

Seasonal distribution of chlorophyll-*a* in the exclusive economic zone (EEZ) of India

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Seasonal distribution of chlorophyll-*a* (chl-*a*) in the different sectors of the EEZ of India was studied based on data from 430 stations over the period from 1962 to 1988. The annual average chl-*a* for the entire euphotic zone of EEZ was 12.0 mg m⁻² whereas the seasonal average was calculated to be 14.2, 12.8 and 7.4 mg m⁻² during premonsoon (February - May), SW monsoon (June-September) and postmonsoon (October-January) respectively. The maximum average (18.0 mg m⁻²) was noticed in the Arabian Sea during premonsoon followed by the Bay of Bengal sector during SW monsoon (14.8 mg m⁻²) and the Lakshadweep Sea during premonsoon (14.5 mg m⁻²). The range of chl-*a* (0.2 to 100.6 mg m⁻²) was found maximum during premonsoon followed by SW monsoon in the euphotic zone of EEZ of India.

The chlorophyll-*a* (chl-*a*) concentration is one of the indicators of the phytoplankton biomass in the sea and is responsible for the photosynthesis. The standing crop of phytoplankton indicates the availability of food for animals at the primary stage. Chlorophyll-*a* concentration has been measured during various expeditions and cruises in different areas of Indian seas. Qasim¹ has described the distribution of chl-*a* in the Indian Ocean. Krey & Babenard² have reported the average values of chl-*a* in the Indian Ocean during SW and NE monsoon seasons. They have also published a map on chl-*a* distribution, based on the data collected during International Indian Ocean Expedition (IIOE). But hardly any attempt has been made to study its seasonal distribution in the Indian seas. Annual and seasonal distribution of chl-*a* for a small sector of the Arabian Sea and the Bay of Bengal have been published³⁻⁸. Therefore, an attempt has been made here to show the chl-*a* distribution in each of the seasons in different sectors of EEZ of India.

Materials and Methods

The data (till 1988) available in the Indian Oceanographic Data Centre of NIO from the International Indian Ocean Expedition (1960-65) and cruises of *INS Darshak*, *R.V. Gaveshani* and *ORV Sagar Kanya* have been used. The EEZ area

is divided into four sectors viz. Arabian Sea, Bay of Bengal, Lakshadweep and Andaman Sea for the present study. A year is divided into three seasons viz. premonsoon (February-May), SW monsoon (June-September) and postmonsoon (October-January). The details for seasonal and sectorwise observations are given in Table 1 and Fig. 1. The Bay of Bengal and Andaman sector were not covered adequately during postmonsoon and SW monsoon respectively. In all 430 profiles of chl-*a* were used to show its distribution in the euphotic zone which extends up to 90 m depth (chl-*a* is mostly restricted up to euphotic zone which is taken up to a depth where the light penetration is 1%). Chlorophyll-*a* was integrated from surface to the euphotic depth and expressed in milligram per square meter (mg m⁻²).

Results and Discussion

The maximum average column chl-*a* in the EEZ was observed during premonsoon (14.2 mg m⁻²) season followed by SW monsoon (12.8 mg m⁻²) and postmonsoon (7.4 mg m⁻²) (Table 2). The annual weighted average for the entire EEZ is 12.0 Mg m⁻². The sectorwise distribution is given below:

Arabian Sea

The concentration of chl-*a* in the Arabian Sea ranged from 0.1 to 96.4 mg m⁻² (Table 1) in

Table 1—Seasonal average chlorophyll-*a* in different sectors of the EEZ

EEZ sectors	Area ($\times 10^6$ km ²)	Seasons	No. of obs.	Chl- <i>a</i> (mg m ⁻²)	
				Range	Average
Arabian Sea	0.6981	Premonsoon	111	0.2-92.9	18.0
		SW monsoon	17	1.5-96.4	7.9
		Postmonsoon	83	0.1-59.6	8.3
		Total	211	Annual	13.4
Lakshadweep Sea	0.230	Premonsoon	15	1.4-100.6	14.5
		SW monsoon	8	1.6-3.3	2.5
		Postmonsoon	21	0.1-16.7	4.3
		Total	44	Annual	7.5
Bay of Bengal	0.516	Premonsoon	32	1.0-34.0	8.1
		SW monsoon	84	1.1-93.2	14.8
		Postmonsoon	1	—	22.0
		Total	117	Annual	13.0
Andaman Sea	0.566	Premonsoon	43	0.4-34.0	8.6
		SW monsoon	2	6.0-14.0	10.0
		Postmonsoon	13	0.5-16.3	5.9
		Total	58	Annual	7.8
Grand Total			430		

