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ARTICLE

# Exhibition of Bleaching Resistance Via Adaptive Bleaching Pattern by Coral Reefs of the Gulf of Mannar during Massive Bleaching Event 2019

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ABSTRACT

Coral reefs in the Gulf of Mannar (GoM) and Palk Bay regions are facing potential threats from climate change, sedimentation and anthropogenic activities. Considerably, coral reefs in these two regions are highly damaged due to frequent bleaching events caused by increased sea surface temperature (SST) recorded over the past two decades. Recently, during February to May 2019, mass bleaching event of corals was documented again in GoM and Palk Bay regions due to increased sea surface temperatures ranged between 32°C to 36°C. Despite of completely bleached corals, some coral colonies of the same bleached coral species have displayed adaptive bleaching pattern (ABP) for survival. This incidence is displayed by the symbiotic zooxanthellae to protect coral polyps from environmental stress such as elevated temperatures. These observations infer that coral colonies with preferential bleaching pattern ability would serve as environmental stress resisting coral colonies which can be used for restoration activities and cryopreservation. Further studies are needed to explain the potential mechanisms or specific environmental drivers responsible for ABP.

## 1. Introduction

Coral reefs are more diverse ecosystems which providing protection and shelters for thousands of staggering marine species whereby maintaining coastal biosphere and coastal protection. These ecosystems provide livelihood to the millions of coastal communities by providing reef fish and molluscs as food and medicine as well as income in the way of ornamental fisheries, tourism and recreation [12]. More significantly, corals control the carbon dioxide in the ocean water and converts $CO_2$ into a limestone shell. However, the increased temperatures and carbon dioxide levels in ocean water are known to cause bleaching of corals as well as reef building crustose coralline algae [1]. Currently, these valuable coral ecosystems are under threat due to climate

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change and anthropogenic activities around the world [8]. Massive bleaching events which occurred during the years 1998, 2005 to 2010 and 2016 due to El Nino have destroyed live coral cover around the globe [3], including the Gulf of Mannar and Palk Bay regions in India [10]. Since coral bleaching events are linked to the climate change, research organisations around the globe have been studying the long term changes pertaining to physico-chemical factors of the world ocean for understanding the impact of climate change on survival of corals and to abate the destruction of coral reefs by effective management programs.

The symbiotic zooxanthellae present in the coral tissues are known to play crucial role in the survival and fitness of the corals from environmental threats such as bleaching events. During the stress conditions, symbiotic zooxanthellae display adaptive mechanism by losing tissue pigments [9]. Differential bleaching pattern is exhibited by fragments within a single coral colony or between colonies and this allow coral colonies to survive under stress conditions, thus avoids complete damage of coral colony [11]. The survival of corals from regional and global threats such as elevated temperatures is completely depends on adaptation mechanism exhibited by the *Symbiodinium* spp. clade and other microbial composition present on coral tissues and mucus [13]. Depending on the adaptation ability exhibited photosymbionts *Symbiodinium* spp., corals tissue colour appears in different pigmentation during bleaching and indicates the fitness of coral hosts [6]. In this study we show such ABP's displayed by corals during a massive coral bleaching event of 2019 recorded in GoM and Palk Bay regions. This study aimed to provide significant findings on ABP observed during bleaching event.

## 2. Material and methods

Coral reef monitoring was conducted on fringing reefs found in different islands under four regions such as Mandapam, Keezhakarai, Vembar and Tuticorin in the Gulf of Mannar region during August 2018 to May 2019. Palk Bay coral were surveyed during May 2019 bleaching event (Figure 1). Corals bleaching in both the regions were surveyed by standard reef assessment methods such as Line Intercept Transect method (LIT) and quadrat estimation [4]. Bleached corals display white color due to the loss of tissues or pigment loss because of expulsion of zooxanthellae. The percentage of bleached corals obtained from LIT data and mean temperature values were visualised in graphs. Identification of corals was made by using standard identification keys [7,14]. Totally, 72 transects in Mandapam, 80 in Keezhakkarai, 20 in Vembar and 15 in Tuticorin and 30 in Palk Bay were laid (10 m line transects) and surveyed the percentage of bleaching. However, this article is aimed to provide the data on corals with ABP. Evidences of underwater photos and videos were also documented using Nikon Coolpix underwater camera for developing baseline databases. Bleached coral reef areas were tagged using handheld Garmin GPS for monitoring further seasonal changes. Seawater quality parameters such as temperature, salinity, pH and dissolved oxygen were analyzed by using Manta+ Water Quality Sonde.

