# STATISTICAL STUDIES AND ECOLOGY OF BENTHIC FORAMINIFERA FROM THE DEPOSITIONAL ENVIRONMENT;

## A Case Study between Mandapam and Tuticorin, South East Coast of India

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**ABSTRACT**

The study area extends for 150 km from Mandapam to Tuticorin, Gulf of Mannar, and Tamil Nadu. Before the commencement of sample collection, a base map in the scale 1: 50,000 was prepared using the toposheets (NO. 58L/13, 58L/1 and 58M/16). The fieldwork was done during the month of March, 2006. A total of 74 sediment samples were collected from beach (6) Offshore (46) and 22 estuarine in the study region. The offshore samples were collected at six transects keeping the stations at Mandapam (5 nos), Valinokkam (5 nos), Vaippar (5 nos), Vembar (5 nos), Kallar, (5 nos) Tuticorin (5 nos) , Off Tamiraparani (10 nos) and Punnaikayal ( 6 nos) Generally, geologists are concerned with complex data set derived out of large amount of samples or variables. Since, the manual interpretation or classification of the data is tedious and involves lot of time; geologists take the help of statistical analysis to arrive at meaningful conclusion. In order to have reasonable interpretation and better understanding of the environmental settings that prevailed in this area, the statistical analyses such as Factor analysis, Species diversity, are being employed here.

KEY WORDS: Statistical Studies, Ecology of Benthic Foraminifera, Depositional Environment, Mandapam and Tuticorin, South East Coast Of India.

### 1. INTRODUCTION

Benthic foraminifera occur epiphytically, epizoically,epifaunally, and infaunally (e.g., Buzas, 1974; Thiel, 1975;Coull et al., 1977; Alexander and DeLaca, 1987; Bernhard,1989; Lutze and Thiel, 1989). They evidently exploit all benthic marine environments, and some soft-shelled forms also inhabit empty foraminiferal tests (Gooday,1986; Moodley, 1990a).

There seem to be two general trends in the vertical distribution of benthic foraminifera in soft sediments. In deep-sea environments, certain species have their maximum densities in deeper sediment layers (below the upper two centimeters) and appear to prefer the associated low oxygen concentrations (Corliss, 1985; Mackensen and Douglas, 1989). The advantage of active migration to these deeper layers would be less competition and predation (Gooday, 1986; Mackensen and Douglas, 1989). There is some evidence that infaunal species are adapted to their habitats, having greater pore densities evenly distributed over most of the test (in response to low oxygen content); their tests have rounded edges and planispiral coiling or have ovate or cylindrical shapes. In contrast, epifaunal species (that live on and within the upper centimeter; Corliss, 1985) are biconvex or plano-convex and either lack pores or have large surface pores on only one side of the test (Corliss and Emerson, 1990).In shallow subtidal and intertidal areas.

Factor analysis is used to uncover the latent structure (dimensions) of a set of variables. It reduces attribute space from a larger number of variables to a smaller number of factors and as such is a "non-dependent" procedure (that is, it does not assume a dependent variable is specified). Factor analysis could be used for any of the following purposes.

### 2. STUDY AREA

The present study area is positioned in the southern coastal tract of Tamilnadu. The coastal stretch between Mandapam and Tuticorin offshore and estuaries extends over a distance of about 150 km in length. The area is located between 8º 45’ to 9º 15’ N 78º 35’ to 79º 15’ E covering the districts of Ramanathapuram and Tuticorin (Fig.1.1& 1.2). The study area is about in the north eastern side by Rameswaram Island, in the east by Bay of Bengal and in the south by Tuticorin port.

