

ORIGINAL PAPER

Macrobenthic Invertebrate Assemblages across Coral Reefs in Chumphon Province, the Western Gulf of Thailand

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Abstract. Macrobenthic invertebrates play important ecological roles in coral reef ecosystems by facilitating nutrient cycling, energy flow, and trophic connectivity. Because their assemblage composition and abundance are sensitive to changes in habitat and environmental conditions, they can provide useful indicators of reef condition and ecosystem health. This study investigated the composition and density of macrobenthic invertebrates at selected coral reef sites in Chumphon Province, the Western Gulf of Thailand. Field surveys were conducted by SCUBA diving along permanent belt transects, with three replicate transects established at each site. Macrobenthic invertebrates were recorded within each transect, and species were identified directly in the field following standard survey procedures. The results showed that the density of macrobenthic invertebrates differed statistically significantly between sites (ANOVA, $p < 0.001$), with the highest density observed at Ko Mat Wai Noi (13.6 ± 1.4 individuals/m²) and the lowest at Ko Rang Banthat (5.4 ± 0.9 individuals/m²). The diversity of macrobenthic invertebrates varied among sites, with Ko Maphrao exhibiting the highest diversity, while Ko Rang Banthat showed the lowest. The dominant species were *Diadema setosum*, *Sabellastarte* sp., and *Bequina semiorbiculata*. The observed spatial variability in macrobenthic invertebrate density highlights differences in ecological conditions among coral reef sites. These results provide valuable baseline data for long-term reef monitoring, biodiversity conservation, and the development of site-specific management strategies for coral reefs in the Western Gulf of Thailand.

Keywords: Benthic community, Coral reef, Macrobenthic invertebrate, Spatial variation, Gulf of Thailand

1. Introduction

Coral reefs are among the most diverse and ecologically important marine ecosystems, providing complex three-dimensional habitats

that support numerous groups of reef-associated organisms. The composition and functioning of reef communities are strongly influenced by spatial variation in physical habitat characteristics, hydrodynamic conditions, benthic cover, and local anthropogenic pressures (Lalas et al. 2023; Wright et al. 2025). Such environmental heterogeneity can generate pronounced differences in community composition and ecological processes even among reefs located within the same geographic region. In the Gulf of Thailand, increasing sea-surface temperatures and marine heatwave frequency represent growing climatic pressures on coral reef ecosystems (Brodnicke et al. 2024; Rovellini et al. 2024; Wetchayont et al. 2024). In addition, recent observations of spatial variation in microplastic contamination among coral reef habitats in the Gulf of Thailand, including reefs in Chumphon Province, further demonstrate that local environmental conditions and anthropogenic influences can differ substantially among reef sites (Sutthacheep et al. 2025). Consequently, assessments incorporating multiple components of reef biodiversity are increasingly important for understanding reef condition and supporting effective conservation and management.

Macrobenthic invertebrates constitute an important component of coral reef biodiversity and contribute to numerous ecological processes, including nutrient cycling, sediment reworking, grazing, bioerosion, secondary production, and trophic transfer. Major groups commonly

associated with coral reef habitats include mollusks, crustaceans, echinoderms, polychaetes, cnidarians, and other benthic taxa. Through their diverse functional roles, these organisms contribute to energy flow and food-web dynamics and may influence the maintenance and recovery of reef ecosystems. Macrobenthic organisms also differ considerably in their tolerance to environmental disturbance, and many species have relatively limited mobility and close associations with benthic substrates. Consequently, changes in their abundance, taxonomic composition, and community structure can integrate the effects of environmental conditions over time, making macrobenthic invertebrates useful biological indicators in marine ecological assessment (Pearman et al. 2018; Head et al. 2018; van der Schoot and Hoeksema 2022; van der Schoot and Hoeksema 2024; van der Schoot and Hoeksema 2025; Han and Han 2024). Recent studies have further emphasized their value in coral reef monitoring. Hadiyanto et al. (2026) demonstrated that benthic invertebrate assemblages can provide meaningful indicators of coral reef ecological condition, with assemblage-based indices responding to variations in water quality, fishing pressure, and habitat heterogeneity. These findings highlight the potential of macrobenthic invertebrates for detecting ecological changes and supporting the assessment and management of tropical coral reef ecosystems.

The distribution of macrobenthic invertebrates within coral reef ecosystems is rarely homogeneous because reef habitats exhibit substantial spatial variability at multiple scales. Differences in substrate characteristics, coral and algal cover, sediment accumulation, depth, water movement, food availability, and biological interactions can influence both the abundance and composition of benthic fauna. Clemente et al. (2024), for example, demonstrated significant small-scale vertical variation in macrofaunal assemblages within a shallow tropical coral reef, emphasizing the importance of fine-scale environmental heterogeneity in structuring benthic communities. Similarly, Armenteros et al. (2024) reported substantial spatial variation in the richness, abundance, and community structure of reef-associated invertebrates across

a large Caribbean reef system and demonstrated that benthic cover and reef-fish abundance contributed to observed community patterns. These findings indicate that spatial comparisons among reef sites can provide important insights into ecological processes and differences in habitat condition. Despite the high diversity of macrozoobenthos associated with tropical coral reefs, information on their distribution and assemblage structure remains geographically uneven, particularly in many parts of Southeast Asia (Biondi et al. 2020; Wolfe and Mumby 2020; Merz et al. 2023; Aulia et al. 2024; Goberdhan et al. 2026).

