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Diversity and habitat characteristics of gastropods and bivalves associated with mangroves on the east coast of Aceh Province, Indonesia

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Abstract. *Mawardi AL, Khalil M, Sarjani TM, Armanda F. 2023. Diversity and habitat characteristics of gastropods and bivalves associated with mangroves on the east coast of Aceh Province, Indonesia. Biodiversitas 24: 5146-5154.* Mangrove areas are vital for various gastropod and bivalve species as breeding, nursery, and stable nutrient supply grounds. This study aims to understand the habitat characteristics and diversity index of gastropods and bivalves and identify the associated species with mangrove vegetation along the east coast of Aceh Province, Indonesia. This research utilized a survey method with gastropod and bivalve sampling conducted using purposive sampling. Sampling was carried out at 6 research locations with varying environmental conditions. Gastropods and bivalves were collected from each research location using 1 m x 1 m plots. All collected gastropod and bivalve samples were preserved in a 4% formalin solution and later identified at the Biology Laboratory of Samudra University. A total of 5,293 individuals of gastropods and bivalves were found in the research locations, comprising 48 species and 21 families. The diversity index of gastropods and bivalves across all research locations showed a moderate criterion, indicating slight pollution on the east coast of Aceh Province. The highest diversity was observed at location 5, far from settlements and active fishing vessel activities. On the other hand, the lowest diversity was found at location 2, an area with active fishing vessel transportation to and from the fish auction site (TPI).

Keywords: Bivalves, coast, gastropods, mangrove

INTRODUCTION

The coastal area of the east coast of Aceh Province, Indonesia, is one of the largest mangrove vegetation regions in Southeast Asia, playing a crucial role in sustaining various species of animals' lives. It is an ideal habitat for gastropods and bivalves (Azmi et al. 2022). Mangrove areas also function as vital sites for breeding and nursery for various species of fish, crustaceans, gastropods, and bivalves while providing a high-nutrient supply zone (Pola et al. 2020). The mangrove ecosystem's rich nutrient content contributes to the abundance of aquatic organisms (Isroni et al. 2023). An ideal environment and an abundant food supply remarkably influence animal populations in an area (Fitriadi et al. 2023; Kudratov et al. 2023). The decomposition of mangrove plant leaves, branches, and twigs becomes a potential food source for plankton, gastropods, and bivalves due to microbial breakdown. Conversely, gastropods also play a vital role in boosting mangrove productivity, primarily through weed cleansing around mangrove roots and stems (Diringer et al. 2019; Yadav et al. 2019).

Gastropods and bivalves constitute macrozoobenthic animal groups often found in areas with sandy and muddy substrates in aquatic environments. These creatures have a widespread distribution, with many residing in either sessile or motile, saltwater, and brackish environments (Kudratov et al. 2023). Macrozoobenthic animals are crucial in controlling sediments, facilitating the circulation of organic materials as an energy source in the food chain, and greatly contributing to the distribution and productivity of aquatic plant vegetation (De Jesús-Carrillo et al. 2020; Desai et al. 2020). These aquatic animals also serve as significant suppliers of high nutritional content to comply with the dietary needs of protein- and carbohydrate-rich communities. Bivalves' high nutritional content makes them a preferred food source, both domestically and for international export (Tabakaeva et al. 2018; Biandolino et al. 2019). High market demand for several macrozoobenthic species has led to continuous exploitation by communities, particularly shellfish and oyster, causing ecological pressure on these aquatic populations (Kumari et al. 2020; Pereira et al. 2023).

Gastropods and bivalves have a relatively sedentary life at the bottom of aquatic environments with slow mobility. As such, these aquatic macrozoobenthic organisms are well-suited indicators of environmental conditions in aquatic regions (Bahtiar et al. 2022; Foster et al. 2022). When an area's environment becomes contaminated, these organisms also become polluted by accumulating pollutants in their bodies, corresponding to the environmental pollutant concentrations (Alhejoj et al. 2017). A higher macrozoobenthic diversity index within a certain environment indicates that the aquatic area remains in good condition, whereas lower macrozoobenthic diversity indicates light to severe pollution (Harahap et al. 2018; Herawati et al. 2020).

