Benthic foraminiferal responses to bottom water characteristics in the Palk Bay, off Rameswaram, southeast coast of India

V Kumar & V Manivannan
1Department of Geology, National College, Tiruchirapalli-620 001, Tamil Nadu, India
2Department of Geology, Government College, Salem 636 007, Tamil Nadu, India

Received 29 August 2000, revised 10 May 2001

Recent benthic foraminiferal assemblages from the shallow shelf sediments of the Palk Bay, off Rameswaram were studied qualitatively and quantitatively. The study revealed that the microfaunal assemblage consisting of 108 benthic foraminiferal species belonging to 50 genera of 27 families. Various bottom water parameters were determined and correlated with the foraminiferal population and seasonal distribution of living population was evaluated. The ecology and distribution of eight widespread and abundant foraminiferal species of the study area viz. Spiroloculina communis, Quinqueloculina seminulum, Triloculina insignis, T. trigonula, Ammonia beccarii, A. tepida, Pararotalia nipponica and Osangularia venusta were discussed in detail. Increase in temperature, salinity and dissolved oxygen content of the bottom water were observed as favourable factors promoting the abundance of living population in the study area.

Foraminifera occur in marine and brackish water environments. The occurrence of benthic species is controlled to a great extent by physical factors viz. depth, temperature, amount of light, turbidity of the water; chemical factors of water viz., salinity, dissolved oxygen and available elements; biological factors viz., available food supply and character of the bottom sediments1-3. Studies have been conducted on the ecology and distribution of Recent benthic foraminifera from east coast4-10 and from west coast11-15 of India. Naidu et al.6 reported, after studying the foraminifera from Visakhapatnam harbour complex, that foraminifera can be used as an indicator for marine pollution. Sreenivasa Rao et al.8 studied the distribution of foraminifera from Nizampatnam bay and determined four assemblages which are influenced by distinct environmental conditions prevailed in the area by means of Q-mode factor analysis. Khare et al.15 studied the foraminifera from off Mangalore and concluded that the distribution pattern of benthic foraminiferal morpho-groups can be correlated with fresh water river discharge. The present work was undertaken to study the influence of bottom water characters on the foraminiferal population and diversity in general, and ecology and distribution of abundant and widespread foraminifera, in particular.

Materials and Methods
Fifty-two sediment and bottom water samples were collected at 13 sampling stations, once in three months, representing four seasons in the year 1987, from the Palk Bay, off Rameswaram (long. 79° 29' to 79° 35' E and lat. 9° 15' to 9° 17'N) (Fig. 1). The samples were collected in depths ranging from < 1 m to 16 m. Unit volume of 25 ml wet sediment from each sample was preserved in formaldehyde solution and the living and dead populations of the foraminifera were quantitatively and qualitatively examined for the ecological studies16.

Fig. 1—Map showing location of sampling stations in the Palk Bay, off Rameswaram, southeast coast of India
The temperature of the bottom water sample was recorded from the built-in thermometer. A portion of water sample at each station was preserved according to Strickland & Parsons to estimate the dissolved oxygen content. To determine the salinity of water, chlorinity was estimated and related by Knudsen equation. The pH values were measured for each of the water sample using pH meter. Nutrients (silicate, phosphate, and nitrate) were estimated using methods described by Strickland & Parsons.

**Results and Discussion**

**Bottom water**

Temperature: In the present area, since the samples were collected from shallow depths, there was no appreciable variation in temperature among the different stations of a season (Figs 2 and 3). However, there was an appreciable variation in temperature during different seasons (Fig. 4). It was generally observed that the population of living foraminifera was more when the temperature was high.

Salinity: In the bottom water, off Rameswaram, the salinity values (Figs 2 and 3) varied from 30 (stations 6, 7 - January) to 35.2 ‰ (station 5, 7 - July). The salinity values did not show any noticeable variations within the stations in particular season, but there was a conspicuous variation among different seasons. The average salinity value was higher during July, which was very closely followed by April (Fig. 4). In the study area, it was observed that the living population of foraminifera was more during these two seasons, which may be attributed, mainly, to salinity values ranges from 33.6 to 35.2 ‰.

