ORIGINAL PAPER

Diversity and Abundance of Benthic Invertebrates on a Coral Reef and an Underwater Pinnacle at Ko Kut, Thailand

Wichin Suebpala,[a] Makamas Sutthacheep,[a] Laongdow Jungrak,[a] Charernmee Chamchoy,[a] Wiphawan Aunkhongthong,[a] Laddawan Sangsawang,[b] Sittiporn Pengsakun,[a] Wanlaya Klinthong,[a] Chanansiri phutthaphibankun,[a] Phatthira Karnpakob,[a] Thamasak Yeemin,[a,*]

[a] Marine Biodiversity Research Group, Department of Biology, Faculty of Science, Ramkhamhaeng University, Bangkok 10240, Thailand
[b] Marine and Coastal Resources Research and Development Center the Eastern Gulf of Thailand Klaeng District, Rayong Province 21170, Thailand

* Corresponding author: *thamasakyeemin@hotmail.com*

Received: 29 March 2025 / Revised: 29 April 2025 / Accepted: 30 April 2025

Abstract. Benthic invertebrates play a crucial role in coral reef ecosystems by contributing to the overall biodiversity and ecological balance. The presence and diversity of benthic invertebrates are often used as indicators of coral reef health, as they are sensitive to environmental changes. This study focuses on comparing the density and composition of benthic invertebrates from coral reef and an underwater pinnacle at Ko Kut, the Eastern Gulf of Thailand. The results showed that the density of benthic invertebrates at Hin Ao Salad (8.18 ± 2.66 individuals/m²) was significantly higher than at Ko Raet (3.21 ± 0.68 individuals/m²) ($p < 0.05$, t = 15.04). Moreover, the diversity of benthic invertebrates was also greater at Hin Ao Salad, with ten species identified, compared to six species at Ko Raet. Common species at both sites included *Diadema setosum*, *Tridacna squamosa*, *Bequina semiorbiculata*, *Pedum spondyloidium*, and *Lamarcka ventricosa*. Interestingly, *Xestospongia* sp., *Spondylous* sp., *Drupella* sp., and *Phyllidia marindica* were found only at Hin Ao Salad. The Shannon-Wiener index (H') and Evenness index (J') at Hin Ao Salad were higher, indicating greater biodiversity and a more balanced distribution of species compared to Ko Raet. This study also highlighted the presence of benthic invertebrates that could attract diving tourists, such as *Xestospongia* sp. and *Phyllidia marindica*. These findings underscore the ecological importance of Hin Ao Salad as a biodiversity hotspot and suggest that the coral reefs in this area could be valuable for conservation and sustainable marine tourism initiatives.

Keywords: Benthic invertebrate, Coral reef, Diversity, Underwater pinnacle

1. Introduction

Underwater pinnacles offer highly favorable conditions for coral growth and support rich biological communities. They serve functions equivalent to coral reefs, which are among the most diverse, structurally complex, and ecologically sensitive marine ecosystems (Yeemin et al., 2020; Galbraith et al., 2021; Sutthacheep et al., 2022; Cresswell et al., 2023; Yeemin et al., 2024). These features act as critical habitats, feeding areas, spawning sites, and nurseries for numerous marine species. Given their ecological significance, underwater pinnacles are valuable natural assets with immense potential for sustainable utilization. They can support marine ecotourism, provide sources for pharmaceutical compounds, sustain productive fisheries, and contribute to long-term carbon storage (Sutthacheep et al., 2022; Yeemin et al., 2024). Collectively, these services enhance national ecological security and promote sustainable economic development. In recent years, underwater pinnacles have gained increasing attention for their growing importance in marine tourism and their potential as sources of bioactive compounds for pharmaceutical development. Coral communities inhabiting these structures provide essential ecosystem services, functioning as habitats, feeding grounds, and nursery areas for a diverse array of marine organisms. These ecological roles highlight their value as biological assets, particularly for fisheries, where they serve as critical spawning and recruitment grounds for economically important marine species (Spurgeon, 1992; Spurgeon, 1999; Yeemin et al., 2001; UNEP, 2004; Mumby et al., 2008;

