Recent Research in Science and Technology 2010, 2(10): 51-58
ISSN: 2076-5061
www.recent-science.com

MARINE BIOLOGY

MONITORING OF *NOCTILUCA* BLOOM IN MANDAPAM AND KEELAKARAI COASTAL WATERS; SOUTHEAST COAST OF INDIA

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Abstract
Monitoring the Harmful Algal Blooms was carried out during July to December 2008 in Mandapam and Keelakarai coastal waters of Tamil Nadu, Southeast coast of India. In the month of October several fishes and shellfishes were died due to *Noctiluca* blooms along these two areas. The present investigation the following species of phyto and zooplankton were found to be common; phytoplankton such as *Coscinodiscus* sp., *Skeletonema costatum*, *Bacillaria paradoxa*, *Thallassiothrix frauenfeldii*, *T. longisima*, *Leptocylindrus* sp., and zooplankton such as *Paracalanus parvus, Acrocalanus gracilis, Pseudodiaptomus serricautatus, Rhincalanus cornutus, R. nasutus, Euterpina acutifrons, Nannocalanus minor, Eucalanus attenuates, E. crassus,* Fish larvae, Fish eggs, Barnacle nauplii, Bivalve larvae, Gastropod larvae, Copepod nauplii and Mysis larvae. The hydrobiological parameters also analysed during bloom and after blooms; the dissolved oxygen (2.6 – 4.9µM L^{-1}) nutrients varied between nitrate (0.66 – 1.01µM L^{-1}) nitrite (0.11 – 0.21µM L^{-1}) phosphate (0.51 – 0.86µM L^{-1}) and silicate (0.81 – 4.2µM L^{-1}).

Keywords: *Noctiluca* Bloom, Fish mortality, Mandapam and Keelakarai, Southeast coast

Introduction

Harmful algal blooms (HABs) are natural phenomena that have occurred throughout history. However, in the past two decades, these events have increased in frequency, intensity, and geographic distribution, causing greater public health and economic effects. Among the 5000 species of extant marine Phytoplankton (Sournia et al., 1991), approximately 300 species can occur in such high numbers that they obviously discolor the sea surface, and approximately 40 species have the capacity to produce potent toxins that can transfer through fish and shellfish to humans (Hallegraeff et al., 1995).

The frequent global occurrence of harmful algal blooms (HABs) has serious impacts on fishery resources and the marine environment, and is thus a pressing topic in marine science. Conventional light and electron microscopy methods are indispensable tools for microalgae species identification; however, they are time consuming and tedious, making it difficult to assay a large number of samples in long-term monitoring and high-throughput projects (Scholin et al., 1996). In addition, the different shapes and sizes of microalgae in varying environmental conditions or in different growth stages make them difficult to count, especially when several morphologically similar algae coexist in samples (Xin et al., 2005). Consequently, other techniques, including flow cytometry and microscopy (FlowCAM) (Sieracki et al., 1998; Jonker et al., 1995), chemotaxonomy (Mackey et al., 1996; Yao et al., 2006), spectrofluorometry for algal classes (Koehne et al., 1999; Jeffrey and Welschmeyer, 1997), oligonucleotide probes and immunoassays have been introduced in the field, and now play increasingly important roles in identifying and monitoring microalgae (Scholin et al., 1996; Simon et al., 2000).

The bloom and impacts of the mixture on marine plankton, such as bacterioplankton, heterotrophic protists and zooplankton, the present investigation was carried out field experiments through Mandapam to Keelakarai coastal waters of Tamil Nadu, Southeast coast of India. Field monitoring in open ocean system is difficult to conduct because of high spatial and temporal variability of the site. For these reasons, there are almost no researches carried out the field experiment on the open system. This study might be the first attempt at the field experiment in the ocean.

