

Distribution of Nutrients in the Western Bay of Bengal

S N DE SOUSA, S W A NAQVI & C V G REDDY
National Institute of Oceanography, Dona Paula, Goa 403 004

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Distribution of phosphates and nitrates in relation to some physico-chemical features of the western Bay of Bengal during Aug.-Sept. 1976 indicated marked regional variations. The mixed surface layer which was associated with high oxygen and low nutrient concentrations increased in thickness from north to south. The intermediate water layer was marked by a steep rise of nutrients associated with oxygen minimum suggesting active decomposition of organic matter. N:P in the upper 75 m was considerably low ranging between 0 and 4.4 by atoms. In contrast to this N:P in the depth range 100-1000 m showed somewhat higher values (6-7). Two regions of upwelling were observed, one near Visakhapatnam and the other near Madras.

Of the 2 arms of the Northern Indian Ocean, the Bay of Bengal and Arabian Sea, the former constitutes a more interesting area owing to its near estuarine nature. Though oceanographic studies in this area have been made they are mostly confined to coastal areas¹. Since the International Indian Ocean Expedition (1960-1965) considerable amount of data have been added²⁻⁶. Sen Gupta *et al.*⁷ have studied the nitrogen and phosphorus compounds and their interdependence on different water types in the area based on data collected during the cruises of *INS Darshak* in March-April 1975. Later with the commissioning of *R V Gaveshani* by NIO, special attention has been given to study in detail the chemical characteristics of the area^{8,9}. The present paper deals with the distribution of the nutrients in relation to some physico-chemical features of the western Bay of Bengal with special reference to upwelling.

Materials and Methods

The data were collected during 7 to 9 cruises of *R V Gaveshani* in Aug.-Oct. 1976. Station positions are given in Fig. 1 and sampling techniques are described elsewhere⁸. Temperature was measured using reversing thermometers. Oxygen was determined by the Winkler method as modified by Carritt and Carpenter¹⁰; while phosphate-phosphorus was determined by the method of Murphy and Riley¹¹ and nitrate-nitrogen using the method of Morris and Riley¹² as modified by Grasshoff¹³. Portions of the samples were preserved in well cleaned stoppered polythene bottles and analyses for salinity were carried out later at the shore laboratory using Mohr-Knudsen titration method.

Results and Discussion

Vertical distribution—Figs 2 and 3 give the vertical profiles of $\text{PO}_4^{3-}\text{-P}$, $\text{NO}_3^- \text{-N}$, O_2 , $\text{S}^\circ\text{‰}$ and temperature along 2 sections normal to the coast near

Visakhapatnam and Madras respectively. Also Figs 4-6 show vertical distribution of these parameters at individual sts 66, 90 and 122 respectively. The mixed surface layer which is very shallow extending to about 25 m in the north at st 66 (Fig. 4) increases in thickness to 75 m towards south at st 122 (Fig. 6). Evidence of upwelling is seen from Figs 2 and 3 which show upward tilting of isolines. From the 2 sections it can be inferred that waters from a depth of 75-100 m reach the surface at Visakhapatnam while at Madras the upwelled water is limited to subsurface depths (25 m). In general, the concentration of nutrients in the mixed layer was low while the oxygen content was high except in places of upwelling. Phosphate-P varied from 0.2 to 0.5 $\mu\text{g-at/litre}$ while nitrate-N was extremely low mostly below the detection limit. Oxygen concentrations ranged

