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†Algal blooms along the coastal waters of southwest India during 2005-08

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Abstract

Monitoring and surveillance of algal blooms along the southwest coast of India, both from the coastal and estuarine stations were made during 2005-08. Algal blooms of *Coscinodiscus asteromphalus* var. *centralis* Ehrenberg were observed during the monsoon 2006 off Kodikkal (near Calicut; 11^0 28 43' N lat., 75^0 36 10' E long.) and *Coscinodiscus* spp. and *Pleurosigma* spp. at Mahe estuary (11^0 42 18' N lat., 75^0 32 36' E). It is inferred that the high ratios of Si:N played a significant role in the formation of algal bloom. An attempt has been made to prepare a fingerprint of these blooms from the available biological and physico-chemical variables which would be helpful for predicting the algal blooms. During the study, eleven species of toxic microalgae were recorded indicating the possibility of potential threat of harmful blooms in the coastal waters of southwest coast of India.

Keywords: *Coscinodiscus asteromphalus* var. *centralis*, algal blooms, southwest coast of India

Introduction

Planktonic algae can proliferate into enormous concentrations up to millions of cells per litre when sufficient conditions of light and nutrients are available and these natural phenomena are termed as blooms. Most of these blooms are extremely beneficial to the marine organisms as a primary source of food for various larvae. However, in some situations algal blooms may have a negative effect causing severe economic losses to aquaculture, fisheries and tourism in addition to major environmental and human health hazards by producing harmful or toxic effect to the ecosystem (Hallegraeff, 1995).

Algal blooms are quite common in Indian waters. Periodic blooms of species such as *Noctiluca scintillans*, *Trichodesmium erythraeum* and *Rhizosolenia* sp have been reported earlier. The events of harmful blooms from coastal waters of Tamil Nadu, Karnataka, Maharashtra and Kerala were reported by Bhat and Matondkar (2004). *Trichodesmium* and *Noctiluca* blooms were the most frequently observed in the Indian waters (Nair *et al*., 1992; Naqvi *et al*., 1998; Sarangi *et al*., 2004; Sahayak *et al*., 2005; Mohanty *et al*., 2007; Padmakumar *et al*., 2008).

Rarely, blooms of Holococcolithophores (Ramaiah *et al*., 2005) and *Coscinodiscus* spp. (Padmakumar *et al*., 2007) appeared in the Indian waters. Besides, five types of cysts belonging to potentially toxic genera of *Alexandrium* and *Gymnodinium* were recorded from Mangalore coast (Godhe *et al*., 2000). In the present study, seasonal monitoring of algal blooms along the southwest coast of India from seven coastal and estuarine stations were made during 2005-2008. Algal blooms of *Coscinodiscus* spp. were observed only during the monsoon 2006 off Kodikkal, Calicut (11^0 28 43'

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N lat., 75^0 36 10'E long.) and species of *Coscinodiscus* and *Pleurosigma* at Mahe estuary (11^0 42 18'N lat., 75^0 32 36'E long.). No other algal blooms were observed in the seven stations studied along the southwest coast from 2005 to 2008. Investigations were carried out on the taxonomy, abundance and ecology of these algal blooms.

Material and methods

The study was conducted in seven stations from Vaadi (near Kollam) in the south (08^0 52 01'N lat.; 76^0 34 26'E long.) to Mahe estuary in the north, (11^0 42 18'N lat.; 75^0 32 36'E long.), along the southwest coast of India from 2005 to 2008 (Fig. 1). From each station, 50 litres of surface water was filtered through 20 bolting silk and the filtrate was preserved in 3% formaldehyde solution for qualitative and quantitative analyses of planktonic microalgae. Pigments were measured in a Hitachi U-2001 UV-visible spectrophotometer following Strickland and Parsons (1972). Microalgae were identified based on standard keys (Subrahmanyan, 1946; Desikachary, 1959; Hendey, 1964; Gopinathan, 1984; Desikachary and Sreelatha, 1989; Tomas, 1997).

