

Diel variation in zooplankton assemblages around Aceh Island, Pahang, Malaysia

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Abstract. *Zamany ABBM, Menxia S, Abdullah MAA, Rahim AA. 2025. Diel variation in zooplankton assemblages around Aceh Island, Pahang, Malaysia. Biodiversitas 26: 4685-4693.* This study investigated diel fluctuations in zooplankton distribution, composition, and abundance in the coastal waters off Aceh Island, Pahang, Malaysia. Sampling was conducted on 24 April 2025 during the dry season, using standardized net tows at five fixed stations during both day and night, with three replicates per station. A total of 54 taxa were identified at night and 49 during the day, with copepods consistently dominating the assemblages—accounting for 97.06% of nocturnal and 80.4% of diurnal abundance. *Euterpina* sp. 1 was the most frequently encountered copepod across both periods. Zooplankton densities ranged from 131.68 to 220.60 ind/m³ (n = 6,178) during the day and 165.2 to 239.0 ind/m³ (n = 11,995) at night. Diversity metrics, including Shannon-Wiener (H') and Pielou's evenness (J'), indicated moderate to high diversity, with greater species richness and evenness observed during nocturnal sampling, particularly at deeper sites (STN 1 and STN 4). These patterns align with existing records from adjacent waters in Pahang and Johor, where copepods consistently dominate the zooplankton community. The study highlights the importance of incorporating diel sampling into biodiversity monitoring, as single-time-point surveys may underestimate community diversity and overlook diel behavioural dynamics such as vertical migration. These findings contribute to the growing baseline data needed for effective ecological assessments and conservation efforts in Malaysian coastal ecosystems.

Keywords: Aceh Island, coastal Malaysia, copepod, diel variation, zooplankton

INTRODUCTION

Aceh Island is a small island situated at the northern boundary of Johor and Pahang, measuring approximately 0.5 km in width and 2.8 km in length, off the southeast coast of Peninsular Malaysia. Although geographically close to Malaysia's marine parks, the island remains outside the main focus of research activities. The state of Pahang hosts one of Malaysia's designated Marine Parks, which includes nine islands such as Tioman, Tulai, Chebeh, and Seri Buat, all of which have been the subject of extensive ecological research (Othman and Azman 2007; Azman and Othman 2013; Shin et al. 2015; Elisa and Azman 2024). In contrast, Aceh Island has received no documented scientific attention with regard to its aquatic ecology. This absence of research highlights a critical knowledge gap, emphasizing both the novelty and importance of the present study. Establishing a first ecological baseline is particularly relevant, as the island's coastal waters are likely to support diverse and ecologically important marine life, with implications for biodiversity conservation and fisheries management.

Zooplankton form a fundamental component of marine ecosystems, occupying both pelagic and littoral zones. They serve as key intermediaries in trophic dynamics by transferring energy from primary producers (phytoplankton) to higher consumers, including commercially valuable fish

species (Castellani and Edwards 2017). Their relatively short life cycles, rapid turnover, and sensitivity to environmental fluctuations make them highly responsive to ecological change, thereby providing reliable bioindicators of ecosystem health and water quality (Parmar et al. 2016). Understanding zooplankton communities is therefore not only central to advancing marine ecology but also essential for informing fisheries management and conservation planning. Along the east coast of Peninsular Malaysia, zooplankton communities have been the subject of numerous investigations (Nakajima et al. 2009; Nakajima et al. 2014; Metillo et al. 2019; Shafie et al. 2023; Elisa and Azman 2024). These studies consistently report copepods as the dominant taxon, typically accounting for more than 80% of overall abundance (Laily and Azman 2017; Nadiah and Azman 2018). The composition and distribution of these assemblages are strongly influenced by environmental variables such as salinity, temperature, and chlorophyll-a concentration (Reymathi 2019), reflecting the close coupling between physical and biological processes in coastal ecosystems.

Despite this body of work, very little is known about diel (day-night) variation in zooplankton communities within Malaysian waters. Globally, Diel Vertical Migration (DVM) is among the most studied behavioral phenomena in plankton ecology, representing the largest synchronized movement of biomass on Earth. In DVM, zooplankton

ascend toward surface waters at dusk to exploit higher phytoplankton concentrations and descend to deeper strata at dawn to evade visual predators. This behavior has been documented across taxa and latitudes, including tropical systems (Aumont et al. 2018). However, there is still debate regarding the extent of DVM in equatorial regions, where relatively stable thermal stratification may reduce the strength of migration. Some researchers suggest minimal diel variation in such waters, while others have reported pronounced nocturnal peaks in abundance (Ismail et al. 2021; Shafie et al. 2023). These contrasting findings underscore the importance of region-specific studies to clarify the role of diel dynamics in structuring tropical zooplankton communities.

