Preponderance of heterotrophic Noctiluca scintillans during a multi-species diatom bloom along the southwest coast of India

ARTICLE *in* INTERNATIONAL JOURNAL OF OCEANS AND OCEANOGRAPHY · JANUARY 2010

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International Journal of Oceans and Oceanography
ISSN 0973-2667 Volume 4, Number 1 (2010), pp. 55-63

http://www.ripublication.com/ijoo.htm

Preponderance of heterotrophic *Noctiluca scintillans* during a multi-species diatom bloom along the southwest coast of India

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Abstract

A red tide of heterotrophic dinoflagellate *Noctiluca scintillans* was observed off Kochi (Southwest coast of India) along with a multi species diatom bloom generated by upwelling induced eutrophic conditions during south west monsoon in August 2008. Spread over an area of ea 5 km^2 the bloom was recorded as viscous fluid of tomato soup consistency. *Noctiluca* cell count of 8.1x 10^8 cells L^{-1} were recorded from the bloom area. The whole area where the bloom occurred was conspicuously bioluminescent. The percentage composition of *N. scintillans* and diatoms in the bloom waters were 56.17% and 43.83% respectively. Diatoms were present in high numbers with cell density 6.32x 10^8 cells L^{-1}. Diatoms were mainly represented by the species belonging to the genera *Chaetoceros, Navicula, Thalassiosira, Coscinodiscus,* and *Nitzschia* which were also the main food item found within the *Noctiluca* cells. Closer observation of the *Noctiluca* cells revealed that the food vacuoles contained diatom cells and remains of these species. It is implied that the abundance of *N. scintillans* could be due to the occurrence of its preferred food species.

Keywords: Dinoflagellates; Diatoms; Eutrophication; *Noctiluca scintillans*; Red tides.

Introduction

Open ocean blooms of the dinoflagellate *Noctiluca* is a common feature all along the west coast of India towards the last phase of the productive seasons. *Noctiluca* is classified as a HAB species as they cause large scale mortality of caged fish [1] and other fin fishes through oxygen depletion, gill clogging and production of NH_3 [2, 3]. Alternate forms of the species, *Noctiluca scintillans* (Macartney) Kofoid & Swezy 1921 (syn. = *Noctiluca miliaris* Suriray) dominate the blooms of the North west (15° to 22° N) and South west coasts (18°N to 15°N) of India. Extensive blooms of the green *Noctiluca* is a recurring phenomenon along the Northern Arabian Sea during the wane winter monsoon season (February- March). Winter monsoon corresponds to the period of peak primary production along the Northern Arabian Sea due to nutrient availability in the surface waters brought about by the combined influence of the cold and dry north easterlies, convective mixing and regenerated production [4]. Green forms of *Noctiluca* that are autotrophic due to the presence of the photosynthetic endosymbiont, *Pedinomonas noctilucae* [5, 6] dominate the blooms both in the open ocean and coastal waters of Northern Arabian Sea [7, 8]. Crashing stages of these blooms to a large extent contributes to the oxygen minimum zones (OMZ) in the intermediate depths of Northern Arabian Sea due to bacterial decomposition of exported organic matter. Unlike this, blooms of the red *Noctiluca* which appears along the South west coast towards the end of the upwelling seasons (June-September) are phagotrophic in nature, lack endosymbionts and feed predominantly on diatoms, bacteria, protozoans, copepods, eggs of copepods and fishes and detritus [9- 12]. Blooms of red *Noctiluca* thus become a competitor to the larvae, juveniles and adults of the oil sardine which shoals the coastal waters during the upwelling seasons for breeding and larval growth. The present paper reports the occurrence of red *Noctiluca scintillans* and its bloom from coastal waters of southwest coast of India.