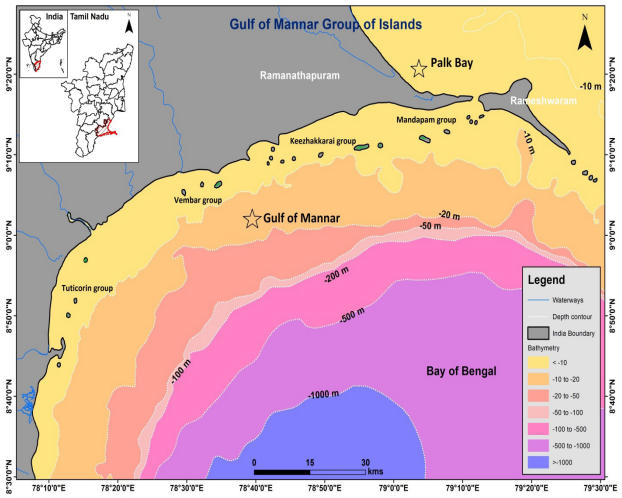


**Figure 1.** Study locations Gulf of Mannar and Palk Bay regions in southeast coast of Tamil Nadu, India

## 3. Results and Discussion

Some bleached and non-bleached massive and branching coral species have displayed ABP by area specific tissue loss. Loss of coral tissue pigmentation through expulsion of *Symbiodinium* was observed at distinct regions of corals such as apical, central, peripheral, basal and medial. ABP was observed to be irregular in all ABP showing coral species. Most of these ABPs observed were linear, irregular and multifocal (Figure 2-4). ABP of corals was not depth specific and species specific. A single colony of a coral species have shown different bleaching patterns in which some part of coral tissue bleached and rest of the part remains healthy or not bleached, perhaps may be under stressed. ABP exhibiting corals were observed to have more immunity and nutrient supply from zooxanthellae. Thus non-bleached tissue regions of corals with ABP ability are more pigmented as healthy corals (Figure 2-4). Although many corals completely bleached, ABP state in some corals indicating the stress resisting capability of zooxanthellae.



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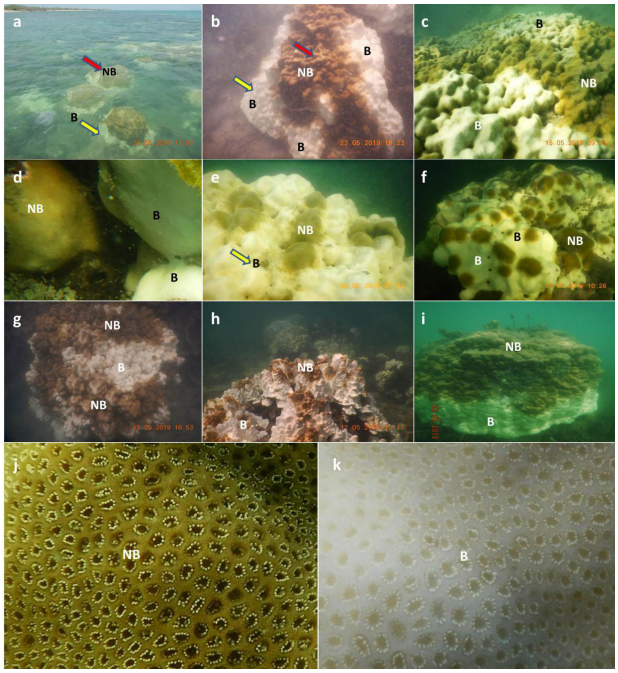


**Figure 2.** Preferential loss of bleaching by *Symbiodinium* sp. in different coral species

***Note:*** B: bleached; C: cyanobacteria; D: dead; DC: dead coral; MA: macroalgae; S: sediment. Different patterns of ABP displayed by colonies of Porites (a-i); Non-bleached (j) and bleached tissue regions (k) of Porites sp., indicating coral polyps.

