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Recent Coral Bleaching Impacts in Reef Ecosystem of Gulf of Mannar and Palk Bay

SADHUKHAN KOUSHIK[1*], CH. RAMESH[1], T. SHANMUGARAJ[1] AND M. V. RAMANA MURTHY[2]

[1]National Centre for Coastal Research, Ministry of Earth Sciences, NCCR Field Research Centre, Mandapam Camp, Tamil Nadu – 623519, India
[2]National Centre for Coastal Research, Ministry of Earth Sciences, Pallikaranai, Chennai - 600 100, Tamil Nadu, India
E-mail: *Sadhukhan.1985@gmail.com*
***Corresponding Author**

ABSTRACT

Coral bleaching now becomes an annual phenomenon in Gulf of Mannar (GoM) and Palk Bay (PB). In 2019 and 2020, reefs are completely bleached by the effect of high sea surface temperature which not only impinge on the reef building corals but also triggers the growth of unwanted macroalgae in live reefs. The consequences of this major threats are long term and fatal to the marine ecosystem. Recurrence of bleaching in 2020 and 2019 occurred during the month of April. The increasing heat in the summer is the main cause of this bleaching. The correlation data between Sea Surface Temperature and increase of bleaching cover is positively correlated in 2019 (R^2=0.715) and 2020 (R^2=0.851). Moreover, it is a negative environmental response by reef building corals which slowly recovered after the temperature drop down. Present study doesn't report any mass mortality of corals and other organisms due to bleaching but this state facilitate the growth of macroalgae on corals which have fatal impact near after. Present study thus infer that no significant bleaching differences observed on the reef building corals but habitat degradation is clearly visible based on field observation. Post bleaching impacts need to be reduced by implementing alternate management intervention programmes to maintain the reef resilience in GoM and PB regions.

KEYWORDS: Bleaching, Recurrence, macroalgae, reef building corals, management, resilience

INTRODUCTION

Coral reef around the world is highly impacted by the increase of sea surface temperature (SST) which in turn affect the livelihood of coastal populations (Spalding and Brown 2015, Eakin et al. 2016). This tropical reef ecosystem provide livelihood to the millions of people through fisheries and tourism. However coral bleaching now becomes a major threat to tropical reef which needs special attention to protect and develop alternative management intervention programme to combat with natural disturbances. The breakdown of symbiotic association of coral host and dinoflagelleate zooxanthllae due to increased thermal stress leads to the expulsion of zooxanthalle from coral host which results the loss of coral colours within the tissue causes coral bleaching (Jokiel and Coles 1990, Brown 1997). Hence, the consequences of coral bleaching are numerous, ranging from short term physiological damage to the widespread mortality (Oliver et al. 2009, Heron et al. 2016). Thus, the physiological damage also leads to the loss of reef resilience and the healthy reef shifted to macroalgal dominant dead reef which could be temporary or permanent depends on the ability of the reef to restore naturally or man-made management programme (Chung et al. 2019). In India, specifically in Gulf of Mannar (GoM), threats followed by bleaching are more susceptible to the mortality of corals which includes macroalgal invasions, coral disease, animal infestation and regular anthropogenic activities such as fishing activities, poison fishing and shoreline operations etc. (Edward et al. 2012, 2017, 2018, Sadhukhan et al. 2020). This coral bleaching event is primarily influenced by thermal anomalies associated with El Nino Southern Oscillation which become more severe and frequent in between 2014 and 2017 due to local anthropogenic stressors and consequently damage the reefs globally (Eakin et al. 2017, Hughes et al. 2017, Oliver et al. 2018). However, this bleaching state if prolong for a long period of times, then coral undergoes mass mortality which in turn degrade a complete reef ecosystem. Moreover, the impact of global warming is highlighting the urgent need for a better understanding of restoring degraded structure and function of reef ecosystem and possible ways to increase reef resilience. Therefore, reef resilience, coral host resistance and altered *Symbiodinium* spp. composition would be a possible response to fight against this climate change induced threats of coral reefs. In GoM and PB regions, reefs are annually hit by the scorching heat waves during summer. SST is triggered by 4-5°C rather than its normal temperature during this time (Sadhukhan et al. 2020). Present study carried out intense underwater survey during March 2019 to August 2020 to estimate the community structure of corals, intensity of bleaching, and species wise vulnerability to bleaching and compare the last year data with the present study to see the effective consequences of back to back occurrence of this bleaching event. This study provides crucial insights into the consequences of 2019 and 2020 thermal stress on coral reefs of Gulf of Mannar.

