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Recurrence of Dinoflagellates, *Noctiluca scintillans* Bloom and Impact on Marine Faunal Communities of Mandapam Coastal Waters in Gulf of Mannar, Southeast Coast of India

Koushik Sadhukhan, Shanmugaraj Thimmu Reddiar and Ramana Murthy Venkata Mallavarapu

National Centre for Coastal Research, Ministry of Earth Sciences, Mandapam Field Research Centre Mandapam Camp- 623 519, India
National Centre for Coastal Research, Ministry of Earth Sciences, Pallikaranai, Chennai- 600 100, India
E-mail: sadhukhan.1985@gmail.com

***Abstract*:** Massive blooms of *Noctiluca scintillans* reoccurred at several regions of Mandapam coastal waters between 22nd September and 30th September, 2020. Bloom lasted for nearly one month, causing mortality of fishes and other marine organisms by facilitating hypoxia condition in the water column. Fifteen locations in four areas, namely Hare Island, Vedhalai seashore, Seniappadarga, Pudhumadam and Manoli Island have been surveyed thoroughly to understand the bloom's intensity and its impact on marine biota. Mass mortality of marine organisms was reported during this survey including fishes, octopus, sea cucumbers, sea anemones, crabs and sea shells due to the bloom incidence. A total of 371 numbers of marine organisms were dead during the bloom. The cell density of *N. scinitillans* bloom was 14.7×10^5 cells l^{-1} in core dense area, 8.6×10^5cells l^{-1} in semi-dense area, 0.47×10^5cells l^{-1} in less dense areas, and 1440 cells $\times$ l^{-1}cells in clear water. Physicochemical parameters measured in the bloom region were sea surface temperature 32.3°C, Salinity 35.78ppt, dissolved oxygen 4.61 mg/l and pH 7.11 ± 1.02, Phosphate 2.831µM, Nitrate 2.407 µM and ammonia 31.324µM. The high level of phosphate triggers the growth of algal bloom which results in sudden drop of dissolved oxygen and triggers the death of fishes and marine invertebrates in the bloom regions. There is no adverse impact found on scleractinian corals. Post bloom investigations are underway to report the further adverse effect on the ecosystem's marine resources or resilience to recover from the sudden natural damage.

Keywords: Algal bloom, *Noctiluca scintillans*, Cell density, Nutrient, Sea surface temperature

Several colossal green colour patches were observed on 22nd September 2020 at different places of Mandapam coastal waters. The same dinoflagellate species bloom was documented last year on 11th September. Microscopic observations of collected samples confirmed *N. scintillans* bloom. The same bloom incident was recorded in the last year from Mandapam coastal waters during September months which last for 14-17 days and causes mass mortality of fishes near to Krusadai Island. *N. scintillans* is a common bloom-forming dinoflagellate in the World Ocean, considered as toxic to the marine organisms, especially for caged fishes (Smyda 1997, Vijayalakshmi et al 2018). Generally, these microscopic heterotrophic unarmoured dinoflagellates are colourless, but they appear as green in colour due to the presence of endosymbiotic free-swimming cells of *Pedinomonas noctilucae* (Gomes et al 2014). The persisting occurrence of *N. scintillans* blooms were well documented in India, including the Arabian Sea (Sulochona et al 2014), Gulf of Mannar (Gopakumar et al 2009, Anatharaman et al 2010, Shanmugaraj et al 2019), Andaman and Nicobar Islands (Dharani et al 2010), Southwest coast of India (Vijayalakshmi et al 2018), and Rushikulya river of Bay of Bengal (Mohanty et al 2007). The present report of *Noctiluca* blooms was more intense near the shore of the mainland than the offshore Islands, which may be a warning sign for the future cage culture practices. This study aimed to highlight the density of the bloom, the role of physic-chemical parameters on the bloom formation, and the impact of bloom on coral reefs.

