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Seasonal distribution and behaviour of nutrients with reference to tidal rhythm in the Mulki Estuary, South-West Coast of India

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Abstract

Some physico-chemical parameters like temperature, pH, dissolved oxygen, ammonia-nitrogen, nitrite-nitrogen, nitrate-nitrogen, phosphate-phosphorus and silicate-silicon were investigated at the Mulki estuary under high and low tide conditions during monsoon, post and premonsoon periods. pH and salinity increased during high tides while dissolved oxygen trend is independent of tidal effects. Whereas ammonia, nitrite, nitrate, phosphate and silicate increased during low tide. Higher values of all the nutrients during monsoon season suggest that the freshwater influx can be a vital source of nutrients for the estuary.

Introduction

Estuaries apart from being the interface between rivers and oceans have been mediating man's predominantly land based activities and interacting with oceans. The study of estuarine regions plays vital role as they are highly productive and play an important role as nursery grounds for many commercially important fishes especially shrimps. Tide is one of the important physical factors governing the environmental features of an estuary. Hence, it is essential to obtain information on the range of variations of some of the environmental parameters with the tidal rhythm. The importance of tidal variations, current patterns and magnitude of freshwater discharge at different periods in estuaries in relation to the environmental parameters are well documented (Qasim and Gopinathan, 1969; Vijayalakshmi and Venugopalan, 1973; Reddy, 1992; Sarala Devi *et al.*, 1983).

Extensive studies have been made pertaining to the spatio-temporal distribution and behaviour of nitrate-nitrogen, phosphate-phosphorus and silicate - silicon in many estuaries of India (Reddy *et al.*, 1993; Gowda and Panigrahy, 1992 and 1995; Choudhary and Panigrahy, 1991; Das *et al.*, 1997). However, studies on the nutrient dynamics in the estuaries of Mangalore coast are meager, though this coast is endowed with extensive areas of estuarine habitats of ample economic value. The present study deals with the spatio-temporal distribution and behaviour of nutrients such as ammonia-nitrogen, nitrite-nitrogen, nitrate-nitrogen, phosphate-phosphorus and silicate-silicon in relation with tide in the Mulki estuary, south-west coast of India.

Material and methods

The Mulki estuary is situated at about 45 km north of Mangalore (13°4'N

74°47'E). The confluence of the Mulki and Pavanje rivers with the Arabian Sea results in the formation of the Mulki estuary (Fig. 1). The estuary is connected to the sea throughout the year and subjected to tidal influence with a range of 1.86 m and influence the water to a length of 6.0 km in Mulki river and 6.6 km in Pavanje river (Reddy, 1982). During the south-west monsoon period (June-September) the estuary is flooded with freshwater influx from the land and the estuarine water become almost fresh. While during non-monsoon period, estuarine water comprises mainly of seawater as the freshwater influx is very much reduced.