However, research on the diversity and habitat characteristics of gastropods and bivalves along the eastern Aceh Province's coastal area is still very limited, leading to

a lack of data on these creatures. Previous studies conducted in the coastal area of Langsa City found only four bivalve species (Mawardi et al. 2021). Nonetheless, data on gastropod and bivalve populations on the eastern coast of Aceh Province are scarce. Therefore, it's essential to research the diversity index and habitat characteristics of gastropods and bivalves in this area, providing local communities and governmental authorities with essential information on the aquatic biota's population conditions. Furthermore, data on gastropod and bivalve populations can indicate environmental conditions, whether they live in good, slightly polluted, or heavily polluted areas.

MATERIALS AND METHODS

Study area

This research employs a survey method with gastropod and bivalve sampling conducted through purposive sampling. Sampling was carried out in three districts/cities along the east coast of Aceh Province, Indonesia namely Aceh Tamiang, Langsa City, and East Aceh, encompassing areas with varying environmental conditions (Table 1).

For each district/city, two research locations were selected with different environmental characteristics, one near residential areas within the mangrove zone and another near the beach and ocean (Figure 1).

Data collection

Gastropods and bivalves were sampled from May to July 2023 in 6 locations study in three districts/cities. Sampling was done using transects extending from the mangrove towards the sea. Gastropods and bivalves were sampled for each research location within a 1 m x 1 m plot. All collected gastropod and bivalve samples at the research locations were preserved in sample bottles containing a 4% formalin solution and later identified at the Samudra University Biology Laboratory. Physicochemical parameters such as water salinity, temperature, and pH were measured by a hand refractometer, a mercury thermometer, and a pH meter, respectively, in situ during gastropod and bivalve sampling.

Data analysis

Diversity Index (H')

The Shannon-Wiener information theory (H') was used (Atlanta et al. 2022) to determine the diversity index of a species as follows:

$$H' = -\sum_{i=1}^{s} Pi \ln Pi$$

Where:
H : Estimation of population diversity
pi : Number of individuals of each species (i=1, 2, 3,...)
s : Number of species
Criteria:
H' < 1 : Low diversity
1 < H' < 3 : Moderate diversity
H' > 3 : High diversity

The correlation between the diversity of gastropods and bivalves with environmental parameters, water salinity, water temperature, and water pH was analyzed statistically using Principal Component Analysis (PCA).

Table 1. Characteristics of environmental conditions at the research locations

Districts/City	Location coordinate	Location characteristic
Aceh Tamiang	4°30’12.77"S 98°25’98.19"E	Location 1 is a mangrove area far from human settlements, near the coastline, and often experiences flooding. Mangrove vegetation species like *Bruguiera gymnorrhiza, Sonneratia caseolaris,* and *Rhizophora mangle* dominate this area. The substrate in this area is predominantly sandy and muddy.
	4°31'74.03 "S 98°19'14.45 "E	Location 2 is a mangrove area close to human settlements, where waterlogging occurs during high tides. This location is dominated by mangrove plants such as *Nypa fruticans, Excoecaria agallocha*, and *Rhizophora mangle*. The substrate in this area is primarily muddy.
Langsa City	4°51’24.01"S 98°01’04.99"E	Location 3 is an area of mangroves close to human settlements, where waterlogging occurs more frequently. Mangrove plant species like *Bruguiera gymnorrhiza, Rhizophora mangle, Rhizophora stylosa,* and *Rhizophora mucronata* dominate this location. The substrate in this area is predominantly muddy and sandy.
	4°55'94.95 "S 98°05'63.43 "E	Location 4 is a mangrove area far from human settlements and near the coastline, serving as a maritime transportation hub for fishermen to go to sea for fishing. Mangrove vegetation species like *Bruguiera gymnorrhiza* and *Rhizophora mangle* dominate this area. The substrate in this area is predominantly sandy and muddy.
East Aceh	4°60'30.26 "S 98°01'74.95 "E	Location 5 is a mangrove area far from human settlements, near the coastline directly connected to the ocean, and often experiences waterlogging. Mangrove vegetation species like *Sonneratia caseolaris* and *Avicennia alba* dominate this area. The substrate in this area is predominantly sandy and muddy.
	4°61'50.06 "S 97°94'73.01 "E	Location 6 is a mangrove area close to human settlements, where waterlogging occurs during high tides. Mangrove plants like *Nypa fruticans, Excoecaria agallocha,* and *Bruguiera gymnorrhiza* dominate this location. The substrate in this area is predominantly muddy.

