

## DISTRIBUTION OF PHYTOPLANKTON PIGMENTS IN AURANGA, AMBIKA, PURNA AND MINDOLA ESTUARIES OF GUJARAT

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### ABSTRACT

Estimation of phytoplankton pigments in four estuaries of South Gujarat indicates that all are fairly productive systems. Mean surface values of pooled chlorophyll fractions for Auranga, Ambika, Purna and Mindola were 12.98, 11.7, 13.98 and 33.46 mg m<sup>-3</sup> respectively and the average concentration of carotenoids in the same order were 5.03, 7.32, 6.03 and 19.87 m-SPU m<sup>-3</sup>. Effect of pollution on phytoplankton production was discernible only at Mindola where the relatively higher level of nutrients stimulated enhanced growth of phytoplankton. Auranga and Ambika estuaries behaved indentially while the other two showed their own specific pattern of distribution for phytoplankton pigments.

**Key-words :** Phytoplankton pigments, chlorophyll, estuary, Gujarat.

### INTRODUCTION

The South Gujarat coast abounds in many river system and estuarine parts of these rivers play an important role in the energy transfer between the coastal and river waters. Some information on the biological productivity of a few estuaries of this area is available (Nair, Gajbhiye, Ram and Desai, 1981; Gajbhiye, Ram, Nair and Desai, 1981 and Desai, Gajbhiye, Ram and Nair, 1981). Rapid industrialisation over the past decade has resulted in setting up of many industries along the coast of Gujarat. The wastes from these factories without prior treatment are being released either into the river or adjacent areas leading to pollution of the aquatic environment. Among the 4 estuaries studied, Ambika and Mindola were found to be relatively polluted by industrial and domestic discharge than Auranga and Purna (Anon., 1980). In the present study an evaluation of phytoplankton pigments in the four rivers has been made for assessing the variability induced by the tide and the prevailing water quality.

All the four rivers - Auranga, Ambika, Purna and Mindola - flow more or less in the eastwest direction and open into the Arabian Sea (Fig. 1) and are influenced by the southwest monsoon. The fresh water influx decreases considerably after September while some of the rivers become almost dry during May-June. Spring tidal ranges at the mouths of Auranga, Ambika,

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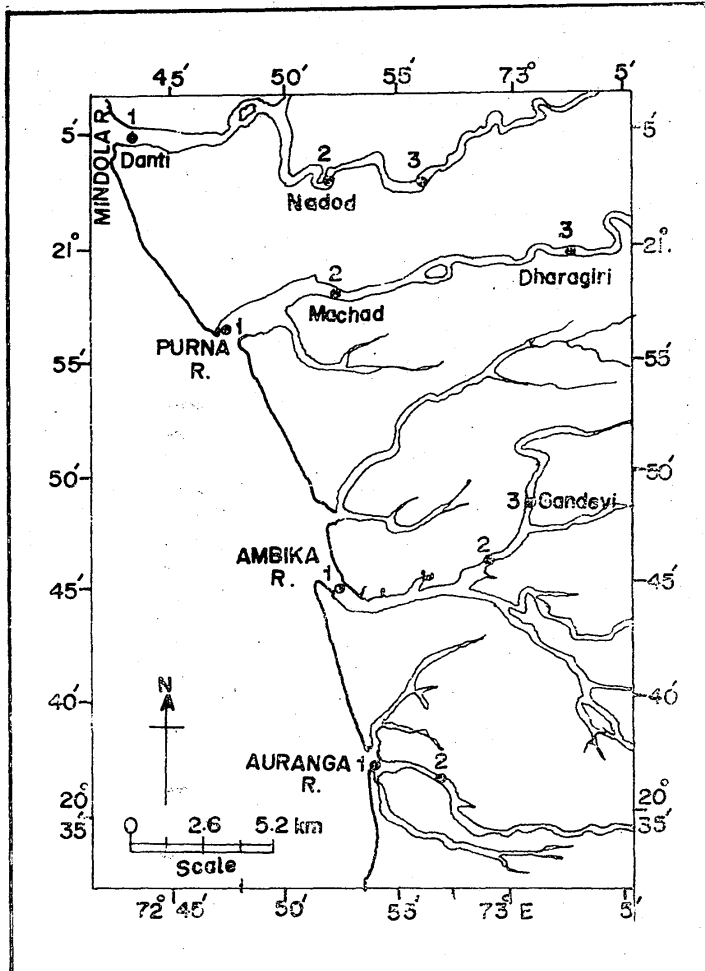


Fig. 1. Map showing the location of stations in four rivers.

