



## MOLLUSCAN DIVERSITY THE MANGROVE ECOSYSTEM OF TARAKAN ISLAND INDONESIA

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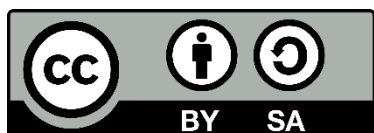
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### ABSTRACT

*This study evaluated the diversity, dominance, and evenness of Mollusca communities in five mangrove locations on Tarakan Island in the face of threats from increasing human population, habitat destruction, and pollution along the coast. The study, conducted from March to August 2023, recorded the distribution of 54 Mollusca species, consisting of 46 species of Gastropoda and 8 species of Bivalvia. The study recorded the highest diversity index ( $H'$ ) of 2.84 for Gastropoda on Andang Island (PA) and the lowest of 1.92 in Gusong Mangrove (GM). In contrast, Bivalvia demonstrated higher dominance in several locations, particularly in Pennsylvania, with a dominance index ( $D$ ) of 0.75. The Juwata mangrove forest, located in the northern part of Tarakan Island, exhibited the highest overall diversity. The results of this study document in detail the diversity of Mollusca species in the mangrove ecosystem of Tarakan Island, providing important baseline data to support conservation and management efforts for mangrove ecosystems in this region.*



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## INTRODUCTION

Mangroves are a vascularized vegetation that has been adapted morphologically and physiologically as well due to the dynamics and physical characteristic of coastal zone (Ong & Gong, 2013). Mangrove also hold significant role to the coastal ecosystem because typical colonies were the habitat of numerous aquatic faunas. As a habitat, mangroves could be a feeding ground (Kumari et al., 2020), spawning ground (Rasmeemasuang & Sasaki, 2015) and animal shelter from predators (Raghunathan et

al., 2018). Mangroves also a foundation of a complex yet diverse ecosystem that can be found along the coasts of tropic and subtropics worldwide Contreras et al., 2018; Kruitwagen et al., 2010). Moreover, mangroves also perform as a protective barrier against predators within their root systems, while also serving as a habitat for various species of organisms, including corals, ascidians, barnacles, molluscan, and sponges (Lazzeri, 2017). Molluscan are an essential component of the mangrove ecosystem, serving as water filters, herbivores, predators, or detritivores.

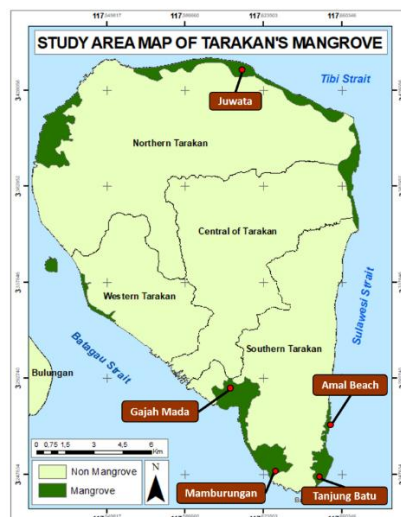
The inevitable urbanization growth along the littoral (Jacquot et al., 2023) lead to the domination of man-made buildings rather than natural ecosystem barrier named mangrove (Kenworthy et al., 2018). Moreover, mangrove forests are subject to anthropogenic pressure due to building projects, garbage dumps (Kesavan et al., 2021), industrial waste (Afonso et al., 2023), ship operations and shrimp ponds (Guerra-García et al., 2021). Uncertainty of natural cycle and environmental processes arise by climate change (Fanous et al., 2023) and human activities are also important factors that exacerbate coastal vulnerability. (Gayo, 2022; Sohaib et al., 2023; Sudhir et al., 2022). This change endangers the flora and fauna in the mangrove ecosystem (Come et al., 2023). The diversity of flora and fauna can be significantly influenced even by minor adjustments leading to the local extinctions.