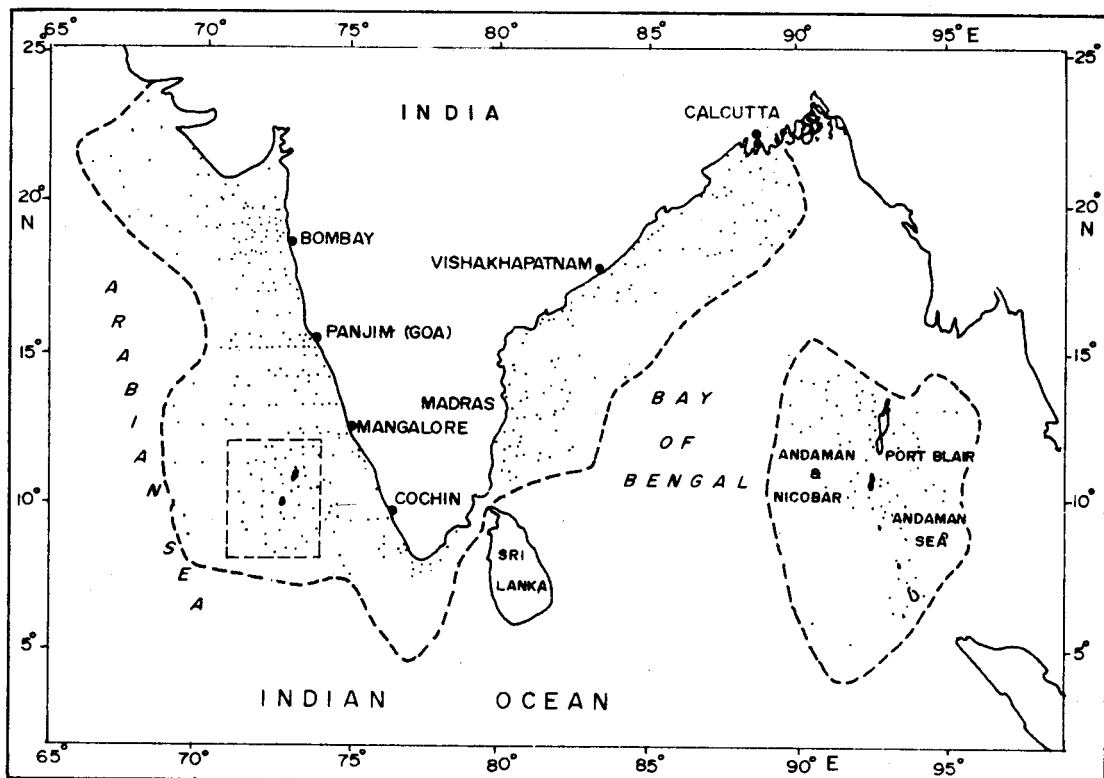


Fig. 1—Map indicating the locations of stations.

different seasons. The maximum fluctuation was observed during premonsoon season followed by SW monsoon and postmonsoon. Similar fluctuation was reported by Sarupria & Bhargava⁹ in the Arabian Sea while calculating primary production in the EEZ of India. The seasonally highest average (18.0 mg m^{-2}) of chl-*a* was observed during premonsoon. Integrated annual average of chl-*a* in the euphotic zone of the region, having an area of $0.698 \times 10^6 \text{ km}^2$, works out to be 13.4 mg m^{-2} or 9.3×10^3 tones. Observations were not enough during the SW monsoon season for statistical analysis. Chlorophyll-*a* distribution (Figs. 2-4) showed high concentration in the euphotic zone in and around waters off Cochin in all the seasons. In general, the chl-*a* concentration was observed above average ($>15 \text{ mg m}^{-2}$) in the northern and southern part of the Arabian Sea in all the seasons except in the SW monsoon where only few observations were available.