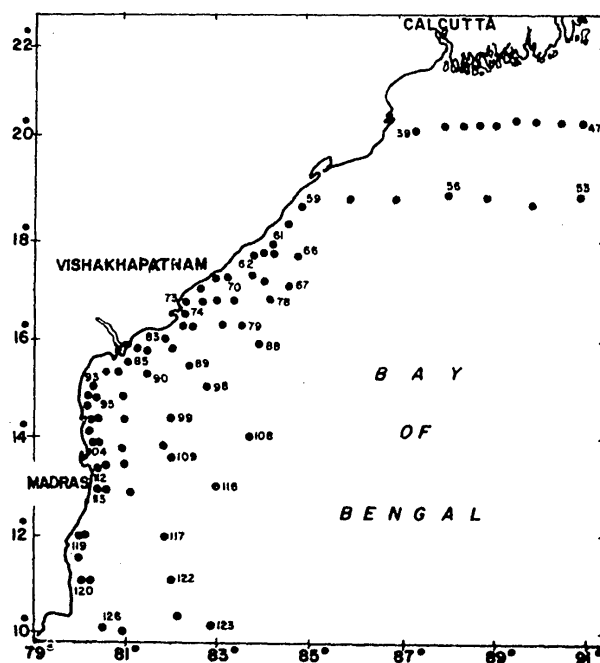


Fig. 1—Station positions

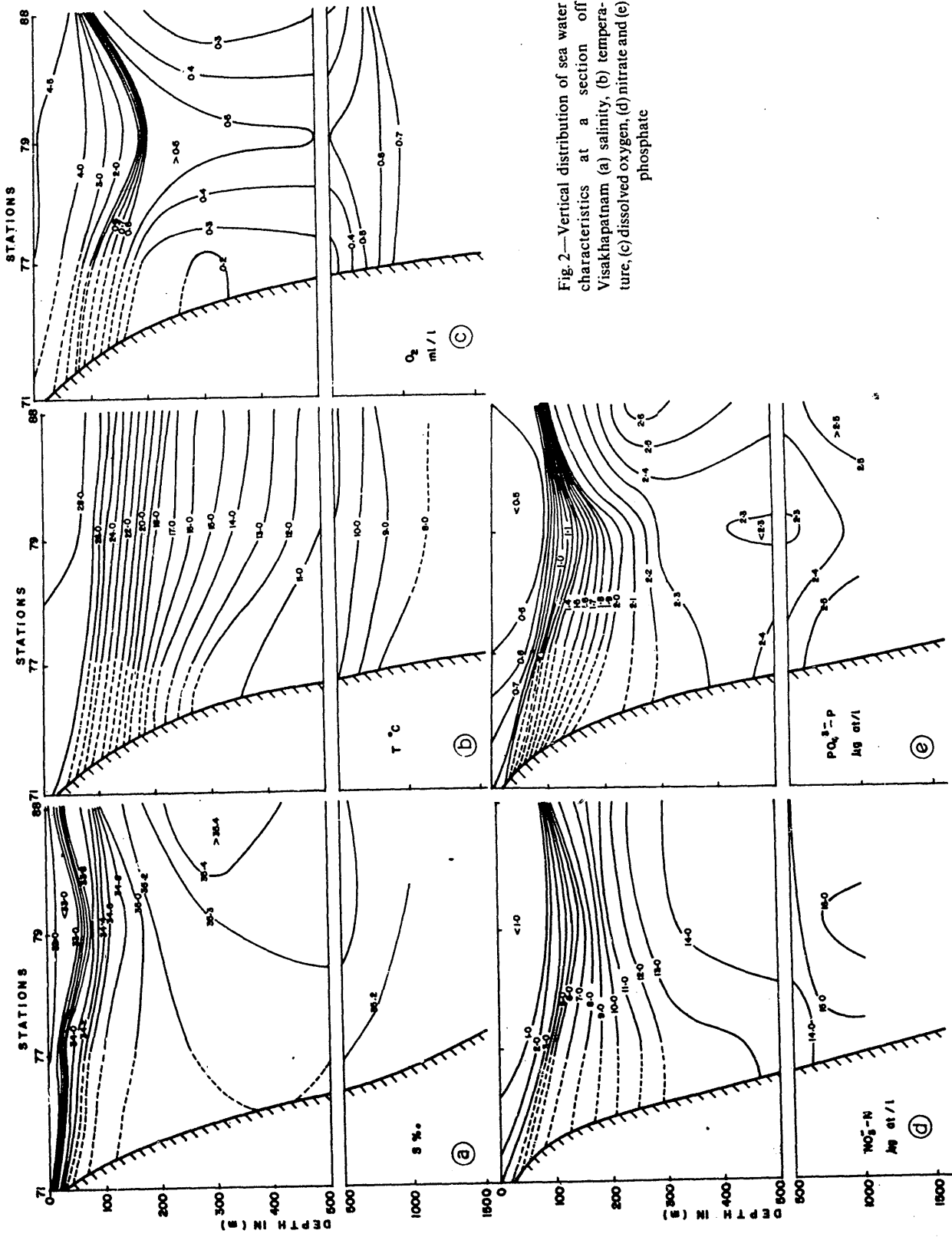


Fig. 2—Vertical distribution of sea water characteristics at a section off Visakhapatnam (a) salinity, (b) temperature, (c) dissolved oxygen, (d) nitrate and (e) phosphate

