Managing recreational diving in temporary closures following the 2010 coral bleaching event in the Andaman Sea

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Abstract The severe coral bleaching event in 2010 led to coral mortality in many dive sites of Thailand. This study focused on management strategies for degraded recreational dive sites following the 2010 coral bleaching event in a marine national park in the Andaman Sea. Popular dive sites in marine national parks such as East of Eden and Ao Faiwab in Mu Ko Similan National Park have been temporarily closed since 2010 in order to build resilience and to enhance coral recovery. The long-term coral reef monitoring program showed that live coral covers at both dive sites increased slightly over the last five years. Coral recruitment rates were also relatively low. As numbers of recreational divers in the Andaman Sea are increasing, the Mu Ko Similan National Park management are considering establishing new dive sites in the park. However we recommend that active coral restoration in small controlled areas for recreational diving should be carried out instead of creating new dive sites. Raising public awareness is also urgently required intensely for coral reef conservation in Thailand in the period of increasing human and climate change impacts.

Keywords: coral bleaching, tourism, management, marine protected area, Andaman Sea

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Introduction

Mass coral bleaching events are recognized as a major threat to coral reef ecosystems worldwide and have resulted in economic losses for coastal communities and industries that rely on them (Hughes et al. 2003; Hoegh-Guldberg et al. 2007; Maynard et al. 2009; Sutthacheep et al. 2013). Because of these ecological and socio-economic impacts, and the relationship to climate change issues, coral bleaching events are important aspects in the public and mass media groups.

Coral reef managers have to carefully consider the sustainability of ecosystem function and services and securing the economic and social values of coral reef resources (Anderson 2007; Cinner et al. 2012; Klinthong and Yeemin 2012; Samsuwan and Yeemin 2012). Therefore appropriate management plans and their effective implementation are required to cope with the coral bleaching impacts (Goreau et al. 2000; West and Salm 2003; Marshall and Schuttenberg 2006; Hoegh-Guldberg 2011; Sutthacheep et al. 2012).

Marine protected areas (MPAs) are an important tool for conservation of marine and coastal resources including coral reef ecosystem (Roberts et al. 2003; Cho 2005; Cicin-Sain and Belfiore 2005; McLeod et al. 2009). This has resulted in establishing a large number MPAs and MPA networks at regional and global scale for managing various type of marine ecosystem (Mora 2011; Venegas-Li et al. 2016). As coral reef ecosystems are especially susceptible to impacts from climate change, particularly mass coral bleaching events during the last three decades, MPAs and MPA networks are widely recommended tool to prevent or mitigate multiple threats to the coral reefs. Although MPA networks are considered as an effective management approach for marine conservation, they should be complemented by other management strategies, including regulations for fisheries and reduction of land-based pollution (Marshall and Schuttenberg 2006; Brian et al. 2009; Yeemin et al. 2012a).

The severe mass coral bleaching event that happened in 2010 affected most coral reefs in Thai waters with more severe and extensive impacts in the Andaman Sea than in the Gulf of Thailand (Yeemin et al. 2010, 2012b). Thailand had served as a case study for managing MPAs following the mass coral bleaching events, and had contributed several recommendations based on the lessons learned from meetings, seminars and conferences among government agencies, non-government organizations, and universities that investigated coral bleaching recovery trends and management issues (Yeemin et al. 2012a). Suggested management interventions included preventing coral damage from snorkeling in the shallow reefs by zoning, reduction of sediment load from coastal development and wastewater discharge from boats and land-based activities into coral reefs, temporary closure of selected dive sites, establishing new diving sites, and conducting research and monitoring for coral conservation and restoration (Yeemin et al. 2012a).

The main objective of this study was to examine various management strategies for degraded recreational dive sites following the 2010 coral bleaching event in Mu Ko Similan, one of popular dive sites in the Andaman Sea. The long-term coral reef monitoring surveys have been conducted to investigate coral community changes in temporary closures and to propose appropriate management strategies for Mu Ko Similan National Park.

