

DISTRIBUTION OF NUTRIENTS IN THE COASTAL AND ESTUARINE WATERS OF GOA

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ABSTRACT

Concentrations of nitrate and phosphate in the coastal waters of Goa varied from 0 to 2.4 μg at 1^{-1} and from 0.1 to 2.4 μg at 1^{-1} respectively, during post and premonsoon periods. In the estuarine region the nutrients like nitrate and ammonia remained higher than those in the coastal waters. The relation between salinity and nutrients suggest that the fresh-water is the main source for the addition of nitrate to the estuary.

Seasonal fluctuation in the primary productivity and chlorophyll a values were noticed in the Mandovi estuary and the adjoining coastal waters. The $\text{NO}_3^- : \text{PO}_4^{3-}$ concentration ratio remained low during post and premonsoon periods when the primary productivity was high. The ratio of change for nitrate and phosphate ($\Delta \text{N} : \Delta \text{P}$) showed a low value of 11 (by atoms). The $\text{NO}_3^- : \text{PO}_4^{3-}$ concentration ratio and the assimilation ratio clearly showed that the nitrate is deficient in these waters during post and premonsoon periods. But the high levels of ammonia (ranging between 0.23 to 7.8 μg at 1^{-1}) available in these waters could suggest that this nutrient compensates to some extent the observed deficiencies of nitrate.

Key-words : Nutrients, coastal waters, estuarine region, monsoon, phytoplankton

INTRODUCTION

The nutrients determine the potential fertility of the water masses (Harvey 1955) and therefore it is important to have an idea about their distribution and behaviour in different geographical locations and seasons. Since little is known about the complex biological processes affecting the nutrient cycle in the estuarine and coastal waters of Goa, a study on nutrient distribution in relation to estuarine mixing and primary productivity cycle in these waters was undertaken. The Mandovi estuary and the adjoining coastal waters were selected (Fig. 1) for this purpose. Mandovi basin covers an area of about 1530 sq. km. consisting of agricultural fields, urban areas, wetlands and industrial outfalls. It is fed by monsoon precipitation and discharge from a catchment area of about 1150 sq. km. Pre-and post-monsoonal fresh water flow is 0.06 $\text{km}^3 \text{ year}^{-1}$. Annual average runoff is estimated to be 16 km^3 (Anonymous 1979). Mandovi river estuary behaves as a mixed estuary during the fair weather period (December to May), while during the monsoon (June to September), it shows stratification depending on the precipitation and the freshwater discharge (Qasim and Sen Gupta 1981).

MATERIAL AND METHODS

A reference station was fixed in the coastal waters at a depth of about 30m off Aguada, lat $15^{\circ}28'N$; long $73^{\circ}39'E$ (Fig. 1) and a series of six stations were fixed in the estuarine transect of the river Mandovi, from its mouth up to 70 km upstream, ending in the freshwater zone. Observations were carried out every month from February 1980 to March 1981. For the measurements of nutrients and hydrographic parameters, samples were collected from surface, mid depth and near bottom at the reference station, while in the estuarine region only surface and near bottom samples were obtained. However, for the primary productivity studies, three or five depths were chosen in the euphotic zone during each sampling period. During monsoon (June to September), due to the formation of sand bar at the Aguada mouth, it was not possible to obtain samples at the reference station. Water samples were obtained using Van Dorn bottles.

