

Frequency Distribution of Foraminifera Off Trivandrum, West Coast of India

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Fifty two species belonging to 31 genera of Recent Foraminifera have been identified from sediment samples collected from the inshore waters. Based on relative abundance of species, it is observed that along the coast, the nearshore region up to 5 m depth is dominated by *Asterorotalia dentata* and others in lesser abundance being *Elphidium advenum* and *Amphistegina radiata*, whereas in the offshore region (10 to 20 m water depth), there is a change in the species composition of the fauna, the most abundant form is *Ammonia beccarii* (Linné) *tepida* and other species include *Operculina ammonoides*, *Nonion asterizans* and *Hanzawaia concentrica*. Comparison of the fauna of the Trivandrum area with that of Cochin region, shows 14 common species and due to prevailing marine conditions, no brackish-water species of the indigenous fauna reported from Cochin region, are encountered from the coastal waters of Trivandrum. Also, faunal trends in relation to pollution caused by the effluent discharge from an industrial plant situated along the coast, are discussed with particular emphasis on pH and species diversity index.

Information on Recent Foraminifera is very essential in the interpretation of both modern and ancient environments. Along with oolites, certain shallow-water species of Foraminifera provide cogent clues to global sea level variations due to eustatic contribution. Owing to their importance on these facets of study, a voluminous literature exists on Recent Foraminifera of the world oceans, but information on this group from the Indian shelf is scanty. A review of the literature on Foraminifera of the inshore waters of India is given by Seibold and Seibold¹. Perusal of this and the reports of others²⁻⁴ shows that only a few have recorded quantitative distribution of foraminiferal species while others pertain to taxonomy or ecology. Obviously not sufficient data are available at present on the relative abundance of foraminiferal species in the Indian coastal waters, though such data will be useful in determining typical shallow-water species of a coastal region based on the most abundant species. Therefore, an attempt has been made here to study foraminiferal distribution in the inshore waters of Trivandrum.

Materials and Methods

Sediment samples were obtained in Jan. 1977 with Van-Veen grab from the nearshore region of Trivandrum (lat. 8° 29' N., long. 76° 57' E) along 3 traverses, viz., Thumba, Travancore Titanium Plant (TTP) and Shankhumugham, perpendicular to the coast. Station locations and processing of samples for faunal analysis were same as given earlier⁵. Species diversity index at each station was calculated using the Simpson's formula⁶:

$$D = 1 - \sum_{i=1}^n p_i^2$$

where D is the diversity and p_i is the fraction of the i th species in a sample. Temperature, salinity, pH, and dissolved oxygen of surface and bottom seawater at sampling sites were measured and data presented in Fig. 1.

Results and Discussion

Sediments—The continental shelf off Trivandrum has a width of about 40 km. The bottom sediments of the inshore waters consist of sand or muddy sand together with fragmented shells. The sea bed between 11 and 28 m is even. The gradient of the sea bed is rather steep for the first 20 m depth and thereafter it becomes relatively gentle. At the outfall area, the sands and shells are yellowish brown to brown because of a coating of iron oxide. The surface currents in the nearshore region of Arabian Sea are northerly from November to January⁷ and as a result there is a drift of brown sands into the northern region during the period of observation.

Distribution and abundance of foraminiferal species—Percentage occurrence of foraminiferal species at different traverses covered in the nearshore region of Trivandrum is given in Table 1. Fifty two species belonging to 31 genera have been identified from the sediment samples and the fauna is dominated by *Rotaliina* followed by *Miliolina* and *Textulariina*. Some salient features of distribution of foraminiferal

