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First quantitative ecological study of the Hin Pae pinnacle, Mu Ko Chumphon, Thailand

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Abstract. The Western Gulf of Thailand holds a rich set of coral reef communities, especially at the islands of Mu Ko Chumphon Marine National Park, being of great importance to Thailand's biodiversity and economy due to its touristic potential. The goal of this study was to provide a first insight on the reef community of Hin Pae, a pinnacle located 20km off the shore of Chumphon Province, a known SCUBA diving site with the potential to become a popular tourist destination. The survey was conducted during May 2019, when a 100m transect was used to characterize the habitat. Hin Pae holds a rich reef community with seven different coral taxa, seven invertebrates, and 44 fish species registered to the moment, besides a high coral cover with more than 50% of live coral. These results put this pinnacle among the richest reef sites in the Gulf of Thailand, whilst its clear and deep water could represent a more stable environment and a refuge to coral reefs biodiversity. Furthermore, the rich community holds a high touristic potential with several ornamental species such as sea anemone, starfish, and butterflyfish. However, a high percentage of dead coral (18%) indicates this site might have suffered disturbances in the past, and further monitoring is needed to understand whether there is a recovering or dying trend for its coral community, and if Hin Pae has indeed the potential to be a deep refuge for Chumphon's reefs.

Keywords: coral community, diversity, ecotourism, reef fish

1. Introduction

The Western Gulf of Thailand hosts some of the most remarkable marine ecosystems in the region due to the presence of rich coral reefs spread throughout its many islands. Reefs in this region provide essential ecosystem services, as food sources, capital income from tourism and small-scale fisheries, as well as coastal

protection. These ecosystems also play significant roles in the Gulf of Thailand regarding public awareness of coastal resources conservation (Cesar, 2000; Yeemin et al., 2006; Wilkinson, 2008). Consequently, coral reefs hold significant benefits to the socioeconomic development in Thailand.

Chumphon Province has several marine tourism hotspots, such as the islands in Mu Ko Chumphon National Park. Visitation in the area steadily grows between 4 and 7% a year, from 1.2 million tourists in 2014 to around 1.52 million in 2018 (Ministry of Tourism and Sports, 2018). The rising number of tourists in Chumphon province increases anthropogenic pressures on coral reefs in visitation areas, slowing down the natural recovery of declined coral reefs. Due to its high megafaunal diversity, Hin Pae pinnacle, located in Mu Ko Chumphon National Park, is a tourist site in the area for snorkeling and SCUBA diving, including whale sharks and sea turtles (Yeemin et al., 2018).

Additionally, Mu Ko Chumphon National Park holds high biodiversity of fish, corals, and invertebrates (Mattos and Yeemin, 2018), in a wide range of conditions, from shallow, turbid nearshore sites such as Kula Island (Sutthacheep et al., 2019) to deep, clear water, offshore stations such as Hin Pae. Hence, this is a crucial area for the conservation of coral reefs and their associated organisms. More interest has been drawn to the coral community on pinnacles in

Chumphon Province in recent years, as these are thought to be less susceptible to natural and human disturbances (Lesser et al., 2009). Therefore, this study aims to provide a first quantitative ecological study on the species richness of the faunal community at Hin Pae pinnacle ecosystem, as well as evaluate its potential as a tourism site in the Mu Ko Chumphon National Park.

2. Materials and Methods

2.1 Study site and data collection

The study site, Hin Pae pinnacle ($10^{\circ}30'03''\text{N}$, $99^{\circ}25'26''\text{E}$), is located approximately 20 km offshore and around 300 m from Ko Ngam Yai (Figure 1). It extends from around 2 m deep at the top to more than 12 m at its bottom.

2.2 Data collection

A visual census was performed to quantify substrate cover, invertebrate, and fish abundance, consisting of a belt transect of 100 m length at a working depth ranging from 15 to 20 m, averaging 18 m. The substrate cover of live coral, dead coral, rubble, sand, and rock were

recorded within 50 cm to each side of the line ($100 \times 1 \text{ m}$), and live coral cover was evaluated as a colony/unit area, in which all coral colonies above 5 cm in diameter were counted and identified to the species level, if possible, following Veron (2000). The invertebrate censuses comprised the same area ($100 \times 1 \text{ m}$) in which all invertebrates were counted as individual/unit areas and identified to species level if possible. Quadrats were also photographed with an underwater camera to reinvestigate the data further. Fish were recorded and counted in a 2 m wide transect (200 m^2) and identified to species level in situ with the further aid of underwater photographs and guide books for dubious taxa (Allen et al., 2015).