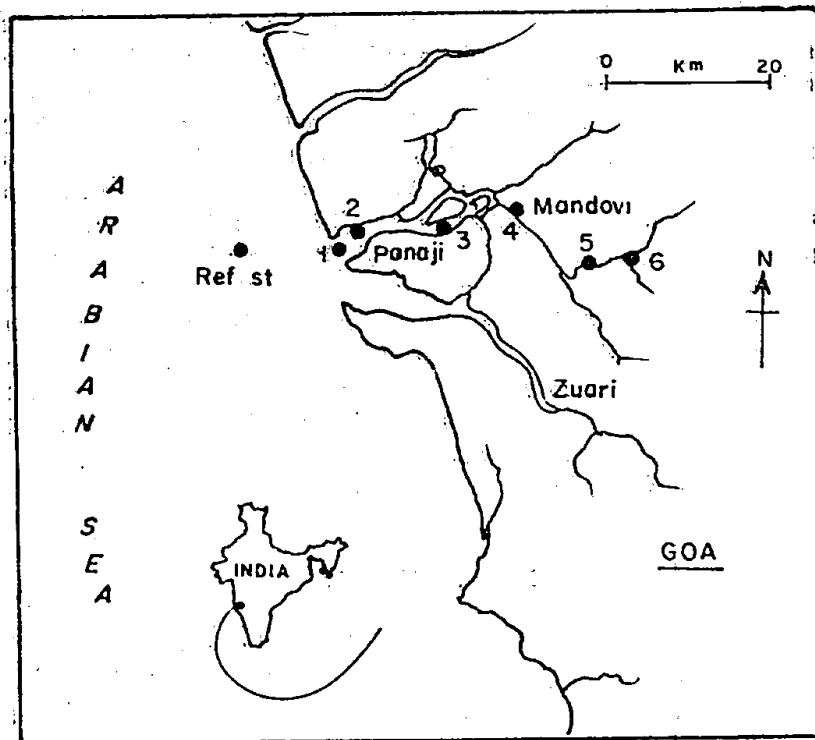


Fig. 1. Map showing the position of the reference station and the transect stations in the Mandovi river estuary.

Phosphate was estimated following Murphy and Riley (1962). The total phosphorous adsorbed on the sediments was estimated by the method of Rochford (1951). Other nutrients were measured following the standard procedures given by Grasshoff (1976). Primary productivity measurements were made using ^{14}C method. The samples were incubated immediately after collection and the radioactivity assayed in the laboratory by liquid scintillation counter. Zooplankton surface tow was taken with the help of Heron Tranter net (mouth area 0.25 m^2 ; mesh size 0.3 mm), at the minimum speed of 1.5 knots. The water filtered was measured with the help of flowmeter. Biomass was determined by displacement method.

RESULTS AND DISCUSSION

Nitrate :

The nitrate distribution in the coastal and estuarine waters of Goa is shown in the Fig. 2 (a, b & c). It can be seen that at the reference station, the concentration ranged from 0.0 to 2.4 and at estuarine region (stn. 1-4) from 0.0 to 8.44 μg at l^{-1} during post monsoon (October to January) and premonsoon (February to May) periods respectively. Nitrate remained high in October and November at the reference station and low during rest of the sampling periods.

