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Temperature and Salinity Are the Probable Causative Agent for the *Trichodesmium erythraeum* (Cyanophyceae) Algal Bloom on the Burmanallah Coastal Waters of South Andaman Island

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Abstract: An intense *Trichodesmium erythraeum* bloom reported in Burmanallah coast of the region of Port Blair in South Andaman Island on 10th April, 2013. The discoloration of surface water noticed varied from pale brown to pinkish red. Microscopic examination of the surface water revealed the blooming of *T. erythraeum* and its density was reported to be around 43,000 Cells.ml^{-1}. Surface water temperature ranged from 30 to 34°C. Salinities varied from 30 to 33PSU and Dissolved oxygen fluctuated between 3.35 mg. L^{-1} to 4.35 mg. L^{-1}. The concentration of nitrate varied from (1.009 to 2.69 µmol. L^{-1}); (r=0.94; p<0.001) nitrite from (0.168 to 0.403 µmol. L^{-1}); (r=0.83; p<0.01) phosphate (0.105-0.342 µmol. L^{-1}); (r=0.95; p<0.001) and silicate (3.33-6.66 µmol. L^{-1}); (r=0.97; p<0.001). The statiscal analysis such as cluster and CCA suggested that high nutrients levels, temperature and salinity were the primary causative agents triggering occurrence of algal bloom (*T. erythraeum*) and indicating deterioration in the water quality in study site. In the present investigation, the *T. erythraeum* bloom on the water quality and phytoplankton community structure indices were noticed. In recent decaded andaman and Nicobar Island (ANI) especially South Andaman have a notable population increased with associated variations and degradation in the water quality of the inhabited coastal region. This study results conclude that in future, the ANI need continuous monitor of physio-chemical parameters for to understand water quality status and better management of coastal ecosystem for future generation and/or preservation of pristine environment of Island ecosystem.

Key words: Phytoplankton · *T. erythraeum* · water quality · Burmanallah · Andaman Island

INTRODUCTION

Phytoplankton is important constituents of the marine food web and comprises 40 % of the total fixed global primary productivity. They initiate the marine food chain, by serving as food to primary consumers, which include zooplankton, shellfish, finfish and others [1]. *Trichodesmium* sp., a marine nitrogen fixing cyanobacterium, forms extensive surface blooms discolouring vast regions of tropical and subtropical seas. It is one of the common bloom forming species found in tropical to subtropical waters particularly, in the eastern tropical and sub-tropical Pacific and Arabian Sea contributing >30% of algal blooms of the world [2]. *Trichodesmium* sp., bloom produces many harmful effects, sometimes causing damage to coastal fish and shellfish fauna [3]. Followed by frequent occurrence of *Trichodesmium* sp., bloom in Indian waters, it has been reported more frequently in the west coast [4,5] as compared to east coast [6,7]. Generally, the bloom of this filamentous alga occurs during hot weather with brilliant sunlight and stable high salinity [8]. Thus, studying the causes that favour the appearance of this bloom has social and economical connotations. This paper documents the occurrence of algal bloom of *Trichodesmium erythraeum* which occurred in the coastal waters of Burmanallah, South Andaman Islands on April, 2013.

