Coral reef conservation and management in a Ramsar site in the Gulf of Thailand

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Abstract Mu Ko Ang Thong, an archipelago in the Gulf of Thailand, was established as a marine national park in 1980 and was also registered as a Ramsar site in 2002. The islands are surrounded by relatively shallow and turbid water, which is greatly influenced by river water from the mainland. We provide baseline data for coral reef conservation and management in Mu Ko Ang Thong National Park, a Ramsar site, in the Western Gulf of Thailand. Assessing coral health and resilience in the national park was carried out to provide scientific data for establishing a master management plan. Coral damages caused by tramping and high sedimentation were frequently observed. We recommend the management strategies that include coral reef zoning for multiple uses, effective tourism management and prevention of land-based pollution. This study highlights the importance of science-based management of coral reefs in marine protected areas for sustainable tourism in Thailand.

Keywords: coral community, coral reef conservation, marine protected area, Ramsar, Thailand, tourism

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Introduction

Coral reefs are increasingly affected by multiple stressors including destructive fishing techniques, overfishing, land-based pollution, sedimentation, diseases, unmanaged tourism, and climate change (Brown and Suharsono 1990; Hughes et al. 2003; Hoegh-Guldberg et al. 2007; Yeemin et al. 2013). Recently, Burke et al. (2011) reported that approximately 75% of coral reefs in the world are classified as being threatened when local stresses are combined with thermal impacts arising from the recent threats of rising seawater temperature, linked to the widespread weakening and mortality of corals because of mass coral bleaching. Coral reef degradation has significant impacts on the

well-being and livelihoods of several hundred million people, in particular, those in reef fishing and tourism sectors vital to the sustainability of regional economies (Moberg and Folke 1999; Yee et al. 2015). Proper management plans and strategies are required to ensure the coral reef ecosystem services.

Marine protected areas (MPAs) are a key conservation tool employed by most countries to manage their marine living resources, particularly coral reefs (Halpern and Warner 2002; Venegas-Li et al. 2016). MPAs have been widely used as fishery management strategies to enhance spawning stocks of economically important species and to increase abundance and biomass of exploited adult fishes, as spillover and recruitment subsidy to the adjacent fishing grounds (Alcala et al. 2005; Lester et al. 2009; Molloy et al. 2009; Cvitanovic et al. 2013). The MPAs concept can be applied for marine biodiversity conservation to protect endangered species, vulnerable communities and ecosystems and to enhance species diversity in nearby unprotected areas (Selig and Bruno 2010; Russ and Alcala 2011). Global and regional efforts to establish ecologically representative and effectively managed MPA networks were documented, especially the Convention on Biological Diversity and the Aichi Targets, the Coral Triangle Initiative on Coral Reefs, Fisheries and Food Security (CTI-CFF) (Balmford et al. 2005; CTI-CFF 2009; White et al. 2014).

One of key MPAs management strategies is integrating scientific information into the decision making process (Roux et al. 2006; Granek et al. 2009). Researchers should work in close collaboration with management agencies to ensure research needed for management is carried out and effectively shared the important information. Many marine national parks in developing countries have limited human resources to manage the parks for tourism. Therefore, they need strong support and collaboration from universities and research institutes to carry out certain research projects for park management purposes. Improvement of collaboration and knowledge transfer among managers and researchers is very important to enhance the knowledge-based management of MPAs at local, regional, and global scales (Cvitanovic et al. 2013).

This study provides scientific data for coral reef conservation in Mu Ko Ang Thong in the Western Gulf of Thailand. We focused on assessing coral health and recruitment as baseline data for updating the management plan, coral reef monitoring programs, and decision making for management interventions in the park for tourism.

Materials and methods

Fig 1. Study areas at Mu Ko Ang Thong Nation Park, the Western Gulf of Thailand

Study sites

The study sites are located in Mu Ko Ang Thong National Park, Surat Thani Province, the Western Gulf of Thailand (Fig. 1). The park is the second marine national park of Thailand and is comprised of 42 relatively small islands. It is approximately 750 km. south of Bangkok and about 31 km far from the northeast of Ko Samui, a popular tourist destination in Thailand. Mu Ko Ang Thong harbors several wetland types, including sandy beach, rocky cliff, mangrove forest, and coral reef. It is recognized as a specific type of wetland ecosystem (Royal Forest Department 1998). The islands are surrounded by shallow, average depth of the water about 10 meters, and turbid water, which is greatly influenced by Tapi River from the mainland. The coral reefs around the islands are at the early stage of development and are narrow reefs around each island. The number of tourists visiting Mu Ko Ang Thong National Park has increased during the last five years (Fig. 2). Popular sightseeing spots are a viewpoint at the top of Ko Angthong (Ko Wua Ta Lap) and a huge emerald

lagoon at the middle of the limestone mountain on Ko Wua Ta Lam (Ko Mae Ko) (Fig. 3). Marine recreation activities include canoeing, kayaking, and at some islands snorkeling.

