

SEASONAL PRIMARY PRODUCTION IN DIFFERENT SECTORS OF THE EEZ OF INDIA

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ABSTRACT

The seasonal and regional variations in the primary production, based on the data collected at 562 stations over the period from 1962 to 1988, are presented. The entire Indian Exclusive Economic Zone (EEZ), measuring 2.01 million km² is divided into four sectors viz., Arabian Sea (0.698 x 10⁶ km²), Bay of Bengal (0.515 x 10⁶ km²), Lakshadweep Sea (0.230 x 10⁶ km²) and Andaman Sea (0.567 x 10⁶ km²). The average seasonal primary production of the EEZ was found to be 682.16 mgCm⁻²d⁻¹ during SW monsoon (June-September), 415.63 mgCm⁻²d⁻¹ during premonsoon (February-May) and 291.56 mgCm⁻²d⁻¹ during NE monsoon (October-January). The maximum seasonal production in all sectors of the EEZ was found during SW monsoon, except in the Lakshadweep Sea where maximum production was found during pre monsoon period. The average annual primary production for the entire EEZ was calculated to be 453.67 mgCm⁻²d⁻¹.

Key-words: Primary production, EEZ of India.

The data on primary production for the EEZ of India are available for different months, but hardly any attempt has been made to arrive at a seasonal picture. Therefore, an attempt has been made to evaluate the primary production in each of the seasons in different sectors as the works of Nair (1970); Qasim (1977, 1982); Radhakrishna, Bhattathiri and Devassy (1978); Kabanova (1968); Cushing (1973); Devassy, Bhattathiri and Radhakrishna (1983); Bhattathiri, Devassy and Radhakrishna (1980) and Desai, Bhargava, and Sarupria (1990) provide annual estimate of primary production for small sectors of the Arabian Sea and Bay of Bengal.

The Exclusive Economic Zone of India, which is about 2/3 of India's landmass, is considered here for the study. It spreads over 2.01 x 10⁶ sq km off the Indian coastline of 7517 kms (including that of Islands). The data available (till 1988) in the Indian National Oceanographic Data Centre of NIO from the International Indian Ocean Expedition (1960-65) and subsequent cruises of INS *Darshak*, R.V. *Gaveshani* and ORV *Sagar Kanya* are used here. All the data used in this paper have been obtained by ¹⁴C method and expressed as mgCm⁻²d⁻¹.

The EEZ is divided into four sectors for the present study. Out of these, two viz., Arabian Sea and Lakshadweep Sea are well studied, while the Bay of Bengal and Andaman Sea have not been covered adequately. The study area has been divided into one degree squares and there are 249 such squares. Among these, a few squares

