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STUDIES ON THE DISTRIBUTION OF CLADOCERA IN THE EASTERN ARABIAN SEA AND THE BAY OF BENGAL

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ABSTRACT

Observations on the distribution and abundance of Cladocera in the continental shelf and the oceanic part of the eastern Arabian Sea and the Bay of Bengal between 4°30'N and 23°N lat. were made during 1985 - '88. Out of the 1,086 samples 159 contained cladocera.

The cladoceran abundance was high in a few places on the continental shelf and was poor in the adjacent oceanic region. The cladoceran concentration of 2,45,899/1000 m³ encountered in a half degree square in the shelf off Cochin was the highest with those of the Wadge Bank off Cape Comorin and the shelf off Karwar taking the second and third places respectively, in the order of abundance. In the Bay of Bengal the population density recorded off Paradip was more than that observed off Madras.

The population abundance observed was comparatively high during July-September in the Arabian Sea and during July-October in the Bay of Bengal and was maximum in August. In the eastern Arabian Sea the concentration of Cladocera in the shelf and the oceanic region was the highest respectively in August and in July. Whereas in the Bay of Bengal the increased abundance in the shelf occurred during July - October and in the oceanic region during March. The Cladocera occurring in the shelf constituted 95.3% and 98.8% respectively in the Arabian Sea and the Bay of Bengal.

In the eastern Arabian Sea the concentration of Cladocera was high between 4°30'N and 10°N lat. during the premonsoon and monsoon seasons and was conspicuously higher in the shelf between 10°N and 15°N lat. during the monsoon season. In the Bay of Bengal, the cladoceran density recorded during the monsoon season was the highest in the shelf between 4°30'N and 10°N lat. In the region north of 20°N lat. the cladoceran population was conspicuous and that observed in the oceanic waters during the postmonsoon was the maximum.

The cladoceran concentration in stations sampled during day time far exceeded that at night except during August in the shelf and March - April and August in the oceanic region.

INTRODUCTION

Marine cladocera are mainly neritic and form a major proportion of the coastal zooplankton often far exceeding the copepods in abundance. Several workers (Madhupratap, 1981; Suseelan *et al.*, 1985; Naomi, 1986) have attributed greater significance to the abundance of Cladocera in the coastal waters as a prey item of the economically important planktivorous fishes of India. Despite its numerically superior abundance during certain seasons and its importance to the pelagic fisheries, a comprehensive account on the distribution, biology and ecology of cladocera of the seas around India is yet to be compiled. Madhupratap (1981) summarised the available information on this group from the coastal and estuarine waters of the southwest coast of India. Della Croce and Venugopal (1972) studied the distribution of cladocera in the Indian Ocean based on 552 samples of the IIOE. Onbe (1985) compiled the distribution and abundance of cladoceran populations in the world oceans. Turner (1984) Paffenhoffer and Orcutt (1986) and Jagger *et al.*

(1988) described the feeding habits and ecology of the marine cladocera. The present paper based on observations made during 1985-'88 describes the distribution, seasonal and diurnal fluctuations in the abundance of cladocera of the shelf and oceanic areas of the eastern Arabian Sea and the Bay of Bengal.

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 a twin Bongo 60 net (mesh aperture 0.33 mm) fitted with a calibrated flow meter, 331 are from the continental shelf and the rest 755 from the oceanic waters, and 159 samples contained cladocera.

Aliquots were analysed whenever the biomass determined by displacement volume exceeded 5 ml. The average number of specimens present in 1000 m³ of water filtered per half a degree square area was estimated.

The area between 4°30'N and 23°N lat. is

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 water. The shelf region of the eastern Arabian Sea or the Bay of Bengal is compared with the respective adjacent 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 cladocera in the seas around India

Figure 1 shows that the cladocera were abundant in a few places on the continental shelf such as the Wadge Bank region (average number of specimens per half a degree square ranging from 5,455 to 1,43,012/1000 m³) off Cape Comorin and Vizhinjam (9,261-68,252/1000 m³), off Cochin (2,45,899/1000 m³) and Karwar (20,573/1000 m³) in the eastern Arabian Sea and off Tuticorin (20,433 - 60,544/1000 m³), and the Coromandal coast (24,483 / 1000 m³) and the region off Paradip (8,870 - 32,793/1000 m³) in the Bay of Bengal. In the shelf waters off Quilon and the oceanic areas off Veraval, Krishnapatnam, Machilipatnam and Kakinada, the concentration encountered was between 1,001 and 5,000/1000 m³. In the Andaman Sea cladoceran abundance was poor.

