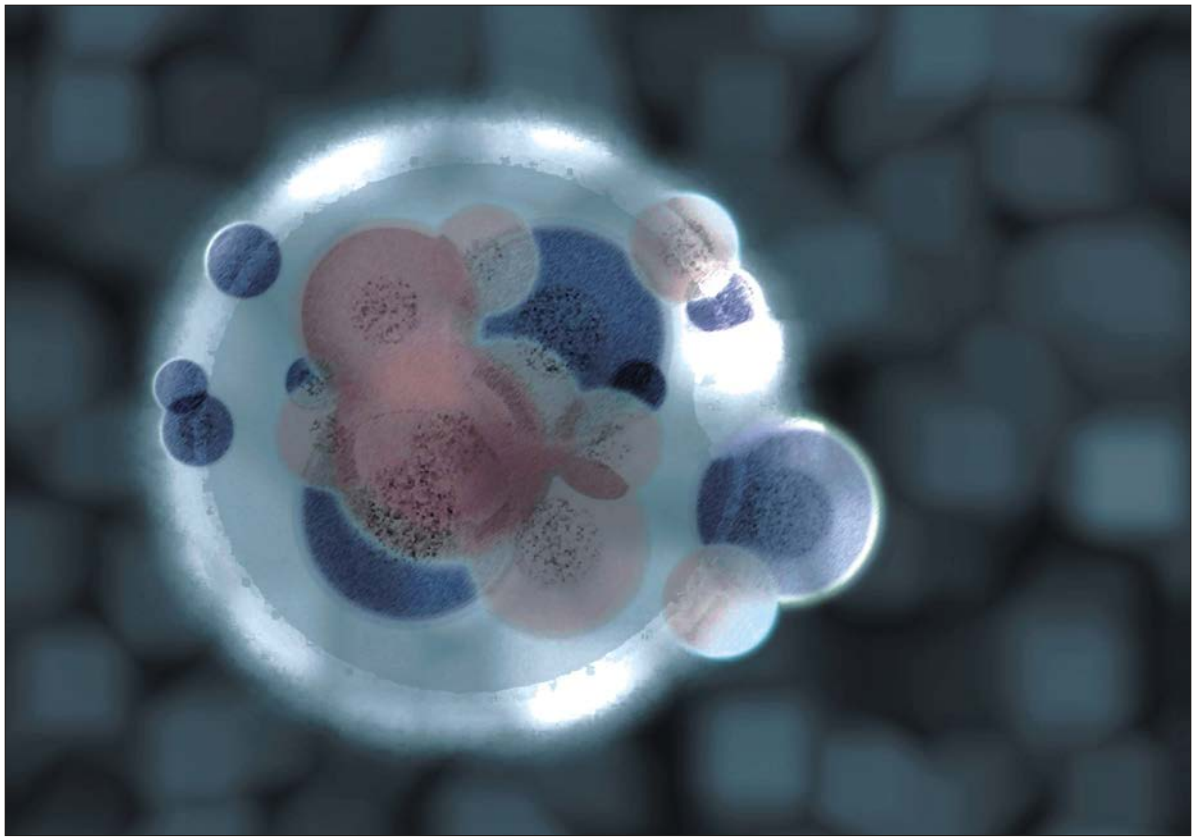




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## Impact of Climate Change Induced Coral Bleaching in the Northern Part of Gulf of Mannar and Palk Bay, Southeast Coast of India

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**Abstract:** Coral reef ecosystem in the Gulf of Mannar and Palk bay have been extensively damaged due to over fishing, sedimentation, dynamite fishing etc. Coral bleaching is an usual phenomena in summer and at extreme case the bleaching response is fatal to the coral. Bottom temperature during the months of April and May 2010 had significant change in both GoM and Palk bay and ranged between 31 to 31.9°C. Massive corals *Porites solida*, *Porites lutea* and *Favia* spp. and branch corals *Acropora cytherea*, *A. intermedia*, *A. formosa*, *A. nobilis* and *Mantipora digitata* were affected. Percentage of coral bleaching during April 2010 was 72 and 75% in GoM and Palk bay, further this level increased to 85.1 and 87.2%, respectively. Coral recovery was found during June to August 2010 in GoM and Palk Bay region. The phenomenon of coral bleaching has been taking place periodically all over the world. Therefore, in spite of the odds, the corals will resurge under the sea, which we need to protect and conserve for our benefit.

