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Seasonal variation of phytoplankton and productivity in the surf zone and backwater at Cochin

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Abstract

Seasonal variation of phytoplankton abundance and productivity were studied in the surf zone of the sea at Cochin and the Cochin backwater with reference to cell counts, chlorophyll *a* and photosynthesis in relation to hydrographic parameters for a period of two years (January 2001 to December 2002). Phytoplankton density and diversity indicated a decline as compared to the earlier studies. In the surf zone, diatoms contributed about 99% of phytoplankton cells. Seasonal cycles observed in the current and earlier studies indicated that there is no regular seasonal trend in the distribution and abundance of phytoplankton in the nearshore waters. The cell counts and productivity values showed wide fluctuation within the seasons and from season to season. In the surf zone, chlorophyll *a* content and photosynthetic productivity recorded higher values during southwest monsoon season and in the backwater during postmonsoon period. The study revealed that the surf zone was relatively more productive in terms of cell density and species diversity as compared to the Cochin backwater. Factors influencing fluctuation and abundance of phytoplankton in the nearshore waters are briefly discussed.

Introduction

Phytoplankton forms the prime component in the trophic cycle of marine and estuarine ecosystems and are influenced by the environmental factors. In recent years, rapid urbanization, industrial developments and fluctuation in the monsoons have affected the physico-chemical and biological characteristics of the coastal waters and the coastal fisheries and associated flora and fauna have suffered the effects of such environmental changes.

Perusal of literature reveals that extensive works carried out on the qualitative and quantitative aspects of phytoplankton and primary productivity in the coastal waters off Cochin and the Cochin Backwater system of the southwest coast of India are mostly confined to the sixties and seventies. As a result, very little information is available on these aspects for the last fifteen to twenty years from the nearshore waters of Cochin and the Cochin backwater. Further, earlier studies have proved that none of the parameters such as cell volume, cell numbers or chlorophyll values can independently give a true picture of the standing crop because of the inherent drawbacks present in each method

(Gopinathan *et al.*, 1974). Considering these in view, this paper deals with the seasonal variation, relative abundance and productivity of phytoplankton in terms of cell number, chlorophyll *a* and photosynthesis in the intertidal surf zone of the sea at Cochin and the Cochin backwater based on monthly data collected for two years from January 2001 to December 2002.

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Material and methods

Water samples for phytoplankton, chlorophyll *a* content, primary productivity and hydrographic parameters were collected from the surface during high tide in the forenoon (0900-1100 hrs) at monthly intervals for a period of two years (2001 and 2002) from three fixed stations in the intertidal surf zone of the sea at Cochin namely Fort Cochin (B.M.), Manaserry and Kannamaly where the depth ranged from 75 cm to 1 metre; and one station in the Cochin backwater at Thevara.

For cell counts, one litre water sample collected from the surface was fixed with 4% Formaldehyde solution and allowed to settle in a plastic container for 24 to 48 hrs. After settling, the water was drained out slowly and the settled material was diluted to 100 ml and a sample of 1 ml of the mixture was drawn and placed in Sedgewick-Rafter counting cell and the phytoplankton cells were identified (upto genus level) and counted and the phytoplankton crop was estimated per litre. For the determination of chlorophyll *a* content, 500 ml of water sample was filtered using Whatman GF/C filter paper and the filtrate dissolved in 90% Acetone and measured the O.D. in a Spectrophotometer and chlorophyll *a* values were determined (Strickland and Parsons, 1972). Rate of photosynthetic production was estimated by the standard procedure of L and D bottle oxygen technique under simulated *in situ* conditions. Incubation time given was two hours and thirty minutes in all the experiments. Due to bacterial interference in the nearshore water samples, 80% of G.P.P. was considered as N.P.P. for uniformity (Selvaraj, 2000; 2002). Determination of salinity, dissolved oxygen, phosphate-P, nitrite-N and nitrate-N in water samples were made according to Strickland and Parsons (1972). Monthly data thus collected from the surf stations and Cochin backwater were treated separately for monthly average from which seasonal averages were calculated for premonsoon (February-May), southwest monsoon (June-September) and postmonsoon (October-January) seasons of the year.