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

The total number of specimens/1000m³ varied from 2,371 to 5,78,107 in the eastern Arabian Sea and from 44,844 to 6,55,767/1000 m³ in the Bay of Bengal.

The mean abundance in the eastern Arabian Sea was the highest (2,665/1000 m³) in the region between 4°30'N and 15°N lat. while it was poor in the region north of 15°N lat. (Fig. 2). On the other hand, in the Bay of Bengal the mean concentration was the highest (7,538/1000 m³) in the regions between 4°30'N and 10°N lat., and 20°N and 23°N lat. while it was low in the region between 10°N and 20°N lat. but not as low as it was observed in the Arabian Sea.

Monthly variations in the seas around India

Figure 3 shows that the cladoceran concentration that increased during the latter part of the postmonsoon months, December and January, continued to be high in February in the succeeding premonsoon season. However, the tendency to increase not only weakened but also reversed in March to severely reduce the abundance in April. The abundance observed in May was slightly more than that of April but increased further till July and recorded the maximum in August. The decline in the cladoceran content registered in September and October was considerable but less drastic than the one which followed in November.

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

The total number varied from 12 to 2,92,571 in the Arabian sea and from 8 to 1,68,872/1000 m³ in the Bay of Bengal.

The mean concentration observed in the Arabian Sea was more during July - September while it was more during July - October in the Bay of Bengal. The abundance of Cladocera both in the Arabian Sea and the Bay of Bengal was the lowest simultaneously in April. In the Bay of Bengal, cladocera were absent during February, June and December.

Monthly variations in the shelf and oceanic areas of the seas around India

The standing crop of the group varied from 143 to 10,74,776/1000 m³ in the shelf waters and from 71 to 17,156/1000 m³ in the oceanic waters.

The average abundance observed in the shelf remained higher than that recorded in the adjacent oceanic waters except in March and was the highest (30,708/1000 m³) in August in the shelf while it was more in July (2,176/1000 m³) in the oceanic waters (Fig. 5). Figure 6 shows the seasonal abundance in the shelf and oceanic waters. The Cladocera observed in the latter region formed 10% or less of the total during the different seasons while the rest was from the shelf. The density of Cladocera in the oceanic waters during the premonsoon was almost the same as that occurred in the postmonsoon but it decreased drastically forming a mere 2% during the monsoon season. The cladoceran abundance showed a moderate increase in the shelf waters during the monsoon over those recorded in the pre- and postmonsoon seasons.