Larson et al., 2015; Woodhead et al., 2019). The biological communities found around underwater pinnacles are composed of key benthic organisms such as hard corals, soft corals, gorgonians, sea anemones, and other sessile invertebrates. These organisms form structurally complex habitats that support a high diversity and abundance of marine fauna, making these areas important sites for fisheries. Notably, the aesthetic appeal of the biota surrounding underwater pinnacles is often greater than that of coral reefs around coastal islands. This is largely due to their offshore locations, greater depths, and more stable environmental conditions, which promote the growth of diverse marine life and reduce the level of disturbance from coastal development and human activities (Wongnutpranont et al., 2020; Sutthacheep et al., 2020; Yeemin et al., 2024).

Benthic invertebrates are increasingly acknowledged as sensitive, integrative bioindicators that yield a more holistic appraisal of aquatic ecosystem status than can be obtained from chemical or microbiological metrics alone (Abdel-Gawad et al., 2014; Bendary et al., 2023; Merz et al., 2023; Oriabure & Ogbeibu, 2024). Because they respond rapidly to both natural variability and anthropogenic stress, changes in their composition and abundance register short-term environmental shifts and broader ecosystem dynamics. Community structure and spatial distribution are governed by a complex suite of physicochemical drivers, notably dissolved-oxygen concentration, temperature, pH, nutrient supply, and contaminant loads (Asadujjaman et al., 2012; Mieszkowska et al., 2013). Beyond mirroring prevailing conditions, macrobenthic assemblages mediate key ecological processes such as organic-matter remineralization and benthic–pelagic coupling, highlighting their dual capacity as indicators and regulators of ecosystem function. Interactions between these organisms and their habitats underpin biodiversity maintenance, stabilise trophic pathways, and bolster the resilience of subtidal ecosystems. Accordingly, rigorous characterization of benthic diversity, distribution, and functional roles is indispensable for evidence-based conservation measures aimed at safeguarding the long-term integrity of vulnerable marine environments (Glynn et al., 2010; Oriabure & Ogbeibu, 2024). This study aimed to characterise the diversity, abundance, and spatial distribution of benthic invertebrate assemblages associated with underwater pinnacles at Ko Raet and Hin Ao Salad in Mu Ko Chang, Trat Province, in the eastern Gulf of Thailand, to provide baseline ecological data for future monitoring and management of these subtidal ecosystems.

The main objective of this study was examining the composition and abundance of benthic invertebrates from coral reefs and an underwater pinnacle at Ko Kut, the Eastern Gulf of Thailand.

2. Materials and Methods

2.1 Location of study sites

The study was conducted on the coral reef (Ko Reat) and an underwater pinnacle (Hin Ao Salad) in Ko Kut at Trat Province, located in the Eastern Gulf of Thailand (Figure 1). Both study sites are far from the mainland, about 50 km and 3-8 m in depth. The research areas were located outside the boundaries of any marine national park, and fishing activities were clearly observed throughout the study period. However, this area has been subjected to negative impacts from increased sedimentation stemming from the nearby mainland and from fishing activities. A summary of the location, environmental characteristics, and human-induced disturbances at each study site.

2.2 Data collection

Coral communities at the study sites were surveyed through SCUBA diving along permanent belt transects, with three replicates established at each site. Substrate composition, including live coral, dead coral, rubble, sand, and other components, was recorded within 50 cm on either side of the transect line (English et al., 1997). Underwater photographs were captured

using a digital camera to facilitate data verification in the laboratory.

Benthic invertebrate underwater surveys were conducted by SCUBA diving using the belt transect method (English et al., 1997). At each study site, a 30 × 1 m² transect was laid parallel to the shoreline, with three replicates. Benthic invertebrates were recorded, enumerated, and identified to the species level on site.

