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Coral Reef Recovery Status in South Andaman Islands after the Bleaching Event 2010

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Abstract The Andaman and Nicobar Islands are one of the Union Territories of India, located in the eastern part of the Bay of Bengal. In 2010 summer, the increment in sea surface water temperature (up to 34℃) resulted in the bleaching of about 74% to 77% of corals in the South Andaman. During this event, coral species such as *Acropora cerealis*, *A. humilis*, *Montipora* sp., *Favia pallida*, *Diploastrea* sp., *Goniopora* sp. *Fungia concinna*, *Gardineroseries* sp., *Porites* sp., *Favites abdita* and *Lobophyllia robusta* were severely affected. This study is to assess the recovery status of the reef ecosystem by estimating the percentage of Live Coral cover, Bleached coral cover, Dead coral with algae, Rubble, Sandy flat, Algal assemblage and other associated organisms. The sedimentation rate (mg cm^{-2} d^{-1}) and coral coverage (%) were assessed during this study period. The average sedimentation rate was ranged between 0.27 and 0.89 mg cm^{-2} d^{-1}. The observed post bleaching recovery of coral cover was 21.1% at Port Blair Bay and 13.29% at Havelock Island. The mortality rate of coral cover due to this bleaching was estimated as 2.05% at Port Blair Bay and 9.82% at Havelock Island. Once the sea water temperature resumed back to the normal condition, most of the corals were found recovered.

Key words coral reef; coral recovery; coral bleaching; sea surface temperature

1 Introduction

The Andaman and Nicobar (A and N) Islands in the eastern part of Bay of Bengal are heavily inhabited by corals. The coral reef ecosystem of the islands is endowed with fringing reefs where pristine and diverse organisms can be found. It consists of a chain of 572 islands stretching from Myanmar (Burma) in the North to Sumatra in the South (6˚–14˚N and 92˚–94˚E). The islands are one of the major coral reef ecosystems; it contains about 12000 km^2 of reef lagoons, coral banks, reef slopes and reef flat areas (Turner *et al*., 2001). The North and South Andaman are dominated by *Porites* sp., while the Middle Andaman and Nicobar are dominated by *Acropora* sp. A total of 203 coral species are identified in the Islands (Turner *et al*., 2001).

Global warming caused by greenhouse gases has elevated both sea surface temperature (SST) and UV-B radiation. Marine biological communities most seriously affected by these changes are those near shoreline, on or close to sea surface (Wafar, 1990). The most historically extreme El Niño Southern Oscillation (ENSO) event elevated SST of tropical oceans by more than 3℃. In India, the 1998 bleaching related mortality of organisms reached as high as 26% in Lakshadweep, 23% in Gulf of Mannar (Arthur, 2000) and 83% in Andaman Islands (Ravindran *et al*., 1999). In 2010, 73% of the total corals in Lakshadweep Island bleached (Vinoth *et al*., 2012).

The major objective of this study is to describe the recovery status of South Andaman reef ecosystem and to assess the stress induced by sedimentation.

2 Materials and Methods

The sessile benthic community of corals was estimated with line intercept transect (LIT) method (English *et al*., 1997). Twelve sites were chosen, of them 9 located in the Port Blair Zone namely North Bay (4), Ross Island (3) and Chidiyatappu (2) and 3 located in the Havelock Island Zone. These sites represented the reef flat and reef slope (Fig.1), which were marked with GARMIN e-Trex handheld GPS device for further monitoring. A 20-meters long flexible underwater tape was laid on the reefs roughly parallel to the shore with five replicates at each site (Fig.2A). The bleaching and post bleaching LIT data were collected in July 2010 and January 2011, respectively. The benthos coming under the transition points were recorded using international codes. The status of

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benthic forms during bleaching event and its corresponding recovery period (up to May 2011) were photographed using SONY DSC P100 equipped with underwater housing.