Recent studies in the Gulf of Thailand further emphasize the value of examining spatial patterns in benthic invertebrate communities. In the Eastern Gulf of Thailand, macroinfaunal assemblages differed among coral reefs and underwater pinnacles and showed distinct patterns among sites characterized by different levels of live and dead coral cover (Sutthacheep et al. 2024). Likewise, surveys at Ko Kut revealed significant differences in benthic invertebrate density and diversity between coral reef and underwater pinnacle habitats, illustrating the influence of local habitat characteristics on reef-associated invertebrate assemblages (Suebpala et al. 2025).

However, comparable contemporary information on the spatial distribution of macrobenthic invertebrates across coral reef sites in the Western Gulf of Thailand remains relatively limited. Establishing such baseline information is particularly important for Chumphon Province, where coral reefs support high marine biodiversity while being exposed to both natural environmental variability and increasing regional climatic pressures. Therefore, the present study aimed to assess the density and spatial distribution of macrobenthic invertebrates across coral reefs in Chumphon Province, the Western Gulf of Thailand. The findings are expected to provide baseline information for evaluating spatial patterns in reef-associated biodiversity, supporting long-term monitoring of reef condition, and informing site-specific conservation and sustainable coral reef management.

2. Materials and Methods

2.1 Location of study sites

The study was conducted at four coral reef sites in Chumphon Province, in the Western Gulf of Thailand: Ko Mat Wai Noi, Ko Mat Wai Yai, Ko Maphrao, and Ko Rang Banthat (Figure 1).

All study sites were located at water depths of approximately 3–8 m. These sites were selected to represent spatially separated coral reef habitats within the study area and to facilitate comparisons of macrobenthic invertebrate density and assemblage characteristics among reefs.

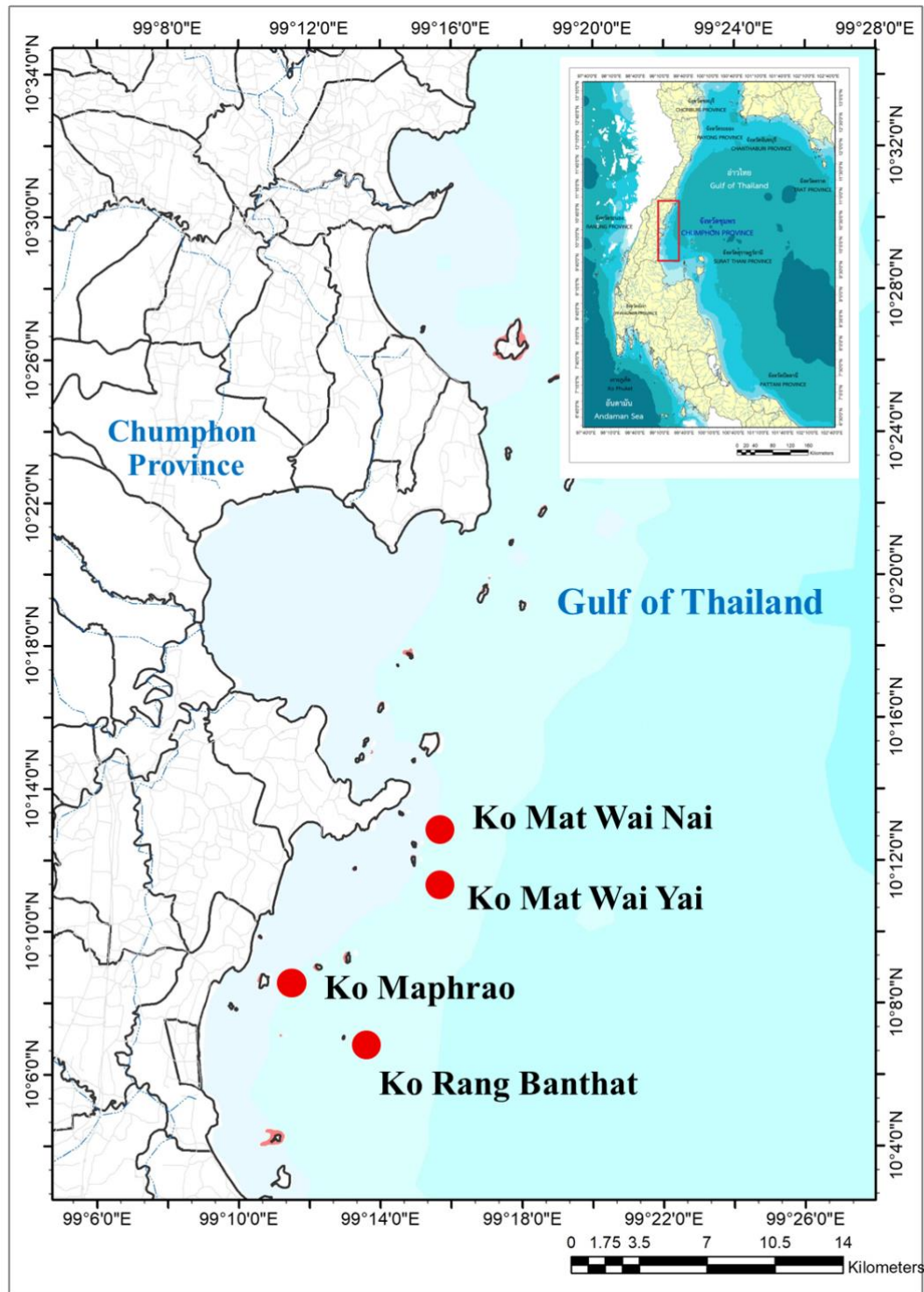


Figure 1 Map of the study sites on a coral reef at Chumphon Province, the Western Gulf of Thailand

Coral reefs in this region are characterized by heterogeneous benthic habitats comprising live corals, dead coral substrates, coral rubble, sand, and other reef-associated substrates, which may influence the distribution and abundance of benthic organisms.

