

Primary production in the southeastern Arabian Sea during southwest monsoon

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Daily primary production averaged 7.74 mgC.m^{-3} at the surface and 95.97 mgC.m^{-2} in the column. The mean chl *a* concentration at the surface was 0.11 mg.m^{-3} and in the column it was 3.43 mg.m^{-2} . Primary production and chl *a* concentrations were observed to be significantly correlated both at the surface and at different light depths.

Information on primary production is necessary for assessing the fertility and predicting the potential of living resources. Although studies on primary production have been carried out in the southeastern Arabian Sea¹⁻⁵, seasonal coverage especially during the southwest monsoon is still meagre. Hence, primary productivity measurements have been carried out and the results are presented in this communication.

Methods

Primary productivity measurements were made from 27 stations in June-July 1987 during 33rd cruise of *ORV Sagar Kanya* (Fig. 1). Secchi disc was used to measure light penetration and depths corresponding to 60, 30, 16 and 1% light penetration were calculated. Water samples from these depths (0-40 m) as well as from the surface were collected with 5 l PVC Niskin sampler. Primary productivity was measured by ¹⁴C method. Samples were incubated for 24 h covered with appropriate neutral density filters on the deck. After incubation, water samples were filtered through $0.45 \mu\text{m}$ Millipore filters and the filters were kept in vials containing 5 ml scintillation cocktail. Radioactivity of these filters was counted in LKB Rack Beta liquid scintillation counter. Chlorophyll *a* (chl *a*) was estimated using Turner design fluorometer.

Results and Discussion

Chl *a* concentration and primary production values both at the surface and in the column are given in Table 1. Exceptionally high values of chl *a* and primary production were recorded in sts 1, 3 and 4 and these values were not considered for

averaging. In fact at sts 3 and 4 total phytoplankton counts were high ($803.12 \times 10^5 \text{ m}^{-3}$ and $1043.02 \times 10^5 \text{ m}^{-3}$ respectively) and was composed of mostly diatoms, dominated by *Nitzschia serriata*, *Chaetoceros socialis* and *Rhizosolenia denticata*. The high phytoplankton number might have probably contributed to the very high chl *a* concentration in these 2 stations leading to high production. Surface chl *a* varied from 0.03 to

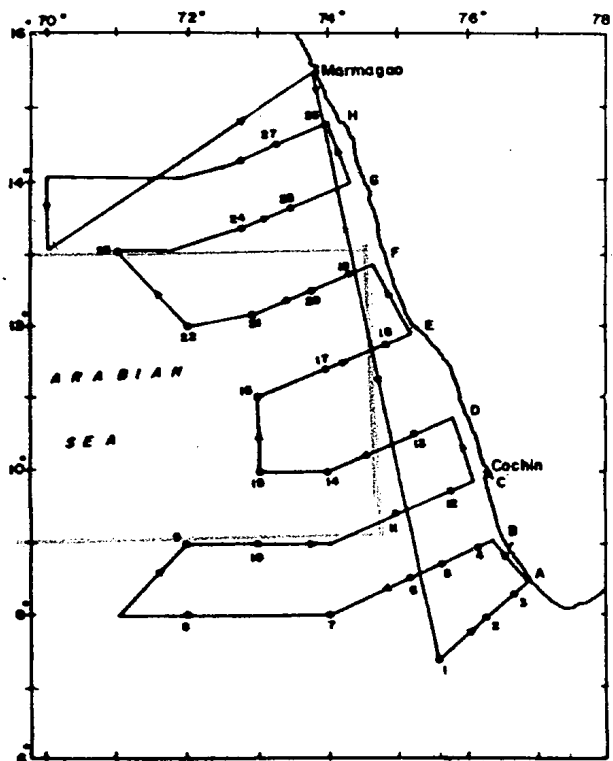


Fig. 1 - Station locations

Table 1 - Chlorophyll concentration and primary productivity in the southern Arabian Sea (June-July 1987)