Materials and methods

The bloom was observed off Kochi (Lat.10^{o}00.103 N and Long. 75^{o}32.396 E) on 19th August 2008 during a cruise in FORV Sagar Sampada along the South west coast of India (Figure 1). The bloom was with brick red discolouration of surface water (Figure 2), spread over an area of 5 km^2. For the qualitative and quantitative analysis of phytoplanktons, 50 litres of discoloured surface water samples were taken using clean plastic bucket and filtered through 20 micron bolting silk and the filtrates were preserved in 1-3% neutralized formaldehyde solution. The *Noctiluca* cells were counted with Sedgwick-Rafter counting chamber using a Nikon Eclipse microscope. *N. scintillans* specimens were examined primarily to identify the ingested food items. The phytoplankton species were identified using Hasle and Syversten [13] for diatoms and Steidinger and Tangen [14] for dinoflagellates. Vertical profiling of parameters like temperature, salinity, density etc was also done using the CTD (Seabird 911 plus CTD) attached sensors to understand the oceanic processes. Sea surface temperature (SST) of the bloom region was measured by a bucket thermometer. Dissolved oxygen was estimated following Winkler method. pH was measured using an electronic Ino Lab (WTW series) pH meter. Chlorophyll *a* was determined by filtering one litre of water sample through GF/F Whatman filter paper. The pigments were extracted using 10 ml of 90% acetone. The solution was centrifuged for about 20 minutes under 5000 rpm and the optical density of the supernatant solution were then measured in a Perkin Elmer UV-Visible spectrophotometer [15]. Nutrients (nitrite, nitrate, phosphate and silicate) were analysed using segmented flow Auto Analyzer (SKALAR) onboard the vessel by following standard procedures [16]. Meteorological parameters were obtained from Automated Weather Station (AWS). Mesozooplankton samples were collected by Multiple Plankton Net (MPN) and Bongo nets. After measuring the biomass by displacement volume method, samples preserved in 5% formaldehyde solution.

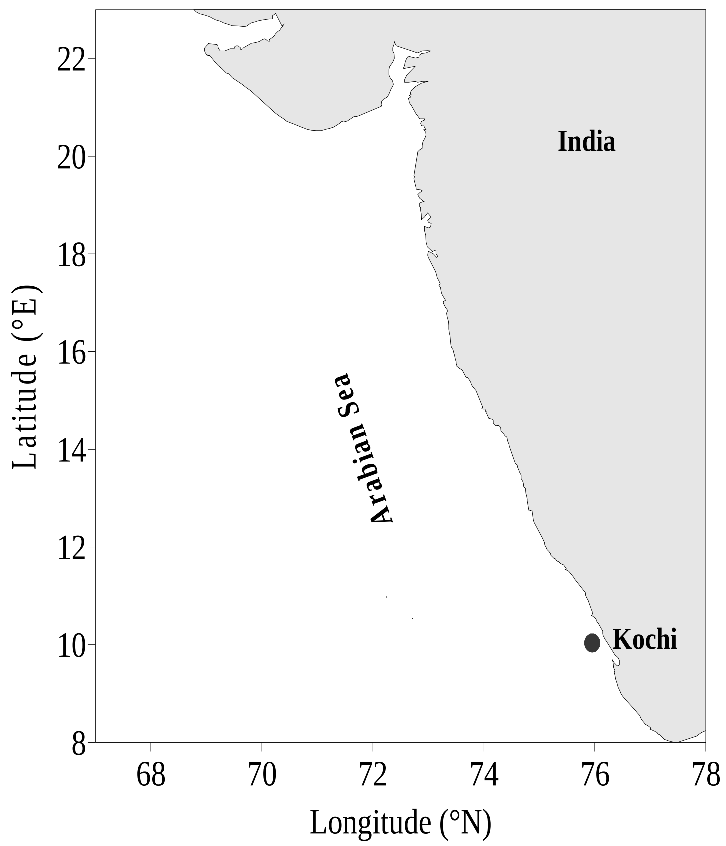

Figure 1: Map showing the location of *Noctiluca* bloom along Southwest coast of India.

