C. refugens |         |
|          |              |        |            | C. variabilis |         |
|          | CIBICIDINAE | CIBICIDINAE | Cibicides | C. bradyi |         |
|          |              |        |            | C. squamosa |         |
|          | NONIONACEA | NONIONIDEA | NONIONINAE | Nonionella | N. auris |
|          |              |        |            | Nonionoides | N. pulchilla |
|          |              |        |            | N. boucanum |         |
|          |              |        |            | N. elongatum |         |
|          |              |        |            | N. grateloup |         |
|          |              |        |            | N. labradoricum |         |
|          | ROTALIINA | ROTALIDAE | ROTALINAE | Ammonia | A. beccarii |
|          |              |        |            | A. dentate |         |
|          |              |        |            | A. tepida |         |
|          |              |        | Asterorotala | A. inflata |         |
|          |              |        |            | A. multispinosa |         |
|          |            |        | Pseudorotalia | P. schoeteriana |         |
|          | ROTALIACEA | CALCARINIDAE | Calcarina | C. umbilicata |         |
|          |              |        |            | E. advenum |         |
|          |              |        |            | E. crispus |         |
|          | ELPHIDIDAE | ELPHIDINAE | Elphidium | E. excavatum |         |
|          |              |        |            | E. incertum |         |
|          |              |        |            | E. hispidulum |         |
|          |              |        |            | E. macellum |         |
|          |              |        |            | E. norwanger |         |
|          |              |        |            | E. poecyanum |         |
|          | NUMMULITACEA | NUMMULITIDAE | Operculina | O. ammonoides |         |
3.1.1. Living Population

All the 124 foraminiferal species collected in the study area are found to have living forms. The suborder wise distribution of abundant living foraminifera revealed that the suborder Rotaliina was best represented with 5 species (Ammonia beccarii, A. tepida, Asterotalia inflata, Elphidium advenum and Noninoides boueanum) followed by Miliolina with one species (Quinqueloculina seminulum). Ammonia beccarii was found to be the most abundant living species followed by Quinqueloculina seminulum in all the samples collected and studied.

The size of the living population varied between 32 and 553 species for each 100ml of wet sediment. The maximum living population was found in Mookaiyur (MK 5 station) in April and minimum in Valinokkam (VN1 station) in January. The observation on the spatial distribution of living foraminifera in the study area revealed that the living foraminifera was found to be abundant in stations 3, 4 and 5 which forms the middle segment of the traverse, while the minimum population is found at the near shore stations (1 and 2).

Seasonally, the maximum population is observed during summer (April) with 2335 specimens and the minimum with 1934 specimens in Theresapuram, 2093 to 2335 specimens in Sippikulam, 1979 to 2220 specimens in Mookaiyur, and 1999 to 2295 specimens in Valinokkam.

The minimum and maximum population size being represented by October and April respectively in all the four traverses. The total living population adding the four traverses, for a season, is minimum 8005 specimens during October and maximum 9139 specimens in April.

3.1.2. Total Population

The total foraminiferal population (Living + Dead) in all the three season has been tabulated below in (Table 3). It was found that in general, during all the collections the total (living + dead) population size was found to be more in stations 3, 4 & 5 and very less in all the shore stations (TP1, SK1, MK1 and VN1) of all the seasonal collections.

The seasonal total (living + dead) population ranges from 6375 to 7236 specimens in Theresapuram, 6306 to 7504 specimens in Sippikulam, 5937 to 7177 specimens in Mookaiyur and 5997 to 6966 specimens in Valinokkam. The minimum and maximum population size being represented by October and April respectively in all the four traverses. The total living population adding the four traverses, for a season, is minimum 24615 specimens during October and maximum 28883 specimens in April.

3.2. Substrate Characteristics

3.2.1. Sand-Silt-Clay-Ratio

A number of studies revealed a very close correlation between the natures of the sediments and the foraminiferal population. The near-shore marine environment which is a turbulent one with the wave and current are being dominant, but in the Palk Strait region it is generally calm, except while during the onset of the north-east monsoon the turbulent conditions prevail [7]. The coastal marine ecosystem of this region is being endangered by high silty sedimentation [8,9,10,11,12,13] because of which bay showing shallowing nature. The relationship between nature of the sediments and the foraminiferal population...
have been studied by many authors [14,15,16,17,18,19]. They have observed that the silty clay sand substrate is found to be the most favorable for the growth and abundance of foraminifera from the different marine ecosystem.

