

# Diurnal Variation in Phytoplankton Pigments in Zuari Estuary, Goa

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Zuari is a large estuary having strong marine influence. The Zuari water in turn influences the Cumbarjua canal. Two stations, one near the mouth and other in the mid-reaches are studied for diurnal variations of phytoplankton pigments during three seasons of the year 1971-72. Total chlorophyll (range) at the mouth region in August, February and April is 0.13 to 3.09, 6.11 to 15.63 and 4.54 to 342 mg/m<sup>3</sup> respectively. In mid-reaches the values are 0.06 to 1.94, 3.65 to 7.21 and 404 to 14.09 mg/m<sup>3</sup> respectively. Maximum concentration is observed in February followed by April and August. Peak values are recorded at mid day when the tide and salinity are high. Chlorophyll (chl.) a is dominant at both the stations except during monsoon and postmonsoon periods when generally chl. c is more in mouth region. The ratios of chl. a to chl. c and chl. a to carotenoids fluctuate, but are mostly greater than one.

**Z**UARI river opens into the Arabian Sea very close to Mandovi river and the two river mouths are separated only by a narrow Cabo Ridge. Zuari is a broad estuary with strong marine influence and having semi-diurnal tide. The distribution of chlorophyll in Goa and Cochin waters have been reported earlier<sup>1-5</sup>. The present communication reports the diurnal variations in phytoplankton pigments in Zuari because of their importance in photosynthesis.

The present investigations are carried out at two stations in Zuari estuary located about 6 km apart. Station 1 is very close to the mouth and station 2 is located in Cumbarjua canal near its confluence with Zuari estuary (Fig. 1). Zuari water traverses through the Cumbarjua canal and reaches Mandovi river during high tide<sup>6</sup>. Therefore, station 2 is predominantly in the zone of Zuari waters and it has been treated here as a part of the middle reaches of Zuari. The average depths at these 2 stations are 6 and 4 m respectively.

## Materials and Methods

Observations were made in Aug. 1971, Feb. 1972 and April 1972. The samples were collected at 3

intervals by a clean plastic bucket from surface water. The salinity and dissolved oxygen were analysed by standard methods of Mohr and Winkler respectively. Pigments were analysed by the method described earlier<sup>3</sup>. The dates were chosen so as to get the maximum tide as predicted for Marmugao Harbour in Indian Tide Tables.

## Results

*On 20/21 Aug. 1971 (monsoon period)* - The temperature range for mouth and mid-reaches was 27.35 to 29°C. At station 1, the maximum temperature of 28.8°C was noticed in the afternoon. At station 2, maximum temperature of 29°C was noticed at 1130 hrs. The range of temperature fluctuation was less at the mouth than in mid-reaches (Fig. 2). The salinity was influenced by monsoon, and varied with the tide from 4.23 to 13.65‰ at station 1 and from 1.65 to 13.4‰ at station 2. The dissolved oxygen values were similar at both the stations and varied between 4.45 and 5.5 ml/litre.

At station 1, chlorophyll (chl.) a values varied from 0.05 to 1.52 mg/m<sup>3</sup> and maximum and minimum concentrations occurred at 1230 and 0330 hrs respectively (Fig. 2). At station 2, the concentrations varied between 0.06 and 0.95 mg/m<sup>3</sup> only but the timings for maximum and minimum were same as at station 1. Chl. b varied between 0 and 0.69 mg/m<sup>3</sup>. Chl. c was generally more than chl. a at station 1 but at station 2 chl. a was dominant throughout. The trend of variations of chl. b and c were same as that of chl. a at station 1 but at station 2, chl. b attained maximum at 1130 hrs (0.82 mg/m<sup>3</sup>) and then gradually decreased to zero at midnight whereas chl. c gradually increased till 1730 hrs (0.65 mg/m<sup>3</sup>) and then decreased to zero. The maximum values of carotenoids were 7.82 and 19.52 mSPU/m<sup>3</sup> at stations 1 and 2 respectively and were invariably more than chl. a.

*3-4 Feb. 1972 (postmonsoon period)* - As compared to the monsoon period the temperatures were low, the ranges at stations 1 and 2 being 26.5 to 27.8°C and 26.5 to 28.8°C respectively (Fig. 3). Salinity was higher, the range being 31.2 to 32.6‰, at station 1 and from 31.02 to 32.37‰, at station 2.