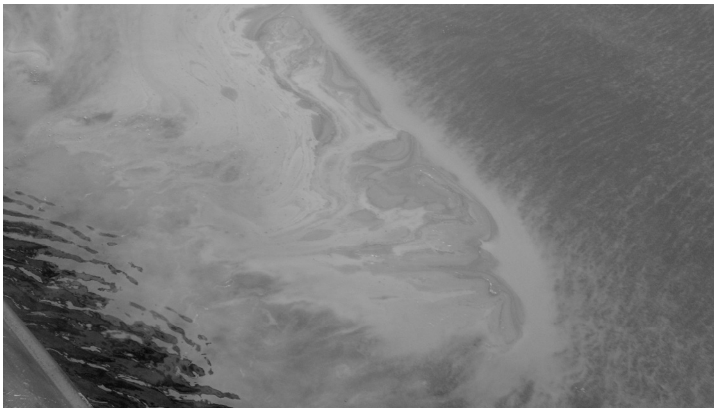

Figure 2: Red *Noctiluca* bloom off Kochi (Lat. 10°00.103 N, Long. 75°32.396 E).

Results and discussion

Examination of the bloom samples collected revealed that the discolouration was caused by the predominance of *Noctiluca scintillans*. The *Noctiluca* cells were large with ~500-1000 µm diameter (Figure 3) that floats with the current and cannot swim actively. Average *Noctiluca* cell count 8.1x 10^8 cells L^{-1} were recorded from the bloom area. The bloom however was, not monospecific. Diatoms were present in high numbers with cell density reaching levels of 6.32x 10^8 cells L^{-1}. The percentage composition of *N. scintillans* and diatoms in the bloom waters were 56.17% and 43.83% respectively. Diatoms belonging to fourteen genera were represented by *Asterionella japonica, Biddulphia mobiliensis, Cerataulina sp., Chaetoceros lorenzianes, Chaetoceros curvisetus, Chaetoceros sp., Coscinodiscus asteromphalus, Eucampia, Fragilariopsis curta, Guinardia spp., Lauderia spp., Navicula delicatula, Nitzschia spp., Pleurosigma acuminatum, Pseudonitzschia spp., Rhizosolenia, Thalassionema nitzschioides* and *Thalassiosira spp.*

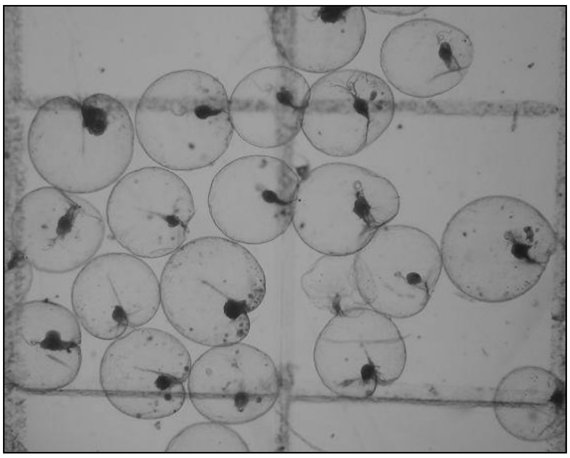

Figure 3: *Noctiluca* cells (40x).

Noctiluca (Latin- means shiner by night) is commonly known as ‘sea sparkles’ because of its ability to produce blue bioluminescence at night times. The bioluminescent characteristic of *N. scintillans* is produced by a luciferin- luciferase system located in thousands of spherically shaped organelles, or “microsources”, located throughout the cytoplasm of this single-celled protist. Nonluminescent populations within the genus *Noctiluca* lack these microsources. It may be bioluminescent except in parts of the northern and eastern Pacific Ocean [17]. It was observed that sparkling bioluminescence lighted up the wakes of the ship at night. This glowing trail of water formed by the passage of ship retains its common name ‘sea sparkle’.

Noctiluca scintillans has been reported as a voracious feeder preying on different micro organic food species of the pelagic food web [18- 20]. Green *N. scintillans* in nature primarily depends on the photosynthetic products of endosymbionts. However, the growth and proliferation of the red form of *N. scintillans* without endosymbionts depend very much on the size, quality and density of the prey [21- 23]. *Noctiluca* collected during this bloom in the southwest Arabian Sea harboured diatoms (*Thalassiosira*, *Pseudonitzschia* etc.) in the food vacuoles suggesting that *N. scintillans* feeds on phytoplankton (Figure 4 and 5). Most of this algae, particularly species of *Pseudonitzschia* are known to produce toxins that can cause fish kill and also lead to shell fish poisoning in humans. However, it is interesting to note that *Noctiluca* can feed toxic phytoplankton and thus function as vector for transfer of such toxins to higher trophic levels [18, 24, 25].