The absence of prior ecological research on Aceh Island further magnifies this gap. Without baseline data, it is impossible to evaluate how zooplankton communities contribute to local food webs, fisheries resources, or ecosystem resilience under environmental change. Baseline assessments are particularly timely given accelerating coastal development and climate-driven changes that could alter the productivity and structure of marine ecosystems.

Therefore, this study represents the first diel (day-night) assessment of zooplankton community structure around Aceh Island. Specifically, it aims to (i) document diurnal variation in zooplankton abundance and composition, (ii) describe spatial distribution patterns across sampling stations, and (iii) provide essential baseline data for ecological monitoring. By integrating diel sampling with taxonomic assessments, the study will generate insights into community dynamics that can inform both biodiversity conservation and sustainable fisheries management in the region. Moreover, the findings will contribute to the broader understanding of zooplankton ecology in tropical marine systems, helping to resolve uncertainties surrounding DVM in equatorial waters.

MATERIALS AND METHODS

Zooplankton samples were collected during both day and night on a single date (5 April 2024) from five sampling stations in the waters off Aceh Island, Pahang (Table 1 and Figure 1). The month of April was selected for sampling as it represents a transitional inter-monsoon period characterized by elevated biological activity, favourable sea conditions, and minimal seasonal disturbances, providing an optimal window for reliable and representative zooplankton data collection in Malaysian coastal waters.

At each station, three replicate samples were obtained using vertical hauls throughout the entire water column. A conical plankton net with a 30 cm mouth diameter and 140 μ m mesh size was hand-towed vertically from the seafloor to the surface. The net was deployed near the sea surface and retrieved through the full depth of the water column. This approach follows established protocols for marine zooplankton sampling (UNESCO 1968; Harris et al. 2000). The total volume of water filtered per haul varied by station depth, with an average depth of 12 m, yielding an estimated

theoretical filtration volume of approximately 0.72 m³ per haul. Immediately after collection, specimens intended for morphological analysis were preserved in a 4% formalin-seawater solution. Zooplankton specimens were identified to the lowest possible taxonomic level using morphological keys and standard references (Newell and Newell 1977; Yamaji 1982; Todd et al. 1996; Fernando 2002; Mulyadi 2004; Conway et al. 2003), with nomenclature verified against the online copepod database of Razouls et al. (2005-2023).

Surface water temperature and salinity were measured using a multiparameter water quality meter (Aquaread Water Monitoring System – AP-2000). Additionally, water samples were collected in the laboratory to determine Chlorophyll- α concentrations. For detailed examination, specimens were photographed using an Olympus SZX9 microscope equipped with a Canon M100 camera for imaging. All collected materials are stored at the Muzium Zoologi, Universiti Kebangsaan Malaysia, Malaysia.

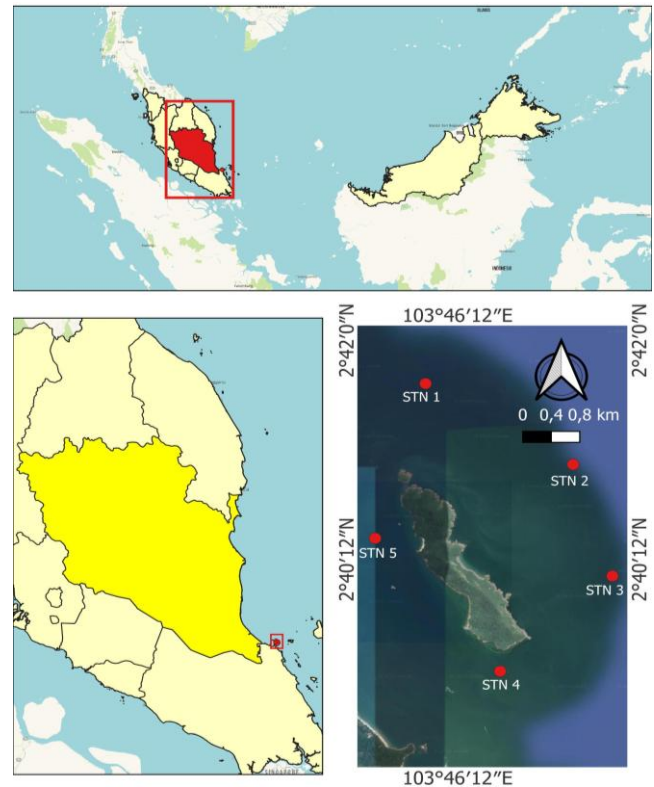


Figure 1. Map of the sampling area around Aceh Island, Pahang, Malaysia, showing five fixed stations (STN 1-5)

Table 1. Geographic coordinates (WGS84) of the five sampling stations around Aceh Island, Pahang, Malaysia

Station	Latitude (°N)	Longitude (°E)	Site description
1	2.69411	103.76597	Sparse coral reef slope
2	2.68303	103.78461	Sandy bottom
3	2.66775	103.78956	Near reef edge
4	2.65469	103.77539	Mixed habitat (coral rubble and sand)
5	2.67292	103.75961	Calm with slight turbid waters

RESULTS AND DISCUSSION

Environmental parameters

Depth profile

Although depth is a fixed feature for each station (Figure 2), minor variation between day and night readings may reflect slight differences in sampling location due to drift or wave action. The depth decreased progressively from ST1 (deepest) to ST5 (shallowest), representing a nearshore to offshore gradient that influences water column structure and vertical migration patterns of zooplankton.

