

DISSOLVED ORGANIC NUTRIENTS AND PHYTOPLANKTON PRODUCTION IN THE MANDOVI ESTUARY AND COASTAL WATERS OF GOA

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ABSTRACT

Total organic nitrogen (TON) and dissolved organic phosphorus (DOP) in the coastal and estuarine waters of Goa varied from 0.6 to 47.1 $\mu\text{g-at N l}^{-1}$ and 0.12 to 3.49 $\mu\text{g-at P l}^{-1}$ respectively. The chlorophyll content of these waters fluctuated from 0.3 to 11.3 mg m^{-3} . The increase in TON and DOP in June and October coincided with the chlorophyll peak, thereby suggesting that these two are derived from planktonic activity. The low values of concentration ratio and assimilation ratio ($\text{NO}_3^- : \text{PO}_4^{3-}$) suggested that inorganic nutrients were deficient in these waters. However, the percentage of TON and DOP in total nitrogen and total dissolved phosphorus varied from 50.7 to 96.6% and 15.3 to 74.6% respectively, during the post and premonsoon months, when the production remained high. A large portion of TON and DON in the coastal and estuarine waters of Goa might serve as an efficient nutrient supplement for the phytoplankton at times of nitrate deficiency.

Key-words : Organic nutrients, organic nitrogen, organic phosphorus, phytoplankton, coastal waters, Mandovi estuary.

INTRODUCTION

Studies on the nutrient chemistry in the coastal waters around India are mostly confined to the analysis of inorganic nutrients like nitrate, silicate and phosphate (De Souza, 1977; De Souza, Sen Gupta, Sanjiri and Rajgopal, 1981; Sankaranarayanan and Qasim, 1969). However, there are increasing evidences to show that besides inorganic nutrients, organic compounds of nitrogen and phosphorus in solution are also actively involved in the growth of marine phytoplankters (Guillard, 1963; Harvey, 1953). Yet only limited information is available on the distribution of organic nitrogen and dissolved organic phosphorus in the inshore and the estuarine waters of India (Qasim and Sen Gupta, 1981; Rao and Rao, 1974, Rajendran and Venugopalan, 1973). Investigations were therefore undertaken to estimate total organic nitrogen and dissolved organic phosphorus along with chlorophyll and phytoplankton production to get an idea about the inter-relationships of these organic nutrients with productivity cycle in the coastal and estuarine waters of Goa.

MATERIALS AND METHODS

A reference station was fixed in the coastal waters of Goa, about 10 km off Aguada coast Lat. $15^\circ 28' \text{N}$, Long. $73^\circ 39' \text{E}$, having a depth of about 30 m. A series of six stations at suitable intervals were worked in the Man-

dovi estuary from the mouth towards the fresh water zone, about 70 km upstream. The depths of stations varied from 4 to 11 m. The last upstream station was relatively shallow with a depth of 1 m (Fig. 1).

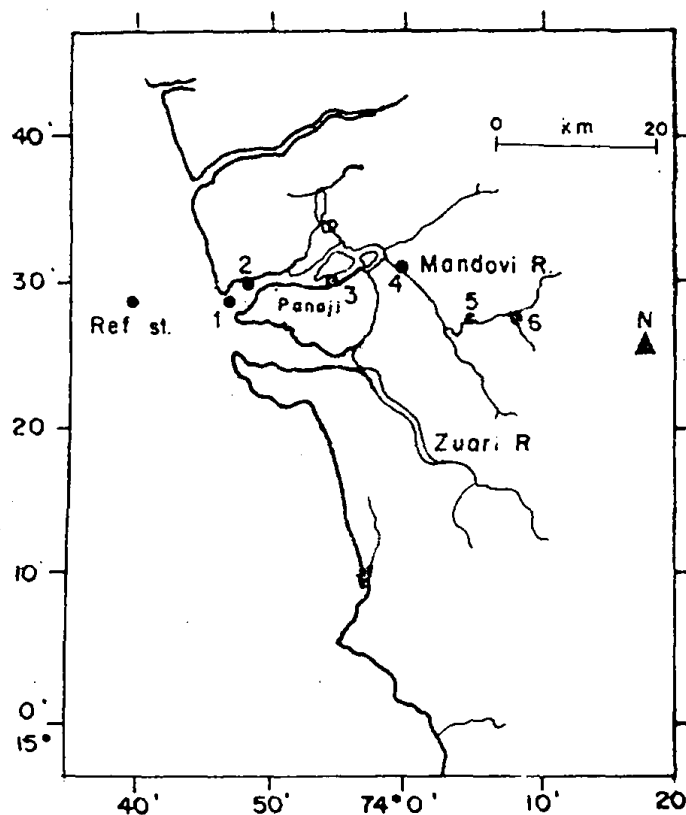


Fig. 1. Map showing the location of reference and transect stations in the coastal waters of Goa.

