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Elevated sea surface temperature during May 2010 induces mass bleaching of corals in the Andaman

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Increasing sea surface temperature (SST) and its consequences on marine ecosystems are widely discussed. Andaman Sea witnessed a few bleaching events during 1998, 2002 and 2005. The present study was taken up to assess the extent of bleaching during 2010 in selected reef sites in the Andaman through line intercept transect survey. It was found that the fully bleached corals as a percentage of total coral cover were maximum at Havelock Island (69.49), followed by South Button Island (67.28), Nicolson Island (56.45), Red Skin Island (43.39), North Bay (41.65) and Chidiyatapu (36.54). Branching corals were the worst affected, whereas the massive corals were found to have relatively withstood the elevated SST. The status of reefs and the variability in bleaching with the progression of SST with respect to different coral species are discussed.

Keywords: Bleaching, climate change, coral reefs, sea surface temperature.

THE Andaman and Nicobar (A&N) Islands are bestowed with the richest coral diversity among all Indian reefs. A total of 177 species of hard corals falling under 57 genera have been reported from these islands[1]. Recent surveys

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Table 1. Survey sites covered under the study

Study site	Latitude/longitude	Characteristics
Red Skin Island	11°32′23.27″N; 92°35′03.98″E	Within Mahatma Gandhi Marine National Park; open to tourists seasonally
North Bay	11°42′21.20″N; 92°45′15.20″E	Popular tourist site
Chidiyatapu	11°29′28.00″N; 92°42′40.00″E	Popular tourist site
Havelock–Aquarium	11°59′59.30″N; 92°55′38.00″E	Diving site
Havelock–Wall	12°03′26.60″N; 92°57′79.50″E	Popular diving site
South Button Island	12°13′42.20″N; 93°01′29.70″E	Protected island
Nicolson Island	12°04′52.00″N; 92°57′34.20″E	Protected island

Table 2. Biophysical status of reefs in the selected study sites (expressed as percentage)

Components of reef substrate	North Bay	Chidiyatapu	Red skin	Havelock–Aquarium	South Button	Havelock–Wall	Nicolson Island
Sand	10.32	42.36	54.09	14.17	0.00	0.00	0.00
Sand + dead corals	0.00	0.00	10.98	15.79	0.00	6.32	0.00
Dead corals	13.65	19.82	10.76	21.46	30.87	47.26	24.08
Dead corals + algae	0.00	0.00	1.48	0.00	0.00	0.00	0.00
Fully bleached corals	30.48	13.82	8.27	20.36	45.29	31.16	42.86
Partially bleached corals	41.59	22.91	8.72	19.11	12.12	13.68	24.39
Live corals (unbleached)	1.11	1.09	2.07	7.41	9.90	0.00	8.67
Soft corals (partially bleached)	2.86	0.00	3.16	1.01	1.83	1.58	0.00
Others (giant clam, anemone, etc.)	0.00	0.00	0.46	0.69	0.00	0.00	0.00
	100.00	100.00	100.00	100.00	100.00	100.00	100.00

have indicated that the numbers could be close to 80% of the global maximum[2]. Bleaching is one of the major threats which has significantly affected the reefs across the globe during different time-periods[3–6]. Corals have symbiotic association with zooxanthellae, the algae which are responsible for the colouration of the corals. Expulsion of the algae leads to the whitening of reef-building corals, widely referred to as bleaching. It is caused by physiological, algal, host-related stresses and various ecological and anthropogenic factors[7–9]. Sea surface temperature (SST) is a critical factor for the wellbeing of symbiotic association of host animals like corals, giant clam and sea anemones with the microalgae.

Surveys conducted in the reefs of the Andaman reveal that the corals have been extensively bleached during April and May 2010 ranging from 37% to 70% in various sites. Similar bleaching events were reported in 1998 and 2002 in this region[10–12]. However, the extent of the current bleaching surpasses the earlier observations.