Results and discussion

Phytoplankton density varied from 12,000 to 322,000 cells/l in the surf-zone

and 7,000-235,000 cells/l in the Cochin backwater. In the earlier report by Gopinathan *et al.* (1974), the cell counts obtained from one litre water samples varied from 90,600 to 606,400 cells/l in the Cochin backwater during 1972-73. In the present study, composition of the phytoplankton (10-100 μm) in the samples comprised of 58 genera (with some genera having more than one species). Gowda *et al.* (2001) recorded 58 species of phytoplankters in the Nethravathi estuary during 1993-94 and the cells varied between 1,132 and 65,514 cells/m^3 which indicated that Cochin backwater is better than Nethravathi estuary with wider species diversity. However, Gopinathan (1972) has recorded about 120 species of phytoplankton in the Cochin backwater during 1970-'72 of which 88 species were diatoms. In the present study, qualitative analysis of phytoplankton was confined to genus level only and 99% of total phytoplankton cells were diatoms. The results indicated that the phytoplankton density and species diversity have been reduced considerably in the intertidal waters of Cochin in recent years due to changes in the climatic condition and water quality of the coastal zone.

Monthly variations of twenty common genera of phytoplankton in the surf zone of the sea at Cochin are presented in Table 1 and that of the Cochin backwater are presented in Table 2 and their seasonwise relative abundance is given in Table 3. Among the 58 genera recorded, species of 13 genera occurred in the surf zone and 7 genera in the Cochin backwater almost throughout the year. In the surf zone, the diatoms which occurred almost throughout the year were species of *Thalassionema, Coscinodiscus, Pleurosigma, Skeletonema, Thalassiosira, Nitzschia, Asterionella, Thalassiothrix, Melosira, Navicula, Biddulphia, Fragilaria* and *Pinnularia* in the order of abundance (Table 1). In the Cochin backwater, species of *Skeletonema, Pleurosigma, Coscinodiscus, Thalassiosira, Melosira, Thalassionema* and *Fragilaria* showed their occurrence almost throughout the year representing the three seasons (Table 2). In the surf zone, species of *Coscinodiscus, Asterionella, Nitzschia, Biddulphia and Pinnularia* showed their abundance during premonsoon months; *Pleurosigma* and *Leptocylindrus* during southwest monsoon months; and species of *Synedra, Thalassionema, Thalassiosira, Thalassiothrix, Navicula* and *Chaetoceros* indicated their abundance during postmonsoon period (Table 3). Among the dinoflagellates, species of *Ceratium* showed their abundance in the surf zone during February and July; *Peridinium* in April and *Gymnodinium* in September.

Stationwise contribution of phytoplankton (Table 4) indicated higher percentage at Kannamaly during premonsoon season in the surf zone indicating a stable environment with good water quality at Kannamaly during premonsoon months. During monsoon and postmonsoon seasons, Cochin harbour mouth station at Fort Cochin showed relatively lower percentage of phytoplankters which could be due to the death and disintegration of cells resulting from admixture of high saline

Table 1. *Monthly mean values of common phytoplankters (cell number/litre) in the surf zone at Cochin showing their fluctuation and abundance*

Genus 2001	Jan.	Feb	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
Diatoms												
Asterionella	1670	170	-	1000	26670	1670	830	250	1170	3830	1830	1500
Biddulphia	5000	670	3830	1000	4670	330	1000	500	830	1000	500	1500
Chaetoceros	15000	-	-	-	-	670	-	-	500	330	-	-
Coscinodiscus	5330	9170	8830	8000	9330	3330	4670	6000	8330	9670	3170	4670
Fragilaria	-	1330	1500	1000	3330	2000	2500	750	3170	1830	500	170
Leptocylindrus	-	-	-	-	-	10340	-	1250	-	3000	-	-
Melosira	5670	3670	3830	2000	3330	-	1000	1000	330	6000	830	2170
Navicula	13000	830	170	3000	1000	-	170	750	3330	3170	1670	670
Nitzschia	7670	2000	2170	16000	2670	2330	1330	1000	7170	3830	1500	830
Pinnularia	-	-	170	8000	2330	1330	670	250	1000	-	500	170
Pleurosigma	9330	2170	4170	5000	3670	2330	16170	10250	9830	3500	1330	1500
Rhizosolenia	5670	-	330	1000	-	1000	1170	-	-	170	-	170
Skeletonema	14330	4670	4670	10000	670	330	6000	4250	3170	5830	2670	330
Synedra	-	-	-	-	-	-	-	-	-	26340	18500	-
Thalassionema	-	1830	6500	5000	11330	12670	6170	2500	5670	31000	8170	1830
Thalassiosira	3000	5500	2330	1000	4670	7330	2330	1250	1500	4170	1330	17500
Thalassiothrix	16330	1170	330	-	330	-	1500	250	1000	10670	670	500
Dinoflagellates												
Ceratium	-	2170	670	-	-	-	2830	-	-	330	-	330
Gymnodinium	-	-	-	-	-	-	-	-	6330	-	-	-
Peridinium	-	-	330	2000	670	670	330	-	-	-	170	170
Others	1330	4320	3500	6000	5660	7330	6170	3500	13830	4330	2670	2170
Total (nos./l)	**103330**	**39670**	**43330**	**70000**	**80330**	**53660**	**54830**	**33750**	**67160**	**119000**	**46000**	**36180**