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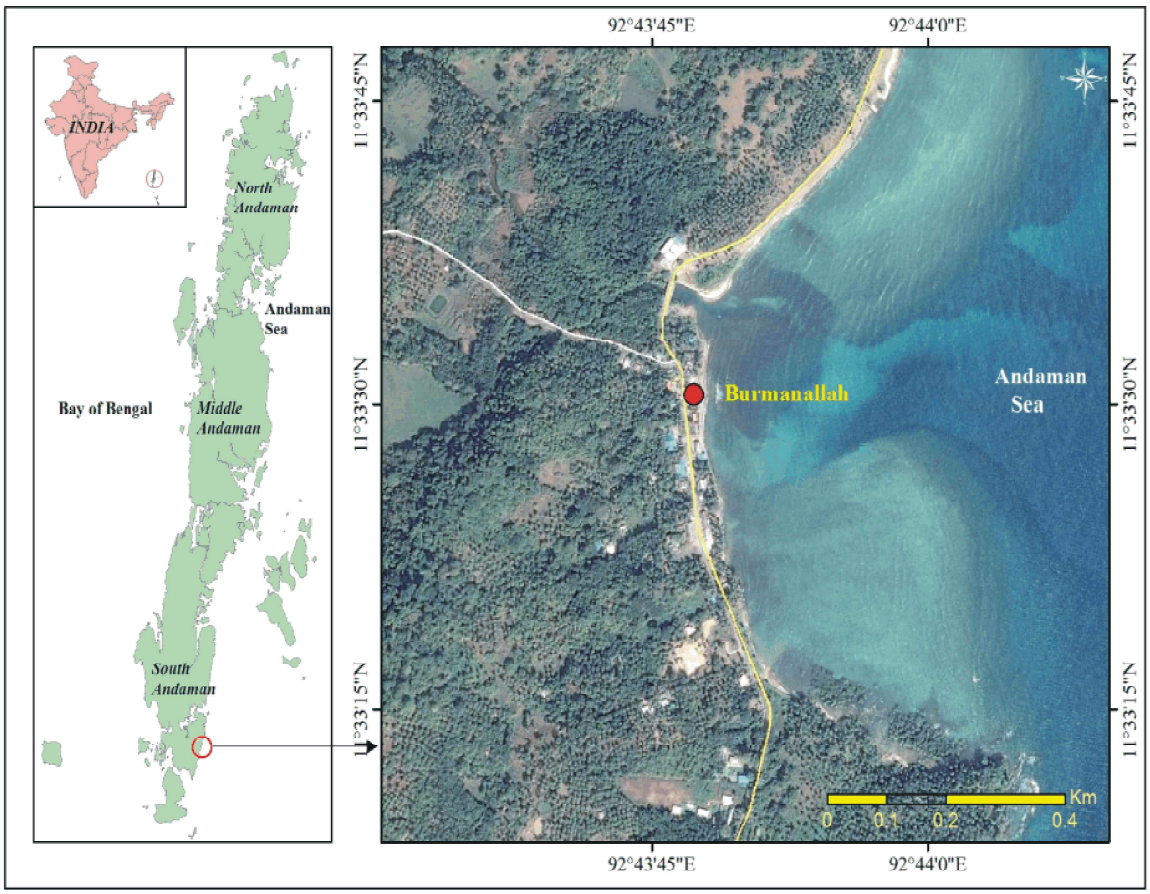

Fig. 1: Map showing Study Area

MATERIALS AND METHODS

Geographical Indications of the Study Area: The present study carried out at the Burmanallah Coast (Lat.11° 33' 20'' N; Long. 92°42'52''E) is an extremely wave action region found in the Port Blair, South Andaman Island, India (Fig. 1). The entire area is bay shaped, with freshwater influxes on both the ends. All these influxes are bordered by dense mangrove forests. The anthropogenic influence is quite low here when compared to the other coastal waters of South Andaman, though there is a small fisherman community on the shore [8].

Sample Collection: Phytoplankton samples collected during bloom period 10th to 16th April, 2013 (bloom first day marked as 1st day to 7th day) continuous sampling by using plankton net (mesh size, 20 µm) at the sea surface layers. After collection, they were fixed with 2% formaldehyde with 10 ml of Lugol's solution/1000 ml and were stored in the polythene containers [9]. The temperature was measured using a standard Celsius Thermometer. Salinity estimated with the help of a Hand Refractometer (ATAGO, Japan). The pH was measured using an OAKTON pH meter. DO and BOD was estimated by the modified Winkler's method and Chlorophyll-*a* estimated using spectrophotometer followed by the acetone method [10] and values are expressed as (µmol. l^{-1}). For the nutrient analysis, surface water samples were collected in clean polyethylene bottles and kept immediately in an icebox and transported to the laboratory for further analysis. Then the water samples filtered using a Millipore filtering systems fitted with 47 µm (0.47 mm dia) GF/C Filter paper (Millipore USA) and analyzed for dissolved inorganic nitrate, nitrite, phosphate, ammonia and reactive silicate adopting the standard procedures described by Strickland and Parson [10].

Enumeration of Phytoplankton Species: 1ml of phytoplankton bloom samples were kept into the Sedgewick-Rafter Counting slide, covered with a cover slip and examined under Nikon Eclipse (TS100, 20X/0.40)

inverted plankton microscope. Species identification of the phytoplankton samples done with the stranded of identification keys [11-15]. Quantitative estimation of phytoplankton was found out by employing Sedgewick-Rafter counting cell [9].

Statistical Analysis: Biodiversity indices were calculated following the standard formulae: species diversity: H' = -ΣPi log Pi; I = 1; richness: D = 1-C; C = Σ Pi2; Pi = ni/N and evenness: J' = H'/log2S [16-18]. The non-meric Multidimensional scaling (nMDS); Cluster and Canonical correspondence analysis (CCA) were applied for phytoplankton species and environmental factors. Correlation coefficients (r) between various environmental parameters and phytoplankton at sampling station in the Burmanellah coastal waters.