2.3 Data analysis

The data was compiled in a digital spreadsheet and further analyzed. Fish and invertebrate density were calculated as individuals per 100 m^2 to standardize results and facilitate future comparisons. Substrate percentage cover was calculated for each category as a relative covered area, while the live coral cover was divided into each identified taxon, and their respective cover percentage was estimated.

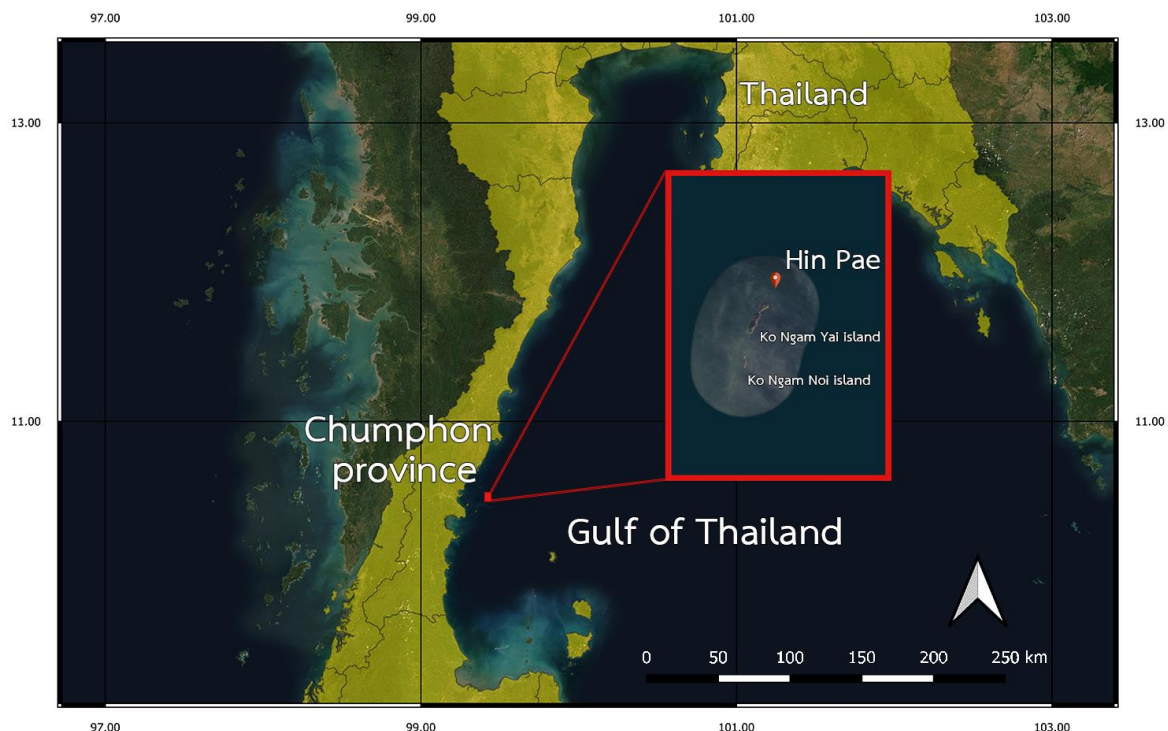


Figure 1. The location of Hin Pae in Chumphon Province, Thailand

3. Results

The results revealed that live coral represented the main substrate found at Hin Pae, while the lowest coverage was rubble, as shown in Figure 2. The dominant species of coral were *Porites lutea* ($38.45 \pm 3.20\%$), while *Galaxea fascicularis*, *Dipsastraea* spp., and *Favites* spp. had similar low abundance ($1.01 \pm 0.09\%$, $1.02 \pm 0.60\%$, and $0.94 \pm 0.09\%$, respectively) (Figure 4). The giant honeycomb oyster and starfish were the most abundant invertebrates (Table 1), while small fish species such as damselfishes and the orange lined cardinalfish represented the most abundant Actinopterygii (Table 2).