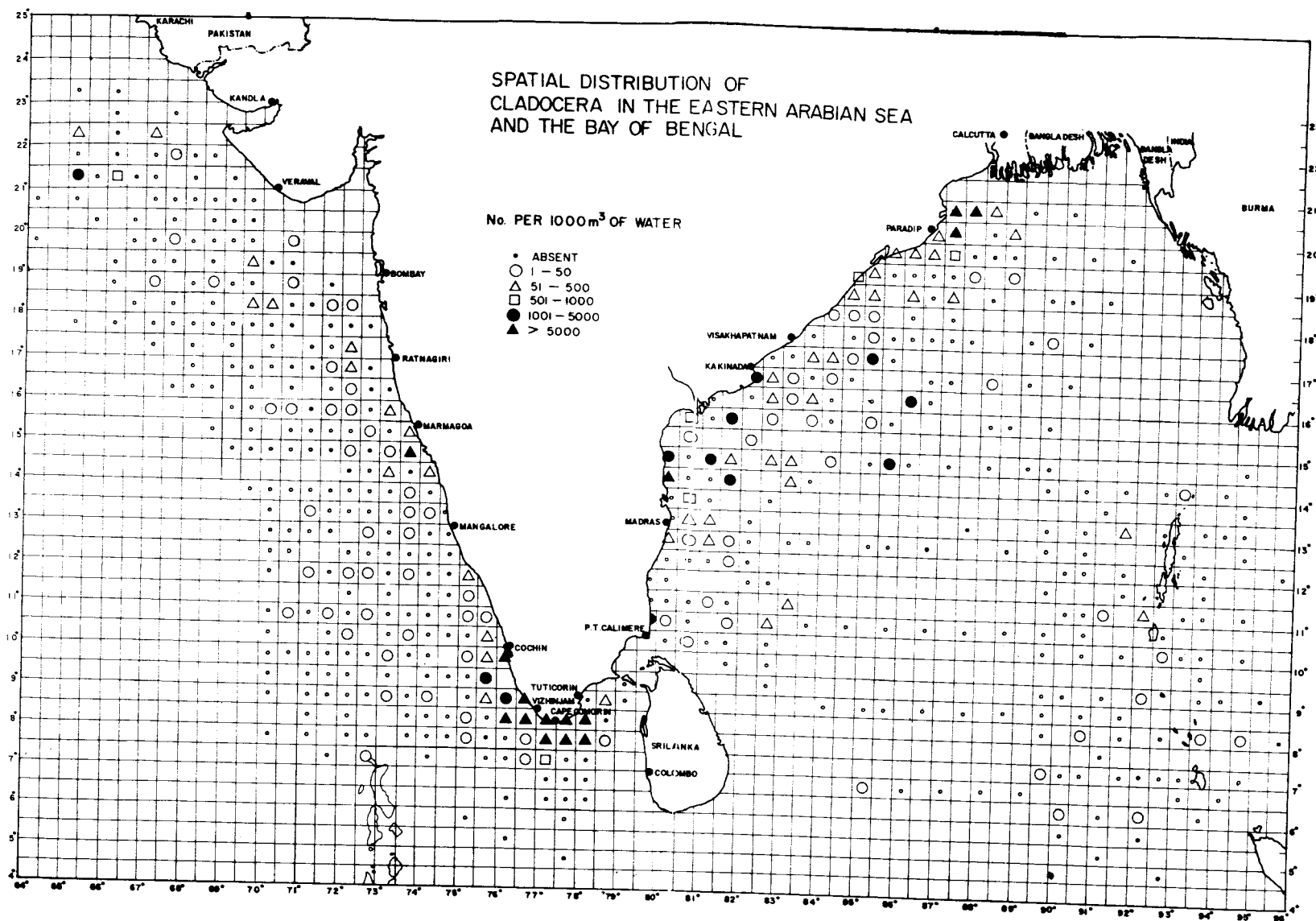


Fig. 1 Spatial distribution of Cladocera in the seas around India.

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

In the Arabian Sea the total number of specimens / 1000 m³ varied from the 435 to 5,71,450 in

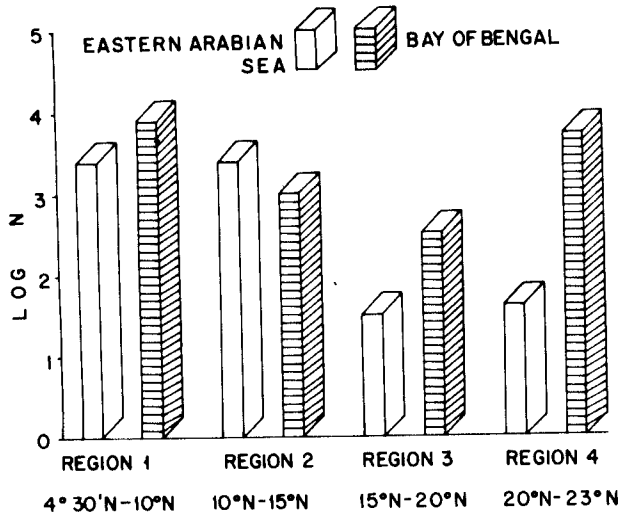


Fig. 2. Region-wise distribution of Cladocera in the eastern Arabian Sea and the Bay of Bengal.

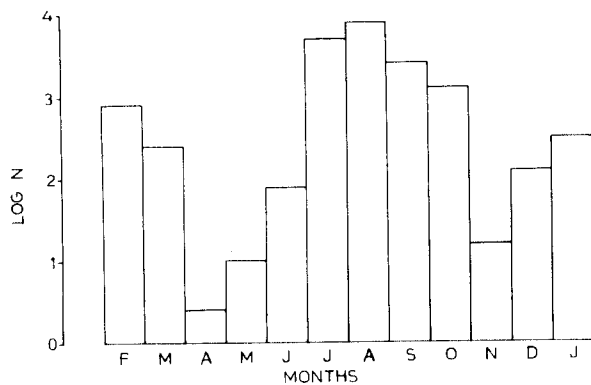


Fig. 3. The monthly variations in the abundance of Cladocera in the seas around India.

