

## Primary Productivity in the North-Eastern Arabian Sea

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Primary productivity, chlorophyll *a* and related data from 23 stations in the NE Arabian sea are presented. Productivity in the waters of shelf region averages  $474.56 \text{ mgC m}^{-2} \text{ d}^{-1}$ , and is almost thrice the offshore average of  $164.39$ . Correlation between chlorophyll *a* and primary production is highly significant. Assimilation number in the shelf region averages 96 and 22 offshore; the variation is attributed to the distribution of nannoplankton. Relationship of light intensity, POC and nutrients with productivity are briefly discussed.

**P** PRIMARY productivity measurements from the coastal waters of India are still meagre. Although a good deal of information is available from the Indian Ocean<sup>1,2</sup> in general there are still large lacunae, especially of the Indian coast. The present study has been made to collect further information in this direction.

Primary productivity, chlorophyll *a*, pheophytin and particulate organic carbon (POC) were measured at 23 stations in the NE Arabian Sea. The data were collected in 3 cruises of RV *Gaueshani* (2nd cruise—February 1977; 3rd cruise—March 1977 and 12th cruise—November 1977). The station locations are given in Fig. 1.

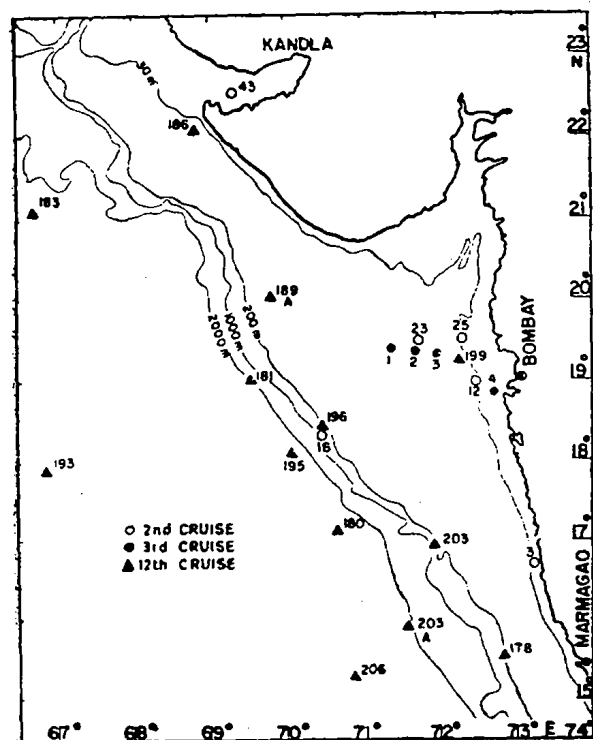


Fig. 1 — Station locations

Samples were collected from the optical depths of 100, 60, 30, 16 and 1% light penetration. Primary production was measured by incubating the samples for 24 hr under simulated *in situ* conditions. Chl. *a* was measured with Turner Designs fluorometer and pheophytin correction applied. POC was determined by wet acid digestion and colorimetry.

South of Ratnagiri, off Wagapur Point (station 3; cruise 2nd), primary productivity in the inshore waters at the surface was  $88.5 \text{ mgC m}^{-3} \text{ day}^{-1}$  and in the column,  $445.35 \text{ mgC m}^{-2} \text{ day}^{-1}$  (Table 1). Chl. *a* and pheophytin were not detectable at the surface. Nutrient concentrations were low.

Off Bombay, during February-March, production was generally high (av.  $46.14 \text{ mgC m}^{-3} \text{ day}^{-1}$  at the surface  $636.51 \text{ mgC m}^{-2} \text{ day}^{-1}$  in the column). Correspondingly, chl. *a* averaged  $0.27 \text{ mg m}^{-3}$  at the surface and  $5.04 \text{ mg m}^{-2}$  in the column and pheophytin  $0.54$  and  $5.77$  respectively. POC was low ( $237.7 \text{ mg m}^{-3}$  and  $8.15 \text{ gm}^{-2}$  at the surface and column respectively). Nutrient values were high (e.g.  $\text{PO}_4\text{-P}$ , surface:  $0.9$  and  $\text{IMC}$ :  $1.14 \text{ } \mu\text{g-at l}^{-1}$ ). In view of the proximity to the shore and concomitant high concentrations of nutrients, production off Bombay, on the average, was high notwithstanding the wide variations encountered. High productivity was recorded very close to Bombay at stations 12 (February) and 199 (November)— $98.97$  and  $57.18 \text{ mgC m}^{-3} \text{ day}^{-1}$  at surface and  $1552.15$  and  $556.23 \text{ mg C m}^{-2} \text{ day}^{-1}$  in the column respectively. Chl. *a* values were also correspondingly high (Table 1).

