

NUTRIENTS IN SOME ESTUARIES OF KERALA

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ABSTRACT

Some environmental parameters and nutrients like inorganic phosphate, nitrate, nitrite and ammonia from four estuaries namely Kallai, Beypore, Korapuzha and Mahe along north Kerala coast were studied for an year (1980-81). In all these estuaries seasonal variations in environmental features were related to the monsoonal cycle and follows the pattern reported for other estuaries of west coast of India.

Inorganic phosphate did not show any clear pattern or pronounced seasonal variations. Inorganic phosphate and ammonia were high at Kallai compared to other three estuaries. All the estuaries showed an increase in nitrate content during monsoon. Nitrite values were high in postmonsoon. Ammonia levels were generally high except at Korapuzha. Nutrient content was in general higher in the bottom waters than in the surface in these estuaries. The present values are compared to the reported figures of other west coast estuaries and discussed.

Key-words : Nutrients, estuaries.

INTRODUCTION

Kerala has a number of river openings along its coastline. Some of these drain into backwaters or lakes prior to emptying into the Arabian Sea. Certain features that most of these rivers share are, short length, lean flow during non-monsoon months, connection with backwaters and the tidal nature of mouths. Over an year these tidal river mouths experience conditions ranging from near fresh water to almost marine depending on the onset, intensity and duration of monsoons. This annual cycle brings in its wake a whole gamut of changes in the physical, chemical and biological features of these systems. This paper deals with variations in some hydrographic features and nutrient content of four lesser known estuaries of Kerala coast viz. Kallai, Beypore, Korapuzha and Mahe.

Some work has been done on the first three estuaries but no published information is available on Mahe. George (1953) studied the planktology and hydrography of Korapuzha. Subsequently Suryanarayana Rao and George (1959) reported on some nutrients and Krishnamoorthy and Vincent (1975) chemical characteristics of the same area. Zooplankton and hydrography

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of Kallai and Beypore were studied by Varkey John (1971) and nutrients by Krishnamoorthy and Vincent (1981).

MATERIALS AND METHODS

Monthly collections were made at a fixed point near the mouths of these estuaries (Fig. 1) from April 1980 to May 1981. Environmental data were

