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Distribution of Benthic Foraminifera and their Palaeoproductivity Changes from Anthakara Nazhi Beach Sediment, West Coast of India

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ABSTRACT

The present study provides details of benthic foraminifera analyzed from hundred beach sediment sub-samples collected from the Anthakara Nazhi beach, Kerala coast, the west coast of India. A total of 27 species of benthic foraminifera were recorded from this region. This study proved that the benthic foraminifera are good proxies to understand the paleoproductivity changes from this region. Oceanographically, important benthic foraminiferal species such as *Ammonia beccarii* along with *Anomalina globulosa, Ammonia gaimardii, Cancris oblongus, Discopulvinulina bertheloti, Gyroidinoides nitidula*, *Gyroidinoides cibaoensis*, *Quinqueloculina seminulum*, *Quinqueloculina venusta* and *Textularia* sp*.* were identified and counted. Benthic foraminifera analyses suggest a high productivity species are *Ammonia beccarii* and *Ammonia gaimardii* from 100 to 80cm and 20 to 5 cm depth an increasing trend an indicative of a shallow-marine environment. A strict interpretation based on the known modern distribution of *Ammonia beccarii* would confine the species to upper shore-face environments. The moderate values of *Cancrisoblongus* from 30 to 10 cm depth indicate by tolerance to mesotrophic-eutrophic conditions. Interval of 70 to 40 cm depth of species *Gyroidinoides nitidula* indicates low organic carbon flux or pulsed food supply and high oxygen environment. From 50 to 20 cm depth, species *Gyroidinoides cibaoensis* has been described from oxygenated deep waters of the north-western Indian Ocean receiving intermediate flux of organic matter.

Keywords: Benthic foraminifera, Paleoproductivity changes, Anthakara Nazhi beach sediment, West Coast of India

INTRODUCTION

Benthic foraminifera are wide range of marine sediments; they are cosmopolitan, have a good fossil preservation and represent a useful tool for palaeoceanography and paleoclimatology studies. Their shells represent a most important and globally significant sink for calcium carbonate. Also, their calcareous or agglutinated tests lend them good fossilization potential. Benthic foraminiferal faunal record provides an important information about deep-sea paleoceanography and paleoclimatology based on their modern ecological preferences (Gupta and Srinivasan, 1992a; Sen Gupta and Machain-Castillo, 1993; Wells *et al.,* 1994; Thomas *et al.,* 1995; Gupta and Thomas, 1999, 2003).

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Benthic foraminifera live at sediment-water interface owing to the availability of bacteria, labile organic matter or dissolved organic matter as the most abundant resources (van der Zwaan *et al.,* 1999) though they can also live at depths within the sediment (Boltovsky, 1966; Brooks, 1967). The population dynamics of deep-sea benthic foraminifera are mostly controlled by two inversely related parameters namely, the flux of organic matter to the sea-floor and concentration of oxygen in the sediment pore water (Gooday and Rathburn, 1999). Species abundance and species occurrence or compositions are immediately affected by organic flux (Herguera, 1992; Berger and Herguera, 1992; Heinz and Hemleben, 2003) and seasonality while resource and competition have long term effects on microhabitat position. The bottom current activity also influences the nature of foraminiferal assemblages (Kuhnt and Collins, 1995). Parameters such as temperature and salinity, which are nearly constant on the sea-floor, are less likely to influence the benthic foraminiferal population (Gage and Tyler, 1991; Tyler, 1995). But occasionally, temperature contrasts between adjacent basins seem to provide the best explanation for faunal differences (Rathburn *et al.,* 1996). Besides, lateral advection of water masses, environmental stability, bottom water carbonate corrosiveness, time, predation, grain-size composition and nature of the substrate as well as evolution influence benthic foraminiferal distribution and diversity (Gupta, 1990; Hayward *et al.,* 2002). The seasonal productivity changes in the oceanographic parameters are reflected in benthic foraminiferal productivity and assemblages. Changes in benthic foraminifera are strongly controlled by biological parameters like temperature, salinity, dissolved oxygen content of the bottom water masses, surface productivity and availability of nutrients, and carbonate saturation (Streeter, 1973; Schnitker, 1974; Corliss, 1979; Corliss and Honjo, 1981;). Numerous recent studies indicate that the benthic foraminiferal faunal composition is strongly correlated to the oxygen content of the ambient water, productivity of the overlying surface waters and the delivery of organic matter to the seafloor (Loubere and Fariduddin, 1999; van der Zwaan *et al.,* 1999; den Dulk *et al.,* 2000).

