Distribution and relative abundance of dominant benthic foraminifera and their palaeoecological significance from beach cores sediment in Kerala coast, India

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Abstract
The study on 365 sediment subsamples have been analyzed for benthic foraminifera from beach cores sediment in Kerala coast, India. The recent benthic foraminiferal faunal record that reveals the paleoecological preferences of the different benthic foraminiferal species are reported in this study. A total of 38 species belonging to 22 genera were identified from the study. For benthic foraminiferal faunal study, dry samples were sieved over 125 μm-size sieve and split into suitable aliquots to obtain ~250 specimens of benthic foraminiferal species identified and counted.

The recent benthic foraminiferal faunal record assemblages were dominated by species are Ammonia beccarii followed by Ammonia gaimardii, Cancris oblongus, Discopulvinulina bertheloti, Gyroidinoides nitidula, Gyroidinoides cibaoensis and Quinqueloculina seminulum etc. The most dominant genus like Ammonia was recorded in all the samples from the study. Benthic foraminiferal species are utilized for biostratigraphy for several years and have also been confirmed very constructive in paleoceanographic and paleoclimatological modernization. This study, benthic foraminifera the major contributor to the marine biotic community is largely employed as an important tool for paleoclimatic reconstruction for high fossilization potential and a wide range of geographical distribution.

Keywords: Benthic foraminifera, Indian monsoon, Palaeoproductivity, Puthenthoodu, Chellanam, Azheekal and Anthakaranazhi beach, West coast of India.

Introduction

The Arabian Sea is characterized by severe phytoplankton production during the summer monsoon (southwest) construction. It is one of the highly productive regions of the world oceans. The wide range of paleoceanographic and paleoclimatology responses can be recorded from sediments of the Arabian Sea.[4,33,34,42] Foraminifers are predominantly marine organisms living on the sea floor or floating in the water column and they have been for the past several centuries, interesting objects to study geologically. These protozoans has adapted to different niches on the seafloor in estuaries, salt marshes and in other marine marginal water bodies. Foraminifers are smaller size and have vast abundance in sea floor sediments of the present day and geological past. Foraminifera are used for ecological and palaeoecological studies of fossil groups to determine the age of the depositional environment.

Benthic foraminifera are constructive in palaeoenvironmental studies as they are easily acquired, live primarily in the uppermost centimeters of sediments[6] and are extremely abundant in marine and estuarine habitats. Benthic foraminifera are an unicellular, preferentially marine microorganism with a hard exoskeleton made up either of calcium carbonate or sediment particles[43] dominate by the marine benthic community[28]. Benthic foraminifera are very sensitive to ambient conditions[19] and thus are often used to reconstruct past climate[44]. Benthic foraminifera taxon prefers to survive in different microhabitats in the upper sediment layers.[15,23,24,37]

Therefore, some of them are able to precisely record bottom water characteristics, when others reveal pore water properties. Numerous studies indicate that benthic foraminiferal faunal composition is strongly linked to the oxygen content of the ambient water, productivity of the overlying surface waters and the delivery of organic matter to the seafloor.[13,29]

Distribution of benthic foraminiferal species abundance and occurrence are directly affected by organic flux[5,21,22,38] and seasonality whereas resource and competition have long term effects on microhabitat position. The seasonal changes in the oceanographic parameters are reflected in benthic foraminiferal productivity and assemblages. Benthic foraminifera are strongly controlled by biological parameters like temperature, salinity, dissolved oxygen content of the bottom water masses, surface productivity, availability of nutrients and carbonate saturation.[7-9,39-41,46,48]

We have documented the distributions and relative abundance of dominant benthic foraminiferal faunal records to understand ecological and palaeoecological changes from Puthenthodu, Chellanam, Azheekal and Anthakaranazhi beach sediment in West coast of India.

Location and oceanographic settings: The study on four beach cores sediment samples were selected from

Puthenthodu beach (Latitude 9°52.8'N, Longitude 76°15.48'E, core length 75cm), Chellanam beach (Latitude 9°47.14'N, Longitude 76°16.40'E, core length 1m), Azheekal beach (Latitude 9°44.59'N, Longitude 76°17.02'E, core length 90cm) and Anthakaranazhi beach (Latitude 9°44.27'N, Longitude 76°17.04'E, core length 1m) located in Kerala coast, India.

The study area is located approximately 40 kms from fort Cochin in the north to Puthenthodu, Chellanam, Azheekal and Anthakaranazhi beach in the south for a length of approximately 26 km. The study area's eastern side is the major backwater system in the west coast of India and is the biggest water body in the Kerala state. The area of 41 rivers brings huge amount of sediments, deltas are not formed owing to the high wave energy condition of the coast. The coastal and near shore sediments were studied over the past few decades by numerous researchers on various aspects such as sea level rising, sedimentation and palaeo-environment in off-shore and on-shore region (Fig. 1).