2.3 Data analysis

The total densities of benthic invertebrates in a coral reef and an underwater pinnacle in Trat Province were statistically analyzed using a Student's *t*-test. The Shannon's diversity index (H′) and Pielou's evenness index (J') were calculated based on the number of individuals from the study sites.

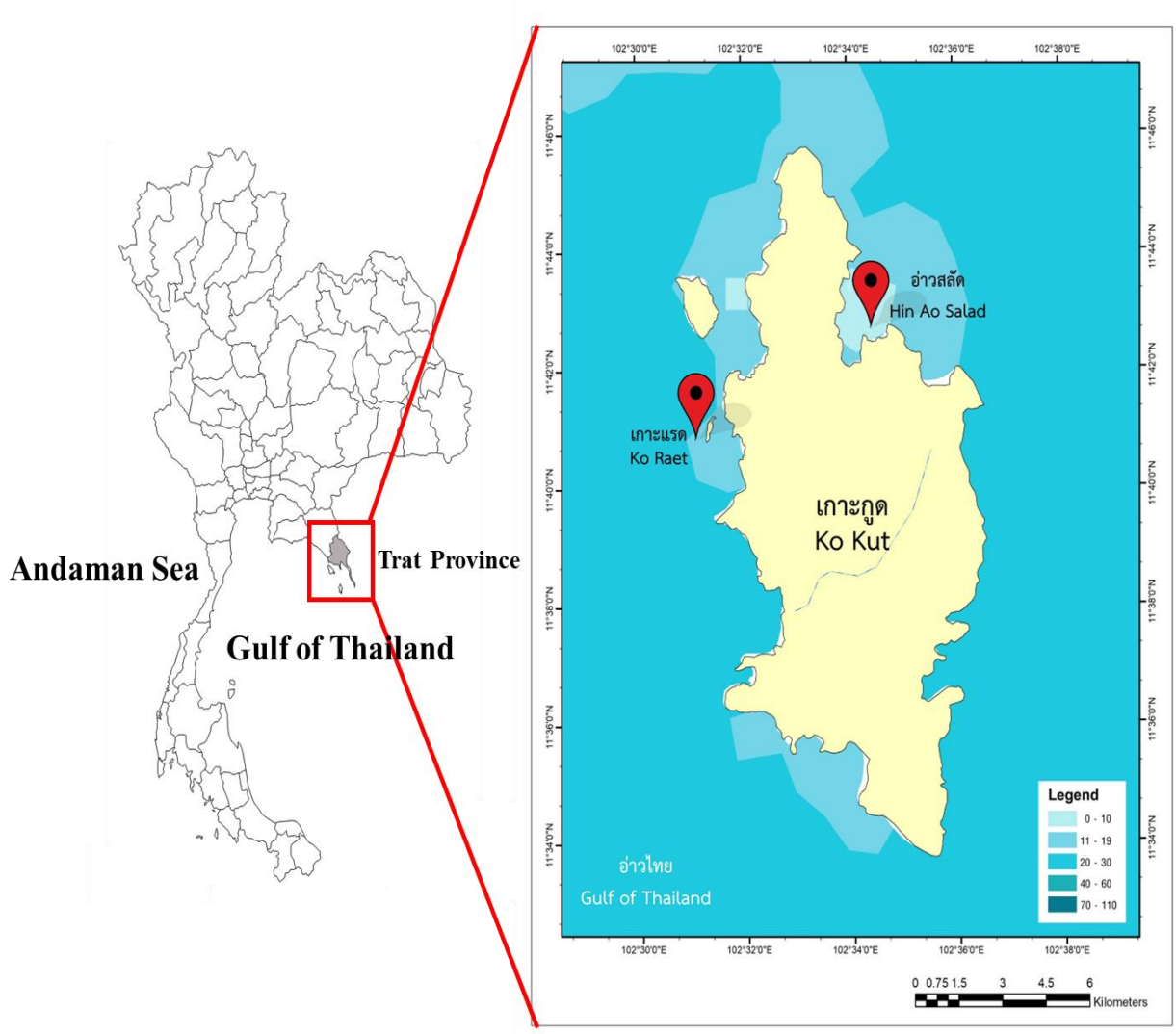

Figure 1. Map of the study sites on a coral reef and an underwater pinnacle at Ko Kut, the Eastern Gulf of Thailand