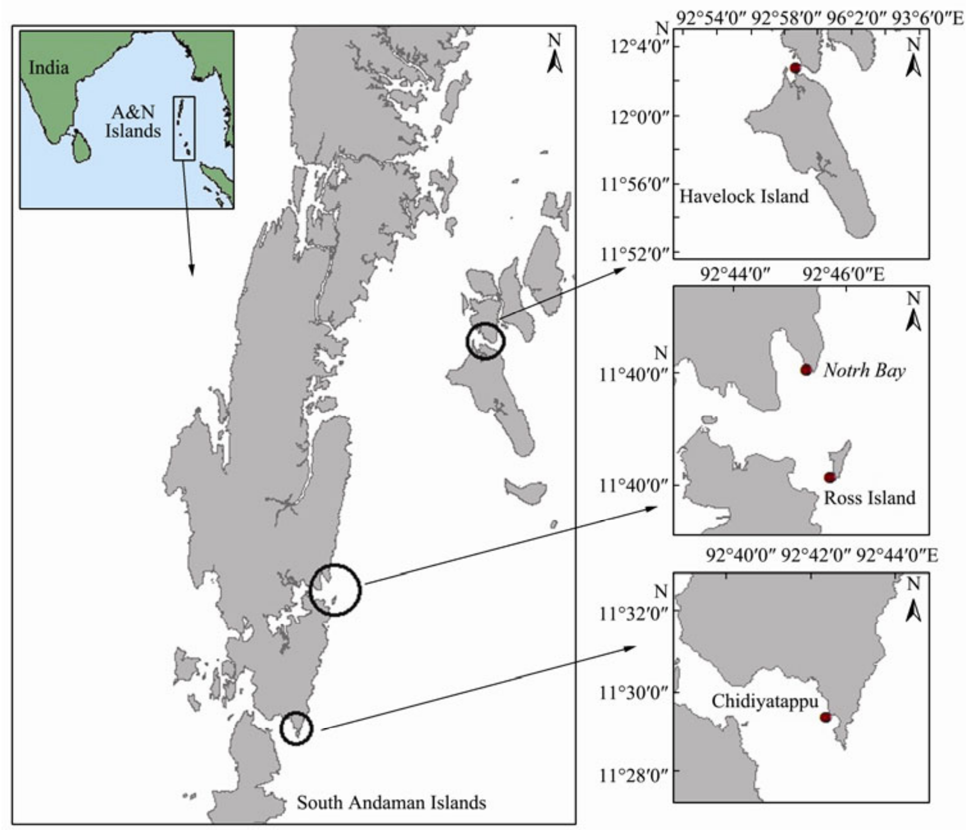

Fig.1 Study sites at South Andaman Islands.