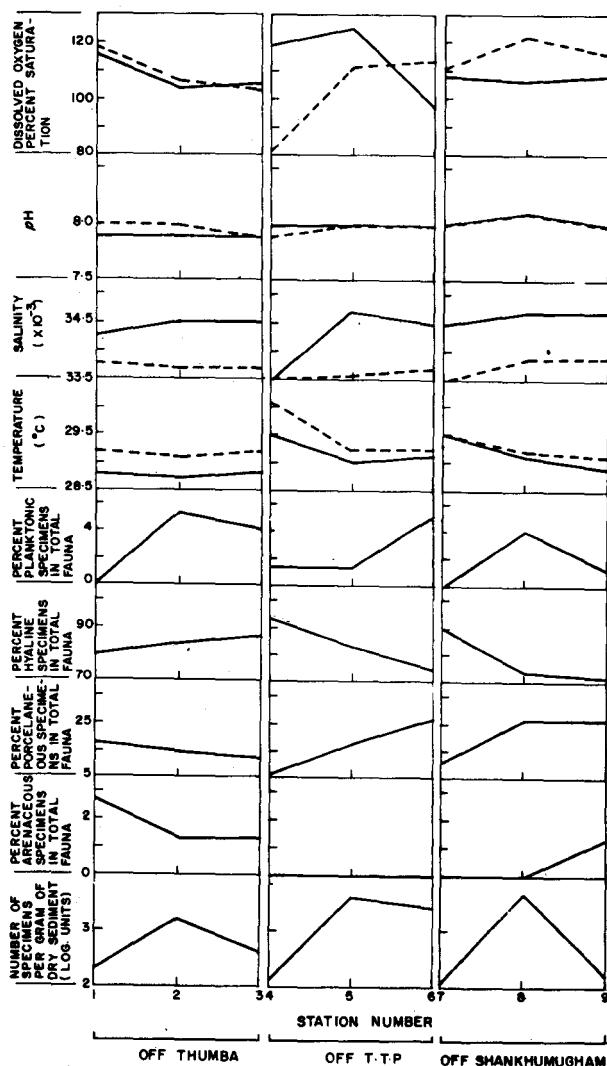


Fig. 1—Physico-chemical characteristics of seawater (--- surface and — bottom) and faunal trends in distribution species at different stations are as follows:

Traverse off Thumba—St 1: The fauna is represented by 18 species with *Asterorotalia dentata* as the most dominant foraminifer forming 33.3% of the total fauna. *Elphidium advenum* is common in the sample while others with percentage ranges: 1-3 and 4-9 are considered here as very rare or rare respectively. The sample is devoid of planktonic specimens.

St 2: The sample is relatively rich in number of species and 32% of the fauna is dominated by a single species—*Ammonia beccarii* (Linne) *tepida*, followed by *Asterorotalia dentata*, *Quinqueloculina seminulum*, *Ammonia beccarii* (Linne) *sobrina* and *Hanzawaia concentrica* in the order of abundance. *Hastigerina siphonifera* and *Globigerina bulloides* together forming 4% in total fauna, are also encountered at this location.

St 3: The sample consists of 21 species, being the highest number observed along this traverse. Among the offshore benthic species, *Operculina ammonoides* is

common in the sample and others which form > 5, but < 10% in total fauna are *Ammonia beccarii* (Linne) *tepida*, *Elphidium crispum*, *Amphistegina radiata* and *Nonion asterizans*. Planktonic specimens form 5.3% of the fauna by a lone species of *Globigerinita glutinata*.

Traverse off TTP—St 4: In comparison with st 1, the sample at this location contains less number of species. Specimens of *Asterorotalia dentata* constitute bulk of the fauna (41.3%). Other common species, viz. *Elphidium advenum* and *Amphistegina radiata* together constitute 29.3% in total fauna. *Quinqueloculina vulgaris* and *Neoconorbina patelliformis* are rare while all other species are very rare. No planktonic Foraminifera are present in the sample.

St 5: The sample is not rich in numerical abundance of species in contrast to st 2. The fauna is dominated by specimens of *Ammonia beccarii* (Linne) *tepida* constituting 34.7% of the fauna. *Asterorotalia dentata* is a common species. Species showing percent occurrence ≥ 4 but < 10 are *Quinqueloculina agglutinans*, *Q. seminulum*, *Amphistegina radiata*, *Nonion asterizans*, *Hanzawaia concentrica* and *Hyalinea balthica*. Planktonic Foraminifera are not encountered at this location.

St 6: The fauna is fairly rich in number of species. *Ammonia beccarii* (Linne) *tepida* is the only species showing the highest percent occurrence in total fauna (22.7%) while other species are around 10 or < 10% in their frequency of occurrence, the common forms being *Quinqueloculina agglutinans* and *Amphistegina radiata*. *Quinqueloculina seminulum*, *Neoconorbina patelliformis*, *Nonion asterizans*, *Hanzawaia concentrica* and *Hyalinea balthica* comprise together 31.9% of the fauna. *Hastigerina siphonifera*, *Globigerina bulloides* and *Globigerinita glutinata* are the planktonic forms observed in the fauna.

Traverse off Shankhumugham—St 7: The fauna is similar to that of st 1, in the number of species and in the presence of some dominant forms such as *Asterorotalia dentata*, *Elphidium advenum* and *Amphistegina radiata*, in the order of abundance. *Ammonia beccarii* (Linne) *sobrina*, *Hanzawaia concentrica* and *Hyalinea balthica* are rare. Planktonic forms are absent in the sample.