Molluscan, one of the animals living in the mangrove ecosystem also influenced by the degradation mentioned (Bürkli & Wilson, 2017; Verones et al., 2022). Molluscs constitute a highly heterogeneous and extensively dispersed taxonomic group (López-Alonso et al., 2022). The second most varies invertebrates in terms of diversity which are estimated more than 0.2 million. Approximately 85,000 species have been documented including 52,525 marine molluscs, 24,000 terrestrial molluscs, and 7,000 found in freshwater ecosystems (Chapman, 2009). In addition, molluscs have significant ecological and economic value as food and cosmetic ingredients (Boissery et al., 2022; Duke & Larkum, 2019). Molluscs are one of the dominant groups in marine communities and contribute greatly to local biodiversity (Rueda et al., 2009; Rubal et al., 2018), comprising up to 25% of species in marine benthos (Appeltans et al., 2012). Furthermore, studies on the spatial and temporal distribution patterns of molluscs are generally considered a proxy for the entire marine benthic community (Martins et al., 2014).

Tarakan was a small populous island located in the northern of Borneo. The characteristic of typical small island tends to surround by mangrove ecosystem. However, the densely populated of the island conduce and accelerate coastal degradation of the mangrove ecosystem which directly hits molluscans population. To minimize the degradation leads to molluscans extincion, safeguarding and conserving the mangrove ecosystem of Tarakan Island require a spotlight effort. However, the conservation effort needed to be conduct with an initial study of existing species availability. Study literature found there numerous molluscan identification study conducted specifically in Indonesia include in Tanah Laut (Nugroho et al., 2019), Tolitoli (Yanti et al., 2022), Banyuwangi (Budiawan et al., 2020), Ambon (Pietersz et al., 2022) , Madura (Adharyan Islamy & Hasan, 2020), Rembang (Astriana et al., 2022), Sambas (Ernawati et al., 2019), Mempawah (Sari et al., 2020), and Bangka (Yuliawati et al., 2021). Those study revealed the molluscan species found in the terrestrial arboreal and coastal as well. However, the molluscans study conducted in Tarakan island found in a minimal number, so this study tried to enrich the recognition of the molluscan in Tarakan. Particularly, this study focused on species inventory of molluscans in the mangrove ecosystem of Tarakan Island.

