Applied Environmental Research

Journal homepage : http://www.tci-thaijo.org/index.php/aer

Dinoflagellate Bloom Produced by *Protoperidinium divergens* Response to Ecological Parameters and Anthropogenic Influences in the Junglighat Bay of South Andaman Islands

Karthik Raji * and Gadi Padmavati

Department of Ocean Studies and Marine Biology, Pondicherry University, Brookshabad Campus, Post Bag No. 1, Port Blair 744112, Andaman and Nicobar Islands, India

* Corresponding author: Email: rkarthicas@gmail.com; Phone: 096-79553525

Article History

Submitted: 17 March 2014/ Accepted: 26 May 2014/ Published online: 17 October 2014

Abstract

The bloom-forming dinoflagellate, *Protoperidinium divergens* has been linked with coastal eutrophication in tropical and subtropical regions. Moderate to intense harmful algal bloom of dinoflagellates *Protoperidinium divergens* (33,500 cells. mL^{-1}) was observed during June 2012 in Junglighat Bay of Port Blair in South Andaman. Bloom of *Protoperidinium divergens* was observed for four days and declined afterwards due to heavy rainfall with low seawater temperature of 24 to 26°C. A total of 63 species and 33 genera were identified. In the present investigation, the following species of phytoplankton and zooplankton were found to be common; phytoplankton such as *Amphora* sp., *Bacteriastrum* sp., *Chaetoceros* sp., *Coscinodiscus* sp., *Rhizosolenia* sp., *Gonyaulax* sp., *Protoperidinium* sp., *Pyrophacus* sp. and zooplankton such as *Paracalanus* sp., *Euterpina* sp., fish eggs, Copepod nauplii, *Codonella* sp. and *Tintinnopsis* sp. Hydrobiological parameters analyzed during and post-bloom showed dissolved oxygen in the range of 2.23 – 4.46 mg.L^{-1}. Nutrients such as nitrate varied from 0.37-1.118µmol.L^{-1}, nitrite from 0.37-1.118 µmol.L^{-1}, phosphate (0.10-0.289 µmol.L^{-1}) and silicate (6.22-9.333 µmol.L^{-1}). Anthropogenic activities increased eutrophication in Junglighat Bay and led to nutrient enrichment in the water column, although precipitation could also have favoured the outbreak of these dinoflagellates.

Keywords: South Andaman; algal bloom; dinoflagellate; *Protoperidinium divergens*

Introduction

Phytoplanktons serve as a vital source of energy in the marine environment. They initiate the marine food chain, by serving as food to primary consumers [1, 2]. Favorable environmental conditions such as adequate levels of nutrients, light and temperature, trigger periods of rapid reproduction of phytoplankton known as ‘blooms’ [3]. Besides normal and periodic blooms of phytoplankton, exceptional, harmful algal blooms also occur [4]. Dinoflagellates are microscopic unicellular organisms belonging to the division of Dinoflagellates [5]. Harmful algal blooms (HABs) are a cause for concern worldwide. Over the years, there has been a marked increase in their occurrence along with their spread to new geographical regions [6]. This apparent global expansion of HABs is linked with increased anthropogenic eutrophication of coastal waters and increased nutrient load [6, 7].

Protoperidinium sp. is a large and ubiquitous genus of marine heterotrophic dinoflagellates. Species of the genus typically follow diatom blooms and are generally coastal in distribution [8]. *Protoperidinium* species have been found to feed on diatoms by means of extracellular digestion of their prey within a pseudopodial “feeding veil” [9]. *P. divergens* is a marine dinoflagellate, forming extensive surface blooms that discolour the seawater; these HABs are commonly referred to as ‘red tide’. According to [10], the HAB events include the proliferation of algae in brackish waters, which can cause massive fish mortality and contaminate the seafood. Approximately 300 species can discolour the sea surface, and approximately 40 species have the capacity to produce potent toxins that can be transferred via fish and shellfish to humans [11]. Few reports are available regarding HABs from the Andaman Islands [9, 12, 13, 14]. This study aimed to fill this gap and enhance the knowledge base covering the physicochemical properties and nutrient flux in the coastal water of the South Andaman Islands, and their influence on *P. divergens* proliferation.