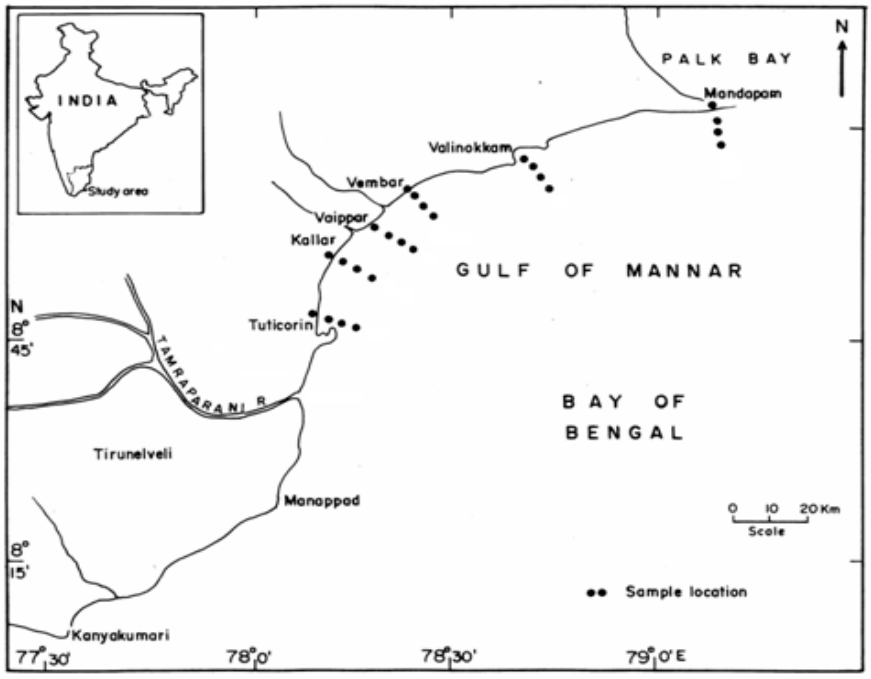


**Fig.1. Sampling Locations of the Study Area**

### 3. MATERIALS AND METHODS

A total of 74 sediment samples were collected from beach (6) Offshore (46) and 22 estuarine in the study region. The offshore samples were collected at six transects keeping the stations at Mandapam (5 nos), Valinokkam (5 nos), Vaippar (5 nos), Vembar (5 nos), Kallar, (5 nos) Tuticorin (5 nos) , Off Tamiraparani (10 nos) and Punnaikayal ( 7 nos) . In order to study the various aspects of Recent brackish and marine foraminifera, surface sediment samples (16 estuarine samples) were also collected from the estuary area, off Tamiraparani, south of Tuticorin, Tamil Nadu, southeast coast of India.

### 4. R- MODE FACTOR ANALYSIS

#### 4.1. FACTOR ANALYTIC DATA MODES

Factor analyses are more suitable in Micropaleontological analytical studies for determining the factors that control the foraminifera distribution with respect to the ecological parameters. Factor analysis produced a correlation matrix for all variables and sorts them into covariant groups (factors) so that depth parameters controlling the foraminifer variability can be inferred from the data. Hence, factor analysis has been employed to reduce the data to set a factors or underlying relationships that identify common properties and processes (Nie *et al*., 1970; Noursis, 1990). The principal axis method extracts communalities from a correlation matrix (Nie *et al*., 1970).

To evaluate significant grouping of factors and related possible environments, factor analysis was run using statistical package SPSS. Varimax factor rotation minimized the number of variables that had loading on any factor. Hence, varimax rotated factor matrix has been applied to describe the factors in the present study.

In the present study, two factor analyses have been carried out for estuary species. In estuary samples genera are taken as variables with respect to stations. A cumulative percentage of 117 species is broadly grouped into 61 genera. Of these, 35 genera occurring very rarely in the study area hence they are grouped as others. Thus, a total of 26 genera were taken into account for the factor analysis, 22 sampling stations were taken as the other variables. The data was then subjected to R- mode factor analysis using SPSS procedure.

### 5. RESULTS AND DISCUSSION

#### 5.1. FACTOR FOR TAMIRAPARANI ESTUARINE

From the results obtained, it is evident that four factors are significant for about 60.29 % of the original data matrix. The variance and cumulative variance of four factors are shown in Table.1. The variable included in this factor-1

account for 20.82% of the total variance in estuary samples. High statistical loading on *Reophax, Spiroplectinella, Textularia, Siphogenerina and others* characterize this factor.