Materials and Methods

Gulf of Mannar covers approximately an area of 10,500 sq. kms lying between 08˚ 35N - 09˚ 25N and 78˚ 08' E to 79˚ 30" E. It is unique for its heterogenous biological resources. The region is not more than 20 meter in depth. There are 21 islands covering of 625 hectares. The islands are classified into 4 groups, namely Mandapam group, Keelakarai group, Vembar group and Tuticorin group. The present study has been made extensively in the Gulf of Mannar. The Gulf of Mannar is influenced by the south west and North east monsoon. Although the south west monsoon is rain during June to September, it does not bring to this

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coast much rain. The north east monsoon which is prevalent during October to December brings heavy rain fall to this area. The tidal amplitude here is about 0.75m during the south west monsoon, the coastal waters in the Gulf of Mannar become turbulent owing to strong winds. Here the Mandapam and Keelakarai is a major in the Palk Bay and lot of trawlers are being operated from this centre and download their catches.

Hydrological parameters

The dissolved oxygen content (ml/l) was analyzed by modified Winkler's method (Strickland and Parsons, 1972). For the analysis of nutrients, surface water samples were collected using clean plastic bucket and the samples were immediately transported to the laboratory and filtered through millipore filtering system. For the analysis of nutrients the standard procedure described by Strickland and Parsons (1972) was followed.

Plankton collection and Preservation

The bloom samples were collected using the IOE plankton net; the mesh size was 335 micron. Paired plankton (Bongo) nets are cast over the side to collect phytoplankton such as diatoms and dinoflagellates and principally zooplankton such as copepods, arrow worms, and invertebrate larvae also collected all the way through that. The pair of nets (known as "Bongo nets") provides some degree of replication for spatial sampling. Note the sampler at lower left, who is holding a protractor that enables to estimate the angle of entry of the wire holding the nets; with this and a measure of the line that is paid out, one can get an estimate of the sampling depth. Most plankton nets are equipped with propeller - driven anemometers, in order to estimate the linear distance towed. With the cross-sectional area, this allows the volume of water sampled to be estimated. Mostly phytoplankton and zooplankton can be sampled with nets, but they are usually taken with pumps or automatically closing bottles. The samples were preserved using 5% diluted formalin and 5% $MgCl_2$ then the samples were stored in the polythene containers. Qualitative analysis for the settling method described by [Sucknova, 1978] was adopted. Numerical plankton analysis was carried out using Utermohl's inverted plankton microscope.

Phytoplankton was identified using the standard works of various authors [Venkatraman, 1939; Subramanyan, 1946; Prescott, 1954; Cupp, 1943; Desikachary, 1959 & 1987; Hendey, 1964, Steindinger Williams, 1970 and Taylor, 1976] for the sake of convenience, the phytoplankton collected were assigned to five major groups diatoms, dinoflagellates., blue-green algae, green algae and silico flagellates.

Result

Monitoring the HABs was carried out during July to December 2008, Mandapam and Keelakarai coastal waters of Tamil Nadu, Southeast coast of India. In the month of October several fin fishes and shellfishes were died due to *Noctiluca* blooms along these two areas. Identification of harmful algae (Phytoplankton), microzooplankton and hydro chemical parameters was also analyzed. During the study period some species of phytoplankton were common in these two areas such as *Coscinodiscus* sp, *Skeletonema costatum*, *Bacillaria paradoxa*, *Thallassiothrix frauenfeldii*, *T. longisima*, *Leptocylindrus* sp., *Oscillatoria limosa* and some following species moderately occurred such as *Odentella mobiliensis, O. sinensis, Pleurosigma elongatum, Triceratium favus, T. reticulatum, Frangilaria oceanica, Rhizosolenia setigera, Coscinodiscus jonesianus, C. eccentricus, Lithodesmium undulatum, Nitzschia* sp. and *Chaetoceros compressus*. Single cell blooms *Noctiluca* sp., (Photos 1-3) were recorded during the month of October and some of the blooms forming species have been recorded during the month of July and August such as *Ceratium macroceros, C. trichoceros, C. tripos, C. harridum, C. extensum, C. falcatum, C. inflatum*, and a species of blue – greens (Cyanophyceae), *Trichodesmium erythraeum* and *Trichodesmium* sp. (Table-1).