3. Results

The investigation of benthic components indicated that live coral was the predominant substrate at the study sites. The other substrate components included rock, dead coral, sand, rubble, and various sessile invertebrates such as sponges, sea whips, sea fans, and sea anemones. The live coral cover at Hin Ao Salad (55.84%) was higher than that at Ko Raet (45.25%). On the other hand, dead coral cover was found at Ko Raet (10.65%), which was higher than that at Hin Ao Salad (0.65%) (Figures 2 and 3).

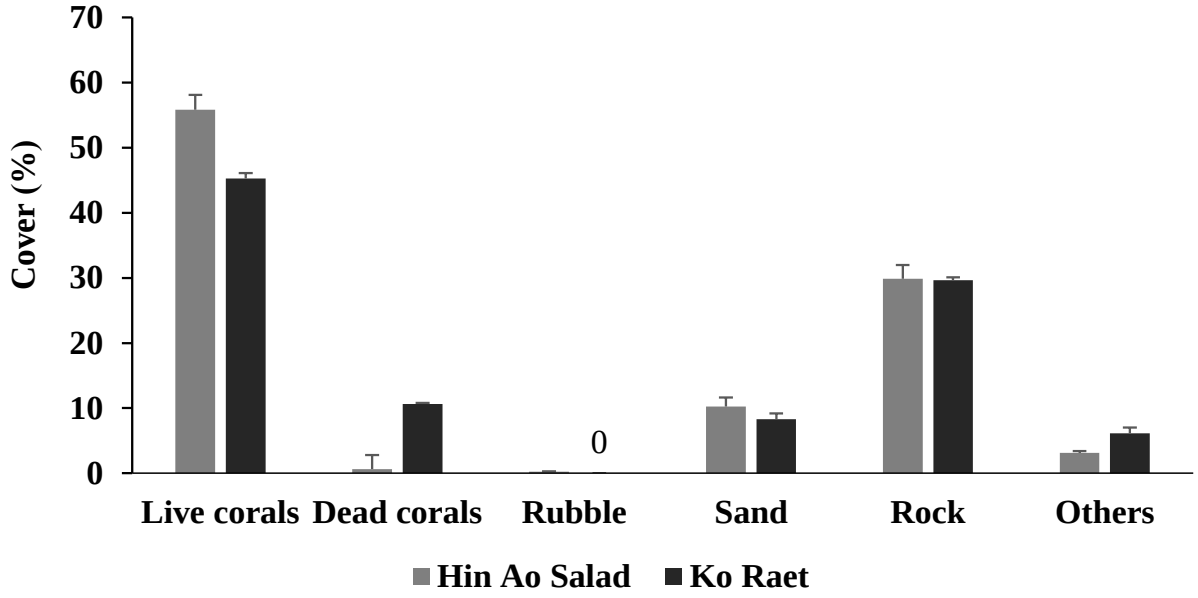

Figure 2. Benthic composition at the study sites (Mean ± SE)

