

Bleaching and secondary threats on the corals of Palk Bay: A survey and Proactive conservation needs

Ravindran¹ J., E. Kannapiran², B. Manikandan¹, R. Mani Murali³ & Anthony Joseph³

¹CSIR- National Institute of Oceanography , Regional center, Dr. Salim Ali Road,
Post Box No 1913, Kochi-682018. India

²Directorate of Distance Education, Alagappa University, Karaikudi-630003, India

³CSIR-National Institute of Oceanography (CSIR), Dona Paula, Goa, India

[Email: jravi@nio.org]

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A survey on bleaching and the secondary threats on bleached corals in the selected sites of Palk-Bay were conducted during May and June 2010. Massive corals represented by the genera *Porites*, *Goniopora*, *Favia* were bleached extensively. Significant portion of the surface of live corals were found dead. Coral recovery after bleaching was at a great risk due to the algal overgrowth and sedimentation which would lead to their death and permanent loss. Destruction of the slow growing corals by natural and altered environmental conditions warrant the proactive conservation approach guided by scientific principles. Current conservation methods in India offers physical protection to corals by entry restriction and a ban on collection of corals under wild life act. This is inadequate as they could not prevent secondary stressors taking toll on corals during environmentally induced stress conditions.

[Keywords: Bleaching, Coral, Sedimentation, SST, Solar irradiance, Stress, Palk Bay]

Introduction

Corals are the major reef building organisms maintaining the structure, function and stability of the reef ecosystems¹. Despite this, corals are being threatened alarmingly by numerous factors such as climate change, diseases, ocean acidification, coastal erosion, storms and anthropogenic activities. Coral reef ecosystems are the most sensitive ecosystem that responds rapidly to the environmental stressors. Corals are visible bio indicators alarming the increasing Sea Surface Temperatures (SST) through bleaching in which the endosymbiotic zooxanthellae is expelled.

A constant rise in the mean solar radiation and SST results in coral bleaching². The incidence of coral bleaching episodes is increasing in both frequency and extent worldwide in the last 20 years³. All mechanisms described so far highlight the role of extreme SST and high solar radiation in triggering coral bleaching. Solar radiation together with increased SST is considered to be the dominant stressors apart from local stress resulting from pollution and anthropogenic activities. Solar radiation especially in the form of UV radiation could potentially damage corals and their symbionts⁴.

Corals and their symbionts produce UV absorbing compounds which play a critical role in blocking the direct effect of UV radiation⁵. Reduction of zooxanthellae density due to high SST and a subsequent decrease in the concentration of UV absorbing compounds will increase the vulnerability of corals to the harmful UV radiation.

The dominant growth of algae over the corals minimizes the substrate area for the settlement of new coral larvae⁶. This dominant growth of algae may be due to eutrophication and availability of nutrients from the decomposing tissue of the bleached corals. Moreover, overexploitation of the herbivorous fishes facilitates the algal dominance⁷. Sedimentation arising from dredging and runoff is one of the major threats to the coral reefs in Southeast Asia⁸. Excessive sedimentation influences the corals in either one of the three ways 1. smothering the colonies thereby preventing them from feeding and killing them, 2. impairing photosynthetic activity of symbiotic zooxanthellae by reducing the availability of sun light and 3. exhausting the energy store of the coral colonies by their continuous secretion of mucus and ciliary action to clear the sediments from their surface. Though some corals are reported to be

sediment tolerant in spare of their metabolic energy, most of the species are highly intolerant to even small amount of sediments⁹. In this study the extent of coral bleaching in Palk Bay following a sharp rise in SST and solar radiation and the effect of secondary threats on the bleached corals was investigated.

Materials and Methods

A fringing reef of 25-30 km long and 300 m wide is found in the Palk Bay region (Figure 1) of Tamilnadu, south east coast of India. The Palk Bay region is divided in to 5 zones as shore, lagoon, shoreward slope, reef crest and seaward slope. The Palk Bay reef is shallow and the water depth is not more than 15 meters. So far 66 species of corals belonging to 23 genera were reported in Palk Bay¹⁰. The waters of Palk Bay are turbulent during the onset of north east monsoon due to the winds of high velocity, whereas it is calm for rest of the seasons²⁷. The study sites were selected randomly along the PalkBay reef where the live coral cover is copious. GPS points of the study sites were given in Table 1.

