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Phytoplankton Composition and Community Structure of Ariyankuppam Estuary and Verampattinam Coast of Pondicherry

G. Ananthan, P. Sampathkumar, P. Soundarapandian and L. Kannan
Center of Advanced Study in Marine Biology,
Annamalai University, Parangipettai-608 502, India

Abstract: Totally 156 species of marine phytoplankton were identified of which Diatoms formed the dominant group followed by Dinoflagellates, Blue Green and Greens. Phytoplankton population density and species diversity were high during the summer season and were invariably sparse during the monsoon season at both the stations. Species richness and evenness of phytoplankton showed an inverse relationship with the dominance index. Distribution of chlorophyll a concentration closely followed the phytoplankton population density and gross primary productivity. Species composition, population density, primary productivity and chlorophyll a concentration was more in the coast due to higher number of autochthonous coastal marine species in addition to allochthonous species from the estuary.

Key words: Dinoflagellates, species richness, dominance index, diatoms

INTRODUCTION

Phytoplankton are primary producers in the marine environment. The secondary (zooplankton) and tertiary (shellfish, finfish and others) producers depend on phytoplankton directly or indirectly for food. Phytoplankton species undergo changes in their distribution due to change in the physical, chemical and biological factors. Moreover, phytoplankton population determines productivity of the estuarine and marine ecosystems (Supate and Bhosale, 1989). In present study species composition, population density and community structure, chlorophyll a content and phytoplankton productivity in the Ariyankuppam estuary and Verampattinam coast of Pondicherry is presented.

MATERIALS AND METHODS

Study Area

Ariyankuppam Estuary (Station 1)

It is located 4 km south of Pondicherry harbour (Lat. 11°54'N; Long. 79°50'E) in the southeast coast of India (Fig. 1). The Pondicherry coastal area is polluted due to the discharge of industrial, domestic and agricultural wastes through small tributaries and channels into the Bay of Bengal.

Verampattinam (Station 2)

The Verampattinam coast is located 4 km south of Pondicherry harbour (Lat. 11°54'N; Long.79°50'E), south east coast of India (Fig. 1). It is main fish landing center of Pondicherry and is busy with fishing activities using mechanized and non-mechanized boats. Several textile and paper mills, distilleries and chemical factories drain their effluents directly into the coastal waters.

Corresponding Author: G. Ananthan, Center of Advanced Study in Marine Biology, Annamalai University, Parangipettai-608 502, India

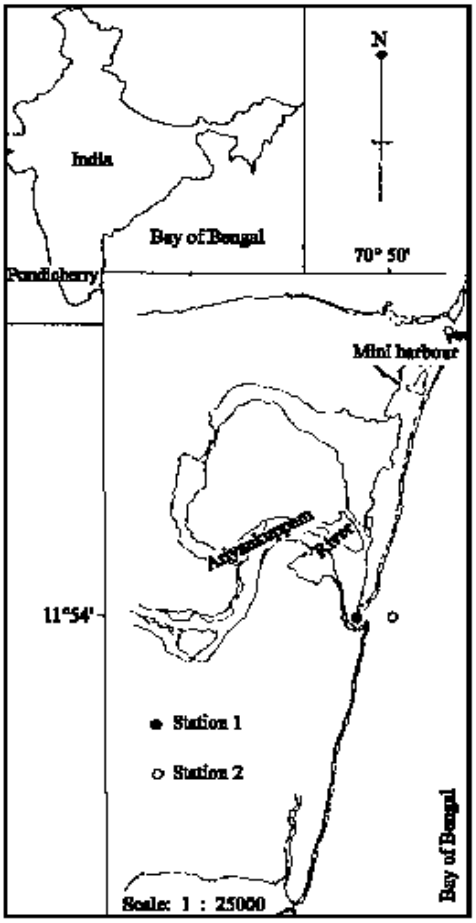

Fig. 1: The study area

Phytoplankton samples were collected at monthly intervals from the surface waters towing plankton net (mouth diameter 0.35 m) made of bolting silk (No 30, mesh size 48 μm) for half an hour. These samples were preserved in 4% neutralized formalin and used for qualitative analysis. For the quantitative analysis of phytoplankton, the settling method described by Sukhanova (1978) was adopted. Numerical plankton analysis was carried out using Utermohl's inverted plankton microscope. Phytoplankton was identified following Venkataraman (1939), Cupp (1943), Subrahmanyan (1946), Prescott (1954), Desikachary (1959 and 1987), Hendey (1964), Steidinger and Williams (1970), Taylor (1976) and Anandan *et al*. (1986).