METHODS

Underwater surveys were carried out at six locations (Site1- Manoli North-N9.2198 E79.1341, Site2 - Manoli North-N9.2197 E79.1325, Site3 - Manoli South-N9.2064 E79.1401, Site4 - Shingle Island-N9.2433 E79.2386, Site5 - Hare Island-N9.2063 E79.0868, Site6 - Munaikadu, Palk Bay-N9.2923 E79.1355) of GoM and PB to measure the extent of bleaching, live coral cover and estimate the different algal growth on corals (Fig. 1). A 20m long LIT and 1m^2 quadrat (English et al. 1997) was employed in triplicate to six locations for estimating bleaching response by reef building corals. Locations were marked with GARMIN handheld GPS device. Photographs were taken as a visual proof of the assessment using Nikon coolpix. SST, pH and Salinity were measured using Eureka Manta-2 3.5 water quality multiprobe Sonde. The different live forms categories of corals were used as per the international standard code (English et al. 1997). Species identification was performed by using earlier literature (Veron 2000, Huang et al. 2014). Data analysis (Correlation, mean±SD and graphical representation) was performed by using MS Office software.

RESULTS

A total of 54 coral species belonging to 12 Families and 20 Genus were studied to assess the bleaching susceptibility in GoM and PB regions (Table 1). Several live form categories are being identified to compare the bleached and non-bleached status of the reefs. Massive corals (*Porite lutea, Porites solida, Goniastrea retiformis, Dipsastraea favus, D. speciosa*), non-Acropora branching corals (*Pocillopora damicornis, Montipora digitata*) submassive corals (*Favites halicora, F. complanata, Pavona* sp) were found to be bleached in maximum than other live form categories in 2020 (Fig.2). Branching Acropora corals in GoM and PB regions are less affected by the bleaching event. *Acropora hyacynthes, A. gemmifera* and *A. formosa* were found to be completely bleached at all stations whereas other *Acropora* sp are either not bleached or partially bleached. In PB, percentage cover of *Acropora* species is less than 10%, hence occurrence of bleached *Acropora* is least in number. Increased sea surface temperature (SST) in GoM and PB was recorded between 32.11 ± 0.4°C and 35.00 ± 0.8°C during the months of March to June 2020 which come across the optimum level for coral growth. In 2019, thermal anomalies lasted for three months which ranged in between 32.75 ± 0.7°C to 34.15 ± 1.2°C (Fig.4). The 2020 coral bleaching is more extreme than 2019 bleaching events where 55 coral species were affected and 23 coral species were documented with bleaching, respectively. Bleaching severity in GoM (MG 57.40±2.30%, KG 35.6±3.21%, VG 41.2±1.89% TG 38.9±5.00%) reef is found more relentless in 2020 whereas in PB (85.0±4.5%), severity is maximum in 2019 (Fig.3). Massive corals are predominant in PB which almost entirely bleached during 2019 bleaching event. Macroalgal invasions during post bleaching interval is a major threat components in coral reefs as favourable high