Materials and methods

Study site

The Mu Ko Similan is a group of islands (8°39′09″N, 97°38′27″E) in the Andaman Sea, about 70 km off the coast of Phang Nga Province, southern Thailand (Fig. 1). It was established as a national park in 1982. The park consists of nine islands, Ko Bangu, Ko Similan, Ko Payu, Ko Hok, Ko Ha, Ko Miang, Ko Payan, Ko Payang, and Ko Huyong. Recently, two remote islands, Ko Bon and Ko Tachai have been included in the park. Following the 2010 coral bleaching event, two popular dive sites Ao Faiwab (Ko Similan) and East of Eden (Ko Payu) have been temporary closed since 2010 for building resilience and enhancing coral recovery.

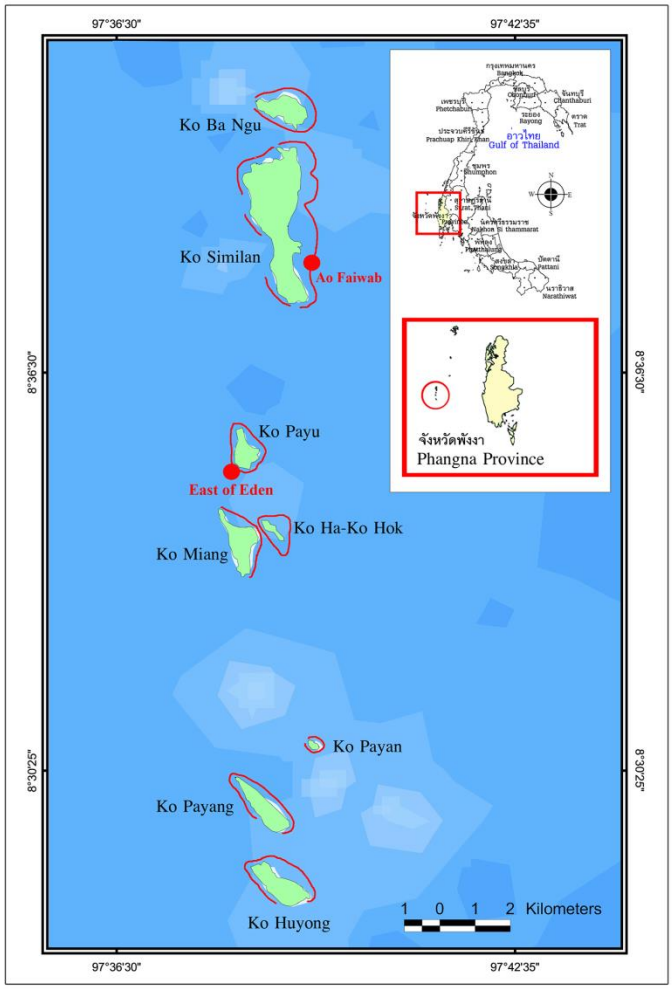


Fig. 1 Map of the study sites at Ao Faiwab and East of Eden, Mu Ko Similan National Park

Long-term coral reef monitoring

At each study site, three 50m permanent belt-transects were set up on the reef slope at about 18 m depth, to examine changes in live coral cover and coral recruitment. This study presents the data

collected during from 2009 (before the mass coral bleaching event) to 2015. The data for the year 2010 were collected in November, about six months after the peak of coral bleaching event. Live coral cover was recorded in each belt transect and hard coral (>5 cm diameter) were identified to species level. The number of visible coral recruits (<5 cm diameter) on natural substrates in each belt-transect were also recorded. All coral recruits were identified to genus level. A one-way ANOVA was used to test the influence of time on the live coral cover and the number of coral recruits for each study site. LSD Method was used as a posthoc analysis.

Results

The surveys before the bleaching event in 2009 showed that averages of live coral cover at East of Eden and Ao Faiwab were 65.1% and 33.4% respectively. However, in 2010 the live coral cover at both study sites dropped to 25.2% and 3.7% (Figs. 2, 3), six months after the bleaching event). The severe coral bleaching event in 2010 caused significant mortality of several hard corals including, *Montipora* spp., *Acropora* spp., *Pocillopora* spp., *Seriatopora hystrix*, and *Porites* spp. The surveys during the year 2011 to 2015 revealed that live coral cover at both study sites slightly increased.