The intensity of solar radiation and SST over Palk Bay was monitored starting from February 2010 and a weekly surveillance on the sign of coral bleaching was conducted by snorkeling from April 2010 in two of the study sites in Palk Bay. The daily 9 km optimum interpolated global SST (MODIS + TMI) data were downloaded from <http://www.misst.org> for the period of Feb 2010 - Jun, 2010. The data is the

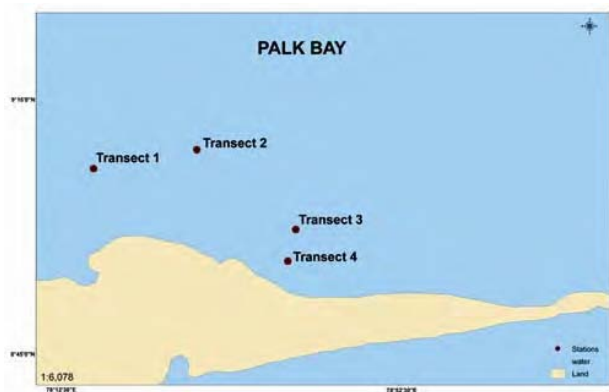


Figure 1—Map showing the study area.

Table 1—GPS points of the study sites

Site 1	Latitude	Longitude
Transect 1	9°17'52.9"N	79°08'97.0"E
Transect 2	9°17'59.7"N	79°08'58.1"E
Site 2		
Transect 3	9°17'16.1"N	79°09'33.0"E
Transect 4	9°17'28.3"N	79°09'72.1"E

merged product of both day and night in the Infra red and microwave wavelengths. From those data, monthly mean SST for 5 months were generated and plotted in FERRET.

Real time data of solar radiation (mW/sq.cm) for every 10 minutes from February to June 2010 was obtained for Palk Bay region from Autonomous Weather Station (AWS) developed at National Institute of Oceanography, Goa. The maximum amount of solar radiation recorded everyday was considered and the mean solar radiation was calculated for each month and was plotted.

Biophysical Survey

Surveillance on the sign of coral bleaching was conducted at regular intervals in the selected reef sites at the depth of 2-3 m in the Palk Bay during the study period. As the SST and solar radiation were steadily rising, we increased the frequency of surveillance during April 2010. After the first signs of bleaching, a biophysical survey on coral bleaching and the secondary threats on the bleached corals were conducted following the line intercept transect method in the month of May and June 2010. Two transects of 20 meters length were laid at each site, one towards the sea ward side and other towards the shore ward side. Life forms under each transect were recorded and the percentage of live coral cover, bleached coral cover, bleached coral with algal cover and dead coral with algae were calculated.

Rate of Sedimentation

Sediment traps were deployed in the study sites at a depth of 2 meters to determine the rate of sedimentation over corals in the month of June 2010. The traps were designed according to English *et al.* 1997 with some modifications. The poly vinyl chloride (PVC) tubes, 5 cm in diameter were cut into 20 cm height pieces and sealed at the bottom. The mouth of the tube was guarded with 8 mm alloy mesh to prevent clogging of the mouth by the entry of the larger organisms. These traps were deployed at the bottom vertically in the survey site to determine the rate of sedimentation. The deployed sediment traps were retrieved after a period of 45 days and the sediment samples were dried at 60°C in hot air oven and quantified.