Table 1. Abundance of invertebrates at Hin Pae

Scientific name	Abundance (ind./100m ²)
<i>Viminella</i> sp.	195
<i>Antipathes</i> sp.	21
<i>Sarcophyton</i> sp.	134
<i>Heteractis magnifica</i>	41
<i>Pteria penguin</i>	41
<i>Echinaster</i> sp.	297
<i>Hyotissa hyotis</i>	587

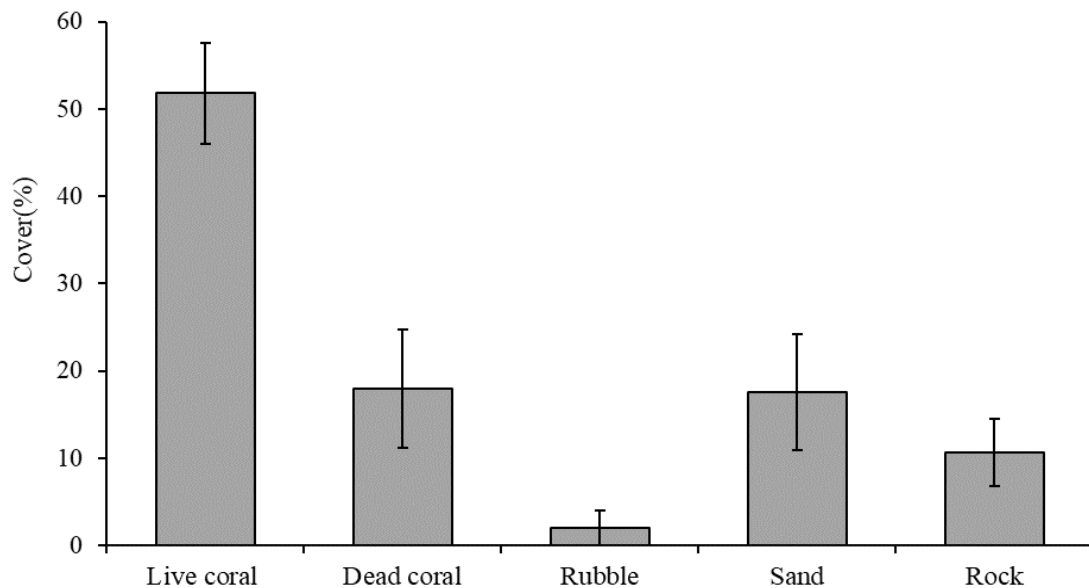


Figure 2. The average percentage of substrate cover at Hin Pae in Chumphon Province



