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Impact of the Diatom *Asterionella glacialis* (Castracane) Bloom on the Water Quality and Phytoplankton Community Structure in Coastal Waters of Gopalpur Sea, Bay of Bengal

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Abstract: Occurrence of mono-species bloom of the diatom *Asterionella glacialis* (Castracane) in the coastal waters of Gopalpur sea, north-western Bay of Bengal and its impact on the water quality and phytoplankton community structure is reported in this paper. The bloom period persisted for about two weeks, from third week of March to 4th April 2004. Population density of phytoplankton discerned manifold increase from 4.63 × 10^4 cells l^{-1} on 22nd February 2004 to 3.96 × 10^7 cells l^{-1} on 26th March 2004. An overwhelming dominance of *Asterionella* contributing about 99.5% of the total phytoplankton count was observed during peak bloom period. Chlorophyll-*a* contents also showed an exponential increase that rose to 237.5 mg m^{-3} during peak bloom period from its pre-bloom concentration of about 3.26 mg m^{-3}. The stable hydrographic conditions coupled with increased nutrient concentrations have triggered the blooming of this diatom species. Termination of bloom occurred with the depletion of nitrate and silicate in the medium water. Phytoplankton community structure in terms of their species diversity, species richness and evenness showed distinct variations during the pre-bloom, bloom and post-bloom periods.

Key words: *Asterionella glacialis* bloom, water quality, phytoplankton, Bay of Bengal.

Introduction

Occurrence of phytoplankton bloom in marine environment, commonly known as *"Red Tide,"* was first reported in the year 1930. Wood (1965) had reported a "red tide" in the Pacific Ocean, while Sato et al. (1966) came across a similar situation in the coastal waters of North-eastern Brazil. Wood (1968) had reported the luxuriant growth of *Gonyaulax tamarensis* leading to the discolouration of surface water in the North Sea. Subsequently, blooming of some more species of dinoflagellates viz. *Gonyaulax acatenella* in the straits of Georgia (Prakash and Taylor, 1966), *Noctiluca* sp. in the western coast of Brittany (Le Fevre and Grall, 1970) and *Dinophysis* sp. in the North Sea (Dodge, 1977) were reported. Diarrheic Shellfish Poisoning (DSP) caused by *Dinophysis fortii* and Neurotic Shellfish Poisoning (NSP) caused by *Gymnodinium* were noticed in 1980s (Shimizu, 1983). Blooming of phytoplankton in marine milieu has always been treated as a nuisance, and as such studies on harmful algal blooms has emerged as one of the priority area of research in oceanography.

Blooming of *Trichodesmium erythraeum* has been found as regular event in Indian seas (Prabhu et al., 1965; Qasim, 1970; Devassy et al., 1978 & 1979; Santhanam et al., 1994). Similarly, blooming of *Noctiluca scintillans* was encountered in the Palk Bay and Gulf of Mannar (Raghu Prasad, 1953 & 1958), coastal waters of

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Kalpakkam (Sargunam et al., 1989) and Andaman Sea (Eashwar et al., 2001). In addition to *Noctiluca,* bloom-like growth of some other dinoflagellates like *Gymnodinium* sp. *Gonyaulax* sp. and *Dinophysis* sp. were also frequently reported in Arabian sea (Bhimachar and George, 1950). However, reports on the bloom forming diatoms along the Indian coasts are scanty. Raghu Prasad (1956) had observed the blooming of *Rhizosolenia* in the coastal waters of Palk Bay and Gulf of Mannar during February and March of 1951 and 1952. Later, Subba Rao (1969) has reported the occurrence of a mono-species bloom of *Asterionella japonica* (=*Asterionella glacialis*) in the coastal waters off Vishakhapatnam. Luxuriant growth of *Asterionella* with some other diatoms were also reported in the Vellar estuary (Mani et al., 1986), coastal waters of Kalpakkam (Satpathy and Nair, 1996) and estuaries and near shore waters of south Orissa coast (Choudhury and Panigrahy, 1989; Panigrahy and Gouda, 1990; Mishra and Panigrahy, 1995; Sasmal et al., 2005). But the impact of this bloom on water quality and other flora and fauna were not studied earlier. Campbell (1996) had opined that, although diatom blooms may not have any serious economic implication, their influence on water quality and thereby, on the existing flora and fauna could be a matter of concern. The present paper describes the impact of *Asterionella glacialis* bloom on water quality and phytoplankton community structure with particular reference to the bloom which occurred during March-April 2004.