Dissolved oxygen: The distribution of dissolved oxygen showed a clear seasonal variation in the

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Fig. 2—Showing the relation between the cumulative percent of widespread and abundant living foraminifera and bottom water parameters (January and April)
bottom waters, off Rameswaram (Figs 2-4). The maximum mean value was observed in the month of April and the minimum in January. Spatially, there was no observable variation noticed among the different stations of a season. The increase in the dissolved oxygen content during April may be due to high photosynthetic activities of phytoplankton. This increase in the dissolved oxygen content coincided with the increase in the living population in the present area, as reported for Vellar estuary by Ramanathan. It was considered that the dissolved oxygen content was one of the important factors governing the standing crop.

**pH:** According to Phleger, hydrogen ion concentration is expected to affect the production of calcareous tests so that at a pH approximately < 7, such forms may not survive. In the present study, the pH values of the bottom water did not show much variation spatially and seasonally (Figs 2-4). Since the fluctuation in the pH values was meager, the water maintained alkalinity throughout, within the limits of the tolerance of the fauna. Because of the small variations in pH, its effect on the distribution of foraminifera was not possible of accurate determination.

**Nutrients:** The variations in the concentration of nutrients—silicate, phosphate and nitrate constituents of the bottom waters for the different stations of different seasons are given in Figs 2 and 3. As the distribution of all the nutrients was meager and erratic spatially, the correlation between them and the living crop cannot be achieved. But it was observed from the mean values (Fig. 4) that the increase of these nutrients showed an inverse relationship with the population.

**Foraminifera**

The qualitative analyses of sediment samples led to the recognition of 108 benthic species consisting of...

Out of the 52 sediment samples collected and analysed from the Palk Bay, the living foraminifera have been observed in all the samples (Table 1). The living population was maximum during April (summer season) and abundant in the intermediate stations (stations 4 to 9) irrespective of any season. Among the 108 species identified, only 85 species were found to be in living condition, which include 9 arenaceous, 34 porcelainous and the rest 42 were perforate forms. Among living, only the eight taxa [viz. Spiroloculina communis, Quinqueloculina seminulum, Triloculina insignis, T. trigonula, Ammonia beccarii, A. tepida, Pararotalia nipponica and Osangularia venusta] were considered to be widespread and abundant in the present area since they were found in living condition in more than 75% of the samples collected and studied.

Distribution of foraminifera

Out of the 108 benthic foraminiferal species recognised in the Palk Bay, 23 were not found in living condition and such species are collectively referred as “dead species” in the present study. Among the rest 85 which are found living, 9 are arenaceous agglutinated, 34 are calcareous porcelainous and the rest 42 are calcareous hyaline. The following 8 species are considered to be widespread and abundantly occur-

Fig. 4—Seasonal mean values of living population and bottom water parameters
The foraminiferal population (living) was found to be more in the summer season (April). This abundance of population may be positively correlated with an increase of temperature, salinity and dissolved oxygen content of the bottom waters. Since there was no observable variation of these bottom water characters among different stations of a season, a positive correlation between them and population cannot be achieved. Kumar et al. have reported that a silty sand substrate and higher calcium carbonate content of sediments favoured an abundant population. The relation between the cumulative percent of abundant and widespread living foraminifera and the various bottom water parameters governing them are given in the Figs 2 and 3.

**Table 1**—Living foraminiferal populations, off Rameswaram (No. of specimens/25 ml. of wet sediment)

<table>
<thead>
<tr>
<th>Period</th>
<th>Station numbers</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>Jan</td>
<td>232</td>
<td>665</td>
</tr>
<tr>
<td>April</td>
<td>20</td>
<td>663</td>
</tr>
<tr>
<td>July</td>
<td>191</td>
<td>365</td>
</tr>
<tr>
<td>Oct</td>
<td>13</td>
<td>812</td>
</tr>
<tr>
<td>Mean</td>
<td>114</td>
<td>626</td>
</tr>
</tbody>
</table>

**Spiroloculina communis** Cushman & Todd—The living representatives were absent only in the shore stations of April and October. Spatially, this species was found to be abundant in the later half stations (7 to 13) of the traverse. As there was no much variation in the bottom water parameters among the stations, it was hard to correlate them with the population of the species. Temporally, this species had higher population in summer and lesser during October. This population variation can be very well correlated positively with the increasing temperature, dissolved oxygen content of the bottom water. The optimum salinity value for higher reproduction was < 3‰. Kumar et al. have observed that the higher calcium carbonate content of the substrate was the main controlling factor for the abundance in the intermediate segment of the traverse.