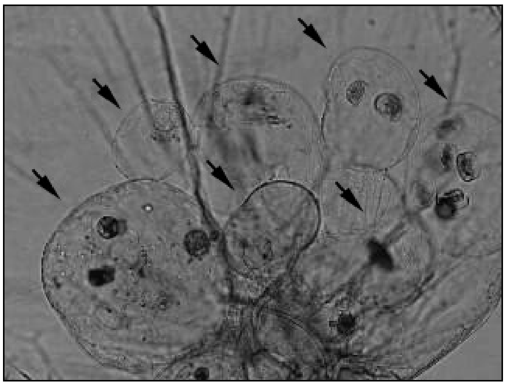

Figure 4: Food vacuoles near the gullet area inside *Noctiluca* cells (200x)

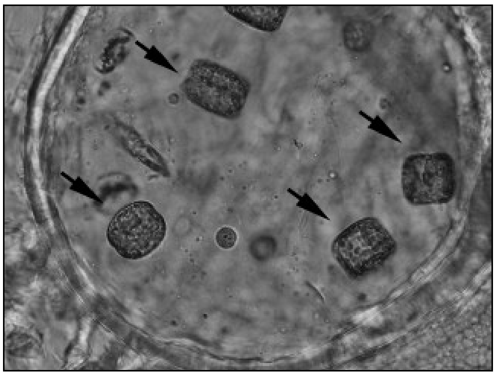

Figure 5: Single food vacuole with diatoms cells inside (400 x).

Noctiluca is a competitor for the food of oil sardine (*Sardinella longiceps*) as both feed on diatoms like *Coscinodiscus, Nitzschia, Fragilaria* and *Thalassiosira* etc [26] and the appearance of *Noctiluca* bloom may have a bearing on the decrease in catch of oil sardines from such areas. It is clear from our observations and enquiries (personal communication with fisher folks) that the commercial fishes particularly the shoaling species like mackerels, sardines, anchovies and fish larvae and zooplankton did not appear in such waters. There was no mortality of fish during the bloom period.

The physicochemical characteristics like, slimy water and increased ammonia concentration of the affected waters were in some way unfavourable for live fishes that they completely avoided such areas.

The sea surface temperature (SST) during this period ranged from 26.03°C to 27.24°C. It has been reported that calm sea with relatively low temperature is favourable for triggering the appearance of the bloom [27]. Relatively stable low temperature, high salinity, calm sea, muggy weather and high prey concentration prevailed during the last phase of upwelling along the southwest coast favored the proliferation and blooming of *Noctiluca.* The salinity value of the bloom station was 34.11 psu.

In the bloom area the dissolved oxygen concentration was high (6.89 ml L^{-1}) due to the increased photosynthetic activity of the diatom cells. This also indicates that the bloom was in its peak period. Normally *Noctiluca* bloom occurs in nutrient enriched waters during the course of plankton succession. High concentration of macronutrients like nitrate, phosphate and silicate in the surface layers during intense upwelling initially favours the proliferation of smaller diatoms. When the nutrient concentration decreases due to assimilation and weakening of upwelling, larger diatoms and dinoflagellates start to dominate and their low growth rate enables them to survive in such conditions. In the present study the bloom area showed lower concentration of nutrients except silicate. The low values of inorganic nutrients (NO_3-N, 0.44 µmol L^{-1} and PO_4-P, 0.19 µmol L^{-1}) indicated that these were being actively utilized by the fairly large standing stock of phytoplankton. The relatively high value of silicates during the bloom (18.29 µmol L^{-1}) probably reflects the silicate excreted from *Noctiluca* which is known to be a consumer of diatoms [28]. Vertical distribution of physico-chemical parameters of the bloom area is represented in figure 6.