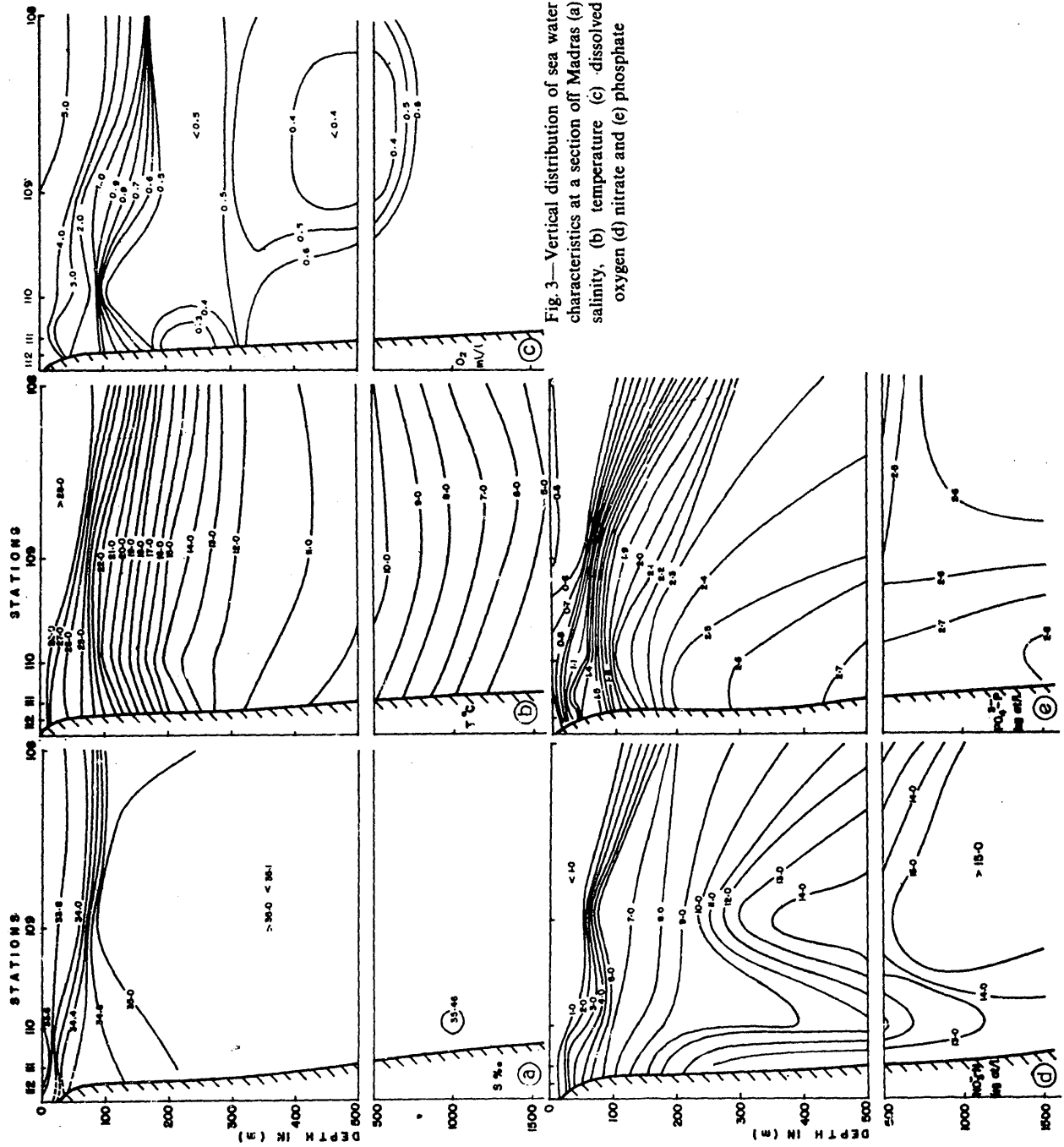


Fig. 3.—Vertical distribution of sea water characteristics at a section off Madras (a) salinity, (b) temperature (c) dissolved oxygen (d) nitrate and (e) phosphate