Material and Methods

In this study, 365 core sediment subsamples have been analyzed for benthic foraminifera from Puthenthodu, Chellanam, Azheekal and Anthakaranazhi beach sediment in Kerala coast, India. From Puthenthodu beach (75 subsamples), At Chellanam beach (100 subsamples), from Azheekal beach (90 subsamples) and Anthakaranazhi beach (100 subsamples) were collected for the present study. For each core sediment sub-sampled at every 1cm interval. The recovered core-sediment samples represent a single lithologic unit, dominantly composed of fine sand. The sediment colour varies from light grey, dark grey, brown, blackish and light brownish grey.

Each sample was soaked in water with half a spoon of baking soda for ~8-12 hours. All soaked samples were washed with a jet of water over 63µm-size sieve and oven-dried at ~50°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 approximately 250 specimens of benthic foraminiferal species identified and counted.

Results

The seasonal variations in the oceanographic parameters are reflected in benthic foraminiferal productivity and assemblages. Changes in benthic foraminifera are controlled by biological parameters like temperature, salinity, dissolved oxygen content of the bottom water masses, surface productivity and availability of nutrients and carbonate saturation.[7,9,48]

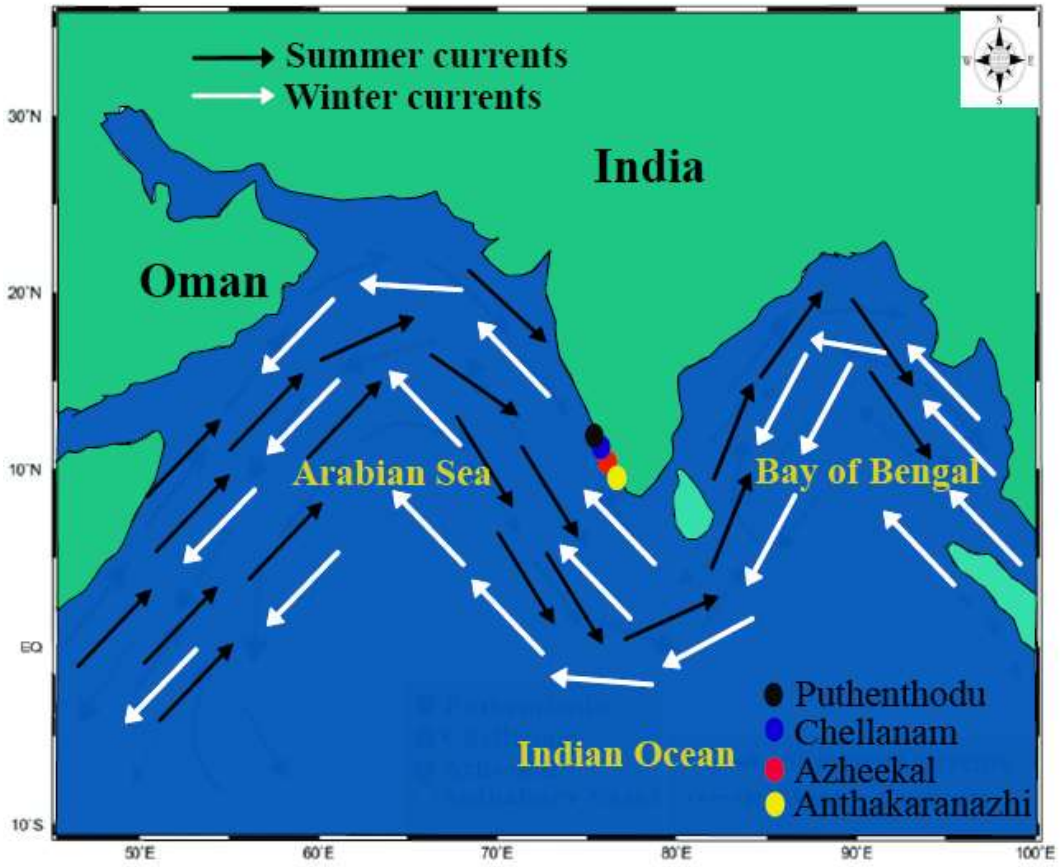

Fig. 1: Location map showing cores sediment from Puthenthodu, Chellanam, Azheekal and Anthakaranazhi beach sediment, located in Kerala coast, India. Block arrow lines indicate suface currents during summer, white arrow lines indicate surface currents during the winter (modified after[41]).

