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Monitoring the Diatom bloom of *Leptocylindrus danicus* (Cleve 1889, Bacillariophyceae) in the coastal waters of South Andaman Island

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Hydrographical parameters were studied and nutrients such as nitrate, nitrite, phosphate and silicate were measured. Temperature ranged from (24.5-27ºC), Salinity ranged from (19-25 psu). Nutrients such as nitrite varied between 0.23-1.009 µmol. l^{-1}, nitrate (0.63-4.71 µmol. l^{-1}), phosphate (0.02-0.23 µmol. l^{-1}) and silicate concentrations remained much higher and exhibited between the ranges of 4.07-10.37 µmol. l^{-1}. Biomass expressed in terms of chlorophyll *a* was high, ranged from 0.09-0.267µg. l^{-1}. It was found out that an increase in the nutrient content has initiated the bloom. In the present investigation, following species of phytoplankton were found to be common; diatoms such as *Bacteriastrum* sp., *Cerataulina* sp., *Chaetoceros* sp., *Corthron* sp., *Coscinodiscus* sp., *Guinardia* sp., *Odontella* sp., dinoflagellates such as *Ceratium* sp., *Gonyaulax* sp., *Gymnodinium* sp., *Prorocentrum* sp and *Protoperidinium* sp. An increase in rain fall (904.0 mm) during September 2012 due to south west monsoon which was also found to be major factor that contributed to the bloom.

[Keywords: Phytoplankton, *Leptocylindrus danicus*, Bloom, Nutrient, Eutrophication, South Andaman Island.]

Introduction

Phytoplankton are the primary producers form the base of food web that support food for the commercially exploited fishes in the marine environment[1-3]. Most of these blooms are extremely beneficial to the marine organisms as it acts as a primary source of food for various larvae. However, in some instance algal blooms may have a negative effect causing severe economic loss to aquaculture, fisheries and tourism in addition to major environmental and health related hazards by producing harmful or toxic effect to the ecosystem Saundprs *et al*[4]. Among the ancient diatom lineages, marine planktonic genus *Leptocylindrus*, of the order Leptocylindrales, exhibits a relatively simple morphology. This species have cylindrical cells with two or more plastids and valves without conspicuous processes or complex ornamentations. Molecular phylogeny resolves the genus as sister to a clade containing most or all other diatoms Sorhannus *et al*[5]. Literature available on the phytoplankton bloom in coastal waters around Andaman Islands is meager[6-9]. Centric diatoms of the genus *Leptocylindrus* are common in the marine environment worldwide. The chain-forming marine centric diatom *Leptocylindrus danicus* is an important component of spring phytoplankton blooms in temperate coastal waters around the world[10-14]. Comprehensive surveys in Danish and Norwegian waters disclosed this species to be a characteristic component of spring and early summer blooms[10,15-18]. One species becomes numerically dominant than the other forms and occur as a mono specific bloom. This is a remarkable phenomenon, especially dependent on the nature of environment. Andaman water is one of the least explored areas with regard to physiochemical and biological studies[19]. Expansion in anthropogenic activity, urbanization, tourism and marine transportation are factors that affect significantly the quality of the coastal waters. Recently Sachithanandam *et al*[6] reported that physico-chemical parameters are induced by climate change may be the reasons for phytoplankton bloom in the coastal waters of North Andaman regions.

Materials and Methods

The Andaman and Nicobar Islands comprise over 572 Islands, situated between 06° 45' and 13°45' N latitude and 92° 10' and 94° 15'

experiences an active South-West monsoon from June-September and North-East monsoon from December-April[20-21]. Present study was conducted in Junglighat Bay (92° 43'56"N and 11° 39'21"E) on the East coast of Andaman situated near the Haddo harbour and is one of the major fish landing centers in Port Blair (Fig. 1). Anthropogenic influence is very high here when compared to the other coastal regions of South Andaman Island[21].