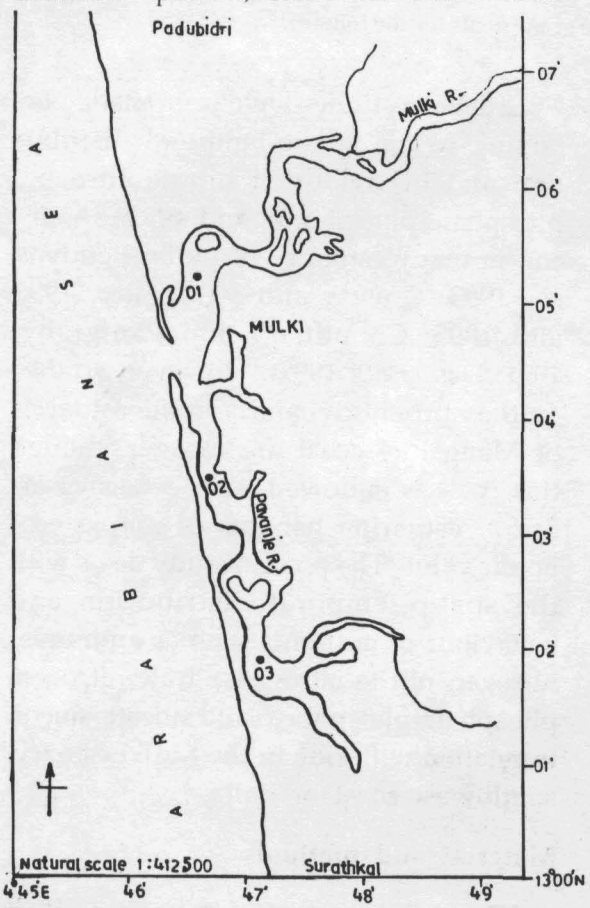

Fig. 1. *Map showing the location of sampling stations in Mulki estuary.*

Sampling was made at monthly intervals from three stations during April 1998 to May 1999. Water samples were collected during both low and high tides from the selected stations. Water temperature and pH were measured by precise mercury-in-glass thermometer and pH meter respectively. Salinity, dissolved oxygen and nutrients such as ammonia-nitrogen, nitrite-nitrogen, nitrate-nitrogen, phosphate-phosphorus and silicate-silicon were estimated following standard methods (Strickland and Parsons, 1972).

Results and discussion

Hydrography

Temperature

Estuarine waters generally tended to be warmer during the premonsoon period (Feb-May) and attained peak values for the temperature during the month of April and May (Fig. 2A). The onset of monsoon greatly influences in reducing the water temperature. The maximum and minimum values of water temperature were 34.6°C (Dec.) and 27.9°C (Oct.) respectively. This seasonal variation of temperature was attributed to the incoming radiation, winds and currents. The seasonal temperature fluctuation reveals variations between high and low tide periods. Though, the general trend during high and low tide periods at different stations followed identical seasonal pattern, the absolute temperature between these two tides are different. However similar seasonal trend was documented by Reddy (1986) and Puranik (1990).