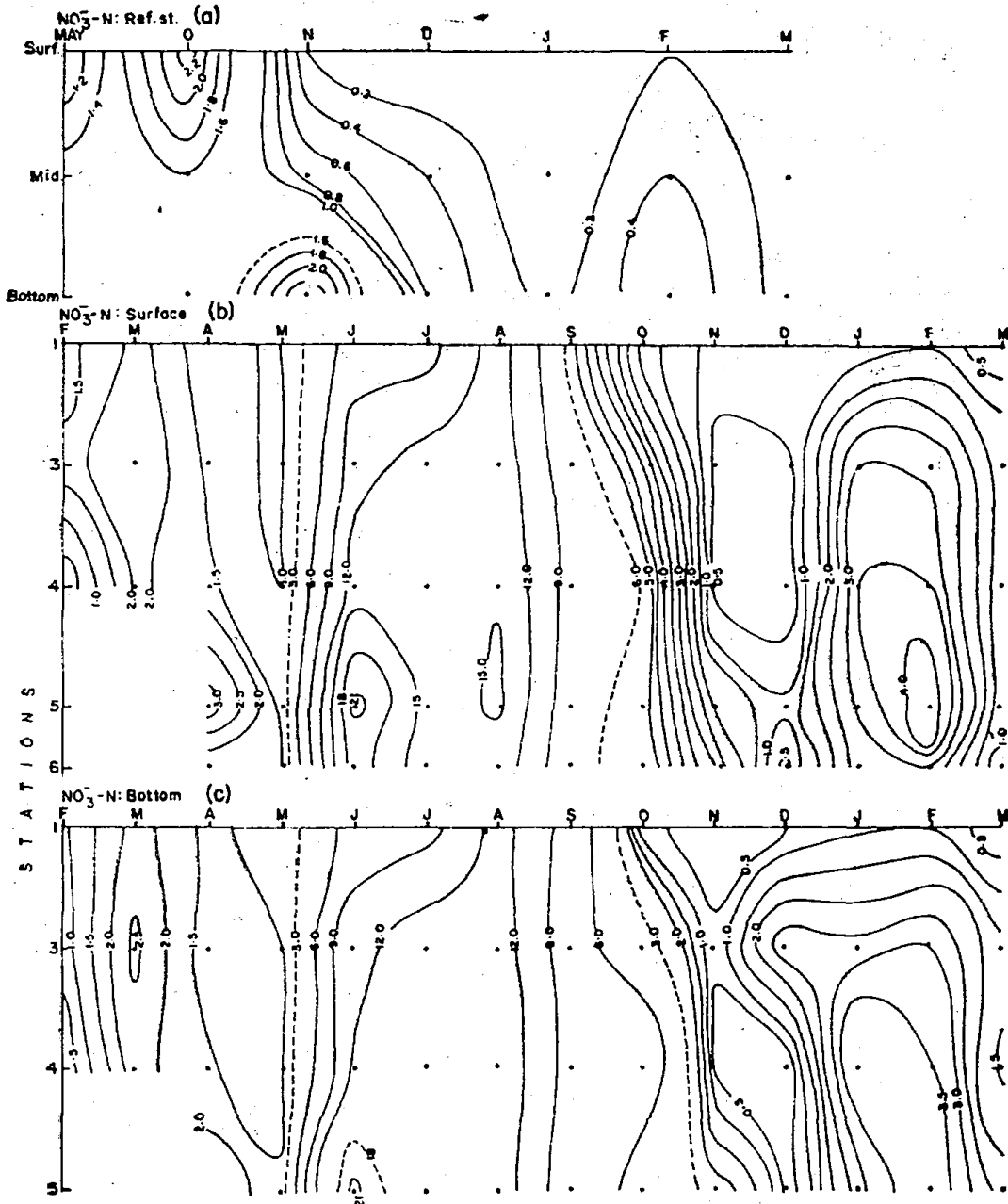


Fig. 2. The nitrate (μg at l^{-1}) distribution at (a) the reference station and (b & c) the transect stations in the Mandovi river estuary.

Seasonal fluctuation of nitrate in the estuarine region indicated a sudden increase in concentration upto a maximum of $13.5 \mu\text{g at l}^{-1}$ at the onset of monsoon (June), remaining high till September — October. Two other minor peaks were also observed with a maximum concentration of 4.4 and $2.6 \mu\text{g at l}^{-1}$ during January—February and March respectively. Similar pattern was also noticed in the upstream freshwater zone covering (stns. 5 and 6.)

