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# †Bloom of *Noctiluca scintillans* (Macartney) in Gulf of Mannar, southeast coast of India

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**Abstract**

From 2.10.08 to 12.10.08 an intense bloom of *Noctiluca scintillans* (Macartney) was observed for the first time in the coastal areas of Gulf of Mannar (southeast coast of India) near Appa Island, Thalaiyari Island and Valai Island and subsequently it intensified into a dense bloom in Muthupettai area and spread from Kilakarai to Pamban. The coastal waters appeared dark green and microscopic examination revealed the presence of *N. scintillans*. The organism is bioluminescent, inflated and sub-spherical. The size of the organism ranged from 400-1200 microns. Though the species is colourless, the presence of photosynthetic green endosymbionts make the water green. The high temperature, salinity and low pH aided the spread of the bloom to adjacent areas of Muthupettai. During the intense period of bloom, the concentration of *N. scintillans* was around 13.5 lakh cells /l, the dissolved oxygen level was below detectable level and the total suspended solids was 510 mg/l, thereby increasing the turbidity and cutting of light to the bottom. This resulted in biodiversity loss in the intensely affected area from Valai Island to Muthupettai coast. The environmental parameters during the waning phase of the bloom were, surface water temperature 29.5° C, salinity 34.2 ppt, dissolved oxygen 4.86 ml/l, phosphate 8.28µ g at/l and ammonia 85 µ g at/l. Further investigations indicated the resilience of the ecosystem to recover from the sudden natural damage.

**Keywords:** Algal bloom, *Noctiluca scintillans*, Gulf of Mannar, loss of biodiversity

## Introduction

In recent years, there are several reports of harmful algal blooms (HABs) in the world oceans. Many instances of the occurrences of algal blooms and consequent mortality of fish in Indian waters have been recorded which were caused mainly by the bluegreen alga, *Trichodesmium erythraeum* or the green flagellate *Hornelia marina*. Bloom formation by *N. scintillans* was also reported. (Prasad, 1953; Subrahmanyan, 1953; Prasad and Jayaraman, 1954; Katti *et al.,* 1988; Shetty *et al.,* 1988; Zaitsev *et al.,* 1988; Sargunam *et al.,* 1989; Cortes *et al.,* 1995; Eashwar *et al.,* 2001; Nayar *et al.,* 2001, Mohanty *et al.,* 2007). *N. scintillans,* commonly called sea sparkle, is a dinoflagellate that can aggregate into a bloom, producing substances that are potentially toxic to marine life. *N. scintillans* is a heterotrophic large (up to 1200 µm), obloid and luminescent dinoflagellate, frequently associated with red tide events (Elbrachter and Qi, 1998). It is considered non-toxic, but is responsible for fish and benthic fauna mortalities associated with anoxia. More recently it has been reported that *N. scintillans* may act as a vector of phycotoxins to higher trophic levels by feeding on toxigenic microalgae (Escalera *et al*., 2007). Increase in seawater viscosity is frequently associated with phytoplankton blooms. The fish would have to use more oxygen in the action of pumping water than the amount they could extract from the pumped water, thus dying due to oxygen deficiency (Jenkinson, 1993).

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Gulf of Mannar, which extends from Rameswaram to Kanyakumari has a chain of 21 Islands (area of each Island 0.95 to 130 ha) along the 140 km stretch between Tuticorin and Rameswaram (08°55'-09°15'N lat. and 78°0'-79°16'E long.). The bloom of *N. scintillans* was observed from 02.10.2008 around the coastal areas of Gulf of Mannar near Appa Island, Thalaiyari Island and Valai Island and later it intensified into dense bloom in Muthupettai area and spread from Kilakarai to Pamban. The bloom led to loss of biodiversity in the core area, resulting in the death of organisms in the lower as well as higher trophic levels. It is well understood that the outbreak of algal bloom in the seas is due to complex interplays between temperature, currents, wind and nutrients. We made an attempt to assess the probable cause of the bloom, the extent of the affected area, the biodiversity loss and the resilience of the ecosystem to recover from the impact of the bloom.