In the north eastern Arabian Sea during November, Radhakrishna *et al.*¹⁰ reported column values between 4 and 28.8 mg m^{-2} whereas in the

present study the values vary between 0.1 to 59.6 mg m^{-2} during postmonsoon period. The values reported here are higher than those reported by Bhattathiri⁵ which varied between 0.9 to 18.9 mg m^{-2} from October to April. High values including in Lakshadweep Sea were found during February-May; whereas the lowest (0.1 mg m^{-2}) value was recorded in January 1984 and the highest (100.6 mg m^{-2}) in May 1981. The seasonal distribution of chl-*a* (Figs. 2 to 4) shows high values in the coastal waters off Gujarat, Goa and Cochin during pre and postmonsoon seasons, whereas the data coverage during monsoon season in the Arabian Sea is very

Table 2—Seasonal average of chlorophyll-*a* in the EEZ of India

	No. of obs.	Chl- <i>a</i> (mg m^{-2})	
		Range	Average
Premonsoon	201	0.2-100.6	14.2
SW monsoon	111	1.1-96.4	12.8
Postmonsoon	118	0.1-59.6	7.4
Total	430	Annual	12.0

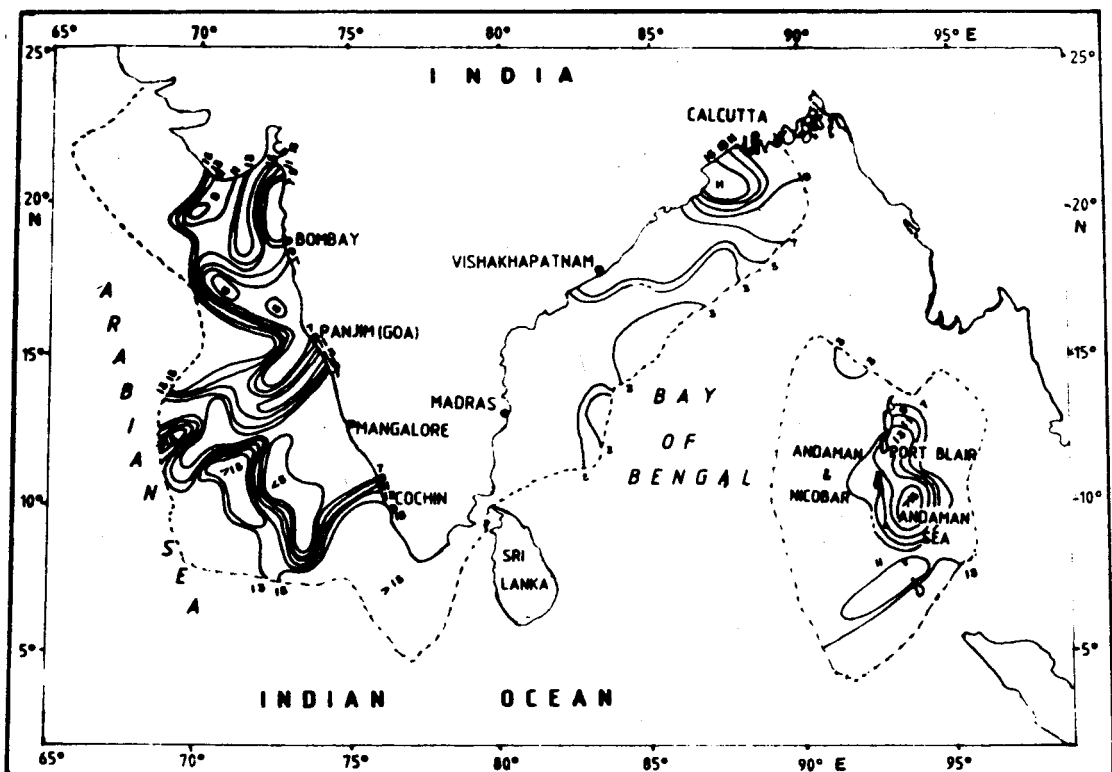


Fig. 2— Distribution of chl-*a* (mg m^{-2}) in the euphotic column during premonsoon (February-May).