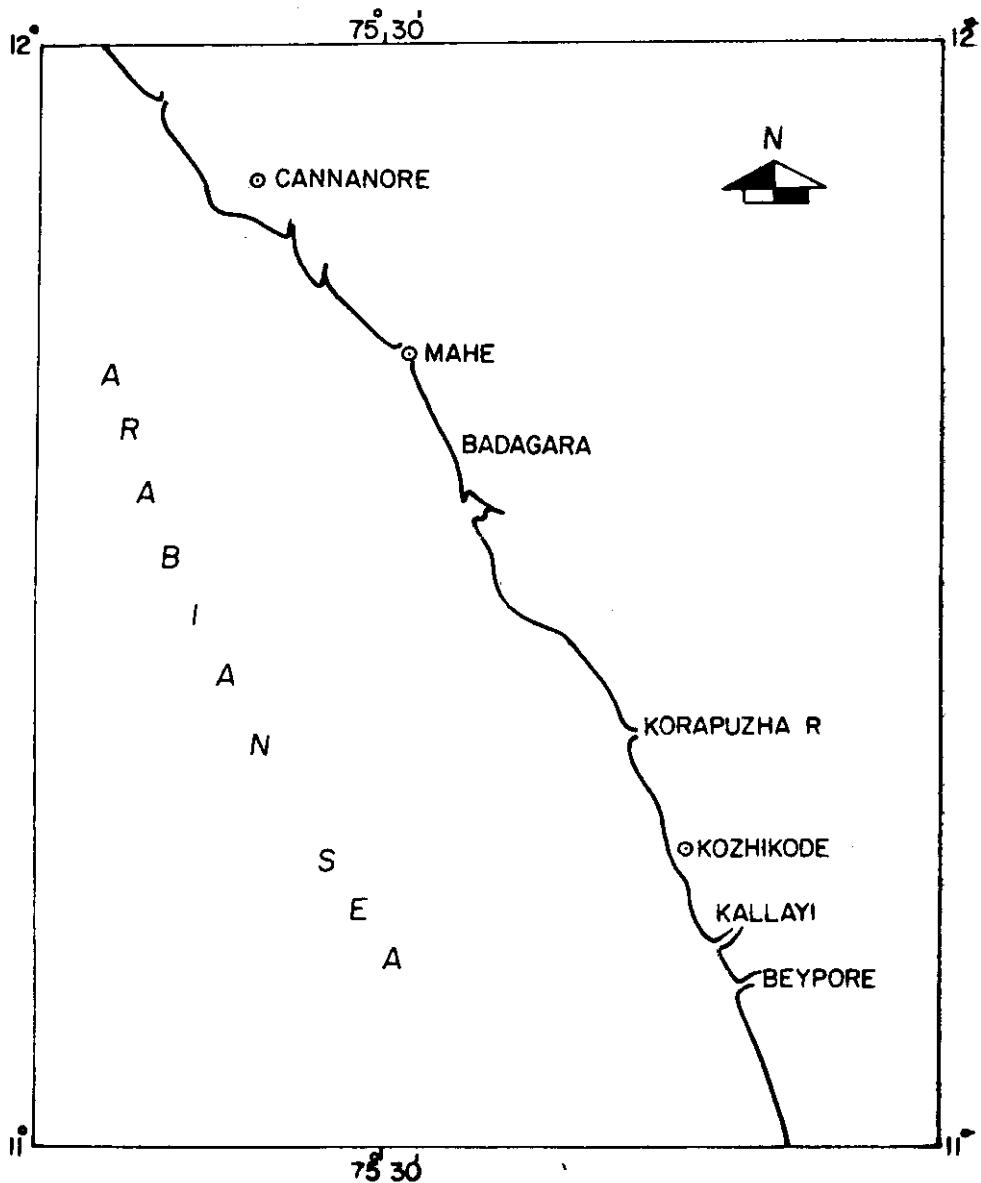


Fig. 1. Station location map.

collected following standard methods. Inorganic phosphate was measured by the method of Murphy and Riley (1962). Estimation of nitrate was made following Morris and Riley (1963) as modified by Grasshoff (1964). Nitrate was measured by Bendschneider and Robinson's (1952) method. Indophenol blue method (Koreloff, 1969) was used for ammonia following the modification suggested by Dal Pont, Hogan and Newell (1974).

Sampling site at Beypore had a depth of 7 - 8 m that at Korapuzha and Mahe 3.5 - 4.0 m and Kallai 1.0 - 2.0 m. Beypore has a large rayon factory several kilometres upstream. Kallai has on its shores one of the biggest timber yards in Asia. Korapuzha and Mahe have retting yards in them. Tidal range is about 1 m in these estuaries.

RESULTS AND DISCUSSION

Environmental features

Table I gives the seasonal and annual averages as well as ranges of environmental features in the four estuaries. Premonsoon (January to May)

Table I. Seasonal and annual averages of some environmental features. Ranges are given in paranthesis (S-Surface and B-Bottom)

		Temp. (°C)	Salinity (‰)	Oxygen (ml/l)	pH
KALLAI					
Premonsoon	S	32.4 (29-34)	33.79 (31.65-35.17)	1.9 (0.82-3.33)	7.67 (7.5-8)
Monsoon	S	29.0 (27-30.3)	4.87 (0.38-12.86)	3.87 (3.47-4.25)	6.96 (6.3-7.5)
Postmonsoon	S	32.0 (31.5-32.5)	27.13 (22.41-31.85)	3.56 (2.98-4.14)	7.6 —
Annual		31.1 (27-34)	22.51 (0.38-35.17)	2.84 (0.82-4.25)	7.41 (6.3-8.0)
BEYPORE					
Premonsoon	S	31.7 (28.9-33.2)	29.92 (23.53-34.12)	3.51 (2.96-4.35)	7.66 (7.4-7.9)
	B	31.0 (28.6-32.8)	31.72 (28.64-34.13)	3.51 (2.83-3.94)	7.75 (7.5-8.0)
Monsoon	S	27.7 (26-30.5)	1.58 (0.21-3.78)	4.42 (3.79-4.82)	6.35 (5.0-7.0)
	B	27.3 (25.5-30)	8.05 (0.21-31.49)	4.29 (1.95-5.34)	6.53 (5.8-7.1)
Postmonsoon	S	31.25 (31-31.5)	9.98 (9.96-10.0)	3.88 (2.98-4.78)	6.68 (6.0-7.5)
	B	30.25 (30-30.5)	22.15 (22.07-22.23)	3.64 (3.29-3.98)	7.63 (7.4-7.85)

Table 1. Contd.