2.2 Data Collection

Coral communities at each study site were surveyed by SCUBA diving along permanent belt transects, with three replicate transects established at each site. Benthic substrate composition, including live coral, dead coral, coral rubble, sand, and other substrate categories, was recorded within 50 cm on both sides of each transect line, corresponding to a total belt width of 1 m, following the method described by English et al. (1997). Underwater photographs were taken using a digital camera along the transects to support subsequent verification and validation of field observations in the laboratory.

Macrobenthic invertebrate were surveyed by SCUBA diving using the belt transect method following English et al. (1997). At each study site, three replicate belt transects, each measuring 30×1 m (30 m^2), were established parallel to the shoreline. All macrobenthic invertebrate occurring within each transect were recorded, counted, and identified to species level *in situ*.

2.3 Data analysis

Differences in the total density of macrobenthic invertebrates among the four study sites were tested using one- way analysis of variance (ANOVA). When significant differences were detected, Tukey's honestly significant difference (HSD) post hoc test was applied to identify

pairwise differences among sites. Prior to analysis, the data were examined for conformity with the assumptions of normality and homogeneity of variances. Statistical significance was accepted at $p < 0.05$.

Macrobenthic invertebrate diversity at each study site was assessed using the Shannon–Wiener diversity index (H') and Pielou's evenness index (J'). Both indices were calculated based on the abundance of individuals recorded at each study site.

Spatial patterns in macrobenthic invertebrate assemblage composition were further examined using non- metric multidimensional scaling (NMDS) based on Bray–Curtis similarity among samples. The resulting ordination was used to visualize similarities and differences in assemblage composition among the four coral reef sites.

3. Results

The benthic composition survey revealed that live coral was the dominant substrate component at most study sites, followed by dead coral, rubble, sand, rock, and other benthic components. The highest live coral cover was recorded at Ko Mat Wai Noi (56.3%), followed by Ko Mat Wai Yai (54.5%) and Ko Maphrao (51.2%), whereas Ko Rang Banthat exhibited the lowest live coral cover (31.3%). Ko Rang Banthat was distinguished by a relatively high proportion of coral rubble, while Ko Mat Wai Yai showed the highest dead coral cover among the four sites. Sand and rock occurred in varying proportions across all study sites, whereas other benthic components contributed only a small percentage of the total cover (Figures 2 and 3).

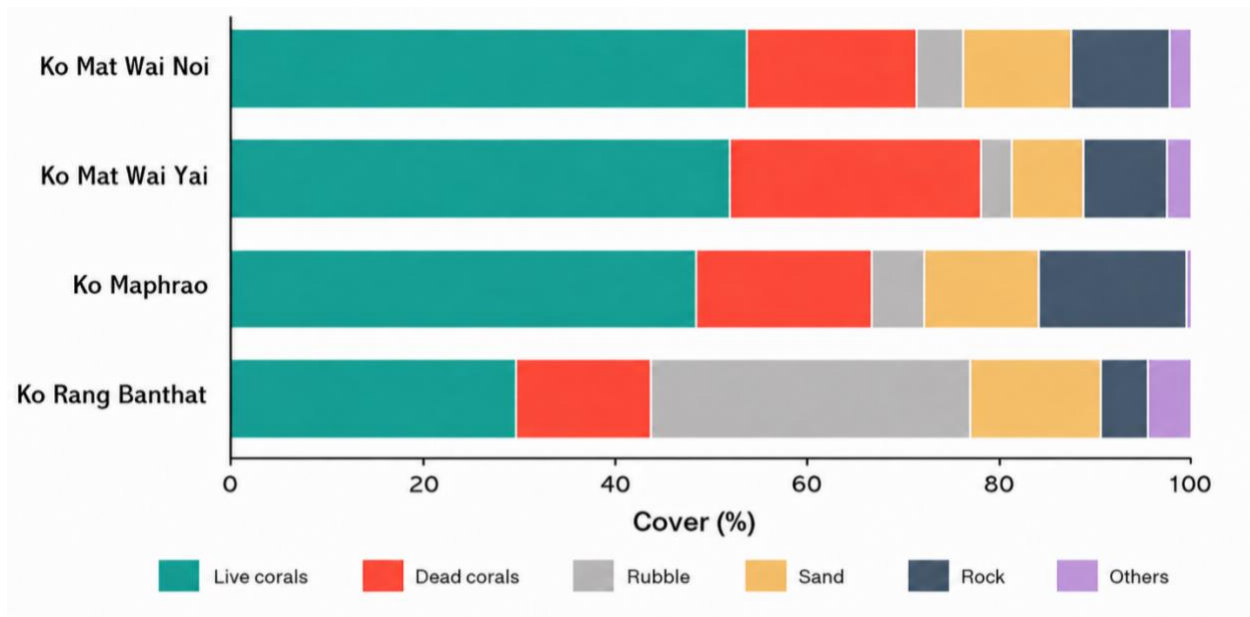


Figure 2 A Benthic composition at the study sites (Mean $\pm$ SE)