**Key words:** Coral reef, Gulf of Mannar, coral bleaching, climate change, temperature

### INTRODUCTION

Coral reefs are complex of calcium carbonate, which form a rocky eminence on the sea floor and grow upwards to the low-tide limit. Coral reefs are some of the most productive ecosystems on earth (Grigg *et al.*, 1984) and are certainly the most productive and species-rich environments in the ocean. It provides feeding, spawning and nursery grounds and shelter for marine organisms. Coral reef ecosystem in the Gulf of Mannar and Palk bay have been extensively damaged due to quarrying, dredging, over fishing, pollution, sedimentation, dynamite fishing etc., resulting in decreased Coral coverage and reduced recruitment. These anthropogenic stresses on reefs have also been exacerbated by several strong El-Nino Southern Oscillation events in the past (e.g., in 1998 and 2002). The fringing coral reefs along the coast of Gulf of Mannar and Palk bay is not only protecting the coast against erosion and Tsunami, but also protect coastal lagoons and other coastal habitats, such as sea grass beds. About 25% of fish population is dependent on coral reefs for survival. Reef fishery is the main economic resource for the people in the main area of Gulf

of Mannar. The other fishery related trades such as souvenir Shells, Holothurians, Shrimps, Lobsters and Ornamental Reef fishes depend on Coral reefs.

Many coral reef areas in the world already declined significantly due to coral mining, coastal development and pollution (Bellwood *et al.*, 2004; Gardner *et al.*, 2003). Mass bleaching was first recorded on Pacific coral reefs in 1984 (Glynn, 1991) and has since also been noticed in other tropical reefs. Widespread mortality of corals bleaching leads to changes in the patterns of distribution, abundance, species diversity and ecological function (Bellwood *et al.*, 2004; Hughes *et al.*, 2003). The phenomenon of coral bleaching was described by Glynn (1984). Corals contain symbiotic, unicellular dinoflagellate microalgae, called zooxanthellae, which is responsible for converting light energy into chemical energy that is used for CO<sub>2</sub> fixation and other assimilatory reactions. These dinoflagellate microalgae provides an energy source for the coral host, however this symbiosis is highly susceptible to extreme environmental conditions (Marshall and Baird, 2000) and anthropogenic impacts (Jones and Hoegh-Guldberg, 1999; Bruno *et al.*, 2001). In recent years, coral bleaching has become a worldwide

phenomenon (Brown *et al.*, 1996; Hoegh-Guldberg, 1999) and is characterised by the release of zooxanthellae from the coral host.

Coral bleaching is an usual phenomena in summer, in the extreme case, the bleaching response is fatal to the coral host and can devastate entire reefs over vast areas of ocean (McClanahan, 2000; Sheppard, 2003). A diverse range of stress factors (e.g., low salinity, low temperature, high sedimentation, aerial exposure, cyanide exposure) can initiate the bleaching response, although anomalously warm Sea Surface Temperatures (SSTs) is the primary triggering factor of large-scale mass bleaching events (Jones *et al.*, 2000; Hoegh-Guldberg, 1999). The 1998 climatic oscillation caused the strongest oceanic warming and it was associated with a severe coral bleaching and mortality globally (Enfield, 2001; Sheppard, 2003). Indeed, coral bleaching has consistently occurred where normal summer sea temperatures have exceeded ambient by 1-2°C for more than a few days (Hoegh-Guldberg, 1999).

The Gulf of Mannar takes the name from Thalaimannar of Sri Lanka and includes chain of 21 coral islands along the stretch from the East longitudes 78° 08' to 79° 30' and the North latitudes from 8° 35' to 9° 25'. The coastline of Gulf of Mannar extends from Rameswaram in the north to Kanyakumari in the south covering a distance

of 140 km. In recent years, Coral bleaching events have been reported with increasing frequency on the Gulf of Mannar and Palk Bay over the past 20 years. Bleaching events occurred in 2002, 2000, 1994, 1996, 1999 and 1984 (Kumaraguru *et al.*, 2003; Arthur, 2000; Pillai, 1996) whereas the first event across the entire reef area occurred in 1987 (Causey, 2001). Coral reefs in the Palk Bay region are distributed on the northern side from Rameswaram Island to Vedhaalai, covering a distance of about 25 km. The Palk Bay is known to have 66 species of corals belonging to 23 genera (Pillai, 1971). They were affected by the recent unusual temperature rise in the sea along the southeast coast, which lead to coral bleaching.