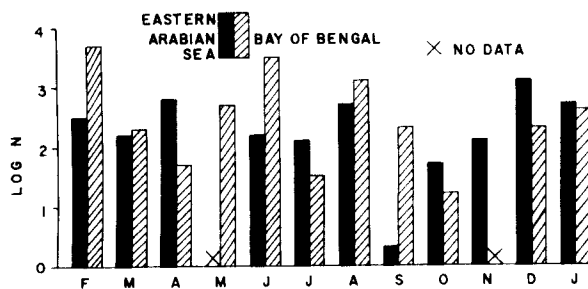


Fig. 4. The monthly variation in the abundance of Cladocera in the eastern Arabia Sea and the Bay of Bengal.

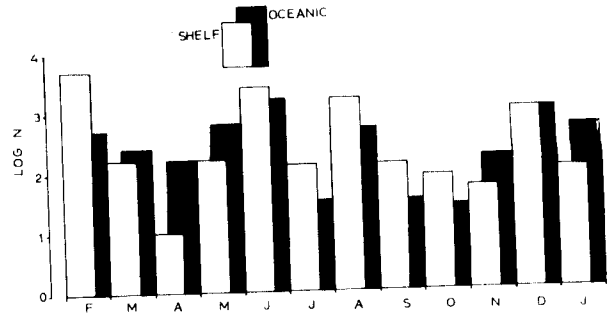


Fig. 5. The monthly variations in the abundance of cladocera in the shelf and oceanic areas of the seas around India.

the shelf and from 12 to 56,428 in the oceanic regions.

Figure 7 shows that the average concentration observed was high in the shelf waters of the Arabian Sea in February (5,554/1000 m³), from July to September (3,809 to 40,818/1000 m³), in January (3,349/1000 m³) and in the oceanic region only during July (3,527/1000 m³). Cladocera were absent in the shelf during March and in the adjacent oceanic area during April, August and September.

In the Bay of Bengal the standing crop of Cladocera varied from 143 to 5,03,326 in the shelf and from 8 to 16,959/1000 m³ in the oceanic areas but they were absent simultaneously in the shelf

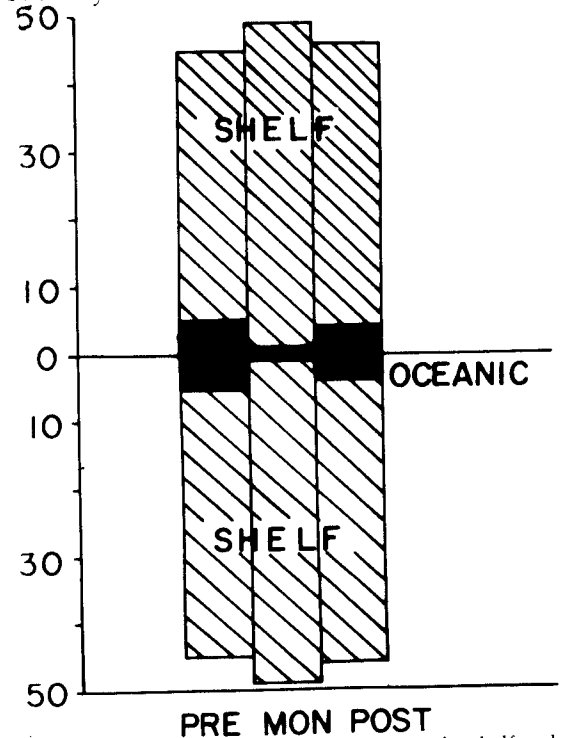


Fig. 6. Seasonal variations of Cladocera in the shelf and oceanic waters of the seas around India.