Materials and methods

1) Description of the study area

Junglighat (92° 43’56"N and 11° 39’21"E) is a moderately polluted area found in the East Coast of Andaman [15] with a sewage influx in the centre of the area. Junglighat Bay is situated near Haddo harbour and is a major fish landing centre for Port Blair. The bay is funnel-shaped with a mouth 3 to 4 times wider than the head end, and receives a large volume of sewage discharge from the 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 significant freshwater influx in the intertidal zone. Average depth of the bay is 4.5 m, and maximum depth at high tide is 6.2 m. Mechanized and motorized boats with fishing trawls land their catches here regularly and release oil, plastics, fish waste and other debris. There is also a well-established fishing settlement which is a key source of sewage and domestic waste.

2) Sample collection and analysis

Phytoplankton samples were collected by using plankton net (mesh size, 20µm) from the surface layers, with each set of samples collected in triplicate. The samples were fixed in 4% formaldehyde solution immediately after collection. Temperature was measured using a standard mercury centigrade thermometer. Salinity was estimated using 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, and chlorophyll (90% acetone method) measurements were carried out spectrophotometrically in the laboratory [16] and expressed as $\mu mol.L^{-1}$.

The triplicate surface water samples were collected in clean polyethylene bottles for analysis of nutrients, which were stored immediately in an ice box before transfer to the laboratory. The collected water samples were filtered by using a Millipore filtering system and then analyzed for dissolved inorganic nitrate, nitrite, reactive silicate and inorganic phosphate, adopting the standard procedures described by [15] and expressed in µmol L^{-1}. For the identification of species, 1 ml of sample were put on a Sedgwick rafter counter slide, covered with a cover glass and examined under light microscope.

Species level identification of the phytoplankton samples were performed using marine phytoplankton identification keys [14, 17, 18, 19]. The eukaryotic phytoplankton cell counts were performed on a Sedgewick Rafter Counting Slide [20].

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

Where N is the total number of phytoplankton cells per liter of water filtered, n is an average number of phytoplankton cells in 1 ml of sample, v is the volume of phytoplankton concentrates and V is the volume of total water filtered.

