ORIGINAL PAPER

Community structure of underwater pinnacles in Mu Ko Si Chang, the Upper Gulf of Thailand

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Received: 23 July 2024 / Revised: 29 August 2024 / Accepted: 30 August 2024

Abstract. Underwater pinnacles serve as critical habitats, support coastal protection, and contribute to human livelihoods through tourism and fishing. Coral communities on underwater pinnacles in the Upper Gulf of Thailand are important marine ecosystems that provide similar ecosystem services as coral reefs. This study aimed to examine community structure of underwater pinnacles in the vicinity of Mu Ko Si Chang, Chonburi Province in the Upper Gulf of Thailand. Four coral communities on underwater pinnacles, namely Hin Sampayu, Hin Kong Nok, Hin Kong Nai and Hin Ta Sin were studied in 2023-2024. The highest percentage of live coral cover was found at Hin Tasin (28.2%) while the lowest one was found at Hin Kong Nai (12.1%). The most dominant coral species were *Porites lutea* and followed by *Plattygyra sinensis*. The highest species diversity index was observed at Hin Kong Nai. The most dominant macrobenthic invertebrates were *Diadema setosum* and followed by *Bequina semiorbiculata*. The most abundant reef fish were *Neopomacentrus cyanomos* and followed by *Chromis cinerascens*. The two-dimensional non-metric multidimensional scaling (NMDS) plots of study sites based on the species compositions of corals, macrobenthic invertebrates, and reef fish exhibited two different groups. The present study underscores the ecological importance of the underwater pinnacles in the Mu Ko Si Chang, and emphasizes the necessity of conservation efforts to safeguard and maintain these valuable ecosystems, which face threats from climate change and other factors.

Keywords: Coral community, conservation, invertebrate, reef fish, underwater pinnacle

1. Introduction

Coral reef ecosystems comprise a variety of diverse and complex habitat configurations, such as fringing reefs that line coastlines, barrier reefs that form offshore, atolls that encircle lagoons, and isolated patch reefs scattered throughout the ocean (Stoddart 1969; Hopley 2011; Tanaka et al. 2013; Yeemin et al. 2013; Zampa et al. 2023). Different environmental conditions, such as depth, distance from shore, and exposure, contribute to forming distinct reef types. Moreover, the ecological patterns and processes along these environmental gradients exhibit predictable variations (Malcolm et al. 2010; Samoilys et al. 2019). The resilience of diverse reef structures also varies, and predicting how these patterns and processes may respond to environmental change is now central to much coral reef science (Harvey et al. 2018; Williams et al. 2019).

Underwater pinnacles are vital components of marine environments, providing numerous ecological, economic, and environmental benefits. These marine features exhibit a diverse array of morphologies, ranging from fully submerged to partially emergent above the water line. Numerous underwater pinnacles situated in the Gulf of Thailand off the coast of Thailand have the potential to evolve into alluring SCUBA diving destinations (Yeemin et al. 2020; Rangseethampanya et al. 2021; Sutthacheep et al. 2022; Yeemin et al. 2022). Additionally, underwater pinnacles help stabilize the seabed, and contribute to sustainable fisheries by offering breeding and feeding grounds for many commercial species (Galbraith et al. 2022).

Coral reefs as well as underwater pinnacles are incredibly valuable ecosystems that provide numerous benefits, often called ecosystem services (Hughes et al. 2012; Abunge et al. 2013). These vibrant ecosystems serve as critical habitats for countless marine species, supporting coastal protection and contributing to the livelihoods of millions through tourism and fishing, which is essential for sustaining reef fisheries and the tourism industry (Holstein et al. 2016; Turner et al. 2017; Gouezo et al. 2019). Additionally, these ecosystems play a significant role in carbon sequestration and offer potential for medical discoveries (Graham et al 2014; Hoegh-Guldberg et al. 2018).

Macrobenthic invertebrates are valuable bioindicators that offer a more comprehensive understanding of aquatic conditions compared to chemical and microbiological data, as they are sensitive indicators of short-term environmental changes (Idowu et al. 2005; Abdel-Gawad et al. 2014; Wang et al. 2021; Merz et al. 2023). The structure, abundance, and distribution of macrobenthic invertebrate communities are frequently influenced by a variety of water quality parameters, such as dissolved oxygen concentrations, temperature, pH, and the presence of contaminants or nutrients in the aquatic environment (Asadujjaman et al. 2012; Mieszkowska et al. 2021). The interactions between macrobenthic species and their surrounding environment are vital for maintaining the biodiversity and resilience of subtidal ecosystems. As such, understanding the distribution, diversity, and ecological roles of macrobenthic communities is essential for effective conservation and management of these fragile marine ecosystems (Glynn et al. 2010; Shepherd et al. 2013).

Reef fishes serve as fundamental components of coral reef and underwater pinnacle ecosystems, playing a critical role in the cycling of materials and the flow of energy within these marine environments (Munday et al. 2008; Parravicini et al. 2013; Ault et al. 2022.) Reef fish are a diverse group of fish species that inhabit reef ecosystems (Nañola et al. 2013; McClanahan et al. 2019; Parravicini et al. 2023). These fish are integral to the health and functioning of reef ecosystems, playing various roles such as herbivores, predators, and symbionts. They contribute to the biodiversity of coral reefs and underwater pinnacles, and are involved in processes like nutrient cycling, maintaining the balance of reef ecosystems, and supporting the food web (Fenner et al. 2012; Pinheiro et al. Sartori et al. 2021; Mattos et al. 2023; Hernández-Andreu et al. 2024). Reef fish communities are influenced by environmental conditions, habitat availability, and interactions with other species, making them complex and dynamic components of marine ecosystems (Pinheiro et al. 2015; Nugraha et al. 2020; Hadj-Hammou et al. 2021; Pinheiro et al. 2023).

The objective of this study was to examine community structure of underwater pinnacles in the vicinity of Mu Ko Si Chang, Chonburi Province, the Upper Gulf of Thailand to enhance understanding of their conditions, tourism potential, and management approaches.

2. Materials and Methods

2.1 Location of study sites

This study was undertaken across coral communities on underwater pinnacles at Mu Ko Si Chang, the Upper Gulf of Thailand, which is an island located in the Gulf of Thailand, about 12 kilometers off the coast of Sri Racha, Chonburi Province. The location, environmental conditions, and anthropogenic disturbances at each study site are summarized in Table 1. Four coral communities including Hin Sampayu, Hin Kong Nok, Hin Kong Nai and Hin Ta Sin were investigated in 2023-2024 (Figure 1).

2.2 Data collection

Coral communities were surveyed using SCUBA diving along permanent belt transects that included scleractinian corals, macrobenthic invertebrates, and reef fish. The scleractinian corals and macrobenthic invertebrates were observed and quantified within three belt transects measuring 50 x 1 m2 (English et al. 1997). The substrate cover, including live coral, dead coral, rubble, sand, and other benthic components, was recorded. Coral species were identified to the species level whenever possible, following the guidelines of Veron (2000). Additionally, photographs were taken with an underwater camera for further verification in the laboratory. All macrobenthic invertebrates were counted and identified to the species level where possible. Reef fish were observed and counted within a 2 m wide transect and identified to the species level on site, using underwater photographs and guidebooks to help with any uncertain species (Allen et al. 2015).

2.3 Data analysis

Shannon's diversity index (H') was calculated for each study site. A one-way ANOVA was used to examine differences in the species diversity index and density for corals, macrobenthic invertebrates, and reef fish across the study sites. When significant differences were identified, the Tukey HSD (Honestly Significant Difference) test was applied to determine which study sites varied. Additionally, cluster analysis and the non-multidimensional scaling method were performed to categorize study sites based on the Bray–Curtis similarity of benthic components, using PRIMER version 7.0.

