Available online at: www.mbai.org.in doi: 10.6024/jmbai.2015.57.1.01806-04

Bloom of micro alga *Chlorella marina* (Butcher) in the Karapad lagoon, Gulf of Mannar, southeast coast of India

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Received: 26 June 2014, Accepted: 11 Feb 2015, Published: 31 March 2015

Original Article

Abstract
A study was conducted to find out the possible cause of sudden changes in the colour of the Karapad lagoon water and associated variation in the hydrography. The discolouration of lagoon water was noticed after the excavation work to deepen the lagoon area by the Municipal authorities to enable free boating. Microscopic examination of the lagoon water revealed the blooming of micro alga *Chlorella marina*. The blooming lasted for a month and has not caused any adverse effect. During the bloom days, the algal cell density attained a peak of 3.1x 105 cells l^{-1} on 5th day. Very high chlorophyll concentration was noticed in the lagoon water during the bloom days than the post bloom days. The studies revealed that the nutrient enrichment due to the re-suspension of sediments from the excavation activities might have triggered the algal outburst in the Karapad lagoon. Along with high nutrients, the surface water temperature and salinity might also have supported the algal proliferation.

Keywords: *Tuticorin Bay, Chlorella marina, discolouration, nutrient enrichment*

Introduction

The Karapad lagoon is an extension of Tuticorin Bay located in the western side off Tuticorin, Tamil Nadu, southeast coast of India, the embankment of which are guarded by luxuriant growth of mangrove *Avicennia marina*. These mangroves harbour the nursery ground for shrimp *Penaeus semisulcatus*, hence the lagoon forms an important source of livelihood. The lagoon often receives effluents from neighboring salt pans on the western side, hence variation in salinity and other parameters are regular here. The water level in the lagoon is maintained through tidal exchange through the adjacent bay on the eastern side.

In connection with converting this lagoon area as a boatyard for recreation purpose, the municipal corporation has excavated the lagoon and removed the excess slush to enable free boating, this removal of large amount of the bottom sediment has caused changes in the hydrography of the lagoon water. This was noticed from sudden changes in the colour of the lagoon during the last week of the July 2013. Apart from the discolouration of the water to greenish yellow, no abnormalities like off order, fish mortality, scum formation etc., have been observed. The rapid increase or proliferation in the population of microalgae often cause discolouration of the seawater called bloom. The occurrence of blooms are spontaneous and remarkable; their growth and persistence are brought about by a combination of physical, chemical and biological factors interacting in ways that are often sudden and unpredictable (Glibert *et al,* 2005). The patchy spatial distribution of algal bloom is usually connected to the physical variability of the water body (Kanonen and Lippanen, 1997). Several reports are available on the incidence of bloom caused by blue green algae, and dinoflagellate from Gulf of Mannar area (Chacko, 1942; Chidambaram and Unny, 1944; Chacko and Mahadevan, 1956; James, 1972; Chellam and Alagarswamy, 1978; Gopakumar *et al.*, 2009). The present study was conducted to identify the causative agents for discolouration of the Karapad lagoon and its adverse effects on hydrography.

Material and methods

Surface water samples were taken from two sampling stations, viz., St.1- the lagoon (8°46'374"N lat.; 78°09'477"E long.) where the discolouration of water occurred and from St.2- the bay water (8°46'386"N lat.; 78°09'491"E long.) adjacent to lagoon on the eastern side. Seawater samples were collected from the lagoon area during the bloom days on 2nd, 3rd, 6th, 8th, 16th and 27th August, until the colour in the lagoon was normalized after 28 days, while the sea water samples from the adjacent Tuticorin bay was collected on 2nd and 27th August to compare the variation during the beginning and end of the bloom days.