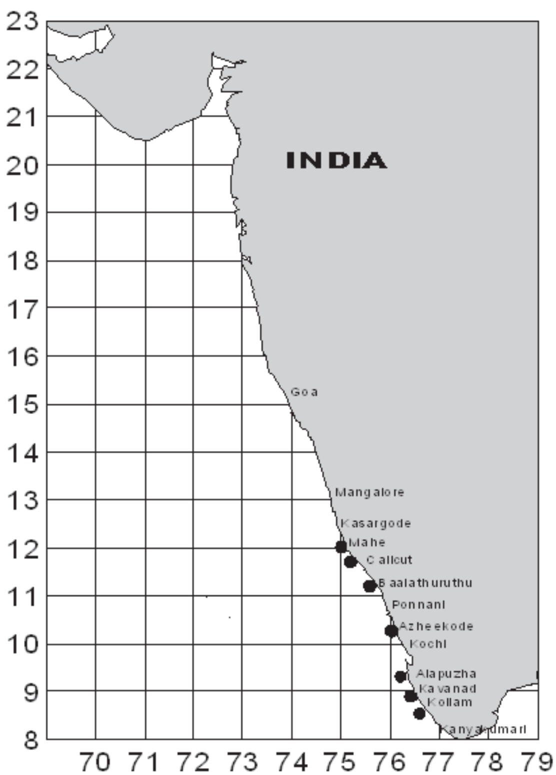

Fig. 1. Station details

Hydrographic variables such as temperature, salinity, pH and dissolved oxygen (DO) were measured *in situ* using standard instruments. Nutrients (nitrate, phosphate and silicate) were analyzed following Strickland and Parsons (1972).

Results and Discussion

A conspicuous discolouration of surface water was found during the monsoon season in 2006, along the northern part of Kerala, especially off Kodikkal (11^0 28 43'N lat.; 75^0 36 10'E long.) and in Mahe estuary (11^0 42 18'N lat.; 75^0 32 36'E long.). It was due to the blooming of centric diatom *Coscinodiscus asteromphalus* var. *centralis.* The entire bloom lasted for one week. The samples were collected on the alternative days from 23rd to 27th August 2006.

Standing crop during the bloom: Off Kodikkal, the cell abundance varied from $7x10^6$ cells L^{-1} on 23rd August 2006 to $13x10^3$cells L^{-1} on the fifth day (27th August, 2006) of observation. While in Mahe estuary, it ranged from $2x10^4$cells L^{-1} on the first day to $1x10^4$cells L^{-1} on the fifth day. The bloom of centric diatom, *Coscinodiscus asteromphalus* var. *centralis,* is the first report from Indian waters. The composition of species changed remarkably during the end of the bloom. While the bloom initially was mono-specific subsequently, at the transitional phases of the bloom crash it was characterized by the increase in species diversity heralding the phenomenon of succession of microalgal vegetation.

Pigment composition: At Kodikkal, during the bloom chlorophyll *a* ranged from 206.5 µg L^{-1} on the first day of observation to 3.29 µg L^{-1} on the fifth day. The highest concentration of chlorophyll *b* was 20.4µgL^{-1} on the first day and the lowest was 0.1µg L^{-1} towards the end. Concentration of chlorophyll *c* varied from 39.3 µg L^{-1} on the first day to 0.79 µg L^{-1} on the fifth day, while carotenoid pigments varied from 11.9 µg L^{-1} on the first day to 2.1 µg L^{-1} on the last day of bloom event (Fig. 2).

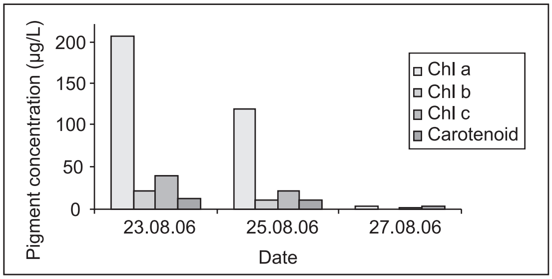

Fig. 2. Pigment concentration off Kodikkal during algal bloom

At Mahe, the concentration of chlorophyll *a* varied from 123 µg L^{-1} on the first day to 5.2 µg L^{-1} on the fifth day. Chlorophyll *b* varied from 0.53 µg L^{-1} to 0.25 µg L^{-1} during this period. The highest value of chlorophyll *c* was 5.36 µg L^{-1} recorded on the first day and the lowest was 2.36 µg L^{-1} on the last day. Carotenoid pigments decreased from 7.26 µg L^{-1} on the first day to 1.91 µg L^{-1} on the last day (Fig. 3).