## MATERIALS AND METHODS

**Description of the study area:** The study was conducted in 7 sites in the Northern part of Gulf of Mannar region between latitudes 09°17'-45°N and longitudes-079°15'-079° 02'E and 4 sites in the Palk Bay region between latitudes 09°17'-45°N and longitudes -079° 15'-079°02'E during April to July 2010. The study area of Gulf of Mannar region consists of seven islands to a length of about 60 km and Palk Bay region consist length of about 25 km (Fig. 1).



Fig. 1: Coral bleaching in the Northern part of Gulf of Mannar and Palk Bay region

**Line intercept transect (LIT) methods:** Benthic life form category of coral reef ecosystems was assessed based on the observations on live coral, bleached coral, coral dead due to bleaching, dead coral with algal cover, rubbles, algal assemblage, seagrass, sand, silt and Mud cover. These benthic compositions were assessed by SCUBA diving using Line Intercept Transect (LIT) techniques following English *et al.* (1997). A 20 M transects were laid randomly perpendicular to the shore at 26 sites in the Gulf of Mannar and Palk Bay region.

**Physico-chemical parameters:** Atmospheric Temperature (AT), Sea Surface Temperature (SST) and Bottom temperature (SBT) was measured using thermometer. Salinity and pH was measured using Refractometer and pH meter. The dissolved oxygen was measured using Winkler's method. Concentrations of nutrients such as calcium, magnesium, phosphate, nitrate and silicate were measured using standard methods.

## RESULTS

Sea surface temperature (SST) in the GoM and Palk bay were similar and ranged between 32.6 and 32.2°C, while there was a reduction in SST from June to August and ranged between 29.9 to 29.1°C in both the regions. Bottom temperature (SBT) during the months of April and May had significant change in both GoM and Palk bay and it was ranged between 31 to 31.9°C, while reduction in SBT was found during June to August in GoM and Palk bay (Fig. 2).

Salinity varied between 35.6 and 33.8 ppt in both GoM and Palk Bay. Increase in salinity from 35 to 35.6 ppt from April to May and slightly declined to 34.0 and 33.8 ppt during July to August in both GoM and Palk bay. pH slightly increased from 7.9 to 8.1 from April to August in both GoM and Palk bay. Dissolved oxygen levels in GoM declined from 4.9 to 4.7 during April to May and again increased to 5.3 mg L<sup>-1</sup> in August. In Palk bay, it slightly increased from 4.7 to 5.0 mg L<sup>-1</sup> from April to May and again, it slightly decreased to 4.9 mg L<sup>-1</sup> in June

and increased to 5.4 mg L<sup>-1</sup> in August. Calcium varied between 420 and 610 mg L<sup>-1</sup> in both GoM and Palk Bay. Magnesium hardness was 1456 mg L<sup>-1</sup> during April and May and it slightly reduced to 1389 mg L<sup>-1</sup> in June and again retained at 1427 mg L<sup>-1</sup> in August at GoM. While in Palk bay steady increase magnesium hardness is from 1389 to 1478 mg L<sup>-1</sup> during April to June and declined to 1456 mg L<sup>-1</sup> in July. Phosphate and Silicate level in both GoM and Palk bay regions was no significant changes from April to August. Whereas Nitrate content in GoM showed a slight increase from 3.8 to 4.0 µg L<sup>-1</sup> from April to May with a slight decrease at 2.51 µg L<sup>-1</sup> during June and again elevated to 3.43 µg L<sup>-1</sup> in July at GoM. In Palk bay, there was a steady increase in nitrate levels from 2.2 to 3.2 µg L<sup>-1</sup> in April to June and decreased to 2.1 µg L<sup>-1</sup> in July to August (Table 1).