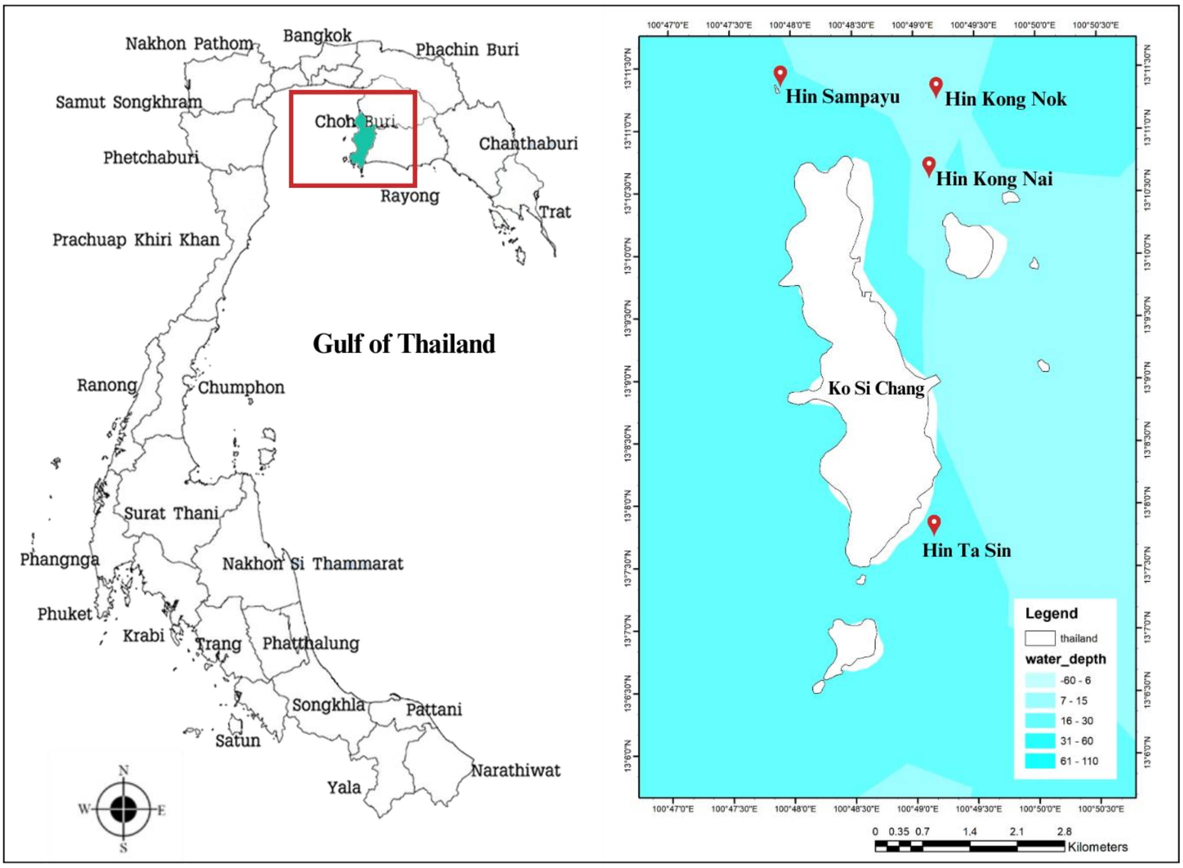


Figure 1. The location of study sites at Mu Ko Si Chang

Table 1. Location and information of the study sites at Mu Ko Si Chang

Study Sites	Latitude (N), Longitude (E)	Distance from the shore (km)	Depth (m)	Water transparency	Anthropogenic disturbances
Hin Sampayu	13°11'21.04" 100°47'54.47"	14.1	5-30	Clear	Tourism (Medium), Fishery (High)
Hin Kong Nok	13°11'28.00" 100°48'49.05"	12.4	4-10	Turbid (High)	Fishery (High)
Hin Kong Nai	13°10'39.59" 100°49'6.91"	11.2	3-9	Turbid (High)	Fishery (High)
Hin Ta Sin	13° 7'53.47" 100°49'3.03"	8.7	0-8	Turbid (Medium)	Fishery (High)

3. Results

3.1 Coral communities

The results indicated that the highest percentage of live coral cover was found at Hin Ta Sin (28.19±3.47), while the lowest one was found at Hin Kong Nai (12.09±1.49) (Figures 2). A total of 21 coral species were found at all study sites. The most dominant coral species were *Porites lutea* and followed by *Platygyra sinensis*. Other dominant coral species were *Turbinaria mesenterina*, *Dipsastraea favus*, *Pavona decussata*, *Acropora grandis* and *Pocillopora acuta* (Figure 3). The highest species diversity index was observed at Hin Kong Nai. The statistical analysis revealed that the species diversity index was significantly different among the study sites (One-way ANOVA, F = 13.52, p<0.05) (Figures 4 and 5).

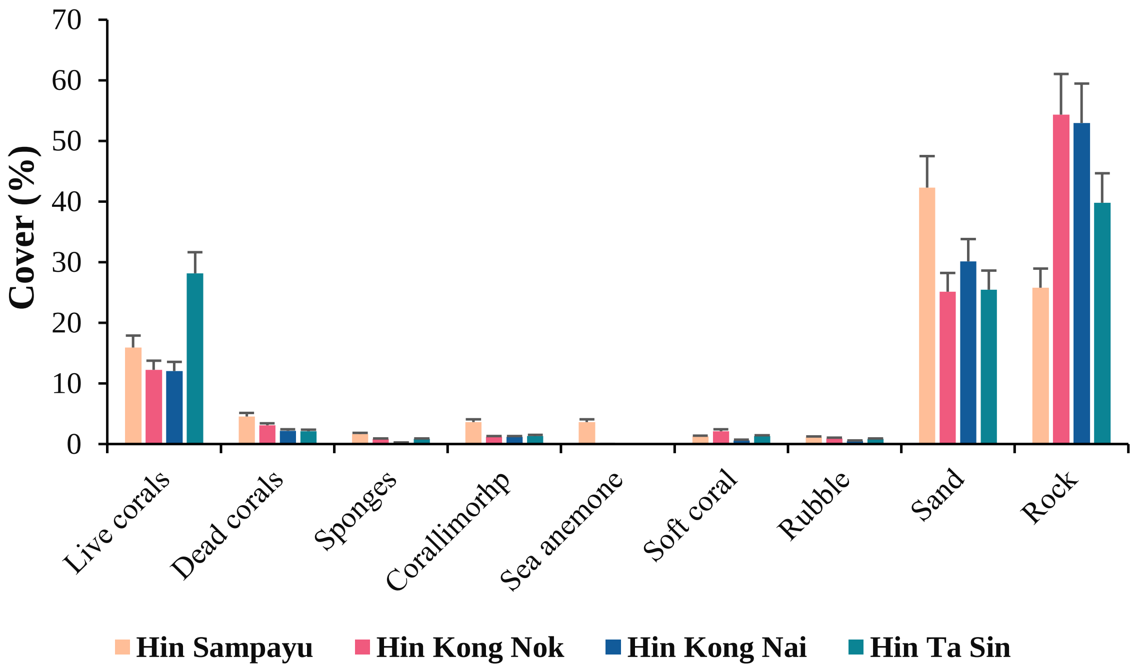


Figure 2. Average percentage cover of live corals, dead corals and other benthic components at the study sites. Error bars indicate standard error of the mean