MATERIAL AND METHODS

Bloom water samples in triplicate were collected from five selected areas of the Mandapam region, namely Hare Island, Vedhalai seashore, Seniappadarga, and Pudhumadam. Locations were marked using a GARMIN e-TREX handheld GPS device (Table 1 & Fig.1). The collected samples were preserved in 8% formalin solution for further analysis. Physico-chemical parameters of the bloom water samples were analyzed using Manta 2+ multi-probe water quality parameters snode (pH, temperature, DO_2, salinity, nitrate, phosphate, and ammonia). *N. scintillans* cells were counted on Sedgwick-rafter counting chamber under 4x and 10x magnification in Lynx binocular microscope. Bloom density was calculated in *Noctiluca* cells per litre. Based on the cell density, the intensity of the bloom was categorized into four

groups called core-dense area (CD), semi-dense area (SD), less-dense area (LD), and clear water (CW). Photographic evidence of the impact of bloom on coastal fauna and coral reefs health status was recorded using NIKON W300 underwater camera.

RESULTS AND DISCUSSION

The coastal water of the Mandapam region appeared in green patches during the bloom period. Water samples analysis revealed the bloom forming dinoflagellates *Noctiluca scintillans* (Fig. 2). The cell density of *N. scintillans* varied at different study sites. The average size ranged from 270 - 1120µm. Cell density of the CD area was 14.7 x 10^5, 8.6

Table 1. Coordinates details of study area

Location	GPS coordinates
Hare Island	N09°12.638' E79°04.796'
	N09°12.393' E79°05.378'
	N09°12.632' E79°05.654'
Vedhalai	N09°15.562' E79°06.195'
	N09°15.154' E79°06.011'
	N09°14.669' E79°05.908'
Seniappa Darga	N09°15.446' E79°02.572'
	N09°15.436' E79°02.444'
	N09°15.409' E79°02.217'
Pudhumadam	N09°15.415' E79°00.614'
	N09°15.542' E79°00.915'
	N09°15.405' E79°01.120'
Manoli Island	N09°11.412' E79°06.732'
	N09°11.806' E79°08.193'
	N09°11.608' E79°06.959'

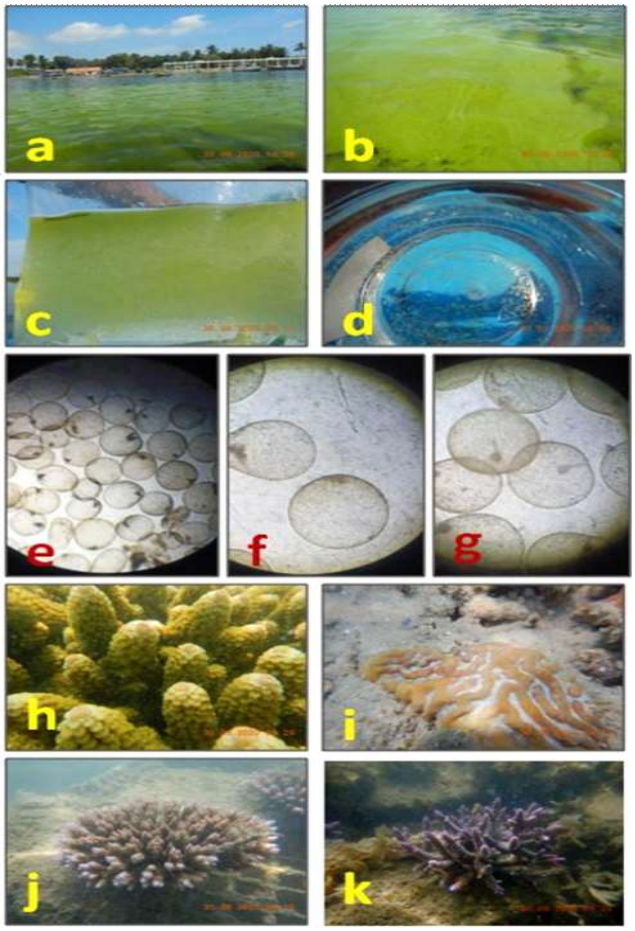

Fig. 2a-d: Field observation of *Noctiluca* bloom; e: Microscopic observation of *Noctiluca* cells (4X magnification); f-g: Microscopic observation of *Noctiluca* cells (4X magnification); h-i: Healthy coral colonies in the natural site during bloom; j-k:Healthy coral colonies in restoration site during bloom