Temperature

Temperature exhibited small but consistent diel fluctuations (Figure 2). Nighttime temperatures were slightly higher at several stations, notably STN 1 and STN 5, with a peak of 31.8°C at STN 5. These differences, while minor, could be attributed to limit convective mixing during the night or residual surface heat in shallow waters. Elevated nighttime temperatures may enhance metabolic activity in planktonic organisms and contribute to changes in vertical distribution (Wang et al. 2020).

Dissolved Oxygen (DO)

Dissolved oxygen levels were generally higher at night, particularly at STN 1 and STN 5, reaching up to 6.99 mg/L (Figure 2). This trend contrasts with typical diel oxygen patterns in some systems, where photosynthetic activity during the day elevates oxygen concentrations. However, in this coastal setting, nighttime cooling and reduced respiration might enhance DO solubility. Higher nighttime DO can support increased zooplankton respiration and aggregation in surface layers.

pH

A distinct diel pattern was observed in pH (Figure 2), with higher values recorded at night (up to 8.8 at STN 1) compared to the daytime (as low as 7.88 at STN 2 and STN 3). This trend likely reflects reduced photosynthetic activity at night and associated changes in dissolved CO₂ concentration. Elevated pH at night may influence the solubility of certain ions and affect larval development stages of marine invertebrates (Gattuso et al. 2015).

Zooplankton composition

A total of 54 zooplankton taxa were identified across all stations throughout the study (Table 2), comprising representatives from five major phyla: Arthropoda (copepods and other crustaceans), Chaetognatha, Annelida, Chordata (larval fish), and Cnidaria/Mollusca. Notably, 49 taxa were recorded during the daytime, increasing to 54 taxa at night, representing 80.4% of the diurnal abundance and 97.06% of the nocturnal abundance. Indicating a modest but ecologically meaningful rise in species richness after sunset.

Copepods were the most dominant group during both diel periods, contributing to 58.4% of total abundance in daytime samples and increasing to 81.9% at night (Figure 3). Dominant copepod taxa included *Euterpina* sp. 1 and *Paracalanus* sp. 1, both small-bodied forms that play vital roles in coastal food webs, with the macrophotography (Figure 4) providing clear visual documentation of their key morphological traits. This overwhelming dominance is consistent with previous findings in Malaysian coastal waters (Laily and Azman 2017; Nadiah and Azman 2018) and reflects their critical role as grazers in pelagic food webs.

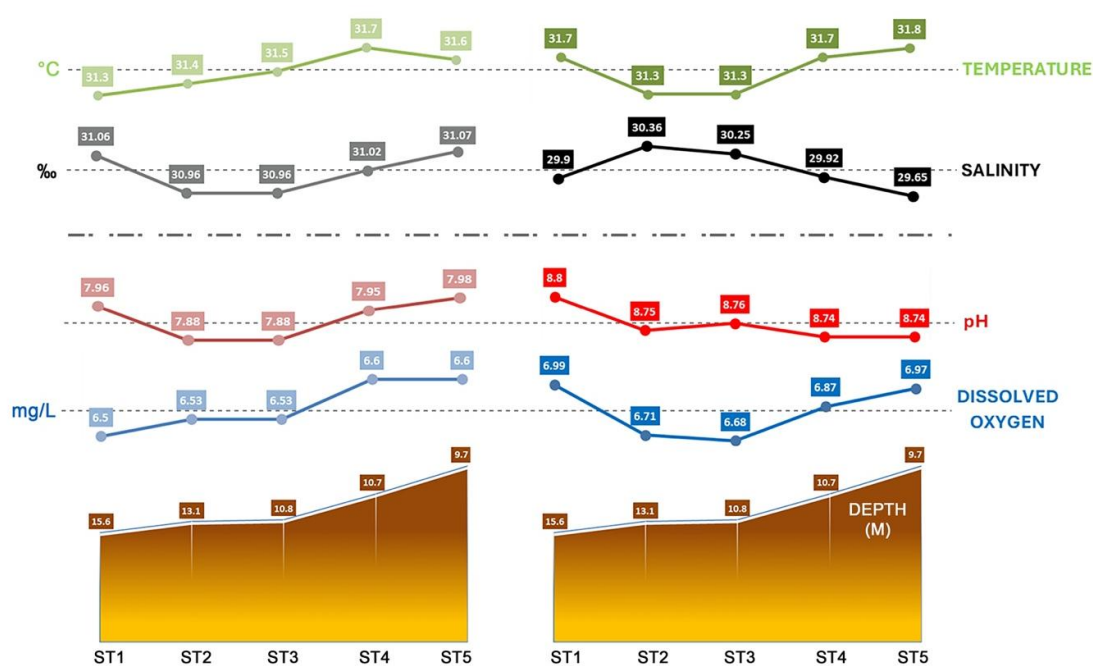


Figure 2. Physico-chemical parameters from Aceh Island, Pahang, Malaysia, for night and day