This study focused on distribution of benthic foraminiferal faunal record as good proxies to understand paleoproductivity changes from Anthakara Nazhi beach sediment, located in Kerala, West coast of India.

LOCATION AND OCEANOGRAPHIC SETTING

The study area is an important part of the South Indian Precambrian terrain surrounded by the Western Ghats on the east and Arabian Sea on the west. In this study, one hundred beach core-sediment samples were collected from Anthakara Nazhi beach sediment (Latitude 9°44.27'N, Longitude 76°17.04'E; core depth 1m) located in the Kerala coast, west coast of India. The study area is located approximately 40kms from Fort Cochin in the north to Anthakara Nazhi beach in the south for a length of 28 km. The study area's eastern side is the largest backwater system in the west coast of India and is the largest water body in Kerala (Fig. 1).

MATERIALS AND METHODS

One hundred beach core-sediment samples were carried out between month of September and October, 2018 from west coast of India. Core depth 1m, sub-sampled in the top 1m length at every 1cm interval. The core sediment samples represent a single lithologic unit, dominantly composed of fine sand. The sediment color varies from dark grey to brown, blackish to light grey and light brownish grey. Every sample was processed by using standard procedures as described in Gupta and Thomas (1999, 2003). Each sample was soaked in water with half a spoon of baking soda for 8-12 hours. Soaked samples were washed with a jet of water over 63µm-size sieve and oven-dried at ~50^{o} C temperature. The dry samples were transferred to labeled borosil glass vials. For Benthic foraminiferal faunal study, dry samples were sieved over 125 µm-size sieve and split into suitable aliquots to obtain ~300 specimens of benthic foraminifera identified and counted.

