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Silicate as the Probable Causative Agent for the Periodic Blooms in the Coastal Waters of South Andaman Sea

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Abstract

Periodic algal blooms of three diatom species such as *Coscinodiscus centralis, Rhizosolenia alata* and *Rhizosolenia imbricata* were observed during September 2011, December 2011 and March 2012 in the coastal waters of South Andaman Sea at Junglighat bay area (11° 39 N and 92° 43 E). The blooms were intense, with *Coscinodiscus* at a concentration of 89,000 cells mL^{-1} (contributing 85 to 98 % to the total phytoplankton population), *Rhizosolenia alata* at a concentration of 13,000 cells mL^{-1} (86-93 %) and *Rhizosolenia imbricata* at a concentration of 19,000 cells. mL^{-1} (91-99 %). Nutrients, most importantly nitrate and silicate have emerged as the key factors controlling phytoplankton growth in this area.

Keywords: Diatom; Blooms; Andaman; Silicate; Junglighat Bay

Introduction

Phytoplankton is key organisms in aquatic ecosystems. They initiate the marine food chain, by serving as food to primary consumers [1, 17]. Phytoplankton undergoes spatiotemporal changes in their distribution due to variation in the influence of hydrographic factors on individual species. Favorable environmental conditions such as adequate nutrients, light and temperature, trigger periods of rapid reproduction called blooms [8]. Literature available on the distribution of phytoplankton in coastal waters around the Andaman Islands is meager [3, 14-15]. Very little is known about the factors i.e. role of nutrients and the impact of other factors, such as light, mixing and dissolved organic matter that contribute to the taxonomic composition of phytoplankton and bloom formation from this area. The Andaman Islands are characterized by a very heavy rainfall almost all through the year owing to the fact that both the monsoon patterns of India affect their climate. Though the Andaman Sea is oligotrophic in nature, eutrophication during monsoon is high as large quantities of sediment and detritus is transported to the Andaman Sea from outside. This appears to supplement the nutritional inadequacy of these waters [12]. This paper attempts to bring attention to the occurrence of periodic diatom blooms in the coastal waters of South Andaman and examines the possible causes for the blooms.

Materials and method

Junglighat Bay (11° 39 N and 92° 43 E) is one of the major fish landing centers in Port Blair, South Andaman Islands. This bay is funnel shaped (Figure 1) with the mouth 3 to 4 times wider than the head end. The average depth of Junglighat Bay is 4.5 meters and maximum depth at high tide is 6.2 meters.

This bay receives a large influx of sewage discharged from adjacent areas. Patches of mangroves are present both at the head end and right side of the bay. The area is enclosed by hills on all three sides and there is a marked freshwater influx in the intertidal region. Mechanized and motorized boats with fishing trawls land their catches here regularly and release oil, plastics, fish wastes, etc. A fishing community is the key source of sewage and domestic waste. Anthropogenic discharge into this area contributes to elevated nutrient concentrations [11].

Monthly collections of plankton samples were made. Each set of samples was collected in triplicate to ensure accuracy. Plankton samples were collected using plankton net (mesh size, 50 μm) from the surface. The plankton samples were fixed in 4% formaldehyde solution and fixed with Lugol's iodine solution immediately after collection. Surface water temperature was measured using a standard mercury Centigrade thermometer. Salinity was estimated with the help of a hand-held refractometer (ATAGO). pH was measured using a pH meter (OAKTON) from Eutech Instruments. Dissolved oxygen was estimated by the modified Winkler's method. *Chlorophyll a* (90% acetone method) was measured spectrophotometrically in the laboratory [16] and expressed as $mg.L^{-1}$.