Note: Coordinates provided in latitude and longitude

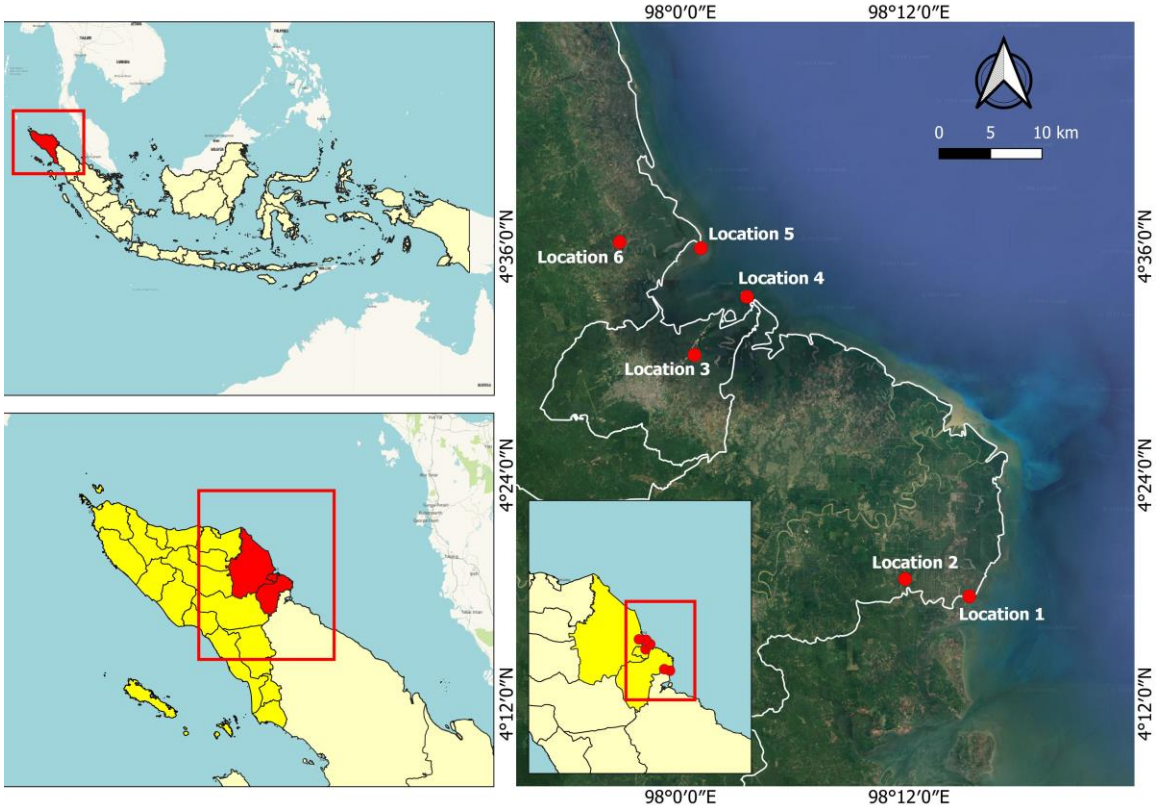

Figure 1. Research location map in the coastal area of Aceh Province, Indonesia

Dominance Index

The dominance index of biota was determined using Simpson's information theory (D) as follows:

$$D = \sum_{i=1}^{s} Pi^2$$

Where: Pi = ni/N
D : Dominance Index
ni : Number of individuals of species i
N : Total number of individuals
Criteria:
$0.0 < D \leq 0.30$: Low dominance
$0.30 < D \leq 0.60$: Moderate dominance
$0.60 < D \leq 1.00$: High dominance