## Material and methods

Surface water samples during the bloom were collected onboard fishing vessel from the surrounding waters of the Valai Island and the nearby coastal waters. The latitude and longitude of the sampling stations were marked using a portable Global Positioning System (Garmin GPS map 76, USA). The sampling stations were from Pamban (09º 16' 47.6" N lat. 79º 11' 17.1" E long.) to Keelakarai (09º 14' 28.5" N lat. 78º 54' 21.6" E long.).

The water sample from the bloom affected stations (Fig.1) was collected following standard sampling procedure (APHA, 1995). The pH and salinity were analyzed using WTW Germany- series Multi 720 water analyzer. The dissolved oxygen was measured by Winkler's titration method using a digital burette and nutrients by the methods described by Parsons *et al*. (1984). The total suspended solids were determined using a millipore filtration unit by estimating the residue retained on pre-weighed glass fiber filter after drying. Chlorophyll *a* was extracted by adding 90%v/v acetone as per standard procedure. For the determination of ammonia in seawater the method of indo-phenol blue reaction of Solarzano (1969) was followed. The meteorological data on atmospheric temperature and wind velocity were obtained from the Field Centre of Central Electrochemicals Research Institute, Mandapam Camp. The water quality and meteorological parameters during 2006-2008 were utilized for comparison with those of the bloom period for interpretation of the cause of the bloom.

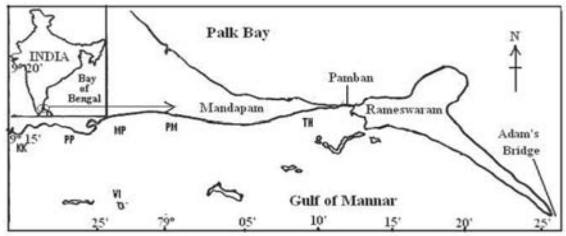


Fig. 1. Location of the study area (KK: Keelakarai; PP: Periapattinam; MP: Muthupettai; PM: Pudhumadam; TH: Thonithurai; VI: Vali Island)

The different species of phytoplankton in the <100 µm size fraction were counted on a Sedgwick-Rafter counting chamber under an Olympus binocular microscope. The density was calculated in cells per liter. During the dense period of the bloom 100-500 ml samples were taken for cell count. The taxonomic identification was carried out following Hasle and Syversten (1997) for diatoms and Steidinger and Tangen (1997) for dinoflagellates. Observations of marine organisms dead in the shoreline from Periapatinam to Pudhumadam as well as the Valai Island were made. Underwater observations of coral reef in Valai Island were also carried out to assess the impact of the bloom on the reefs.

## Results and Discussion

The coastal waters had a deep green colour during the bloom period (Fig. 2). Microscopic examination revealed the presence of *N. scintillans*. The organism is bioluminescent, inflated and sub-spherical (Fig. 3). The size ranged from 400 to 1200 microns. Though the species is colourless, the presence of photosynthetic green endosymbionts *Protoeuglena noctiluca* Subrahmanyan turned the water green. A maximum cell count of 13.5 x $10^5$ cells/l was observed on 9.10.08 at Muthupettai.

Fig. 2. Discoloration of coastal water due to the bloom

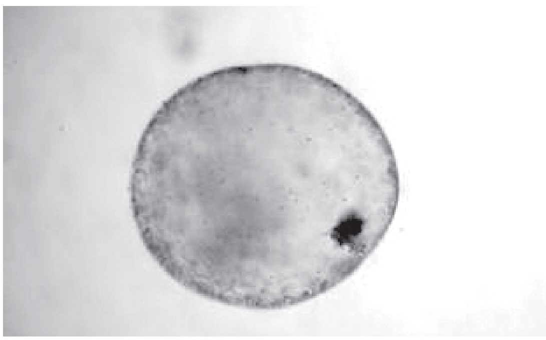

Fig. 3. *Noctiluca scintillans* as seen under the microscope

The cell density of *N. scintillans* was higher than that reported by previous observers. Mohanty *et al.* (2007) recorded 2.38 x $10^5$ cells/l off Orissa in the Bay of Bengal during April 2005. The colour of the bloom reported by Mohanty *et al.* was red whereas Eashwar *et al*. (2001) observed *N. scintillans* bloom in Port Blair Bay in July 2000 which turned the coastal waters to vivid green colour.

