ORIGINAL PAPER

Meiofaunal communities in coral reefs and an underwater pinnacle in Trat and Rayong Provinces, the Eastern Gulf of Thailand

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Abstract. Coral reef ecosystems are complex ecosystems that bear the high biological diversity of the oceans. Soft bottom habitats in coral reef ecosystems, such as sand and rubble, are important components. Meiofauna studies in coral reef ecosystems in Thailand are relatively limited, although coral reefs are important ecosystems in coastal zones of tropical countries and their ecosystem services are very significant. The present study examined the composition and density of meiofauna from coral reef and underwater pinnacle ecosystems in Trat and Rayong Provinces, the Eastern Gulf of Thailand. The meiofauna was sampled using a PVC meiocores of 3.5 cm diameter. This study identified twenty-one major taxa. The highest densities of meiofauna on coral communities in Rayong Province (4,384.47 ± 32.96 individuals/10 cm^2) were significantly higher than those in Trat Province (344.29 ± 20.10 individuals/10 cm^2). The composition and abundance of meiofauna significantly varied among the study sites. The dominant groups were Foraminifera, Nematoda, Polychaeta, Harpacticoida, Ostracoda, and Bivalvia. The cluster analysis showed that the meiofauna in coral communities could be divided into three groups i.e., Group 1: Trat Province, in the areas of Ko Raet, Ko Rayang Nok and Ao Salad; Group 2: Ko Man Nok and Hin Phoeng in Rayong Province and Group 3: Ko Man Nai in Rayong Province. This study provides the important knowledge of composition and density of meiofauna in coral reef and underwater pinnacle sediments from the Eastern Gulf of Thailand. This is the first study on meiofauna community from an underwater pinnacle in Thai waters and reiterates the importance of underwater pinnacles which have ecosystem services as same as coral reefs.

Keywords: coral reef, diversity, Gulf of Thailand, meiofauna, underwater pinnacle

1. Introduction

Meiofauna consist of diverse organisms inhabiting a wide range of aquatic environments, including both marine and freshwater habitats. They can distribute from shallow coastal waters to the deep seas. Meiofauna inhabit a wide range of sedimentary environments, from muddy benthic sediments with small particle sizes to coarse shell sand with large particles. Some meiofauna have adhesive organs to hold onto the surfaces of large birds and various animals (Oh et al., 2023). Meiofauna are the important components in coral reef ecosystem and constitute a valuable biodiversity that functions as a important tool for ecological investigation and the evaluation of environmental impact (Jaiharn et al. 2015; Oh et al. 2023). Meiofauna represent a principal assemblage of coastal benthic organisms and play an important role in energy transfer within the trophic levels (Danovaro et al. 2007; Kramer et al. 2013; Sarmento et al. 2015). Coral reefs are among the most prolific and diverse ecosystems, hosting high organism diversity within marine ecosystems. They encompass over thirty percent of the total marine species richness. Recent research in tropical countries has predominantly centered on macrofauna, leaving a scarcity of comprehensive investigations into meiofauna (Semprucci et al. 2013).

Coral reefs hold immense significance within tropical marine environments owing to their remarkable biodiversity and substantial economic contributions to global societies. Notably, these ecosystems play a pivotal role in furnishing essential food resources, employment opportunities, tourism attractions, coastal safeguarding, pharmaceutical, and cosmetic resources, as well as bearing cultural importance (Kittinger et al.

2012; Costanza et al. 2014; Fisher et al. 2015; Spalding et al. 2017; UN Environment Programme et al. 2018; Morrison et al. 2019; Dyshlovoy and Honecker 2020; Knowlton et al. 2021). The annual economic values of coral reefs on a global scale have the potential to reach an estimated total of THB 300 trillion (Costanza et al. 2014).

Nevertheless, there has been a decline in the condition of coral reefs and their associated ecosystem services over the past few decades (Knowlton 2001; Pandolfi et al. 2003; Hoegh-Guldberg et al. 2019). Coral reefs are one of the marine ecosystems facing the highest level of endangerment (McCauley et al.2015; IPCC 2019). Coral reefs also exhibit susceptibility due to their delicate responsiveness to both local stressors like overfishing and pollution and global stressors, notably the release of carbon dioxide into the atmosphere, leading to oceanic warming and acidification (Sutthacheep et al. 2022).

Coral reef ecosystems significantly contribute to primary productivity. The dominant microhabitat on coral reefs such as algal turfs, have the potential to cover 30–80% of the total surface area (Maida and Ferreira 1997; Fabricius and De'ath 2001; Wismer et al. 2009; Hoey and Bellwood 2010). Meiofauna are important assemblages within the coral reef ecosystems (Sarmento et al., 2012). The distribution patterns of meiofauna can be analyzed to explain environmental factors controlling habitat boundaries and assessing environmental conditions (Mendes et al., 2010; Donnici and Barbero, 2002; Toefy and Gibbons, 2014; Mello et al., 2014). However, studies on meiofauna communities from coral reefs are very limited and this research is the first study in Thailand to examine meiofauna community from an underwater pinnacle. The main objective of this study was examining composition and abundance of meiofauna from coral reefs and an underwater pinnacle in Trat and Rayong Provinces, the Eastern Gulf of Thailand.

