Egyptian Journal of Aquatic Biology & Fisheries
Zoology Department, Faculty of Science,
Ain Shams University, Cairo, Egypt.
ISSN 1110 – 6131
Vol. 29(1): 2037 – 2054 (2025)
www.ejabf.journals.ekb.eg

Gastropod Community Structure in Mangrove Ecosystems on the North Coast of Bangkalan, Indonesia

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ARTICLE INFO

Article History:
Received: April 7, 2023
Accepted: Sep. 10, 2024
Online: Feb. 17, 2025

Keywords:
Community structure,
Gastropods,
Mangrove ecosystem,
Rhizopora sp.,
Bangkalan

ABSTRACT

Gastropods play a vital role in mangrove ecosystems by contributing to the decomposition process through litter fragmentation, which accelerates microbial breakdown. This study aimed to assess the community structure of gastropods in the mangrove ecosystem on the north coast of Bangkalan. Research was conducted from September to November 2022 using a 10x10m² mangrove transect with 3 plots per station, and a 1x1m² transect for gastropods. Gastropods were classified into treefauna and epifauna. A total of 22 species were identified across 14 research stations, including *Assiminea ovata*, *Cassidula aurisfelis*, *Cerithidea cingulata*, *Cerithidea obtusa*, *Littoraria melanostoma*, and *Turbo setosus*. The most frequent epifauna were *Cerithidea cingulata* and *Telescopium telescopium*, while *Cerithidea obtusa* dominated treefauna. The diversity index ranged from 0.36 to 1.94, the evenness index from 0.33 to 0.97, and the dominance index from 0.18 to 0.78, indicating a moderately stable ecosystem. Simple linear regression analysis revealed a weak relationship between gastropod abundance and mangrove density ($r = 0.14$, $R^2 = 0.02$), suggesting minimal correlation between the two variables. Overall, the gastropod community structure was classified as moderate.

INTRODUCTION

Gastropods are part of the invertebrates and one of the marine biotas with high diversity in mangrove ecosystems **(Lee, 2008; Purnama *et al*., 2024a)**. In Indonesia, a biodiverse archipelago, gastropods contribute significantly to the ecological functions of mangroves **(Setyadi *et al*., 2021)**. Mangrove ecosystems in Indonesia, including those located on the north coast of Bangkalan, East Java, are critical in maintaining the balance of coastal ecosystems, function in nutrition cycling, beach stabilization, and providing habitat for a variety of species **(Strong *et al*., 2008; Putro *et al*., 2023)**. Due to their high productivity, mangroves contribute significant nutrients to coastal environments, supporting a diverse range of macrobenthic organisms **(Thampanya *et al*., 2006; Hastuti *et al*., 2016; Soeprobowati *et al*., 2023)**. The unique position of mangrove between terrestrial and mangrove ecosystems facilitates the transfer of nutrients from land to sea, enriching coastal waters **(Kumara *et al*., 2010; Adyasari *et al*., 2021)**.

The diversity of gastropods in Indonesia is remarkable, with a wide range of species found in different mangrove ecosystems. This diversity is influenced by varying environmental conditions, including salinity, sediment type, and vegetation type **(Eleinin *et al.*, 2021)**. The role of gastropods in mangrove ecosystems as detritivores in mangrove ecosystems is crucial, as they break down and process leaf litter, thereby accelerating the decomposition process by microorganisms **(Pawar, 2012; Suresh *et al*., 2012)**. The mangrove ecosystem of Indonesia hosts an impressive diversity of gastropods, reflecting the country's varied geography and climatic conditions, while also providing a variety of ecological niches for these gastropods **(Kumara *et al*., 2010; Setyadi *et al*., 2021)**. Gastropods in mangrove ecosystems are frequently the indicators of environmental change and ecosystem health **(El Sorogy *et al*., 2013)**. Understanding gastropod community structure, including species variation and influencing factors, is essential for mangrove ecosystem assessment and management **(Zvonareva *et al*., 2015)**.

Environmental changes significantly impact ecosystem balance, especially the connection between gastropods and mangroves. One of the most influential changes is salinity **(Langston & Spence, 1995)**. Mangroves and gastropods have a distinct tolerance level to salinity. Imbalances in salinity could potentially lead to a decrease in biodiversity, as species incapable of adapting to these changes would become extinct or migrate to other habitats **(Sari & Rosalina, 2016)**. Gastropod densities in mangrove ecosystems are also influenced by anthropogenic activities, such as fishing and the presence of predators such as crabs and reptiles **(Sitnikova *et al*., 2010)**. These influences are compounded by the limited mobility of gastropods, making them highly vulnerable to disturbance **(Levinton *et al*., 1995; Nicolai & Ansart, 2017)**. In addition, environmental pollution and contamination are contributing factors that threaten the balance and damage the growth of mangroves and gastropods **(Allen *et al*., 2001)**. These conditions not only destabilize the ecosystem but also directly reduce biodiversity. These imbalances in the ecosystem decrease the ability of mangroves and gastropods to function optimally, therefore threatening the future sustainability of the ecosystems **(Gab-Alla *et al.*, 2010)**. Previous studies have shown that the distribution and abundance of gastropods in mangrove ecosystems could be diverse depending on these environmental factors **(Printrakoon *et al*., 2008)**.

Despite the abundance of mangrove forests at the study site (north coast of Bangkalan Regency), there is a lack of research examining the gastropod community structure and their connection with mangrove density in over large areas. This study aimed to measure and determine the community structure of gastropods on the north coast of Bangkalan Regency, with an emphasis on their connection to *Rhizophora* sp., the dominant mangrove species at this study site. Through this research, it is expected that more in-depth information on the distribution, abundance, and ecological role of gastropods in this mangrove ecosystem could be obtained.