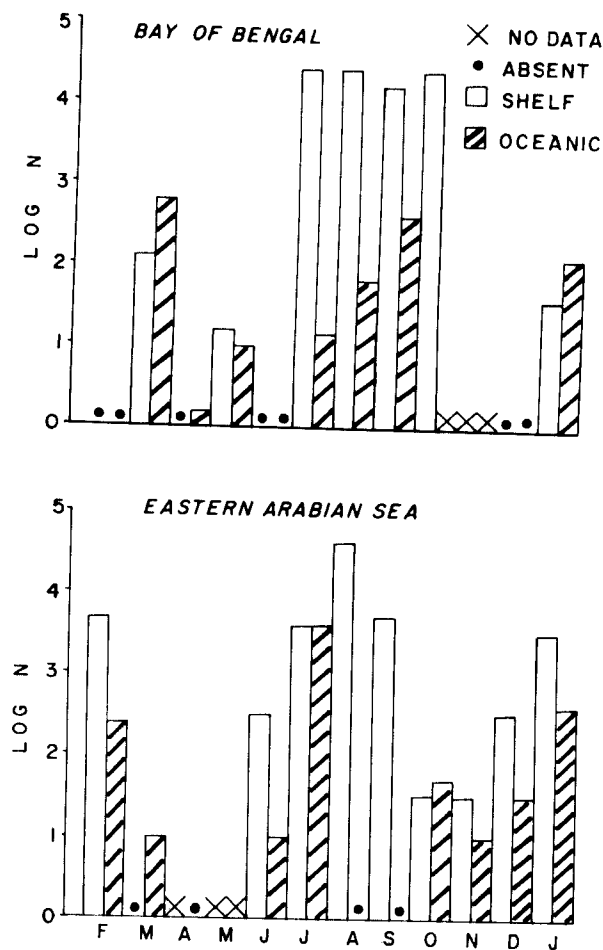


Fig. 7. The monthly variations in the abundance of Cladocera in the shelf and oceanic waters of the eastern Arabian Sea and the Bay of Bengal.

and oceanic waters in February, June and December and once in the shelf waters alone during April.

The mean cladoceran density observed was high in the shelf waters of the Bay of Bengal (10,924-23,968/1000 m³) during July - October and in the adjacent oceanic area during March (565/1000 m³) and September (421/1000 m³).

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

In the eastern Arabian Sea a greater portion of Cladocera forming as much as 95.3% occurred in the continental shelf and the rest 4.7% was found in the oceanic area (Fig. 8a).

In the eastern Arabian Sea the continental shelf corresponding to the region between latitude

4°30'N and 10°N was rich in Cladocera during the premonsoon and monsoon seasons whereas, in the adjacent oceanic area of the same region, the increase recorded in the monsoon was conspicuous.

Between latitudes 10°N and 15°N the cladoceran abundance observed in the shelf during the monsoon season was impressive and the concentration was the highest (total number : 5,75,441 and mean number : 13,382/1000 m³) recorded from the Arabian Sea during 1985-'88.

In the Bay of Bengal, 92.8% of Cladocera occurred in the shelf waters and the rest in the oceanic area (Fig. 8b).

Between latitudes 4°30'N and 10°N the abundance observed in the monsoon season in the shelf waters was the highest recorded (Total number : 6,55,314; and mean number : 40,957 / 1000 m³)

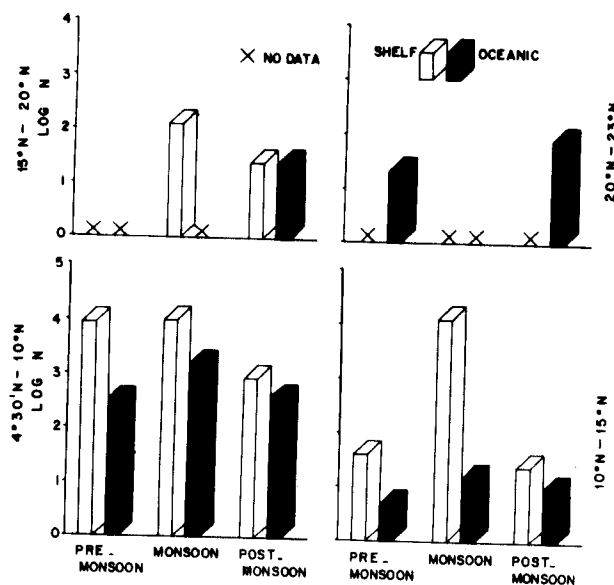
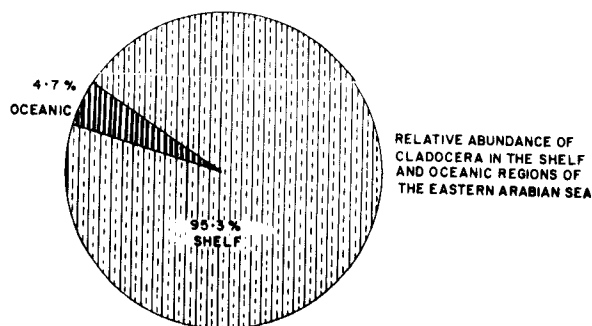


Fig. 8a. Region-wise seasonal distribution of Cladocera in the shelf and oceanic waters of the eastern Arabian Sea.