Table 2. Zooplankton taxa from five sampling stations around Aceh Island, Pahang, Malaysia, arranged alphabetically by phylum and down to the lowest identifiable taxonomic level

Taxa	D	N
Annelida		
<i>Tomopteris</i> sp. 1	•	
Polychaete Larvae (sp. 1)	•	•
Polychaete Larvae (sp. 2)	•	•
Polychaete Larvae (sp. 3)	•	•
Polychaete Larvae (sp. 4)		•
Arthropoda		
Amphipoda		
Hyperid sp. 1	•	
<i>Metaprotella</i> sp. 1	•	
Decapoda		
Lucifer sp. 1	•	
Megalopa Larvae	•	•
Zoea sp. 1	•	•
Zoea sp. 2	•	
Euphausiacea		
Euphausiid Larvae sp. 1	•	
Euphausiid sp. 2		•
Mysida		
<i>Acanthomysis quadrispinosa</i>	•	•
<i>Prionomysis aspera</i>	•	
Copepoda		
Calanoida		
<i>Acartia</i> sp. 1		•
<i>Acartia</i> sp. 2		•
<i>Acrocalanus</i> sp. 1		•
<i>Calanus</i> sp. 1	•	
<i>Calanopia</i> sp. 1		•
<i>Canthocalanus</i> sp. 1		•
<i>Centropages</i> sp. 1	•	•
<i>Paracalanus</i> sp. 1		•
<i>Parvocalanus</i> sp. 1	•	•
<i>Pontella</i> sp. 1		•
<i>Temora</i> sp. 1		•
<i>Temora</i> sp. 2		•
<i>Tortanus</i> sp. 1	•	•
Cyclopoida		
<i>Oithona</i> sp. 1	•	•
<i>Oithona</i> sp. 2	•	•
<i>Oithona</i> sp. 3	•	•
<i>Oithona</i> sp. 4		•
<i>Sapphirina</i> sp. 1	•	
Harpacticoida		
<i>Clytemnestra</i> sp. 1	•	•
<i>Euterpina</i> sp. 1	•	•
<i>Longipedia</i> sp. 1		•
<i>Microsetella</i> sp. 1	•	•
<i>Microsetella</i> sp. 2		•
<i>Macrosetella</i> sp. 1	•	
Poecilostomida		
<i>Corycaeus</i> sp. 1	•	•
<i>Corycaeus</i> sp. 2		•
<i>Corycaeus</i> sp. 3		•
<i>Corycaeus</i> sp. 4		•
<i>Oncaea</i> sp. 1	•	•
<i>Oncaea</i> sp. 2	•	
Ostracoda		
<i>Pistocythereis</i> sp. 1	•	•
<i>Neocytheretta</i> sp. 1		•
Cyprid sp. 1		•

Sessilia		
<i>Nauplii balanus</i> (sp. 1)	•	•
<i>Nauplii balanus</i> (sp. 2)	•	•
<i>Nauplii balanus</i> (sp. 3)		•
<i>Nauplii balanus</i> (sp. 4)		•
<i>Nauplii balanus</i> (sp. 5)		•
<i>Nauplii balanus</i> (sp. 6)		•
<i>Nauplii balanus</i> (sp. 7)		•
Stomatopoda		
Stomatopoda sp. 1	•	
Chaetognatha		
<i>Parasagitta</i> sp. 1	•	•
<i>Sagitta</i> sp. 2	•	•
Chordata		
Fish larvae (sp. 1)	•	•
Fish larvae (sp. 2)	•	•
Fish larvae (sp. 3)	•	•
Fish egg (sp. 1)		•
Fish egg (sp. 2)		•
Oikopleura sp. 1	•	•
Oikopleura sp. 2		•
Cnidaria		
<i>Hydromedusa</i> sp. 1	•	•
<i>Hydromedusa</i> sp. 2	•	
<i>Hydromedusa</i> sp. 3	•	
<i>Hydromedusa</i> sp. 4	•	
<i>Hydromedusa</i> sp. 5	•	
<i>Hydromedusa</i> sp. 6	•	
<i>Hydromedusa</i> sp. 7	•	
<i>Hydromedusa</i> sp. 8	•	
Salpidae sp. 1	•	
Larva anthozoa sp. 1	•	
Mollusca		
Larva gastropoda sp. 1	•	