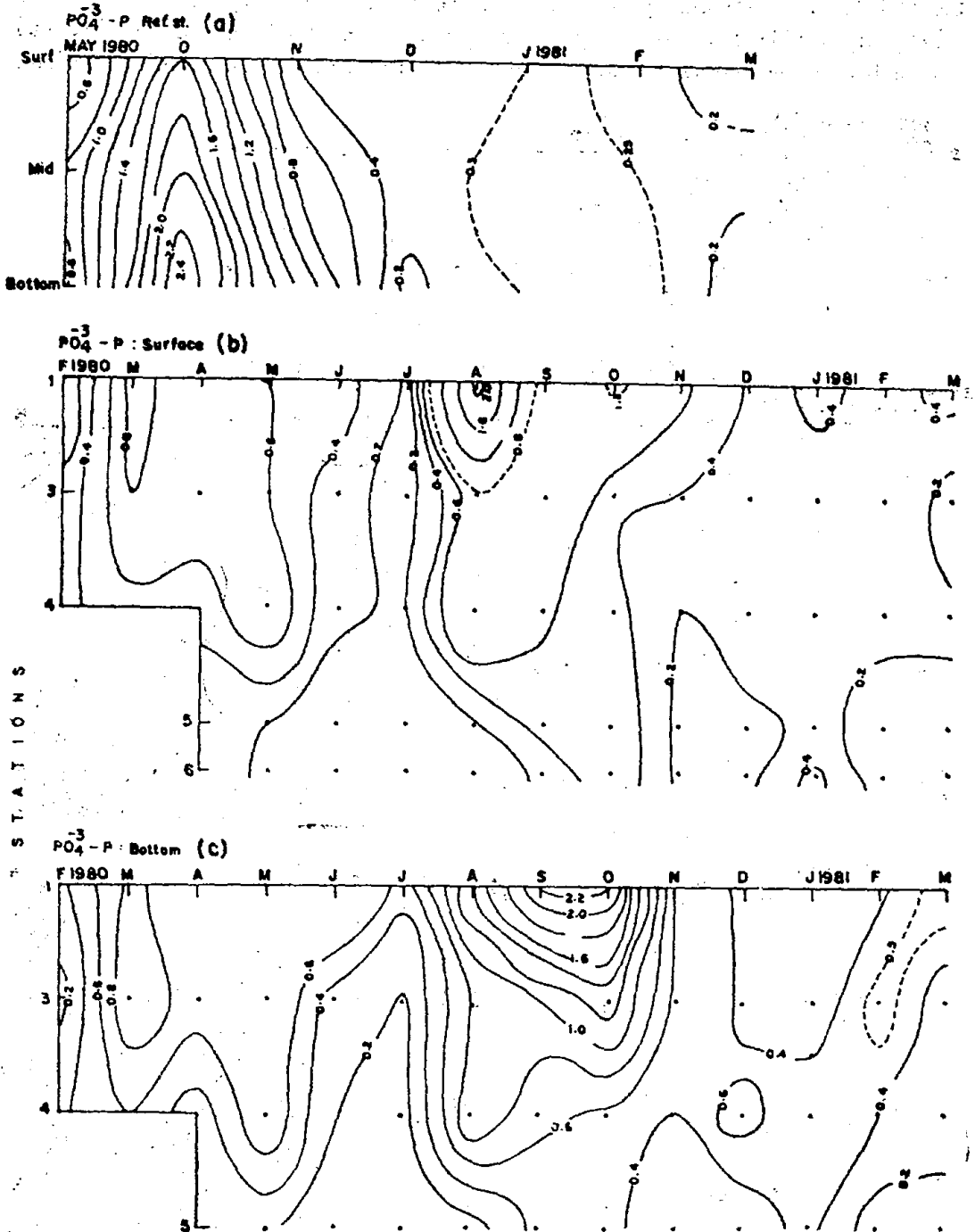


Fig. 3. The inorganic phosphate ($\mu\text{g at l}^{-1}$) distribution at (a) the reference station and (b & c) the transect stations in the Mandovi river estuary.

Phosphate :

The variation of phosphate at the reference station is shown in the figure 3a. The phosphate content remained high between 0.39 to 2.4 μg at l^{-1} in October–November (post-monsoon) and decreased later from 0.1 to 0.29 μg at l^{-1} till March 1981. The changes in phosphate concentrations during postmonsoon in the estuarine region were similar to those noticed at the reference station. Slightly higher values with a maximum concentration of 0.97 μg at l^{-1}

