ORIGINAL PAPER

Coral community structures on shallow reef flat, reef slope and underwater pinnacles in Mu Ko Chumphon, the Western Gulf of Thailand

Wiphawan Aunkhongthong[a], Thamasak Yeemin[a], Ploypailin Rangseethampanya[a], Charernmee Chamchoy[a], Chainarong Ruengthong[b], Watchara Samsuvan[b], Montaphat Thummasan[c], Makamas Sutthacheep[a, *]

[a] Marine Biodiversity Research Group, Faculty of Science, Ramkhamhaeng University, Bangkok, Thailand
[b] Chumphon Marine National Park Operation Center 1, Department of National Parks, Wildlife and Plant Conservation, Chumphon Province, Thailand
[c] Green Biology Research Division, Research Institute of Green Science and Technology, Shizuoka University, Shizuoka 422-8529, Japan

*Corresponding author: *smakamas@hotmail.com*

Received: 22 August 2020 / Revised: 28 April 2021 / Accepted: 29 April 2021

Abstract. The coral reef ecosystem is the most diverse and productive marine ecosystem in the world. Coral reefs provide high species diversity which enhances a community survival rate when the condition of the environment is changed. Coral reefs are commonly found widely distributed in depths up to 30m, and various environmental factors drive different community compositions. This study examined coral community structures on shallow reef flats, reef slopes, and underwater pinnacles in the Western Gulf of Thailand. The field surveys were conducted at three coral reefs, including Ko Mattra, Ko Lawa, and Ko Kula and three underwater pinnacles, i.e., Hin Thong Vo, Hin Jen Talay, and Hin Ang in Mu Ko Chumphon, using a belt transect method. The results revealed that the percentages of live coral cover at most study sites were relatively high (over 50%). We found a high species diversity of corals at the underwater pinnacles. The most dominant coral at all three study sites was Porites lutea. The other dominant corals were Favites spp., *Dipsastraea* spp., and *Diploastrea heliopora*. This study highlights the importance of underwater pinnacles in the Gulf of Thailand for their ecosystem services, particularly providing fishery products and incomes from tourism.

Keywords: coral community, diversity, *Porites lutea*, Gulf of Thailand

1. Introduction

Most coral reefs in the Indo-Pacific can be divided into four different zones: reef flat, crest, slope, and back (Bellwood et al., 2017). Community structure (total cover, intra-zonal spatial organization, diversity and dominance, size class distribution) differs in each zone in response to physical factors combined with biological interactions (Done, 1982).

The reef flat is a relatively shallow reef zone, varying about 0.5-1.5 meters in depth. This zone experiences a wide range of variations in temperature, salinity, and sediment accumulation. In addition, due to the occasional exposure to the air at low tide, corals growth is limited (Thornborough and Davies, 2011). Reef flats often show a low level in coral cover and/or diversity, mostly dominated by a few characteristic species (Mayer; 1918; Stephenson et al., 1931; Wells, 1954; 1957; Spencer-Davies et al., 1971; Morrisey, 1980). Thus, the maximum diversity of corals in shallow areas, as mentioned above, depends on wave exposure, slope, and light (Wells, 1954).

A reef slope is an extending area from the reef crest that descends into a slope to deeper water. It is represented by dense coral growth and diversity. This zone receives illumination is low due to the increasing depth. In the deeper part of the slope, the coral cover declines as light become less available. Coral communities in this area have diversity and complexity that generally exceeds that on the reef flats (Sheppard, 1982). Corals on reef slopes usually are much more subtle than on reef flats (Done, 1982). Reef slopes generally have appreciable gradients. Only a few are smoothly continuous or complex

due to structural variations, usually caused by a past decrease in sea levels or irregular growth (Sheppard, 1982).

Underwater pinnacles in the tropical region are important marine habitats that provide similar functions and services as coral reefs. The structure of the underwater pinnacle influences the diversity and composition of reef-associated organisms. They hold varied characteristics, which could be either wholly submerged or exposed over the surface.

The objective of this study was to examine the coral community structures on shallow reef flats, reef slope, and underwater pinnacles in the Western Gulf of Thailand and provide further insights on the ecology of these areas. Currents data are limited.

2. Materials and Methods

2.1 Study sites

This study was carried out on coral reefs with three different characteristics. The shallow reef flat and reef slope at Ko Mattra, Ko Lawa, and Ko Kula, and three underwater pinnacles, including Hin Thong Wo, Hin Jen Talay, and Hin Ang were observed (Table 1 and Figure 1) All study site is located in Mu Ko Chumphon National Park, Chumphon Province, the Western Gulf of Thailand.