## **MATERIALS AND METHODS**

### *Detailed description of the region*

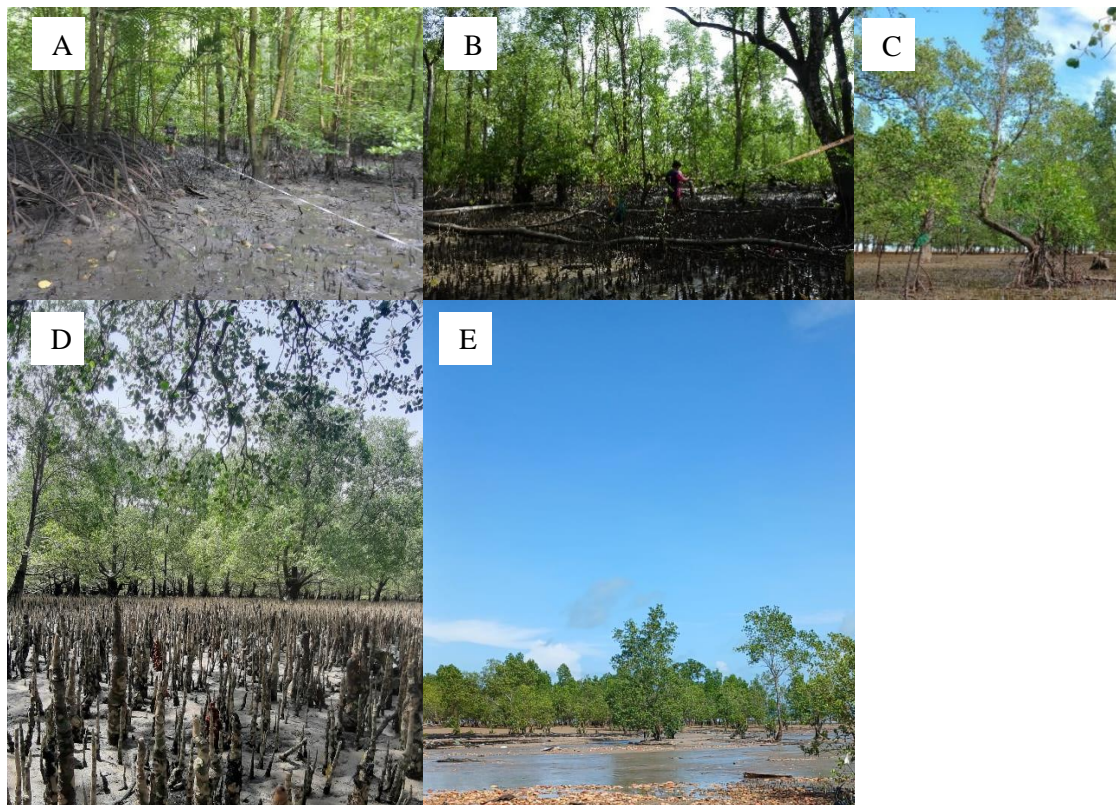


**Figure 1.** Map showing the study areas in mangrove ecosystem of Tarakan. Figure Legend: Gajah Mada (GM), Mamburungan (MB), Tanjung Batu (TB), Juwata (JW), and Amal Beach (PA).

Situated at the northernmost point of the island of Kalimantan, the island is coordinated by the coordinates 117°30'50"–117°40'12" BT and 3°14'23"–3°26'37" LU. Five neighboring regions comprise the island's mangrove forests: Gajah Mada (GM) at coordinates (N 3°18'15", E 117°34'35), Mamburungan (MB) at 3°16'25", E 118°36'45, Tanjung Batu (TB) at 4°14'27", E 113°38'53, Juwata (JW) at 2°26'21", E 117.34'33", and Amal Beach (PA) at 5°15'33"E 117°39'13.

### ***Collection of specimens***

Based on the diversity and habitat characteristics of Figure 1, we selected 5 locations on Tarakan Island, namely Gajah Mada, Mamburungan, Tanjung Batu, Juwata, and Amal Beach, to evaluate the diversity of molluscs. These locations were selected based on their diversity and the characteristics of the habitats depicted in Figure 1. Surveys were done from March to August 2023, coinciding with the watershed period. We made a 100-meter transect line perpendicular from the shoreline to the mangrove forest at each of the 5 locations. Every 10 m of the transect line formed a square (1 x 1 m), with 3 transects at each observation location, and a total of 30 plots at each location covering the entire study area (Figure 2).



**Figure 2.** Research location A. Gajah Mada, B. Mamburungan, C. Pantai Amal, D. Tanjung Batu, E. Juwata

Molluscan of various species are systematically collected from square areas, while arboreal Molluscan are obtained from specific structures found in mangroves, such as stems, roots, and pneumatophore. Bivalvia encompasses the remains and scales obtained by abrasion of surfaces such as rocks and shells. The identification process involved referencing taxonomic descriptions provided by (Abbott & Dance, 1982), (Carpenter & Niem, 1998), and (2018) (Jagadis et al., 2018), as well as examining earlier specimens from other locations (Golding et al., 2007).

### ***Statistical analyses***

The study's analysis aimed to depict the state of Mollusca in Tarakan Island's mangrove forest area. We calculate the diversity index using the Shannon-Wiener formula (Krebs, 1994). We calculate the dominance index using the dominance formula (D) Simpson (Krebs, 1994). The Morisita index is used to determine the species distribution pattern in the habitat (Brower & Zar, 1998).

## **RESULTS AND DISCUSSION**

In the coastal region of Tarakan Island, a grand total of 54 species were documented. Along the coast of Tarakan Island, up to 46 species of gastropods predominate. As shown in Table 1, bivalves contain eight species. Varying between 20 and 34 species complete the species diversity in each region of Tarakan Island. Bullidae (129), Assimineidae (375), Cerithiidae (463), Littorinidae (550), Nassariidae (158), Neritidae (617), and Potamididae (217) comprise the majority of gastropod families. Mactridae (117) and Placunidae (25) are the subsequent most numerous bivalve families. Apparent arboreal members of the Littorinidae family inhabit the bark, roots, and leaves of mangrove trees. The Amal Beach mangrove forest exhibited the greatest diversity of Molluscan (38 species), whereas the Tanjung Batu mangrove forest exhibited the least (26 species). Certain categories of gastropods, including those belonging to the genera Cerithidea, Cassidula, Melampus, Littoraria, Telescopium, Neripteron, and Pirenella, were found exclusively in muddy substrate mangrove environments. Nerita and Nassarius species are frequently encountered in both mangrove and non-mangrove habitats characterised by rocky substrata. Species of Spisula, the resultant bivalves, were exclusively detected in mangrove habitats.