The sites in the Andaman, which were surveyed under this pilot study during January–June 2010 are listed in Table 1. Three 100 m transects were laid for surveys on the bottom topography, live coral cover and extent of bleaching (full/partial)[13]. The atmospheric temperature and SST were measured *in situ* using a mercury bulb thermometer. Time-series data of air temperature of Andaman were obtained from the Automatic Weather Station with SD Data Logger (iMETOS, Australia), installed at Bloomsdale, South Andaman (11°38′50″N; 92°39′13″E). For the satellite-derived SST data, MODIS Global Level 3 Mapped Thermal IR daytime SST from Aqua and Terra sensors, available at the Physical Oceanography Distributed Active Archive Center (PODAAC) site of NASA was used[14]. Maps with 4.63 km spatial resolution covering the area surrounding the A&N Islands were analysed. Daily SST maps for the period 20 April to 12 May 2010 were analysed to see the change in SST during the period when bleaching was observed. Eight-day averaged SST maps from 4 April to 12 May of 2002 and 2005 were also studied. SST maps from the NASA JPL–PODAAC site available in HDF format were read using the software binary codes provided with the data and converted to tiff image format. Further processing was done using ERDAS–IMAGINE and ARC–GIS software for display and analysis of the maps. SST in the vicinity of the selected coral bleaching sites was noted for the period during which bleaching was observed.

The reef substratum in the selected sites was studied (Table 2) and the extent of live coral cover as a percentage of different components of reef substrates, excluding sand was found to be the highest in North Bay (81.60), followed by the Nicolson Island (75.92), South Button Island (67.31), Chidiyatapu (65.61) and Havelock Island (Wall and Aquarium; 45.80). The live corals as estimated here included both bleached and unbleached ones. Among the selected sites, the percentage cover of reef associates and soft corals was the highest in the transects laid in Red Skin island (7.89).

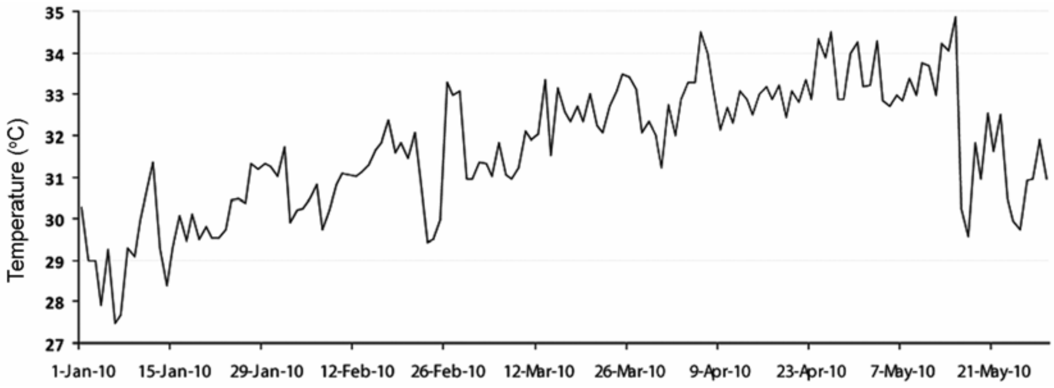

Figure 1. Temporal variation in maximum air temperature in Andaman.