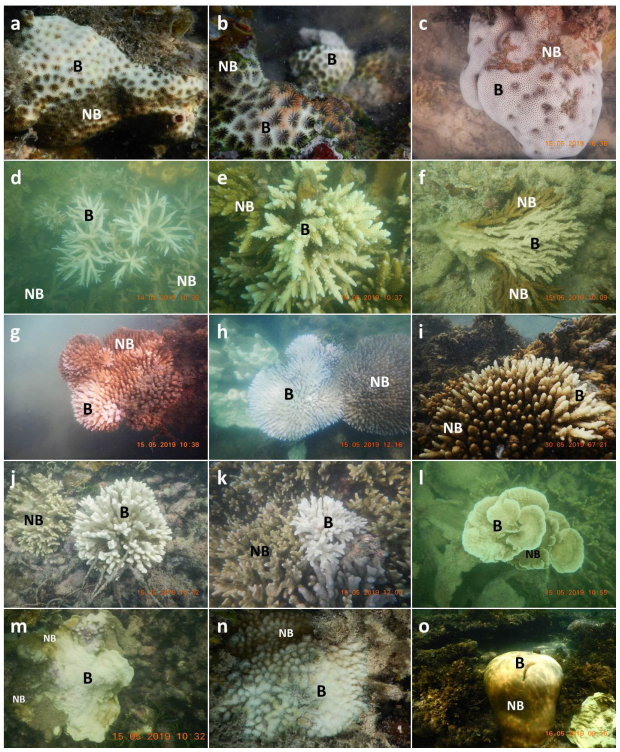


**Figure 3.** Preferential bleaching pattern in Goniastrea sp.

***Note:*** (a-c), Acropora formosa (d), Acropora sp. (e), A. cytherea (f), A. digitifera (g&h), A. millepora (i), Montipora digitata (j&k), M. foliosa (l), Montipora sp. (m), Hydnophora microconos (n) and Goniastrea retiformis (o).

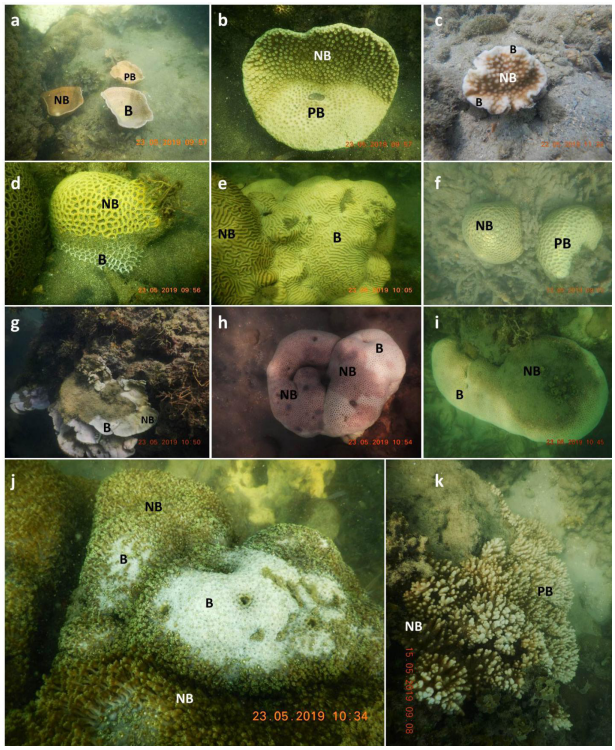


**Figure 4.** Preferential bleaching pattern in *Turbinaria mesenterina* (a), *T. peltata* (b), *Turbinaria sp*. (c), *Favites flexuosa* (d), *Platygyra sinensis* (e), *F. flexuosa* (f), *Echinopora lamellosa* (g), sub massive *Dipsastraea* sp. (h&i), *Galaxea* sp. (j) and a soft coral *Sinularia* sp. (k)