Triplicate surface water samples were collected separately in clean polyethylene bottles for analysis of nutrients, and stored immediately in an ice box for transport to the laboratory. The collected water samples were filtered by using a Millipore filtering system and then analyzed for dissolved inorganic nitrate, nitrite, and ammonia, reactive silicate, inorganic phosphate, adopting the standard procedures described by Strickland and Parsons (1972) and expressed in $\mu g.\ L^{-1}$. To identify the species of phytoplankton, 1 to 2 drops of the sample was put on a slide, covered with a coverslip and examined under light microscope.

The phytoplankton samples were identified by reference to identification keys [19, 3, 4, 2]. Phytoplankton cell counts were performed using a Sedgewick-Rafter Counting Slide [4].

$$N = [n \times v \times 1000] / V$$

where N is the total number of phytoplankton cells per liter of water filtered, n is an average number of phytoplankton cells in 1 ml of sample, v is the volume of phytoplankton concentrates, V is the volume of total water filtered. The data were processed using Microsoft Excel and SPSS v.14 software packages. Analysis of variance (one-way ANOVA) was applied to test the differences among independent groups (physico-chemical variables) and the chlorophyll-a content.

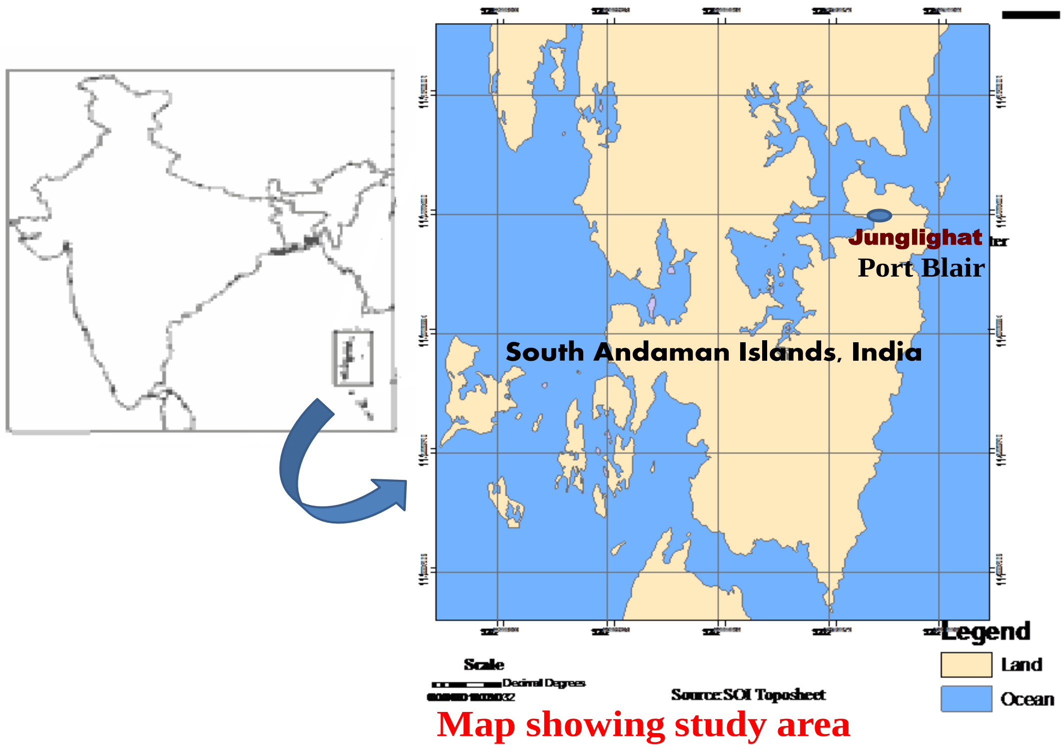

Figure 1 Geographical location of the study area.

Results

Since monthly sampling was carried out, the months before and after the month when the bloom occurred are denoted as pre-bloom and post-bloom periods, respectively.