Water samples for the measurement of the different hydrographical parameters and nutrients were collected every month from three depths; surface, mid waters and near bottom, at the reference station and from surface and near bottom at the estuarine stations from February, 1980 to March 1981. However, for measurement of primary productivity, the water samples were obtained from 3 to 5 depths in the euphotic zone using Van Dorn samplers.

Due to sand bar formation at the Aguada mouth during the southwest monsoon, boat traffic was closed and hence it was not possible to collect samples at the reference station from June to September. The ^{14}C incubation for the measurement of primary productivity was carried out on board the vessel itself and radioactivity was assayed using liquid scintillation counter. Total organic nitrogen (TON) and dissolved organic phosphorus (DOP) were estimated using persulphate oxidation method described by Grasshoff (1976). Urea was measured by diacetyl monoxime method (Newell, Morgan and

Cundy, 1967) and inorganic nutrients were estimated by the methods given in Grasshoff (1976).

RESULTS AND DISCUSSION

The total organic nitrogen content at the reference station varied from 2.5 to 35.7 $\mu\text{g-at l}^{-1}$ during the postmonsoon (Oct. to Jan.) and premonsoon (Feb. to May) periods (Fig. 2a). And the integrated mean values of TON varied from 4.1 to 24.56 $\mu\text{g-at l}^{-1}$ (Fig. 4). The average TON values attained a peak in November, but during most of the period the concentrations remained more or less constant. The vertical distribution indicated that the values were neither uniform nor showed regular pattern of increase or decrease.

In the estuarine region (stns. 1 to 4) the annual TON values showed a bimodal cycle of variations with concentrations ranging from 0.6 to 47.1 $\mu\text{g-at l}^{-1}$ (Fig. 2b & c). Except for the month of June, the TON remained low throughout the monsoon period. The monthly mean values of TON at the estuarine region (stns. 1, 3 & 4) varied from 2.53 to 23.65 $\mu\text{g-at l}^{-1}$ (Fig. 4). The TON peaks were observed from April to June and from October to December. In the upstream portion of the estuary (stns. 5 & 6), TON remained lower than in the downstream stations. The TON concentration in the bottom waters of the estuary usually remained higher than that in the surface waters.

The integrated mean values of urea at the reference station varied from 0.23 to 1.58 $\mu\text{g-at l}^{-1}$ and those at the estuarine stns. 1, 3 & 4 varied from 0.19 to 2.82 $\mu\text{g-at l}^{-1}$. Similarly, the integrated mean values of total inorganic nitrogen ($\text{NH}_4^+ + \text{NO}_2^- + \text{NO}_3^-$) at the reference station varied from 0.6 to 3.99 $\mu\text{g-at l}^{-1}$ and those at the three estuarine stations varied from 2.27 to 16.17 $\mu\text{g-at l}^{-1}$ (Fig. 4).

Dissolved organic phosphorus (DOP) at the reference station varied within a narrow range of 0.12 to 0.87 $\mu\text{g-at l}^{-1}$ (Fig. 3a), while the integrated mean values ranged from 0.23 to 0.48 $\mu\text{g-at l}^{-1}$ (Fig. 4). In the estuarine waters, DOP fluctuated between 0.3 to 1.77 $\mu\text{g-at l}^{-1}$ except for a high value of 3.49 $\mu\text{g-at l}^{-1}$ in September (Fig. 3b & c). The mean values in the three estuarine stations (stns. 1, 3 & 4) varied from 0.06 to 0.92 $\mu\text{g-at l}^{-1}$ (Fig. 4). These values are somewhat similar to those reported for Cochin backwaters, which ranged from 0.1 to 5.5 $\mu\text{g-at l}^{-1}$ (Sankaranarayanan and Qasim, 1969) and those between 0.1 to 3.1 $\mu\text{g-at l}^{-1}$ in the coastal waters off Waltair (Rao and Rao, 1974). The changes in DOP in the estuarine stations varied independently of each other when compared to the reference station. The DOP concentration remained much lower in the upstream portion of the estuary (stns. 5 & 6) varying between 0.03 to 0.6 $\mu\text{g-at l}^{-1}$ (Fig. 3b & c). Vertical distribution of DOP, both at the estuarine and reference station, indicated that the values were heterogeneous.