Nigam [20] studied the samples off Damon-Bombay sector and observed that large foraminiferal populations are associated with low energy area and the living foraminifera are almost absent in samples near the high energy environment (sand bar). According to the author the shifting substrate near the sand bar keeps the benthonic foraminifera in suspension, not allowing them to attach to the substrate and to flourish; the instability is too severe for any species to survive.

Jayaraju and Reddi [21] have found that the fine grained bottom sediment serve as favourable substrate for the microorganisms. Reddy and Reddy [22] found that silt dominated clay represent the most accommodative substrate for higher foraminiferal count.

Mendes et al. [23] from their study revealed that the type of substrate controls the type foraminiferal assemblage. Highest number of tests of *Eggerella scaber*, *Planorbulina mediterranensis* and *Cribrionion gerthi* are found in sediments dominated by sandysilt, while *Bulimina aculeate*, *Epistominella vitrea* and *Cassidulina laevigata* show highest number of tests in samples characterized by sandy silty clay.

Kumar et al., [16] after their study on the ecological and pollution aspects of benthic foraminifera from the Palk Bay, off Rameswaram, concluded that the siltysand type substrate favoured higher foraminiferal population.

**Figure 3.a.** Relative abundance of Sand-Silt-Clay (October)

**Figure 3.b.** Relative abundance of Sand-Silt-Clay (January)

**Figure 3.c.** Relative abundance of Sand-Silt-Clay (April)
An attempt has been made to understand the relationship between the substrate and the foraminiferal population in the present study area. The relative percentages of sand silt and clay for all the sediment samples taken from the 28 stations (4 traverses) and for all the 3 collections are shown in (Figure 3a-c).

Trefethen’s [4] textural nomenclature has been used to describe the sediment types of the study area. Of the 12 possible sediment types of Trefethen, the sediments taken from the various parts of the study area fell only in three sediment types viz., sand, silty sand and clay sand (Table 4). The rest of the sediment types of Trefethen are not represented in the sediments of the study area.

Table 4. Spatial distribution of sediment types for all the 3 seasons

| Month | Sand      | Silty sand | Claysand |
|-------|-----------|------------|----------|
| October | SK-1, MK-1, VN-1 | TP-1, TP-2, TP-3, TP-4, TP-5, TP-6, TP-7, SK-2, SK-3, SK-4, SK-5, SK-6, SK-7, MK-2, MK-3, MK-4, MK-5, MK-6, MK-7, VN-2, VN-3, VN-4, VN-5, VN-6, VN-7 | SK1 |
| January | VN-1 | TP-1, TP-2, TP3, TP4, TP5, TP-6, TP7, SK-2, SK-3, SK-4, SK-5, SK-6, SK-7, MK-1, MK-2, MK-3, MK-4, MK-5, MK-6, MK-7, VN-2, VN-3, VN-4, VN-5, VN-6, VN-7 | |
| April | SK-1, MK-1, VN-1 | TP-1, TP-2, TP3, TP4, TP5, TP-6, TP7, SK-2, SK-3, SK-4, SK-5, SK-6, SK-7, MK-2, MK-3, MK-4, MK-5, MK-6, MK-7, VN-2, VN-3, VN-4, VN-5, VN-6, VN-7 | |

It is observed that the shore stations except in Therassapuram all the other three areas are encountered with sandy substrate during October and April. In January, only the shore station of Valinokkam was sandy in nature. The only clay sand substrate was found in SK1 during January. All the other stations, the substrate type are silty sand. The living foraminiferal population is found to be very less (< 75 specimens per unit volume of wet sediment) wherever the substrate is sandy.

Sampling stations 2, 6 and 7 of all the traverses, except station 7 of Mookaiyur, the living population is found to be relatively higher (>250 specimens per unit volume of wet sediment) in samples collected during all the seasons.

In all these stations the type of the substrate being silty sand.

Similarly, the samples taken in stations 3-5 account for higher living population (> 325 specimens per unit volume of wet sediment) has been recorded in all the seasons. And it is interesting to note that in all these stations the sediment type is silty sand.

The above observations clearly indicate that silty sand serves as a favourable substrate for the thriving and higher reproduction of the foraminifera in the study area.

As in the case of living population, stations with silty sand substrate have higher total population in all the three collection viz., October, January and April.

3.2.2. Calcium Carbonate

There are three main controlling factor of calcium carbonate content of deep-sea sediments; a) productivity of carbonate secreting organisms; b) dissolution of calcareous tests during and after deposition; c) dilution by non-calcareous material.

Jeyaraju et al., [24] after a detailed study of the relationship between foraminiferal population and sediments of Kovalam and Tuticorin area. He observed that the “spatial variation in calcium carbonate had a bearing on the abundance of foraminifera and showed roughly a positive relation”.