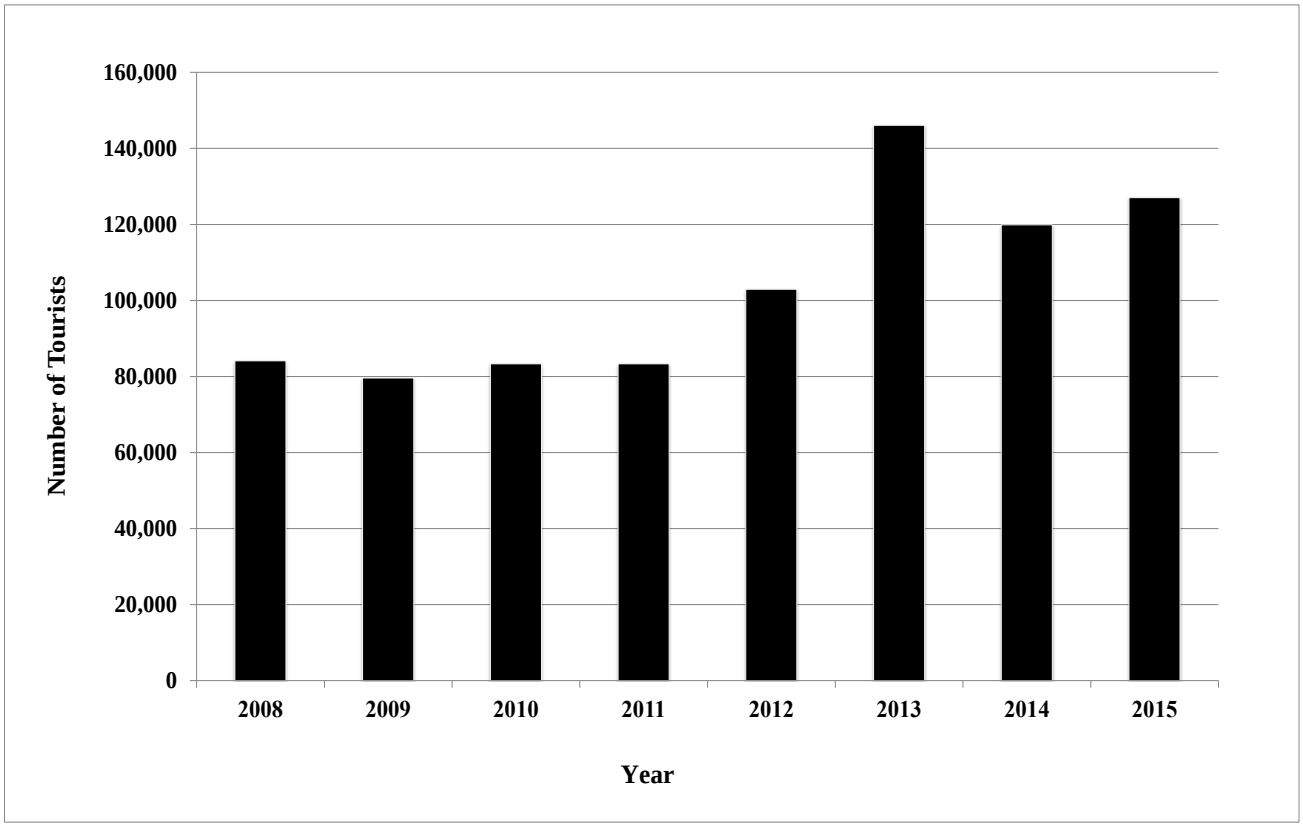
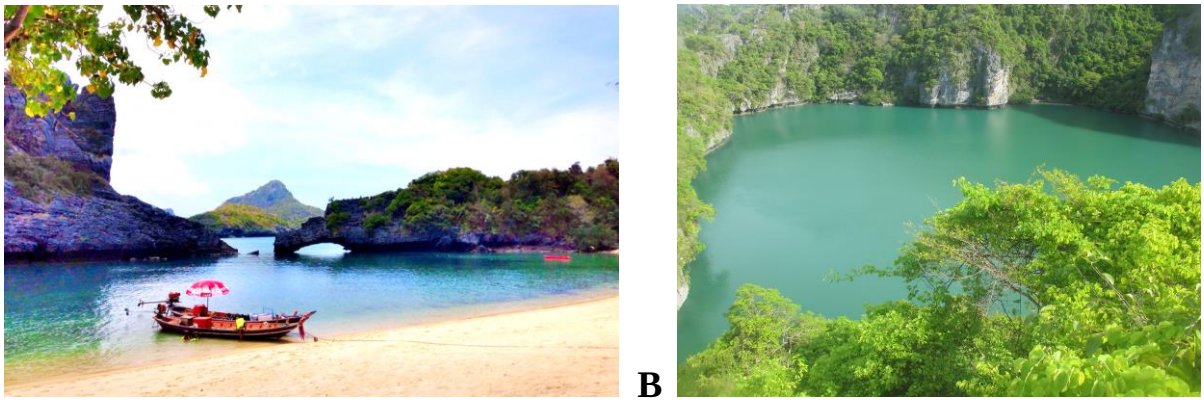