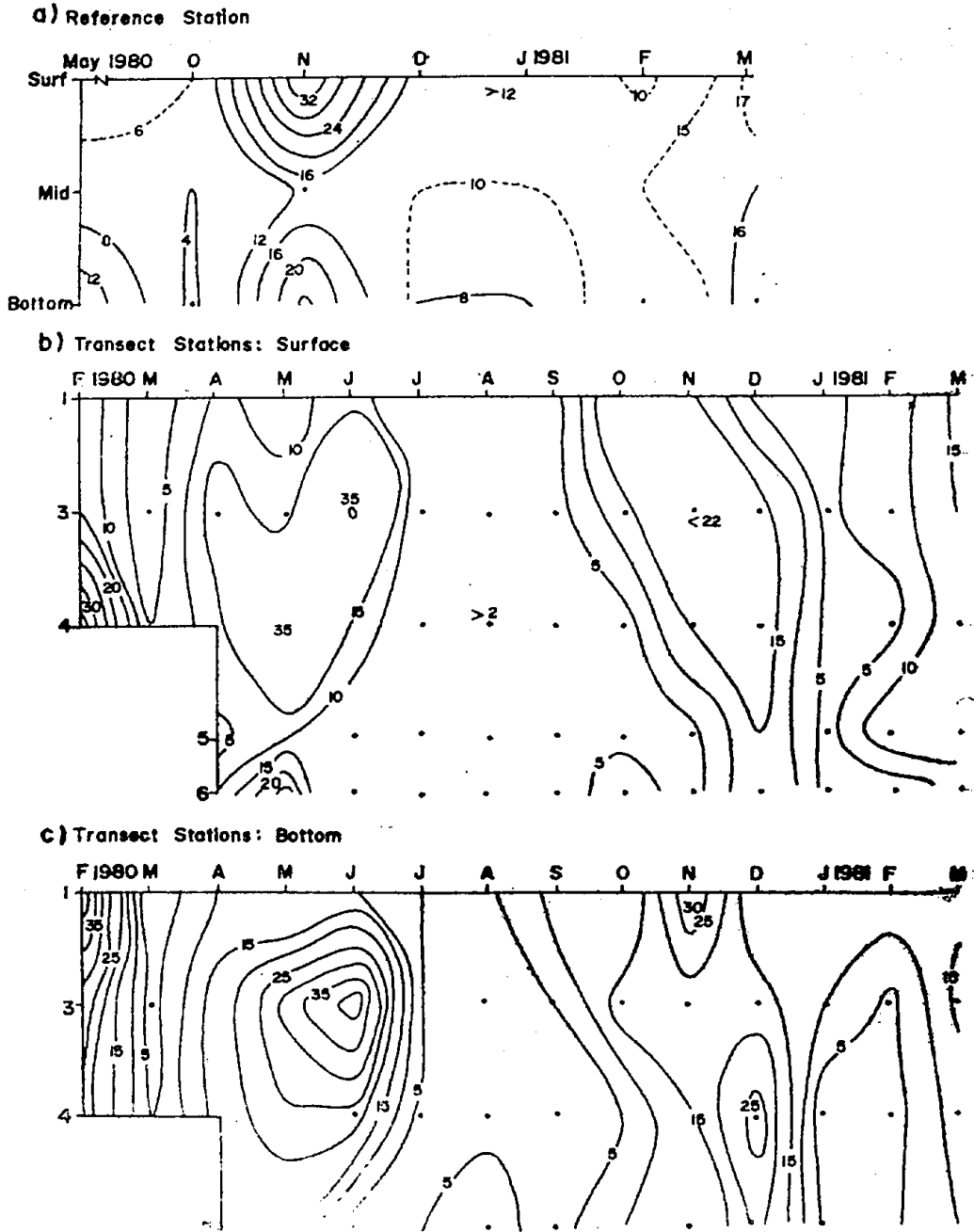


Fig. 2. Distribution of total organic nitrogen ($\mu\text{g-at l}^{-1}$) at (a) the reference station and (b & c) the transect stations.