St 8: *Ammonia beccarii* (Linne) *tepida*, the most abundant species observed at this location constitutes 21.3% of the total fauna. *Hanzawaia concentrica* and *Nonion asterizans* are common forms. Others falling into the range of per cent occurrence between 5 and 10 are *Quinqueloculina seminulum*, *Q. vulgaris*, *Asterorotalia dentata* and *Ammonia beccarii* (Linne) *sobrina*. Planktonic Foraminifera form 4% of the total fauna, represented by a single species—*Globigerinita glutinata*.

Table 1—Percentage Occurrence of Foraminiferal Species in Total Population

	St No.:	Traverse								
		Thumba			T.T.P.			Shankhumugham		
	Water depth (m):	1 5	2 10	3 20	4 5	5 10	6 20	7 5	8 10	9 20
<i>Textularia agglutinans</i>	2.7	—	—	—	—	—	—	—	—	—
<i>T. candeiana</i>	—	—	—	—	—	—	—	—	—	1.3
<i>T. conica</i>	—	1.3	—	—	—	—	—	—	—	—
<i>Trochammina nana</i>	—	—	1.3	—	—	—	—	—	—	—
<i>Spiroloculina antillarum</i>	—	—	—	—	—	—	—	1.3	—	2.7
<i>Quinqueloculina agglutinans</i>	2.7	—	2.7	1.3	5.3	10.7	—	2.7	6.7	—
<i>Q. lamarckiana</i>	1.3	—	1.3	—	—	—	—	—	—	2.7
<i>Q. seminulum</i>	2.7	9.3	4.0	—	5.3	9.3	2.7	9.3	6.7	—
<i>Q. vulgaris</i>	2.7	1.3	2.7	4.0	2.7	1.3	2.7	9.3	1.3	—
<i>Triloculina circularis</i>	—	—	—	—	—	—	—	1.3	2.7	1.3
<i>T. fichteliana</i>	—	—	—	—	—	—	—	—	1.3	—
<i>T. linnaeana</i>	—	—	—	—	—	—	—	—	1.3	—
<i>T. oblonga</i>	4.0	1.3	—	—	—	—	—	—	—	—
<i>T. tricarinata</i>	4.0	1.3	1.3	—	1.3	1.3	2.7	—	—	2.7
<i>T. trigonula</i>	—	—	—	—	1.3	1.3	—	—	—	—
<i>Hauerina bradyi</i>	—	—	—	—	—	1.3	—	—	—	—
<i>H. fragilissima</i>	—	—	—	1.3	1.3	1.3	—	—	—	—
<i>H. ornatissima</i>	—	—	—	—	—	—	—	—	—	1.3
<i>Sorites marginalis</i>	—	1.3	—	—	—	—	—	—	—	—
<i>Cornuspira involvens</i>	—	—	—	—	—	—	—	—	—	1.3
<i>Bolivina lobata</i>	—	—	—	—	2.7	—	—	—	—	—
<i>B. nobilis</i>	—	1.3	—	—	—	1.3	—	—	—	—
<i>B. tortuosa</i>	—	1.3	—	—	—	—	—	—	—	—
<i>Brizalina striatula</i>	—	—	—	—	—	—	—	—	—	1.3
<i>Reussella spinulosa</i>	—	—	1.3	—	1.3	—	—	—	—	—
<i>Neoconorbina patelliformis</i>	—	—	—	4.0	—	4.0	1.3	2.7	2.7	—
<i>Rosalina concinna</i>	—	—	1.3	—	—	—	—	—	—	—
<i>R. vilardeboana</i>	—	—	—	—	—	1.3	—	—	—	1.3
<i>Conorhoides advena</i>	—	—	2.7	—	—	—	—	—	—	—
<i>Asterorotalia dentata</i>	33.3	12.0	5.3	41.3	14.7	4.0	36.0	9.3	5.3	—
<i>A. inflata</i>	—	—	—	—	—	—	2.7	—	—	—
<i>Ammonia beccarii</i> (Linné) <i>sobrina</i>	1.3	8.0	—	2.7	2.7	—	4.0	5.3	4.0	—
<i>A. beccarii</i> (Linné) <i>tepida</i>	4.0	32.0	6.7	—	34.7	22.7	1.3	21.3	8.0	—
<i>Operculina ammonoides</i>	6.7	2.7	24.0	8.0	2.7	2.7	2.7	—	6.7	—
<i>Elphidium advenum</i>	12.0	1.3	4.0	16.0	2.7	1.3	13.3	2.7	6.7	—
<i>E. craticulatum</i>	1.3	—	1.3	—	—	—	1.3	—	—	—
<i>E. crispum</i>	—	—	6.7	2.7	—	1.3	—	—	—	5.3
<i>E. aff. discoidale</i>	—	—	—	—	1.3	—	—	—	—	—
<i>Hastigerina siphonifera</i>	—	2.7	—	—	—	1.3	—	—	—	—
<i>Globigerinoides ruber</i>	—	—	—	—	—	—	—	—	—	1.3
<i>Globigerina bulloides</i>	—	1.3	—	—	—	1.3	—	—	—	—
<i>Globigerinita glutinata</i>	—	—	5.3	—	—	2.7	—	4.0	—	—
<i>Globorotalia tumida</i>	—	—	—	—	—	—	—	—	—	1.3
<i>Eponides repandus</i>	2.7	—	—	—	—	—	—	—	—	—
<i>Poroeponides lateralis</i>	—	—	—	—	—	—	2.7	—	—	—
<i>Amphistegina radiata</i>	9.3	4.0	6.7	13.3	6.7	10.7	10.7	2.7	14.7	—
<i>Cibicides floridana</i>	—	—	—	—	—	—	1.3	—	—	—
<i>C. refulgens</i>	—	2.7	—	—	—	—	—	—	—	—
<i>Planorbulinella larvata</i>	—	—	4.0	—	—	—	—	—	—	—
<i>Nonion asterizans</i>	1.3	5.3	9.3	2.7	4.0	7.9	—	10.7	9.3	—
<i>Hanzawaia concentrica</i>	4.0	8.0	4.0	1.3	5.3	4.0	4.0	14.7	1.3	—
<i>Hyalinea balthica</i>	4.0	1.3	4.0	1.3	4.0	6.7	8.0	—	—	2.7