RESULTS AND DISCUSSION

Diversity of gastropods and bivalves

A total of 5,293 individuals of gastropods and bivalves were found across three districts/cities on the east coast of Aceh Province, namely Aceh Tamiang, Langsa City, and East Aceh. Among them, 2,838 individuals were gastropods, and 2,455 individuals were bivalves. These coastal biota species rely on direct and indirect mangrove vegetation as their habitat; each species, whether gastropod or bivalve, exhibits diverse lifestyle and food acquisition characteristics. For example, gastropods from the Neritidae family are found in mangrove vegetation, which feeds on moss and weeds that grow on these plants. Meanwhile, the bivalves found at research locations that depend on mangroves is *Anadara granosa* (Linnaeus, 1758); this species consumes plankton and other microorganisms that live in mangrove areas. Apart from that, the presence of mangroves is also vital in maintaining sediment during tides as a habitat for the bivalves' life cycles (Cantrell 2022; Kitolelei et al. 2022). Gastropod and bivalve species associated with mangrove vegetation at the research locations are shown in Figures 2 and 3.

The eastern coast of Aceh Province shows ideal environmental conditions for gastropods and bivalves, which have a very diverse distribution pattern, most likely based on the sedimentary characteristics of the coastal area. We observed 48 species in total in the area, among which gastropods dominate bivalves regarding the number of species and individuals. The nature of bivalve life, which mostly immerse their bodies in the substrate, is one of the main factors for these animals to live in muddy and sandy sediment conditions as an ideal habitat (Kathiresan and Bingham 2001; Wiraatmaja et al. 2022). Suppose the substrate conditions do not support these animals; in that case, they cannot immerse their bodies, so predators and environmental changes between seasons seriously threaten them. Uncontrolled exploitation of this clam by the community is also one of the causes of increased degradation. In contrast, gastropods dominate substrate and mangrove vegetation on roots, stems, leaves, and twigs. Some species of gastropods even live by sticking to the rock. Moreover, high adaptability to environmental changes is also crucial in the sustainability of gastropod and bivalve populations (Tan and Zheng 2020; Tan et al. 2020).

Figure 2. Gastropod species found at the research locations: 1. *Telescopium telescopium*, 2. *Telescope snail*, 3. *Pleurocera canaliculata*, 4. *Turritella terebra*, 5. *Volegalea cochlidium*, 6. *Murex trapa*, 7. *Cerithidea anticipata*, 8. *Cerithidea cingulata*, 9. *Cerithidea obtusa*, 10. *Cerithidae quadrata*, 11. *Terebralia sulcata*, 12. *Lymnaea stagnalis*, 13. *Costellariidae archives*, 14. *Ellobium aurismidae*, 15. *Ellobium aurisjudae*, 16. *Chicoreus cappucinus*, 17. *Tenguella granulata*, 18. *Pugilina cochlidium*, 19. *Ficus papyratia*, 20. *Conus martensi*, 21. *Cassidula aurisfelis*, 22. *Pythia plicata*, 23. *Phallium bandatum*, 24. *Littoraria angulifera*, 25. *Littoraria articulata*, 26. *Strombus canarium*, 27. *Natica marochiensis*, 28. *Polinices mammilla*, 29. *Nerita articulata*, 30. *Nerita filose*, 31. *Nerita lineata*, 32. *Nerita violacea*, 33. *Nerita undata*

Figure 3. Species of bivalves found at the research locations: 1. *Anadara aquatica*, 2. *Anadara granosa*, 3. *Cerastoderma edule*, 4. *Crassostraea cucullata*, 5. *Geloina erosa*, 6. *Geloina expansa*, 7. *Geloina bengalensis*, 8. *Marcia hiantina*, 9. *Mactra violacea*, 10. *Meretrix meretrix*, 11. *Placuna placenta*, 12. *Perna viridis*, 13. *Adula californiensis*, 14. *Mytilus trossulus*, 15. *Modiolus auriculatus*

Ditribution of gastropods and bivalves

Gastropods and bivalves exhibit considerable family and species number variations in the research locations. A total of 13 gastropod families comprising 33 species were found at the research locations. Among these, *Potamididae* family was dominant, represented by 10 species. In contrast, 15 bivalve species from 8 families were identified. Bivalve species at the research locations were predominantly from 2 families: *Mytilidae* and *Corbiculidae*. The distribution of gastropods and bivalves at the research locations can be observed in Table 2.

Upon analysis of species and family numbers, 21 gastropod and bivalve families were discovered, spread across 48 aquatic species. The gastropod population is more dominant at the research locations than the bivalve population. Thirteen gastropod families were identified, encompassing 33 gastropod species, while only 8 bivalve families were found, accounting for 15 species. The location with the most dominant presence of both gastropod and bivalve species and families was Location 5, which consisted of 19 families and 24 species. Conversely, the lowest numbers were observed at Location 2 (Figure 4).