Results and Discussion

The mean intensity of solar radiation was above 100 mW/sq.cm during February 2010 to April 2010

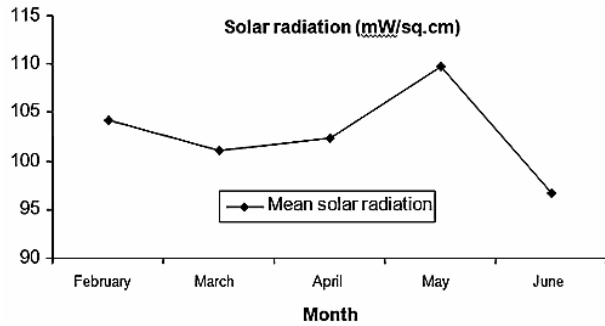


Figure 2a—Mean solar radiation (mW/sq.cm) during February 2010 to June 2010 in the Palk Bay region.



Figure 2b—Number of days the intensity of solar radiation exceeds a maximum of 100mW/sq.cm during the study period.

(Figure 2a). This was in direct proportion to the number of days in which the intensity of solar radiation exceeds a limit of 100 mw/sq.cm. The number of days in which the incident of solar radiation was >100 mw/sq.cm was increasing from month of February, March and April as 24, 29, 30 days respectively (Figure 2b). The mean intensity of solar radiation was below 100 mW/sq.cm during May and June 2010. Similarly the mean SST also showed a constant increase from February 2010 ranging from 28°C to a maximum of 31.5°C in April 2010 (Figure 3). Coral bleaching occurs when the Sea surface temperature maxima exceeds 31°C and remained high for more than 30 days¹¹. The coexistence of high solar radiation and SST during the month of April 2010 could have triggered the bleaching event reported in this study. This is supported by a survey made among fishermen in the Palk Bay who observed the ‘whitening of corals’ and our visual observation during the first week of May 2010 in which the corals belonging to the genera *Porites*, *Goniopora*, *Favia* showed the signs of partial bleaching with excessive mucus secretion. Though the solar radiation came down during May

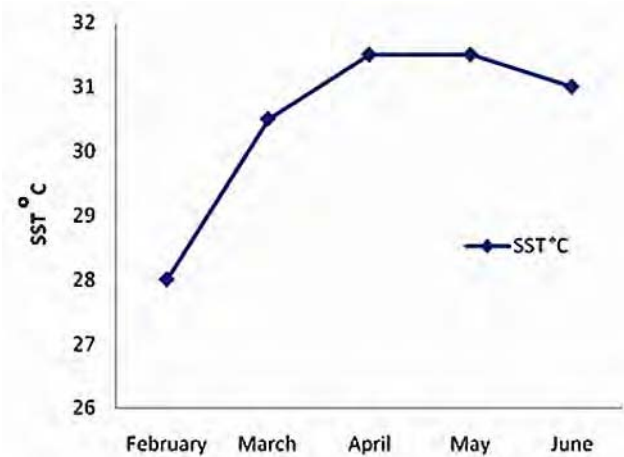


Figure 3—Mean sea surface temperature (SST) during February 2010 to June 2010 in the Palk Bay region.

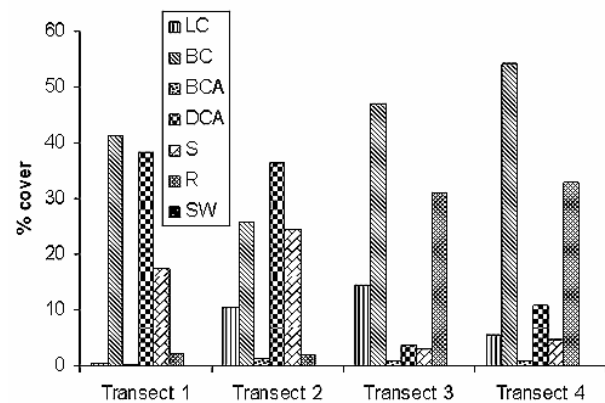


Figure 4—Status of live corals and bleached corals in the study sites of Palk Bay during May 2010. LC- Live coral, BC- Bleached coral, BCA- Bleached coral with algal cover, DCA – Dead coral with algal cover, S – Sand, R- Rubbles, SW- Seaweeds.

2010 the mean SST continued to be more than 30°C which resulted in complete bleaching of all the massive corals in the study site in next few days.