from 5 ml/litre at the surface to 3.5 ml/litre at 50 m. The regions of upwelling were marked by surface waters with high salinities and high nutrients while the temperature and dissolved oxygen content were lower than the corresponding offshore stations. It is evident from the comparison of the values in Table 1 that upwelling is stronger near Visakhapatnam compared to that near Madras. The difference in upwelling intensity between the 2 regions in this season can be attributed to the relatively stronger winds near Visakhapatnam¹⁴. Comparatively lower salinity observed near Visakhapatnam may be attributed to the dilution effect caused by the cyclonic gyre formed at the head of the Bay during this period which results in a southerly set current along the east coast of India bringing in low salinity waters from the north¹⁵.

The intermediate water was marked by a steep rise in nutrients associated with low oxygen concentrations suggesting that this water has undergone chemical changes due to its longer residence time and oxidation of large quantities of organic matter sinking from the overlying waters.

Fig. 2 shows the vertical section normal to the coast at Visakhapatnam and running in northwest-southeast direction. It is evident from the figure that in the upper 100 m or so the isolines are sloping up towards the coast indicating clearly the upward movement of water. This results in bringing to the surface, water from a depth of about 100 m having higher salinity, phosphate-P and nitrate-N and lower oxygen and temperature. The figure also shows a less intense offshore convergence centered around st 79.

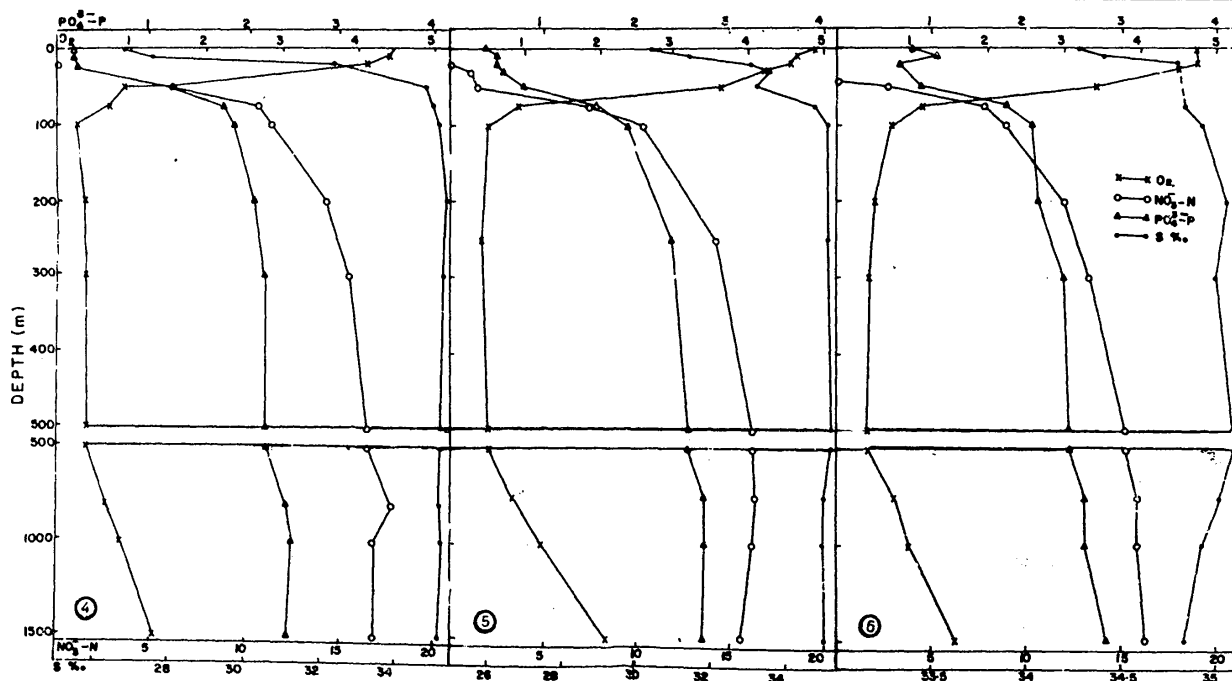
Fig. 3 shows the vertical section off Madras running in east-west direction. It can be seen that the isolines are tilting upwards towards the coast. This upward movement carries nutrient rich water to the surface from a depth between 50 to 100 m. However, the effect of upwelling appears to be partly neutralized by the prevailing surface current system which during this period of time is parallel to the coast in southerly direction carrying with it low salinity water from the large river system of Godavari and Krishna, and consequently the effect of upwelling is weaker near the coast.