		Temp. (°C)	Salinity (‰)	Oxygen (ml/l)	pH
Annual	S	30.1 (26-33.2)	16.95 (0.21-34.12)	3.89 (2.96-4.82)	7.05 (5.0-7.9)
	B	29.5 (25.5-32.8)	21.15 (0.21-34.13)	3.83 (1.95-5.34)	7.26 (5.8-8.0)
KORAPUZHA					
Premonsoon	S	31.4 (28.4-33.0)	29.62 (24.25-33.42)	3.56 (3.02-4.42)	7.51 (6.95-8.0)
	B	31.2 (27.8-33.0)	30.7 (24.98-33.58)	3.52 (2.75-4.20)	7.44 (6.95-8.0)
Monsoon	S	27.7 (25.2-29.0)	3.77 (0.21-11.96)	3.97 (2.66-4.74)	6.42 (6.0-7.0)
	B	27.2 (26.2-28.5)	5.49 (0.38-16.85)	3.71 (2.66-4.40)	6.6 (6.2-7.0)
Postmonsoon	S	29.6 (29.2-29.9)	26.7 (25.46-27.94)	2.28 (2.19-2.39)	7.55 (7.3-7.8)
	B	29.1 (28.9-29.2)	30.6 (30.23-30.97)	2.84 (2.39-3.29)	7.56 (7.4-7.75)
Annual	S	29.8 (26.2-33.0)	19.97 (0.21-33.42)	3.52 (2.19-4.74)	7.1 (6.0-8.0)
	B	29.3 (25.2-33.0)	20.99 (0.38-33.58)	3.49 (2.19-4.4)	7.1 (6.2-8.0)
MAHE					
Premonsoon	S	30.7 (29.4-32.5)	33.68 (30.26-35.17)	3.85 (2.47-4.68)	7.49 (6.9-8.05)
	B	30.1 (28.8-32.0)	33.94 (30.97-35.36)	3.85 (3.34-4.37)	7.59 (6.9-8.1)
Monsoon	S	27.8 (26.5-29.0)	3.12 (0.21-8.13)	4.53 (3.72-5.45)	6.48 (5.6-7.1)
	B	27.2 (26.2-28.0)	10.87 (0.21-29.38)	4.19 (2.83-5.03)	6.66 (5.8-7.8)
Postmonsoon	S	30.1 (30.0-30.1)	29.09 (26.0-32.18)	3.09 (2.35-3.82)	7.68 (7.6-7.75)
	B	29.8 (29.5-30.0)	30.37 (26.17-34.58)	3.87 (3.6-4.14)	7.7 (7.6-7.8)
Annual	S	29.6 (26.5-32.5)	22.11 (0.21-35.17)	3.98 (2.35-4.68)	7.13 (5.6-8.05)
	B	29.0 (26.2-32.0)	24.52 (0.21-35.36)	3.98 (2.83-5.03)	7.22 (5.8-8.1)

showed lower oxygen, higher temperature, salinity and pH. During the monsoon season (June to October) low salinities, especially at the surface, a reduction in temperature and pH and an increase in dissolved oxygen levels could be seen. Postmonsoon (November-December) was the period of transition when these systems shifted from fresh water domination to the marked marine in-

fluence of the premonsoon. The present pattern of seasonal variation in the environmental features, linked to the monsoonal cycle is noticeable in other southwest coast estuaries also. The three seasons telescope into each other to be repeated over the years.

While other features in the four estuaries were similar oxygen was consistently lower at Kallai (Table I). Variations in pH were mostly uniform within the water column, as noted for Cochin backwaters by Sankaranarayanan and Qasim (1969). Some degree of stratification was noted at Beypore and Mahe late in the monsoon season. Surface and bottom salinities at Mahe differed by 18‰ in September and 21‰ in October. At Beypore the difference was prominent (28‰) in September. These higher salinities which occurred along with lower oxygen at the bottom are attributed to the intrusion of upwelled water from the sea. These two estuaries have greater sill depth and navigation channels for small craft which facilitates sea water incursion.

Nutrients

Figs. 2 and 3 show the seasonal distribution of nutrients in the surface and bottom waters of the four estuaries. Seasonal and annual averages for the water column with ranges are given in Table II.

Kallai

Inorganic phosphate values were quite variable here (Fig. 2) being lower in the postmonsoon season (November–December). An annual range of 0.67–6.4 $\mu\text{g at/l}$ was noted (Table II). The peak value of 92.96 $\mu\text{g at/l}$ in March 1981 is difficult to explain in the absence of any point source. Phosphate values here exempting this stray high value were still higher (Figs. 2 and 3, Table II) compared to other estuaries studied.

