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STUDIES ON THE DISTRIBUTION OF RECENT PLANKTONIC FORAMINIFERA IN THE ARABIAN SEA AND THE BAY OF BENGAL

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ABSTRACT

Observations on the distribution of Recent planktonic Foraminifera in the waters of the continental shelf and the adjacent oceanic waters and the Andaman and Nicobar Islands between 4°30'N and 23°N lat. made during 1985-'88 are presented and discussed.

Of the 1,086 stations sampled 281 contained planktonic Foraminifera. The abundance of the planktonic Foraminifera was greater in the Bay of Bengal than that in the eastern Arabian Sea. In the eastern Arabian Sea the continental shelf off Bombay and Ratnagiri and the oceanic waters off the Wadge Bank area off Cape Comorin were rich in planktonic Foraminifera. In the Bay of Bengal the concentration was high in the shelf waters of Tuticorin and off the Point Calimere - Nagapattinam coast. However, the population density of 35,135/1000 m^3 encountered in a half a degree square in the oceanic region off Pondicherry was the highest in the seas around India.

While the monthly maximum occurred simultaneously, in the shelf and oceanic regions of the eastern Arabian Sea in December, in the Bay of Bengal the abundance recorded in February was the highest hardly differing from that observed in June. The planktonic Foraminifera of the shelf region constituted 54 and 68% respectively in the eastern Arabian Sea and the Bay of Bengal.

The foraminiferal content of the continental shelf between 10°N and 15°N lat. recorded during the premonsoon season in the eastern Arabian Sea and Bay of Bengal and in the oceanic region between 15°N and 20°N lat. in the eastern Arabian Sea during the same season was very high. Whereas in the oceanic waters of the Bay of Bengal between 10°N and 15°N lat. the maximum occurred during the monsoon season.

The difference between the samples collected during day time and at night in the foraminiferal abundance was marginal. However, the day samples contained more Foraminifera in June and the night samples in February. The samples collected during day time from the continental shelf were comparatively rich in planktonic Foraminifera. Little difference occurred in the foraminiferal content of the day and night samples from the oceanic waters.

INTRODUCTION

The number of species of planktonic Foraminifera inhabiting the world oceans are less than the benthic species but are far more useful to man than the latter in the study of palaeoecology and palaeoclimatology and as indicators of water masses, upwelling, regions of high productivity and pollution.

Murray (1897) pioneered studies on the distribution of planktonic Foraminifera. Phleger (1954) compiled the methods of study involving living planktonic Foraminifera and their distribution. Berger (1969) summarised the information on ecology and distribution of the planktonic Foraminifera of the world oceans. Be (1977) reviewed the ecological, zoogeographical and taxonomic aspects of the Recent planktonic Foraminifera. Jijung (1985) evaluated the information on this group from the eastern Arabian Sea. However, according to Phleger (1954), Berger (1969) and Rao *et al.*, (1989) work on the Recent planktonic Foraminifera from plankton tows is meagre when compared to the wealth of information already available on this group settled into sediments of the world oceans a long time ago.

Therefore, the primary objective of the present paper that incorporates observations made during 1985-'88 utilising the sampling facilities available on board FORV *Sagar Sampada* is to study the distribution of the Recent planktonic Foraminifera and the seasonal and diurnal variations in their abundance on the eastern Arabian Sea and the Bay of Bengal between 4°30'N and 23°N lat. and 65°E and 96°E long.

MATERIAL AND METHODS

Out of the 1,086 samples of zooplankton collected by oblique hauls from an average depth of 150 m to the surface using the twin Bongo 60 net (mesh aperature 0.33 mm) fitted with a calibrated

flow meter, 331 are from the continental shelf and the rest 755 are from the oceanic waters and 281 samples contained planktonic Foraminifera.

Aliquots were analysed whenever the biomass determined by displacement volume exceeded 5 ml. The average number of specimens present in 1000 m^3 of water per half a degree square area was estimated.

The area between 4° 30'N and 23°N lat. divided into four regions viz. (1) 4°30'N - 10°N lat., (2) 10°N - 15°N lat., (3) 15°N - 20°N lat. and (4) 20°N - 23°N lat. and these regions are compared. The combined faunal content of the continental shelf on either side of the Indian subcontinent is compared with that of the contiguous oceanic waters. The shelf region of the eastern Arabian Sea or the Bay of Bengal is compared with the respective contiguous oceanic region. Monthly, seasonal and day-night variations in those regions are also compared. Besides, three seasons namely, premonsoon from February to May, monsoon from June to August and postmonsoon from September to January in the following year are identified for the purpose of comparison of the variations between the seasons.

