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Assessing Mangrove Gastropod Biodiversity: Composition, Abundance, and Ecological Indices in Mempawah, West Kalimantan, Indonesia

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ABSTRACT

West Kalimantan boasts vast mangrove ecosystems, particularly in Mempawah Regency, which play a crucial role in supporting biodiversity, including diverse gastropod communities. Gastropods are important as detritivores, predators, and bioindicators of environmental conditions in mangrove ecosystems. This study aimed to analyze the structure of the gastropod community in the mangrove area of Sungai Bakau Kecil Village. The research was conducted in August 2024 using a simple random sampling method at five stations. Sampling was achieved with 1×1m² quadrat transects, and species identification was done in the laboratory. The results showed 11 species from 7 families, with *Pirenella cingulata* as the dominant species at all stations. The highest density was found at station II (73.49 ind/m²), while the lowest density was found at station III (40.53 ind/m²). Ecological index analysis showed moderate to high diversity with Shannon-Wiener index (H') ranging from 1.89-2.75, uniformity index (E) between 0.56-0.82, and Simpson's dominance index (C) between 0.18-0.42, indicating a reasonably diverse gastropod community, without the dominance of certain species. The results of this study provide scientific information on the diversity and distribution patterns of gastropods in mangrove ecosystems. They can be the basis for conservation efforts and sustainable mangrove management in Sungai Bakau Kecil Village.

INTRODUCTION

West Kalimantan has the potential for mangrove ecosystems that grow and is widely distributed in several coastal areas, including Mempawah Regency. This region covers around 3,153.80 ha of mangrove forest, with ±99.71 ha located in Mempawah Timur District **(National Mangrove Map, 2023)**. Sungai Bakau Kecil is one of the villages in this district possessing an area of 16.95km² **(BPS Mempawah Regency, 2024)**. Earlier research reported the diversity of mangrove species in Sungai Bakau Kecil Village, including *Rhizophora*, *Avicennia*, *Bruguiera*, and *Sonneratia*, with low to medium density levels **(Marini *et al*., 2018; Zuswiryati *et al*., 2022**). In ecological terms, mangroves provide important feeding and breeding grounds, nursery areas, and shelter for various types of aquatic organisms **(Arceo-Carranza *et al*., 2021; Ulva *et al*., 2024)**. **Wang and Gu (2021)** reported that almost 90% of aquatic organisms spend their life cycle in mangrove ecosystems. This is mainly due to the role of mangrove ecosystems as nutrient carriers **(Cock *et al*., 2021)**. Mangrove forests produce litter that is degraded by microorganisms into a source of nutrients. These nutrients are then directly utilized by the diverse marine and terrestrial organisms inhabiting the mangrove environment **(Selviani *et al*., 2024)** including gastropods.

Gastropods, belonging to the phylum mollusc, are one of the vital components in mangrove ecosystem. They are the largest class and have high species diversity with around 80,000 identified species **(Bouchet *et al*., 2005)**. This class is widely distributed in various aquatic habitats, ranging from freshwater (~4000 species), marine (~5000 species), and terrestrial environments (~4000 species) **(Strong *et al*., 2008)**. Furthermore, **Purnama *et al*. (2024)** reported that as many as 61 gastropod species were found in mangrove area, where they contribute to ecosystem stability. In mangrove ecosystem, gastropods occupy various habitats, both as infauna that burrow themselves into muddy substrates to feed and shelter, as well as epifauna that live on the surface of the substrate and are directly impacted by the surrounding environment. In addition, other species are found as treefauna, which attach to various parts of mangrove trees such as roots, stems, and leaves to find food and protection from tidal or predator. Numerous studies have reported the crucial role of gastropods as keystone species in mangrove ecosystems **(Ortega-Jiménez *et al*., 2021; Supriatna *et al*., 2023)**. As a key component, the presence or absence of gastropods can provide information about environmental conditions and the health of the mangrove habitat. The diversity and abundance of gastropods is closely related to the condition of the mangrove, where healthy mangrove support high species diversity **(Wintah *et al*., 2021; Hilmi *et al*., 2022)**.