Table 1. Shows the check list of phytoplankton in Mandapam and Keelakarai

S. No.	Species Name	Mandapam	Keelakarai
	Family: Coscinodisceae(Diatoms)		
1	*Coscinodiscus centralis*	-	+
2	*C. lineatus*	+	+
3	*C. asteromphalus*	+	+
4	*C. eccentricus*	+	+
5	*C. gigas*		+
6	*C. thorii*	+	+
7	*C. jonesianus*	+	+
8	*C. radiatus*	+	
9	*Planktoniella sol*	-	+
10	*Skeletonema costatum*	-	+
11	*Thalassiosira* sp.		+
12	*Cyclotella seriata*	+	+
	Family : Triceratiinae (Diatoms)		
13	*Lithodesmium undulatum*	-	+
14	*Ditylum brightwellii*	+	-
15	*Triceratium reticulatum*	+	-
16	*T. favus*	-	+
	Family : Chaetoceraceae (Diatoms)		
17	*Chaetoceros affinis*	+	-
18	*C. curvicetus*		+
19	*C.compressus*	+	+
20	*C. dydymus*	+	
21	*C. diversus*	-	+
22	*C. lorenzianus*	+	+
23	*C. peruvians*	+	-
24	*C. indicus*	-	+
25	*C. diversus*	+	+
26	*Bacteriostrum hyalinum*	+	+
27	*B. delicatulum*	+	-
28	*B. comosum*	+	-
29	*B. varians*	+	-
	Family: Biddulphoidae (Diatoms)		
30	*Odentella sinensis*	+	+
31	*O. mobiliensis*	+	+
	Family : Solenoidae (Diatoms)		
32	*Leptocylindrus danicus*	-	+
33	*L. minimus*	-	+
34	*Rhizosolenia styliformis*	+	+
35	*R. robusta*	+	-
36	*R. stolterfothii*		+
37	*R. crassipina*	+	-
38	*R. cylindrus*		+
39	*R. alata*	+	+
40	*R. castracanei*	-	+
41	*R . setigera*	+	+
42	*Guinardia flaccida*	-	+
43	*Bacillaria paradoxa*	-	+
44	*Isthima inervis*	+	+
	Family: Euodicidae (Diatoms)		
45	*Hemidiscus cuneiformis*	-	+
46	*Hemidiscus sinensis*	-	+
	Order:Pennales (Diatoms)		
	Family: Fragilarioideae		
47	*Climacosphenia moniligera*	+	-
48	*C. elongata*	+	-
49	*Frangilaria oceanica*	+	-
50	*Rhaphoneis amphiceros*	-	+
51	*Thalassionema nitzschioides*	+	+
52	*Thalassiothrix frauenfeldii*	+	+
53	*Thalassiothrix longissima*	+	+
54	*Astrionellapsis* sp.	+	+

	Family: Naviculaceae		
55	*Pleurosigma angulatum*	-	+
56	*P. elongatum*	-	+
57	*Pleurosigma* sp.	+	
58	*P. normanii*	-	+
59	*Gyrosigma* sp.	-	+
60	*Nitzshia longissima*	+	+
61	*N. sigma*	+	
62	*N. seriata*	-	+
63	*Nitzschia* sp.	-	+
64	*Navicula hennneydii*	-	+
65	*Navicula* sp.	+	+
66	*Cymbella marina*	-	+
67	*Pinnularia alpina*	+	
	Dinophyceae (Dinoflagellates)		
	Class: Pyrrophyceae		
	Order: Dinophysiales		
68	*Dinophysis caudata*	+	+
	Order:Peridiniales		
69	*Ceratium macroceros*	+	+
70	*C. furca*	+	
71	*C. tripos*	+	+
72	*C. trichoceros*	+	+
73	*C.kofoidii*	+	
74	*C. falcatum*	-	+
75	*C. minutum*	+	+
76	*C. horridum*	-	+
77	*C. teres*	-	+
78	*Protoperidinium oceanicum*		
79	*P.depressum*	+	-
80	*Noctiluca* sp.	-	+
	Cyanophyceae (Blue green algae)		
81	*Trichodesmium* sp.	+	+
82	*Oscillatoria* sp.	-	+