Species diversity index (H) was calculated using the Shannon and Weaver (1949) formula. Species richness (SR) was calculated as described by Gleason (1922). Evenness index (J') was calculated using the formula of Pielou (1966). Dominance index (δ) was calculated using the formula of Mc Naughton (1967). Chlorophyll a in phytoplankton was estimated using the standard method described by Strickland and Parson (1972). Primary productivity was estimated by adopting the light and dark bottle technique (1972) and the productivity was expressed as g cm^{-3} h^{-1}. The study was carried out from January 2000 to December 2001.

Based on the northeast monsoon which is normally prevalent during October to December at Pondicherry, four main seasons have been categorized in a calendar year viz., post monsoon (January-March), summer (April-June), pre monsoon (July-September) and monsoon (October-December).

To know the difference in phytoplankton distribution between stations 1 and 2 analysis of variance (ANOVA) was applied.

RESULTS

Monthly variations in phytoplankton species composition, species diversity, richness, evenness, dominance, chlorophyll a concentration and primary productivity were recorded for a period of two years from January 2000 to December 2001 at station 1 and 2.

Species Composition

A total of 156 species of phytoplankton were identified during the present study period from both the stations (Table 1). Of the 156 species recorded, 113 species belong to diatoms (Bacillariophyceae), 20 species to dinoflagellates (Dinophyceae), 12 species to blue-greens (Cyanophyceae), 11 species to greens (Chlorophyceae). The difference in phytoplankton distribution between both the stations was statistically analyzed and presented in Table 2.

At station 1, 87 species of diatoms, 13 species of dinoflagelates, 11 species in each of blue-greens and greens constituting a total of 122 species were recorded. At station 2, 111 species of diatoms, 19 species of dinoflagellates, 5 species of blue-greens, 8 species of greens constituting a total of 144 species were recorded. Phytoplankton species numbering 34 (27 species of diatoms and 7 species of dinoflagellates) were restricted to station 1 whereas 14 species (3 species of diatoms, 1 species of dinoflagellates, 6 species of blue-greens, 3 species of greens) were restricted to station 2. Species numbering 109 (84 species of diatoms, 12 species of dinoflagellates, 5 species of blue-greens, 8 species of green) were found at both the stations. Percentage contribution of each group of phytoplankton was thus in the decreasing order as follows. Diatoms>dinoflagellates > Blue-greens. Station 2 recorded more percentage of diatoms and dinoflagellates than station 1.

Percentage Composition

At station 1, percentage composition of diatoms ranged between 60.75 and 82%. Minimum (60.75%) was recorded during the monsoon season (2000) and the maximum (82.98%) during the premonsoon season (2000). Percentage composition of dinoflagellates ranged from 6.98 to 16.34%. Minimum (6.98%) was recorded during the monsoon season (2001) and the maximum (16.34%) during the summer season (2001). Percentage composition of blue-greens ranged between 6.29 and 13.35%. Minimum (6.29%) was recorded during the premonsoon season (2000) and the maximum (13.35%), during the monsoon season (2000). Percentage composition of greens ranged between 1.33 and 18.72%. Minimum percentage 1.33% was recorded during the summer season (2000) and the maximum (18.72%), during the monsoon season (2001).

At station 2, percentage composition of diatoms ranged between 65.29 and 89.70%. Minimum (65.29%) was recorded during the monsoon season (2001) and the maximum (98.70%), during the summer season (2000). Percentage composition of dinoflagellates ranged between 6.31 and 19.23%. Minimum (6.31%), was recorded during the summer season (2000) and the maximum (19.23%) during the premonsoon season (2001). Percentage composition of blue-greens ranged between 3.63 and 13.25%. Minimum (3.63%) was recorded during the postmonsoon (2000) and the maximum (13.25%) during the monsoon season (2001). Percentage composition of greens ranged between 0 and 9.96%. No greens were observed during the summer (2000 and 2001) and premonsoon (2000) seasons and the maximum (9.96%) was recorded during the monsoon season (2001).

