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Impact of *Noctiluca scintillans* Bloom on Coastal Fauna of Mandapam Region in Gulf of Mannar Marine Biosphere Reserve, Southeast Coast of Tamil Nadu, India

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ABSTRACT

On 11th September, 2019, coastal waters near to offshore islands of Mandapam region appeared in dark green colour, which is caused by bioluminescent dinoflagellate *Noctiluca scintillans*, commonly called as Sea Sparkle. Extensive monitoring was carried out during 11th to 25th September, 2019 to assess the impact of this bloom on offshore islands of Mandapam region of Gulf of Mannar coastal fauna. Mass mortality of variety of fish, sea shells and sea snakes washed ashore on Kundukal area in Mandapam region was observed due to the sudden raise of *Noctiluca scintillans* bloom. No negative impact on coral reefs was recorded from Mandapam group of Islands. Reef building corals remain healthy during and after the bloom formation. There is no significant (p value 0.2111, $p<0.05$) difference was found in the environmental parameters investigated before and after the bloom formation. Nutrient rich environment and favourable environmental parameters might have helped coral symbionts to respond positively which in turn accelerate the density of zooxanthellae without doing any negative effect on coral holobiont and consequently that leads to maintain a healthy reef condition during this bloom formation.

Key Words**:** Algal Bloom; Coral Reefs; Fish Mortality; Water Quality

INTRODUCTION

Tropical algal bloom events have become a frequent phenomenon as a result of increased coastal eutrophication, long dispersal of ballast water discharge and changes in ocean climate (Heisler et al. 2008, Rabalais et al. 2009). Since 1908, a total of 108 cases of algal blooms were reported from Indian coastal waters, of which *N. scintillans* and *Trichodesmium erythraeum* bloom are most common (D'Silva et al. 2012). Nutrient enriched waters and increased sea surface temperature are the major causes of *Noctiluca* blooms which substantially affecting marine communities (Gopakumar et al. 2008). In South east coast of India, *Noctiluca* bloom was reported from Gulf of Mannar and Palk Bay which results in sudden death of fishes, sea shells, sea snakes and other benthic fauna (Gopakumar et al. 2008, Prasad 1953, Sampathkumar and Balasubramanian 2010). Gulf of Mannar (GoM) harbours a rich marine biodiversity which composed of 4,223 species of flora and fauna. The GoM area extends from Rameswaram to Tuticorin and exhibits a chain of 21 islands with offshore fringing coral reefs inhabited in a depth range of 0.5m to 8m (ENVIS 2015). Recently, in between 1st and 2nd week of September 2019, *N. scintillans* bloom was first appeared around the coral reefs of Gulf of Mannar (GoM) region and later it intensified into dense bloom which resulted the surface water in dark green from 11th September onwards. The bloom persisted for several days. This incident resulted in mass mortality of several fish, sea shells and sea snakes. The present communication addresses the preliminary observation on the impact of bloom on marine organisms, probable causes of the bloom and assesses the health of reef building corals during bloom formation.

MATERIALS AND METHODS

Field surveys were carried out around the Mandapam group of islands and main land regions of Gulf of Mannar. Locations of the sampling sites (Site 1: N09°13.185' E79°07.949', Site 2: N 09°12.397' E 79°08.417', Site 3: N 09°11.978' E 79°04.607', Site 4: N 09°13.334' E 79°05.177', Site5: N09°14.763'E79°13.246', Site 6 N09°14.687' E79°14.223') were marked with GARMIN e-Trex handheld GPS device. Greenish coloured sea water was collected using water sampler bottles and observed under microscopy to identify the organisms responsible for massive green colour bloom. Environmental parameters including depth, temperature, salinity, pH, and dissolved oxygen (DO) were analysed using by Manta2+ Water Quality Sonde. Nutrient analysis of water sample was also measured. Photographic evidence of the impact of bloom on coastal fauna and the health status of coral reefs were recorded by using NIKON W300 underwater camera.

RESULTS AND DISCUSSION

To estimate the health of coral reefs, random sampling on the reef regions with live coral cover was done and coral colonies were counted and categorized into six distinct groups named as healthy corals, dead corals, sediment affected corals, macroalgae affected coral, diseased corals and bloom affected corals.On the restoration sites of National Centre for Coastal Research, reef health was monitored by photographic evidence. Statistical analysis was performed by using formula incorporated in MS Excel. Two way ANOVA between water quality parameters and live coral cover were measured for the data obtained before and after bloom formation.