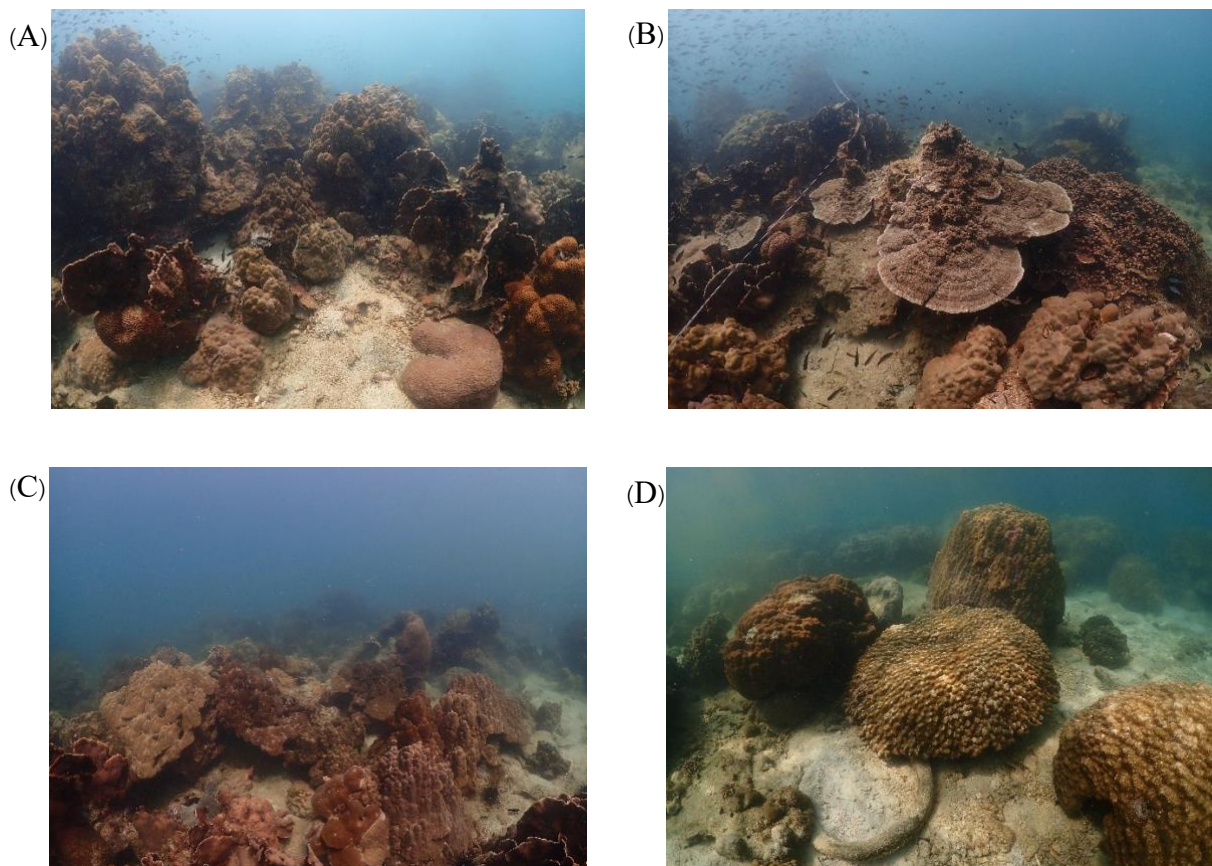


Figure 3 Coral communities at the study sites (A) Ko Mat Wai Noi, (B) Ko Mat Wai Yai, (C) Ko Maphrao, (D) Ko Rang Banthat

The results showed that the density of macrobenthic invertebrates differed significantly among the four coral reef sites (One-way ANOVA, $p < 0.001$; Figure 4). The highest density was recorded at Ko Mat Wai Noi (13.6 ind./m²), followed by Ko Maphrao (8.5 ind./m²), Ko Mat Wai Yai (6.1 ind./m²), and Ko Rang Banthat (5.4 ind./m²).

A total of 18 macrobenthic invertebrate taxa were recorded across the study sites. *Diadema setosum* and *Sabellastarte* sp. were the only taxa recorded at all study sites, indicating their broad distribution across the surveyed reefs. Ko Mat Wai Noi was characterized mainly by *D. setosum*, *Lamarcka ventricosa*, and *Beguinia semiorbiculata*, whereas Ko Maphrao supported relatively prominent occurrences of *B. semiorbiculata*, *L. ventricosa*, and *Sabellastarte* sp. At Ko Mat Wai Yai, *D. setosum* and *B. semiorbiculata* were prominent, together with several taxa that showed more restricted distributions. Ko Rang Banthat was characterized primarily by *D. setosum* and *L. ventricosa*, along with several low-abundance taxa that were not recorded at the other sites. Overall, the observed differences in species occurrence and relative abundance indicate clear spatial variation in macrobenthic invertebrate assemblage

composition among the surveyed coral reefs. *Tridacna crocea*, *T. maxima*, and *Holothuria atra* were recorded exclusively at Ko Mat Wai Noi, whereas *Synaptula* sp. was found only at Ko Rang Banthat (Figures 5 and 6). The Shannon – Wiener index (H') and Evenness index (J') were significantly among the study sites ($p < 0.05$) (Figure 7).

In addition, several visually distinctive macrobenthic invertebrates of potential interest to diving tourists were recorded at the study sites, including *Junceella* sp., *Xestospongia* sp., *Spirobranchus giganteus*, *Tridacna squamosa*, and *Jorunna funebris* (Figure 8).

The NMDS ordination based on Bray–Curtis similarity revealed clear spatial variation in macrobenthic invertebrate assemblages among the study sites. At the 60% similarity level, Ko Mat Wai Noi, Ko Mat Wai Yai, and Ko Maphrao clustered together, while Ko Rang Banthat was clearly separated from the other sites. This pattern corresponded with differences in species composition, as *Cypraea tigris*, *Pteria penguin*, *Atrina vexillum*, and *Synaptula* sp. were recorded exclusively at Ko Rang Banthat (Figure 9).