Nitrate values were low (Fig. 2) except early in the monsoon season (June–July). Barring a single value in April (2.59 $\mu\text{g at/l}$) and the exception noted above the rest of the values were below 1 $\mu\text{g at/l}$ indicating that there is little nitrate-nitrogen available in this system for most of the year. This estuary, however, supports a rich phytoplankton population for most of the year (Kumaran — personal communication). It could be that this population is either using up all the regenerated nitrates or is utilising alternate nitrogen sources.

Majority of nitrite values as in the case of nitrates fell below 1 $\mu\text{g at/l}$. The range was nil to 2.64 $\mu\text{g at/l}$ during the period of observation. Nitrite values also peaked simultaneously with nitrates. Fair concentrations were found from June to August.

Ammonia showed three peaks during the period of study, one in July, another in February, 1981 and a third one in May, 1981. The increase noted with the onset of the monsoon persisted through the season. Postmonsoon

values were lower and premonsoon values fluctuating (Fig. 2). This estuary had higher ammonia content as compared to the other three estuaries with values ranging from 4.36 to 28.55 $\mu\text{g at/l}$ (Table II).

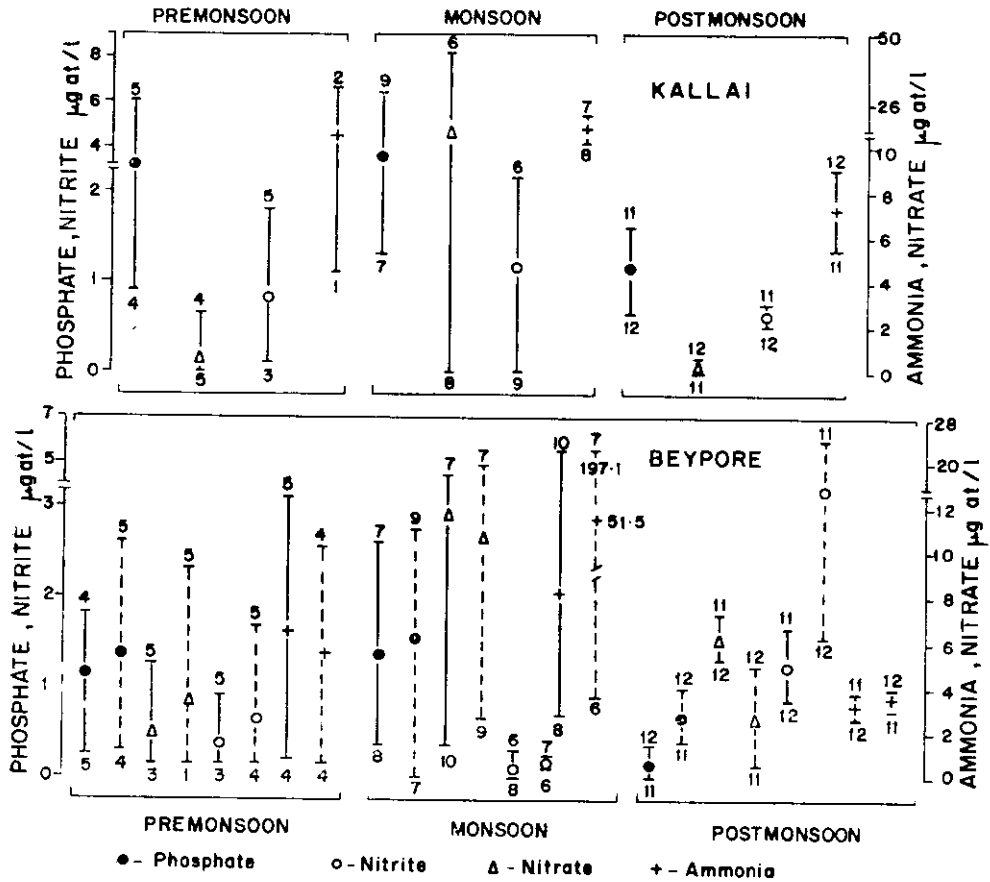


Fig. 2. Seasonal averages and ranges of nutrients at Kallai and Beypore. Vertical lines denote the range. Numbers at the top and bottom indicate the month during which the values occurred. (Continuous lines—Surface. Broken lines—Bottom)

Beypore

An increase in phosphate content was noticed here early in the monsoon season, June–July at the surface and May–June at the bottom. Subsequently the values dropped and picked up during the dry months. Values ranged from nil to 2.59 $\mu\text{g at/l}$ at the surface and nil to 2.75 $\mu\text{g at/l}$ at the bottom. This range is higher compared to the figures of Krishnamoorthy and Vincent (1981). In general, bottom values were slightly higher, the variations being seldom

Table II. Seasonal and annual averages of nutrients for the water column. (Values are in $\mu\text{g at/l}$ and ranges are given in parantheses).