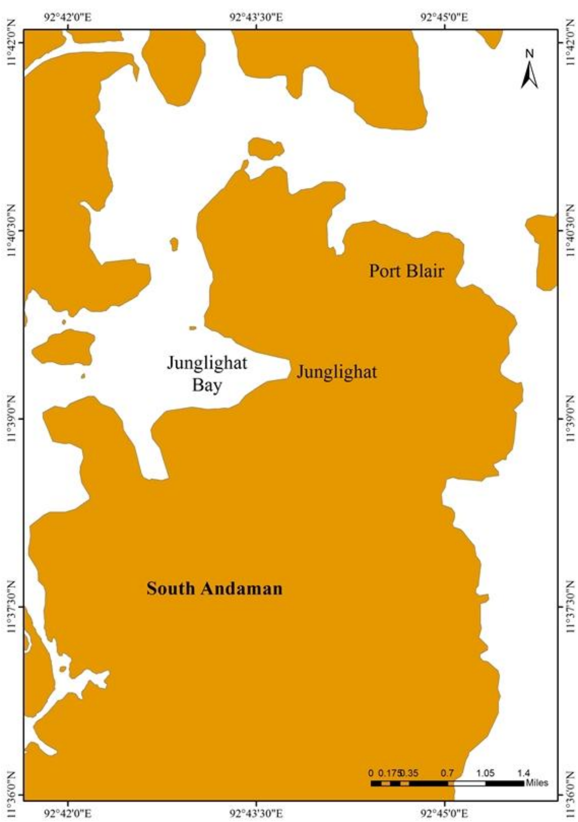

Fig. 1—Map showing Study Area Junglighat Bay

Monitoring the algal bloom of centric diatom viz. *Leptocylindrus danicus* was carried out during the month of September 2012 at Junglighat Bay, South Andaman. Plankton samples were collected by using a plankton net (mesh size, 20µm) at the surface layers. Plankton samples were fixed in 4% formaldehyde solution immediately after collection. Temperature was measured using standard mercury Centigrade Thermometer. Salinity was estimated with the help

E longitude in North-South direction. The Islands have a land area of 8,293 sq. Km. Climate in the Andaman and Nicobar Island is typically tropical with annual rainfall of about 3000 mm and

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[22] and Chlorophyll-*a* (90% acetone method) estimation was carried out spectrophotometrically in the laboratory[23] and expressed as µmol. L^{-1}. Primer 6 was used for the Cluster analysis[24].

Surface water samples were collected in clean polyethylene bottles for the analysis of nutrients, which were kept immediately in an Ice box, and then transported to the laboratory. The collected water samples were filtered by using a Millipore filtering (0.47µm) system and then analyzed for dissolved inorganic nitrate, nitrite, reactive silicate and inorganic phosphate, adopting the standard procedures[23] and expressed in µmol. l^{-1}.

In laboratory, 1ml of the preserved phytoplankton sample was taken in the Sedgewick-Rafter Counting slide[25] covered with a cover slip and examined under the Nikon inverted plankton microscope to identify the specimens up to the species level. Species level identification of the phytoplankton samples was done with the help of valid identification keys[26-29]. The phytoplankton cell counts were performed on Sedgewick Rafter Counting Slide[25].

$$N = \frac{n \times v \times 1000}{V}$$

Where N is the total number of phytoplankton cells per liter of water filtered

n is an average number of phytoplankton cells in 1mL of sample

v is the volume of phytoplankton concentrates

V is the volume of total water filtered.

Result

A total of 44 species belonged to 23 genera were identified at Junglighat Bay. Diatoms (29 species belonged to 18 genera) and dinoflagellates (14 species belonged to 5 genera) were the most important taxonomic groups observed in this region. The bloom of *Leptocylindrus danicus* was recorded for the first time in South Andaman Islands. During the study period certain genus of diatoms such as *Coscinodiscus* sp., *Corthron* sp., *Odontella* sp., *Bacteriastrum* sp., *Chaetoceros* sp., *Guinardia* sp., *Hemiaulus* sp., *Pleurosigma* sp., *Pseudo-nitzschia* sp. and dinoflagellates such as *Ceratium* sp., *Gonyaulax* sp., *Gymnodinium* sp., *Protoperidinium* sp., *Prorocentrum* sp., etc (Table 1) were found to be common.