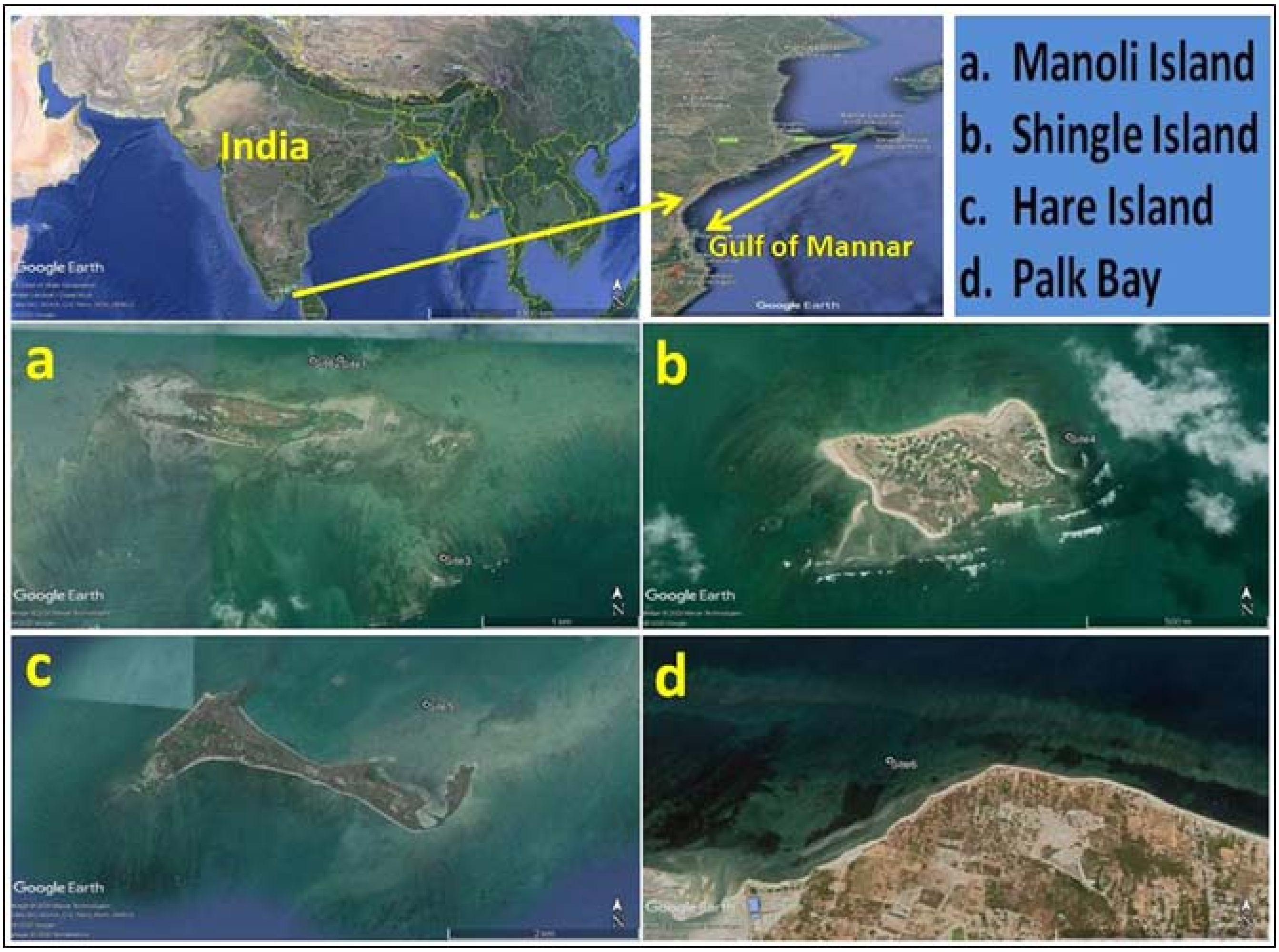

Figure 1. Study area

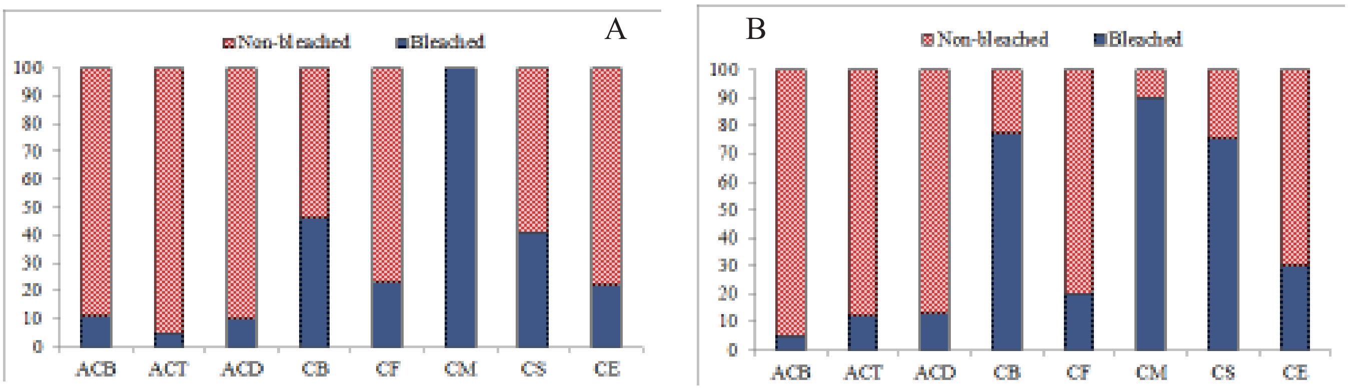

Figure 2. Bleached and non-bleached status of live form categories in 2019 (A) and in 2020 (B)