St No.	Surface chl <i>a</i> (mg.m ⁻³)	Surface production (mgC.m ⁻³ d ⁻¹)	Column chl <i>a</i> (mg.m ⁻²)	Column production (mgC.m ⁻² d ⁻¹)
1	1.02	3.84	6.81	290.84
2	0.14	10.07	2.98	124.19
3	3.18	134.42	46.44	1256.19
4	2.26	232.25	28.07	1972.06
5	0.07	8.49	3.28	256.48
6	0.06	2.92	1.45	60.85
7	0.05	9.26	1.71	70.77
8	0.07	3.56	2.90	55.63
9	0.09	3.88	3.29	105.92
10	0.07	2.16	2.80	41.11
11	0.03	5.41	1.67	35.69
12	0.14	22.64	6.47	155.23
13	0.21	16.24	11.00	131.70
14	0.05	1.19	2.53	41.63
15	0.05	1.88	2.38	49.48
16	0.04	1.84	1.63	75.13
17	0.04	11.04	1.73	94.83
18	0.20	31.47	10.03	216.23
19	0.15	8.17	3.29	127.50
20	0.17	4.47	2.25	54.80
21	0.05	2.22	2.04	59.02
22	0.19	4.07	2.34	98.79
23	0.05	2.34	2.40	68.83
24	0.06	11.36	2.95	76.05
25	0.20	1.07	2.90	77.31
26	0.23	13.79	6.72	133.87
27	0.12	6.23	1.50	92.32
Mean	0.11	7.74	3.43	95.97

3.18 mg.m⁻³ and averaged 0.11 mg.m⁻³. Column chl *a* ranged from 1.45 to 11 mg.m⁻² (av. 3.43 mg.m⁻²). Bhargava *et al.*⁴ reported a value of 0.12 mg.m⁻³ for surface chl *a* and 8.52 mg.m⁻² for the column in the same area during postmonsoon (October-December 1976). Gomes⁵ reported a variation from 0.11 to 0.24 mg.m⁻³ at the surface and 3.8 to 17.8 mg.m⁻² in the column in the Arabian Sea in premonsoon (January-February 1982). Compared with the chl *a* values at the surface and in the column reported by Qasim⁶ for the northern Arabian Sea, the values reported for the southern Arabian Sea are less.

Primary production at the surface ranged from 1.07 to 22.65 mgC.m⁻³d⁻¹ (av. 7.74). Exceptionally high values were encountered in the shelf region off Trivandrum (134.42 mgC.m⁻³d⁻¹) and off Quilon (232.25 mgC.m⁻³d⁻¹). In the offshore region, values of primary production were less than that recorded for the shelf region. However, at st 24, a fairly high value was recorded (11.4 mgC.m⁻³d⁻¹).

Column production integrated for the euphotic zone varied from 35.69 to 256.48 mgC.m⁻²d⁻¹ (av. 95.97 mgC.m⁻²d⁻¹; Table 1). In the shelf region, productivity averaged 160 mgC.m⁻²d⁻¹ exclusive of high values localised around off Trivandrum and Quilon. In the offshore region, production averaged 74 mgC.m⁻²d⁻¹. However, production < 50 mgC.m⁻²d⁻¹ was encountered in C and D transects and pockets of high production (100 mgC.m⁻²d⁻¹) were recorded at sts 9 and 22. A comparison of earlier data on primary production from the same area showed that the mean value recorded in the present study is close to the value recorded during *Anton Brunn*¹ expedition and less than others²⁻⁶. Taking the study area as 5.03 × 10⁵ km², total production would be 17.84 × 10⁶ tonnes C.y⁻¹. Qasim⁶ reported a value of 518 × 10⁶ tonnes C.y⁻¹ as total production in the northern Arabian Sea, thereby showing that the northern region is more fertile than the southern region.

Correlation between primary production and chl *a* was significant both at the surface as well as in the column. The predictive equations are:

Surface pp (mgC.m⁻³d⁻¹) = 1.16 + 58.4 surface chl *a* in mg.m⁻³ ($r=0.86$).

Column pp (mgC.m⁻²d⁻¹) = (37.1 column chl *a* in mg.m⁻²) - 8.9 ($r=0.9$)

Column pp (mgC.m⁻²d⁻¹) = 42.5 + 520 surface chl *a* in mg.m³ ($r=0.85$).

Such a close correlation between column primary production and surface chl *a* suggests that it would be possible to deduce the magnitude of euphotic zone productivity over vast areas from the surface chl *a* concentrations alone, which can be instantaneously measured by remote sensing techniques. At different light depths also there was significant correlation between primary productivity and chl *a* concentrations (at 60% $r=0.82$, at 30% $r=0.94$ and at 16% $r=0.92$ for $n=27$). However at 1% light depth there was no correlation.

