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9B Coral communities in extreme environments

Effects of coral bleaching and recovery potential of coral reefs at Mu Koh Surin, the Andaman Sea

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Abstract. Elevated seawater temperatures in summer months of 2010 were associated with widespread coral bleaching in the Andaman Sea. The present study examines the impact of coral bleaching and recovery potential of coral reefs at Mu Koh Surin National Park, Thailand. The percentages of dead corals following the bleaching event for all ten study sites were over 50%. The highest percentage of coral mortality was at Hin Pae (71.3%) while the lowest one was at Ao Tao (53.9%). Most *Acropora* and *Pocillopora* colonies were affected at all sites and their mortality rates were very high (>90%). Spatial variation in coral bleaching and subsequent mortality was clearly observed with reflecting differences in depth, reef profile and water flow. The densities of coral juveniles were relatively high (6.1-11.0 juveniles.m^{-2}). The major groups of coral juveniles were also high taxonomic diversity, including *Acropora* spp., *Fungia* spp., *Favia* spp., *Favites* spp., *Goniastrea* spp. *Platygyra* spp. *Diploastrea heliopora*, *Cyphastrea* spp., *Porites* spp., *Coeloseris mayeri*, *Gardineroseris planulata*, *Pachyseris* spp., *Ctenactis* spp. *Lithophyllon* sp., *Pectinia* sp., *Turbinaria* spp., *Astreopora* sp., *Montipora* spp., *Pocillopora* spp. and *Galaxea* spp. Certain coral communities at Mu Koh Surin exhibit recovery potential after the coral bleaching event therefore the tourism management plan for protection of these coral communities is urgently needed in order to ensure the sources of coral larvae for coral recovery in the Andaman Sea.

Key words: coral bleaching, mortality, recovery, Mu Koh Surin, Andaman Sea.

Introduction

Seawater temperatures are predicted to increase because of an impact of climate change, potentially causing more frequent and severe mass coral bleaching phenomena (Hoegh-Guldberg 1999; Burke et al. 2011). Obvious changes in coral community structure are documented at many locations. Patterns of susceptibility of different corals to bleaching have been documented from various studies. They vary within and among regions as well as within and among coral reefs (Hoeksema 1991; Loya et al. 2001; McClanahan et al. 2004; Yeemin et al. 2010). The difference in susceptibilities of the different coral taxa results in changing of their relatively abundance following a mass bleaching event, or replacing high susceptible and abundant corals by other benthic organisms, such as macroalgae, sponges and sea anemones (Chen and Dai 2004; McClanahan et al. 2007; Hughes et al. 2007; Baker et al. 2008).

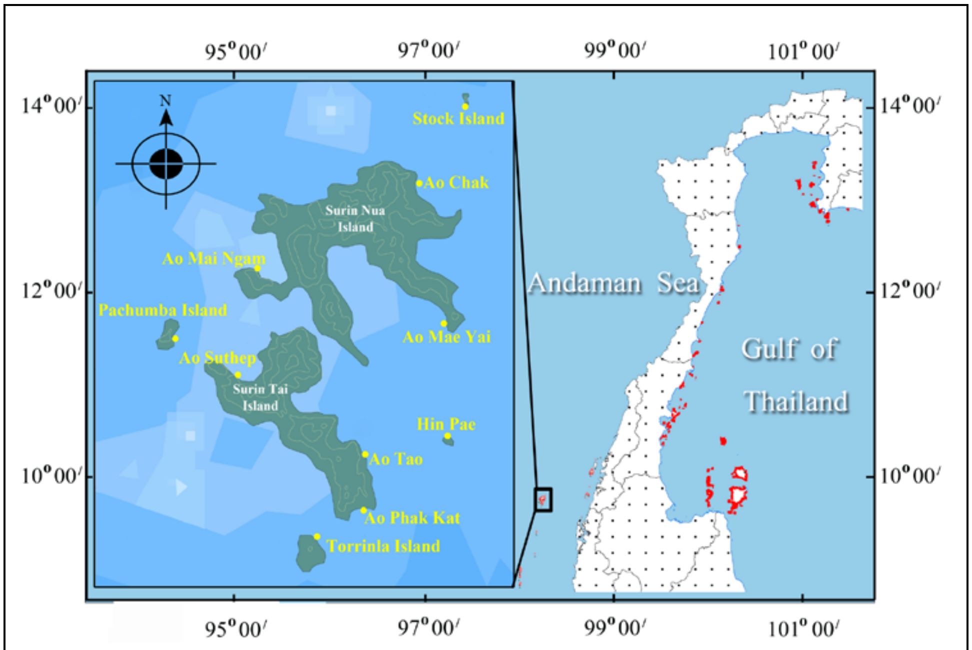
Understanding of survival of juvenile coral colonies would improve the ability to predict the potential for coral recovery from the impacts of coral bleaching events as well as interpretation of spatio-temporal variability in coral community structure (Connell et al. 1997; Knowlton 2001). Previous studies showed that coral recovery from mass coral bleaching events is influenced by several environmental factors, such as larval supply from healthy reefs and additional stresses (Brown and Suharsono 1990; Obura 2005; Wooldridge 2009; Yeemin et al. 2009).