Fig. 1. Map showing the study area

x 10^5 in SD, 47 x 10^3 in LD and 2840 cells l^{-1} in clear waters. Among all the study sites, Vedhalai seashore showed the maximum bloom density with 19 x 10^5 cells l^{-1} (Fig. 3). Massive mortality of fish death documented from Pudumadam, Seniappa Darga and southern side of the Manoli Island. Semi-dense bloom was observed near Hare Island, which doesn't have any adverse effect on the coral reefs (Fig. 2). The bloom was more intense on 24th, 25th, 26th in Vedhalai seashore, and 28th, 29th was in Pudhumadam. The bloom intensity was declined after 29th September, and on 30th September Based on field observation, bloom was concentrated up to 1.7m depth, and no bloom formation was found beyond 2m. Coral reef Monitoring in natural and restored sites revealed the unaffected, normal and healthy state of corals found in reef sites.

A total of 310 dead specimens were counted from the mainland coast of which fishes are 84.19%, crustaceans are 7.74%, Echinodermata 2.90%, Mollusca 2.26%, Sea anemones 1.61% and sea snakes are 1.29% (Fig. 4). Among the fishes, 22 different families were dead due to this bloom effect. Based on the field observation and statistical analysis, mortality was major for Puffer fish (Tetraodontidae) 17.24%, snake eel (Ophichthidae) 9.96%, Parrot fish (scaridae) 9.96% followed by Silver sillago (Sillaginidae) and Moray eel (Muraeinidae) 7%, (Fig. 5). In southern side of the Manoli Island, 61 marine organisms were dead in the bloom area which includes 74% of fishes, 21% of Octopus, 2% of Jellyfish and 3% of Sea cucumber. Among the fishes, mortality of scaridae (Parrot fish) family fishes was 24%, Lathrinidae (Emperor fish) was 13% followed by Lutjanidae (Snappers), Siganidae (Rabbitfish), Tetraodontidae (Porcupine fish), Muraenidae (moray eel) and Balistidae (Triggerfish) (Fig. 6, 7 & 8). Bloom in several places of Manoli Island was found to be decomposed by the bacteria and settled down to the bottom which causes a serious change in the oxygen level of the water and it causes the death of marine organism specially those lives inside the rocks or underneath of the rocks such as eel, groupers, octopus etc.