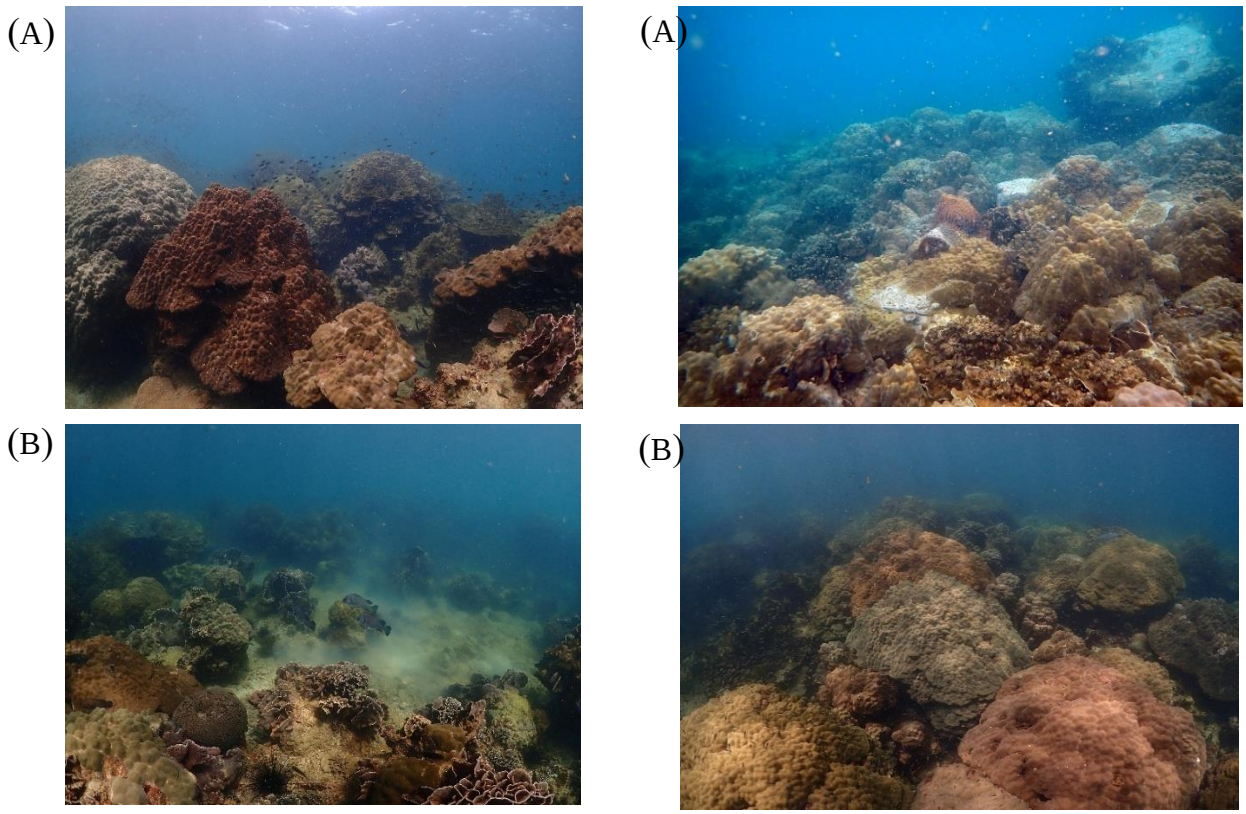

Figure 3. Coral communities at the study sites (A) Ko Raet (B) Hin Ao Salad

The results showed that the density of benthic invertebrates on coral communities at Hin Ao Salad (8.18 ± 2.66 individual/m2) was significantly higher (t-test, $p<0.05$, t =15.04) than that Ko Reat (3.21 ± 0.68 individual/m2) (Figure 4). The diversity of benthic invertebrates at Hin Ao Salad was higher than at Ko Reat. Ten species of benthic invertebrates were found at Hin Ao Salad, while six species were found at Ko Reat. *Diadema setosum, Tridacna squamosa, Bequina semiorbiculata, Pedum spondyloidium*, and *Lamarcka ventricosa* were found at both study sites. *Xestospongia* sp., *Spondylous* sp., *Drupella* sp., and *Phyllidia marindica* were found only in Hin Ao Salad (Figures 5 and 6). The Shannon-Wiener index (H') and Evenness index (J') at Hin Ao Salad are higher than those at Ko Raet (Table 1). Benthic invertebrates that are interesting for diving tourists include: *Xestospongia* sp. and *Phyllidia marindica* (Figure 7).