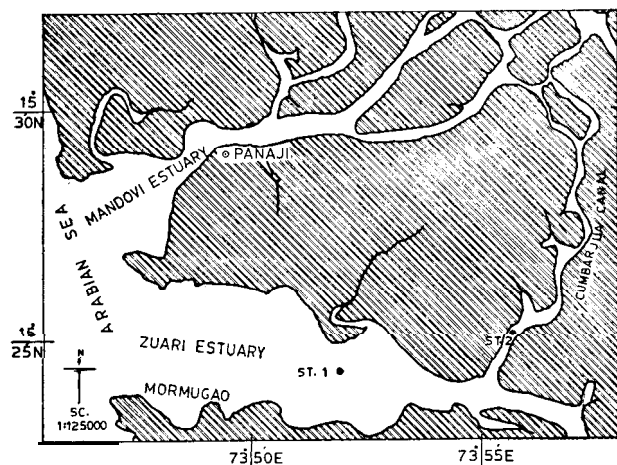


Fig. 1 — Sampling stations in Zuari estuary and the connecting Cumbarjua canal

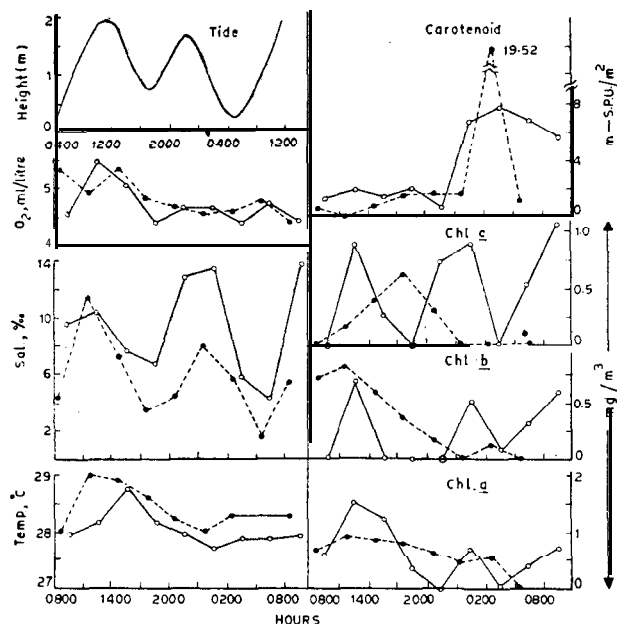


Fig. 2 — Variations in environmental factors and pigments at stations 1 (○—○) and 2 (●---●) during August (monsoon period)

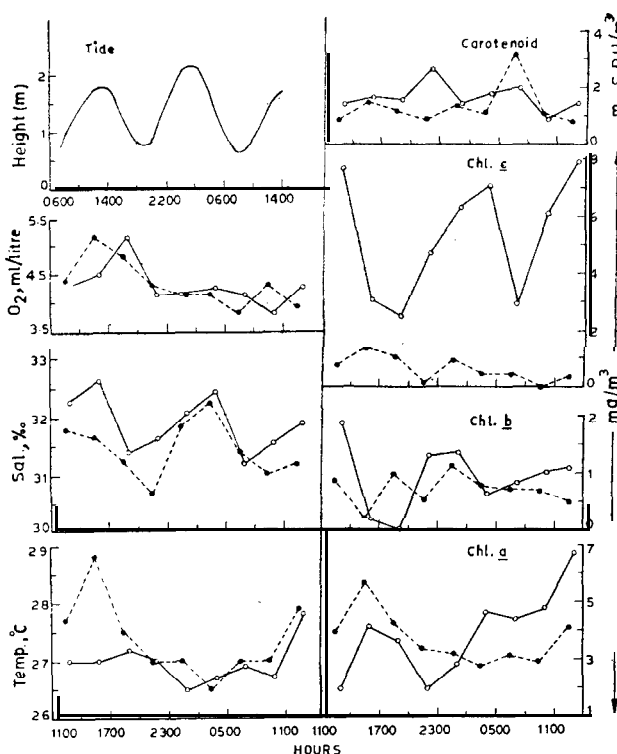


Fig. 3 — Variations in environmental factors and pigments at stations 1 (○—○) and 2 (●---●) during February (post-monsoon period)

The dissolved oxygen values varied between 3.81 and 5.15 ml/litre at both the stations. The maximum and minimum at station 1 as compared to station 2 were behind by about 3 hr. The distribution of dissolved oxygen also showed a trend similar to that of temperature.