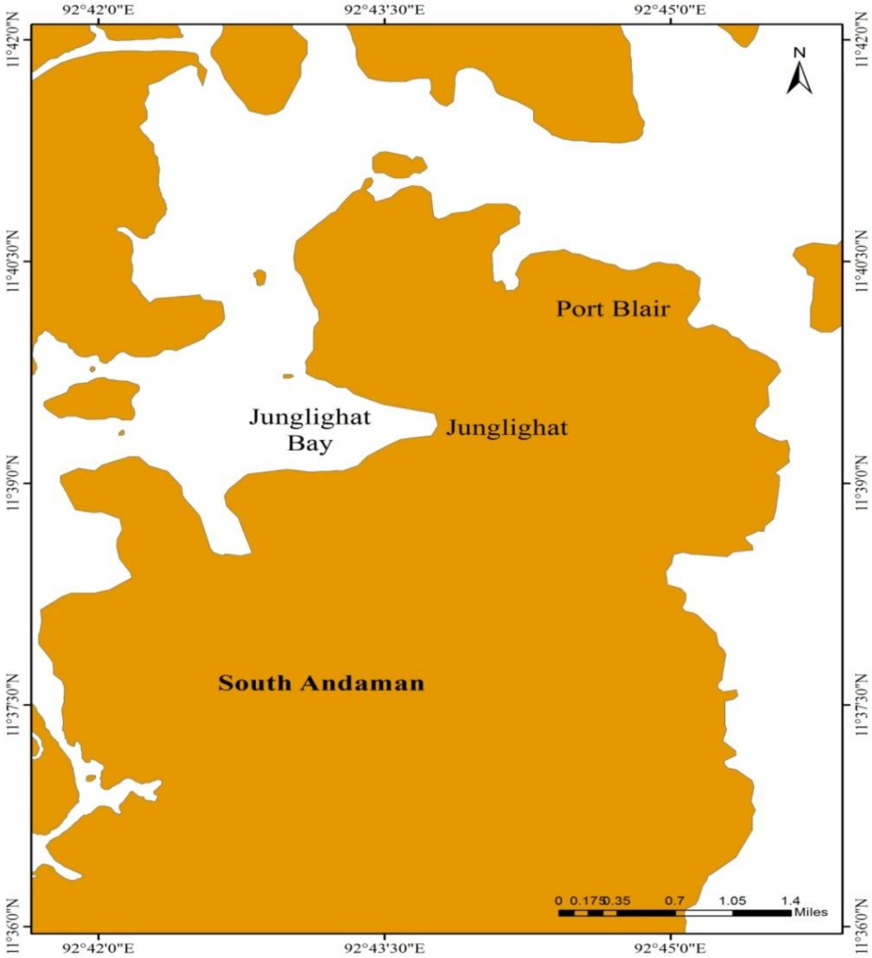

Figure 1 Map of the study area: Junglighat Bay

Results

1) Species composition

Moderate to intense blooms of the dinoflagellate *Protoperidinium divergens* was observed during the month of June 2012 in Junglighat Bay, South Andaman Island. A total of 62 species and 32 genera were identified. Diatoms comprised 36 species and 22 genera, dinoflagellates comprised 24 species and 8 genera. One cyanophyceae and silicoflagellates were the most important taxonomic groups observed. During June 2012, Red and brown color patches were observed in the study area. The bloom-forming species *Protoperidinium divergens* was found to dominate 95-98% in the Sedgewick-Rafter Counting slide, with a density of 33,500 cells mL^{-1} (Fig.2).

No fish mortality was encountered during the bloom. However, the event led to the exclusion of other phytoplankton species. Nevertheless, some phytoplankton species still persisted in small numbers, regardless of bloom intensity. Notable among these were *Amphora* sp., *Bacteriastrum* sp., *Chaetoceros* sp., *Coscinodiscus* sp., *Rhizosolenia* sp., *Gonyaulax* sp., *Protoperidinium* sp, and *Pyrophacus* sp. (Table1). Among the zooplankton species such as *Paracalanus* sp., *Euterpina* sp., fish eggs, Copepod nauplii, *Codonella* sp., *Tintinnopsis* sp. were also recorded in low numbers. The bloom was found to correlate with the heavy rainfall (401.0 mm) recorded in June 2012 [21]. Diatom species were relatively low in number; this species might have been grazed upon by *Protoperidinium divergens*.

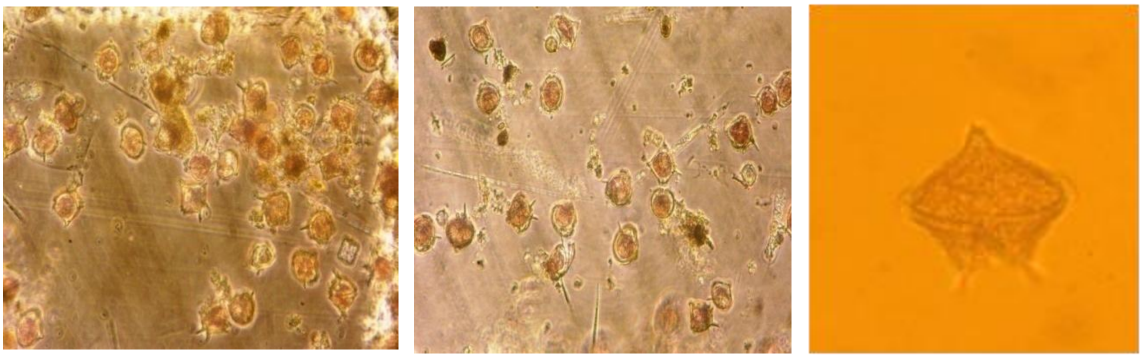

Figure 2 Microscopic views of the bloom-forming dinoflagellate *Protoperidinium divergens*