temperature triggers the growth of unwanted macroalgae and the inverse relation between decreased number of herbivores fishes with high growth rate of macrolagae dominate the reef quickly. The linear regression data (R^2 – 0.715 during 2019 and R^2- 0.851 during 2020) of SST infer that increased temperature triggers the bleaching cover of corals in selected study sites and bleaching response reduce while temperature drops down below 32°C which support the positive correlation between them (Fig.5). Macroalgal invasions were found to be maximum at Mandapam group (33%) followed by Keezhakarai (31%) and Tuticorin group (15%) was documented during the present study (Fig.

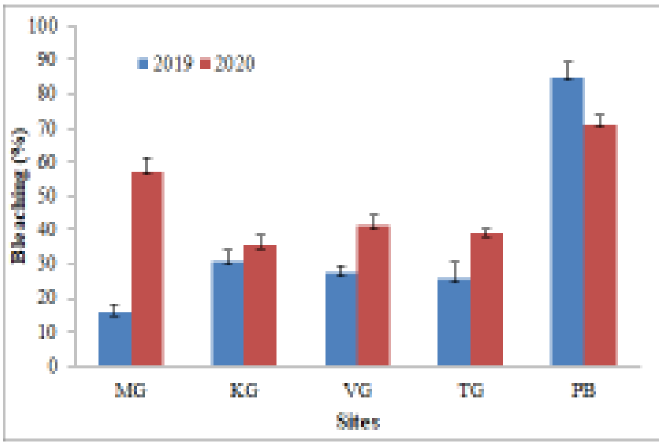

Figure 3. Comparative analysis of bleaching susceptibility in GoM and Palk Bay

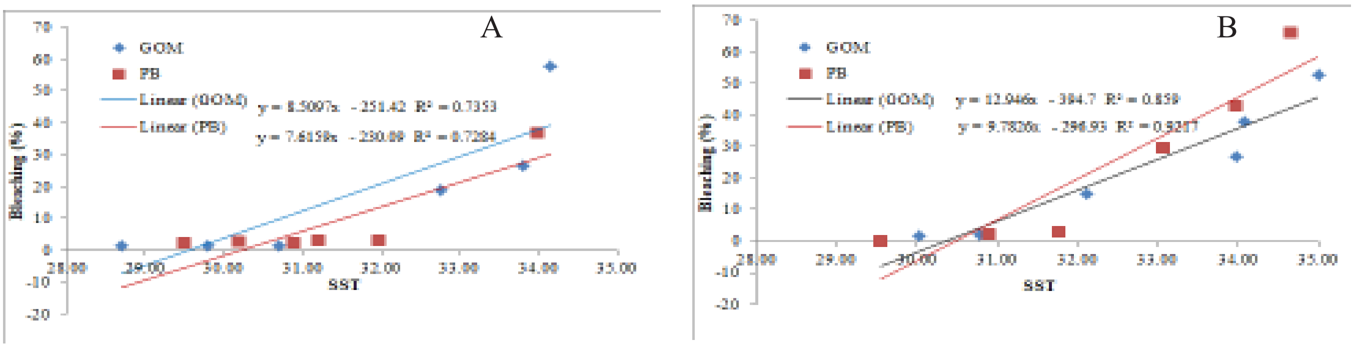

Figure 5. Correlation of Temperature and Bleaching cover of corals in GoM and PB in 2019 (A) and in 2020 (B)

6). Mass mortality of corals was not observed during the survey. But few colonies of coral were dead due to prolong bleaching and macroalgal growth on coral surface. Many coral colonies showed differential bleaching pattern in both consecutive years which described as the following categories a) same colonies with complete and partial bleaching (Fig. 7a), b) bleaching difference among the same species, and c) two colonies of same species one is bleached other is healthy (Fig.7b-c). GoM and PB reef also faced interesting bleaching pattern in which thermo-sensitive coral species named as staghorn corals are more resistant than the thermos-resilient coral species like *Favites* sp., *Porites* sp. and *Dipsastraea* sp (Fig. 7d-f).