1) Hydrography

The study was conducted from August 2011 to April 2012, with samples collected every month. During this period, water temperature varied from 24-28˚C. Higher temperature (28˚C) was recorded during October, November 2011 and April 2012. Salinity ranged from 31 to 35‰ and increased during October and December. Both water temperature and salinity were generally low during the monsoon month (September). Dissolved oxygen varied from 3.2 mg L^{-1} to 4.5 mg. L^{-1}, with higher values (4.2-4.5 mg L^{-1}) recorded during January and February 2012. The low oxygen value recorded during September (3.2 mg. L^{-1}) could be due to the occurrence of a diatom bloom of *Coscinodiscus centralis* (Tables 1, 2 and 3).

Chlorophyll *a* concentrations varied from 0.07- 0.167 µg l^{-1} (Tables 1, 2 and 3). Higher values of chlorophyll a (0.167 µg L^{-1}) was recorded during September 2011, 0.147 µg L^{-1} in December 2011 and 0.142 µg L^{-1} March 2012, due to bloom-forming diatoms such as *Coscinodiscus centralis, Rhizosolenia alata* and *Rhizosolenia imbricate*. Population density and chlorophyll *a* did not show any significant correlation ($p>0.05$), whereas a positive correlation ($p<0.05$) was found between chlorophyll *a* and nutrients.

Table 1 Physicochemical parameters in Junglighat Bay – *Coscinodiscus centralis* bloom

Physicochemical parameters	**Pre-bloom Aug 2011**	**Bloom Sep 2011**	**Post-bloom Oct 2011**
Temperature (°C)	24	25	28
Salinity (‰PSU)	33	32	33.5
pH	7.5	7.7	7.7
Dissolved oxygen (mg L^{-1})	3.7	3.2	3.52
Chlorophyll a (mg L^{-1})	0.09	0.167	0.08
Nitrite (µmol L^{-1})	0.32	0.99	0.21
Nitrate (µmol L^{-1})	2.7	5.6	0.57
Phosphate (µmol L^{-1})	0.42	0.58	0.46
Silicate (µmol L^{-1})	6.07	13.1	4.2

Table 2 Physicochemical parameters in Junglighat Bay – *Rhizosolenia alata* bloom

Parameters	**Pre-bloom Nov 2011**	**Bloom Dec 2011**	**Post-bloom Jan 2012**
Temperature (°C)	28	26	28
Salinity (‰PSU)	32	29	32
pH	8.3	8.0	8.2
Dissolved oxygen (mg L^{-1})	4.2	3.92	4.2
Chlorophyll a (mg L^{-1})	0.08	0.147	0.07
Nitrite (µmol L^{-1})	0.35	0.99	0.5
Nitrate (µmol L^{-1})	0.92	3.82	1.14
Silicate (µmol L^{-1})	4.58	14.42	6.074
Phosphate (µmol L^{-1})	0.49	0.60	0.36

Table 3 Physicochemical parameters in Junglighat Bay – *Rhizosolenia imbricata* bloom

Parameters	**Pre-bloom Feb 2012**	**Bloom Mar 2012**	**Post-bloom Apr 2012**
Temperature (°C)	26	26	28
Salinity (‰PSU)	31	33	32
pH	8.2	7.9	7.8
Dissolved oxygen (mg L^{-1})	4.46	4.2	4.02
Chlorophyll a (mg L^{-1})	0.09	0.142	0.08
Nitrite (µmol L^{-1})	0.67	0.74	0.11
Nitrate (µmol L^{-1})	1.21	1.01	1.21
Phosphate (µmol L^{-1})	0.05	0.071	0.052
Silicate (µmol L^{-1})	5.70	7.99	5.74

2) Bloom forming species

During September 2011, the cell numbers and chlorophyll *a* (Table 1) identify *Coscinodiscus centralis* as the species responsible for the massive bloom of 95,000 cells. ml^{-1} during the month of September. *Coscinodiscus centralis* was the most abundant species in the study area, and was responsible for blooms with high relative abundance (99.9%) which led to mono-specific populations (Figure 2).

