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RESEARCH ARTICLE

NUTRIENTS AND ITS INFLUENCE ON BIOLOGICAL PRODUCTIVITY ALONG KERALA COAST, INDIA

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ABSTRACT

The present study was undertaken with an aim to estimate the health of marine environment of Kerala in terms of primary production, chlorophyll *a* and community structure of phytoplankton with respect to existing environmental conditions. Maximum productivity (27.26 mg C m^{-3} h^{-1}), chlorophyll-*a* concentration (3.83 mg m^{-3}) and phytoplankton density (5928 cells L^{-1}) were observed at Paravur, where as low productivity, chlorophyll *a* and phytoplankton count were observed at Veli. Maximum diversity of phytoplankton was encountered at Kasaragod. A total of 29 genera of phytoplankton comprising 23 diatoms, 4 dinoflagellates and each of blue green algae and green algae were identified. The most common diatom encountered in the study was *Chaetoceros*, *Coscinodiscus* and *Pleurosigma*. The acidic effluent discharged from Travancore Titanium Products Limited (TTP) seems to have adversely affected the phytoplankton diversity, abundance and the primary productivity at Veli. Along the Kerala coast, Phytoplankton abundance, community structure and biomass could be controlled by spatial variability of nutrients and species specific association with respect to differences in the hydrographical conditions and anthropogenic inputs from point sources.

INTRODUCTION

Kerala is one of the important maritime states in the south west coast of India having 580 km of coastline. Along the south west of India, upwelling brings nutrient to euphotic zone, which leads to marked increase in phytoplankton growth thereby increasing chlorophyll and primary productivity. Health of the coastal area mainly depends on plankton community. Any factor affecting the production of plankton directly affects the plankton feeders such as commercial fishes. Ocean health is mainly affected by the pollution activities. The quantum of pollution caused by untreated sewage in the coastal marine system is alarming since

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rivers, backwaters and the sea are interconnected. Pollution of one water body naturally gets transmitted to next one ultimately resulting in coastal pollution. Also industrial and wastewater discharge in to the coastal area drastically affect the overall biological health of coastal area. Since occurrence and abundance of phytoplankton indicate water quality in terms of pollution and is thus significant in the exploitation of fishery potential. Measurement of primary productivity is essential for the estimation of level of fish production and potential of exploitable fisheries (Boyd *et al.,* 1979). Since the cycling of organic matter is a fundamental concept in biological oceanography, attention should be devoted to primary production as the starting point in the cycle. Also primary production, being the first link in the food web in the sea, may indirectly indicate the relative fertility of coastal waters. In Assessment of trophic status, phytoplankton standing crop estimation become prerequisite which indicates the total plant material available at the primary stages of the food chain. Chemical characteristics, especially nutrient prevailing in the water column play crucial role in biological characteristics Malone (1980). Nutrients are necessary for adequate growth and production of phytoplankton. Studies on primary productivity, chlorophyll *a* and plankton characteristics at certain areas of west coast of India are studied by Rajagopalan *et al* (1992), Varsheny *et al.,* (1983), Rany Mary *et al.,* (1987), chlorophyll *a* by Sarala devi *et al.,*(1997), Desai *et al.,* (1984) and plankton distribution was studied by Subramanyan (1959). Kerala ranked third in the marine fish production. So study on the qualitative and quantitative nature of biological characters like pigment concentration, primary productivity and phytoplankton along the coastal transect is essential to safe guard the fisher folk community.

MATERIALS AND METHODS

Water and phytoplankton samples were collected from 2.0 km offshore of nine transects along the state of Kerala starting from south Thiruvananthapuram to north Kasaragod (Fig.1) during March 2005. Oxygen was measured using Winkler's method (UNESCO, 1994). Samples for

Fig.1. Location map showing sampling sites along the Kerala coast.

pH were collected in 100 ml glass bottles, poisoned with 100 µl of saturated mercuric chloride and sealed air-tight. The pH was measured using a ROSS combination glass electrode (ORION 8102U) and pH meter (ORION 555A). Analytical precision for pH of samples was ± 0.005. All carboys, filtering devices, glassware and tubings were acid-washed (10% HCl) and rinsed thrice with deionized water prior to use. It was then rinsed twice with their own volume of sample, capped and stored in the dark at 4 ^{o}C until analysis. Analyses for nutrients (Nitrate, Phosphate and Silicate) were done within 6h of collection, following filtration through 0.45µ filters into pre-cleaned containers. Concentrations were determined by standard methods following Grasshoff *et al.* (1999). Primary productivity was estimated using light and dark bottle technique following Strickland and Parsons (1972). Water sample collected for phytoplankton (1000 ml) were preserved in Lugol's solution and taxonomic analysis were carried out under a microscope as per standard methods. Chain forming cells are counted on per cell basis and empty cells are excluded.