Biophysical survey in May 2010 in the study sites showed that the bleached corals were the largest benthic category ranging a maximum of 41.3% to a minimum of 25.8%. *Porites* were the dominant forms among the massive colonies and were completely bleached (Figure 7a). Comparatively the percentage of live corals were reduced, ranging a maximum of 14.6% to a minimum of 0.6%. Sand were found to some extent in the transects 1 and 2 and rubbles of *Acropora* sps were found widespread in the transects 3 and 4 (Figure 4).

Subsequent biophysical survey in June 2010 revealed the growth of fleshy and turf algae and sedimentation taking toll over the bleached corals.

The percentage of live corals in the study sites ranges from a maximum of 25% to a minimum of 0.8%. Whereas, the percentage of bleached corals covered with algae was comparatively greater than that of the live corals and bleached corals, ranging a maximum of 39.6% to a minimum of 24%. In addition, the dead corals with algal cover accounts for a maximum of 40.5% to a minimum of 2.5% of the records. Sand and rubbles were found in all the transects ranging from a maximum of 19.6% and 30.1% to a minimum of 4.5% and 0.4% respectively (Figure 5). Almost all the corals were bleached and either partially or fully covered with the algae and sediment smothering them. Sedimentation was found high at the reef sites of Palk Bay. Average sediment rate varied between

82-153 mg/cm²/day (dry weight) in the sites under study. This could be due to the sediments brought from Gulf of Mannar during South west monsoon through the channel which separates Rameshwaram Island from Mandapam Peninsula¹². Microbiological analysis of the sediments using the selective media revealed the presence of numerous enteric bacteria, coliforms, *Streptococci* and *Vibrio species*, suggesting that the source of sediments could be terrigenous discharges.

The overall scenario explains that the bleached corals were highly threatened by the secondary stressors for their recovery. Initially this bleaching event was thought to be localized, but similar scenario has been reported in different parts of south east Asia including Indonesia, Thailand, Philippines, Maldives and in some parts of East Africa where after one month of bleaching most of the bleached corals were found dead with algal cover which reduced the live coral cover by up to 16%¹³ and in Andaman Islands, the live coral cover was reduced <10%, and the bleached coral cover exceeded >45% showcasing the wide spread effects of increased SST globally during 2010²⁸. Generally corals undergo bleaching when there is a persistent stress. SST recorded over Palk Bay region showed that the mean SST reached a maximum of 31.5°C in the first half of 2010, which was the highest in the past 7 years (Figure 6). Both photosynthetically active radiation (PAR 400-700 nm) and UV radiation (UVR 200 nm-400 nm) were known

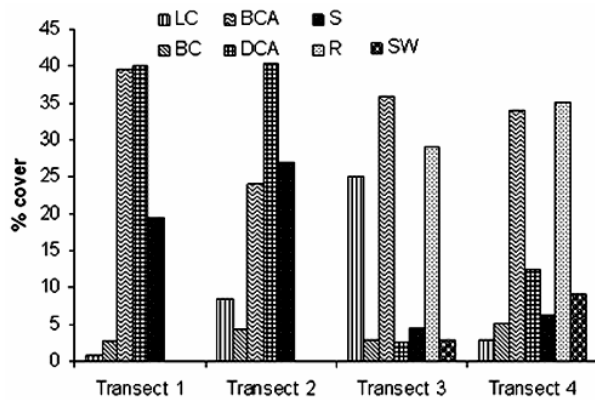


Figure 5—Status of Life forms in the study sites of Palk Bay during June 2010.