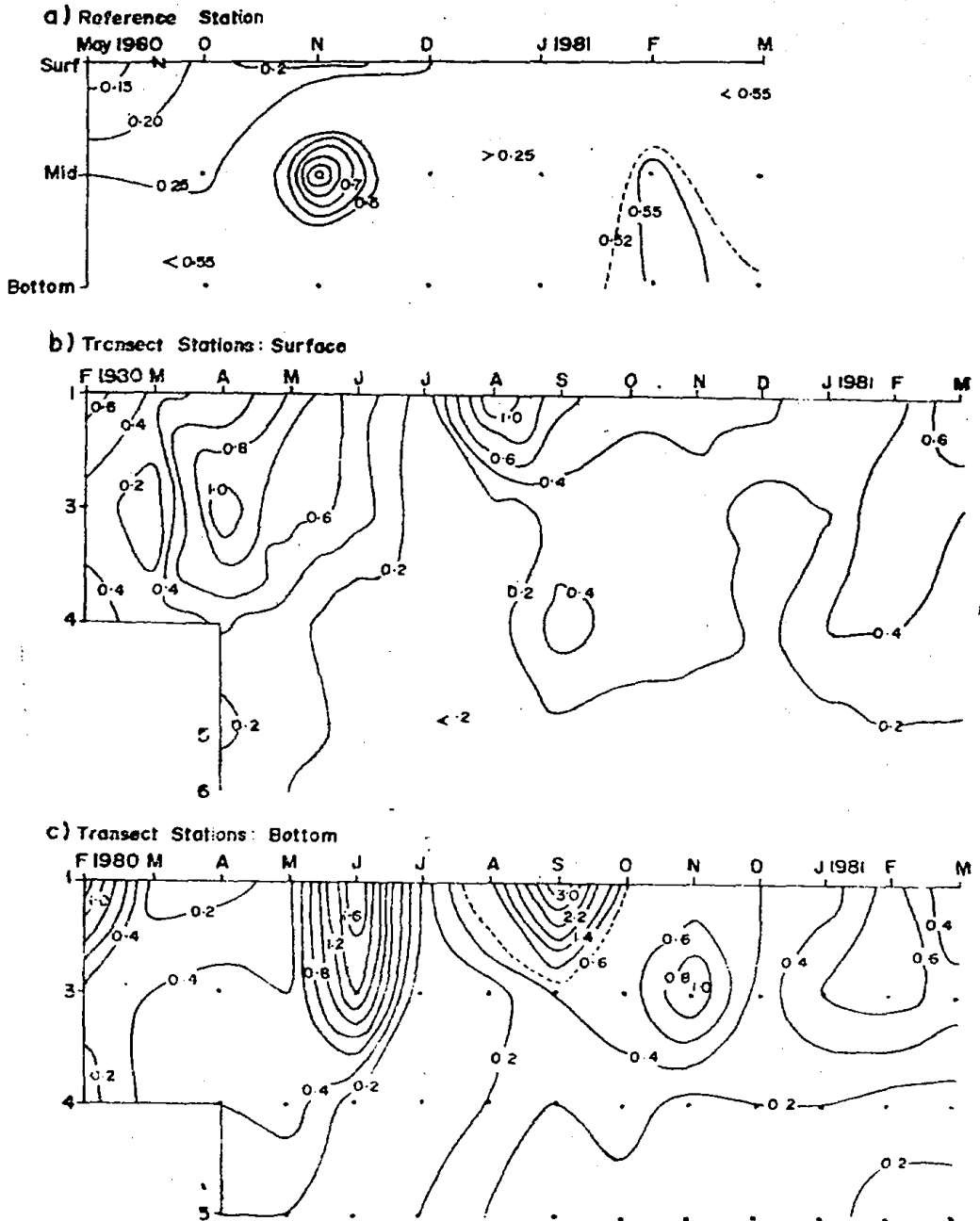


Fig. 3. Distribution of dissolved organic phosphorus ($\mu\text{g-at l}^{-1}$) at (a) the reference station and (b & c) the transect stations.