Phytoplankton was identified in the generic level (Lenore *et al*., 1989; Santhanam *et al*., 1987 and Krishnapillai 1986). For chlorophyll estimation, 1000 ml of water sample filtered through Millipore filter paper (47 mm dia. and 0.45 µm pore size) and the pigments were extracted in 90 % acetone, the acetone extract was measured at 664, 665 and 750 nm (Strickland and Parson 1972; Lenore *et al*., 1989).

RESULTS AND DISCUSSIONS

Among stations, surface water temperature ranged from 26.0°C (Paravur) to 28.3°C at Alleppey. There was significant fluctuation in salinity among the stations, maximum salinity of 34.6 was recorded at Veli and the minimum (14.7) was recorded at Cochin. Among the stations, Veli recorded the lowest pH (3.6) where the highest (8.23) was recorded from station Paravur. There was not much variation in dissolved oxygen (DO), recorded at Veli near shore. The pH values showed great fluctuation among the stations. The present study recorded an acidic pH of 3.60 at effluent discharge point of Veli, indicating the extremity of acidic factory effluents discharged from Travancore Titanium Product (TTP). Similar observations were also made by (Robin *et al*., 2002; Prijilal, 2003). pH below 5 considerably reduces the primary productivity of coastal waters (Bijumon *et al*., 2000), which in turn can adversely affect the yield of fisheries resources. Also pH between 8 and 9 might be lethal to some of the faunal species (Albaster and Loyed, 1980). From the result it is clear that in coastal waters of the Thiruvananthapuram coast have been exposed to the increased threat of industrial pollution. Madhuprathap *et al*., (1979) reported that death of organisms from the effluent could be due to severe change in pH of water, which will create stress on

Table 1. Distribution of nutrient along Kerala coast, March 2005

Stations	Nitrate nitrogen ($\mu molL^{-1}$)		Silicate ($\mu molL^{-1}$)		Inorganic phosphate ($\mu molL^{-1}$)	
	*S	*B	*S	*B	*S	*B
Veli	4.92	5.17	3.28	2.97	2.06	2.78
Paravur	5.84	6.32	2.91	2.31	1.42	1.64
Kayamkulam	3.98	4.38	1.85	1.47	2.32	2.36
Alleppey	4.02	4.63	1.96	1.14	2.25	2.47
Cochin	5.02	5.98	3.32	2.28	1.98	2.12
Ponnani	4.84	5.43	2.83	2.34	1.36	1.43
Calicut	5.62	6.14	3.02	2.63	1.78	1.84
Cannanore	4.92	5.08	2.68	2.12	2.18	2.27
Kasaragod	5.16	5.52	2.41	2.09	2.56	2.65

*S-Surface; *B-Bottom

Table 2. Biological characteristics along Kerala coast, March 2005

Stations	*Primary productivity ($mgCm^{-3}h^{-1}$)	*Chlorophyll *a* ($mg\ m^{-3}$)	*Phytoplankton ($cells\ L^{-1}$)
Veli	3.15	0.85	330
Paravur	27.26	3.83	5928
Kayamkulam	16.5	2.14	3010
Alleppey	19.98	1.17	2940
Cochin	18.21	2.82	3864
Ponnani	21.46	3.36	5522
Calicut	23.68	3.77	5780
Cannanore	17.22	2.94	5238
Kasaragod	21.92s	3.56	5728

*-Surface

Table 3. Quantitative and qualitative results of phytoplankton density (cells L^{-1}) along Kerala coast, March 2005