Fig. 2 shows the pooled average values of primary production and chl *a* concentration for all stations at different light depths. Primary production profile demonstrates that there is no pronounced maximum at intermediate light depths, as in the non-monsoon months. Primary production at surface was not significantly different from that at 60% light depth ($F=0.59$; $d.f=1,48$) and the primary production maximum lying at or near the surface can be explained as a consequences of a greater cloud coverage in the monsoon months. Chl *a*, on the other hand registered a declining

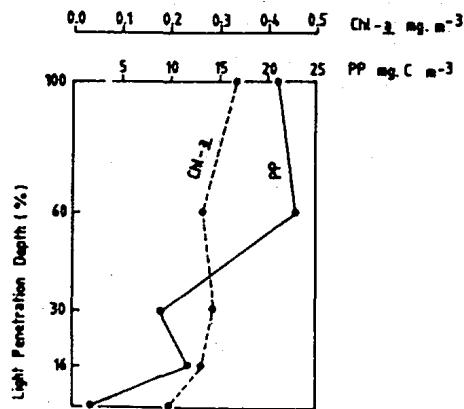


Fig. 2 – Primary production and chl *a* concentration in relation to different light penetration depths.

trend from 100 to 1% light penetration depth. Bhargava *et al.*⁴ reported maximum production at the surface in the southeastern Arabian Sea as in the case of the present study. Subsurface maximum in primary production was recorded in the southwestern Arabian Sea³ and in the northern Arabian Sea.⁷

Distribution of primary production and chl *a* in relation to latitudes (Fig. 3) showed a peak at 8° lat. Minimum production was at 13° lat. Latitudinal fluctuations in chl *a* concentrations followed the same pattern as that of primary production.

Among the nutrients NO₃ and NO₂ were present in measurable quantities within the euphotic zone only at sts 1,3,4,6,12,13, and 26. Phosphate was present in almost all the stations both at the surface and in column integrated for the euphotic zone, and hence it would not be a limiting nutrient for primary production. This would mean that the primary production in most of the stations is probably regulated by the rate of supply of regenerated nitrogen. By contrast in the upwelling zone where there was surplus nitrate in the water column, primary production was very high. It was also observed that there was evidence of upwelling all along the coastline over the shelf. The intensity of upwelling decreased as one

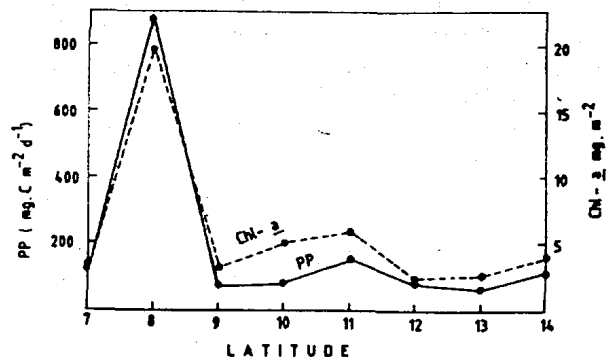


Fig. 3 – Primary production and chl *a* concentration in relation to different latitudes

moved towards the north (S R Shetye-personal communication). It was also observed that upwelling was intense around 8° lat. when monsoon was very active and it subsided with fair weather. This is reflected in the distinct peak of primary production observed at 8° lat. It is well known that upwelling acts as first link in the food chain and enriches the euphotic zone leading to a bloom of phytoplankton.

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References

- 1 Anon, *Anton Brunn, Final Report, Cruise no. 2* (Woods Hole Institute of Oceanography, Woods Hole, USA) 1965.
- 2 Anon, *Meteor Forschungsergebnisse*, Riech O.No. 9 (Gebruder Bortntraeger, Berlin, FRG) 1971, 120.
- 3 Radhakrishna K, *Mar Biol* 4 (1969) 174.
- 4 Bhargava R M S, Bhattathiri P M A, Devassy V P & Radhakrishna K, *Indian J Mar Sci*, 7 (1978) 267.
- 5 Gomes H R, *Studies on the dissolved organic matter in the marine environment*, Ph.D. thesis, University of Bombay, 1985.
- 6 Qasim S Z, *Deep-Sea Res*, 29 (1982) 1041.
- 7 Radhakrishna K, Devassy V P, Bhargava R M S & Bhattathiri P M A, *Indian J Mar Sci*, 7 (1978) 271.