Purna and Mindola are 3.4, 4.7, 4.8 and 5.9 m respectively. Estuarine waters of Auranga and Mindola get vertically well mixed while towards the upper reaches (station 2) a gradient especially during the ebb tide is observed. In Purna some stratification due to the incomplete mixing of river water and sea water is noticeable (Anon., 1980).

#### MATERIALS AND METHODS

From all the estuaries, collections were made from 2-3 stations, st. 1 selected in the mouth region, st. 2 at a location upto which the river is navigable and st. 3 in the weak tidal zone (Fig. 1). During the study from October 1978 to October 1979, water samples were collected for the estima-

tion of chlorophyll a, b and c and carotenoids covering ebb and flood tides and analysis was done following Strickland and Parsons (1968).

## RESULTS

### Auranga

At the river mouth the pooled chlorophyll values and carotenoids showed variation and the values ranged from 3.53 to 32.62 mg m<sup>-3</sup> and from 3.57 to 15.8 m-SPU m<sup>-3</sup> respectively (Table I). Pigment values were relatively high in May than in October. In October, variation in phytoplankton pigments over a 10 hour period were not much. Only one sample was taken at st. 2 and the values were lower than that recorded at st. 1. Mean values for chlorophyll (a + b + c) and carotenoids were high for the flood period (Table V). The chl. a/b ratio showed wide fluctuations, while chl. a/c ratio was usually below 0.5. Chl. a to carotenoid ratio was less than 1.

Average salinity at st. 1 in October was 23.04‰ and this increased to 35.25‰ during May (Anon., 1980). In May the recorded salinity at st. 2 was 32.05‰. The pH ranged between 7.7 and 8.3. Variation in dissolved oxygen at st. 1 and 2 were 5.6 to 8.2 and 6.0 to 7.8 mg/l respectively indicating that the water is free from any organic pollution. Observed nitrate and phosphate values at st. 1 were within the range of 3.5–17.36 and 2.16–9.75 µg-at l<sup>-1</sup>. At st. 2 recorded value for nitrate was 3.5 µg-at l<sup>-1</sup> and that for reactive phosphorus was 3.0 µg-at l<sup>-1</sup>.

### Ambika

The pooled chlorophyll and carotenoid pigments in this river showed a variation of 2.26–26.57 mg m<sup>-3</sup> and 1.13–27.74 m-SPU m<sup>-3</sup> respectively

**Table I.** Values of phytoplankton pigments during ebb (Eb) and flood (Fl) periods at different stations in Auranga river.

Station	Date	Time	Tide	Chl. mg m <sup>-3</sup>			Pooled values of Chl. mg m <sup>-3</sup>	Carotenoids m-SPU m <sup>-3</sup>	Ratios		
				a	b	c			Chl. a/b	Chl. a/c	Chl. a/carotenoids
1	13.5.79	1830	Eb	3.30	1.01	18.98	23.28	5.80	3.27	0.17	0.57
1	14.5.79	0130	Fl	5.28	2.20	25.14	32.62	8.54	2.4	0.21	0.62
1	"	1330	Fl	3.58	3.32	15.90	22.80	12.09	1.08	0.23	0.30
1	17.5.79	1900	Fl	3.05	3.03	15.72	21.80	15.80	1.01	0.19	0.19
1	5.10.79	1700	Eb	1.88	1.41	5.68	8.97	4.42	1.33	0.33	0.43
1	"	1900	Eb	1.77	0.28	1.48	3.53	3.57	6.32	1.20	0.50
1	"	2100	Eb	1.58	0.93	4.32	6.83	3.96	1.70	0.37	0.40
1	"	2300	Fl	1.71	0.76	5.33	7.79	4.43	2.25	0.32	0.39
1	6.10.79	0100	Fl	1.68	1.26	3.90	6.84	3.79	1.33	0.43	0.44
1	"	0300	Eb	1.68	1.12	3.79	6.58	4.58	1.5	0.44	0.37
2	13.5.79	1600	Fl	4.30	2.34	5.22	11.86	3.36	1.84	0.82	1.28

