

High Sea Surface Temperature induces Local Coral Bleaching in Gulf of Mannar and Palk Bay regions, South East Coast of India – A Status Report

*¹Koushik Sadhukhan, ¹Ramesh C.H., ¹Shanmugaraj T., and ²Ramana Murthy M.V.

¹National Centre for Coastal Research, Ministry of Earth Sciences, NCCR Field Research Centre, Mandapam Camp, Tamil Nadu – 623519, India.

²National Centre for Coastal Research, Ministry of Earth Sciences, Pallikaranai, Chennai - 600 100, Tamil Nadu, India.

*Corresponding E-mail Address : sadhukhan.1985@gmail.com

ORCID ID: Koushik Sadhukhan - 0000-0003-2361-3929, Ramesh Chatragadda - 0000-0002-8838-0583, T Shanmugaraj - 0000-0002-4860-7317, M.V. Ramana Murthy 0000-0002-6219-2728

Accepted August 25, 2020

Coral bleaching in Gulf of Mannar and Palk Bay was encountered while intensive reef health monitoring surveys conducted during the month of April to May, 2019. Surveys were carried out at 12 different locations of Gulf of Mannar and 2 locations of Palk Bay region. Reef building coral genera *Porites* sp., *Acropora* sp., *Montipora* sp., *Favites* sp., and *Dipsastraea* sp. were found to be affected by this bleaching event. The level of bleaching was 15.9% in Mandapam group, 31.0% in Keezhakarai group, 27.3% in Vembar group, 25.6% in Tuticorin group and 85.0% in Palk Bay group. High Sea surface temperature (32.5°C - 35.6°C) recorded during the month of April and May was about 4°C - 5°C, which is more than the average temperature range (26°C - 30°C) recorded in Gulf of Mannar and Palk Bay. Among the different live coral forms, massive corals (36.0 %) were more vulnerable than other branching coral forms. In Palk Bay, bleaching was observed only in massive corals upto a depth of 5m. Soft corals *Sinularia* sp, *Sarcophyton* sp. were also partially bleached in Gulf of Mannar. No bleaching was observed at more than 5m depth. A total of 23 species were assessed to estimate the degree of bleaching under the category of complete bleached, partially bleached and non-bleached. The study highlighted that bleaching is species specific and depth specific. Branching corals showed high adaptive resilience than massive corals in Gulf of Mannar and Palk Bay in comparison to previous bleaching event which could be a good sign of quick recovery of reef areas.

Key Words: Branching corals, Coral Bleaching, Gulf of Mannar, Massive corals, Palk Bay, Sea Surface temperature, *Symbiodinium* spp.

INTRODUCTION

Coral bleaching is natural event in which hermatypic or reef building corals lose its symbionts called zooxanthellae under high environmental stress which in turn leads to the whitening of coral host (Hughes et al., 2016). Bleached corals are not dead corals but they are dying slowly due to lack of food, immune response and colour. Corals are usually capable to recover from bleaching however they die at extreme conditions. Since 1998, effects of global warming specially increased Sea Surface Temperature (SST) is markedly decline the health of diverse coral reef ecosystem through mass bleaching, ocean acidification and local anthropogenic pressures (Graham et al., 2007; Hughes et al., 2017; Camp et al., 2018). Coral reefs in Gulf of Mannar (GoM) and Palk Bay are annually being affected by the bleaching event due to average SST increased from 29.5°C to 34.5°C during the month of April and May (Edward et al., 2008). Annual coral bleaching in Gulf of Mannar is local and tend to recover within a period of three months (Edward 2009; Edward et al., 2018). Fringing reefs of GoM are formed mainly around 21 offshore uninhabited islands which extend from the Tuticorin in north to Rameswaram in South (ENVIS, 2015). Reefs are comparatively shallow with a depth range between 0.5m to 8m. Average Sea surface temperature of Gulf of Mannar and Palk Bay region range between 25°C and 29°C throughout the year (Edward, 2008). In Palk Bay, Reefs are mainly patchy comprising of less diversity of reef building corals. In order to assess the routine reef health monitoring survey in both GoM and Palk Bay, coral bleaching has been found widespread at low levels across the reef area. Hence, the present study aims to undertake rapid monitoring of the coral health in both the regions, assess the extent of bleaching both species specific and depth wise and also observed the bleaching pattern of different coral species.