Fig 2. Number of tourist visiting at Mu Ko Ang Thong Nation Park, the Western Gulf of Thailand during 2008 – 2015 (Source:www.dnp.go.th)



A **B**

Fig 3. Tourist attractions at Mu AngThong National Park A) Ko Samsao (west) B) Talay Nai in Ko Wua Ta Lam (Ko Mae Ko)

Ten study sites were selected, i.e., Ko Thaiphlao , Ko Thong Thang Thaeng, Ko Wua Kantang, North of Ko Sam Sao, East of Ko Sam Sao, West of Ko Sam Sao, West of Ko Wua Ta Lam, North of Ko Ang Thong, East of Ko Ang Thong and West of Ko Ang Thong.

Coral community surveys

The coral community surveys were conducted in April 2014 and 2015. The coral communities were found at about 1-5 m in depth. At each study site, live coral cover was observed in three belt-transects of 50x1 m^2 and coral colonies (≥5 cm in diameter) were counted and identified to a species level, if possible, and their coverage was quantitatively estimated. Covers of dead corals, rubble, sand and rock were recorded. In this study, covers of dead corals, rubble and rock were combined as available substrate. The quadrats were also photographed with an underwater camera for reinvestigating of data.

To examine juvenile coral densities, quadrats (16x16 cm^2 for each) were randomly placed on available substrates at each study site using scuba diving and number of juvenile coral colonies (≤ 5 cm in diameter) was carefully observed and counted. All juvenile coral colonies were identified to family level.

Data analysis

In order to test the differences of live coral cover, juvenile coral, and coverage of available substrate among study sites, one-way ANOVA was applied. To meet the assumption of parametric data analysis, the data on live coral cover, juvenile coral, and available substrate for each site were treated with square-root transformation (x+0.5) prior to the analysis of variance. Fisher's Least Significant Difference (LSD) test was used to determine differences of means among study sites in case the ANOVA is significant.

Results

The means of the live coral coverage were in the range of 7.13 - 64.29% and were significantly different among the study sites (One-way ANOVA, $p<0.05$) (Fig. 4). High live coral coverage (>50%) was observed at Ko Thong Thang Thaeng and Ko Ang Thong (east and south) while the lowest live coral coverage (7.13%) was observed at Ko Wua Ta Lam. The dominant corals were *Porites* spp., *Goniopora* spp. and *Platygyra sinensis*. There were many snorkelers at Ko Thaiphlao, Ko Sam Sao and Ko Ang Thong during the field survey periods. Partial mortality of the coral colonies caused by tramping and high sedimentation was frequently observed at several study sites.