**Table.1. The values of variance and cumulative variance in Estuarine region**

| No | Eigen Values | Variance | Cumulative variance |
|---|---|---|---|
| 1 | 6.94 | 20.82 | 20.62 |
| 2 | 3.12 | 14.48 | 35.30 |
| 3 | 2.29 | 12.93 | 48.23 |
| 4 | 2.13 | 12.11 | 60.34 |

These species are more dominant in the estuarine environment. The factor one display a positive value genera is widely distributed in the junction of estuary and river mouth which is supposed to be genera of tolerance. Murray (1971) observed that the ecology of *Textularia* has temperature 27.5-32.2° C; salinity 32 to 35.8‰; dissolved oxygen 9.4-11.4 ml/l; organic matter 0.16-0.98%; and silt sand and sand are the favourable conditions. It is concluded that the genera of factor -1 are wide fluctuation in ecological conditions.

Factor-2 is represented by the genera *Spiroloculina, Triloculina, Rupertianella,* which has the unique distribution. As evidenced from the high average positive loadings indicate the near shore environmental species.

Factor-3 is loaded on the genera *Epoinoides, Asterorotalia, Pseudorotalia.* The predominant occurrence of these genera noticed in premonsoon estuarine samples prefers the siltysand and muddy substrates in offshore environments

Factor-4 is loaded on the genera *Edentostomina, Adelosina, Asterorotalia, Spiroloculina, Reussella, Planorbullinella, Amphistegina, Hanzawia, Elphidium, and Pseudorotalia.* The predominant occurrence of these genera noticed in premonsoon estuarine samples prefers the siltysand and muddy substrates.

## 6. OFFSHORE FACTOR ANALYSIS

From the results obtained, it is evident that four factors are significant for about 72.240% of the original data matrix. The variance and cumulative variance of four factors are shown in Table.2

The variable included in this factor account for of the total variance in this offshore sample. High statistical loading on *Fissurina, Globigerina, Bolivina, Brizalina,* and *others* are showing strong positive loadings. These species are characteristics of fine grained sediment, high salinity. The positive factor of the above species indicates the influence of deeper environment in shallow marine region. Factor - 1 display a positive value genera which is widely distributed in the offshore stations, supposed to be a deeper environment tolerant fauna transported towards the nearshore environment.

**Table.2. The values of variance and Cumulative variance in offshore Region**

| No | Eigen Values | Variance | Cumulative variance |
|---|---|---|---|
| 1 | 9.771 | 25..022 | 25.022 |
| 2 | 4.220 | 24.027 | 49.050 |
| 3 | 3.577 | 13.695 | 62.745 |
| 4 | 1.936 | 2.564 | 72.240 |

Factor-2 is represented by *Spiroloculina, Rupertianella, Pararotalia, Ammonia, Pseudorotalia* are positively loading with depth. The following species indicate the mixed environment with estuarine and adjoining shelf region.

Factor-3 is represented by *Textularina, Triloculina, Amphistegina, Hanzavia,* are positively loading. The following species indicate the mixed environment with estuarine and dominant in nearshore environment.

Factor-4 is more or less suitable to factor 3represented by *Textularina, Triloculina, Amphistegina, Hanzavia, Rupertianella,* are positively loading. The following species indicate the mixed environment with estuarine and nearshore environment.