In every area surveyed, *Littoraria melanostoma* and *Bulla striata* were identified. *Polinices flemingianus* and *Polinices mammilla* are frequently observed exhibiting activity during low tide in mangroves characterised by sandy substrates. Species of *Clithon* are frequently observed affixed to roots or concealed behind rocks during low tide, where they establish colonies. All study locations produced representatives of the Ellobidae family, with the exception of Mamburungan mangrove forest, where *Auriculastra radiolata* was exclusively documented. *Saccostrea cucullata* and other edible oysters are typically discovered attached to rocks or mangrove forests. Gathering rock oysters from the designated area during low tide can be utilised as a nutrition source. Destroyed piles of *Teloscopium telescopum* shells, which had been utilised as bait or as food, were observed in the mangrove forest (site).

**Table 1.** List of Molluscann species recorded in mangrove ecosystem of Tarakan Island.

No.	Famili	Spesises	Tarakan Island Mangrove Forest Area				
			GM	MB	TB	PA	JW
Bivalvi							
a							
1	Placunidae	<i>Placuna sella</i> (Gmelin, 1791)	4	-	-	4	17
2	Mactridae	<i>Spisula raveneli</i> (Conrad, 1832)	-	-	4	3	5
3		<i>Spisula subtruncata</i> (da Costa, 1778)	-	2	2	3	-
4		<i>Meretrix meretrix</i> (Linnaeus, 1758)	-	-	4	93	1
5	Pholadidae	<i>Cyrtopleura costata</i> (Linnaeus, 1758)	-	-	1	-	2
6	Ostreidae	<i>Saccostrea cucullata</i> (Born, 1778)	-	-	1	-	3
7	Arcidae	<i>Anadara granosa</i> (Linnaeus, 1758)	2	4	1	5	-
8	Hipponicidae	<i>Cheilea cicatricosa</i> (Reeve, 1858)	-	-	-	-	1
	Total attendance		2	2	6	5	6
	Sub-total		6	6	13	108	29
Gasropoda							
1	Ariophantidae	<i>Macrochlamys indica</i> (Godwin-Austen, 1883)	-	-	1	3	-
2		<i>Subulina octona</i> (Bruguière, 1789)	2	1	-	-	1
3	Assimineidae	<i>Assiminea brevicula</i> (L. Pfeiffer, 1855)	283	90	-	1	1
4	Cerithiidae	<i>Cerithium coralium</i> (Kiener, 1841)	-	363	-	10	3
5		<i>Clypeomorus pellucida</i> (Hombron & Jacquinot, 1848)	-	3	1	3	2
6		<i>Cerithium dialeucum</i> (R. A. Philippi, 1849)	-	57	-	19	2
7	Costellariidae	<i>Vexillum maduranum</i> (Dekkers, 2007)	1	-	3	11	-
8	Ellobiidae	<i>Cassidula aurisfelis</i> (Bruguière, 1789)	-	6	-	-	-
9		<i>Pythia pachyodon</i> (Pilsbry & Y. Hirase, 1908)	4	-	1	4	11
10		<i>Cassidula nucleus</i> (Gmelin, 1791)	11	15	-	-	4
11		<i>Auriculastra radiolata</i> (Morelet, 1860)	2	-	2	-	1
12		<i>Pythia cecillei</i> (R. A. Philippi, 1847)	-	1	-	-	-
13		<i>Pythia plicata</i> (Ferussac, 1821)	-	1	-	1	-
14	Haminoeidae	<i>Haminoea navicula</i> (da Costa, 1778)	13	-	-	-	-
15	Littorinidae	<i>Littoraria filosa</i> (G. B. Sowerby I, 1832)	-	18	126	5	51
16		<i>Littoraria melanostoma</i> (Gray, 1839)	10	6	69	-	36
17		<i>Littoraria bengalensis</i> (D. Reid, 2001)	23	2	34	6	60
18		<i>Littoraria intermedia</i> (R. A. Philippi, 1846)	-	4	31	2	67
19	Mangeliidae	<i>Eucithara antillarum</i> (Reeve, 1846)	-	-	-	9	1
20		<i>Volema myristica</i> (Röding, 1798)	6	-	-	2	-
21	Nassariidae	<i>Chicoreus capucinus</i> (Lamarck, 1822)	4	50	-	19	1
22		<i>Indothais gradata</i> (Jonas, 1846)	2	5	-	-	1
23		<i>Stramonita haemastoma</i> (Linnaeus, 1767)	-	4	-	4	1