The sea water samples from these two stations were collected following the standard sampling procedures (APHA, 1995). Temperature was measured using a mercury thermometer with an accuracy of ± 0.1°C. Water samples were collected for parameters like, salinity, pH, dissolved oxygen, productivity, TSS, TDS and carbon dioxide were analysed according to the standard procedures (Strickland and Parson, 1968). The nutrients like nitrite, nitrate, phosphate, silicate and chlorophyll were estimated by the methods described by Parsons *et al.* (1984) and Ammonia by indo-phenol blue reaction method (Solarzano, 1969). Phytoplankton samples were also collected and enumerated on a Sedgwick-Rafter counting chamber under a stereo- zoom binocular microscope and the density was calculated and expressed in cells per litre. The species identification was done by following the classical work of Santhanam and Ramanathan (1987). The values of all the parameters were used for statistical analysis to test the correlation by using SPSS 7.5 statistical package.

Results and discussion

The variation in the hydrological parameter in the lagoon during the bloom days is given in Table 1. Inside the lagoon, the water was found light green in colour initially, then turned to yellowish green when the bloom was advanced (Fig.1). Microscopic examination revealed the presence of monospecific micro algae *Chlorella marina*, which is spherical in shape, about 2.75- 5.5μm in diameter. There was a gradation in the algal biomass noticed in the lagoon area, on the first day of sampling on 2nd August 2013, the algal biomass was 3.1x 10^5 cells l^{-1} , which attained a peak of 3.12 x10^5 cells l^{-1} on 3rd August 2013 and decreased to 1.7 x10^5 cells l^{-1} on 8th August 2013 and to 1.1 x10^5 cells l^{-1} on 16th August 2013 indicating the declining phase and lowered to the minimum of 7 x10^4 cells l^{-1} on 27th August 2013 as shown in Table 1. The algal cell density recorded in the present study was lower than 13.5 x10^5 cells l^{-1} as observed earlier in Muthupettai (Gopakumar *et al.*, 2009) and 28 x10^7 cells l^{-1} in Calicut (Jugunu and Kripa, 2009) and 1.75 x10^7 cells l^{-1} in Karapad bay (Santhanam *et al.*, 1994) and is in conformity with 3.01 x10^5 cells l^{-1} along the southwest coast observed by Venugopal *et al.*, (1979) and is higher than 2.38 x10^5 cellsl^{-1} observed by Mohanty *et al.*, (2010). Though fish mortality was a regular phenomenon along the Gulf of Mannar due to algal bloom (Chacko., 1942; Chidambaram and Unni., 1944; Chellam and Algar swamy 1978; Gopakumar *et al.*, 2009), no fish mortality have been noticed in the present study area. In the bay water, the algal cell density was normal with a mean value of 4 x 10^4 cells.l^{-1} observed during the bloom days (Fig. 4)

A wide fluctuation was noticed in both air and surface water temperature in the lagoon water, which might be due to the shallowness. In the lagoon, the air temperature was fluctuated between 29.5 and 34°C while the surface water temperature was found between 25 and 35°C (Table 1) which was comparatively higher than 32.5 - 33°C and 31.5-32°C for air and water temperature observed in the Bay (Fig.2). It is inferred that the enhanced temperature in the surface water of the lagoon might have influenced the algal growth as agreed by Mohanty *et al.*, (2010) which stated that the

Fig.1. Discolouration of the lagoon during *Chlorella marina* blooming.

Table 1. Water quality parameters and algal population in the lagoon area during the bloom days