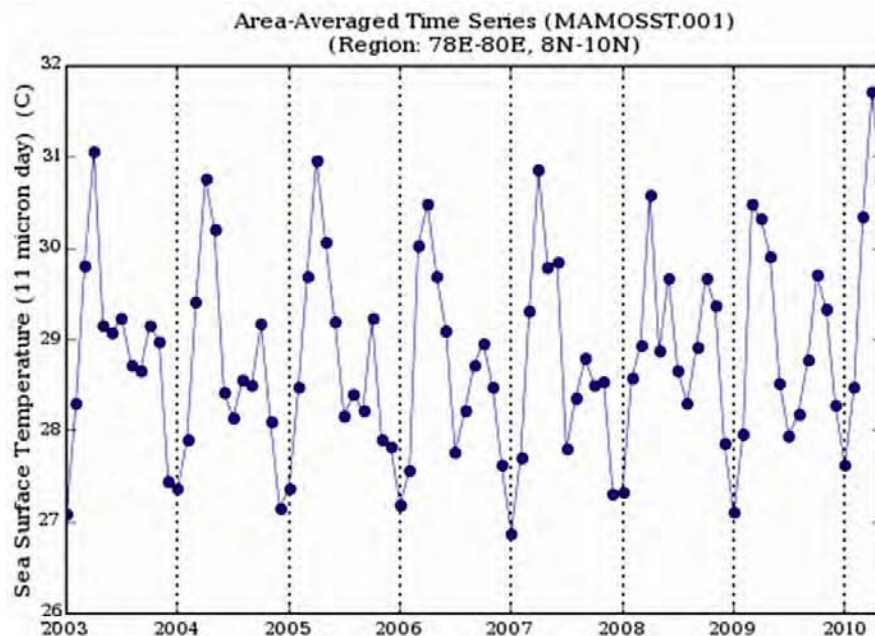


Figure 6—Sea surface temperature (SST) graph for the past 7 years over the Palk Bay region.

to affect corals by means of bleaching³ and cause tissue damage¹⁴. Maximum amount of solar radiation recorded in a day over the Palk Bay region was 121.9 mW/sq.cm and it was recorded during the month of May 2010. The optimum temperature for the growth of corals is usually 28°C. When this level exceeds more than 30°C the corals lose their thermal tolerance which subsequently leads to an increase in the frequency of occurrence of bleaching events either twice or thrice in a year. Increasing frequency of coral bleaching has been forecasted by the IPCC report¹⁵. Even a slight increase of 1°C will affect the corals in a worse manner causing them to expel their symbiotic partner¹⁶ which supports 98% of the host's nutritional requirements. Though many mechanisms have been hypothesized for this expulsion of zooxanthellae, oxidative stress was known to be responsible for this loss of zooxanthellae when it was exposed to higher temperatures¹⁷. It is well known that expulsion of zooxanthellae will subsequently lead the corals to starve and die unless they were not gained again at the earliest.

Corals can recover from bleaching when the environmental conditions are favorable. Coral bleaching was previously observed during 1998 and 2002 in Palk Bay. Though the coral recovery was slow during 1998 bleaching event; its recovery was fast during 2002 that within three months nearly 35% of the corals recovered¹⁸. However, the December 2004 Indian Ocean tsunami reduced the live coral cover significantly in the Palk Bay from 26.7% to 19.2%¹⁹. Present conditions in Palk Bay seem to be very poor for the coral recovery. This is evident from the filamentous, turf and fleshy algae found overgrowing the bleached corals (Figure 7b, c, d) and excessive sediments over the coral surface (Figure 7e, f). The corals partially bleached were still under stress as a thick mucus layer was formed in the portion of the unbleached *Porites* colony (Figure 7g). Coral bleaching was also considered to be an adaptive process of corals for reshuffling the population of zooxanthellae for their increased resistance³. But the case was different in Palk Bay, as the corals were restricted from their recovery by secondary stressors among which algal over growth and sedimentation were predominant. Algal over growth will lead the reef into algal dominant one affecting the services of the reef. The recovery of coral reefs from algal dominance was very rare and it may take even years²⁰. But *Acropora* species have been reported to recover rapidly from this type of algal dominance by the rapid

regeneration of affected coral tissues and faster calcification rates without any settlement of new coral colonies in Keppel islands, Great Barrier Reef⁷. Such recovery mechanisms were not known with the slow growing massive colonies like *Porites* species.

