

Plankton Studies in the Estuarine & Nearshore Regions of Mandovi & Zuari

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Biological and chemical data collected for the preparation of a master plan for pollution control in the rivers Mandovi and Zuari and the adjacent coastal area were processed to study the ecological conditions. Both phytoplankton and zooplankton populations were rich during monsoon as compared to the pre and postmonsoon with a negative correlation with salinity. N:P ratios were generally low and did not show much variation. Phytoplankton biomass in these areas was not limited by either phosphate or nitrate.

Mandovi and Zuari estuaries are 2 tropical estuaries which could geologically be classified as 'drowned river valley' estuaries formed by the Holocene rise in the sea level¹. These are more or less tidal stream estuaries being influenced by sea water inflow to a considerable distance inland with seasonal freshwater runoff. Many observations on physical, chemical and biological parameters of these estuaries have been carried out earlier over limited areas and time. Recently a project to prepare a master plan for pollution control in the rivers Zuari and Mandovi was carried out to study the water quality in the 2 rivers as well as in the adjacent coastal area for 1 yr (Oct. 1977 to Sep. 1978). During that period, besides physical and chemical parameters, biological data on phytoplankton population and zooplankton biomass were also collected to understand the ecological conditions of this area. Earlier reports indicate that the primary and benthic productions in this estuary are quite high²⁻⁴. Studies on the phytoplankton and zooplankton from this area are mainly limited to the abundance and diversity of different groups^{5,6}. Therefore, in the present study more emphasis is laid on the relationships of salinity, phosphate and nitrate with the primary and secondary producers in the mouth of the 2 rivers Mandovi and Zuari and the adjacent coastal areas.

Materials and Methods

Fig. 1 shows the station locations in the Mandovi (M1), Zuari (Z1) and Coastal (C2) regions. Monthly collection of the samples (including plankton) was carried out from 0800 hrs to 2000 hrs at 3 hr intervals and the samples were mixed together for analysis. Surface water samples were collected for phytoplankton estimations, and preserved in 2-3% formalin. An aliquot of 50 ml was transferred to a sedimentation chamber and allowed to settle for 2 days. The supernatant was removed and the cells in the chamber

were counted under an inverted microscope. Zooplankton samples were collected by horizontal hauls using Heron Tranter net of 300 μ m mesh size. The volume of water filtered through the net was measured with a TSK 487 flowmeter attached to the net. The samples were preserved and the biomass was determined by displacement method. Estimations of salinity were carried out by conductivity measurements using Autosal (Guildline Model 8400) inductive salinometer. Nitrate and Phosphate were estimated following standard methods⁷.

In the absence of any data for phytoplankton and zooplankton throughout the 12 months, some published results^{2,3} were used.

Results and Discussion

Phytoplankton—Varying physical and chemical

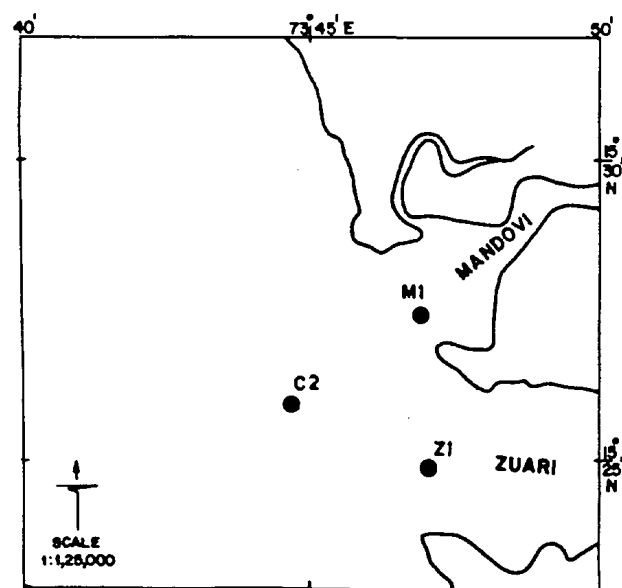


Fig. 1—Station location in the rivers Mandovi (M1), Zuari (Z1) and coastal area (C2)