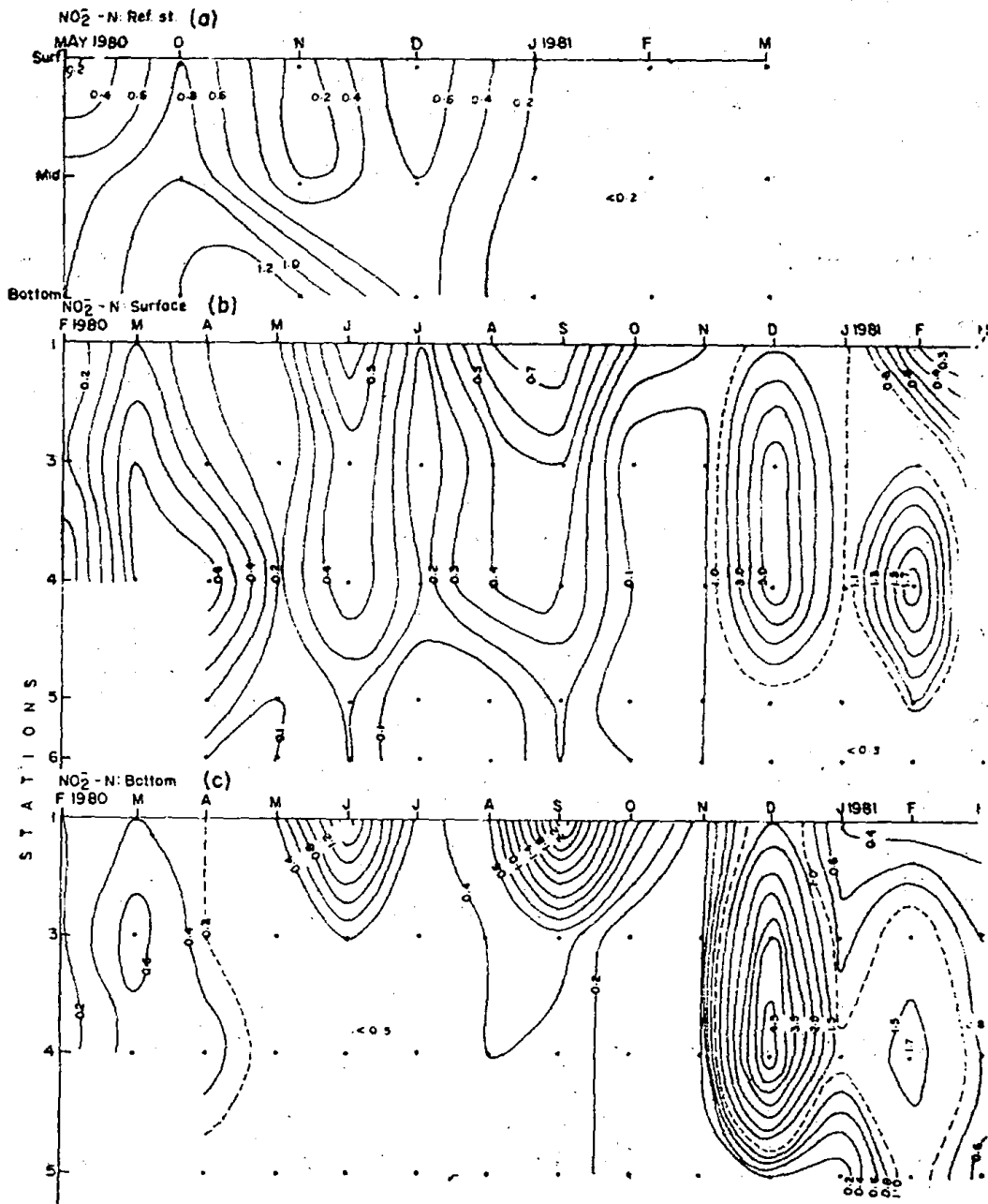


Fig. 4. The nitrate (μg at l^{-1}) distribution at (a) the reference station and (b & c) the transect stations in the Mandovi river estuary.

could be observed during premonsoon of 1980 (Fig. 3b & c). However during monsoon (June—July), the concentrations remained low (min. value 0) but increased sharply to a maximum of $2.24 \mu\text{g at l}^{-1}$, in September till October.