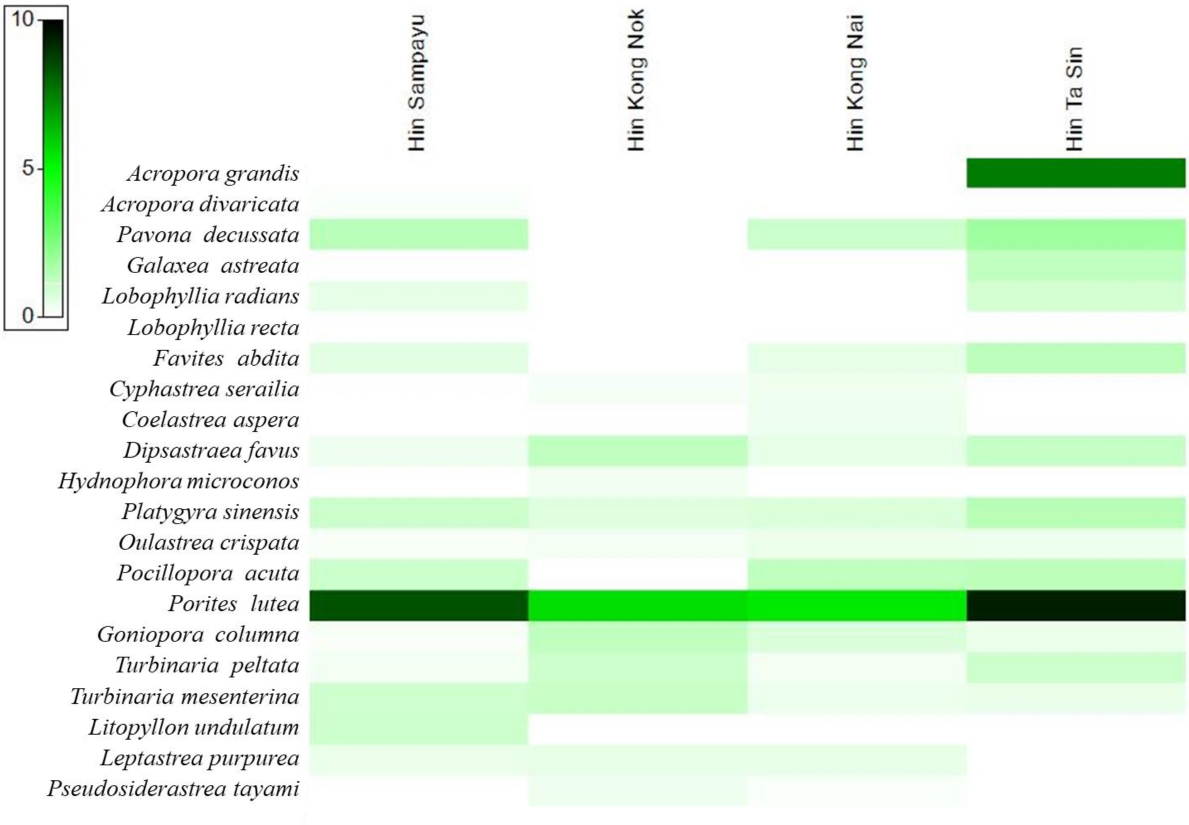


Figure 3. Species composition of live corals at the study sites

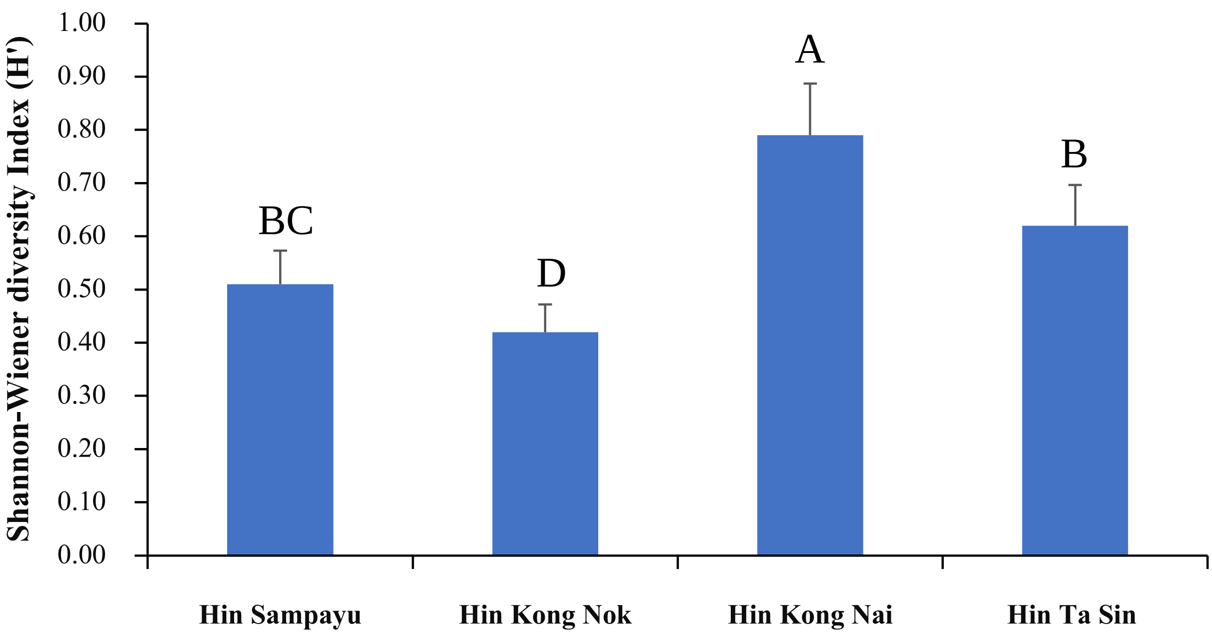
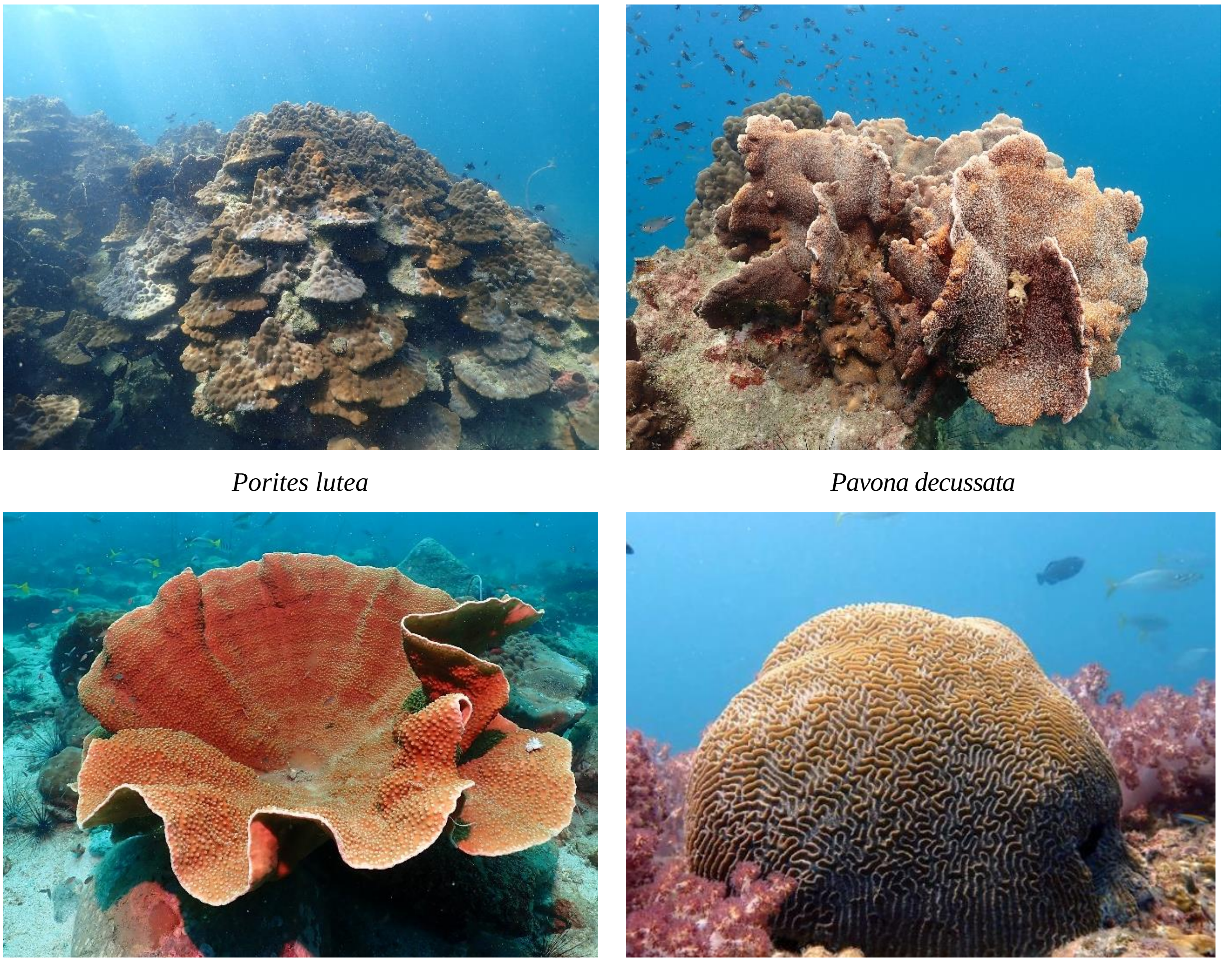


Figure 4. Shannon-Wiener index of diversity (mean ± SE) of coral species for each study site. Different letters above indicate statistical differences (one-way ANOVA, $p < 0.05$), as determined by Tukey's HSD



Porites lutea | *Pavona decussata*

Turbinaria mesenterina | *Platygyra sinensis*

Figure 5. Underwater photographs showing dominant coral species at the study sites

3.2 Macrobenthic invertebrates

The results showed that the highest density of macrobenthic invertebrates was observed at Hin Sampayu (7.01±0.82 ind.m-2) while the lowest one was found at Hin Tae Nok (3.30±0.54 ind.m-2) (Figure 6). The most dominant macrobenthic invertebrates were *Diadema setosum* and followed by Bequina semiorbiculata. Other dominant macrobenthic invertebrates were Atrina vexillum, *Junceella* sp., *Sabellastarte* sp. and *Pedum spondyloideum* (Figure 7). The highest species diversity index was observed at Hin Kong Nok. The statistical analysis showed that the species diversity index was significantly different among the study sites (One-way ANOVA, F = 56.77, $p < 0.05$) (Figures 8 and 9).