The analysis of the habitat characteristics of gastropoda and bivalvia associated with mangrove vegetation revealed significant variation. Gastropoda species inhabited mangrove vegetation by attaching roots, leaves, branches, and twigs of mangrove plants, accounting for 27.27% of the total. In comparison, the remaining 72.73% were found on the surface of substrates. The habitat characteristics for bivalvia species differed due to their general nature of attaching their bodies to substrates. Consequently, none of these species were found attached directly to mangrove vegetation. Instead, 93.33% of bivalvia species inhabited their habitat by burying their bodies within the substrate. The habitat characteristics of gastropoda and bivalvia associated with mangrove vegetation can be observed in Figure 5 and Figure 6.

Analysis of diversity indices at the research location revealed that the diversity of gastropods and bivalves varied, yet it falls under moderate diversity. Based on the research location, diversity index data for gastropods and bivalves ranged from H'=1.52 to 2.33, still within the moderate diversity criteria. The dominance indices of gastropods and bivalves at the research location also showed significant variation, ranging from low to moderate dominance (Table 3).

Measurement of environmental physicochemical data as a supportive aspect of the research activity in the habitat of gastropods and bivalves is crucial. This is because each animal species has varying tolerance to changes in the environmental physicochemical factors. These factors are measured concurrently with collecting gastropod and bivalve samples in situ, encompassing water salinity, pH, and temperature. Environmental factors that positively correlate with the diversity of gastropods and bivalves at the research location are water pH, whereas water salinity and water temperature have a negative correlation (Figure 7).

Gastropods and bivalves are dominant species in coastal areas, living sedentary or motile lives within their habitats. These animals have slow mobility and typically inhabit the seabed, making them common environmental bioindicators (Al et al. 2022; Liu et al. 2022). Research results show that 100% of bivalve habitat characteristics involve living on

the seabed by burying themselves in substrates or attaching to rocky substrates and decaying wood. In contrast, gastropods show different habitat preferences, with 72.73% living on substrates and 27.27% on mangrove vegetation such as roots, trunks, and leaves. These coastal organisms play a significant role in maintaining the coastal ecosystem's balance in food chains and soil fertility (Palit et al. 2022). Gastropods also exhibit mutualistic symbiosis with mangrove vegetation, contributing to mangrove fertility and productivity while depending heavily on the mangrove ecosystem for an ideal habitat and food source (Yadav et al. 2019). Gastropods are vital in separating organic waste from mangrove vegetation, such as leaves, branches, and plant debris, into nutrient-rich organic material for the surrounding environment (Ariyanto 2019).

Table 2. Gastropods and bivalves distribution and habitat characteristics of research locations