**Quinqueloculina seminulum** (Linn)—The living specimens of *Q. seminulum* occurred in 41 samples. Spatially, more population was noticed in the middle segment of the traverse (stations 3 to 9). The living forms were found to be abundant during April and minimum during October. The temporal distribution of this species can be positively correlated with the higher temperature and dissolved oxygen content of the bottom water. The optimum salinity value for higher reproduction was < 3‰. Kumar et al. have observed that the higher calcium carbonate content of the substrate was the main controlling factor for the abundance in the intermediate segment of the traverse.

**Triloculina insignis** (Brady)—The living specimens were absent in the first and last stations of all the collections. In general, the living specimens were more concentrated in the intermediate stations (4 to 10). Temporal distribution of the species revealed that the living population was greater during summer (April) followed by January. During the monsoon seasons the living population size was considerably small. In this area, it was found that the active reproduction for *T. insignis* occurred between January and April, with more reproductive activity in April.

**Triloculina trigonula** (Lamarck)—The living population was completely absent in the shore station and minimal in the second. The concentrations were more in the intermediate stations of the traverse. Temporally, the maximum living population was seen in summer (April) which was followed by winter (January) while both the monsoons witnessed a lower living population size. Complete absence of living forms in the first station as well as the minimum in the second station showed that the near-shore turbulence caused by the wave action was not favourable for the thriving of *T. trigonula*. The smaller population size during July and October may be due to the monsoon weather and bay depressions. This species prefers quiet water as in the case of *T. insignis*.

**Ammonia beccarii** (Linne)—Phleger & Lankford reported that the reproduction of *Streblus beccarii* (Linne) occurs in frequent intervals and is not related to the season. Boltovskoy stated that *Rotalia beccarii* did not show any seasonal periodicity and assumed that reproduction occurred at frequent intervals throughout the year. The spatial distribution of this species in the present area was erratic. Seasonally, the
living population size was maximum during SW monsoon followed by winter and minimum during NW monsoon and summer.

*Ammonia tepida* (Cushman)—Spatially, the distribution of *A. tepida* reveals that they were comparatively lesser in the last 3 stations of any traverse. Temporally, the total living population for a season was found to be maximum during April, followed by January and was minimum during October. Bradsaw observed from the laboratory experiments that the reproduction of *A. tepida* occurred only between 20° - 30°C, with optimum conditions from 25° - 30°C and salinity values between 20 – 40‰. In the present study, this species occurs in living condition in almost all the samples, indicating its tolerance to considerable upward and downward fluctuations of environmental factors. The distribution of the fauna of the present area reveals that the optimum conditions for the abundance of this species are—temperature 31.5°C - 32.6°C; dissolved oxygen - 6.0 ml/l; salinity < 34.5‰ and low nutrient values.

*Pararotalia nipponica* (Asano)—The distribution of *P. nipponica* reveals that the population was found to be more in stations between 1 and 7. Temporally, the population was found to be maximum during January, followed by July and minimum during October. In general, the living specimens were found to be more in the earlier two stations, moderate in the intermediate stations and lesser in the last four stations. Thus, one of the controlling factors of this species in the present area was depth. The optimum conditions for the abundance of living population of *P. nipponica* are: temperature 26.4° - 26.8°C; salinity 30.2 - 30.8 ‰ and dissolved oxygen 2.8 - 3.6 ml/l.

*Osangularia venusta* (Brady)—The living specimens of *O. venusta* were more concentrated in the intermediate stations and were absent in station 13 and minimum in stations 1, 11, and 12 during any season. Seasonally, living population size showed a maximum during summer (April - 6271 specimens) followed by southwest monsoon (July - 5611 specimens). The active reproduction of the fauna seemed to occur irrespective of the season. A correlation of *O. venusta* population with different ecological parameters measured shows that this species is tolerant of extreme changes of ecological conditions.

The distribution and ecology of widespread and abundant living foraminifera revealed that among the eight species, *Ammonia beccarii* is found to have maximum reproduction during southwest monsoon and *Pararotalia nipponica* during winter. For *Osangularia venusta*, the active reproduction seems to occur irrespective of the season. The other five species reproduce actively during summer. In general, in the present area, the increase in temperature, salinity and dissolved oxygen content of the bottom waters are causative factors for the abundance of the living population.

**Acknowledgement**

The authors thank the authorities of Fisheries Department, Tamil Nadu for providing motor launch to collect samples for the present work (Ph.D work of the first author). They also express their gratitude to the Head, Department of Geology, University of Madras, Chennai and the Principal, National College, Tiruchirapalli for the permission to utilise the laboratory facilities.

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