Figure 4. Densities of benthic invertebrates on coral communities at the study sites (*t*-test, $p<0.05$)

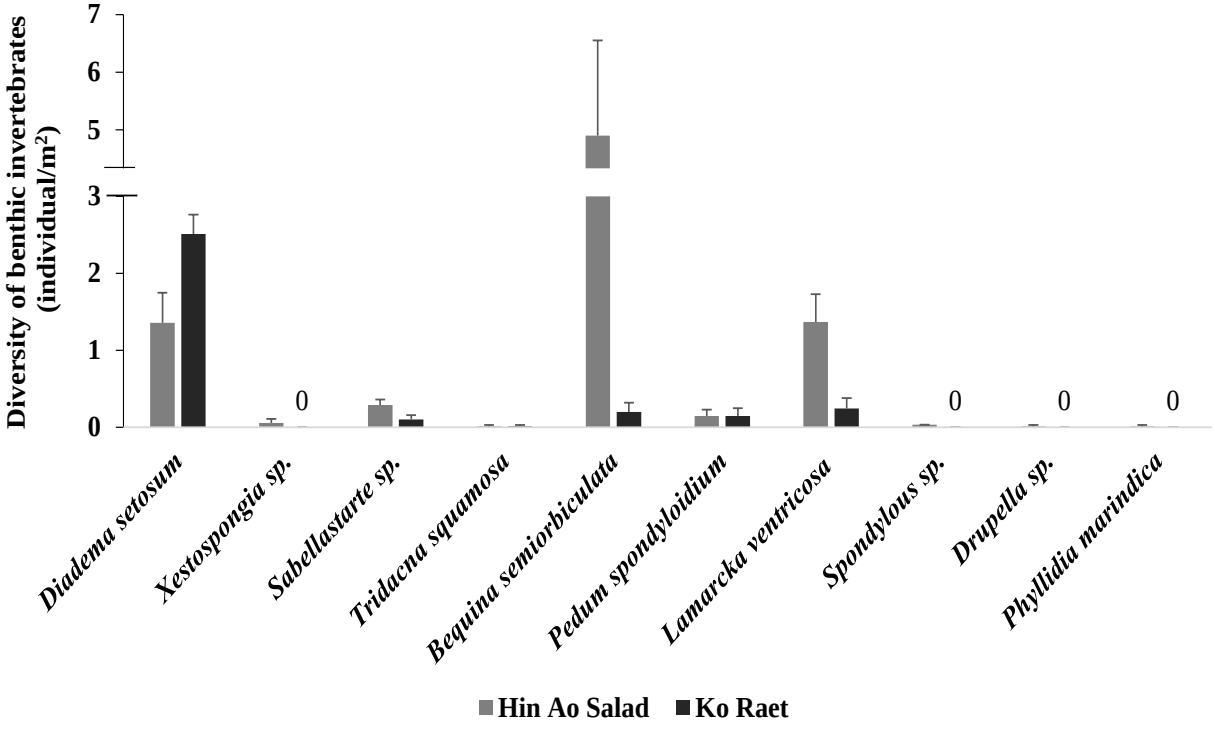

Figure 5. Diversity of benthic invertebrates on coral communities at the study sites

Diadema setosum

Pedum spondyloidium

Lamarcka ventricosa

Bequina semiorbiculata

Figure 6. Dominant benthic invertebrates at the study sites

Xestospongia sp.