RESULTS

During 10th April 2013, occurrence of the micro algal bloom of *T. erythraeum* was observed in Burmanallah coastal region off Port Blair in South Andaman Island. Water in the region was red and brown colour patches were observed. Qualitative and quantitative analyses of bloom samples revealed that in the bloom areas, *T. erythraeum* species contributed (43,000 cells. ml^{-1}) 90% and the remaining 10% was predominantly composed of diatoms, dinoflagellates and silicoflagellates (Fig. 2a-c). A total of 77 species and 39 genera identified in the Burmanallah costal water. Diatoms (56 species, belonging to 28 genera) and dinoflagellates (18 species and 9 genera) were the most important taxonomic groups observed. Silicoflagellate comprised 2 species belonging to one genus and the bloom species included cyanophyceae *T. erythraeum*. No fish mortality was encountered during the bloom period. However, the event led to the exclusion of other phytoplankton species. Nevertheless, some phytoplankton species still persisted in small numbers, regardless of bloom intensity. During the study period certain genus such as diatoms *Bacteriastrum* sp., *Biddulphia* sp., *Chaetoceros* sp., *Coscinodiscus* sp., dinoflagellates such as *Ceratium* sp., *Cochlodinium* sp., *Dinophysis* sp., *Gonyaulax* sp., *Gymnodinium* sp., *Lingulodinium* sp., *Oxytoxum* sp., *Prorocentrum* sp. and *Protoperidinium* sp., were recorded (Table 1).

Physico-chemical Parameters Analysis and its Significance: The hydrological parameters were also analyzed during the bloom period of 10th - 16th April 2013; low rainfall (21.3 mm) was recorded (Metrological department, Port Blair). Surface water temperature varied from 30 to 34°C (r=0.83; $p<0.01$), with higher temperature (34°C) was recorded during 1st and 3rd day. In the case of salinity ranged from 30 to 33 PSU (r=0.70; $p<0.1$) and increased during the 3rd day of the bloom period. Dissolved oxygen varied from (3.35 mg. L^{-1} to 4.35 mg. L^{-1}), with higher values (4.35 mg. L^{-1}) recorded during 7th day. The low oxygen value recorded during 1st day (3.35 mg. L^{-1}) could be due to the occurrence of a cyanophyceae bloom of *T. erythraeum*.

Nitrite concentrations varied from 0.168 to 0.403 µmol. L^{-1}, while nitrate concentrations remained much higher than nitrite (1.0-2.69 µmol. L^{-1}). Phosphate levels fluctuated between (0.1-0.3 µmol. L^{-1}). Silicate concentration remained much higher, ranging from 3.3 to 6.6 µmol. L^{-1}. The relative amount of nitrate: silicate and nitrate: phosphate was higher during periods of algal bloom. In general, the present study results including the relationships between the phytoplankton and hydrological parameter were clearly shown in CCA analysis. The phytoplankton in 7th day remained influenced by salinity. During 4th day, phytoplankton was influenced by temperature, dissolved oxygen, nitrite and chlorophyll-*a*. At the 2nd and 5th day, phytoplankton influenced by silicate, phosphate, pH and nitrate influenced the phytoplankton abundance (Fig. 5).