**Bimo Aji Nugroho<sup>1</sup>, and Erisa Ayu Waspadi Putri. Molluscan diversity**

No.	Famili	Spesises	Tarakan Island Mangrove Forest Area				
			GM	MB	TB	PA	JW
24	Neritidae	<i>Muricopsis chiarae</i> (Bozzetti, 1991)	7	-	4	-	1
25		<i>Nassarius melanioides</i> (Reeve, 1853)	7	-	-	4	1
26		<i>Nassarius olivaceus</i> (Bruguière, 1789)	4	-	6	4	-
27		<i>Nassarius pullus</i> (Linnaeus, 1758)	1	-	2	6	-
28		<i>Nassarius stolatus</i> (Gmelin, 1791)	-	-	9	3	8
29		<i>Clithon oulaniensis</i> (Lesson, 1831)	-	-	-	3	-
30		<i>Nerita balteata</i> (Reeve, 1855)	-	-	84	2	57
31		<i>Neritina cornucopia</i> (W. H. Benson, 1836)	-	-	-	3	-
32		<i>Nerita squamulata</i> (Linnaeus, 1758)	-	-	99	5	43
33		<i>Clithon castaneum</i> (Hombron & Jacquinot, 1848)	-	-	-	51	-
34		<i>Nerita chamaeleon</i> (Linnaeus, 1758)	-	-	22	-	4
35		<i>Nerita oryzarum</i> (Récluz, 1841)	-	-	113	2	45
36		<i>Nerita fulgurans</i> (Gmelin, 1791)	-	-	30	72	36
37	Potamididae	<i>Cerithidea obtusa</i> (Lamarck, 1822)	-	-	-	16	1
38		<i>Cerithidea quoyii</i> (Hombron & Jacquinot, 1848)	1	4	-	5	5
39		<i>Pirenella alata</i> (R. A. Philippi, 1849)	49	114	-	8	2
40	Columbellidae	<i>Telescopium mauritsi</i> (Butot, 1954)	8	2	-	4	2
41		<i>Zafra minuscula</i> (Gould, 1860)	-	14	4	-	2
42	Naticidae	<i>Notocochlis tigrina</i> (Röding, 1798)	-	-	3	5	1
43		<i>Polinices didyma</i> (Röding, 1798)	1	3	-	3	1
44		<i>Polinices mammilla</i> (Linnaeus, 1758)	-	-	1	5	1
45	Trochidae	<i>Umbonium vestiarium</i> (Linnaeus, 1758)	-	-	-	9	5
46	Bullidae	<i>Bulla striata</i> (Bruguière, 1792)	7	11	-	-	2
Total attendance			21	20	15	28	25
Sub-total			28	25	20	33	34

In mangrove regions, the diversity of gastropods is greater than that of bivalves because gastropods are more resistant to the harsh conditions of the mangrove environment (Nugroho et al., 2019). Moreover, numerous examples of physiological adaptations exist (Leung et al., 2020; Stickle et al., 2015), morphological (Gutierrez, 1988), and behavioral (Chapperon et al., 2017; Iacarella & Helmuth, 2011; Reid, 1985). These adaptations may differ throughout different life stages (Tanaka & Maia, 2006; Waki, 2017). The specifics of the research's findings are presented in **Table 1**. The findings of this research indicate that the Mamburungan and Tanjung Batu ecosystems possess the greatest diversity of Molluscan, as illustrated in the table 1. Finding of this reaserch was found to be associated with the favourable ecological conditions that continue to exist in both habitats. The physical characteristics of the environment have a crucial role in the survival and activity of gastropods. A favorable habitat is essential for their breeding, foraging, and overall existence (Pyron & Brown, 2015; Satyam & Thiruchitrambalam, 2018). The *Avicennia marina* species is the dominant plant in the coastal mangroves of Tarakan Island. This species is known to create a suitable habitat and provide food, which results in a high diversity of Molluscan. Additionally, it has been



observed that the presence of *Avicennia marina* can lower the pH of the environment (Kabir et al., 2014; Mohanta et al., 2020).