2. Materials and Methods

2.1 Location of study sites and sample collection

Six study sites in Trat and Rayong Provinces, the Eastern Gulf of Thailand were selected in this study (Figure 1). The study sites in Trat Province were coral reefs at Ko Raet, Ko Rayang Nok, and Ao Salad (Ko Kut), about 38 km from the mainland and approximately 3-8 m in depth. Tourism activities were clearly observed at Ko Raet and Ao Salad. The study sites in Rayong Province included the coral reefs at Ko Man Nai and Ko Man Nok and an underwater pinnacle, Hin Phoeng which are tourism areas. Ko Man Nai and Ko Man Nok are located about 6 – 7 km from the mainland and about 3-8 m in depth. Hin Phoeng is located about 30 km from the mainland and approximately 15 – 16 m in depth. All study sites are not in the jurisdiction of marine national park and fishing activities were obviously found during the study period.

The coral communities at the study sites were investigated by SCUBA diving along a permanent belt transect with three replicates. The substrate compositions, i.e., live coral, dead coral, rubble, sand, and others were recorded within 5 0 cm of each side of the transect line (English et al. 1997). The underwater photographs were taken by a digital camera for data rechecking in the laboratory.

The meiofauna were sampled by SCUBA divers from the coral communities. The sediment samples for the meiofauna study were collected using PVC meiocores of 3.5 cm diameter. The meiocores were randomly inserted into the sediment down to a depth of 10 cm and then the samples were preserved in 10% buffered formalin. The meiofauna samples were stained with Rose Bengal and sieved through a 63 μm mesh net in the laboratory. They were sorted, identified, and counted using a stereoscopic microscope.

The grain size measurement was conducted using a standard method of dry sieve analysis (English et al.,1997).

2.2 Data analysis

The total densities of meiofauna on coral communities in Trat and Rayong Provinces were statistically analyzed using a Student's *t* test. One-way Analysis of Variance (ANOVA) was used to detect the differences in total density of meiofauna among the study sites. Where significant differences were found, the Tukey HSD (Honestly Significant

Difference) test was used to determine which study sites statistically differed. The similarity of the composition of meiofauna in coral communities was evaluated with a cluster analysis using Non-metric Multidimensional Scaling (NMDS).