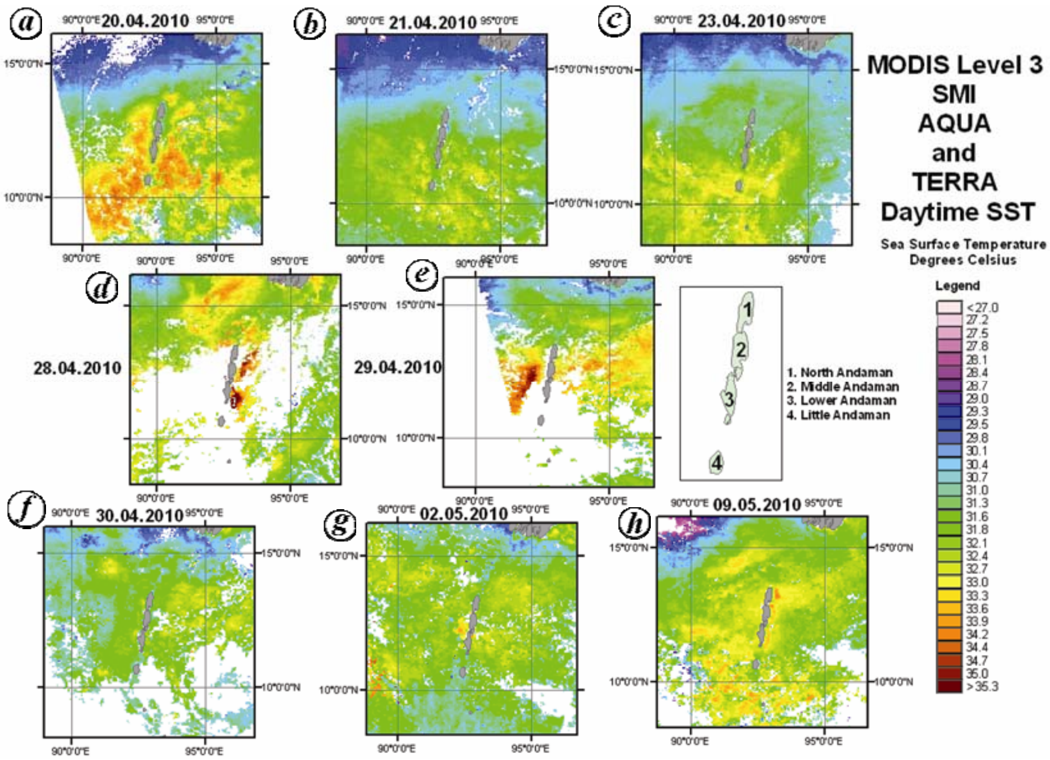

Figure 2. Modis Level 3 SMI Aqua and Terra daytime sea surface temperature (SST) showing gradual increase from 20 April to 9 May 2010.

The bleaching of corals started in the first week of May 2010. The preceding month was characterized by hot and humid climate during which the maximum atmospheric and SST recorded were 34°C and 31°C respectively. During summer, SST rise of 2–3°C above the normal maximum can kill the corals[15]. Corals can also live in hotter parts where the summer temperature reaches 31°C (ref. 16). The average sea-water temperature during the first week of May in all the study sites was 33.8 ± 0.6°C, which resulted in extensive bleaching in different parts of the islands. The atmospheric temperature showed a sudden increase in air temperature in the first, third and fourth weeks of April (Figure 1). The air temperature remained high in the study sites up to the first week of May, with corresponding increase in SST. Subsequently, the temperature dropped to approximately 30°C, due to rains.

The MODIS-derived SST maps for selected time-periods for the areas surrounding A&N Islands (Figure 2) showed consistently high temperatures in the range 31–32°C during the last two weeks of April 2010 in the sites, except in Chidiyatapu, where it ranged from 32.1°C to 33.3°C. The temperature was seen to have increased during the first week of May to around 33°C until the second week of May and dropped with the onset of monsoon in the second–third weeks of May. As the A&N Islands are