2.2 Survey methods

Field surveys were conducted on shallow reef flats (about 0.5-1.5 meter in depth), reef slopes (about 2-7 meter in depth), and underwater pinnacles (about 5-12 meter in depth) (Figure 2). The coral communities were investigated by SCUBA diving along a permanent belt transect with three replicates. The substrate cover of live coral, dead coral, rubble, sand, and algae were recorded within 50 cm to each side of the line (English et al. 1997). The coral species were identified to genus and/or species level if possible, following Veron (2000). An underwater camera took photographs for data recheck in the laboratory
.

2.3 Statistical analysis

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 and expressed in percentage. Diversity values were analyzed by Shannon Wiener's diversity index (Krebs, 1989) to characterize the local diversity, to make comparisons among reef zone. Furthermore, evenness values were analyzed by the Pielou index (Pielou, 1966).

Table 1. Location of each study site

Reef zone	Study site	Location	
Shallow reef flats and Reef slopes	Ko Mattra	10°24'6.96"N	99°21'5.22"E
	Ko Lawa	10°21'43.71"N	99°18'28.39"E
	Ko Kula	10°15'35.87"N	99°15'20.99"E
Underwater pinnacles	Hin Thong Wo	10°01'14.0"N	99°15'17.0"E
	Hin Jen Talay	9°48'09.1"N	99°18'22.4"E
	Hin Ang	9°50'28.1"N	99°14'10.1"E