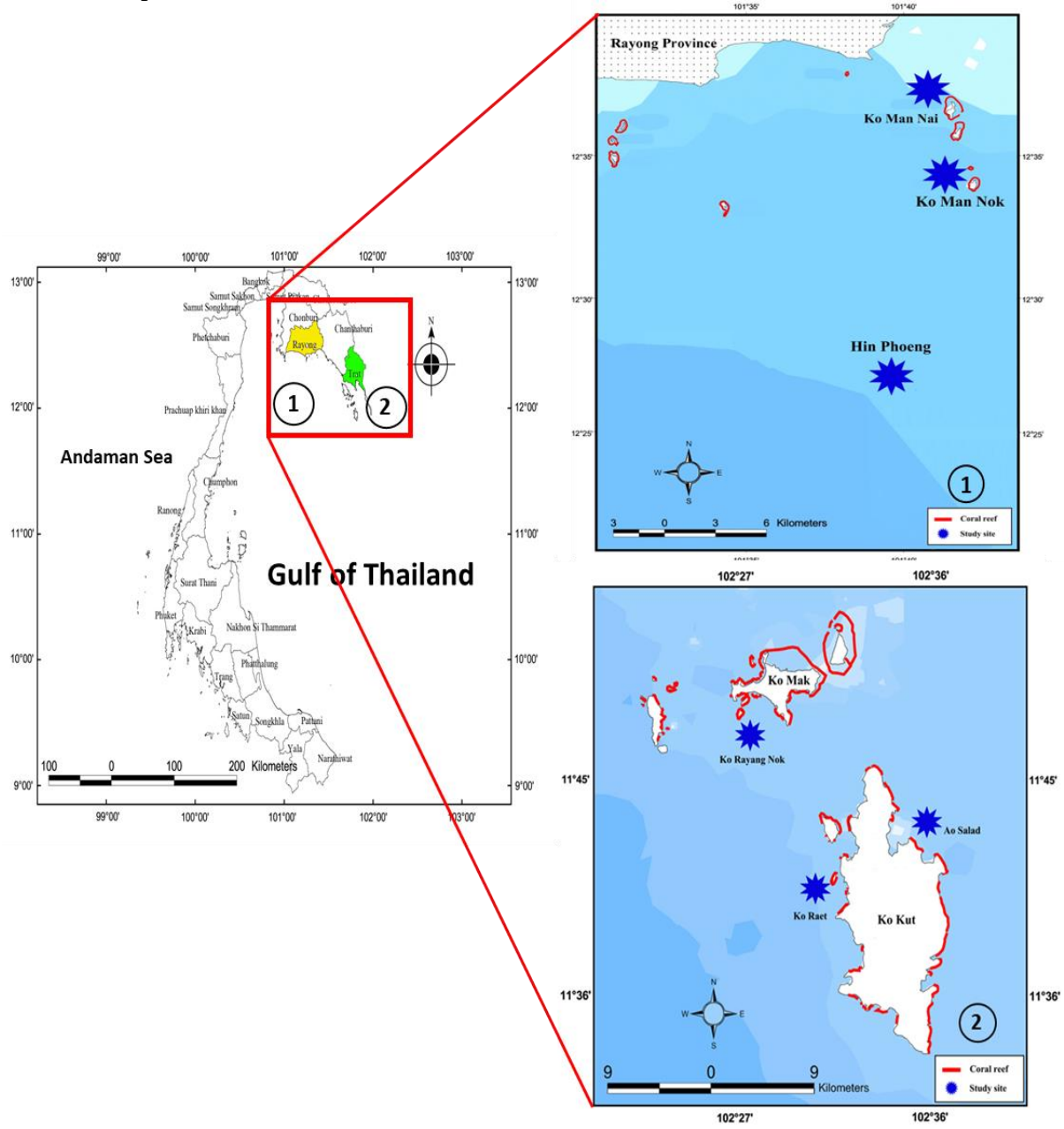


Figure 1. Map of the study sites in Trat and Rayong Provinces, the Eastern Gulf of Thailand

3. Results

The benthic components investigation revealed that live coral was the major component of the substrates at the study sites. The other components were sand, rubble, rock, dead coral, and other sessile invertebrates, including soft corals and sea anemones. The live coral cover at Hin Phoeng, Rayong Province, was the highest (79.21%), followed by Ko Raet (69.37%) in Trat Province, while high dead coral covers were found at Ko Man Nok (19.45%) and Ko Man Nai (17.27%), indicating that the coral communities at Ko Raet, Ko Rayang Nok, and Ao Salad, Trat Province, and Hin Phoeng at Rayong Province, are in very good condition (Figures 2 and 3). The analysis of median grain sizes indicated that the particle size at Hin Phoeng, Rayong Province was higher than other study sites (Figure 4).

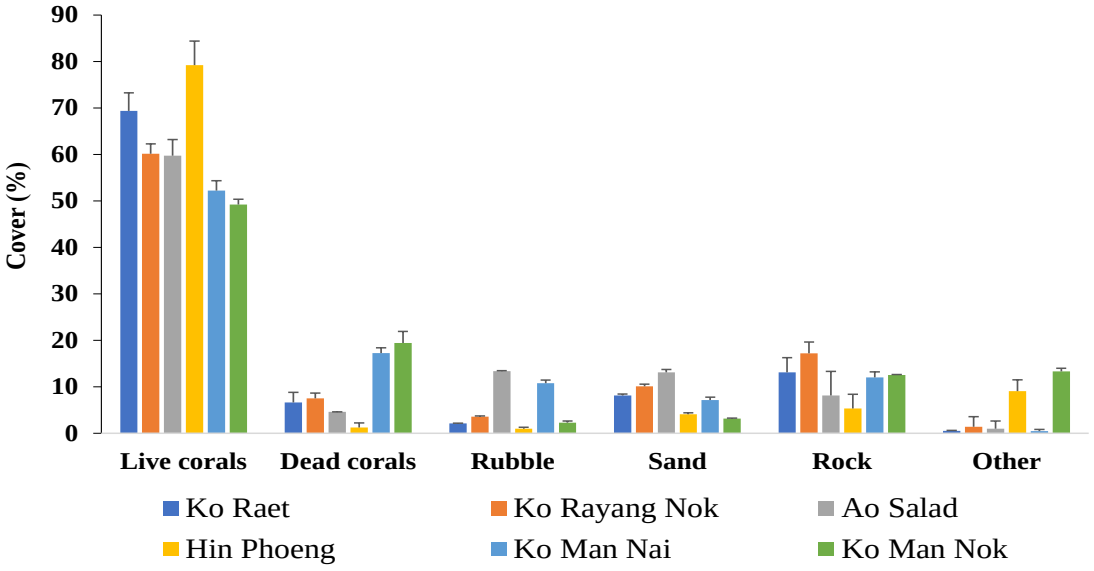
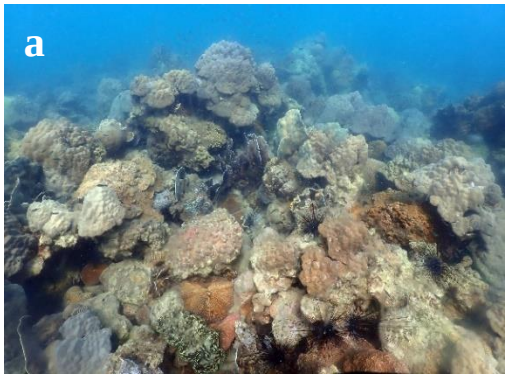


Figure 2. Benthic composition at the study sites (Mean ± SE)



Ko Raet

Ko Rayang Nok

Ao Salad

Hin Phoeng

Ko Man Nai

Ko Man Nok

Figure 3. Coral communities at the study sites (a) Trat Province (b) Rayong Province