Phytoplankton Population Density

At station 1, Phytoplankton population density varied form 12,000 to 76,200 cells L^{-1}. Minimum (12,000 cells L^{-1}) was recorded during the monsoon in November 2000 and the maximum

Table 1: Checklist of phytoplankton species recorded from January 2000 to December 2001 at stations 1 and 2

Name of the species	Station 1	Station 2
Bacillariophyceae (Diatoms)	+	+
Achnanthes brevipes Ag.	+	+
A. longipes Ag.	+	+
Amphiprora sp.	+	+
Amphora coffeaeformis (Ag.) Kutz	+	-
A. holsatica Hust.	-	+
A. ostrearia Breb	+	+
A. ovalis (Kutz.) Kutz.	-	+
A. proteus Greg.	-	+
Asterionella glacialis Castr. = (*A.japonica* Cl. and Moller)		
Bacillaria paradoxa Gmel. = *B. paxillifer* (Muller)	+	+
Bacteriastrum comosum Pavill	+	+
B. delicatulum Cl.	+	-
B. hyalinum Lauder	+	-
Bellerochea malleus (Btw.) V.H	+	+
Biddulphia heteroceros Grun.	+	+
B. mobiliensis (Bail.) Grun.	+	+
Cerataulina bergonii (Perag.H.) Schutt	+	+
Chaetoceros affinis Lauder	+	+
C. compressus Lauder	-	+
C. curvisetus Cl.	-	+
C. diversus Cl.	+	+
C. messanensis Castr.	-	+
C. orientalis Schiller	-	+
Corethron hystrix Hensen	+	+
Coscinodiscus centralis Ehr.	+	+
C. curvatulus Grun.	+	+
C. gigas Ehr.	+	+
C. lineatus Ehr.	+	+
C. marginatus Jan. = *C. janischii* A.S.	+	+
C. radiatus Ehr.	-	+
C. sublineatus (Grun.) V.H.	+	+
Cyclotella meneghiniana Kutz.	+	+
C. stelligera (Cl. and Grun.) V.H	+	+
Cymbella cistula (Hemp.) Kirchner	+	+
C. turgida Greb. non Hass.	+	+
Diploneis interrupta (Kutz) Cl.	+	+
D. robustus Subrahm. Non (Cl.) Euler.	-	+
D. smithii (Breb.) Cl.	+	+
Ditylum brightwellii (West) Grun.	+	+
D. sol (Grun.) De Toni	-	+
Eucampia cornuta (Cl.) Grun.	+	+
Fragilaria intermedia (Grun.) Grun.	+	+
F. oceanica Cl. = *F. arctica* Grun.	+	+
Guinardia flaccida (Castr.) Perag. H.	-	+
Gyrosigma acuminatum (Kutz.) Rabenh.	+	+
G. balticum (Ehr.) Rabenh.	+	+
Hemidiscus hardmannianus (Grev.) Mann.	+	+
Lauderia annulata (Grev.) Cl.	+	+
Leptocylindrus danicus Cl.	+	+
L. minimus Gran	+	+
Lithodesmium undulatum Ehr.	+	+
Mastogloia minuta Grev.	-	+
Melosira sulcata (Ehr.) Kutz	+	+
Melosira sp.	-	+
Navicula capitata (Ehr.) Rabenh.	+	+
N. clavata Greg.	+	+
N. gastrum (Ehr.) Kutz	-	+
N. gracilis Ehr. = *Pinnularia gracilis* (Ehr.) Ehr.	+	+
N. granulata Berb. Non Ehr.	+	+
N. hasta Pant	-	+
N. indica Ehr.	+	+