Currently, increasing human activities such as coastal development, land clearing, deforestration, mining industry, and pollution have negative impacts both directly and indirectly on mangrove ecosystems as gastropod habitats. These threat influence the species composition and abundance of gastropods, which they are very sensitive to changes in environmental conditions. Alterations in habitat quality can disrupt the overall balance of the ecosystem. Consequently, understanding the structure and abundance of gastropod populations in mangrove habitats is essential for effective management and conservation of these critical ecosystems. This knowledge will help ensure the sustainability of both gastropod communities and the broader ecosystem services mangroves provide. Therefore, the objective of this study was to assess the species composition and abundance of mangrove gastropods in Sungai Bakau Kecil Village, Mempawah Regency, West Kalimantan, Indonesia.

MATERIALS AND METHODS

1. Research location

This study was conducted in August 2024 on the mangrove ecosystem of Sungai Bakau Kecil Village, Mempawah Regency, West Kalimantan, Indonesia (Fig. 1). The determination of research location was conducted using purposive sampling method, consisting five stations with relatively similar ecological characteristics, such as mangrove types and substrate conditions. The mangrove species found in this area includes *Avicennia marina*, *Bruguiera gymnorrhiza*, *Rhizophora apiculata*, *Sonneratia alba*, and *Nypa fruticans*. Sampling at all stations is expected to provide comprehensive information regarding the structure of the gastropod community in these mangrove area.

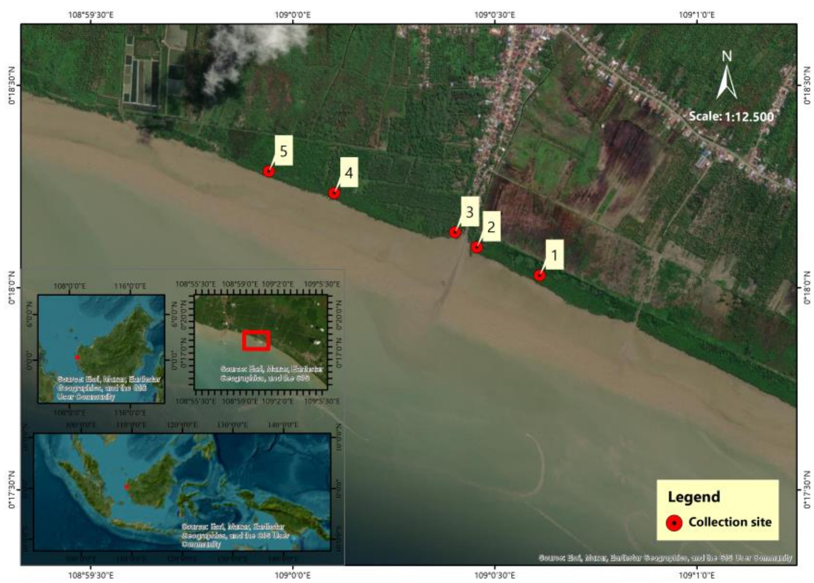

Fig. 1. Sampling location of mangrove gastropods in Sungai Bakau Kecil Village, West Kalimantan, Indonesia

Table 1. Environmental characteristics of the study area

Station	Sampling point	Ecological characteristic
I	0°18'2.63" N and 109° 0'33.56" E	Mangrove type are *Rhizophora* and *Avicennia* with muddy substrates
II	0°18'6.87" N and 109° 0'26.49" E	Mangrove type are *Rhizophora* and *Avicennia* with muddy substrates

III	0°18'7.75" N and 109° 0'24.29" E	Mangrove type are *Rhizophora*, *Avicennia*, and *Bruguiera* with muddy substrates
IV	0°18'14.47" N and 109° 0'5.95" E	Mangrove type are *Rhizophora*, *Avicennia*, and *Sonneratia* with muddy substrates
V	0°18'17.92" N and 108° 59'54.30" E	Mangrove type are *Rhizophora*, *Avicennia*, *Bruguiera*, and *Sonneratia* with sandy-mud substrate

2. Samples collection

The extent of the mangrove area at each station varies from the shoreline to the inland region, leading to variations in the number of observation plots used for sampling. A 1×1m² quadratic plot was used for gastropod sampling, which were randomly placed within the designated study area. At station I, a total of 30 sampling plots, station II had 40 plots, station III had 75 plots for sampling, while station IV consisted of 60 plots, and station V included 45 sampling plots. The number of plots at each station was determined based on the size of the mangrove area, ensuring a proportional sampling effort in each location. This approach ensured that the sampling was representative of the overall gastropod community across the different sites. Epifaunal and arboreal (treefauna) gastropods were collected manually by hand-picking, utilizing hand scoops and gloves for efficient and careful sampling **(Purnama *et al*., 2019; Salwiyah *et al*., 2022)**.