Percentage of live coral cover was 10.4% in April, decreased to 5.0% in May again coral cover increased to 10.7, 18.7 and 20.5% in June, July and August at GoM (Fig. 3). Similarly in Palk bay, it was 6.2% in April declined to 3.5% during May and again increased to 9.1, 14.3 and 14.4% during June, July and August. Whereas bleached coral cover was steadily declined during April and Jun, with no bleaching during July and August in GoM and Palk bay regions. Coral dead due to bleaching was varied between 22.1 and 13.4% in May to August in both the

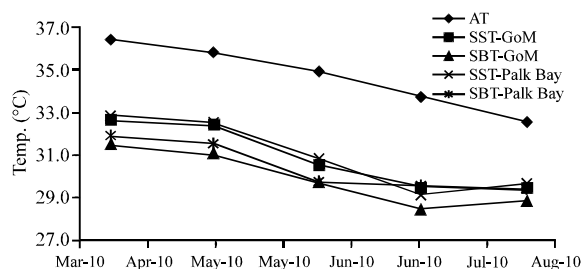


Fig. 2: Temperature during bleaching in the GoM and Palk Bay, Atmospheric temperature (AT), Sea surface temperature (SST), Bottom temperature (SBT), Gulf of Mannar (GoM)

Table 1: Physico-chemical parameters during the coral bleaching in the GoM and Palk Bay

| Parameters                              | Gulf of mannar-2010 |      |      |      |      | Palk Bay-2010 |      |      |      |      |
|-----------------------------------------|---------------------|------|------|------|------|---------------|------|------|------|------|
|                                         | April               | May  | Jun  | July | Aug  | April         | May  | Jun  | July | Aug  |
| Salinity (ppt)                          | 35.0                | 35.5 | 34.5 | 34.0 | 33.8 | 35.6          | 35.4 | 35.1 | 35.0 | 34.8 |
| pH                                      | 7.9                 | 7.9  | 8.0  | 8.1  | 8.1  | 7.9           | 8.0  | 7.9  | 8.0  | 8.1  |
| DO (mg L <sup>-1</sup> )                | 4.9                 | 4.7  | 5.1  | 5.1  | 5.3  | 4.7           | 5.0  | 4.9  | 5.1  | 5.4  |
| Calcium (mg L <sup>-1</sup> )           | 427                 | 560  | 600  | 563  | 480  | 604           | 480  | 560  | 610  | 420  |
| Mgso <sub>4</sub> (mg L <sup>-1</sup> ) | 1453                | 1456 | 1389 | 1456 | 1427 | 1385          | 1411 | 1478 | 1456 | 1535 |
| Phosphate (µg L <sup>-1</sup> )         | 2.7                 | 2.8  | 3.4  | 2.9  | 3.5  | 2.9           | 2.7  | 2.5  | 3.2  | 3.3  |
| Nitrate (µg L <sup>-1</sup> )           | 3.8                 | 4.0  | 2.5  | 3.4  | 2.7  | 2.3           | 2.8  | 3.3  | 2.5  | 2.1  |
| Silicate (µg L <sup>-1</sup> )          | 17.5                | 19.8 | 15.8 | 18.4 | 16.2 | 17.7          | 18.7 | 13.5 | 15.5 | 17.4 |

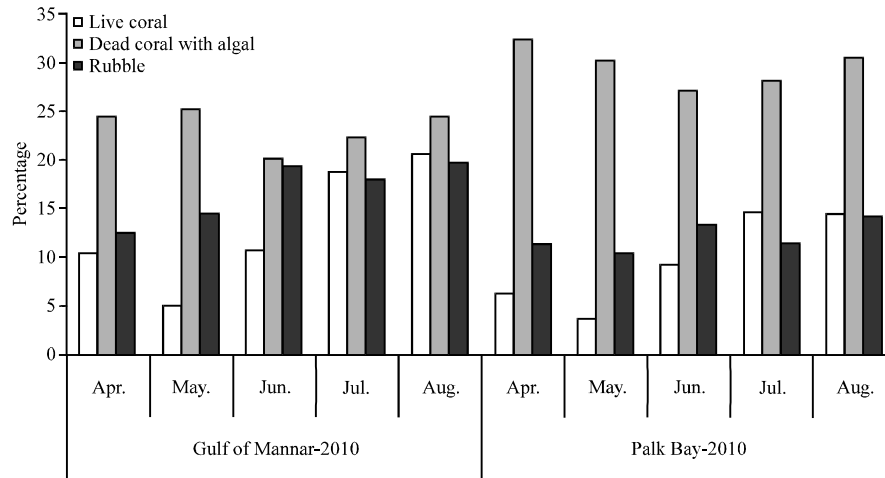


Fig. 3: Percentage of coral covers during bleaching phenomenon in the GoM and Palk Bay

