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Seasonal distribution of phytoplankton in the surf waters off Gopalpur, east coast of India

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Abstract

The distribution of phytoplankton in surf waters off Gopalpur (Lat. 19°6'N and Long. 84°56'E), east coast of India showed that the species composition and population density indicated well-marked seasonal variation. In total, 66 species of diatoms, 12 dinoflagellates, 3 blue-green and 2 green algae were encountered. The population density of phytoplankton ranged from 3.92 x 10^4 to 7.23 x 10^6 cells l^{-1}. Higher population density and Chlorophyll *a* was observed in March when there was a bloom of *Asterionella glacialis* (=*Asterionellopsis glacialis*). The diversity indices showed considerable variations with minimum values in March in coincidence with the *Asterionella* bloom.

Keywords: Distribution, phytoplankton, surf waters, Orissa, east coast India

Introduction

Surf zone represents a very complex and dynamic ecosystem within the coastal zone. The inhabitant flora and fauna here are exposed to severe environmental stress generated by marine process and man made activities. The phytoplankton crop in the surf waters is normally dominated by diatoms comprising a mixture of some benthic and pelagic species. Short duration bloom of diatoms leading to the discoloration of surf water, surf foam, and beach sands have been reported from many parts of the world (Lewin and Schaefer, 1983; Talbot *et. al.*,1990; Campbell, 1996) Considering the importance of surf water phytoplankton in surf zone ecology, their taxonomy and ecology have also been elaborately studied (Lewin and Rao, 1975; Mclachlan and Lewin, 1981; Odebrecht *et al.*, 1995), but such studies in India are quite meager. The present paper deals with the seasonal change in species composition, species diversity and abundance of phytoplankton in surf waters off Gopalpur, (Orissa) along the east coast of India.

Materials and methods

The study was undertaken at Gopalpur, situated on the south Orissa coast. The beach configuration, climate and tidal rhythm at Gopalpur on Sea have been described earlier by Sahu *at al.* (2005). The width of the surf zone at Gopalpur varies between 50 – 150 m providing an excellent opportunity to study its ecological aspects.

Surf water samples for estimation of hydrographical parameters, nutrients, qualitative and quantitative analyses of phytoplankton and Chlorophyll-*a* were collected using a clean plastic bucket at every fortnight during February 2004- January 2005 from a fixed station beyond the break zone opposite to light house (Lat 19° 6' N & Long. 84° 56'E). All collections were made during mid-tide. Air and water temperature were recorded immediately after collection using a standard digital thermometer of 0.1°C accuracy. Surf water for analysis of salinity, nutrients, dissolved oxygen (DO) and phytoplankton were drawn into diffe-rent containers and transported to laboratory. All chemical analyses, estimation of Chlorophyll *a* and phaeophytin were made adopting the methods given by Parsons *et al.* (1984). For phytoplankton analysis, a liter of water sample was treated with 2 ml of Lugol's Iodine solution and allowed to stand for 2 days. The supernatant water was siphoned out phase-wise till the volume was reduced to < 100 ml. The concentrated plankton mixture was preserved with 3% neutralized formaldehyde. The volume was then made to exactly 100 ml, from which 1 ml was taken on a Sedgewick-Rafter cell and counted under a binocular research microscope. During March and April, when the surf water was over-riched with *Asterionella*, a haemocytometer was used for counting the phytoplankton cells. Standard taxonomic monographs of Subramanian (1946, 1968, and 1971) for diatoms and dinoflagellates and Fristch (1935) for green and blue-

green algae (Cyanobacteria) were followed. The values of total density and species-wise density were used to compute different diversity parameters like species richness (D), species diversity (H') and species evenness (J).

Results

Hydrography: The surf water temperature showed marked seasonal variations and followed the atmospheric temperature (Fig.1). Minimum surf-water temperature of 24.9° C was recorded in January 2005, while the maximum value of 30.1°C was recorded in October 2004. Salinity showed well-marked fluctuations, which ranged from $23.7x10^{-3}$ in September to $34.5x10^{-3}$ in June. It exhibited a unimodal pattern of annual cycle. Dissolved oxygen contents showed a sharp increase from 3.9ml l^{-1} in February to 6.3ml l^{-1} in March. The annual cycle of DO approached trimodal behaviour.