Table 1: Continued

Name of the species	Station 1	Station 2
N. longa (Greg.) Ralfs	+	+
N. lyra Ehr.	+	+
Nitzschia acicularis (Kutz.) W.Sm.	+	+
N. closterium (Ehr.) Sm.	+	+
N. filiformis (W. Sm.) Schutt	+	+
N. longissima (Breb.) Ralfs	+	+
N. obtuse W. Sm.	-	+
N. paradoxa (Gmelin) Grun.	-	+
N. scalpelliformis Grun.	-	+
N. seriata Cl.	+	+
N. sigmoidea (Nitz.) W.Sm.	-	+
O. sinensis (Grev.) Grun.	+	+
Pinnularia ambigua Cl.	+	+
Planktoniella sol (Wallich) Shutt.	+	+
Pleurosigma aestuarii Berb. W.Sm.	+	+
P. angulatum (Kuetz.) W.Sm.	+	+
P. balticum (Ehr.) W.Sm.	+	+
P. carinatum Donk.	+	+
P. elongatum W.Sm.	+	+
P. normanii Ralfs	+	+
Podosira montagnei Kutz.	-	+
Rhaphoneis discoides Subrahm. R.	+	+
Rhabdonema mirificum W.Sm.	-	+
Rhizosolenia alata Btw.	+	+
R. castracanei Peraq. H.	+	+
R. cylindrus Cleve	+	+
R. hebetata Bail.	-	+
R. imbricata Btw.	+	+
R. robusta Norman	+	+
R. setigera Btw.	-	+
R. styliformis Btw.	+	+
Schroederella delicatula (Perag.) Pavill.	-	+
Skeletonema costatum (Grev.) Cl.	+	+
Skeletonema sp.	-	+
Stephanopyxis palmeriana (Grev.) Grun.	+	+
Streptotheca indica Karsten	+	+
Surirella elegans Ehr.	+	+
S. ovalis Breb.	+	+
Synedra formosa Hant.	+	+
S. ulna (Kutz.) Ehr.	+	+
Tabellaria fenestrata (Lyng.) Roth	+	+
Thalassionema nitzschioides Grun.	+	+
Thalassiosira coramandeliana Subhm. R.	-	+
T. eccentrica (Ehr.)	+	+
T. margaritae (Freng.) Kosl.	+	+
T. subtilis (Ostenf.) Gran.	+	+
Thalassiothrix frauenfeldii Grun. Non Cl.	+	+
T. longissima Cl. Grun.	+	+
Triceratium dubium Btw.	+	+
T. favus Ehr.	+	+
T. reticulum Ehr.	+	+
Tropidoneis vitrea (W.Sm.) Cl.	-	+
Dinophyceae (Dinoflagellates)		
Ceratium breve (Ost. Schm.) Sch.		
C. fusus (Ehr.)	+	+
C. furca (Ehr.)	+	+
C. extensum (Gourret) Cleve.	+	+
C. gibberum Gourret	-	+
C. trichoceros (Ehrenberg) Kofoid	-	+
C. tripos (O.F. Mull.) Nitzsch.	+	+
Dipnophysis caudata Saville-Kent	-	+
D. hastate Stein	+	+

Table 1: Continued

Name of the species	Station 1	Station 2
D. miles Stein	-	+
Gymnodinium breve Davis	+	+
Gymnodinium sp.	+	+
Noctiluca scintillans (Mac.) Ehr.	+	+
Prorocentrum micans Ehr.	+	+
Prorocentrum sp.	+	+
Protoperidinium conicum (Gran) Belech	+	+
P. divergens (Ehrenberg) Balech	+	+
P. elegans Cleve.	-	-
P. mediterraneum (Kofoid) Balech	-	+
P. oceanicum (Van.) Bale	+	
Cyanophyceae (Blue-Greens)		
Anabaena macrospora Kutz.	-	+
Anabaena sp.	+	-
Gloeocapsa sp.	+	+
Lyngbya martensiana Mene. Ex. Gomont	+	-
Merismopedia elegans Smith A.Br.	+	+
M. glauca (Ehr.)	+	+
Nostoc linkia Kutz.	+	-
Oscillatoira limosa Ag. Ex Gomont	+	-
O. chlorina Kutz. Ex Gomont	+	-
Oscillatoria sp.	+	+
Spirulina major Kutz.	+	-
Trichodesmium erythraeum Ehr.	+	+
Chlorophyceae (Greens)		
Actinastrum sp.	+	+
Chlorella sp.	+	+
Desmidium swartzii Kutz.	+	-
Pediastrum simplex (Meyer) Lemm.	+	+
P. dulex Meyer.	+	+
Pediastrum sp.	+	-
Protococcus vulgaris Lemm.	+	+
Scenedesmus acuminatus (Turp.) Kutz.	+	+
S. quadricauda (Trup.) Bre.	+	+
Spirogyra sp.	+	+
Tetrastrum sp.	+	+