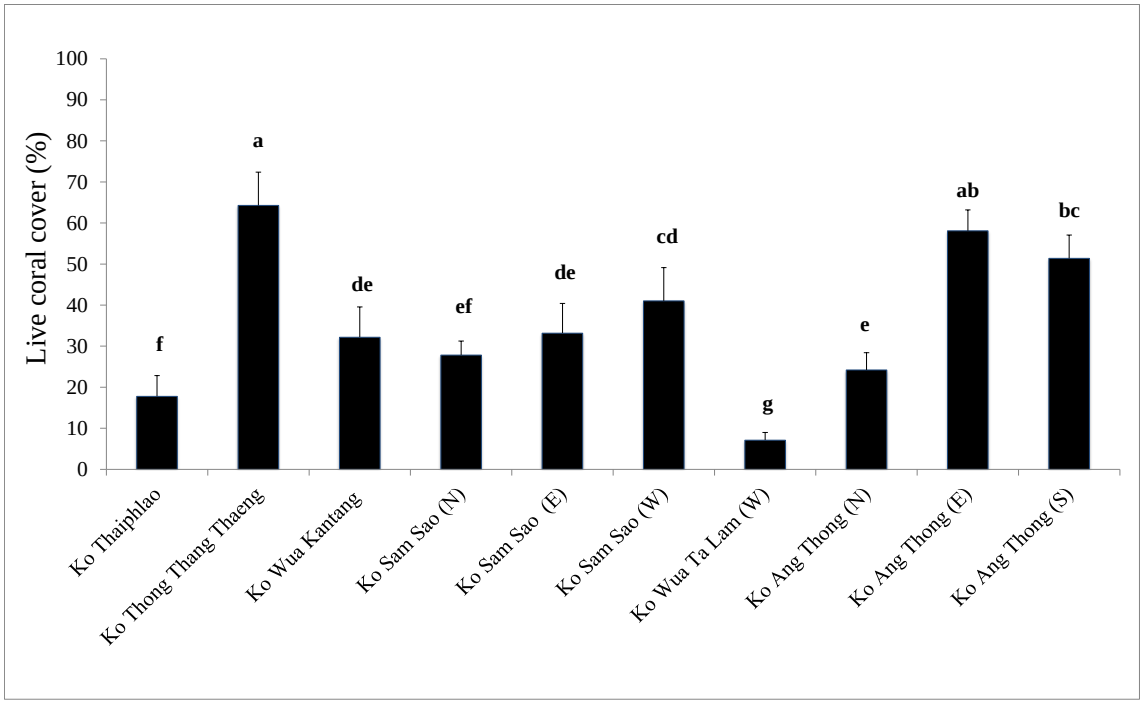


Fig. 4 Live coral cover of large colonies at each study site (means ± SE, $p<0.05$)

The available substrates, dead corals, rubble and rock, were in the range of 32.68 – 74.04% and significantly different among the study sites (One-way ANOVA, $p<0.05$) (Fig. 5). The high percentage of dead corals (>40%) were found at most study sites, except Ko Thong Thang Thaeng , Ko Sam Sao (west) and Ko Ang Thong (east). High rubble coverage was observed at Ko Wua Ta Lam (west).

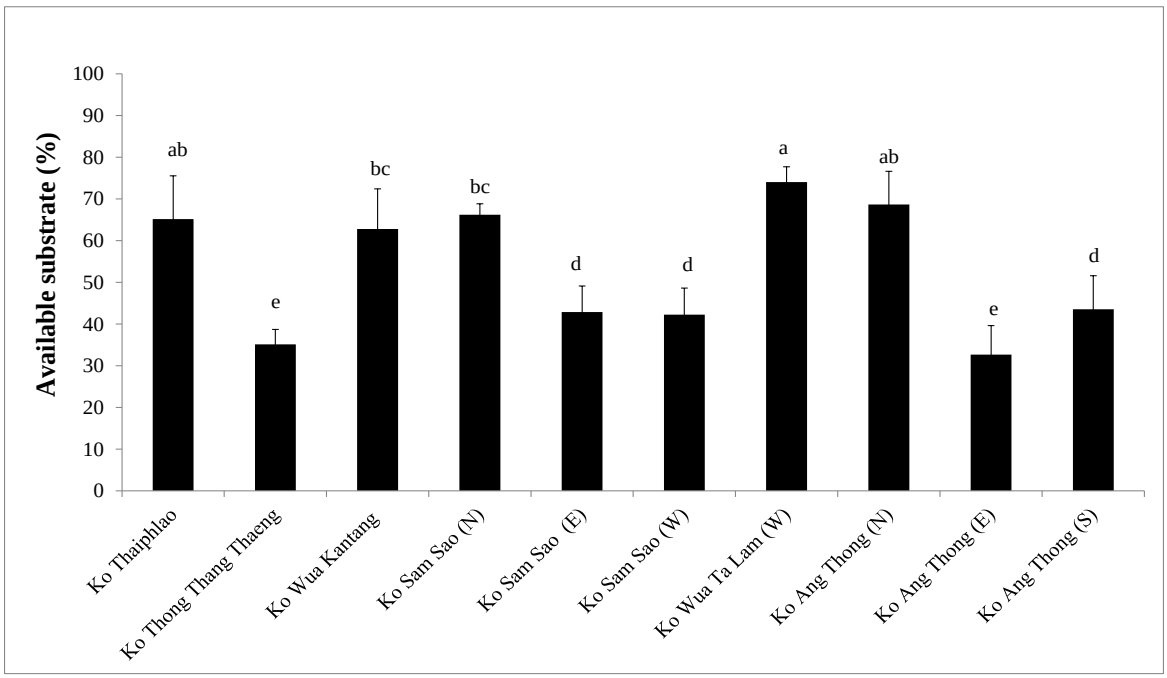


Fig. 5 Available substrates at each study site (means ± SE, $p<0.05$)