Manivannan et al. [25] have also studied the relation of sediment parameters and foraminiferal population during four seasons of a year from off the coast of Tuticorin. They have observed that the CaCO3 percentage is found to be more between stations 3 and 8 (intermediate segment of each traverse) mainly due to the presence of pearl and chunk beds in Tuticorin shelf. It was in these segments of the traverse, the foraminiferal population was found to be higher showing a positive correlation with CaCO3.

A detailed study on the foraminiferal population and sediment parameters from the Palk Bay, off Rameswaram by Kumar et al. [16] have stated that foraminiferal population is directly proportional to the CaCO3 content of the sediments. The CaCO3 content in the middle segment of the traverse, coinciding with the alignment of coral reefs, is found to be higher that favours higher population.

![Comparison between the foraminiferal population and distribution pattern of Calcium carbonate percentage](image_url)

*Figure 4. Foraminiferal population and distribution pattern of Calcium carbonate percentage (Mean)*
In the present study, the mean calcium carbonate content varies from 27.05% to 28.87% during October and April respectively. It is evident that in the study area, the calcium carbonate content was found to be lesser in percentage in all the shore stations and is higher in stations between 3, 4, 5 and 6 where the substrate was made of coral dust. Temporally, higher percentage of CaCO₃ prevailed during April was one of the congenial factor for higher population during that period (Figure 4). It was evident that in the study area, the calcium carbonate content was found to be lesser in percentage in all the shore stations and was higher in stations 3, 4, 5 & 6 where the substrate is made of coral dust. The study of spatial distribution of CaCO₃ in the study area in general, is found to show positive correlation with population of foraminiferal fauna (Figure 5a-c).

Relation between the foraminiferal population and distribution pattern of Calcium carbonate percentage revealed that the CaCO₃% > 26.0% was accounted for higher foraminiferal population (> 325 specimens per 100 ml. of wet sediment) in all the samples collected and studied. The comparison also revealed that the shore stations of all the collections where the CaCO₃% is between 20 and 25, experienced with lower population (< 75 specimens) of foraminiferal fauna.

Seasonally, higher percentage of CaCO₃ observed during April was one of the controlling factors for higher population. Spatially, distribution of CaCO₃ in the study area showed a positive correlation with population of foraminiferal fauna.

![Figure 5a](image)

![Figure 5b](image)
3.3.3. Organic Matter Content

The organic matter content helps in both diversity and density of the foraminiferal populations [26-34]. Kumar et al. [16] 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 and found that the living foraminiferal population has inverse relationship with organic matter content.

Bergin et al. [35] from their study on the response of benthic foraminifera and ostracoda to heavy metal pollution reported that the number of species increases with increasing organic matter content in the Gediz river estuary and in the Gulf of Izmir. Eric Armanyot et al. [36] stated that foraminifera density is low and species richness is high in sediments with a low organic matter.

Organic matter content in the study area varies from 0.705 % (station TP5, April) to 1.964 % (station TP1, October). The mean organic matter content varies from 0.83 % to 0.95 % during April and October respectively (Table 5). In general the organic matter content was higher in the first three stations from the shore and lower in the later stations. In the present study, organic matter content has somewhat inverse relationship with the population abundance. The study revealed that an optimum amount (0.70 - 0.93%) of organic matter along with other parameters plays an important role.

| SEASON  | CaCo3 (%) | OM (%) | Sand (%) | Silt (%) | Clay (%) | Population |
|---------|------------|--------|----------|----------|----------|------------|
|         |            |        |          |          |          | Living     | Total  |
| OCTOBER | 27.05      | 0.93   | 76.61    | 13.75    | 9.64     | 2020       | 6210   |
| JANUARY | 26.86      | 0.95   | 75.74    | 13.36    | 10.89    | 2113       | 6911   |
| APRIL   | 28.87      | 0.83   | 76.32    | 13.71    | 9.97     | 2306       | 7321   |

Figure 5c. Spatial distribution of Living benthic foraminifera in actual numbers and substrate characters (CaCO3 and Organic matter) (April)

Figure 6. Foraminiferal population and distribution pattern of Organic matter percentage.
A comparison between the temporal distribution of foraminiferal population and percent distribution of organic matter revealed that the higher living population of foraminiferal fauna (>325 specimens per unit volume of wet sediment) found to be present in stations with organic matter content 0.70 - 0.93 % (Figure 5a-c). The population was found to be less where the sample has an organic matter percentage > 1.0 %.