Elevated seawater temperatures in summer months of 2010 were associated with widespread coral bleaching in the Andaman Sea, especially Mu Koh Surin, Mu Koh Similan and almost islands in Trang Province, Thailand. The present study examines the impact of coral bleaching and recovery potential of coral reefs at Mu Koh Surin National Park, Thailand.

Material and Methods

Mu Koh Surin, one of popular diving sites in the world, located at the upper Andaman Sea (in Phangnga Province), about 60 km from the shoreline. It consists of many granitic islands and two exposed pinnacles. Ten study sites were set up for a long-term monitoring program (Fig. 1).

Permanent belt transects, 100x1 m^2 were used to quantify and assess the extent of coral mortality following the bleaching event in March 2011, at all study sites. All large coral colonies (>5 cm diameter) within the belt transects were identified to species, counted, and their conditions recorded to calculate the percent of coral mortality. The number of visible juvenile coral colonies (≤5 cm diameter) were also identified to genus and measured in the belt transects.



Stock Island	N 9° 28' 44.26" E 97° 54' 10.87"	Ao Chak	N 9° 27' 17.65" E 97° 53' 50.53"
Ao Mai Ngam	N 9° 26' 48.30" E 97° 51' 4.56"	Ao Mae Yai	N 9° 25' 27.55" E 97° 53' 50.80"
Ao Suthep	N 9° 24' 58.46" E 97° 50' 46.70"	Pachumba Island	N 9° 24' 31.41" E 97° 50' 2.09"
Hin Pae	N 9° 23' 45.37" E 97° 53' 44.65"	Ao Tao	N 9° 22' 51.23" E 97° 52' 53.79"
Ao Phak Kat	N 9° 22' 51.23" E 97° 52' 53.79"	Torinla Island	N 9° 25' 5.01" E 97° 51' 9.43"

Figure 1: The study sites at Mu Koh Surin, the Andaman Sea

All data were tested for normality and homogeneity of variances. A one-way ANOVA was used to test the influence of location on percent of coral mortality and density of juvenile coral. Where significant differences were established, Scheffe's test was employed to determine which group(s) differed.

Results

The coral mortality following the 2010 bleaching event varied significantly among the study sites (Fig. 2, Table 1). The percentages of dead corals following the bleaching event for all ten study sites were over 50%. The highest percentage of coral mortality was at Hin Pae (71.3%) while the lowest one was at Ao Tao (53.9%). Most *Montipora*, *Acropora* and *Pocillopora* colonies were affected and their mortality rates were very high (>90%) (Fig. 3). Spatial variation in coral bleaching and subsequent mortality was clearly observed with reflecting differences in depth, reef profile and water flow.

The densities of coral juveniles were relatively high and varied significantly among the study sites (Fig. 4, Table 2). The highest density of juvenile corals was at Hin Pae (11.0 juveniles.m^{-2}) whereas the lowest one was at Ao Mae Yai (6.1 juveniles.m^{-2}).