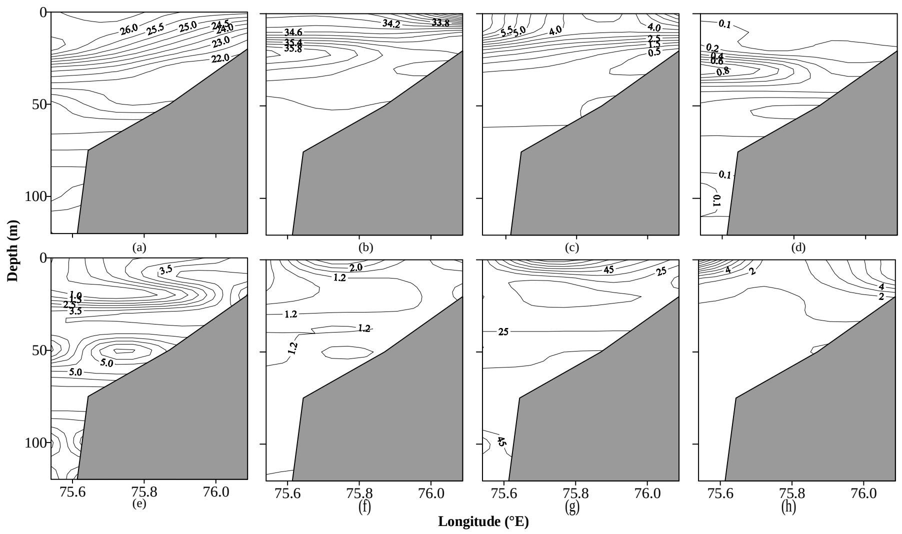

Figure 6: Vertical distribution of **(a)** Temperature (°C) **(b)** Salinity (psu) **(c)** Dissolved Oxygen (ml L^{-1}) **(d)** Nitrite (µmol L^{-1}) **(e)** Nitrate (µmol L^{-1}) (**f**) Silicate (µmol L^{-1}) (**g**) Phosphate (µmol L^{-1}) and **(h)** Chlorophyll *a* (µg L^{-1}) in the bloom area.

The analysis of pigments in the bloom area revealed relatively high values of chlorophyll *a* (12.342 µg L^{-1}). These high values observed may be probably due to diatoms associated with *Noctiluca* as the heterotrophic *Noctiluca* cells observed here lacked the green endosymbiont *Pedinomonas noctilucae*. In the present study zooplankton biomass was lower in the bloom area (993.17 ml $1000m^{-3}$) compared with the adjacent stations (1707.01 ml $1000m^{-3}$). Copepods represented the major group in all the stations with a comparative decrease in bloom stations. The reasons for the reduced zooplankton biomass were 'animal exclusion' ascribable to the direct effects of external metabolites or ectocrines produced by the *Noctiluca* bloom and also by the competition for food resources between *Noctiluca* and zooplankton.

Conclusion

The reasons for the preponderance of *Noctiluca* are not clearly understood, but we hypothesize that *Noctiluca* multiplies rapidly and form aggregation only when the calm conditions prevail in the area, because turbulent conditions seem to be unfavourable for their rapid growth and blooming. Another factor is diatom abundance, if *Noctiluca* is present or carried into an area where there is rich diatom population, they multiply rapidly and form bloom provided the sea is calm. It is evident from the present study that the bloom of *Noctiluca* takes place only in the calm sea during or preceded by diatom bloom.

High primary production along the west coast during the monsoons owing to nutrient enrichment of the waters from upwelling and estuarine discharges probably sets the stage for blooming of non-autotrophic forms like *Noctiluca*. Normally along the west coast, red tides are generally reported between the July to October, coinciding with the end of the upwelling season, when the weather is warmer with far longer hours of sunshine. The frequency of *Noctiluca* red tides has increased considerably in the coastal waters and it is believed to be linked with the eutrophication of coastal waters and the *Noctiluca* bloom probably is a biological indicator of eutrophication.

Acknowledgements

The authors are grateful to all the participants of FORV Sagar Sampada cruise during 18th to 20th August 2008 for the help rendered in sampling. This investigation was carried out under the Marine Living Resources Programme funded by Ministry of Earth Sciences, Govt. of India, New Delhi.

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