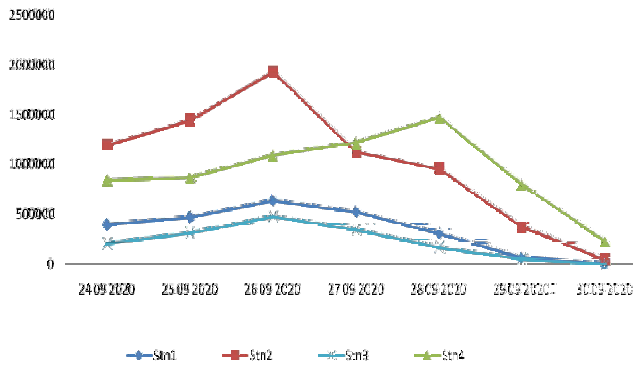

Fig. 3. Day-wisecell density of *Noctiluca scintillans* in GoM

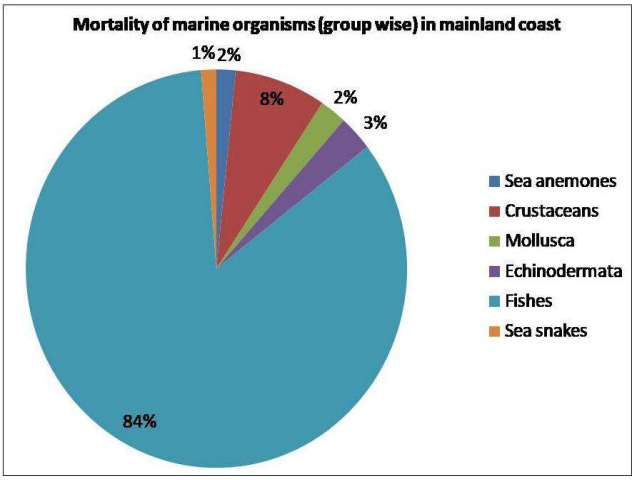

Fig. 4. Mortality of marine organism in mainland coast

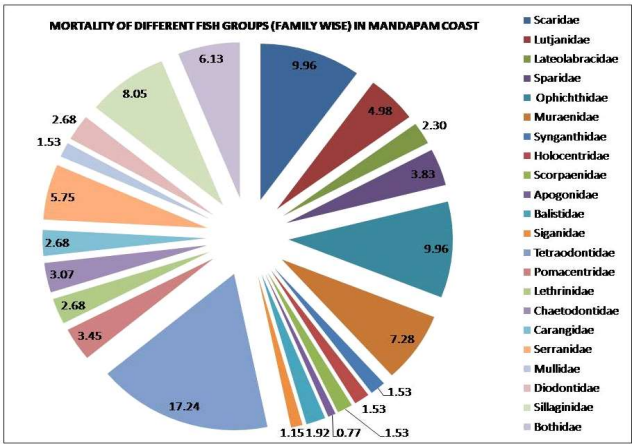

Fig. 5. Mortality of different fish families recorded in Mandapam Coast

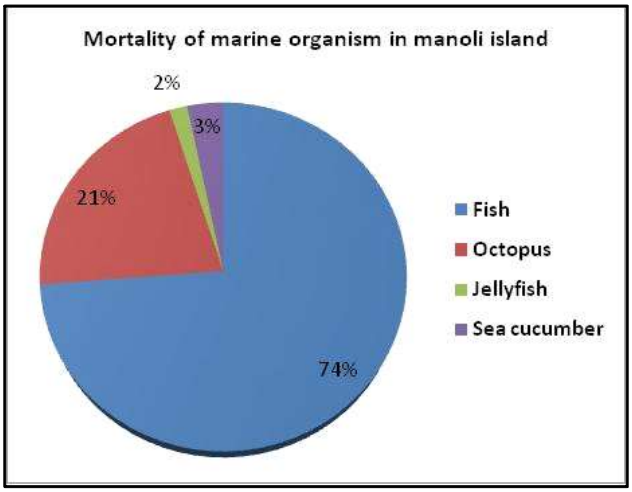

Fig. 6. Mortality of marine organism in Manoli Island

Nutrient analysis of the water samples collected from bloom affected area reported that phosphate level (PO_4^{3-}) was high 2.831 µM, while nitrate (NO_3^-) and ammonium (NH_4^+) contents were under the optimum limit. During the warning phases, the environmental parameters are SST 33.2°C, pH was 7.2, and $DO_2$was 4.61mg/l (Table 2). The presence of a high amount of nutrients in the water lowers the concentration of oxygen and causes asphyxiation. The low level of oxygen in water caused by *Noctiluca scintillans* bloom is the major cause of fish death and other marine organism in Mandapam waters. The sudden increase of phosphate content triggers the *Noctiluca* bloom, which might be occurred in present study (Montani et al 1998). Heavy wind and strong current patterns appear to disperse the *Noctiluca* bloom from the Mandapam region to the southern part of Sri Lanka. Gopakumar (2009) observed the transition period between summer and monsoon in GoM is exposed to high wind variable and strong monsoon driven currents and within 7 days, a sharp decline of *Noctiluca* cell density was observed (12-14 x 10^5 cells l^{-1} to 2-9 x 10^3 cells l^{-1}).