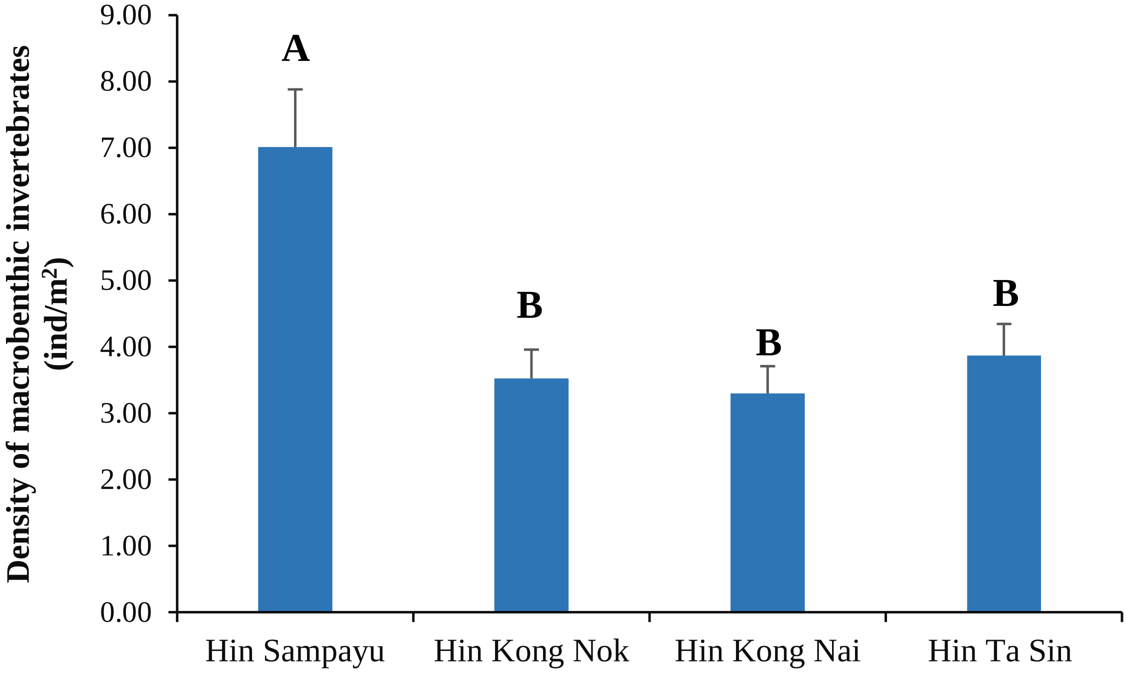


Figure 6. Densities of macrobenthic invertebrates at each study site (mean ± SE). Different letters above indicate statistical differences (one-way ANOVA, $p < 0.05$), as determined by Tukey's HSD

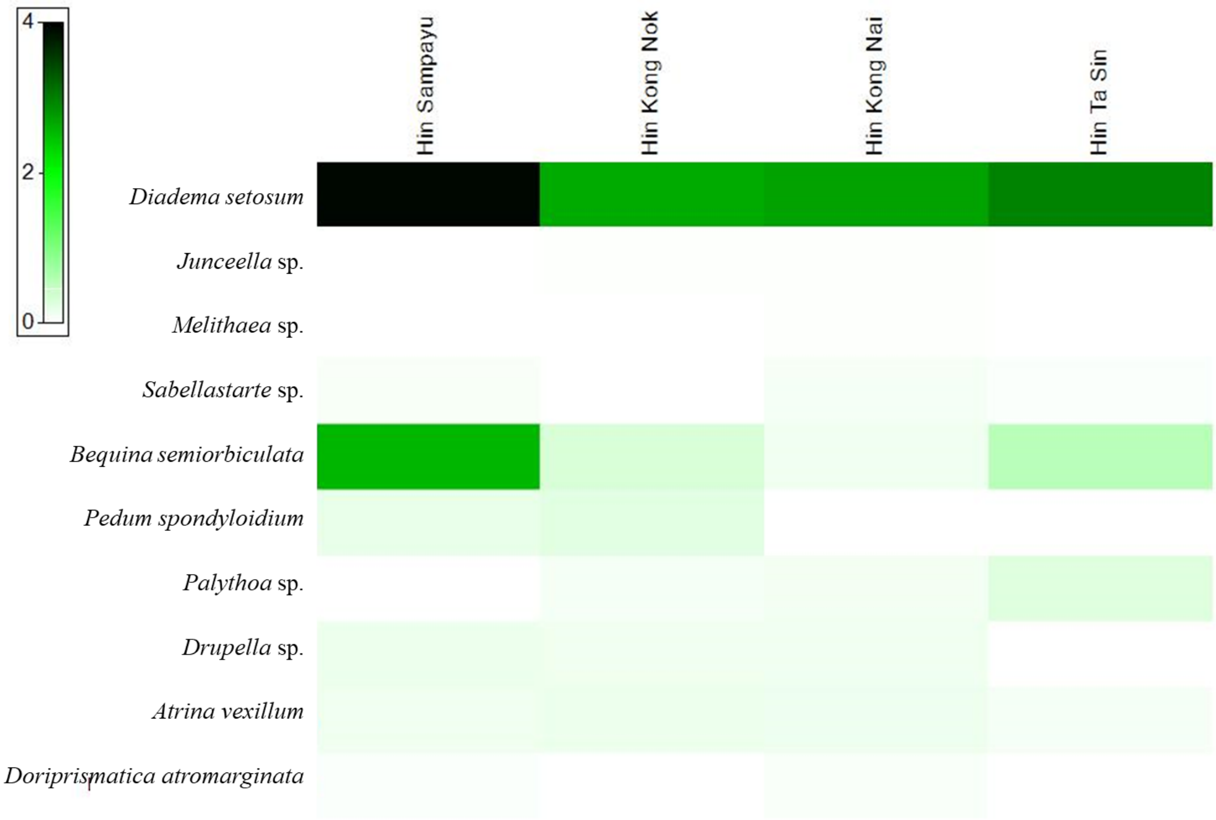


Figure 7. Species composition of macrobenthic invertebrates at each study site

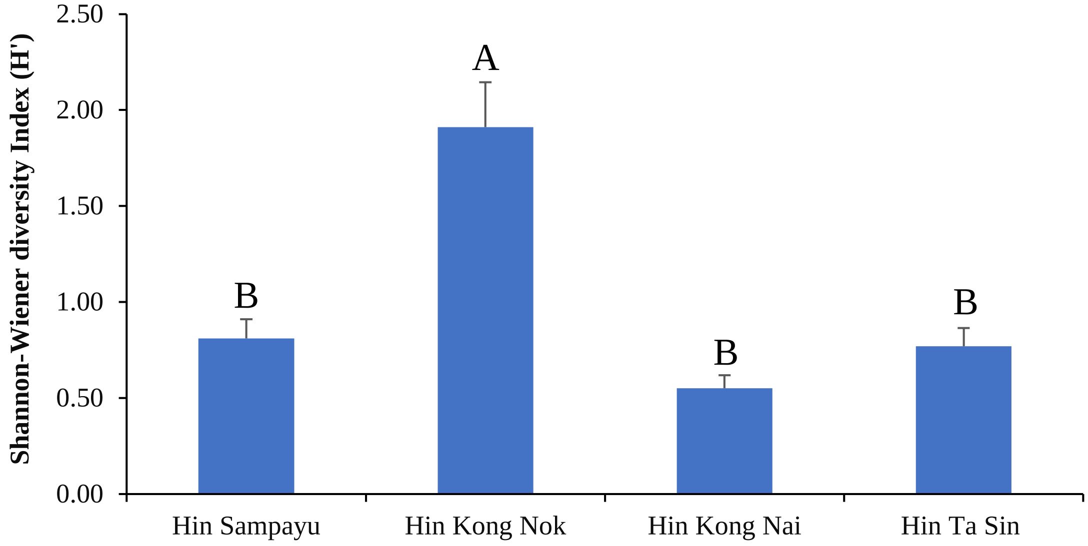
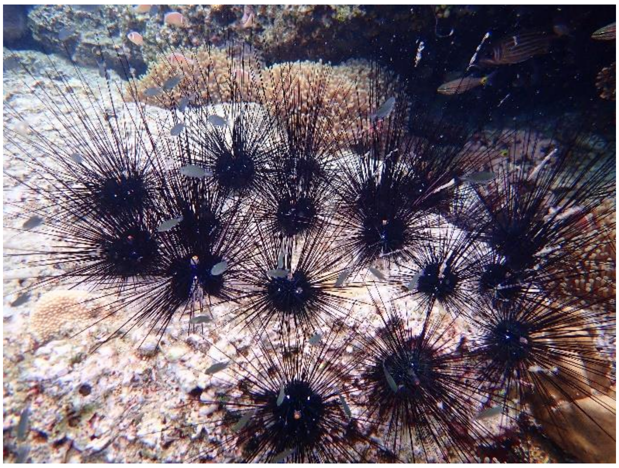


Figure 8. Shannon-Wiener index of diversity (mean ± SE) of macrobenthic invertebrates for each study site. Different letters above indicate statistical differences (one-way ANOVA, $p < 0.05$), as determined by Tukey's HSD.



Diadema setosum

Sabellastarte sp.

Pedum spondyloideum

Beguina semiorbiculata

Figure 9. Underwater photographs showing dominant macrobenthic invertebrates at the study sites

3.3 Reef fish

The results revealed that the highest density of reef fish was observed at Hin Ta Sin (2697.47±230.36 ind/100m2) while the lowest one was found at Hin Kong Nai (677.38±66.40 ind/100m2) (Figure 10). A total of 32 reef fish species were found at the study site. The most abundant reef fish were *Neopomacentrus anabatoides* and followed by *Neopomacentrus cyanomos*. Other dominant reef fish species were *Chromis cinerascens*, *Siganus javus* and *Sargocentron rubrum* (Figures 11, 12 and 13).