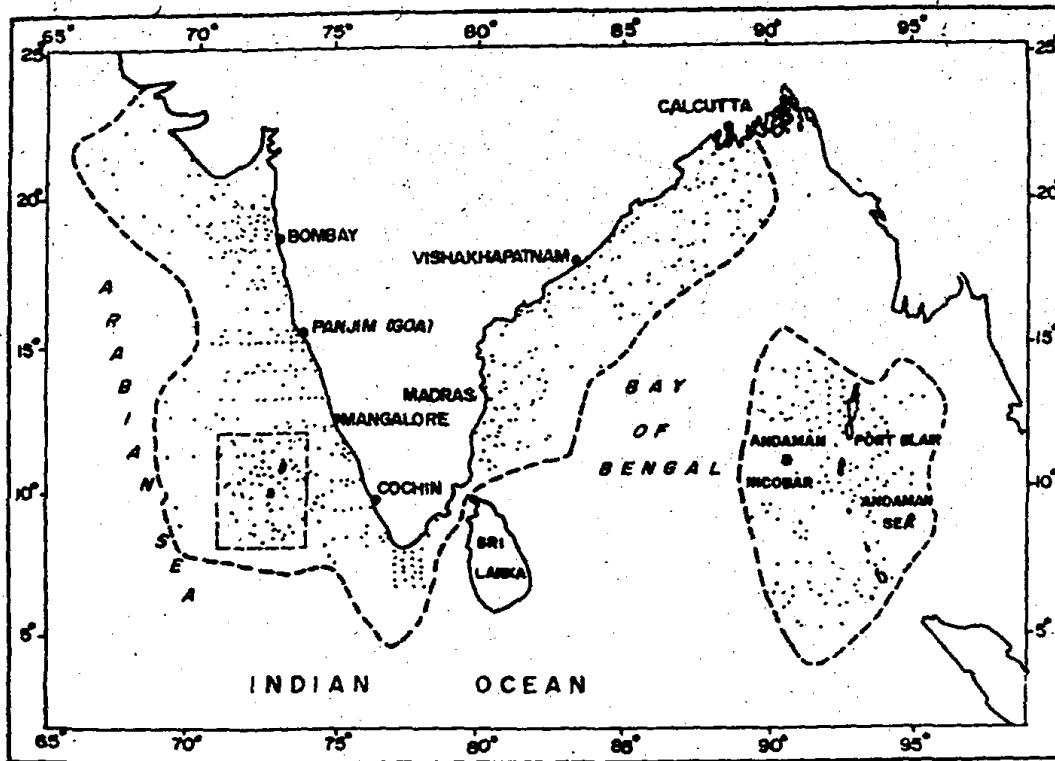


Fig. 1. Map indicating the location of stations.

Table I - Average seasonal primary production in different sectors of the EEZ.

EEZ Sectors	Area in km ² x 10 ⁶	Seasons	No. of Obs.	Production (mgCm ⁻² d ⁻¹)	
				Range	Average
Arabian Sea	0.698	Premonsoon	77	30.0 - 1552.15	550.63
		SW monsoon	50	30.0 - 4550.00	720.94
		NE monsoon	80	15.0 - 1390.00	289.74
		Total	207	Average	490.74
Lakshadweep Sea	0.230	Premonsoon	21	12.0 - 648.00	335.09
		SW monsoon	12	40.0 - 1225.00	161.46
		NE monsoon	14	21.0 - 263.00	152.23
		Total	47	Average	236.29
Bay of Bengal	0.516	Premonsoon	75	70.0 - 1530.00	466.75
		SW monsoon	64	49.03 - 3608.23	765.90
		NE monsoon	5	6.0 - 46.00	24.80
		Total	144	Average	584.36
Andaman Sea	0.566	Premonsoon	130	3.0 - 860.00	319.19
		SW monsoon	11	70.0 - 1960.00	586.73
		NE monsoon	23	196.1 - 1044.02	440.68
		Total	164	Average	354.17

have not been covered in any season. These gaps, wherever possible, have been filled up by interpolation. The contours were drawn at the interval of 100 units. The total number of observations are 562 (Fig. 1). The year has been divided into three seasons viz., pre-monsoon (February-May), SW monsoon (June-September) and NE monsoon (October-January). The details for seasonal and areawise observations are given in Table I.

The highest average column production in the entire EEZ was observed during the SW monsoon ($682.16 \text{ mgCm}^{-2}\text{d}^{-1}$) period followed by premonsoon ($415.63 \text{ mgCm}^{-2}\text{d}^{-1}$) and NE monsoon ($291.56 \text{ mgCm}^{-2}\text{d}^{-1}$). The yearly weighted average for the entire EEZ is $453.67 \text{ mgCm}^{-2}\text{d}^{-1}$. The sectorwise data analysis for column primary production (pp) is as follows :

Arabian Sea

The values of pp in the Arabian Sea ranged between 30.0 and $1552.15 \text{ mgCm}^{-2}\text{d}^{-1}$ (av. 550.63) in premonsoon, 30.0 and $4550 \text{ mgCm}^{-2}\text{d}^{-1}$ (av. 720.94) in SW monsoon and 15 and $1390.0 \text{ mgCm}^{-2}\text{d}^{-1}$ (av. 289.74) in NE monsoon. The annual average production has been computed as $490.74 \text{ mgCm}^{-2}\text{d}^{-1}$. Qasim (1982), while reviewing the productivity studies in the northern Arabian Sea obtained the highest average ($921.33 \text{ mgCm}^{-2}\text{d}^{-1}$) during SW monsoon season which is higher than the present estimate. The average column production in the northeastern Arabian Sea reported by Radhakrishna, Devassy, Bhattathiri & Bhargava (1978) was $700.00 \text{ mgCm}^{-2}\text{d}^{-1}$ during December to May. Cushing (1973) estimated the production rate at various places and reported $1160.00 \text{ mgCm}^{-2}\text{d}^{-1}$ in upwelling areas of the Arabian Sea and $760 \text{ mgCm}^{-2}\text{d}^{-1}$ in the Arabian Sea during SW monsoon period. In the present study during the same period similar trends were noticed. However pp values are low in the present study. This may be due to the weighted average, which is based on different years whereas that of Cushing (1973) is based on one year only.