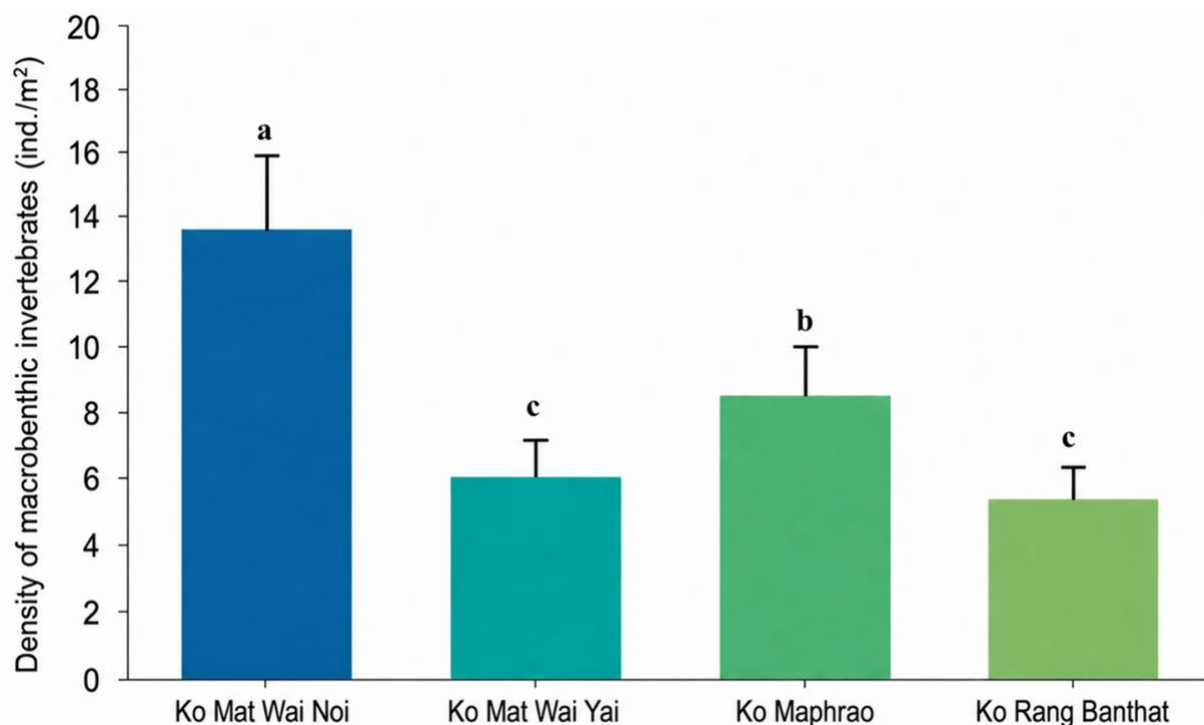


Figure 4 Density of macrobenthic invertebrate on coral reefs at the study sites (One-way ANOVA, $p < 0.05$)

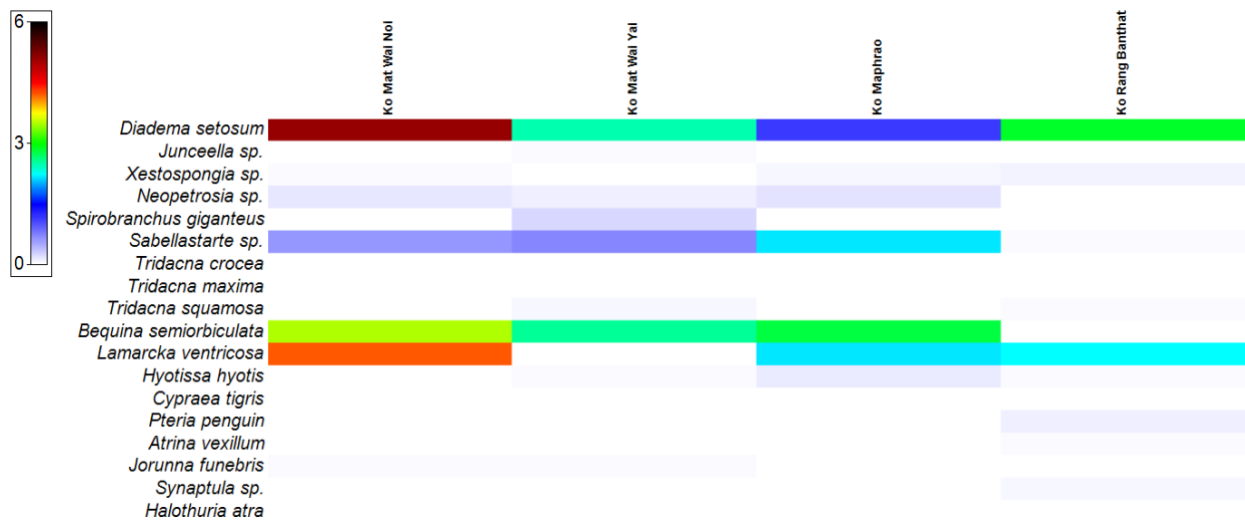


Figure 5 Composition of macrobenthic invertebrates on coral reefs at the study sites