Table 2: Status of benthic compositions during the coral bleaching in the Gulf of Mannar and Palk Bay

| Benthic compositions        | Gulf of mannar-2010 |      |      |      |      | Palk Bay-2010 |      |      |      |      |
|-----------------------------|---------------------|------|------|------|------|---------------|------|------|------|------|
|                             | April               | May  | Jun  | July | Aug  | April         | May  | Jun  | July | Aug  |
| Live coral                  | 10.4                | 5.0  | 10.7 | 18.7 | 20.5 | 6.2           | 3.5  | 9.1  | 14.3 | 14.4 |
| Bleached coral              | 26.7                | 16.4 | 10.0 | -    | -    | 22.0          | 11.5 | 4.3  | -    | -    |
| Coral dead due to bleaching | -                   | 12.1 | 12.9 | 15.3 | 13.4 | -             | 12.2 | 13.7 | 13.1 | 13.2 |
| Dead coral with algal       | 24.3                | 25.1 | 20.1 | 22.2 | 24.2 | 32.2          | 30.1 | 27.0 | 28.0 | 30.4 |
| Rubble                      | 12.3                | 14.4 | 19.3 | 18.0 | 19.5 | 11.1          | 10.3 | 13.3 | 11.3 | 14.0 |
| Algal assemblage            | 7.1                 | 8.3  | 6.0  | 8.2  | 6.3  | 10.2          | 13.8 | 15.1 | 13.5 | 10.7 |
| Seagrass                    | 3.4                 | 2.4  | 2.3  | 2.4  | 3.1  | 4.2           | 3.4  | 3.0  | 4.2  | 4.8  |
| Sand/silt/mud               | 14.2                | 15.2 | 18.0 | 14.2 | 12.2 | 11.3          | 14.0 | 12.4 | 13.0 | 12.5 |
| Other                       | 1.6                 | 1.1  | 0.7  | 1.0  | 0.8  | 2.8           | 1.2  | 2.1  | 2.6  | 1.0  |

Table 3: Species level percentage of corals bleaching in the Gulf of Mannar and Palk Bay

| Species name                 | Gulf of mannar | Palk Bay |
|------------------------------|----------------|----------|
| <i>Acropora formosa</i>      | +++            | ++++     |
| <i>Acropora nobilis</i>      | +++            | ++++     |
| <i>Acropora cytherea</i>     | ++++           | ++++     |
| <i>Acropora intermedia</i>   | +++            | +++      |
| <i>Acropora hyacinthus</i>   | +++            | ++++     |
| <i>Montipora digitata</i>    | ++++           | ++++     |
| <i>Montipora divaricata</i>  | ++             | +++      |
| <i>Montipora foliosa</i>     | ++             | +++      |
| <i>Porites lutea</i>         | ++++           | ++++     |
| <i>Porites lichen</i>        | ++++           | ++++     |
| <i>Porites solida</i>        | ++++           | ++++     |
| <i>Favites additta</i>       | ++             | +++      |
| <i>Favia favius</i>          | ++++           | ++++     |
| <i>Favia pallida</i>         | ++             | +++      |
| <i>Goniastrea retiformis</i> | +++            | +++      |
| <i>Turbinaria</i> sp.        | +++            | +++      |
| <i>Leptoria</i> sp.          | +++            | ++++     |
| <i>Platygyra</i> sp.         | +++            | ++++     |

–: No bleaching, +: 25% bleaching, ++: 50% bleaching, +++: 75% bleaching, ++++: 100% bleaching

regions. Dead coral with algal association was 24.3 and 32.2% in April, while declined to 22.3 and 28% in July and slightly increased to 24 and 30.4% at August in GoM and Palk Bay regions. Rubble composition was 12.3 and 11.1% during April, slightly increased to 19.5 and 14% during August in GoM and Palk bay regions, respectively. Algal

assemblage was also slightly increased from April to August in GoM and Palk bay regions. Seagrass, Sand, Silt, Mud and other content in GoM and Palk bay regions exhibited no significant changes from April to August (Table 2).

GoM had a less effect when compared to Palk bay, with maximum level of bleaching (100%) was found in 11 species at Palk bay and 6 species at GoM of 18 species found. At 75% bleached level, about 8 species was found to be affected in GoM and 7 species in Palk bay (Table 3). GoM had an higher level of 50% recovery of corals affected due to bleaching was found in 3 species (*P. lutea*, *P. lichen* and *P. solida*) while in Palk bay it was found only in two species (*P. lutea* and *P. solida*). About 25% recovery level was found in 12 species of GoM while it was only 5 species in Palk Bay. Higher recovery percentage was found in GoM when compared to Palk bay (Table 4).