Sl. No.	Name of Organisms/ Species	STATIONS							
		Veli	Paravur	Kayamkulam	Alleppey	Cochin	Ponnani	Calicut	Cannanore
1	*Asterionella* sp	_	3680	650	150	2464	5018	2230	117
2	*Amphora sp*	_	_	_	90	8	_	_	_
3	*Bacteriastrum* sp	_	16	_	15	_	_	10	_
4	*Biddulphia* sp	_	_	280	450	104	40	40	63
5	*Cyclotella* sp	_	_	_	_	_	2	_	_
6	*Ceratium* sp	36	24	110	60	56	_	80	27
7	*Chaetoceros* sp	108	1024	300	180	328	184	1890	234
8	*Corethron* sp	_	_	_	30	24	_	_	_
9	*Coscinodiscus* sp	54	144	620	435	168	60	280	162
10	*Dinophysis* sp	_	32	20	_	32	_	20	_
11	*Distephanes* sp	_	_	_	_	_	_	10	_
12	*Ditylum* sp	_	56	_	_	_	2	20	_
13	*Eucampia* sp	_	_	_	60	_	_	_	_
14	*Leptocylindrus sp*	_	96	30	_	80	_	_	_
15	*Navicula* sp	_	_	_	_	_	8	_	_
16	*Nitzschia* sp	_	72	350	75	24	16	70	_
17	*Peridinium* sp	18	40	60	75	176	_	30	9
18	*Planktoniella sp*	_	_	10	_	16	_	10	_
19	*Pleurosigma* sp	18	32	200	315	32	40	30	9
20	*Prorocentrum sp*	_	_	_	15	_	_	_	_
21	*Rhizosolenia* sp	_	528	60	180	144	14	310	4536
22	*Skeletonema sp*	_	_	_	_	_	16	_	_
23	*Spirogyra* sp	_	_	_	_	_	_	_	27
24	*Streptotheca* sp	_	_	_	_	_	2	_	_
25	*Thalassionema* sp	96	_	120	330	96	42	650	_
26	*Trichodesmium* sp	_	_	_	30	_	_	100	54
27	*Thalassiosira* sp	_	_	_	75	40	_	_	_
28	*Triceratium* sp	_	_	10	_	_	2	_	_
29	*Thalassiothrix* sp	_	184	190	375	72	76	_	_
	Total cell density (cells L^{-1})	**330**	**5928**	**3010**	**2940**	**3864**	**5522**	**5780**	**5238**

normal metabolism of overall aquatic life which is reflected on plankton growth and primary productivity. Nitrate nitrogen in surface water was 3.98 and 5.84 $\mu molL^{-1}$ at Kayamkulam and Paravur respectively. The results indicate that NO_3-N concentration in bottom waters is always slightly higher than the surface concentration, which ranged from 4.38 at Kayamkulam to 6.32 $\mu molL^{-1}$ at Paravur. Results clearly indicate higher concentration of NO_3-N in estuaries like Paravur, Kochi, Kozhikode and Kasaragod than close to beach locations. This may be due to the biological oxidation of organic nitrogen originated from domestic and municipal sewage and industrial wastes. The results also agree with the previous observations made by Ouseph *et al*. (2001) and Liss and Spencer (1970).

Silicate is essential for the growth of diatoms and dinoflagellates, which possess frustule, composed of silica. The concentration of silicate is also governed by dissolution of river borne particulate material and removal of Silicon through adsorption by suspended solids and co-precipitated with humic substances (Liss and Spencer, 1970). The surface silicate concentration fluctuated between 1.85 to 3.32 $\mu molL^{-1}$at Kayamkulam and Cochin respectively. Surface water concentration of SiO_2 was higher than that of bottom waters. The bottom concentration found 1.14 at Alleppey to 2.97 $\mu molL^{-1}$ at Veli. This clearly indicates that fresh water discharge is the prime contributor of silica in the marine ecosystem. This is an agreement with the results of the studies conducted by Gouda and Panigrahy (1992). Inorganic phosphates in estuarine and coastal waters play an important role in energy transformation processes of biological