Materials and Methods

Gopalpur is a small beach resort situated on the east coast of India at Lat. 19°16'N and Long. 84°54'E. The coast line of Gopalpur is fairly straight and the beach is covered with surf water extending up to a distance of 200 m seaward from the highest high water mark. A shallow brackish water creek is situated on the eastern side of the township through which organic wastes are debauched into the sea. During an environmental study of the surf zone through sampling schedule at fortnight intervals, dark brown patches of *Asterionella* cells were found in the surf-foam and on the beach sands on 24th March 2004. Following this observation, collection of water samples from a fixed station (Figure 1) was made for analysis of physico-chemical properties and qualitative and quantitative aspects of phytoplankton. The sampling intensity was increased to every alternative day during the entire bloom period of 24th March-4th April 2004.

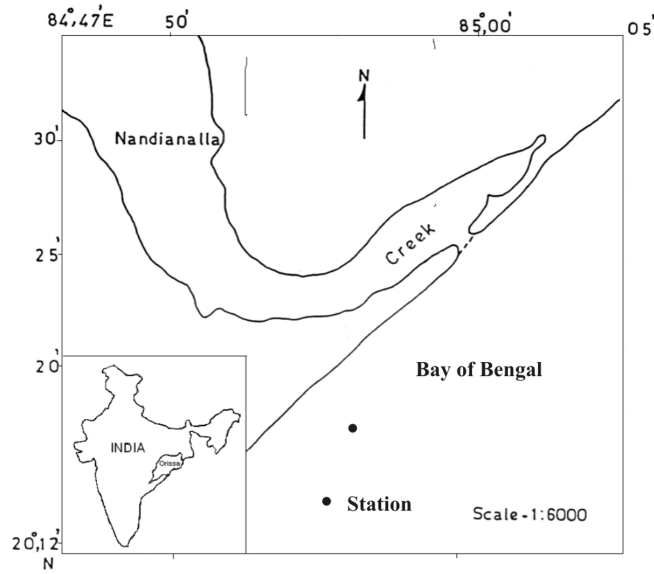

Figure 1: Gopalpur coast showing study areas.

Air and water temperature and pH were measured in the field immediately after the collection using standard thermometer and a Bio-Chem field pH meter respectively. Water samples for estimation of salinity, nutrients, dissolved oxygen (DO), phytoplankton standing stock and pigment were drawn into separate containers and transported to laboratory for further analysis. All chemical analysis viz., salinity, DO, nutrients and pigments were made adopting the methods described by Parsons et al. (1984). Samples for phytoplankton studies were first treated with 1% Lugol's iodine solution, and then preserved with 3% neutralised formaldehyde. After three days of sedimentation, the supernatant water was decanted out so as to reduce the volume to 100 ml. One ml of the concentrated homogenous aliquot was transferred to a Sedgewick-rafter cell and was examined under a binocular research microscope. Different species of phytoplankton present on the cell were identified using standard works of Cupp (1943), Subramanian (1946) and Desikachary (1987). They were counted species-wise and mean of three such counts was taken for computing the species-wise density and total density. Three species diversity indices such as species diversity ($H' \sum_{i=1}^{s} Pi \log_e Pi$; (Shannon-Weaver, 1963), species richness ($D = \frac{S-1}{\log_e N}$; Gleason, 1922) and evenness ($J = \frac{D}{\log_e S}$; Pielou, 1966) were computed to elucidate the change in the community structure of phytoplankton.