The bloom forming species *Leptocylindrus danicus* was found to be dominant (67,000 cells. l^{-1}) contributed 95-99% (Fig. 2a-b) to the total phytoplankton population. The occurrence of bloom was found to be in correlation with a heavy rainfall of (904.9 mm) during south west monsoon for a period of four days[30].

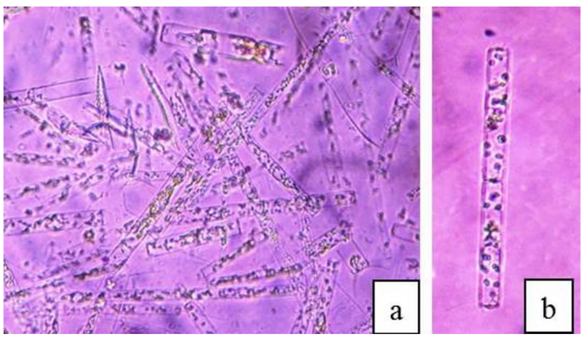

Fig. 2a,b—*Leptocylindrus danicus* bloom colony form and individual cells.

The number of species (S) and range of diversity indices in the study area are shown in (Table 2). Maximum number of species (25) were recorded on 6th day with total individuals (N) found to be 67112. Margalef richness (D) was high (2.3) during the 6th day and lowest value (0.9) was recorded on 1st day.

Pielous evenness (J') was high (J=0.08) and lowest value (0.01) was recorded during the 1st and 6th day respectively. The species diversity was high during the 6th day (H'=0.24) and low (H'=0.02) recorded during first day (Table 2).

Two distinct groups formed during bloom period between 1st to 4th day showing >90% similarity but there was much variation in second group i.e. 5th and 6th day of sampling during the bloom period (Fig. 3).

The hydrological parameters were also analyzed during and after the bloom. During the bloom period, surface water temperature ranged from 24.5-27ºC and atmospheric air temperature ranged from 23-25ºC (Fig. 4).

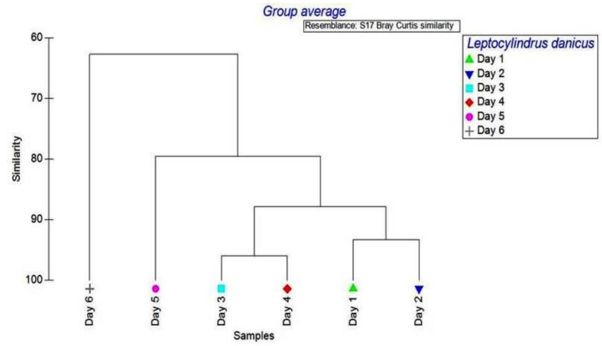

Fig. 3—Cluster analysis forming groups during the *Leptocylindrus danicus* bloom in Junglighat Bay.

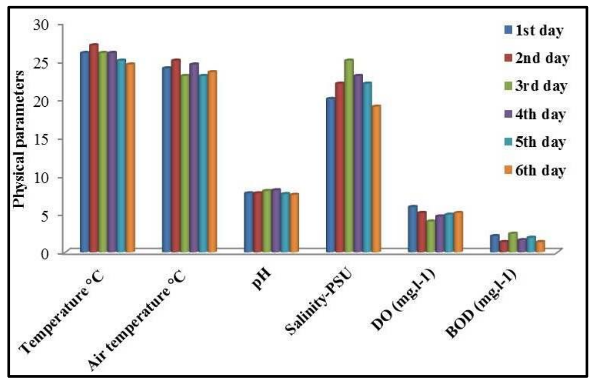

Fig.4—Environmental parameters of study area during the bloom period September (25th-30th).

