

**CLUSTER ANALYSIS AND ECOLOGY OF LIVING BENTHONIC  
FORAMINIFERIDS FROM INNER SHELF OFF RATNAGIRI,  
WEST COAST, INDIA**

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CLUSTER ANALYSIS AND ECOLOGY OF LIVING BENTHONIC  
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Abstract

Q-mode cluster analysis explains the spatial distribution data of living benthonic foraminiferids from the inner shelf off Ratnagiri. Two main biotopes and two sub-biotopes are recognised within the study area; biotope A, characterised by *Trochammina inflata* (Montagu), covers the inner shelf north of Ratnagiri and demarcates the influence of fresh-water from Shastri and Vashishti rivers. Biotope B characterised by *Nonion* and *Ammonia* covers the inner shelf south of Ratnagiri and represents less influence of fresh water from Rajapur and Vaghotan rivers. Two sub-biotopes in B are represented by the additional occurrence of *Ammobaculites agglutinans* and *Nonionella* respectively. Relatively low and high rate of sedimentations were noted in areas of biotopes A and B respectively.

INTRODUCTION

Cluster analyses are being applied extensively to the various fields of foraminiferology viz. ecological studies of benthonic foraminifers (Kaesler, 1966); biofacies analysis (Mello and Buzas, 1968; Ujiie and Nagase, 1971); evaluation of fossil assemblages (Valentine and Peddichord, 1967); taxonomy (Barnett, 1974); marine environmental analysis (Schafer and Scott, 1976; Erskian and Lipps, 1977). Efforts have been made to apply this technique to foraminiferal data from the Indian region (Nigam, unpublished thesis, 1978).

This paper presents the results of a cluster analysis of living benthonic foraminiferal assemblages from the inner shelf off Ratnagiri. The details of taxon, stationwise distribution of foraminiferids, depth of stations and organic matter content have been omitted here, as these have already been published elsewhere (Setty and Nigam, 1978; Nigam *et al.*, 1979; Setty *et al.*, 1979).

MATERIAL AND METHODS

The twenty-three samples used in the present study were collected from the inner shelf at depths of 18-51 m off Ratnagiri during the 17th Cruise of *RV Gave-shani* (Fig. 1). The samples were collected with a Van Veen grab (area 400 cm<sup>2</sup>) and La Fond-Dietz snapper (area 104 cm<sup>2</sup>), the top 1 cm layer was separated from each sample and mixed with Rose Bengal to stain living benthonic foraminiferids (Walton, 1952). Living benthonic foraminiferal assemblages only were studied; dead forms were excluded as these may not be indigenous to the environment. After excluding the species of limited or rare occurrence (< 5% at one station only), 25 species were selected for statistical analysis (Appendix 1).

Q-MODE CLUSTER ANALYSIS

First, the correlation coefficient ( $r$ ) between two given stations was calculated based on the percentage ratio of specimens of every taxon to the total number of specimens. The calculations were done on DCM microsystem 1101 (programmable calculator) by the formula used by Ujiie and Nagase (1971):

$$r = \frac{\frac{1}{n} \sum_{i=1}^n (x_i - \bar{x})(y_i - \bar{y})}{\sqrt{\frac{1}{n} \sum_{i=1}^n (x_i - \bar{x})^2} \sqrt{\frac{1}{n} \sum_{i=1}^n (y_i - \bar{y})^2}}$$

Where  $x_i$ : is the relative abundance (i.e., percentage of living specimen of a taxon in the assemblage) of taxon in the assemblage  $x$  of first sample

$y_i$ : is the relative abundance of the same taxon in another assemblage  $y$  of second sample

$n$ : is the total number of taxa in the two assemblages being compared.