The rate of column production (Fig. 2) in premonsoon, shows high value ($1050 \text{ mgCm}^{-2}\text{d}^{-1}$) off Gujarat coast and offshore areas between Goa and Mangalore. This decreases gradually towards south and offshore to $150 \text{ mgCm}^{-2}\text{d}^{-1}$. This may be due to the shallowness of the photic depth which is a characteristic feature of fertile water (Qasim, 1982) and latitudinal variation of light energy. The SW monsoon data (Fig. 3) indicate high rates of pp off Cochin and Cape Comorin and decreasing trend from Cochin to Mangalore sectors. During NE monsoon (Fig. 4) the productivity rates are quite low compared to other seasons. High production rate is also found off Bombay coast and the coastal area between Mangalore and Cochin.

The average annual rate of pp shows high rates in the nearshore waters between Goa and Mangalore. This is followed by the nearshore waters along Kerala and

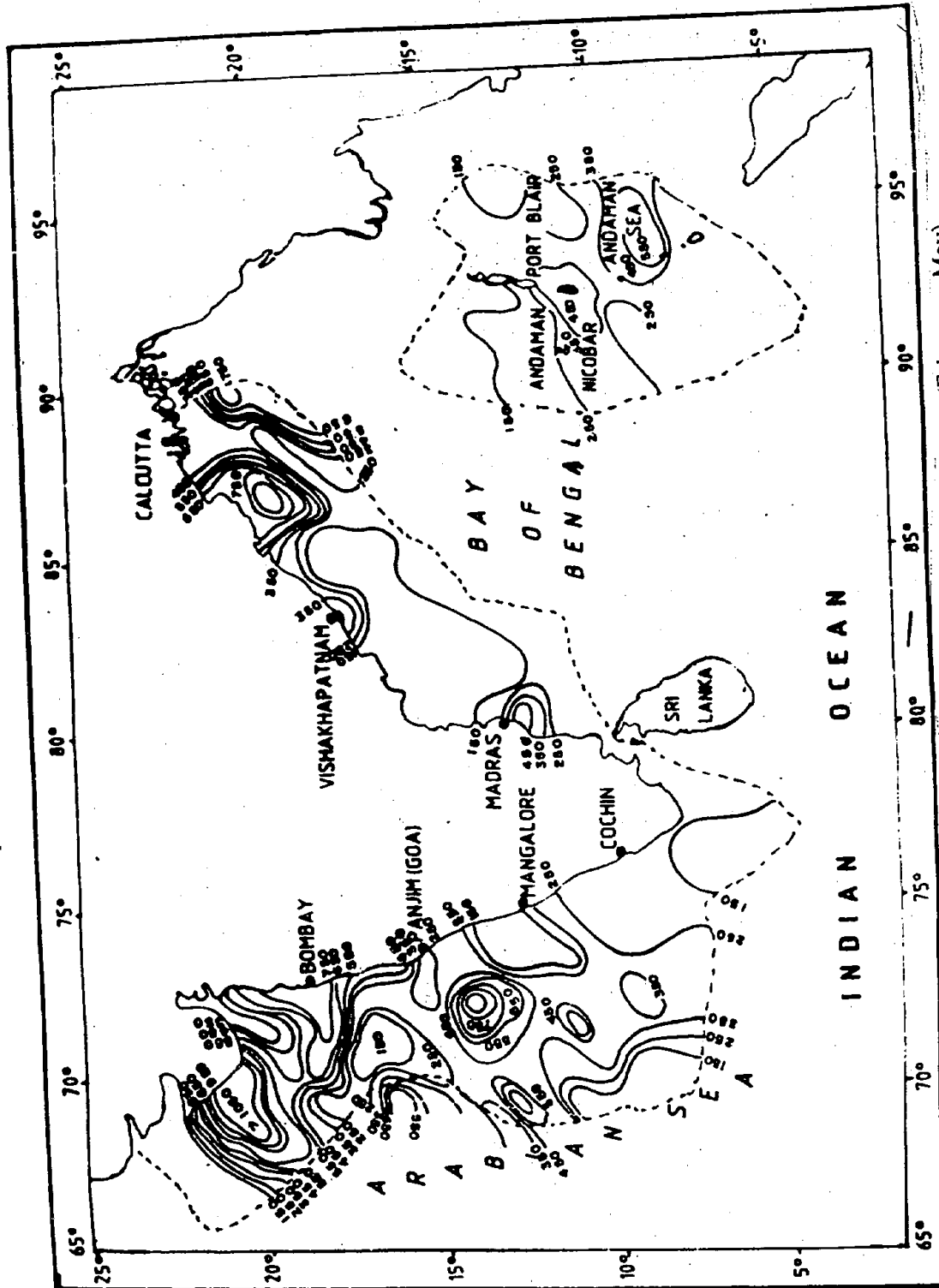


Fig. 2. Rates of column primary production $\text{mgCm}^{-2}\text{d}^{-1}$ during premonsoon (February - May)