(Table II). In general, high values were recorded in May. Distribution of pigments at 1 and 2 was almost similar. Ten-hour variability study indicated maximum concentration of pigments at 1830 hr except that the total chlorophyll at st. 2 was maximum at 0000 hr. Invariably the flood tide yielded higher values of chlorophyll and carotenoids (Table V). A single observation was made at st. 3. The observed values were higher than that recorded for sts. 1 and 2 for the same month. The chl. a/b ratio indicated wide fluctuation. Ratios of chl. a/c and chl. a/carotenoids showed limited variation.

There was wide variation in salinity and at st. 1 it varied from 6.97 in September to 35.90‰ in May. The range in pH was from 7.1 to 8.3. Variation in DO at sts. 1 and 2 were from 5.1 to 7.1 and 0 to 5.7 mg l<sup>-1</sup> respectively. The lowest DO values were observed in May during low tide. High levels of BOD were recorded at st. 2. Variation in nitrate values were from 1 to 13.07 µg-at l<sup>-1</sup>. The range in the concentration of reactive phosphorus was from 0.55 to 7.01 µg-at l<sup>-1</sup>.

### Purna

The pooled chlorophyll values varied from 2.22 to 53.23 mg m<sup>-3</sup> and carotenoids from 0 to 15.72 m-SPU m<sup>-3</sup> (Table III). Relatively higher values were recorded in September. Distribution of phytoplankton pigments at sts. 1

**Table II.** Values of phytoplankton pigments during ebb (Eb) and flood (Fl) periods at different stations in Ambika river.

Station	Date	Time	Tide	Chl. mg m <sup>-3</sup>			Pooled values of Chl. mg m <sup>-3</sup>	Carotenoids m-SPU m <sup>-3</sup>	Ratios		
				a	b	c			Chl. a/b	Chl. a/c	Chl. a/carotenoids
1	3.5.79	1900	Fl	5.02	4.44	17.11	26.57	26.26	1.13	0.29	0.19
1	10.5.79	1630	Eb	1.09	2.29	12.68	16.06	2.74	0.48	0.09	0.39
1	11.5.79	1230	Fl	3.03	3.14	15.72	21.89	4.02	0.96	0.19	0.75
1	..	1330	Fl	5.22	4.34	13.16	22.72	6.40	1.20	0.40	0.82
1	30.9.79	1230	Eb	1.07	0.45	2.96	4.48	1.13	2.38	0.36	0.90
1	..	1430	Eb	0.84	0.63	1.95	4.95	1.53	1.33	0.43	0.50
1	..	1630	Eb	2.17	0.76	2.94	5.87	3.96	2.86	0.74	0.55
1	..	1830	Fl	3.72	3.52	12.38	19.62	8.39	1.06	0.30	0.44
1	..	2230	Eb	1.04	0.87	2.64	4.55	5.64	1.20	0.39	0.18
1	1.10.79	0030	Eb	0.66	0.00	1.60	2.26	3.57	0	0.41	0.18
2	3.5.79	2100	Fl	3.94	7.28	6.49	17.72	5.95	0.54	0.61	0.66
2	10.5.79	2200	Eb	3.74	3.33	6.94	17.01	3.06	1.12	0.54	1.22
2	11.5.79	0200	Fl	1.99	1.06	23.31	26.36	27.74	1.88	0.09	0.07
2	30.9.79	1200	Eb	1.84	0.28	2.34	4.46	5.40	6.57	0.79	0.34
2	..	1600	Eb	3.28	0.98	4.03	8.28	3.57	3.35	0.81	0.92
2	..	1800	Eb	5.46	1.72	6.96	14.14	9.00	3.17	0.78	0.61
2	..	2000	Eb	0.66	0.03	1.60	2.28	5.18	22.0	0.41	0.13
2	..	2200	Eb	1.27	0.79	3.64	5.71	5.18	1.61	0.35	0.25
2	..	0000	Fl	2.02	1.94	12.32	16.28	6.56	1.04	0.16	0.31
3	..	1200	Eb	4.36	1.69	3.68	9.73	7.63	2.58	1.18	0.57

and 2 are comparable while st. 3 sustained relatively low values. Diurnal variation in phytoplankton pigments indicated maximum values at 21.30 hrs at st. 1 and 16.30 hrs at st. 2. Higher values of pigments were always associated with ebb period (Table V). Chl. a/b ratio showed wide variation while ratios of chl. a/c and chl. a/carotenoids were invariably less than 1.