Results and Discussion

Physico-chemical Parameters

The coastal zone habitats in general are fragile and susceptible to subtle changes due to human interference and marine processes operating in them. Blooming of phytoplankton constitute one of the important biological event taking place in coastal marine ecosystems. In Indian seas and their associated estuaries, phytoplankton bloom occurs almost regularly during late winter and pre-monsoon months, when the hydrographical conditions are nearly stable and there was an enrichment of surface water caused due to upwelling (Ganapati and Subba Rao, 1957; LaFond, 1957; Gouda and Panigrahy, 1996). Thus occurrence of phytoplankton bloom is considered as a good indicator of the change in water quality. During the present study, based upon the concentration of *Asterionella glacialis* density, the period of observation has been divided as pre-bloom (February-early March), bloom (late March-early April) and post-bloom periods (mid April-May). A summary account of hydrographical parameters such as temperature, salinity, dissolved oxygen, pH and nutrients (nitrate, phosphate and silicate) are given in Table 1. Each of these physicochemical properties exhibited visible changes during the pre-bloom, bloom and post-bloom situations. The surface water temperature decreased from 26.8°C in February to 24.9°C in late March, and thereafter registered a steady increase reaching the maximum value of 30.1°C in May. The fall of temperature believed to have triggered the rapid proliferation of *Asterionella.* Instances of local upwelling leading to cooling of surface water and nutrient enrichment has been reported as a common event in this part of the Bay of Bengal during late winter (Choudhury and Panigrahy, 1989; Gouda and Panigrahy, 1999). Sea water salinity has increased from 30.4 PSU in February to 32.5 PSU in April and then decreased to 30.9 PSU in May. The higher salinity values of March/April also could be due to the influence of upwelling in this part of the Bay of Bengal in late winter. A prominent change was observed with respect to the DO contents of the pre-bloom (3.9 ml l^{-1}), bloom (6.3 ml l^{-1}) and post-bloom (4.3 ml l^{-1}) periods. The higher oxygen values during active bloom period could be due to the photosynthetic release of oxygen by the bloom-forming diatoms. The fall in oxygen content in April/May could on the other hand be ascribed to the decomposition of senescent phytoplankton cells involving rapid consumption of DO. The pH values, however, did not show much variation and it lied between 8.02 and 8.23.

All the three nutrients, i.e nitrate, phosphate and silicate showed significant variations during the pre-bloom, bloom, and post-bloom periods. Their concentration increased by about 60-80% during the post-bloom period when compared with those of bloom period. The values of nitrate ranged 0.88-1.42 µg at l^{-1}, while phosphate and silicate contents ranged 0.20-0.58 µg at l^{-1} and 21.44-32.64 µg at l^{-1} respectively. Rapid fall of nitrate and silicate occurred coupled with an exponential increase of *A. glacialis* density. Termination of bloom in

Table 1: Physicochemical Properties of Surface Waters in Gopalpur Sea during February-May 2004

Date	*Temp. (°C)*	*Salinity (x 10^3)*	*DO (ml l^{-1})*	*Nitrite (µg-at-l^{-1})*	*Nitrate (µg-at-l^{-1})*	*Phosphate (µg-at-l^{-1})*	*Silicate (µg-at-l^{-1})*	*N:P*
Pre-bloom								
22nd Feb. 2004	26.8	30.8	3.90	0.12	1.42	0.58	32.64	2.5:1
Bloom								
March 2004								
24th	26.2	30.4	4.95	0.10	1.24	0.20	24.82	6.2:1
26th	26.6	31.6	6.30	0.10	0.96	0.32	23.10	3:1
28th	24.9	31.0	5.06	0.17	0.88	0.23	21.52	3.8:1
30th	25.6	31.4	6.07	0.14	1.08	0.27	21.44	4:1
April								
01st	27.6	31.7	5.17	0.10	0.98	0.26	21.74	3.8:1
04th	27.3	32.0	5.96	0.14	1.32	0.20	22.05	6.6:1
Post-bloom								
18th April 2004	28.1	32.5	6.02	0.11	1.41	0.34	23.51	4.2:1
May 2004								
02nd	28.8	30.9	5.30	0.15	1.37	0.41	27.23	3.3:1
20th	30.1	31.2	4.27	0.12	1.38	0.47	29.02	3:1

consonance with depletion of these two nutrients has endorsed the findings of Smetacek (1988) that, in tropical coastal water, nutrients always limit the phytoplankton growth. Termination of diatom blooms in coincidence with the fall of nitrate and silicate has also been reported earlier in Vellar estuary (Mani et al., 1986), coastal waters off Visakhapattanam (Subba Rao, 1969) and near-shore water off Gopalpur (Choudhury and Panigrahy, 1989). The phosphate content, although has decreased simultaneously during the bloom period of *A. glacialis*, the N:P ratio varied between 2.5:1 and 6.6:1, values much less than the Redfield's ratio of 16:1. It suggested that the role of phosphate is of minor significance in accelerating the growth of *Asterionella*.