Observations

Spatial distribution of planktonic Foraminifera in the seas around India

The distribution of the stations from which the samples are collected are shown in Fig. 1. The concentration was very high in the shelf waters off Ratnagiri and Bombay, off Cape Comorin and the Wadge Bank area, off Tuticorin and off the Point Calimere - Nagapattinam coast. However, the mean density of planktonic Foraminifera observed in a half a degree square area in the oceanic region off Pondicherry, was the highest (35,135/1000 m^3) recorded during 1985-'88.

Region-wise distribution in the eastern Arabian Sea and the Bay of Bengal

The standing crop of planktonic Foraminifera varied from 1,392 to 67,952 specimen/1000 m^3 in the eastern Arabian Sea and from 4,488 to 2,43,156/1000 m^3 in the Bay of Bengal.

In the Arabian Sea between latitudes 4°30'N and 10°N and 15°N and 20°N, the mean concentration of Foraminifera was high (382 - 450/1000 m^3) when compared to that recorded in the latitudes between 10°N and 15°N or the sparse distribution in the region north of 20°N (Fig . 2). On the contrary, in the Bay of Bengal, the mean concentration observed between latitudes 10°N and 15°N (1,474/1000 m^3) was the highest and was far less north of 15°N.

Monthly variations of Foraminifera in the seas around India

Figure 3 shows that the foraminiferal abundance attained maximum at least once every season as observed in February in the premonsoon and in December in the postmonsoon varying slightly from the yearly maximum (total number of specimens: 1,24,542, mean : 1, 946/1000 m^3) recorded in the southwest monsoon in June. The foraminiferal content which remained steady during March-April increased considerably in May. After the steep fall observed in July following the yearly maximum in June, the increase in the abundance observed in August was remarkable.

Monthly mean abundance in the eastern Arabian Sea and the Bay of Bengal

The total number of specimens per 1000 m^3 in the eastern Arabian Sea varied from 136 to 82,321 and in the Bay of Bengal from 212 to 1,21, 265.

In the Arabian Sea the monthly mean abundance varied widely from a few numbers recorded in September to more than a thousand in December (2-1,176/1000 m^3). In the Bay of Bengal, the decrease in abundance observed during February - April from 4,546 to 50 and during August -October from 1,385 to 16 as well as the increase during April - June from 50 to 2,887 and during October - January from 16 to 383 were gradual (Fig. 4).

Monthly distribution in the shelf and oceanic waters of the seas around India

The standing crop of these organisms ranged from 37 to 64,253 in the shelf waters and in the oceanic waters from 8,33 to 79,507/1000 m^3.

The foraminiferal abundance in the shelf waters exceeded that recorded in the adjacent oceanic waters except during March - May, in November and January (Fig. 5). The mean concentration was the highest in February in the shelf (4,943/1000 m^3) and in June in the oceanic region (1,228/1000 m^3).

During the premonsoon season the density of Foraminifera observed in the continental shelf was nearly four times greater than that recorded in the