Note: • = Occurrence. D = Daytime, N = Nighttime. Table continues across two columns

Beyond copepods, annelid larvae, chaetognaths, and fish larvae (Chordata) represented significant proportions of the remaining zooplankton (Figure 3). Notably, chaetognaths (arrow worms) were slightly more abundant during the day, suggesting possible avoidance of surface waters at night, possibly due to predator avoidance or vertical positioning of prey. In contrast, larval fish and polychaete larvae showed increased abundance at night, likely associated with their own diel vertical migrations or synchronized emergence patterns. Consistent with prior work, chaetognaths displayed a vertically stratified pattern often associated with predator avoidance and prey-field positioning (Terazaki and Marumo 1982; Pearre 1973), whereas larval fish (Boehlert et al. 1992; Leis 1993) and polychaete larvae (Alldredge and King 1985; Hill 1991) increased at night, reflecting typical diel vertical migrations or nocturnal emergence dynamics. The group classified as “other crustaceans”, which included ostracods, amphipods, and mysids, displayed a higher richness at night, although their overall contribution to abundance remained modest. Similarly, meroplanktonic groups such as cnidarians and mollusks were observed in low numbers, mostly during nighttime samples with the macrophotography (Figure 5), providing detailed visual records that complement their ecological interpretation despite their low abundance.

