ORIGINAL PAPER

Coral community on an underwater pinnacle at a new dive site in Surat Thani Province, Thailand

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Abstract The Western Gulf of Thailand has been an important area for marine ecosystems in Thai waters because it harbors the most biologically rich and productive marine and coastal ecosystems. Underwater pinnacles are the hotspots of biodiversity, attracting substantial tourist interest in SCUBA diving. This study aimed to provide the first insight into the coral community of Hin Tai Plao, Mu Ko Ang Thong, Surat Thani Province, a SCUBA diving site with high potential to become a popular tourist destination. The coral community was studied using a belt-transect method, at about 5-10 m. in depth. Thirteen common coral taxa were recorded. The dominant coral species were *Porites lutea*, *Lobophyllia hemprichii* and *Diploastrea heliopora*. The coral cover was high with over 40%. The dominant macrobenthic invertebrates included *Xestospongia* sp., *Sabellastarte* sp., *Beguina semiorbiculata*, *Tridacna squamosa* and *Holothuria leucospilota*. The abundant reef fish were *Neopomacentrus anabatoides*, *Sphyraena flavicauda*, *Taeniamia fucata*, *Neopomacentrus cyanomos*, *Caesio caerulaurea*, *Pomacentrus cuneatus*. The results revealed that Hin Tai Plao is a refuge for reef organisms. It has a high potential for promoting to be a marine ecotourism site. The coral community at Hin Tai Plao shows high resilience to global climate change. This study provides important baseline data on underwater pinnacles in Surat Thani Province to support marine and coastal resources management

Keywords: underwater pinnacle, coral community, ecotourism, diving, management

1. Introduction

Coastal communities around the world, particularly in tropical countries, obtain various goods and services from the coral reefs and their associated ecosystems. These services include providing chances for tourism and recreation, food provision, coastline protection, and erosion control. (Cesar 2000; Yeemin et al. 2006; Brander et al. 2007). Coral reefs also regulate environmental balance such as the generation of beach and coral sands, maintenance of biodiversity and genetic resources, carbon sequestration, and waste assimilation. (Worm et al. 2006; Hughes et al. 2012; Cinner et al. 2016; Eddy 2021). Coral reefs are highly productive, making them a hot spot of biodiversity and creating a significant source of income, particularly from the fishery and tourism industries. (Bruno 2019; McMahon et al. 2016; Zheng et al. 2021). The Western Gulf of Thailand has been a crucial area for marine ecosystems in Thailand as it harbors the most biologically rich and productive marine and coastal ecosystems. Invertebrates are important components of marine and coastal ecosystems, especially coral reefs (Gibson et al. 2011; Jungrak et al. 2021).

Reef fish are the most diverse and important sources of food security and ecotourism. They also support ecosystem processes that are vital and provide income to the coastal communities (Brewer 2011; Thyresson et al. 2013; de Mattos and Yeemin 2018; Rangseethampanya et al. 2021). An underwater pinnacle in the tropical region is one of the important marine ecosystems that provide similar functions and services as coral reefs. Many underwater pinnacles are generally found Thai waters, both in the Gulf of Thailand and the Andaman Sea. They are the hotspots of biodiversity, attracting substantial tourist interest for SCUBA diving (Sutthacheep et al. 2020; Aunkhongthong et al. 2021).

Marine biodiversity-based tourism has developed around the world during the last decades (Cisneros-Montemayor et al. 2013; Giglio et al. 2020). Recreational diving is one of the important marine tourism activities (Spalding et al 2017). Thailand has become the center of SCUBA diver training in Southeast Asia for many years (Wongthong and Harvey 2014; Hein et al. 2015). SCUBA diving tourism can generate economic benefits for coastal communities, particularly income generated by tourists (Emang et al. 2016). It may also enhance public awareness of marine and coastal ecosystems through marine ecotourism programs (Wongnutpranont et al. 2020). Effectively managing SCUBA diving tourism is needed to mitigate negative impacts on marine ecosystems. SCUBA divers usually use the diversity of marine organisms on reefs as one of the criteria for dive site selection (Uyarra et al. 2009; Giglio et al., 2015; Hausmann et al. 2017; Yeemin et al. 2021). Conservation of reef organisms is very important for sustainable tourism development.