MATERIALS AND METHODS

1. Study area

This study was conducted along the north coast of Bangkalan Regency, East Java Province. Data were collected from September to November 2022. The data collection location was divided into 14 stations, which were distributed into 6 sub-districts: Kamal, Socah, Bangkalan, Arosbaya, Sepulu, and Tanjungbumi sub-districts. A map of the data collection site can be seen in Fig. (1). Tools and materials used in this study were the global positioning system (GPS), roller meter, raffia rope, camera, scissors, stationery, sewing meter, mangrove identification book, and gastropods identification book.

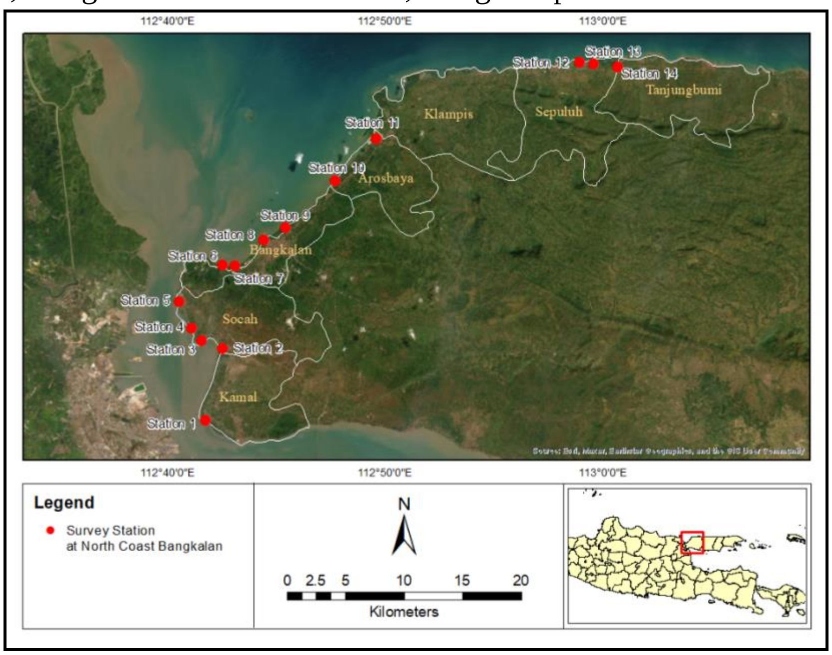

Fig. 1. Mangrove study location on the north coast of Bangkalan District, Indonesia

2. Sampling

Study on gastropod community structure includes mangrove identification, gastropod identification, mangrove density, diversity index, evenness index, and Simpson's dominance index. Data collection of type identification and mangrove density using square measuring 10x10m^2 were conducted at 14 study stations, with each station consisting of three squares. Gastropod sampling was conducted using 1x1m transect 15 subplots at 1 station. Sampling was divided into 2, namely epifauna (above the substrate) and treefauna (roots, stems, and leaves). Data and samples were collected during low tide. Samples of gastropods that have been collected were stored in plastic samples, then they were thoroughly cleaned and later identified and calculated at the Integrated Laboratory of Trunojoyo University Madura.

Gastropod identification was made by observing morphological characteristics such as shell shape, shell width, shell length, shell color, apex, whorl, body whorl, siphonal canal, spire, suture, aperture, and columella **(Islamy & Hasan, 2020)**. The data obtained were analyzed by knowing the morphological characteristics based on **Dekker and Orlin (2000)**, and taxonomic in the World Register of Marine Species **(WoRMS Editorial Board, 2019)**. Illustration of gastropod and mangrove sampling can be found in Fig. (2).

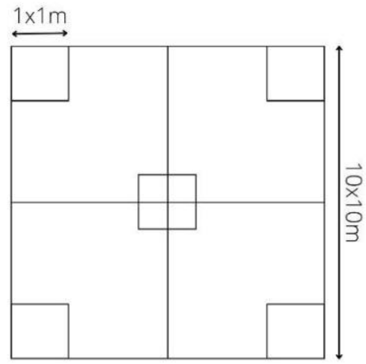

Fig. 2. Illustration of gastropod sampling and mangrove density

3. Analysis

The calculation of gastropod community structure was carried out using the following equations.

3.1 Mangrove density

Mangrove density quality standards are presented in Table (1). According to **Bengen *et al*. (2023)**, mangrove tree density is calculated using the following formula:

$$Di = ni/A \ (tree/100m)^2$$

Description:

Di : Density

ni : Number of trees

A : Area of sampling transect

Table 1. Quality standard criteria for mangrove density

Criteria	Density (trees/100m)^2
High	>15
Medium	<10-15
Low	<10

3.2 Diversity index

The condition of gastropods and the surrounding ecosystems could be assessed through the diversity index. The Shannon Wiener diversity index was calculated using the following equation:

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

H’ = diversity index
S = number of species/species richness
Pi = fraction of the entire population
Shannon-Wiener diversity index criteria are shown in Table (2).

Table 2. Diversity index criteria values

Diversity index	**Category**
>2.41	Very good
1.81 - 2.4	Good
1.21 - 1.8	Medium
0.61 - 1.2	Bad
<0.6	Very bad

3.3 Evenness index

The evenness index calculations were conducted using evenness index formula of Pielou. Evenness index was calculated using the following formula:

$$E = \frac{H'}{\mathrm{Log}_2\, s}$$

Description:
E : Evenness index
H' : Diversity index
S : Total number of species

The evenness index describes the pattern of individual distribution of a species in the ecosystem **(Munthe *et al*., 2012)**. Evenness index values are shown in Table (3).