Intense vivid green colour bloom of microalgae was observed in the Mandapam region during 11th to 25th September 2019. Under microscopic observation, the bloom was confirmed as *Noctiluca scintillans* which is characterized by a substantial bloom forming obloid luminescent dinoflagellates frequently associated with red tides. Maximum density of *N. scintillans* was recorded approximately 15×10^5 cells/ L^{-1} whose size ranges in between 250-1100 µm (Figure 1a-c). Parrot fish, eels, serranids, carangids, goatfish, pipe fishes, snappers and barracudas were found dead on shore of the Islands. Sea shells such as Cowrie (*Cyprea* sp.), *Lambis* sp., *Turbo* sp. were also dead and washed ashore due to this bloom effect (Figure 1d-i). Results indicated that measuring of temperature, salinity, pH and dissolved oxygen during before and after the bloom formation has not showed

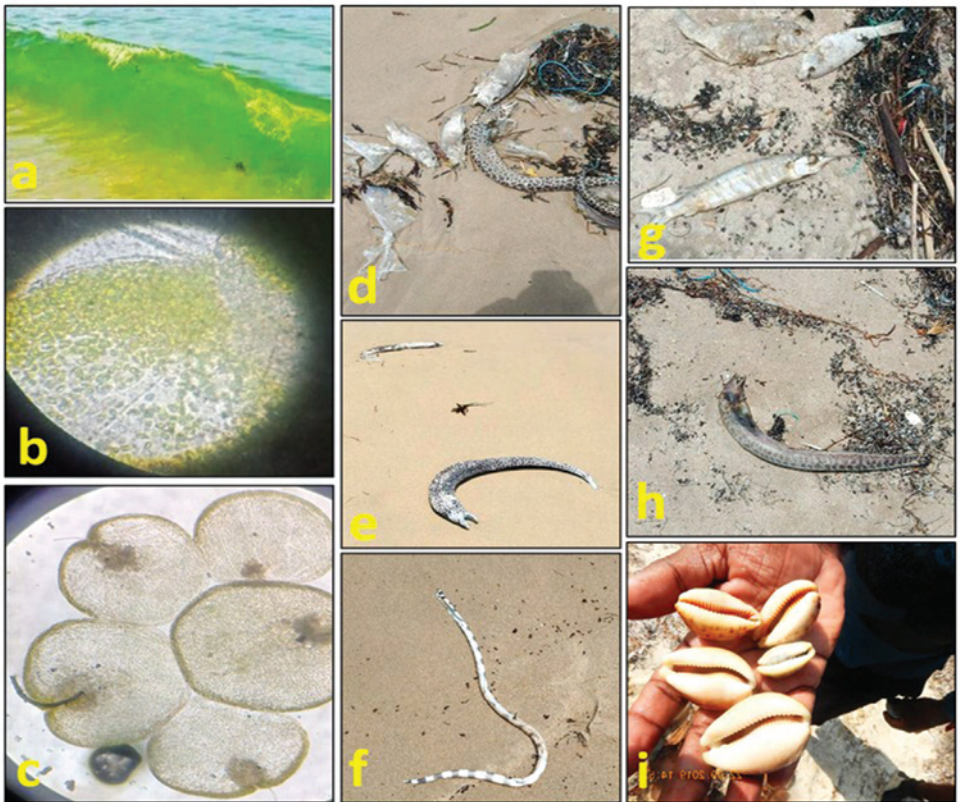

Figure 1.**a-c:** *Noctiluca scintillans* bloom, and cells under microscopic observations; **d-i:** Negative impact of bloom on marine organisms- Mass mortality of fishes, snakes and sea shells occurred in Mandapam region of Gulf of Mannar.

any statistically significant (*p* value 0.2111, p<0.05) differences which may alter the toxicity of water (Table 1). During the bloom formation, phosphate content of water was found to be higher (1.6722±0.04µM) than its normal range, whereas nitrate (1.6577±0.11 µM) and ammonia (0.0113±.0.12 µM) were under optimum limit (Table 2). Based on the field observations, it is evident that corals are not negatively affected by this bloom formation (Figure 3). Other factors such as sedimentation, macroalgal invasion, disease have affected the corals in Mandapam group of Islands for the last few years. But the *Noctiluca scintillans* bloom did not kill reef building corals in Mandapam group of Islands. In Shingle Island, Krusadai Island and Manoliputti Island sedimentation and macroalgae damaged more than 20% of corals (Figure 2), whereas in Hare Island (29.0%) and Manoli Island (9.0%), corals are mostly affected by high sedimentation. Monitoring of the restored corals are being conducted bimonthly. Recruited corals remain healthy after the bloom formation. No negative impact was observed on transplanted corals. Photographic evidence of the coral health has been documented before and after the bloom formation (Figure 4).