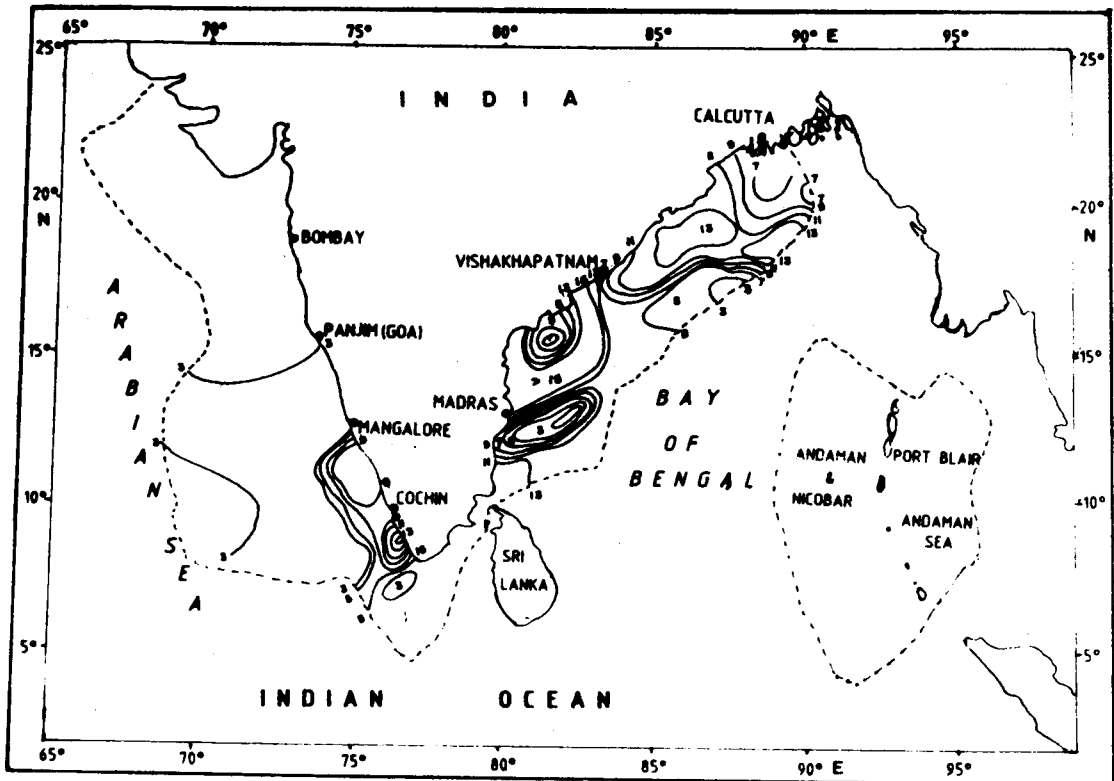


Fig. 3—Distribution of chl-*a* (mg m^{-2}) in the euphotic column during SW monsoon (June-September).

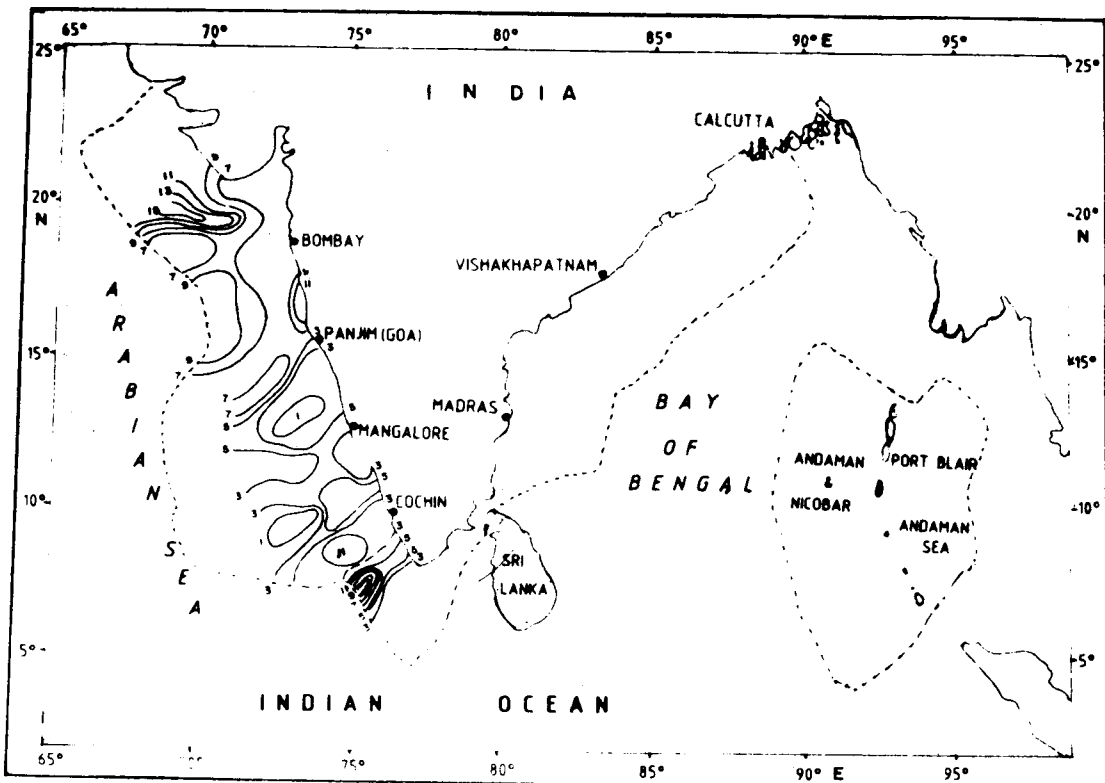


Fig. 4—Distribution of chl-*a* (mg m^{-2}) in the euphotic column during post monsoon (October-January).