In the present study, organic matter content is somewhat having negative correlation with the population abundance (Figure 6). But with its optimum amount (0.70 - 0.93 %) along with other parameters like CaCO₃ content, depth and water parameters like salinity, dissolved oxygen content and temperature plays a supporting role.

4. Discussion

4.1. Sand-silt-clay Ratio

By comparing the sediment types of the various stations with that of the living and total population of the foraminiferal species, it was observed that the shore stations except in Theresapuram, all the other three areas are encountered with sandy substrate during October and April. Substrate type in most of the samples are siltysand while only one samples is claysand.

The living as well as total foraminiferal populations are found to be very less wherever the substrate was found to be sandy. In stations 2, 6 and 7 of all the traverses, except station 7 of Mookaiyur, the living population is >250 specimens per unit volume of wet sediment, while the samples collected in stations 3-5, the living population is higher (> 325 specimens per unit volume of wet sediment) in all the seasons, because of the other parameters are congenial in this middle segment of all traverses, in all the seasons. And it is interesting to note that in all these stations the sediment type is siltysand.

4.2. Calcium Carbonate

In the present study, the mean calcium carbonate content is found to be the lowest (27.05%) for the sediment samples taken in October and is highest (28.87%) for the sediment samples taken in April. It is evident that in the study area, the calcium carbonate content is found to be lesser in percentage in all the shore stations and is higher in stations between 3, 4, 5 and 6 where the substrate is made of coral dust. Temporally, higher percentage of CaCO₃ prevailed during April is one of the congenial factor for higher population during that period. The study of spatial distribution of CaCO₃ in the study area in general, is found to show positive correlation with population of foraminiferal fauna. The analysis of temporal variation of CaCO₃ also shows a direct relationship with foraminiferal population.

4.3. Organic Matter

A comparison between the temporal distribution of foraminiferal population and percent distribution of organic matter reveals that the maximum population of foraminiferal fauna is observed in April, encountered with lower organic matter content (0.83 %). The population is found to be less where the sample has an organic matter percentage > 1.0 %.

Organic matter content in the study area varies from 0.705 % (station TP5, April) to 1.964 % (station TP1, October). In general the organic matter content was higher in the first two stations from the shore and lower in the later stations.

A comparison of the data relating to organic matter content with living foraminiferal population shows that in the study area, these two parameters are somewhat having negative correlation. Though the organic matter content is not an effective factor that controls the population abundance, along with other parameters like CaCO₃ content, depth and water parameters like salinity, dissolved oxygen content and temperature plays a supporting role.

Distribution and ecological study of the abundant and wide spread foraminiferal species reveals that the following seven species namely Ammonia beccarii, A. tepida, Asterotalia inflata, Elphidium advenum, Noninoides boueannum and Quinqueloculina seminulum prefer higher calcium carbonate content and lower organic matter content of the substrate prevailed during summer season (April) for higher reproduction and abundance of population. The optimum conditions for a higher reproduction of these species in the present area are as follows: CaCO₃: > 26 %; Organic matter: 0.7-0.93 %.

5. Conclusion

1. The faunal analysis has contributed to the identification of 124 foraminiferous species belonging to 59 genera, 39 families and 21 super-families of 5 sub-orders.
2. The foraminiferal population both as living and total are found to be more in the samples collected during summer season. Spatial distribution of the foraminiferal fauna revealed that the siltysand substrate seem to be congenial for higher reproduction and population abundance. Among, 124 foraminifera species identified, the following species were considered abundant and widespread occurring; they are Ammonia beccarii, A. tepida, Asterotalia inflata, Elphidium advenum, Noninoides boueannum and Quinqueloculina seminulum. All these species prefer the environmental conditions that prevailed during April (summer) for higher reproduction and abundance of population, in the study area.
3. In general, the higher calcium carbonate content along with lower organic matter of the bottom sediments was suggested for an abundance of living population.
4. Spatially, the type of substrate and percentage of calcium carbonate are the main controlling factor for the population distribution, while organic matter played a secondary role. The favorable substrate for higher population seems to be siltysand. In general, the populations of these species were directly proportional to the calcium content along with higher sediment fines of the substrate.
Acknowledgements

The authors are sincerely thankful to the authorities of National College (Autonomous), Thriruchirappalli for providing the lab and infrastructural facilities and their helpful cooperation. The first author is grateful to Rev. Sr. Lilirose (Administrator, B.K College, Amalagiri, and Kerala), Rev. Sr. Rose Valiyaparambil (Former Principal, B.K College, Amalagiri, and Kerala), Dr. Leena Mathew (Principal, B.K College, Amalagiri, and Kerala) for giving permission to pursue the research.

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