Percentage of live coral cover was 28 and 22% during April and it reduced to 14.9 and 12.9% in May at GoM and Palk bay regions, respectively. Once again it increased to 31.8 and 33.6% in GoM and Palk bay during June. Further recovery level was enhanced to 60.5 and 54.1% in GoM and Palk bay regions. Bleached coral percentage was very

Table 4: Species level percentage of corals recovery in the Gulf of Mannar and Palk Bay

| Species name                 | Gulf of Mannar | Palk Bay |
|------------------------------|----------------|----------|
| <i>Acropora formosa</i>      | +              | +        |
| <i>Acropora nobilis</i>      | +              | –        |
| <i>Acropora cytherea</i>     | –              | –        |
| <i>Acropora intermedia</i>   | +              | +        |
| <i>Acropora hyacinthus</i>   | –              | –        |
| <i>Montipora digitata</i>    | –              | –        |
| <i>Montipora divaricata</i>  | +              | –        |
| <i>Montipora foliosa</i>     | +              | –        |
| <i>Porites lutea</i>         | ++             | ++       |
| <i>Porites lichen</i>        | ++             | +        |
| <i>Porites solida</i>        | ++             | ++       |
| <i>Favites additita</i>      | +              | +        |
| <i>Favia favius</i>          | +              | –        |
| <i>Favia pallida</i>         | +              | +        |
| <i>Goniastrea retiformis</i> | +              | –        |
| <i>Turbinaria</i> sp.        | +              | –        |
| <i>Leptoria</i> sp.          | +              | –        |
| <i>Platygyra</i> sp.         | +              | –        |

–: No recovery, +: 25% recovery, ++: 50% recovery, +++: 75% recovery

high during during April and this level reduced from 72.0 and 78.0 to 0.0% in August 2010 in GoM and Palk bay regions. Coral dead due to bleaching was 0% during April and further it increased gradually to 55.0% in June and a reduction was occurred in August in GoM. In Palk bay, 0% coral dead due to bleaching in April increased to 50.6% in June and gradually reduced to 45.9% in August.

Percentage of coral bleaching during April was 72 and 75% in GoM and Palk bay, further this level increased to 85.1 and 87.2%, respectively (Fig. 4 and 5). This level gradually reduced and reached to 39.5 and 45.9% in GoM and Palk bay regions respectively. Percentage of coral recovery was 0.0% during April and May in GoM and Palk bay regions. Gradual increase in percentage of coral recovery was found during June to August in GoM and Palk Bay region.