In the Gulf of Kutch proper only 1 station was occupied (No. 43). The waters were very turbid and the euphotic zone was only 1.5 m although depth to the bottom was 29 m. Nutrient concentrations were high throughout the water column (surface to bottom) due to the influence of the Indus river discharge on the north. But production was low:  $66.05 \text{ mgC m}^{-3} \text{ day}^{-1}$  near the surface,  $40.62$  at 1.5 m and  $80 \text{ mgC m}^{-2} \text{ day}^{-1}$  integrated for the euphotic zone. Obviously, light was a limiting factor because of the high turbidity which in turn was due to the constant churning up of bottom sediments caused by the prevailing tidal bores on the one hand and the Indus river land runoff on the other.

In the north-eastern Arabian Sea, productivity in the shelf region was much higher than offshore. In the present study, the average value of 14 stations on the shelf for the surface was  $40.69 \text{ mg}$  as compared to  $4.9 \text{ mg}$  offshore (9 stations). Similarly, column productivity was  $474.56$  being 3 times higher than the offshore value of  $164.39 \text{ mgC m}^{-2} \text{ day}^{-1}$ .

Chl. *a* concentration varied from 0 to  $1.5 \text{ mg m}^{-3}$  at the surface. Higher concentrations, however, were encountered at lower depths. There was a very positive correlation significant at 0.001 level between chl. *a* and primary productivity at various light penetration depths as well as over the euphotic column (integrated). Correlation between light intensity and primary productivity was positive (significant at 0.02 level) but there was no correlation between light intensity and chl. *a* concentration at different depths. Mean values of primary production

TABLE 1 — PRODUCTIVITY AND NUTRIENT DATA AT VARIOUS STATIONS

Station No.	Surface					Column									
	Primary productivity mgC m <sup>-3</sup> day <sup>-1</sup>	Chloro- phyll <i>a</i> mg m <sup>-3</sup>	Pheophytin mg m <sup>-3</sup>	PO <sub>4</sub> -P µg at l <sup>-1</sup>	NO <sub>3</sub> -N µg at l <sup>-1</sup>	NO <sub>2</sub> -N µg at l <sup>-1</sup>	NH <sub>4</sub> -N µg at l <sup>-1</sup>	Primary producti- vity mgC m <sup>-3</sup> day <sup>-1</sup>	Chloro- phyll <i>a</i> mg m <sup>-2</sup>	Pheophytin mg m <sup>-2</sup>	POC µgC m <sup>-3</sup>	PO <sub>4</sub> -P* µg at l <sup>-1</sup>	NO <sub>3</sub> -N* µg at l <sup>-1</sup>	NO <sub>2</sub> -N* µg at l <sup>-1</sup>	NH <sub>4</sub> -N* µg at l <sup>-1</sup>
	2ND CRUISE														
3	88.52	—	—	0.19	0.09	—	0.56	445.35	6.87	8.33	—	0.22	0.22	—	1.26
12	98.97	0.56	1.91	0.65	2.72	0.17	1.45	1552.15	12	13.61	—	0.71	2.69	0.19	0.7
18	4.36	—	—	0.21	1.19	ND	0.92	387.08	15.52	8.97	—	0.76	2.51	ND	0.88
23	38.06	0.42	0.91	—	—	—	—	579.1	1.83	7.11	—	—	—	—	—
25	62.35	—	—	1.9	2.96	0.48	2.28	873.65	—	—	—	2.25	3.22	0.71	2.95
43	66.05	0.21	0.69	1.28	2.4	0.56	2.17	80	0.52	1.73	—	1.44	3.12	0.66	1.99
	3RD CRUISE														
1	6.71	0.07	0.03	0.42	1.59	0.07	4.6	202.79	4.34	3.22	13.65	0.73	2.5	0.24	3.12
2	6.29	0.08	0.03	0.31	0.79	0.03	1.83	326.77	5.18	4.91	8.25	0.71	3.2	0.09	1.93
3	41.08	0.2	0.24	0.72	2.51	3.44	2.21	637.99	5.54	5.49	8.12	1	3.02	1.11	2.26
4	69.51	0.29	0.12	1.42	6.01	0.47	3.58	283.15	1.36	0.55	2.07	1.44	6.11	0.54	3.4
	12TH CRUISE														
178	3.58	0.06	0.04	0.29	ND	ND	0.38	210.17	6.23	8.63	70.97	0.81	ND	ND	ND
180	4.16	0.02	0.04	0.13	0.76	0.22	1.5	128.51	8.45	3.42	32.67	0.7	0.15	0.19	0.61
181	2.88	0.07	0.05	0.21	0	0.4	0.38	118.91	6.37	9.34	30.71	0.77	1.5	0.49	0.41
183	3.96	0.09	0.01	0.36	0	0.49	8	111.76	4	5.11	20.1	0.92	0.16	0.29	0.5
186	16.11	0.17	0.1	0.47	0	0	9.06	312.07	10.92	7.96	18.47	0.5	0.36	ND	9.68
189 A	8.67	0.09	0.03	0.13	0	0.03	10.27	177.4	6.86	4.34	25.9	0.5	0	0.11	6
193	6.01	0.04	0.03	0.27	3.49	0.28	14.19	182.83	5.33	5.57	30.34	0.97	3.03	0.2	14.5
195	4.5	0.05	0.03	0.21	0	0.3	5.13	120	5.09	6.4	28.1	0.33	6.08	0.37	8.87
196	5.37	0.12	0.06	0.27	0	0.3	13.29	99.58	8.93	2.49	16.3	0.59	1.17	0	11.44
199	57.18	1.5	0.3	0.33	1.53	ND	4.68	556.23	28.8	2.1	13.5	0.64	0.65	ND	4.98
203	5.74	0.08	0.03	0.12	1.4	0.12	9.06	230.08	4.25	5.54	9.7	0.96	3.32	0.29	6.54
203 A	8.02	0.04	0.06	0.12	0.85	0.06	12	257.64	12.87	8.15	21.87	0.42	4	0.12	4.97
206	7.68	0.08	0.02	0.11	ND	0.06	4	297.89	21.07	8.66	34.85	0.43	ND	ND	—