parameters make the estuaries specialised environments. Estuarine organisms have to be tremendously adaptive to put up with the stress imposed upon by the fluctuations of environmental conditions in these estuaries which are caused mainly by tides and monsoon. The former causes short terms changes while the latter causes seasonal changes. In Zuari (Z1) and Mandovi (M1) and coastal (C2) stations, during the premonsoon and postmonsoon a truly marine condition prevails. Salinity values range from 34.5 (M1) to 36.62‰ (C2) and 32.41 (M1) to 35.19‰ (C2) during pre and postmonsoon respectively. During monsoon months salinity was considerably reduced (~20‰) in these areas due to freshwater discharge from the rivers. Therefore, in these areas estuarine and marine, euryhaline marine and truly estuarine species preferring slightly high salinities are dominant during the pre and postmonsoon and during monsoon, these organism are flushed out of the estuary and replaced by low saline species.

Phytoplankton counts during premonsoon varied from 6500 to 26000 cells/litre at M1 as compared to 8800 to 22600 and 6500 to 29500 cells/litre at sts Z1 and C2 respectively (Fig. 2A). Not much variation

could be observed during postmonsoon, whereas, during monsoon a comparatively higher algal population was recorded. During monsoon it varied from 8500 to 371000 and 3600 to 387500 cells/litre at M1 and Z1 respectively. The only observation during monsoon at C2 (September) showed a higher phytoplankton count as compared to M1 and Z1. In general, the over all algal crop showed higher concentration at M1 compared to Z1 and C2. Detailed faunestic composition was not studied. However, the dominating groups were identified. During premonsoon diatoms dominated followed by dinoflagellates. *Coscinodiscus*, *Navicula*, *Thalassiothrix*, *Pleurosigma*, *Chaetoceros*, etc. were found to be dominant among diatoms. Among the dinoflagellates, *Ceratium*, *Peridinium*, *Dinophysis* and *Noctiluca* dominated. The order of abundance during postmonsoon was almost similar to that of premonsoon.

Zooplankton—Zooplankton biomass varied drastically from 6.42 to 89.7 g/1000 m³ at C2 during premonsoon as compared to 8.8 to 89.2 and 41.1 to 67.4 g/1000 m³ at M1 and Z1 respectively (Fig. 2B). Throughout monsoon zooplankton biomass was higher in these areas with a maximum of 175 g/1000 m³ at M1 during August. The average biomass values were higher at M1 during monsoon (132.37 g/1000 m³) and postmonsoon (41.06 g/1000 m³) periods. The corresponding average values at Z1 and C2 during monsoon and postmonsoon were respectively 71.1 and 73.7 g/1000 m³ and 21.85 and 27.25 g/1000 m³. During premonsoon an entirely different picture could be obtained. M1 recorded the lowest average value (46.6 g/1000 m³) as compared to 54.9 and 53.47 g/1000 m³ respectively at sts Z1 and C2. Throughout the course of study copepods, decapod larvae, ctenophores, chaetognaths, sergestids, fish eggs and larvae were the major constituents of the zooplankton population.

Plankton and salinity—Salinity is an important ecological factor controlling the phytoplankton growth and distribution in the estuarine and nearshore waters. A close association between salinity changes in the environment and the abundance of phytoplankton and zooplankton has been well established. Qasim *et al*⁸ have shown that photosynthetic rates of different phytoplankton were higher when salinities were between 10 and 25‰. A negative correlation between salinity and phytoplankton cell counts (excluding the monsoon values) was reported in Cochin backwaters⁹ with a correlation coefficient $r = -0.79$. A similar phenomenon was observed by Ryther *et al.*¹⁰ from the Senix Creek, where the correlation between cell counts and salinity was high ($r = -0.875$). Many of the tropical phytoplankton organisms seem to be well adapted to changes in salinity¹¹. In the present study a rich phytoplankton count was observed during