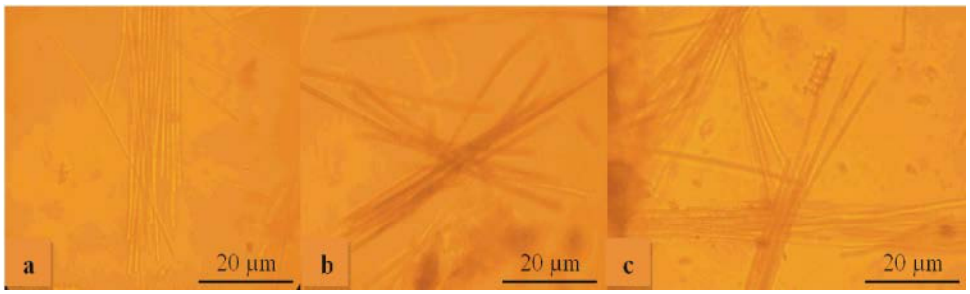

Fig. 2a-c: *T. erythraeum* bloom forming species

Table 1: The check list of phytoplankton in Burmanellah during bloom

S. No.	Species Name	1st day	2nd day	3rd day	4th day	5th day	6th day	7th day
				Cyanophyceae				
1	*Trichodesmium erythraeum*	+	+	+	+	+	+	+
Diatom								
2	*Achnanthes brevipes*	+	+	+	-	+	+	-
3	*Amphora* sp.	+	+	-	+	+	-	+
4	*Asterionella glacialis*	+	-	+	+	-	+	-
5	*Bacteriastrum furcatum*	-	+	-	+	+	-	-
6	*Biddulphia pulchella*	+	+	+	-	-	-	+
7	*Biddulphia sinensis*	+	+	+	+	+	+	-
8	*Cerataulina pelagic*	-	+	+	-	+	-	+
9	*Chaetoceros affinis*	+	+	+	-	-	+	-
10	*Chaetoceros compressus*	-	+	-	+	-	-	-
11	*Chaetoceros curvisetus*	+	-	+	-	+	-	+
12	*Chaetoceros decipiens*	-	+	-	+	-	+	-
13	*Chaetoceros orientalis*	+	-	+	+	+	-	-
14	*Chaetoceros peruvianus*	-	+	+	-	+	-	+
15	*Chaetoceros tortissimum*	+	-	-	+	-	+	-
16	*Coscinodiscus centralis*	-	+	-	-	-	+	-
17	*Coscinodiscus granii*	+	-	+	-	+	-	-
18	*Coscinodiscus jonesanus*	-	+	-	+	-	-	-
19	*Cylindrotheca closterium*	+	-	-	+	-	+	+
20	*Cylindrotheca gracilis*	-	+	+	-	-	-	-
21	*Cymbella* sp.	-	+	-	+	+	-	-
22	*Ditylum brightwellii*	-	+	-	+	-	+	-
23	*Guinardia blavyanus*	-	+	-	-	-	-	+
24	*Guinardia flaccida*	+	-	+	+	+	-	-
25	*Hemiaulus sinensis*	-	+	-	-	-	-	-
26	*Leptocylindrus danicus*	+	-	+	+	-	+	+
27	*Leptocylindrus minimus*	-	+	-	-	+	-	-
28	*Licmophora remulus*	-	-	-	+	-	-	-
29	*Mastogloia erythraea*	+	-	+	-	+	+	+
30	*Navicula* sp.	+	+	-	+	-	-	-
31	*Nitzschia lorenziana*	+	-	-	+	+	-	-
32	*Nitzschia closcrium*	-	-	+	-	+	+	-
33	*Nitzschia longissima*	+	+	-	-	-	-	+
34	*Nitzschia sigma*	+	+	+	-	-	+	-
35	*Nitzschia* sp.	+	-	-	-	+	-	-
36	*Pleurosigma affine*	-	-	-	+	-	+	-
37	*Pleurosigma angulatum*	-	+	-	-	+	-	-
38	*Pleurosigma cf. strigosum*	-	-	+	-	-	-	-
39	*Pleurosigma elongatum*	+	-	-	+	-	+	-
40	*Pleurosigma normanii*	-	-	+	-	+	-	+
41	*Proboscia alata*	-	+	-	-	-	-	-
42	*Pseudo-nitzschia australis*	+	-	-	+	-	+	-
43	*Pseudo-nitzschia pungens*	+	-	+	-	+	-	-
44	*Pseudosolenia calcar-avis*	+	+	-	+	-	-	+
45	*Rhizosolenia alata*	-	-	-	+	-	-	-
46	*Rhizosolenia cylindrus*	+	-	+	-	+	-	+
47	*Rhizosolenia hebetata*	-	-	+	-	-	+	-
48	*Rhizosolenia imbricate*	+	+	-	+	-	-	-
49	*Rhizosolenia robusta*	-	-	+	-	-	-	+
50	*Rhizosolenia styliformis*	+	-	-	-	+	-	-
51	*Surirella fumiensis*	+	+	-	+	-	-	+
52	*Surirella fastuosa*	+	-	+	-	-	+	-
53	*Thalassionema frauenfedii*	-	-	+	-	+	-	-
54	*Thalassionema nitzschioides*	-	+	-	+	-	-	+
55	*Thalassiosira decipiens*	+	-	-	-	-	-	-

Table 1: Continued

S. No.	Species Name	1st day	2nd day	3rd day	4th day	5th day	6th day	7th day
56	*Thalassiothrix longissima*	-	-	+	-	+	-	+
57	*Triceratium reticulatum*	+	+	-	+	-	-	-
				Dinoflagellate				
58	*Ceratium furca*	+	-	+	-	-	-	+
59	*Ceratium fusus*	+	-	-	+	+	-	-
60	*Ceratium massiliense*	-	+	-	-	-	-	+
61	*Ceratium tripos*	+	-	+	+	-	-	-
62	*Cochlodinium potykrikoides*	+	-	-	-	-	+	-
63	*Dinophysis caudata*	-	+	-	+	+	-	-
64	*Gonyaulax conjuncta*	+	-	-	+	-	-	+
65	*Gymnodinium catenatum*	-	+	-	-	-	+	-
66	*Lingulodinium cf.polyedrum*	-	-	+	-	-	-	-
67	*Oxytoxum scolopax*	+	-	-	+	-	-	+
68	*Prorocentrum micans*	-	+	-	-	+	+	-
69	*Protoperidinium depressum*	+	-	+	-	-	-	-
70	*Protoperidinium crassipes*	-	-	-	+	-	-	-
71	*Protoperidinium denticulatum*	-	+	-	-	+	-	+
72	*Protoperidinium divergens*	+	-	-	+	-	-	-
73	*Protoperidinium elegans*	-	-	+	-	-	+	-
74	*Protoperidinium obtusum*	+	+	-	-	-	-	-
75	*Protoperidinium pentagonum*	+	-	+	+	+	-	+
Silicoflagellate								
76	*Dictyocha crus*	+	-	+	-	+	-	-
77	*Dictyocha fibula*	+	-	+	-	-	-	+

Note: (-) absent; (+) Population density in single cell.