During December 2011, *Rhizosolenia alata* (Figure 3) caused bloom with considerable cell densities in the coastal waters of south Andaman (13,000 cells. ml^{-1}) and contributed 86-93% to total phytoplankton density.

During March 2012, *Rhizosolenia imbricate* (Figure 4) dominated 91-99% of the total phytoplankton biomass. Based on these data, *Rhizosolenia imbricata* was identified as the bloom-forming species with a population density of 19,000 cells. ml^{-1}.

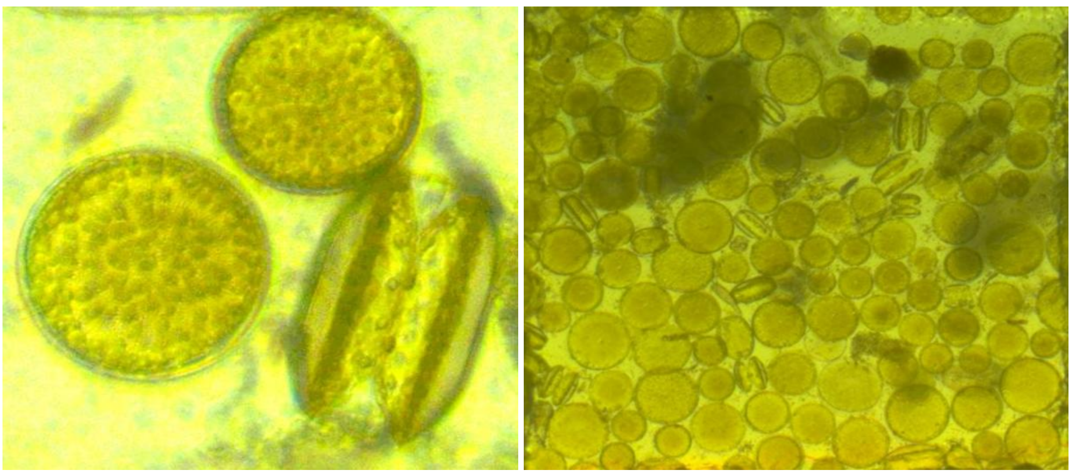

Figure 2 Microscopic view of the bloom-forming diatom *Coscinodiscus centralis*.