Table 3. Evenness index criteria values

Evenness index	**Category**
e>0.6	High
0.4<e<0.6	Medium
E<0.4	Low

3.4 Simpson’s dominance index

The dominance index was calculated using the Simpson index of dominance formula as follows:

$$C = \frac{N\,(N-1)}{\sum ni\,(ni-1)}$$

C = Simpson’s index of dominance
Ni = number of individuals of the species
N = number of individuals of all the species

Simpson's dominance index has a value close to 0 or low, indicating that no species dominates; the ecosystem is more stabilized, and the ecological pressure is relatively small. Dominance index values close to 1 indicate that the distribution of individuals of each species is not equitable, and the ecosystem is less stable and healthy.

3.5 *Normality test*

The regression calculation of the association between gastropod density and mangrove density was conducted with a normality test. Normality test is one of the stages in determining regression. The normality test aims to determine the data distribution and the hypothesis based on that the data are normally or abnormally distributed **(Mishra *et al*., 2019)**. The correlation test was conducted to determine the connection of several variables, specifically mangrove density and gastropod density. This correlation variable data test uses Microsoft Excel software. Correlation between mangrove density and gastropod density structure uses regression analysis that generates a correlation coefficient. The results of the correlation coefficient criteria **(Sugiyono, 2014)** are shown in Table (4).

Table 4. Correlation coefficient criteria

Coefficient interval	Description
0,00 - 0,19	Very low
0,20 - 0,39	Low
0,40 - 0,59	Medium
0,60 - 0,79	Strong
0,80 - 0,99	Very strong

RESULTS

1. Mangrove density

The results showed that the density of *Rhizopora* sp. mangroves found in the research transects at 14 stations had different density at each station. Station 8 recorded the highest mangrove density value with a value of 2900/ha, while the lowest mangrove density value was at station 12 where no *Rhizopora* sp. was found at all. The results of the mangrove density are shown in Table (5).

Table 5. Distribution of mangrove species identified on transects at the study site

Station	Mangrove density		Category
	$100/m^2$	trees/ha	
1	19	1900	High
2	2	200	Low
3	14	1400	Low
4	19	1900	High
5	10	1000	Low
6	21	2100	High
7	6	600	Low
8	29	2900	High
9	6	600	Low
10	17	1700	High

11	21	2100	High
12	0	0	Low
13	6	600	Low
14	4	400	Low

2. Gastropod composition

The results of the research at 14 stations showed that the composition of gastropods found in the research transect identified as many as 22 species. The most common type of gastropod found was *Cerithidae obtusa* where as many as 12 stations found this type of gastropod, then followed by *Littoraria melanostoma* and *Telescopium telescopium*. The gastropod distribution is shown in Table (6).

Table 6. Gastropod distribution on the north coast of Bangkalan District, Indonesia

Species	Station													
	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Assiminea ovata								√						
Cassidula aurisfelis	√	√	√	√				√					√	
Cassidula nucleus	√	√	√	√	√	√		√	√	√			√	
Cerithidae cingulate	√	√	√		√				√	√	√		√	√
Cerithidae obtusa	√	√	√	√	√	√		√	√	√	√	√	√	√
Cerithideopsilla alata							√			√	√			√
Chicoreus capunicus	√	√	√	√	√	√				√				
Crassipira												√		
Cypeomorus pellucida												√		
Ellobium aurisjudae						√			√					
Littoraria articulata			√			√				√				√
Littoraria cerinifera	√			√	√	√				√	√		√	√
Littoraria melanostoma	√	√	√	√	√	√	√	√	√	√	√			√
Littoraria scabra			√		√							√	√	
Murex occa			√											
Myoseotella		√												
Nerita articulata			√	√	√	√				√				
Nerita exuvia			√											
Telebralia palustris	√													
Telescopium	√	√	√		√	√	√	√	√	√	√		√	
Terebralia sulcata												√	√	√
Turbo setosus												√		

3. Gastropod density

The results of the research at 14 stations showed that the density of gastropods found in the research transect had a range of values of 5.9-48.1ind/ m^2. The lowest density value of gastropods was at station 3 with a value of 5.9ind/ m^2, while the highest value was at station 10, with a value of 48.1ind/ m^2.

Table 7. Gastropod density on the north coast of Bangkalan, Indonesia

Station	Gastropod density (individuals/m^2)
1	26.2
2	10.4
3	5.9
4	7
5	14
6	16.6
7	26
8	20.8
9	8.2
10	48.1
11	9.8
12	31.8
13	38.4
14	26.3

4. Gastropod community structure

4.1 Epifauna

The results showed that the diversity index of gastropod epifauna shown in Table (8) had the highest diversity value at station 1 (H' = 1.51) and the lowest value was at station 7 with a diversity value of (H' = 0.36). The highest evenness index value was at station 1 (E = 0.69) and the lowest was at station 6 (E = 0.39). Of the 14 research stations, there were only 4 stations categorized as dominance index, namely stations 5, 6, 7 and 14. The results showing the diversity index of epifauna are depicted in Table (8).

Table 8. Diversity index of gastropods epifauna on the North Coast of Bangkalan

Station	Diversity (H')		Evenness (E)		Dominance (D)	
	Value	Category	Value	Category	Value	Category
1	1.51	Medium	0.69	High	0.27	ND
2	1.21	Medium	0.62	High	0.37	ND
3	0.96	Low	0.54	Medium	0.50	ND
4	1.13	Medium	0.63	High	0.40	ND
5	0.94	Low	0.68	High	0.51	D
6	0.69	Low	0.39	Low	0.69	D
7	0.36	Low	0.52	Medium	0.78	D

8	1.21	Medium	0.68	High	0.43	ND
9	0.98	Low	0.61	High	0.43	ND
10	1.29	Medium	0.66	High	0.31	ND
11	1.21	Medium	0.75	High	0.32	ND
12	1.13	Medium	0.82	High	0.34	ND
13	1.21	Medium	0.68	High	0.34	ND
14	0.75	Low	0.47	Medium	0.63	D

4.2 Treefauna

The results showed that the diversity index of gastropod treefauna shown in Table (9) had the highest diversity value at station 3 (H' = 1.94), and the lowest value was at station 12 with a diversity value of (H' = 0.45). The highest evenness index value was at station 2 (E = 0.97) and the lowest was at station 12 (E = 0.33). Of the 14 research stations, there were only 5 stations categorized as dominance index, namely stations 7, 8, 11, 12, and 14. The results showing the diversity index of treefauna are illustrated in Table (9).