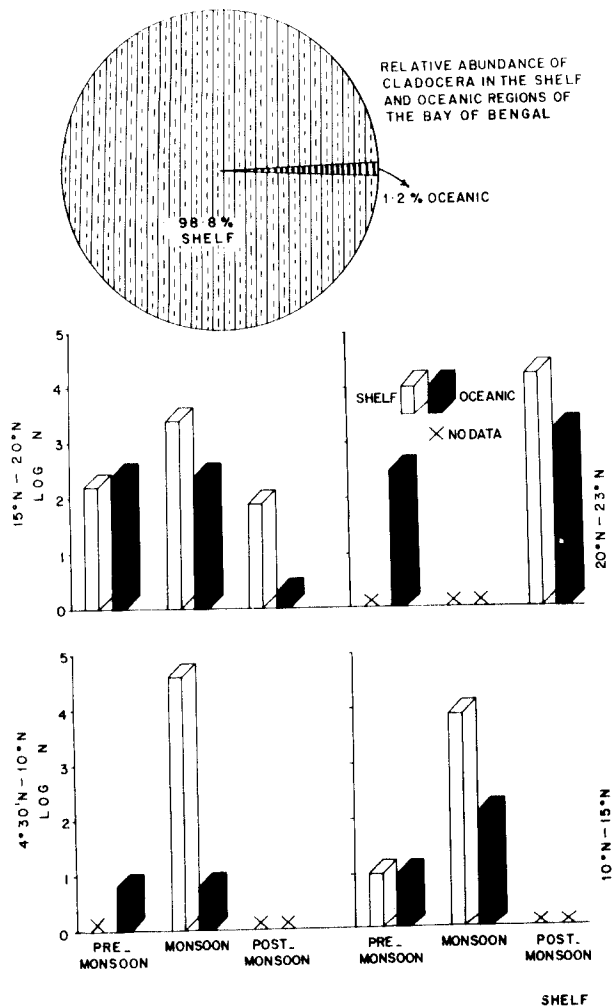


Fig. 8b. Region-wise seasonal distribution of Cladocera in the shelf and oceanic waters of the Bay of Bengal.

during this study. The density of Cladocera observed in the monsoon season between latitudes 10°N and 20°N and in the region north of 20°N recorded in the postmonsoon season was high. Besides, the concentration recorded in the postmonsoon season in the oceanic area north of 20°N was comparatively more than those recorded in other parts of the Bay of Bengal during the season.

Monthly variations in abundance during day and at night in the seas around India

Figure 9 shows that the cladoceran content of the stations sampled during the day time and those at night differed markedly. The night samples were richer in March, April and August but the day samples contained more Cladocera during the remaining months, except in November when Cladocera were equally abundant in the day as well as the night samples.

Though the difference in the cladoceran content of the day and night samples could hardly be discernible during the monsoon season, the contrast during the postmonsoon was immense with Cladocera of the night samples forming a mere 5% (Fig.

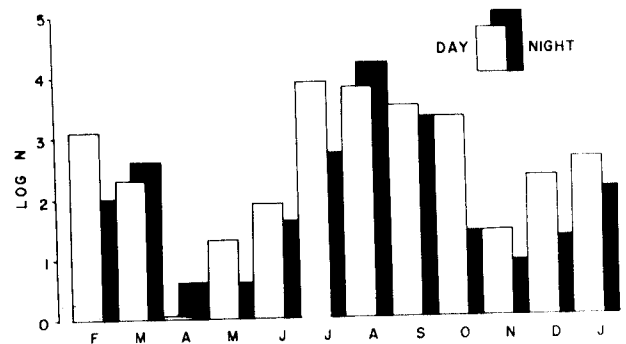


Fig. 9. The monthly variations in the abundance of Cladocera during day and at night in the seas around India.

10). On the other hand, during the premonsoon, the Cladocera of the night samples formed 20%.

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

Cladoceran component of the day samples from the continental shelf was higher; constituting more than 50% except in August, than that of the night samples, or the day/night samples from the oceanic part of the eastern Arabian Sea/Bay of Bengal (Fig. 11). The day samples from the oceanic region were richer in Cladocera than the night