Phyllidia marindica

Figure 7. Benthic invertebrates that are interesting for diving tourists

Table 1. Shannon diversity index and evenness index at the study sites

Study sites	H’	J’
Hin Ao Salad	1.17	0.51
Ko Raet	0.82	0.46

4. Discussion

The investigation revealed notable differences in benthic composition and invertebrate diversity between the two study sites, Hin Ao Salad and Ko Raet, suggesting that localized environmental factors may play a critical role in shaping benthic community structure. The predominance of live coral cover at both sites highlights their ecological significance; however, the relatively higher percentage observed at Hin Ao Salad (55.84%) compared to Ko Raet (45.25%) indicates better reef condition and potentially lower anthropogenic stress in this area. In contrast, the higher dead coral cover recorded at Ko Raet (10.65%) may be indicative of past disturbances, including sedimentation, physical damage, or disease-related coral mortality (Hughes et al., 2010). Recent studies have also observed similar trends in other regions, showing that dead coral cover often correlates with disturbances such as extreme weather events or human-induced pressures (Bruno et al., 2021; Edwards et al., 2022).

The significantly greater density and diversity of benthic invertebrates at Hin Ao Salad, as demonstrated by statistical analysis (t = 15.04, p<0.05), reflect more favorable habitat complexity and environmental conditions. Previous studies have shown that structurally complex reefs tend to support higher biodiversity by providing shelter and niche space for various invertebrates (Graham and Nash, 2013). The presence of ten benthic invertebrate species at Hin Ao Salad, compared to only six at Ko Raet, further supports this notion. Similarly, a study by Barros et al. (2022) confirmed that habitat complexity on coral reefs supports greater species richness and diversity, with structurally complex reefs offering a variety of microhabitats for benthic organisms.

Recent studies from 2024-2025 further emphasize the role of reef structure in supporting biodiversity. For example, a study by Roberts et al. (2024) highlighted that areas with higher structural complexity, such as underwater pinnacles and coral colonies, provide critical microhabitats for a wide range of benthic species, leading to greater species diversity. Additionally, research by Zhang et al. (2025) found that coral reefs with a higher degree of structural complexity are more resilient to environmental disturbances, supporting more stable invertebrate populations. These findings align with the results of this study, which suggests that Hin Ao Salad's greater habitat complexity plays a significant role in sustaining a higher density and diversity of benthic invertebrates.

Interestingly, certain species such as *Xestospongia* sp. and *Phyllidia marindica*, which are often considered charismatic or attractive to recreational divers (Woodhead et al., 2019), were found exclusively at Hin Ao Salad. This underlines its potential for low-impact ecotourism development and reef-based environmental education. The presence of bioindicator species like *Diadema setosum* at both sites may also reflect the resilience or recovery potential of the coral reef systems (Carpenter and Edmunds, 2006). Recent research by Zhang et al. (2021) further supports the use of *Diadema* sp. as key indicators for coral health, especially in areas impacted by climate change and anthropogenic activities.

The higher values of the Shannon-Wiener diversity index (H') and evenness index (J') at Hin Ao Salad reinforce the conclusion that this site supports a more balanced and stable benthic invertebrate community. These metrics, widely used in ecological studies, are useful indicators of biodiversity and community health (Magurran, 2004; Paredes et al., 2022). Overall, the findings suggest that management and conservation efforts should prioritize areas like Hin Ao Salad for long-term ecological monitoring and sustainable marine tourism.

Acknowledgements

We are most grateful to the staff of Marine Biodiversity Research Group, Faculty of Science, Ramkhamhaeng University and Department of National Parks, Wildlife and Plant Conservation, 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) and Ramkhamhaeng University (RU).

References

Abdel-Gawad SS, Mola HR (2014) Macrobenthic invertebrates in the main channel of Lake Nasser, Egypt. Egyptian J Aquat Res 40(4):405-414

Barros AG, Pereira RA, Silva MS (2022) Habitat complexity and its effects on the diversity of benthic invertebrates in tropical coral reefs. Mar Environ Res 174:105589

Bendary RE, Ibrahim SM, Goher ME, Elsaied HE, El Shabrawy GM, El Mordy MA, Khalil MT (2023) Taxonomic and functional structure of macrobenthic invertebrate communities and their response to environmental variables along the subbranches of the Nile River (rayahs), Egypt. Environ Sci Pollut Res 30(11):28803-28817