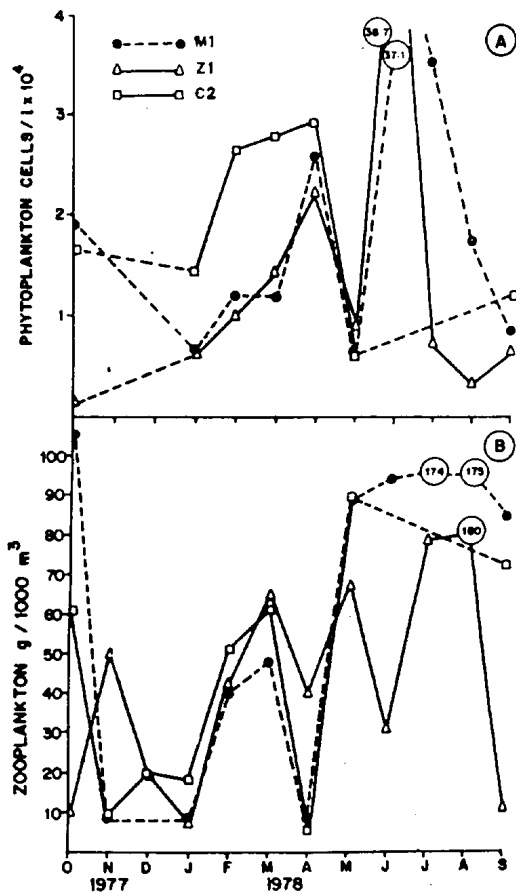


Fig. 2—Monthly variations of phytoplankton cells (A) and zooplankton biomass (B)

monsoon, when the salinity was considerably low (~20‰). Treating the whole data together and assuming the entire area of observation as one system we deduced the regression equation of phytoplankton cell concentration and salinity as $y = 323090 + (-8740)x$, with $r = -0.63$. Compared to the values reported for Cochin backwaters⁹ correlation coefficient for the present study was slightly lower. It may be due to the fact that the observations were confined to the mouth of the rivers and the coastal area where the salinity seldom was >20‰.

A close association between the salinity changes in the environment and zooplankton abundance has been studied by Wellershaus¹². He found the abundance and diversity of microzooplankton to be positively correlated to salinity and suggested that the stability of the environment is achieved only during the post and premonsoon months and the zooplankton population is rich and diverse during this period. The present observation contradicts that of Wellershaus¹² but is in agreement with that of Goswami *et al.*¹³. At a station little away inside the river from Z1 Goswami *et al.*¹³ recorded average biomass values during monsoon, postmonsoon and premonsoon as 513, 221, and 177 g/1000 m³ respectively. Goswami and Selvakumar⁶ reported the highest mean zooplankton biomass value of 220 g/1000 m³ at a station closer to Z1 during September. In the present study, the zooplankton biomass in the entire area during monsoon was higher than that recorded during pre and postmonsoon. It has been reported earlier⁸ that the enrichment of nutrients associated with sudden fall in temperature and salinity result in higher phytoplankton production. A positive relationship between phytoplankton and zooplankton could be observed in the present study. It is interesting to note that a negative relationship exists between zooplankton biomass and salinity ($r = -0.67$). The

regression equation of zooplankton biomass and salinity had the relation $y = 276.99 + (-6.78)x$ for the entire area.

Plankton and nutrients—The annual ranges of phosphate and nitrate in the area were 0.51 to 2.31 and 0.75 to 10.25 µg-at/litre respectively (Table 1). At M1 (Fig. 3A) phosphate values were higher both during monsoon and postmonsoon compared to premonsoon. Almost similar values were obtained for Z1 also (Fig. 3B). Coastal waters were comparatively rich