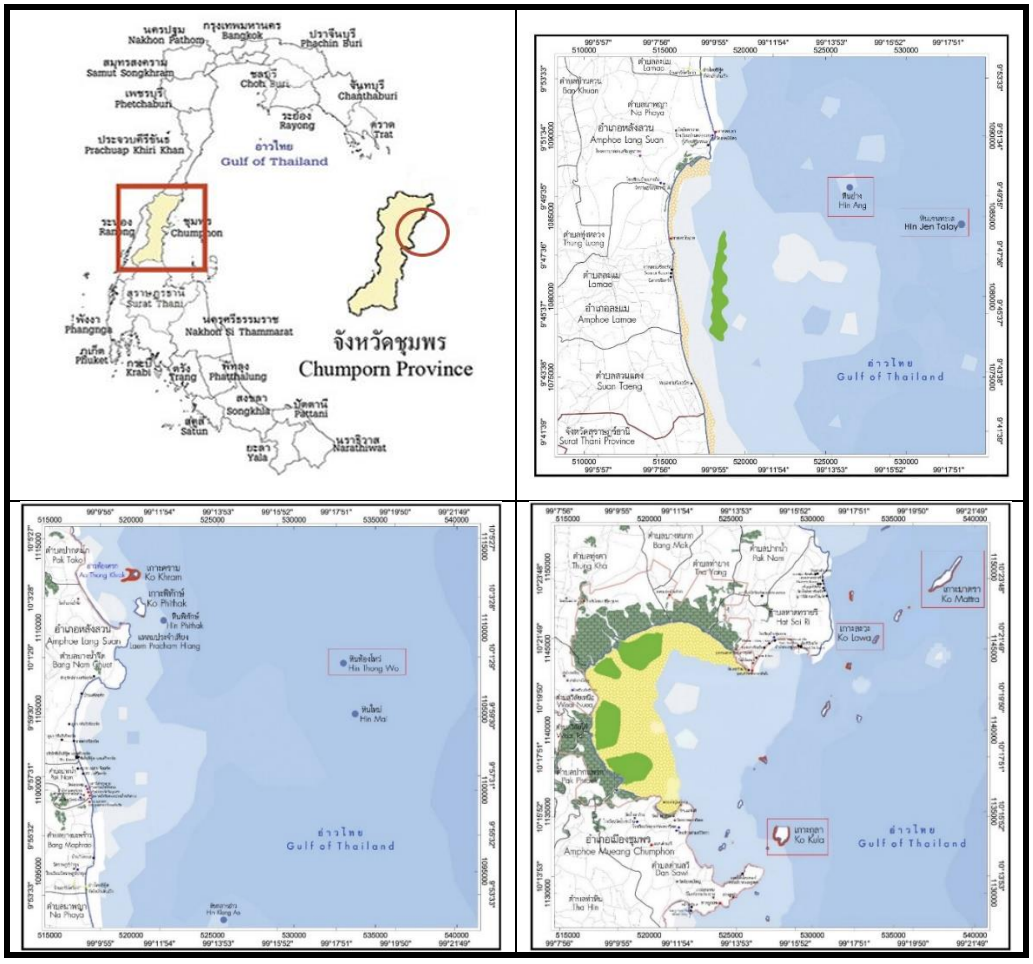

Figure 1. Location of each study site

3. Results

3.1 Coral coverage

The results indicated that the percentages of live coral coverage at most study sites were relatively high. The highest live coral cover of shallow reef flat was found at Ko Mattra (67.50±8.09%), while the lowest one was found at Ko Kula with (9.67±1.16%). The highest live coral cover of reef slope was also found at Ko Mattra (68.11±6.75%), while the lowest one was found at Ko Lawa (50.70±7.52%). The underwater pinnacle, Hin Thong Wo, showed the highest live coral cover (66.60±9.79%), while the lowest one was observed at Hin Ang (35.01±4.20%), as showed in table 2

3.2 Coral species composition

A total of 35 species were recorded in this study. Coral communities of reef slope showed a high coral diversity, while the lowest one was observed at shallow reef flat. The coral *Porites lutea* was observed as the most dominated species at all reef zones. A total of 20 coral species were observed at reef slopes. The most dominated coral was *P. lutea,* along with *Pavona decussata*, *Goniopora columna*, *Pavona varians*, and *Dipsastraea pallida*. A total of 17 coral species were observed at underwater pinnacles. The most abundant coral was *P. lutea,* followed by *G. columna*, *Favites* spp., *Dipsastraea* spp., and *Turbinaria mesenterina*. The coral species richness of shallow reef flats was relatively low because there were only thirteen corals species at the study sites. The most abundant coral was *P. lutea,* followed by *Pavona frondifera, P. decussata*, *Favites abdita*, and *G. columna*. (Figure 3).

Figure 2. Underwater photographs of coral communities at study sites (A) Coral communities of shallow reef flats, (B) Coral communities of reef slope, and (C) Coral communities of underwater pinnacles

Table 2 Average percentage cover of live corals, dead corals and other benthic components at the study sites with a standard deviation

Study sites		Live corals	Dead corals	Rubble	Sand	Algae	Other
Shallow reef flats	MT	67.50±8.09	28.40±3.41	1.00±0.12	1.86±0.22	-	1.24±0.15
	LW	57.42±6.89	24.88±2.98	6.90±0.83	9.05±1.09	-	1.75±0.21
	KL	9.67±1.16	5.14±0.62	12.33±1.48	29.67±3.56	42.69±5.12	0.50±0.06
Reef slopes	MT	68.11±6.75	17.48±4.52	2.57±1.55	11.82±3.40	-	0.02±0.03
	LW	50.70±7.52	30.78±1.42	1.87±1.72	9.25±3.76	-	7.40±3.69
	KL	57.60±0.85	6.19±4.22	0.02±0.03	30.30±6.20	-	5.89±1.15
Underwater pinnacles	TW	66.60±9.79	22.79±2.73	0.13±0.22	4.00±1.41	-	6.53±2.99
	JT	63.88±7.66	24.00±2.88	-	8.52±1.02	-	3.60±0.43
	HA	35.01±4.20	52.34±6.28	1.15±0.14	8.94±1.07	-	2.56±0.31