Intense bloom of *N. scintillans* was observed from 2.10.08 to 13.10.08 from Pudhumadam to Periapattinam and the cell density ranged from 5.1x $10^5$ cells/l to 13.5 x $10^5$ cells/l with the total exclusion of other phyto and zooplankton. At Pamban during the same period amphipods, fish eggs and larvae, and different diatoms *viz., Cyclotella meneghiniana*, *Synedra formosa, Nitzschia sigmoides*, *Thalassiosira subtilis*, *Coscinodiscus concinnus*, *Corethron hystrix*, *Guinardia flaccida, Climacosphenia moniligera*, *Climacosphenia elongata*, *Thalassionema nitzschioides*, *Thallassiothrix longissima* and *Mastogloia minuta* were observed.

Observations on 14.10.08 indicated that the bloom had started its declining phase and the cell count was 1.6x $10^5$ cells at Valai Island station II. On 15.10.08 the cell densities of diatoms noted at Muthupettai and Kilakarai were *Ceratium furca* (5000 cells/l), *Ceratium tripos* (8000 cells/l), *Synedra formosa* (6000 cells/l), *Pleurosigma directum* (4000 cells/l), *Gyrosigma balticum* (6000 cells/l), *Navicula distans* (9000 cells/l), *Nitzschia seriata* (5000 cells/l), *N. closterium* (3000 cells/l), *Mastogloia minuta* (3000 cells/l), *N. sigmoides* (2000 cells/l) and *Thallassiothrix longissima* (5000 cells/l) indicating that the bloom of *N. scintillans* had declined. Along the shoreline of the mainland from Periapattinam to Pudumadam, diverse groups of marine fauna were dead and washed ashore during the bloom period (Fig. 4). The dead animals were mainly coral reef associated which indicated that the bloom had first affected coral reef around the Islands.

Fig. 4. Fishes and other organisms dead and washed ashore at Valai Island

During $5^{th}$ – $9^{th}$ October, 2008, nearly 14 tonnes of commercially important fishes were washed ashore from Pudumadam to Periapattinam landing centre. The dead animals noticed ashore in the Islands and coasts of Muthupettai, Periappatinam, Pudumadam were rabbitfishes, moray eels, goatfishes, serranids, carangids, silverbellies, barracudas, halfbeaks, seabass, flathead, surgeonfishes, threadfin breams, snappers, breams, silverbiddies, theraponids, anchovies, lesser sardines, *Psammorperca* spp., lizardfishes, endangered animals such as seaturtles, seahorses; ornamental fishes like chaetodontids, parrotfishes, damselfishes, squirrelfishes, clownfishes; sea snakes, molluscs (cuttlefishes, squids, *Trochus* sp., *Cypraea* sp., clams (*Cardium* sp., *Donax* sp.;) crabs (*Portunus pelagicus*, *Charybdis natator*); jellyfishes, sea anemones, sea cucumbers and polychaetes.

Underwater observations during the declining phase of the bloom on 14.10.08 showed that the corals were partially or completely bleached and the seaweeds were degenerating. There were no associated fishes in the severely affected coral reefs at Valai Island. The death of the marine organisms as well as the bloom led to the formation of thick mucus-like layer, which settled on the seaweeds, corals and the bottom sediment substratum. This led to the death of almost all the marine fauna and flora due to asphyxiation.