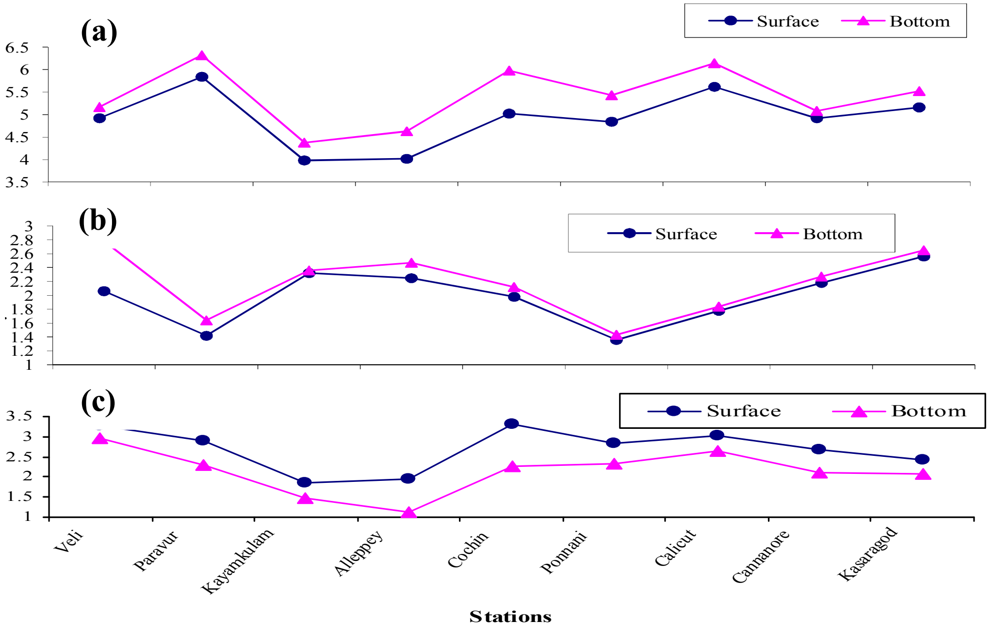

Fig. 2. Variation of nutrients along Kerala coast [a] Nitrate - N (µmolL^{-1}) [b] Phosphate - P (µmolL^{-1}) [c] Silicate-Si (µmolL^{-1}).

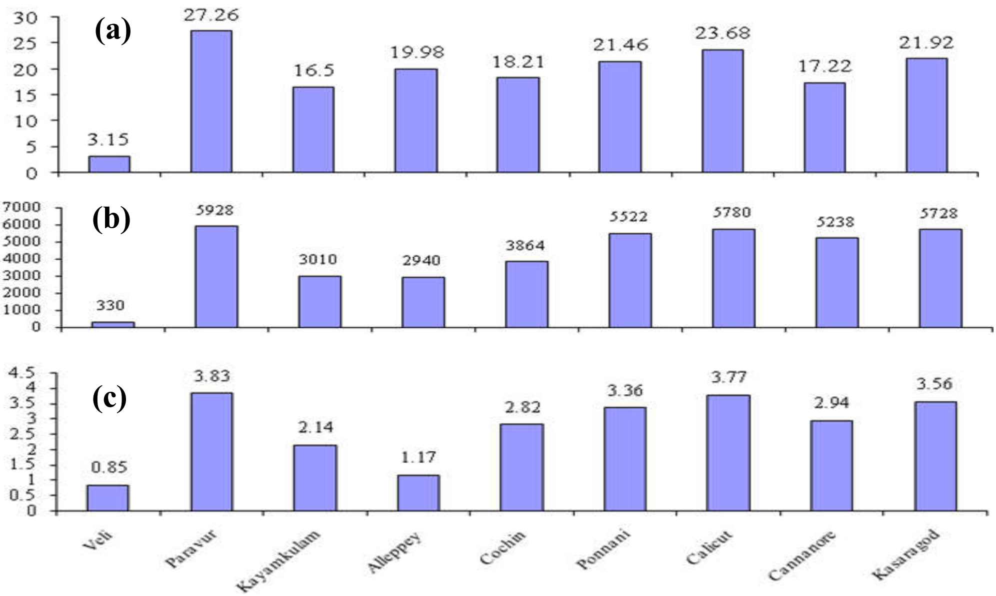

Fig.3.Variation of Biological parameters along Kerala coast [a] Primary Productivity (mgCm^{-3}h^{-1}) [b] Phytoplankton density (cells L^{-1}) [c] chlorophyll-*a* (mg m^{-3}).

systems. The major source of phosphorus are domestic sewage, detergent, agricultural runoff with fertilizer and industrial wastewater. The maximum surface concentration of inorganic phosphate (2.56 $\mu molL^{-1}$) was reported at Kasaragod and the minimum (1.36 $\mu molL^{-1}$) at Ponnani. Inorganic phosphate in bottom samples was slightly higher than that of the surface water, which ranged from 1.43 $\mu molL^{-1}$at Ponnani and 2.78 $\mu molL^{-1}$at Veli. Comparatively lower values in the estuarine transect indicate dilution with fresh water and to the great silt load that remove phosphorus from marine environment (Lakshmanan *et al.,* 1987). Removal of phosphate can also be attributed to biological utilization (De Souza *et al*., 1981). Results are presented in Table 1 and Fig. 2.