Phytoplankton

Taxonomic Composition

The checklist of phytoplankters and their distribution encountered during the study period is given in Table 2. In total, 59 species consisting of 48 diatoms (Bascillariophyceae), nine dinoflagellates (Dinophyceae), one blue-green algae (Cyanophyceae) and one green algae (Chlorophyceae) were recorded. Significant variation had occurred in phytoplankton composition of the pre-bloom, bloom and post-bloom periods. As many as 40 species were encountered during post-bloom period, while it was 34 during pre-bloom and 22 during bloom period. The standing crop of phytoplankton was represented by only ten species on 1st April 2004. Only four species of diatoms viz., *A. glacialis, Guinardia flaccida, Nitzschia longissima* and *Nitzschia sigma* along with three dinoflagellates such as *Ceratium tripos, Ceratium furca* and *Peridinium* sp. and the blue-green algae *Trichodesmium erythraeum* had occurred during the entire period of observation. The bloom period population was overwhelmingly rich with *A. glacialis* making the surf water almost like a green coloured soup. The phytoplankton assemblage of the post-bloom period remained floristically richer, compared to the bloom as well as pre-bloom periods. Thus, a quick species succession of phytoplankton took place with change of the environmental conditions following the termination of *A. glacialis* bloom.

Species Diversity

The diversity indices of phytoplankton showed wide range of variations with highest species diversity of 5.40 in February (pre-bloom period). The lowest species

Table 2: Systematic List of Phytoplankters Encountered during the Pre-bloom, Bloom and Post-bloom Periods in the Coastal Waters of Gopalpur Sea

	Pre-bloom	*Bloom*	*Post-bloom*
Diatoms			
Asterionella glacialis Castracane	+	+	+
Amphora intersecta Schmidt	-	-	+
Amphora binodis Gregory	-	-	+
Biddulphia mobiliensis (Baily) Grun.	+	+	+
Biddulphia sp.	+	+	+
Biddulphia sinensis Greville	-	-	+
Chaetoceros curvisetus Cleve	+	+	-
Chaetoceros peruvianus Brightwell	+	+	-
Cocconeis distans Gregory	-	-	+
Cocconeis rivalis Schmidt	-	-	+
Coscinodiscus eccentricus Ehrenberge	+	+	+
C. oculusiridis Ehr.	+	-	-
C. radiatus Ehr.	-	+	-
Cymbella aspera (Ehr.) Cleve	-	-	+
Diploneis weissflogii Schmidt	-	-	+
Eucampia cornuta (Cleve) Grun.	+	+	-
Fragilaria oceanica Cleve	-	+	+
Guinardia flaccida (Castracane) Pergallo	+	+	+
Gramatophora marina (Lyngbye) Kuetz	-	-	+
Leptocylindricus danicus Cleve	+	+	-
L.minimus Gran	-	-	+
Melosira moniliformis Muller	-	+	-
Navicula longa Gregory	+	+	-
Nitzschia longissima Brebisson	+	-	+
N. sigma Kutz.	+	-	+
Paralia sulcata (Ehr.)k Cleve	-	-	+
Pleurosigma normanii Ralfs	-	-	-
P. carinatum Donk.	+	-	-
Rhizosolenia sp.	+	+	-
R. stolterfothii Peragallo	+	+	-
R. setigera Brightwell	+	-	+
R. crassispina Schroeder	+	-	-
R. castracanei Peraq. H.	-	+	-
R. alata Brightwell	-	-	+
R. berginii Lebour	+	-	-
Rhabdonema punctatum Harv. Bailey	-	-	+
Skeletonema costatum Greville	+	-	-
Stephanopyxis palmeriana (Grav.) Grun	+	+	-
Streptotheca indica Karstan	+	-	-
Streptotheca sp.	+	-	+
Thalassionema nitzschioides Grun.	+	-	+

(contd.)

