

Distribution, factor analysis and ecology of benthic foraminifera within inner shelf regime of Vengurla-Bhatkal sector, West Coast, India

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Abstract

One hundred and two taxa of benthic foraminifera are reported from the neritic environment (15–60 m) of Vengurla–Bhatkal area. Q-mode factor analysis reveals 6 important foraminiferal assemblages accounting for 92% of the information given in original data matrix. The assemblages are – *Nonion* – *Bulimina Ammobaculites*, *Bolivina*. *Bulimina* – *Nonionella* – *Ammobaculites Nonionella* – *Bulimina* and *Ammonia*. Based on the ecology of the fauna it is concluded that a general hyposalinal environment prevails in the study area. Geographical distribution of well-known hyposalinal species/assemblage can be used to study the spread of brackish water along the coastal area.

INTRODUCTION

As part of the Institutional project 'Distribution, ecology and significance of foraminiferal fauna of the western continental shelf of India' several surficial samples are being collected on board *R/V Gaveshani* in the Arabian Sea since 1976. These samples were studied earlier (Nigam *et al.*, 1979; Setty *et al.*, 1979; Setty and Nigam, 1980; Nigam and Sarupria, 1981; Nigam and Thiede, 1983) covering the inner shelf area between Dabhol to Vengurla. The present work is an extension of the same studies further south, covering the inner shelf region between Vengurla to Bhatkal.

The main objective of this study is to present the distribution and ecology of foraminiferal fauna from this region. This also includes the results of factor analysis. Some of the aspects of foraminiferal studies in shallow seas (up to 15 m depth) of this region have already been reported (Bhatia and Kumar, 1976; Setty and Nigam, *in Press*).

MATERIAL AND METHOD

The 24 surficial sediment samples used in the present study were collected from the inner shelf from depths ranging between 18–58 m during the 17th and 18th cruises of *R/V Gaveshani* (Fig. 1). Samples were collected with a La Fond-Dietz snapper (area 104 cm²). The top 1 cm layer was separated from each sample and washed over a 63 μ m mesh. On an average, 500 specimens of foraminifera were picked from + 63 μ m fraction of sediments. Percentage distribution data were subjected to Q-mode factor analysis using FORTRAN IV 'Program package for factor analysis' (Mahadevan and Fernandes, 1983) on ND-100 at the computer centre of the National Institute of Oceanography.

ENVIRONMENT

Physical setting

The continental shelf between Vengurla and Bhatkal is bordered by the Western Ghats. The width of the coastal plain varies from 24 km in the northern part to

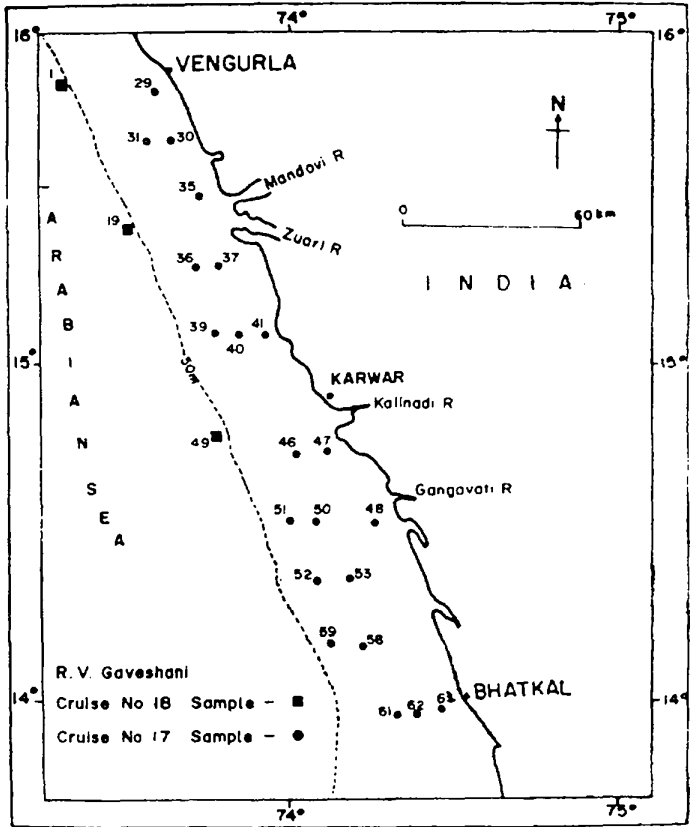


Figure 1. Station location map.

78 km in the southern. Three main rivers flow across the coastal plain. They are Mandovi and Zuari in Goa and Kalinadi in North Kanara.