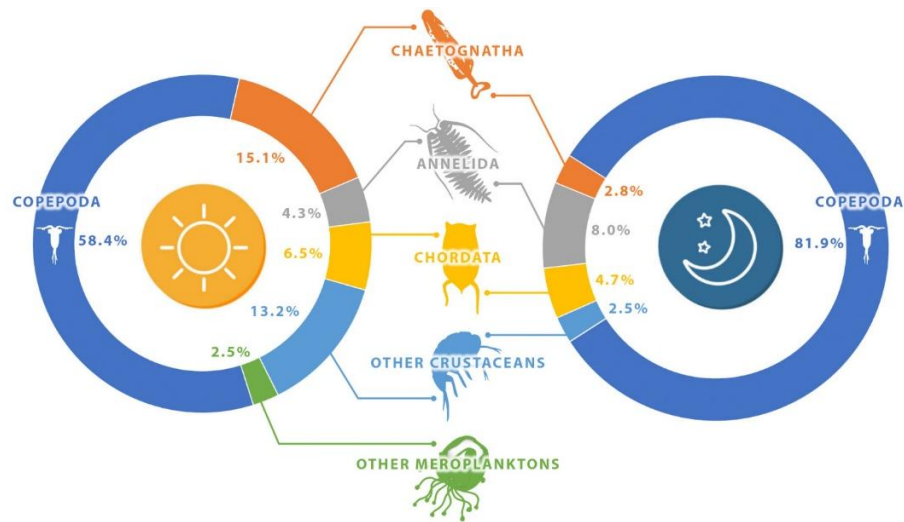


Figure 3. Faunal composition of zooplankton for day and night

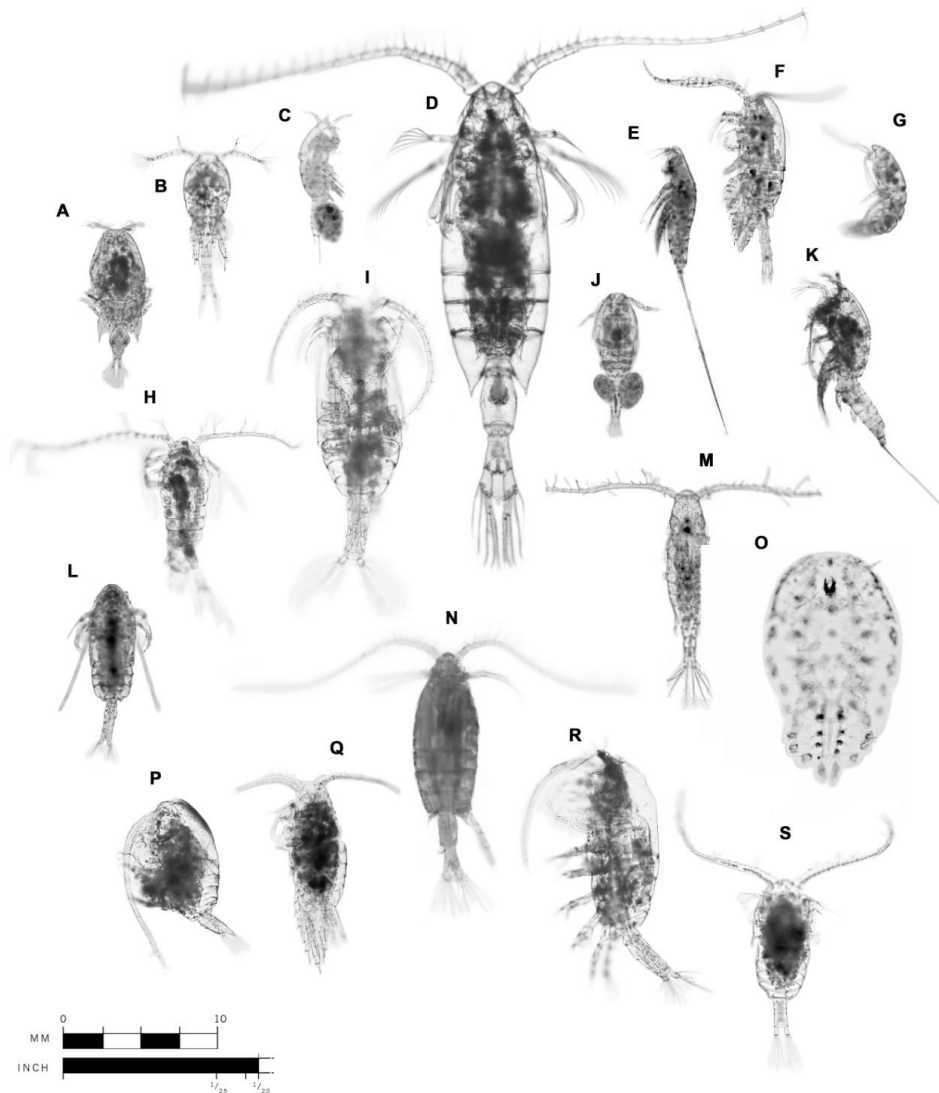


Figure 4. Some commonly found copepods from the study area. A. *Corycaeus* sp. 1, B. *Oncaea* sp. 1, C. *Euterpina* sp. 1, D. *Canthocalanus* sp. 1, E. *Microsetella* sp. 1, F. *Centropages* sp. 1, G. *Clymnestra* sp. 1, H. *Tortanus* sp. 1, I. *Temora* sp. 1, J. *Oithona* sp. sp., 1, K. *Longipedia* sp. 1, L. *Acrocalanus* sp. 1, M. *Acartia* sp. 1, N. *Calanopia* sp. 1, O. *Sapphirina* sp. 1, P. *Temora* sp. 1, Q. *Pontella* sp. 1, R. *Paracalanus* sp. 1, S. *Parvocalanus* sp. 1

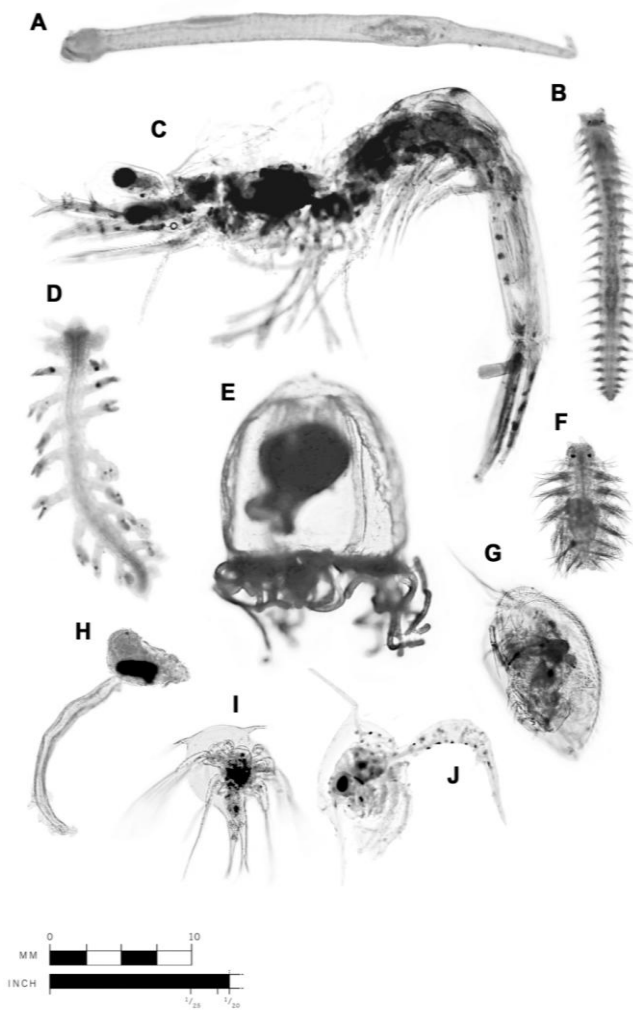


Figure 5. Other common zooplanktons found in the study area. A. Chaetognatha, B. Polychaete, C. Euphausiid, D. *Tomopteris*, E. *Hydromedusa* sp., F. Polychaete larvae, G. Ostracoda, H. *Oikopleura*, I. *Balanus* nauplii, J. Crab zoea