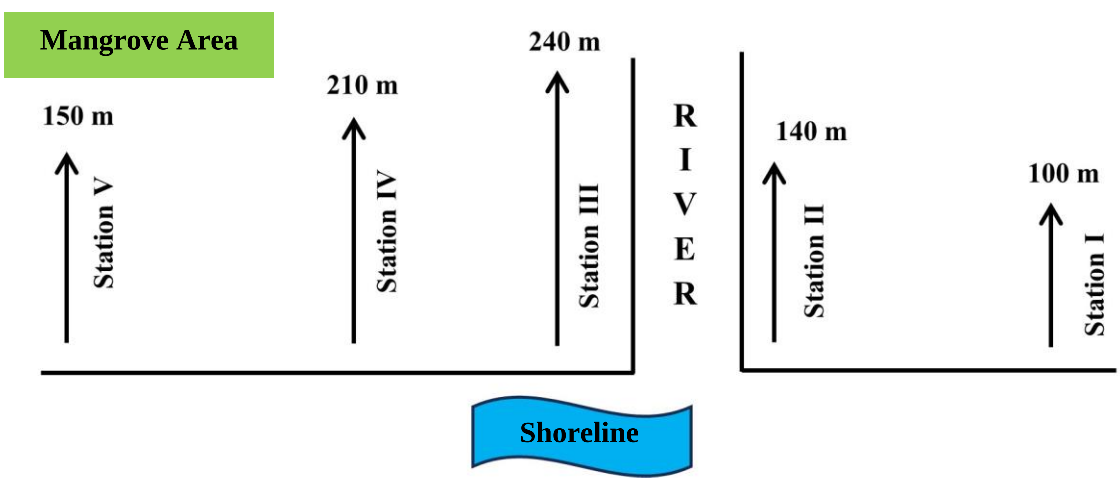

Fig. 2. Illustration of samples collection

The identification of mangrove gastropods was conducted in the Laboratory of Marine Science, Universitas Tanjungpura, referred to sources such as the "World Register of Marine Species" (https://www.marinespecies.org), Molluscabase (https://www.molluscabase.org), the Collection of Worldwide Seashells (https://idscaro.net), as well as various reputable journals and textbooks, including **Dharma (1998, 2005)**, **Poutiers (1998)**, **Cappenberg *et al*. (2006)**, **Arbi (2014)**, **Dolorosa and Gallon (2014)**, **Reid and Ozawa (2016)**, **Islamy and Hasan (2020)** and **Hilmi *et al*. (2022)**.

3. Data analysis

Species abundance refers to the density of individuals from various gastropod species within a specific unit area of the mangrove habitat. The abundance of gastropods was calculated using the formula proposed by **Yasman (1998)**:

$$K = \frac{ni}{A}$$

Where, K represent the abundance of gastropod species (ind/m²); n_i is the number of individual gastropods (ind); and A denotes the sampling area (m²).

The diversity index of gastropods in the mangrove ecosystem reflects species richness and evenness, indicating the overall health of the habitat. A higher diversity index suggests a well-balanced ecosystem, while a lower value may indicate environmental stress or dominance by a few species. The diversity index (H') was calculated using the Shannon-Wiener formula, as described by **Odum (1993)**

$$H' = -\sum_{i=1}^{n} \left(\frac{ni}{N}\right) \ln (ni/N)$$

Where, H' represents the diversity index; n_i denotes the number of individual gastropods (ind); and N is the total gastropod count (ind). According to **Wilhm (1975)**, the diversity index is categorized as low if H' < 1, moderate if 1 < H' ≤ 3, and high if H' > 3.