The two-dimensional non-metric multidimensional scaling (NMDS) plots of the study sites are based on the species compositions of coral species, macrobenthic invertebrates, and reef fish. Hin Ta Sin is isolated from the other sites, indicating that its corals, macrobenthic invertebrates, and reef fish are significantly different. Hin Kong Nok, Hin Sampayu, and Hin Kong Nai are grouped closely together, suggesting that these sites have similar marine communities in terms of corals, macrobenthic invertebrates, and reef fish. Hin Ta Sin has high population density and species diversity of the underwater pinnacles, with the complex reef structures. On the other hand, Hin Sampayu, Hin Kong Nok, and Hin Kong Nai are located close to each other and exhibit similar population density and species diversity of the underwater pinnacles. These underwater pinnacle formations are patchy and spread out. (Figure 14.)

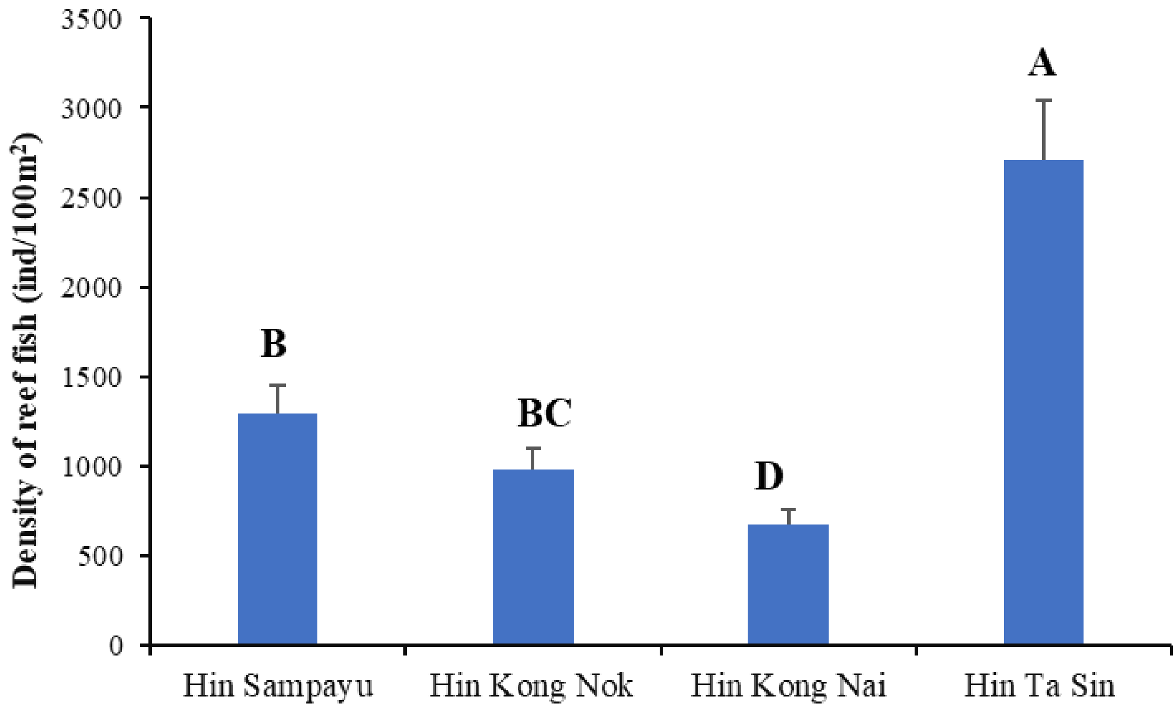


Figure 10. Densities of reef fish at each study site (mean ± SE). Different letters above indicate statistical differences (one-way ANOVA, $p < 0.05$), as determined by Tukey's HSD

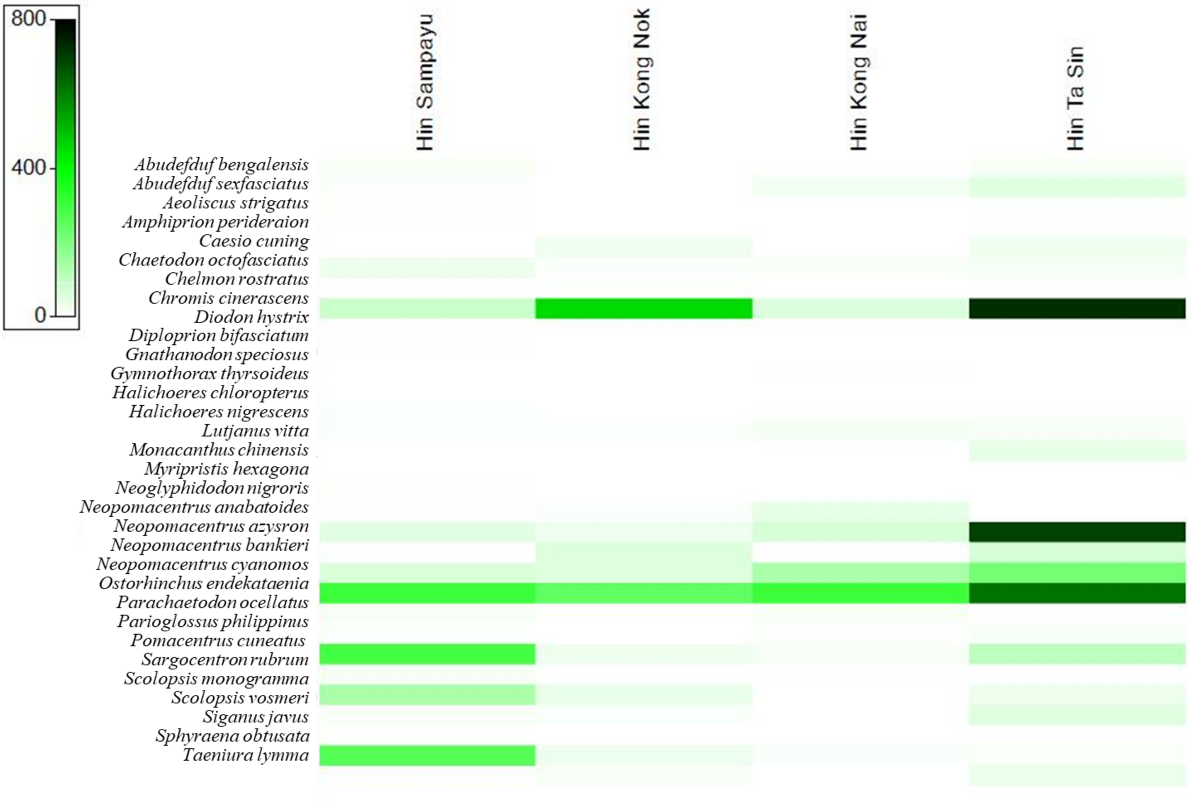


Figure 11. Species composition of reef fish at each study site

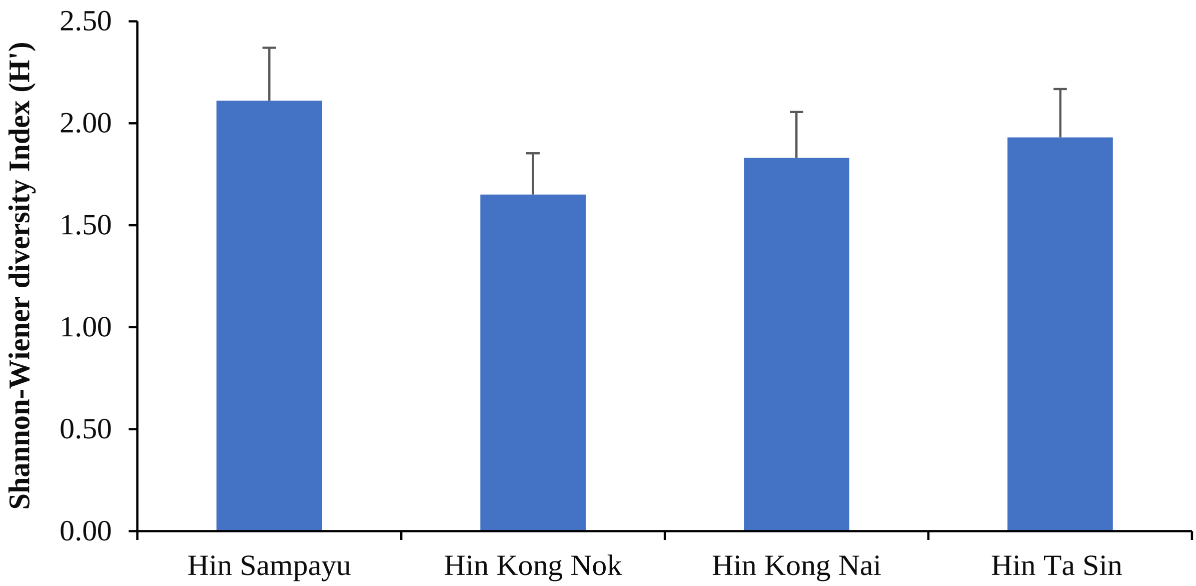


Figure 12. Shannon-Wiener index of diversity (mean ± SE) of reef fish for each study site