\*Integral mean concentration values; — = no data; ND = not detectable.

SHORT COMMUNICATIONS

and chl. *a* for all stations at different light penetration depths are as follows:

Light penetration (%) depth	Primary productivity mg/m <sup>3</sup>	Chl. <i>a</i> mg/m <sup>3</sup>
100	26.77	0.212
60	12.29	0.282
30	11.54	0.241
16	9.29	0.261
1	5.47	0.193

The assimilation number (AN — primary productivity per unit chl. *a*) in the column averaged 96 in the shelf region varying from 24 at the deepest station to 208 at the shallowest station. Offshore, the AN averaged 22 varying from 11 to 34. This would indicate that the shelf productivity was due not only to chl. *a* but also to other accessory pigments. Earlier observations in the nearshore waters of Arabian Sea<sup>3,4</sup> showed that nanoplankton, composed mainly of flagellates that contain accessory pigments like other chlorophylls, xanthophylls, carotenoids, etc., accounted for 40-100% of the primary production. Our preliminary observations, on the other hand, show that the contribution of nanoplankton in the offshore waters is relatively less. This, to a certain extent, accounts for the low AN in the deeper waters. It is further observed that liberation of extracellular carbon per unit chl. *a* is much less in the shelf region as compared to offshore. This also would account for the observed lower values of carbon particulate fixation per unit chl. *a* offshore, where carbon assimilated during photosynthesis is simultaneously lost in extracellular liberation.

Correlation between light intensity and primary productivity was significant at 2.5% level (correlation coeff. 0.21 for n 107). However, the correlation between light intensity and chl. *a* distribution was not significant implying a patchy distribution of chlorophyll in the euphotic zone.

The pheophytin distribution followed the same trend as chl. *a*.

POC values (Table 1) did not show significant correlation with chl. *a* or productivity, either at the surface or in the column. Its distribution did not show any clear trend in the shelf or offshore. Similarly, nutrient concentrations (PO<sub>4</sub>-P, NO<sub>3</sub>-N, NO<sub>2</sub>-N and NH<sub>4</sub>-N) also had no significant relationship with productivity or chl. *a*, indicating that

nutrients are not a limiting factor for production during this study. They varied widely within stations and between stations (Table 1).

From the present data, the average primary productivity for the shelf region of Maharashtra and Gujarat is calculated as 474.56 mgC m<sup>-2</sup> d<sup>-1</sup>. This value is considerably higher than Kuzmenko's<sup>5</sup> range of <100 mg. Likewise, the present average of 1054.19 mgC m<sup>-2</sup> d<sup>-1</sup> found off Bombay is higher than Kuzmenko's range of 500 mg<sup>5</sup>. His range for waters off Gulf of Kutch is very high (>1000 mg) and for a station at the entrance of the Gulf he reported 2.23 gC m<sup>-2</sup> d<sup>-1</sup> (ref. 5). The station in the present study was well inside the Gulf with a productivity of 80 mgC m<sup>-2</sup> d<sup>-1</sup>.

Silas<sup>6</sup> reported the average primary productivity for the west coast within 50 m depth as 1.24 and between 50 and 200 m depth as 0.63 gC m<sup>-2</sup> d<sup>-1</sup>. These values are very high in comparison to the present values. In this connection, the statement by Krey and Babenerd<sup>1</sup>, "the experimental techniques, especially the measurements of primary production by <sup>14</sup>C experiments and in particular, the incubation techniques, analytical methods and laboratory equipment employed differ so widely that data standardization is virtually impossible" is significant. Photosynthetic efficiency of phytoplankton depends on the time of sampling (whether day or night), season, hydrographic features, water mass characteristics and location of the station and unless the methodology is standardized, it is not always meaningful to compare the data of different authors. "Variability in time and heterogeneity in space which are naturally inherent in oceanic biological parameters"<sup>1</sup> make comparison of data rather troublesome.

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