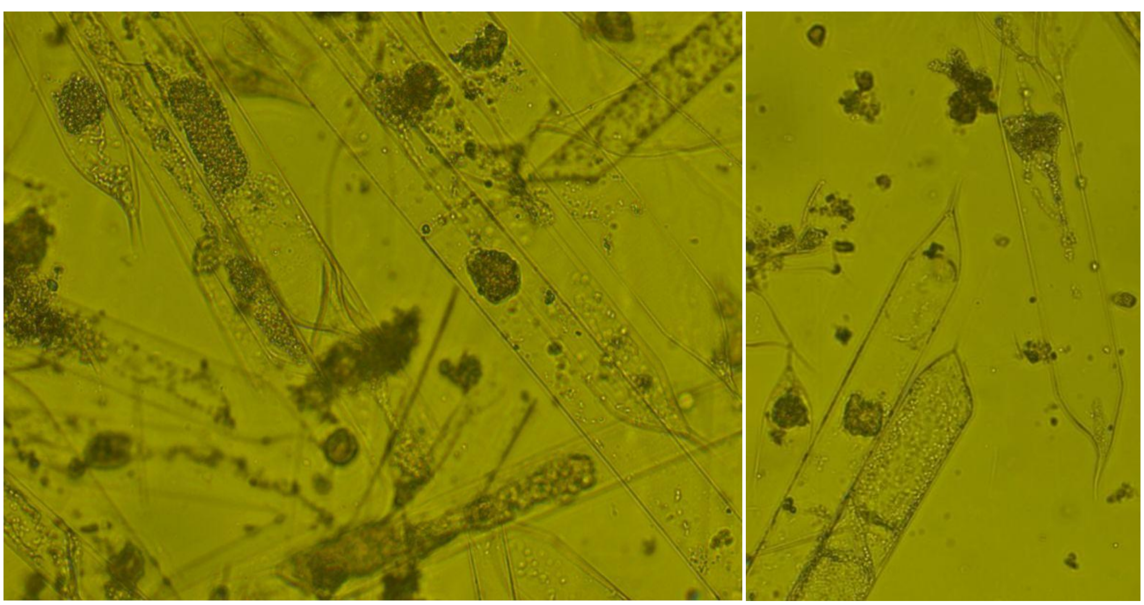

Figure 3 Bloom-forming diatoms*Rhizosolenia alata* as viewed under the microscope.

3) Physicochemical parameters

September was the month with the maximum recorded rainfall after the advent of the 2011 monsoon, and also the month of highest rainfall in 2011. During December 2011, rainfall was also heavy due to Cyclone *Thane*. Blooms of both *Coscinodiscus centralis* and *Rhizosolenia alata* were triggered by nutrient inputs transported by runoff during rainfall during these periods. In contrast, in the case of *Rhizosolenia imbricata*, the bloom occurred at the end of a low-rainfall period, which led to a sudden burst of nutrients, eliciting the bloom. The fluctuations in temperature and salinity merely reflect the changes brought by rainfall. It can be said that both parameters were at optimal levels to maintain the blooms. Fluctuations in temperature, salinity and pH are co-incidental with the bloom and are not causative agents. Dissolved oxygen was very low during the bloom, indicating utilization of oxygen by the rapidly-multiplying diatoms and the chlorophyll *a* level was highest during the bloom, indicating the productivity of such a massive number of diatoms.

It is evident from the graph (Figure 5) that higher nitrate: silicate ratios favour the occurrence of a diatom bloom.

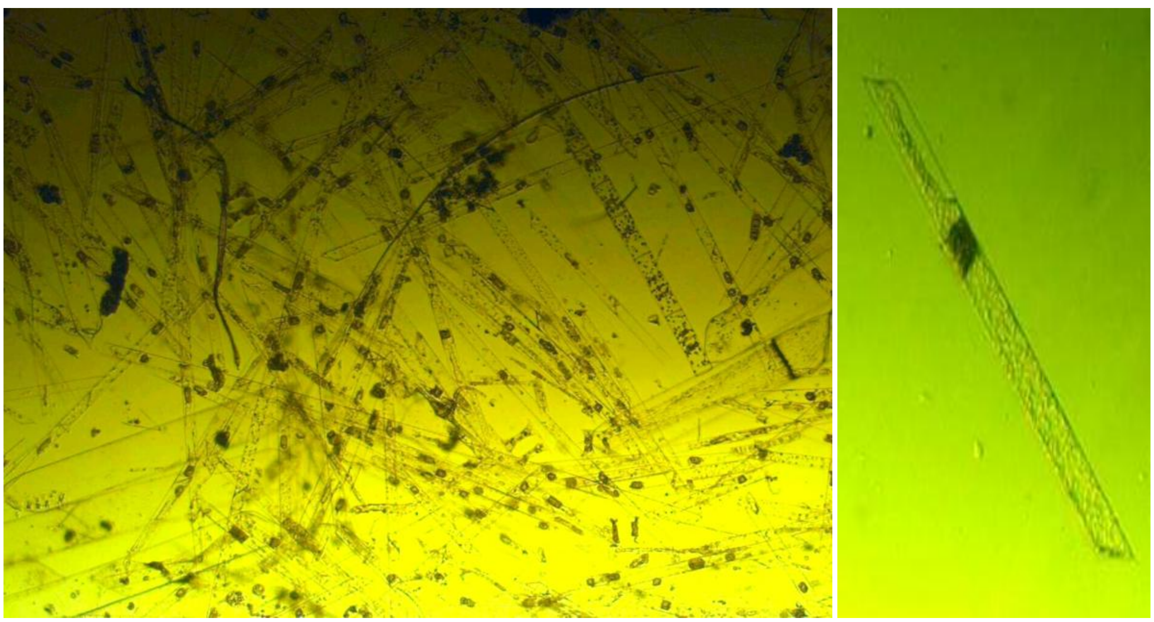

Figure 4 Bloom-forming diatoms *Rhizosolenia imbricate* under the microscope.