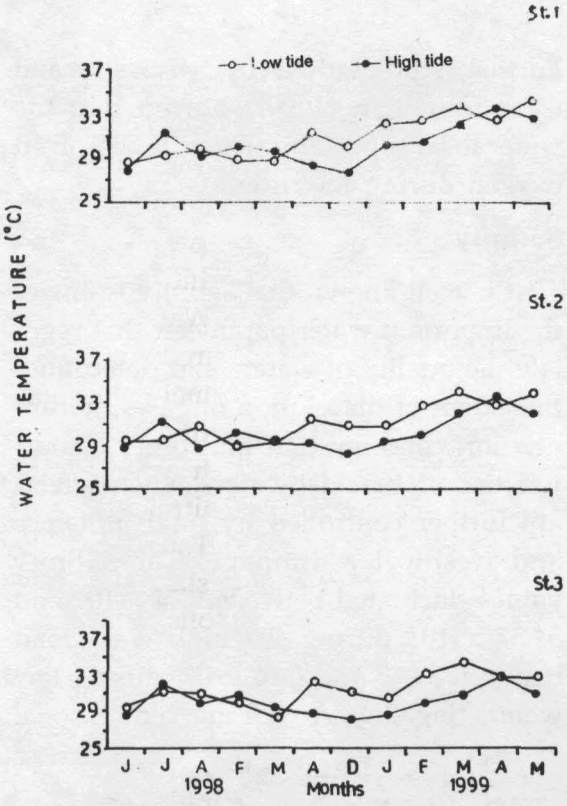

Fig. 2A. *Monthly variations of water temperature at different stations*

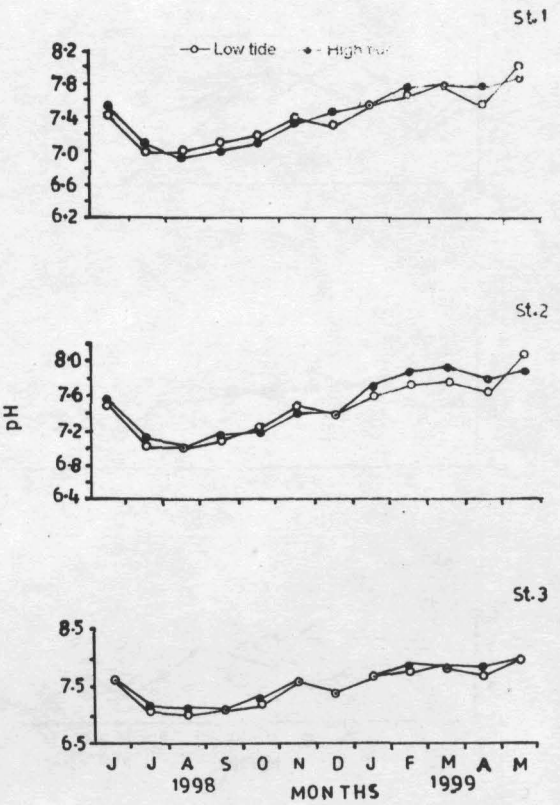

Fig. 2B - *Monthly variations of pH at different stations*

pH

The pH of water varied between 7.03 and 7.69 during high tide, while it varied between 6.96 and 8.03 during low tide (Fig. 2B). Generally higher values during high water and low water were recorded during April and May, while the lower values were recorded in July for both the tides. The values did not show much fluctuation seasonally except that the water was alkaline during summer, when the influx of freshwater was minimum and the waters in the estuary was dominated by seawater. This was in tune with the observations of earlier workers (Sudhir, 1990 and Sahu, 1981). The lower values of pH recorded during the present study also compares well with the observations of earlier workers (Sahu, 1981 and Reddy, 1982).

Dissolved oxygen

It is well known that the temperature and salinity affect the dissolution of oxygen. In the present investigation, the waters in the estuary were found to be well oxygenated during high and low tides at all the stations. The data reveal that the dissolved oxygen fluctuated between 3.01 and 5.95 ml/l during high tide and between 5.55 and 3.59 ml/l during low tide period (Fig. 2C). Higher values of dissolved oxygen were recorded during monsoon months at almost all the stations and is due to the copious supply of low saline

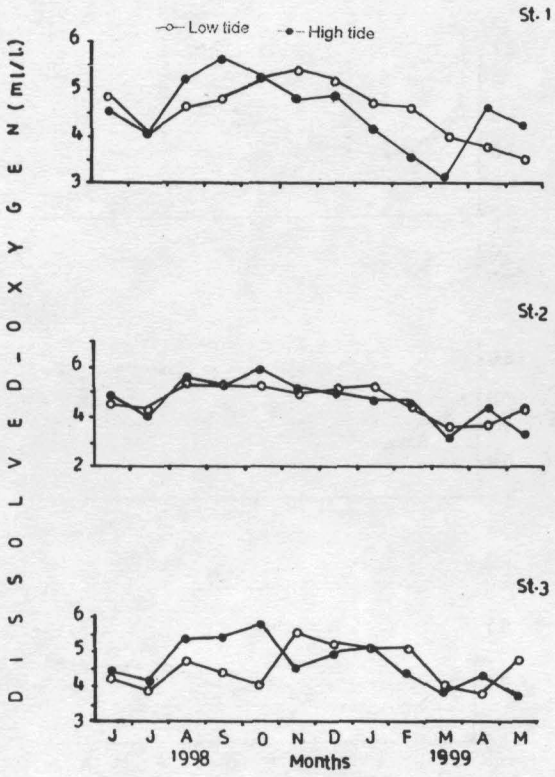

Fig. 2C - *Monthly variations of dissolved oxygen at various stations*

and low temperatured water from the river. While the relatively lower values during October could be due to utilization of oxygen for decomposition of organic matter in the terrigenous sediments, whereas the lower values of May could be owing to the higher rate of decomposition due to variations in the temperature. The present investigation does not show any clear-cut relation between oxygen concentration and tide (Fig. 2). However, Pillai *et al.* (1973) observed that the dissolved oxygen concentration is influenced by tides. In contrast, Singbhal (1973) stated that dissolved oxygen trend in Mandovi estuary was independent of tidal effects. Further, studies done by Sai Sastry and Chandramohan (1990) showed that the water to be supersaturated with dissolved oxygen during low tide.