	Phosphate Inorganic	Nitrate	Nitrite	Ammonia
KALLAI				
Premonsoon	3.45 (0.9-5.96)	0.61 (0 - 2.54)	0.58 (0.1-1.77)	13.9 (4.36-28.55)
Monsoon	3.60 (1.3-6.41)	14.23 (0 - 43.46)	1.16 (0 - 2.64)	15.7 (11.52-20.29)
Postmonsoon	1.41 (0.67-1.6)	0.27 (0 - 0.53)	0.63 (0.33-0.73)	7.24 (5.44-9.04)
Annual	3.15 (0.67-6.41)	5.42 (0 - 43.46)	0.8 (0 - 2.64)	13.54 (4.36-28.55)
BEYPORE				
Premonsoon	1.26 (0.26-2.59)	2.88 (0.58-9.12)	0.53 (0.2 - 1.64)	5.97 (0.88-13.77)
Monsoon	1.45 (0-2.75)	11.26 (13.6-19.04)	0.05 (0 - 0.3)	11.31 (2.88-46.02)
Postmonsoon	0.43 (0-1.0)	4.54 (0.59-7.19)	2.16 (0 - 6.13)	3.30 (2.58-3.87)
Annual	1.22 (0-2.75)	6.23 (0 - 19.04)	0.67 (0 - 6.13)	7.61 (0.88-46.02)
KORAPUZZHA				
Premonsoon	1.59 (0.26-4.43)	1.60 (0.29-3.68)	0.59 (0 - 2.45)	4.80 (1.77-7.27)
Monsoon	1.54 (0.43-2.37)	6.23 (0.63-10.75)	0.10 (0 - 0.43)	4.18 (2.21-7.44)
Postmonsoon	0.96 (0 - 2.33)	1.43 (0 - 2.43)	1.15 (0.42-2.81)	12.40 (2.83-33.57)
Annual	1.53 (0 - 4.43)	4.31 (0 - 10.75)	0.61 (0 - 2.81)	5.50 (1.77-33.57)
MAHE				
Premonsoon	1.30 (0 - 2.66)	2.87 (0 - 7.34)	0.80 (0.11-2.82)	7.10 (0 - 24.64)
Monsoon	1.18 (0 - 5.04)	10.04 (0.4-18.09)	0.04 (0 - 0.11)	12.47 (1.68-60.89)
Postmonsoon	0.63 (0 - 1.18)	0.66 (0 - 1.06)	0.65 (0.42-1.04)	2.96 (1.52-7.75)
Annual	1.15 (0 - 5.04)	5.20 (0 - 18.09)	0.50 (0 - 2.82)	8.58 (0 - 60.89)