Mu Ko Ang Thong is an archipelago in the Western Gulf of Thailand. The Mu Ko Ang Thong National Park was established in 1980 and recognized as a Ramsar site in 2002. The park is the second marine national park in Thailand and is comprised of 42 relatively small islands. The Mu Ko Ang Thong contains high coral reef biodiversity in turbid water and supports marine ecotourism. (Royal Forest Department 1998; Sutthacheep et al. 2016). Marine ecotourism is one of the tourism industry's fastest-growing subsectors internationally (Leposa 2020). The number of tourists in coastal provinces continues to increase (Masud et al. 2017; Cusack et al. 2021).) This study aimed to provide the first insight into the coral community of Hin Tai Plao, Mu Ko Ang Thong, Surat Thani Province, a SCUBA diving site with high potential to become a popular tourist destination.

2. Material and Methods

2.1 Study site

The study site, Hin Tai Plao (9° 42' 46.01" N, 99° 40' 35.56" E), is located in Mu Ko Ang Thong National Park, the Western Gulf of Thailand (Figure 1). Mu Ko Ang National Park is a marine protected area under the Department of National Parks, Plant and Wildlife Conservation management. The study of coral community on an underwater pinnacle was conducted at the depth of 5 to 12 meters.

2.2 Data collection and analysis

The coral community was investigated by SCUBA diving along a permanent belt transect with three replicates. The substrate compositions, i.e., live coral, dead coral, rubble, sand, and algae, were recorded within 50 cm of each side of the line (English et al. 1997). The coral species were identified to species level if possible, following Veron (2000). The underwater photographs were

taken by a digital camera for data recheck in the laboratory.

The macrobenthic invertebrates were examined at the same area (100 x 1 m) in which all invertebrates were counted and expressed as individuals per unit area and identified to species level, if possible. The underwater photographs were also taken with a digital camera to investigate the data further.

Reef fish were recorded and counted in a 2 m wide transect (200 m²) and identified to species level in situ with the further aid of underwater photographs and guidebooks for dubious taxa (Allen et al. 2015).