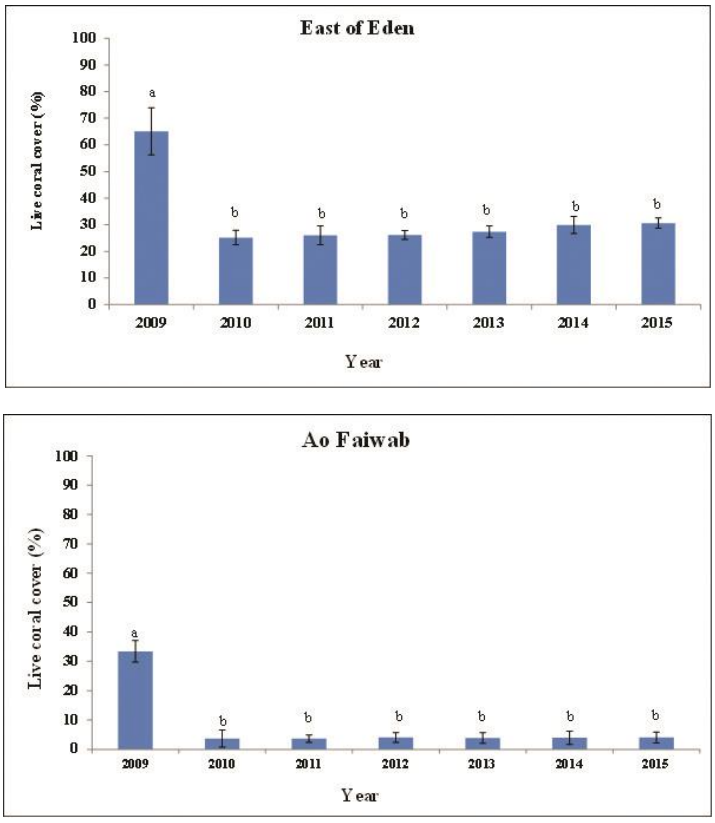


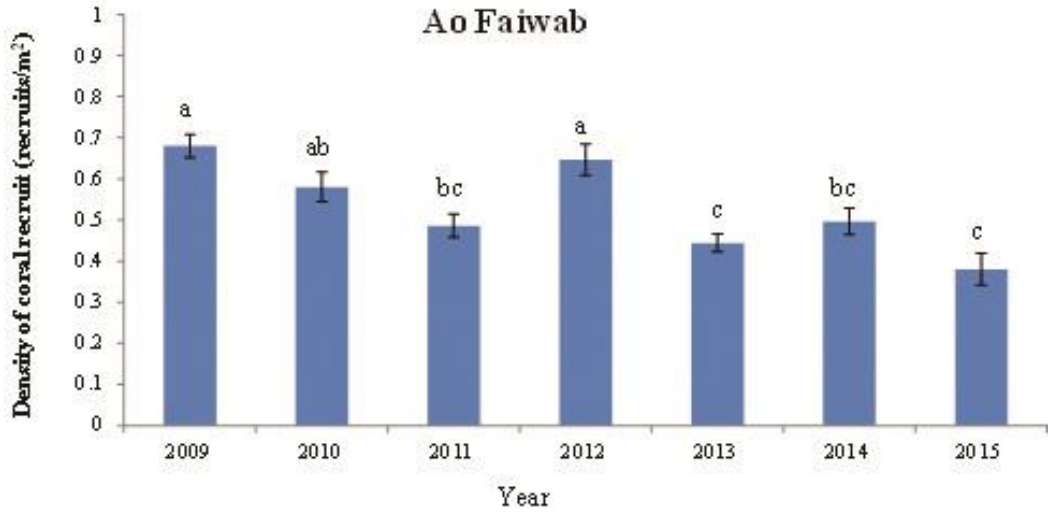
Fig 2. Live coral cover of large colonies (±SE) at A) East of Eden and B) Ao Faiwab during 2009 to 2015 (one-way ANOVA, LSD test, $p<0.05$)

Fig 3. Coral communities at A) East of Eden and B) Ao Faiwab before and after the 2010 mass coral bleaching event