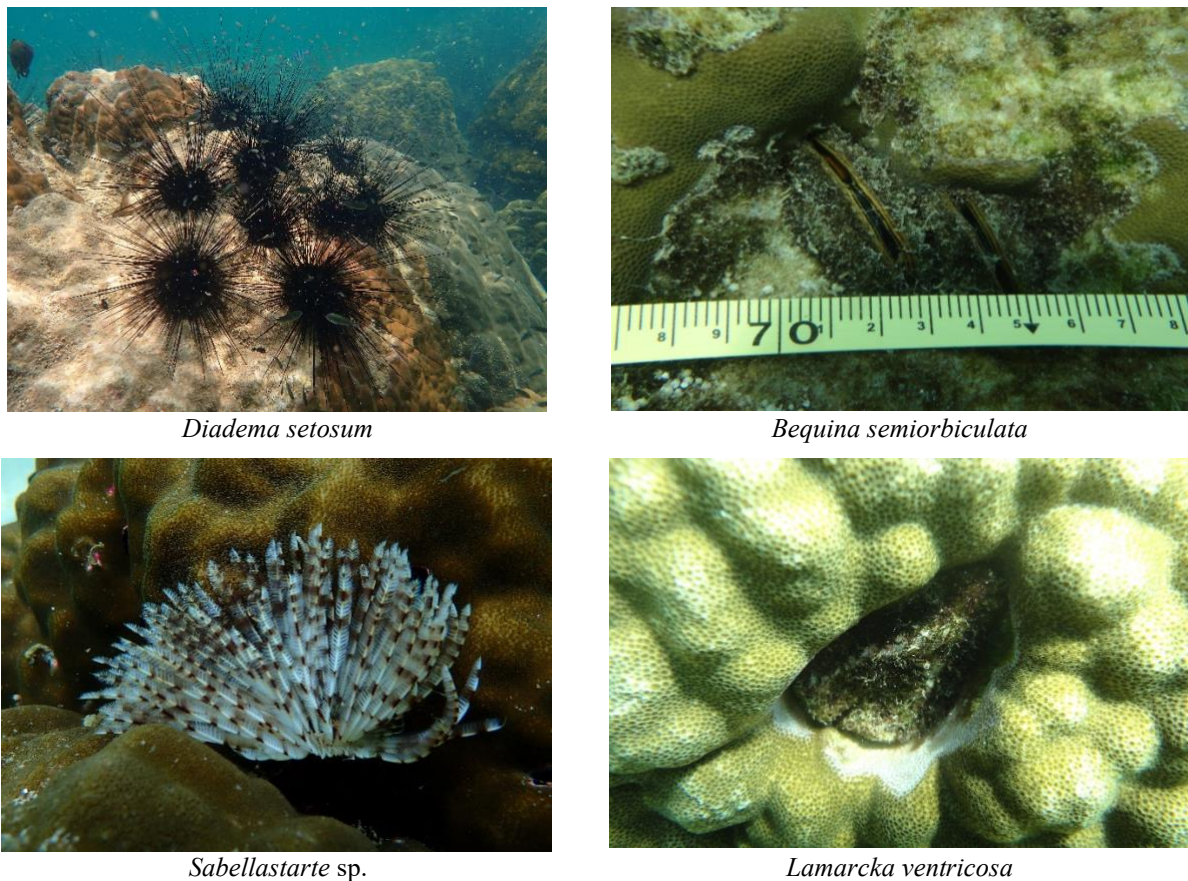


Figure 6 Dominant benthic invertebrates at the study sites

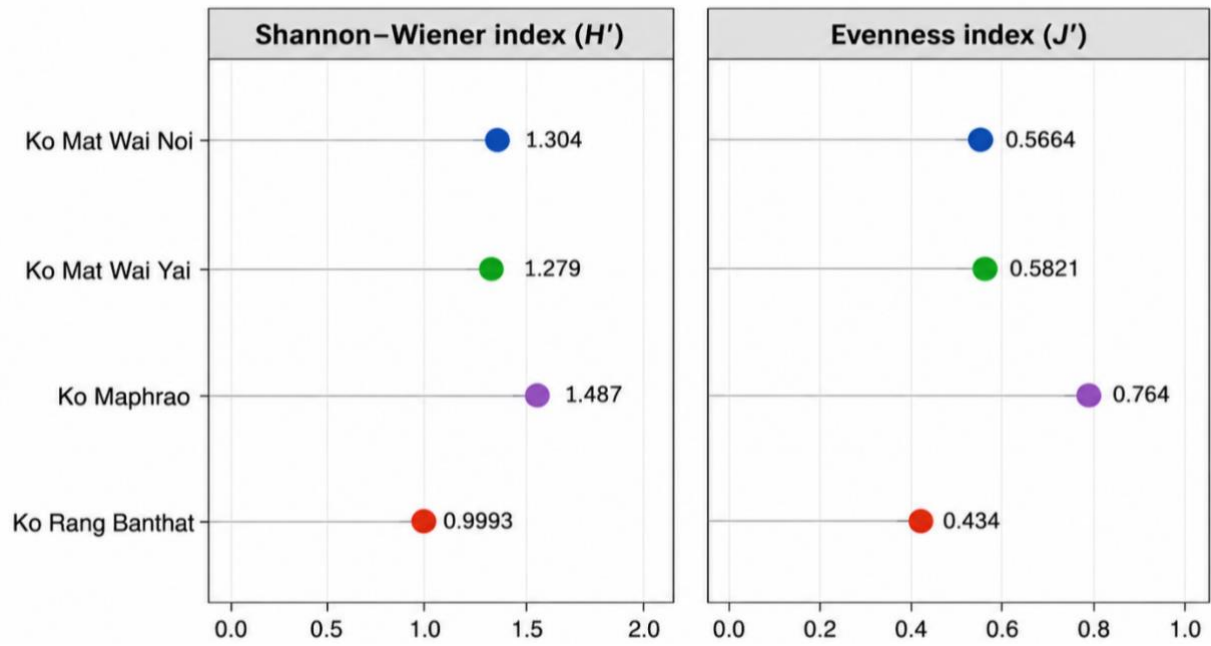
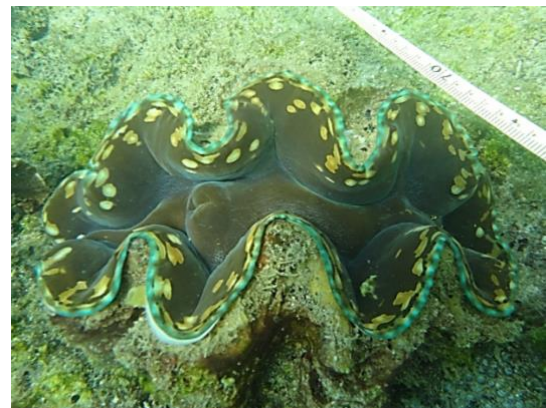