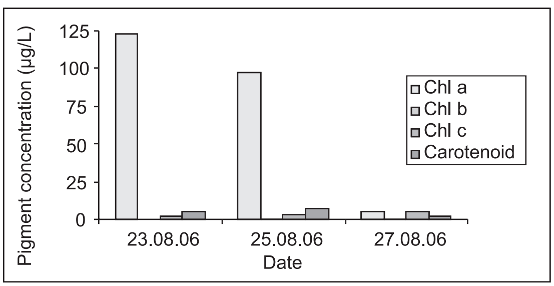

Fig. 3. Pigment concentration at Mahe Estuary during algal bloom

The fluctuations of chlorophyll *a, b, c* and carotenoid concentrations during the bloom indicated the type and magnitude of algal composition. The significant hike of chlorophyll *c* and carotenoids showed the dominance of diatoms. Initially the bloom was at its exponential phase as evident from the standing crop and chlorophyll. On the third day, slight decrease in the pigments was observed signaling the transition of exponential phase to the stationery phase. Further decrease in the standing crop and pigments shows that the bloom was in the late stationary phase and enters into the decline and death phases.

Temperature, salinity and pH: At Kodikkal, sea surface temperature varied from 27 to 28 ^{0}C, salinity was 34 psu on the first and second days and increased to 35 psu on the third day. pH was 8.2 on the first day and decreased to 7.8 on the fifth day (Fig. 4). At Mahe, temperature varied from 25 to 29^{0}C. Salinity ranged from 32 to 34 psu and pH showed a variation from 7.8 on the first day to 8 on the third and fifth day of observation (Fig. 5).

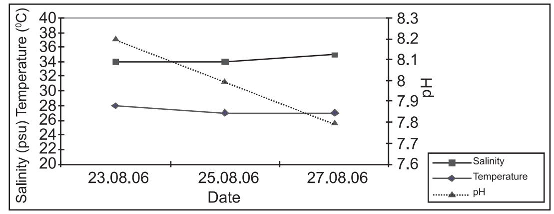

Fig. 4. Temperature, salinity and pH of water samples off Kodikkal during algal bloom

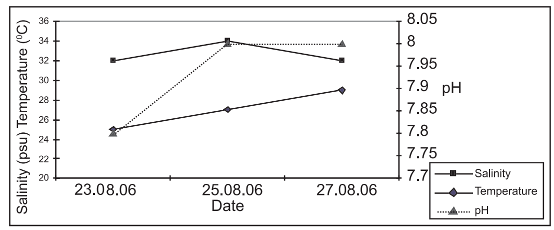

Fig. 5. Temperature, salinity and pH of water samples at Mahe Estuary during algal bloom

Nutrients, DO and primary productivity: Off Kodikkal, the concentration of nitrate varied from 4.2 µmol L^{-1} to 1.2 µmol L^{-1} and phosphate concentration varied from 2.8 µmol L^{-1} on the first day to 0.7 µmol L^{-1} on the fifth day. It was 42.2 µmol L^{-1} to 33.6 µmol L^{-1} for silicate from the initial to the last day of observation. The concentration of nitrite was below detectable ranges. Dissolved oxygen varied from 6.04 mg L^{-1} to 8.2 mg L^{-1}. The primary production was 5.61 gC/m^{3}day^{-1} at the initial day and decreased to 2.5 gC/m^{3}day^{-1} on the fifth day during the bloom at Kodikkal (Fig. 6). The low values were corresponding to the crash and high values were recorded during the initial observation.