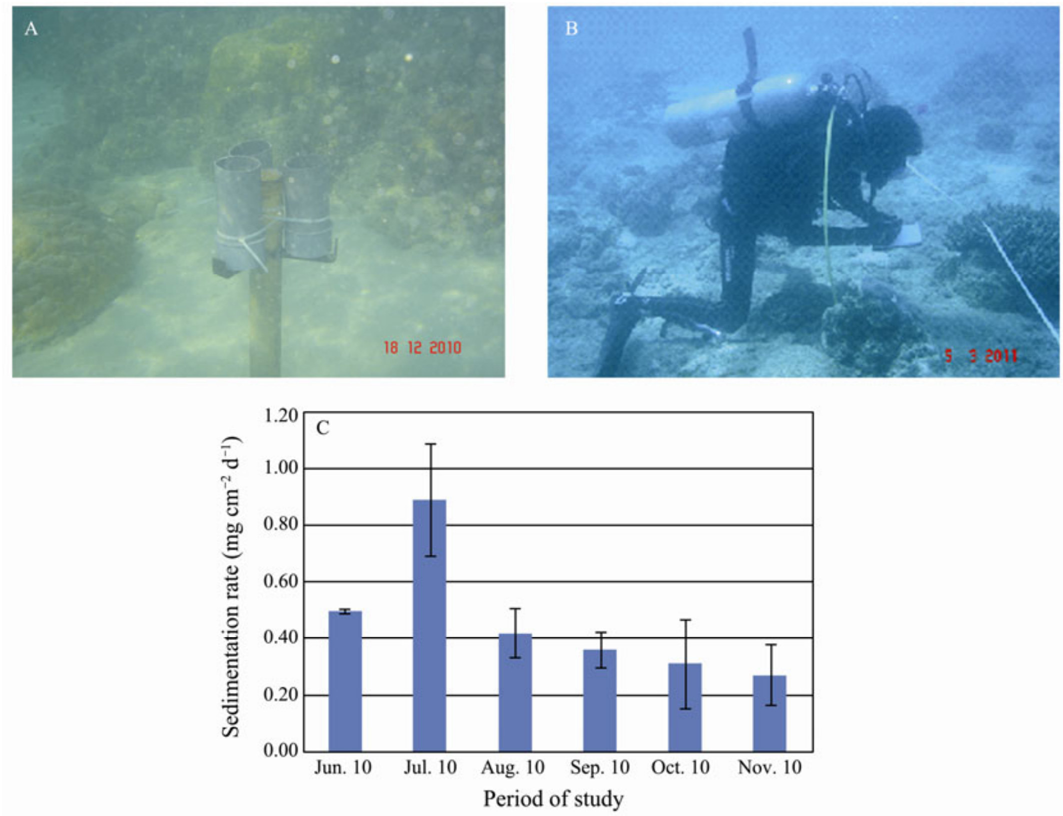

Fig.2 Sediment trap model and line intercept transect method as described earlier (English *et al*., 1997) and sedimentation rate. A, Erected sediment trap in the coral reef environment of Port Blair Bay; B, Line intercept transect for biophysical status analysis; C, Sedimentation rate of Port Blair Bays ($n=3$) recorded during the bleaching event of 2010.

The raw data collected were sorted and assessed using AIMS Reef Monitoring Data Entry System (ARMDES V1.6 Data Entry Program–Long term reef monitoring project, Australian Institute of Marine Sciences). The percentage cover was calculated for different life-forms in the reef ecosystem. The cumulative percentage of hard coral cover, algae and abiotic forms were also estimated using this package.

Sediment traps were custom-devised with the method described earlier (English *et al.*, 1997), each contains 3 plastic containers that can measure 11.5 cm in height. Three sediment traps were placed in Port Blair Bay Zone to assess the sedimentation rate (Fig.2B). The accumulated sediments were analyzed monthly and expressed as sedimentation rate ($\mathrm{mg\,cm^{-2}\,d^{-1}}$).

3 Results and Discussion

During the bleaching event of 2010, SST rose from 30.5℃ to 34℃ (April to May 2010) within the bays of Port Blair. The SST data (NOAA, 2011) of National Environmental Satellite, Data, and Information Service (NESDIS) showed 1–2℃ increase above the normal at Andaman and Nicobar Islands from 1st April to 24th May, 2010. During this period, coral species such as *Acropora cerealis*, *A. humilis*, *Montipora* sp., *Favia pallida*, *Diploastrea* sp., *Goniopora* sp. *Fungia concinna*, *Gardineroseries* sp., *Porites* sp., *Favites abdita* and *Lobophyllia*