Salinity

It is well known that salinity is one of the important water parameter that regulate the quality of waters and determines the extent of dissolution of gases, hydrogen ion concentration and other characteristics of brackishwaters. Such effects are further controlled by tidal influence and freshwater drainage. The salinity values fluctuated between 0.14 x 10^{-3} and 34.37 x 10^{-3} during the high water and between 33.75 and 0.14 x 10^{-3} during low waters (Fig. 2D). A well marked seasonal

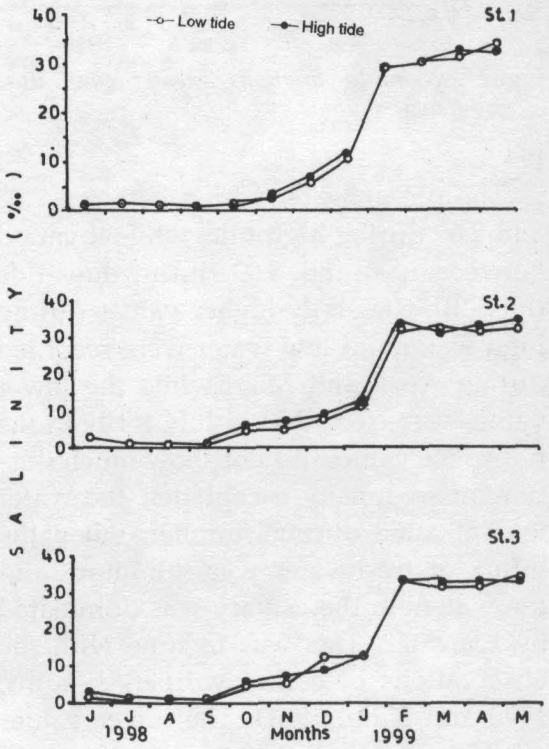

Fig. 2D. *Monthly variations of salinity at different stations*

fluctuation with relatively low values during monsoon months and higher but fluctuating values during the pre and postmonsoon seasons were noticed. The salinity appears to be similar for all the stations.

Nutrients

Ammonia

Ammonia is considered to be the most preferred form by marine flora. This nitrogenous nutrient is liable to undergo fluctuation by way of nitrification and denitrification. In the present instance ammonia generally followed a trimodal pattern of distribution (Fig. 3A) with a primary peak appearing during June and September followed by smaller peaks during October and November. The concentration during the study period varied from 0.13 to 22.43 µg-at/l during high tide and from 0.25 to 25.59 µg-at/l during low tide. Reddy and Gupta (1985) recorded a bimodal pattern of distribution in Mulki estuary and recorded peak ammonia value (11.6 µg-at/l) during December. Higher values recorded at station 2 during the study period is possibly related to its prioximity to the nearby cold storages from where ammonia is used as a refrigerant could have found its way into the estuarine water by either tank washing or accidental spillage. The monsoon peaks observed at all the stations were perhaps due to the initial increase in the drainage (Nagarajaiah and Gupta, 1983). Similar observations were made by Sarala Devi *et al.*, (1983) in Vellar estuary. Ammonia-nitrogen showed positive significant correlation with temperature, nitrite-nitrogen and phosphate - phosphorus during low tide while it is independent of all the parameters during high tide (Table 1 and 2).

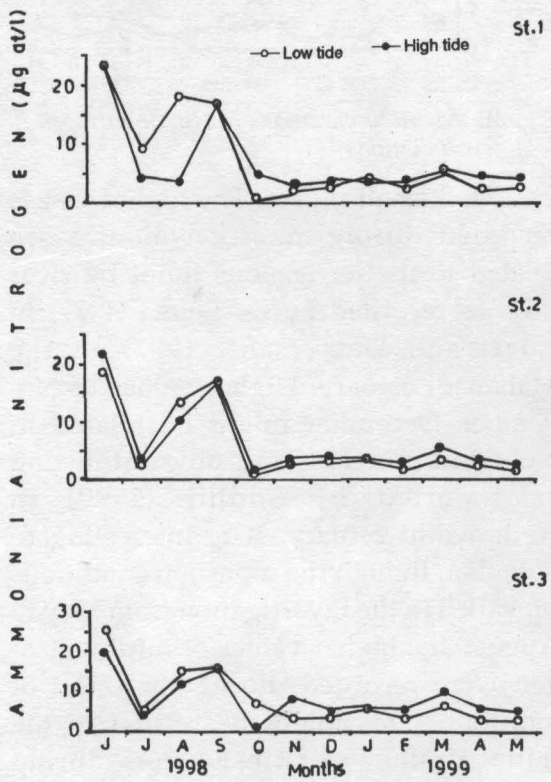

Fig. 3A *Monthly variations of Ammonia nitrogen in different stations*

Nitrite-nitrogen

The nitrite-nitrogen concentration varied from 0.18 to 1.47 µg-at/l during high tide and from 0.06 to 2.42 µg-at/l during low tide. From fig. 3 B, it is evident that nitrite-nitrogen registered a gradual increase and reached its highest peak in the month of June and July at almost all the stations and thereafter the values dropped during the month of August and in the rest of the periods, seasonal distribution