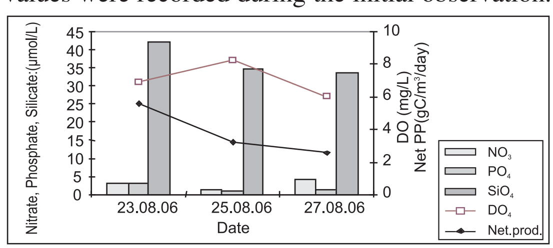

Fig. 6. Nutrients, DO and primary production during algal bloom off Kodikkal

At Mahe estuary, the concentration of nitrate ranged from 6.38 µmol L^{-1} to 2.8 µmol L^{-1} from day one to day five. It was 5.1 to 0.78 µmol L^{-1} for phosphate and silicate varied from 44.6 to 37.4 µmol L^{-1}. The nitrite concentration was nil or below detectable ranges. Dissolved oxygen ranged from 5.2 mg L^{-1} to 6.7 mg L^{-1}. Similarly, the primary production ranged from 4.4 gC/m^3 day^{-1} to 1.5 gC/m^3 day^{-1}. The highest value was on the initial day and the lowest on the final day of collection (Fig. 7). The highest values of all the variables were recorded on the initial day and the lowest values at the end of the bloom.

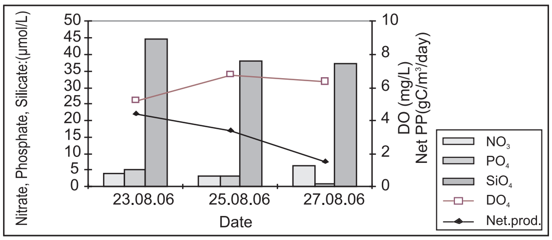

Fig. 7. Nutrients, DO and primary production during algal bloom at Mahe Estuary

Silicate constitutes one of the most important nutrients regulating the phytoplankton growth and proliferation and ultimately to its blooming and is essential for the formation of siliceous frustules of diatoms (Kristiansen and Hoell, 2002). The recorded silicate values were in the range of 33.6 to 44.6 µmol L^{-1}. The N: P ratios in two stations were quite low while Si:N ratios were moderately higher. The Si:N ratios varied from 13:1 to 8:1 in Kodikkal and from 11:1 to 6:1 in Mahe, starting from the initial day to the end of the bloom event. It is observed that the high of Si:N ratio was one of the important factors responsible for such diatom bloom.

The most remarkable comment in connection with planktonic microalgal blooms is not why they occur but rather what mechanisms control the species which occur at a given time and place (Richardson, 1997). Marine environment provides many different niches that can be exploited by different microalgal species and each species has its own specific combination of necessities to the external environment, such as light, micro and macronutrients. It may be possible to identify a fingerprint of each bloom producing species describing its external requirements. So, matching the environmental condition at any given time to the fingerprints of microalgal species potentially occurring in an area would provide a basis for predictive models pertaining to the probable development of algal blooms. A probable fingerprint was prepared from the available data on the biological and physico-chemical variables recorded during the bloom of *C. asteromphalus* var. *centralis* Ehrenberg (Fig. 8).

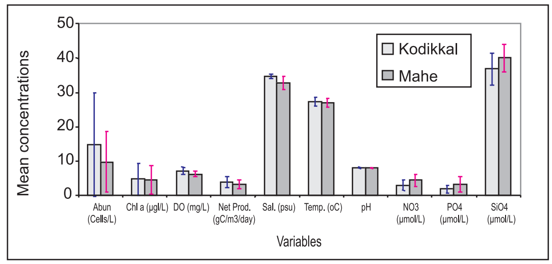

Fig. 8. Concentration of variables during *Coscinodiscus* bloom of monsoon 2006

The probable fingerprint for *Coscinodiscus asteromphalus* var. *centralis* bloom was derived from the mean values of available physicochemical variables recorded at Kodikkal and Mahe. The cell abundance was 2.3x10^5 cells L^{-1} and 1.7$10^5$ cells L^{-1}, chlorophyll *a* was 109.6 µg L^{-1} and 75.4 µg L^{-1}. The corresponding natural logarithm *ln* values were used to plot the chlorophyll *a* and cell abundance. Primary production was 3.79 and 3.11 gC/m^3 day^{-1} at Kodikkal and Mahe estuary respectively. The mean salinity was 32.67 and 34.67 psu, temperature was 27 and 27.3^0 C, while pH was 7.9 to 8 recorded off Kodikkal and Mahe estuary. The concentration of nitrate was 4.38 µmol $L^{-1}$and 2.88 µmol L^{-1}, phosphate was 3.06 and 1.6 µmol L^{-1} and silicate was 40.08 µmol $L^{-1}$and 36.8 µmol L^{-1}, recorded from Kodikkal and Mahe respectively. The nitrite concentrations were recorded below detectable ranges in both stations (Fig. 8).