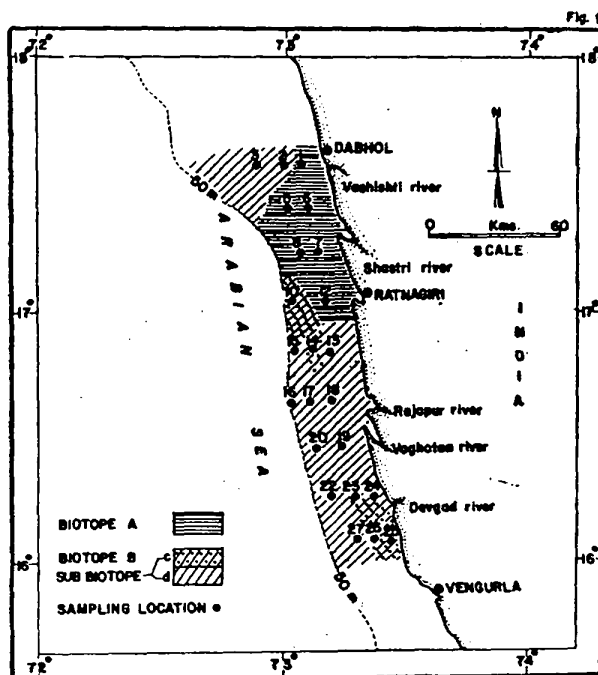


Figure 1. Sample location map and Geographical distribution of biotopes.

In this way assemblages of 23 stations were compared among themselves and a matrix ( $23 \times 23$ ) was obtained composed of 253 correlation coefficients (excluding those of main diagonal which are all equal to 1.0). The Q-mode clustering technique was applied on this matrix to sort the station data into clusters that can be plotted to define regions of comparatively similar faunal composition (i.e., biotopes), within the study area. For clustering, 'weighted pair group method with simpel

arithmetic average' was used (Sokal and Sneath, 1963), as this method is easy for computation and widely used by several workers. The results of the cluster analysis are presented graphically in the form of a two-dimensional hierarchy dendrogram in which samples are presented along horizontal axis and relative degree of similarity between the samples in each cluster along the vertical axis (Fig. 2).

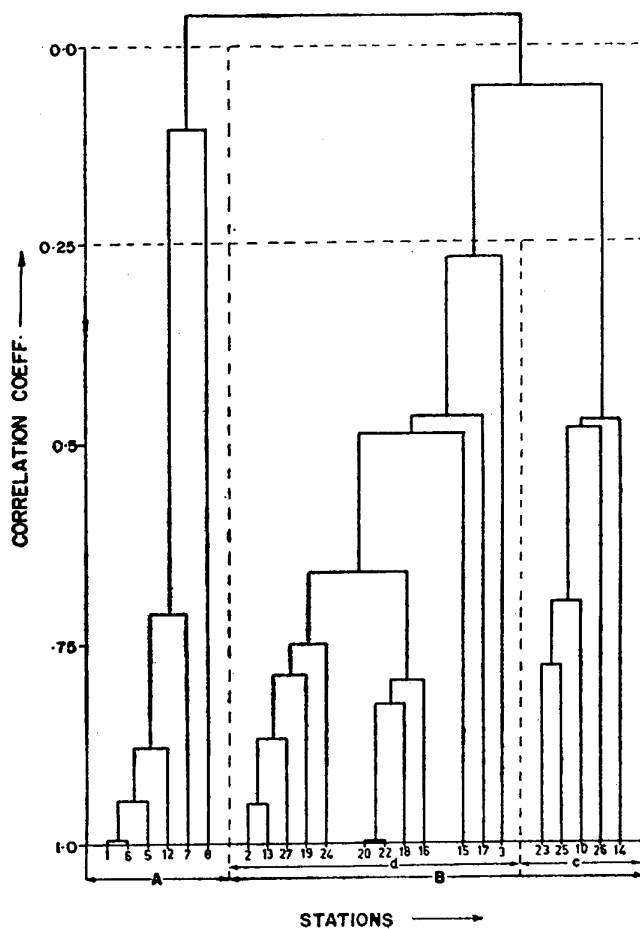


Figure 2. Dendrogram showing results of Q-mode cluster analysis.