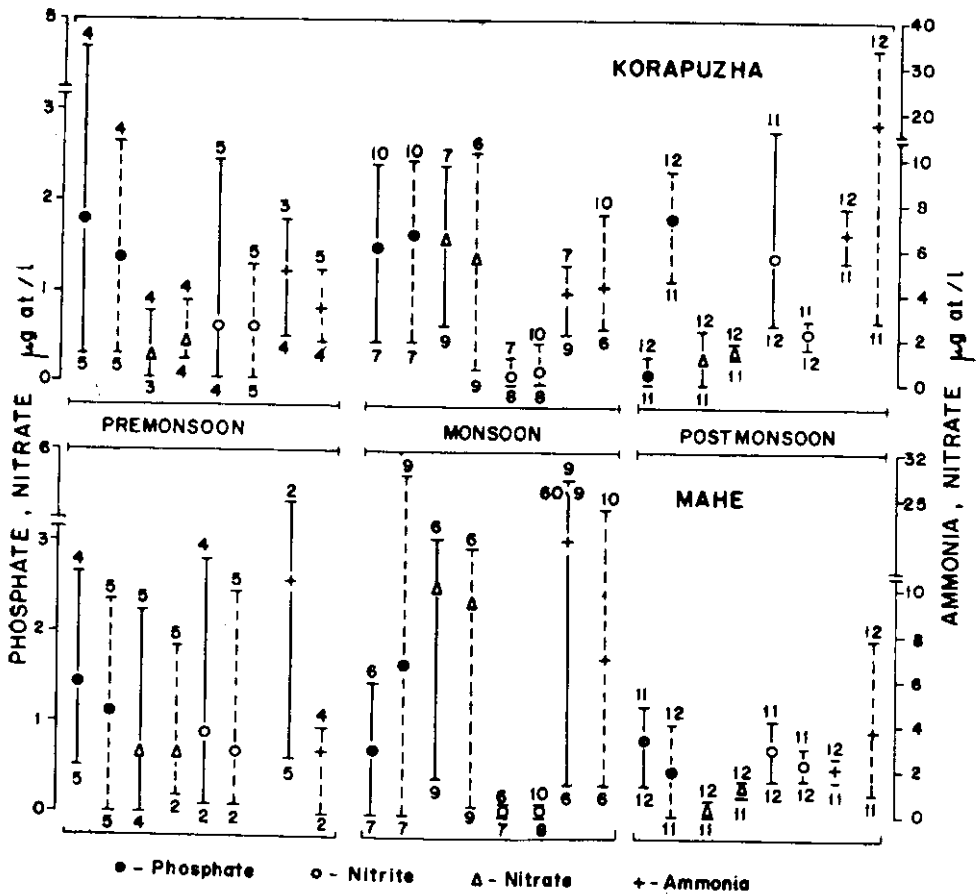


Fig. 3. Seasonal averages and ranges of nutrients at Korapuzha and Mahe. Vertical lines denote the range. Numbers at the top and bottom indicate the month during which the values occurred. (Continuous lines—Surface. Broken lines—Bottom)

uniform in the water column. A consistent pattern of seasonal variation was not apparent here also.

Nitrate values here registered a sharp increase with the onset of the monsoon season attaining peak in July with $17.67 \mu\text{g at/l}$ at the surface and $19.04 \mu\text{g at/l}$ at the bottom. Moderately high levels were found both at the surface and bottom for the rest of the season. During postmonsoon (November–December) values at the surface were still high but those at the bottom dropped. During the dry season it dropped further to remain low till April 1981. The increase seen in May 1981 is probably associated with the pre-monsoonal showers. Most of the values during the monsoon season were higher compared to the highest ($6.4 \mu\text{g at/l}$) reported by Krishnamoorthy and Vincent (1981). At Beypore unlike Kallai nitrate values seldom dropped to very low levels (Table II).

Nitrite ranged from nil to $1.66 \mu\text{g at/l}$ at the surface and nil to $6.13 \mu\text{g at/l}$ at the bottom. Both the peaks occurred in November. For the rest of the year nitrite was very low with two exceptions (Fig. 2). The peak value ($6.13 \mu\text{g at/l}$ at the bottom) was the highest recorded for all the estuaries studied (Table II). This coincided with the minimum nitrate value at the bottom ($0.58 \mu\text{g at/l}$) while at the surface fair concentrations of nitrate was obtained ($7.2 \mu\text{g at/l}$). The surface peak, however, was much smaller.

Ammonia showed two peaks at the surface in October 1980 and May 1981 (Fig. 2). This increase was seen at the bottom also. A very high value ($197.18 \mu\text{g at/l}$) was obtained at the bottom in July. Values at the surface, however, were very low in July.

Korapuzha

A small increase in phosphate content was noted early in the monsoon (June) both at the surface and at the bottom. Surface values were moderately high in the monsoon season except in July, remained lower during November–January and increased again to reach peak values in April (Fig. 3). Bottom values remained fairly high with some fluctuations till April whereafter it dropped. Range of fluctuation was higher at the surface ($0-4.43 \mu\text{g at/l}$) than at the bottom. These figures (Table II, Fig. 3) in general are higher than those reported by Suryanarayana Rao and George (1959).

The June–July increase in nitrate was evident here also. Higher levels were maintained at the surface for a longer period here (Fig. 3). Nitrate content of the water column dropped with the advent of the dry season, the bottom values being marginally higher (Fig. 3). Suryanarayana Rao and George (1959) have reported a range of nil to $15.7 \mu\text{g at/l}$ for this estuary which is much higher than the present range (Table II). This estuary had much lesser quantities of nitrates present in it throughout the period of observation (Table II and Figs. 2 and 3) as compared to the other three estuaries. Nitrite content increased in the water column in November 1980 and May 1981. Both these increases coincided with low nitrate levels. Except for the above, nitrite content of the water column was low for most of the year, a feature noted for other estuaries also (Figs. 2 and 3).