The means of the densities of juvenile corals during the study periods were 8.22 – 37.38 colony m^{-2} and were significantly different among the study sites (One-way ANOVA, $p<0.05$) (Fig. 6). The highest average density of juvenile corals was found at Ko Sam Sao (north) while the lowest average was found at Ko Ang Thong (east). Nine families of juvenile corals were commonly observed, including Pocilloporidae, Siderastreidae, Agariciidae, Fungiidae, Merulinidae, Dendrophyllidae, Mussidae, Faviidae and Poritidae (Fig. 7).

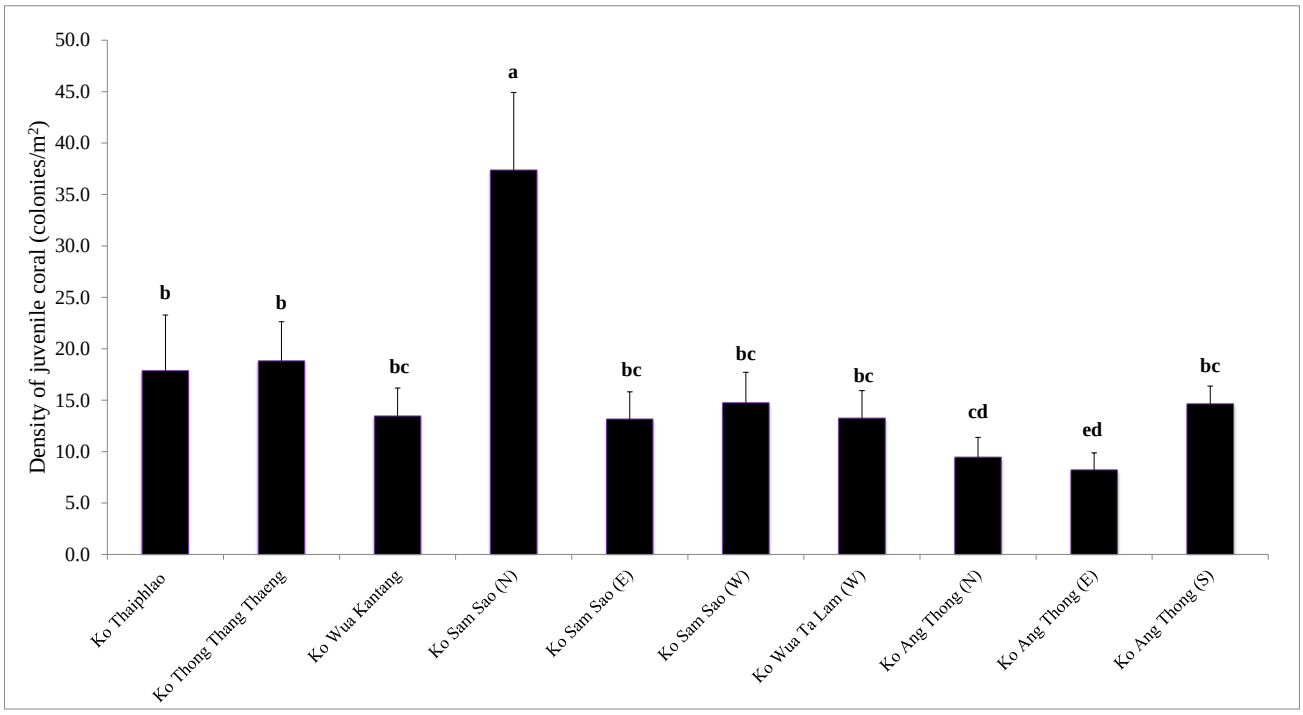


Fig. 6 Density of juvenile coral colonies at each study site (means ± SE, $p<0.05$)