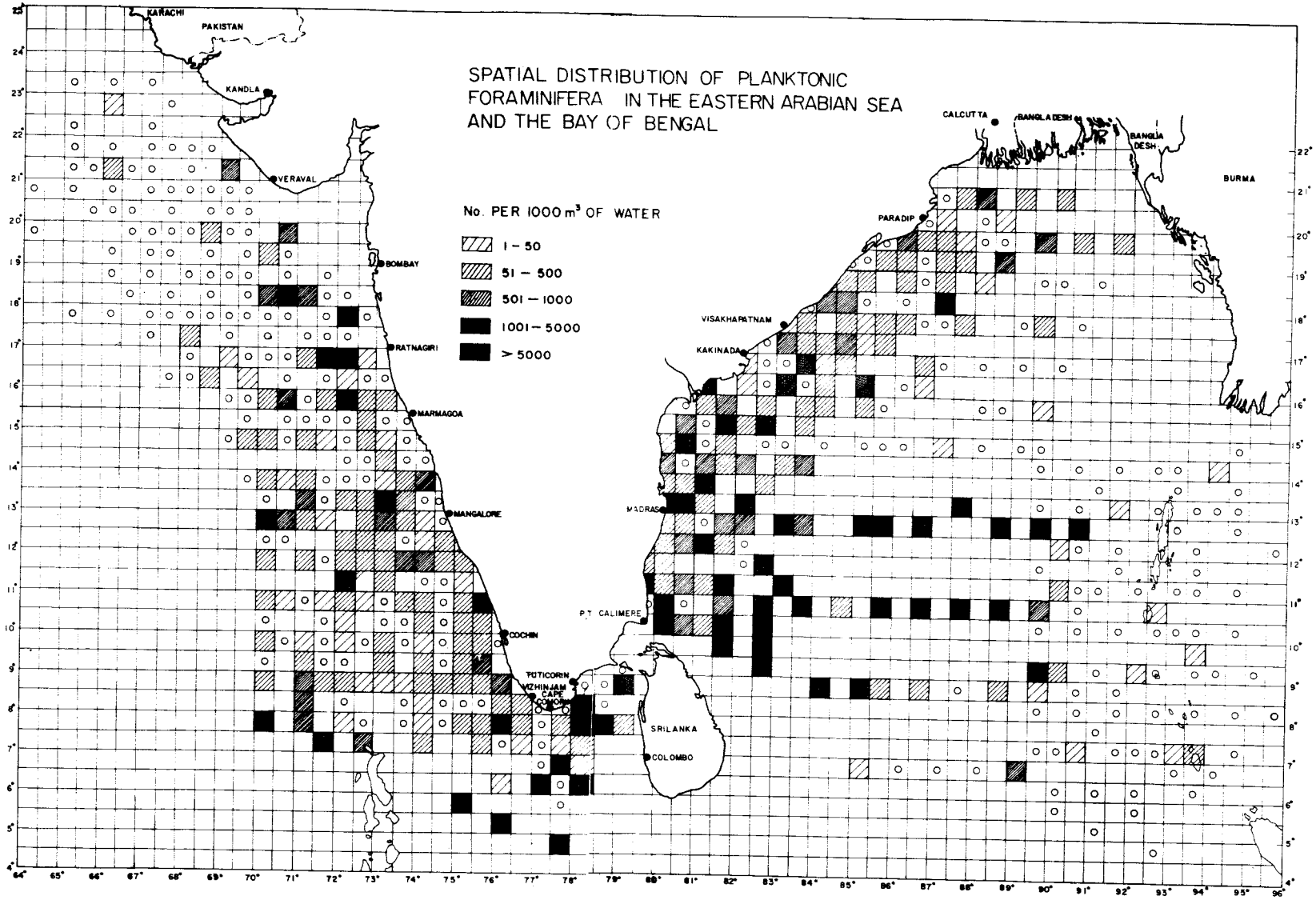

Fig. 1. Spatial distribution of planktonic Foraminifera in the seas around India.

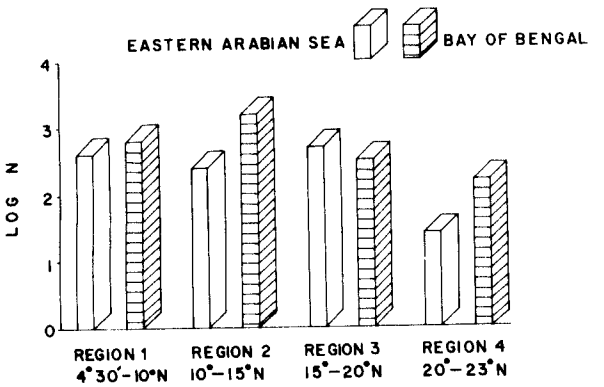

Fig. 2. Region-wise distribution of planktonic Foraminifera in the eastern Arabian Sea and the Bay of Bengal.

oceanic area (Fig. 6). But this difference in the abundance between the shelf and the adjacent areas was greatly reduced during the monsoon season and disappeared altogether in the postmonsoon season.

Monthly variations in the shelf and oceanic waters of the eastern Arabian Sea and the Bay of Bengal

In the eastern Arabian Sea the standing crop of planktonic Foraminifera in the shelf ranged from 42 to 40,807 and from 51 to 41,514 specimens/1000 m^3 in the oceanic areas.

Figure 7 shows that the average concentration observed in the shelf was the highest (1,974/1000 m^3) in December and was the lowest in March. Besides, the foraminiferal abundance observed in February and August was noticeably high. In the adjacent oceanic areas Foraminifera showed an increasing trend from February to April and more conspicuously from September to December.

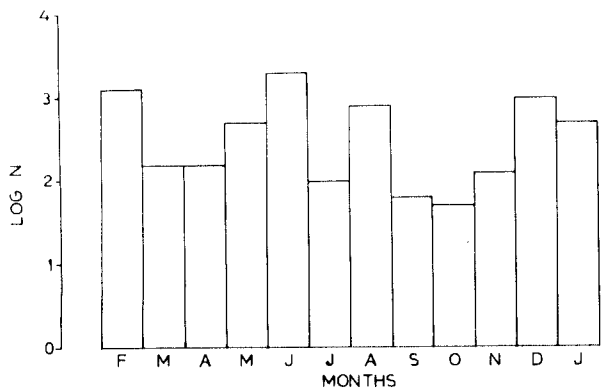

Fig. 3. The monthly variations in the abundace of planktonic Foraminifera in the seas around India.