St 9: Of the 3 traverses, only this section records the greatest number of species at this location. The fauna is dominated by forms characteristic of offshore fauna, they being *Amphistegina radiata*, *Nonion asterizans*, *Ammonia beccarii* (Linne) *tepida*, *Quinqueloculina agglutinans*, *Q. seminulum*, *Operculina ammonoides*, *Elphidium advenum*, *E. crispum*, *Asterorotalia dentata* and *Ammonia beccarii* (Linne) *sobrina* in the order of species abundance. *Globigerinoides ruber* and *Globorotalia tumida* are the planktonic species found at this location.

It is obvious from the above distribution of foraminiferal species that the nearshore region (~5 m water depth) is dominated by *Asterorotalia dentata* with subdominant forms of *Elphidium advenum* and *Amphistegina radiata*. At depths 10 and 20 m of all traverses, the samples consist of species, which are characteristic of offshore fauna, viz. *Ammonia beccarii* (Linne) *tepida*, *Operculina ammonoides*, *Nonion asterizans* and *Hanzawaia concentrica*. Species occurring at all stations along the three traverses are *Quinqueloculina vulgaris*, *Asterorotalia dentata*, *Elphidium advenum*, *Amphistegina radiata* and *Hanzawaia concentrica*.

Abundance of Foraminifera—Although low concentration of Foraminifera occurs at st 3, the general trend of distribution of total population in all the traverses is that it increases with distance from the coast. Abundance of the fauna varies from 120 to 4480 specimens per gram of dry sediment with a greater variation from place to place (Fig. 1).

Foraminiferal test types—Distributional trends of test types of Foraminifera, viz. arenaceous, porcelaneous and hyaline, are shown in Fig. 1. The arenaceous specimens are represented by two families: Textulariidae and Trochaminidae and their percentage in total fauna varies from 1.3 to 2.7. They are absent at all stations of TTP traverse. On the contrary, Foraminifera with porcelaneous tests are better represented than arenaceous forms with percentage range of 6.6 to 26.7 and constituted by 3 families—Nubeculariidae, Miliolidae and Soritidae. All other forams (Rotaliina) of the fauna are hyaline type.

Comparison of present fauna with that of Cochin region—Cochin region has been chosen to ascertain whether there is any faunal similarity as faunal survey at Cochin has been made during the same premonsoon period¹ and it also gives quantitative distribution of foraminiferal species in the sediments of inshore waters. It is observed that since marine conditions exist along the Trivandrum coast, no brackish-water species of the indigenous fauna recorded off Cochin¹ are present in the Trivandrum area. This is due to the fact that no major rivers and backwaters as in Cochin region open along the coast. Although 52 species have

been recorded from the Trivandrum area and 68 species from Cochin region¹, only 14 species are common to both—*Textularia conica*, *Triloculina tricarinata*, *T. trigonula*, *Bolivina lobata*, *Brizalina striatula*, *Ammonia beccarii* (Linne) *sobrina*, *Ammonia beccarii* (Linne) *tepida*, *Asterorotalia dentata*, *A. inflata*, *Elphidium advenum*, *E. crispum*, *E. aff. discoidale*, *Nonion asterizans* and *Hanzawaia concentrica*.