Figure 7 Shannon diversity index and evenness index at the study sites



Jorunna funebris



Tridacna squamosa



Xestospongia sp.



Spirobranchus giganteus

Figure 8 Macrobenthic invertebrates of interest to diving tourists

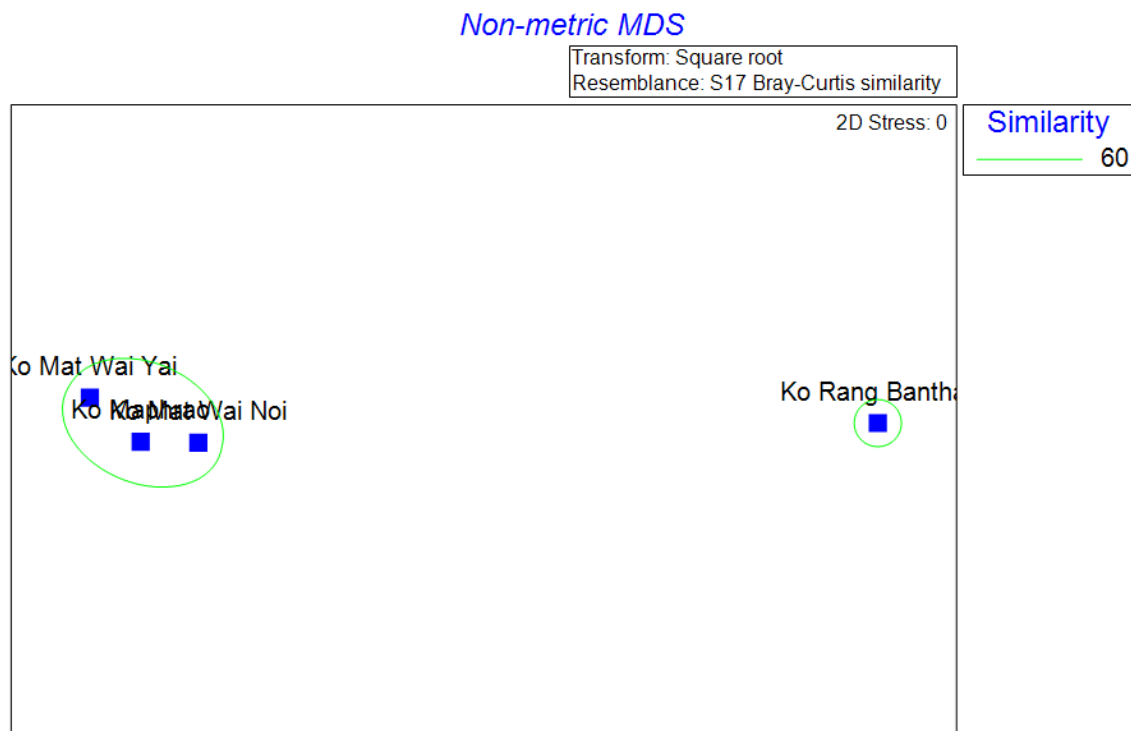


Figure 9 Dendrogram for hierarchical clustering of 4 study sites using complete linkage of Bray-Curtis similarities of macrobenthic invertebrates

4. Discussion

The present study revealed clear spatial differences in macrobenthic invertebrate communities among the four coral reef sites in Chumphon Province. These differences were evident in total density, diversity, species composition, and the NMDS ordination. The study sites also differed considerably in benthic composition. Ko Mat Wai Noi, Ko Mat Wai Yai, and Ko Maphrao were characterized by relatively high live coral cover, whereas Ko Rang Banthat had lower live coral cover and a greater proportion of coral rubble. Together, these findings indicate that coral reefs located within the same geographic region can support different macrobenthic invertebrate communities.

The highest density of macrobenthic invertebrates was recorded at Ko Mat Wai Noi, which also had the highest live coral cover among the four sites. In contrast, Ko Rang Banthat had the lowest macrobenthic density and the lowest live coral cover, together with a relatively high proportion of coral rubble. This pattern suggests that local habitat characteristics may influence the abundance of macrobenthic

invertebrates. Coral reefs contain a variety of microhabitats associated with live corals, dead coral surfaces, rubble, sand, and other benthic substrates, and differences in the availability of these habitats can affect the occurrence and abundance of reef-associated invertebrates. Recent studies have similarly shown that benthic cover and habitat heterogeneity contribute to spatial variation in reef invertebrate communities (Abrecht et al. 2022; Armenteros et al. 2024; Hadiyanto et al. 2026). However, the relationship observed in the present study should not be interpreted as evidence that live coral cover alone determines macrobenthic density, as other environmental and biological factors may also contribute to differences among sites.