2) Physico-chemical parameters

Hydrological parameters were analyzed both during and post-bloom. Physico-chemical variables measured from surface water during the bloom are presented in Table 2. Surface water temperature ranged from 26 to 27°C, pH varied from 7.6-7.8, and salinity ranged from 20 to 31 (PSU). Salinities were found to be significantly higher during the bloom period.

Dissolved oxygen levels in the study area were found to range from 2.234 to 4.467 mg L^{-1}, while biological oxygen demand (BOD) ranged from 1.451-1.893 mg L^{-1}. Nutrient concentrations during the bloom period were high (Figure 3). Nitrite concentrations varied between 0.37-1.118 µumol L^{-1}, while nitrate concentrations remained much higher than nitrite (0.37-1.118 µmol.L^{-1}). Phosphate levels fluctuated between 0.10-0.289 µmol L^{-1}. Silicate concentration remained much higher, ranging from 6.22-9.333 µmol L^{-1}. Further, chlorophyll *a* was recorded in the range of 0.085 to 0.133 µg L^{-1}, with a peak in concentration observed in June 2012 (0.133 µg L^{-1}).

These high nutrient levels are probably due to decay of the cells of the bloom-forming organisms during sampling, in addition to nutrients contributed by the heavy rainfall and higher freshwater runoff from the coast. These high nutrient loads then triggered the *Protoperidinium divergens* bloom.

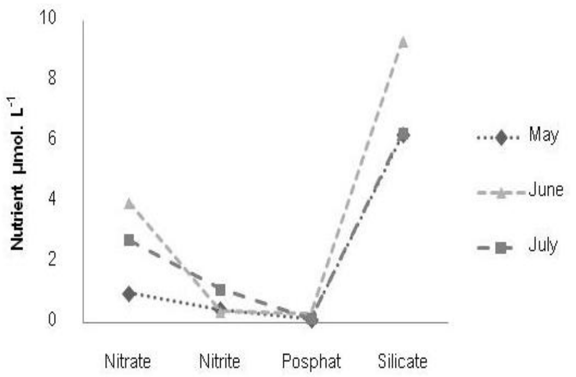

Figure 3 Variations in nutrient concentration during the bloom May 2012 to July 2012

Discussion

Though earlier studies reported a HAB of *Noctiluca* bloom in the area, the current study encountered no fish mortality during the bloom, although the bloom event led to exclusion of most plankton [12]. Algal blooms are used for aquaculture and fisheries operations, but in some situations algal blooms can have a negative effect, causing severe economic losses to aquaculture, fisheries and tourism operations and also have major environmental and human health impacts [11]. HABs appear to have increased in frequency, intensity and geographic distribution worldwide, posing a threat to coastal fisheries and fish/shellfish aquaculture throughout the world [11, 22]. It is, however, difficult to quantify such outbreaks in order to document trends since there are so many different types of blooms with so many different impacts [22]. Heterotrophic dinoflagellates genus *Protoperidinium* was abundant during dinoflagellates blooms, and much less abundant during diatom blooms as observed in this study has reported from the coastal waters of southern California [23, 24]. For identification, the plate patterns and the cate forms of living taxonomic authorities used to identify specimens were [25, 26, 27, 28]. Previous studies reported the maximum abundance of *Protoperidinium* in the coastal waters of southern California of 24 *Protoperidinium* mL^{-1} [24]. During the study period the dissolved oxygen was very low, as found in an earlier study of dinoflagellates of *Noctiluca* bloom period, during which dissolved oxygen concentrations were drastically reduced, reaching a low of (4.2 $mg.L^{-1}$). Nutrient concentrations were high during the bloom period; silicate concentration was present at higher levels than other nutrients. In this area during the *Noctiluca* sp bloom period, phosphate concentration was very high. Seasonal blooms occur annually as a result of changes in temperature and nutrient availability, whereas red tide outbreaks are localized and are triggered by a variety of factors which are species- and region-specific [4, 12]. This paper documents the first occurrence of a HAB of the colonial form of *P. divergens* in the Junglighat Bay of South Andaman Island. Consequently, continuous monitoring of the water column and phytoplankton compositions is needed to assess the HAB risk and its impact on the tropical coastline. The present work has indicated that phytoplankton can serve as good bio-indicators of environmental disturbances.