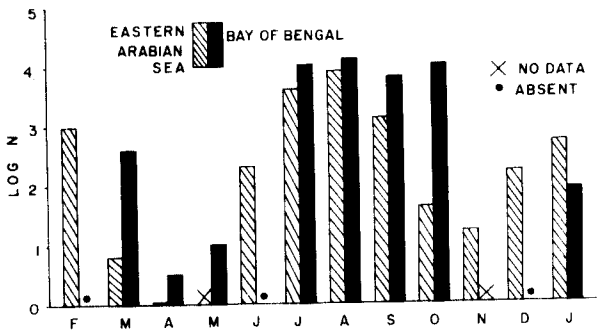

Fig. 4. The monthly variation in the anundace of plancktonic Foraminifera in the eastern Arabian Sea and the Bay of Bengal.

In the Bay of Bengal the total number of specimens observed in 1000 m^3 of water varied from 37 to 55,170 in the shelf and from 2,267 to 76,272 in the oceanic area.

The variations in the shelf and adjacent oceanic regions were similar from February to June and again from August to December. However, the mean concentration in the shelf and oceanic waters recorded in June was the highest (11,248 and 2,007/1000m^3 respectively).

Region-wise seasonal distribution in the shelf and oceanic waters of the eastern Arabian Sea and the Bay of Bengal

The planktonic Foraminifera present in the oceanic area formed 46.4% of the total observed in the eastern ArabianSea (Fig. 8a).

Foraminifera were absent in the waters of the continental shelf except between 10°N and 15° N lat. during the premonsoon and north of 15°N lat. in the premonsoon and the monsoon seasons. It may be

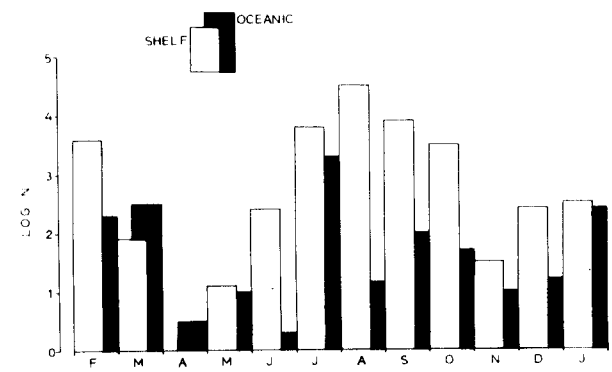

Fig. 5. The monthly variations in the abundace of planktonic Foraminifera in the shelf and oceanic areas of the seas around India.

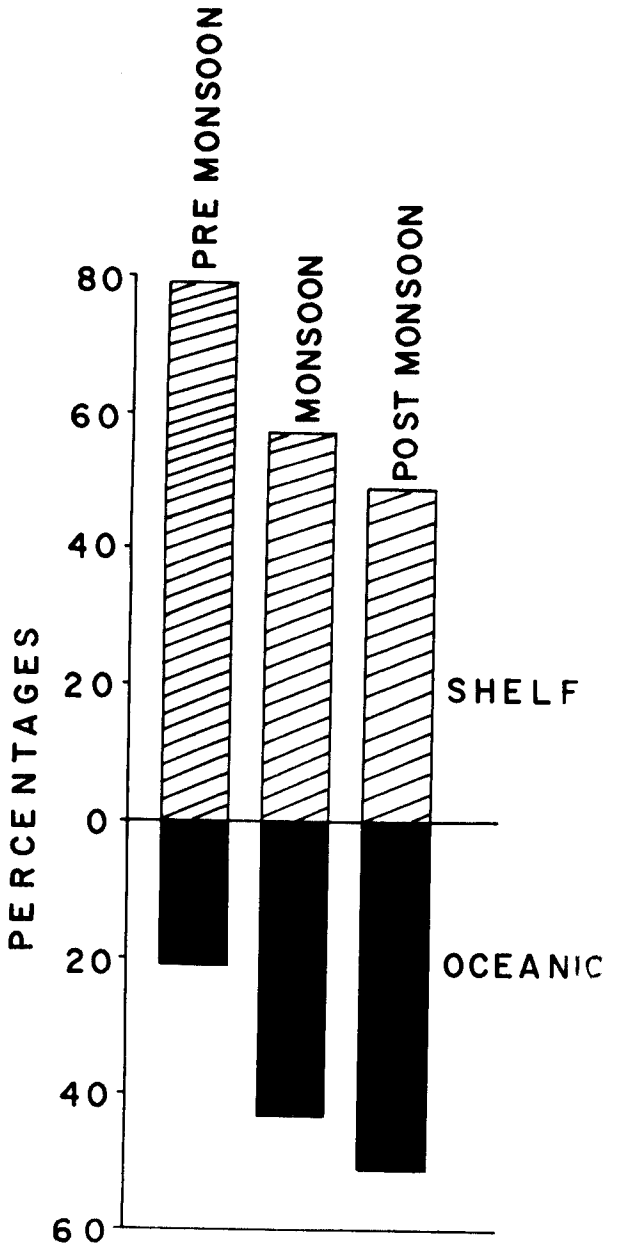

Fig. 6. Seasonal variations of planktonic Foraminifera in the shelf and oceanic waters of the seas around India.

seen that the planktonic Foraminifera were almost equally abundant in the oceanic area, between 4°30'N and 15°N lat. in all the three seasons. Whereas, between 15°N and 20°N lat. this group was abundant during the premonsoon and postmonsoon seasons, but recorded a perceptible decrease in the monsoon season.