Table 1. *Correlation coefficient between different hydrographical parameters during high tide.*

	Temperature	pH	Salinity	Dissolved oxygen	Ammonia	Nitrite	Nitrate	Phosphate	Silicate
Temperature	-	0.4147	0.6639*	-0.5675	-0.1531	0.0997	-0.2604	-0.1840	-0.3985
pH	-	-	0.9014*	-0.7470*	-0.1737	0.0031	-0.3411	-0.1821	-0.7530*
Salinity	-	-	-	-0.7071*	-0.3434	-0.1031	-0.5188	-0.3880	-0.7729*
Dissolved oxygen	-	-	-	-	0.2063	-0.4308	-0.0610	-0.0267	0.3561
Ammonia	-	-	-	-	-	-0.0203	0.3431	0.4622	0.1337
Nitrite	-	-	-	-	-	-	0.7931*	0.5461	0.6014*
Nitrate	-	-	-	-	-	-	-	0.7979*	0.7450*
Phosphate	-	-	-	-	-	-	-	-	0.3962
Silicate	-	-	-	-	-	-	-	-	-

* r significant at P > 0.05

Fig. 3B. *Monthly variations of Nitrite-nitrogen in different stations*

exhibited small pulses. The higher vlaues recorded during monsoon months are related to the terrigenous input by river flow as recorded by De Souza (1977) in Zuari and Das *et al.*, (1977) in the Mahanadi estuary. Higher values of November/December might be related to biological processes and physical mixing as reported by Sudhir (1990) in Nethravathi estuary. It is interesting to note that, though the monsoon conditions prevailed in the investigation from May to August, the higher values of nitrite-nitrogen were recorded during the onset of monsoon. This might be related to the initial drainage of freshwaters during monsoon. The concentration showed a great increasing trend from August onwards till November-December and it was

attributed to the changes in chemistry of estuarine waters consequent to the onset of monsoon. Nitrate-nitrogen distrubution is directly related with nitrate-nitrogen and silicate-silicon during high tide (Table 1), while it has got positive significant correlation with all other nutrients (Table 2) during low tide.

Nitrate-nitrogen

Nitrate-nitrogen concentration varied from 1.90 to 79.63 µg-at/l during high tide and from 1.15 to 74.71 µg-at/l during low tide. Generally, the higher values were recorded during monsoon months both in high and low tides (Fig. 3C). Similar ob-

Fig. 3C *Monthly variations of Nitrate-nitrogen in different stations*

Table 2. *Correlation coefficient between different hydrographical parameters during high tide.*

	Temperature	pH	Salinity	Dissolved oxygen	Ammonia	Nitrite	Nitrate	Phosphate	Silicate
Temperature	-	0.8057*	0.8956*	-0.4073	-0.5937*	-0.5097	-0.5128	-0.4604	-0.6557*
pH	-	-	0.8470*	-0.3050	-0.4033	-0.6071*	-0.5467	-0.1240	-0.7699*
Salinity	-	-	-	-0.5440	-0.4227	-0.6063*	-0.5742	-0.3830	-0.8014
Dissolved oxygen	-	-	-	-	0.0580	-0.1705	-0.1867	-0.1722	0.2572
Ammonia	-	-	-	-	-	0.6466*	0.3817	0.6229*	0.2630
Nitrite	-	-	-	-	-	-	0.7222*	0.7554*	
Nitrate	-	-	-	-	-	-	-	0.7222*	0.7554*
Phosphate	-	-	-	-	-	-	-	-	0.3105
Silicate	-	-	-	-	-	-	-	-	-