MATERIAL AND METHODS

Assessment of live coral cover and bleached corals were performed by underwater visual observation and following Line Intercept Transect method (English et al., 1997). 20m long LIT were laid in

triplicate, parallel to the islands in 12 reef sites of GoM and 2 sites in Palk Bay to assess the intensity of bleaching. Photographs were taken as a visual proof of the assessment using Nikon Coolpix. SST, pH and salinity were measured using Manta 2 water quality multi-probe gadget. 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).

RESULTS

Average extent of coral bleaching observed was 24.95±5.08% in Gulf of Mannar and 75.0% in Palk bay. A total of 23 species of corals belonging to 11 genera were recorded as bleached either completely or partially at different study sites ([Table 1](#)). Intensity of bleaching in the live coral was higher in Keezhakarai group (31.0±5.39%) followed by Vembar group (27.3±3.17), Tuticorin group (25.6±6.25%) and Mandapam group (15.9±5.51%) of Gulf of Mannar respectively ([Figure 1](#)). There is no sign of coral mortality observed due to bleaching during the survey. But regular monitoring is still undergoing to check the prevalence of bleaching and the extent of SST data. SST and atmospheric temperature data were collected from January to May 2019. Average SST was varied from 28.69 ± 0.4 in January 2019 to 33.8±0.7 in May 2019 which indicated that average SST rises 5°C more than the optimum temperature (23°C-29°C) required for coral survival ([Table 2](#)). During the survey, Massive corals were found to be the most affected by bleaching in both the regions. Among the coral form categories, percentage of bleaching in massive corals were 36.0% followed by Non Acropora branching corals (23.3%) ([Figure 2](#)). In Palk Bay, 100% bleaching of massive corals, *Porites* sp. was observed ([Figure 3a, b](#)). Corals in GoM and Palk Bay showed uniform bleaching pattern with increase of depth. No bleaching was observed below the depth of 5m. Maximum bleaching was recorded between 0m-2m depth and *Porites* sp. were the most affected coral genera ([Table 3](#)). Among the coral species *Porites solida*, *Porites lutea*, *Porites lichen*, *Montipora digitata*, *Montipora*

Table 1. Extent of Bleaching to Different Coral Species.

SI No.	Species	MG	KG	VG	TG	Palk Bay
1	<i>Acropora formosa</i>	CB, PB	PB	NB	NB	-
2	<i>Acropora ahyacinthes</i>	CB, PB	PB	NB	NB	NB
3	<i>Acropora digitifera</i>	CB, PB	CB, PB	NB	-	-
4	<i>Acropora gemmifera</i>	PB	NB	PB	-	-
5	<i>Acropora valeniennesi</i>	NB	PB	NB	NB	
6	<i>Acropora nobilis</i>	NB	NB	PB	-	-
7	<i>Pocillopora damicornis</i>	CB, PB	CB	NB	PB	
8	<i>Symphyllia radians</i>	PB	-	CB	-	-
9	<i>Montipora digitata</i>	CB, PB	CB, PB	CB	CB	-
10	<i>Montipora foliosa</i>	PB	PB	NB	NB	-
11	<i>Montipora aequituberculata</i>	NB	-	PB	-	-
12	<i>Porites solida</i>	CB, PB	CB	CB	CB	CB
13	<i>Porites lutea</i>	CB, PB	CB	CB	CB	CB
14	<i>Porites lichen</i>	PB	PB	CB	NB	CB
15	<i>Platygyra lamellina</i>	NB	PB	PB	-	-
16	<i>Leptoria phrygia</i>	NB	-	PB	-	-
17	<i>Goniastrea retiformis</i>	PB	CB, PB	PB	PB	-
18	<i>Dipsastraea favus</i>	PB	CB, PB	CB	PB	-
19	<i>Dipsastraea speciosa</i>	PB	PB	CB	PB	-
20	<i>Favites complanata</i>	NB	-	NB	-	-
21	<i>Favites halicora</i>	NB	PB	NB	-	-
22	<i>Hydnophora microconos</i>	PB	PB	CB, PB	-	-
23	<i>Hydnophora exesa</i>	PB	-	CB, PB	-	-