Benthic foraminiferal faunal record

Puthenthodu beach: The distribution of recent benthic foraminiferal faunal record from Puthenthodu, Chellanam, Azheekal and Anthakaranazhi beach sediment provides constructive information about the palaeoenvironmental implication from the west coast of India. A total of 18 species of benthic foraminifera were recorded from puthenthodu region. The oceanographically an important benthic foraminiferal species are *Ammonia beccarii* followed by *Ammonia gaimardii, Cancris oblongus, Discopulvinulina bertheloti, Elphidium crisphum, Globobulimina pacifica, Gyroidinoides nitidula, Gyroidinoides cibaoensis, Planularia cassis, Quinqueloculina seminulum, Robulus* sp., *Spiroloculina* sp., *Spiroloculina cummunis, Textularia* sp., *Textularia gaudryina, Textularia goesii ,Trifarina angulosa* and *Trifarina bradyi* were recorded in the study (Figs 2 to 5; Table 1).

The high productivity species are *Ammonia beccarii* and *Ammonia gaimardii* showing an abrupt increase ~75 to 60cm and 10 to 5cm depth, an increasing trend indicates by shallow-marine environment (Fig. 2; panel a and b). Species *Cancris oblongus* is from 25 to 15cm depth, an increasing trend indicates of tolerance to mesotrophic-eutrophic conditions (Fig. 3; panel a).

Table 1
List of species, recorded from Puthenthodu, Chellanam, Azheekal and Anthakaranazhi beach sediments in Kerala coast, India.

S.N.	Species Name	Maximum and Average %
1	*Ammonia beccarii*	101.0, 46.00
2	*Ammonia gaimardii*	103.5, 42.11
3	*Amphistagina lessoni,*	0.62, 0.01
4	*Anomalina globulosa*	3.19, 0.45
5	*Astrononion umbilicatulum*	0.66, 0.02
6	*Astrononion stelligerum*	0.72, 0.03
7	*Cancris oblongus*	49.11, 8.22
8	*Calcarina venusta*	0.53, 0.01
9	*Cassidulina carinata*	1.12, 0.03
10	*Cibicides bradyi*	3.66, 0.43
11	*Cibicides* sp.	1.30, 0.06
12	*Discopulvinulina bertheloti*	3.66, 0.41
13	*Discopulvinulina subbertheloti*	1.18, 0.05
14	*Elphidium advena*	1.32, 0.05
15	*Elphidium crisphum*	1.18, 0.03
16	*Elphidiella hannai*	0.71, 0.03
17	*Elphidium* sp.	0.60, 0.02
18	*Epistominella exigua*	0.97, 0.02
19	*Gyroidinoides cibaoensis*	12.59, 3.39
20	*Gyroidinoides nesoldanii*	8.59, 1.97
21	*Gyroidinoides nitidula*	51.25, 9.93
22	*Miliolinella subrotunda*	0.73, 0.03
23	*Nonion scaphum*	0.61, 0.02
24	*Planularia australis*	0.66, 0.03
25	*Planularia cassis*	0.60, 0.02
26	*Quinqueloculina semimulum*	4.12, 0.34
27	*Quinqueloculina venusta.*	1.71, 0.10
28	*Quinqueloculina* sp.	1.97, 0.31
29	*Robulus gibbus*	0.49, 0.01
30	*Robulus iota*	0.52, 0.01
31	*Robulus* sp.	0.98, 0.05
32	*Rosalina* sp.	0.85, 0.03
33	*Sigmoilopsis schlumbergeri*	0.89, 0.03
34	*Spiroloculina cummunis*	0.73, 0.02
35	*Spiroloculina* sp.	0.85, 0.02
36	*Textularia gaudryina*	0.61, 0.01
37	*Textularia goesii*	1.50, 0.10
38	*Textularia* sp.	4.61, 0.51