Nutrients: The concentrations of nitrate (NO_3^--N), phosphate (PO_4^{3-}-P) and silicate (SiO_4^{4-}-Si) showed conspicuous seasonal fluctuations (Fig.2). The nitrate contents varied between 0.84 μg at-l^{-1} in April and 2.61μg at-l^{-1} in September. But the phosphate values ranged from 0.09 μg at-l^{-1} in March to 0.92 μg at-l^{-1} in September. The values of Nitrate: Phosphate ratio fluctuated between 2.41:1 & 11.44:1 corresponding to the months of December and March respectively. Silicate concentrations remained much higher than nitrate and phosphate, which ranged from 9.34 - 36.96 μg at-l^{-1}. Higher values were observed during August-October when the salinity was low. The annual cycle of silicate showed unimodal oscillation at par with salinity.

Phytoplankton: The phytoplankton community comprised of a mixture of some benthic and pelagic components. Diatoms formed the most abundant and dominant group represented by 66 species. As many as

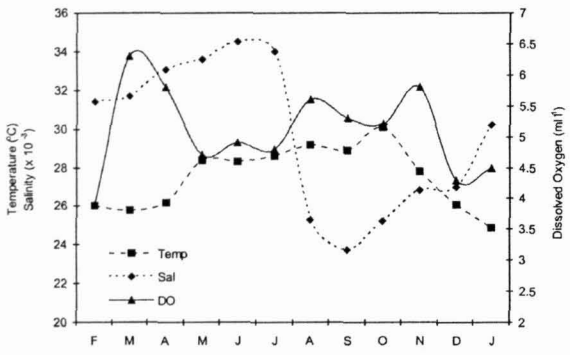

Fig.1. Monthly variations of temperature (°C), salinity (x 10^{-3}) and dissolved oxygen (ml l^{-1}) in surf waters off Gopalpur during February '04 – January '05.

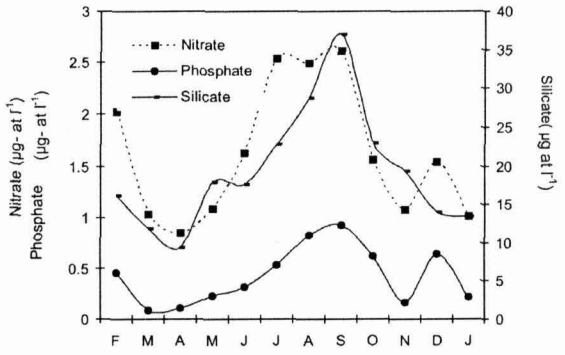

Fig.2. Monthly variations of nutrients in surf waters off Gopalpur during February '04 – January '05

48 species belonged to order-Centrales, while only 18 belonged to order-Pennales. Heterogeneous pictures were observed in the species composition of phytoplankton in different months. Highest number of 40 species comprising 33 diatoms, 4 dinoflagellates, 2 Cyanobacteria and one green alga were encountered in February 2004, whereas, only 14 species comprising 10 diatoms, 3 dinoflagellates and 1 blue-green alga (*Trichodesmium erythraeum*) were noticed in March 2004. There was a dense aggregation of *Asterionella* cells in March.

Although the species composition showed significant monthly variations, 10 diatoms such as *Thalassiosira eccentrica, Bacteriastrum hyalinum, Chaetoceros affinis, Guinardia flaccida, Leptocylindricus danicus, Proboscia alata, Nitzschia longissima, Navicula longa, Asterionella glacialis and Pleurosigma elongatum* were encountered almost throughout the period of observation. Similarly, the common dinoflagellates were *Ceratium furca, C. tripos* and *Peridinium oratum. Trichodesmium erythraeum*, which was more frequent during February-April, remained absent during August-October. Two more Cyanobacteria species viz. *Oscillatoria* and *Anabaena* were found in plankton collections during August –October 2004.