[Note: MG- Mandapam Group, KG- Keezhakarai Group, VG- Vembar Group, TG- Tuticorin Group; CB- Completely Beached, PB- Partially Bleached, NB: Non Bleached]

foliosa, *Acropora formosa*, *Turbinaria peltata*, *Platygyra lamellina*, *Hydnophora microconos* were found to be bleached in reef areas (Figure 3c-3g). Other recorded coral species were partially bleached (Table 1). *Acropora* or staghorn corals remain healthy in most of the reefs even at depths of 0.5m to 2m (Figure 3i and 3j). Percentage of bleaching in *Acropora* colonies was observed to be 18.7%. Soft corals *Sinularia* sp. were also found bleached in Keezhakarai group of Islands (Table 3,

Figure 3h).

DISCUSSION

Coral bleaching in Gulf of Mannar and Palk Bay becomes annual phenomenon since 2005, but major coral mortality was observed during 2010 and 2016 bleaching event. In 2016, Intensity of coral bleaching was higher in Mandapam group of

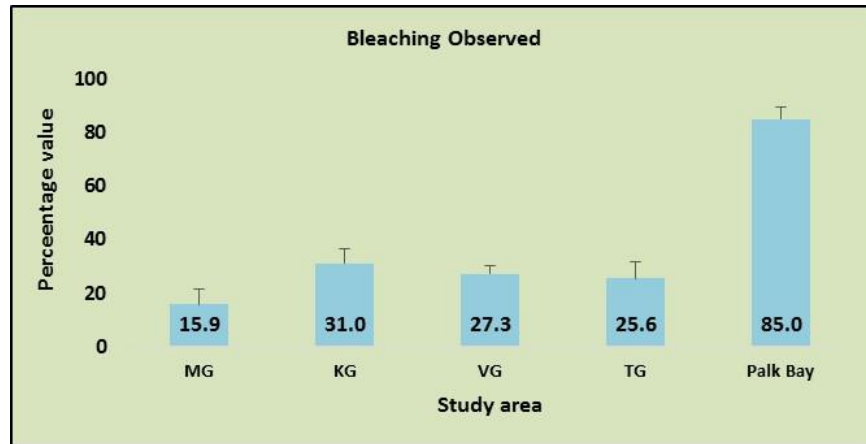


Figure 1. Intensity of Bleaching in Gulf of Mannar and Palk Bay Reef.

Table 2. Water Quality Parameters of all study sites.

Month	SST		pH		Salinity	
	GoM	Palk Bay	GoM	Palk Bay	GoM	Palk Bay
January	28.69 ± 0.4	29.50 ± 0.2	8.17 ± 0.1	7.89 ± 0.5	32.12 ± 0.4	32.00 ± 0.2
February	29.80 ± 0.5	30.2 ± 0.3	7.60 ± 0.6	7.23 ± 0.9	33.26 ± 0.7	32.66 ± 0.5
March	30.70 ± 0.5	30.90 ± 0.1	7.69 ± 0.5	7.80 ± 0.3	33.80 ± 0.07	33.11 ± 0.3
April	32.75 ± 0.7	31.20 ± 0.04	7.65 ± 0.7	7.70 ± 0.4	33.75 ± 0.6	33.2 ± 0.8
May	33.8 ± 0.7	31.97 ± 0.6	7.80 ± 0.8	7.75 ± 0.4	34.65 ± 0.5	33.89 ± 0.9