DISCUSSION

Coral reefs are complex and diverse ecosystem on a planet earth that provide home to thousands of marine organism and directly support marine biodiversity. The structure and function of this ecosystem is too sensitive relating to the environmental factors specifically SST. Moreover, this tropical underwater rainforest is vulnerable to the threats of increased sea surface temperature which could lead to the collapse of ecological integrity of marine ecosystem at several reefs worldwide by the occurrence of coral bleaching events. For survival, coral needs to adapt them in this altered environment. Therefore, present study investigated the number of coral species affected by bleaching in recent years and how bleaching patterns change the coral response in GoM and PB. In this context, a total of 55 coral species were recorded of which 36.36% of coral species are completely bleached (CB), 52.73% of coral species are partially bleached (PB) and 36.35% of corals are not bleached (NB) (Table1). Family Merulinidae and Poritidae corals are severely bleached (17 species) whereas only seven species of Acroporidae corals are bleached during the present study (Table1). During summer in GoM and PB, air temperature crosses nearly 40°C and SST ranged between 31.0°C to 36°C but optimum coral growth found here in between 26°C - 31°C (ENVIS 2015). Hence the increased sea surface temperature annually causes coral bleaching events and now corals are highly exposed to the thermal stress. Present study showed that almost all live form categories of corals are affected by recurrence of bleaching during summer in 2019 & 2020 and SST reaches near to 35°C in April and May (Fig.4). Our results are consistent with global climate change impact reported during 2014-16 due to ENSO climatic event occurred in Indo-