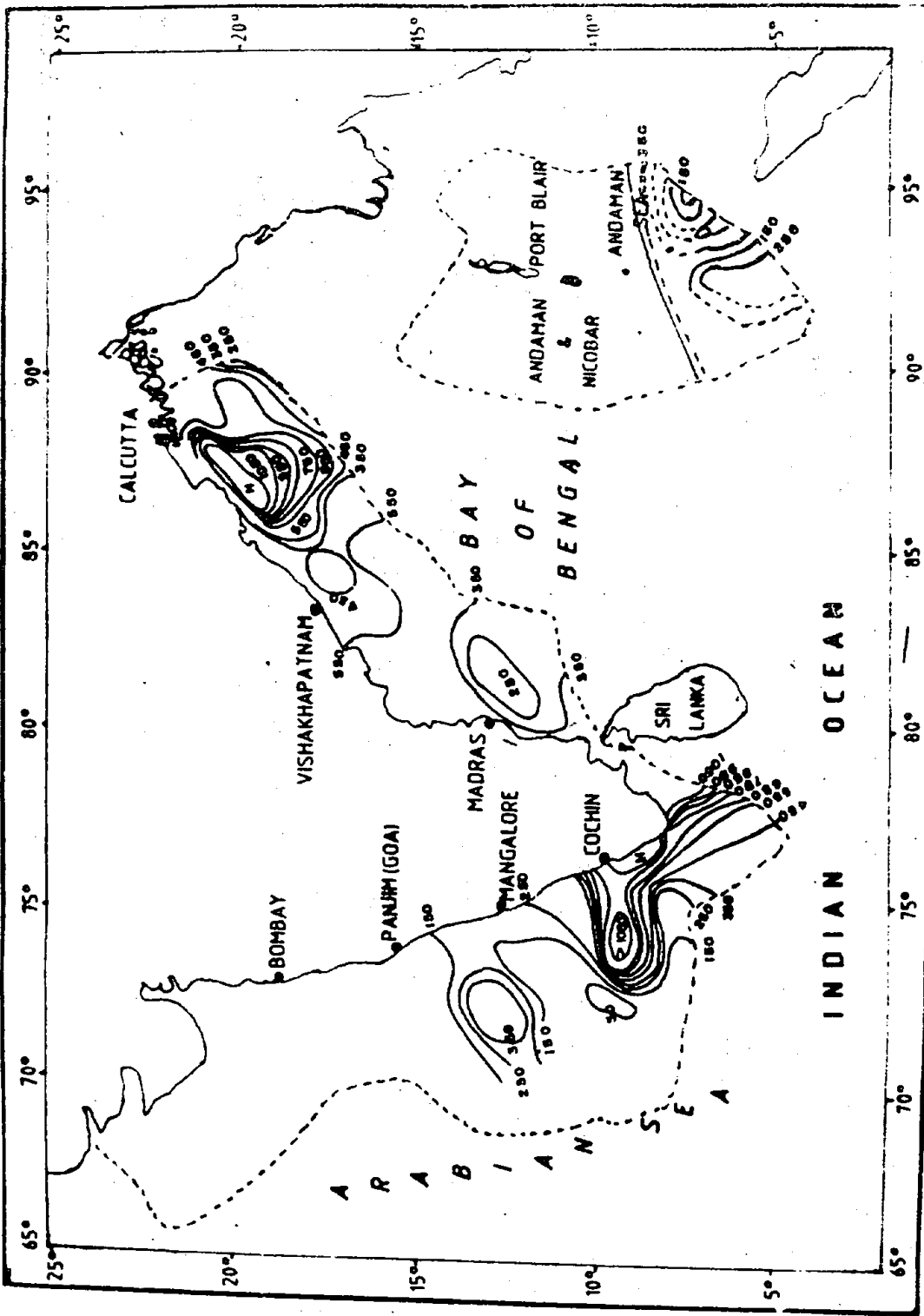


Fig. 3. Rates of column primary production $\text{mgCm}^{-2}\text{d}^{-1}$ during SW monsoon (June - September)