Parameters	Date of Sampling					
	2nd Aug'13	3rd Aug'13	6th Aug'13	8th Aug'13	16th Aug'13	27thAug'13
AT (°C)	33.00	38.00	29.5	33.00	37.2	32.0
SST(°C)	32.00	31.00	25.00	34.00	35.00	31.5
Salinity (ppt)	63.33	66.65	57.16	41.51	45.3	36.53
GPP (mg.C.l-1day-1)	34.606	29.282	12.423	7.065	0	13.31
NPP (mg.C.l-1day-1)	23.958	13.309	5.325	0	0	7.9855
Chlorophyll (µg. l-1)	26.615	19.991	38.848	11.202	10.28	3.5344
Ammonia (µg.l-1)	125.1	85.4	168.8	106.9	115	88.8
D.O (ml.l^{-1})	3.7939	3.2766	3.1041	6.035	3.816	4.3113
Nitrate (µg.l-1)	1.6785	0.839	0.474	0.328	0.912	0
Nitrite (µg.l-1)	1.8562	2.5191	2.5412	1.6573	0.68501	0.5524
Phosphate (µg.l-1)	3.447	4.2074	4.1567	6.4378	2.9908	3.4977
Silicate (µg.l-1)	25	22.8	12.4	10	52.04	4.2
pH	7.81	7.64	7.38	7.49	7.98	7.42
T.S.S (g.l-1)	788	818	911	880	411	470
CO2 (mg.l-1)	123	0	0	0	0	25
Algae cell density (cells l-1)	3.1x105	3.12 x105	3 x105	1.7 x105	1.1 x105	7 x104

temperature has been recognized as an important factor that control the algal growth.

The pH did not show any significant variations during the bloom period and found ranged from 7.1-7.9 and 7.4-7.98 in the bay water and lagoon respectively. However, the salinity was higher during the start of bloom and became normal towards the end of bloom in the lagoon (Table 1). It is understood that the salinity of the lagoon was influenced by the intrusion of high saline water effluent from the nearby salt pan, hence fluctuated between a minimum of 36.5 ppt to a maximum of 66.7ppt (Table 1). The higher salinity might have supported the growth of algae in the lagoon water. Ouyang *et al.*, (2010) also reported that the net photosynthetic evolution of *C. marina* is increased

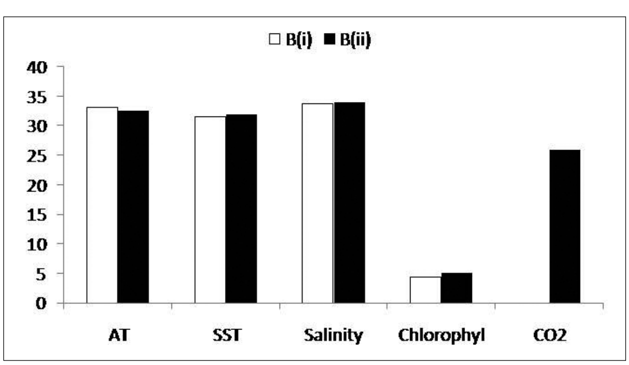

Fig.2. Variation in temperature, salinity, chlorophyl and carbondioxide concentration in the Tuticorin Bay (i - on 2nd August 2013 and ii - on 27th August 2013)

with increasing salinity and is capable of tolerating higher temperature and salinity more effectively. Statistically significant correlation was noticed between salinity and chlorophyll concentration and salinity and algal biomass ($p<0.05$). The salinity was normal in the bay water and ranged between 33.7 and 33.92 ppt (Fig.2).

In the lagoon, the dissolved oxygen was comparatively lower during the growth phase and slightly increased during the declining phase and ranged between the lowest of 3.1 ml L^{-1} on 6th August 2013 to 6.1 ml L^{-1} on 8th August 2013 (Table1). The mean value was 4.05 ± 0.4 ml L^{-1}. The higher dissolved oxygen content during the advanced period might be due to the photosynthetic release of dissolved oxygen by high algal biomass. Similar observations of higher dissolved oxygen in the growth phase of the bloom has been reported previously (Mohanty *et al.*, 2010 and Gopakumar *et al.*, 2009). In the bay, the dissolved oxygen was little bit higher and ranged between 3.6 to 4.31ml L^{-1} with a mean of 3.96 ± 0.2 ml L^{-1} (Fig. 3). Similarly a gradation in the GPP and NPP were noticed during the algal outburst in the lagoon. It was higher during the beginning days and lower towards the end. Such observation of higher productivity during the bloom period has been reported in previous studies (Devassy *et al.*, 1978; Santhanam *et al.*, 1994; Jyothibabu *et al.*, 2003) pointed out that the enhanced primary production could be due to the increased carbon requirement during the initial phase for constituting the necessary biomass of algae. In the bay water, it was 15.97mg C l^{-1} day^{-1} and 18.6 97mg C l^{-1} day^{-1} and 18.6