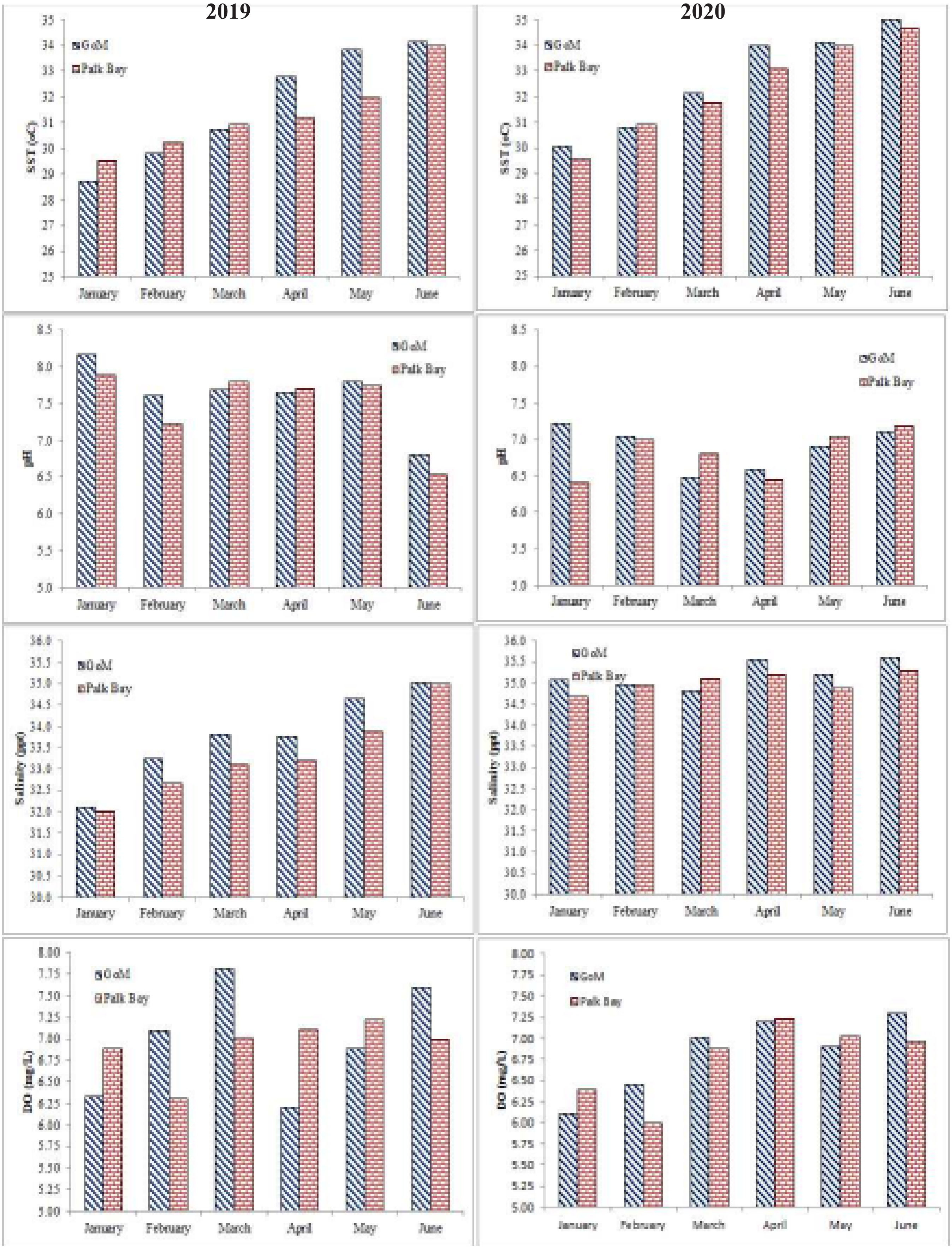

Figure 4. Month wise water quality parameters in GoM and PB

Table 1. Species specific bleaching susceptibility in GoM and PB

Sl No.	Scleractinian species	Bleaching		Non-bleaching
		CB	PB	
Family: Acroporidae				
1	*Acropora hyacynthes*	†		
2	*Acropora humilis*			†
3	*Aropora gemmifera*	†	†	
4	*Acropora formosa*	†		
5	*Acropora cervicornis*			†
6	*Acropora tenuis*		†	
7	*Acropora cytherea*		†	
8	*Montipora digitata*	†	†	
9	*Montipora verrilli*			†
10	*Montipora verrucosa*			†
11	*Montipora tuberculosa*			†
12	*Montipora foliosa*		†	
Family: Pocilloporidae				
13	*Pocillopora damicornis*	†	†	
Family: Faviidae				
14	*Dipsastraea favus*	†	†	
15	*Dipsastraea sepciosa*	†	†	
16	*Dipsastraea stelligera*	†	†	
17	*Dipsastraea pallida*			†
Family: Merulinidae				
18	*Favites complanata*	†		
19	*Favites halicora*	†	†	
20	*Favites abdita*			†
21	*Favites flexuosa*			†
22	*Favites colemani*			†
23	*Goniastrea retiformis*	†	†	
24	*Goniastrea pectinata*		†	
25	*Goniastrea edwardsi*		†	
26	*Cyphastrea serailia*		†	
27	*Cyphastrea microphthalma*		†	
28	*Cyphastrea japonica*		†	
29	*Platygyra lammelina*	†		
30	*Platygyra sinensis*		†	
31	*Platygyra daedelea*		†	
32	*Merulina mapliata*		†	
33	*Leptoria phrygia*		†	
34	*Hydnophora microconos*		†	
35	*Hydnophora exesa*		†	
36	*Echinopora lamellosa*		†	
Family: Poritidae				
37	*Porites solida*	†	†	
38	*Porites lutea*	†	†	
39	*Porites lichen*		†	
40	*Porites cylindrica*		†	
41	*Goniopora minor*			†
42	*Goniopora planulata*			†
Family: Scleractinian Incertae Sedis				
43	*Leptastrea purpurea*			†
44	*Leptastrea transversa*			†
Family: Mussidae				
45	*Symphyllia radians*		†	
46	*Symphyllia recta*		†	
Family: Plesiasteridae				
47	*Plesiastrea versipora*			†
Family:Dendrophyllidae				
48	*Turbinaria peltata*	†	†	
49	*Turbinaria mesenterina*	†	†	
Family:Agariciidae				
50	*Pavona explanulata*		†	
51	*Pavona duerdeni*	†	†	
52	*Pavona varians*	†		
Family: Euphyllidae				
53	*Galaxea fascicularis*	†		
Soft corals				
54	*Sinularia* sp.	†	†	