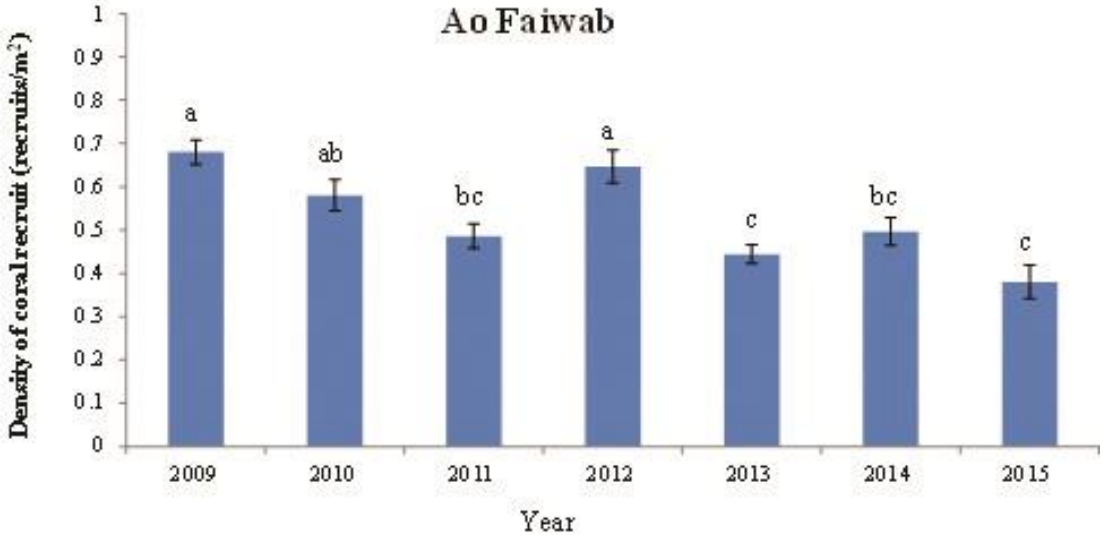
Density of coral recruits at both study sites differed significantly between year (one-way ANOVA, $p<0.05$) (Figs. 4, 5). The dominant coral recruits were *Pavona* spp., *Pocillopora* spp., *Porites* spp. and *Acropora* spp. The density of coral recruits at both study sites was relatively low.

Discussion

The coral communities at East of Eden and Ao Faiwab were dominated by corals that are susceptible to bleaching, therefore the severe bleaching event in 2010 resulted to coral degradation (Yeemin et al. 2012a). This study showed that the live coral cover at both reef sites slightly increased after the bleaching event. However, despite the increase in live coral cover the density of coral recruits was low. The Department of National Parks, Wildlife and Plant Conservation (DNP) realized the impacts of coral bleaching and decided to temporarily close several popular dive sites, including East of Eden and Ao Faiwab in order to build resilience and to enhance coral recovery.



A



B

Fig. 4 Density of coral recruits (±SE) at A) East of Eden and B) Ao Faiwab during 2009 to 2015 (one-way ANOVA, LSD test, $p<0.05$)

The DNP has also implemented several measures for managing coral reefs and marine resources for tourism development, such as repair and maintenance of existing buoys and installation of new buoys, promoting better knowledge and understanding of responsible tourism, increasing awareness and promoting a better understanding of the coral bleaching event, etc. (Klinthong and Yeemin 2012; Yeemin et al. 2012a).