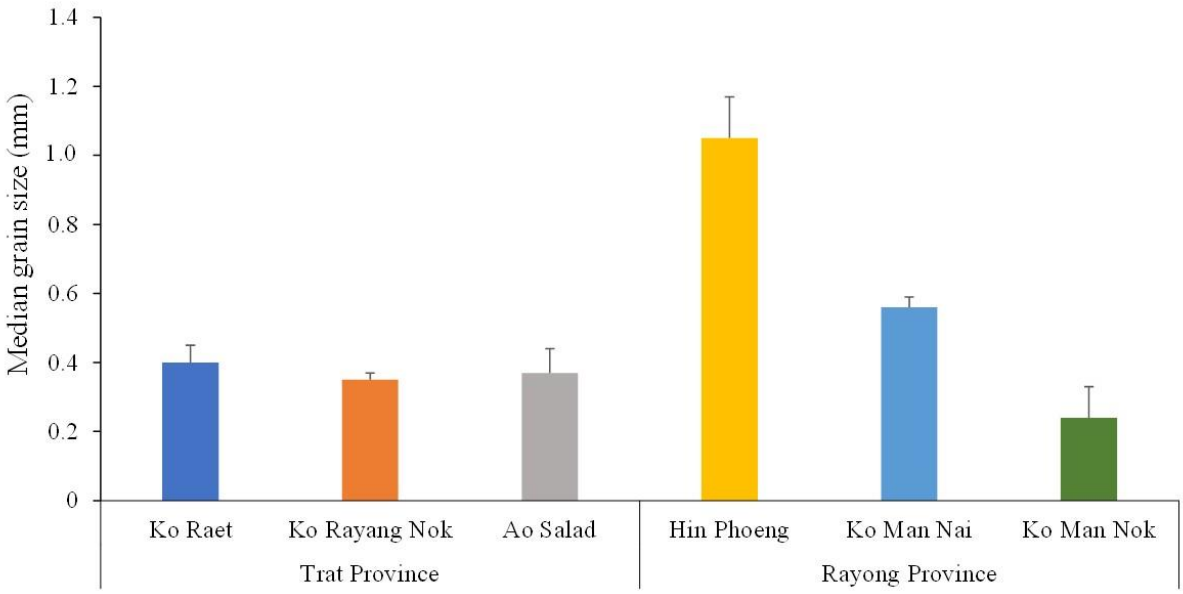


Figure 4. Median grain sizes at the study sites (Mean ± SE)

The results showed that the density of meiofauna on coral communities in Rayong Province (4,384.47 ± 32.96 individuals/10 cm^2) was significantly higher (t-test, $p<0.05$) than that in Trat Province (344.29 ± 20.10 individuals/10 cm^2) (Figure 5) because of high density of Foraminifera. However, the diversity of meiofauna in Trat Province was higher than those in Rayong Province (Figure 6). Twenty-one taxa of meiofauna were found in Trat Province, while fifteen taxa were found in Rayong Province. Foraminifera, Nematoda, Bivalvia and Ostracoda were found at all study sites. Ciliophora, Isopoda, Amphipoda, Tanaidacea, Cumacea and Amphioxiformes were found only in Trat Province while Ophiurae were observed in Rayong Province. The dominant taxa in Trat Province were Foraminifera, Nematoda and Harpacticoida while Foraminifera, Ostracoda and Bivalvia were dominant in Rayong Province (Figure 7). The statistical analysis revealed that the densities of meiofauna on coral communities were significantly different among the study sites (One-way ANOVA, $p<0.05$; Figure 8).

The cluster analysis using Non-metric Multidimensional Scaling (NMDS) showed that at 60% Bray-Curtis similarity, the meiofauna in coral communities could be divided into three groups. i.e., Group 1: Trat Province, in the areas of Ko Raet, Ko Rayang Nok and Ao Salad; Group 2: Ko Man Nok and Hin Phoeng in Rayong Province and Group 3: Ko Man Nai in Rayong Province (Figure 9 and Figure 10). Ciliophora, Isopoda, Amphipoda, Tanaidacea, Cumacea and Amphioxiformes were found only at the study sites in Group 1 whereas Ophiurae were found only at the study site in Group 3.