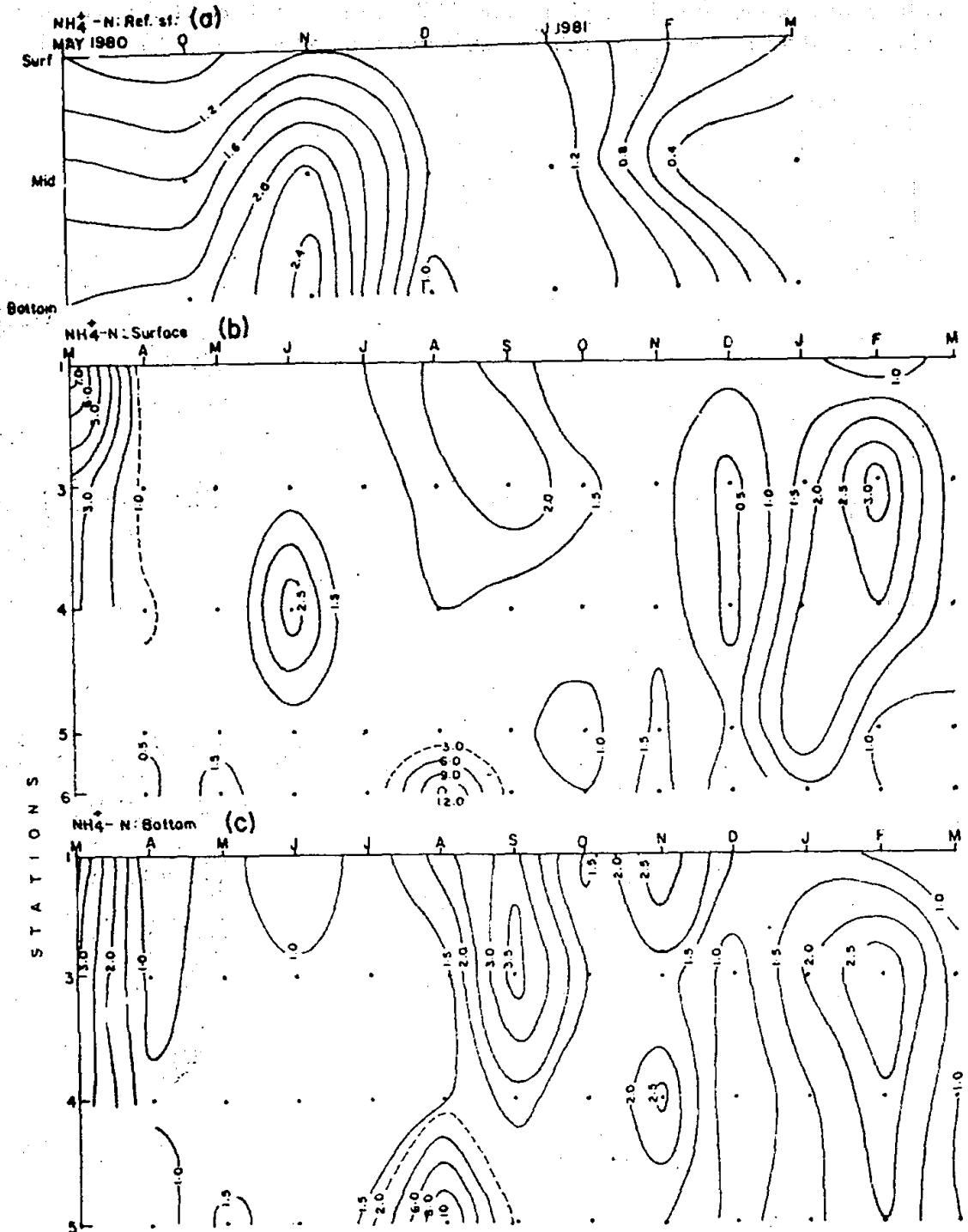


Fig. 5. The ammonia ($\mu\text{g at l}^{-1}$) distribution at (a) the reference station and the transect survey stations in the Mandovi river estuary.

Nitrite :

Nitrite at the reference station varied from 0.02 to 1.18 $\mu\text{g at l}^{-1}$, during post and premonsoon periods (Fig. 4a). Like nitrate the mean nitrite concentration of the offshore water column remained high during October—December. The nitrite concentrations at the estuarine transect stations varied at short intervals of time and except for the month of December the concentrations varied between 0.00 to 1.71 $\mu\text{g at l}^{-1}$, which was lower compared to the nitrate concentrations (Figs. 2b & c and 4b & c).

Ammonia :

Ammonia varied from 0.23 to 2.5 $\mu\text{g at l}^{-1}$ during post and premonsoon periods at the reference station (Fig. 5a). As in the case of nitrate, ammonia also remained high during October and November with an increase in values towards the bottom waters.