Algal blooms in Indian waters are mainly influenced by the seasonal upwelling, eutrophication due to nutrient enrichment in water by industrial and sewage

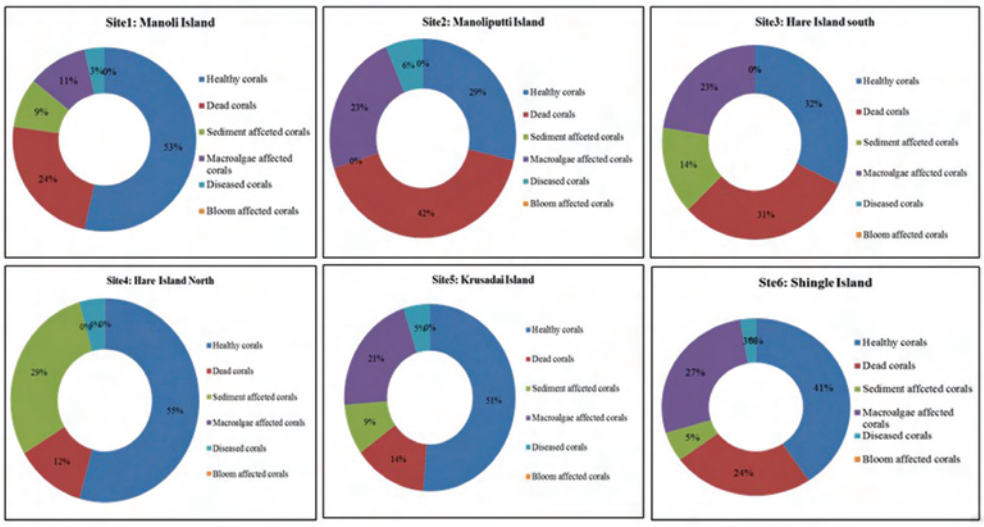

Figure 2. Health status of reef building corals during bloom formation.

Table 1. Two way Anova analysis of environmental parameters before and after bloom formation.

Summary	Count	Sum	Average	Variance		
Before bloom	4	83.83	20.9575	263.8344917		
	4	82.55	20.6375	254.2823583		
	4	84.69	21.1725	253.9016917		
	4	82.53	20.6325	260.638825		
	4	83.2	20.8	251.1919333		
After bloom	4	82.89	20.7225	259.925025		
	4	79.74	19.935	250.1885667		
	4	81.91	20.4775	261.9249583		
	4	77.3	19.325	232.2745667		
	4	79.45	19.8625	222.341025		
pH	10	70.5	7.05	0.434333333		
Temperature	10	321.36	32.136	3.160093333		
Salinity	10	360.28	36.028	0.180706667		
Dissolved O_2	10	65.95	6.595	0.182583333		
ANOVA						
Source of Variation	SS	df	MS	F	P-value	F critical
Rows	11.6859725	9	1.298441389	1.464806671	0.211107531	2.250131
Columns	7507.576848	3	2502.525616	2823.166488	8.08021E-34	2.960351
Error	23.9334775	27	0.886425093			
Total	7543.196298	39				

Table 2. Nutrient analysis of water samples collected during bloom formation.

Date of Sample Collection	Nitrate (µM)	Ammonia (µg L^{-1})	Phosphorus (µM)
11.09.2019	1.6722±0.04	1.2957±0.12	1.6577±0.11
18.09.2019	0.4012±0.07	1.491±0.17	1.6579±0.10
22.09.2019	0.8844±0.03	1.4022±0.06	1.8550±0.03