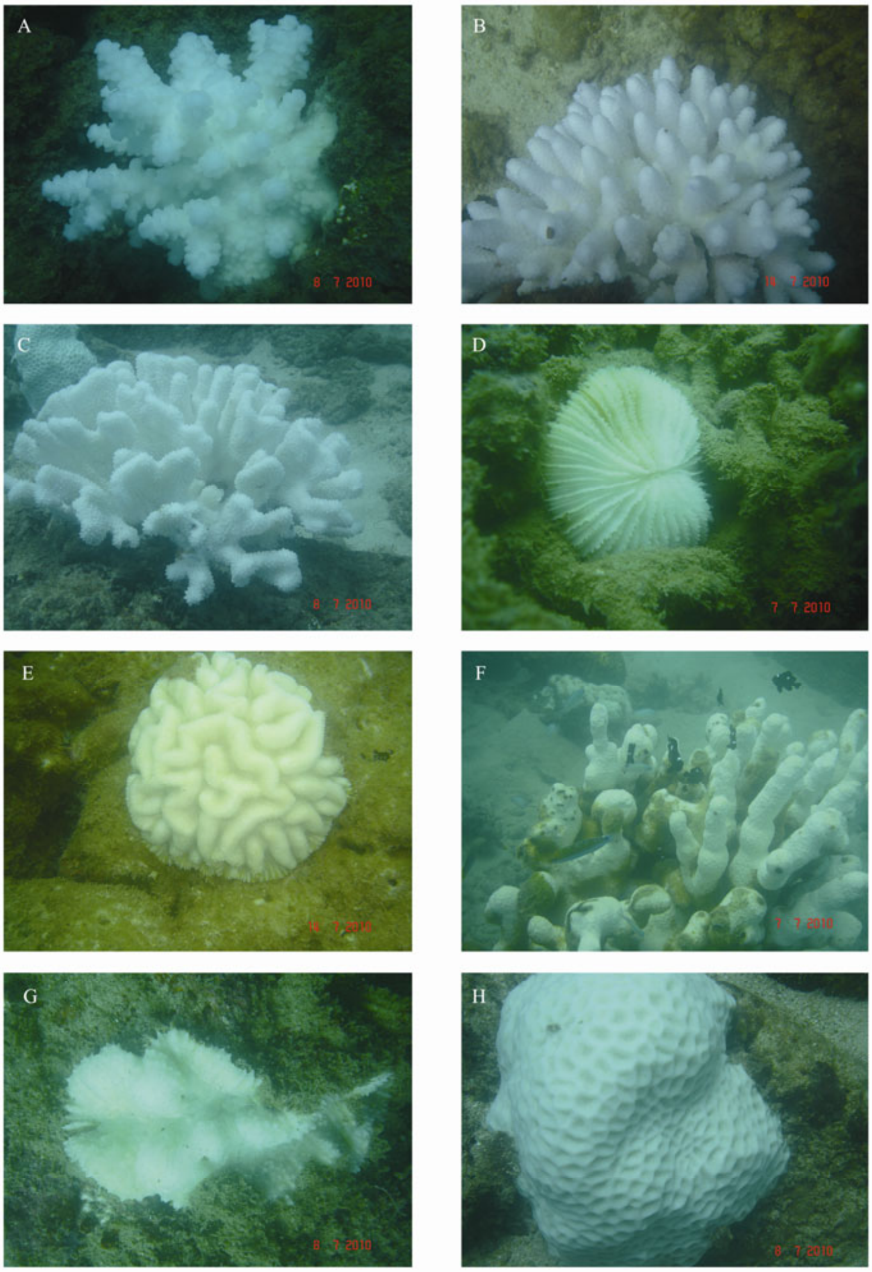

Fig.3 Bleached coral colonies recorded at Port Blair Bay and Havelock Island in July 2010. A, *Acropora cerealis* Dana 1846; B, *Acropora humilis* Dana 1846; C, *Pocillopora eydouxi* Edwards and Haime 1860; D, *Fungia danai* Edwards and Haime 1851; E, *Symphyllia* sp.; F, *Porites harrisoni* Veron 2000; G, *Oxypora crassisphosa* Nemenzo 1979; H, *Gardineroseries* sp.

robusta were severely affected (Fig.3). This catastrophic bleaching and high SST were also reported in the nearby countries like Indonesia (Sukresno, 2010) and Thailand (Klinthong and Yeemin, 2011; Cook, 2010).

Sedimentation rate of Port Blair Bay is monitored at a monthly interval for another ongoing study. The sedimentation rate observed in this ongoing study was purposely correlated with that observed in present study in order to assess the impact of siltation during the recovery process if any (Fig.2C). In this study, the minimum sedimentation (0.27 $mg\,cm^{-2}\,d^{-1}$) was observed in November 2010, and the maximum (0.89 $mg\,cm^{-2}\,d^{-1}$) was observed in July 2010. The onset of south-west monsoon (highest rain fall of 600.2 mm) in July 2010 and resulting land runoff might be responsible for the highest sedimentation rate in the period (IMD, 2010). In contrast, the lowest rate was observed during the post-monsoon period (October to November 2010).