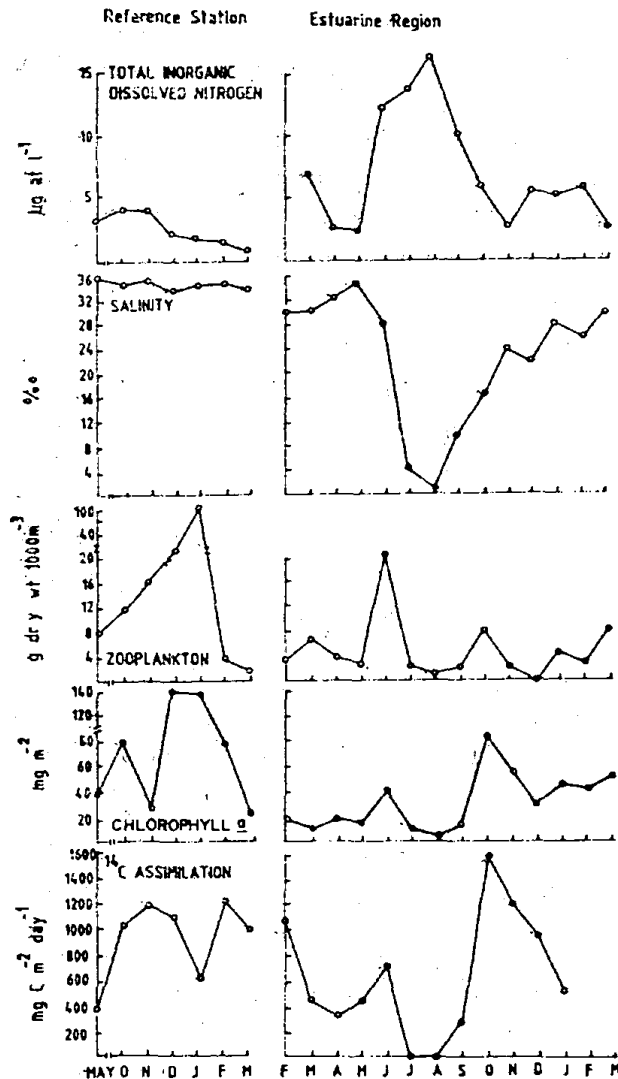


Fig. 6. Monthly mean variation of different parameters in the coastal and estuarine waters (stns. 1 to 4).

In the estuarine waters (stns 1 to 4), the ammonia content varied from 0.33 to 7.81 μg at l^{-1} (Fig. 5 b & c) showing peaks at short intervals of time. The concentrations during monsoon remained high especially towards the upper estuarine region with a maximum of 12.5 μg l^{-1} at station 6. Similarly a single high value with a maximum of 7.8 μg at l^{-1} , was observed in March 1980 at station 1.

Chlorophyll a and primary productivity

In the euphotic zone (stn. 6) chlorophyll *a* varied from 24 to 137 mg m^{-2} and primary productivity from 380.5 to 1231.3 $\text{mg C m}^{-2} \text{ day}^{-1}$ during post-monsoon and premonsoon periods respectively at the reference station. In the estuarine region (stns. 1 to 4) chlorophyll *a* of the water column ranged from 1.2 to 98.3 mg^{-2} and the primary productivity from 0.9 to 1846.5 $\text{mg C m}^{-2} \text{ day}^{-1}$ during the complete annual cycle of observations. Chlorophyll *a* and primary productivity remained high in the beginning of postmonsoon both at the estuarine and coastal waters (Fig. 6). However, during monsoon the estuarine waters behaved in a different manner. Sharp peaks of chlorophyll *a* and primary productivity were noticed in the beginning of monsoon in June and at the cessation of monsoon in October, but the production remained low during peak monsoon period (July and August). The zooplankton biomass at the reference station increased steadily towards a peak in January. But at the estuarine regions the peaks of zooplankton biomass almost coincided with the peaks in chlorophyll *a* and primary productivity especially, in June and October.

Salinity-nutrient relationship

Average salinity values of the estuarine stations were found to be 31.9, 11.2 and 22.6‰ for permonsoon, monsoon and postmonsoon (1980-81), respectively.

An inverse relation was found between nitrate concentrations in estuarine region and the salinity (Table I). This indicates that the major inflow of nitrate to the estuary is from freshwater sources.

The phosphate concentrations showed direct correlation with salinity during post and premonsoon periods (Table I), which obviously suggests that the phosphate input from the riverine freshwater source, especially from stations 5 and 6 (Fig. 3) is relatively low.

It is evident from the salinity values (Fig. 6) that during premonsoon the estuary is dominated by marine waters (mean salinity 31.9‰). This reduced substantially the supply of nitrate and phosphate to the estuary from the freshwater source. But the phytoplankton production remained moderately high during this period (Fig. 6).

The salinity and phosphate values did not show significant correlation during monsoon (Table II). It has already been indicated that during monsoon

Table I — Correlation coefficient values (r) of salinity with nitrate and phosphate during different periods.

	Salinity v/s nitrate		Salinity v/s phosphate	
	n	r	r	r
Premonsoon	44	-0.566*	0.545*	
Monsoon	32	-0.414*	0.139***	
Postmonsoon	32	-0.341*	0.326**	

* $\geq 95\%$, ** 90%. *** not significant, n = number of values.

Table II — Mean values of concentration ratio of nitrate : phosphate and available nitrogen : phosphate at the coastal (A) and estuarine (B) waters respectively.