The highest surface productivity of 27.26 $mgCm^{-3}h^{-1}$ was reported at Paravur and 3.15 $mgCm^{-3}h^{-1}$ at Veli. According to Banse (1984) along the south west coast of India, upwelling starts with the offset of summer monsoon (May to June) and intensifies in July to August. The study reveals that surface productivity drastically decreased at Veli. Low phytoplankton count and diversity encountered in Veli may be due to acidic effluents discharged from the Travancore Titanium Products. The high suspended load in the water column at Veli might have obstructed the proper penetration of light and interfered in the process of photosynthesis. Similar observation also made by Varshney (1983) and Ouseph (2001). Chlorophyll *a* content and plankton density at Veli substantiate this inference.

It is obvious that chlorophyll *a* concentration positively correlated with plankton density and nutrient concentration. The chlorophyll concentration ranged from 0.85 at Veli and 3.83 mg m^{-3} at Paravur. The maximum phytoplankton population count coincided with the peak value of chlorophyll *a* (Tiwari and Vijayalakshmi; 1998). The maximum chlorophyll *a* content was recorded at Paravur, which also coincided with the cell count of phytoplankton. Chlorophyll *a* concentration at Veli indicates an unhealthy condition of standing crop. The enhanced nutrient supply to coastal waters might have resulted in high phytoplankton and chlorophyll *a* production (Banse, 1984). Generally, low pigment concentration was observed during the study period which was also noticed by Asha *et al.* (2002), Bijumon *et al.,* (2000). The present study clearly indicated interrelationship between nutrients and chlorophyll *a* concentration. Saraladevi *et al*. (1997) also made similar observation along the southwest coast of India.

The phytoplankton standing crop ranged between 330 a Veli to 5928 cells L^{-1}at Paravur. The dominant phytoplankton observed were

Chaetoceros and *Thalassionema* at Veli,
Asterionella and *Chaetoceros* at Paravur,
Asterionella and *Coscinodiscus* at Kayamkulam,
Biddulphia and *Coscinodiscus* at Alleppey,
Asterionella and *Chaetoceros* at Cochin,
Asterionella and *Chaetoceros* at Ponnani,
Asterionella and *Chaetoceros* at Calicut,
Rhizosolenia and *Chaetoceros* at Cannanore,
Chaetoceros and *Asterionella* at Kasaragod.

From the results it is clear that nutrients have a direct relationship with phytoplankton abundance. This is in contrary to the opinion of Devassy and Goes (1989) which states that nutrients act as a limiting factor for phytoplankton growth. Among the 29 genera identified 23 genera belong to Bacillariophyceae, 4 belong to Dinophyceae, each genus of Cyanophyceae and Chlorophyceae were identified. Paravur, Kozhikode and Kasaragod showed relatively high plankton density(Table.2, 3 and fig.3)., which might be due to high nutrient concentration, prevailed in the water column. Bhatt *et al.* (1999) also reported that nutrients favored the growth of phytoplankton. Veli recorded the lowest phytoplankton population. This decline in density as well as diversity might be due the effect of TTP effluents. This statement is an agreement with the observation by Bijumon *et al.,* (2000) and Ouseph *et al.,*(2001).

CONCLUSIONS

Comparatively lower productivity, pigment concentration and phytoplankton standing crop were observed along the Kerala coast during the present study. The results clearly indicate that the plankton characteristics directly in tune with nutrient concentration. Among the nine stations investigated Paravur, Kochi and Calicut reported slightly higher nutrient concentration. From the result it is obvious that waste from industry, urban and fish processing centres reached the coastal region could have increased the nitrogenous nutrients, especially in estuarine area. Both nitrate nitrogen and inorganic phosphate showed slightly higher values at bottom compared to surface unlike the distribution of silicate. Biological nature of Veli transect is found drastically affected by the TTP effluents in terms of low standing crop of phytoplankton and diversity. Bacillariophyceae was found to be the dominant class followed by Dinophyceae and Cyanophyceae. The maximum phytoplankton diversity was observed at Kasaragod. *Asterionella*, *Ceratium*, *Chaetoceros*, *Coscinodiscus* and *Rhizosolenia* were the major genera identified. The present study provides baseline information on productivity, pigment concentration and community structure of phytoplankton, which could be useful for any future ecological assessment of the marine environment of Kerala.

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