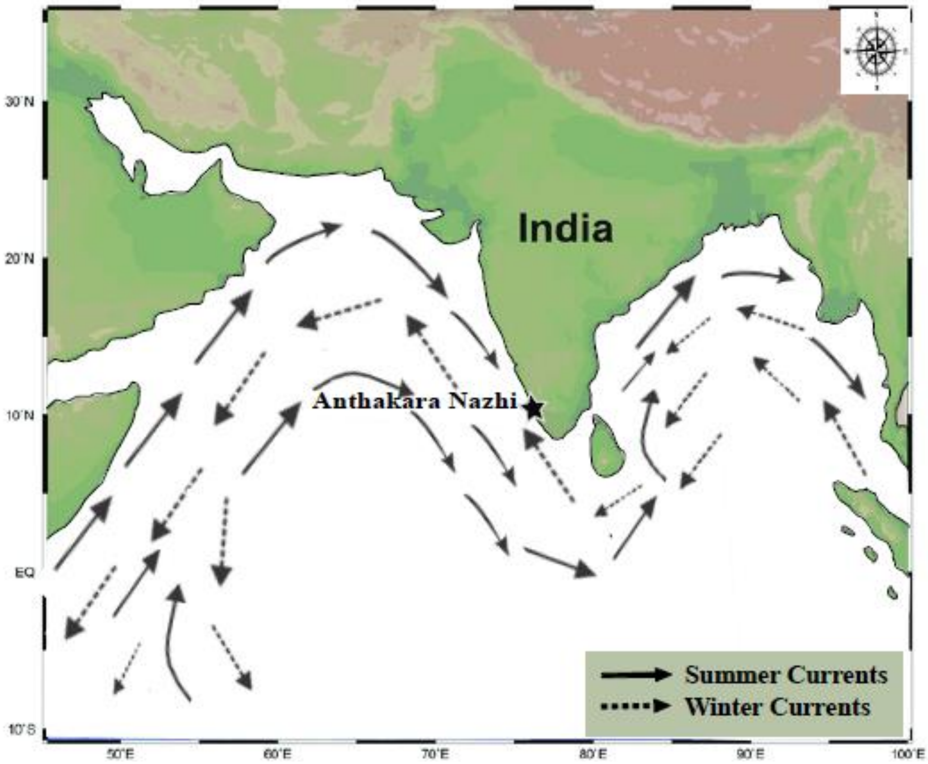

Fig. 1: Location map showing core-sediment from Anthakara Nazhi beach, located in West coast of India. Thick arrow lines indicate suface currents during summer monoon, dotted arrow lines indicate surface currents during winter monsoon.

RESULT

The distribution of benthic foraminiferal faunal record from Anthakara Nazhi beach sediment samples provides useful information about the reconstruction of paleoclimatology, paleoceanography and palaeoproductivity changes in west coast of India. In this study, 27 species of benthic foraminifera were recorded. The dominant species are *Ammonia beccarii, Ammonia gaimardii, Anomalina globulosa*, *Cancris oblongus, Discopulvinulina bertheloti, Gyroidinoides nitidula*, *Gyroidinoide scibaoensis*, *Quinqueloculina seminulum*, *Quinqueloculina venusta* and *Textularia* sp*.* were recorded from Anthakara Nazhi beach sediment (Table-1). The high abundances of *Ammonia beccarii* and *Ammonia gaimardii* from 100 to 80cm and 20 to 5cm depth increasing trend an indicative of a shallow-marine environment with sandy bottom. Species *Cancris oblongus* from interval of 30 to 10 cm depth indicates tolerance to mesotrophic-eutrophic conditions (Fig.2). From 70 to 40 cm depth, the species *Gyroidinoides nitidula* indicate the low organic carbon flux or pulsed food supply and high oxygen environment. This species shows an environment with intermediate organic flux and intermediate to high seasonality during the Plio-Pleistocene. The interval of 50 to 20 cm depth, species *Gyroidinoides cibaoensis* has been described from oxygenated deep waters of the north-western Indian Ocean receiving intermediate flux of organic matter (Fig.3). The distribution pattern of benthic foraminifera in this core-sediment indicates that some taxa are dominant in a particular zone whereas others are present throughout the sequence (Figs. 2-6).