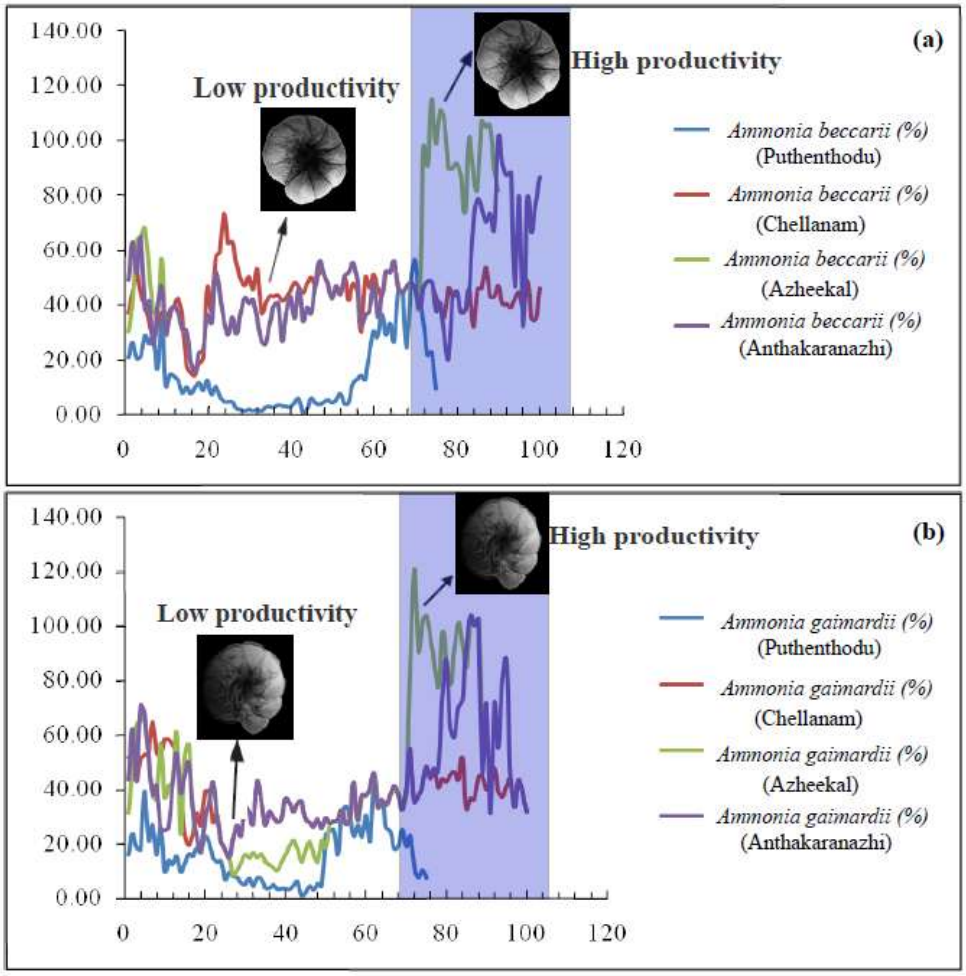

Fig. 2: Relative abundance of most dominant benthic foraminiferal species are *Ammonia beccarii* (panel; a) and *Ammonia gaimardii* (panel; b) from Puthenthodu, Chellanam, Azheekal and Anthakaranazhi beach sediment in west coast of India

Chellanam beach: A total of 32 species of benthic foraminifera were recorded from core Chellanam beach sediment. The most dominant species are *Ammonia beccarii* along with *Ammonia gaimardii*, *Anomalina globulosa*, *Quinqueloculina seminulum*, *Cancris oblongus*, *Discopulvinulina bertheloti*, *Gyroidinoides nitidula*, *Gyroidinoides cibaoensis*, *Gyroidinoides nesoldanii* and *Astrononion umbilicatulum* were identified from this region (Figs 2 to 5; Table 1).

A high productivity species of benthic foraminifera like *Ammonia beccarii* and *Ammonia gaimardii* from 100 to 70cm and 30 to 5cm indicate by high organic productivity during the summer, where surface productivity changes may also be driven by winter winds from 70 to 30 cm (Fig 2; panel a and b).

Azheekal beach: A total of 31 benthic foraminiferal species were recorded from Azheekal beach sediment. The most abundant benthic foraminifera forms were found in the beach core sediment such as *Ammonia beccarii* along with *Ammonia gaimardii*, *Cancris oblongus*, *Gyroidinoides nitidula*, *Gyroidinoides nesoldanii*, *Miliolinella subrotunda*, *Anomalina globulosa*, *Astrononion umblicatulum*, *Astrononion stelligerum*, *Calcarina venusta*, *Cibicides bradyi*, *Cibicides* sp. *Cassidulina modeloensis*, *Discopulvinulina bertheloti*, *Discopulvinulina subbertheloti*, *Elphidium advena*, *Elphidium crisphum*, *Gyroidinoides cibaoensis*, *Nonion scaphum*, *Planularia cassis*, *Planularia australis*, *Quinqueloculina seminulum*, *Quinqueloculina venusta*, *Quinqueloculina sp.*, *Quinqueloculina venusta*, *Robulus gibbus*, *Robulus* sp., *Rosalina* sp., *Spiroloculina* sp. *Textularia goesii* and *Textularia* sp. (Figs. 2 to 5; Table 1).