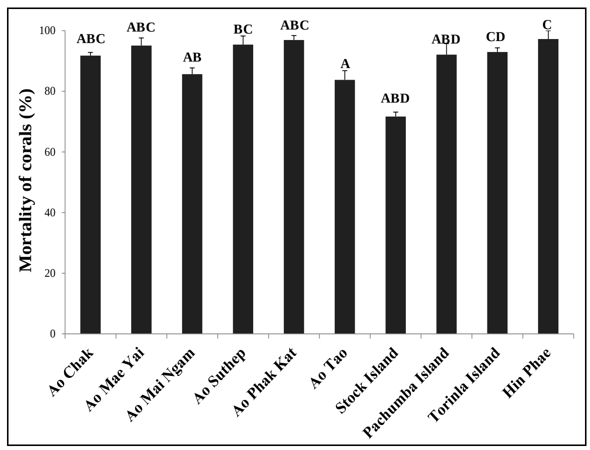


Figure 2: Coral mortality after the 2010 bleaching event for each study sites (Mean±SD). Different letters are significantly different (Scheffe's *test*, p<0.05).

Source of variation	df	Mean square	*F*	*p*
One-way ANOVA test				
Between study sites	9	91.097	9.986	<0.001*
Within study sites	20	9.122		
Total	29			

*Significant difference (P<0.05), df: Degree of freedom

Table 1: Results of one-way ANOVA examining the influence of study site on mortality of corals.

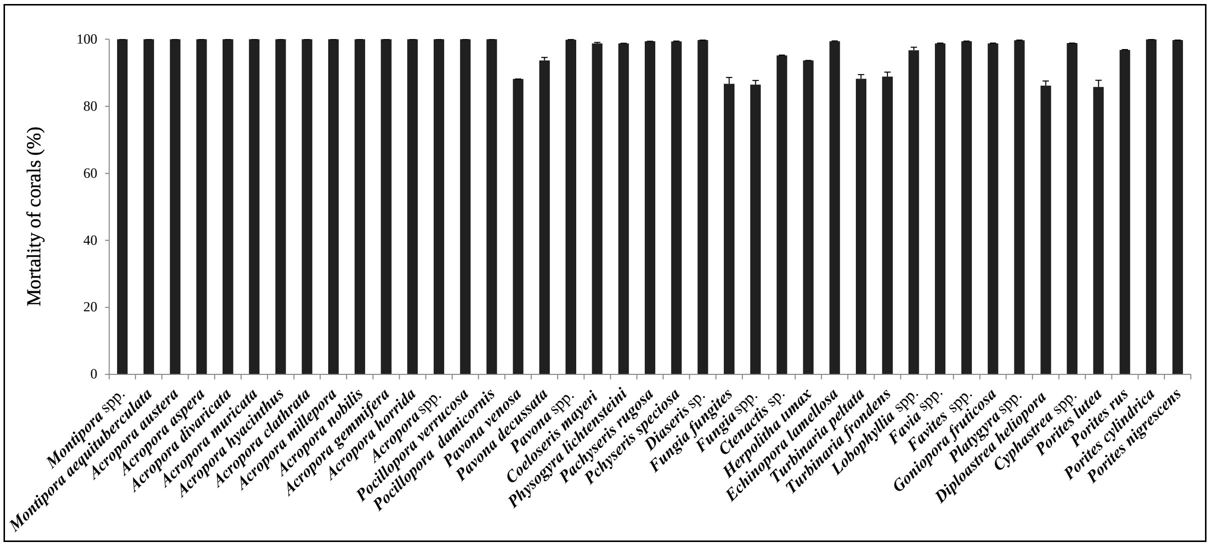


Figure 3: Coral mortality after the 2010 bleaching event for each species (Mean±SD)