(contd.)

Thalassiosira subtilis (Ostenfeld) Gren.	+	-	-
T. eccentrica (Ehr.) Cleve	-	-	+
T. lineata Jouse	-	-	+
T. oestrupii (Osten.) Proschkina-Laverenko	-	-	+
Thalassiothrix longissima (Cleve) Grun	+	-	+
T. frauenfeldi Grun	-	-	+
Trachyneis antillarum (Cleve & Gran)	-	-	+
Dinoflagellates			
Ceratium tripos Muller	+	+	+
C. furca Ehrenberg	+	+	+
Exuviella compressa Barley & Ostenfeld	+	-	-
Gonyaulax minima Matzenauer	+	-	-
G. Polyedra Lebour	+	-	-
Gymnodinium sp.	-	-	+
Noctiluca sp.	-	-	+
Peridinium oceanicum Vanhoffen	+	+	+
Pyrostis fusiformis (W. Thompson) Murray	-	-	+
Blue-green algae			
Trichodesmium erythraeum Ehr.	+	+	+
Green algae			
Enteromorpha intestinalis L. Link	+	+	+

diversity value of 0.004 was noticed on 30th March, when *A. glacialis* population density was extraordinarily high i.e., over 99% of total phytoplankton counts. The species diversity values during the bloom period varied between 0.004 and 0.027 indicating the predominance of *A. glacialis* in the phytoplankton community. The values of species richness and evenness also showed a similar trend as was noticed with respect to the species diversity. The highest and lowest species richness was obtained on 22nd February and 4th April respectively. The values of evenness too remained low (0.004) during the peak bloom period, while it was 1.53 in February. The changes in diversity indices of phytoplankton suggested a significant alteration in the phytoplankton community structure during the pre-bloom, bloom and post-bloom periods.

Phytoplankton Density

Population density and relative abundance of *A. glacialis* with respect to total density is depicted in Figure 2. The total phytoplankton density showed a sharp increase from 4.63×10^4 cells l^{-1} on 22nd February to 3.96×10^7 cell l^{-1} on 26th March. The lowest density was observed in February, when the share of *Asterionella* population was only about 2.45%. The population density grew rapidly during bloom period and declined from mid-April onwards. The lowest value of 4.37×10^4 cells l^{-1} was noticed in May. There was a massive dominance (99.01 ± 0.61%) of *A. glacialis* during 24th March-4th April 2004. The contribution of other phytoplankters during these days was scarce and they made sporadic appearance. Such total preponderance of *Asterionella* sp. leading to a mono-species bloom status were reported earlier along the Vishakhapatnam coast by Subba Rao (1969) and off Gopalpur (Choudhury and Panigrahy, 1989). The share of the other species during the pre-bloom period was about 97.55%, which fell to 0.92 ± 0.57% during the period of *Asterionella* bloom (Figure 2b). The population density of other phytoplankters began increasing from mid-April onwards with reduction in *A. glacialis* population. The percentage contribution of *Asterionella* by mid-April has reduced to 39.5% (Figure 2c). There was a constant decline in *Asterionella* population due to its replacement by other species and its share in May fell to 3.94%. This leads to conclude that other species of phytoplankton fail to compete with *Asterionella* under the changing environmental conditions of late winter in the northwestern Bay of Bengal.

Distribution of chlorophyll-*a* and phaeophytin are given in Table 3. The values of chlorophyll-*a* and phaeophytin showed wide range of variations during the pre-bloom, bloom and post-bloom periods. The chlorophyll-*a* content in February was at 3.68 mg m^{-3}, which increased to reach a maximum value of 237.5 mg m^{-3} on 26th March. A rapid fall in chlorophyll-*a* started from mid-April and it is reduced to 3.26 mg m^{-3} on 20th May. The phaeopigment concentrations varied from 1.35 to 130.83 mg m^{-3}. Higher values were observed during the later part of the bloom period and the maximum value of 130.83 mg m^{-3} was observed on 30th March. This could be ascribed to the presence of more amounts of senescent cells of *A. glacialis* in the phytoplankton community in these days. Such high values of phaeo-pigments due to the interference of dead and decaying cells have been reported earlier in near-shore and estuarine environments (Panigrahy and Gouda, 1990; Gouda and Panigrahy, 1996).