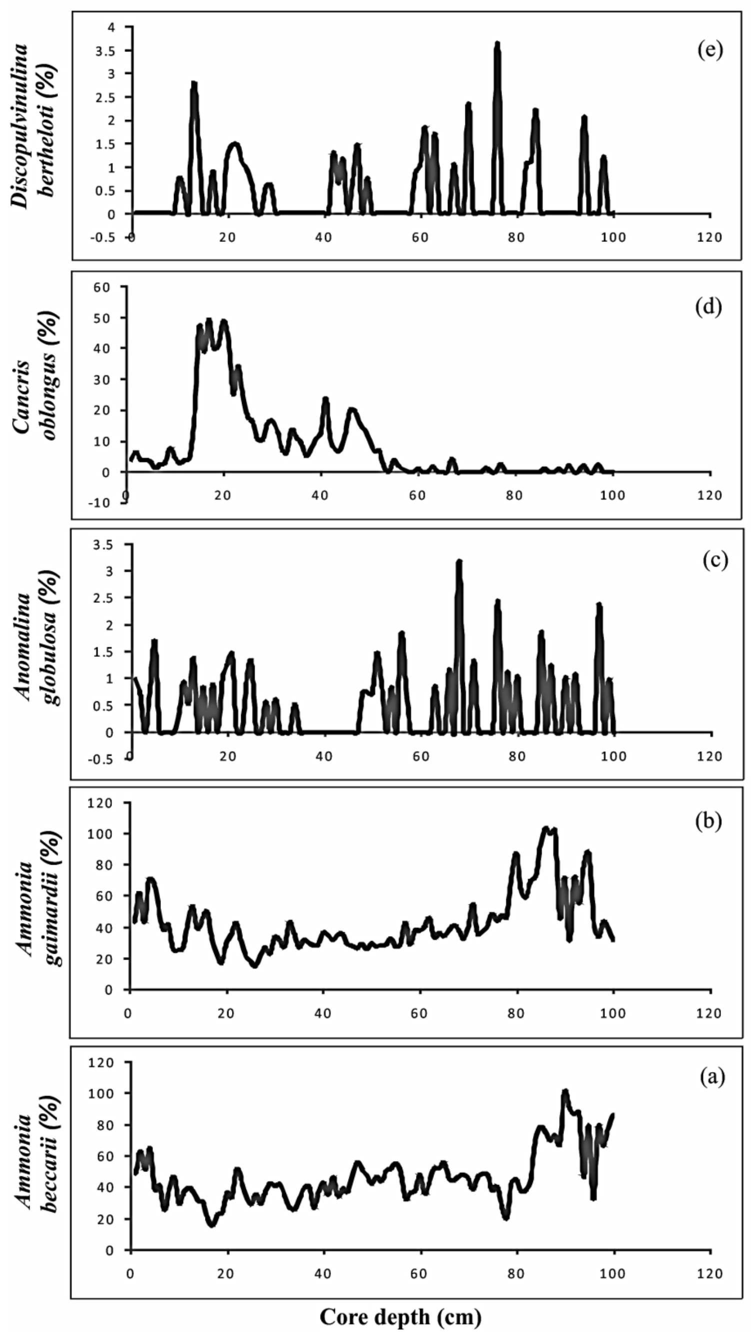

Fig. 2: Percent distribution of dominant benthic foraminiferal species *Ammonia beccarii* (panel a), *Ammonia gaimardii* (panel b), *Anomalina globulosa* (panel c), *Cancris oblongus* (panel d) and *Discopulvinulina bertheloti* (panel e) at Anthakara Nazhi beach sediment in west coast of India.

Species diversity of benthic foraminifera at Anthakara Nazhi beach sediment, scatter plot of *Ammonia beccarii* and *Ammonia gaimardii* against with core depth (cm) show positive correlations with R^2=0.329 and 0.186, respectively. Correlation between *Cancris oblongus* and *Textularia* sp. against with core depth (cm) have recorded positive correlation with R^2= 0.290 and 0.280, respectively. Species of *Gyroidinoides cibaoensis* and *Gyroidinoides nitidula* plotted with core depth (cm) show a weak positive correlation with R^2= 0.224 and 0.003, respectively (Fig.5).