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## 7. CLUSTER ANALYSIS

Cluster analysis is being applied extensively to the various fields of foraminiferal ecology studies of the benthic foraminifera (Nigam, 1982). Using cluster analysis, Talib and Farooqi (1994) have suggested that entire west coast of India may be included in the mixed environment. Nigam and Sarupriya (1981) based upon the clusters have identified two biotopes and attributed the same to the prevalence of relative low and high sedimentation. By using cluster analysis, Naidu (1990) has concluded that reworked foraminifera are deposited in the Kalingapattinam shelf, east coast of India. Similarly, Kumar (1988), Manivannan (1989), Khare (1992) and Jayaraju (1993) have attempted the foraminiferal study using cluster analysis. An attempt has been made to grouping the stations in the study area using cluster analysis. The data has been subjected to Q- mode cluster analysis using SPSS Programme.
In the present study 76 sediment samples have been collected from Tamiraparani Estuary and Adjoining shelf area off Tuticorin and Punnaikayal. Were taken as variable with respect to living species.
A cumulative of 36 living species are broadly grouped as 17 genera. Of these, nine species of 8 genera occur very rarely in the study area. They are grouped as others. Thus a total of 10 genera were taken into account for cluster analysis. The data was then subjected to Q-mode cluster analysis using Terrastat programme.
Relationship has been computed using the Elucidain distance coefficient dij as per the formula given below. Where X is denoted the Kth variable measured on the object i and j. In all the kth variable measured on object and dij is the distance between object and I and j. Cluster analysis is beinbg performed by using weight pair group averaging method. In view of the advantage of this technique, the researcher has attempted it through SPSS Statistical Package in the present work.
For clustering "weight pair group method, with simple arithmetic average has been used as the same is easy for computation and is widely used by severeal workers (Nigam, 1982; Bhalla and Nigam, 1988). The results of the cluster analysis are presented graphically in the form of two dimensional hierarchy dendrogram in which stations are presented along horizontal axis relative degree of similarity between the samples in each cluster along the vertical axis.

## 8. Q-MODE CLUSTER ANALYSIS

In the present study, in order to find out the similarity among the stations, the total number of living genera in different depths is added together for the respective station .The assemblages of the different stations are compared among themselves and matrixes of 8 X 8 composed of correlation coefficients are obtained. The Q-mode clustering is applied on this matrix to sort out the respective stations, data into clustering that can be plotted to define the region of comparatively similar faunal composition i.e. biotopes within the study area.

## 9. CLUSTER ANALYSIS FOR ESTUARINE SAMPLES

### 9.1.ESTUARINE

From the results obtained, it is evident that four factors are significant for about 60.29 % of the original data matrix. The variance and cumulative variance of four factors.

### 9.2.ESTUARINE PRE MONSOON

BIOTOPE A Stations in Estuarine
8,13,5,6,1,19,20,2,3,22,11,17

In, Biotope A, most of the estuarine stations are grouped together with few offshore stations, generally indicate the mixed environment conditions.

Biotope B –sub biotope B

The stations 16, 18, 4, 21, 7 indicate the abundance of estuarine species parbalarly. *Ammonia.beccari, Elphidium discoidale*, etc

The sub biotope c shows the stations 12, 10, 14, 15 are grouped together are situated in the central part of estuarine region with environmental conditions.

### 9.3. OFF SHORE

BIOTOPE A Stations (Offshore) only Tuticorin & Punnaikayal
8, 9, 11, 10
BIOTOPE B 12, 13,7,16,15,5
BIOTOPE C 14, 2, 3,6,14

Bio tope: A

The stations 8, 9, 10, 11 grouped together in Biotope A the distribution of species indicate the shallow water environment group together.

Bio tope: B

In biotype B – Most of the deeper species grouped together in this station

Bio tope: C

Indicate the mixed environment shallow offshore environment.

### 10. LIVING/DEAD RATIO

Living/Total ratio has been widely used to estimate relative sedimentation de-position rates in the nearshore areas. To obtain an idea about the nature of sedimentation rate, it is possible to use the relationship between the quantities of living and dead tests (Boltovskoy and Wright, 1976).

Walton (1955) has used living/dead ratios to demarcate the non depositional areas in the Todas bay, Baja California and he has proposed the following calculation to determine the relative sedimentation rate.

$$R = \frac{\text{Number of living foraminifera}}{\text{Number of Total (Living + dead) foraminifera}} \times 100$$

Faster sedimentation rate implies stronger dilution of tests by clastic material and it gives a higher living/total proportion with higher sedimentation rates (Lankford, 1959). Abundant living specimens relative to the total population should indicate relatively rapid addition of sediment and small living population relative to total population would indicate a slow rate of supply of sediment (Phleger, 1960) have explained the large "R" significance for the fast and a small "R" for the slow deposition of sediments in Quinta island area.