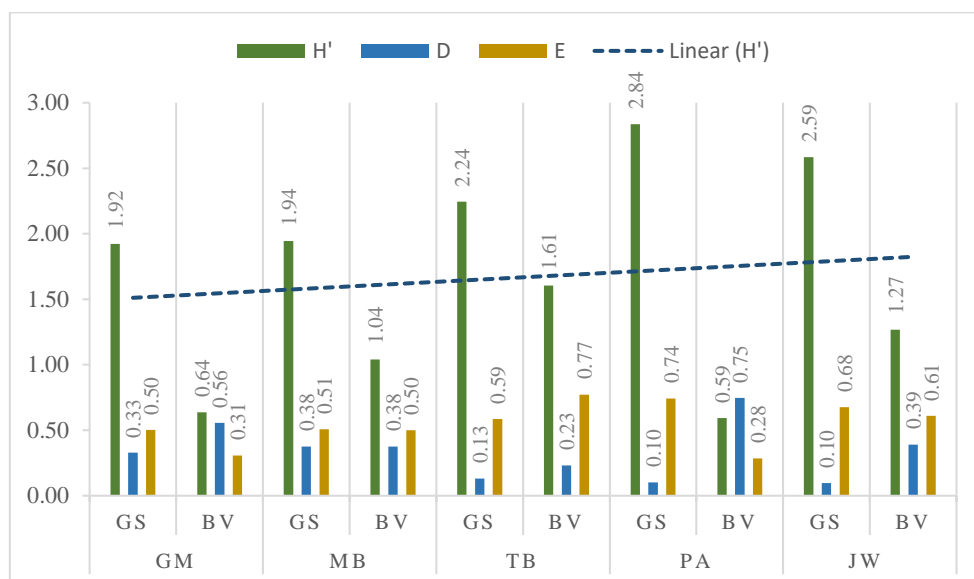
The dominant families in the mangrove area are Ellobidae, Littorinidae, Potamididae, and Neritidae. These families are frequently observed in Southeast Asia and the Indo-Pacific (Kantharajan et al., 2018; Mohanraju, 2015). Bivalves are typically found in a restricted range inside the tidal zone due to their specialized diet of larvae and specific environmental needs (Meijer et al., 2021; Queiroz et al., 2020; Vorsatz et al., 2021). There were a restricted number of species observed, precisely 8 types. *Meretrix meretrix* significantly dominates the mangrove environment. The species exhibits dominance due to its capacity to acclimate to fluctuations in the tidal ecosystem of the mangrove region (Kabir et al., 2014; Kruitwagen et al., 2010).

The mangrove forest on Tarakan Island is severely impacted by illegal logging of mangroves, as well as the introduction of harmful substances and pollutants, particularly from both treated and untreated wastewater. Furthermore, the growth of fish and prawn ponds on Tarakan Island diminishes the area occupied by mangroves, which consequently depletes carbon stocks (Eid et al., 2020), the decrease in organic sediment (Bao et al., 2013), and the deterioration of community health (Sowah et al., 2023). Complex waste management and subsequent impacts on coastal ecosystems ensue as a direct consequence of the correlation between the quantity of garbage produced and the increase in human population (Asante et al., 2023; Jacquot et al., 2023; Sobhani & Danehkar, 2023).

*Anadara granosa*, *Saccostrea cucullata*, and *Meretrix meretrix* contribute to inland fisheries in various nations, including Indonesia (Astria et al., 2022; Kasnadiya et al., 2023; Rohmah & Muhsoni, 2020). Further research is needed to determine the extent to which the reduction in environmental conditions of the mangrove ecosystem on Tarakan Island affects Molluscan species along the shore. The characteristics of mangroves are dominated by tides. Plastic and polyethylene provide a significant risk to biodiversity in several mangrove habitats worldwide (Ahmed et al., 2022; Johnson et al., 2023; Mendes et al., 2023; Xiao et al., 2021). At high tide, plastic garbage originating from residential areas in nearby neighborhoods will accumulate. Rubbish accumulates above mangroves due to their intricate root system. Consequently, the habitat conditions of benthic fauna groups, particularly Molluscan, are impacted by these conditions.