Neopomacentrus anabatoides

Siganus javus

Chromis cinerascens

Sargocentron rubrum

Figure 13. Underwater photographs showing dominant reef fish at the study sites

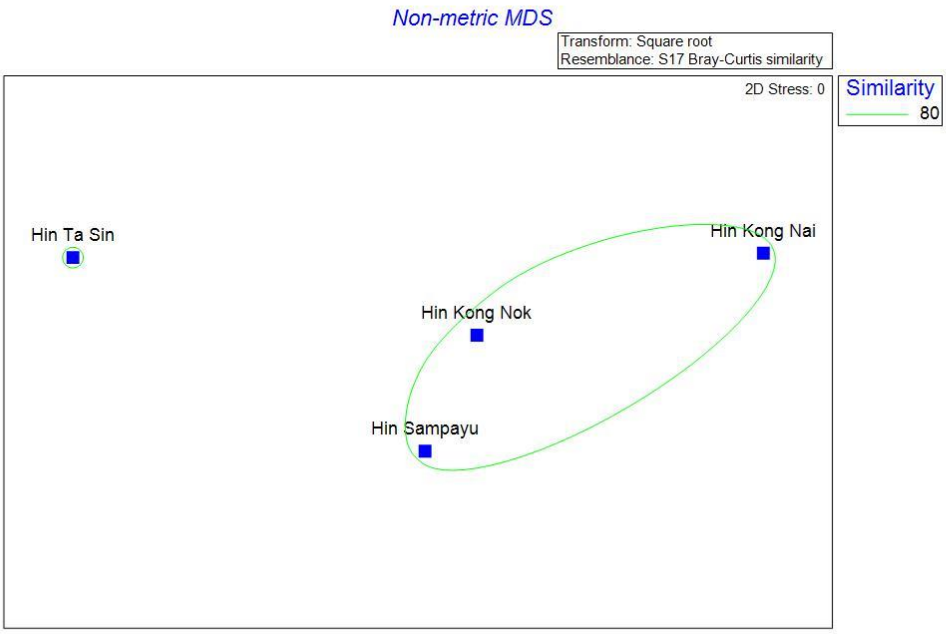


Figure 14. Two-dimensional non-metric multidimensional scaling plots depicting the species composition of corals, macrobenthic invertebrates, and reef fish across the study sites.

4. Discussion

The results revealed the highest percentage of live coral cover at Hin Ta Sin and the lowest at Hin Kong Nai. In total, 21 coral species were *Porites lutea* and *Platygyra sinensis* being the most dominant. Other prominent species included *Turbinaria mesenterina*, *Dipsastraea favus*, *Pavona decussata*, *Acropora grandis*, and *Pocillopora acuta*. The study sites are dominated by the coral *P. lutea*, which is renowned for its resilience to environmental challenges. The presence of other coral species, such as *P. sinensis* and *T. mesenterina*, suggest the adaptability of these corals to varying environmental conditions (Hughes et al. 2003; Sutthacheep et al. 2019; Yeemin et al. 2023). A total of thirty scleractinian coral species were identified at the underwater pinnacles located in Surat Thani Province. The most abundant coral species were *P. lutea*, followed by *P. acuta*. The community composition of coral communities found on these underwater pinnacles resembles that of coral reef ecosystems in the Gulf of Thailand. (Yeemin et al. 2009; Sutthacheep et al. 2018; Yeemin et al. 2023). Several underwater pinnacle ecosystems exhibited high resilience owing to favorable environmental conditions and reduced susceptibility to elevated seawater temperature anomalies, intense storms, and land-based pollution. The predominant coral species observed on underwater pinnacles, such as *Porites lutea*, *Diploastrea heliopora*, and *P. sinensis*, are the primary reef-building organisms that also provide critical shelter for benthic invertebrates and reef fish communities (Sutthacheep et al. 2018; Yeemin et al. 2023).

The primary macrobenthic invertebrates identified at the study sites include the sea urchin *Diadema setosum*, Feather Duster *Junceella* sp., the Christmas tree worm *Spirobranchus giganteus*, and the sea slug *Jorunna funebris*, are visually appealing and attract tourists, making them valuable resources for promoting marine ecotourism in the Gulf of Thailand (Piló et al. 2016; Niyomthai et al. 2019). Our findings indicate that the sea urchin Diadema setosum is a predominant macrobenthic invertebrate on the underwater pinnacles, likely because sea urchins can evade predators, particularly certain reef fish species. Additionally, human activities like overfishing and global environmental changes can influence sea urchin populations (Aunkhongthong et al. 2020; Pengsakun et al. 2020; Zirler et al. 2023). Therefore, management strategies, such as regulating sea urchin exploitation and establishing marine protected areas, are necessary.

The high density of reef fish, 4,337±587.60 ind/100m2, was found at Hin Bai, the Western Gulf of Thailand and have a high density of reef fish, reiterating the ecological function of underwater pinnacles as a shelter for these marine organisms. In this study the abundant reef fish observed on the underwater pinnacles were *Neopomacentrus anabatoides*, *Neopomacentrus cyanomos*, and *Siganus virgatus*, similar to those found on the underwater pinnacles in the Western Gulf of Thailand (Sutthacheep et al. 2022). These reef-associated fish populations can serve as valuable resources for both the tourism industry and local fisheries (Rangseethampanya et al. 2021). A previous study indicate that the underwater pinnacles harbor a high abundance of reef fish species (Yeemin et al. 2020). Some underwater pinnacles, such as Hin Khao in Mu Ko Tao, the Western Gulf of Thailand exhibited a high density and diversity of reef fish species. These underwater pinnacles have significant potential for marine-based ecotourism activities (Sutthacheep et al. 2022).

Water circulation in the Gulf of Thailand varies seasonally. Coral reefs in the Gulf of Thailand are found in shallow, turbid waters (Phongsuwan et al. 2013; Yeemin et al. 2013;

Ballesteros et al. 2018). The underwater pinnacle Hin Ang Wang in deeper waters (0–10 m.) can provide a suitable habitat for reef organisms, especially compared to shallow coral reefs in the Western Gulf of Thailand (Pengsakun et al. 2022). Underwater pinnacle ecosystems have the potential to serve as refugia for reef organisms due to their more stable environmental conditions and reduced susceptibility to disturbances (Holstein et al. 2016; Quimpo et al. 2018; Cusack et al. 2021). The underwater pinnacles in Mu Ko Si Chang, particularly Hin Sampayu and Hin Ta Sin, have high potential to be developed as marine ecotourism sites and toward to carbon neutral tourism.

Marine ecotourism tourism encourages visitors to experience diverse marine environments through sustainable (Moreno et al. 2009; Rees et al. 2010; Hernández et al. 2023). Reef-based tourism has emerged as a prominent segment of the global tourism industry (Dimmock 2007; Burke et al. 2011). SCUBA diving is a prominent form of marine tourism (Lucrezi et al. 2017). Thailand has established itself as a prominent destination for SCUBA diving education and certification within the Southeast Asian region (Asafu-Adjaye et al. 2008; Wongthong et al 2014; Sangthong et al. 2023). High volumes of tourists can overwhelm reef ecosystems, increasing stress (McLeod et al. 2021; Nama et al. 2023). Overcrowding can lead to an imbalance in the reef ecosystem, as some species may be disturbed more than others, altering the natural balance of marine life (Mcleod et al. 2018; Brandl et al. 2019; Schiettekatte et al. 2022). Mu Ko Si Chang has been extensively utilized for a variety of human activities, such as the establishment of residential communities and shipping ports.

These diverse uses have had significant impacts on the marine ecosystems, particularly the reef ecosystem (Pengsakun et al. 2019). Effective management of underwater pinnacles requires proper plans, policies, guidelines, enforcement, monitoring, and environmental education programs. Recreational diving strategies should prioritize responsible resource use, address stakeholder socio-economic needs, and provide a satisfying diving experience (Mcleod et al 2019; Schoepf et al 2023). The findings of this study suggest that marine ecotourism could be leveraged as a means to protect the coral reef ecosystems around Mu Ko Si Chang while also promoting sustainable tourism practices in the region.

The investigation revealed that the underwater pinnacles at Mu Ko Si Chang, in the Upper Gulf of Thailand, supported a diverse array of scleractinian corals, macrobenthic invertebrates, and reef fishes, particularly at the Hin Ta Sin. The underwater pinnacles in this study must be properly managed through appropriate types of management interventions. This entails establishing marine protected areas under the Marine and Coastal Resources Management Promotion Act -B.E. 2558 (2015), navigating the development process of the Locally Managed Marine Area (LMMA) approach to addressing the challenges of its local implementation and maintenance. Additionally, implementing resilience-based management (RBM) and other effective area-based conservation measures (OECMs), e.g. monitoring coral health, regulating tourism and fishing activities, and promoting community engagement, is crucial to ensuring the protection and preservation of these fragile coral ecosystems. These strategies are important for strengthening a policy on protecting 30% of global oceans by 2030 under the Kunming-Montreal Global Biodiversity Framework. Effective management of these unique coral reef ecosystems is crucial to conserve their biodiversity and ecological functions for the long-term (Sutthacheep et al.

2022b; Whomersley et al. 2022; Brown et al. 2023; Li et al. 2023).