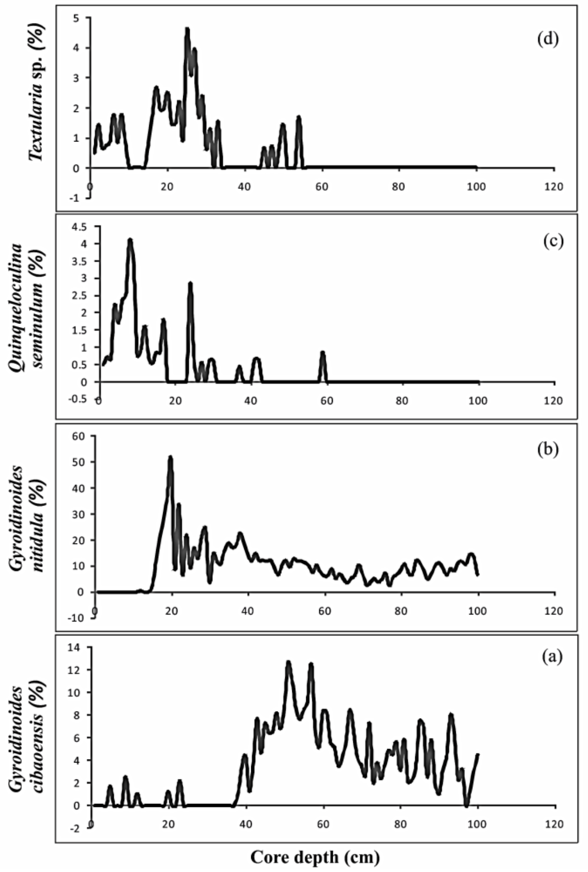

Fig.3: Percent distribution of dominant benthic foraminiferal species *Gyroidinoides cibaoensis* (panel a), *Gyroidinoides nitidula* (panel b), *Quinqueloculina seminulum* (panel c) and *Textularia* sp. (panel d) at Anthakara Nazhi beach sediment in west coast of India.

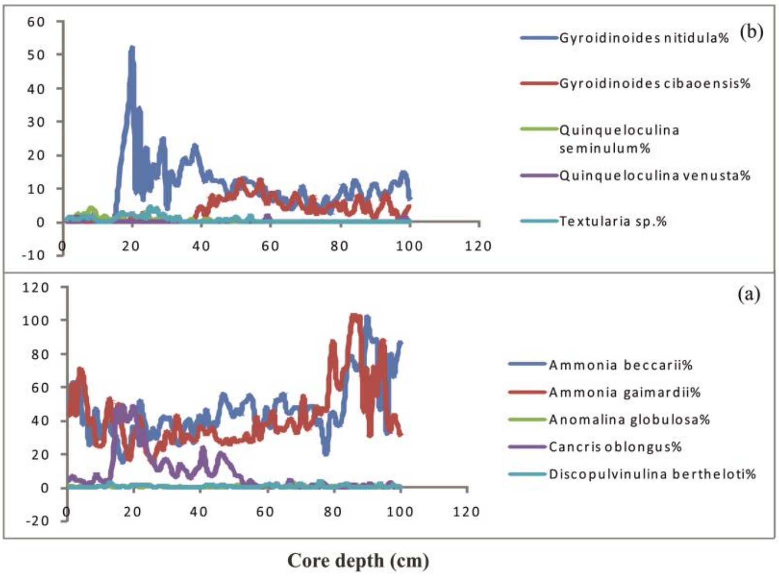

Fig.4: Distribution of dominant benthic foraminiferal species at Anthakara Nazhi beach sediment in west coast of India.

DISCUSSIONS

Benthic foraminiferal faunal record is strongly correlated to the oxygen content of the ambient water, productivity of the overlying surface waters and the delivery of organic matter to the seafloor (Loubere and Fariduddin, 1999; van der Zwaan *et al.,* 1999; den Dulk *et al.,* 2000). Benthic foraminiferal fauna in the Arabian Sea are distinct than those from the southern Indian Ocean because the former is climatically and oceanographically a distinct region, marked by high organic food production and flux to the sea floor causing a prominent Oxygen Minimum Zone (OMZ). In this study, benthic foraminifera have been used to understand water-mass changes in the southeastern Arabian Sea driven by monsoon wind impact in the surface ocean.