The results of the physico-chemical parameters of the water samples (Table 1) showed that the total suspended solids and chlorophyll *a* values were very high during the bloom. This had led to increase in the turbidity of water and visibility was nil. The dissolved oxygen level was nil during intense bloom and it resulted in the mortality of corals and coral-associated biodiversity. The phosphate level was very high (8.28µ g at/l) during the decline of the bloom while ammonia (92.31µ g at/l) and Chlorophyll *a* (115.89µ g at/l) were the highest. The same trend was observed by Eashwar *et al*. (2001) in Port Blair Bay. The silicate values were less (3.26-nil µ g at/l) during the bloom period in all stations (Table 1) and this could be due to the utilization of silicate by the bloom.

Zooplankton was nil in all the intensely affected stations and the salinity value was high during the bloom phase. Prasad (1956) also observed an inverse relationship between salinity and zooplankton in Mandapam waters. According to Jayaraman (1954) the most important factor governing the seasonal distribution of salinity in these waters is the two monsoon driven current systems. During the transition period of the monsoons, the currents are more variable and the wind velocity was also higher in May and September (Fig. 5) for the three years (2006-2008). A mass balance occurs between the water mass in the Palk Bay and that of the Gulf of

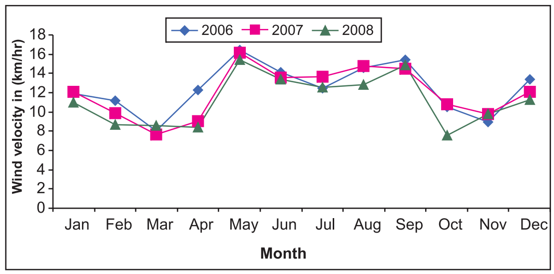


Fig. 5. Variation in wind velocity during the bloom for the period 2006-2008

Table 1. Physicochemical parameters observed during the bloom

| Station | Date | pH | Salinity ppt | D.O. ml/l | T.S.S mg/l | Ammonia µg at/l | Phosphate µg at/l | Silicate µg at/l | Nitrite µg at/l | Nitrate µg at/l | Chlorophyll *a* mg/m3 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Muthupettai | 9.10.08 | 6.11 | 37.2 | nil | 510 | 50 | 0.321 | 3.297 | 1.763 | 1.842 | not observed |
| Periayapattinam | 9.10.08 | 6.64 | 37.4 | nil | 490 | 2.63 | 38.02 | 0.256 | 0.538 | 0.597 | not observed |
| Pamban | 10.10.08 | 7.89 | 37.1 | 3.17 | 86 | 3.823 | 0.25 | nil | 0.36 | 1.052 | 1.12 |
| Pudumadam | 10.10.08 | 7.12 | 37 | 1.09 | 154 | 3.724 | 18.02 | 1.231 | 0.735 | 0.379 | 37.49 |
| Pudumadam | 13.10.08 | 7.37 | 36.9 | 0.99 | 115 | 30.94 | 0.819 | nil | 0.221 | 0.735 | 6.051 |
| Pamban | 13.10.08 | 7.77 | 35.4 | 4.49 | 92 | 2.31 | 0.42 | 5.198 | 0.0953 | 1.289 | 3.051 |
| Periayapattinam | 14.10.08 | 7.7 | 36.2 | 3.05 | 236 | 92.31 | 8.279 | 0.074 | 0.854 | 0.854 | 115.89 |
| Vali island Stn I | 14.10.08 | 8.03 | 34.7 | 5.02 | 26 | 18.18 | 2.755 | nil | 0.973 | 1.526 | 29.97 |
| Vali island Stn II | 14.10.08 | 7.52 | 33.8 | 2.67 | 28 | 85 | 0.079 | 0.404 | 0.221 | 0.893 | 37.03 |
| Muthupettai | 15.10.08 | 7.49 | 36.3 | 3.87 | 43.4 | 28.97 | nil | 1.231 | 0.636 | 1.585 | 19.45 |
| Kelakarai | 15.10.08 | 7.71 | 35.9 | 4.04 | 32.2 | nil | 0.325 | 0.487 | 0.004 | 1.15 | 5.63 |
| Periayapattinam | 15.10.08 | 7.84 | 35.6 | 4.18 | 39.3 | 3.21 | nil | 2.13 | 0.236 | 2.31 | 14.31 |
| Vali island Stn I | 18.10.08 | 7.94 | 34.2 | 5.02 | 45 | 2.83 | 0.416 | 3.26 | 0.231 | 3.2 | 7.796 |
| Vali island Stn II | 18.10.08 | 7.94 | 34.2 | 4.52 | 32 | 2.15 | 0.321 | 7.63 | 0.186 | 2.14 | 1.149 |
| Thonithurai | 20.10.08 | 7.7 | 29.2 | 4.86 | 38.3 | 2.042 | nil | 12.47 | 0.34 | 0.636 | 7.325 |
| Muthupettai | 17.11.08 | 7.89 | 34.6 | 4.83 | 21.2 | 1.59 | nil | 1.231 | 0.182 | 0.715 | 1.12 |