Family	Species	Location						Habitat characteristics
		1	2	3	4	5	6	
Gastropoda								
Potamididae	*Cerithidae quadrata* G.B.Sowerby II, 1866	+	+	-	-	-	+	SS
	Costellariidae archives	+	-	-	-	-	-	SS
	Tenguella granulata Duclos, 1832	+	-	+	+	-	-	SS
	Cerithidea cingulata Gmelin, 1791	-	-	+	-	-	-	SS
	Cerithidea anticipata Iredale, 1929	-	-	+	-	-	-	SS
	Terebralia sulcata Born, 1778	-	-	-	-	+	-	SS
	Cerithidea obtusa Lamarck, 1822	-	-	-	-	-	+	SS
	Telescope snail	-	-	-	-	-	+	SS
	Telescopium telescopium Linnaeus, 1758	+	+	-	+	+	+	SS
	Lymnaea stagnalis Linnaeus, 1758	-	-	-	-	+	-	SS
Neritidae	*Nerita violacea* Gmelin, 1791	-	+	-	-	-	-	MV
	Nerita articulata A.Gould, 1847	-	-	+	-	+	-	MV
	Nerita lineata Gmelin, 1791	-	-	+	+	-	+	MV
	Nerita filosa Reeve, 1855	-	-	+	-	-	-	MV
	Nerita undata Linnaeus, 1758	-	-	+	-	-	-	MV
Ellobiidae	*Ellobium aurisjudae* Linnaeus, 1758	-	+	-	-	-	-	SS
	Pythia plicata Férussac, 1821	-	-	-	-	+	-	MV
	Ellobium aurismidae Linnaeus, 1758	-	-	-	-	-	+	SS
	Cassidulla aurisfelis Bruguière, 1789	-	-	-	-	-	+	SS
Littorinidae	*Littoraria angulifera* Lamarck, 1822	-	-	+	-	-	-	MV
	Littoraria articulata R.A.Philippi, 1846	-	-	-	-	+	-	MV
Pleuroceridae	*Pleurocera canaliculate* Say, 1821	-	-	-	+	-	-	SS
Naticidae	*Natica marochiensis* Gmelin, 1791	-	-	-	-	+	-	SS
	Polinices mammilla Linnaeus, 1758	-	-	-	-	+	-	SS
Turritellidae	*Turritella terebra* Linnaeus, 1758	-	-	-	-	+	-	SS
Conidae	*Conus martensi* E.A.Smith, 1884	-	-	-	-	+	-	SS
Ficidae	*Ficus papyratia* Say, 1822	-	-	-	-	+	-	SS
Melongenidae	*Volegalea cochlidium* Linnaeus, 1758	-	-	-	-	+	-	SS
	Pugilina cochlidium Linnaeus, 1758	-	-	-	-	+	-	SS
Strombidae	*Strombus canarium* Linnaeus, 1758	-	-	-	-	+	-	SS
Cassidae	*Phallium bandatum* Perry, 1811	-	-	-	-	+	-	MV
Muricidae	*Chicoreus capucinus* Lamarck, 1822	-	-	-	-	+	-	SS
	Murex trapa Röding, 1798	-	-	+	-	-	-	SS
Bivalvia								
Arcidae	*Anadara aquatica*	+	-	-	-	+	-	IS
	Anadara granosa Linnaeus, 1758	+	-	-	-	+	-	IS
Mytilidae	*Modiolus auriculatus* Krauss, 1848	+	-	-	-	-	-	IS
	Perna viridis Linnaeus, 1758	-	-	-	-	+	-	IS
	Mytilus trossulus A.Gould, 1850	-	-	-	+	-	-	IS
	Adula californiensis R.A.Philippi, 1847	-	-	-	-	-	+	IS
Placunidae	*Placuna placenta* Linnaeus, 1758	+	-	-	-	-	-	IS
Corbiculidae	*Geloina erosa*	-	+	-	-	-	+	IS
	Geloina expansa Mousson, 1849	-	-	-	-	-	+	IS
	Geloina bengalensis Lamarck, 1818	-	-	-	-	-	+	IS
	Mactra violacea Gmelin, 1791	-	-	-	-	+	-	IS
Veneridae	*Marcia opima* Gmelin, 1791	-	-	-	-	+	-	IS
Meretricinae	*Meretrix meretrix* Linnaeus, 1758	-	-	-	-	+	-	IS
Cardiidae	*Cerastoderma edule* Linnaeus, 1758	-	-	-	-	+	-	IS
Ostreidae	*Crassostrea cucullate* Born, 1778	-	-	+	+	+	+	SS

Note: (+) indicates presence, (-) indicates absence. MV: Mangrove Vegetation, SS: Substrate Surface, IS: In the Substrate