Coral species observed at a depth of zero to 2 meter such as *Porites solida*, *P. lutea*, *Montipora digitata, A. hyacinthus* were completely bleached. Other coral species observed at the depth of 2 to 4 meters such as *Acropora formosa, A. hyacinthus, Montipora digitata, M. foliosa, Pocillopora damicornis, Goniastrea retiformis, Platygyra sinensis, Dipsastraea favus, Turbinaria* sp. and *Dipsastraea speciosa* were partially bleached. *Porites* species observed in Palk Bay region were completely bleached at depths of zero to 4 m. Corals distributed at >5 meter have not faced any bleaching. It was observed that in some sites massive *Porites* sp. were completely bleached but adjacent colonies of branching corals *Montipora digitata* and *Acropora* sp. were not bleached in GoM (Figure 5). In Palk Bay region, 98% of *Porites* colonies were bleached and other corals were not seen abundant in the study area, thus bleaching percentage was not determined for other coral types in Palk Bay. Despite of massive bleaching, ABP displaying corals stand distinctly in reef flats, indicating their efficiency to tolerate severe SST. There was no massive bleaching in *Acropora* corals but observed only ABP. However, heavy sedimentation observed in Mandapam group islands is found to damage branching corals greatly, while massive corals are mostly affected

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by macroalgal assemblage. ABP patterns which are due to symbiotic zooxanthellae mediation to coral survival has been observed in other reef ecosystems [5]. Such similar observation has also been identified in the present study, thus this study in concurrence with previous studies.

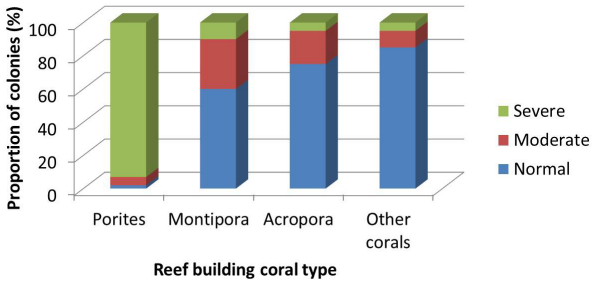


**Figure 5.** Proportion (%) of bleaching in reef building coral colonies of GoM indicated as severe, moderate and normal based on the intensity of tissue loss or pigment loss

Field observations clearly shows that corals exposed to extreme environmental factors such as temperature and sedimentation are more likely to be damaged than corals away from these conditions. Initially, stressed corals expelled symbiotic zooxanthellae along with external mucus and these damaged areas are the potential gate ways for killing corals completely. Damaged tissue regions are highly weak to avoid sedimentation, thus such damaged regions are found with more sedimentation. Deposition of sedimentation on damaged corals subsequently promoted the growth of cyanobacteria and macroalgal assemblage. Altogether, sedimentation and algal growth kills damaged corals by causing smothering through toxic sulphides production (Figure 6).

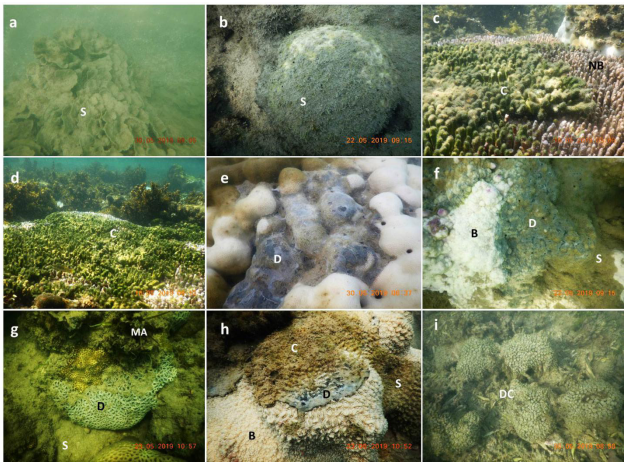


**Figure 6.** Gradual destruction of different corals by natural stress factors. Large amount of sediment deposition on *Echinopora* sp.