Benthic foraminiferal species are *Ammonia beccarii* and *Ammonia gaimardii* showing an abrupt increase and *Cancris oblongus* shows an abrupt decease at 90 to 70cm and 18 to 5cm depth (Figs. 2 and 3). This suggests rapid response of benthic foraminifera to the organic flux to the shallow seafloor. Species *Cancris oblongus* indicates of pulsed food supply, low to intermediate organic flux and high seasonality (Fig. 3).

Anthakaranazhi beach: A total of 27 benthic foraminiferal species were reported from Anthakaranazhi beach sediment in Kerala coast, India. In this core most dominant benthic foraminiferal species are *Ammonia beccarii*, *Ammonia*

gaimardii, *Anomalina globulosa*, *Cancris oblongus*, *Discopulvinulina bertheloti*, *Gyroidinoides nitidula*, *Gyroidinoides cibaoensis*, *Quinqueloculina seminulum*, *Quinqueloculina venusta* and *Textularia* sp. (Figs. 2 to 5; Table 1).

The relative abundances of *Ammonia beccarii* and *Ammonia gaimardii* from 100 to 80cm and 20 to 5cm depth, show an increasing trend indicates of the shallow-marine environment (Fig.2; panel a and b). From 70 to 40 cm depth, the species *Gyroidinoides nitidula* indicate by low organic carbon flux or pulsed food supply and high oxygen environment (Fig. 4; panel c).

The distribution pattern of Pie-chart reveals that the relative abundance of 38 benthic foraminiferal species belongs to 22 genera were reported in the study (Fig. 5; Table 1). The following benthic foraminiferal species have been widely distributed in the study region in most of the stations namely: *Ammonia beccarii*, *Ammonia gaimardii*, *Anomalina globulosa*, *Amphistagina lessoni*, *Astrononion umbilicatulum*, *Astrononion stelligerum*, *Cancris oblongus*, *Calcarina venusta*, *Cassidulina carinata*, *Cibicides bradyi*, *Cibicides* sp., *Discopulvinulina bertheloti*, *Discopulvinulina subbertheloti*, *Elphidium advena*, *Elphidium crisphum*, *Elphidium* sp., *Elphidiella hannai*, *Epistominella exigua*, *Gyroidinoides cibaoensis*, *Gyroidinoides nesoldanii*, *Gyroidinoides nitidula*, *Miliolinella subrotunda*, *Nonion scaphum*, *Planularia australis*, *Planularia cassis*, *Quinqueloculina semimulum*, *Quinqueloculina venusta*, *Quinqueloculina* sp., *Robulus gibbus* ,*Robulus iota*, *Robulus* sp., *Rosalina* sp., *Sigmoilopsis schlumbergeri*, *Spiroloculina cummunis*, *Spiroloculina* sp., *Textularia gaudryina*, *Textularia goesii* and *Textularia* sp. from Puthenthodu, Chellanam, Azheekal and Anthakaranazhi beach sediments in the west coast of India (Table 1).