Range of chl. *a* values was from 1.97 to 6.66 mg/m<sup>3</sup> at station 1 and 2.78 to 5.69 mg/m<sup>3</sup> at station 2 (Fig. 3). As compared to monsoon chl. *b* and

chl. *c* concentrations had increased and their respective ranges were 0.2 to 1.8 mg/m<sup>3</sup> and 1.0 to 7.85 mg/m<sup>3</sup>. The peak concentrations of chl. *a* and *c* were directly related to high tide conditions. The carotenoid values were low ranging between 0.9 and 2.55 mSPU/m<sup>3</sup>. The variations were less, the pattern of pigment distribution was irregular.

During this observation at station 1, chl. *c* was more abundant than chl. *a* but at station 2 it was vice versa.

**28/29 April 1972 (premonsoon period)** — The environmental conditions, particularly temperature and salinity, were very stable (Fig. 4). The temperature varied between 30.5 and 31.5°C with maximum at 1430 to 1500 hrs and minimum after midnight. The salinity was almost uniform and varied between 36.0 and 36.36‰, at station 1 and 35.98 and 36.56‰ at station 2. The oxygen values showed different trends at two stations and the values varied between 4.03 and 5.71 ml/litre and 3.58 and 4.93 ml/litre at stations 1 and 2 respectively. Generally low values were recorded during low tide.

Chl. *a* at both the stations (Fig. 1) had large variations (3.43 to 10.13 mg/m<sup>3</sup>). The total chlorophyll and chl. *a* were more towards mouth region as compared to middle reaches. Their distribution did not follow any definite pattern. However, at station 1 higher concentration was found during high tide and at station 2 during low tide. The range of chl. *b* was 0 to 1.75 mg/m<sup>3</sup> at station 1 and 0 to 1.9 mg/m<sup>3</sup> at station 2. Chl. *c* showed large variations from 0 to 5.4 mg/m<sup>3</sup>. The distribution pattern of all the chlorophylls was similar and their peak concentrations occurred at the same time. The carotenoid values varied between 0.16 and 3.57 mSPU/m<sup>3</sup> at station 1 and from 0.94 to 2.85 mSPU/m<sup>3</sup> at station 2 and followed the distribution pattern of chl. *a* at these stations but concentrations.

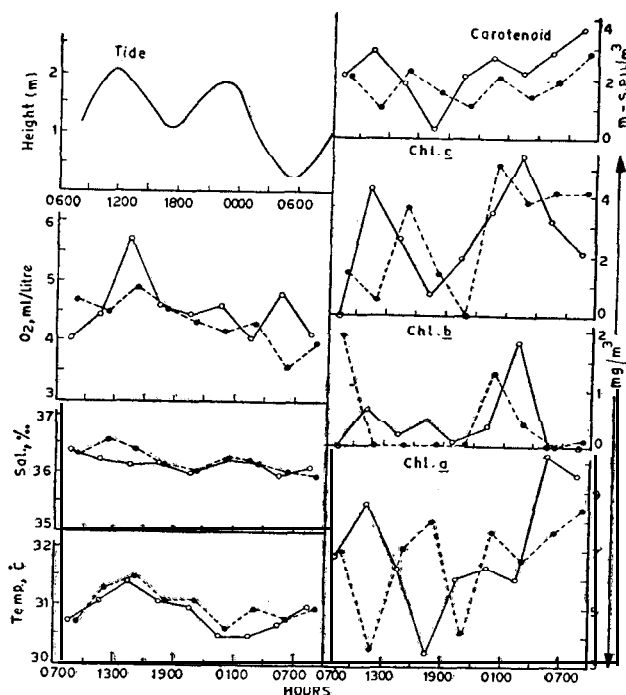


Fig. 4 — Variations in environmental factors and pigments at stations 1 (○—○) and 2 (●---●) during April (premonsoon period)

were always lower than chl. *a*. Thus during this season chl. *a* was dominant at both the stations; chl. *b* was negligible; and chl. *c* was always less than chl. *a*. The ratios of chl. *a* to *c* and chl. *a* to carotenoids were always higher than one.