Acknowledgements

We are most grateful to the staff of Department of Marine and Coastal Resources, Sichang island marine animal banks by communities for communities under the Royal Patronage of Her Royal Highness Princess Maha Chakri Sirindhorn, and Marine Biodiversity Research Group, Faculty of Science, Ramkhamhaeng University, for their support and assistance in the field. This research was supported by Thailand Science Research and Innovation (TSRI), National Science, Research and Innovation Fund (NSRF) by the Program Management Unit Competitiveness (PMUC), and Ramkhamhaeng University (RU).

References

Abdel-Gawad SS, & Mola HR (2014) Macrobenthic invertebrates in the main channel of Lake Nasser, Egypt. Egyptian Journal of Aquatic Research 40(4):405-414

Abunge C, Coulthard S, Daw TM (2013) Connecting marine ecosystem services to human well-being: Insights from participatory well-being assessment in Kenya. Ambio 42(8):1010–1021

Allen TD, Golden TD, Shockley KM (2015) How effective is telecommuting? Assessing the status of our scientific findings. Psychological science in the public interest 16(2): 40-68

Asadujjaman M, Hossain MB, Shamsuddin M, Amin MA, Azam AKM (2012) Occurrence and abundance of macrobenthos of Hatiya and Nijhum Dweep Islands, Bangladesh. Middle-East Journal of Scientific Research 11(2):184-188

Asafu-Adjaye J, & Tapsuwan S (2008) A contingent valuation study of scuba diving benefits: Case study in Mu Ko Similan Marine National Park, Thailand. Tourism Management 29(6): 1122-1130

Ault JS, Smith SG, Johnson MW, Grove LJW, Bohnsack JA, DiNardo GT, ... Acosta A (2022) Length-based risk analysis of management options for the southern Florida USA multispecies coral reef fish fishery. Fisheries research 249:106210

Aunkhongthong W, Phoaduang S, Wongnutpranont A, Sutthacheep M, Sangmanee K, Yeemin T (2020) Population densities of a sea urchin Diadema setosum on shallow reef flats in the Gulf of Thailand. Ramkhamhaeng International Journal of Science and Technology 3(3):13-20

Ballesteros LV, Matthews JL, Hoeksema BW (2018) Pollution and coral damage caused by derelict fishing gear on coral reefs around Koh Tao, Gulf of Thailand. Marine pollution bulletin 135:1107-1116

Brandl SJ, Tornabene L, Goatley CH, Casey JM, Morais RA, Côté IM, Bellwood DR (2019) Demographic dynamics of the smallest marine vertebrates fuel coral reef ecosystem functioning. Science 364(6446):1189-1192

Brown, J R, Eichhorst, B, Hillmen, P, Jurczak, W, Kaźmierczak, M, Lamanna, N, Shadman, M. (2023) Zanubrutinib or ibrutinib in relapsed or refractory chronic lymphocytic leukemia New England Journal of Medicine, 388(4), 319-332

Burke L, Reytar K, Spalding M, Perry A (2011) Reefs at risk revisited. Washington, DC: World Resources Institute (WRI)

Cusack C, Sethi SA, Rice AN (2021) Marine ecotourism for small pelagics as a source of alternative income generating activities to fisheries in a tropical community. Biol Conserv 261:09242

Dimmock K (2007) Scuba diving, snorkeling, and free diving. In Water-based tourism, sport, leisure, and recreation experiences (pp. 128-147)

English S, Wilkinson C, Baker V (1997) Survey manual for tropical marine resources. Australian Institute of Marine Science. 390 pp

Fenner D (2012) Challenges for managing fisheries on diverse coral reefs. Diversity 4(1):105-160

Galbraith GF, Cresswell BJ, McCormick MI, Bridge TC, Jones GP (2021) High diversity abundance and distinct fish assemblages on submerged coral reef pinnacles compared to shallow emergent reefs. Coral Reefs 40: 335-354

Glynn PW, & Enochs IC (2010) Invertebrates and their roles in coral reef ecosystems. Coral reefs: an ecosystem in transition 273-325

Gouezo M, Golbuu Y, Fabricius K, Olsudong D, Mereb G, Nestor V, ... Doropoulos C (2019) Drivers of recovery and reassembly of coral reef communities. Proceedings of the Royal Society B, 286(1897): 20182908

Graham NA, Chong-Seng KM, Huchery C, Januchowski-Hartley FA, Nash KL (2014) Coral reef community composition in the context of disturbance history on the Great Barrier Reef, Australia. PloS one 9(7): e101204

Hadj-Hammou J, Mouillot D, Graham NA (2021) Response and effect traits of coral reef fish. Frontiers in Marine Science 8:640619

Hernández MMG, Leon CJ, García C, Lam-González YE (2023) Assessing the climate-related risk of marine biodiversity degradation for coastal and marine tourism. Ocean & Coastal Management 232:106436

Hernández-Andreu R, Félix-Hackradt FC, Schiavetti A, Texeira JL, Hackradt CW

(2024) Marine protected areas are a useful tool to protect coral reef fishes but not representative to conserve their functional role. Journal of Environmental Management 351:119656

Hoegh-Guldberg O, Kennedy EV, Beyer HL, McClennen C, Possingham HP (2018) Securing a long-term future for coral reefs. Trends in ecology & evolution 33(12): 936-944

Holstein D, Smith TB, Appeldorn RS (2016) Ecosystem services provided by mesophotic coral ecosystems. In: Baker EK, Puglise KA & Harris PT (eds.) Mesophotic Coral Ecosystems - A Lifeboat for Coral Reefs? The United Nations Environmental Programme and GRID - Arendal, Nairobi and Arendal. pp. 63–66

Hughes KD, Jennings JE, Brush C, Carter S, Welter F (2012) Extending women's entrepreneurship research in new directions. Entrepreneurship theory and practice 36(3): 429-442

Hughes, T P, Kaeda, J, Branford, S, Rudzki, Z, Hochhaus, A., Hensley, M L, Radich, J P (2003) Frequency of major molecular responses to imatinib or interferon alfa plus cytarabine in newly diagnosed chronic myeloid leukemia New England Journal of Medicine, 349(15), 1423-1432

Idowu EO, & Ugwumba AAA (2005) Physical chemical and benthic faunal characteristics of a Southern Nigeria Reservoir. The zoologist 3:15-25

Li, Y, Choi, H, Leung, K, Jiang, F, Graham, D Y, Leung, W K (2023) Global prevalence of Helicobacter pylori infection between 1980 and 2022: a systematic review and meta-analysis The lancet Gastroenterology & hepatology, 8(6), 553-564

Lucrezi S, Milanese M, Markantonatou V, Cerrano C, Sarà A, Palma M, Saayman M (2017) Scuba diving tourism systems and sustainability: Perceptions by the scuba diving industry in two Marine Protected Areas. Tourism management 59:385-403

Mattos FM, Yeemin T, Sutthacheep M, Feitosa JL (2023) Biogeographic and environmental drivers of reef fish diversity in coastal islands of the Gulf of Thailand. Marine Ecology Progress Series 724: 33-46

McClanahan TR (2019) Coral reef fish communities, diversity, and their fisheries and biodiversity status in East Africa. Marine Ecology Progress Series 632:175-191

Mcleod E, Anthony KR, Mumby PJ, Maynard J, Beeden R, Graham NA, ...Tamelander J (2019) The future of resilience-based management in coral reef ecosystems. Journal of environmental management 233: 291-301

McLeod E, Shaver EC, Beger M, Koss J, Grimsditch G (2021) Using resilience assessments to inform the management and conservation of coral reef ecosystems. Journal of Environmental Management 277:111384

Mcleod, E, Anthony, K R, Mumby, P J, Maynard, J, Beeden, R, Graham, N A, Tamelander, J (2019) The future of resilience-based management in coral reef ecosystems Journal of environmental management, 233, 291-301

Merz E, Kitahara MV, Flores AA (2023) A legacy of invasive sun corals: Distinct mobile invertebrate assemblages at near-reef coral-dominated rubble. Marine environmental research 188:105974

Mieszkowska N, Firth L, Bentley M (2013). Impacts of climate change on intertidal habitats. MCCIP Science Review 2013:180-192

Moreno A, & Amelung B (2009) Climate change and coastal & marine tourism: Review and analysis. Journal of Coastal Research 1140-1144

Munday PL, Jones GP, Pratchett MS, Williams AJ (2008) Climate change and the future for coral reef fishes. Fish and Fisheries 9(3): 261-285

Nama S, Shanmughan A, Nayak BB, Bhushan S, Ramteke K (2023) Impacts of marine debris on coral reef ecosystem: A review for conservation and ecological monitoring of the coral reef ecosystem. Marine Pollution Bulletin 189: 114755

Nañola CL Jr, Aliño PM, Carpenter KE (2011) Exploitationrelated reef fish species richness depleted in the epicenter of marine biodiversity. Environmental Biology of Fishes, 90(4): 405–420. doi: 10.1007/s 10641-010-9750-6.