\+ Present - Absent

The present investigation the zooplankton and microzooplankton was also recorded; from that some species of zooplankton frequently recorded such as *Paracalanus parvus, Acrocalanus gracilis, Pseudodiaptomus serricautatus, Rhincalanus cornutus, R. nasutus, Euterpina acutifrons, Nannocalanus minor, Eucalanus attenuates, E. crassus,* Fish larvae, Fish eggs, Barnacle nauplii, Bivalve larvae, Gastropod larvae, Copepod nauplii and Mysis larvae. Some species were found to be rare in these two coastal regions such as *Luciferhanseni*, *Microsetella* sp., *Acartia erythrea*, *Temora turbinata*, *Centropages furcatus*, *Pseudodiaptomus aurivilli* and *Eucalanus* sp. The microzooplankton like *Favella philippinensis*, *F. brevis*, *Globigernia opima* and *Tintinnopsis* sp were commonly observed during bloom time (Table 1). The hydrological parameters also analyzed during bloom and after blooms; the dissolved oxygen (2.6 – 4.9µM L^{-1}) nutrients varied between nitrate (0.66 – 1.01µM L^{-1}) nitrite (0.11 – 0.21µM L^{-1}) phosphate (0.51 – 0.86µM L^{-1}) and silicate (0.81 – 4.2µM L^{-1}) Fig (1-5).

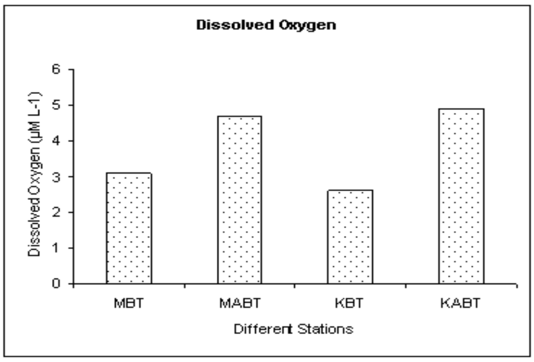
Table 2. Shows the check list of zooplankton in Mandapam and Keelakarai

S. No.	Species Name	Mandapam	Keelakarai
	Zooplankton		
	Order:Copepoda		
	Sub order: Calanoida		
	Family: Calanidae		
1	*Nannocalanus minor*	+	+
2	*Canthocalanus pauper*	+	-
	Family: Eucalanidae		
3	*Rhincalanus* sp	+	+
4	*Eucalanus elongatus*	-	+
5	*E. crassus*	-	+
	Family: Paracalanidae		
6	*Paracalanus parvus*	+	+
7	*P. aculeatus*	+	+
8	*Acrocalanus gibber*	+	-
9	*A. gracilis*	+	+
10	*A. monachus*	-	+
	Family: Centropagidae		
11	*Centropages orsinii*	+	+
12	*C. furcatus*	+	-
13	*C. tenuiremiss*	+	+
14	*C. alcocki*	+	-
15	*Isias tropica*	+	-
	Family: Pseudodiaptomidae		
16	*Pseudodiaptomus aurivilli*	+	+
17	*P. serricautatus*	+	+
	Family:Temoridae		
18	*Temora* sp.	+	-
	Family: Arietellidae		
19	*Metacalanus aurivilli*	+	-
	Family: Candaciidae		
20	*Candacia* sp.	-	+
	Family: pontellidae		
21	*Calanopia* sp.	-	+
22	*C. minor*	+	-
23	*Labidocera acuta*	+	-
24	*L. pectinata*	+	+
25	*L. pavo*	+	-
	Family: Acartiidae		
26	*Acartia spinicauda*	+	+
27	*A. erythraea*	+	-
28	*A. danae*	+	-
29	*A. southwelli*	-	+
	Suborder: Harpacticoida		
	Family: Ectinosomidae		
30	*Microsetella norvegica*	+	+
	Family: Macrosetellidae		
31	*Macrosetella gracilis*	+	-
32	*M. oculata*	+	-
	Family: Clytemnestridae		
33	*Clytemnestra scutellata*	+	+
	Family: Tachidiidae		
34	*Euterpina acutifrans*	+	+
	Family: Metidae		
35	*Metis jousseaumei*	+	+
	Suborder:Cyclopoida		
	Family: Oithonidae		
36	*Oithona similes*	+	+
37	*O. brevicornis*	+	+
	Family:Corycaeidae		
38	*Corycaeus danae*	+	-
39	*C. catus*	+	-