Table 2. *Monthly mean values of common phytoplankters (cell number/litre) in the Cochin backwater showing their fluctuation and abundance*

Genus 2002	Jan.	Feb	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
Diatoms												
Asterionella	-	-	-	-	-	-	500	2000	500	-	500	-
Biddulphia	4000	-	-	-	-	-	-	1000	1000	500	-	2000
Chaetoceros	8000	-	-	-	-	-	-	-	500	-	-	-
Coscinodiscus	-	6000	4000	4000	2000	2000	4500	43000	3000	4000	8500	11500
Fragilaria	-	1500	3000	1800	1000	-	500	-	1500	1000	500	-
Leptocylindrus	-	-	-	-	-	4000	-	-	500	1000	-	-
Melosira	-	1500	500	2000	4000	-	2000	15000	500	1500	1000	2500
Navicula	4000	-	-	330	1000	-	-	-	500	-	1000	-
Nitzschia	-	500	500	1000	2000	1000	12500	10000	5000	-	-	-
Pinnularia	-	-	-	670	2000	-	1000	-	500	500	-	-
Pleurosigma	4000	1500	2000	2180	3000	-	2500	85000	4000	1000	1500	4500
Rhizosolenia	3000	-	-	-	-	-	-	-	-	-	-	1000
Skeletonema	9000	-	3000	1330	1000	-	9500	56000	-	6000	42000	-
Synedra	-	-	-	-	-	-	-	-	-	2000	-	-
Thalassionema	-	2000	500	830	-	-	500	5000	3500	1500	5000	7000
Thalassiosira	-	-	-	330	1000	4000	500	16000	5500	1000	3500	57000
Thalassiothrix	3000	-	-	330	1000	-	-	1000	500	-	-	-
Dinoflagellates												
Ceratium	-	-	-	-	-	-	-	-	1000	-	-	1000
Gymnodinium	-	-	-	-	-	-	-	-	-	-	500	
Others	-	4000	1000	2000	1000	1000	2500	1000	16000	2500	4500	1000
Total (nos./l)	35000	17000	14500	16800	19000	12000	36500	235000	44000	22500	68500	87500

Table 3. *Season-wise relative abundance of common phytoplankters in the samples of the surf zone and backwater at Cochin and their contribution in photosynthesis (%) (2001-2002)*

	PRM		SWM		PSM	
	Surf	**B.W.**	**Surf**	**B.W.**	**Surf**	**B.W.**
Diatoms						
Asterionella	11.93	-	1.87	0.92	2.90	0.22
Biddulphia	4.35	-	1.28	0.61	2.63	3.05
Chaetoceros	-	-	0.55	0.16	5.03	3.75
Coscinodiscus	15.14	23.77	10.66	16.02	7.50	11.24
Fragilaria	3.07	10.87	4.03	0.61	0.81	0.71
Leptocylindrus	-	-	5.54	1.37	1.00	0.47
Melosira	5.50	11.89	1.11	5.34	4.82	2.34
Navicula	2.14	1.96	2.03	0.16	6.08	2.34
Nitzschia	9.79	5.94	5.65	8.70	4.54	-
Pinnularia	4.49	3.98	1.55	0.45	0.22	0.24
Pleurosigma	6.43	12.95	18.42	27.95	5.15	5.15
Rhizosolenia	0.57	-	1.03	-	1.97	1.87
Skeletonema	8.57	7.90	6.57	20.00	7.61	26.70
Synedra	-	-	-	-	14.72	0.94
Thalassionema	10.58	4.93	12.90	2.75	13.46	6.31
Thalassiosira	5.79	1.96	5.92	7.94	8.54	28.82
Thalassiothrix	0.79	1.96	1.32	0.45	9.25	1.41
Dinoflagellates						
Ceratium	1.22	-	1.36	0.30	0.22	0.47
Gymnodinium	-	-	3.02	-	-	0.22
Peridinium	1.28	-	0.48	-	0.11	-
Others	8.36	11.89	14.71	6.27	3.44	3.75
Total (nos./l)	**58340**	**16830**	**52340**	**81870**	**76130**	**53370**

PRM = Premonsoon, SWM = Southwest monsoon and PSM = Postmonsoon

and low saline waters by the influence of high and low tides and flood flow. The relatively higher percentage of cells recorded at Manaserry station during monsoon and postmonsoon periods was due to frequent blooming of *Pleurosigma* sp. and *Nitzschia* sp. during southwest monsoon months and *Thalassionema* and *Thalassiosira* during postmonsoon months at this station.