* r significant at P > 0.05

servations were made by Nair *et al.*, (1984) in Ashtamudi estuary and Ayakkannu (1989) in Kallidam estuary. The higher values during monsoon season are attributed to the terrestrial input through riverine discharge. The smaller peaks observed during postmonsoon season (September and October) are believed to be related to both monsoonal input and utilization. With respect to tides, higher values were encountered during low tides. While comparing the values between stations, it becomes evident that the stations situated near the bar mouth (St. 1 and 2) always registered slighly higher values of this nutrient when compared to that of the station (St. 3) which is situated away from the bar mouth. Distribution of nitrate-nitrogen has got positive significant correlation with nitrate-nitrogen, phosphate-phosphorus and silicate-silicon during both high tide (Table 1) and low tide (Table 2).

Phosphate-phosphorus

The phosphate-phosphorus concentration was same throughout the estuarine stretch. The maximum concentrations were generally found during monsoon season, however, at majority of the stations, the premonsoon period (March-May) showed an increasing trend. In general, the postmonsoon season did not contribute very much to the nutrient budget. Phosphate-phosphorus concentration generally fluctuated between 0.10 to 3.97 and 0.05 to 5.14µg-at/l during high and low tide respectively. Annual cycle of phosphate-phosphorus showed trimodal oscillations during both the tides. Rapid fall of phosphate-phosphorus was noticed during September and March together with nitrate-nitrogen. This could be related to depletion of phosphate-phosphorus simultaneously with nitrate-nitrogen as a consequence of the blooming of diatom as reported by earlier workers (Choudhary and Panigrahy, 1991). The levels of phosphate-phosphorus began increasing from April onwards till the highest value was reached in June. High phosphate-phosphorus content during monsoon season (Fig. 3D) together with strong negative correlation (P= 0.05) between salinity and phosphorus for the estuary. Positive significant correlation existed between phosphate-phosphorus and all other nutrients except silicate-sili-

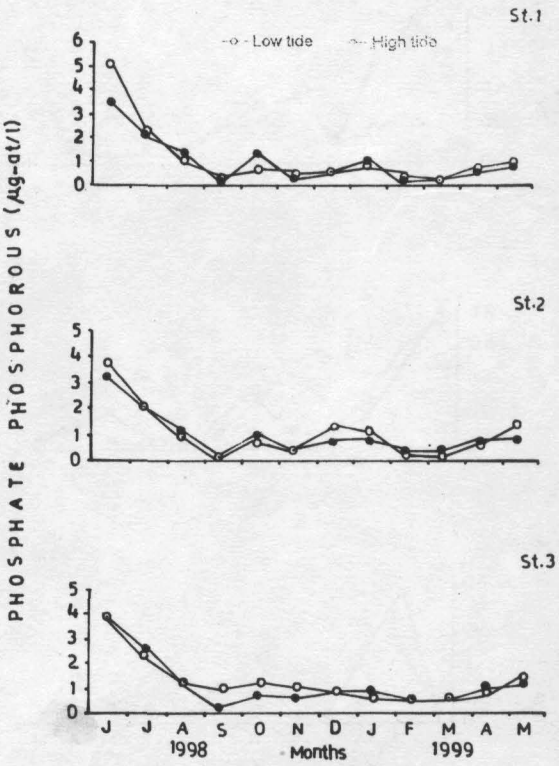

Fig. 3D. *Monthly variations of phosphate-phosphorus in different stations*

Table 3. *Analysis of variance (ANOVA) for monthly variations of phosphate-phosphorus*

Source of variation	Degree of freedom	SSQ	MSSQ	F-ratio
Stations	2	0.7627	0.3813	5.05*
Months	11	69.1936	6.2903	83.82*
Tides	1	0.1770	0.1770	2.34*
Station x Months	22	1.6423	0.0747	0.99
Station x Tides	2	0.0000	0.0000	0.00
Months x Tides	11	1.0268	0.0933	1.24
Error	22	1.6609	0.0755	
Total	71	74.4633		

* Significant at $P < 0.05$

con during low tide (Table 2) and it was only with silicate-silicon during high tide (Table 1).