Ammonia was also low in this estuary by comparison. Values for the water column fell in the range of nil to $2.8 \mu\text{g at/l}$ except for a single high value ($33.57 \mu\text{g at/l}$ in December, 1980) at the bottom. Range of fluctuations of this nutrient also was small here compared to the other three estuaries (Table II).

Mahe

Inorganic phosphate increased at the surface and bottom early in the monsoon season (June). Surface values dropped later in the season and picked up during the dry months to reach a peak in April (Fig. 3). At the bottom a second increase was noted in September which was followed by low levels till May 1980 when a further increase was noted. The range observed was

nil to $2.66 \mu\text{g at/l}$ and nil to $5.04 \mu\text{g at/l}$ at the surface and bottom respectively. This estuary had lower phosphate content throughout the period of study compared to others (Figs. 2 and 3 and Table II).

Nitrate in the water column increased here also with the advent of the monsoon season, remaining high from June–August and decreased in the following months prior to another increase in May 1981. For most of the year values were less than $2 \mu\text{g at/l}$. Nitrate content ranged from nil to $18.09 \mu\text{g at/l}$ at the surface and $0.42\text{--}16.85 \mu\text{g at/l}$ at the bottom.

Nitrite concentrations ranged from nil to $2.82 \mu\text{g at/l}$ at the surface and nil to $2.45 \mu\text{g at/l}$ at the bottom. Surface values were high in April 1980 remained low till May next with the exception of November. At the bottom only a single peak was noticed in May 1981. Here also, increase in nitrite content corresponded with an increase in nitrate values, as in Kallai estuary.

Ammonia at the surface was high in September–October and in February. Surface values peaked in September and the bottom ones in October. Unlike Korapuzha and Beypore ammonia content at the surface was higher here as compared to the bottom values (Figs. 2 and 3).

Inorganic phosphate distribution in the estuaries studied did not show any well defined pattern. Values were found to be quite variable and changes in concentration seldom being uniform in the water column. Peak values at Beypore ($2.75 \mu\text{g at/l}$) and Mahe ($5.04 \mu\text{g at/l}$) were observed at the bottom while at Korapuzha it was found at the surface ($4.43 \mu\text{g at/l}$). As regards seasonal effects, though all the estuaries showed some increase in phosphate content early in the monsoon (Figs. 2 and 3), higher levels were not maintained for any considerable length of time in any of these estuaries. So also the distribution of this nutrient in the water column was not uniform in the monsoon season even though vertically homogenous conditions prevailed (Table I). It may also be mentioned that none of these estuaries had any appreciable plant pigments during this season (Kumaran — personal communication) which largely eliminates possible variations by photosynthetic activity. Hence it seems that even though some enrichment in this nutrient happens with the first pulse of the monsoons no significant contributions are made from the river run-off. De Souza, Sen Gupta, Sanzgiri and Rajagopal (1981) however have observed the peaks in phosphate concentration to correspond to the monsoon season. Suryanarayana Rao and George (1959) and Sankaranarayanan and Qasim (1969) have also arrived at similar conclusions.

Seasonal effects being marginal the observed changes in instantaneous concentrations are perhaps more influenced by local phenomena. The interchange of phosphorus between sediment and water is known to be one of the major factors governing phosphate concentrations of overlying waters. Sediments of estuaries are several times richer in phosphate compared to overlying water (Moore, 1930) and are also reported to entrap phosphate in times of excessive run-off (Jittis, 1959). Resuspension of sediments by tidal influence is

common to all these systems. This disturbance of surficial sediments and the consequent changes could perhaps be responsible for the unsystematic variations noticed. Regenerative property of sediments is also known to play a vital role governing nutrient concentrations (Reddy and Sankaranarayanan, 1972).

All these estuaries showed a substantial increase in nitrate content early during the monsoon season from June to August during which time rainfall in this area is intense. Much lower levels with some fluctuations were encountered during the rest of the period of observation. Variable rates of uptake and regeneration could account for the changes in the nitrate content observed. Though variations in values were seldom common to the water column, absolute values at surface and bottom did not differ much, probably due to the shallow nature of these water bodies. It could however, be seen that for most of the year nitrate content in all these estuaries is low and that other sources of nitrogen are possibly utilized especially in the premonsoon season when photosynthetic activity is high in all these estuaries (Kumaran — personal communication).