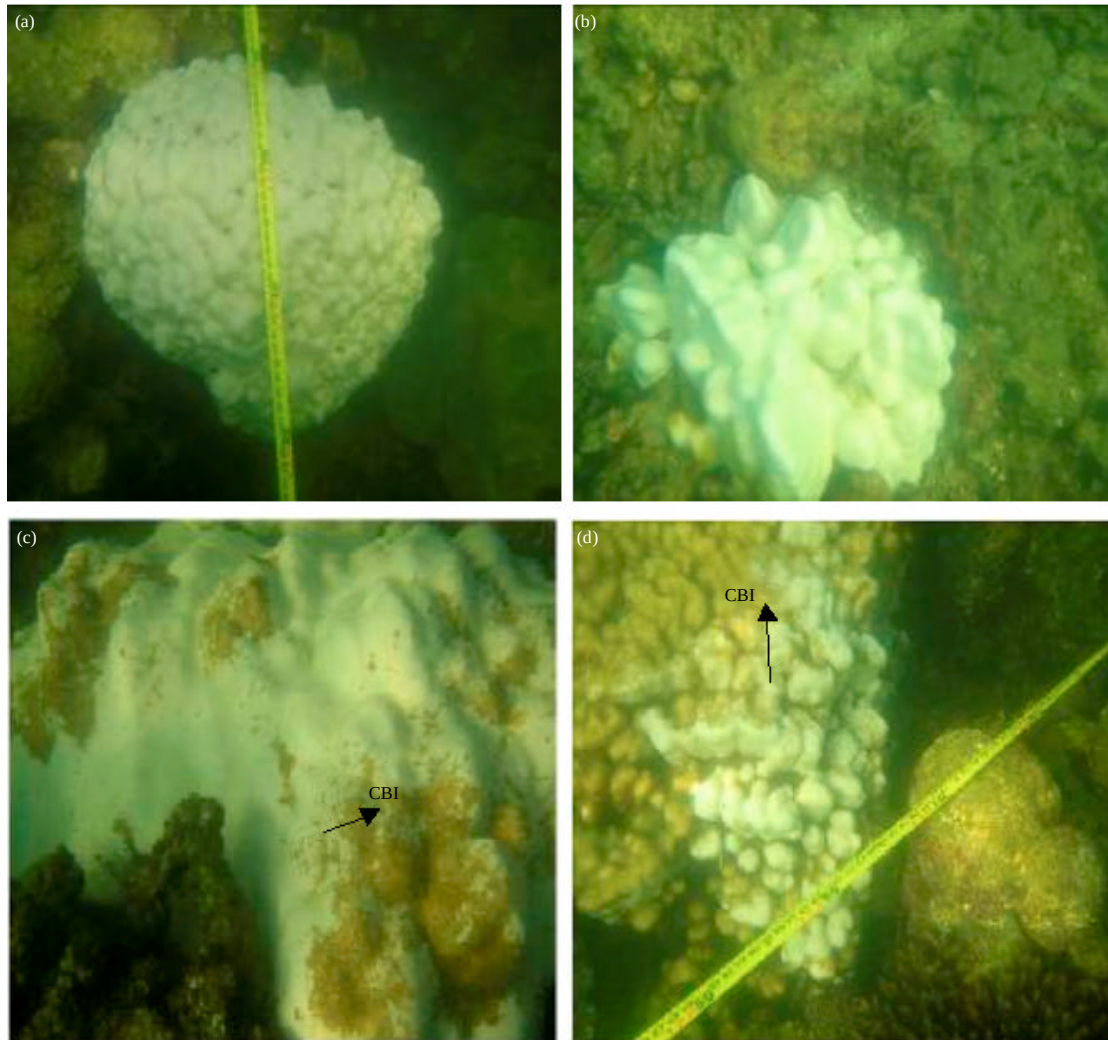


Fig. 4(a-d): Coral bleaching and Cyanobacterial infection (CBI) after bleaching

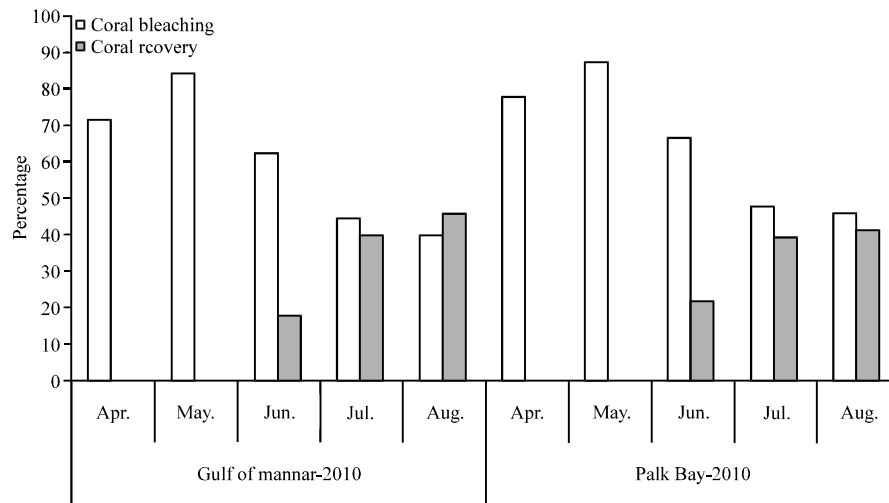


Fig. 5: Percentage of coral bleaching and recovery

## DISCUSSION

Global warming is widespread and serious implications for coral reef ecosystem. Although it is expected that sea water temperature played a major role in the bleaching events in Gulf of Mannar and Palk Bay. This study suggests that sea water temperature level was considerably higher than normal summer bleaching, which was 32.5°C in the peak of summer. A significant rise of the sea surface temperature leads corals death, though they may partially or fully recover from bleaching events. The assessment of this study compared favorably to Kumaraguru *et al.* (2003) found that coral bleaching phenomenon might have occurred due to unusual rise in surface sea water temperature in the peak of summer in Palk Bay India. Arthur (2000) has also reported that coral bleaching increases the SSTs above the seasonal average can trigger widespread bleaching in Indian coral reef regions. The percentage of corals bleaching in the study region varied from 72 to 83% depending upon the species prevalent in the area. The present coral bleaching was found to high impact compared to the 2000 and 2002 bleaching observed in the Gulf of Mannar and Palk Bay region (Kumaraguru *et al.*, 2003; Arthur, 2000).