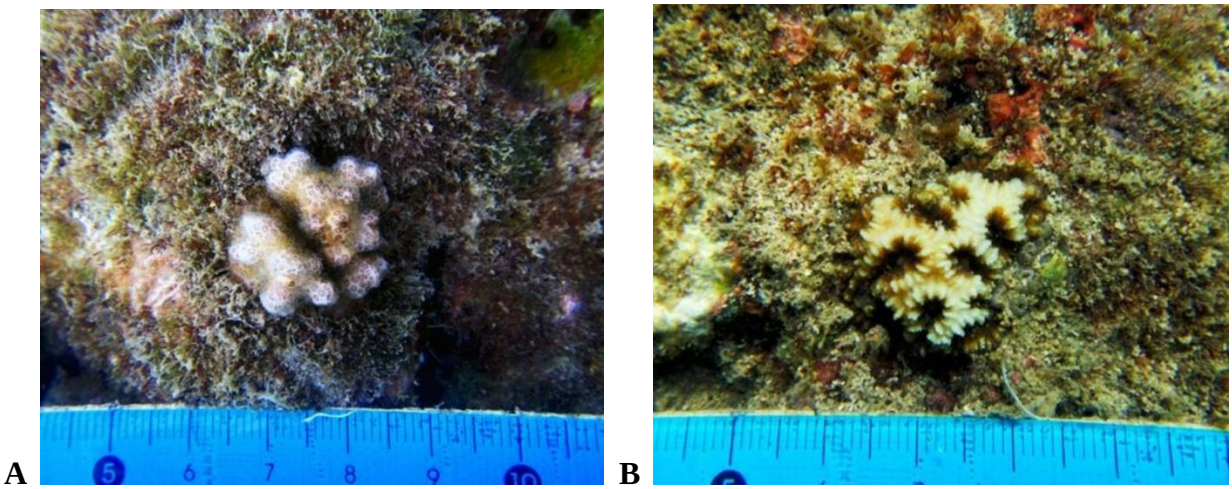


Fig. 7 Dominant juvenile corals at Mu Ko Ang Thong National Park A) *Pocillopora sp.* B) *Favia sp.*

Discussion

Mu Ko Ang Thong National Park, as a marine national park and a Ramsar site, plays major roles for enhancing fish stocks, tourism development, and marine biodiversity conservation. As the park is located in a relatively high productivity area of the Western Gulf of Thailand, it is recognized as an important breeding and nursery ground for several economically important species, particularly Indo-Pacific mackerel (*Rastrelliger brachysoma*), which is one of the most important pelagic species for the Thai cuisine (Saikliang 2014).

Tourism in the western coast of the Gulf of Thailand, Prachaup Khiri Khan, Chumphon, and Surat Thani Provinces has been rapidly developed. Mu Ko Ang Thong National Park has high potential for tourism. The scientific data obtained from this study was used for revising the park management plan. Several management strategies from the coral reef restoration plan of Thailand (Suraswadi and Yeemin 2013) could be applied to Mu Ko Ang Thong National Park, including reducing threats from tourism such as control and monitoring of divers to avoid contact and damage to coral reefs, avoid bringing divers to risky and fragile reef areas, zoning reef areas encouraging tourist boat operators to have proper waste and garbage management, apply mooring buoys in all diving areas, encourage use of a snorkeling trail, applying carrying capacity in tourism site, applying code of practice to reduce impact from tourism activity, creating a network between stakeholders for co-management, create regulation for tourist operators to use mooring buoys and to have proper waste management, monitor impacts from tourism activity to coral reef, monitoring of coral reefs at tourism sites, encourage local participation in monitoring plan, and study on improving monitoring techniques related to tourism activity. Several measures including reducing threats from water pollution and sedimentation strategies should be also considered for implementation.

Integrating scientific research into the decision-making process for the management of marine national parks is very important for adaptive management strategies to enhance coastal ecosystem resilience. This study provides crucial scientific data, especially coral health status and coral recovery potential, in Mu Ko Ang Thong National Park which can be used for conservation and management of the park to ensure the sustainability of natural resources and tourism business. Moreover, this study highlights the importance of good collaboration of coral reef researchers from Thai universities and managers from the Department of National Parks, Wildlife, and Plant Conservation to work more collaboratively towards the conservation of marine and coastal resources.

Acknowledgements

We would like to thank staffs of the Department of National Parks, Wildlife and Plant Conservation and Marine Biodiversity Research Group, Faculty of Science, Ramkhamhaeng University for their field work assistance. This study was funded by a budget for research promotion from the Thai Government awarded to Ramkhamhaeng University and Department of National Parks, Wildlife, and Conservation.

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