Bottom topography

The continental shelf in the study area has an average width of 80 km and the depth of shelf break varies from 90 to 120 m. The shelf is smooth and featureless up to a depth of 50 m. Beyond that depth small scale prominences and undulations appear. The clayey silt forms a relatively narrow band confined to < 50 m water depth and within a distance of 25 to 35 km from the coast. Beyond this, there are sands. In contrast to the generally uniform distribution of clayey silt present on the inner shelf of the west coast, the inner shelf of Bhatkal has silt sized material (Nair *et al*, 1978).

Chemistry

The amount of calcium carbonate in the sand fraction ($> 63 \mu\text{m}$) is < 30% in the inner shelf clayey silt. It varies from 50 – 70% in the outer shelf sands. Organic

carbon content in sediment varies from 0.6 to 3.5% (Ambre, Unpublished data). It is observed that low values of organic carbon are associated with coarse sediments. The calcium carbonate shows an inverse relationship with organic carbon.

RESULTS

Study of 24 samples yielded 102 species belonging to 48 genera. In some of the samples considerable amount of reworked fauna were noticed. Majority of them belong to *Quinqueloculina*, *Triloculina*, *Spiroloculina*, *Cibicides*, *Nummulites* (*Operculina*), *Amphistegina*, *Elphidium* and *Ammonia*.

In order to study the relationship between foraminifera and present day environment, only Recent foraminifera were considered. Based on the percentage distribution of various foraminiferal species, a matrix of 34 variables (33 genera + miscellaneous) was subjected to Q-mode factor analysis. Six factors were obtained explaining 92% of the information given in original data matrix. Variance and cumulative variance are given in Table I. Figure 2 shows the contours corresponding to factor

TABLE I. Variance and cumulative variance of the factors.

Factor Number	Variance	Cumulative Variance
1	47.9	47.9
2	15.5	63.4
3	10.3	73.7
4	8.7	82.4
5	4.9	87.3
6	4.7	92.0

loading at different stations for the six factors. The factors are further described as assemblages and named after one or more important constituents in each factors as determined from factor score matrix. They are :

- Factor 1 (47.9 %) : *Nonion-Bulimina* assemblage
- Factor 2 (15.5 %) : *Ammobaculites* assemblage
- Factor 3 (10.3 %) : *Bolivina* assemblage
- Factor 4 (8.7 %) : *Bulimina-Nonionella*
Ammobaculites assemblage
- Factor 5 (4.9 %) : *Nonionella-Bulimina* assemblage
- Factor 6 (4.7 %) : *Ammonia* (large) assemblage

DISCUSSION

Assemblages

Nonion-Bulimina assemblage : *Nonion* is the most dominant taxon in the study area. This is represented mainly by one species—*Nonion boeuanum*. The next important species is *Bulimina exilis*. *Nonion* is a genus which prefers hyposalinal to normal marine environment (Murray, 1973) and its species *N. boeusanum* is a