### Discussion

As seen from the pigment distribution the minimum concentration occurred in morning and maximum at noon except during premonsoon period in mouth region while in mid-reaches minimum was observed in late evening and maximum in noon in pre- and postmonsoon periods. The maxima of chl. *a* and *c* generally coincided with high salinity (tide). At the mouth region as well as in middle reaches the maximum and minimum concentrations of total chlorophyll also were invariably found coinciding with high and low salinity respectively. The mean total chlorophyll (mg/m<sup>3</sup>) for 24 hr at the 2 stations is shown below:

Season	Mouth region (station 1)	Middle region (station 2)
August (monsoon)	1.36	1.07
February (post- monsoon)	10.15	5.02
April (premonsoon)	9.57	9.78

Thus at mouth region which has influence of neritic waters, the chlorophyll concentration is more compared to middle reaches.

Yentsch and Ryther<sup>7</sup> and Yentsch and Scagel<sup>8</sup> expressed light as a causative factor for the diurnal distribution of chlorophyll while Bhargava<sup>3</sup> has pointed out that the tide factor is responsible for chlorophyll variations in Mandovi estuary. But in this estuary it is at the coincidence of high tide and mid-day that the peak of total chlorophyll was observed. However, at station 2 during premonsoon the maximum was found at midnight during high tide. This probably indicates that the neritic waters bring in chlorophyll rich phytoplankton during flood and dominate over ebb tide crop of phytoplankton. Therefore, it appears that in this estuary also, to a great extent, tide influences concentration of the plant pigments.

The relation between chlorophyll and dissolved oxygen cannot be generalized.

It is seen from Table 1 that at station 1 during monsoon and postmonsoon periods chl. *a* was less than chl. *c* but in April when the environment was stable and near marine conditions were existing, chl. *a* dominated. High values of chl. *c* may be due to the presence of dead chlorophyll from suspended material<sup>5</sup>. Further the ratios of chl. *a* to chl. *c* were fluctuating and were less than 1, which indicate a poor physiological state for phytoplankton. At the same station, in monsoon the carotenoid values were higher than chl. *a* and the ratio of chl. *a* to carotenoids was also less than 1. This indicates the presence of unhealthy and chlorotic phytoplankton population<sup>9</sup>. But in premonsoon period the ratios of chl. *a* to *c* and chl. *a* to carotenoid were always higher than 1 and indicate the healthy state of phytoplankton. At station 2, all the times chl. *a* dominated. The values of plant carotenoids were

TABLE 1 — DISTRIBUTION OF PIGMENTS, THEIR PERCENTAGES AND RATIOS AT STATIONS 1 AND 2 IN ZUARI ON (i) 20/21 AUG. 1971, (ii) 3/4 FEB. 1972 AND (iii) 25/29 APRIL 1972