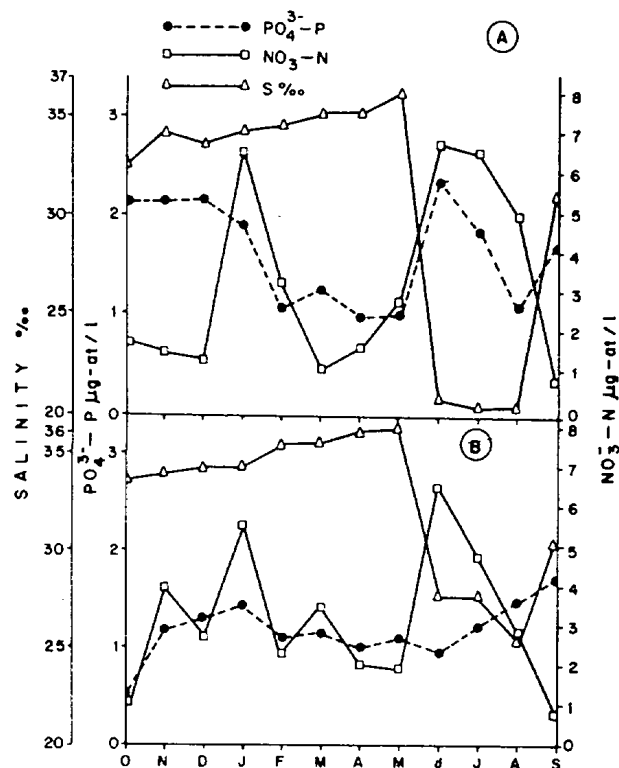


Fig. 3—Variations in concentration of $PO_4^{3-} - P$, $NO_3^- - N$ and salinity at st M 1 (A), st Z 1 (B)

Table 1—Range and Mean Concentrations of $PO_4^{3-} - P$, $NO_3^- - N$ and $S‰$ at Different Seasons

	$PO_4^{3-} - P$ (µg-at/litre)			$NO_3^- - N$ (µg-at/litre)			$S‰$		
	M1	Z1	C2	M1	Z1	C2	M1	Z1	C2
Postmonsoon (October-January)									
Range	1.9-2.7	0.51-1.44	0.89-1.95	1.33-6.62	1.11-5.62	1.75-10.25	32.41-34.28	33.68-34.35	33.62-35.19
Mean	2.09	1.11	1.32	2.81	3.40	4.47	33.61	34.04	34.42
Premonsoon (Feb-May)									
Range	0.97-1.24	0.99-1.16	1.22-1.74	1.10-3.25	1.95-3.5	1.05-9.49	34.50-36.10	35.39-36.14	35.92-36.62
Mean	1.06	1.08	1.46	2.18	2.45	3.93	35.26	35.71	36.24
Monsoon (June-September)									
Range	1.06-2.31	0.97-1.66	2.13*	0.75-6.8	0.75-6.6	0.87*	20.08-30.97	25.52-30.36	31.08*
Mean	1.70	1.26		4.78	3.71		22.98	27.76	

*September observation only

in NO_3 during pre and postmonsoon. The pattern of phosphorus supply and utilization in natural populations of phytoplankton is characterised by highly variable rates of uptake and release which bear little apparent relation to the physiological needs of the plankton¹⁴. Estimates of minimum phosphate requirements for phytoplankton growth vary greatly. Thus, half saturation constants for uptake (K_m values) vary 0.58 $\mu\text{g-at/litre}$ for *Thalassiosira pseudonana*¹⁵, 0.6 $\mu\text{g-at/litre}$ for *Scenedesmus* sp.¹⁶, 0.8 $\mu\text{g-at/litre}$ for *Cyclotella maneghiniana*¹⁷, 0.12, 0.15 and 0.17 $\mu\text{g-at/litre}$ respectively for *Asterionella japonica*, *Biddulphia sinensis* and *Ceratium furca*¹⁸, and up to 16 $\mu\text{g-at/litre}$ for *Euglena* sp.¹⁹. Throughout the year the areas studied could maintain phosphate concentration well above the K_m values reported above indicating that phytoplankton growth in these areas were not limited by the lack of phosphate. Taft *et al.*²⁰ reported that measured phosphate uptake in Chesapeake Bay exceeded the phosphate uptake required for photosynthesis up to 100 times. This suggests that photosynthesis is dependent on reserves of intracellular and perhaps dissolved organic P under different ambient nutrient regimes and further implies that varying physiological conditions of the plankton cells may be responsible for the wide range of fluxes observed.