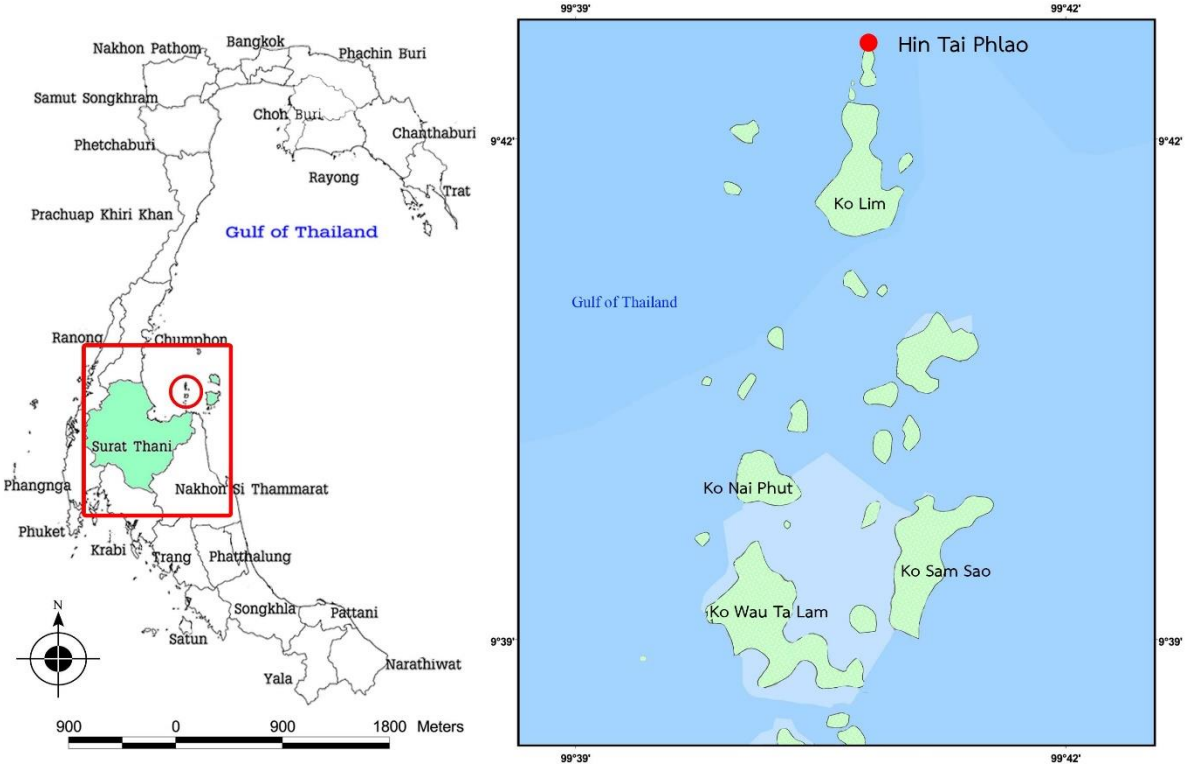

Figure 1. Map of the study site at Hin Tai Plao, Surat Thani Province, the Western Gulf of Thailand

3. Results

The benthic composition of the coral community at Hin Tai Plao mainly consisted of scleractinian coral, rock and sand (Figure 2). The mean live coral cover was 42.1%. The mean covers of dead coral and rubble were 10.6% and 5.7%, indicating a very good coral reef condition. The live coral coverage ranged from 1.2% (*Acropora millepora*) to 9.5% (*Porites lutea*). The common species included *Diploastrea heliopora*, *Lobophyllia hemprichii*, *Platygyra sinensis*, *Dipsastraea speciosa*, *Fungia fungites*, *Galaxea fascicularis*, *Montipora aequituberculata*, *Pavona decussata*, *Turbinaria frondens*, *Favites abdita*, and *Goniopora columna* **(**Figure 3).

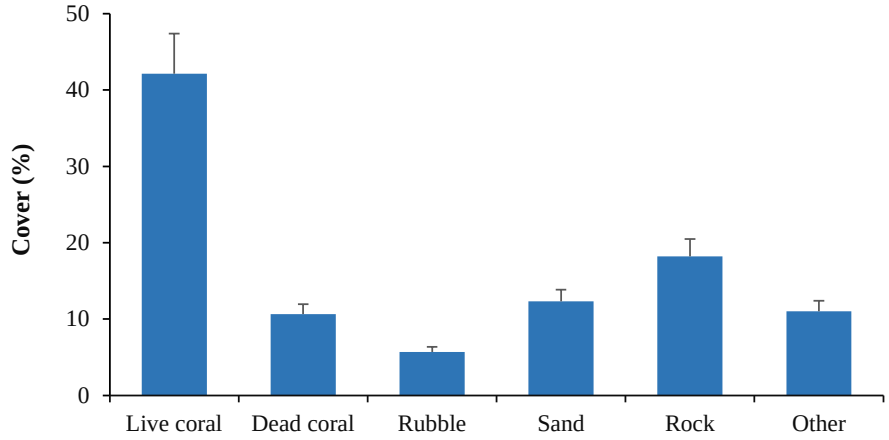

Figure 2. Benthic composition at the study site (mean ± SE)

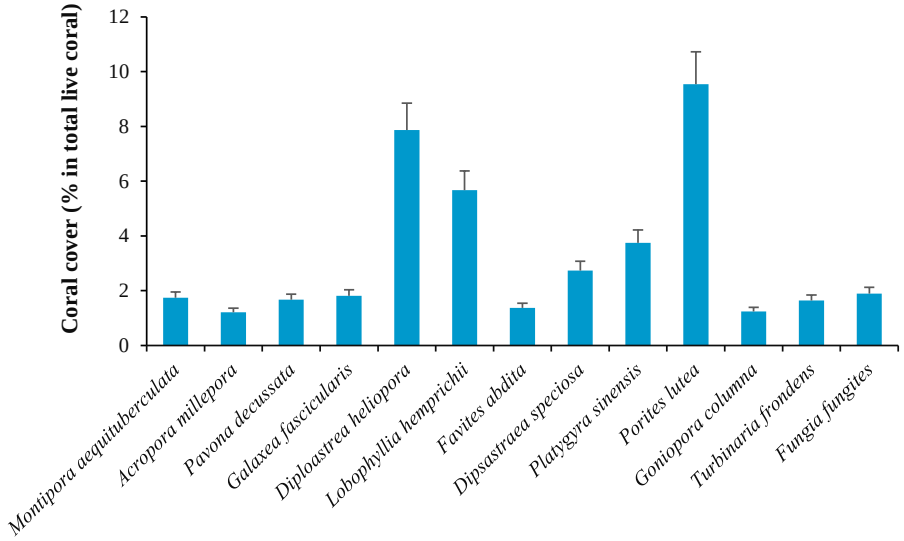

Figure 3. Species composition of live coral cover at the study site (mean ± SE)