	Micro-zooplannkton		
	Foraminifera		
40	*Globigerna opima*	+	-
41	*Globigerna* sp.	+	-
	Spirotricha		
42	*Tintinopsis cylindrica*	-	+
43	*T. tocantinesis*	+	-
44	*T. beroidea*	+	+
45	*Tintinopsis* sp.	+	-
46	*Favella brevis*	+	-
47	*F. philipiensis*	+	+
	Hydroida		
48	*Obelia* sp.	+	+
	Cladocera		
49	*Evadne* sp.	+	-
	Decapoda		
50	*Lucifer hanseni*	+	+
	Sagittoida		
51	*Sagitta* sp.	+	-
	Larval forms		
52	Bivalve veliger	+	+
53	Gastropod veliger	+	+
54	Crustacean nauplii	-	+
55	Copepod nauplii	+	+
56	Barnacle nauplii	+	+
57	Cypris larvae of barnacle	+	-
58	Shrimp larvae	+	-
59	Crab zoea	+	+
60	Polychaete larvae	-	+
61	Fish eggs	+	+
62	Fish larvae	+	-
63	Mysis larvae	+	+

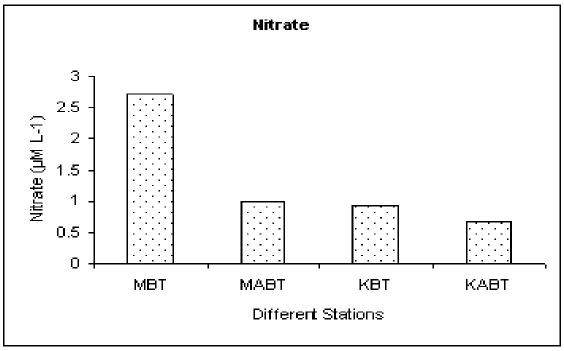
+ Present - Absent

Fig 1. Shows the Dissolved oxygen content during Bloom & after Bloom Period



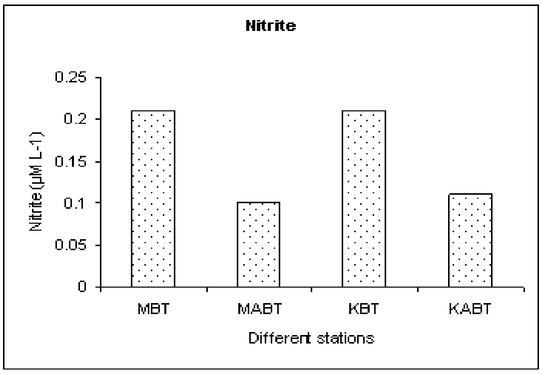
MBT - Mandapam Bloom Time; MABT – Mandapam After Bloom
KBT – Keelakarai Bloom Time; KABT – Keelakarai After Bloom