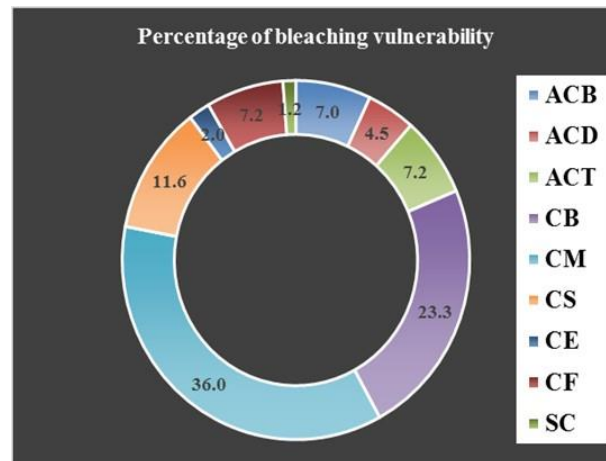


Figure 2. Bleaching susceptibility to different coral form categories.

Islands and live coral cover were drastically reduced to 22.69% in October 2016 whereas live

coral cover was recorded 38.86% during 2015 (Edwrad et al., 2018). In the present study, extent

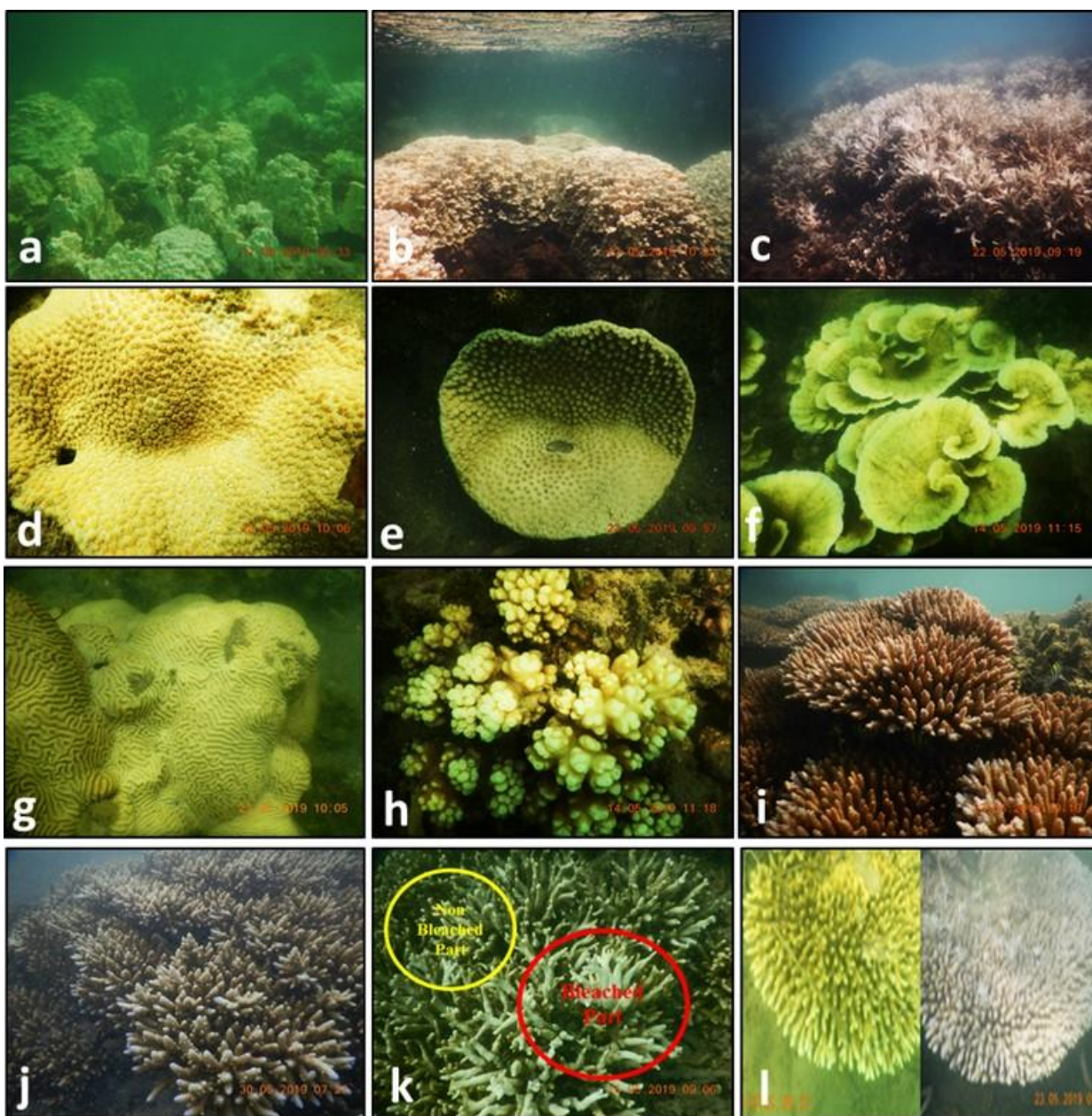


Figure 3 a-b. Bleaching of Massive corals *Porites* sp.; c. Bleaching of non *Acropora* branching corals *Montipora digitata*; Bleached corals: d. *Hydnophora microconos*, e. *Turbinaria peltata*, f. *Montipora foliosa*, g. *Platygyra lamellina*, h. *Sinularia* sp; i-j. Healthy colony of *Acropora digitifera* and *Acropora gemmifera* in depth of 0.5m. k: Different bleaching pattern observed in large colony of *Montipora digitata*; l: Two separate Colony of *Acropora hyacinthus* showed different intensity of bleaching (completely bleached and non-bleached) on the same depth and same reef.

of bleaching was around 24.95% but coral mortality still not encountered in both regions. During April – May 2019, there is no report of Mass bleaching event from global coral reef data (NOAA, 2019).