Discussion

Vertical migration

Zooplankton populations consistently increased at night across all five sampling stations, supporting the presence of Diel Vertical Migration (DVM) behavior, in which zooplankton ascend toward surface waters after dusk to exploit higher phytoplankton availability and escape visual predators. Such behavior has been widely documented across taxa and latitudes, including tropical systems (Aumont et al. 2018). In the present study, zooplankton densities varied between 131.68-220.60 ind/m³ (n = 6,178) during the day and 165.2-239.0 ind/m³ (n = 11,995) at night. The most pronounced change was observed at STN 1, where abundance increased from 131.68 ind/m³ during the day to 180.75 ind/m³ at night, marking a 37% increase. At STN 2, the values rose from 150.25 ind/m³ to 198.4 ind/m³, representing a 32% increase. STN 3 also showed a notable rise, with abundance shifting from 175.4 ind/m³ in the day to 210.55 ind/m³ at night, a 20% gain. A more modest change was recorded at STN 4, where abundance moved from 220.6 ind/m³ to 239 ind/m³, an 8% increase. Finally,

STN 5 recorded an increase from 140 ind/m³ in the day to 165.2 ind/m³ at night, equivalent to an 18% rise (Figure 6). These percent increases are consistent with findings from other tropical reef environments. For example, Nakajima et al. (2008a) found significantly higher abundances of large zooplankton at night over coral reefs in Tioman Island, Malaysia, especially during late night hours, which they attribute to diel migration and avoidance of visual predators. Similarly, in Isla del Coco National Park, Pacific Costa Rica (Alvarado et al. 2011), abundant increases at night across coral reef substrates were driven largely by copepod and nauplius stages moving into reef water after dusk, likely as a predator-avoidance strategy. This pattern suggests upward migration of zooplankton into surface waters after sunset, likely to exploit food availability while avoiding visually oriented predators (Ringelberg 2009). STN 4, which recorded the highest overall abundance both day (220.60 ind/m³) and night (239.00 ind/m³), appears to be a biologically productive area with consistent food supply and favorable conditions. Similar patterns were observed in coral reefs of Redang Island, Malaysia, where zooplankton abundance and biomass increased significantly during the night in productive reef zones, particularly among larger size classes, suggesting stable environmental conditions and prey availability (Nakajima et al. 2008b). Likewise, in Isla del Coco National Park, nocturnal peaks of zooplankton over coral substrates were linked to favorable reef conditions acting as feeding grounds and refuges for migrating zooplankton (Esquivel-Garrote and Morales-Ramírez 2020). This trend reinforces the ecological understanding that zooplankton become more concentrated near the surface after dark to optimize feeding opportunities and minimize predation risk (Cohen and Forward 2016).

Taxonomic variation

A comparative assessment of zooplankton communities between daytime and nighttime across the five sampling stations around Aceh Island revealed distinct diel variations in taxonomic richness, species diversity (H'), and evenness (J') (shown in Figure 7). Across all stations, the number of taxa was consistently higher at night compared to the day. STN 1 recorded an increase from 35 taxa during the day to 40 taxa at night, representing a 14% rise. STN 2 showed a similar pattern, with richness increasing from 38 to 42 taxa, a 10% increase. At STN 3, the number of taxa rose from 40 during the day to 45 at night, marking a 13% gain. STN 4 exhibited the highest richness, with 49 taxa at night compared to 44 in the daytime, corresponding to an 11% increase. Meanwhile, STN 5 recorded 30 taxa during the day, increasing to 36 taxa at night, the largest relative change at 20%. This pattern of elevated nocturnal diversity is consistent with previous observations in tropical waters, such as in the Mertang Archipelago, Malaysia, where zooplankton diversity was also reported to be generally higher at night (Azwa-Liza et al. 2025). Similar diel patterns have been observed in the Andaman Sea, where nighttime zooplankton assemblages showed significantly higher richness and abundance due to vertical migration behaviours (Satapoomin and Nishida 2000), and in the

coastal waters of the Philippines, where nocturnal peaks in diversity were linked to predator avoidance and feeding strategies (Villanoy et al. 2011). These patterns reflect the influence of nocturnal vertical migration, a behavioral adaptation in which zooplankton ascend toward surface layers at night to exploit food resources while minimizing predation risk (Ringelberg 2009). Beyond predator avoidance, such shifts may also reflect synchronized reproductive or emergence cycles, particularly among meroplanktonic groups such as mollusks and polychaetes, which often release larvae during nighttime to enhance dispersal and reduce daytime predation. The higher nighttime diversity and evenness suggest a more balanced representation of taxa when diel migrators mix with resident surface assemblages, leading to increased trophic complexity and altered prey availability for higher consumers such as larval fish. In tropical coastal systems like Aceh Island, these dynamics are further shaped by stable thermal stratification, nutrient pulses, and the interaction of reef-associated and pelagic communities, underscoring the importance of diel studies in capturing the ecological processes driving biodiversity patterns.