The species composition also varied considerably among the study sites. Of the 18 macrobenthic invertebrate taxa recorded, *D. setosum* and *Sabellastarte* sp. occurred at all four sites, indicating that these taxa were widely distributed across the surveyed reefs. Similar observations have been reported from other coral reefs in the Gulf of Thailand, where *D. setosum* was among the commonly recorded

benthic invertebrates (Suebpala et al. 2025). In contrast, several taxa showed restricted distributions in the present study. *T. crocea*, *T. maxima*, and *H. atra* were recorded only at Ko Mat Wai Noi, whereas *C. tigris*, *P. penguin*, *A. vexillum*, and *Synaptula* sp. occurred exclusively at Ko Rang Banthat. These differences demonstrate that each reef supported a particular combination of macrobenthic taxa.

The restricted occurrence of several taxa is particularly important when interpreting differences among the study sites. Although Ko Rang Banthat had the lowest total density and relatively low live coral cover, it supported several taxa that were not recorded elsewhere. Therefore, a reef with a lower overall abundance of macrobenthic invertebrates should not necessarily be considered less important for biodiversity. Similarly, the occurrence of *T. crocea*, *T. maxima*, and *H. atra* only at Ko Mat Wai Noi highlights the contribution of this site to the diversity of the study area. These results emphasize the importance of considering species composition together with total density when assessing coral reef biodiversity. This approach is consistent with recent coral reef monitoring studies that incorporate several groups of benthic invertebrates, including *Diadema*, giant clams, and sea cucumbers, as complementary indicators of ecological condition (Hadiyanto et al. 2026).

Significant differences in the Shannon–Wiener diversity and Pielou’s evenness indices further demonstrate that macrobenthic community structure was not uniform among the four reefs. These differences indicate variation not only in the number of taxa present but also in how individuals were distributed among taxa. Spatial variation in diversity and evenness is expected in coral reef environments because habitat structure and benthic composition can vary substantially over relatively short distances. Studies from other tropical reefs have also reported strong small-scale differences in the abundance, richness, and composition of reef-associated invertebrate communities (Armenteros et al. 2024; Clemente et al. 2024). Therefore, the differences observed among the Chumphon reefs likely reflect local

ecological characteristics rather than a uniform regional pattern.

The NMDS analysis provided additional evidence of spatial differentiation among the macrobenthic invertebrate assemblages. At the 60% Bray–Curtis similarity level, Ko Mat Wai Noi, Ko Mat Wai Yai, and Ko Maphrao clustered together, whereas Ko Rang Banthat was clearly separated from the other sites. This pattern indicates that the first three sites supported relatively similar assemblages, while the species composition at Ko Rang Banthat was more distinct. The NMDS pattern was consistent with the occurrence of *C. tigris*, *P. penguin*, *A. vexillum*, and *Synaptula* sp. exclusively at Ko Rang Banthat. The relatively high proportion of coral rubble at this site may also provide habitat conditions different from those at the other reefs. Similar spatial differentiation of benthic assemblages has been reported from coral reefs in the Eastern Gulf of Thailand, where differences in community composition were observed among sites with contrasting benthic characteristics (Sutthacheep et al. 2024). Thus, the separation of Ko Rang Banthat in the NMDS ordination appears to represent a distinct assemblage rather than simply a reef with lower macrobenthic density.

In addition to their ecological importance, some of the macrobenthic invertebrates recorded in this study may contribute to the recreational and educational value of the reefs. Visually distinctive taxa such as *Junceella* sp., *Xestospongia* sp., *S. giganteus*, *T. squamosa*, and *J. funebris* are conspicuous components of coral reef biodiversity and may be of interest to diving tourists. A previous study at Ko Kut in the Eastern Gulf of Thailand similarly highlighted conspicuous benthic invertebrates, including *Xestospongia* sp. and nudibranchs, as potentially interesting organisms for diving tourism (Wee et al. 2019; Suebpala et al. 2025). Nevertheless, the present study did not directly examine tourist preferences; therefore, their tourism value should be regarded as a potential additional benefit of maintaining reef biodiversity.

Overall, the results demonstrate substantial spatial variation in macrobenthic invertebrate

communities among coral reefs in Chumphon Province, even within a relatively limited geographic area. Ko Mat Wai Noi supported the highest macrobenthic density and several taxa that were not recorded at the other sites, whereas Ko Rang Banthat supported a compositionally distinct assemblage despite having lower live coral cover and total macrobenthic density. These contrasting patterns emphasize that coral reef biodiversity is multidimensional and cannot be adequately represented by a single ecological variable (López-Pérez et al. 2023; Cadier et al. 2024; McWilliam et al. 2026). Assessments of reef condition should therefore integrate live coral cover with information on the abundance, diversity, and species composition of reef-associated organisms, as habitat characteristics and community composition can provide complementary ecological information that may not be captured by coral cover alone (Oh et al. 2025). Changes in species composition and the occurrence of particular taxa can also provide valuable information on spatial and temporal ecological variation and environmental pressures (Monchanin et al. 2025; Wu et al. 2025). Recent developments in coral reef monitoring further support the inclusion of benthic invertebrate assemblages as complementary indicators of ecological condition (Hadiyanto et al. 2026). The baseline information generated by the present study therefore provides a foundation for long-term monitoring of macrobenthic communities, detection of site-specific ecological changes, and the development of conservation and sustainable tourism strategies for coral reefs in Chumphon Province.

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