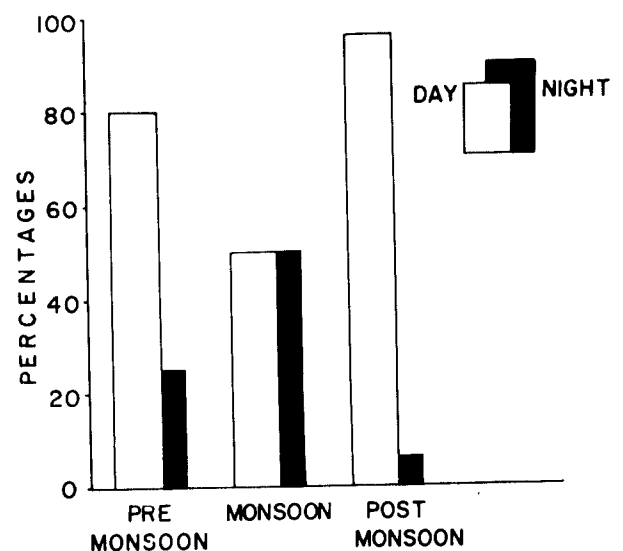


Fig. 10. Seasonal variations of Cladocera during day and at night in the seas around India.

samples of the shelf as well as the oceanic region and in the latter region except during March - April and August. However, the night samples from the samples from the oceanic region contained a significant percentage of the Cladocera except in May.

In the shelf waters the cladoceran content of the night samples of the premonsoon season was nil and that of the postmonsoon season was less

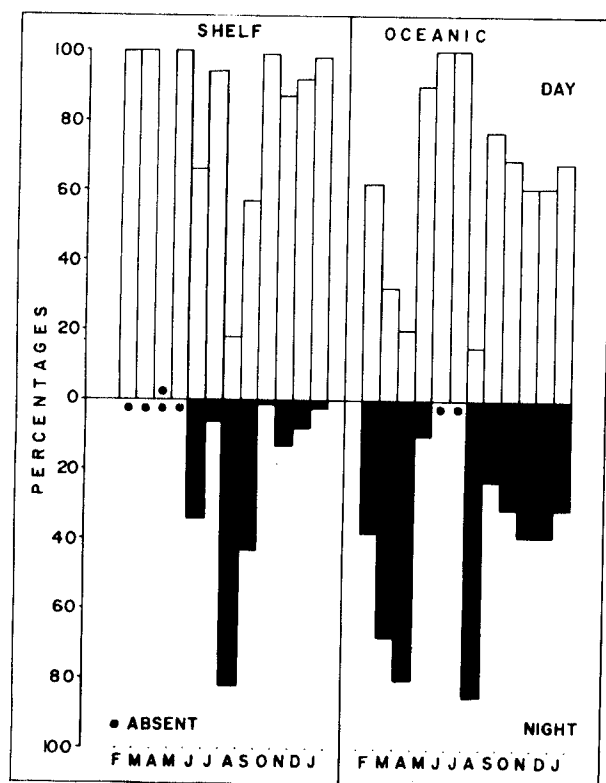


Fig. 11. The monthly variations in the abundance of cladocera in the shelf and oceanic waters during day and at night in the seas around India.

than 5%. But during the monsoon season the concentration in the night samples exceeded that recorded in the day samples (Fig. 12).

In the oceanic waters during the premonsoon season the cladoceran content of the night samples nearly equalled that of the day samples. In the monsoon season Cladocera were present almost exclusively in the day samples. Whereas, in the postmonsoon season Cladocera were more in the samples collected during the day than those at night.

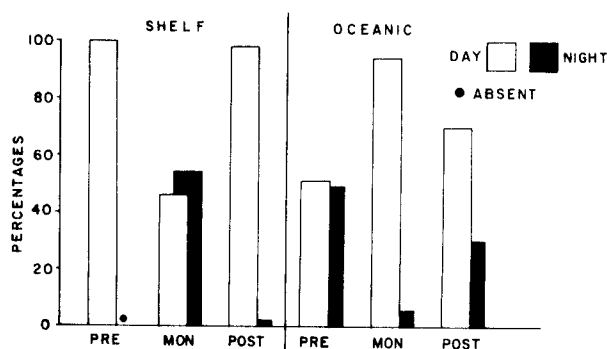


Fig. 12. Seasonal variations of Cladocera in the shelf and oceanic waters during day and at night in the seas around India.

DISCUSSION

The distribution of cladocera between $4^{\circ}30'N$ and $23^{\circ}N$ lat. and $65^{\circ}E$ and $96^{\circ}E$ long. shows that the regions between $4^{\circ}30'N$ and $15^{\circ}N$ lat. on the continental shelf of both the eastern Arabian Sea and the Bay of Bengal are more densely populated than the rest of the continental shelf as well as the entire adjacent oceanic areas (Fig. 2). It may be seen that the cladoceran abundance occurred in the coastal waters known for high biological productivity and adjacent to major fish landing centres. The concentration of Cladocera estimated in a half a degree square off Cochin (Fig. 1) was the highest (2,45,899/1000m³). It also shows that the Cladocera abounded in the Wadge Bank area off Cape Comorin and the coastal waters of Vizhinjam and Karwar and off Tuticorin, Coromandel coast and Paradip. The increased abundance and seasonal fluctuations of these planktonic crustaceans in the waters of the Wadge Bank, off Tuticorin, Coromandel coast and Paradip are reported for the first time. According to Paffenhofer (1983) cladocerans occur in high concentrations in the nearshore upwelling regions.