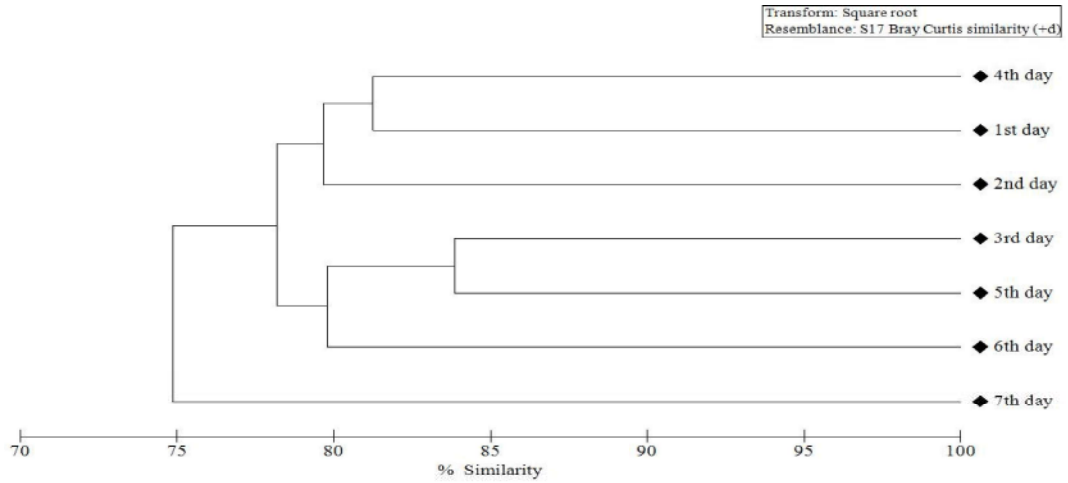

Fig. 3: Cluster analysis of the *T. erythraeum* bloom in Burmanellah bay

Strong positive correlation was found between temperature, salinity, pH, chlorophyll-*a*, nitrite, nitrate, phosphate, silicate, GPP and NPP and dissolved oxygen was negative correlation shown in the (Table 2). During the bloom period chlorophyll-*a* concentration varied from (0.1 to 0.25 µg. l^{-1}); (r=0.96; p<0.001) higher values of chlorophyll-*a* (0.25 µg. l^{-1}) was recorded 1st day followed by lowest value recorded 7th day. During the study period phytoplankton density ranged from (29261-43150 cells. ml^{-1}). The highest phytoplankton density recorded in 1st day (43150 cells. ml^{-1}) and lowest phytoplankton density recorded in 7th day (29261cells. ml^{-1}). Surface primary productivity values were in the range of (3.66 gC/ m3/ day-5.91 gC/ m3/ day). Highest gross primary production was recorded during 1st day (5.91 gC/ m3/ day). The net primary production ranged from (2.87 to 4.24 gC/ m3/ day); (p<0.001) Highest surface net primary production (4.24 gC/ m3/ day) was recorded in 1st day and the lowest valves were recorded in 6th day.