Monthly distribution of water tempera-

Table 4. *Stationwise contribution of phytoplankton crop(%) at Cochin*

Station	PRM	MON	PSM	AM
Kannamaly (surf) sea	36.7	25.5	27.0	29.7
Manassery (surf) sea	31.1	34.8	33.1	33.0
Fort Cochin (surf) B.M.	22.6	10.5	19.1	17.4
Cochin backwater	9.6	29.2	20.8	19.9

PRM = Premonsoon, MON = Monsoon, PSM = Postmonsoon, AM = Annual mean

ture, salinity and dissolved oxygen indicated almost the same trend in the surf zone and Cochin backwater throughout the year with relatively higher values of temperature and lower values of salinity and dissolved oxygen recorded in the Cochin backwater (Fig. 1). Phosphate and nitrate concentrations were in general higher in the Cochin backwater. Nitrate values indicated a decline in the surf zone during postmonsoon months with increase in phytoplankton cell counts (Figs. 1 and 2).

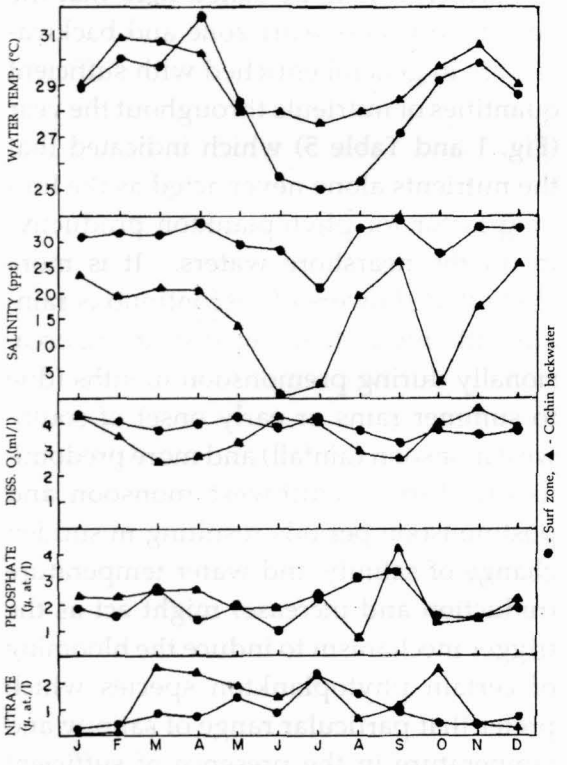

Fig. 1. *Monthly variations of hydrographic parameters in the surf zone at Cochin and the Cochin backwater (mean values of 2001 & 2002)*

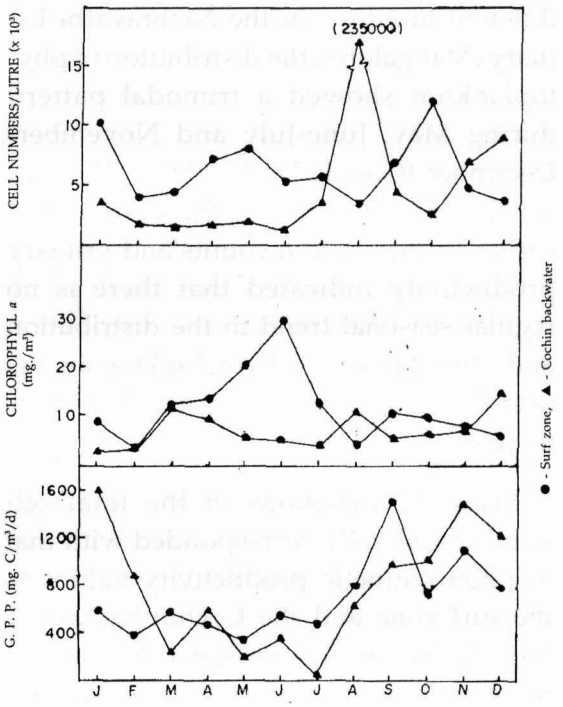

Fig. 2. *Monthly variations of phytoplankton cell counts, chlorophyll a content and photosynthetic productivity in the surf zone at Cochin and the Cochin backwater (mean values of 2001 & 2002)*