#### RESULTS AND DISCUSSION

At the O level of clustering which considers only positive and negative matches, the stations can be classified into two separate biotopes A and B. The geographical distribution and major faunal characteristic of each biotope is discussed below.

*Biotope A.* This biotope includes 6 stations and covers the area north off Ratnagiri (Fig. 1). *Trochammina inflata* which is a hyposaline species (Murray, 1971) is the major foraminiferal species of this biotope. Hence, it indicates the large influx of fresh water in this area from Shastri and Vashisti rivers.

*Biotope B.* This biotope comprises of 17 stations south of Ratnagiri (Fig. 1). The biotope is characterised by the dominance of *Nonion* and *Ammonia* species. Both these genus represent hyposaline to hypersaline lagoon and inner shelf environment (Murray, 1973). But the absence (or rare presence) of hyposaline species *Trochammina inflata* and presence of the normal marine genus *Nonionella* in almost all the stations suggests that the effect of freshwater influx from Vaghotan and Rajapur rivers is comparatively less. Stations 2 and 3 are apparently influenced to a less extent by the freshwater discharge because of being farther from fresh water source.

At the 0.25 level of correlation biotope B can be classified into two sub-biotopes c and d.

Sub-biotope - c consists of 6 stations, their geographical distribution indicates that stations 10 and 14 represent intermediate environmental condition that occur at the boundary of the two major biotopes. Stations 23, 25 and 26 are situated at the mouth of river Devgad. This sub-biotope indicates the mixing of fresh and marine waters but not to the same degree as at the Shastri and Vashishti river. The occurrence of *Ammobaculites agglutinans* in this biotope is also indicative of fresh water influence (see Bhatia and Kumar, 1976).

The sub-biotope - d is characterized by a normal marine assemblage that includes *Nonionella* which is a normal marine genus preferring muddy sediments in temperate to tropical climates and is common in the shelf and bathyal zone (Murray, 1973; Erskian and Lipps, 1977).

*Relationship of biotopes to organic matter living/total ratio of benthonic foraminifera and rate of sedimentation.* It is well known that organic matter is often concentrated in areas of rapid sedimentation (Trask and Patnode, 1943 in Bordovskiy, 1965). The rate of sedimentation can be inferred on the basis of living/total (L/T) ratio of foraminifera (Phleger, 1955). Thus the relationship of each biotope with organic matter and L/T ratio of benthonic foraminifera is also discussed here.

Biotope A is characterised by low organic matter (3.04 - 4.18%) suggesting a low rate of sedimentation. Stations in biotope B have high values of organic matter (3.33 - 6.18%) indicating a high rate of sedimentation. However, average L/T ratio of foraminifera is high (> 5%) in biotope A and low (< 5%) in biotope B giving different conditions. Information about the rates of sedimentation in this area is also available indirectly from the sub-bottom profiles of the near coastal areas surveyed during Cruises 29, 48 and 49 of *RV Gaveshani*. These profiles indicate the thickness of top clay layer is 4 to 6 m in area A whereas it is 5 to 11 m in area B. The clays apparently overlie the calcareous sand which has been dated to be 10,000 years before present. On this basis it is inferred that the rate of sedimentation is high in area B and low in area A. Results obtained from sub-bottom profiles and organic matter confirm each other, while results based on L/T ratio of foraminifera differ, which may be due to the anomalous stationwise distribution of the L/T ratio as reported earlier (Setty and Nigam, 1978).

From the analysis noted above it can be concluded that the influx of fresh water (high in biotope A and low in B) and rate of sedimentation (low in biotope A and high in B) might be one of the large factors contributing to clustering.

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## APPENDIX 1

List of living benthonic foraminiferids referred to in cluster analysis (references marked by an asterisk are original to the species).