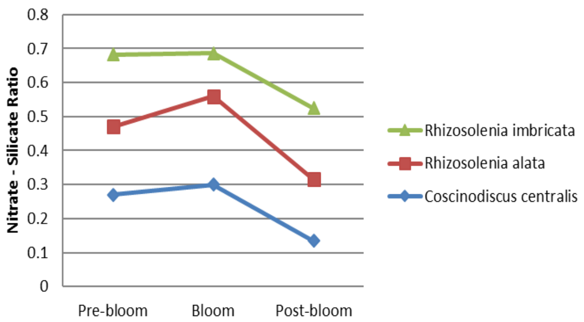

Figure 5 Nitrate-silicate ratios during pre-bloom, bloom and post-bloom periods.

Discussion

During the blooms, temperature varied in a narrow range (25-26°C) and concentration of nutrients (nitrate, silicate and phosphate) was high. Chlorophyll *a* concentrations in Junglighat Bay during September (0.167 μg L^{-1}) and December (0.147 μg L^{-1}) 2011 and March (142 μg L^{-1}) corresponded to the periodic blooms in this area. Chlorophyll *a* and nutrients showed a positive correlation (p<0.05; one-way, ANOVA). In this study, silicate and nitrate levels showed almost a two-fold increase in concentrations (Tables 1, 2 & 3) during the blooms. N: Si ratio influences the composition of phytoplankton. Bloom-forming diatom species require silicon as a major nutrient and nitrate: silicate ratio influence the composition of phytoplankton as observed in this study has been reported earlier [5-6, 9-10, 13, 18,]. In very low concentrations, dissolved silicon (DSi) becomes the limiting nutrient for the growth of diatoms [5]. It may appear that nitrate and silicate are both causative agents for these blooms, but previous research has shown that a bloom of diatoms is always accompanied by an increase in silicate concentration in the surrounding waters [5]. Also, previously, blooms of dinoflagellates in this area have been caused by increase in nitrate concentration alone (Arun Kumar *et al*, unpublished data). This leads us to conclude that despite the significant increase in nitrate along with an increase in silicate concentration, silicate was responsible for triggering the bloom of diatoms. Previous studies [5] pointed out the dominance of flagellate communities and the absence of diatom dominance during periods of eutrophication. This concept is baffling as it questions the occurrence of diatom bloom during rainfall which normally favors eutrophication. But we can presume that silicon influx is coincidental to the rainfall and production of large quantities of detritus from dissolved organic matter which remains suspended, enriching the food value of the water column [12]; this process could have triggered the diatom bloom in our study. Though the actual source of silicate during these particular conditions is unclear, it is now evident that silicate is the causative agent for the recurring diatom blooms in the Junglighat Bay area of Andaman.

Conclusion

The present study indicated that silicate was the causative agent for the frequent blooms in the Junglighat region. The general nutrient profiling of the Andaman Sea, especially various coastal areas is suggested as it is important to gain a greater understanding of the influence of nutrients on marine life. Further studies are needed on the qualitative and quantitative impact of these periodic blooms on organisms at higher trophic levels, and especially onlandings of economically important planktivorous fish species. Such studies will allow more precise assessment of the economic impact of diatom blooms. The authors propose a complete nutrient profiling of this area during various seasons to understand, in a periodic sense, the nutrient patterns of this anthropogenically influenced bay.

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