**MT = Ko Mattra, LW = Ko Lawa, KL = Ko Kula, TW = Hin Thong Wo, JT = Hin Jen Talay, HA = Hin Ang

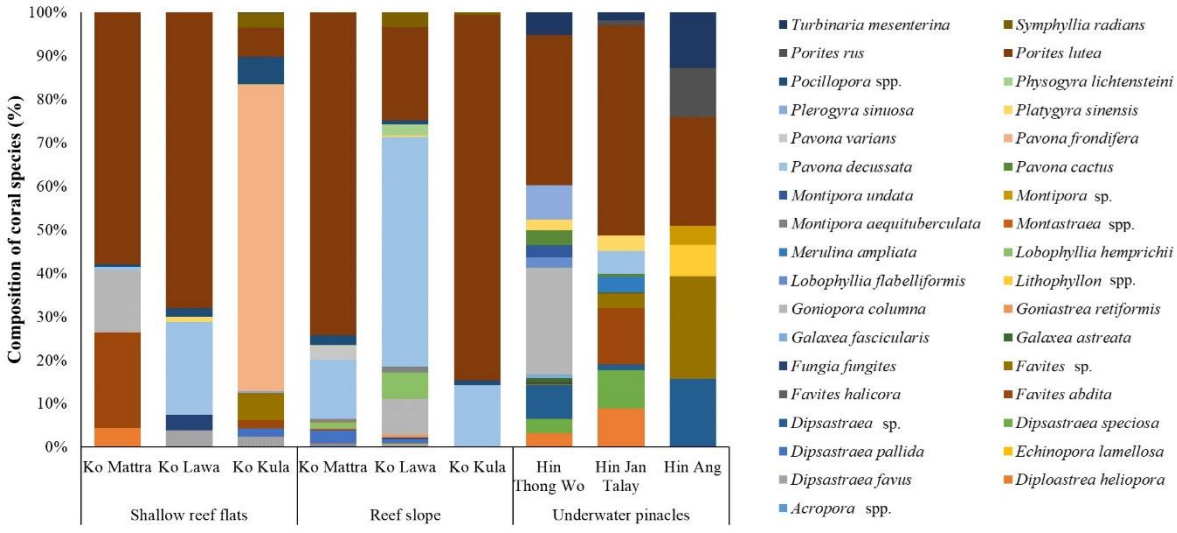

Figure 3. Composition of coral species at each study site

3.3 Coral species diversity

Both Shannon Diversity Index and Pielou Evenness Index results showed the same trend, in which the highest value was observed at underwater pinnacles. The values of the Shannon Diversity Index was ranged between 0.69±0.11-0.99±0.04, and Pielou Evenness Index was ranged between 0.27±0.02-0.41±0.06 (Table 3).

Table 3 Shannon Diversity Index and Pielou Evenness Index value in each reef zone

Study site	Shannon Diversity Index (H')	Pielou Evenness Index (J')
Shallow reef flats	0.72±0.02	0.37±0.06
Reef slopes	0.69±0.11	0.27±0.02
Underwater pinnacles	0.99±0.04	0.41±0.06

4. Discussion

The massive coral *Porites lutea* was the most abundant coral in the Gulf of Thailand due to *Porites lutea* can grow in turbid water and low salinity (Sakai et al., 1986; Yeemin et al., 2009). Each part of the coral reef has a different characteristic. Reef flats experience various physical stress such as temperature, salinity, sedimentation, and accumulation, along with daily exposure to the sunlight when the tide is low (Brown and Dunne, 2008; Camp et al., 2018). These physical environmental factors may limit overall coral growth and development (Glynn, 1976), which results in this part of a reef representing low coral richness. In addition, coral species diversity has increased in a zone dominated by a single species largely through non-lethal fragmentation and transportation, but it has decreased in a zone of most equitable species distribution (Dollar, 1982).

The coral communities in our study were similar when compared to other studies in this region. However, the coral communities of shallow reef flat at Ko Kula showed a high abundance of macroalgae similar to the coral communities at Ko Samui (Yeemin et al., 2009; Sakai et al., 2018; Sutthacheep et al., 2019). Degraded coral reefs are frequently associated with changes in community structure when macroalgae become the dominant component (Done, 1992; McManus and Polsenberg, 2004; Norstrom et al., 2009). Our study exhibits macroalgae-dominated communities in shallow reef flat at Ko Kula that macroalgae can restrain the recruitment and survival of corals (Hughes et al., 2007).

From the results of this study, considering a high species composition and species diversity in underwater pinnacle, it can be seen that underwater pinnacles, which might have the potential to be an essential spawning, nursery, and feeding grounds for numerous organisms, especially for coral recruitment

.

5. Conclusion

The results of this study have found that live coral coverage was relatively high at all study sites. Furthermore, high coral richness was found at reef slopes followed by underwater pinnacles. Also, the value of diversity and evenness index showed the highest value at underwater pinnacles, which represented the most diverse communities compared to other study sites. It can be seen that underwater pinnacles in the Gulf of Thailand may have an essential function for the ecosystem services, particularly providing fishery products and incomes from tourism.

Acknowledgments

We are most grateful to the staff of Marine National Park Operation Center Chumphon, Department of National Parks, Wildlife, and Plant Conservation. The staff of Marine Biodiversity Research Group, Faculty of Science, Ramkhamhaeng university assistance in the field. This research was funded by the National Science and Technology Development Agency (NSTDA) and a budget for research promotion from the Thai Government to Ramkhamhaeng University.