Pacific coral reef (Couch et al. 2017). However, huge coral loss due to the bleaching event has not been observed in the present study which might be helped the coral species to adapt the resistance ability as back to back thermal episode encounter in Gulf of Mannar and Palk Bay reef. Many coral species are also now adapting with this high temperature. Earlier work evident that continuous increase of thermal anomalies is able to promote the resistance to bleaching (Grottoli et al. 2014). Such adaptation has

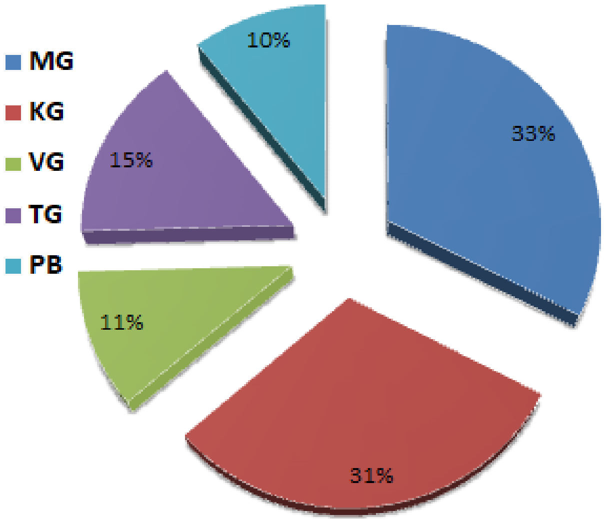

Figure 6. Extent of post bleaching effect of macroalgal invasions in GoM and Palk Bay

also been observed in reefs of Gulf of Kacchh, India (Yogesh Kumar et al. 2016). The reason behind this increased resistance capacity is still unclear to us but some hypothesis remain exist such as physiological adaptation of coral holobiont, genetic variation or alteration of *Symbiodinium* spp. (Roche et al., 2018), replacement of dominant taxa in reef (Hughes et al. 2003) or successful new recruitment to the alternative sites (Camp et al. 2017). Till date, five coral bleaching in GoM and two coral bleaching events in PB have been documented earlier and all studies reported branching *Acropora* corals were more susceptible to bleaching than massive corals *Porites* sp (Arthur 2000, Ravindran et al. 2012, Manikandan 2016). Krishnan et al. (2018) reported the multiple bleaching patterns in GoM and PB corals and interestingly Acropora corals were more thermo-resilient rather than massive corals. Present study also revealed that massive corals are more thermo-sensitive (>80% bleached) to bleaching rather than branching Acropora corals (<20% bleached) (Fig.2). The changes in bleaching pattern could be undergone adaptive bleaching which needs to be further investigate either this adaption arise through physiological and genetic variation of the coral hosts, the dinoflagellate algae and associated microorganisms, and/or through community change. Despite of severe and widespread bleaching on reefs in GoM and PB, there is no significant loss of coral cover in 2019 and 2020 bleaching event. But in 2016, severe bleaching was observed on the Great Barrier Reef following a mass mortality of corals were documented from there which causes 50% loss of corals in GBR (Hughes et al. 2018). Post bleaching impact on coral reefs are found to be abundant by excessive algal growth on live as well as existing dead corals in Mandapam and Keezhakarai group of Islands (Fig.6). However, earlier studies claimed that such changes from healthy reef to macroalgal dominated reef are either permanent or temporary which completely depends on the resistance capacity of the reef ecosystem. If the changes are severe, then reef recovery considerably more difficult (Walker et al. 2004, Chung et al. 2019). In the present study, recovery has been observed after the two months of bleaching and local stressors are minimized by several management intervention programme such as coral restoration, artificial reef structure which is implemented by local government authority and NCCR research team. Existence of different bleaching pattern within intra-species and inter-species (Fig. 7) supposed to be capable of adapting the thermal stress by altering the most resilient coral symbionts species which termed as algal switching or algal shuffling (Krishnan et al. 2018). However, present study inferred that sequential seasonal thermal stress may lead to coral bleaching event more frequent in GoM and PB, but it also help to improve the resistance ability of corals in the context of climate change. However, resilience based management programme could be a beneficial approach to protect and conserve this ecologically important marine ecosystem.