and 31.9 mg C l^{-1} day^{-1} on the first day of sampling on 2nd day and on 27th August 2013 for GPP and NPP respectively (Fig.3).

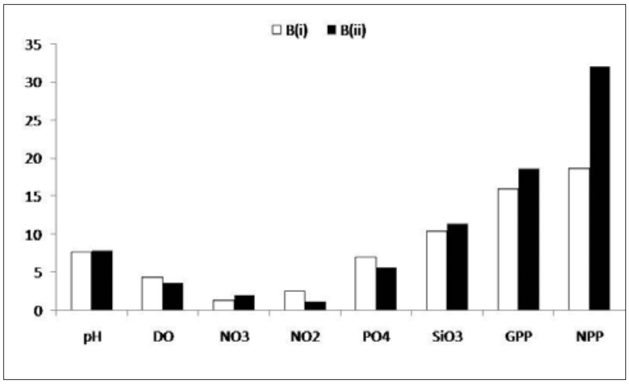

Fig.3. Variation in pH, DO, nitrate, nitrite, phosphate, silicate, GPP and NPP concentration in the Tuticorin bay (i - on 2nd August 2013 and ii - on 27th August 2013)

Very high chlorophyll concentration was noticed in the lagoon water during the bloom days. It was 26.6 μg ml^{-1} on the first day of sampling on 2nd August 2013 and attained a peak of 38.8 μg ml^{-1} on 6th August 2013 and decreased after one week and reduced to 3.5 μg ml^{-1} on the end of bloom day (27th August 2013) (Table1). However in the Karapad bay, normal level of 4.34 μg ml^{-1} was observed on 2nd August 2013 and 5.13 μg ml^{-1} towards the end of sampling on 27th August 2013 (Fig.3). Very high significant positive correlation was observed between Chlorophyll and algal biomass ($p<0.05$). Such high level of chlorophyll concentration during bloom days and low during the declining phase was also reported earlier (Nayak *et al.*, 2000., Dharani *et al.*, 2004; Gopakumar *et al.*, 2009; Madhu *et al.*, 2011; Mohanty *et al.*, 2010).

The ammonia concentration was found normal in the lagoon water during the bloom days. The blooming has no way affected the ammonia concentration, as there was not much variation observed between stations. It was ranged between 85.4 to 168.8 μg ml^{-1} with a mean 115.0$\pm$121.4 μg ml^{-1} in the lagoon water and between 103.6 μg ml^{-1} to 147.2 μg ml^{-1} with a mean of 125.4$\pm$21.9 μg ml^{-1} in the Karapad bay. There was a proportionate increase in the suspended solid concentration in the lagoon, as the bloom advanced. It was comparatively higher during the bloom period with the highest of 911 mg L^{-1} on 6th August 2013 and reduced towards the declining phase (Table1). In the Bay water, the TSS was normal and varied between 290 and 340 mg L^{-1} with a mean of 315 $\pm$25.1 μg ml^{-1} (Fig.4). The higher algal cell density and chlorophyll might have influenced the TSS, as there was a significant positive correlation observed between chlorophyll and TSS and TSS and algal cell density ($p<0.01$). Similar observation of high TSS during bloom days was also reported previously (Dharani *et al.*, 2004; Gopakumar *et al.*, 2009). In the lagoon area, the carbon dioxide concentration was detected on the first day of sampling and it was nil during the remaining period. A low level of 26 and 25 mg l^{-1} were observed in the bay and lagoon area on the end of the sampling on 27th August 2013.