Foraminifera occurring in the oceanic waters formed 31.6% of the total observed in the Bay of Bengal (Fig. 8b).

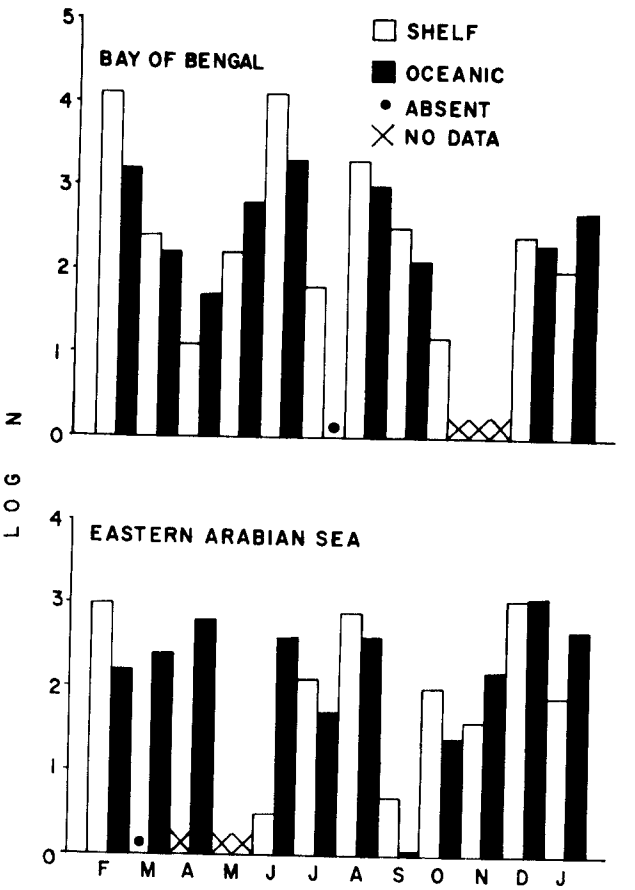

Fig. 7. The monthly variation in the abundace of planktonic Foraminifera in the shelf and oceanic waters of the eastern Arabian Sea and the Bay of Bengal.

Forminifera were absent during the premonsoon in the shelf between latitudes 4°30'N and 10°N. The foraminiferal abundance in the shelf waters between 10°N and 15°N lat. during the premonsoon was the highest (Total number : 55,240, mean : 3,946/1000 m^3) and that recorded in the postmonsoon season was the lowest, but in the oceanic area this group showed conspicuous increase during the monsoon season. The seasonal variations in the shelf between15° and 20°N lat. were almost similar to those recorded between 10°N and 15°N lat., but in the oceanic area the abundance decreased considerably in the monsoon season.

Monthly variations in abundance during day and at night

During May and September, Foraminifera were equally abundant in the samples collected during day as well as at night (Fig. 9). The day samples contained slightly more Foraminifera during

March, June, August, November and December but comparatively much less than the night samples during July and October.

Foraminifera were equally abundant in the day and night samples during the postmonsoon season (Fig. 10). However, the formainiferal content of the night samples was much more than that of the day samples during the premonsoon season and much less in the monsoon season.

Monthly variations in the shelf and oceanic waters during day and at night

The foraminifera observed in April and June in the shelf exclusively belonged to the day samples (Fig. 11) as these were absent in the former month in the night samples and formed a mere 2% in the latter month. Increased abundance of Foraminifera was observed in the night samples in February, March, July and October and in the day samples from April to June, November and December.