However, the present bleaching event was more or less similar to the 1998 event in Gulf of Mannar. Kumaraguru *et al.* (2003) reported that more than 75% death of corals occurred and recovery of those reefs was very slow it took more than one year for recovery. Similar to these investigations, our assessment showed that coral bleaching was high and recovery was very less, this is due to the long duration of water temperature, over

sedimentation and outstanding water turbidity, our study proposed that these parameters contributed to more loss and less recovery of corals in study area. According to Pillai (1971) reported, towards the seaward side of the island in the Gulf of Mannar, the high velocity waves hit against the reef edge (wave breaker) and a fall in the velocity of waves cause the wave induced current forms which moves towards the island and drop the littoral sediment on reef leading to coral. This study also suggested that Southwest monsoon increased water flow and mass transfer of inorganic nutrients and dissolved gases across the diffuse boundary layer between the water column and the coral tissue, thereby likely reducing oxidative stress and limiting photoinhibition (Lesser *et al.*, 1994), which in turn may prevent or minimize coral bleaching (Finelli *et al.*, 2006; Nakamura *et al.*, 2005).

During survey remarkable event was noticed that was invasion of micro algae formed new colony on bleached coral reef. According to McField (1999) Cyanobacterial infections appeared to be a secondary infection after bleaching. Edmunds (1991) found that coral diseases peak incidence at the end of the warmest season. Invasion of micro algae is one of major reason for less recovery and high mortality of corals in Gulf of Mannar and Palk Bay. In this study, we found that Massive corals *Porites solida*, *Porites lutea* and *Favia* spp. and branch corals *Acropora cytherea*, *A. intermedia*, *A. formosa*, *A. nobilis* and *Mantipora digitata* was affected among this *Porites lutea*, *Acropora cytherea* and *Montipora digitata* was 75 to 100% highly affected. Inconsistent bleaching of coral species on the same reef suggests that there is a range of tolerance within species. There was a difference



in susceptibility to bleaching stress among the corals at Gulf of Mannar and Palk Bay. Marshall and Baird (2000) confirmed that fast growing and short-lived branching *Montipora* spp. was susceptible to coral bleaching phenomena due to temperature. Fabricius (1995) also ranked the alcyonaceans *Sinularia* and *Lobophytum* as being highly susceptible to coral bleaching, although their life history characteristics (slow growth, limited recruitment and low mortality) are different to those of *Montipora* spp.

The bleaching of 1998 phenomena destroyed most shallow water corals in the Gulf of Mannar, causing a significant reduction in the live coral cover, particularly among branching *Acropora* spp. (Venkataraman, 2000). In similar to these investigations, our post coral bleaching assessment showed that recovery of *Acropora cytherea* very less because it suffer from growth rates and reproductive potential (Goreau and Macfarlane, 1990; Szmant and Gassman, 1990) and several species may go locally extinct in the process. The coral bleaching not only affected *Acropora* spp. but also affected *Porites* spp. Even though, *Porites* spp. was recovered from coral bleaching. Fundamentally, *Porites* spp. are dominant members of coral reef communities because the tissue is deeper-seated in the skeleton (Hoegh-Guldberg and Salvat, 1995) that provided better production from high temperature than in *Acropora* spp. and *Pocillopora* spp., a characteristic of skeleton that may responsible for recovery of *Porites* spp. from coral bleaching. Observations of post bleaching events suggest that relative recovery rates among specie may be related to colony morphology.

## CONCLUSION

Although the corals have got bleached, they need to be protected because these bleached reefs will slowly recover in time by way of new growth of coral colonies over the old ones. The optimistic point to note here is that if we look at the scientific records, this phenomenon of coral bleaching has been taking place periodically all over the world. Therefore, in spite of the odds, the corals will resurge under the sea, which we need to protect and conserve for our benefit.

## ACKNOWLEDGMENT

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