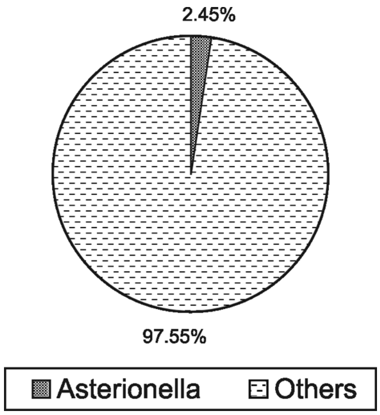

Fig. 2(a) Pre-bloom

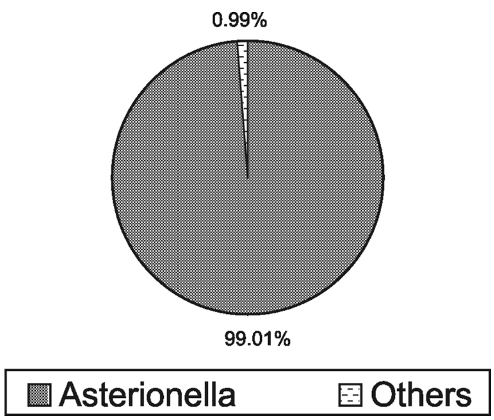

Fig. 2(b) Bloom (Avg. of 24th March – 4th April)

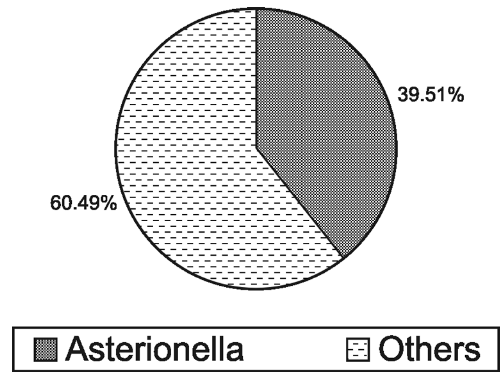

Fig.2(c) Post-Bloom (April, 2004)

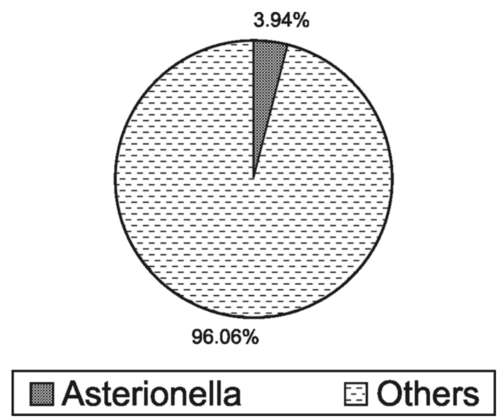

Fig. 2(d) Post-Bloom (May 2004)

Figure 2: Relative abundance of *A. glacialis* and other phytoplankters in coastal waters of Gopalpur during pre-bloom (a), bloom (b) and post-bloom (c) periods.

Table 3: Distribution of Chlorophyll-*a* and Phaeophytin Pigments during February-May 2004

Date	*Phytoplankton density*	*Chlorophyll-a (mg m^{-3})*	*Phaeophytin (mg m^{-3})*
Pre-bloom			
2nd February 2004	4.63×10^4	3.68	11.60
Bloom			
March 2004			
24th	72.2×10^6	99.0	16.21
26th	3.96×10^7	237.5	21.36
28th	2.53×10^7	188.5	50.73
30th	1.65×10^7	139.0	130.83
April 2004			
01st	9.99×10^6	63.0	49.40
04th	2.01×10^6	66.0	6.68
Post-bloom			
18th April 2004	4.12×10^5	16.5	13.35
May 2004			
01st	4.37×10^4	3.28	3.86
20th	6.99×10^4	3.26	1.35

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