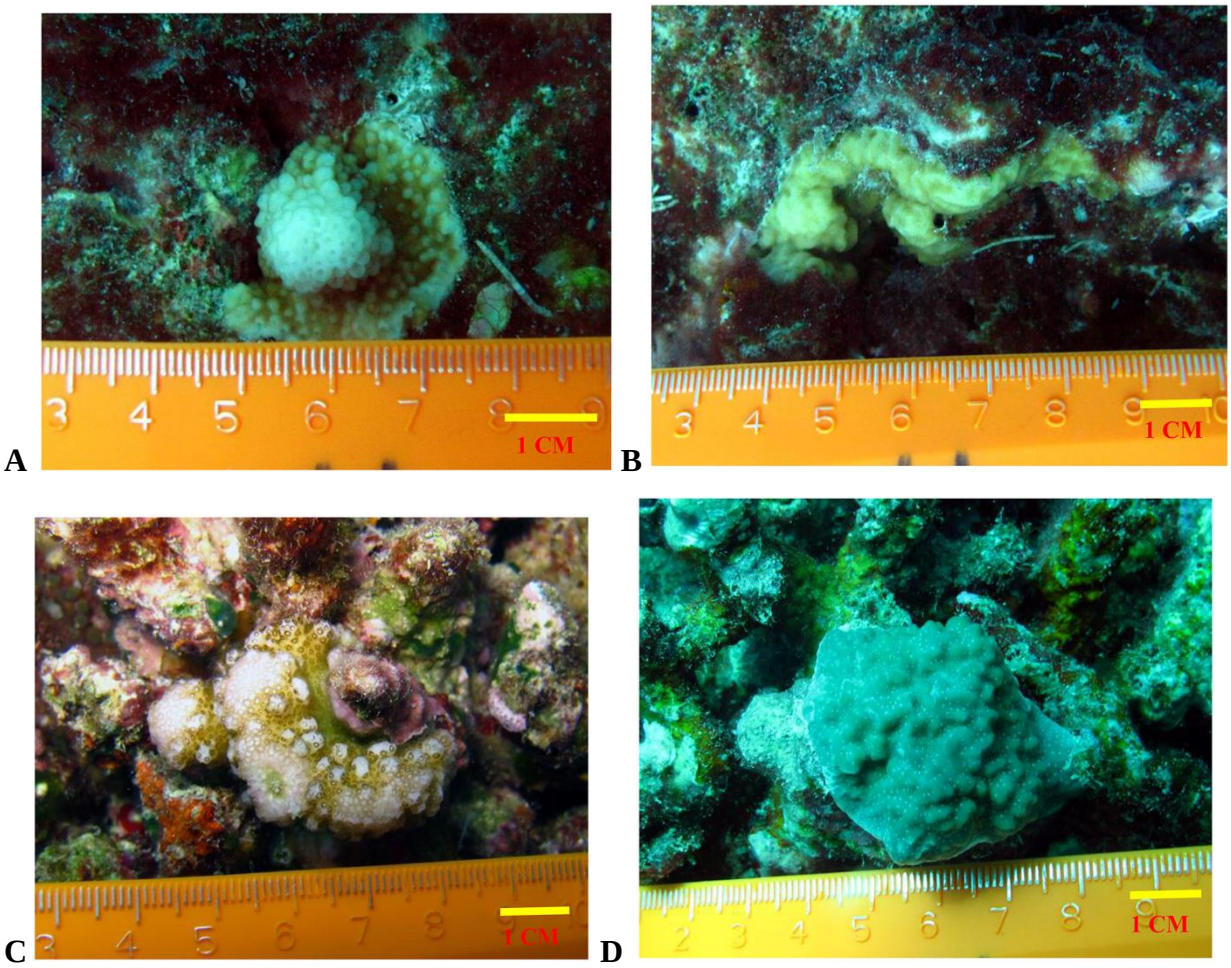


Fig. 5 Coral recruits on natural substrates at East of Eden and Ao Faiwab A) *Acropora spp.* B) *Pavona sp.* C) *Pocillopora sp.* D) *Porites sp.*