Salinity variation at the mouth of the estuary was 1.46–31.93‰. At st. 3 almost fresh water conditions prevailed. The pH varied from 7.7 to 8.6. Values of DO varied from 5.6 to 8.1 mg/l. Fluctuations in nitrate values during the period of study were from 5.57 to 10.0  $\mu\text{g-at l}^{-1}$ . Phosphate values showed a variation from 2.36 to 4.62  $\mu\text{g-at l}^{-1}$ .

### Mindola

Total chlorophyll (a + b + c) and carotenoids at the 3 stations varied from 2.60 to 168.14  $\text{mg m}^{-3}$  and from 0.34 to 211.0  $\text{m-SPU m}^{-3}$  respectively (Table IV). Values of phytoplankton pigments were higher in September. Pigment values estimated for a 10 hr period indicated wide fluctuation and maximum values were obtained at 18.00 hrs (station 1) and 1615 hrs (station 2). The mean values of phytoplankton pigments showed higher values during ebb tide at st. 1, while at st. 2 the values were higher at the flood period (Table V). Chl. a/b ratio varied at all the stations. Chl. a/c and chl. a/carotenoids ratios were comparable except in September at st. 2 and 3.

**Table III.** Values of phytoplankton pigments during ebb (Eb) and flood (Fl) periods at different stations in Purna river.

Sta- tion	Date	Time	Tide	Chl. $\text{mg m}^{-3}$			Pooled values of Chl. $\text{mg m}^{-3}$	Carote- noids $\text{m-SPU m}^{-3}$	Ratios		
				a	b	c			Chl. a/b	Chl. a/c	Chl. a/ carote- noids
1	21.4.79	1500	Eb	0.64	7.85	0	8.49	0.92	0.08	0	1.44
1	25.4.79	1400	Fl	0.40	0.21	4.66	5.27	0	1.90	0.09	0
1	28.9.79	0730	Fl	4.52	4.16	18.94	27.62	10.07	1.09	0.24	0.45
1	"	0930	Eb	1.71	0.93	3.13	5.77	6.70	1.84	0.55	0.26
1	"	1130	Eb	2.02	2.22	9.02	13.26	7.64	0.91	0.22	0.26
1	"	1330	Eb	3.53	2.82	12.56	18.91	8.38	1.25	0.28	0.42
1	"	1530	Fl	2.72	1.68	12.04	16.44	7.08	1.82	0.23	0.38
1	"	1730	Fl	3.18	1.51	11.84	16.32	7.86	2.11	0.27	0.40
1	"	1930	Fl	2.74	2.57	1.03	6.34	7.78	1.07	2.66	0.36
1	"	2130	Eb	7.94	6.03	25.19	39.16	15.72	1.32	0.32	0.51
2	26.4.79	0600	Eb	0.30	3.97	3.12	7.29	3.12	0.05	0.09	0.09
2	28.9.79	0830	Eb	6.36	3.01	21.36	30.73	7.92	2.11	0.30	0.80
2	"	1030	Eb	8.38	5.40	30.50	44.28	14.80	1.55	0.27	0.57
2	"	1230	Eb	0.42	0.27	1.53	2.22	0.79	1.56	0.27	0.53
2	"	1430	Eb	4.35	1.51	5.88	11.75	7.41	2.88	0.74	0.59
2	"	1630	Eb	6.30	1.24	45.70	53.34	7.92	5.08	0.24	0.80
2	"	1830	Fl	3.04	0.88	6.32	10.34	7.26	3.45	0.48	0.42
2	"	2030	Fl	1.08	0.24	4.21	5.54	1.27	4.5	0.21	0.85
3	"	1245	Eb	1.28	0.83	1.99	4.09	3.50	1.54	0.64	0.37
3	"	2045	Eb	2.17	0.76	3.95	6.88	5.65	2.06	0.55	0.38

**Table IV.** Values of phytoplankton pigments during ebb (Eb) and flood (Fl) periods at different stations in Mindola river.