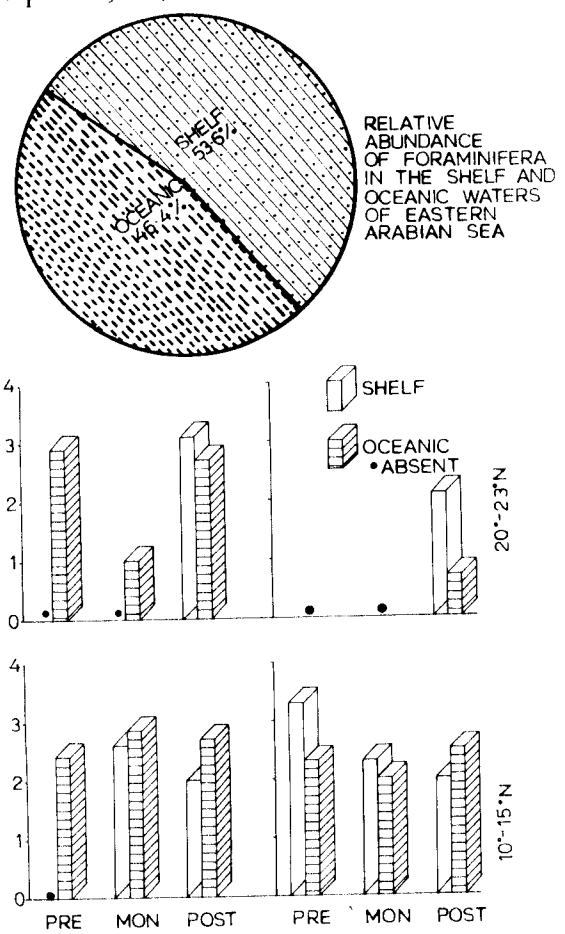

Fig. 8a. Region-wise seasonal distribution of planktonic Foraminifera in the shelf and oceanic waters of the eastern Arabian Sea.

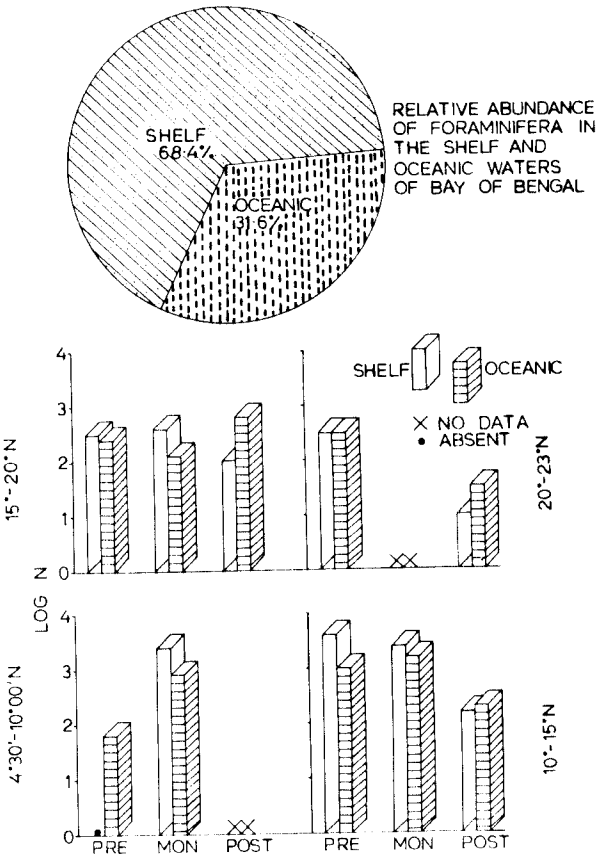

Fig. 8b. Region-wise seasonal distribution of planktonic Foraminifera in the shelf and oceanic waters of the Bay of Bengal.

In the oceanic region, the density of Foraminifera observed in the day samples during February - March was more than 75%. It also formed more than 50% during June, August, October and November. In the night samples this group formed more than 50% during April-May, July, September and December - January.

During the premonsoon season 90% of the Foraminifera was present in the samples collected during night in the shelf waters. But a greater portion of this pelagic fauna was present in the day samples during the monsoon and postmonsoon seasons (Fig. 12).

In the oceanic waters, the foraminiferal abundance of the day samples was slightly more than that of the night samples during the premonsoon and monsoon seasons whereas it was considerably higher in the night samples during the postmonsoon season.

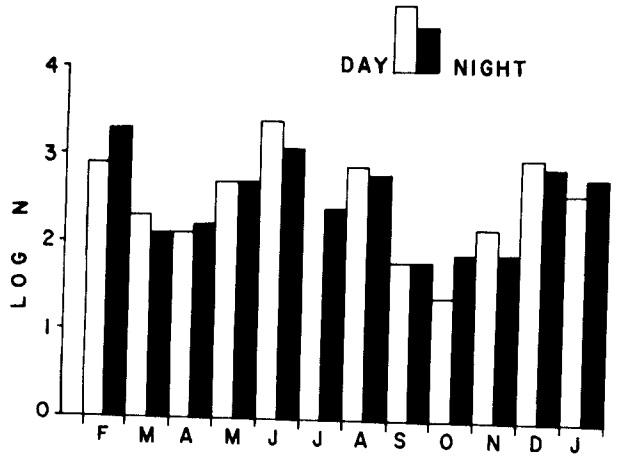

Fig. 9. The monthly variation in the abundace of planktonic Foraminifera during day and at night in the seas around India.

Discussion

Observations made during 1985-'88 in the seas around India show that the Recent planktonic Foraminifera were more abundandant in the Bay of Bengal than in the eastern Arabian Sea (Fig.1).