Hence, it was expected that coral may recover from this annual bleaching event which generally depends on the intensity and duration of temperature elevation. Coral recovery can also be

Table 3. Depth specific coral bleaching in Gulf of Mannar and Palk Bay.

Depth	MG	KG	VG	TG	Palk Bay
0m-2m	<i>Acropora</i> sp., <i>Porites</i> sp., <i>Montipora</i> sp., <i>Goniastrea</i> sp.	<i>Acropora</i> sp., <i>Porites</i> sp., <i>Montipora</i> sp., <i>Pocillopora</i> sp., <i>Dipsastraea</i> sp., <i>Goniastrea</i> sp., <i>Platygyra</i> sp., <i>Sinularia</i> sp.	<i>Porites</i> sp., <i>Montipora</i> sp., <i>Dipsastraea</i> sp., <i>Platygyra</i> sp., <i>Symphyllia</i> sp., <i>Hydnophora</i> sp., <i>Favites</i> sp., <i>Goniastrea</i> sp., <i>Leptoria</i> sp.	<i>Porites</i> sp., <i>Montipora</i> sp., <i>Dipsastraea</i> sp., <i>Goniastrea</i> sp., <i>Acropora</i> sp.	<i>Porites</i> sp., <i>Favites</i> sp., <i>Dipsastraea</i> sp.
>2m-4m	<i>Porites</i> sp.	<i>Porites</i> sp., <i>Montipora</i> sp., <i>Goniastrea</i> sp., <i>Dipsastraea</i> sp.	<i>Porites</i> sp., <i>Montipora</i> sp., <i>Dipsastraea</i> sp., <i>Symphyllia</i> sp., <i>Hydnophora</i> sp.	<i>Montipora</i> sp., <i>Dipsastraea</i> sp.	<i>Porites</i> sp., <i>Dipsastraea</i> sp.
>4m-6m	No bleaching	<i>Porites</i> sp.	No bleaching	No bleaching	<i>Porites</i> sp.