Figure 3. Coral reefs at Hin Pae in Chumphon Province

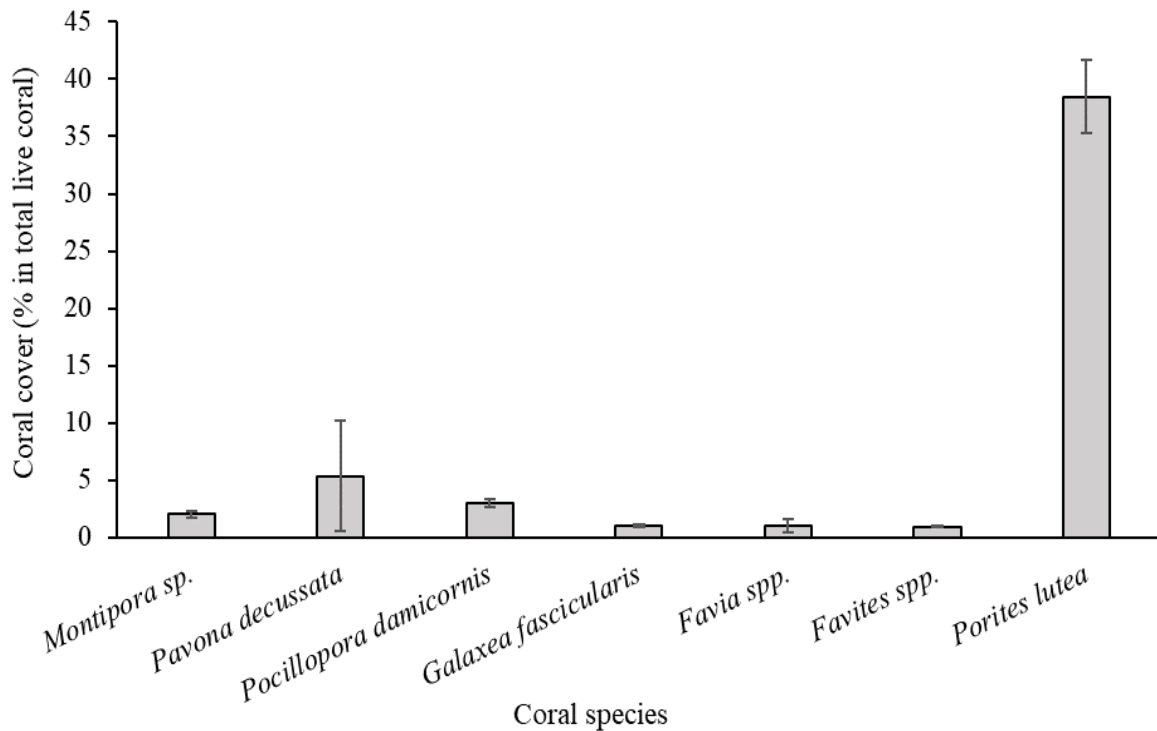


Figure 4. Species composition of live corals at Hin Pae in Chumphon Province

4. Discussion

Hosting a rich community of coral reef species such as fish, oysters, sea anemones, and several echinoderms, Hin Pae pinnacle is characterized by a typical reef like environment. Encompassing at least seven hard coral taxa, 44 reef fish, and seven more invertebrates, this first ecological study indicates that Hin Pae guards similar conditions to the richest coral reef sites in the Gulf of Thailand (Satapoomin, 2000; Yeemin et al., 2009). While most sites in the region present high turbidity and shallow waters (Chou et al., 1991; Sudara et al., 1991; Wattayakorn, 2006), the pinnacle's deep and clear waters seem to form a propitious habitat for settlement and growth of corals. Past studies have pointed to the potential of pinnacles as deep-water refugia for reef organisms, as those hold more stable conditions and are considered less susceptible to disturbances such as high temperatures and pollution (Lesser et al., 2009; Bongaerts et al., 2010). This is especially true in the Gulf of Thailand, as several coral reefs are nearshore, where anthropogenic impacts and high turbidity due to freshwater runoffs are accentuated (Wattayakorn, 2006).

Hin Pae's potential as a deep-water refuge is evidenced by the high coral cover found in the area (over 50%), especially when compared to other sites in the Gulf, which often remain under 50% of live coral cover (Yeemin et al., 2009). The dominant species on our survey was *Porites lutea*, which also figures as the most abundant taxa in several sites in the Gulf of Thailand and the Andaman sea (Phongsuwan et al., 1994; Yeemin et al., 2009; Sutthacheep et al., 2012), especially due to its tolerance to turbid waters and low salinity (Sakai et al., 1986), and reported resistance to bleaching (Yeemin et al., 2009). This scleractinian coral is among the dominating reef builders in the region (Goreau, 1963), and its presence in this site ensures shelter for several micro-benthos (Hylleberg, 1994) and a substrate above where some midwater fish species tend to remain (Lieske and Myers, 2001). These features also differentiate Hin Pae from other pinnacles in the region, which lack such coral rich environments, often dominated by rocky and sandy substrates.