pH values varied from 7.5-8.1. During the study period these parameters did not show any correlation with bloom appearance as they remained almost stable during pre-bloom, bloom and post bloom periods. The salinity ranged from 19- 25 psu and dissolved oxygen ranged from (4.02-5.9 mg.l^{-1}). During the first day, dissolved oxygen was high (5.9 mg. l^{-1}). Biological oxygen demand ranged from 1.33-2.42 mg. l^{-1} (Fig. 4). Dissolved inorganic nutrients such as nitrate, nitrite, phosphate and silicate concentration and biological parameter such as chlorophyll *a* values showed much variation (Table 3). During the bloom period (September 2012) a high amount of rainfall has been recorded (904.9 mm) and comparatively less rainfall was reported during the pre bloom period August 2012 (406.4 mm) it was much less (252.4 mm), during post bloom period.

The heavy rainfall during September 2012 caused the bloom and simultaneously the salinity

(20 psu) was also lower at that point of time while nitrate ranged from 0.63 – 4.71 µmol. l^{-1} and nitrite 0.23-1.009 µmol. l^{-1}. Phosphate concentration exhibited a range from 0.02 to 0.23 µmol.l^{-1} during the bloom while Silicate concentration remained much higher and varied from 4.07-10.37 µmol. l^{-1} (Table 4).

Table 1—The check list of phytoplankton in Study site during bloom period

S. No.	Species Name	1st day	2nd day	3rd day	4th day	5th day	6th day
	Diatom						
1	*Bacteriastrum furcatum* (Shadbolt)	-	+	+	+	-	-
2	*Cerataulina pelagica* (Cleve) Hendey	-	-	-	+	-	+
3	*Chaetoceros affinis* (Lauder)	-	-	+	-	-	+
4	*C. curvisetus* (Cleve)	-	-	+	-	+	+
5	*C. decipiens* (Cleve)	+	+	+	+	-	+
6	*C. didymus* (Ehrenberg)	-	-	-	-	-	+
7	*C. diversus* (Cleve)	-	-	-	-	+	+
8	*C. wighamii* (Brightwell)	-	+	-	+	-	-
9	*Corthron ceriophilum* (Castracane)	-	-	+	-	-	-
10	*Coscinodiscus asteromphalus* (Ehrenberg)	-	-	-	-	+	+
11	*C. centralis* (Ehrenberg)	+	+	+	+	+	+
12	*C. granii* (Gough)	+	+	+	+	-	+
13	*C. marginatus* (Ehrenberg)	+	-	+	-	-	-
14	*Dactyliosolen fragilissimus* (Bergon)	-	-	-	-	-	+
15	*Ditylum brightwellii* (West)	-	-	-	-	+	+
16	*Guinardia striata* (Stolterfoth)	-	+	+	-	-	-
17	*Hemiaulus sinensis* (Greville)	-	-	+	-	-	-
18	*Lauderia annulata* (Cleve)	-	-	+	+	-	+
19	*Leptocylindrus danicus* (Cleve)	+	+	+	+	+	+
20	*L. minimus* (Gran)	-	+	+	+	-	-
21	*Navicula* sp. (Bory)	-	-	-	-	+	+
22	*Nitzschia sigma* (Kutzing)	-	-	-	-	-	+
23	*Odontella mobiliensis* (Bailey)	+	+	+	-	-	+
24	*O. sinensis* (Greville)	-	+	+	-	-	-
25	*Pleurosigma* sp. (Smith)	-	-	-	+	-	-
26	*P. strigosum* (Smith)	-	-	-	-	+	-
27	*Pseudo-nitzschia* sp. (Peragallo)	+	-	-	+	+	+
28	*Rhizosolenia setigera* (Brightwell)	-	+	-	-	+	-
29	*Skeletonema costatum* (Greville)	-	-	-	-	+	-
	Dinoflagellate						
31	*Ceratium furca* (Ehrenberg)	+	+	+	+	+	+
32	*C. fusus* (Ehrenberg)	+	+	+	+	+	-
33	*C. lunula* (Schimper)	-	-	-	+	+	-
34	*C. trichoceros* (Ehrenberg)	-	+	-	+	-	-
35	*Gonyaulax conjuncta* (Wood)	-	-	-	-	-	+
36	*G. polygramma* (Stein)	-	+	-	-	-	+
37	*Gymnodinium catenatum* (Graham)	+	-	-	-	-	+
38	*Prorocentrum micans* (Ehrenberg)	-	+	+	-	+	+
39	*Protoperidinium biconicum* (Dangeard)	-	-	-	-	+	+
40	*P. depressum* (Bailey) Balech	+	+	+	+	+	-
41	*P. divergens* (Ehrenberg)	+	+	+	+	+	-
42	*P. pentagonum* (Gran)	-	-	+	-	-	+
43	*P. pyriforme* (Paulssen) Balech	-	+	-	-	-	+
44	*P. steinii* (Jorgensen) Balech	-	-	+	-	-	-