The diversity parameters such as species richness (D), species diversity (H') and species evenness (J) of surf water phytoplankton showed conspicuous monthly variations (Table 1). The highest species richness (D) value of 3.07 bits per individual was noticed in February 2004, when the species diversity (H') value was 5.41 and evenness (J) value was 1.53. Lowest value of all the diversity parameters (D=0.19; H'=0.01; J=0.02) were observed in March, when the cells of *Asterionella glacialis* was overcrowded in phytoplankton community. The diversity indices started increasing from April onwards as

Table 1. *Diversity indices of phytoplankton in surf waters off Gopalpur, east coast of India during Feb. 2004 - Jan. 2005*

Month	Species Diversity (H')	Species Richness (D)	Species Evenness(J)
Feb.	5.41	3.07	1.53
Mar.	0.01	0.19	0.02
Apr.	0.03	0.93	1.04
May.	2.67	0.93	1.04
Jun.	3.81	1.57	1.29
Jul.	4.03	1.7	1.34
Aug.	2.95	1.23	1.07
Sept.	2.73	1.6	0.96
Oct.	3.09	1.26	0.83
Nov.	3.52	1.05	1.52
Dec.	1.93	0.98	1.44
Jan.	2.75	1.97	1.09

a result of the recruitment of new species following the termination of *Asterionella* bloom.

The monthly variations of population density, chlorophyll-*a* and phaeopigment are shown in Figure 3. The population density varied from 3.92x 10^4 -7.23 $Cell^{-1}$ showing a bimodal oscillation with primary peak in May and secondary peak in November. Relative abundance of different groups exhibited significant variations (Fig.4), wherein diatoms contributed 69 - 96% and dinoflagellates from 3 - 19% of the total density. The values of

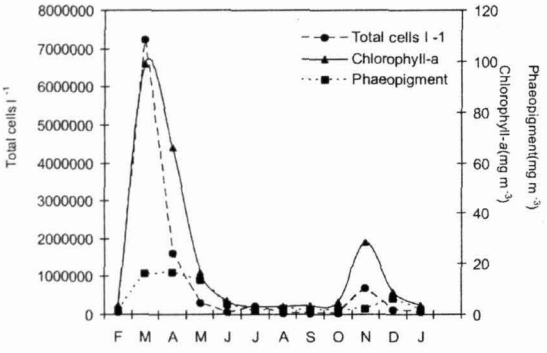

Fig.3. Monthly variations in phytoplankton density and pigment contents at Gopalpur during February '04 – January '05

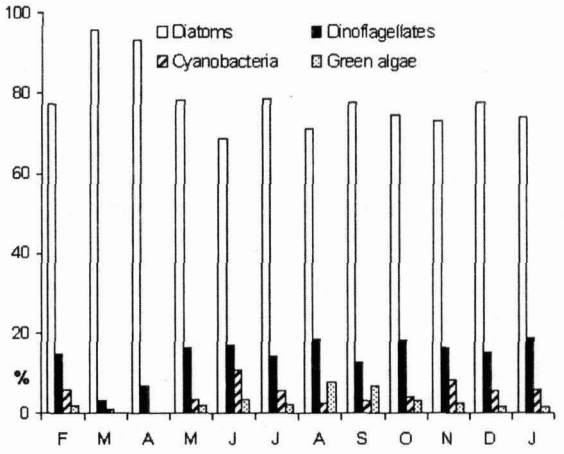

Fig.4. Relative abundance of surf water phytoplankters at Gopalpur during February '04 –January '05.

chlorophyll-*a* ranged from 3.31 – 99.12 mg m^{-3}. Both, chlorophyll-*a* and phaeopigment concentrations followed the population density.

Results of correlation analysis between phytoplankton density, chlorophyll *a* and phaeopigment with different physicochemical parameters are given in Table 2. Negative correlation was observed between the phytoplankton density and nutrients, whereas the plankton density and chlorophyll-*a* discerned a strong positive correlation (Fig.5).

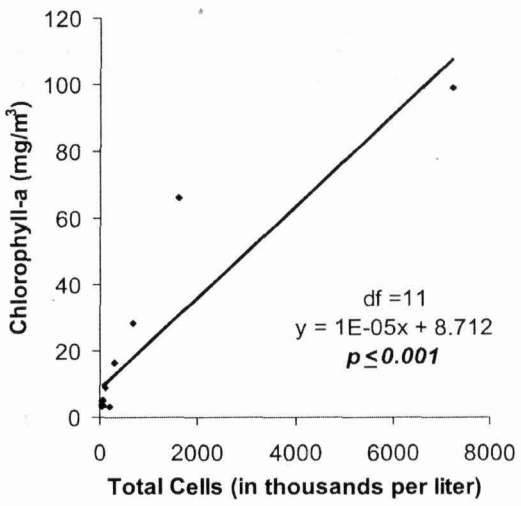

Fig.5. The scattered diagram with fitted regression line indicating the relationship between plankton cell density and chlorophyll-*a*.