Table 9. Diversity index of gastropods treefauna on the north coast of Bangkalan

Station	Diversity (H')		Evenness (E)		Dominance (D)	
	Value	Category	Value	Category	Value	Category
1	0.88	Medium	0.55	Medium	0.46	ND
2	1.73	Medium	0.97	High	0.18	ND
3	1.94	Medium	0.88	High	0.19	ND
4	1.27	Medium	0.79	High	0.35	ND
5	1.69	Medium	0.87	High	0.21	ND
6	1.20	Medium	0.62	High	0.44	ND
7	0.64	Low	0.92	High	0.56	D
8	0.47	Low	0.34	Low	0.74	D
9	1.39	Medium	0.87	High	0.29	ND
10	1.15	Medium	0.59	Medium	0.44	ND
11	0.79	Low	0.57	Medium	0.56	D
12	0.45	Low	0.33	Low	0.78	D
13	1.07	Medium	0.60	High	0.49	ND
14	0.79	Low	0.49	Medium	0.60	D

5. Correlation of mangrove density and gastropod density

The results of data processing of mangrove and gastropod correlations are shown in Fig. (3). Correlation of mangrove density and gastropod density resulted in a value of r = 0.1428, R^2 = 0.0204. The results showed the correlation between mangrove density and gastropod density, as shown in Fig. (3).

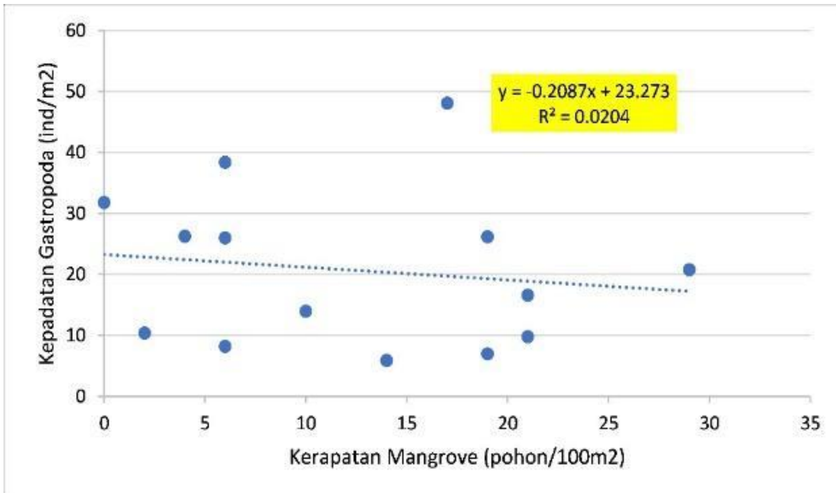

Fig. 3. Correlation graph of mangrove density and gastropod density

DISCUSSION

Bangkalan Regency hosts extensive mangrove forests, primarily composed of species from the genus *Rhizophora*, including *Rhizophora mucronata* and *Rhizophora apiculata*, both of which are characterized by high stand densities **(Nugraha *et al*., 2024b)**. The highest recorded mangrove density was observed at Station 8, where it reached a value of 29,100 individuals per square meter, classifying it as high density **(Prasetya *et al*., 2017)**. This high-density categorization is supported by the dominance of *Rhizophora mucronata*, a species well-adapted to coastal environments. *Rhizophora mucronata* is prevalent in this region, particularly in areas with silt and clay substrates, which provide favorable growth conditions for the genus *Rhizophora* **(Bandibas & Hilomen, 2016)**. This species demonstrates a strong capacity to thrive in brackish water habitats along coastlines, with growth regulated by physical factors such as tidal regimes, contributing to its widespread distribution along the Indonesian coastline **(Sungkar *et al*., 2018; Ramadhani *et al*., 2022)**.

Station 12, situated in the Jung Koneng mangrove ecotourism area, exhibited the lowest recorded mangrove density, with the absence of *Rhizophora* species. According to the Kepmen LH No. 201 of 2004, mangrove stands with a density below 1,000 individuals per hectare are categorized as low density. This finding is consistent with previous studies; **Nugraha *et al*. (2024a)** reported a low mangrove density in the Jung Koneng area of Bangkalan. The low density observed at Station 12 is likely due to unfavorable environmental conditions, such as nutrient limitations or poor substrate quality. Comparative studies in other areas, such as **Supriadi *et al*. (2015)** in Mertajasah Village, Bangkalan Regency, reported higher mangrove densities, which were attributed to more favorable environmental conditions that support mangrove growth **(Agustini *et al*., 2016)**. Similarly, the low density at Station 12 underscores the need for rehabilitation initiatives. As highlighted by **Dale *et al*. (2014)**, restoration efforts are crucial to enhance mangrove cover, addressing nutrient deficiencies and environmental degradation to promote ecosystem recovery and long-term sustainability.