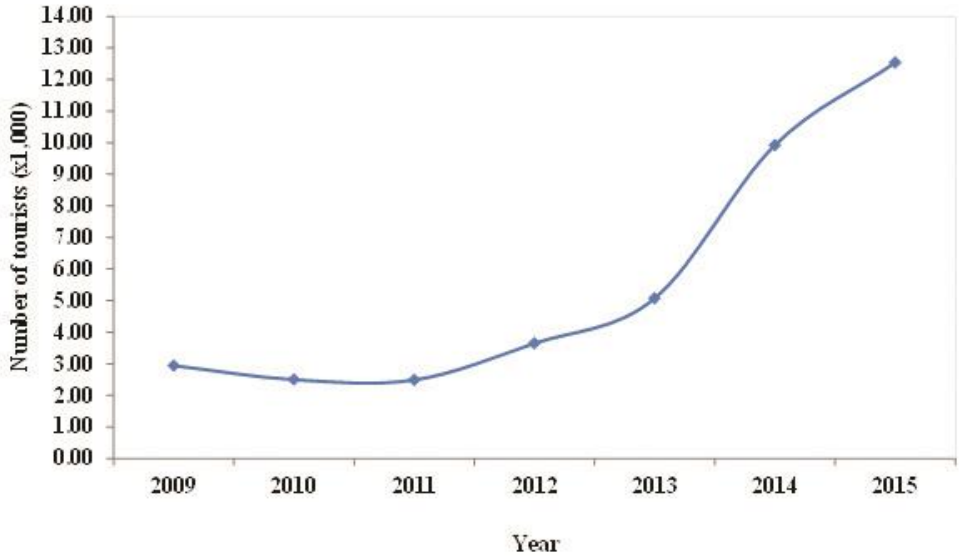


Fig. 6 Number of tourists at Mu Ko Similan National Park during 2009 – 2015 (Source: www.dnp.go.th)

A  B 

Fig. 7 A) Snorkelers and B) scuba divers at Mu Ko Similan National Park

Various types of tourism business, including diving and other marine tourism, are very important sources of income for communities along the coastline of Thailand and the country economy (Samsuvan et al. 2012). The DNP statistics revealed that number of tourists, including snorkelers and scuba divers, entering Mu Ko Similan remarkably increased during the past few years (Figs. 6, 7). This is consistent with the national policy to increase tourist numbers and to enhance tourism growth of Thailand. The DNP needs proper management strategies to cope with the increased numbers of tourists. One of the management strategies for recreational diving is establishing new dive sites in the park or rotational dive site use. We suggest that the DNP should not establish a new dive site in Mu Ko Similan National Park and should reserve reef sites in the park as possible. Whenever a new diving site is established, it can still be degraded if enforcement of regulations in the park is weak. However, active coral restoration in small controlled areas may be carried out to cater for snorkelers and scuba divers at some temporary closures. Recently, achievements of selected coral reef restoration projects and guidelines for restoration techniques have been widely published (Yeemin et al. 2006; Chou et al. 2009; Edwards 2010; Cabaitan et al. 2015; Rinkevich 2015). A case study on managing bleached coral reefs in Thailand showed the achievement of using artificial substrates for coral recruitment and ecotourism at tourist hotspots with the participation of local communities in managing natural resources and environment (Sutthacheep et al. 2012). Raising public awareness is also required for coral reef conservation in Thai waters in the face of increasing anthropogenic and climate change impacts. This study highlights the importance of selected appropriate management strategies for conserving the coral reef ecosystem.

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References

Andersson JEC (2007) The recreational cost of coral bleaching- A stated and revealed preference study of international. Ecol Econ 62:704–715

Cabaitan PC, Yap HT, Gomez ED (2015) Performance of single versus mixed coral species for transplantation to restore degraded reefs. Restor Ecol 23:349–356

Cho L (2005) Marine protected areas: a tool for integrated coastal management in Belize. Ocean Coast Manage 48:932–947

Chou LM, Yeemin T, Yaman ARBG, Vo ST, Alinõ P, Suharsono (2009) Coral reef restoration in the South China Sea. Galaxea JCRS 11:67–74

Cicin-Sain B, Belfiore S (2005) Linking marine protected areas to integrate coastal and ocean management: a review of theory and practice. Ocean Coast Manage 48:847–868

Cinner JE, McClanahan TR, Graham NAJ, Daw TM, Maina J, Stead SM, Wamukota A, Brown K, Bodin Ö (2012) Vulnerability of coastal communities to key impacts of climate change on coral reef fisheries. Sci Tech 22:12–20

Edwards AJ (2010) Reef Rehabilitation Manual. Coral Reef Targeted Research and Capacity Building for Management Programme, St. Lucia, Australia.