Evenness and diversity patterns

In terms of community evenness, as measured by Pielou's Evenness Index (J'), all stations showed an increase at night. Nighttime J' values ranged from 0.50 to 0.62, compared to daytime values between 0.44 and 0.59. This indicates that the zooplankton community becomes more evenly distributed at night, likely due to a reduction in the dominance of particular species and a more balanced representation of taxa. Such balanced distributions may be a result of decreased competition or predator pressure in surface waters during nighttime hours (Parmar et al. 2016).

Shannon-Wiener Diversity Index (H') exhibited a parallel diel trend, with nighttime values ranging from 2.78 to 3.07, which were notably higher than daytime values that ranged from 2.41 to 2.67. For instance, in the Mertang Archipelago (Peninsular Malaysia), zooplankton H' was similarly elevated at night compared to daytime values (Azwa-Liza et al. 2025). Likewise, in nearshore systems around coral reefs, zooplankton communities exhibited significantly higher species richness and diversity after sunset, particularly in larger size fractions at coral reef sites (Chew et al. 2018).

STN 4 again recorded the highest diversity at night ($H' = 3.07$), indicating a richer and more complex community structure under nocturnal conditions. The increased diversity at night suggests elevated activity, feeding, and mixing of multiple zooplankton groups, most prominently copepods such as *Euterpina* sp. and *Paracalanus* sp. which are known to dominate nighttime assemblages (Cohen and Forward 2016; Nadiah and Azman 2018).

Environmental drivers

The diel differences in taxa richness, diversity, and evenness highlights the dynamic and responsive nature of zooplankton assemblages in Aceh Island's coastal waters. Collectively, these findings suggest that nighttime conditions support higher biodiversity and more equitable

community structure, driven largely by behavioral adaptations and diel fluctuations in environmental conditions. Recent tropical studies (Feng et al. 2022; Tao et al. 2022) have demonstrated that zooplankton richness, diversity, and evenness exhibit significant variation between day and night, influenced by environmental factors such as temperature and dissolved oxygen, underscoring the importance of diel sampling in biodiversity assessments.

The observed diel variations in taxa richness, diversity, and evenness reflect the highly dynamic and environmentally responsive nature of zooplankton communities in the coastal waters of Aceh Island. These results indicate that nighttime conditions tend to support greater biodiversity and a more balanced community structure, likely due to behavioral patterns such as diel vertical migration and shifts in environmental factors such as light, temperature, and predation pressure. Supporting this, recent studies in tropical regions (Feng et al. 2022; Tao et al. 2022) have demonstrated significant day-night differences in zooplankton diversity, driven by key environmental variables including temperature and dissolved oxygen. These results highlight the importance of incorporating both daytime and nighttime sampling in biodiversity assessments to capture the full ecological complexity of zooplankton assemblages (Castellani and Edwards 2017; Amorim and do Nascimento Moura 2021).

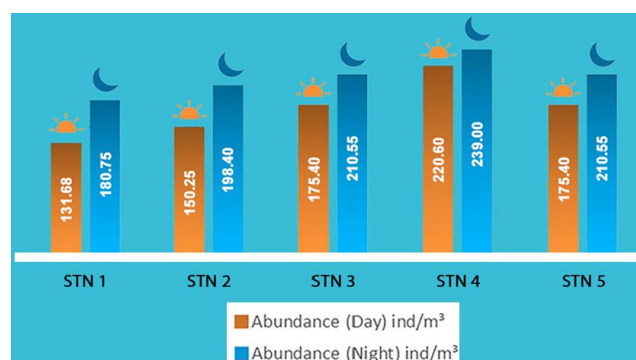


Figure 6. Zooplankton abundance (individuals m^{-3}) during day (orange) and night (blue) at each station



Figure 7. Diversity indices at each station, including evenness (J'), Shannon index (H'), and number of taxa

In conclusion, this study highlights marked diurnal and spatial variation in zooplankton assemblages in the waters surrounding Aceh Island, Pahang, with significant differences in community composition between day and night. Notably, zooplankton abundance and species richness were significantly higher during nocturnal periods, likely driven by diel vertical migration behaviors and reduced predation pressure under low-light conditions. Copepods consistently dominated the assemblages, reaffirming their ecological importance in the local planktonic food web. Environmental parameters such as depth and temperature were also found to play key roles in shaping spatial distribution patterns. These findings emphasize the necessity of incorporating diel sampling strategies into biodiversity monitoring frameworks, as single-time-point surveys may fail to capture the full extent of species diversity and dynamic ecological processes. By accounting for both temporal and spatial variability, such approaches provide a more holistic understanding of planktonic ecosystems, which is crucial for informing future ecological assessments and guiding conservation planning in Malaysia's coastal waters.

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