***Note:*** (a) and Dipsastraea favus (b); development and propagation of filamentous cyanobacteria over sedimented Acropora coral fragments (c&d); dead coral regions of Porites sp. (e), encrusting Montipora sp. (f), Dipsastraea sp. (g) and H. microconos (h) due to toxic gases; dead coral Galaxea astreata being broken by rough waves.

Reef monitoring surveys conducted during monsoon and post-monsoon seasons in 2018 have revealed very good recovery of coral reefs in GoM. However, elevated temperatures have again triggered the coral bleaching, and thus inhibiting the development of corals in these regions. During the monsoon and post-monsoon seasons (August 2018 to February 2019) the Sea surface temperature was ranged between 28.7°C to 31°C and there was no bleaching event during this period. However, the elevated temperature range of 32°C to 36°C has resulted coral bleaching during the months of February, 2019 to May 2019 (Figure 7). Previously, during 2016 bleaching event SST was 34°C [10]. However, in the present study, SST is relatively increased up to two degrees centigrade i.e. 36°C in 2019. A recent study indicated the bleaching threshold temperature value in the Gulf of Mannar region was 30.60°C [2]. In order to abate the destruction of corals from extreme temperatures and to conserve the coral reefs for future generations, immediate global actions are needed to curb future warming [8]. During this study there was no bleaching in reef building crustose coralline algae. It indicated that this bleaching event is due to increased SST but not due to ocean acidification [1]. Underwater surveys conducted in reef flats of islands under GoM and Palk Bay regions have revealed the depth specific and species specific bleaching. However, ABP is found to be neither depth specific nor species specific. Perhaps these ABP's are might be due to different life forms of *Symbiodinium* spp. or replacement of old symbiotic consortium tissues in bleached corals with new *Symbiodinium* spp. [9]. On the other hand, blooms of cyanobacteria, *Trichodesmium erythraeum*, dinoflagellate, *Protoperidinium* sp. and jellyfish, *Pelagia noctiluca* were also recorded during this mass bleaching event period in GoM.

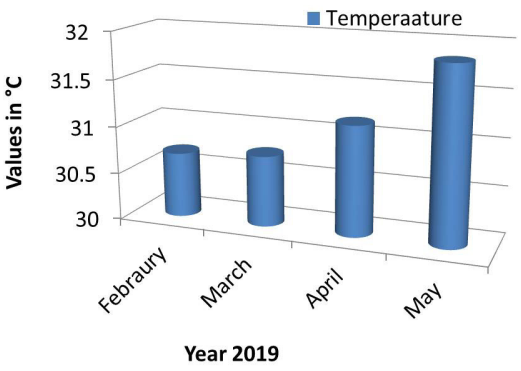


**Figure 7.** Mean temperature recorded during summer in GoM

Rapid recovery of bleached as well as ABP corals would be regained after sea surface temperatures drop to normal temperature levels. Nevertheless, now the recov-



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ery of these bleached corals is also depended on various factors such as persistence of high surface temperature, algal invasion, sedimentation and anthropogenic activities like fishing. Therefore, coral reef ecosystem is needed to be protected and require special management considerations in order to conserve their biodiversity and to provide sustainable livelihood to coastal community. Further monitoring and surveys are being carried out to study the algal dynamics and sedimentation effect on these bleached corals with special reference to recovery patterns of bleached corals. Also, the spatial shift and settlement pattern of new coral colonies in the dead reefs are under investigation. On the other hand, anthropogenic activities such fishing activities are needed to be monitored in the reef environment to facilitate the recovery of bleached corals. Further seasonal surveys would be conducted in Mandapam, Keezhakkarai, Vembar and Tuticorin group of Islands as well as in Palk Bay regions throughout summer, pre-monsoon and post-monsoon months.

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