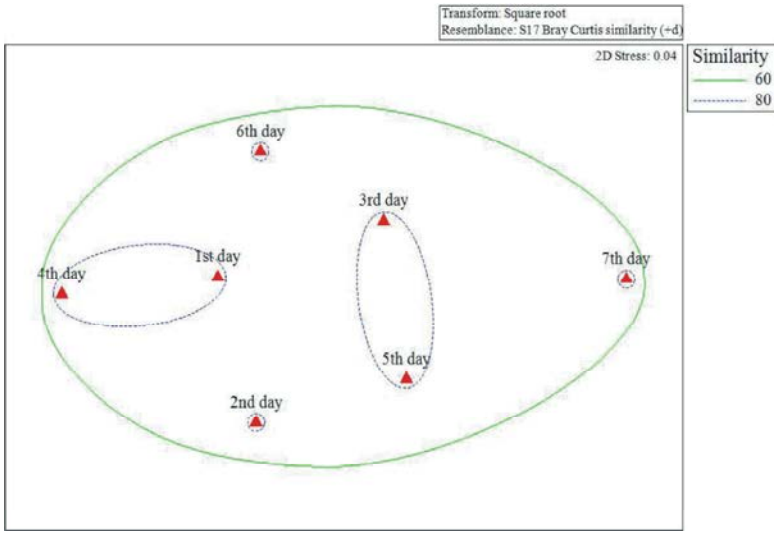

Fig. 4: nMDS Multi Dimensional Scaling showing variation of all the days

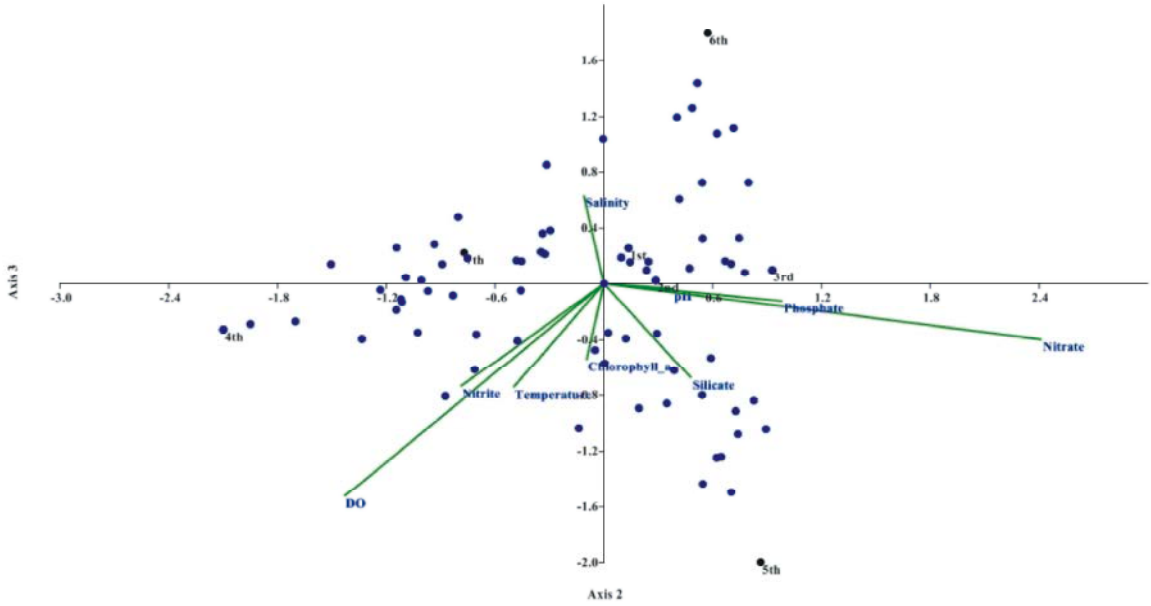

Fig. 5: CCA of the environmental variables and phytoplankton bloom of *T. erythraeum*

Table 2: Spearman rank correlation coefficients (r) between various environmental parameters and phytoplankton at sampling station in the Burmanellah

Parameters	Tem°C	Salinity	pH	DO	Chl-*a*	NO_2	NO_3	PO_4	SiO_4	GPP	NPP	CP
Tem°C	1											
Salinity	0.93[a]	1										
pH	0.85[b]	0.89[b]	1									
DO	-0.72	-0.74	-0.80	1								
Chl-*a*	0.87[b]	0.71[c]	0.75[c]	-0.84	1							
NO_2	0.88[b]	0.72[c]	0.74[c]	-0.74	0.94[a]	1						
NO_3	0.76[c]	0.69[c]	0.67[c]	-0.85	0.83[b]	0.70[c]	1					
PO_4	0.83[b]	0.72[c]	0.79[c]	-0.93	0.96[a]	0.84[b]	0.91[a]	1				
SiO_4	0.90[a]	0.79[c]	0.87[b]	-0.88	0.97[a]	0.90[a]	0.86[b]	0.98[a]	1			
GPP	0.82[b]	0.73[c]	0.85[b]	-0.93	0.95[a]	0.86[b]	0.87[b]	0.99[a]	0.98[a]	1		
NPP	0.89[b]	0.80[c]	0.87[b]	-0.91	0.96[a]	0.88[b]	0.88[b]	0.99[a]	1.00[a]	0.99[a]	1	
CP	0.83[b]	0.70[c]	0.81[b]	-0.89	0.96[a]	0.94[a]	0.83[b]	0.95[a]	0.97[a]	0.97[a]	0.96[a]	1

a=p<0.001; b=p<0.01 & c=p<0.1 (CP-Cyanophyceae), (p=significance level)