Monthly distribution of phytoplankton showed a trimodal pattern in the surf zone at Cochin (Fig. 2) with their peaks observed during October (119,000 cells/l); January (103,330 cells/l) and during April-May (70,000 to 80,330 cells/l). The Cochin backwater showed the primary peak during August (235,000 cells/l) and second-

ary peak during December (87,500 cells/l). The tertiary peak supposed to occur during March-May (premonsoon months) was not clear in the present study (Fig. 2). Qasim *et al.* (1974) and Sumitra *et al.* (1974) have also reported trimodal distribution pattern in the Cochin backwater but in different months. In the Nethravathi Estuary (Mangalore), the distribution of phytoplankton showed a trimodal pattern during May, June-July and November-December (Gowda *et al.*, 2001). The seasonal cycle observed in the current and earlier studies on cell counts and primary productivity indicated that there is no regular seasonal trend in the distribution and abundance of phytoplankton in the nearshore waters which varied from year to year.

Seasonal variations in the total cell number generally corresponded with that of photosynthetic productivity values in the surf zone and the Cochin backwater (Fig. 2). The results indicated higher values of cell counts during August-January due to occasional blooming of certain species of diatoms. The diatoms which indicated symptoms of blooming (by their abundance) during southwest monsoon period were *Pleurosigma* sp. (August) and *Nitzschia* sp. (September); and during postmonsoon period were *Synedra* sp. (October), *Thalassionema* sp. (October and November) and *Thalassiosira* sp. (December) in the intertidal waters of Cochin.

The results of the present study confirmed that the changes in salinity and water temperature (whether decrease or increase) associated with high nutrient concentration in the nearshore waters due to climatic changes and fluctuation in the rainfall occurring within the seasons and from season to season are chiefly responsible for the blooming and abundance of phytoplankton especially during monsoon and postmonsoon periods (Figs. 1 & 2). The influence of salinity on the phytoplankton abundance in the coastal waters has been discussed in detail by Qasim *et al.* (1972). According to Gopinathan (1972), in the nearshore waters where much dilution occurs, salinity, temperature and nutrients are the main factors controlling the abundance of phytoplankton.

Further, it is to be stated here that the nearshore waters (surf zone and backwater) are in general enriched with sufficient quantities of nutrients throughout the year (Fig. 1 and Table 5) which indicated that the nutrients alone never acted as the limiting factor for phytoplankton productivity in the nearshore waters. It is more likely that showers of discontinuous rainfall with intermittent gaps occurring occasionally during premonsoon months (due to summer rains or early onset of southwest monsoon rainfall) and more predominantly during southwest monsoon and postmonsoon periods resulting in sudden change of salinity and water temperature (reduction and increase) might act as the trigger mechanism to induce the blooming of certain phytoplankton species which prefer that particular range of salinity and temperature in the presence of sufficient nutrients in the coastal waters and backwater environment.

Table 5. *Seasonwise range and mean values of hydrographic parameters in the surf zone and backwater at Cochin during 2001-2002*

Parameters	PRM (Feb. - May)	MON (June - Sept.)	PSM (Oct. - Jan.)
		SURF ZONE	
Water Temp. (°C)	28.3 - 31.6 (29.9)	24.9 - 28.3 (25.7)	28.7 - 29.9 (29.1)
Salinity (ppt)	29.1 - 33.9 (31.5)	18.8 - 34.1 (28.9)	26.1 - 33.7 (30.8)
Diss. Oxygen (ml/l)	3.66 - 4.46 (4.00)	3.00 - 4.34 (3.73)	3.05 - 4.42 (3.83)
PO_4 - P (μgat/l)	1.11 - 3.18 (1.91)	1.01 - 4.00 (2.36)	1.07 - 2.21 (1.66)
NO_2 - N (μgat/l)	0.84 - 2.11 (1.22)	0.03 - 1.64 (0.63)	0.28-0.85 (0.53)
NO_3 - N (μgat/l)	0.32 - 1.37 (0.77)	0.50 - 4.01 (1.34)	0.16 - 1.13 (0.35)
		COCHIN BACKWATER	
Water Temp. (°C)	28.0 - 31.5 (29.9)	26.5 - 29.2 (28.0)	29.0 - 30.7 (29.6)
Salinity (ppt)	13.8 - 21.7 (18.6)	0.4 - 21.7 (12.1)	1.1 - 27.3 (17.3)
Diss. Oxygen (ml/l)	2.23 - 4.78 (3.00)	2.19 - 4.21 (3.05)	3.29 - 4.93 (4.14)
PO_4 - P (μgat/l)	1.21 - 4.01 (2.36)	0.96 - 4.66 (2.31)	1.07 - 2.74 (1.84)
NO_2 - N (μgat/l)	0.68 - 8.90 (4.54)	0.26 - 0.70 (0.32)	0.04 - 0.68 (0.45)
NO_3 - N (μgat/l)	0.0 - 4.73 (1.68)	0.53 - 3.87 (1.33)	0.0 - 2.97 (0.75)