About 77% of corals were bleached during July 2010 in Port Blair Bay and 21.1% of the corals were found recovered during January 2011 (Fig.4). Similarly, in Havelock Island, about 74% of corals were bleached during July 2010 and 13.29% of the corals were found recovered (Fig.4). In Port Blair Bay, dead coral with algae (DCA) and rubble cover increased up to 2.00% and 2.45%, respectively (Fig.4); whereas in Havelock Island the DCA and rubble cover were found increased up to 9.82% and 2.05%, respectively.

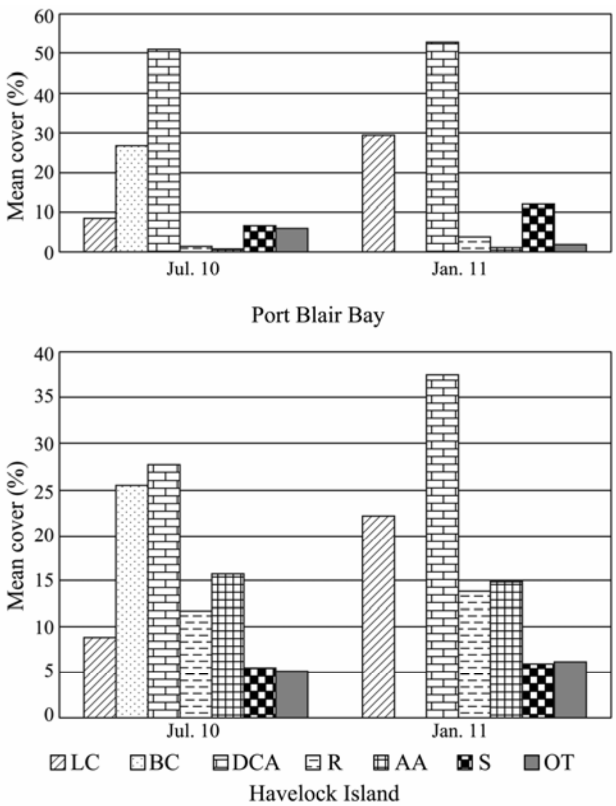

Fig.4 Comparison of bio-physical status of life-form categories between bleaching event of 2010 and post-bleaching time. LC, live coral; BC, bleached coral; DCA, dead coral with algae; R, rubble; AA, algal assemblage; S, sand; OT, Others.

During the recovery period, new recruitment and rejuvenation were observed in common. Fig.5 shows the comparative bleaching and post bleaching status of *Porites harrisoni*. Extended polyps were observed at all sites (Fig.6). The recovery of coral was instantaneous in the massive forms of all sites (Fig.6) including *Diploastrea heliopora*, *Goniopora somaliensis*, *G. minor*, *Porites harrisoni*, *Lobophyllia hemprichii*, *L. corymbosa*, *Symphyllia radians*, *S. recta*, *S. erythraea*, *Platygyra sinensis*, *P. verweyi*, *Diploria strigosa*, *Pavona decussate*, *Lithophyllon undulatum*, *Physogyra lichtensteini*, *Favites pentagona*, *Galaxea fascicularis* and *Goniastrea edwardsi*. On the other hand, the branching forms like *Acropora aspera*, *A. cerealis* and *A. humilis* were severely damaged due to the bleaching impact.