The mean values of dissolved inorganic phosphate in the estuarine and coastal waters varied from 0.16 to 2.0 $\mu\text{g-at P l}^{-1}$ (Fig. 4). The DOP concentration varied almost within the same limits as that of dissolved inorganic phosphates (Fig. 4).

The mean chlorophyll concentration and the rate of primary productivity in the euphotic zone of the reference station varied from 0.3 to 4.7 mg m^{-3} and from 380.5 to 1231.3 $\text{mg C m}^{-2} \text{ day}^{-1}$ respectively during post and premonsoon periods. The observations on the annual cycle of chlorophyll and primary productivity of the estuarine stations showed surface chlorophyll concentrations to range from 0.5 to 11.3 mg m^{-3} and primary productivity from 0.9 to 1205.5 $\text{mg C m}^{-2} \text{ day}^{-1}$ (Fig. 4). The chlorophyll concentration and the primary productivity remained high in June and in October–November. Zooplankton biomass at the reference station varied from 1.4 to 104.8 $\text{g dry wt. } 1000 \text{ m}^{-3}$ and the monthly mean values at the estuarine region (stns. 1, 3 & 4) varied from 0.3 to 20.7 $\text{g dry wt. } 1000 \text{ m}^{-3}$ (Fig. 4).

The increase in TON and DOP in June and November followed the peaks of zooplankton and phytoplankton production (Fig. 4) which suggest that these fractions of organic nitrogen and phosphorus are derived from the excretion and/or decomposition of planktonic organisms (Corner and Davies, 1971; Pomeroy, Mathews and Min, 1963; Solorzano and Ehrlich, 1977). On the other hand, the high TON values encountered in April–May, when both fresh water runoff as well as production remained low, suggests that the organic nitrogen is derived from the activities of the human settlements on the banks of the estuary. While TON remains low during the monsoon period (July to September), the mean DOP values fluctuated from a minimum concentration of 0.06 $\mu\text{g-at l}^{-1}$ in July to a maximum of 0.92 $\mu\text{g-at l}^{-1}$ in September. Since primary production and the concentration of DOP & TON in the upstream portion of the estuary were low (Figs. 2b & c and 3b & c) during this period, the input of these fractions from land runoff, and from *in situ* regeneration appear to be low. However, the estuarine waters are characterised by high levels of suspended sediments during monsoon and wide fluctuations of DOP values during this period appear to be due to the adsorption and subsequent desorption of organic phosphorus compounds on suspended sediments, as observed with the inorganic fractions (Verlencar, 1984; Pomeroy, Smith and Grant, 1965). Similar observations have been reported in some of the turbid estuaries like Cochin backwaters and Tamar estuary, where the DOP did not show any relation with productivity, and hence the same was ascribed to the exchange of DOP with the suspended sediments (Sankaranarayanan and Qasim, 1969; Butler and Tibbitts, 1972).

The organic nitrogen is subjected to remineralisation in the marine environment (Hattori, 1982). The remineralization of organic nitrogen was very obvious from November, 1980 to March, 1981. The decrease in organic nitrogen from December to February, corresponded with an increase in urea and available nitrogen in the estuarine waters (Fig. 4).