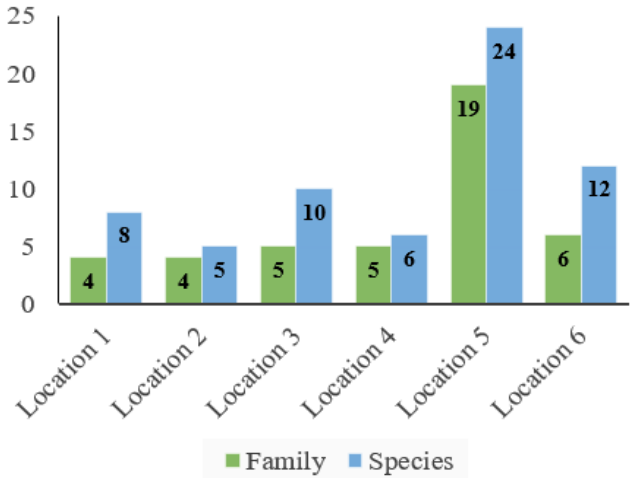

Figure 4. Composition of gastropoda and bivalvia at each researched location

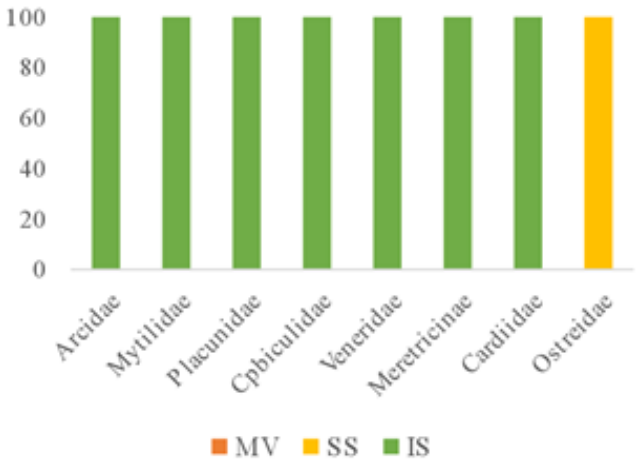

Figure 6. Characteristics of bivalve habitat in the Aceh Province

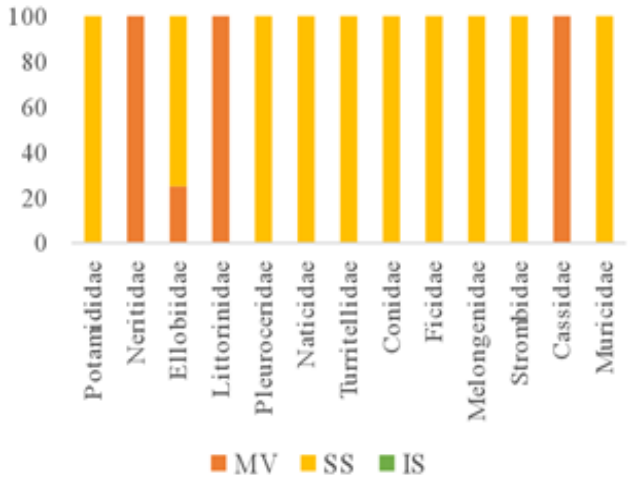

Figure 5. Habitat characteristics of gastropoda inAceh Province

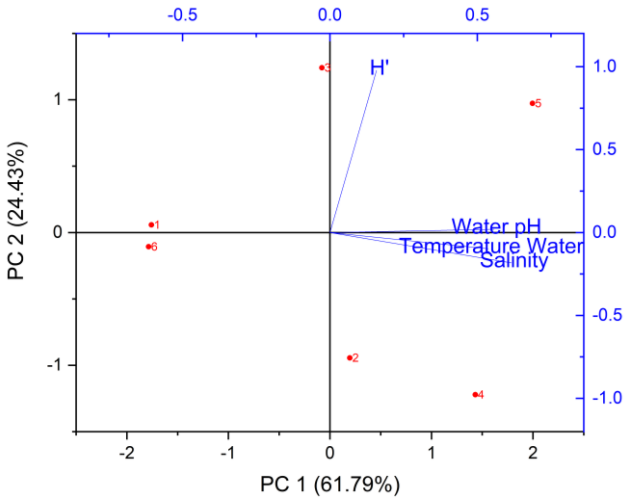

Figure 7. Principal component analysis of physicochemical environmental data at the research locations

Table 3. Diversity Index (H') and Dominance Index (C) of gastropods and bivalves

Districts/Cities	Location	H'	Category	C	Category
Aceh Tamiang	1	1,79	Moderate	0,20	Low
	2	1,52	Moderate	0,24	Low
Langsa City	3	2,25	Moderate	0,12	Low
	4	1,51	Moderate	0,32	Moderate
East Aceh	5	2,33	Moderate	0,16	Low
	6	1,73	Moderate	0,22	Low