Moreover, the elevated SST of the study sites might be due to delayed onset of southwest monsoon resulting in the prolonged summer period (IMD, 2010). This unusual SST observed in the summer 2010 was reported in combination with El Niño followed by La Nina (Eakin, 2010). There were three bleaching events reported (Kri- shnan *et al.*, 2011) at A and N Islands in the years 1998, 2002 and 2005 prior to current bleaching event. Similarly, the impact of 2002 bleaching and recovery of corals in the Palk Bay region was reported and its recovery was estimated as 57% within a three months period (Kumaraguru *et al.*, 2003). Winter *et al.* (1998) compared 30 years records of SST with coral bleaching and accepted the intra- annual

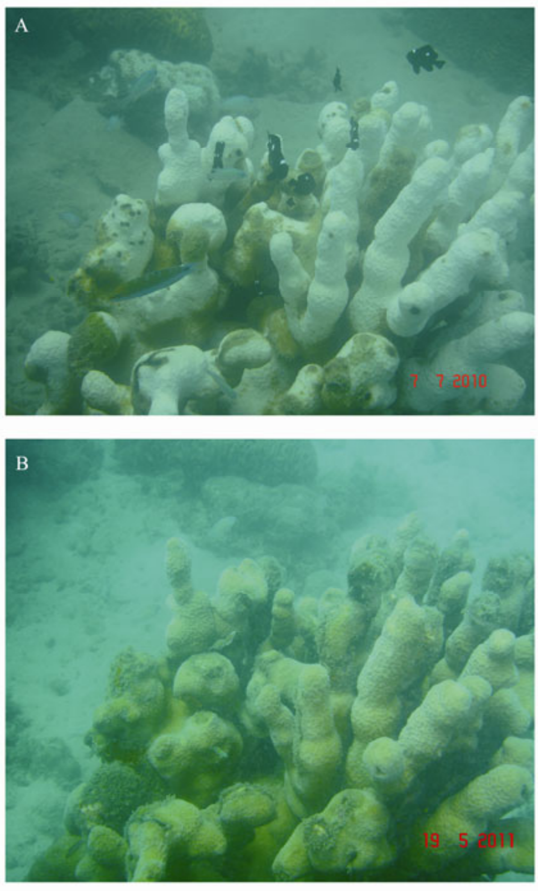

Fig.5 A, *Porites harrisoni* Veron 2000 during bleaching (July 2010); B, Same coral observed post-bleaching (May 2011).