It is of interest to mention the observation of Seibold and Seibold¹ that *Asterorotalia pulchella* = *trispinosa* and *Pseudorotalia schroeteriana* are known only from the east coast of India. So far, they are not recorded from the Arabian Sea and it is possible that these species are endemic to the Bay of Bengal.

Cosmopolite fauna—It includes species which have a world-wide distribution and typical forms from the samples are *Quinqueloculina seminulum*, *Triloculina oblonga*, *T. tricarinata*, *Cornuspira involvens* and *Globigerinita glutinata*; they also confirm one hypothesis that the species which are cosmopolite in distribution, have a long geological range. As these species are not affected by environmental variations including water depth, they are of little importance in palaeoecological studies.

Planktonic Foraminifera—In general, the inner shelf is poor in planktonic Foraminifera and in the present study, their percentage ranges from 1.3 to 5.3. *Hastigerina siphonifera*, *Globigerinoides ruber*, *Globigerina bulloides*, *Globigerinita glutinata* and *Globorotalia tumida* are the species observed from the samples. Owing to their pelagic nature, the occurrence of 5 planktonic species from the nearshore region, has no ecological significance in the interpretation of bottom sediments.

Ecology—The nature of foraminiferal assemblages in any marine environment is reflected by the variations of certain ecological factors like temperature, salinity, pH and dissolved oxygen of the waters in the area. In the present study, observations on these environmental parameters of the inshore waters of Trivandrum up to 20 m depth are given in Fig. 1.

As the area surveyed for the foraminiferal fauna is shallow, variations in the above ecologic factors among the stations covered are not of much significance. Thus, evidence obtained is not substantial in defining limiting factors for the abundance of certain foraminiferal species. However, they indicate prevalence of marine conditions along the coast, which is typical of an environment of shallow warm waters of Indo-Pacific region except at the polluted site.

Pollution and diversity index—In contrast to the nearshore areas of Thumba and Shankhumugham, which are free from any threat of serious pollution, the inshore waters (~10 m) of TTP are very much polluted

with the effluent discharge from the Titanium Plant. At polluted sites (sts 4 and 5), the diversity index of Foraminifera is low, being 0.85 as compared with other non-polluted stations where it is relatively higher varying from 0.86 to 0.93 in the qualitative and quantitative structure of the total population. The pollution intolerant species of miliolids are less at the polluted sites and their place is taken by more tolerant forms of *Ammonia beccarii*—perhaps having a very high biotic potential as shown by laboratory studies of Bradshaw⁸⁻¹⁰.

At the discharge point on the beach and also at the outfall area, surface of the calcareous tests is corroded due to dissolution effect of the effluents⁵ with a low pH range from 1.4 to 3. In the inshore waters of TTP (~5m), pH shows a wide fluctuation depending on the mixing of the effluents with seawater. However, in shallow waters (5 to 20 m) pH ranges from 7.9 to 8. The pH increases with distance from the shore along the TTP traverse.

Krumbein and Garrels¹¹ reported that pH values <7.8 do cause solution effect on calcareous foraminiferal tests. Bradshaw¹⁰ demonstrated in two species of Foraminifera—*Ammonia beccarii* (Linné) *tepida* and *Spirillina vivipara*—differences in sensitivity to variation in pH and observed that former tolerated low pH values for a longer duration of time than the latter.

Waters in the vast open sea contain more CO₂ than in the atmosphere or in the living biota of the land. Hence lowering of pH does not normally happen even with moderate discharge of acid pollutants since they are greatly neutralised by CO₂ system of seawater. This fact is amply supported by pH observations made by Günter¹² for over 5 y in the German Bight (the North Sea 20 to 30 km northwest of Helgoland), which is also polluted with the acid wastes from the Titanium

dioxide production. However, in the shallow inshore waters of Trivandrum, the discharge of pollutants as noted here not only alters the pH, but those like H₂SO₄ even in small percentage proportion also adversely affect the developmental stages of marine organisms and this has been observed in herring, *Clupea harengus* L by Kinne and Rosenthal¹³. From the above findings it is evident that the discharge of acid wastes from Titanium Plant into the inshore waters of Trivandrum coast needs to be regularly monitored and controlled in view of its toxic nature.

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