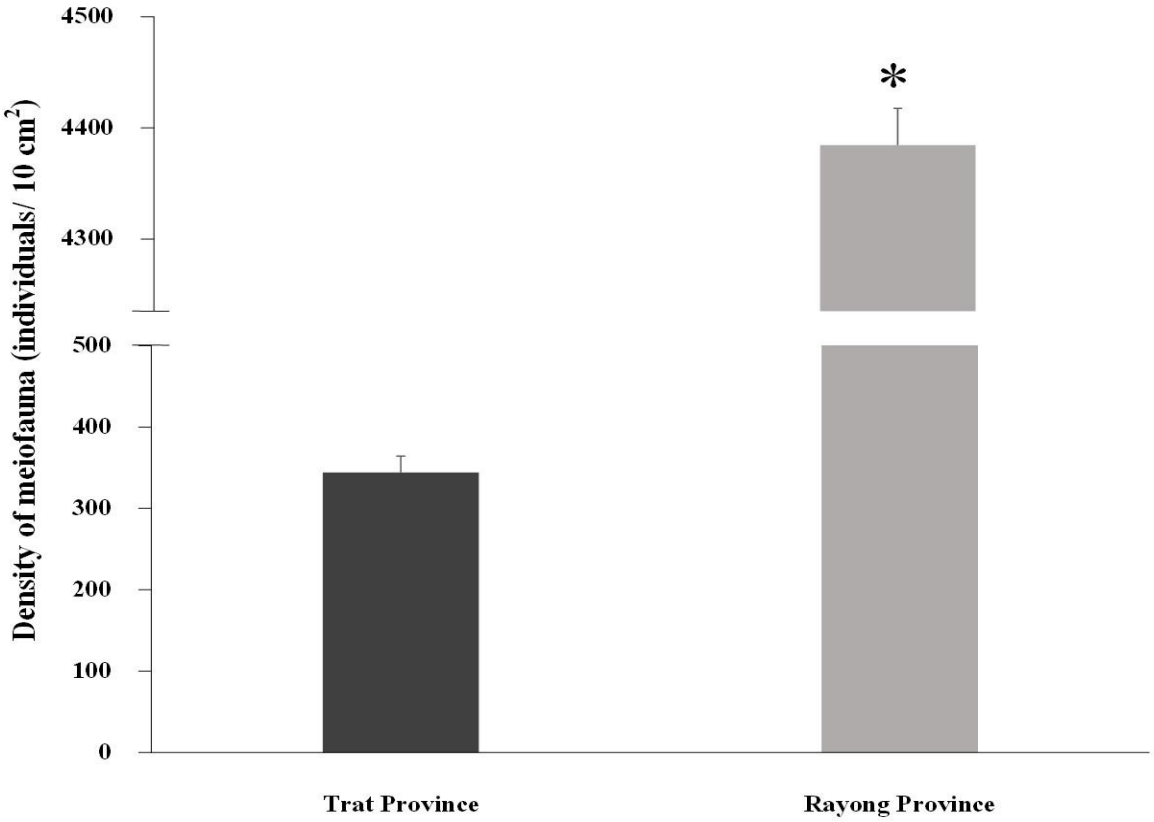


Figure 5. Densities of meiofauna on coral communities at Trat and Rayong Provinces (t-test, $p<0.05$)