Conclusion

The present study indicated that high nutrient levels and temperature were the primary causative agents triggering occurrence of HABs in the Junglighat Bay region. The general nutrient profiling of the Andaman Sea, especially in anthropogenically influenced coastal areas, is suggested, as it is important to gain a greater understanding of the influence of nutrients on marine life. Physico-chemical factors such as nutrient fluxes, currents, tides, upwelling and downwelling, convergence and divergence and related frontal boundaries have also been indicated as initiation factors for red tide species of *Protoperidinium divergens*. 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 Junglighat Bay.

Acknowledgements

The authors are grateful to the Head of the Department, Ocean Studies and Marine Biology, Pondicherry University, Port Blair for providing facilities. We would also like to express our thanks to Mr. A. Saravanan, Department of Disaster Management, Pondicherry University, for preparing the map of the study area. We are very much obliged to Mr. M. Arun Kumar, Dept. of Ocean Studies and Marine Biology, Pondicherry University. Most of all, we are very much thankful to all the fisherman without whose help this work could not have been accomplished.

Table1 Check list of phytoplankton in Junglighat Bay, May to July 2012

No	Species	Pre-bloom	Bloom	Post bloom
	Class Bacillariophyceae (Diatom)			
1	*Amphora obtusa*	+	-	-
2	*Amphora* sp.	-	+	-
3	*Asterianella glacialis*	+	-	-
4	*Bacteriastrum delicatulum*	-	+	-
5	*Chaetoceros atlanticus*	+	-	-
6	*Chaetoceros curvisetus*	+	+	-
7	*Chaetoceros decipiens*	+	-	-
8	*Chaetoceros lorenzianus*	-	+	-
9	*Chaetoceros orientalis*	+	-	-
10	*Coscinodiscus asteromphalus*	+	-	+
11	*Coscinodiscus centralis*	+	-	+
12	*Coscinodiscus granii*	+	+	+
13	*Coscinodiscus marginatus*	-	-	+
14	*Coscinodiscus radiatus*	+	+	-
15	*Ditylum brightwellii*	+	-	-
16	*Entomoneis sulcata*	+	-	-
17	*Eucampia cornuta*	-	+	-
18	*Eucampia zoddiscus*	-	+	-
19	*Guinardia flaccida*	-	-	+
20	*Guinardia striata*	-	+	-
21	*Gyrosigma diminutum*	+	-	-
22	*Hemidiscus cuniformis*	-	+	+
23	*Lauderia annulata*	-	+	-
24	*Leptocylindrus danicus*	+	+	+
25	*Meuniera membranacea*	+	-	-
26	*Navicula* sp.	+	-	-
27	*Nitzschia closterium*	+	-	-

Table1 Check list of phytoplankton in Junglighat Bay, May to July 2012 *(continued)*