Table 2. *Values of correlation coefficient (r) showing the relationship between different physico-chemical parameters and phytoplankton*

	Temp.	Sal.	DO	Nitrate	Phosphate	Silicate	Phyto-plankton	Chloro-phyll -*a*	Phaeo-pigment
Temp.	1								
Sal.	-0.344	1							
DO	0.179	-0.169	1						
Nitrate	0.523	-0.335	-0.222	1					
Phosphate	0.548	**-0.667**[a]	-0.235	**0.860**[c]	1				
Silicate	**0.745**[b]	**-0.621**[a]	0.067	**0.800**[b]	**0.818**[c]	1			
Phytoplankton	-0.378	0.221	**0.630**[a]	-0.393	-0.487	-0.398	1		
Chlorophyll-a	-0.420	0.279	**0.704**[b]	-0.574	**-0.629**[a]	-0.527	**0.915**[c]	1	
Phaeopigment	-0.350	0.451	0.436	**-0.625**[a]	**-0.593**[a]	-0.575	**0.669**[a]	**0.828**[c]	1

a = Significant at 5% level; b = Significant at 1% level ; c = Significant at 0.1% level

Discussion

The surf zone represents one of the most turbulent and hydro-dynamically active ecosystems prone to subtle changes in spatio-temporal scale under the influence of local climate and oceanographic processes. During winter (December-February), the hydrographical features of the Bay of Bengal remain stable, except a few instances of local upwelling occurring in late winter i.e. February & March. The result of localized upwelling in the shelf triggers the rapid growth of diatoms like *Asterionella glacialis* reaching a bloom status (Gouda and Panigrahy, 1996). In summer season (April-June), which represents the rough and hot weather season over the Bay of Bengal of the Indian east coast, the high energy long waves disturb the surf zone flora and fauna. The monsoon season represents the period of low salinity and high nutrient due to continental influence.

The hydrochemical properties and phytoplankton community in the surf water of Gopalpur exhibited well-marked seasonal variations. Among the different hydrographical parameters studied, salinity exhibited sharp decrease during August/September as a result of the influx of freshwater into the bay from the adjacent creek, through which flood water of Nandianala is debouched into the bay. Interestingly, there was a sharp increase in DO in March, and this could be attributed to the photosynthetic release of oxygen by the bloom forming diatom *Asterionella glacialis*. The nutrient concentration in surf water showed record fall during March and April, which could be ascribed to their cells uptake by the diatom cells. Such rapid fall of nutrients during bloom phase has been reported earlier in different parts of the Bay of Bengal (Mani *et al*, 1986; Gouda and Panigrahy, 1996). Concentration of all the nutrients had increased during April/May suggesting their quick replenishment by microbial regeneration at the sea bottom. All the three nutrients especially nitrate and silicate showed significant increase during August-September denoting their continental origin and addition through fresh water influx. Despite the changes in concentration of nutrients, the Nitrate: Phosphate (N:P) ratio remained much lower than the Redfield ratio of 15:1, which suggested that, the role of nitrate is more important than phosphorous affecting the phytoplankton growth in this region.

The floristic composition of phytoplankton of the present study closely resembled the inshore water taxa off Gopalpur Sea reported by Gouda and Panigrahy (1996) and those of Vellar Estuary and its adjacent nearshore waters reported by Mani *et al.* (1986).

The cell counts of phytoplankton showed well-marked seasonal variations with a sharp increase in March. Such an exponential increase of phytoplankton cells from 3.92×10^4 cells l^{-1} to 7.23×10^6 cells l^{-1} had occurred due to the accumulation of *Asterionella* cells in the surf water, added from nearshore waters attached on to the wave generated bubbles. The cell counts had shown rapid decrease in May following the dispersion of *Asterionella* bloom. The annual cycle of phytoplankton density, and

chlorophyll-*a* exhibited bimodal oscillations as was reported elsewhere along Indian coasts (Gouda and Panigrahy,1996; Mani *et al.*,1986). Strong positive correlation ($P \leq 0.001$) between the cell density and chlorophyll-*a* as noticed during the present study too is a common feature in Indian seas (Gouda and Panigrahy, 1996). However, almost a 30-fold increase in chlorophyll-*a* from 3.31 mg m^{-3} in August to 99.12 mg m^{-3} in March was an exceptional event which had occurred due to the blooming of *Asterionella.*