The diversity index ( $H'$ ) provides an overview of the diversity of species in a community. The high  $H'$  value in gastropods at the Amal Beach location (2.84) indicates a very diverse community, where many species are present with a relatively balanced number of individuals (Figure 3). This is due to the heterogeneous environment at the Amal Beach Location, which supports the diversity of gastropod species (Alonso et al., 2022). Factors such as the availability of various types of food, diverse microhabitats, and low competitive pressure from other species can contribute to this high diversity (Waki, 2017). Conversely, the lower  $H'$  value at the Gajah Mada Location (1.92) indicates a more homogeneous environment or greater competitive pressure from certain dominant species, reducing species diversity. The  $H'$  value at the Amal Beach Location (0.59) shows that there are fewer Bivalves species than Gastropods. This could be because Bivalves have trouble adapting to the local environment or because Gastropods are more common and use more of the resources that are there. The high  $H'$  value at the Tanjung Batu location (1.61) indicates a greater variety of species and perhaps a more even distribution of resources, supporting the presence of various Bivalvia species (Guerra-García et al., 2021).



**Figure 3.** Diversity Index ( $H'$ ), Dominance Index ( $D$ ), and Evenness Index ( $E$ ) of Gastropods and Bivalves in Five Research Locations GM (Gajah Mada), MB (Mamburungan), TB (Tanjung Batu), PA (Pantai Amal), JW (Juwata), BV (Bivalvia), GS (Gastropoda).

The dominance index ( $D$ ) measures how much one or a few species dominate a community. Lower  $D$  values indicate that no species significantly dominates, whereas high  $D$  values indicate that a particular species dominates. The low  $D$  value for gastropods

at the Amal Beach site (0.10) indicates that no species strongly dominates the community, which is consistent with the high diversity and evenness observed. A variety of species exploit resources evenly in this stable and balanced community (Dusabe et al., 2024; Iannuzzi et al., 1996). In contrast, the higher D value at the Gajah Mada site (0.33) may indicate the presence of a more competitive or adaptive dominant species, which controls most of the resources and limits the presence of other species. The high D index for Bivalves at the Amal Beach site (0.75) indicates the strong dominance of one or a few species, which may be due to environmental conditions that only favor certain species. Factors such as water quality, substrate type, or the availability of specific foods may play an important role. This dominance could also mean that Bivalvia faced greater competitive pressure from other groups (e.g., Gastropoda) at the Amal Coast Site, causing only the most adaptive species to survive (Al-Behbehani et al., 2010; Primost et al., 2016).

The evenness index (E) describes the relative distribution of individuals across species in a community. A high E value indicates that species in the community have nearly equal numbers of individuals, while a low E value indicates that some species have significantly more individuals than others. The relatively high evenness index in gastropods, especially in Amal Beach (0.74) and Juwata (0.68), indicates that the populations at these sites are equally distributed among the species. This could indicate that the environment at these sites provides stable conditions where no species has a significant competitive advantage (Ramo'n & Amor, 2001; Wu et al., 2017). In contrast, the lower E value in Gajah Mada (0.50) may indicate an imbalance in the community, where some species dominate while others are less common. The low E index in Amal Beach (0.28) indicates a very uneven distribution of individuals, where one or a few Bivalvia species strongly dominate, while others may only be present in tiny numbers. This could be due to highly selective environmental conditions or to strong ecological pressures, such as predation or competition, which only allow a few species to reproduce effectively (Anderson & Pospahala, 1970; Djamaluddin, 2018; Pietersz et al., 2022).

## **CONCLUSION**

This study evaluated the diversity, dominance, and evenness of Gastropods and Bivalves in five mangrove sites on Tarakan Island, recording 54 species (46 Gastropods

and 8 Bivalves). Gastropods showed higher diversity, with diversity indices ( $H'$ ) ranging from 1.92 (lowest in GM) to 2.84 (highest in PA). Species dominance was more prominent in Bivalves, especially in PA, with dominance indices ( $D$ ) reaching 0.75. In contrast, gastropods had lower dominance indices, ranging from 0.10 to 0.38. Gastropods' evenness ( $E$ ) was also more stable, with the highest value of 0.74 in PA, whereas Bivalves showed a less even distribution. This study highlights important differences in community structure between Gastropods and Bivalves and their contributions to coastal ecosystem dynamics. The mechanisms underlying these diversity and dominance patterns and their impacts on overall ecosystem function require further research.

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