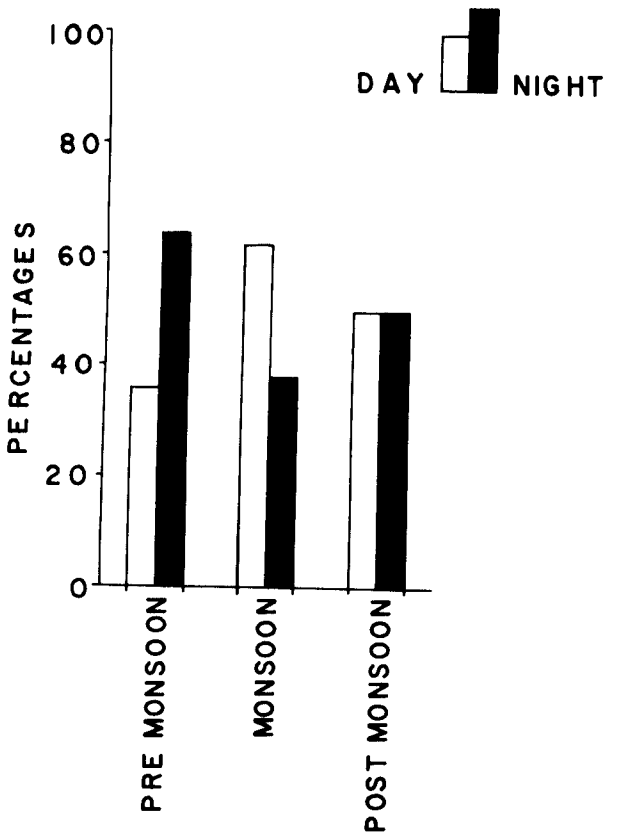

Fig. 10. Seasonal variations of planktonic Foraminifera during day and at night in the seas around India.

In the eastern Arabian Sea, the increased abundance of this pelagic fauna was observed in the region off Bombay where, according to Rao (1972) the fertility of the area is enhanced by the mixing of Antarctic water with the Red Sea water, Indian equatorial water and the Indian central water found along the west coast of India. The region next in abundance in the Arabian Sea is the Wadge Bank area off Cape Comorin which was found to be one of the most productive coastal areas in the world where three seas meet with the distinct pattern of water currents, and enrichment of the water column in the euphotic zone by upwelling in the SW monsoon (Rao *et al.*, 1988). The other areas where the abundance of Foraminifera was conspicuous (mean number 1,001 - 5,000/1000 m^3) are those off Angria Bank, Vengurla, Mangalore and Calicut. All these regions along the west coast of India come under the influence of upwelling leading to replenishment of nutrients and subsequent high production of plankton and fish during the SW monsoon or early postmonsoon (Prasad, 1969). According to Jijung (1985) the living planktonic Foraminifera is more abundant at 0 to 10 m depth of the euphotic

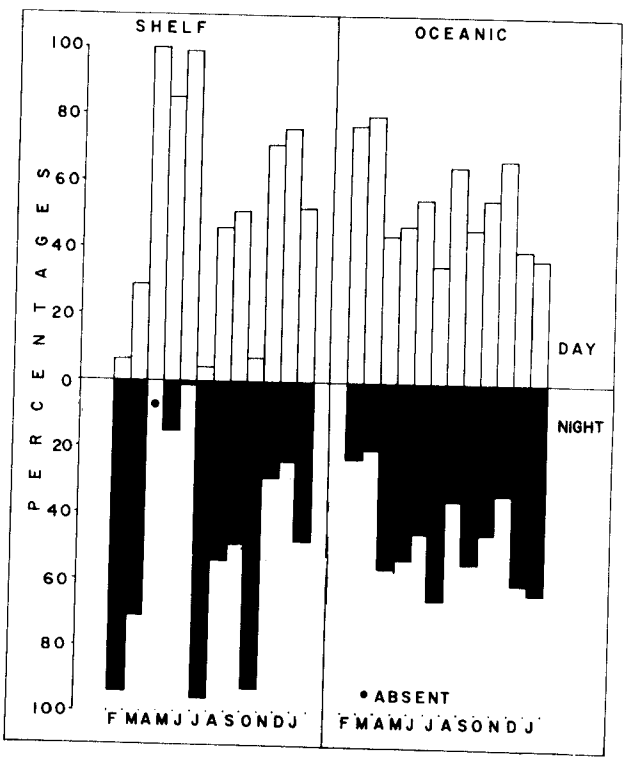

Fig. 11. The monthly variations in the abundance of planktonic Foraminifera in the shelf and oceanic waters during day and at night in the seas around India.