References

Bellwood DR, Goatley CH, Bellwood O (2017) The evolution of fishes and corals on reefs: form, function and interdependence. Biological Reviews 92(2):878-901

Brown BE, Dunne RP (2008) Solar radiation modulates bleaching and damage protection in a shallow water coral. Marine Ecology Progress Series 362:99-107

Camp EF, Schoepf V, Mumby PJ, Hardtke LA, Rodolfo-Metalpa R, Smith DJ, Suggett DJ (2018) The future of coral reefs subject to rapid climate change: lessons from natural extreme environments. Frontiers in Marine Science 5:4 doi:10.3389/fmars.2018.0000

Dollar SJ (1982) Wave stress and coral community structure in Hawaii. Coral Reefs 1(2):71-81

Done TJ (1982) Coral zonation: its nature and significance. Perspectives on coral reefs. Australian Institute of Marine Science, Townsville, p 277

Done TJ (1992) Phase shifts in coral reef communities and their ecological significance. Hydrobiologia 247:121-132

English S, Wilkinson C, Baker V (eds) (1997) Survey Manual for Tropical Marine Resources (2nd Edition). Australian Institute of Marine Science. ASEAN-Australia Marine Project. Queensland, Australia

Glynn PW (1976) Some physical and biological determinants of coral community structure in the eastern Pacific. Ecological Monographs 46(4):431-456

Hughes TP, Rodrigues MJ, Bellwood DR, Ceccarelli D, HoeghGuldberg O, McCook L, Moltschaniwskuj N, Pratchett MS, Steneck RS, Willis B (2007) Phase shifts, herbivory, and the resilience of coral reefs to climate change. Current Biology 17:360-365

Krebs CJ (1989) Ecological methodology. Harper and Row, New York, pp 107-147

Mayer AG (1918) Ecology of the Murray Island coral reef. Zoology 1(4):211-214

McManus JW, Polsenberg JF (2004) Coral-algal phase shifts on coral reefs: ecological and environmental aspects. Progress in Oceanography 60:263-279

Morrissey J (1980) Community structure and zonation of microalgae and hermatypic corals on a fringing reef flat of magnetic island (Queensland, Australia). Aquatic Botany 8:91-139

Nolan KA, Callahan JE. Beachcomber biology: The Shannon-Weiner species diversity index. Proceedings 27th Workshop/Conference of the Association for Biology Laboratory Education (ABLE), p 383

Norstrom AV, Nystrom M, Lokranta J, Folke C (2009) Alternative states on coral reefs: beyond coral-macroalgal phase shifts. Marine Ecology Progress Series 376:295-306

Pielou EC (1966) The measurement of diversity in different types of biological collections. Journal of Theoretical Biology 13:131-144

Sakai K, Yeemin T, Snidvongs A, Yamazato K, Nishihira M (1986) Distribution and community structure of hermatypic corals in the Sichang Islands, inner part of the Gulf of Thailand. Galaxea 5:27-74

Sheppard CRC (1982) Coral populations on reef slopes and their major controls. Marine Ecology Progress Series 7:83-115

Spencer-Davies P, Stoddart DR, Sigee DC (1971) Reef forms of Addu atoll, Maldives islands. Symposia of the Zoological Society of London 28:217-259

Stephenson TA, Stephenson A, Tandy G, Spender M (1931) The structure and ecology of Low Isles and other reefs. British Museum

Sutthacheep M, Chamchoy C, Pengsakun S, Klinthong W, Yeemin T (2019) Assessing the resilience potential of inshore and offshore coral communities in the western Gulf of Thailand. Journal of Marine Science and Engineering 7:408; doi:10.3390/jmse7110408

Sakai K, Yeemin T, Pensakun S, Klinthong W, Samsuvan W. Assessing coral reef resilience to climate change in Thailand. Ramkhamhaeng International Journal of Science and Technology 1(1):22-34

Thornborough KJ, Davies PJ (2011) Reef flats. Encyclopedia of Modern Coral Reefs 869-876

Veron JEN (2000) Corals of the World. Australian Institute of Marine Science. Townsville, Australia, Volume 1-3

Wells JW (1954) Recent corals of the Marshall Islands. United States Geological Survey Professional Paper 260(1):285-486

Wells JW (1957) Coral reefs. In: Treatise on Marine Ecology. Hedgpath J (ed.) Geological Society of America Memoir. 67:609-631

Yeemin T, Saenghaisuk C, Sutthacheep M, Pengsakun S, Klinthong W, Saengmanee, K (2009) Conditions of coral communities in the Gulf of Thailand: a decade after the 1998 severe bleaching event. Galaxea 11:207-217