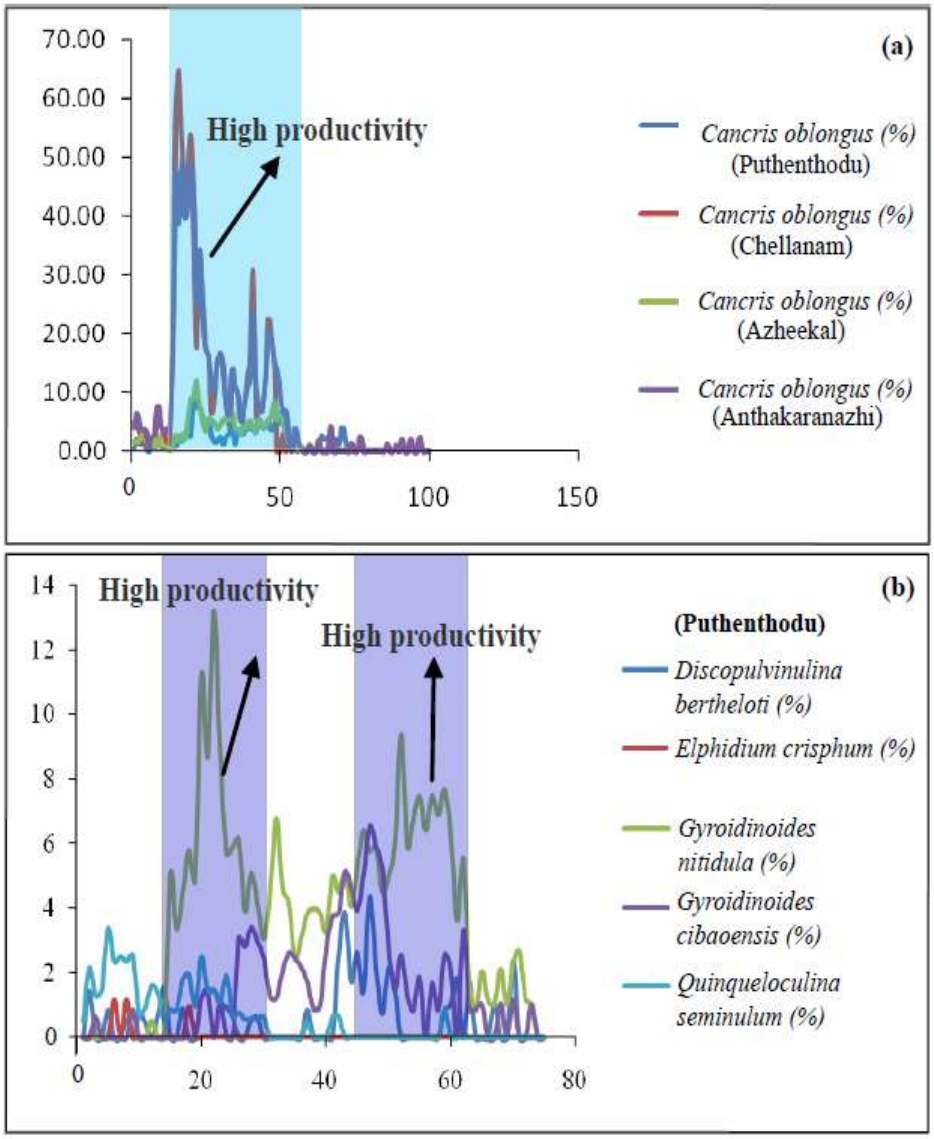

Fig. 3: Relative abundance of most dominant benthic foraminiferal species are *Cancris oblongus* (panel; a) from four beach sediments and *Discopulvinulina bertheloti, Elphiduum crisphum, Gyroidinoides nitidula, Gyroidinoides cibaoensis* and *Quinqueloculina seminulum* (panel; b) from Puthenthodu beach sediment in west coast of India