The population density of macrobenthic invertebrates ranged from 1.3% (tube worm *Sabellastarte* sp.) to 6.0% (sea cucumber *Holothuria leucospilota*) (Figure 4). The common macrobenthic invertebrates included the half-round cardita *Beguina semiorbiculata* (12 individuals/100 m^2), the giant barrel sponge *Xestospongia testudinaria* (8 individuals/100 m^2), and the giant calm *Tridacna squamosa* (4 individuals/100 m^2). A total of 30 reef fish species were found at the study site. The most abundant reef fish was the silver demoiselle *Neopomacentrus anabatoides*. The abundant reef fish species were *Sphyraena flavicauda*, *Taeniamia fucata*, *Neopomacentrus cyanomos*, *Caesio caerulaurea*, *Pomacentrus cuneatus*. The common reef fish species included *Pomacentrus chrysurus*, *Siganus javus*, *Lutjanus lemniscatus*, *Siganus virgatus*, *Scolopsis vosmeri*, *Abudefduf bengalensis*, *Chelmon rostratus*, *Lutjanus carponotatus*, *Chaetodon octofasciatus*, *Chaetodon wiebeli*, *Siganus guttatus*, *Diodon histrix*, *Scolopsis ciliata*, *Halichoeres chloropterus*, *Upeneus tragula*, *Cheilodipterus quinquelineatus*, *Ostorhinchus endekataenia*, *Pomacanthus annularis*, *Heniochus acuminatus*, and *Diagramma pictum* (Figure 5).

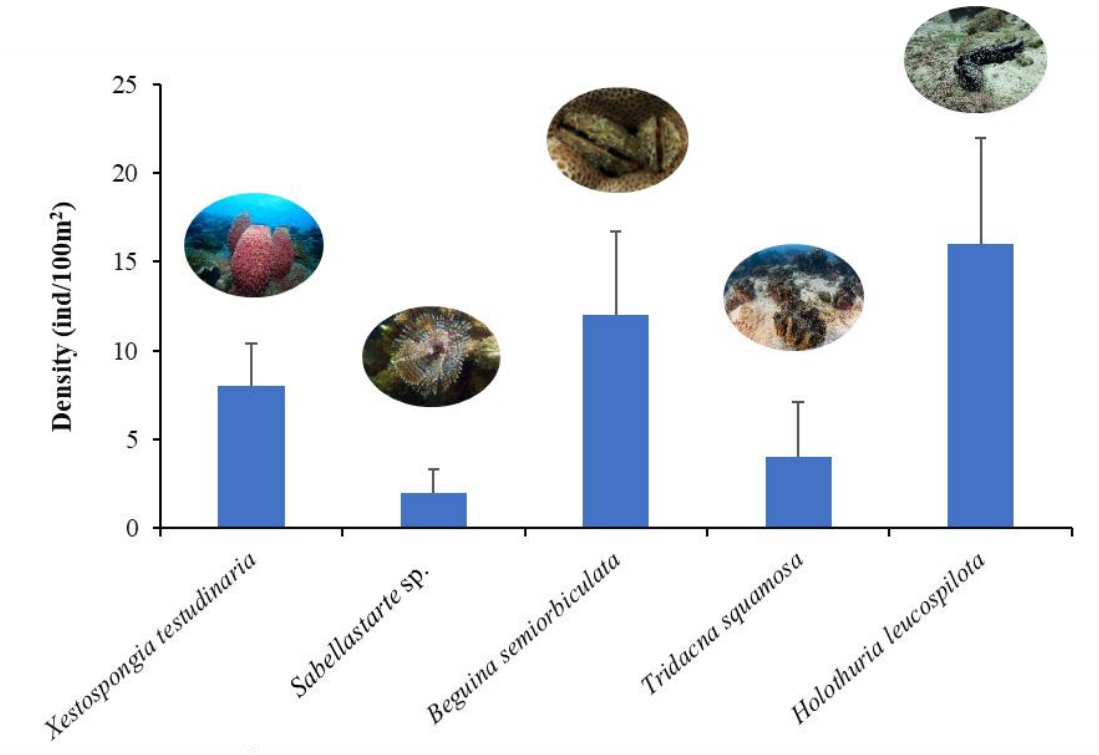

Figure 4. Abundance of macrobenthic invertebrates at the study site (mean ± SE)