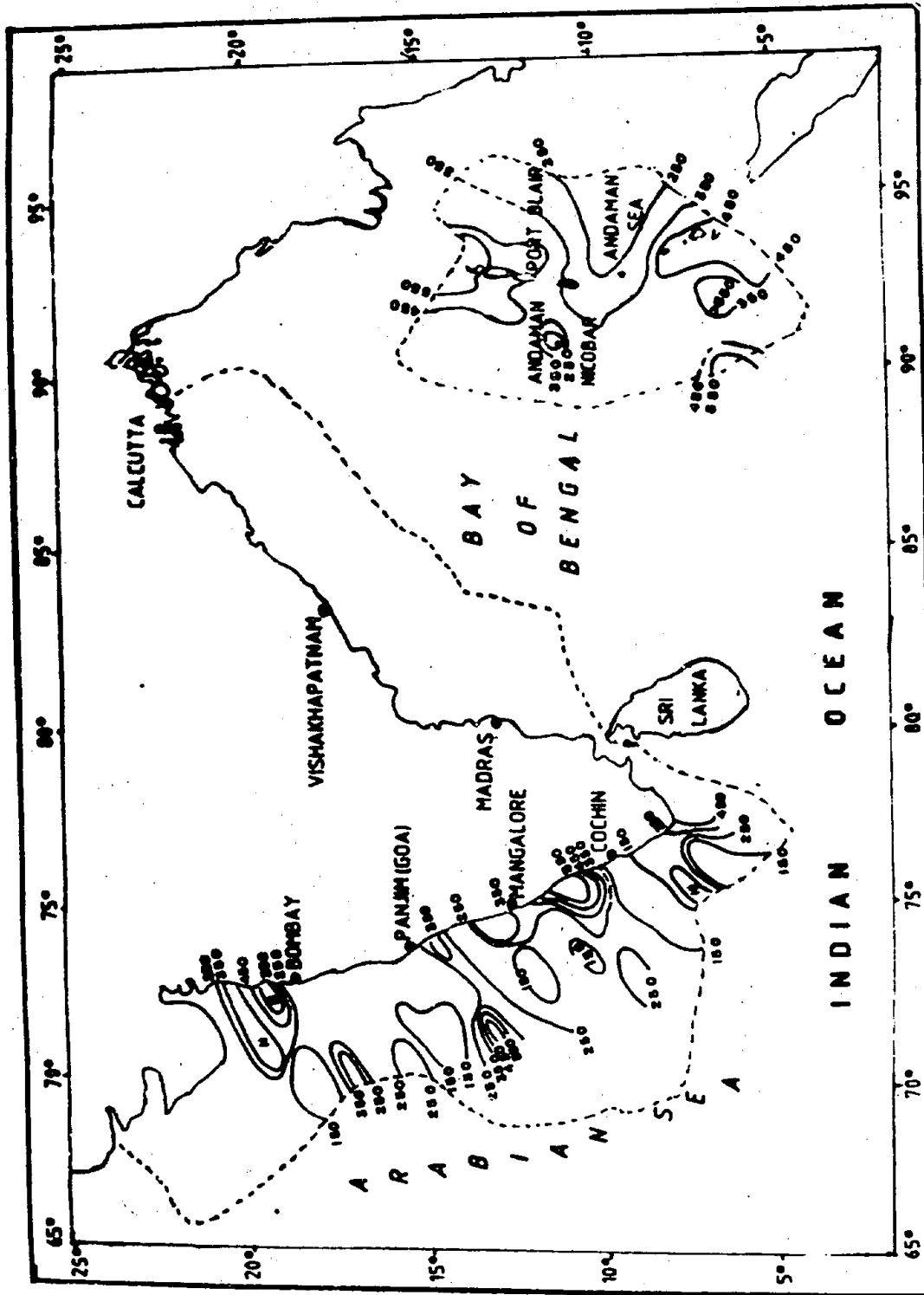


Fig. 4. Rates of column primary production $\text{mgCm}^{-2}\text{d}^{-1}$ during NE monsoon (October - January.)

Bombay coasts. As expected the values decrease towards offshore. A rate of 700-900 $\text{mgCm}^{-2}\text{d}^{-1}$ is seen off Bombay and Gujarat.

Lakshadweep Sea

In the Lakshadweep Sea, the premonsoon average is maximum (335.09 $\text{mgCm}^{-2}\text{d}^{-1}$) followed by SW monsoon (161.46 $\text{mgCm}^{-2}\text{d}^{-1}$) and NE monsoon (152.23 $\text{mgCm}^{-2}\text{d}^{-1}$). The ranges for the three seasons are 12.0 to 648.0 in premonsoon; 40.0 to 1225.0 in SW monsoon and 21.0 to 263.0 $\text{mgCm}^{-2}\text{d}^{-1}$ in NE monsoon. These values indicate that maximum fluctuation in production is in SW monsoon period whereas the highest production is observed during premonsoon period. In this area Bhattathiri and Devassy (1979) reported average column production of 372 $\text{mgCm}^{-2}\text{d}^{-1}$ during premonsoon period. It is observed that the production was found to be less in the waters very near to the islands. The maximum average production was observed during premonsoon, whereas in other three sectors it is observed during SW monsoon.

Bay of Bengal

In the Bay of Bengal, the column production varies from 70.0 to 1530 $\text{mgCm}^{-2}\text{d}^{-1}$ in premonsoon, 49.03 to 3608.23 $\text{mgCm}^{-2}\text{d}^{-1}$ in SW monsoon and from 6 to 46.0 $\text{mgCm}^{-2}\text{d}^{-1}$ in NE monsoon. The respective averages being 466.75, 765.9 and 24.8 $\text{mgCm}^{-2}\text{d}^{-1}$ in