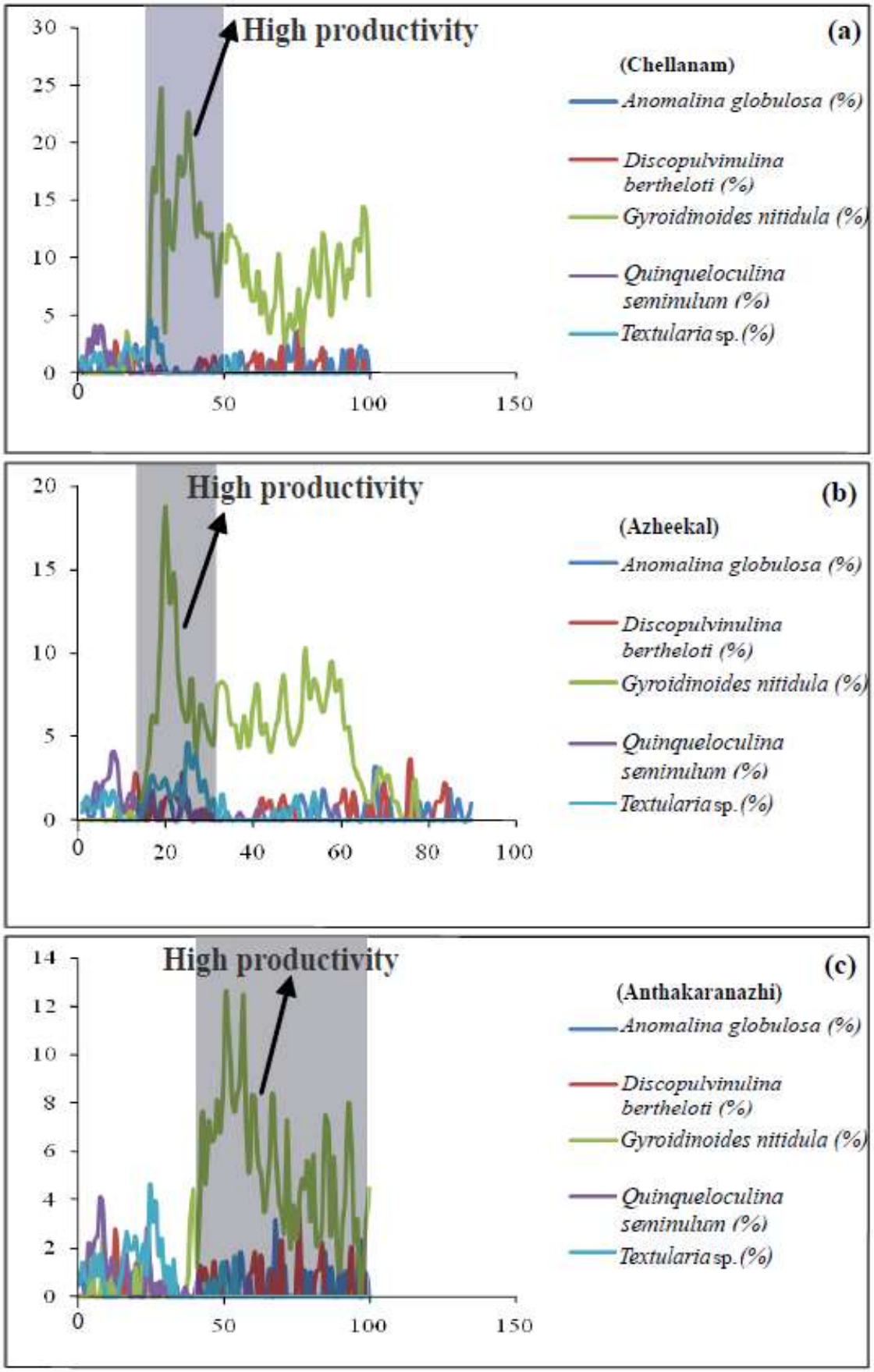

Fig. 4: Relative abundance of most dominant benthic foraminiferal species are *Anomalina globulosa, Discopulvinulina bertheloti, Gyroidinoides nitidula, Quinqueloculina seminulam* and *Textularia* sp. (panels; a, b and c) from Chellanam, Azheekal and Anthakaranazhi beach sediments in west coast of India

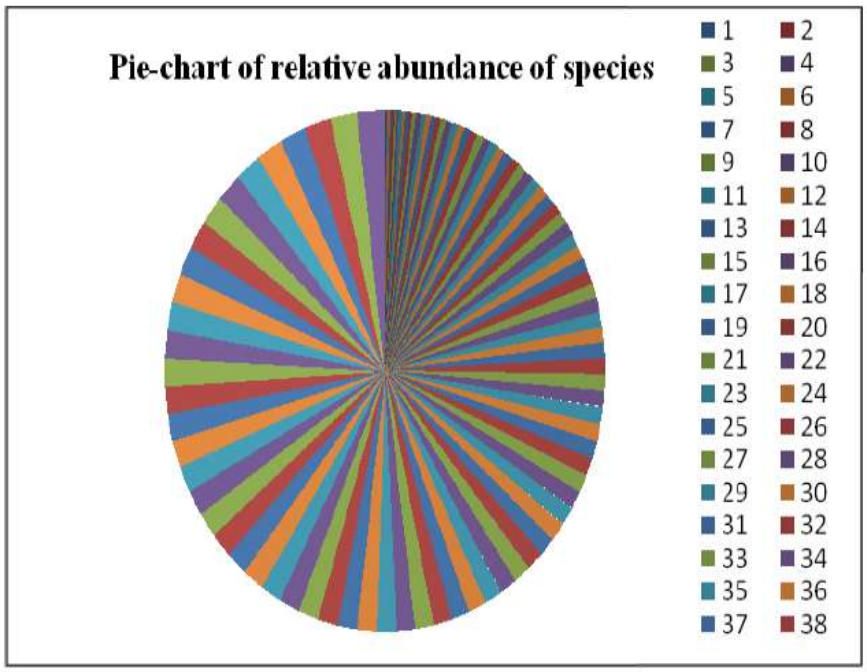

Fig. 5: Pie-chart of relative abundance of recent benthic foraminiferal species are *Ammonia beccarii, Ammonia gaimardii, Anomalina globulosa, Amphistagina lessoni, Astrononion umbilicatulum, Astrononion stelligerum, Cancris oblongus, Calcarina venusta, Cassidulina carinata, Cibicides bradyi, Cibicides* sp., *Discopulvinulina bertheloti, Discopulvinulina subbertheloti, Elphidium advena, Elphidium crisphum, Elphidium* sp., *Elphidiella hannai, Epistominella exigua, Gyroidinoides cibaoensis , Gyroidinoides nesoldanii, Gyroidinoides nitidula, Miliolinella subrotunda, Nonion scaphum, Planularia australis, Planularia cassis, Quinqueloculina semimulum, Quinqueloculina venusta, Quinqueloculina* sp., *Robulus gibbus ,Robulus iota, Robulus* sp., *Rosalina* sp., *Sigmoilopsis schlumbergeri, Spiroloculina cummunis, Spiroloculina* sp., *Textularia gaudryina, Textularia goesii, Textularia* sp. from Puthenthodu, Chellanam, Azheekal and Anthakaranazhi beach sediments in west coast of India