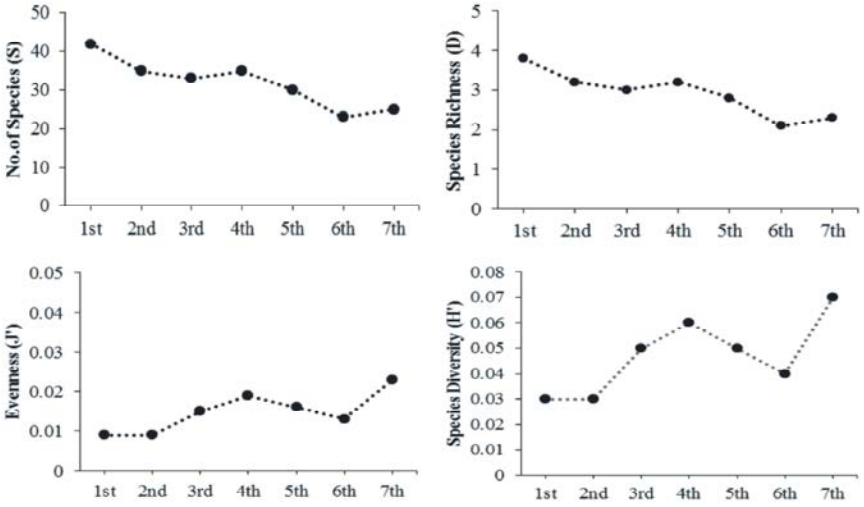

Fig. 6: Number of species (S), Total individuals (N), Species richness (D), Evenness (J') Species diversity (H') during the bloom period

Species Diversity and Cluster Analysis: The number of species (S) and range of diversity indices in the study area are shown in (Fig. 6). The maximum numbers of species recorded during in the 1st day (42) and the Species richness (D) (3.8) during 1st day and lowest value was recorded (2.11) at 6th day. Evenness (J') was high (J'=0.023) and lowest value recoded (0.009), followed by higher species diversity (H'=0.073) during the 7th day and the lowest diversity (H'=0.03) was recorded during the first day (Fig. 6). Diagrams (Fig. 3) shows that the two distinct groups during bloom species composition between 3rd, 5th and 6th day almost similar and 1st, 2nd and 4th groups 80% similarity but there was a much variation in 7th day. The nMDS is done based on square root transformed average abundances and Bray-Curtis similarities by comparing the phytoplankton assemblages among the sampling sites. The nMDS ordination revealed a low stress level (i.e <0.04) suggesting the configuration is ideally close to actual dissimilarities. The ordination plot spatially grouped the samples relatively well into 7 different days. Samples are overlaid with the dendogram similarity result 60-80% similarity. Data points day1, day 3, day 4 and day 5 & day 2 day 6 and day 7 is an outlier (Fig. 4).

DISCUSSION

T. erythraeum bloom outbreak was observed in summer season in Indian coast [7]. *T. erythraeum* resulted in an increase in temperature during the bloom. Most of the marine blue green algae exhibit substantial growth in the temperature ranged between 25-35°C [5]. Earlier reports [8,19-22] also showed the prevalence maximum temperature during the *T. erythraeum* bloom period (32 to 34°C). Previous studies [23,24] reported around 22 algal blooms along the west (10 algal blooms) and east coasts (12 algal blooms) of Indian Ocean including Andaman Sea from 1908 to 2013 (Table 3). Moreover, the east coast of India eyewitness majority of blooms by cyanophyceae were the dominated. The present bloom was noticed during relatively high temperature conditions 34ºC. Temperature has long been recognized as an important factor that controls *Trichodesmium* abundance. Cyanobacteria are the sensitive to lowest temperatures and they are apparently excluded in the winter months due to lower temperature [25]. The results of this study are in accordance with the previous studies. This bloom was occurred during the summer month, which is a dry period or summer season for Andaman and Nicobar islands. This is contrary to the frequent diatom blooms observed earlier by the authors in the coastal waters of south Andaman which occurred only during the rainy months [26]. This once again proved that cyanobacterial species are not dependent on the nutrient flux which is brought by the rainfall unlike the diatoms which are nutrient dependent. A significant reduction in nitrate concentration was noticed during the bloom period. A similar reduction of nitrate concentration during *T. erythraeum* bloom has also observed in the west coast of India [6,7]. In the case of phosphate constitutes the most inorganic nutrient which can limit the phytoplankton production in tropical coastal marine ecosystem and there by the overall ecological processes. Many authors have