less to generalize. These observations show higher concentration in and around Cochin waters. The annual pattern of distribution by taking weighted mean of all seasons shows higher concentration of chl-*a* off Gujarat and south of Cochin waters.

Lakshadweep Sea

The sea around Lakshadweep is shown within the boundary of the EEZ of the Arabian Sea. The average which is based on only 44 observations was 7.5 mg m^{-2} which is quite low in comparison to all the three sectors of the EEZ. In the Lakshadweep Sea, the seasonal trend remained the same, as noticed in the Arabian Sea (14.5 in premonsoon; 4.3 in postmonsoon and 2.5 mg m^{-2} in SW monsoon). The integrated annual average in the euphotic zone of Lakshadweep Sea which is having an area round $0.23 \times 10^6 \text{ km}^2$ was worked out to be 1.72×10^3 tones. In the same area, Bhattathiri⁵ had estimated chl-*a* concentration in October, December, March and April and reported its range from 8.9 to 18.9 mg m^{-2} with maximum value in December. The low concentration of chl-*a* was noticed near the islands, which increased in waters away from the coasts during pre and postmonsoon seasons. The north of Lakshadweep Sea had high concentration of chl-*a* ($> 15 \text{ mg m}^{-2}$) during premonsoon season.

Bay of Bengal

The concentration of chl-*a* in the Bay of Bengal was very similar to that of the Arabian Sea. The annual average in the region is 13.0 mg m^{-2} or 6.7×10^3 tones whereas the seasonal average showed that it was maximum (22.0 mg m^{-2}) in postmonsoon. It was followed by SW monsoon (14.8 mg m^{-2}) and postmonsoon (8.1 mg m^{-2}). The maximum chl-*a* variation, observed during SW monsoon season ($1.1\text{--}93.2 \text{ mg m}^{-2}$), was followed by premonsoon. Similar feature was also observed in the Arabian Sea in this season. The annual variation was less than that of the Arabian Sea. In the region, Bhattathiri, *et al.*¹¹ reported value to vary from 1.1 to 50.7 mg m^{-2} . Present study shows much higher range. This difference may be due to the value of pheopigments included in the IIOE data and it may be about 10% of the values (Banse¹²). Figures 2-4 show some of the highest pockets of chl-*a* in coastal waters off Calcutta and

Visakhapatnam during premonsoon and SW monsoon season, whereas nothing can be said for this region during postmonsoon season as only one observation was available. Sarupria & Conkright¹³ also reported seasonal averages in the northern Indian Ocean and the higher average (23.2 mg m^{-2}) during postmonsoon period in the offshore region including the EEZ waters of the Bay of Bengal. They also reported highest value in the region during SW monsoon 1988 (106.0 mg m^{-2}).

Andaman Sea

The EEZ around Andaman and Nicobar Islands is spread between lat. 14° to 5°N and long. 89° to 95°E . The annual average of chl-*a* in the Andaman Sea was 7.8 mg m^{-2} or 4.38×10^3 tones. This annual average is half of the Bay of Bengal average. Sarupria & Conkright¹³ reported the annual average in the region (19.3 mg m^{-2}) while calculating the chl-*a* in the northern Indian Ocean. In the present study, observations were taken in the EEZ waters nearer to the coast. The seasonal average concentration in the region was comparable to that in the Bay of Bengal during premonsoon, whereas chl-*a* values were lower than that of the Bay of Bengal during postmonsoon and SW monsoon seasons. The maximum variation in the region was observed during premonsoon season ($0.4\text{--}34.0 \text{ mg m}^{-2}$). Similar observation was reported by Sarupria & Conkright¹³. Seasonal concentration of chl-*a* in the region in nearshore waters is high ($> 15 \text{ mg m}^{-2}$) and it gradually decreases as the distance increases from the shore during premonsoon season. Observations in SW monsoon were not adequate for discussion.

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