Discussion

Benthic foraminiferal faunal assemblages are 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 [13, 29,50]. Benthic foraminifera have been extensively used to reconstruct deep-ocean circulation and bottom water routes in different ocean basins as well as in the reconstruction of past climatic changes due to vast knowledge availability on modern ecology of benthic foraminifera.[14,18,20,25]

Benthic foraminiferal biofacies and their palaeoenvironmental preferences from Puthenthodu, Chellanam, Azheekal and Anthakaranazhi beach sediment record: The high productivity species of benthic foraminifera *Ammonia beccarii* indicate by a euryhaline and shallow sea environment[51]. Species *Ammonia beccarii* indicates of shallow-marine environment[47]. Species *Anomalina globulosa* is an epifaunal benthic foraminifer which has been found connected with low to intermediate organic carbon flux and high oxygen content of bottom water[11,20]. Species *Anomalina globulosa* occurs in the eastern Indian Ocean and is assumed to be an indicator of moderate organic carbon flux and well-oxygenated bottom water[20]. The genus *Astrononion* has a cosmopolitan distribution and is known from the middle Eocene to recent. *Astrononion umbilicatulum* has been observed in the Gulf of Aden associated with low primary productivity and well oxygenated bottom water[1].

Environmental preference of *Cancris oblongus* indicates of tolerance to mesotrophic-eutrophic conditions. This species maintained a high abundance along with opportunistic species as well as oxygenated bottom waters in the low oxygen environments. *Cancris oblongus* has been considered as a characteristic of well-oxygenated bottom waters with pulsed food supply, low to intermediate organic flux and high seasonality[49]. This species *Cancris oblongus* has been considered as a typical of well-oxygenated bottom waters. *Discopulvinulina bertheloti* is typically an intermediate organic flux to the sea floor[17]. This species has commonly been reported as a surface dweller linked with well-aerated bottom waters and low organic flux in the Atlantic.[10,16,30,45]

Gyroidinoides nitidula as a dominant species from the study region occupying shallow infaunal microhabitat[35]. This species indicates of limited food environment in the Mediterranean Sea[12] and pulsed food supply in the South Atlantic[31]. Species *Gyroidinoides nitidula* also indicates an environment with intermediate organic flux and intermediate to high seasonality during the Plio-Pleistocene[20]. Mackensen et al[31] suggest that this species indicates of low organic carbon flux or pulsed food supply

and high oxygen content of deep-sea environment. *Gyroidinoides cibaoensis* has been described from low oxygenated deep waters of the north-western Indian Ocean with moderate flux of organic matter[19].

The genus *Quinqueloculina* has been observed in cold and well-oxygenated deep waters with strongly pulsed food supply[20]. Species *Quinqueloculina seminulum* prefers near-shore shallow marine environment and is also found in outer and inner shelf in high-energy environments[27].

The genus *Textularia* prefers to living in coarse sediments and high energy environments[3,32]. The environmental preference of *Textularia* spp. has been suggested in coarse sediments and high speed of bottom currents[3,32].

Species *Miliolinella subrotunda* serves to raise the test far above the sediment surface. The test is lifted into the area of laminar flow and in the deep sea larger tubes (up to 6 mm total height) can reach the turbulent zone above the sediment surface[2]. Species *Nonion scaphum* suggests gradual evolution of environment from estuarine complex to near shore and finally into coastal plain. Species *Sigmoilopsis schlumbergeri* is marked by low organic carbon flux or pulsed food supply and high oxygen content environment[31]. This species is abundant in the top 1.5cm of sediments of the seep zone in Eel River[36]. The genus *Cibicides* is connected to well-oxygenated bottom water in the Arabian Sea[26] and low organic flux rates[17].

Conclusion

Totally, 38 benthic foraminiferal species belongs to 22 genera have been identified from Puthenthodu, Chellanam, Azheekal and Anthakaranazhi beach sediment in west coast of India. This study projected that beach sediments are much constructive for thriving of benthic foraminiferal species in the study region. The most high productivity species in all the regions are *Ammonia beccarii* and *Ammonia gaimardii* indicative of a shallow-marine environment.

The intermediate productivity species are *Cancris oblongus*, *Gyroidinoides nitidula* and *Gyroidinoides cibaoensis* indicate by low organic carbon flux or pulsed food supply and high oxygen environment. This suggests that 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 a vital factors scheming foraminiferal distribution in the study. We have documented the distribution and relative abundance of benthic foraminifera.

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