Contrarily, ratio between living and dead species cannot be practiced for relating sedimentation rate because they depend upon the existing living species, which in turn, controlled by ecological parameters (McGlasson, 1959). Another problem is that the number of empty tests depends not only on the sedimentation rate but also on the degree of preservation in the substrate (Boltovskoy and Wright, 1976). have explained that living/total are not reliable indicators of relative deposition rates in James river estuary. has reported slow rate of deposition from the Qatar Peninsula area in Persian Gulf and attributed the same to relative ratio of living/total in such a way that the high ratio indicates relative rapid addition of sediment other than the foraminifera while small ratio indicates a show rate of supply of sediment.While discussing the living/total ratios on the tail of the grand banks of Newfoundland, the utility of such ratios as indicators of relative sedimentation in areas of active currents.

The area of their investigation is under the influence of Labrador current and Gulf stream as well as local eddies. However, they thought that the high living/total ratios in a part of the area probably indicate a relative rapid deposition of sediment. Matoba (1970) has reported high ratios and high sedimentation in the innermost parts of the Matsusuhima Bay, Japan. Similar attempts have been made in the island seas of the Malay Archipelago.

On the basis of this ratio, high sedimentation at subtidal zone of Azan bay, Korea. Based upon Living/Total ratio, Alve (1990) has suggested an increasing sedimentation rate on the western side of Fjord compared to eastern side of Fjord, SE Norway.

Walton (1955) has observed living/total ratio of 0.2% to 0.66% in Aqua Hadina lagoon and 0% to about 0.5% in Los Penansqutos lagoon. In lower San Antonio Bay, Mesquite Bay, and Aranses Bay along the Central Texas coast, it is recorded to less than 3% ratios. This is attributed to the low deposition of sediments. Scot, et al., (1976) observed 0.01 to 0.5% at San Diego Bay. Seibold and Seibold (1981) found 1.3% to 10.6% in Cochin lagoon and concluded low sedimentation rate. Nigam (1982) has reported only 5.0% in nearshore area of Dabol-Vengurla sector, west coast of India. Jayaraju (1993) has observed the average ratios of 5.2% at Kovalam, 4.7% at Kanyakumari, 5.2% at Manappad, 6.9% at Tiruchendur and 7.1% at Tamirabarani during monsoon period. Kumar, et al., (1996) reported low sedimentation rate off Rameshwaram because of low organic matter content.

Based on L/T ratio in the study area, a relatively faster rate of sedimentation is observed in the estuary as well as in the adjoining offshore region. The L/T ratio in the estuary is from 5.76 to 18.3. Similarly, the ratio for the adjoining shelf area is from 2.51 to 30.8. From this observation, it is concluded that spatially and temporally in the estuary and adjoining shelf a fast sedimentation rate is noticed.

## 11. SPECIES DIVERSITY

From a study of species diversity, the author has made an attempt to compare the sediment samples in terms of the number of species they contain and the distribution of their abundance or proportions (in the respective sampling stations).

Species diversity is a useful indicator of maturity in communities (higher diversities being related to higher maturity) and of ecological trends, because it can be assumed that areas supporting diverse species have, generally, better life conditions.

According to Walton (1964), the faunal variability, also known as faunal diversity, is the number of ranked species of a counted or estimated population whose cumulative percentage constitutes 95% of the total population. This characteristic is obtained by ranking the percentage occurrence of each species and cumulating the percentages. The variability value (V) is calculated from the difference between the number of species at one-hundredth and fifth percentiles ($NS_{100}$ - $NS_5$).

These values have the same environmental significance as the total number of species but are not affected by those occurrences of rare species that constitute fractional percentages of the total populations.Hussain *et al*. (1996b) studied the faunal diversity from off Tuticorin, in the Gulf of Mannar. They observed higher diversity values during SW monsoon and lower values during NE monsoon. They further observed higher depths and siltysand substrate favour the abundance of fauna.