Table 2: Analysis of variances (ANOVA) for the difference in Phytoplankton distribution between Stations 1 and 2

Parameters	Source of variation	df (n-1)	SS	MS = SS/df	F =MSB/MSW
Phytoplankton	Between	1	0.09626262	0.09626262	18.20371
population density	Within	46	0.101582537	0.083440298	
Species	Between	1	3.718567	3.718567	16.69437**
diversity	Within	46	10.24622	0.2227438	
Species	Between	1	8.250214	8.250214	18.58541**
richness	Within	46	20.41977	0.4439081	
Species	Between	1	-0.051907349	-0.051907349	0.38757901**
evenness	Within	46	0.1001816	-0.03217786	
Dominance	Between	1	-0.051907349	-0.051907349	8.6855244**
index	Within	46	3650.502	79.35875	
Chlorophyll a	Between	1	1.168753	1.168753	6.047068*
	Within	46	8.890694	0.1932759	
Gross	Between	1	1.074013	1.074013	9.303809**
Primary production	Within	46	5.310147	0.115438	

*: Significant at 5% level ($p<0.05$), **: Significant at 1% level ($p<0.01$)

(76,200 cells L^{-1}), during the summer season in May 2001. At station 2 it varied from 18,000 to 92,625 cells L^{-1}. Minimum (18,000 cells L^{-1}) was recorded during the monsoon season in December x2000 and the maximum (92,625 cells L^{-1}), during the summer season in May 2001. Phytoplankton

population density showed non-significant variation between two stations (Table 2). In general, summer season recorded more phytoplankton population density than other seasons at both the stations.

Species Diversity

At station 1, diversity index (H) varied form 3.11 to 5.02. Minimum (3.11) was recorded during the monsoon season in October 2001 and the maximum (5.02) during the summer season in May 2001. At station 2, it varied from 3.52 to 5.38. Minimum (3.52) was recorded during the monsoon season in December 2001 and the maximum (5.38), during the summer season in June 2000. Higher species diversity index obtained during the summer season coincided with higher density of phytoplankton population.

Species Richness

At station 1, species richness varied from 1.13 to 3.38. Minimum (1.13) was recorded during the monsoon season in October 2000 and the maximum (3.38), during the summer season in May 2001. At station 2, it varied from 1.55 to 3.91. Minimum (1.55) was recorded during the postmonsoon season in March 2001 and the maximum (3.91), during the same season but in January 2001. Species richness varied among seasons and stations.

Species Evenness

Station 1, species evenness index (J) varied from 0.82 to 0.99. Minimum (0.82) was recorded during the monsoon season in October 2001 and the maximum (0.99), during the same season but in October and November 2000. At station 2, it varied from 0.77 to 0.99. Minimum (0.77) was recorded during the monsoon season in December 2001 and the maximum (0.99), during the postmonsoon season in February 2000.

Dominance Index

At station 1, dominance index (δ) varied from 13.12 to 53.7. Minimum (13.12) was recorded during the summer season in May 2001 and the maximum (53.70) during the postmonsoon season in March 2001. At station 2, it varied from 8.99 to 30.91. Minimum (8.99) was recorded during the summer season in June 2000 and the maximum (30.91), during the postmonsoon season in March 2000. Dominance variation showed significant variation between stations and seasons (Table 2).