Goreau TJ, McClanahan TR, Hayes RL, Strong A (2000) Conservation of coral reefs after the 1998 global bleaching event. Conserv Biol 14:5–15

Hoegh-Guldberg O, (2011) Coral reef ecosystems and anthropogenic climate change. Reg Environ Change 11:S215–S227

Hoegh-Guldberg O, Mumby PJ, Hooten AJ , Steneck, RS, Greenfield P, Gomez E, Harvell CD, Sale PF, Edwards AJ, Caldeira K, Knowlton N, Eakin CM, Iglesias-Prieto R, Muthiga N, Bradbury RH, Dubi A, Hatziolos ME (2007) Coral reefs under rapid climate change and ocean acidification. Science 318 (5857):1737–1742

Hughes TP, Baird AH, Bellwood DR, Card M, Connolly SR, Folke C, Grosberg R, Hoegh-Guldberg O, Jackson JBC, Kleypas J, Lough JM, Marshall P, Nystrom M, Palumbi SR, Pandolfi JM, Rosen B, Roughgarden J (2003) Climate change, human impacts, and the resilience of coral reefs. Science 301(5635):929–933

Keller BD, Gleason DF, McLeod E, Woodley CM, Airame S, Causey BD, Friedlander AM, Grober-Dunsmore R, Johnson JE, Miller SL, Steneck RS (2009) Climate Change, Coral Reef Ecosystems, and Management Options for Marine Protected Areas. Environ Manage 44:1069–1088

Klinthong W, Yeemin T (2012) Impact of Coral Bleaching at Mu Koh Similan National Park. Proc 12th Int Coral Reef Symp, p 4

Marshall PA, Schuttenberg H (2006) A reef managers guide to coral bleaching. Great Barrier Reef Marine Park Authority, Townsville

McLeod E, Salm R, Green A, Almany J (2009) Designing marine protected area networks to address the impacts of climate change. Front Ecol Environ 7(7):362–370

Mora C (2011) Effectiveness of the global network of marine protected areas. In: Claudet, J. (Ed.), Marine Protected Areas: A Multidisciplinary Approach. Cambridge University Press, Cambridge, pp 334–346

Rinkevich B (2015) Climate change and active reef restoration—ways of constructing the "reefs of tomorrow". J Mar Sci Eng 3:111–127

Roberts CM, Branch G, Bustamante RH, Castilla JC, Dugan J, Halpern BS, Lafferty KD, Leslie H, Lubchenco J, Mcardle D, Ruckelshaus M, Warner RR (2003) Application of ecological criteria in selecting marine reserves and developing reserve networks, Ecol Appl 13:215–228

Samsuvan W, Yeemin T (2012) Tourist perception of coral bleaching in the Andaman Sea. Proc 12th Int Coral Reef Symp, p 4

Sutthacheep M, Pengsakun S, Chueliang P, Suantha P, Sakai K, Yeemin T (2012) Managing bleached coral reefs in the Gulf of Thailand. Proc 12th Int Coral Reef Symp, p 5

Sutthacheep M, Pengsakun S, Yucharoen M, Klinthong W, Sangmanee K, Yeemin T (2013) Impacts of the mass coral bleaching events in 1998 and 2010 on the western Gulf of Thailand. Deep-Sea Research II 96:25–31

Venegas-Li Rn, Cros A, White A, Mora C (2016) Measuring conservation success with missing Marine Protected Area boundaries: A case study in the Coral Triangle. Ecol Indic 60:119–124

West JM, Salm RV (2003) Resistance and resilience to coral bleaching: implications for coral reef conservation and management. Conserv Biol 17:956–967

Yeemin T, Sutthacheep M, Pettongma R (2006) Coral reef restoration project in Thailand. Ocean

Coast Manage 49:562–575

Yeemin T, Saenghaisuk C, Sittiporn P, Klinthong W, Sangmanee K, Yucharoen M , Donsomjit W, Saengsawang L, Nuclear P, Sutthacheep M (2010) Status of coral reefs in Thailand following the 2010 coral bleaching event. In: Kimura T , Tun K(eds) Status of Coral Reefs in East Asian Seas Region: 2010. Ministry of the Environment, Japan, pp 29–49

Yeemin T, Mantachitra V, Plathong S, Nuclear P, Klinthong W, Sutthacheep M (2012a) Impacts of coral bleaching, recovery and management in Thailand. Proc 12th Int Coral Reef Symp, P 5

Yeemin T, Saenghaisuk C, Yucharoen M, Klinthong W, Sutthacheep M (2012b) Impact of the 2010 coral bleaching event on survival of juvenile coral colonies in the Similan Islands, on the Andaman Sea coast of Thailand. Phuket Mar Biol Cent Res Bull 71:93–102