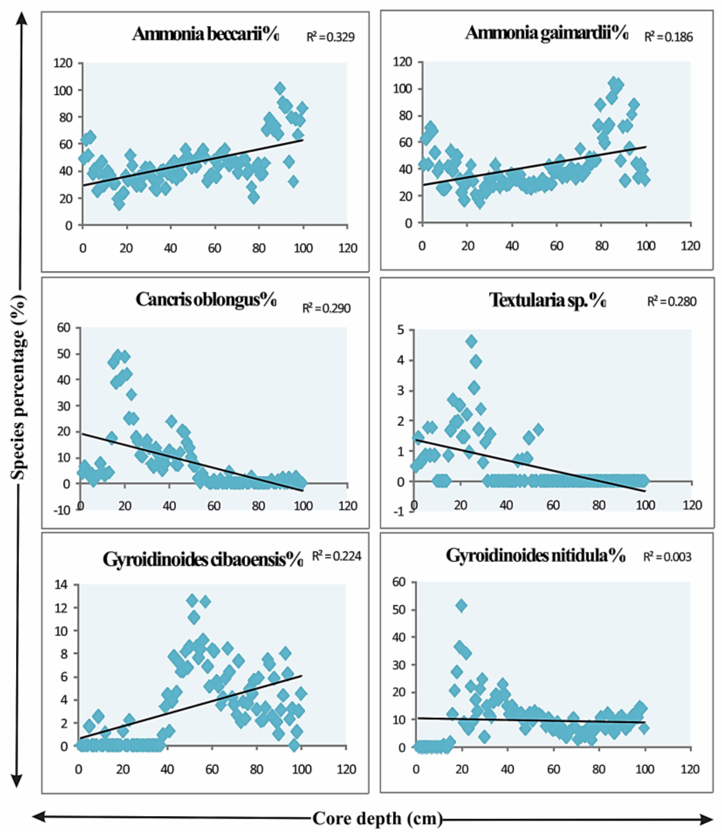

Fig. 5: Scatter plot of percent distribution of benthic foraminiferal species against with core depth (cm) at Anthakara Nazhi beach sediment in west coast of India.

Benthic foraminifera and their ecological preferences:

The presence of benthic foraminiferal species *Ammonia beccarii* indicates a euryhaline and shallow sea environment (Wang *et al.,* 2009). Species of *Ammonia beccarii* are indicative of a shallow-marine environment with sandy bottom (Sgarrella and Moncharmont, 1993). Distribution of *Ammonia beccarii* would confine the species to upper shore face environments (Hayward *et al.,* 2004). Ecological preferences of *Anomalina globulosa* is an epifaunal benthic foraminifer which has been found associated with low to intermediate organic carbon flux and high oxygen content of bottom water (Corliss and Chen, 1988; Gupta and Thomas, 2003). *Anomalina globulosa* occurs in the eastern Indian Ocean, an indicator of moderate organic carbon flux and well-oxygenated bottom water (Gupta and Thomas, 2003). Ecological preference of *Cancris oblongus* indicates tolerance to mesotrophic-eutrophic conditions.