Table 2. Reef fish species and their abundance at Hin Pae. Families are ordered by evolutive order following Nelson et al., 2016

Family	Species	Abundance (ind/100m ²)
Muraenidae	<i>Gymnothorax thyrsoideus</i> (Richardson, 1845)	1
Holocentridae	<i>Myripristis hexagona</i> (Forsskål, 1775)	4
	<i>Sargocentron rubrum</i> (Forsskål, 1775)	1
Apogonidae	<i>Cheilodipterus quinquelineatus</i> Cuvier, 1828	10
	<i>Cheilodipterus macrodon</i> (Lacepède, 1802)	1
	<i>Osthorhinchus cyanosoma</i> (Bleeker, 1853)	1
	<i>Taeniamia fucata</i> (Bleeker, 1853)	465
Gobiidae	<i>Parioglossus philippinus</i> (Herre, 1945)	1
Pomacentridae	<i>Chromis cineracens</i> (Cuvier, 1830)	97
	<i>Dascyllus trimaculatus</i> (Rüppell, 1829)	2
	<i>Neopomacentrus anabatooides</i> (Bleeker, 1847)	1194
	<i>Neopomacentrus cyanomos</i> (Bleeker, 1856)	525
	<i>Pomacentrus alexanderae</i> Evermann & Seale, 1907	3
	<i>Pomacentrus chrysurus</i> Cuvier, 1830	12
	<i>Pomacentrus coelestis</i> Jordan & Starks, 1901	3
Carangidae	<i>Carangoides bajad</i> (Forsskål, 1775)	2
Labridae	<i>Anampses neoguinaicus</i> Bleeker, 1878	1
	<i>Halichoeres chrysotaenia</i> (Bleeker, 1853)	3
	<i>Halichoeres leucurus</i> (Walbaum, 1792)	1
	<i>Halichoeres nigrecens</i> (Bloch & Schneider, 1801)	3
	<i>Hemigymnus melapterus</i> (Bloch, 1791)	1
	<i>Labroides dimidiatus</i> (Valenciennes, 1839)	2
	<i>Thalassoma lunare</i> (Linnaeus, 1758)	8
Gobiesocidae	<i>Diademichthys lineatus</i> (Sauvage, 1883)	2
Pempheridae	<i>Pempheris oualensis</i> Cuvier, 1831	2
Serranidae	<i>Cephalopholis boenak</i> (Bloch, 1790)	6
	<i>Cephalopholis Formosa</i> (Shaw, 1812)	6
	<i>Diploprion bifasciatum</i> Cuvier, 1828	2
	<i>Epinephelus areolatus</i> (Forsskål, 1775)	1
	<i>Epinephelus corallicola</i> (Valenciennes, 1828)	1
	<i>Epinephelus merra</i> Bloch, 1793	1
Chaetodontidae	<i>Chaetodon octofasciatus</i> Bloch, 1787	2
	<i>Chaetodon wiebeli</i> Kaup, 1863	5
Lutjanidae	<i>Lutjanus argentimaculatus</i> (Forsskål, 1775)	1
	<i>Lutjanus vitta</i> (Quoy & Gaimard, 1824)	39
Caesionidae	<i>Caesio caerulaurea</i> Lacepède, 1801	17
	<i>Caesio cuning</i> (Bloch, 1791)	34
Siganidae	<i>Siganus guttatus</i> (Bloch, 1787)	1
	<i>Siganus virgatus</i> (Valenciennes, 1835)	1
Nemipteridae	<i>Scolopsis bilineata</i> (Bloch, 1793)	1
	<i>Scolopsis ciliata</i> (Lacepède, 1802)	40
	<i>Scolopsis margaritifera</i> (Cuvier, 1830)	2
	<i>Scolopsis vosmeri</i> (Bloch, 1792)	2
Ostraciidae	<i>Ostracion cubicus</i> Linnaeus, 1758	1