Deposition of sediment over the bleached corals and live corals will kill the coral polyps by smothering them²¹ and drove the growth of turf algae as a thin mat over the surface of corals and these algae will cover the corals completely due to its faster growth rate²². Though bleaching is a common phenomena occurring in hot seasons, the secondary stressors like algal overgrowth and sedimentation is a matter of much concern as they interfere with the coral recovery and results in the permanent loss of coral colonies. The permanent loss of corals may subsequently affect the biodiversity and thereby the functioning of the entire ecosystem.

The presence of dense mucus floc over the corals indicated the severe environmental stress such as sedimentation²³. When the sedimentation persists, it cuts off the light essential for the photosynthesis by their symbiotic partner and subsequently the corals starve for their energy, thereby leaving them under stress. This could also lead to bleaching. Sediment tolerant corals evolved mechanisms to wash their surface through mucus secretion and also by ciliary movements of the polyps²⁴. Both the mechanisms were energy consuming. During bleaching, corals starve for energy due to non availability of photosynthates from their symbionts as their symbiotic zooxanthellae were expelled. As a result, corals were unable to protect themselves from sedimentation. This eventually lead to the deposition of silt over the corals and serve as a substrate for the growth of algae. However there were no reports that sedimentation solely induced the bleaching event. In this case sedimentation could be considered as cofactor acting synergistically with solar radiation and SST causing the coral bleaching. It was also suspected that this sedimentation hopefully brought a load of nutrients resulting in eutrophication which will favor the algal growth¹². It is possible that the sediments may carry pathogens which hold the potential to cause coral diseases. Coral bleaching increased the susceptibility of the corals to the diseases²⁵ especially the warmer sea waters might favor pathogenic bacteria to triumph over the normal surface microbial community.

Coral reefs are the main source behind the livelihood of millions of people in and around the coral reef area. They either directly or indirectly