possible by the adaptive response of corals with increased temperature stress by climate change impacts (Kennedy et al., 2002; Hoegh-Guldberg, 2004). This acclimatization or adaptation is developed from the condition to past exposure of acute or chronic thermal stress on coral species (Brown et al., 2002). Different coral species have different ability to respond on the increased thermal stress in which coral symbionts *Symbiodinium* spp. plays significant role (Sampayo et al., 2009). Therefore, future of coral reefs critically depends on the ability of corals to respond to the rapid environmental changes by gaining more thermally tolerant symbiotic partner (Kinzie et al., 2001). Bleaching of corals both in GoM and Palk Bay in recent study showed a unique pattern in which

massive corals which are normally thermos-resilient have bleached completely and staghorn corals which generally thermos-sensitive found more resistant to thermal stress. In spite of strong heat exposure in 0m-2m depth, *Acropora gemmifera*, *Acropora digitifera*, *Acropora hyacinthes* were not bleached or in few cases partially bleached (Figure 3i and 3j), whereas 100% bleaching of *Porites* sp. recorded from Palk Bay reef in the same depth range (Figure 3a and 3b). The high resilient features of *Acropora* sp. against increased thermal stress in Gulf of Mannar and Palk bay had been revealed since 2007 (Krishnan et al., 2018). Hence it can clearly be stated that branching corals (*Acropora* sp.) in GoM possibly acquired the high thermal tolerant coral symbiont following the previous

bleaching events and that became the key determinant factors for their resistance to bleaching. Other encrusting coral species *Hydnophora* sp., *Symphyllia* sp., *Leptastrea* sp., *Platygyra* sp. were partially bleached and may recover easily from this local bleaching event. Different bleaching pattern were also observed in different colonies of same species (*Acropora* sp., *Montipora* sp., *Goniastrea* sp. and *Dipsastraea* sp.) (Figure 3k and 3l) which might be occurred due to the physiological response of coral symbionts that termed as *Symbiodinium* spp. shuffling which completely depends on corals capacity to change the relative abundances of their symbionts and in turn increase their thermal tolerance. Post bleaching threats to coral reefs in GoM is prevalent.

During bleaching, corals loss immunity and affected by several microbial infections and invasive native algal species (Edward et al., 2012). To facilitate the natural recovery of corals in GoM, local anthropogenic threats such as pollution, shoreline operation, fishing practices must be reduced to minimal limits by implementing proper conservation management protocols. Alternative management strategy such as coral reef restoration can also be encouraged to improve the natural recruitment process in degraded reef areas. NCCR has already initiated Coral Reef restoration programme in Mandapam group of islands to facilitate the natural recruitment process of corals and improve the live coral cover in degraded reef ecosystem. Therefore, understanding the distribution of *Symbiodinium* spp. within coral tissue in different reef region of India can improve our ability to manage, restore and predict the health of coral reefs in future. Despite of all such remedial action taken up by management interventions, the future of coral reefs critically depends on their ability to respond to the rapid environmental changes with new adaptive strategy.

ACKNOWLEDGEMENTS

Authors are grateful to the Ministry of Earth Sciences (MoES), Government of India for financial support and Chief Wildlife Warden, Tamil Nadu Forest Department for research permission in Marine National park. Authors are also thankful to Field Assistant for field assistance during the survey.