Table 3: Algal bloom of (Cyanophyceae) along the west & east coast of India

S.NO	Causative organism	Place of occurrence	Year	Season	Reference
		West coast of India			
1.	*Trichodesmium erythraeum* & *Trichodesmium hildebrontii*	Ullal, off Mangalore coast	13th & 21st March 1964	Pre-Monsoon	[33]
2.	*Trichodesmium erythraeum*	Minicoy Island, Lakshadweep	May-June 1965	South West Monsoon	[34]
3.	*Trichodesmium erythraeum*	Laccadive island	April 1968	Pre-Monsoon	[35]
4.	*Trichodesmium erythraeum*	Near-shore waters of Goa	March 1972	Pre-Monsoon	[36]
5.	*Trichodesmium erythraeum*	Coastal waters of Goa	February-April 1975	Pre-Monsoon	[37]
6.	*Trichodesmium erythraeum*	Ratnagiri-Mangalore & Laccadive island	March 1977	Pre-Monsoon	[38]
7.	*Trichodesmium erythraeum*	Mangalore-Quilon	6-20th May 2005	Pre-Monsoon	[39]
8.	*Microcystis aeruginosa*	Chalakudy River in Central Kerala	March 2008	Pre-Monsoon	[40]
9.	*Trichodesmium erythraeum*	Off Kollam, Kochi & Kannur, Kerala coast	29th May-11th June 2009	Onset Of South West Monsoon	[41]
		East coast of India			
10.	*Trichodesmium erythraeum*	Krusadai island, Gulf of Mannar	May 1942	Pre-Monsoon	[42]
11.	*Trichodesmium erythraeum*	Southern coast of Pamban, Gulf of Mannar	May 1942	Pre-Monsoon	[43]
12.	*Trichodesmium erythraeum*	Porto Novo, Tamil Nadu	March 1964, 1965, 1969, 1972	Pre-Monsoon	[36] [44,45,46]
13.	*Trichodesmium thiebautii*	Gulf of Mannar, Tamil Nadu	March-April & September 1973	Pre-Monsoon; South West Monsoon	[47]
14.	*Trichodesmium erythraeum*	Tamil Nadu-off Kolkata	11th April 2001-25th April 2001	Pre-Monsoon	[6]
15.	*Trichodesmium erythraeum*	Kalpakkam, Tamil Nadu	16th March 2007	Pre-Monsoon	[7]
16.	*Trichodesmium erythraeum*	Mandapam& Keelakarai, Tamil Nadu	October 2008	Post Monsoon	[48]
17.	*Microcystis aeruginosa*	Vellar estuary, Tamil Nadu	December 2009	North East Monsoon	[49]
18.	*Trichodesmium* sp.	Port Blair Bay, South Andaman Island	May 2011	South West Monsoon	[21]
19.	*Trichodesmium erythraeum*	Burmanallah, West Coast of Andaman Sea	March 2012	Pre-Monsoon	[8]
20.	*Trichodesmium erythraeum*	Phoenix Bay jetty, Port Blair andaman	March 2013	Pre-Monsoon	[20]
21.	*Trichodesmium erythraeum*	Open water andaman Sea	April 2013	Pre-Monsoon	[50]

also documented similar increase of phosphate content during the occurrence of bloom of *Trichodesmium* [27,28], the salinity was found to be the highest (33 PSU) during the bloom period. A gradual increase in salinity was noticed during the study period. The salinity condition close to the typical value of 33 PSU and above is known to support the growth and abundance of *T. erythraeum* [5]. Previous studies [29] have also confirmed the fact that stable salinity conditions close to a typical value of 32 PSU and also dissolved oxygen was found to be lower during the bloom period and above are known to support the growth and abundance *Trichodesmium* sp. Similarly, increase of DO content during *T. erythraeum* bloom has also been reported earlier [7]. This is probably due to the decaying of the cells of the bloom forming species during sampling. The nitrate concentration was at its lowest during the bloom period and this is in accordance with the previous studies [6]. Nitrite and phosphate showed insignificant variations during the study period. The silicate concentration showed a marked decrease during the bloom. This concurs with the patterns observed in the previous studies on non-diatom species [30]. Chlorophyll-

a is a well-accepted index for phytoplankton abundance and population of primary producers in an aquatic environment [31]. *T. erythraeum* 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 the coastal zone. Present bloom *T. erythraeum* were monitored for seven days continuously in the month of April 2013 in an enclosed bay where the anthropogenic activities are more due to the over flux of nutrient input into the bay by land runoff. Earlier studies reported that chlorophyll-*a* concentration (0.16µg. l^{-1}) was much higher in the South Andaman Islands during the bloom period of *Coscinodiscus centralis, Rhizosolenia alata, R. imbricate, T. erythraeum* and *Protoperidinium divergens* [19]. Another study [8] recorded maximum chlorophyll-*a* concentration (0.161µg. l^{-1}) during the *T. erythraeum* bloom period. Primary productivity is the main criterion for assessing the relative fertility of a particular region. Along with this, photosynthetic pigments are the index of phytoplankton production of an area. The biological productivity of the coastal waters is dependent to a major extent on the distribution of photosynthetic pigments in the euphotic zone [32].

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