Phytoplankton chlorophyll a

At station 1, concentration of chlorophyll a varied from 0.02 to 0.91 mg m^{-3}. Minimum (0.02 mg m^{-3}) was recorded during the monsoon season in December 2000 and the maximum (0.91 mg m^{-3}), during the summer season in May 2001. At station 2, it varied from 0.04 to 2.13 mg m^{-3}. Minimum (0.04 mg m^{-3}) was recorded during the monsoon season in December 2000 and the maximum (2.13 mg m^{-3}), during the summer season in June 2001 (Fig. 2).

Gross Primary Productivity

At station 1, gross primary productivity varied from 0.25 to 1.25 g cm^{-3} h^{-1}. Minimum (0.25 g cm^{-3} h^{-1}) was recorded during the monsoon season in November and December 2000 and 2001 and the maximum (1.25 g cm^{-3} h^{-1}), during the summer season in May (2000 and 2001) and June 2000. At station 2. it varied from 0.50 to 1.51 g cm^{-3} h^{-1}. Minimum (0.50 g cm^{-3} h^{-1}) was recorded during the monsoon season in November (2000 and 2001) and December 2000 and the maximum (1.51 g cm^{-3} h^{-1}), during the summer season in May (2000 and 2001) and June 2000 (Fig. 3).

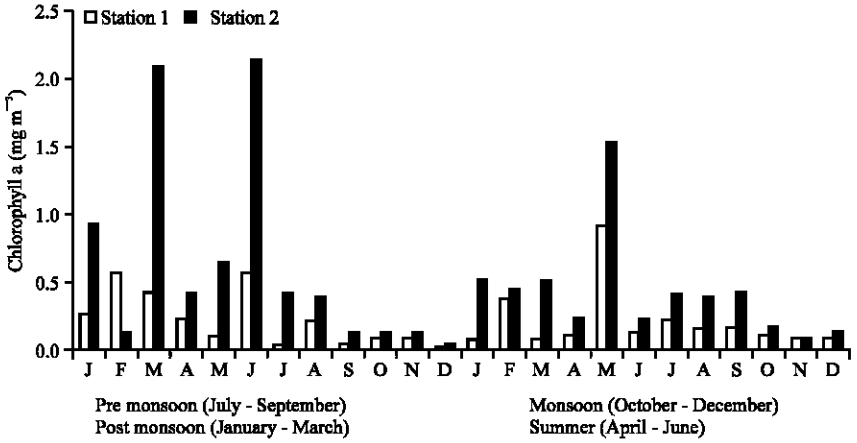

Fig. 2: Monthly variations in the chlorophyll a concentration from January 2000 to December 2001 at stations 1 and 2

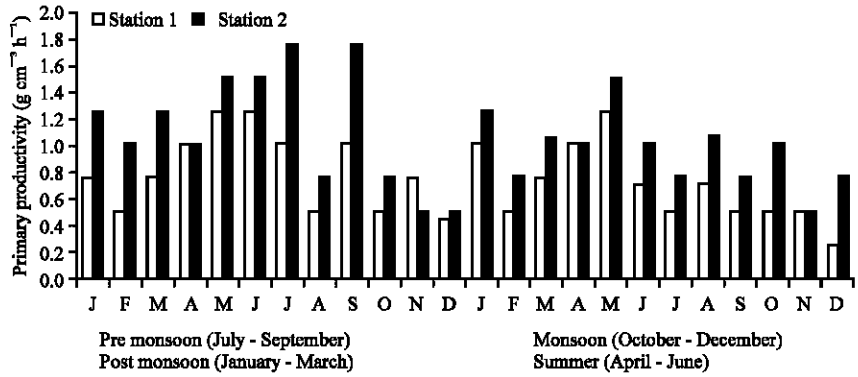

Fig. 3: Monthly variations in gross primary productivity recorded from January 2000 to December 2001 at stations 1 and 2

DISCUSSION

In the present study, diatoms formed the dominant group followed by Dinoflagellates and blue-greens at both the stations. Percentage contribution of each group of phytoplankton was thus in the decreasing order as follows. Diatoms>dinoflagellates > Blue-greens. Station 2 recorded more percentage of diatoms and dinoflagellates than station 1.