Station	Date	Time	Tide	Chl. $\text{mg m}^{-3}$			Pooled values of Chl. $\text{mg m}^{-3}$	Carotenoids $\text{m-SPU m}^{-3}$	Ratios		
				a	b	c			Chl. a/b	Chl. a/c	Chl. a/ carotenoids
				1	6.4.79	0800			Eb	5.88	4.88
1	15.4.79	0900	Eb	0.90	0.11	1.07	2.08	0.34	8.18	0.84	2.65
1	23.9.79	0800	Eb	3.12	2.33	11.20	16.64	6.7	1.34	0.28	0.47
1	"	1000	Eb	4.20	2.97	11.96	19.13	7.16	1.41	0.35	0.59
1	"	1200	Eb	5.14	4.62	19.10	28.86	9.30	1.11	0.27	0.55
1	"	1600	Fl	1.69	1.52	11.60	14.81	7.68	1.11	0.15	0.22
1	"	1800	Eb	6.08	6.72	25.94	38.74	8.24	0.90	0.23	0.74
1	"	2000	Eb	5.14	4.62	19.10	26.90	9.30	1.11	0.27	0.55
2	5.4.79	1500	Eb	2.19	5.13	19.87	27.18	12.82	0.43	0.11	0.17
2	6.4.79	0800	Eb	4.06	3.90	13.62	21.58	22.95	1.04	0.30	0.18
2	15.4.79	0715	Eb	5.22	4.34	13.16	22.72	8.70	1.20	0.40	0.60
2	"	1645	Fl	10.45	8.93	23.02	42.40	26.10	1.17	0.45	0.40
2	23.9.79	1015	Eb	8.64	1.26	33.76	43.67	15.56	6.86	0.26	0.56
2	"	1215	Eb	11.77	1.26	10.78	23.81	10.73	9.34	1.09	1.20
2	"	1415	Eb	34.32	21.73	24.06	80.11	10.73	1.58	1.43	3.20
2	"	1615	Fl	95.28	26.40	46.46	168.14	211.00	3.61	2.05	0.45
2	"	2015	Eb	12.46	11.06	33.14	56.66	23.78	1.13	0.38	0.52
3	"	1400	Eb	9.72	4.22	15.17	29.11	9.30	2.30	0.64	1.05
3	"	1800	Fl	13.36	1.73	4.42	19.51	16.45	7.72	3.02	0.81

**Table V.** Mean values of chlorophyll (a + b + c) and carotenoids during ebb (Eb) and flood (Fl) periods at different stations in the four estuaries.

Station	Pooled values of chl. ( $\text{mg m}^{-3}$ )		Carotenoids ( $\text{m-SPU m}^{-3}$ )	
	Eb	Fl	Eb	Fl
	Auranga 1	9.84	18.27	4.47
Ambika 1	6.36	22.70	3.10	11.27
	8.80	20.12	5.57	13.42
Purna 1	17.11	14.40	7.87	6.56
	24.94	7.94	6.99	4.27
Mindola 1	22.79	14.81	8.83	7.68
	36.51	105.27	13.58	118.55

The overall variation in salinity at the mouth of the river was 4.72 to 33.82‰. At st. 2 penetration of sea water was weak and the maximum salinity recorded in April is only 7‰. pH values ranged from 7.5 to 8.7. Variation in DO was 0.9 to 7.7 mg/l. In line with low DO, BOD values sometimes exceeded 10 mg/l. (Anon., 1980). The decrease in DO values from the mouth towards the upstream direction was quite evident. Nitrate values showed a fluctuation from 8.79 to 21.29  $\mu\text{g-at l}^{-1}$ . The range in phosphate values was from 1.94 to 6.03  $\mu\text{g-at l}^{-1}$ .