- Ammobaculites agglutinans* (d'Orbigny) \**Spirolina agglutinans* d'Orbigny, 1846, foram. foss. du Bassin Tertiaire de Vienne, Paris, p. 137, pl. 7, figs. 10-12.
- Ammonia annectens* (Parker and Jones) \**Rotalia beccarii* (Linne) var. *annectens* Parker and Jones, 1865, Philos. Trans., v. 155, p. 387, 422, pl. 19, figs. 11a-c.
- Ammonia beccarii* (Linne) \**Nautilus beccarii* Linne, 1758, Syst. Nat., Ed. 10, v. 1, p. 710, pl. 1, figs. 1a-c.
- Ammonia dentata* (Parker and Jones) \**Rotalia beccarii* (Linne) var. *dentata* Parker and Jones, 1865, Philos. Trans., v. 155, p. 387, 422, pl. 19, figs. 13a-c.
- Ammonia papillosus* (Brady) \**Rotalia papillosa* Brady, 1884, Challenger Rept. Zool., v. 9, p. 708, pl. 106, fig. 9.
- Bolivina attica* (Parker, 1958) \*Rept. Swedish Deep-Sea Expt. v. 8, Sed. Core., no. 4, p. 356, pl. 2, figs. 12-14.
- Bolivina punctata* d'Orbigny - Brady, 1884, Challenger Rept, Zool., v. 9, p. 417, pl. 52, figs. 18-19.
- Bolivina striatula* Cushman, 1922, \*Carnegie Inst. Washington, v. 17, p. 27, pl. 3, fig. 10.
- Bolivina subaenariensis* Cushman, 1922, \*U.S. Nat. Mus. Bull., no. 104, pl. 3, p. 46, pl. 7, fig. 6.
- Bulimina exilis* Brady, \**Bulimina elegans* d'Orbigny var. *exilis* Brady, 1884, Challenger Rep., Zool, v. 9, p. 399, pl. 50, figs. 5-6.
- Cancris auricula* (Fichtel and Moll) \**Nautilus auricula* Fichtel and Moll, 1798, Test, Micr., p. 108, pl. 20, fig. a-f.
- Cancris sagra* (d'Orbigny) Parker 1954, Bull. Mus. Comp. Zool., v. III, no. 10, p. 532, pl. 10, figs. 15, 21.
- Elphidium falunicum* (Allix) Cushman, 1939, U.S. Geol. Soc. Prof. Paper 191, p. 46, pl. 12, figs. 5-6.
- Florilus grateloupi* (d'Orbigny) \**Nonionina grateloupi* d'Orbigny, 1826, Ann. Sci. Nat. (Paris), p. 294, no. 19.
- Florilus Scaphum* (Fichtel and Moll) \**Nautilus scapha* Fichtel and Moll, 1798, Test. Mir., p. 108, pl. 20, figs. a-c.
- Nonion boucanum* (d'Orbigny) \**Nonionina boueana* d'Orbigny, 1846, Foram. Foss. du Bassin Tertiaire de Vienne, Paris, p. 108, pl. 5, figs. 11-12.
- Nonion elongatum* (d'Orbigny) \**Nonionina elongata* d'Orbigny 1826; Ann. Sci. Nat., Paris, Ser. 1, v. 7, p. 1294, no. 20.
- Nonion* sp. A
- Nonion* sp. B
- Nonionella auriculla* Heron - Allen and Earland, 1930, \*Royal Micropal. Soc., p. 192, pl. 5, figs. 68-70.

- Nonionella auris* (d'Orbigny) - \**Valvulina auris* d'Orbigny 1839, Voyage dans l'Amerique Meridionale, V, p. 5, *Foraminiferas*, Paris, p. 47, pl. 2, figs. 15-17.
- Nonionella basispinata* (Cushman and Moyer) - \**Nonion pizarrense* (Berry) var. *basis pinata* Cushman and Moyer, 1930, Cush. found. foram. Res. Contr., Vol. 6, No. 3, p. 54, pl. 7, fig. 18.
- Nonionella turgida* (Williamson) - \**Rotalia turgida* Williamson, 1858, Roy. Soc., pp. 50-51, pl. 4, figs. 95-97.
- Trochammina inflata* (Montagu) - \**Nautilus inflata* Montagu, 1808, Test. Britannica, p. 81, fig. 3.
- Virgulinea pertusa* (Reuss) - Loeblich and Tappan, 1964, Treatise on Invertebrate Paleontology, pt. c, protista 2, p. 734, pl. 600 (11-13).