	Nitrate : Phosphate		*Available Nitrogen : Phosphate	
	A	B	A	B
Feb 1980	—	3.1	—	—
Mar	—	2.9	—	8.6
Apr	—	2.2	—	4.2
May	2.1	1.5	4.8	3.1
Jun	—	24.5	—	29.2
Jul	—	56.6	—	63.2
Aug	—	12.0	—	13.9
Sep	—	6.7	—	9.9
Oct	0.8	3.9	2.0	5.5
Nov	1.4	0.9	4.6	5.2
Dec	1.3	1.9	8.8	13.2
Jan 1981	0.1	7.2	4.9	14.1
Feb	1.6	6.3	5.0	14.1
Mar	0.1	3.1	3.8	7.6

* Available N = Total dissolved inorganic nitrogen.

the estuary is dominated by freshwater and that the contribution of phosphate from freshwater is little. Surprisingly the phosphate values in monsoon i.e. during June-July remained low while during the later part of the monsoon (August-September) they increased especially towards the lower reaches of the estuary. Primary productivity during July to September is markedly reduced. Nitrate and phosphate content did not show any significant correlation during this period. These observations suggest that physical-chemical processes are more important than the biological processes in determining the phosphate distribution in the estuary during monsoon. The waters become highly turbulent during monsoon due to heavy land drainage and strong swells and wind waves at Aguada Bay (Murty, Das, Nair, Veerayya and Varadachari 1976). This gives rise to the increase in the suspended solids in water due to river bed erosion (Anonymous 1981). Under such conditions it is possible that the suspended sediments may take part in physico-chemical reactions with certain labile ions like-phosphates (Pomeroy, Smith and Grant, 1965). Analysis of adsorbed phos-

phates in the estuarine bed sediments along different transect stations during different seasons indicated high values varying between 0.42 to 2.65 μg at P g^{-1} of dry sediment. The concentrations of adsorbed phosphates were found to be higher ($> 1.5 \mu\text{g}$ at g^{-1}) in the fine silty sediments at the estuarine mouth and the reference station, than those of the sandy sediments ($< 1.4 \mu\text{g}$ at g^{-1}) in the upper reaches of the estuary.

Seasonal changes in nitrate concentrations suggest that this nutrient is utilised quickly and attains a limiting concentrations during many occasions. This could also be seen from $\text{NO}_3^- : \text{PO}_4^{3-}$ concentration ratio which remained sufficiently low (Table II), both in the estuarine and coastal waters of Goa during the productive periods of post and premonsoon.

As a measure of the biological influence on nutrient content, an assimilation ratio ($\Delta \text{N} : \Delta \text{P}$) was calculated from linear least square regression of nitrate and phosphate values for the post and premonsoon periods. The $\Delta \text{N} : \Delta \text{P}$ value for estuarine region (stns. 1, 3 & 4) was found to be 10:1 (by atoms) and when the values of the reference station were also incorporated, this ratio increased to 11, which is almost similar. It can be noted from the results that in the present study area, $\text{NO}_3^- : \text{PO}_4^{3-}$ concentration (Table II) as well as the assimilation ratios remained lower than the classical Redfields ratio of 16 during post and premonsoon periods when the phytoplankton production was high. In the Cochin backwaters $\text{NO}_3^- : \text{PO}_4^{3-}$ concentration ratio was also reported to be low when primary productivity (range : 266 to 383 $\text{mg C m}^{-2} \text{ day}^{-1}$) was high (Qasim, Wellershaus, Bhattathiri & Abidi 1969). However if ammonia nitrogen is added to the nitrate contents the N : P concentration ratio increases to a maximum of 8.8 and 14.1 in the coastal and estuarine region respectively, during post and premonsoon periods (Table II). Ammonia as such is known to be utilised in preference to nitrate in the coastal and oceanic waters in different regions (McCarthy, Taylor and Jay 1977; Eppley, Renger, Harrison and Cullen, 1979). It could be deduced therefore that sufficiently high levels of ammonia, varying between 11 to 87% of total inorganic N content ($\text{NO}_3^- + \text{NO}_2^- + \text{NH}_4^+$) available in these coastal and estuarine waters do help to compensate the observed anomaly in N:P ratio due to nitrate. During the low supply of nitrate to the estuary as is the case in premonsoon, the high phytoplankton production could probably be sustained by the reduced sources of N like ammonia and nitrite. Possible sources of ammonia input to these waters could be from land run-off, zooplankton excretion (Ketchum 1962) or remineralisation of organic matter. The distribution of phosphate on the other hand suggests that the availability of this nutrient is adequate to meet the required demand of primary producers in the Mandovi estuary and the adjacent coastal waters.

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