No	Species	Pre-bloom	Bloom	Post bloom
	Class Bacillariophyceae (Diatom)			
28	*Odontella aurita*	+	-	-
29	*Pleurosigma elongatum*	+	-	-
30	*Pleurosigma* sp.	-	-	+
31	*Pleurosigma strigosum*	+	-	-
32	*Rhizosolenia shrubsolei*	-	+	-
33	*Skeletonema costatum*	-	+	-
34	*Thalasiossira decipiens*	-	+	-
35	*Thalassionema nitzschioides*	-	-	+
36	*Thalassionema frauenfeldii*	-	+	+
	Class Dinophyceae (Dinoflagellates)			
37	*Ceratium furca*	+	-	+
38	*Ceratium fusus*	+	+	+
39	*Ceratium lineatum*	-	-	+
40	*Ceratium lunula*	-	+	-
41	*Ceratium macroceros*	+	-	-
42	*Dinophysis caudata*	+	-	+
43	*Dinophysis tripos*	-	-	+
44	*Gonyaulax conjuncta*	-	-	+
45	*Gonyaulax* sp.	-	+	-
46	*Gymnodinium catenatum*	-	-	+
47	*Prorocentrume marginatum*	+	-	-
48	*Prorocentrum micans*	+	+	+
49	*Prorocentum balticum*	+	-	+
50	*Protoperidinium biconicum*	+	-	-
51	*Protoperidinium conicoides*	-	+	+
52	*Protoperidinium conicum*	-	+	-
53	*Protoperidinium depressum*	+	+	+
54	*Protoperidinium divergens*	-	+	+
55	*Protoperidinium leonis*	-	-	+
56	*Protoperidinium pyriforme*	+	-	-
57	*Protoperidinium pentagonum*	+	-	-
58	*Pyrocystis obtusa*	-	-	+
59	*Pyrophacus horologium*	+	-	-
60	*Pyrophacus steinii*	+	+	-
	Class: Cyanophyceae (Cyanobacteria or Blue-green algae)			
61	*Trichodesmium erythraeum*	-	+	-
	Class Dictyochophyceae (Silicoflagellates)			
62	*Dictyocha octonaria*	-	-	+

Note : (-) Absent; (+) Present

Table 2 Physicochemical parameters in Junglighat Bay during the *Protoperidinium divergens* bloom

Parameters	Pre -Bloom May 2012	Bloom June 2012	Post –Bloom July 2012
Salinity (PSU)	20	31	28
Temperature (°C)	27	26	27
pH	7.6	7.7	7.8
Dissolved Oxygen (mg.L^{-1})	4.35	2.234	4.46
Biological oxygen demand (mg.L^{-1})	1.893	1.451	1.779
Chlorophyll a (µg.L^{-1})	0.085	0.133	0.086
Rain fall (mm)	597.0	401.0	298.0

References

[1] Ananthan, G., Sampathkumar, P., Soundarapandian, P., Kannan, L. 2004. Observation on environmental characteristics of Ariyankuppam estuary and Verampattinam coast of Pondicherry. J. Aqua. Biol., 19: 67-72.

[2] Tas, B., Gonula, A. 2007. An ecologic and taxonomic study on phytoplankton of a shallow lake. Turkey. J. Environ. Biol., 28: 439-445.

[3] Castro, Peter and Huber, E. Michael. 2003. Marine Biology, 4th ed. McGraw-Hill Higher Education, New York, U.S.A 461.

[4] Richardson, K. 1997. Exceptional phytoplankton blooms. In: Advances in Marine Biology, J. H. S. Blaxter and A. J. Southward (Eds.). 31: 302-383.

[5] Fensome, R. A., Taylor, F. J. R., Norris, G., Sarjeant, W. A. S., Wharton, D. I., Williams, G. L. 1993. A classification of living and fossil dinoflagellates. Am. Museum Natural Hist. Micropaleontol., 7**:** 1-351.

[6] Anderson, D. M., Glibert, P., Burkholder, M. J. M. 2002. Harmful algal blooms and eutrophication: nutrient sources, composition and consequences. Estuaries, 25: 704-726.

[7] Hallegraeff, G. A. 1993. Arcview of harmful algal blooms and their apparent global increase. Phycologia. 32: 79-99.

[8] Taylor, F. J. R. 1990. Phylum Dinoflagellata. In: Margulis et al. (eds), Handbook of Protoctista. Jones and Bartlett Publishers, Boston, pp. 419-437.