Mannar and it could be the reason for weak current during the bloom period. Daily variation in wind velocity as shown in Fig. 6 revealed that it was low from Oct. 2nd to Oct.9th in comparison to the previous years indicating that the current speed also would have been low. The visual observations at Pamban showed that the current direction changed on Oct. 10th in 2008.

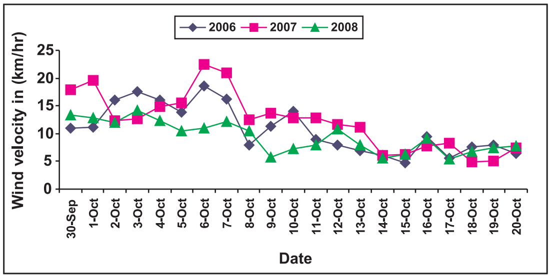


Fig. 6. Daily variation in wind velocity during the bloom for the period 2006-2007

It was noted during the period that at the narrow strip of coastal area from Kilakarai to Pamban the air temperature was considerably high (Fig. 7). This, combined with the nutrient load brought in by the higher amount of rainfall of the previous months could have resulted in the occurrence of the bloom. The bloom persisted in the affected areas for more than ten days due to favourable environmental parameters. High temperature, salinity, low pH, absence of water currents, high concentration of nutrients, absence of rain and the favorable wind direction towards the shore were the major factors which influenced the sustenance of the bloom around the Islands and coastal waters. The coastal area affected was comparatively shallow and semi-enclosed and this resulted in spreading the bloom

Fig. 7. Variation in air temperature during the bloom for the period 2006-2008

even to the bottom waters causing oxygen deficiency. The corals and the associated biodiversity of the area were adversely affected. The decaying and fouling of dead organisms led to considerable increase in ammonia and total suspended solids, which resulted in mortality of a large variety of marine organisms in the area.

The environmental parameters noted during the waning phase of the bloom period were surface water temperature (29.5°C), salinity (34.2 ppt), dissolved oxygen (4.86 ml/l), phosphate (8.28 µg at /l) and ammonia (85 µg at / l). As weather conditions changed in the area and heavy rains started from 12th October, the water quality improved on subsequent days. The current direction was from north to south as the northeast monsoon gained strength. This increased the dissolved oxygen, brought down the temperature, salinity and nutrients in the water to the normal levels.

Fig. 8. Bleached corals and degenerating seaweeds

Subsequent observations during November – December, 2008, showed that the physico-chemical parameters returned to normalcy. However, corals in the core affected area did not show any sign of restoration. Seaweeds were found to grow over the dead coral colonies (Fig. 8). A few reef fishes *viz.*, rabbitfishes, surgeonfishes, moray eels, carangids, snappers and theraponids were found recruited to the habitats. It is quite evident that the occurrence of blooms in coral reef areas is detrimental to the corals and the associated fauna. The recovery of the coral reef ecosystem is much slower and the loss of biodiversity is much severe since the restoration of coral colonies and their associated biodiversity is a long-term process.

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