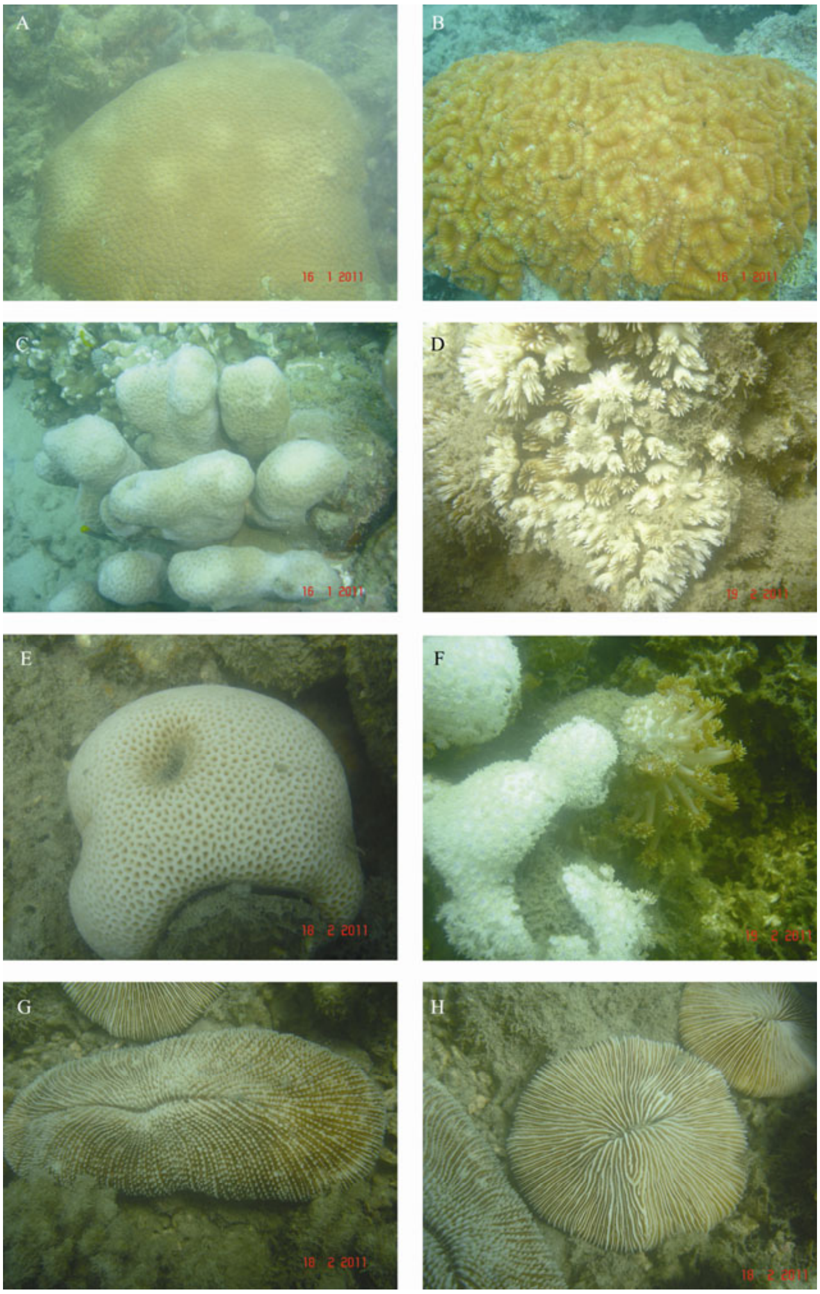

Fig.6 Recovered and partially recovered coral fauna observed during post-bleaching period. A, *Diploastrea heliopora* Lamarck 1816; B, *Lobophyllia hemprichii* Ehrenberg 1834; C, *Pavona clavus* Dana1846; D, *Galaxea fascicularis* Linnaeus, 1767; E, *Goniastrea retiformis*; F, *Goniopora* sp. G, *Ctenactis echinata* Pallas 1766; H, *Fungia* sp.

relationship between temperature and the incidence of bleaching.

Sedimentation rate is one of the factors which influence the coral bleaching and its simultaneous degradation. In Indian coastal region, numerous reports emerged on the impacts of sedimentation rate on coral reef ecosystem (Suresh, 1991; Wilson *et al*., 2005; Marimuthu *et al*., 2010). A comparative study indicated that the highest sedimentation rate observed in the Port Blair Bay was thirty four times less than that of the Gulf of Mannar region (30 mg cm^{-2} d^{-1}) (Marimuthu *et al*., 2010), and forty seven times less than that of the Palk Bay region (42 mg cm^{-2} d^{-1}) (Wilson *et al*., 2005). Similarly, the minimum sedimentation rate was observed seven times less than that of the Gulf of Mannar (2 mg cm^{-2} d^{-1}) and three times less than that of the Palk Bay (1 mg cm^{-2} d^{-1}). Hence, the sedimentation rate observed in the Port Blair Bay was very minimal compared with the other Indian coastal regions such as Gulf of Mannar and Palk Bay. Thus the sedimentation rate observed in present study was insignificant.

Expulsion of associated zooxanthellae due to stress is known as bleaching. This expulsion may be of many reasons (Celliers and Schleyer, 2002; Kumaraguru *et al*., 2003), and the majority of researchers denoted that the increase in SST will lead to the bleaching of corals (Baird and Marshall, 1998; Arthur, 2000; Kumaraguru, 2000; Kumaraguru *et al*., 2003). Bleached corals require suitable environment with appropriate light condition and less sedimentation to recover (Pearson, 1981; Marimuthu *et al*., 2011). The mean SST observed during the recovery study period (December 2010 to January 2011) was about 29.5℃ and the transparency recorded ranged from 8 to 10 m. NESDIS have shown that the SST was 1℃ lower than that of the normal during Dec. 2010 at South Andaman Islands (NOAA, 2011). Hence all these conditions were helpful for the recovery of the bleached species except *Acropora* sp. which was more vulnerable to natural impacts like El Niño and La Niña.

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