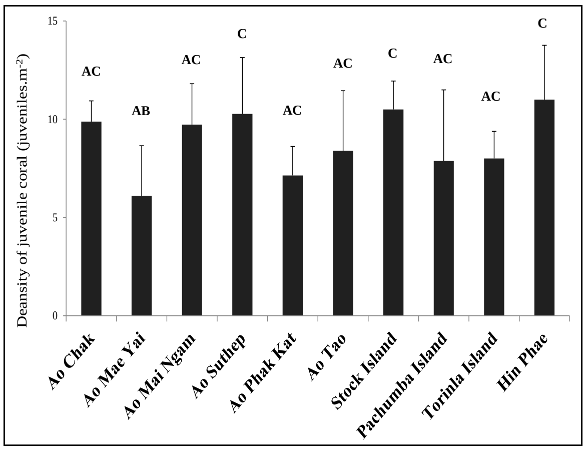


Figure 4: Density of juvenile coral after the 2010 bleaching event for each species (Mean±SD). Different letters are significantly different (Scheffe's *test*, p<0.05).

The major groups of coral juveniles were also high taxonomic diversity, including *Acropora* spp., *Fungia* spp., *Favia* spp., *Favites* spp., *Goniastrea* spp. *Platygyra* spp. *Diploastrea heliopora*, *Cyphastrea* spp., *Porites* spp., *Coeloseris mayeri*, *Gardineroseris planulata*, *Pachyseris* spp., *Ctenactis* spp. *Lithophyllon* sp., *Pectinia* sp., *Turbinaria* spp., *Astreopora* sp., *Montipora* spp., *Pocillopora* spp. and *Galaxea* spp. (Fig. 5).

Source of variation	df	Mean square	*F*	*p*
One-way ANOVA test				
Between study sites	9	7.827	7.167	<0.001*
Within study sites	20	1.092		
Total	29			

*Significant difference (P<0.05), df: Degree of freedom

Table 2: Results of one-way ANOVA examining the influence of study site on density of juvenile corals.

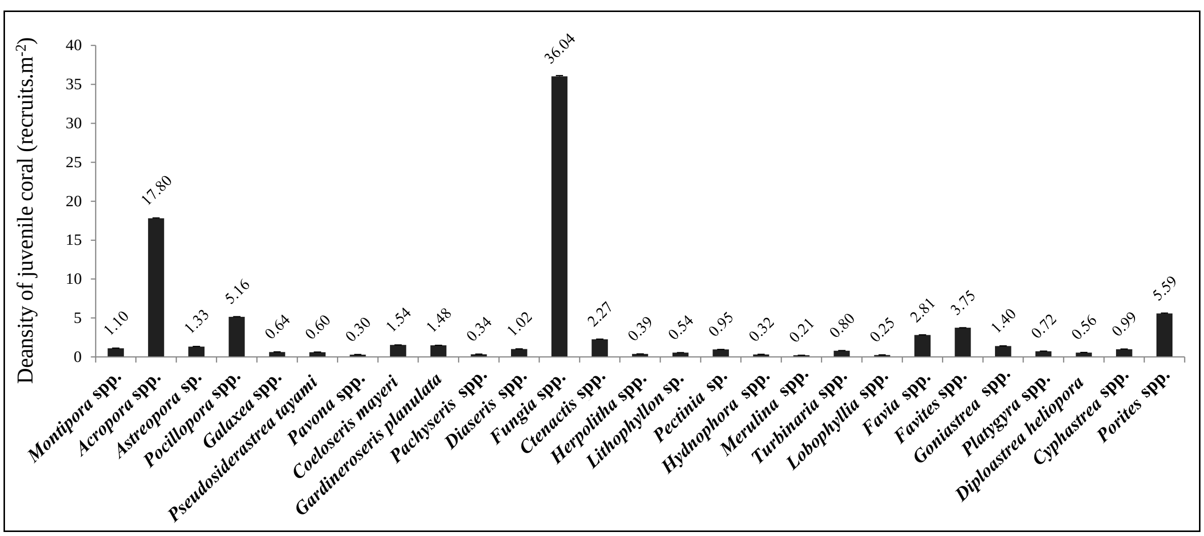


Figure 5: Density of juvenile coral after the 2010 bleaching event for each species (Mean±SD)

Discussion

This study suggests large changes in the benthic cover and coral species composition of reefs in the Mu Koh Surin National Park from the past. The coral bleaching event in 2010 at Mu Koh Surin National Park corresponded to a period of anomalies of sea surface temperature during April-September (NOAA/ NESDIS Coral Reef Watch 2010). Coral communities in the Andaman Sea were affected by the severe coral bleaching events in 1991 and 1995 (Phuket Marine Biological Center 2010) but the impacts were lower than the 2010 bleaching event and their recovery following the disturbances at several locations have been documented (Yeemin et al. 2010).