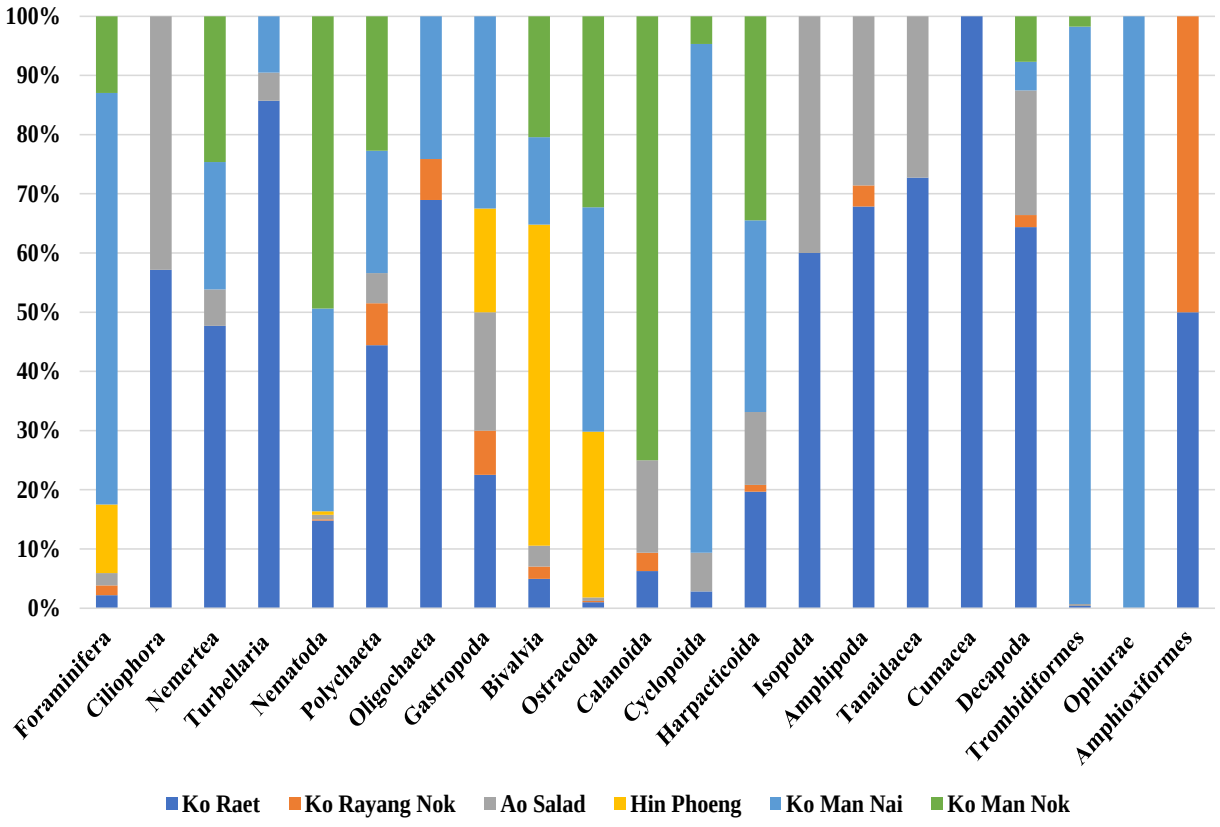


Figure 6. Composition of meiofauna on coral communities at the study sites

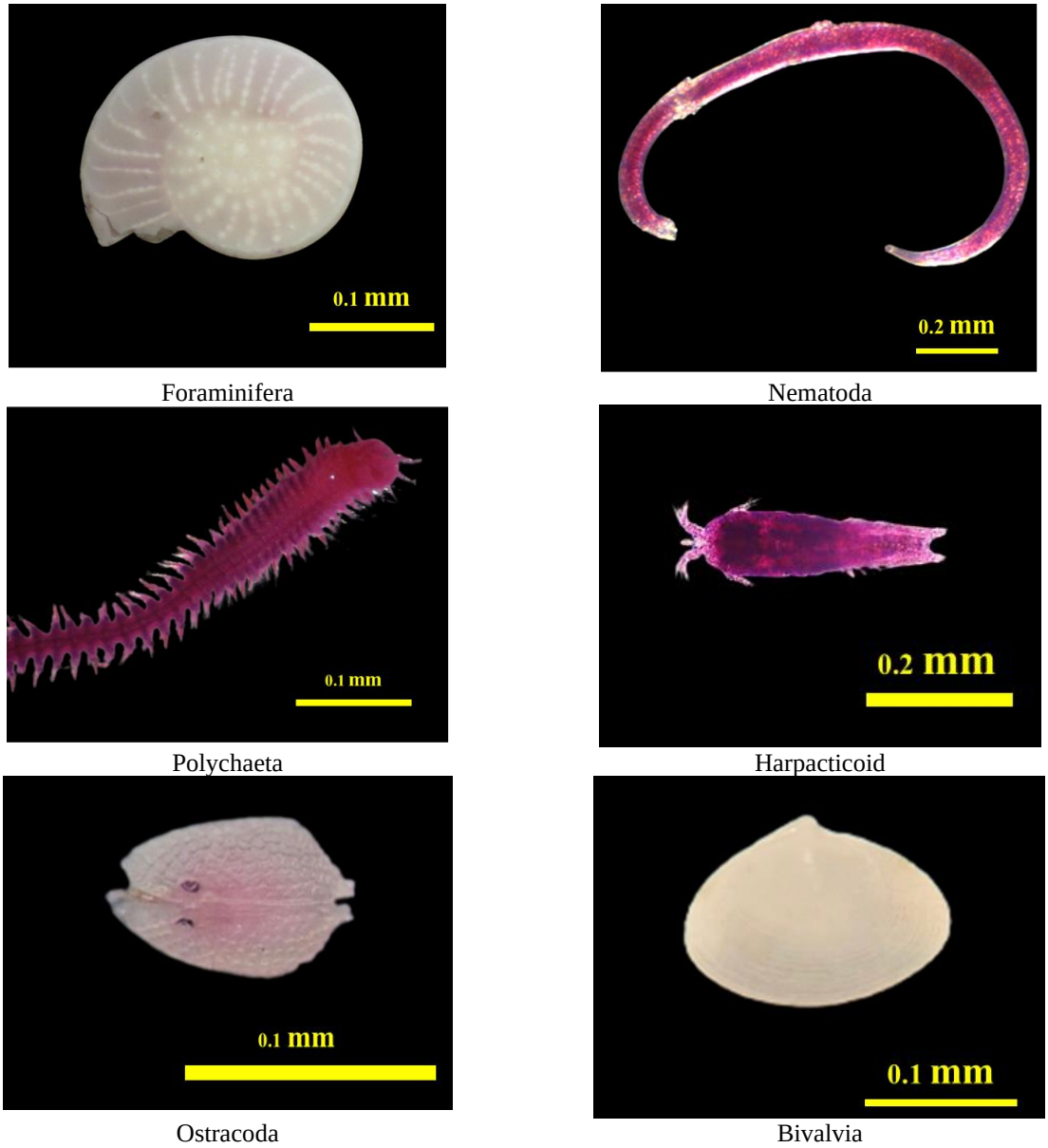