Results of ANOVA carried out on phosphate-phosphorus concentration are presented in the Table 3. A significant difference in the concentration of phosphate-phosphorus was evidenced due to stations, months and tide at 5% level of significance. However, the interaction due to stations versus months, stations versus tides and months versus tides were not found to be significantly different.

Silicate-silicon

Levels of reactive silicate with present study varied from 1.57 and 101.64 µg-at/l during high tide and between 5.45 and 103.82µg-at/l during low tide (Fig. 3 E). Silicate-silicon concentration exhibited bimodal oscillations, both peaks were encountered corresponding to monsoon and post monsoon seasons. Gradual seaward decrease coupled with higher monsoonal concentrations indicate that intrusion of silicate into the estuary mainly takes place through surface runoff, which is in agreement with the earlier observations made in Cochin backwater (Anirudhan and Nambisan, 1991), Mandovi and Zuari estuaries (De Souza *et al.*, 1981), Vellar estuary (Chandran and Ramamoorthy, 1984) and Mahanadi estuary (Upadhyaya, 1988). Lowest silicate

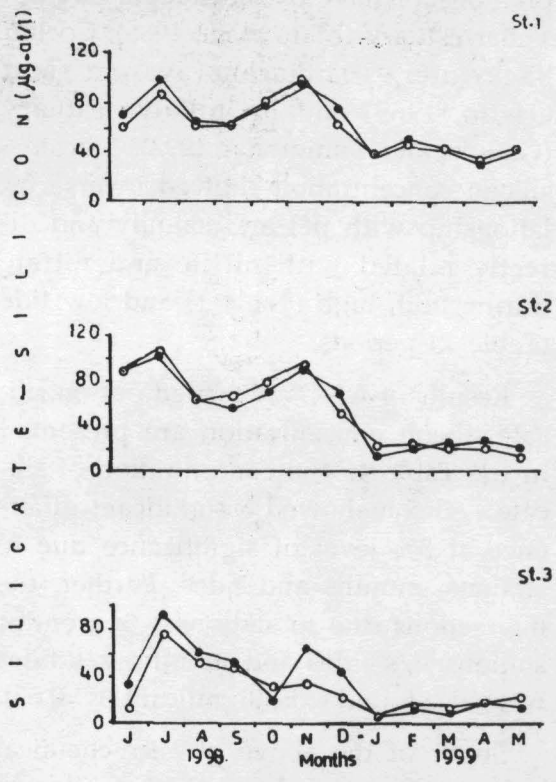

Fig. 3E. Monthly variations of Silicate-silicon in different stations

Table 4. *Analysis of variance (ANOVA) for monthly variations of silicate-silicon*

Source of variation	Degree of freedom	SSQ	MSSQ	F-ratio
Stations	2	11090.2	5545.1	174.20*
Months	11	37024.8	3365.9	105.74
Tides	1	153.3	153.3	4.82*
Station x Months	22	6285.8	285.7	8.98*
Station x Tides	2	158.3	79.1	2.49*
Months x Tides	11	843.0	76.6	2.41*
Error	22	700.3	31.8	
Total	71	56255.7		

*Significant at $P < 0.05$

concentrations during premonsoon season suggest that biological utilization act as an important factor associated with removal of silicate from the medium. Similar instances of silicate depletion during premonsoon have also been reported from Vellar estuary (Mani *et al.*, 1986), Cochin backwater (Sankaranarayanan and Qasim, 1969) and Rushikulya estuary (Gowda and Panigrahy, 1992). Silicate - silicon concentration showed inverse relationship with pH and salinity and directly related with nitrite and nitrate during both high (Table 1) and low tide (Table 2) periods.

Results of ANOVA carried out on silicate-silicon concentration are presented in the Table 4. The concentration of silicate - silicon showed a significant difference at 5% level of significance due to stations, months and tides. Further, the interactions due to stations v/s months, stations v/s tides and months v/s tides were also found to be significant ($P = 0.05$).

Study of the above physico-chemical parameters revealed that the incursion of seawater effects pH, salinity and dissolved oxygen. However, higher values of dissolved oxygen during ebb tide in postmonsoon season indicates photosynthetic activity in the upper reaches of the estuary. Higher values of all the nutrients during ebb tide suggest that the freshwater influx can be a vital source of nutrients for the estuary.

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