The results of this study clearly show that the 2010 coral bleaching event was the most severe at Mu Koh Surin. The subsequent coral mortality at ten study sites were 71.7-97.2%. A previous study revealed that dead corals at the ten study sites of Mu Koh Surin were 14.0-43.1% (Saenghaisuk 2007). Spatial variation in bleaching and subsequent mortality of certain coral taxa may reflect differences in depth, reef profile and water flow (Saenghaisuk and Yeemin 2011). This study shows high variable of bleaching intensity at small spatial scale that may be partly explained by interactive effects of various environmental factors such as hydrodynamic conditions, differential adaptation or acclimation of the coral/algal symbiosis (McClanahan 2000; Penin et al. 2007).

In this study, *Acropora* spp. and *Pocillopora damicornis* were most susceptible to coral bleaching. These coral taxa were categorized as the losers of coral reefs in Okinawa (Loya et al. 2001). Many studies at several reef sites in the Indo-Pacific clearly documented that branching coral species were among the first to bleach and subsequent mortality (Yamazato 1981; Glynn 1988; Brown and Suharsono 1990; Hoegh-Guldberg and Salvat 1995; Sheppard 1999; Edwards et al. 2001; Sutthacheep et al. 2010). Coral colony morphology can affect bleaching vulnerability and subsequent coral mortality. Branching corals are the most susceptible while massive and encrusting are more survival colonies (Loya et al. 2001).

The results of this study are consistent with those of Loya et al. (2001) who showed a high survival of small *Acropora* colonies on certain reef sites but an almost complete mortality of large *Acropora* colonies during the 1998 coral bleaching event in Okinawa. Juvenile coral colonies are more resistant to high SST and high irradiance compared with larger coral colonies because passive diffusion rates are more rapid for juvenile coral colonies (Nakamura and van Woesik 2001; Bena and van Woesik 2004). Most juvenile corals are found in shaded crevices where they can be sheltered from direct irradiance. (Loya et al. 2001). Juvenile coral colonies of *Acropora* also contain high concentrations of fluorescent proteins, which have photo-protective properties (Salih et al. 2000; Papina et al. 2002). A high concentration of photo-protective proteins in planulae and juvenile coral colonies may facilitate survival during this stage as well as during coral bleaching events (van Woesik 2000; Bena and van Woesik 2004). Interestingly, we found a high survival of small coral, *Fungia* as well so it is required further studies to examine their life history strategies under the coral bleaching events.

Densities of juvenile corals in Mu Koh Surin are low (6.1-11.0 juveniles.m^{-2}), in comparison to other coral reef sites (McClanahan 2000; Roth and Knowlton 2009). The survey on juvenile corals in Maldivian coral reefs, one year after the warmest recorded El Nino event of 1997-1998, showed that juvenile corals were abundant (29 juveniles.m^{-2}) but the most common juveniles were in genera previously reported as subordinate genera, e.g., *Pavona* and *Coscinarea*. Therefore recovery of coral reefs in Mu Koh Surin may require a long period of time.

The diving sites at Ao Chak, Ao Mae Yai of Surin Nua Island, Ao Tao of Surin Tai Island, Pachumba Island and Torinla Island have been temporarily closed in order to build resilience of the coral reefs and to enhance coral recovery. We suggest a high potential for coral recovery at these diving sites because of the large number of surviving juvenile coral colonies. However, the tourism management plan for protection of these coral communities is still urgently needed in order to ensure the coral recovery.

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