Note: (-) absent; (+) occurrence

Table 2—Number of species (S), Individuals (N), Margalef diversity (D), Pielous evenness (J') and Shannon (H') during September (25th - 30th).

Days	(S)	(N)	(D)	(J')	H' (loge)
1st	12	67112	0.990	0.006	0.016
2nd	19	58694	1.639	0.031	0.031
3rd	22	51182	1.937	0.037	0.034
4th	17	47193	1.487	0.032	0.037
5th	18	36624	1.618	0.011	0.032
6th	25	23259	2.387	0.075	0.241

Table 3—Nutrients values (µmol. l^{-1}) & Chlorophyll-*a* (µg l^{-1}) on study site during bloom period from 25th to 30th September 2012

Days	NO_2	NO_3	PO_4	SiO_4	Chl -*a*
1st day	0.90	3.36	0.21	10.37	0.26
2nd day	0.57	3.02	0.23	5.55	0.24
3rd day	0.67	4.71	0.13	8.14	0.18
4th day	1.0	3.70	0.07	7.40	0.14
5th day	0.40	2.6	0.05	6.29	0.16
6th day	0.23	0.63	0.02	4.07	0.09

NO_2-Nitrite; NO_3 _ Nitrate; PO4 – Phosphate; SiO4 – Silicate; Chl–*a* - Chlorophyll-*a*

Table 4—Hydrographical parameters during the study period August 2012 to October 2012

Hydrological parameters	Pre bloom August 2012	Bloom September 2012	Post bloom October 2012
Salinity (PSU)	26	20	26
Water temperature (ºC)	26.5	26	28
Air temperature (ºC)	25	24	26
pH	7.6	7.7	7.7
Dissolved oxygen (mg.1^{-1})	4.46	5.91	4.13
Biological oxygen demand (mg.1^{-1})	1.89	2.12	1.44
Nitrite (µmol.1^{-1})	1.24	0.67	0.235
Nitrate (µmol.1^{-1})	3.70	5.38	2.69
Phosphate (µmol.1^{-1})	0.24	0.327	0.23
Silicate (µmol.1^{-1})	5.18	8.14	4.81
Chlorophyll *a* (µg. 1^{-1})	0.06	0.167	0.09
Rainfall (mm)	406.4	904.9	252.4

Analysis of physical parameters showed that salinity fluctuated drastically. Dissolved oxygen and biological oxygen demand also altered to a lesser extent mainly due to the high rainfall influencing freshwater input into the coastal waters. The chlorophyll *a* concentration was high on the first day (0.267µg. l^{-1}) but during pre and post bloom, physicochemical parameters and nutrients concentration such as nitrite, nitrate, phosphate and silicate concentrations were found to be very low compared to the bloom period. Chlorophyll *a* concentration was also recorded to be very low before and after the bloom period (Table 4). This is probably due to the decaying of the cells after the bloom. The nutrient inputs are due to the runoff caused by the heavy rainfall and this trigger for *L. danicus* bloom. Also, the heavy fluctuations found in salinity evinced the impact of rainfall on the coastal waters. The variation in Dissolved Oxygen indicated the presence of high number of phytoplankton and other species continuously utilizing oxygen for survival.