[9] Jacobson, D. M., Anderson, D. M. 1986. The cate heterotrophic dinoflagellates: Feeding behaviour and mechanisms. J. Phycol., 22: 249-258.

[10] Geohab, 2001. Global Ecology and Oceanography of Harmful Algal Blooms, GEOHAB Science Plan. In: Patricia M and Pitcher G (eds) IOC, SCOR, Baltimore and Paris.1-87.

[11] Hallegraeff, G.M.1995. Harmful algal blooms: a global overview. Manual on harmful marine micro algae. IOC-UNESCO Manual and Guides No.33: 1-22.

[12] Eashwar, M., Nallathambi, T., Kuberaraj, K., Govindarajan, G. 2001. Noctiluca blooms in Port Blair, Andamans. Current Sciences., 81:203–206.

[13] D’ Silva, M. S., Anil, A. C., Naik, R. K., Costa, P. M. 2012. Algal blooms: a perspective from the Coasts of India Nat. Hazards 63: 1225-1253.

[14] Sachithanandam, V., Mohan, P. M., Kathik, R., SaiElangovan, S. and Padmavati, G. 2013. Climate change influence the phytoplankton bloom (prymnesiophyceae: *Phaeocystis* spp.) in North Andaman coastal region. Indian J. Geo. Mar. Sci., 42: 58-66.

[15] SaiElangovan, S., Arun Kumar, M., Karthik, R., Siva Sankar, R., Jayabarathi, R., Padmavati, G. 2012.Abundance, Species Composition of microzooplankton from the coastal of Port Blair, South Andaman. Aquatic Biosystems.1: 1-20.

[16] Strickland, J. D. H., Parson, T.R. 1972. A practical handbook of seawater analysis. Bull. Fish. Res. Bd. Canada. Bull No: 167p.

[17] Venkataraman, G. 1939. A systematic account of some South Indian diatoms. Proc. Ind. Acad. Sci. Section B.10: 85-192.

[18] Cupp, E. 1943. Marine Plankton Diatoms of the West Coast of North America. University of California Press Berkeley and Los Angeles, Berkeley, CA.5:1-238.

[19] Santhanam, R., Ramanathan, N., Venkataramanujam, K. V., Jegatheesan, G. 1987. Phytoplankton of the Indian Seas (An aspect of Marine Botany). Daya Publishing House, Delhi- 110 006.

[20] Guillard, R. R. L. 1978. Counting slides. In: A. Sournia (ed) Phytoplankton Manual, UNESCO, Paris.337.

[21] Anon. 2013. Report on the rainfall of Port Blair. Department of Statistics and Economics. Andaman and Nicobar Administration. pp.1-2.

[22] Anderson, D. M. 1998. Study of red tide monitoring and management in Hong Kong: literature review and background information. Technical Report No. 1, Hong Kong Agriculture and Fisheries Department.120.

[23] Torrey, H. B. 1902. An unusual occurrence of dinoflagellata on the California coast. Am. Nat.36: 187-192.

[24] Allen, W. E.1949. Data files, 1917-1949. Accession No. 81- 19. Scripps Institution of Oceanography Archives, University of California, San Diego, pp. 390-396.

[25] Balech, E. 1988. Los dinoflageladosdel Atlantico Suboccidental, Publnesespec. Inst. Esp. Oceanogr. 1: 1-310.

[26] Dodge, J. D. 1982. Marine dinoflagellates of the British Isles. Her Majesty's Stationery Office, London. 301p.

[27] Dodge, J. 1985. Marine dinoflagellates of the British Isles, 2.Auflage. Crown, Souththampton, U.K.303p

[28] Taylor, F. J. R. 1976. Dinoflagellates from the International Indian Ocean Expedition. A report on material collected by R/V “Anton Bruun” 1963-1964.Bibliotheca Bot., 132**:** 1-234