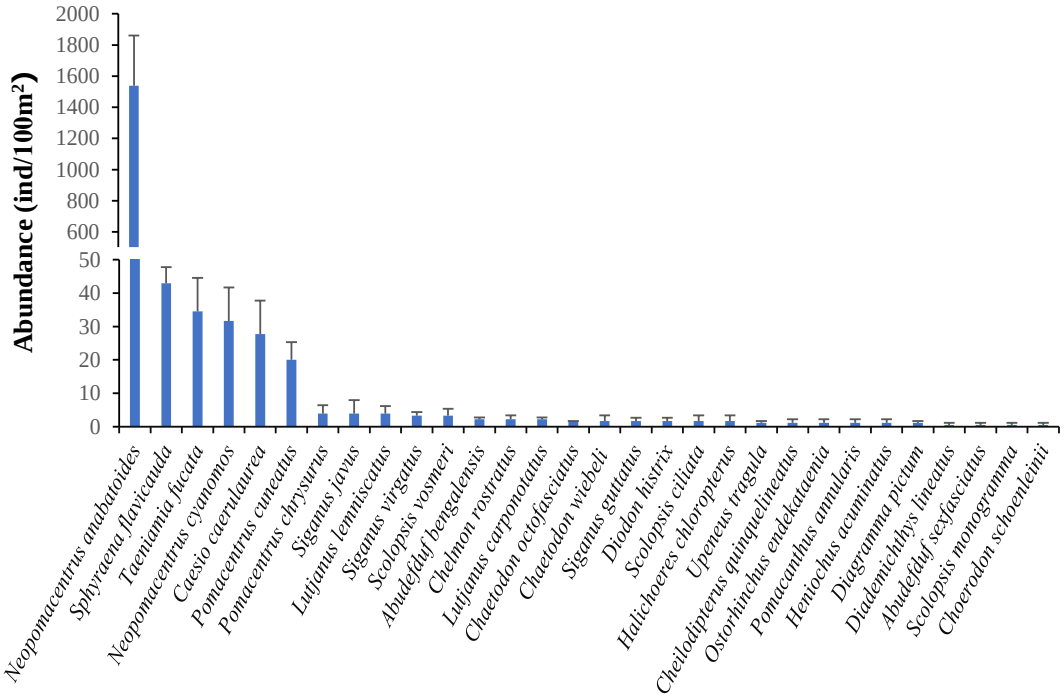

Figure 5. Species composition of reef fish at the study site (mean ± SE)

Many beautiful and interesting reef organisms were observed at the study site such as anemone coral *Goniopora columna*, giant barrel sponge *Xestospongia testudinaria*, giant calm *Tridacna squamosa*, blue ring angelfish *Pomacanthus annularis*, Hong Kong butterflyfish *Chaetodon wiebeli* and yellowtail barracuda *Sphyraena flavicauda* (Figure 6.)

Anemone coral *Goniopora columna*

Giant barrel sponge *Xestospongia testudinaria*

Giant calm *Tridacna squamosa*

Blue ring angelfish *Pomacanthus annularis*

Hong Kong butterflyfish *Chaetodon wiebeli*

Yellowtail barracuda *Sphyraena flavicauda*

Figure 6. Some beautiful reef organisms for SCUBA divers

4. Discussion

The coral reef-like environment of Hin Tai Plao harbors a relatively high diversity of scleractinian corals with a live coral cover of over 40%. Thirteen coral taxa, 30 reef fish and 5 macrobenthic invertebrates were commonly observed. The present study revealed that Hin Tai Plao exhibited similar environmental conditions to the coral reefs in the Gulf of Thailand (Satapoomin 2000; Yeemin et al. 2009; Sutthacheep et al. 2016, 2019, 2020). This underwater pinnacle is a rich community of coral reef species such as hard corals, fish, tube worms, and sea cucumbers.