Discussion

Seasonal variability of phytoplankton and/or bloom outbreak in the study area is largely due to the intense rainfall during November 2012 which has led to increased nutrient inputs. The export of nutrient concentrations to the oceans has increased three fold times compared to pre-industrial, pre-agricultural levels[31]. Since the early days of phytoplankton ecology, nutrients have been known for controlling the phytoplankton community structure and biomass[32, 33, 34, 35, 21].

Earlier studies conducted weekly in Narragansett Bay, Rhode Island recorded phytoplankton abundance during 1960 to 1979 indicating that *L. danicus* appears after the annual winter-spring diatom bloom, occasionally developing into a dominant component of the late spring flora. It may become numerically important during the autumn diatom pulse, though its appearance during the summer is rare. While the dynamics of the winter-spring bloom have been intensively investigated[36], environmental factors regulating the growth of those species which succeed the winter-spring flora are poorly understood. In fact, only empty frustules with ultra-structural features distinct from those of other *Leptocylindrus* species are observed in nature, almost always colonized by the protozoan *Solenicola setigera* Pavillard[37], and the growth of *L. danicus* in axenic batch culture exhibited a temperature dependent day length effect. Optimum temperature for growth for this species is between 15 and 20ºC, with lower temperatures significantly depressing cell division rates[38]. During the study period in September 2012 high rainfall was observed (904.9 mm).

Fluctuations of the salinity, DO, pH and nutrients in the coastal water habitats are due to the influx of freshwater from land run off, caused by monsoonal rainfall and tidal variations[39, 21]. The fluctuation of atmospheric temperature, seawater temperature, salinity and the nutrients such as nitrite, nitrate and phosphate concentration fluctuations have initiated the bloom. *L. danicus* could be also responsible for local increases in the concentrations of chlorophyll *a* and seem to be very important in terms of the fertility of in the coastal zone. Present bloom *L. danicus* was monitored for six days continuously in the month of September 2012 in an enclosed bay where the anthropogenic activities enhanced over flux of nutrient input into the bay by land runoff.

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[40-46]. The events of harmful blooms from coastal waters of Tamil Nadu, Karnataka, Maharashtra, and Kerala were reported by Bhat & Matondkar[40]. *Trichodesmium* and *Noctiluca* blooms were most frequently observed in the Indian waters[41- 46]. Previous studies in Andaman indicate the blooms of *Noctiluca scintillans, Coscinodiscus centralis*, *Rhizosolenia alata, Rhizosolenia imbricate* and *Trichodesmium erythraeum* was caused by the land runoff which was initiated by heavy rainfall, bringing very high nutrient levels into the coastal waters[8-9, 21]. Most of the blooms occurring during monsoon can be the result of increased discharge of nutrients by land runoff, precipitation and upwelling[47-48]. Consequently, it is essential to have a continuous monitoring of water column and phytoplankton compositions for this bloom and its impact on tropical coastline. Moreover, the present work has indicated that the coastal water of this bay is fast in response to environmental perturbations with phytoplankton as good bio-indicators of disturbance. The present work indicates the absence of phytoplankton community dynamics and population structure in this region. *L. danicus* bloom is reported for the first time in this Island. So it is necessary to carry out detailed studies of water column and planktonic compositions for identifying blooms and their possible impacts along the coastline.

Conclusion

The present study indicated that high nutrient levels, temperature, rainfall and salinity were the primary causative agents triggering occurrence of algal bloom *Leptocylindrus danicus* in the Junglighat Bay. This study explains the nutrients most importantly nitrate and silicate have emerged as the key factors controlling phytoplankton growth in this area. This study suggest a continuous need to assess the nutrient profile in the water column, the taxonomic composition and production of phytoplankton especially from the Junglighat Bay of south Andaman to understand the bloom pattern and their probable impacts along the coastline of south Andaman. In future, this research sites need continuous monitor of physio-chemical parameter for to understand better management of coastal ecosystem for future generation or preservation of pristine environment of Island ecosystem.

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