Diatoms have emerged as the most dominant group (69-96%) in the surf water phytoplankton followed by dinoflagellates (3-19%). Among the diatoms, centric forms remained more dominant over pennates except in March and April when there was a huge accumulation of *Asterionella* cells in surf zone plankton. Such dominance of *Asterionella* in surf water leading to discoloration of surf foams has been reported earlier in many parts of the world. (Talbot and Bate, 1987; Du Preez *et al.*, 1990; Campbell, 1996)

The results obtained during this study and discussions made thereon have shown that the most fascinating attribute of the surf zone water of Gopalpur is the huge accumulation of *Asterionella glacialis* cells in March leading to the discolouration of its surf foam. The accumulation of *Asterionella* seems to have occurred due to the migration of cells from near shore areas through the wave generated bubbles. Nutrients, more importantly the nitrate and silicate have emerged as the main factors controlling the phytoplankton growth in the near shore and surf waters along the Gopalpur coast.

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References

Campbell, E. E. 1996. The global distribution of surf diatom accumulations, *Rev. Chil. Hist. Nat.*, 69: 495-50.

Du Preez, D. R., E. E.Campbell and G. C. Bate. 1990. First recorded bloom of the diatom *Asterionella glacialis* Castracane in the surf-zone of the Sundays River beach, South Africa. *Bot. Mar.*, 32: 503-504.

Fristch, F. E.1935. *The Structure and Reproduction of Algae*, Vol. II. Cambridge Univ. Press, London.791pp

Gouda, R. and R. C. Panigrahy. 1996. Ecology of phytoplankton in coastal waters off Gopalpur, east coast of India. *Indian J. Mar. Sci.*, 25: 146-150.

Lewin, J. and C. T. Schaefer. 1983. The role of phytoplankton in surf ecosystems, *In:* McLachalan A. and T. Erasmus (Eds.) Sandy Beaches as Ecosystems. Dr. W. Junk Publishers, The Hague, p. 381-389.

———— and V. N. R. Rao. 1975. Blooms of surf-zone diatoms along the coast of the Olympic Peninsula, Washington. VI. Daily periodicity phenomena associated with *Chaetoceros armatum* in its natural habitat. *J. Phycol.*, 11: 330-338.

Mani, P., K. Krishnamurthy and P. Palaniappan. 1986. Ecology of phytoplankton blooms in the Vellar estuary, East coast of India. *Indian J. Mar. Sci.*, 15: 24-28.

McLachlan, A. and J. Lewin. 1981. Observations on surf phytoplankton blooms along the coasts of South Africa. *Bot. Mar.*, 24: 553-557.

Odebrecht, C., A. Z. Segatto and C. A. Freitas. 1995. Surf-zone chlorophyll-*a* variability at Cassino beach, southern Brazil, *Estuar. Coast. Shelf Sci.*, 41: 81-90.

Parsons, T. R., Y. Maita and C. M. Lalli. 1984. *A manual of chemical and biological methods for seawater analysis.* Pergamon Press, New York, 173 pp.

Sahu Gouri, A.K. Mohanty and R.C. Panigrahy. 2005. Species composition and diversity of diatoms in the intertidal sediments of Gopalpur coast, Bay of Bengal. *J. Mar. Biol. Ass. India,* 47(2) : 201-204.

Subramanian, R. 1946. A systematic account of marine plankton diatoms of the Madras coast. *Proc. Indian Acad. Sci.*, 24: 1-197.

————.1968. *The Dinophyceaes of Indian Seas Part-I, Genus Ceratium,* Marine Biological Association of India, 129 pp.

————1971. *The Dinophyceaes of Indian Seas Part-II. Peridiniaceae.* Marine Biological Association of India. 134 pp.

Talbot, M. M. B., G. C. Bate and E. E. Campbell. 1990. A review of the ecology of surf-zone diatoms, with specific reference to *Anaulus australis, Ocean Mar. Biol. Annul Rev.*, 28: 155-175.

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