All these estuaries showed some increase in nitrite levels in the post-monsoon (November–December) and in May 1981, in the water column, probably related to the premonsoonal showers. Nonetheless a clear relationship with the monsoons as in the case of nitrates is not apparent. Sankaranarayanan and Qasim (1969) found vertical gradient and peaks in nitrite concentrations in the Cochin backwaters during the monsoon season. They have however, observed that the vertical gradient cannot adequately be explained by fresh water discharge alone.

Ammonia concentrations were found to be generally high in all the estuaries except at Korapuzha (Table I, Fig. 1). The range of values obtained in the present study is much higher than that of DeSouza (1977) for Zuari estuary. Peaks occurred during different times of the year in these estuaries. Kallai showed increases in July and February and May, Beypore in July and October, Korapuzha in December and Mahe in September–October and February (Figs. 2 and 3).

In the Zuari estuary DeSouza (1977) noticed an increase in ammonia and nitrate values in the beginning of the monsoon season and a decrease as the season progresses. While this observation holds good for nitrate, increase in ammonia content could be seen only at Kallai and Beypore.

The monsoonal rains, the major event that initiates and maintains cyclic changes in these estuaries over the years was found to influence hydrographic features and nutrient content differently. Hydrographic features remaining similar and comparable in time, distribution of nutrients differed from one estuary to another.

As the instantaneous concentrations of phosphate values are subject to lot of unsystematic changes it was thought that the averages for the year

would perhaps be better in assessing the level of enrichment of this nutrient in these estuaries. Inorganic phosphate concentration is a useful index of the state of eutrophication of water bodies (Ketchum, 1967). Yentch and Ryther (1957) placed $2.8 \mu\text{g at/l}$ as the approximate limit for unpolluted water and Ketchum (1967) as $2.55 \mu\text{g at/l}$. Ketchum (1967) held the view that $2.55 \mu\text{g at/l}$ is the upper limit of phosphate concentrations in eutrophication of estuaries. Kallai had consistently higher levels for most of the year which other estuaries surpassed these limits only at times (Figs. 2 and 3). The annual average for Kallai is $3.15 \mu\text{g at/l}$ (disregarding the stray high values) which is well above these reported limits.

Seasonal ranges of phosphates and nitrates for some estuaries along the west coast of India are given (Table III). Inorganic phosphate values were somewhat comparable values in all these estuaries during the postmonsoon

Table III. Ranges of inorganic phosphate and nitrate in some estuaries of the west coast of India (in $\mu\text{g at/l}$).

Name of Estuary	Inorganic Phosphate			Nitrate		
	Premonsoon	Monsoon	Postmonsoon	Premonsoon	Monsoon	Postmonsoon
Mandovi*	0.6 - 1.0	1.0 - 2.8	0.6 - 2.4	1.0 - 2.0	4.0 - 20.0	1.1 - 12.7
Zuari*	0.6 - 1.0	1.0 - 2.4	0.5 - 2.0	1.3 - 7.0	3.0 - 13.0	2.3 - 12.7
	0 - 2.66	0 - 5.04	0 - 1.13	0 - 7.34	0.4 - 18.09	0 - 1.06
Korapuzha	0.26- 4.43	0.43- 2.37	0 - 2.33	0.29- 3.68	0.63- 10.75	0 - 2.43
Beypore	0.26- 2.59	0 - 2.75	0 - 1.0	0.58- 9.12	1.36- 19.04	0.59- 7.19
Kallai	0.9 - 5.96	1.3 - 6.41	0.67- 1.6	0 - 2.54	0 - 43.46	0 - 6.53
Cochin	2.05- 7.06	0.86-10.41	3.02- 4.43	7.14-20.87	2.6 - 24.37	4.65- 39.48

* Desouza et al., 1981.

season only. It could be that the levels encountered in these estuaries represent the excess of phosphate available as the autotrophic uptake did not match the regeneration processes and inputs from other sources. If that be the case these estuaries along the southwest coast with their higher fertility have a greater potential to get eutrophic in much shorter span of time than the estuaries along the central west coast.

ACKNOWLEDGEMENTS

The authors are thankful to the Director, National Institute of Oceanography, Goa, for facilities and encouragement. They also thank S/Shri P. S. Gore and O. Raveendran, Regional Centre of NIO, Cochin, for their generous help in the collection of samples. Two of the authors (KNR and DZ) are grateful to the CSIR for the award of fellowships.

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