Figure 7. Dominant taxa of meiofauna at the study sites

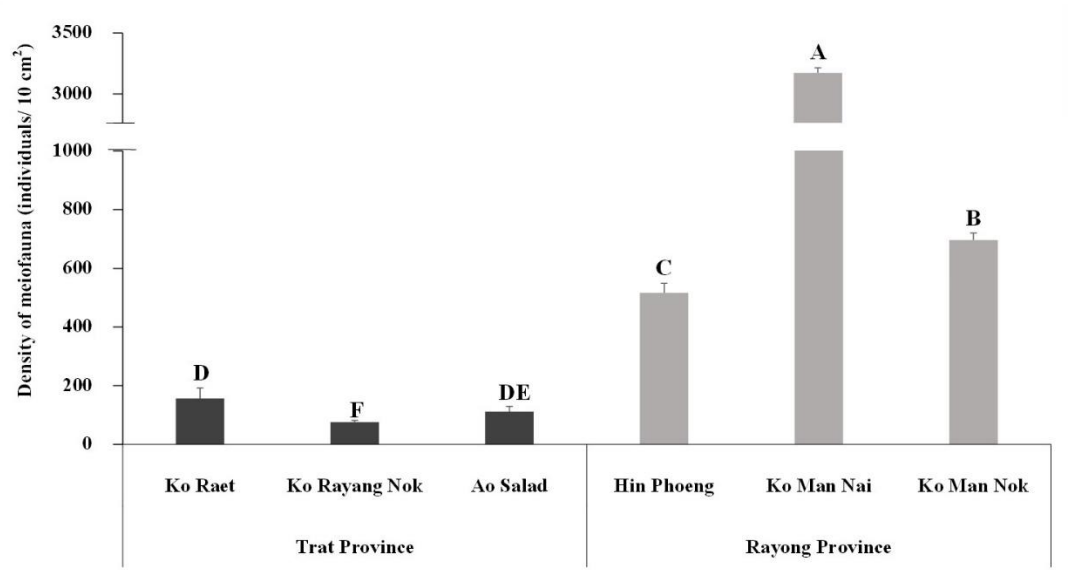


Figure 8. Density of meiofauna on coral communities at the study sites (One-way ANOVA, $p<0.05$)