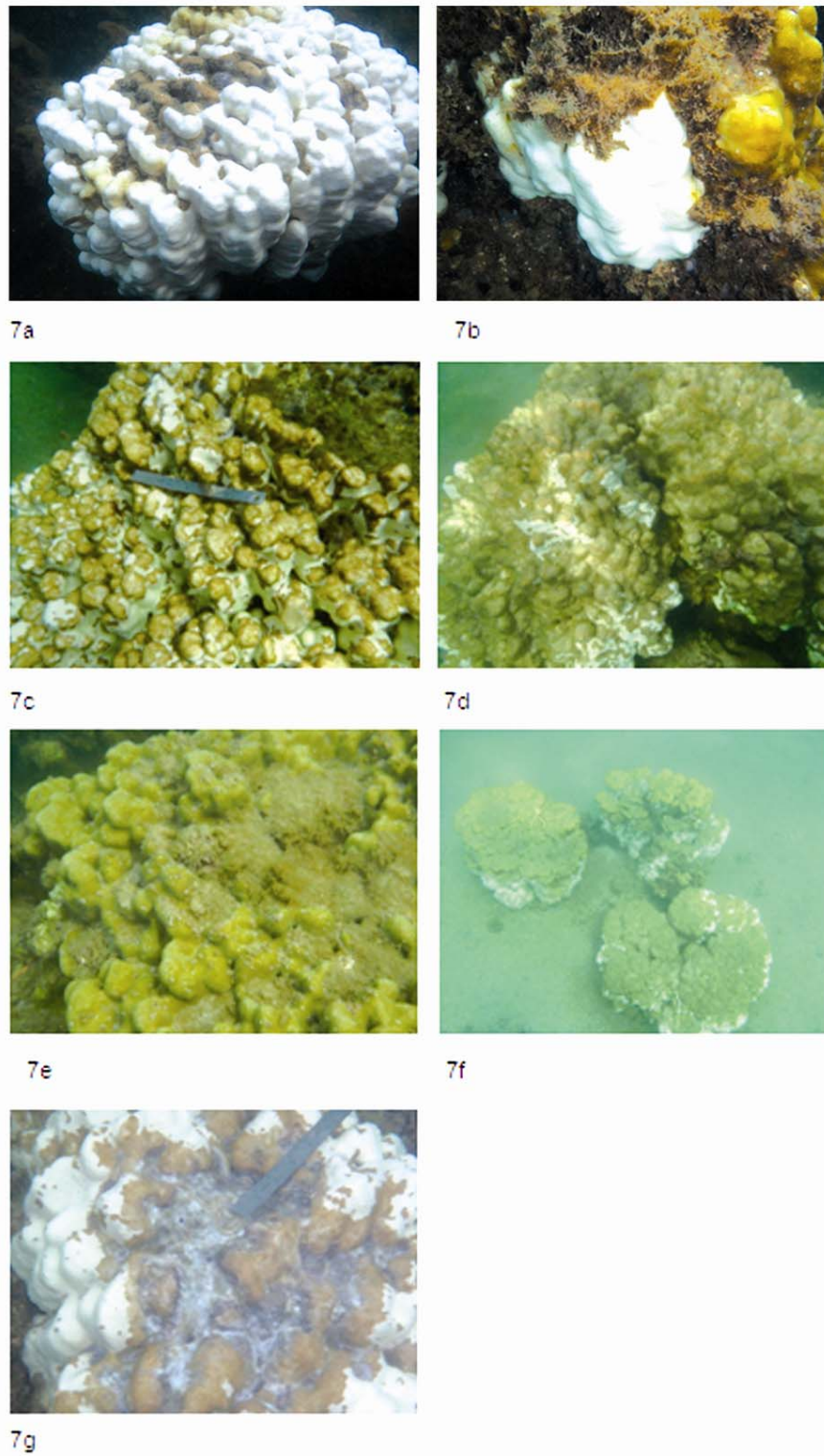


Figure 7 (a-g) —7a-Bleached *Porites* colony, 7b-Fleshy algae smothering and covering a bleached *Porites* colony, 7c-Filamentous algae overgrowing a bleached colony, 7d-turf algae grown as a thin mat over a bleached colony, 7e –silt deposition over a healthy *Porites* colony, 7f-deposition and algal overgrowth over a bleached *Porites* colony 7g-Mucus secretion by unbleached portion of a *Porites* colony- Indicator of stress.

depends upon the flora and fauna associated with the coral reefs. Coral reefs in the Palk Bay were extensively degraded in the past and it is being threatened by the local habitants and by the natural forces at present. One cannot protect corals from bleaching caused by increased SST, UV irradiance and elevated CO₂ level which are natural or due to long term human intervention with nature. However the reefs can recover if the other stressors such as nutrient influx and sedimentation were kept under control or minimal. It is difficult to estimate the duration of reef recovery because of the implications of other factors such as disease outbreak, algal competition, mass mortality of reef herbivores and human influences like over fishing, careless boating, mining, sedimentation etc. Added to this, is the bottom composition of Palk Bay, as major area of Palk Bay comprises a sandy bottom which do not support coral larval settlement and recruitment. The rate of sedimentation in Palk Bay is likely to be increased in the forthcoming years mainly due to developmental activities along the coast and river banks in the mainland. Destructive fishing practices like bottom trawling and use of purse seining still exists in Palk Bay which would continuously stir up the sediments from the bottom and allow them to settle on corals. Since the coral reefs are degraded at a rate faster than their growth, there is an immediate need to find out the solutions through alternate forms of fish harvest and production, effective management practices by the local body of government and habitat restoration practices. With this continuing trend of threats, coral mortality could exceed 95%³ regionally due to extinctions in the next few years leaving a big question mark behind the survival and livelihood of coastal population depending on the coral reef resources.

Conclusion

This studies clearly portrays the effects of increased SST and solar radiation over corals which are subsequently led down from recovery by their secondary stressors. Present study highlights the gradual rise in the SST and solar radiation in the earlier part of the year with grim consequences over corals. It is the chain of secondary stressors that sprayed their dominance over corals and critically triggered a fresh scientific care for corals apart from the existing laws. The effects of extreme environmental conditions are not restricted to corals, but to the entire ecosystem by means of affecting the nutrient recycling and productivity of that ecosystem.

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