REFERENCES

- Brown BE, Downs CA, Dunne RP and Gibb SW (2002). Exploring the basis of thermos tolerance in the reef coral *Goniastrea aspera*. *Mar. Ecol. Prog. Ser.*; 242:119–129. doi:10.3354/meps242119.
- Camp EF, Schoep V, Mumby PJ, Hardtke LA, Rodolfo-Metalpa R, Smith DJ and Suggett DJ (2018). The Future of Coral Reefs Subject to Rapid Climate Change: Lessons from Natural Extreme Environments. *Frontiers in Mar. Sci.*, 5: 4. doi: 10.3389/fmars.2018.00004.
- Edward JKP (2009). Annual coral bleaching in Gulf of Mannar, South Indian Coast. *Mar. Bull.*, 1(1 and 2): 18.
- Edward JKP, Mathews G, Raj KD and Tamelander J (2008). Coral reefs of the Gulf of Mannar, southeastern India – observations on the effect of elevated SST during 2005–2008. In *Proceedings of the 11th International Coral Reef Symposium*, Fort Lauderdale, Florida, USA.
- Edward JKP, Mathews G, Raj KD, Thinesh T, Patterson J, Tamelander J and Wilhelmsson D (2012). Coral reefs of Gulf of Mannar, India – Signs of Resilience. *Proceedings of the 12th International Coral Reef Symposium*, Cairns, Australia.
- Edward JKP, Mathews G, Raj KD, Laju RL, Bharath MS, Arasamuthu A, Dinesh Kumar P, Bilgi DS and Malleshappa H (2018). Coral Mortality in Gulf of Mannar, Southeastern India, due to bleaching caused by elevated sea temperature in 2016. *Curr. Sci.*, 114(9): 1967–1972.
- English S, Wilkinson C and Baker V (1997). *Survey Manual for Tropical Marine resource*. Australian Institute of Marine Sciences, Townsville, Australia, 390p.
- ENVIS (2015). Database on Gulf of Mannar Biosphere Reserve. Department of Environment and Forest, Government of Tamilnadu, pp 1-74.
- Graham NAJ, Wilson SK, Jennings S, Polunin NV, Robinson J, Bijoux JP and Daw TM (2007). Lag effects in the impacts of mass coral bleaching on coral reef fish, fisheries, and ecosystems. *Conserv. Biol.*, 21: 1291–1300.
- Hoegh-Guldberg O (2004). Coral reefs in a century of rapid environmental change. *Symbiosis*; 37:1–31
- Huang D, Benzoni F, Fukami H, Knowlton N, Smith ND and Budd AF (2014). Taxonomic classification of the reef coral families Merulinidae, Montastraeidae, and Diploastraeidae (Cnidaria: Anthozoa: Scleractinia). *Zool. J. Linn. Soc.*, 171(2): 277–355. doi:10.1111/zoj.12140
- Hughes L, Steffen W and Rice M (2016). *Australia's Coral Reefs under Threat from Climate Change*, Climate Council of Australia Ltd, Potts Point, pp 1–22.
- Hughes TP, Kerry JT, Noriega MA, Romero JGA, Anderson KD, Baird AH, Babcock RC, Beger M, Bellwood DR, Berkelmans R, Bridge TC, Buttler IR, Byrne M, Cantin NE, Comeau S, Conolly SR, Cumming GS, Dalton SJ, Pulido GD, Eakin CM, Figueira WF, Gilmour GP, Harrison HB, Heron

- SF, Hoey AS, Hobbs JPA, Hoogenboom MO, Kennedy EV, Yang Kuo C, Lough JM, Lowe RJ, Liu G, Mc Culloch MT, Malcom HA, Mc William MJ, Pandolif JM, Pears RJ, Pratchett MS, Schoepf V, Simpson T, Skirving WJ, Sommer B, Torda G, Wachenfelid DR, Willis BL and Wilson SK (2017). Global warming and recurrent mass bleaching of corals. *Nature*; 543: 373–377.
- Kennedy VS, Twilley RR, Kleypas JA, Cowan JH and Hare SR (2002). Coastal and marine ecosystems and global climate change: potential effects on US resources. Pew Center on Global Climate Change, Arlington.
- Kinzie RA, Takamaya R, Santos SA and Coffon MA (2001). The adaptive bleaching hypothesis: experimental tests of critical assumptions. *Biol. Bull.*, 200: 51-58.
- Krishnan P, Purvaja R, Sreeraj CR, Raghuraman R, Robin RS, Abhilash KR, Mahendra RS, Anand A, Gopi M, Mohanty PC, Venkataraman K and Ramesh R (2018). Differential bleaching pattern in corals of Palk bay and the Gulf of Mannar. *Curr. Sci.*, 114 (3): 679-685.
- NOAA (2019). <https://coralreef.noaa.gov/coralsinthenews/welcome.html#>
- Sampayo EM, Dove S and LaJeunesse TC (2009). Cohesive molecular genetic data delineate species diversity in the dinoflagellates genus *Symbiodinium*. *Mol. Ecol.*, 18: 500-519.
- Veron JEN (2000). *Corals of the World*. Townsville: Australian Institute of Marine Science, Volumes 1-3, 1410p.