the three seasons. The NE monsoon average is based on five observations hence it is not a representative figure for the Bay of Bengal as well as for the season. High production is found in the offshore area between Visakhapatnam and Calcutta during SW monsoon (Fig. 3) and premonsoon (Fig. 2).

Seasonal data coverage in the Bay of Bengal is not very comprehensive. The productivity during SW monsoon period reported by earlier authors is summarised below:

	Column production ($\text{mgCm}^{-2}\text{d}^{-1}$)		
	1976 (Radhakrishna, Bhattathiri and Devassy, 1978)	1977 (Devassy, Bhattathiri and Radhakrishna, 1983)	1978 (Bhattathiri, Devassy and Radhakrishna, 1980)
Minimum	49.66	140.0	120.0
Maximum	606.37	5590.0	3410.0
Average (No. of Observations)	315.43 (29)	640.0 (74)	980.0 (33)

However, the production off Madras and at the mouth of Cauvery River was 3000 $\text{mgCm}^{-2}\text{d}^{-1}$ which is slightly higher than that at other places. In the present study the average value during SW monsoon period is 765.90 $\text{mgCm}^{-2}\text{d}^{-1}$ and the average for the entire year is 584.36 $\text{mgCm}^{-2}\text{d}^{-1}$. This high figure could be due to less number of observations in NE monsoon, a season of low productivity. The offshore waters

(Depth > 200 m) show a low rate of production ($30-500 \text{ mgCm}^{-2}\text{d}^{-1}$), while nearshore waters (Depth < 200 m) between Calcutta and Visakhapatnam exhibit high rates *i.e.* $1100 \text{ mgCm}^{-2}\text{d}^{-1}$ (Fig. 3). In general, the pp rates do not follow any particular trend in this area.