discharge, agricultural runoff during monsoon season (Gomes et al. 2000, Prasanna Kumar et al. 2002, Anil et al. 2002, D'Silva et al. 2012). But Mandapam region of Gulf of Mannar and Palk Bay does not receive any major discharge of industrial effluents, sewage contents and agricultural runoff as of a low rainfall region of South east coast of India (ENVIS 2008). Therefore, the source of present *Noctiluca scinitillans* bloom might be appeared from the long distance dispersal of ballast water in between southern side of Gulf of Mannar and Mannar region of Sri Lankan Coast. Nutrient content such as Nitrogen, phosphate and ammonia in Gulf of Mannar ranges in between 0.3-1.3µM, 0.055-0.9µM and 0.5-23.0µM respectively (NOIS 1998). In the present study, phosphate content (1.7-1.9µM) in seawater found to be higher which might have triggered the growth of *Noctiluca* bloom in Mandapam region. Other environmental parameters were not significantly differed (p value 0.2111, $p<0.05$) during before and after the bloom formation, specially temperature and dissolved oxygen. Therefore, it is assumed that discharge of ballast water and long distance dispersal of *Noctiluca scintillans* through wind and current actions causes the bloom in Mandapam region of Gulf of Mannar. In the incidence of *Noctiluca* blooms, mortality of fishes (Parrot fish, eels, serranids, carangids, goatfish, Pipe fishes, Snappers and Barracudas), sea snakes (*Laticauda colubrina*) and sea shells were encountered from Shingle Island, Krusadai Island, Manoli Island, Manoliputti Island and Hare Island of GoM. Causes of death of fishes occurred through gill suffocation and, sea snakes and sea shells death occurred due to asphyxiation by the thick layer of algal bloom.

Based on the monitoring data and photographic evidence collected from the coral reefs of Mandapam region during the bloom event, it has been investigated that no mortality of corals were observed due to presence of *Noctiluca scintillans* in the water column (Figure 3). Outer surface of Coral skeleton were also not affected by the mucus like layer produced after the death of *Noctiluca* bloom (Figure 3). Maximum utilization of plant nutrients, particularly nitrogen and phosphorous by zooxanthellae makes the coral holobiont responsive in a

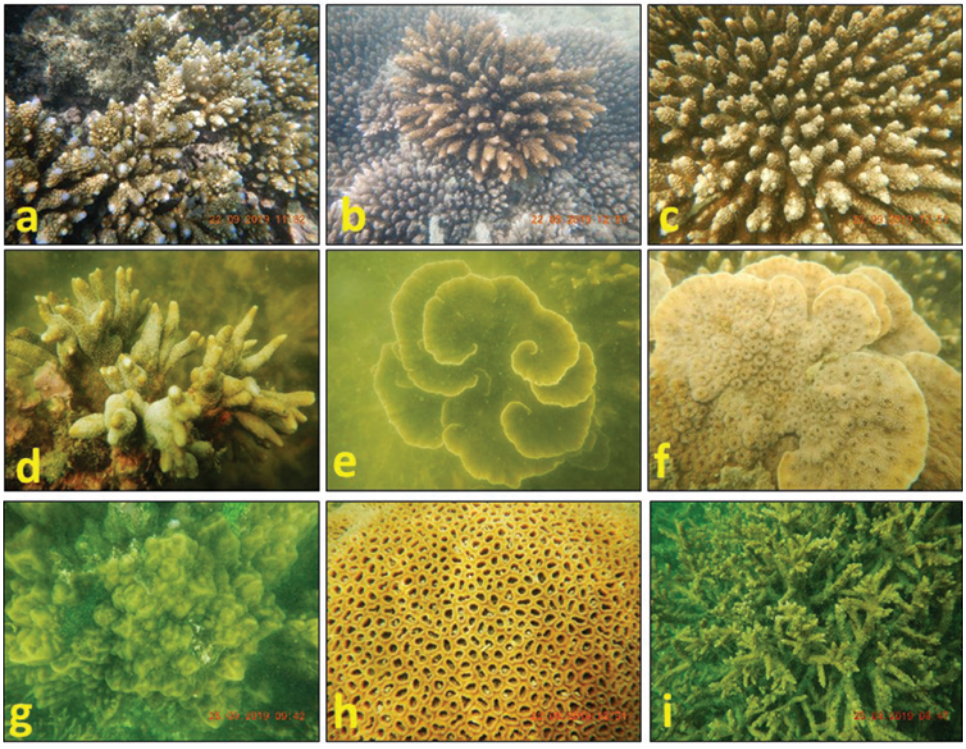

Figure 3. Photographic evidence of healthy coral colonies after bloom formation: a-c: *Acropora* sp.; d-e. *Montipora* sp.; f. *Echinopora* sp. g. *Favites* sp.; h. *Dipsastraea* sp.; i. *Acropora* sp, No sign of mucus settlement on corals by dead remains of *N. scintillans* and other organisms.