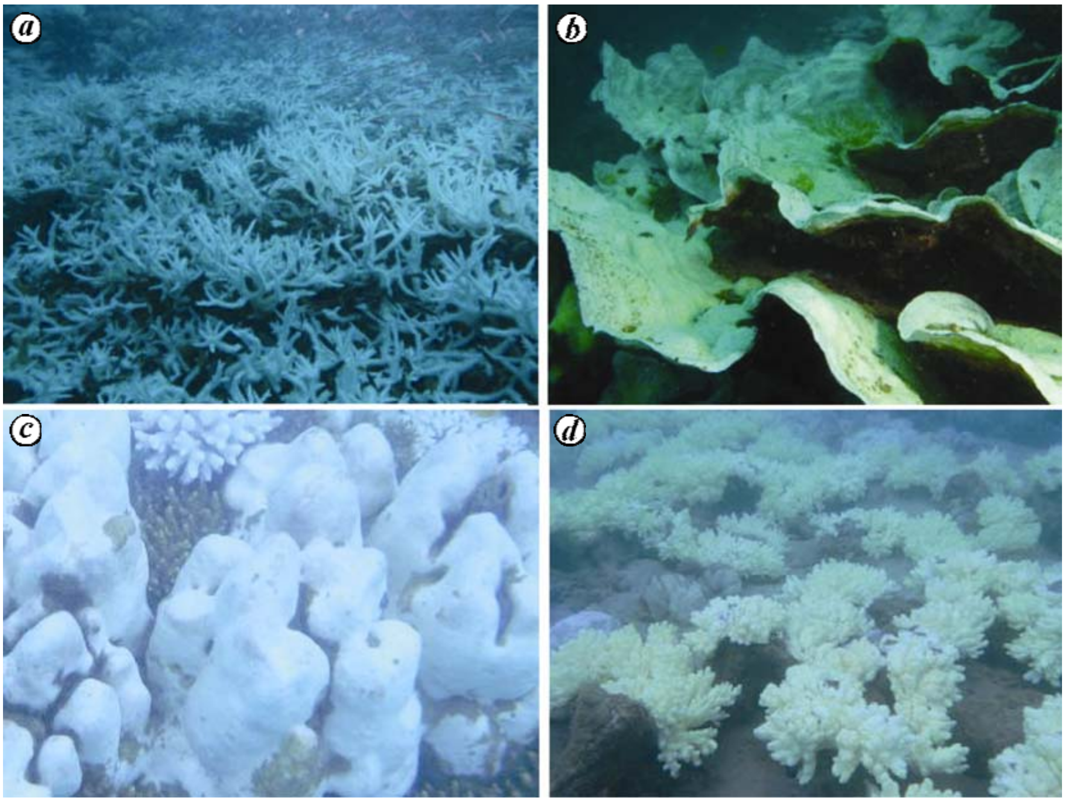

Figure 3. Bleached corals as observed during May 2010. ***a***, Branching coral (*Acropora* spp.); ***b***, Plate coral (*Echinopora lamellosa*); ***c***, Massive coral (*Porites solida*) and ***d***, Parially bleached soft corals (*Sinularis* sp.).

covered with clouds during most of the year, it is difficult to obtain continuous and cloud-free SST imagery. The average SST in the similar period during 2002 and 2005, when varying degrees (20–40%) of bleaching were observed in the Andaman[10,11], was 32.5 ± 0.6°C and 30.8 ± 0.5°C respectively. Eight-day SST data of 2002, when higher incidence of coral bleaching was recorded at these sites, showed that the temperature ranged from 31.6°C to 32.2°C in the last three weeks of April and moderated to 31.3°C–31.9°C during the first week of May 2002. The SST at Chidiyatapu, however, showed higher values in the range 32.2–32.7°C during April 2002. The weekly SST for the last three weeks of April 2005 ranged between 30.8°C and 32.2°C, and it decreased to 29.8–31.1°C during the first week of May 2005. These observations clearly indicate the development of relatively warm water masses near and around the islands during the last three weeks of April almost every year. Vivekanandan *et al.*[17] observed that bleaching occurred when the summer SST maxima exceeded 31°C and remained high for over three days. The current bleaching event, considered to be the worst since 1998, can be attributed to the prolonged higher SST (> 31°C) in the region during April–May. It is predicted that the annual average SST would increase in all the regions in the Indian seas by 3–3.5°C during 2000–99, and in Andaman region, if the summer temperature exceeded 31.4°C for over a few weeks, then bleaching would occur[17].