Niyomthai P (2019) Assessing abundance of the giant clams Tridacna spp. on shallow reef flats in the gulf of Thailand. Ramkhamhaeng International Journal of Science and Technology 2(2): 20-27

Nugraha WA, Mubarak F, Husaini E, Evendi H (2020) The correlation of coral reef cover and rugosity with coral reef fish density in East Java Waters. Jurnal Ilmiah Perikanan dan Kelautan, 12(1):131-139

Parravicini, V, Kulbicki, M, Bellwood, D R, Friedlander, A M, Arias-Gonzalez, J E, Chabanet, P, Mouillot, D. (2013) Global patterns and predictors of tropical reef fish species richness. Ecography, 36(12), 1254-1262

Pengsakun, S, Hamanee, S, Saengthongsuk, O, Avirutha, A, Rakklin, P, Klinthong, W, Sutthacheep, M. (2022) High resilience of coral communities at Hin Ang Wang, Surat Thani Province and a proposed management strategy

Pengsakun, S, Klomjit, A, Sutthacheep, M, Yeemin, T, Chamchoy, C. Phantewee, W (2020) Impacts of natural disturbances on the population dynamics of the sea urchin Diadema setosum at Khang Khao Island, the Upper Gulf of Thailand Ramkhamhaeng International Journal of Science and Technology, 3(2), 44-49

Pengsakun, S., Yeemin, T, Sutthacheep, M, Samsuvan, W, Klinthong, W, Chamchoy, C (2019) Monitoring of coral communities in the inner Gulf of Thailand influenced by the elevated seawater temperature and flooding Acta Oceanologica Sinica, 38, 102-111

Phongsuwan, N, Chankong, A, Yamarunpatthana, C, Chansang, H, Boonprakob, R, Petchkumnerd, PBundit, O A (2013) Status and changing patterns on coral reefs in Thailand during the last two decades. Deep sea research part II: Topical Studies in Oceanography, 96, 19-24

Piló, D, Ben-Hamadou, R, Pereira, F, Carriço, A, Pereira, P, Corzo, A, Carvalho, S (2016). How functional traits of estuarine macrobenthic assemblages respond to metal contamination?. Ecological indicators, 71, 645-659

Pinheiro HT, Goodbody-Gringley G, Jessup ME, Sheperd B, Chequer AD & Rocha LA (2015) Upper and lower mesophotic coral reef fish communities evaluated by underwater visual censuses in two Caribbean locations Coral Reefs, 35(1): 139–151. doi 10.1007/s00338-015-1381-0

Pinheiro, H T, MacDonald, C, Quimbayo, J P, Shepherd, B, Phelps, T A, Loss, A C, Rocha, L A (2023) Assembly rules of coral reef fish communities along the depth gradient. Current Biology, 33(8), 1421-1430

Pinheiro, H. T, MacDonald, C, Quimbayo, J P, Shepherd, B, Phelps, T A, Loss, A C, Rocha, L A (2023) Assembly rules of coral reef fish communities along the depth gradient. Current Biology, 33(8), 1421-1430

Quimpo, T J R, Cabaitan, P C, Olavides, R D D, Dumalagan Jr, E E, Munar, J, Siringan, F P (2018) Preliminary observations of macrobenthic invertebrates and megafauna communities in the upper mesophotic coral ecosystems in Apo Reef Natural Park, Philippines. Raffles Bulletin of Zoology, 66

Rangseethampanya, P, Chamchoy, C, Yeemin, T, Ruengthong, C, Thummasan, M, Sutthacheep, M (2021) Coral community structures on shallow reef flat, reef slope and underwater pinnacles in Mu Ko Chumphon, the Western Gulf of Thailand. Ramkhamhaeng International Journal of Science and Technology, 4(1), 1-7

Rees, S E, Rodwell, L D, Attrill, M. J, Austen, M C, Mangi, S C (2010) The value of marine biodiversity to the leisure and recreation industry and its application to marine spatial planning Marine Policy, 34(5), 868-875

Sangthong, S, & Soonsan, N (2023) An analysis of destination reputation, perceived value and environmentally responsible behavioral intention of domestic tourists to scuba diving in Andaman coast, Thailand ABAC Journal, 43(1), 103-115

Sartori, G, Taylor, M. L, Sebastian, P, & Prasetyo, R. (2021) Coral reef carnivorous fish biomass relates to oceanographic features depending on habitat and prey preference. Marine Environmental Research, 172, 105504

Schiettekatte, N M, Brandl, S. J, Casey, J M, Graham, N A, Barneche, D R, Burkepile, D E, Parravicini, V. (2022). Biological trade-offs underpin coral reef ecosystem functioning. Nature Ecology & Evolution, 6(6), 701-708

Schoepf, V, Baumann, J H, Barshis, D J, Browne, N K, Camp, E F, Comeau, S, Sommer, B (2023) Corals at the edge of environmental limits: A new conceptual framework to re-define marginal and extreme coral communities. Science of the Total Environment, 884, 163688.

Shepherd SA, Toral-Granda V & Edgar GJ (2003) Estimating the abundance of clustered and cryptic marine macro-invertebrates in the Galapagos with particular reference to seacucumbers. Noticias de Galapagos, 62: 36–39

Sutthacheep, M (2022) Coral community at a new dive site on an underwater pinnacle in Surat Thani Province, Thailand. Ramkhamhaeng International Journal of Science and Technology, 5(3), 1-12

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(11), 408

Sutthacheep, M, Yeemin, T, Aliño, P M (2022) Reef ecology in the Western Pacific for adaptation to global change In Coral Reefs of the Western Pacific Ocean in a Changing Anthropocene (pp. 55-98) Cham: Springer International Publishing

Tanaka, K., Ohde, S, Cohen, M. D., Snidvongs, A, Ganmanee, M, McLeod, C W (2013) Metal contents of Porites corals from Khang Khao Island, Gulf of Thailand: Anthropogenic input of river runoff into a coral reef from urbanized areas, Bangkok. Applied geochemistry, 37, 79-86

Turner, J A, Babcock, R C, Hovey, R, Kendrick, G A (2017) Deep thinking: a systematic review of mesophotic coral ecosystems. ICES Journal of Marine Science, 74(9), 2309-2320

Wang, X, Yan, J, Bai, J, Shao, D, & Cui, B (2021) Effects of interactions between macroalgae and seagrass on the distribution of macrobenthic invertebrate communities at the Yellow River Estuary, China. Marine Pollution Bulletin, 164, 112057

Whomersley, P, Bell, J, Clingham, E, Collins, M A, Feary, D A, Stockill, J, Bamford, K. (2022) Working towards a blue future: Promoting sustainability, environmental protection and marine management: Examples from the UK Government Blue Belt Programme and current international initiatives. Frontiers in Marine Science, 9, 861632

Wongthong, P, & Harvey, N (2014) Integrated coastal management and sustainable tourism: A case study of the reef-based SCUBA dive industry from Thailand Ocean & coastal management, 95, 138-146

Yeemin T, & Pengsakun SP (2020) First quantitative ecological study of the Hin Pae pinnacle, Mu Ko Chumphon, Thailand. Ramkhamhaeng International Journal of Science and Technology 3(3): 37-45

Yeemin T, Pengsakun S, Yucharoen M, Klinthong W, Sangmanee K, Sutthacheep M (2013) Long-term changes in coral communities under stress from sediment Deep Sea Research Part II: Topical Studies in Oceanography 96: 32-40

Yeemin, T, Pengsakun, S, Yucharoen, M, Klinthong, W, Sangmanee, K, Sutthacheep, M (2013) Long-term changes in coral communities under stress from sediment Deep Sea Research Part II: Topical Studies in Oceanography, 96, 32-40

Yeemin, T, Sutthacheep, M, Pengsakun, S, Klinthong, W, Aunkhongthong, W, Limpichat, J, Jowantha, M. (2023). Diversity of scleractinian corals, microbenthic invertebrates and reef fish on underwater pinnacles in Surat Thani Province, Thailand. Ramkhamhaeng International Journal of Science and Technology, 6(2), 71-85

Yeemin, T, Sutthacheep, M, Pengsakun, S., Klinthong, W, Aunkhongthong, W, Limpichat, J, & Jowantha, M (2023) Diversity of scleractinian corals, microbenthic invertebrates and reef fish on underwater pinnacles in Surat Thani Province, Thailand. Ramkhamhaeng International Journal of Science and Technology, 6(2), 71-85

Zampa G, Azzola A, Bianchi CN, Morri C, Oprandi A, Montefalcone M (2023) Patterns of change in coral reef communities of a remote Maldivian atoll revisited after eleven years. PeerJ 11 e16071

Zampa G, Azzola A, Bianchi CN, Morri C, Oprandi A, Montefalcone M (2023) Patterns of change in coral reef communities of a remote Maldivian atoll revisited after eleven years. PeerJ 11 e16071

Zirler, R, Schmidt, L M, Roth, L, Corsini-Foka, M, Kalaentzis, K, Kondylatos, G, Bronstein, O. (2023). Mass mortality of the invasive alien echinoid Diadema setosum (Echinoidea: Diadematidae) in the Mediterranean Sea. Royal Society Open Science, 10(5), 230251