The coral reef ecosystems in the Gulf of Thailand are found in shallow waters with high turbidity (Sakai et al. 1986; Chou et al. 1991; Sudara et al. 1991; Wattayakorn, 2006; Yeemin et al. 2013). The underwater pinnacle Hin Tai Plao is in deeper waters (5 – 12 m.), compared to coral reefs in the Western Gulf of Thailand, can be a good habitat for hard corals and other reef animals. Mesophotic reef studies have showed the potential of deep reefs as refugia for reef organisms because they are more stable environmental conditions and are less susceptible to coral bleaching events, heavy storms and pollution (Lesser et al. 2009; Bongaerts et al. 2010). Many coral reefs in the Gulf of Thailand are in nearshore areas and experienced human impacts, particularly high turbidity and water pollution derived from coastal development (Wattayakorn 2006; Heery et al. 2018). The long-term changes of coral communities in the Western Gulf of Thailand (2004-2010) were assessed by integrated examination of sedimentation rates, coral community structures and coral recruitment patterns, revealing that the sedimentation rates during the study periods had means ranging from 29.49-59.53 $mg/cm^2/d^1$. The coral community structures did not change much during the study periods, with means of live coral cover 20.47-27.87% (Yeemin et al. 2013). Hin Tai Plao has high potential to be a refuge because it harbors high coral cover (over 40%), and a diversity of reef animals, compared to other reef sites in the Gulf of Thailand, which are under 50% of live coral cover (Yeemin et al. 2009; Pengsakun et al. 2019). The coral *Porites lutea* is the most dominant coral species at Hin Tai Plao and it is also the most abundant coral taxa in most reef sites in the Gulf of Thailand (Yeemin et al. 2009; Sutthacheep et al. 2012, 2018), because of its tolerance to turbid waters, low salinity and resistance to bleaching (Sakai et al. 1986; Yeemin et al. 2009, 2013; Sutthacheep et al. 2013; Pengsakun et al. 2019). This hard coral species is one of the key reef builders (Goreau 1963), and its ecological function is as a shelter for several benthic invertebrates and reef fish (Hylleberg 1994; Lieske and Myers 2001; Niyomthai et al. 2019; Yeemin et al. 2021). Hin Tai Plao is different from other underwater pinnacles in Mu Ko Angthong, which are not occupied by corals. Hin Tai Plao shows high potential for SCUBA diving because of its complex reef structures, supporting a high diversity of beautiful reef organisms. Several underwater pinnacles in the Western Gulf of Thailand should be developed and promoted as marine ecotourism destinations. Some underwater pinnacles can be protected for fishery resources and support sustainable fisheries. Developing new dive sites can reduce pressures from recreational diving activities and enhance natural coral recovery in main dive sites. Coral reefs are usually popular marine ecotourism sites, particularly snorkeling and SCUBA diving which are increasing in the past decades (Wood 2001; Spalding et al. 2017; Wongnutpranont et al. 2020; Yeemin et al. 2021). The beautiful and

interesting reef animals, especially anemone coral *Goniopora columna*, giant barrel sponge *Xestospongia testudinaria*, giant calm *Tridacna squamosa*, blue ring angelfish *Pomacanthus annularis*, Hong Kong butterflyfish *Chaetodon wiebeli* and yellowtail barracuda *Sphyraena flavicauda*, can support this underwater pinnacle to SCUBA divers. However, the recreational carrying capacity of Hin Tai Plao should be examined as a management tool to reduce pressures from SCUBA diving activities (de Matos and Yeemin 2018; Sutthacheep et al. 2018; Yeemin et al. 2018; Rangseethampanya et al. 2021).

The severe coral bleaching events occurred in the Gulf of Thailand in the years 1998 and 2010 (Yeemin et al. 2009; Hoeksema et al. 2012; Sutthacheep et al. 2013). Some inshore and offshore reef sites in the Western Gulf of Thailand, such as Ko Losin offshore reef sites and Mu Ko Chumphon nearshore coral reefs showed low resilience to coral bleaching events (Sutthacheep et al. 2019). However, relatively low coverages of dead coral and rubble were observed at Hin Tai Plao, implying that its coral community is highly tolerant to coral bleaching events. Some coral reef ecosystems in the Gulf of Thailand have declined remarkably and they are consistent with most coral reefs in the world. Coastal development, fishing and tourism activities may have resulted in coral reef degradation. Appropriate management intervention, particularly reducing threats from tourism, water pollution, sedimentation and fisheries to coral reefs (Suraswadi and Yeemin 2013). Active coral restoration at Hin Tai Plao may not be needed if there is no severe anthropogenic disturbance. The number of divers should be controlled to be at below the carrying capacity level. Strict law enforcement is required to mitigate any negative impacts on this coral community.

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