A total of 22 gastropod species have been identified along the north coast of Bangkalan. These include *Assiminea ovata*, *Cassidula aurisfelis*, *Cassidula nucleus*, *Cerithidea cingulata*, *Cerithidea obtusa*, *Cerithideopsilla alata*, *Chicoreus capucinus*, *Crassipira*, *Cypeomorus pellucida*, *Ellobium aurisjudae*, *Littoraria articulata*, *Littoraria cerinifera*, *Littoraria melanostoma*, *Littoraria scabra*, *Murex occa*, *Myosotella*, *Nerita articulata*, *Nerita exuvia*, *Telebralia palustris*, *Telescopium*, *Terebralia sulcata*, and *Turbo setosus*. Notably, *Cerithidea obtusa* was observed at nearly all sampling stations, highlighting its widespread presence. The *Cerithidea* genus is well-known for its extensive distribution in mangrove ecosystems, attributed to its high adaptability to various substrate types, including sand and clay sand, which are conducive to its survival. According to **Susanto *et al*. (2022)**, the mangrove forests in Bangkalan Regency are characterized by sandy and clay mud sediments, providing a favorable habitat for adult gastropods that thrive in such environments due to the abundance of food resources **(Nishihira *et al*., 2002)**. The wide distribution of the *Cerithidea* genus in mangrove habitats contributes to its high abundance, as supported by previous studies **(Yuniarto, 2003; Manullang *et al*., 2018)**. This observation is congruent with the findings of **Ozawa *et al*. (2015)**, who noted that *Cerithideopsilla*, a genus of potamidid snails, is highly abundant in sedimentary intertidal zones and beneath mangrove trees along tropical and subtropical Indo-West Pacific coastlines. The high density of a particular species in a specific area, such as *Cerithidea*, often reflects its ability to occupy larger habitats and its capacity for effective development and adaptation **(Odum, 1971)**. In comparison to the gastropod communities in Sedati, East Java, where *R. venosa* was the most commonly encountered species **(Melati *et al*., 2021)**, the gastropod species composition along the north coast of Bangkalan is notably different. These differences in species composition can be attributed to variations in environmental parameters, with certain species unable to tolerate fluctuating conditions. **Muskananfola *et al*. (2020)** further emphasized that the temporal and spatial variation in the abundance and diversity of macrobenthic organisms is influenced by factors such as organic matter content, sediment grain size, and salinity. The distribution and abundance of gastropods at each station are likely influenced by substrate composition and nutrient availability. For instance, Station 8, which exhibited the highest mangrove density, is dominated by fine substrates such as silt and clay, known for their high nutrient retention and organic matter content. These conditions support detritivorous gastropods by providing ample food resources. In contrast, the sandy substrate at Station 12, with its lower capacity for nutrient retention and organic matter accumulation, offers less favorable conditions, potentially explaining the reduced gastropod presence. Quantifying substrate types (e.g., sand, mud, or silt) and nutrient levels (e.g., total organic carbon and nitrogen) at each location would further clarify these patterns by linking edaphic conditions with gastropod community dynamics.

The condition of an environment can be assessed using biological indicators such as the Shannon-Wiener diversity index (H'), evenness index (E), and Simpson's dominance index (D) **(Hartati *et al.*, 2024)**. In this study, diversity indices were calculated for epifauna and treefauna across 14 research stations using the standard formula for Shannon-Wiener diversity, which accounts for species richness and the proportional abundance of each species. The diversity index (H') for epifauna ranged from 0.36 to 1.51. Station 7, with a diversity index of 0.36, recorded the lowest epifauna diversity, despite the station having high mangrove density. On the other hand, Station 1 exhibited the highest diversity (H' = 1.51), which is also characterized by high mangrove density. Similarly, for treefauna, Station 12 had the lowest diversity index of 0.45, while the highest value of 1.94 was observed at Station 3, both stations having dense mangrove coverage.

The diversity of gastropods on the north coast of Bangkalan exceeds the diversity values reported in other regions such as Nusa Lembongan and Perancak, where the indices range between 0.55 and 1.26 **(Simanullang *et al.*, 2024)**. **Amin *et al*. (2009)** argued that diversity indices provide more comprehensive insights into environmental conditions than the analysis of individual species alone. The medium-to-high diversity at Stations 1 and 3 suggests favorable ecological conditions, likely due to sufficient nutrient availability, as posited by **Wintah (2021)**. A statistical analysis using ANOVA (Analysis of Variance) revealed significant differences ($P< 0.05$) between the diversity indices of various stations, confirming spatial variation in community structure.

The evenness index (E), which reflects the distribution of individuals among species, ranged from 0.33 to 0.97 across the study area. Higher evenness values, close to 1, indicate a more balanced distribution of individuals across species, implying a stable community with less competitive exclusion **(Purnama *et al.*, 2024b)**. The lowest evenness index for epifauna was recorded at Station 6 (E = 0.39), while the highest value was observed at Station 1 (E = 0.69). For treefauna, the lowest evenness index (E= 0.33) was found at Station 12, and the highest (0.97) at Station 2. These variations reflect differences in species interactions and environmental heterogeneity. Comparatively, the evenness values from Langkat Regency, North Sumatra Province, ranged from 0.67 to 0.79 **(Manullang *et al.*, 2018)**, slightly lower than the values recorded in this study. Stations with higher evenness generally show more balanced ecological interactions, with no species overwhelmingly dominant. However, significant variation in evenness across stations suggests that some areas may experience ecological instability due to environmental pressures.

The dominance index (D), which measures the degree to which one or a few species dominate the community, ranged from 0.18 to 0.78. Most stations fell within the "No Dominance" (ND) category, indicating a relatively balanced community structure. However, dominance was observed at several stations: for epifauna at Stations 5, 6, 7, and 14, and for treefauna at Stations 7, 8, 11, 12, and 14. The dominance index values suggest that, while no single species dominated the entire study area, certain stations showed signs of species dominance, possibly due to localized environmental factors such as sediment composition or nutrient availability. Previous studies, such as **Dewiyanti *et al*. (2021)**, reported similarly low dominance values for gastropods in Pusung Cium Island, Aceh Tamiang, which were attributed to favorable water quality and substrate conditions. According to **Hilmi *et al*. (2022)**, low dominance values are often associated with optimal physical and chemical parameters of the environment, supporting diverse macrozoobenthos communities.