CONCLUSION

Coral bleaching now becomes a major threat to tropical coral reef ecosystem worldwide. GoM and PB reef are also affected by increased sea surface temperature and coral bleaching is now considered as annual event here. It is the time to see how coral reefs resist themselves against increased SST in result of climate change impacts to near future. Regular health monitoring and water quality monitoring provide long term baseline information to protect the structure and function of the complex ecosystem and develop conservation management plan and to choose the thermo-resilient target species for management intervention programme such as Coral reef restoration. Post bleaching effect results to high growth of macroalgae on live reefs needs to be restricted by harvesting the macroalgae seasonally and use them for developing coastal livelihood.

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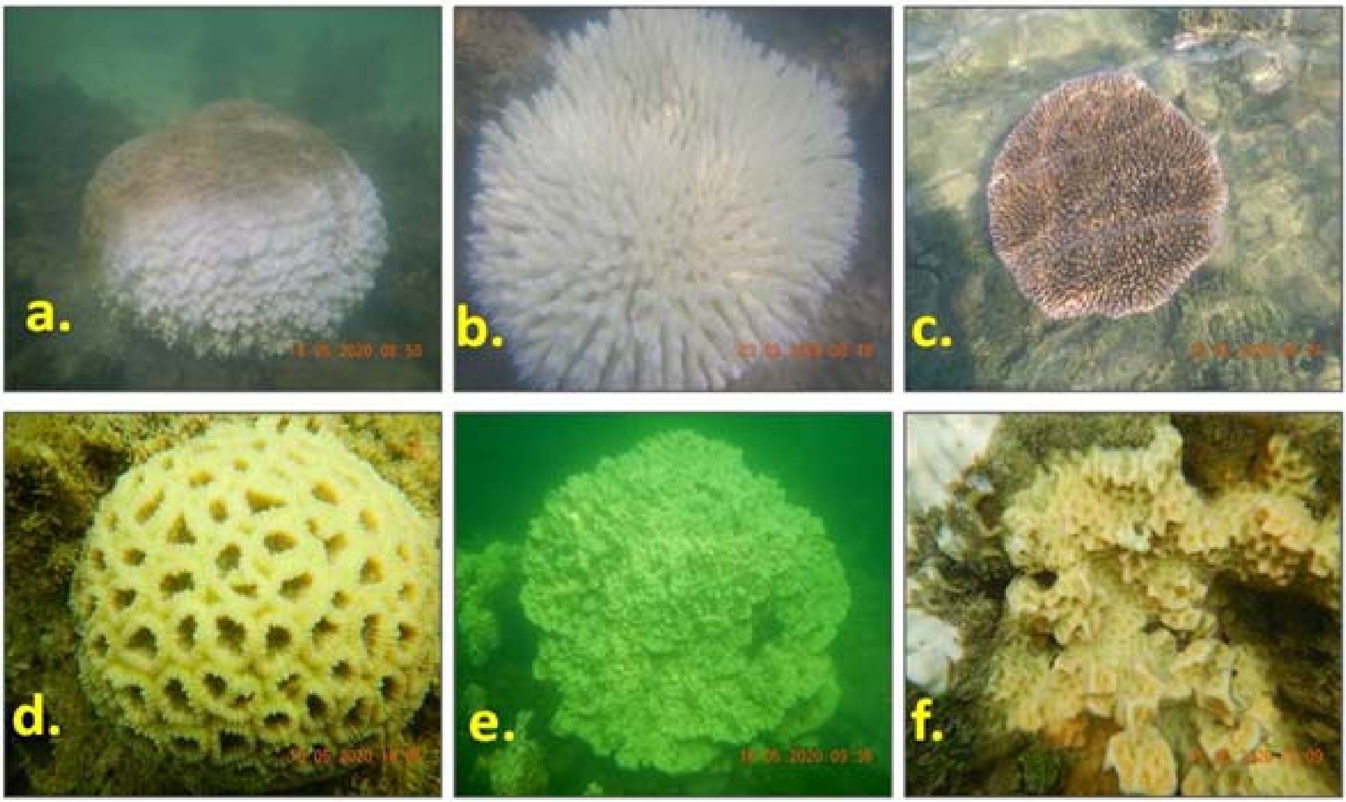

Figure 7. Different bleaching patterns in coral species: a. Bleached and non-bleached part in a single colony of a species; b-c: same species but one is bleached, other is healthy; d-f: bleaching of thermo-resilient massive corals

Authors' contributions

All authors contributed equally

Conflict of Interest

No potential conflict of interest was reported by the author(s).

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