It was observed that the branching corals (*Acropora* spp.) were the worst affected due to bleaching. The predominant species were *Acropora formosa*, *Acropora nobilis*, *Acropora robusta*, *Acropora breuggemanni* and *Acropora grandis*. In South Button, vast beds of *Acropora* spp. recorded almost 100% bleaching. In one of the dive spots in Havelock (Wall), the encrusting corals, *Diplostrea heliopora* were extensively bleached, whereas the plate corals, *Echinopora lamellosa* were the predominant fully bleached coral species in North Bay. Even massive corals (*Porites* sp.) were found to have fully bleached in some of the study sites, though the overall extent of bleaching was less compared to fragile branching corals. The variability in the impact of corals with respect to thermal stress has been already reported[18–20]. It is important to note that while corals can survive acute short-term exposures over a few hours[7,21], there are no examples of coral species or genotypes that can survive chronic exposures to 3–6°C increase above the summer sea temperature for more than a month at a particular site[22,23]. Hoegh-Guldberg *et al.*[24] observed that there could be variation in the onset of bleaching between species, but no species is adapted to sustain even a marginal increase in SST for a prolonged exposure. Mass bleaching of soft corals has been reported in Australia[6] and Thailand[25]. However, in

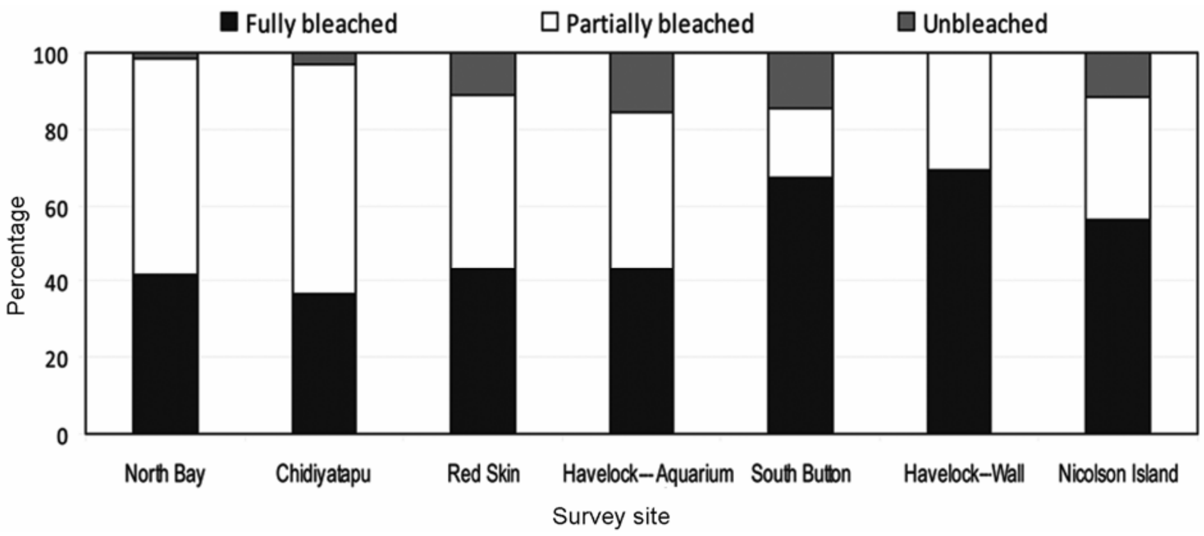

Figure 4. Status of actual coral cover in Andaman and extent of bleaching.