In order to find out the species diversity in the study area, the relative percentages of Foraminifera (living + dead), in terms of genera, for the 38 surface sediment-sampling stations, were calculated (Tables 5.1- 5.2). The diversity values are calculated with the method proposed by Walton (1964).An analysis and discussion on the diversity values for the Foraminifera assemblage of each of the two seasons, during which the study has been made, are given below:

### 11.1 ESTUARINE SAMPLES

The aerial distribution of the total number of Foraminifera species ranges from 15 species in stations R19, E20 to 75 species in station M32.

Stations R5, R6, R10, R11, R13, and Off Tamiraparani are recorded more than 40 taxa.

Stations R1, R3, R4, R7, R8, R9, R12, R15, R16, R17, R18, are recorded between 20 - 40 species; Stations R2, R14, are recorded less than 20 taxa.

The minimum diversity value (15) is recorded at station R16 & R 14and the maximum (75) at offshore station. The relatively higher number of taxa encountered at the aforesaid stations is attributed to the nature of substrate, the more favorable being sand (stations Off Punnaikayal) and sitysand (stations R13 and R16).

## 12. CONCLUSION

Foraminifera have been successful inhabitants of every aquatic environment from deep oceans to brackish water lagoons, estuaries and even rarely in freshwater streams, lakes etc. In addition, studies on recent foraminifer's fauna from the seas and other marine marginal water bodies of India, especially along the south east coast, have to be still explored in detail. Hence, in order to know their distribution in different habitats in Mandpam and Tuticorin, Gulf of Mannar and the Tamirabarani estuary sediments, the present study has been taken up to enhance the existing knowledge on foraminifera of east coast of India.

Sediment and bottom water samples were collected from the estuary and offshore region. In total, 22 estuarine samples, 6 beach samples and 46 offshore samples were collected. Thus, totally 74 sediment and water samples have

been collected. The depth of sample collection in offshore area ranges from 5.4 m to 25.3 m. Standard procedures adopted for the evaluation of different environmental parameters are incorporated.

Previous research work on Recent foraminifera from the east and west coasts of India, and also from other parts of the world has been reviewed, and a brief synopsis of the hydrographical and sedimentological studies carried out in various marginal marine localities of India has been presented. A total of 117 foraminiferal taxa belonging to 61 genera, 30 families, 14 super families, and 5 suborders have been identified. For the sake of brevity, an update synonymy and remarks for the established species are given. For lucid illustrations, SEM photomicrographs of selected species depicting different views have been given.

The frequency and diversity of the living and total (living + dead) population sizes in each sample of estuary, beach and Offshore have been determined. Various sedimentological parameters such as organic matter, $CaCO_3$ and bottom water parameters like temperature, salinity and dissolved oxygen have been measured. The total population of foraminifera ranges from 7262 to 10549 in the shelf, and for the estuary it ranges from 5854 to 6831. This is attributed to lower and higher values of organic matter in estuary and offshore regions, respectively. Similar trend is noticed with the population in relation to calcium carbonate content in the estuary as well as in the offshore. Calcium carbonate content is generally found to be directly proportional to the population size in both the estuary and shelf area.

A positive relationship between dead species and carbonate content has proved that carbonate content recorded in this sediment must have been the product originated from the *insitu* or other factors probably the drifted shells and from coral environments. The sand-silt-clay ratios were estimated and siltysand, sandy substrates have been predominantly found in the study area. In the estuary and shelf area, the populations of living as well as total foraminiferal populations are on the higher side when the temperature is more. From the overall distribution of the fauna in the present area, it may be observed that the temperature condition is within the tolerance for the thriving of foraminifera fauna throughout the year.