Bruno JF, Stachowicz JJ, Reed DC (2021) Coral reef ecosystems in the Anthropocene: Status and challenges. Nature Sustainability 4(7):123-135

Carpenter RC, Edmunds PJ (2006) Local and regional scale recovery of Diadema promotes recruitment of scleractinian corals. Ecol Lett 9(3):271–280

Cresswell BJ, Galbraith GF, Harrison HB, McCormick MI, Jones GP (2023) Coral reef pinnacles act as ecological magnets for the abundance, diversity and biomass of predatory fishes. Mar Ecol Prog Ser 717:143-156

Edwards CA, Rilov G, Shears NT (2022) The long-term impacts of sedimentation on coral reef ecosystems in the Indo-Pacific. Mar Pollut Bull 184:114299

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

Graham NAJ, Nash KL (2013) The importance of structural complexity in coral reef ecosystems. Coral Reefs 32(2):315–326

Hughes TP, Graham NAJ, Jackson JBC, Mumby PJ, Steneck RS (2010) Rising to the challenge of sustaining coral reef resilience. Trends Ecol Evol 25(11):633–642

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

Magurran AE (2004) Measuring biological diversity. Blackwell Science, Oxford

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

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

Mumby PJ, Broad K, Brumbaugh DR, Dahlgren CP, Harborne AR, Hastings A, Sanchirico JN (2008) Coral reef habitats as surrogates of species, ecological functions, and ecosystem services. Conserv Biol 22(4):941-951

Oriabure PA, Ogbeibu AE (2024) Ecological structure of macrobenthic invertebrates of the Benin River, Southern Nigeria, before the seaport development project. J Sustain Dev 17(6):1-25

Paredes S, López J, Alvarez R (2022) Assessing coral reef health with ecological indices: The case of the Mediterranean Sea. Ecological Indicators 138:108702

Roberts CM, McClanahan TR, Cameron A (2024) Coral reef ecosystem functioning and the impact of human activities: A global review. Science Advances 7(15):eabf7623

Sutthacheep M, Yeemin T, Hamanee S, Avirutha A, Rangseethampanya P, Pengsakun S, Limpichat J, Dumpupha P, Kongdee S (2022) Assessing coral communities on underwater pinnacles as new marine protected areas at Ko Tao, Surat Thani Province.

Ramkhamhaeng Int J Sci Technol 5(3):25-43

Sutthacheep S, Pengsakun S, Phoaduang S, Rongprakhon S, Ruengthong C, Hamanee S, Yeemin T, (2020) First quantitative ecological study of the Hin Pae pinnacle, Mu Ko Chumphon, Thailand. Ramkhamhaeng Int J Sci Technol 3(3):37-45

Wongnutpranont A, Pengsakun S, Ruengthong C, Hamanee S, Sutthacheep M, Yeemin T (2020) Assessing potential sites for marine ecotourism in Chumphon Province, Thailand. Ramkhamhaeng Int J Sci Technol 3(3):21-19

Woodhead AJ, Hicks CC, Norström AV, Williams GJ, Graham NAJ (2019) Coral reef ecosystem services in the Anthropocene. Funct Ecol 33(6):1023–1034

Yeemin T, Sutthacheep M, Aunkhongthong W, Chamchoy C, Jungrak L, Chaithanavisut N, Sukkeaw M (2024) Community structure of underwater pinnacles in Mu Ko Si Chang, the Upper Gulf of Thailand. Ramkhamhaeng Int J Sci Technol 7(2):15-35

Zhang M, Yu J, Liu X (2021) The role of Diadema urchins in maintaining coral reef health under environmental stress. Mar Ecol Prog Ser 669:57-67

Zhang M, Yu J, Liu X (2025) The role of Diadema urchins in maintaining coral reef health under environmental stress. Mar Ecol Prog Ser 669:57-67