Time hr	Total chloro- phyll ( <i>a</i> + <i>b</i> + <i>c</i> ) mg/m <sup>3</sup>	Percentage in total			Ratios	
		chlorophyll			<i>a/c</i>	<i>a/car.</i>
		<i>a</i>	<i>b</i>	<i>c</i>		
(i) 20/21 AUG. 1971						
Station 1						
0930	0.64	100.00	—	—	—	0.44
1230	3.09	49.19	22.33	28.48	1.73	0.73
1530	1.51	82.78	—	17.22	4.81	0.92
1830	0.35	100.00	—	—	—	0.17
2130	0.73	—	—	100.00	—	0.65
0030	2.09	33.01	24.40	42.58	0.78	0.10
0330	0.13	38.46	61.54	—	—	0.01
0630	1.24	29.84	26.61	43.55	0.69	0.06
0930	2.34	29.07	24.79	46.15	0.63	0.12
Station 2						
0830	1.40	49.29	50.71	—	—	1.11
1130	1.94	48.97	42.27	8.76	5.59	—
1430	1.89	46.56	31.75	21.69	2.15	1.13
1730	1.83	44.26	20.22	35.52	1.25	0.52
2030	1.20	53.33	15.00	31.67	1.68	0.42
2330	0.46	100.00	—	—	—	0.31
0230	0.70	78.57	21.43	—	—	—
0530	0.06	100.00	—	—	—	5.66
0830	—	—	—	—	—	—
(ii) 3/4 FEB. 1972						
Station 1						
1300	11.54	17.07	16.38	66.55	0.26	1.40
1600	7.37	56.31	2.31	41.38	1.36	2.55
1900	6.11	59.57	—	40.43	1.47	2.36
2200	7.97	24.97	16.31	58.72	0.43	0.77
0100	10.47	27.63	12.89	60.08	0.45	1.99
0400	12.30	37.64	5.12	57.24	0.66	2.63
0700	8.16	53.68	10.29	36.03	1.49	2.19
1000	11.84	40.12	8.70	51.18	0.78	5.22
1300	15.63	42.61	7.04	50.35	0.85	4.53
Station 2						
1230	5.60	71.25	15.71	13.04	5.47	4.53
1530	7.21	78.92	3.05	18.03	4.38	3.98
1830	6.22	68.33	15.59	16.08	4.25	3.60
2130	4.08	83.58	13.23	3.19	26.23	3.97
0030	5.20	60.77	21.73	17.50	3.47	2.32
0330	4.01	69.33	19.70	10.97	6.32	2.44
0630	4.30	73.02	16.74	10.23	7.14	0.99
0930	3.65	50.55	19.45	—	—	2.91
1230	4.95	82.02	10.30	7.68	10.68	5.08
(iii) 28/29 APRIL 1972						
Station 1						
0830	6.66	100.00	—	—	—	3.33
1130	13.42	63.49	4.69	31.82	2.00	2.99
1430	9.02	70.07	—	—	2.49	3.47
1730	4.54	75.55	9.47	28.16	5.04	21.44
2030	7.88	75.38	—	24.62	3.06	3.02
2330	10.09	62.93	3.07	33.99	1.85	2.42
0230	13.06	44.79	13.63	41.58	1.08	2.77
0530	13.31	76.11	—	23.89	3.19	3.66
0830	11.62	81.67	—	18.33	4.46	2.66
Station 2						
0900	10.28	66.44	18.68	14.88	4.46	3.38
1200	4.04	87.13	—	12.87	6.77	3.78
1500	10.84	65.13	—	34.87	1.87	3.24
1800	9.48	84.49	—	15.51	5.45	3.80
2100	4.04	99.26	0.74	—	—	4.27
2400	14.09	54.01	9.30	36.69	1.47	3.71
0300	10.77	60.91	3.81	35.28	1.73	5.01
0600	11.78	64.69	—	35.31	1.83	4.14
0900	12.67	66.14	0.71	33.15	2.00	2.94

always less than those of chl. *a*. The ratios of chl. *a* to chl. *c* and chl. *a* to carotenoids, therefore, were always more than 1 suggesting good physiological state of phytoplankton. These ratios were highly fluctuating particularly during monsoon at both the stations. Yentsch and Scagel<sup>8</sup> also reported such fluctuating ratios in the waters of East Sound, Washington.

The present study, therefore, indicates ecological differences between the mouth region and mid-reaches. The differences between chlorophyll concentrations and oxygen values are very marked and are influenced by tidal conditions. Further, it is observed that though chlorophyll is less in mid-reaches its physiological condition seems to be better than at the mouth region. However, in an ever changing estuarine environment like Zuari estuary where so many other factors are operating, the amount of active chlorophyll coming from living organisms is not yet known.

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#### References

1. DEHADRAI, P. V., *Proc. Indian Acad. Sci.*, 72 (1970), 56.
2. DEHADRAI, P. V. & BHARGAVA, R. M. S., *Indian J. mar. Sci.*, 1 (1972), 52.
3. BHARGAVA, R. M. S., *Indian J. mar. Sci.*, 2 (1973), 27.
4. SHAH, N. M., *Bull. natn. Inst. Sci. India*, 38 (1970), 727.
5. QASIM, S. Z. & REDDY, C. V. G., *Bull. mar. Sci.*, 17 (1967), 95.
6. DAS, P. K., MURTY, C. S. & VARADACHARI, V. V. R., *Indian J. mar. Sci.*, 1 (2) (1972), 95.
7. YENTSCH, C. S. & RYTHER, J. H., *Limnol. Oceanogr.*, 2 (1957), 140.
8. YENTSCH, C. S. & SCAGEL, R. F., *J. mar. Res.*, 17 (1958), 567.
9. KETCHUM, B. H., RYTHER, J. H., YENTSCW, C. S. & CORWIN, N., *Mar. Res.*, 14 (1958), 132.