Fig 2. Shows the Nitrate content during Bloom & after Bloom Period



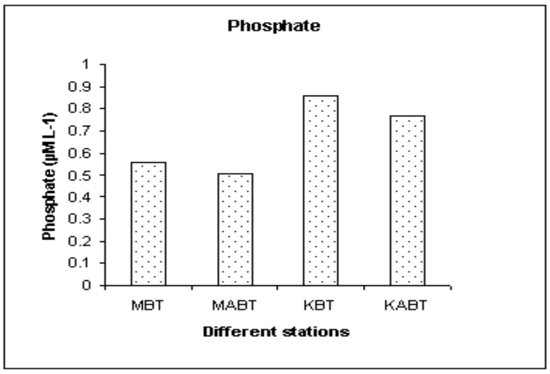
MBT - Mandapam Bloom Time; MABT – Mandapam After Bloom
KBT – Keelakarai Bloom Time; KABT – Keelakarai After Bloom

Fig 3. Shows the Nitrite content during Bloom & after Bloom Period



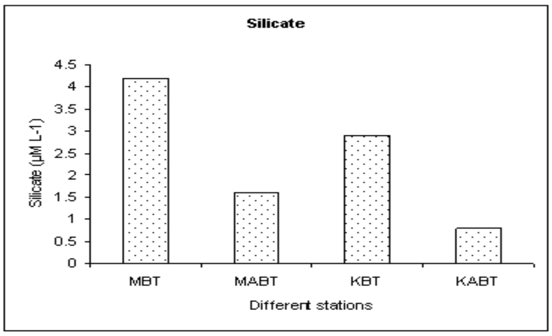
MBT - Mandapam Bloom Time; MABT – Mandapam After Bloom
KBT – Keelakarai Bloom Time; KABT – Keelakarai After Bloom

Fig 4. Shows the Phosphate content during Bloom & after Bloom Period



MBT - Mandapam Bloom Time; MABT – Mandapam After Bloom
KBT – Keelakarai Bloom Time; KABT – Keelakarai After Bloom

Fig 5. Shows the Silicate content during Bloom & after Bloom Period



MBT - Mandapam Bloom Time; MABT – Mandapam After Bloom
KBT – Keelakarai Bloom Time; KABT – Keelakarai After Bloom

Discussion

Harmful algal blooms (HABs) appear to have increased in frequency, intensity and geographic distribution worldwide. This increase is not only a threat to the coastal fish/shellfish aquaculture throughout the world (Anderson, 1998; Hallegreaff et al., 1995). 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 (Anderson, 1998). According to the earlier study the present investigation has reported that fishes and shellfishes were affected due to *Noctiluca* bloom.

Available external nutrient supplies can have a major influence on microalgal. Various workers (Pratt, 1966; Keating, 1977; Sharp et al., 1979) have reported the presence of toxic metabolites in culture filtrates from various algae. Myklestad et al. (1995) showed that cell-free filtrates of P-deficient cultures of *Chrysochromulina* strongly inhibited the growth of the diatom *Skeletonema costatum*. The addition cultures of microalgae under nutrient-deficient conditions (N or P) had a strong negative effect (Skovgaard and Hansen, 2003). The earlier reports strongly supportive to our present investigation for the period bloom the (N and P) content is more which enhance the growth of *Noctiluca*.

In summary, southeast Indian coastal waters has many HAB species, most of which have increased in frequency, abundance, regional extent and impact over the past few decades as population, agriculture and animal operations, and fertilizer usage have increased. In addition to increased nutrient loads, the estuaries, rivers and embayments of the region are also highly modified by declines in shellfish stocks and wetlands (e.g., Steel, 1991; Rothschild et al., 1994), leading to multiple stressors which collectively and synergistically lead to habitat change and alterations in tropic structure, including HAB proliferations.

Acknowledgement

This work was supported by a Ministry of Earth Sciences (Centre for Marine Living Resources and Ecology – V. N. Sanjeevan) New Delhi, India and the higher authorities of Annamalai University, Tamil Nadu, India, for which the authors are grateful.

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