In the present investigation, the fingerprint of the bloom made up from available variables was evaluated by comparing the presence of the same species (*C. asteromphalus* var. *centralis*) from the entire sampling stations along the southwest coast during the period 2005-08. The same species was recorded thrice including the bloom event during the course of this investigation.

As a part of the regular monitoring in the monsoon 2006, the same species was recorded from the same stations (Kodikkal and Mahe) just one week before the bloom. However the concentrations of the standing crop, pigments and nutrients did not appear close to those of the bloom (Fig. 9).

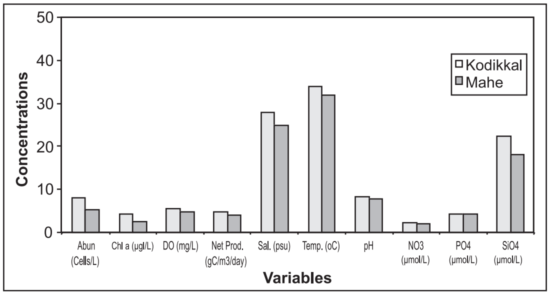

Fig. 9. Concentration of variables during *Coscinodiscus* bloom of monsoon 2006 (Non-blooming phase)

Similarly during the monsoon 2007, at Azheekode (10^0 11' 02 N lat. and 76^0 09' 22 E long.) the same species was recorded. However, the physico-chemical variables were quite different from those of Kodikkal and Mahe at the time of the bloom (Fig. 10). It may be assumed that the physico-chemical variables prevailed at Kodikkal and Mahe during August 2006 are essential for the bloom event. In the absence of such condition the bloom formation was found to be inhibited as evidenced from other stations where the same species was recorded.

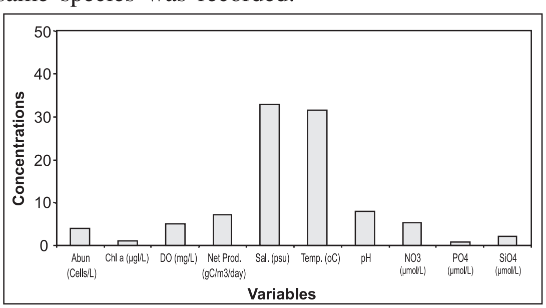

Fig. 10. Concentration of variables during *Coscinodiscus* bloom off Azheekode during the monsoon 2007 (Non-blooming phase)

This is the first detailed report of *C. asteromphalus var. centralis* Ehrenberg bloom from Indian waters. The N:P ratios in two stations were quite low while Si:N ratios were comparatively higher. It is inferred that the high ratios of Si:N played a significant role in the formation of the algal bloom.

This study also recorded eleven species of toxic microalgae belonging to three taxonomic classes, Bacillariophyceae, Dinophyceae and Cyanophyceae. These include one species from Cyanophyceae (*Microcystis aeruginosa* Kutzing), two from Bacillariophyceae (*Amphora coffeaeformis* (Agardh) Kutzing; *Pseudonitzschia seriata* (Cleve) Peragallo) and rest were from Dinophyceae (*Coolia monotis* Meunier; *Dinophysis acuminata* Claparède and Lachmann; *Dinophysis caudata* Saville-Kent; *Dinophysis fortii* Pavillard; *Dinophysis miles* Cleve; *Dinophysis tripos* Gourret; *Gonyalux monilatum* (Howell) Taylor and *Prorocentrum lima* Ehrenberg). Presence of these algae indicates a potential threat to our coastal environment on the event of probable bloom formation.

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