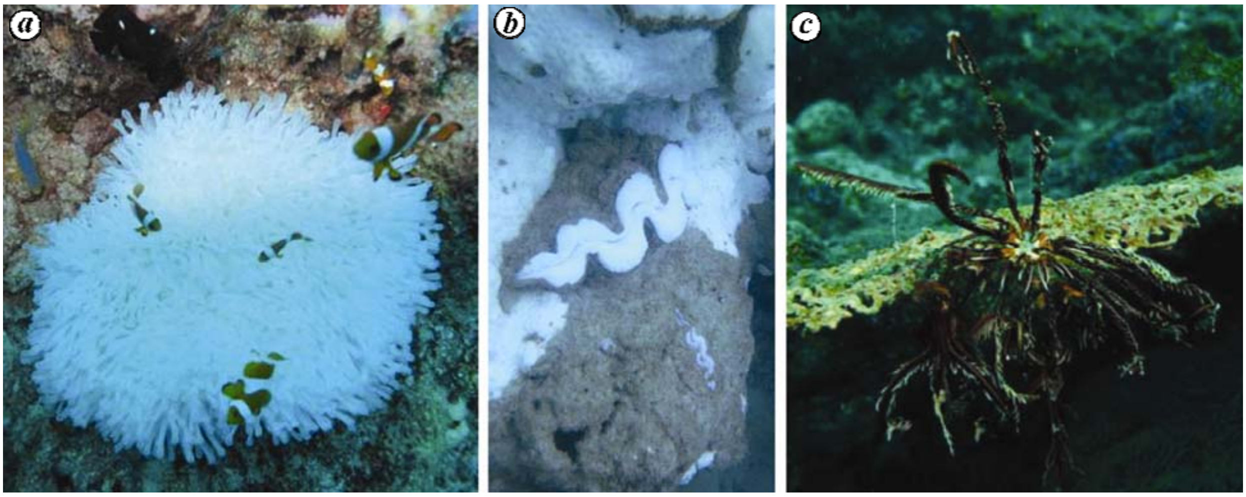

Figure 5. Reef associates affected by elevated SST during May 2010. ***a***, Bleached sea anemone (*Heteractis magnifica*); ***b***, Bleached giant clam (*Tridacna* sp.) and ***c***, Withering brittle stars.

all the survey sites in the Andaman, soft corals belonging to *Sarcophyton* sp. and *Sinularia* sp. had been only partially bleached. The different types of corals bleached due to elevated SST are shown in Figure 3.

The coral cover estimated at the different study sites was analysed separately to determine the extent of bleaching. It was found that the fully bleached corals as a percentage of total estimated coral cover (unbleached, partially bleached and fully bleached) were maximum at Havelock Island (Wall; 69.49), followed by South Button Island (67.28), Nicolson Island (56.45), Havelock Island (43.45), Red Skin Island (43.39), North Bay (41.65) and Chidiyatapu (36.54). The percentage of normal corals (unaffected by the elevated SST) was maximum at the diving sites studied in Havelock Island (15.80), followed by South Button Island (14.71) and Red Skin Island (10.86, Figure 4). The bleaching was not confined to the reef-building corals, but also observed among some of the reef communities like sea anemone and giant clam, which are also known to have symbiotic association with the zooxanthellae. The brittle stars in South Button Island were apparently in stress on the first day of observation of bleaching, but started withering their arms as the period of elevated SST prolonged and the extent of bleaching in corals progressed (Figure 5).

The fact that even 1–2°C increase in temperature results in widespread bleaching implied that most corals live close to their thermal limits[26]. However, it was observed that there was variation in the bleaching pattern between the species and within the same species in different locations, which could be attributed to the higher thermal thresholds of certain species owing to their exposure to high temperature in their sub-habitats (e.g. warm tidal pools)[27]. In the current study no variation in the

Figure 6. Corals in South Button Island showing filamentous algal growth over the fully bleached corals (August 2010).

coral-associated fishes could be found at the study sites following bleaching, as reported earlier[16]. The variation in the susceptibility of different coral species to elevated temperature would mean that climate change would result in different yet less diverse reef communities in the short term[24,26].

Bleaching and subsequent growth of new coral species is part of the natural selection process[16]. Indian coral reefs have experienced 29 widespread bleaching events since 1989 (www.reefbase.org), but intense bleaching occurred in 1998 and 2002 (refs 16, 28). The corals which were affected to the extent of 60–70% during the earlier events of bleaching recovered, but those fully bleached died. Subsequent surveys in August indicated that algae have deposited over the fully bleached corals (Figure 6). It is only hoped that the affected corals in the current bleaching event in the Andaman would recover to their original status, given the prevailing favourable environment, following the onset of monsoon. However, the frequency of bleaching events is set to increase[17] owing to the global trends in the atmospheric and SST. Hence systematic studies on the status of the affected reefs in the Andaman would provide valuable clues on possible alteration in the thermal tolerance of corals in the region.

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