Andaman Sea

In the Andaman Sea, the maximum average production is noticed during the SW monsoon ($586.73 \text{ mgCm}^{-2}\text{d}^{-1}$) followed by NE monsoon ($440.68 \text{ mgCm}^{-2}\text{d}^{-1}$) and premonsoon ($319.19 \text{ mgCm}^{-2}\text{d}^{-1}$). Bhattathiri (1984) reported column production with maximum range and average values during the SW monsoon and lowest in premonsoon in Andaman Sea. He reported column production ranging from 120 to 615 $\text{mgCm}^{-2}\text{d}^{-1}$ with an average of 273 in February 1979. He has also reported an average of $426 \text{ mgCm}^{-2}\text{d}^{-1}$ ranging from 196 to $1218 \text{ mgCm}^{-2}\text{d}^{-1}$ during January 1980. The annual average production ($354.17 \text{ mgCm}^{-2}\text{d}^{-1}$) shows that the Andaman Sea is more productive than the Lakshadweep Sea.

The primary productivity data given above is an index for the fertility of the EEZ and can form basis for estimating the fishery potential of this area (Desai, Bhargava and Sarupria, 1990).

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REFERENCES

- Bhattathiri, P.M.A. and V.P. Devassy, 1979. Biological characteristics of the Lakshadweep Sea. *Indian Journal of Marine Sciences*, 8: 222-226.
- Bhattathiri, P.M.A., V.P. Devassy and K. Radhakrishna, 1980. Primary production in the Bay of Bengal during SW monsoon of 1978, *Mahasagar-Bulletin of the National Institute of Oceanography*, 13:315-323.
- Bhattathiri, P.M.A., 1984. Primary production and some physical & chemical parameters of Lakshadweep and Andaman Sea. Ph.D. Thesis, University of Bombay, pp 190.
- Cushing, D.H., 1973. Production in the Indian Ocean and the transfer from the primary to the secondary level. In: *The Biology of the Indian Ocean, Ecological Studies*, 3, B. Zeitschel (Ed.) Springer-Verlag, Berlin, Heidelberg, New York: 475-486.

- Desai, B.N., R.M.S. Bhargava and J.S. Sarupria, 1990. Estimates of fishery potentials of the EEZ of India. *Estuary, Coastal Shelf Science*, 30: 635-639.
- Devassy, V.P., P.M.A. Bhattathiri and K. Radhakrishna, 1983. Primary production in the Bay of Bengal during August, 1977. *Mahasagar-Bulletin of the National Institute of Oceanography*, 16: 443-447.
- Kabanova, J.G. 1968. Primary production of the northern part of the Indian Ocean. *Oceanology*, 8: 214-225.
- Nair, P.V.R., 1970. Primary productivity of the Indian Seas. *Bulletin of the Central Marine Fisheries Research Institute, Mandapam Camp. No. 22, Mimeo*, 56 pp.
- Qasim, S.Z., 1977. Biological productivity of the Indian Ocean. *Indian Journal of Marine Sciences*, 6: 122-137
- Qasim, S.Z., 1982. Oceanography of the northern Arabian Sea. *Deep Sea Research*, 29: 1041-1068.
- Radhakrishna, K., 1969. Primary productivity studies in the shelf waters off Alleppy, south west India during the post monsoon, 1967, *Marine Biology*, 4: 174-181.
- Radhakrishna, K., 1978. Primary production of the Bay of Bengal during March-April, 1975, *Indian Journal of Marine Sciences*, 7: 58-60.
- Radhakrishna, K., P.M.A. Bhattathiri and V.P. Devassy, 1978. Primary productivity of the Bay of Bengal during August- September, 1976. *Indian Journal of Marine Sciences*, 7: 94- 98.
- Radhakrishna, K., V.P. Devassy, P.M.A. Bhattathiri and R.M.S. Bhargava, 1978. Primary production in north eastern Arabian Sea. *Indian Journal of Marine Science*, 7: 137-139.
- Radhakrishna, K., V.P. Devassy, R.M.S. Bhargava and P.M.A. Bhattathiri, 1978. Primary production in the northern Arabian Sea. *Indian Journal of Marine Sciences*, 7: 271-275.