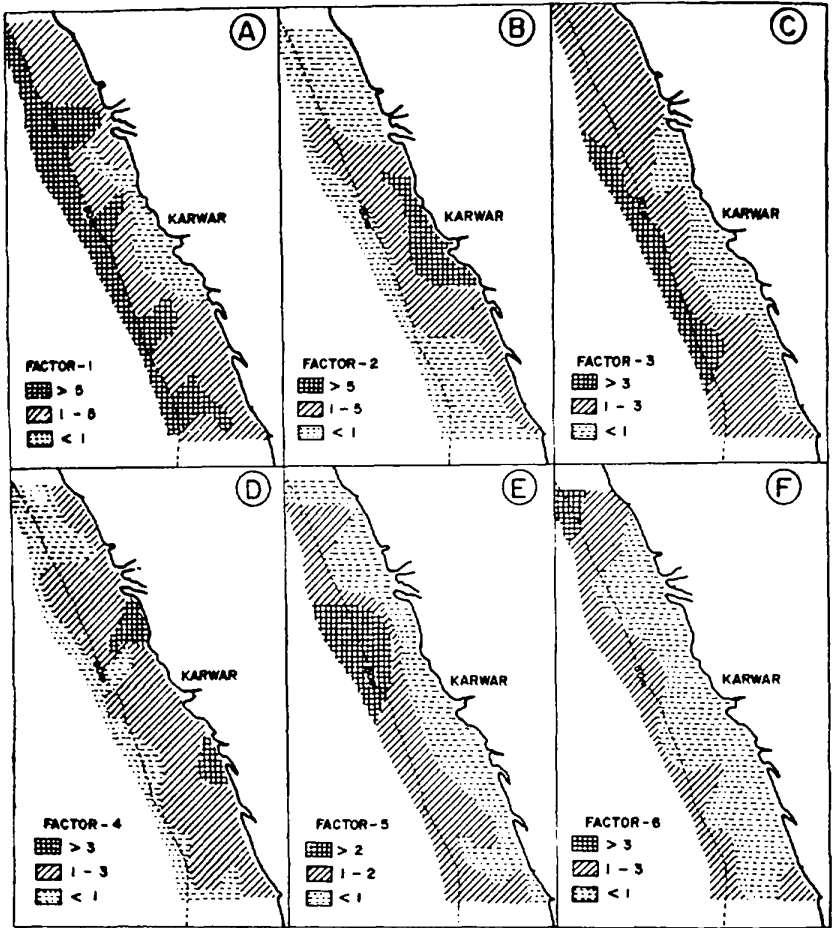


Figure 2. Distribution of factors 1 to 6.

widely reported species from shelf region of the west coast of India (Setty and Nigam, 1980; Nigam, 1986). Similarly, *Bulimina* is a genus which prefers 32-36‰ salinity and bathyal to marginal environment (Murray, 1973) and *B. exilis* prefers the areas least affected by fresh water runoff (Nigam and Thiede, 1983). In the present study area this assemblage is dominant seaward and reduced towards the coast (Figure 2a). The minimum values of factor loading are observed near the mouth of Kalinadi.

Ammobaculites assemblage: *A. persicus* is the dominant species in this assemblage. Maximum concentration of this assemblage was noticed in the inshore area close to the mouth of Kalinadi river (Figure 2b). This assemblage is typical of

hyposalinal environment (Nigam, 1984, 1986) and suggests high influx of fresh water from Kalinadi, unlike the other rivers in this section such as Mandovi and Zuari rivers.

Bolivina assemblage: *Bolivina*, which has a depth range from bathyal to marginal marine environment (Murray, 1973) is the most important genus of this assemblage. The other two constituents of this assemblage are *Nonion* and *Nonionella*. As *Nonionella* is a genus of normal marine habitat, it indicates withdrawal of fresh water. This assemblage shows maximum factor loading at stations deeper than 40 m and gradually decreasing towards the coast (Figure 2c). It also shows preference for coarse sediment and lower content of organic carbon.

Bulimina-Nonionella-Ammobaculites assemblage: This assemblage is a complex assemblage and its constituents have different ecologies. Maximum occurrence was encountered on both sides of the mouth of Kalinadi river (Figure 2d). The moderate occurrence of this assemblage covers almost the entire study area. However, it is either absent or very rare in some of the seaward stations.

Nonionella-Bulimina assemblage: *Nonionella-Bulimina* assemblage shows the highest concentrations in deeper stations in the northern half of the study area. This assemblage gradually decreases towards the coast while large area covered by shallow stations are marked by rare occurrence (Figure 2e). Composition of this assemblage indicates a preference for a normal marine environment. *Bolivina* also contributes significantly to this factor. This prefers normal marine conditions and thus strengthens the marine nature of this factor.

Ammonia (large) assemblage: This assemblage is dominant at one station only at the northern extremity of the study area (Figure 2f). Its moderate occurrence covers 6 stations while it is rare in large parts of the study area. Dominant contributor species for this factor are *A. annectens* and *A. papillosus*. The other two important species are *A. tepida* and *A. sobrina*.

FORAMINIFERA AND ENVIRONMENT

Fresh water influence

Salinity affects the geographical distribution of foraminifera, and its effect is much more pronounced in areas where there is considerable mixing of sea water with fresh water (Boltovskoy and Wright, 1976). Some species of foraminifera are euryhaline and these forms are found in marginal marine environments. Some euryhaline species live in hyposaline and hypersaline waters also. The majority of hyposaline species are confined to that environment and are rarely found in normal marine conditions. By contrast, all hypersalinal species also live in marine conditions (Murray, 1973). Therefore, geographical distribution of well-known hyposalinal species/assemblage can be used to study the spread of fresh water from rivers in coastal areas.

The general hyposalinal conditions are indicated by the distribution of *Ammonia* assemblage (Figure 2f). Variable environmental conditions including periodic hypersalinity are often mentioned as favourable for this fauna (Walton, 1964).

In the present study area, this assemblage extends towards the deeper region, which means that mixing of fresh water and sea water occurs quite far from the coast. The presence of extensive hyposalinal conditions can be inferred adjacent to

the mouth of river Kalinadi from the concentration of the *Ammobaculites* assemblage there (Figure 2c).