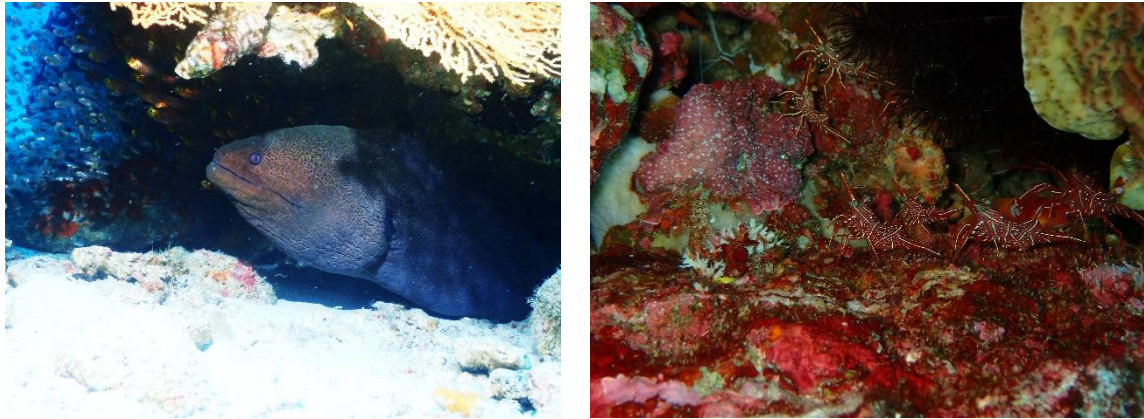


Figure 5. Marine organism at Hin Pae in Chumphon Province

In addition, the fish community around Hin Pae resembles those found in previous studies, where the dominance of small pelagic damselfishes (*Neopomacentrus* spp., *Chromis cineracens*) was also noted (Manthachitra and Cheevaporn, 2007; Songploy et al., 2013, 2017a). The high abundance of the Orange lined cardinalfish (*Taeniama fucata*) is probably related to the high coral cover since this species likes to shelter in the spaces between coral colonies and caves (Allen and Erdmann, 2012; Allen et al., 2015). Although shallow water taxa were not present in this survey, the deeper habitat held larger species, such as the planktivorous fusiliers (*Caesio* spp.), which tend to form aggregations around slope edges and are thus commonly seen around pinnacles (Lieske and Myers, 2001; Allen et al., 2015). Mesocarnivores like snappers (*Lutjanus* spp.) and groupers (*Epinephelus* spp.) were also registered, which are rarely seen on shallower waters of the Gulf (Manthachitra and Cheevaporn, 2007; Songploy et al., 2017). Altogether, those groups occupy larger home ranges than smaller shallow water species, besides holding high ecologic and economic relevance (Jones et al., 1991; Levin and Grimes, 2002; Farmer and Ault, 2011).

All considered, Hin Pae displays a rich contemplative habitat, holding high potential for SCUBA diving due to its complex coral structures, supporting a species rich environment. In general, coral reefs are the most popular environments for marine eco-tourism, and interactive activities such as snorkeling and SCUBA diving are increasingly gaining adepts over the past years (Wood, 2001; Spalding et

al., 2017). The aggregated contemplative value of a coral rich environment with abundant invertebrates such as sea anemone, starfishes, and giant oysters (Table 1.), as well as ornamental reef fish such as the Hongkong butterflyfish (*Chaetodon wiebeli*) and the neon damselfish (*Pomacentrus coelestis*) (Table 2), demonstrate a high potential of this area to attract tourists. In addition, the area holds a capacity of 15-18 divers per time, making it an excellent place to reduce pressures from main SCUBA diving sites (Sutthacheep et al., 2018; Yeemin et al., 2018).

However, high coverage of dead coral was also registered in Hin Pae, which might indicate previous bleaching events affecting the area. In fact, at least two mass bleaching events happened in the Gulf of Thailand in the past three decades (Hoeksema et al., 2012; Sutthacheep et al., 2013b, 2013a), causing up to 90% of bleaching and 49% of mortality (Yeemin et al., 2009; Sutthacheep et al., 2012; 2013a), in addition to less extensive bleaching in 2016. Previous studies also point that even a decade years after mass bleaching events, coral communities were not completely recovered (Yeemin et al., 2009; Yucharoen et al., 2015). Thus Hin Phae's high coverage of dead coral might be a consequence of past bleaching. Furthermore, this might evidence a higher sensibility to heat disturbances than expected to pinnacle environments. Further monitoring is needed to understand whether these events could threaten this habitat and its associated species.

Our study indicates that the Hin Pae pinnacle holds a rich coral reef fauna and a significant conservation potential for its high coral cover and fish diversity, and we expect the invertebrate and fish species list to be expanded as more surveys are done. This first quantitative ecological study should be used as a baseline for future studies in the area in which coral cover, invertebrate, and fish dominance can be compared. Furthermore, the area has a higher touristic potential than its current use and could become a popular diving site in the Gulf of Thailand. Lastly, continuous monitoring is recommended to understand if there is a tendency of increasing coral mortality or recovery in this pinnacle.

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