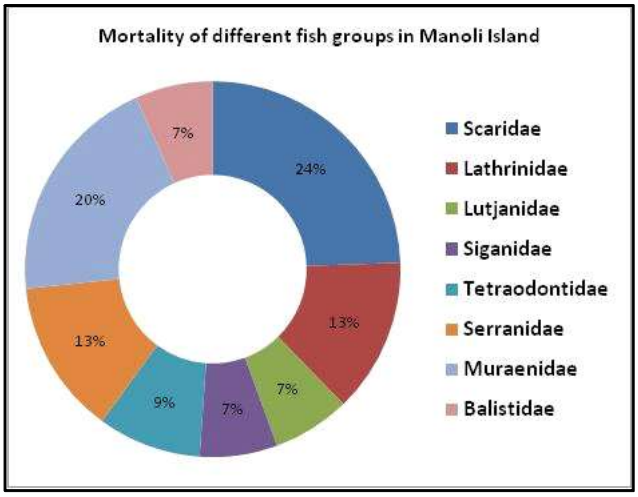

Fig. 7. Mortality of different fish groups in Manoli Island

Physicochemical parameters during the intense bloom formation were not drastically changed. Consistent monitoring of water quality parameters revealed no sharp changes in the DO_2, as documented by Eashwar et al (2001). Average DO_2 content was between 4.61mg/l to 4.88 mg/l (Table 1). The earlier report strongly supports our present observation of high SST in Mandapam regions could have triggered *Noctiluca* to form intense bloom in the Vedhalai seashore and Pudhumadam area (Gopakumar 2009). Based on visual observation, constant current between Manoli and Hare Island channel might reduce the massive accumulation of *Noctiluca* cells. Therefore, bloom appeared in Hare Islands as less dense (LD) and clean water (CW). Although several reports concluded that nutrient enrichment causes algal

Fig. 8a-e. Mortality of marine organism found in southern side of the Manoli Island, f-l: mortality of fishes and crabs photographed in Pudumadam area of Mandapam village

Table 2. Water quality parameters of study sites during Noctiluca bloom (Mean± SD)

Study area	pH	SST	Salinity	DO_2
1	7.00±0.30	30.02±0.06	35.24±0.22	5.21±0.08
2	7.13±0.09	31.81±1.02	35.17±0.36	5.10±0.10
3	7.45±0.02	31.77±0.07	35.82±0.19	6.07±0.13
4	7.30±0.03	30.16±0.45	35.55±0.10	5.43±0.75
5	6.11±0.09	30.41±0.09	36.00±0.32	4.11±0.30
6	6.27±0.11	31.28±1.00	35.89±0.45	4.72±0.05
7	8.00±0.07	31.70±0.06	36.09±0.19	5.09±0.21
8	8.10±0.01	32.61±0.54	35.22±0.07	5.89±0.15
9	8.25±0.04	32.44±0.06	35.17±0.21	6.10±0.22
10	7.75±1.07	31.47±0.49	34.89±0.14	5.29±0.50
11	8.90±0.07	31.81±0.19	34.77±0.11	4.76±0.12
12	8.02±0.03	31.99±0.26	34.61±0.09	4.00±0.28
13	7.38±0.15	32.19±0.12	35.51±0.35	3.42±0.42
14	8.02±0.09	32.00±0.24	35.24±0.12	3.00±1.54
15	8.12±0.17	32.19±1.06	35.06±0.27	2.53±0.90

bloom and, as a consequence, it adversely effects on coral reefs, there is also some other cases where corals respond positively to the higher nutrient concentration in water in terms of growth, survival, and resistance to bleaching (Bongiorni et al 2003, McClanahan et al 2003, Dunn et al 2012, Aouititen et al 2021). In the present study, no mortality of corals was observed during the survey, and no information on marine mammal's death was reported from local fishermen communities. In summary, the repetitive occurrence of *Noctiluca* bloom in the Gulf of Mannar might not have any fatal effect. Still, it could increase the multiple stressors which collectively and synergistically lead to habitat change and alteration in trophic structures. Continuous monitoring of physicochemical parameters and nutrient analysis could identify algal blooms' trend and further effect on the GoM marine ecosystem.

CONCLUSION

Noctiluca bloom observed in Mandapam Coastal Water is unique because it appeared twice within a gap of one year at the same time which earlier never reported from this region. The repeated bloom occurrence causes severe impact on marine faunal communities especially on fishes and marine invertebrates of Gulf of Mannar which leads into an economic loss to the coastal communities of Gulf of Mannar. The present study doesn't find any impact on scleractinian corals which provides a sign of reef resilience and a hope of healthy reef recovery after this fatal bloom incident.

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