Relationship with substrate, organic carbon and carbonate content

Some of the authors like Brady (1884) observed a correlation between distribution of various benthic species and the nature of bottom sediments. The later review (Boltovskoy and Write, 1976) however, showed that contradictory evidences were given by various authors regarding the ecological control of various substrate conditions. The role played by organic carbon in the substrate is diverse. Some-time it can produce acidic conditions and thus reduce the fauna. But in other

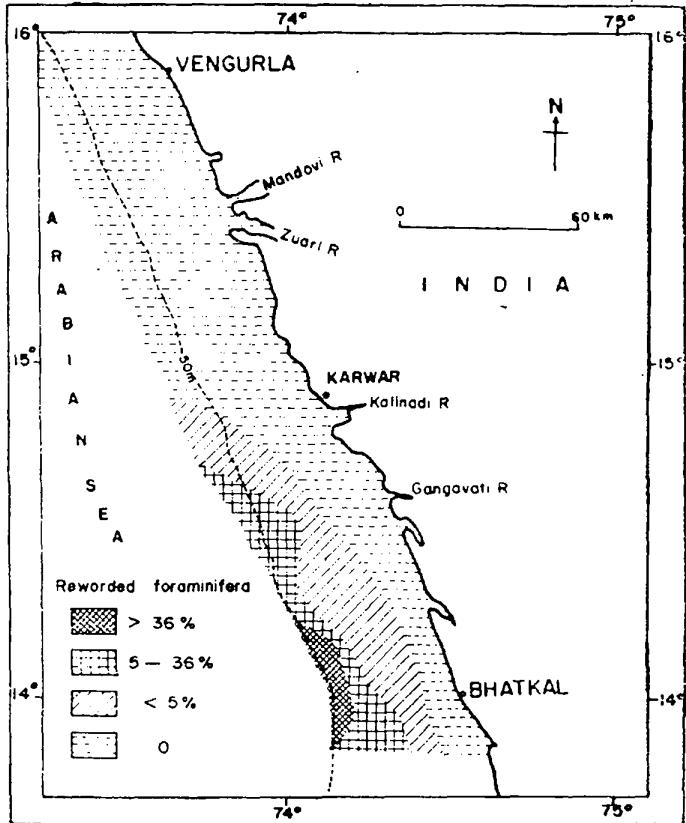


Figure 3. Percentage of reworked fauna in the total fauna.

situations, it enhances the nutritive content in substrate and becomes favourable to foraminifera. Setty and Nigam (1982) observed that foraminiferal populations and organic carbon contents differ in various types of substrate.

In view of the above, an attempt has been made to study the relationship of foraminifera with substrate and their organic carbon content. *Nonionella*, *Bolivina*,

Bulimina and *Nonion* are prominent in medium to coarse (silty sand/sand) substrate with low to medium values of organic carbon. *Ammobaculites* is abundant in clayey silt and higher values of organic carbon. Rare fauna like *Cibicides* and Miliolids are abundant in sand with low organic carbon and gradually get less and finally disappear with decrease in sediment size and increasing organic carbon.

Besides substrate and organic carbon, calcium carbonate also plays an important role in ecology of foraminifera. In the present study area, *Ammobaculites* is abundant in areas of hyposalinal environment where values of CaCO₃ are low. Similar observation for agglutinated foraminifera was made by Greiner (1970) in the Gulf of Mexico, who suggested that agglutinated foraminifera which do not require CaCO₃ dominates the zone of low CaCO₃ availability (low temperature, low salinity). Miliolide and *Cibicides* are abundant in areas of high CaCO₃ content. *Nonion*, *Nonionella*, *Bolivina*, *Bulimina* are abundant in areas of high CaCO₃ and less so with decrease in values for CaCO₃ content.

Older reworked fauna

At some stations, earthy coloured, dull lustered, highly abraded and large size (e.g. diameter of *Nummulites* 1.5 mm, *Elphidium* 1.23 mm, *Quinqueloculina* 1.1 mm. etc.) foraminiferal tests were recorded. Their mode of preservation indicates that they are older in age. Percentage distribution of such specimens with reference to total population is shown in Figure 3. They are confined to sandy and silty sand substrate. The faunal composition indicates that they are all Pleistocene in age and probably deposited during the low sea level about 11,000 years B.P. (Nair and Hashimi, 1980). In general, the size of the older fauna is larger than the present-day fauna. Based on a series of culture studies, Bradshaw (1970) concluded that the largest tests formed under the coolest conditions. Following this, it is concluded that temperature was cooler during the deposition of these sediments, as compared to present-day environment.

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