No significant seasonal variation in the concentrations of nitrate is observed. At M1 and Z1 maximum values were observed during monsoon, whereas, in the coastal area maximum values were recorded during post and premonsoon. The ratios of concentration of N:P were generally low and did not show much variations. During monsoon N:P ratios varied between 0.4:1 (C2) to 2.9:1 (Z1). Bhattathiri *et al.*² observed during monsoon that N:P ratio varied between 0.4:1 and 21:1 in Mandovi whereas it ranged from 0.1:1 to 39:1 in Zuari. In both the estuaries they obtained negative correlations between production and nutrients (NO_3^- -N and PO_4^{3-} -P) with correlation coefficients (r) -0.065 and -0.02 respectively for Zuari and -0.29 and -0.12 respectively for Mandovi. This indicates that instantaneous concentration of nutrients is not as important as regeneration rate to affect production. Ryther *et al.*¹⁰ found that some of the estuarine diatoms are able to grow in waters of unusually low N:P ratio and suggested that nitrogen appears to be the element ultimately limiting the size of the algal population. However, N:P ratios for the water column can be misleading because the phytoplankton specific growth rate at steady state has been shown to be a function of cellular nutrient content rather than external concentrations in the water column¹⁵. On the other

hand, nutrient uptake rate is dependent on both internal and external substrate concentrations and at low N:P ratios nitrogen may eventually limit phytoplankton specific growth rate unless nitrogen is rapidly recycled¹⁶.

Davies²¹ indicated that the half saturation constants for uptake (K_m values) of nitrate are of the order of 0.1 to 10 $\mu\text{g-at/litre}$ in a wide range of phytoplankton species. There was probably only one occasion in our records when NO_3^- values encroached the upper end of this range and throughout it was well above the lower end. Therefore, it could be concluded that the present data do not indicate any possibility of nitrate or phosphate to limit production in these areas.

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References

- 1 Murty C S, Das P K, Nair R R, Veerayya M & Varadachari V V. *Indian J mar Sci*, 5 (1976) 9.
- 2 Bhattathiri P M A, Devassy V P & Bhargava R M S, *Indian J mar Sci*, 5 (1976) 83.
- 3 Dwivedi S N, Bhargava R M S, Parulekar A H, Selvakumar R A, Singbal S Y S & Sankaranarayanan V N, *Indian Fish Ass*, 3 (1973) 113.
- 4 Parulekar A H & Dwivedi S N, *Indian J mar Sci*, 3 (1974) 41.
- 5 Devassy V P & Bhargava R M S, *Mahasagar-Bull natn Inst Oceanogr*, 11 (1978) 195.
- 6 Goswami S C & Selvakumar R A, *Proceedings symposium on warm water zooplankton* (Spl. Publ. UNESCO/NIO) 1977, 226.
- 7 Grasshoff K (Ed), *Methods of sea water analysis* (Verlang Chemie New York) 1976.
- 8 Qasim S Z, Bhattathiri P M A & Devassy V P, *Mar Biol*, 12 (1972) 200.
- 9 Devassy V P & Bhattathiri P M A, *Indian J mar Sci*, 3 (1974) 46.
- 10 Ryther J H, Yentch C S & Vaccaro R F, *Biol Bull*, 115 (1958) 115.
- 11 Qasim S Z, *Mahasagar-Bull natn Inst Oceanogr*, 13 (1980) 117.
- 12 Wellershaus S, *Hydrobiol Bull*, 8 (1974) 213.
- 13 Goswami S C, Selvakumar R A & Usha Goswami, *Mahasagar Bull natn Inst Oceanogr*, 12 (1979) 247.
- 14 Jeffrey R E, *Limnol Oceanogr*, (1979) 906.
- 15 Fuhs G W, *J Phycol*, 5 (1969) 312.
- 16 Rhee G Y, *J Phycol*, 9 (1973) 495.
- 17 Tilman D & Kilham S S, *J Phycol*, 12 (1976) 375.
- 18 Qasim S Z, Bhattathiri P M A & Devassy V P, *Mar Biol*, 21 (1973).
- 19 Blum J J, *J gen Physiol*, 49 (1966) 1125.
- 20 Taft J L, Taylor W R & Mc Carthy J J, *Mar Biol*, 33 (1975) 21.
- 21 Davies A G, *J mar Biol Ass UK*, 50 (1970) 65.