Nitrate-phosphate ratios—N:P ratios calculated in the Bay of Bengal appear to be considerably low. A wide range of variations is observed in the upper 75 m (0 to 4.4 by atoms) the lowest being from the area south of Madras where unusually high phosphate

Table 1—Physico-chemical Parameters off Madras and off Visakhapatnam

	Off Madras		Off Visakhapatnam	
	Coastal	Offshore	Coastal	Offshore
Temp. °C	28.7-29.8	28.5-29.1	27.2-28.6	27.7-28.4
Diss. oxygen (ml/l)	4.4-4.9	4.3-5.2	3.9-4.6	4.3-4.4
Sal. ‰	32.83-34.74	32.70-33.89	31.69-34.38	30.69-33.00
Phosphate-P (µg-at/l)	0.5-0.7	0.4-0.6	0.3-0.8	0.2-0.4
Nitrate-N (µg-at/l)	ND-0.6	ND	ND-0.2	ND

ND = not detectable



Figs 4 to 6—Vertical distribution of oxygen, nitrate-N, phosphate-P and salinity at sts 66(4), 90(5) and 122(6)

concentrations were encountered. In contrast to this N:P in the depth 100-1000 m was somewhat constant (between 6 and 7). Redfield¹⁶ found that nitrate and phosphate were used up simultaneously in constant proportion by phytoplankton and concluded that the N:P in sea water as well as in plankton was generally close to 15:1 by atoms, when corrected for salt error. Variations from Redfield's ratios have been frequently reported¹⁷⁻¹⁹. Riley²⁰ suggested that the low N:P in the coastal waters and estuaries may be due to slow rate of regeneration of nitrate compared to phosphate. In the Bay of Bengal the upper layers are considerably diluted by runoff and precipitation causing a sharp stratification at the halocline. In the absence of adequate supply of inorganic nitrogen from the deeper layers, the organisms assimilate some organic forms of nitrogen preferentially which may result in the decrease in N:P. Another process which probably affects the N:P in the deeper layers is denitrification. It has been reported that 30-40% of available nitrate is lost as a result of denitrification in the intermediate layers of the Bay of Bengal^{7,8}.

There is a wide range of variations in the nutrient concentrations in the Bay of Bengal, both spatial and depthwise. The concentration of NO_3^- -N and PO_4^{3-} -P was low near the river mouths. Apparently, the contribution of nitrate and phosphate by the rivers along the east coast of India to the Bay of Bengal is not significant. Similar results have been observed by Rajendran *et al.*²¹ for silicate distribution. In the region south of Madras it is observed that the concentration of nitrate and phosphate was high throughout the water column. The data on oxygen, salinity and temperature suggest that processes other than upwelling might be responsible for such high concentrations. Sewell²² has shown that the Antarctic bottom water which contains high concentrations of PO_4^{3-} -P and oxygen flows into the Bay of Bengal in northeasterly direction and is deflected to the northwest by the earth's rotation and impinges on the east coast of southern India and Sri Lanka. In summer, this water probably reaches the surface to compensate for the loss of water from the surface due to evaporation²³. N:P has been found to be low. In the

upper 75 m, it varies from zero to 4.4:1 by atoms while in deeper layers it shows higher values between 6 and 7. Low N:P has been attributed to (i) slow process of regeneration of nitrogenous matter compared to phosphatic matter and (ii) the loss of nitrogen due to denitrification.

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