High phytoplankton population density and species diversity were observed during the summer season at both the stations. During this season, the phytoplankton was dominated by diatoms such as *Amphora coeffeaeformis*, *A. ovalis*, *Bellerochea malleus*, *Biddulphia heteroceros*, *B. mobiliensis*, *Chaetoceros affinis*, *C. diversus*, *Coscinodiscus centralis*, *C. lineatus*, *C. gigas*, *Cyclotella* sp., *Diploneis interrupta*, *Gyrosigma balticum*, *Melosira sulcata*, *Navicula capitata*, *N. clavata*, *N. gracilis*, *N. longa*, *Nitzschia closterium*, *N. longissima*, *Odentella sinensis*, *Pleurosigma angulatum*, *P. normanii*, *Rhizosolenia alata*, *R. styliformis*, *R. imbricata*, *Thalassionema nitzschioides*, *Thalassiosira eccentrica*, *Thalassiothrix frauenfeldii*, *Triceratium favus* and dinoflagellates such as *Ceratium favus*, *C. furca*, *C. trichoceros*, *Dinophysis caudate*, *Protoperidinium conicum* and *Prorocentrum* sp.

The phytoplankton population density was maximal (76,200 cells L^{-1} at station 1 and 92, 625 cells L^{-1} at station 2) during the summer season. The phytoplankton species were invariably sparse during the monsoon season. Minimum population density (12,000 cells L^{-1} at station 1 and 18,000 cells L^{-1} at station 2) was also recorded during this season. This was due to the combined effects of physico-chemical parameters such as heavy rainfall, increased turbidity and reduced salinity, temperature and pH and flushing of populations by monsoonal floods (Gouda and Panigraphy, 1989).

At both the stations, maximum species diversity (5.02 bits/ind. at station 1 and 5.38 bits/ind. at station 2) was observed during the summer season and the minimum diversity (3.11 bits/ind. at station 1 and 3.52 bits/ind. at station 2) was observed during the monsoon season. Several works (Akpan and Offem, 1993) pertaining to the phytoplankton species diversity carried out along the southeast coast where the present study area is also located, recorded lesser values due to the high value of population density and less species diversity than those of the present study where higher diversity was noticed though population density was low.

Species richness was maximal (3.38) during the summer season and minimal (1.13) during the monsoon season at station 1. At station 2, the maximal (3.91) and minimal (1.55) values were observed during the postmonsoon season. Low species richness recorded during the monsoon season and higher values recorded during the other seasons could be correlated with lower and higher salinity values respectively as suggested by Govindasamy (1992).

Evenness values showed more or less similar seasonal fluctuations at both the stations during the present study period. At both the station species evenness index was high (0.99) during the monsoon and postmonsoon seasons and comparatively low (0.82) at station 1 and 0.77 at station 2 during the monsoon season. Higher values of evenness recorded during the monsoon and postmonsoon seasons coincided with lower population density of phytoplankton.

Chlorophyll a is the principal photosynthetic pigment responsible for primary production in the aquatic realms. High concentration of phytoplankton Chlorophyll would result in high values of productivity and reflect on high phytoplankton biomass. In the present study, chlorophyll a concentration was low during the monsoon season and high during the summer season, coinciding with lower (monsoon season) and higher (summer season) population density and gross primary productivity respectively. In general, distribution of chlorophyll a closely followed the phytoplankton cell counts and the maximum value was obtained during the peak phytoplankton population density as reported by Gouda and Panigrahy (1989) and Akpan and Offerm (1993).

Gross primary productivity values showed a wide range of fluctuations in the present study (0.25 to 1.51 g cm^{-3} h^{-1}) as reported by Govindasamy (1992) from the Coromandel coast, Sampathkumar (1992) from the Trabqyebar-Nagapattinam coast. In the present study, the maximum value of gross primary productivity (1.113 g cm^{-3} h^{-1}) was recorded during summer season at station 2. This is more or less similar to the value (1.113 g cm^{-3} h^{-1} reported earlier by Valsaraj and Rao (1992) from the Madras Coast.

Of the two stations investigated, station 2 recorded more species composition, population density, primary productivity and Chlorophyll a concentration than station 1, probably owing to its autochthonous species in addition to the allochthonous estuarine species.

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