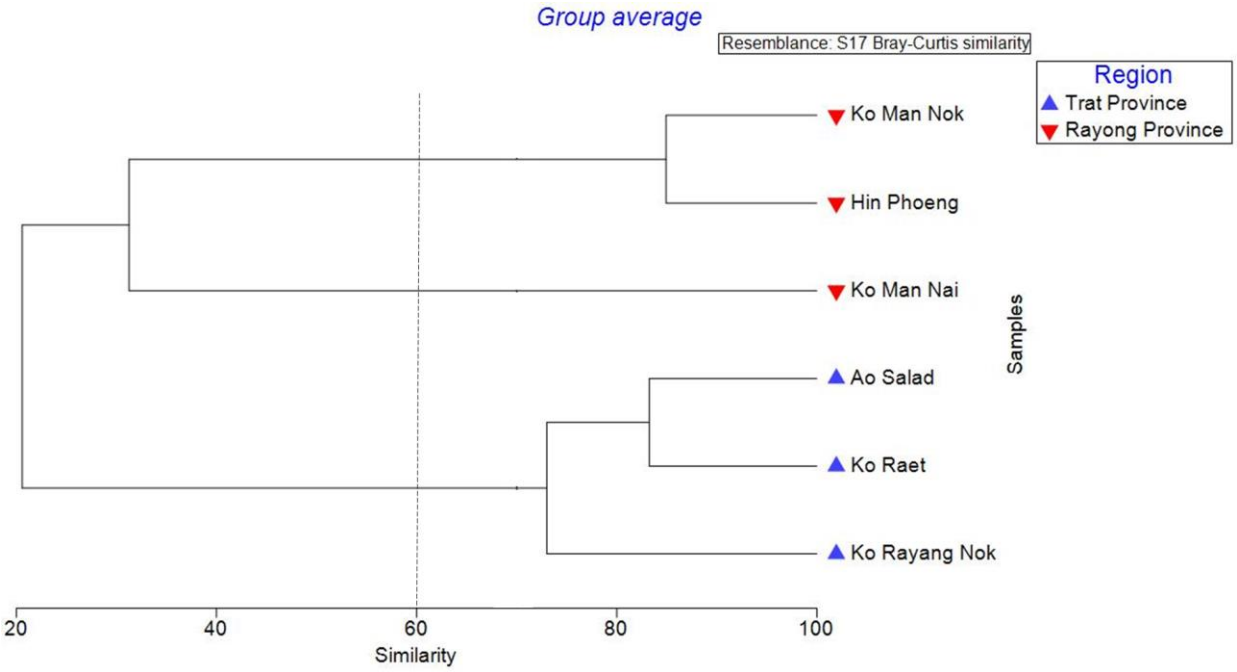


Figure 9. Dendrogram

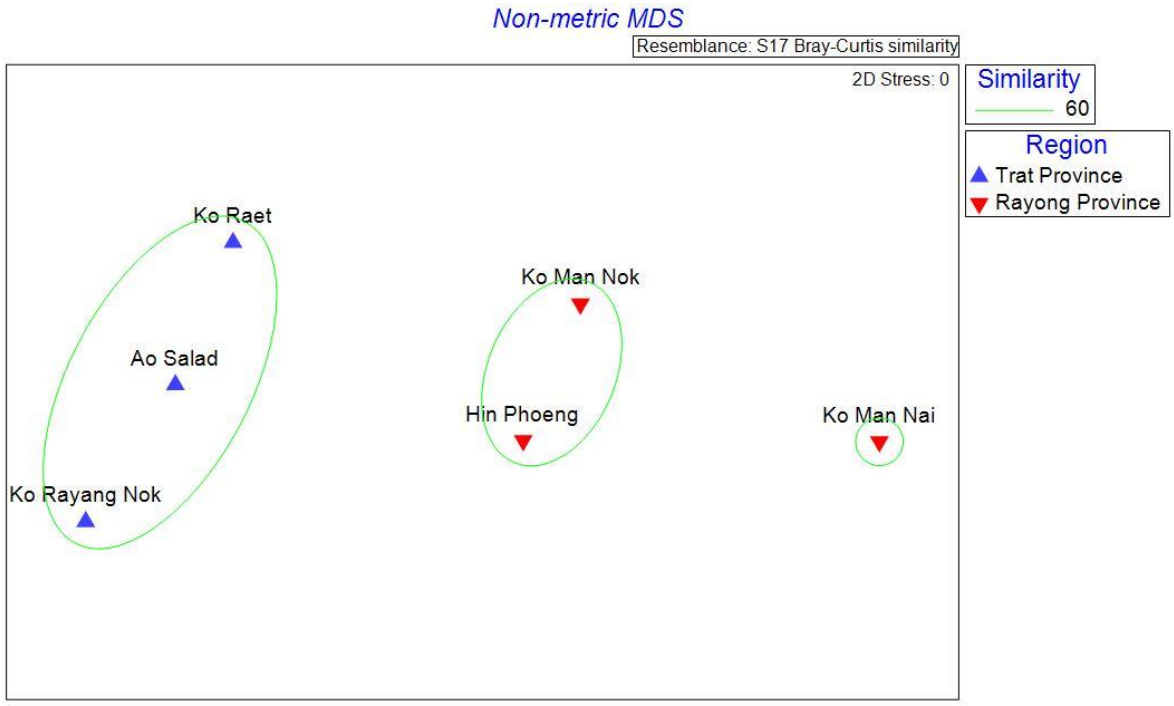


Figure 10. nMDS ordination showing similarity of species composition of meiofauna at each study site

4. Discussion

The present study revealed that the densities of meiofauna on coral communities in Rayong Province were significantly higher than those in Trat Province due to high abundance of Foraminifera. Previous studies showed that Foraminifera can be bioindicators of water quality and reef health (Schueth and Frank 2008; Uthicke et al. 2010; Natsir and Subkhan 2012). The Foraminifera in Reef Assessment and Monitoring Index (FI) values showed a positive correlation with good quality of seawater and a negative correlation with high organic matter content. Therefore, FI is proposed

to be a parameter for assessing the coral reef health in Malaysia (A'ziz et al. 2021). Intensive studies on Foraminifera on coral communities in the Gulf of Thailand are needed for improving the coral reef monitoring programs. However, the composition of meiofauna in Trat Province was significantly higher than that in Rayong Province. All study sites in Trat Province are located far from the mainland and may receive lower impacts from land-based pollution.

The present study showed that Foraminifera, Nematoda, Polychaeta, Harpacticoid Copepoda, Ostracoda, and Bivalvia were the dominant taxa among meiofauna which are similar to the dominant taxa of meiofauna from a Pacific coral reef in Costa Rica (Guzmán et al., 1987; Neira et. al., 2018) and in coastal areas of South Korea (Kim and Lee 2000; 2004; Oh et al. 2023). The main groups of meiofauna on coral reefs in Mu Ko Surin, the Andaman Sea were also Foraminifera, Nematoda, Copepoda and Polychaeta. Moreover, positive correlations between the abundance of total meiofauna and live coral and dead coral cover ratio were observed in copepoda, nematoda, and turbellaria groups (Sangmanee et al. 2022). A study on relationships between meiofauna and nematodes with micro-habitat type from the outer reef and lagoon habitats of the Maldives revealed that coral fragments and rubble from the outer reefs may trap the finest sediment, which can contribute to making diversity of micro-habitats for both infaunal (Tricoma, Richtersia, Ptycholaimellus and Molgolaimus) and epifaunal (Epsilonematidae and Draconematidae genera) (Semprucci et al. 2013). A study from a Pacific coral reef in Costa Rica showed that the highest diversity of meiofauna was found in coarse, heterogeneous sands with the highest percentage of carbonates. The meiofauna also revealed a high degree of horizontal aggregation and showed a distribution pattern of macro- and meiofauna in various compositions of sediments (Guzmán et al., 1987). Meiofauna were also affected by certain environmental factors, particularly seawater temperature, salinity, and dissolved oxygen and related variables (Kim et al. 2023).

Ocean acidification is a significant risk to marine ecosystems. Coral reefs are widely known as the most sensitive ecosystem by ocean acidification (van Hooidonk et al. 2014). A mesocosm experiment was carried out from Recife de Fora Municipal Marine Park, Porto Seguro, Bahia, Brazil to examine the effects of seawater acidification on meiofauna community from a coral reef. Most meiofauna groups showed different responses to ocean acidification. Nematoda, Ostracoda, Turbellaria, and Tardigrada showed their highest densities in low-pH treatments, particularly at the pH reduction of 0.6 units, pH 7.5 whereas harpacticoid nauplii were strongly negatively impacted by low pH. However, the densities of major groups of meiofauna, Harpacticoida and Polychaeta, did not show significant differences because of pH. The trophic structure and function of coral reefs can be affected by ocean acidification because meiofauna are important in the food web coral reef ecosystems (Sarmento et al. 2015). Understanding on the meiofauna communities on coral reef and underwater pinnacle ecosystems in the Gulf of Thailand are very important for managing these ecosystems under the global change crisis.

This study provides the important knowledge of composition and density of meiofauna in coral reef and underwater pinnacle sediments from the Eastern Gulf of Thailand. This is the first report on meiofauna community from an underwater pinnacle in Thai waters and reiterates that the underwater pinnacles are important as same as the coral reef ecosystems.

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