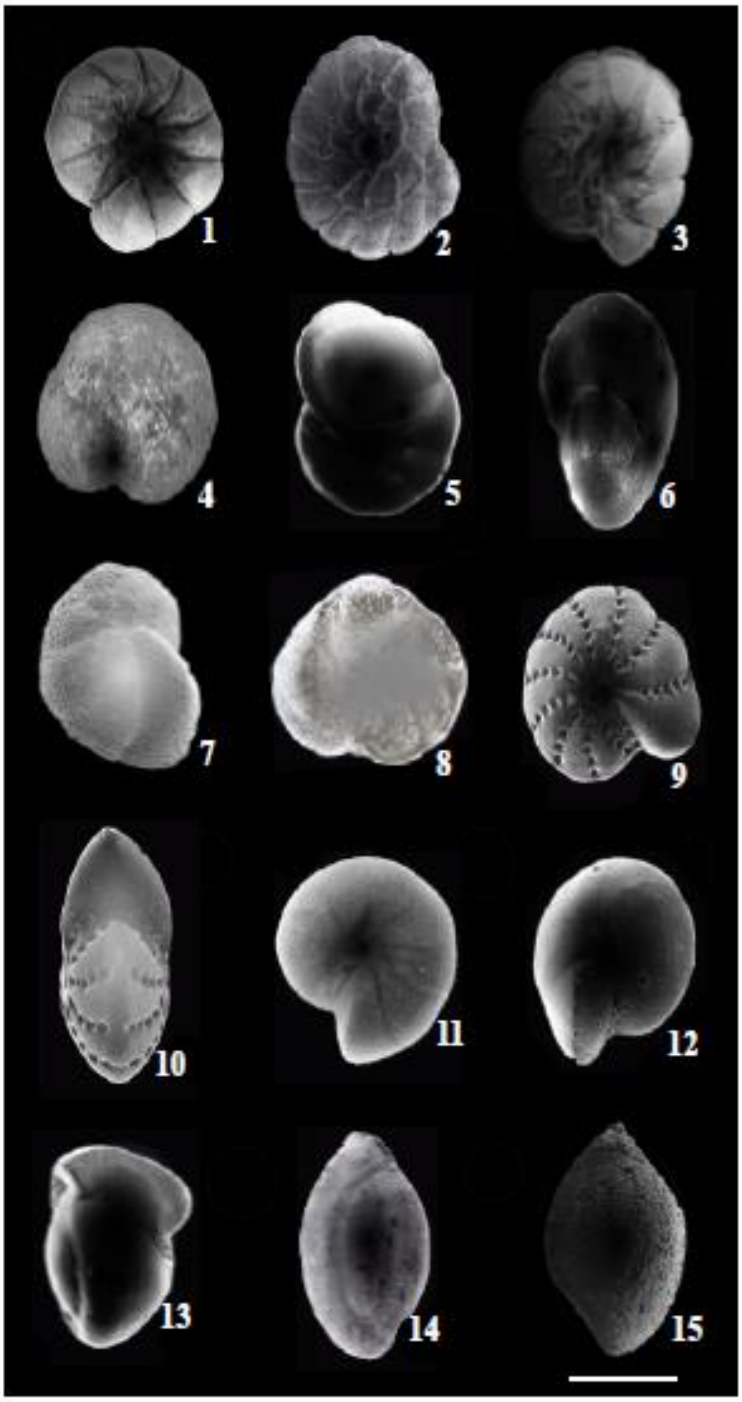

Fig.6: Distribution of dominant benthic foraminiferal species *Ammonia beccarii* Linnaeus, Umbilical and Spiral view; 1-2. *Ammonia gaimardii* d'Orbigny, Umbilical view; 3. *Anomalina globulosa* Chapman and Parr, Spiral view; 4. *Astrononion umbilicatulum* Uchio, Side and Apertural view; 5-6. *Cibicidesbradyi* Trauth, Side view; 7. *Discopulvinulina bertheloti* d'Orbigny, Spiral view; 8. *Elphidiumadvena* Cushman, Side and Umbilical view; 9-10. *Gyroidinoides soldanii* d'Orbigny, Apertural Side view; 11. *Gyroidinoides nitidula* Schwager, Side and Apertural view; 12-13. *Quinqueloculina seminulum* Linnaeus,Sideview;14.*Sigmoilopsis schlumbergeri* Silvestri, Side view; 15, from Anthakara Nazhi beach sediment in west coast of India.

Table-1: List of species, recorded from the study.