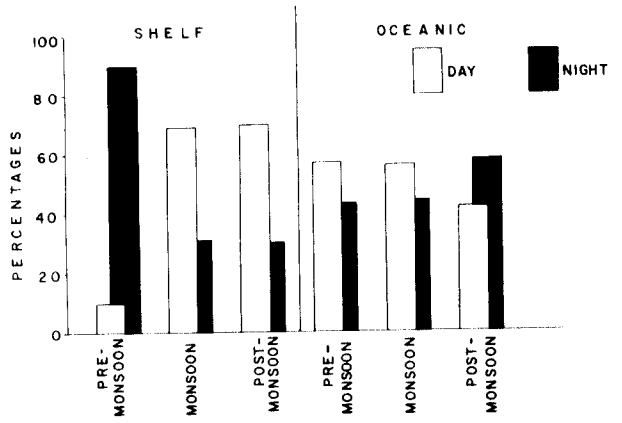

Fig. 12. Seasonal variations of planktonic Foraminifera in the shelf and oceanic waters during day and at night in the seas around India.

zone in the eastern Arabian Sea and the variations in the abundance appear to be governed by upwelling events which may vary seasonally and spatially.

The areas where high concentration of planktonic Foraminifera was observed in the Bay of Bengal are in the shelf waters off Tuticorin, Gulf of Mannar, off Point Calimere and Porto Novo (Fig. 1). Incursion of nutrient rich Antarctic bottom water in the Gulf of Mannar was already reported by Sewell (1932). The oceanic regions between Pondicherry and Madras, and those off Andhra coast are also rich in the living planktonic Foraminifera. A mean concentration of 15,965 specimens/1000 m^3 was encountered both in the shelf region off Tuticorin and Porto Novo and the highest population density (35,135 specimens/1000 m^3) observed in this study was found in the oceanic waters between Pondicherry and Madras. According to Murray (1897) the planktonic Foraminifera are highly abundant in the regions of open ocean with strong surface currents. Berger (1969) reported that surface water with high nutrient content generally support largest populations of planktonic Foraminifera. Upwelling is prevalent off Madras and Visakhapatnam during premonsoon and monsoon periods (Murty and Varadachari, 1968) but is predominant off Vishakahapatnam (Rao *et al.* 1986) during the same period. Upwelling is also reported in the coastal areas of the north western Bay enriching the surface waters (Sankaranarayanan and Reddy, 1968). According to Rao *et al* . (1989) high standing crops of planktonic foraminiferal abundance is connected with and dependent on upwelling.

The population density of this pelagic fauna in the eastern Arabian Sea was the highest in the region between 15°N and 20°N lat. and the abundance observed in the region from 4°30'N to 15°N lat. was conspicuous (Fig. 2). On the other hand, in the Bay of Bengal, between 4°30'N and 20°N lat. the concentration was fairly good and that observed between 10°N and 15° N lat. was the highest. According to Jijung (1985) provinces or zonations occur in the eastern Arabian Sea and latitudinal variation can be a major factor in controlling the distribution of planktonic Foraminifera in such wide ranging faunal zonations or provinces apart from the other important factors such as temperature and salinity. Be and Tolderlund (1971) remarked that the latitudinal distribution and abundance of planktonic Foraminifera are temperature dependent.

The abundance of living Foraminifera was maximum in December in the eastern Arabian Sea and in February in the Bay of Bengal (Fig. 4). It may be seen that in the eastern Arabian Sea 53.6% of this group occurred in the shelf and the rest in the oceanic waters. In the Bay of Bengal, the foraminiferal abundance from the shelf waters accounted for 68.4% of the total (Fig. 8b). It is reported that the increase in the living planktonic foraminifera manifests towards the outer shelf and slope (Setty, 1978).

Seasonal variations of foraminiferal abundance in the four regions show that in the eastern Arabian Sea the population density was high in the shelf waters between 10°N and 15°N lat. and in the oceanic waters between 15°N and 20°N lat. during the premonsoon season (Fig. 8a). On the other hand, in the Bay of Bengal, high concentration of this pelagic fauna was encountered in the shelf waters between 10°N and 15°N lat. during the premonsoon season and in the oceanic waters during the monsoon season (Fig. 8b). Latitudinal distribution of planktonic Foraminifera in the eastern Arabian Sea and the Bay of Bengal and the impact of seasonal upwelling on their abundance has already been discussed elsewhere in this account.

The number of stations sampled during day for this study was 659 and at night was 427. Monthly variations in the abundance show that the foraminiferal content was the highest in the day samples in June and in the night samples in February (Fig. 9). In general, the variations in monthly abundance

of planktonic Foraminifera collected during day and at night was marginal. However, Fig. 11 shows that the concentration of this pelagic fauna in the shelf was distinctly higher in the day time than at night whereas in the oceanic regions though the day samples were more abundant in living Foraminifera than the night samples the difference was not as conspicuous as observed in the shelf. High concentrations of planktonic Foraminifera in plankton tows made during the day time than at night were reported by Be and Hamlin (1967), Berger (1969) and Rao *et al.* (1988). According to Berger (1969), diurnal variations appear to be the strongest for small forms of shallow water Foraminifera in fertile regions.

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