The salinity values of the estuarine water are ranging from 19.82 to 31.3 ppt, and the salinity values of the marine water are ranging from 31.8 to 34.5 ppt. Some foramiiferal species characteristic of brackish water such as *Textularina* occur only or more in the estuary. Few species like *Globigerina*, occur only or more in the shelf region. Few species occur both in estuary and shelf region as a mixed environment. The characteristic estuarine species such as *Brizalina striatula*, *Spiroloculina affixa* and noted hypersaline, tidal marshy taxa like *Trochammina inflata*, *Loxostomina limbata* and *Discorbinella bertheloti* have been recorded in the outer estuarine region of the Tamiraparani River. The occurrence of *Textularia conica* and *Amphistegina radiata* supports the fact that the off-shore region off Mandapam to Tuticorin is a coral rich environment. The record of species like *Ammobaculites exiguus*, *Eponoides repandus*, *Loxostomina durrandii*, *Rosalina globularis* and *Siphogenerina virgula* supports the fact that study area, off Mandapam and Tuticorin is a shallow marine and tropical environment.Out of the 117 species recorded in the shelf sediments, 37 were never found in living condition. They have been referred to as "Dead Species". The remaining 80 are living species occurring in the offshore region. Out of the 83 species identified from the estuary, 26 were "Dead Species".

In order to understand the environmental settings that prevailed in this area, an attempt has been made to study the statistical analyses such as factor analysis, Cluster analysis. Rate of sedimentation can be inferred from Living/Total ratio and it is observed a relatively faster rate of sedimentation in the estuary and shelf region. Species diversity in estuary is generally low compared to the offshore area. From the total number of species, *Ammonia beccarri*, *A. dendata*, *Pararotalia nipponica*, *Pararotalia calcar*, *Osangularia venusta*, *Elphidium crispum* shows a prolific abundance in this region. The total distribution of foraminifera is higher at Mandapam and Tuticorin in the south than the other stations. The lower species diversity is noticed in Kallar and Vallinokkam region. The configuration of coastal morphology is also one of the controlling factors for the distribution of foraminifera.

In estuary, the diversity values are less in few stations particularly in the river mouth estuarine region. Higher diversity values indicative of greater "spread" or species "richness" is exhibited by stations R13, R16, and off Punnaikayal region. From these observations, it may be inferred that the samples collected away from the coast are environmentally more congenial for the thriving of diverse taxa. In the adjoining shelf area, higher diversity values observed, may be correlated with relatively deeper depths, which are environmentally more congenial for the thriving of diverse taxa. It is also inferred that sand, and siltysand are the favourable substrates for the thriving and abundance of the fauna.

The sediment texture, organic matter and carbonate content studies clearly indicate the nature of deposition environments. From the analysis of grain size data, different frequency curves have been plotted and they delineated the erosional and depositional environments. The mean grain size shows the spatial variation along the study area. From the analysis of scatter plots, CM pattern, and log- normal distribution, it is entrenched that characteristic environment of deposition mainly by riverine and beach is dominant in this region. Grain size studies shows the frequency curves vary from unimodal to bimodal in places of river discharge from the Vembar, Kallar, Vaippar and

Tamiraparani, as a result of which an additional sub-population is deposited. Otherwise, the nature of the frequency curve is controlled primarily by wave dynamics and littoral currents. The mean size of the sediments is finer in the Mandapam sector, where low-energy conditions prevail and accretionary processes are taking place; this is corroborated by the positive skewness of the sediments. The sleekness values characteristically discriminate the energy conditions obtaining in the study region: low energy in the Mandapam sector, higher energy in the Valinokkam sector and a mixture of high and low energy in the Tuticorin sector. The CM pattern indicates the deposition of sediments in graded suspension. The binary plots help to discriminate the different environmental conditions prevailing in the study region.

The sand silt clay ratios clearly indicate the dominance of sand and silty sand in the offshore region. The sandy nature may be due to the transportation of sediments from riverine and other sources of environment. In estuary, the organic matter concentration is much favorable for deposition. The turbidity is low in the estuary region which may also favour for organic matter accumulation. Coralline rocks are exposed in the coastal segments in the north of Tuticorin and the fringing reefs are arranged around the chain of 21 islands, which may favour for the organic matter and carbonate content in this region. The organic matter Vs sand shows negative correlation, may be due to erosional activities of the sediments.