PRM = Premonsoon, MON = Monsoon, PSM = Postmonsoon

Chlorophyll *a* values did not show any remarkable relationship corresponding to the variations in the cell counts and primary productivity. This could be to some extent, due to the variations in the chlorophyll content of the different species constituting the total phytoplankton biomass. The unusual hike in the chlorophyll *a* values observed during May-June, which was not proportionately reflected in the primary productivity values (Fig. 2) indicated that its origin could be mostly from detritus and partly from the recently dead cells (in suspension) resulting from sudden changes in the hydrographic features and the churning process caused by strong wave action in the surf zone which occur during May-June months consequent to

the onset of southwest monsoon. Turbidity caused by these factors could be another reason for low productivity.

Seasonal mean values of cell counts, chlorophyll *a* and primary productivity for the surf zone and the Cochin backwater during 2001 and 2002 are given in Table 6. In the surf zone, chlorophyll *a* content and photosynthetic productivity indicated higher mean values during southwest monsoon period and in the backwater during postmonsoon season. In general, the phytoplankton productivity fluctuated much in the surf zone and backwater within the seasons and from season to season. The fluctuation was largely because of relative predominance of one or more species which formed dense concentrations and at times blooms.

Table 6. *Seasonal variations of phytoplankton with reference to cell number, chlorophyll and photosynthesis in the surf zone and backwater at Cochin during 2001-2002*

Phytoplankton	PRM	MON	PSM	AM
Surf zone at Cochin				
Cell number (nos./l)	58340	52340	76130	62270
Chlorophyll *a* (mg/m^3)	10.36	15.64	8.35	11.03
G.P.P. (mgC/m^3/d)	0.504	0.931	0.837	0.757
N.P.P. (mg C/m^3/d)	0.403	0.745	0.670	0.606
Cochin backwater				
Cell number (nos./l)	16830	81870	53370	50690
Chlorophyll *a* (mg/m^3)	6.14	4.93	8.85	6.64
G.P.P. (mgC/m^3/d)	0.446	0.498	1.316	0.753
N.P.P. (mgC/m^3/d)	0.357	0.398	1.053	0.603

PRM = Premonsoon, MON = Monsoon,
PSM = Postmonsoon, AM = Annual mean

The primary productivity was found to vary from station to station in the surf zone. The primary productivity experiments conducted in the surf zone at these three stations during 1996-99 (Selvaraj, 2000) indicated relatively higher mean values at Fort Cochin during premonsoon (1.029 g C/m^3/d), Manaserry during monsoon (0.946 g C/m^3/d) and at Kannamaly during postmonsoon season (0.625 g C/m^3/d); and the seasonwise mean values (average of 3 stations) indicated higher productivity in the postmonsoon period (1996-99). The present study indicated that the surf zone was relatively more productive than the Cochin backwater in terms of cell number, chlorophyll content and species diversity.

A similar study undertaken in the surf-zone of the Moplah Bay at Cannanore (north Kerala) during 1991-92 (Selvaraj and Molly Varghese, 1999) showed the average primary productivity (G.P.P.) values of 0.763, 0.559 and 0.716 g C/m^3/d during premonsoon, monsoon and postmonsoon months respectively while the mean G.P.P. values of the surf zone at Cochin in the present study were 0.504, 0.931 and 0.837 g C/m^3/d respectively. Net primary production contributed 80% of G.P.P. Annual mean values of the surf zones at Moplah Bay and Cochin were 0.679 and 0.757 g C/m^3/d respectively which also indicated that

the surf zone of the sea at Cochin was relatively productive along the southwest coast of India.

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