In summary, the gastropod communities along the north coast of Bangkalan exhibit high diversity, relatively balanced evenness, and low dominance, suggesting a stable ecosystem with minimal ecological stress. These findings are consistent with the work of **Melati *et al*. (2021)**, who noted that a high diversity index, coupled with a high evenness index, indicates minimal species dominance and greater ecosystem stability. The statistical tests confirm that environmental parameters, such as sediment texture and nutrient content, play a crucial role in shaping gastropod community structure, highlighting the need for continued monitoring to detect any future ecological changes.

The correlation analysis between mangrove density and gastropod density revealed a weak positive relationship ($r = 0.1428$, $R^2 = 0.0204$), indicating that mangrove density exerts minimal influence on the abundance of gastropods in this region. Based on **Sugiyono (2014)** correlation criteria, a correlation value between 0.00 and 0.19 falls within the "very low" category. This result aligns with earlier studies suggesting that gastropod abundance is not universally linked to mangrove vegetation. **Farahisah *et al*. (2023)** also emphasized that only certain gastropod species exhibit strong associations with mangrove habitats. The distribution and density of gastropods are influenced by a variety of factors, including habitat type, availability of shelter and food, predation pressure, and interspecies competition **(Ariyanto *et al*., 2020; Ebadzadeh *et al*., 2024)**. These ecological dynamics highlight that while mangroves can provide important habitat, other environmental variables may have a more significant role in shaping gastropod communities.

CONCLUSION

Research along the north coast of Bangkalan identified 22 gastropod species, including *Assiminea ovata*, *Cassidula aurisfelis*, *Cassidula nucleus*, *Cerithidea cingulata*, *Cerithidea obtusa*, *Cerithideopsilla alata*, *Chicoreus capucinus*, *Crassipira*, *Clypeomorus pellucida*, *Ellobium aurisjudae*, *Littoraria articulata*, *Littoraria cerinifera*, *Littoraria melanostoma*, *Littoraria scabra*, *Murex occa*, *Myosotella*, *Nerita articulata*, *Nerita exuvia*, *Telescopium telescopium*, *Terebralia sulcata*, and *Turbo setosus*. The gastropod community structure indicates moderate ecosystem stability, as evidenced by the diversity index (H') ranging from 0.36 to 1.94, the evenness index (E) from 0.33 to 0.97, and the dominance index (D) from 0.18 to 0.78, with several species showing dominance in certain areas. A weak negative correlation was observed between mangrove density, particularly of the genus *Rhizophora*, and gastropod density, with a very low correlation coefficient (r = 0.1428) and determination coefficient (R^2 = 0.0204). This suggests that uneven mangrove density, especially at Station 12, is contributed to the low gastropod density. These results emphasize the need for mangrove rehabilitation to restore ecosystem balance, alongside conservation efforts focusing on maintaining nutrient-rich sediment, which serves as a crucial habitat for mangrove-associated fauna.

REFERENCES

Adyasari, D.; Pratama, M.A.; Teguh, N.A.; Sabdaningsih, A.; Kusumaningtyas, M.A. and Dimova, N. (2021). Anthropogenic impact on Indonesian coastal water and ecosystems: Current status and future opportunities. Mar. Poll. Bull., 171: p.112689.

Agustini, N.T.; Ta'alidin, Z. and Purnama, D. (2016). Struktur komunitas mangrove di desa Kahyapu Pulau Enggano. Jurnal Enggano, 1(1): 19-31.

Allen, J.A.; Ewel, K.C. and Jack, J. (2001). Patterns of natural and anthropogenic disturbance of the mangroves on the Pacific Island of Kosrae. Wetl. Ecol. Manag., 9: 291-301.

Amin, B.; Ismail, A.; Arshad, A.; Yap, C.K. and Kamarudin, M.S. (2009). Gastropod assemblages as indicators of sediment metal contamination in mangroves of Dumai, Sumatra, Indonesia. Water air soil poll., 201: 9-18.

Ariyanto, D.; G Bengen, D.; Prartono, T. and Wardiatno, Y. (2020). Distribution and abundance of *Cerithideopsilla djadjariensis* (Martin 1899) (*potamididae*) on *Avicennia marina* in Rembang, Central Java, Indonesia. Egypt. J. Aquat. Biol. Fish., 24(3): 323-332.

Bandibas, M. and Hilomen, V. (2016). Crab biodiversity under different management schemes of mangrove ecosystems. Glob. J. Environ. Sci. Manag., 2(1): 19-30.

Bengen, D.G.; **Yonvitner, Y. and Rahman, R. (2023).** Technical Guidelines for Mangrove Introduction and Management. IPB Press, Bogor.

Dale, P.E.R.; Knight, J.M. and Dwyer, P.G. (2014). Mangrove rehabilitation: a review focusing on ecological and institutional issues. Wetl. Ecol. Manag., 22: 587-604.

Dekker, H. and Orlin, Z. (2000). Check-list of Red Sea mollusca. Spirula, (1): 3-46.

Dewiyanti, I.; Harbi, M.; ElRahimi, S.A.; Ulfah, M. and Damora, A. (2021). Community structure of gastropods and bivalves associated in mangrove ecosystem at Pusung Cium Island, Seruway, Aceh Tamiang. IOP Conference Series: Earth and Environmental Science (Vol. 674, No. 1, p. 012026). IOP Publishing.

Ebadzadeh, H.; Shojaei, M.G. and Seyfabadi, J. (2024). The effect of habitat structural complexity on gastropods in an arid mangrove wetland. Wetl. Ecol. Manag., 32(1): 139-151.