The eastern coastal areas of Aceh Province host 48 species of gastropods and bivalves, consisting of 33 gastropod species and 15 bivalve species that are associated with mangrove vegetation directly or indirectly. The mangrove ecosystem is crucial for aquatic organisms, providing an ideal habitat for nurturing and foraging (Truong and Do 2018). The moderate diversity of gastropods and bivalves also indicates that the area provides adequate food resources for various animal species, suggesting that these coastal regions of Aceh Province are only lightly contaminated. Research findings show that locations near settlements and areas used for fishing have lower gastropod and bivalve populations than areas further away from human activity. Improperly managed domestic waste and fishing vessel activities threaten the environment, particularly aquatic animals with

limited mobility. Pollutants from domestic waste and oil spills from fishing vessels accumulate as hazardous sources of metals in the environment, affecting various animal species, including humans, who rely on marine resources for their daily needs (Akpoghelie et al. 2021).

The research results also reveal that the dominance index is generally low, indicating that in most research locations, gastropod and bivalve populations are distributed normally without any species dominating the environment. This condition suggests that the environment supporting these animal populations ranges from good to slightly contaminated. Such lightly contaminated environments can be tolerated by various species, especially coastal biota that reside on the seabed and tend to be sedentary (El-Gendy et al. 2021). Only in location 4 was a moderate dominance index found. This area is a maritime transportation zone for fishing vessels, resulting in pollution from vessel activities. This pollution allows only certain species to survive in contaminated water conditions caused by chemical waste and oil spills from vessel activities. Other species with lower adaptation to pollutants may migrate elsewhere, and some may even die (Maximillian et al. 2019).

Gastropods and bivalve populations as aquatic biota, which mostly live on the sediment in a sessile and motile manner, found populations that varied greatly in terms of several species and individuals with varying environmental characteristics based on community activities. The family Potamididae from the gastropod class dominates the population, which reaches 10 species with the characteristics of living habitats on sedimentary substrates. The higher the community activity in a location, the lower the population of gastropods and bivalves; however, in locations where community activity is relatively low, the population of these aquatic biota is higher. This phenomenon shows that benthic organisms are very sensitive to community activities that pollute the environment, both domestic and chemical wastes, from oil and oil spills due to the activities of ships and fishing boats. Animals that live on the sea bottom substrate with low mobility are relatively more exposed to and accumulate pollutants from the environment (Stewart et al. 2021). Animal species with high adaptability to pollutants in waters will survive, but animals with low adaptability will migrate, and certain species will even die. This also indicates that each species of gastropods and bivalves has varying adaptation abilities to environmental pollution between one species and another. The higher the adaptability to a polluted environment, the higher the animal's tolerance for environmental degradation (Loria et al. 2019).

Physical and chemical parameters of the environment are important in the characteristics of animal habitats. However, they did not significantly affect the survival of gastropods and bivalves in the mangrove area of the eastern coast of Aceh Province. There was no significant difference in the water temperature data at the study locations, only ranging from 29-30°C, and the water pH ranging from 6.6 to 6.7. Significant differences were found in water salinity between one location and another, ranging from 25‰ to 32‰. The water's salinity, temperature, and pH at the research location are suitable as a habitat for gastropods and bivalves living in the mangrove ecosystem (Baderan et al. 2019). Indeed, our results align with Mawardi et al. (2021), who showed that gastropods and bivalves can live in habitats with water temperatures ranging from 26-32°C, pH range 6.2-7.8, and water salinity in the range 25-32‰. In addition, water salinity in the mangrove area is a phenomenon that occurs regularly based on seasonality. During the dry season, water salinity in the mangrove ecosystem area is relatively higher compared to the rainy season. Rainwater eroded from land towards the coast causes a more dominant composition of fresh water, which lowers water salinity.

High attention and awareness are necessary from various stakeholders, including the community, government, and other institutions, to collaboratively manage the environment in an eco-friendly manner and preserve it in synergy. Coastal area management must be a top priority because it represents the convergence of all-natural environmental issues. Coastal areas are highly susceptible to ecological degradation due to human activities and climate change, leading to the loss of various animal species crucial for ecosystem stability (Lu et al. 2018; Bennett 2019; Pahri et al. 2023). This research serves as a reference, highlighting that coastal areas experiencing fishing vessel transportation and human settlements generate domestic waste and fuel waste, such as oil spills from fishing vessels, leading to environmental contamination, subsequent declines in various animal populations, and environmental degradation.

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