In the offshore marine samples, the sand Vs carbonate content shows negative correlation. It clearly indicates that due to the erosional activities whatever sediments deposited near the Tamiraparani estuary in that region are transported to the marine region and were drifted towards northern direction by longshore current, hence the deposition of carbonate in the sediments shows negative correlation.

The offshore and the estuary area fauna have been compared with the fauna reported from different localities and other localities in the Indo-Pacific and East African region, to analyse their distribution and abundance and also know their faunal affinity and zoogeographic implications. A majority of taxa are found to be common or having close affinity with the fauna reported from the east and west coasts of India and other coastal margins of the Indo-Pacific region, showing a strong Indo-Pacific faunal affinity and exhibiting a shallow and tropical water habitat. It is further concluded that the foramgeographical province of the study area may rather belong to " Mixed zone " of Indo- pacific and East pacific faunal provinces.

A review of the comparison of estuary and offshore area fauna with those from various other localities in the east and west coasts of India reveals the following: The following taxa are common to the study area and east, west coasts of India: *Reophax pilulifer, Reophax scorpiurus* var. *testacea, Ammoscalaria runiana, A. tenuimargo, Nouria polymorphinoides, Spiroplectinella sagittula, Bigenerina nodosaria, Textularia bocki, T. conica, T. dupla, Subfischerina galapagosensis, Edentostomina milletti, Spiroloculina aequa, S. affixa, S. depressa, Cycloforina semiplicata, Quinqueloculina cristata, Q. kerimbatica, Pyrgo laevis, Triloculina rotunda, T. striatotrigonula, Nodosaria catesbyi, Lenticulina limbosa, L. macrodiscus, Lagena interrupta, L. sulcata* var. s*picata, Favulina hexagona, Oolina laevigata, Fissurina cucullata, F. laevigata, Glandulina laevigata, Globorotalia tumida, Neogloboquadrina dutertrei, Pulleniatina obliquiloculata, Globigerinella aequilateralis, Orbulina universa, Bolivina hadai, B. persiensis, Loxostomina durrandii, Saidovina karreriana, Globobulimina ovata, Siphogenerina virgula, Neouvigerina interrupta, Uvigerina senticosa, Cancris oblonga, Eponides repandus, Helenina anderseni, Rosalina macropora* and *Nonionella stella.*

The distribution of benthic foraminifera, their diversity and their population density combined with the distribution of physical and chemical parameters have been studied in order to provide new indication for estimating bottom sediment conditions. In the study area at Tuticorin the diversity and assemblages are less near the harbor region. High concentrations of heavy metals such as Cr, Cu, Zn, Cd, and Pb have a marked effect upon foraminiferal distribution. This is characteristics of a restricted or confined environment under stress caused by high level of industrial and domestic pollution.

The tolerance to pollution of *Ammonia beccarii* is well represented by an oligotypic assemblage which characterizes the first 0 – 50 cm sediments. Based on the presence of dead population, it could be speculated that *Ammonia beccarri* and *A.tepida, E.crispum* is the most opportunistic species, able to compete successfully in polluted environments and can be considered as a heavy metal pollution indicator in the harbour areas near Tuticorin.

Significantly, the percentage morphological deformities have not been observed in the foraminiferal tests except few species like *Osangularia venusta* and *Pararotalia nipponica, Ammonia beccarri, A. Dendata, Spiroloculina,* but the higher number of broken species are observed in the offshore and estuary samples. Several species exhibited morphological deformities, but their percentage was observed to be very less, there by rendering it difficult to point towards the anthropogenic stress for the abnormalities observed. It is however, proposed that this inner shelf particularly Tuticorin region may be on the verge of becoming extremely contaminated, unless indiscriminate disposals of industrial effluents and domestic sewage is restricted, and that continuous geochemical and foraminiferal monitoring are imperative for this purpose. The complex nature of anthropogenic activities in the coastal region, however offers a formidable challenge for environmentalists, ecologists and micropaleontologists.

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