Eleinin A.H.A.M.; El-Karim, R.M.G.; Habib, M.R.; Zayed, K.M. and Ali, R.E.M. (2021). Identification of the gastropod snails and shells collected from Ain El-Sokhna region, Red Sea, Egypt. Egypt. J. Aquat. Biol. Fish., 25(3): 101-117.

El-Sorogy, A.; El Kammar, A.; Ziko, A.; Aly, M. and Nour, H. (2013). Gastropod shells as pollution indicators, Red Sea coast, Egypt. J. Afr. Earth Sci., 87: 93-99.

Farahisah, H.; Azizah, N.; Dewiyanti, I. and Yulvizar, C. (2023). Relationship of mangrove snail's abundance (Cerithidea sp.) with mangrove density at mangrove ecosystem in Banda Aceh and Aceh Besar. *IOP Conference Series: Earth and Environmental Science* (Vol. 1221, No. 1, p. 012057). IOP Publishing.

Gab-Alla, A.; Fouda, M. and Morsy, W. (2010). Ecology of Avicennia marina mangals along Gulf of Aqaba, South Sinai, Red Sea. Egypt. J. Aquat. Biol. Fish., 14(2): 79-93.

Hartati, R.; Widianingsih, W.; Zainuri, M. and Wardiatno, Y. (2024). Using macrobenthic community structure and biotic indices to assess the ecological status of Wulan Estuary, Demak, Indonesia. Biodiversitas, 25(7): 3073-3087.

Hastuti, E.D.; Anggoro, S. and Pribadi, R. (2016). Dynamic linkages of mangrove Rhizophora mucronata and its environment parameters in Semarang and Demak coastal area. Int. J. Appl. Environ. Sci., 11(1): 279-293.

Hilmi, E.; Sari, L.K.; Cahyo, T.N.; Dewi, R. and Winanto, T. (2022). The structure communities of gastropods in the permanently inundated mangrove forest on the north coast of Jakarta, Indonesia. Biodiversitas, 23(5): 2699-2710.

Islamy, R.A. and Hasan, V. (2020). Checklist of mangrove snails (Mollusca: Gastropoda) in south coast of Pamekasan, Madura Island, East Java, Indonesia. Biodiversitas, 21(7): 3127-3134.

Krebs, C.J. (1989). Ecology: The Experimental Analysis of Distribution and Abundance, Third Edition. Harper and Row Publishers, New York.

Kumara, M.P.; Jayatissa, L.P.; Krauss, K.W.; Phillips, D.H. and Huxham, M. (2010). High mangrove density enhances surface accretion, surface elevation change, and tree survival in coastal areas susceptible to sea-level rise. Oecologia, 164: 545-553.

Langston, W.J. and Spence, S.K. (1995). Biological factors involved in metal concentrations observed in aquatic organisms. In "Metal speciation and bioavailability in aquatic systems" Tessier, A. and Turner, D.R. (Eds.), John Wiley & Sons, Chichester, pp. 407– 478.

Lee, S.Y. (2008). Mangrove macrobenthos: assemblages, services, and linkages. Journal of Sea Research, 59(1-2): 16-29.

Levinton, J.S.; Martinez, D.E.; McCartney, M.M. and Judge, M.L. (1995). The effect of water flow on movement, burrowing, and distributions of the gastropod Ilyanassa obsoleta in a tidal creek. Marine Biology, 122: 417-424.

Manullang, T.; Bakti, D. and Leidonald, R. (2018). Structure of gastropod communities at mangrove ecosystem in Lubuk Kertang village, West Berandan District, Langkat Regency, North Sumatera Province. IOP Conference Series: Earth and Environmental Science (Vol. 122, No. 1, p. 012103). IOP Publishing.

Melati, V.H.; Sari, L.A.; Cahyoko, Y.; Arsad, S.; Pursetyo, K.T.; Dewi, N.N. and Idris, M. (2021). Gastropod community structure as environmental change signals for tropical status in Sedati Waters, Indonesia. Ecol. Eng. Environ. Tech., 22: 82-90.

Mishra, P.; Pandey, C.M.; Singh, U.; Gupta, A.; Sahu, C. and Keshri, A. (2019). Descriptive statistics and normality tests for statistical data. Ann. Card. Anaesth., 22(1): 67-72.

Munthe, Y.V.; Aryawati, R. and Isnaini, I. (2012). Community Structure and Distribution of Phytoplankton in the Sungsang Waters of South Sumatra. Maspari Journal, 4(1): 122-130.

Muskananfola, M.R.; Purnomo, P.W. and Sulardiono, B. (2020). Impact of environmental factors on macrobenthos distribution and abundance in mangrove ecosystems on the Northern Coast of Java. AACL Bioflux, 13(5): 2745-2756.

Nicolai, A. and Ansart, A. (2017). Conservation at a slow pace: terrestrial gastropods facing fast-changing climate. Conserv. Physiol., 5(1): p.cox007.

Nishihira, M.; Kuniyoshi, M. and Shimamura, K. (2002). Size variation in *Trebralia palustris* (Gastropoda: Potamididae) of Iriomote Island, Southern Japan, and its effect on some population characteristics. Wetl. Ecol. Manag., 10: 243-247.

Nugraha, W.A. (2010). Litter production (fallen leaves) on various types of mangroves in Bangkalan. Jurnal Kelautan, 3(1): 66-69.

Nugraha, W.A; Sannisa, A.L. and Insafitri, I. (2024a). High Diversity of Mangrove Ecosystem on the North Coast of Bangkalan, East Java, Indonesia. Egypt. J. Aquat. Biol. Fish., 28(4): 2131-2146.

Nugraha, W.A.; Ambariyanto, A. and Insafitri, I. (2024b). The mangrove ecosystems on the north coast of Bangkalan, Indonesia, and its potential for mangrove ecotourism. Biodiversitas, 25(2): 859-868.