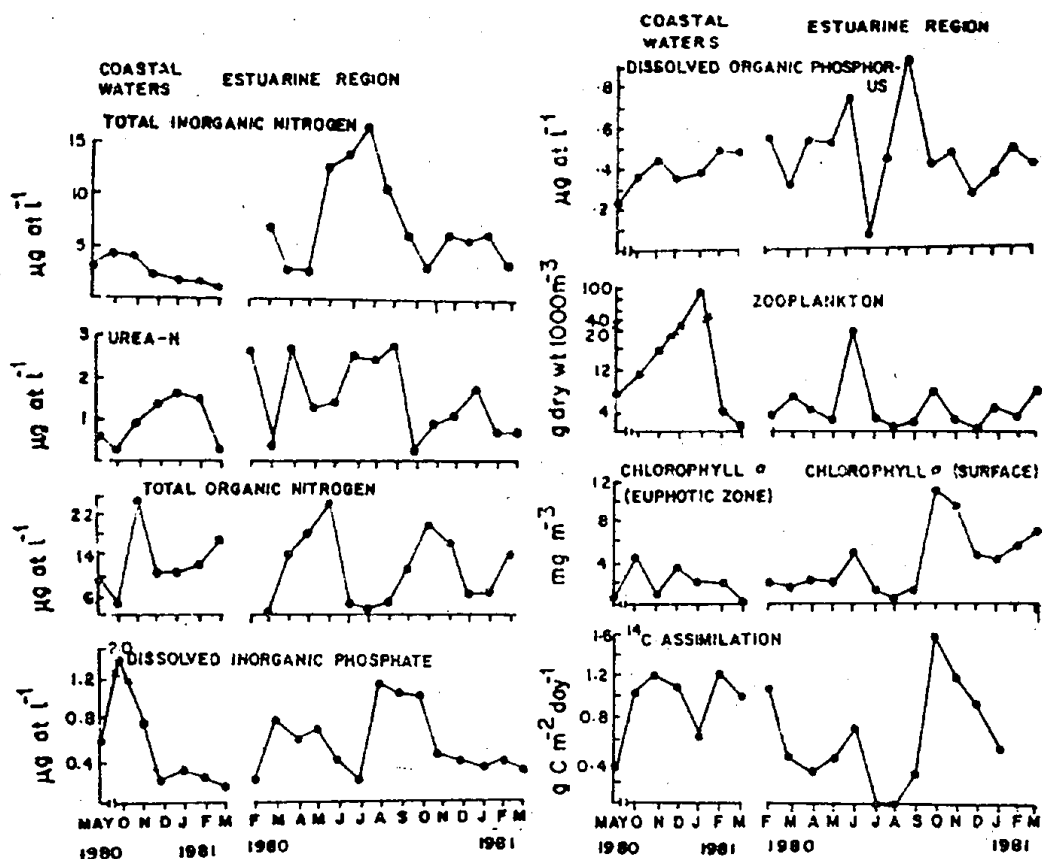


Fig. 4. Monthly mean variations in different parameters in the coastal and estuarine stations (stns. 1 to 4).

It was earlier reported (Verlencar, 1984) that the concentration ratio of $\text{NO}_3^- : \text{PO}_4^{3-}$ and available nitrogen : PO_4^{3-} , frequently remained anomalous during the productive period of pre and postmonsoon seasons. The assimilation ratio ($\Delta \text{N} : \Delta \text{P}$) of $\text{NO}_3^- : \text{PO}_4^{3-}$ also attained a low value of 11. These observations suggest that dissolved inorganic nitrogen was in deficit in these waters. However, it is well known that organic nitrogen in dissolved form may be available for the direct utilization by phytoplankton to some extent (Guillard, 1963) and also as remineralisation products in the form of urea, ammonia and nitrates (McCarthy, Taylor and Jay, 1977). Similarly DOP may be converted rapidly to inorganic form (Watt and Hynes, 1963). The total organic nitrogen and dissolved organic phosphorus were therefore calculated as percent of total nitrogen and total dissolved phosphorus. From Table I, it can be seen that the percentage of total organic nitrogen in the coastal and estuarine waters varied from 50.7 to 96.6 during the post and premonsoon periods except in March, 1980. This is a fairly large proportion of nitrogen available to overcome the inorganic nitrogen deficiency of phytoplankters in these waters. The DOP percentage similarly varied from 15.3 to 74.6. This fraction of phosphorus may be utilised by phytoplankton directly (Harvey,

Table I. Total organic nitrogen (TON) and dissolved organic phosphorus (DOP) respectively as the percent of total nitrogen and total dissolved phosphorus in the coastal and estuarine waters.

Month	TON (%)		DOP (%)	
	Coastal waters	Estuarine waters	Coastal waters	Estuarine waters
Feb. 1980	—	—	—	69.2
March	—	27.0	—	27.3
April	—	84.3	—	45.2
May	73.5	88.7	25.8	40.7
June	—	65.8	—	63.5
July	—	23.5	—	22.2
August	—	16.6	—	26.6
Sept.	—	31.8	—	46.5
Oct.	50.7	66.9	15.3	27.7
Nov.	87.2	89.2	35.8	50.5
Dec.	83.5	74.7	59.6	37.9
Jan. 1981	89.9	54.1	54.5	49.2
Feb.	90.6	52.8	65.7	55.2
March	96.6	84.9	74.6	53.4

1953) or as its decomposition product in the form of inorganic phosphate (Qasim, Bhattathiri and Devassy, 1973) when the latter assumes low values in the coastal waters during post-monsoon season. The proportions of TON and DON available in the coastal and estuarine waters of Goa may therefore serve directly or indirectly as the efficient nutrient supplement for the primary producers in these waters.