The nutrients like nitrate, nitrite and phosphate were noticed to be low in the lagoon water compared to bay water. The nitrate concentration was varied between 1.35 and 2.007 μg L^{-1} in the bay water and 0.47 and 1.7 μg L^{-1} in the lagoon water and nitrate was found nil towards the end of bloom. Nitrite concentration was higher during the first week of the bloom in the lagoon water with the maximum of 2.54 μg L^{-1} on 6th August 2013 and was decreased towards the end of the bloom period with the lowest of 0.55 μg ml^{-1} (Table 1), whereas it was varied from 1.19 to 2.54 μg L^{-1} in the bay water. The phosphate concentration was lowest (3.4 μg ml^{-1}) on the first day of bloom and attained a peak of 6.4 μg ml^{-1} on 8th August 2013 and decreased during the declining period (Table 1). In the bay water, the phosphate was varied between 5.63 and 6.9 μg L^{-1}. A similar decreasing trend of nitrite, nitrate, and phosphate during bloom days have been reported earlier (Mani *et al.*, 1986; Santhanam *et al.*, 1994; Satpathy and Nair, 1996 and Perumal *et al.*, 1999).

The silicate concentration was comparatively higher in the lagoon water. It was 25 μg L^{-1} on the first day of sampling and attained a peak of 52.04 μg L^{-1} on 16th Aug'13. A minimum of 4.2 μg L^{-1} noticed towards the end of the bloom period on 27th August 2013 (Table 1). In the bay water it was 10.4 μg L^{-1} on the first day and 11.4 μg L^{-1} on the last day of sampling. The mean values were 21.07$\pm$6.9 μg L^{-1} and 10.9$\pm$0.5 μg L^{-1} in the lagoon and bay water respectively. Similar trend of higher silicate during bloom days was reported earlier in Port Blair (Dharani *et al.*, 2004). Relatively the high concentration of reactive silicate during bloom days may be the silicate released from the dead and decaying algae or from the excretion of algae (Subba Rao, 1969).

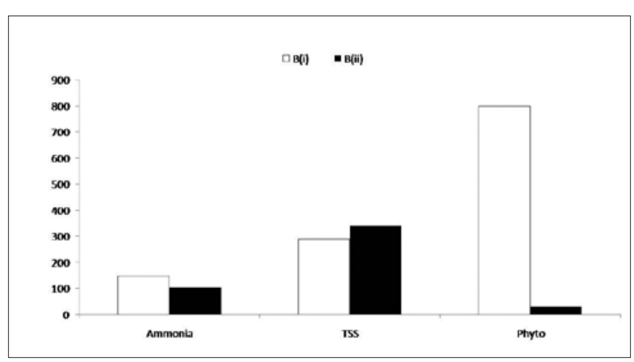

Fig.4. Variation in ammonia, TSS and phytoplankton population in the Tuticorin bay (i - on 2nd August 2013 and ii - on 27th August 2013)

The present study clearly indicated that the nutrient enrichment due to the re-suspension of sediments from the excavation activities in association with enriched salinity and water temperature might have triggered the algal outburst in the Karapad lagoon. The dredged sediment is one of the primary source of nutrients to the algae, which has been of greater concern in the eutrophication of surface water (Anne and Fred, 1981). The practice of dredging is usually causing a number of environmental impacts, including altered topography and hydrography, which has resulted in the damage of flora and fauna (Elijah *et al*., 2008). This study warrants the need for the constant monitoring of physico chemical parameters of Tuticorin coastal waters, where dredging and associated reclamation activities to maintain adequate navigational depth was a constant phenomenon for a quite longer period.

Acknowledgements

The authors thank the Director, CMFRI, Kochi and the Scientist-in-Charge, Tuticorin Research Centre of CMFRI for the support and facilities provided.

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