Odum, E.P. (1971). Fundamentals of Ecology. WB Saunders Company, Philadelphia.

Ozawa, T.; Yin, W.; Fu, C.; Claremont, M.; Smith, L. and Reid, D.G. (2015). Allopatry and overlap in a clade of snails from mangroves and mud flats in the Indo-West Pacific and Mediterranean (Gastropoda: Potamididae: Cerithideopsilla). Biol. J. Linn. Soc., 114(1): 212-228.

Pawar, P.R. (2012). Molluscan diversity in mangrove ecosystem of Uran (Raigad), Navi Mumbai, Maharashtra, West Coast of India. Bull. Environ. Pharmacol. Life Sci., 1(6): 55-59.

Purnama, M.F.; Prayitno, S.B.; Muskananfola, M.R. and Suryanti, S. (2024a). Tropical gastropod density and diversity in the mangrove forest of Totobo Village, Southeast Sulawesi, Indonesia. Biodiversitas, 25(4): 1663-1675.

Purnama, M.; Prayitno, S.B.; Muskananfola, M.R. and Suryanti, S. (2024b). Ecological indices of mangrove gastropods community in nickel mining impacted area of pomalaa, southeast sulawesi. Biotropia, 31(3): 359-371.

Putro, S.P.; Anarizta, L.A.; Muhammad, F.; Adhy, S. and Helmi, M. (2023). The roles of macrobenthic molluscs structure in assessing ecological status at mangrove and aquaculture areas. Jurnal Teknologi, 85(6): 27-35.

Prasetya, J.D.; Ambariyanto, A; Supriharyono, S. and Purwanti, F. (2017). Mangrove health index as part of sustainable management in mangrove ecosystem at Karimunjawa National Marine Park Indonesia. Adv. Sci. Lett., 23(4): 3277-3282.

Printrakoon, C.; Wells, F.E. and Chitramvong, Y. (2008). Distribution of molluscs in mangroves at six sites in the upper Gulf of Thailand. The Raffles Bull. Zool., 18: 247-257.

Ramadhani, A.; Ambarwati, R. and Gumilang, R.S. (2022). Diversity and abundance of water birds in the mangrove area of south coast of Bangkalan, Madura Island, Indonesia. Biodiversitas, 23(6): 3277-3284.

Sari, S.P. and Rosalina, D. (2016). Mapping and monitoring of mangrove density changes on tin mining area. Procedia Environmental Sciences, 33: 436-442.

Setyadi, G.; Rahayu, D.L.; Pribadi, R.; Hartati, R., Wijayanti, D.P.; Sugianto, D.N. and Darmawan, A. (2021). Crustacean and mollusk species diversity and abundance in the mangrove communities of Mimika District, Papua, Indonesia. Biodiversitas, 22(10): 4146-4157.

Simanullang, D.R.; Bengen, D.G.; Natih H.N.M. and Zamani, N.P. (2024). Spatial Distribution and Association of Gastropods in Mangrove Ecosystem in The Coast of Nusa Lembongan and Perancak Bali. Biodiversitas, 25(6): 2382-2392.

Sitnikova, T.; Soldatenko, E.; Kamaltynov, R. and Riedel, F. (2010). The finding of North American freshwater gastropods of the genus *Planorbella Haldeman*, 1842 (Pulmonata: Planorbidae) in East Siberia. Aquatic Invasions, 5(2): 201-205.

Soeprobowati, T.R.; Jumari, J.; Hidayat, J.W.; Muhammad, F.; Al Falah, M.H.; Cahyani, N.K.D. and Gell, P. (2023). Water Quality Status of Mangrove Ecosystem in Bedono, Sayung, Demak, Central Java. Pollution, 9(4): 1374-1385.

Sungkar, O.F.; Khanza, S. and Pangestu, R.A. (2018). Antibacterial Activity of Powder Enriched with Rhizopora Mucronata Fruit Extract Concentration. Jurnal Teknologi Pangan, 2(2): 135-141.

Strong, E.; Gargominy, O.; Ponder, W. and Bouchet, P. (2008). Global diversity of gastropods (Gastropoda; Mollusca) in freshwater. Hydrobiologia, 595: 149–166.

Sugiyono, S. (2014). Mixed Methods Research Methods. Alfabeta, Bandung.

Suresh, M.; Arularasan, S. and Srikumaran, N. (2012). Screening on antimicrobial activity of marine gastropods Babylonia zeylanica (Bruguière, 1789) and Harpa conoidalis (Lamarck, 1822) from Mudasalodai, southeast coast of India. Inter. J. Pharm. Pharm. Sci., 4: 552-556.

Thampanya, U; Vermaat J.E.; Sinsakul, S. Panaptukkul, N. (2006). Coastal erosion and mangrove progradation of southern Thailand. *Estuar*. *Coast Shelf Sci*., 68: 75-85.

Wintah, W.; Nuryanto, A.; Pribadi, R.; Sastranegara, M.H.; Lestari, W. and Yulianda, F. (2021). Distribution pattern of gastropods and physical chemical factors in the Kebumen mangrove forest, Indonesia. Aquacult. Aquarium Conserv. Legis., 14(4): 1855-1864.

WoRMS Editorial Board. (2019). World Register of Marine Species. Available from: http://www.marinespecies.org.

Yuniarto, R. (2003). Gastropod community structure in mangrove vegetation of the Sedodo River estuary, Demak. Faculty of Fisheries and Marine Science, Universitas Diponegoro, Semarang.

Zvonareva, S.; Kantor, Y.; Li, X. and Britayev, T. (2015). Long-term monitoring of Gastropoda (Mollusca) fauna in planted mangroves in central Vietnam. Zoological studies, 54: 1-16.