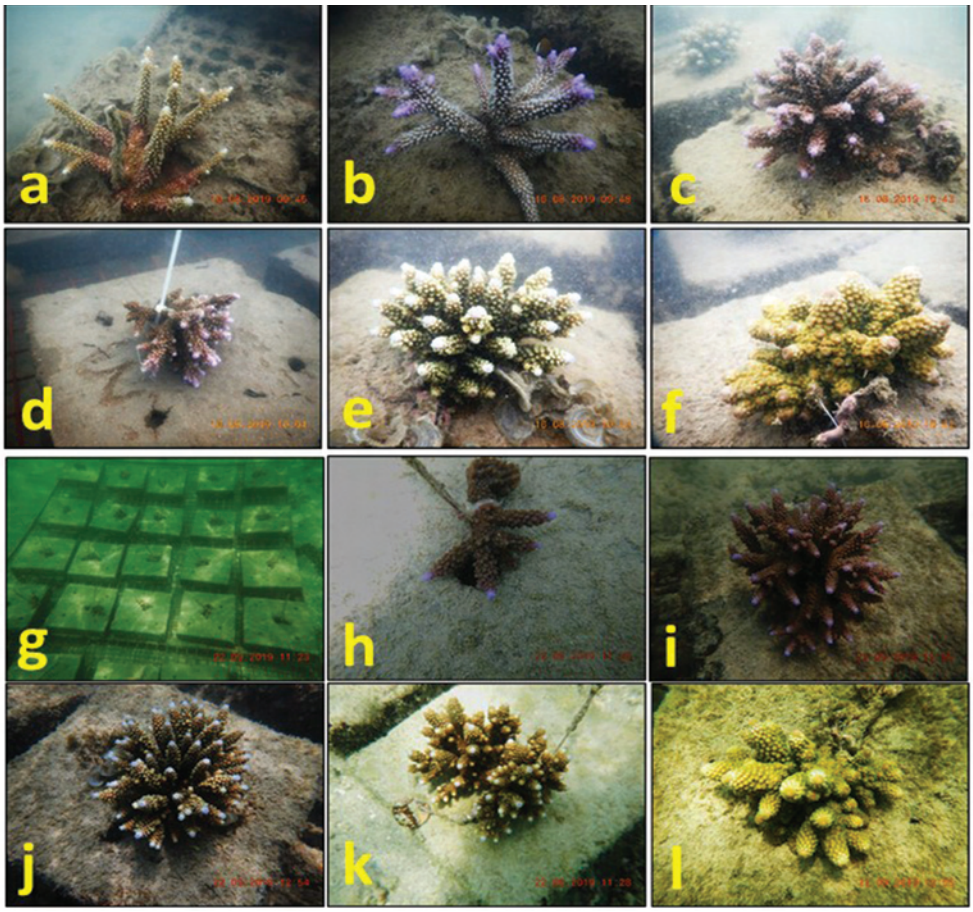

Figure 4. Healthy coral colonies in NCCR coral nursery sites: a-f: Healthy coral colonies before bloom formation (16-08-2019); g-l: Healthy coral colonies after bloom formation (22-09-2019).

nutrient rich environment (Dubinsky and Jokiel 1994). Coral holobiont and its symbionts called zooxanthellae respond positively if there is no other environmental stress such as increased temperature or heat waves exist at the same time (Koop et al. 2001, McClanahan et al. 2003, Angelo and Widenmann 2014). Earlier report also found that high level of nitrogen concentration in sea water promoted growth of zooxanthellae and increased symbiont density without doing any negative effect on coral holobiont (Fabricius 2005). Hence in the present study, increased phosphate concentration might be triggered the *Noctiluca* bloom formation in Mandapam group of Islands, but the favourable nutrient enrichment both nitrate and phosphate concentration and positive physiological performance of zooxanthellae hold the key to maintain good health condition of reef building corals.

CONCLUSION

In summary, *Noctiluca scintillans* bloom during the period of 11th September to 24th September, 2019 killed many fishes, sea shells and sea snakes which washed ashore near to Kundakal point of Rameswaram taluka. No negative impact on reef building corals was observed during this bloom formation. The precise source of bloom formation is still unclear but it is presumed that discharge of ballast water in between southern side of Gulf of Mannar and Mannar region of Sri Lankan coast might be the cause of the bloom. Research team of National Centre for Coastal Research (NCCR) is periodically monitoring the health of coral reefs and collects real time data on water quality parameters for providing more precise information on algal bloom formation and its impacts on marine organisms and coral reefs in GoM.

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Author contributions: T. Shanmugaraj conceived and designed the study, corrected the draft manuscript, K. Sadhukhan conducted the field work and statistical analysis of the data, and prepared the manuscript, R.Chatragadda helped in statistical analysis and species identification, and edited the manuscript, and M.V. Ramana Murthy coordinated the study and gave technical advice.

Conflict of Interest: The authors declare no competing interests.

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