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REFERENCES

- Butler, E.I. and S. Tibbitts, 1972. Chemical survey of Tamar Estuary: I. Properties of waters. *Journal of Marine Biological Association, U.K.* **52**: 681-699.
- Corner, E.D.S. and A.G. Davies, 1971. Plankton as a factor of nitrogen and phosphorus cycle in the sea. *Advances in Marine Biology*, **9**: 101-204.
- De Souza, S.N., 1977. Monitoring some environmental parameters at the mouth of Zuari River, Goa. *Indian Journal of Marine Sciences*, **6**: 114-117.
- De Souza, S.N., R. Sen Gupta, S. Sanjiri and M.D. Rajgopal, 1981. Studies on nutrients of Mandovi and Zuari river systems. *Indian Journal of Marine Sciences*, **10**: 314-321.
- Grasshoff, K., 1976. *Methods of Seawater Analysis*. Verlag Chemie, New York, 317 pp.

- Guillard, R.R.L., 1963. Organic sources of nitrogen for marine centric diatoms. In: *Symposium on Marine Microbiology*, edited by C.H. Oppenheimer, Charles C. Thomas Publisher, Springfield, Illinois, U.S.A. p. 93-104.
- Harvey, H.W., 1953. Note on absorption of organic phosphorus compounds by *Nitzschia closterium* in the dark. *Journal of Marine Biological Association, U.K.*, **31**: 475-476.
- Hattori, A., 1982. The nitrogen cycle in the sea with special reference to biogeochemical processes. *Journal of Oceanographic Society of Japan*, **38**: 245-265.
- McCarthy, J.J., W.R. Taylor and L.T. Jay, 1977. Nitrogenous nutrition of plankton in Chesapeake Bay: I. Nutrient availability and phytoplankton preferences. *Limnology and Oceanography*, **22**: 996-1011.
- Newell, B.S., B. Morgan and J. Cundy, 1967. Determination of urea in sea water. *Journal of Marine Research*, **25**: 201-202.
- Pomeroy, L.R., H.M. Mathews and H.S. Min, 1963. Excretion of phosphate and soluble organic phosphorus compounds by zooplankton. *Limnology and Oceanography*, **8**: 50-55.
- Pomeroy, L.R., E.E. Smith and C.M. Grant, 1965. The exchange of phosphate between estuarine waters and sediments. *Limnology and Oceanography*, **10**: 167-172.
- Qasim, S.Z., and R. Sen Gupta, 1981. Environmental characteristics of the Mandovi-Zuari estuarine system in Goa. *Estuarine, Coastal and Shelf Science*, **13**: 557-578.
- Qasim, S.Z., P.M.A. Bhattathiri and V.P. Devassy, 1973. Growth kinetics and nutrient requirements of tropical marine phytoplankters. *Marine Biology*, **21**: 299-304.
- Rajendran, A. and V.K. Venugopalan, 1973. Distribution of dissolved, particulate and mud phosphorus in Vellar estuary. *Indian Journal of Marine Sciences*, **2**: 13-18.
- Rao, C.V. and T.S.S. Rao, 1974. Distribution of dissolved nitrogen and phosphorus in the Bay of Bengal. *Journal of Marine Biological Association of India*, **16**: 775-790.
- Sankaranarayanan, V.N. and S.Z. Qasim, 1969. Nutrients of Cochin Backwaters in relation to environmental characteristics. *Marine Biology*, **2**: 236-247.
- Solorzano, L., and E. Ehrlich, 1977. Chemical investigations of Loch Etive Scotland. II. Dissolved organic compounds. *Journal of Experimental Marine Biology and Ecology*, **29**: 65-79.
- Verlencar, X.N., 1984. Nutrient distribution in relation to phytoplankton production in the estuarine and coastal waters of Goa. *Hydrobiologia* (in press).
- Watt, W.D., and F.R. Hynes, 1963. Tracer study of phosphorus cycle in sea water. *Limnology and Oceanography*, **8**: 276-285.