## References

- BARNETT, R. S., (1974) An application of numerical taxonomy to the classification of the nummulitidae (foraminifera). *Jour. Paleont.*, v. 48, no. 6, pp. 1247-1263.
- BHATIA, S. B. and KUMAR, S., (1976) Recent benthonic foraminifera from the inner shelf area around Anjdiv Island, off Binge, West Coast of India. *1st Int. Symp. on benthonic foraminifera of continental margin. Part A, Ecology and Biol. Maritime sediment spec.*, Pub. 1, pp. 239-249.
- BORDOVSKIY, O. K., (1965) Source of organic matter in marine basins. *Marine Geology*, v. 3, no. 1, pp. 5-31.
- ERSKIAN, M. G. and LIPPS, J. H., (1977) Distribution of foraminifera in the Russian River estuary, northern California. *Micropaleontology*, v. 23, no. 4, pp. 453-469.
- KAESLER, R. L., (1966) Quantitative re-evaluation of ecology and distribution of recent foraminifera and ostracoda of Todos Santos Bay-Baja California, Mexico. *Univ. Kansas Paleont. Contr.*, paper 10, 50 p.
- MELLO, J. F. and BUZAS, M. A., (1968) An application of cluster analysis as a method of determining biofacies. *Jour. Paleont.*, v. 42, no. 3, pp. 747-758.
- MURRAY, J. W., (1971) *An Atlas of British Recent foraminifera*. Heinemann Educational Books Ltd., London, 244 p., 96 pls.
- (1973) *Distribution and ecology of living benthonic foraminifera*. Heinemann Educational Books Ltd., London, 274 p.
- NIGAM, R., SETTY, M. G. A. P. and AMBRE, N. V., (1979) A checklist of Benthic foraminifera from the inner shelf of Dabhol-Vengurla region, Arabian Sea. *Jour. Geol. Soc. India*, v. 20, no. 5, pp. 244-247.
- PHLEGER, F. B., (1955) Ecology of foraminifera in southeastern Mississippi delta area. *Bull. Amer. Ass. Petrol. Geol.*, v. 39, pp. 712-752.
- SCHAFER, C. T. and SCOTT, D. B., (1976) Multidisciplinary environmental analysis of a coastal area. *Report of Activities, Part C, Geol. Surv. Canada*, paper 76-1C, pp. 1-3.
- SETTY, M. G. A. P. and NIGAM, R., (1978) Micro-environments and anomalous benthic foraminiferal distribution with the neritic region of Dabhol-Vengurla sector of Arabian Sea. (Abstract) *VII Indian Coll. Micropal. and Strat.* (Madras), p. 1.
- SETTY, M. G. A. P., NIGAM, R. and AMBRE, N. V., (1979) Graphic pattern of foraminiferal dominance in the nearshore area of Central West Coast of India. *Mahasagar Bull. Nat. Inst. Ocean.*, v. 12, no. 3, pp. 195-199.
- SOKAL, R. R. and SNEATH, P. H. A., (1963) *Principles of Numerical Taxonomy*. W. H. Freeman & Co., San Francisco, 359 p.
- UJIE, H. and NAGASE, K., (1971) Cluster analysis of living planktonic foraminifera from the south-eastern Indian Ocean. In *Proc. II Plank. Confer. Roma, 1970*, ed. by A. Frinacci: Ediz. Tecnoscienza, Roma 1971, pp. 1251-1258.
- VALENTINE, J. W. and PEDDICHORD, R. G., (1967) Evaluation of fossil assemblages by cluster analysis. *Jour. Paleont.*, v. 41, no. 2, pp. 502-507.
- WALTON, W. R., (1952) Technique for recognition of living foraminifera. *Contr. Cushman Found. Foram. Res.*, v. 3, pp. 56-60.

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