Figure 2 shows that in the eastern Arabian Sea the Cladocera were abundant on the continental shelf in the region between $4^{\circ}30'N$ and $15^{\circ}N$ lat. where, between $5^{\circ}N$ and $10^{\circ}N$ lat. according to Warren *et al.* (1966) upwelling was particularly intense in the southwest monsoon season and between $7^{\circ}N$ and $16^{\circ}N$ lat. where prevalence of upwelling was reported by Panikkar and Jayaraman (1966) during the southwest and early postmonsoon seasons. In the Bay of Bengal also the Cladocera were abundant where upwelling and enrichment of nutrients are reported to occur in regions between Madras and Vishakhapatnam

during the pre- and postmonsoon periods (Murty and Varadachari, 1968) and in the coastal waters of north western Bay of Bengal (Sankaranarayanan and Reddy, 1968). The cladoceran abundance observed off Veraval was though lower in intensity than those described earlier in this account occurred in a region enriched by the incursion of nutrient rich Persian Gulf waters (Rao *et al.*, 1979). It may also be seen that the cladoceran populations are concentrated in certain areas on the continental shelf forming 95.3 and 98.8% of the total observed respectively in the eastern Arabian Sea and the Bay of Bengal (Fig. 8a and 8b).

All these appear to indicate an explosive rate of reproduction owing to parthenogenesis (Onbe, 1977; 1985) occurs on the continental shelf in the monsoon season at the time of upwelling. It may be mentioned here that the upwelled water is characterized by low temperature, high salinity and high density as it ascends and spreads along the continental shelf. Perhaps the resting cladoceran eggs in the sediments are borne towards the surface where at moderately high temperature the eggs hatch causing the explosion in the population of the Cladocera (swarms) which eclipses the other components of the coastal zooplankton. The occurrence of such swarms frequently during the monsoon and early postmonsoon in the coastal waters off Karwar (Naomi, 1986), off Cochin (Naomi and Mathew MS, and off Vizhinjam (Rani Mary *et al.*, 1981) have been reported earlier. Such swarms off Cochin were sometimes associated with the blooms of *Fragilaria oceanica* (Naomi and Mathew MS) or with those of *Trichodesmium* and pteropods (Sakthivel and Haridas, 1974).

The cladoceran abundance observed in the eastern Arabian Sea was high during February and July - September and in the Bay of Bengal during July - October (Fig. 4). While the concentration observed in the shelf region of both the eastern Arabian Sea and the Bay of Bengal was the highest in August, that of the contiguous oceanic areas attained maximum in July in the former and March in the latter.

Figures 8a and 8b show that Cladocera were abundant during the premonsoon and monsoon seasons between 4°30'N and 15°N lat. in the eastern Arabian Sea as reported earlier by Madhupratap (1981) along the southwest coast of India but the concentration in the shelf together with that of the

adjacent oceanic waters observed during the monsoon season was the highest. On the other hand, in the Bay of Bengal the cladocera were abundant in the monsoon and postmonsoon seasons. The concentration of Cladocera was high in the shelf between 4°30'N and 10°N lat. in the monsoon season, and in the shelf and oceanic waters of the region north of 20°N lat. in the postmonsoon season.

The cladoceran content was more in the samples collected in the day time than those sampled in the night except in March and August (Fig. 9). The number of stations sampled in the day time and in the night was respectively 659 and 427. The total number of specimens observed in the day samples was 13,59,840 and in the night samples it was 6,98,579 with a mean of 2,063 and 1,636/1000 m³ respectively. According to Onbe (1977) the pattern of diurnal migrations performed by *Penilia avirostris* of Sididae is far less distinct than the other members of Polyphemidae and Podonidae which aggregated densely at the surface during day but migrated downwards to the intermediate layers at night leaving the surface sparse. Bosch and Taylor (1973) felt that the inactivity of these pelagic crustaceans might make them sink to the deeper layers at night.

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