S.No	Species Name	Maximum and Average %
1	*Ammonia beccarii*	101.0, 46.00
2	*Ammonia gaimardii*	103.5, 42.11
3	*Anomalina globulosa*	3.19, 0.45
4	*Astrononion umbilicatulum*	0.66, 0.02
5	*Cancris oblongus*	49.11, 8.22
5	*Calcarina venusta*	0.53, 0.01
7	*Cibicides bradyi*	3.66, 0.43
8	*Discopulvinulina bertheloti*	3.66, 0.41
9	*Discopulvinulina subbertheloti*	1.18, 0.05
10	*Elphidium advena*	1.32, 0.05
11	*Elphidium crisphum*	1.18, 0.03
12	*Elphidiella hannai*	0.71, 0.03
13	*Epistominella exigua*	0.97, 0.02
14	*Gyroidinoides cibaoensis*	12.59, 3.39
15	*Gyroidinoides nesoldanii*	8.59, 1.97
16	*Gyroidinoides nitidula*	51.25, 9.93
17	*Quinqueloculina semimulum*	4.12, 0.34
18	*Quinqueloculina venusta.*	1.71, 0.10
19	*Quinqueloculina* sp.	1.97, 0.31
20	*Robulus gibbus*	0.49, 0.01
21	*Robulus* sp.	0.98, 0.05
22	*Rosalina* sp.	0.85, 0.03
23	*Sigmoilopsis schlumbergeri*	0.89, 0.03
24	*Spiroloculina* sp.	0.85, 0.02
25	*Textularia gaudryina*	0.61, 0.01
26	*Textularia goesii*	1.50, 0.10
27	*Textularia* sp.	4.61, 0.51

Cancris oblongus has been considered as a typical of well-oxygenated bottom waters and pulsed food supply, low to intermediate organic flux and high seasonality (Tyson and Pearson, 1991). Species *Discopulvinulina bertheloti* is characteristically an intermediate organic flux to the seafloor (Gooday, 2003). This species has usually been reported as a surface dweller associated with well-aerated bottom waters and low organic flux in the Atlantic (Lutze and Colbourn,1984; Corliss,1985; Fariduddin and Loubere,1997; Schmiedl *et al.,*1997). Species *Gyroidinoides nitidula* indicates low organic carbon flux or pulsed food supply and high oxygen environment (Mackensen *et al.,* 1995; De Rijk *et al.,* 1999). This species shows an environment with intermediate organic flux and intermediate to high seasonality during the Plio-Pleistocene (Gupta and Thomas, 2003).

Environmental preference of *Gyroidinoides cibaoensis* has been described from low oxygenated deep waters of the north-western Indian Ocean with moderate flux of organic matter (Gupta, 1999). The genus *Quinqueloculina* has been observed in cold and well-oxygenated deep waters with strongly pulsed food supply (Gupta and Thomas, 2003). Species *Quinqueloculina seminulum* prefers near-shore shallow marine environment and is also found in outer and inner shelf in high-energy environments (Laprida *et al.,* 2007). The genus *Textularia* prefers to live in coarse sediments and high energy environments (Altenbach *et al.,* 2003; Murray; 1991). Ecological preference of *Textularia* spp. has been suggested in coarse sediments and high speed of bottom currents (Altenbach *et al.,* 2003; Murray; 1991).

CONCLUSION

A total of 27 species belonging to 16 genera were identified from the study region. This study suggests that fine sediment in Anthakara Nazhi beach are much favourable for blooming of foraminiferal species. *Ammonia beccarii* and *Ammonia gaimardii* is the most dominated benthic foraminiferal species in this region followed by *Anomalina globulosa*, *Cancris oblongus, Discopulvinulina bertheloti, Gyroidinoides nitidula*, *Gyroidinoides cibaoensis*, *Quinqueloculina seminulum*, *Quinqueloculina venusta* and *Textularia* sp. Benthic foraminifera show pronounced changes at this core. For instance, high productivity species *Ammonia beccarii* and *Ammonia gaimardii* shows an abrupt increase and *Cancris oblongus, Gyroidinoides cibaoensis*, and *Gyroidinoides nitidula* show abrupt decease at 100 to 80cm depth (Figs. 2 and 3). This suggests rapid response of benthic foraminifera to the organic flux to the shallow seafloor. The high organic productivity, the low salinity condition and fine sediment texture are the most important factors controlling foraminiferal distribution in Anthakara Nazhi beach region.

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