## DISCUSSION

All the four estuaries studied are fairly productive systems. Mean values of pooled chlorophyll for the entire period of observation were 12.98, 11.7, 13.98 and 33.46  $\text{mg m}^{-3}$  respectively for Auranga, Ambika, Purna and Mindola estuaries. Average values of carotenoids for the above estuaries amounted to 5.03, 7.32, 6.03 and 19.87  $\text{m-SPU m}^{-3}$ . The pigment values are comparable with the reported values from Narmada, another estuary from South Gujarat (Gajbhiye, Ram, Nair and Desai, 1981). However, the present observed values reported here are higher than that estimated for the Mandovi and Zuari estuaries of Goa (Bhargava and Dwivedi, 1976). In general, among the different components of phytoplankton pigments chlorophyll *c* and carotenoids were in higher concentration than the other fractions. Chl. *b* formed the lowest fraction. In an estuarine system, substantial quantity of dead chlorophyll coming from detritus and stirred up sediments also contribute to the high values of chl. *c* and carotenoids (Qasim and Reddy, 1967; Gajbhiye, Ram Nair and Desai, 1981).

There was no consistent relationship between chl. *a*, *b* and *c* and carotenoids. Such fluctuations between the different fractions of phytoplankton pigments had been reported for the Cochin backwaters (Qasim and Reddy, 1967) and Mandovi-Zuari estuarine complex (Bhargava and Dwivedi, 1976). Ratio of chl. *a* to *c* indicates the physiological state of phytoplankton and for a healthy crop it should be less than unity (Bhargava and Dwivedi, 1976). A low ratio of chl. *a* to carotenoid would suggest a chlorotic, unhealthy population (Ketchum, Ryther, Yentsch and Corwin, 1958) and in all the above estuaries the ratio was usually less than 1.

Influence of tide on the distribution of phytoplankton pigment was limited to a few observations. In the Cochin backwaters the value of chlorophyll decreased with the flood or immediately after high waters and increased at the low water (Qasim and Gopinathan, 1969). In the Vellar estuary, higher value of pigments were reported for flood tide (Vijayalakshmi and Venugopalan, 1973). Pigment values were invariably high for the flood period in Auranga and Ambika estuaries. In Purna, high values of phytoplankton pigments were recorded during ebb tide. At Mindola st. 1, values were high for ebb period while at st. 2 a reverse pattern was observed.

Findings on the seasonal variation of phytoplankton pigments at Mandovi-Zuari estuarine system (Bhargava and Dwivedi, 1976) and Narmada estuary (Gajbhiye, Ram, Nair and Desai, 1981) would indicate a peak in phytoplankton during the premonsoon period. The present study was limited to a few months (April/May and Sept./Oct.) covering two seasons. Higher values of pigments in Auranga and Ambika were observed during the premonsoon period while in Purna and Mindola towards the end of the monsoon period.

All the four rivers are receiving sewage as well as industrial effluents. However, the quantity of industrial waste received was more for Ambika and

Mindola rivers. The waste water contained high organic load and this affected the DO level of the receiving water (Anon., 1980). The effect was minimum in Auranga river which maintained good water quality. Estuarine part of Purna river also had fairly good water quality. Deteriorating conditions prevailed in Ambika and Mindola rivers. Studies on zooplankton from these estuaries indicated some inimical conditions in the polluted estuaries (Nair, Gajbhiye, Ram and Desai, 1981). Concomitant with the deteriorating water quality of Ambika and Mindola some reduction in zooplankton biomass and population density of certain groups were observed. The nitrate concentration was maximum in Mindola estuary with concomitant high values of phytoplankton pigments. Pollution may bring about an enrichment of algal nutrients in waters and this may selectively stimulate the growth of some types of phytoplankton (Palmer, 1980).

The overall picture showed an identical pattern of phytoplankton pigment distribution in Auranga and Ambika while the Purna and Mindola estuaries presented an entirely different pattern. Auranga and Ambika were characterised by maximum production during the premonsoon period, higher productivity at the mouth than in the upper reaches and invariably the flood tide sustained higher values of phytoplankton pigments. In the other two estuaries maximum production was confined to the monsoon period only with higher values towards the interior of the estuary and a general increase in pigment values for the ebb period.

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