The evenness index (E) was determined using the formula by **Odum (1993)**, as follows:

$$E = \frac{H'}{In\ S}$$

In this formula, H' denotes the diversity index, while S represents the total number of gastropod species recorded. The evenness index is categorized as low if E ≤ 0.5, moderate if 0.5 < E ≤ 0.75, and high if 0.75 < E ≤ 1.

The dominance index (C) quantifies the extent to which certain species dominate a community. It helps determine whether a community is primarily controlled by one or a few species or if species are more evenly distributed. The dominance index was calculated using the formula by **Berger-Parker (1970)**:

$$C = \sum_{i=1}^{n} \frac{ni\ (ni - 1)}{N\ (N - 1)}$$

Where, n_i represents the number of individual gastropods, and N is the total count of individuals across all species. The index ranges from 0 to 1, where a value of $0 < C \leq 0.5$ signifies perfect evenness or an equal distribution of individuals (no species dominates the community) across all species within the community. In contrast, a value of $0.5 < C \leq 1$ indicates that a dominant species is present **(Kitikidou *et al*., 2024)**.

RESULTS

1. Mangrove gastropods composition

In the mangrove area of Sungai Bakau Kecil Village, 11 species of gastropods were recorded belonging to 9 genera and 7 families. Among all the gastropods identified, Ellobidae is the family with the greatest species diversity (three species), followed by Littorinidae and Potamididae, which each represented by two species. In addition, other families like Neritidae, Assimineidae, Haminoeidae, and Onchidiidae only consisted of one species. In terms of species distribution, there were six species found at all sampling stations, where their presence indicates a wide distribution in the study area. Meanwhile, other species were only found at certain stations, showing that they may have particular habitat preferences or environmental conditions that restrict their presence in the mangrove area of Sungai Bakau Kecil Village (Table 2).

Table 2. Mangrove gastropods from Sungai Bakau Kecil Village, Mempawah Regency

Family	Species	Behavior patterns	Station				
			I	II	III	IV	V
Littorinidae	*Littoraria scabra*	TF	+	+	+	+	+
	Littoraria melanostoma	TF	+	+	+	+	+
Ellobiidae	*Cassidula aurisfelis*	EF, TF	+	-	+	+	+
	Cassidula nucleus	EF, TF	+	-	+	+	+
	Ellobium aurisjudae	EF, TF	-	+	+	+	+
Potamididae	*Pirenella cingulata*	EF, TF	+	+	+	+	+
	Cerithidea obtusa	EF, TF	+	+	+	+	+
Neritidae	*Neritona labiosa*	EF	+	+	+	+	+
Assimineidae	*Sphaerassiminea miniata*	EF	+	+	+	+	+
Haminoeidae	*Haloa crocata*	EF	-	+	+	-	-
Onchidiidae	*Platevindex coriaceus*	TF	+	+	-	+	+

(+) present ; (-) absent ; (EF) epifauna ; (TF) treefauna

The discovered species such as *Littoraria scabra* (Linnaeus, 1758), *L. melanostoma* (Gray, 1839), *Cassidula aurisfelis* (Bruguière, 1789), *C. nucleus* (Gmelin, 1791), *Ellobium aurisjudae* (Linnaeus, 1758), *Pirenella cingulata* (Gmelin, 1791), *Cerithidea obtusa* (Lamarck, 1822), *Neritona labiosa* (G.B. Sowerby I, 1836), *Sphaerassiminea miniata*, *Haloa crocata* (Pease, 1860), and *Platevindex coriaceus* (C. Semper, 1880) (Fig. 3), exhibit different morphological features and morphometric characteristics. These variations support the adaptation of gastropods to environmental conditions in mangrove habitats.

Field observations disclosed that gastropods were especially found on various substrates, acting as epifauna found on the ground floor, and were also serving as treefauna which attach themselves to different parts of mangrove trees, including the roots, trunks, and leaves (Fig. 4). Vertically, *L. scabra*, *L. melanostoma*, and *P. coriaceus* attach to different parts of the mangrove tree, while *N. labiosa*, *S. miniata*, and *H. crocata* were only found on the substrate surface. Interestingly, several other gastropod species showed a wider ecological range, being found both arboreal and benthic habitat that depends on environmental conditions and species-specific behaviors.

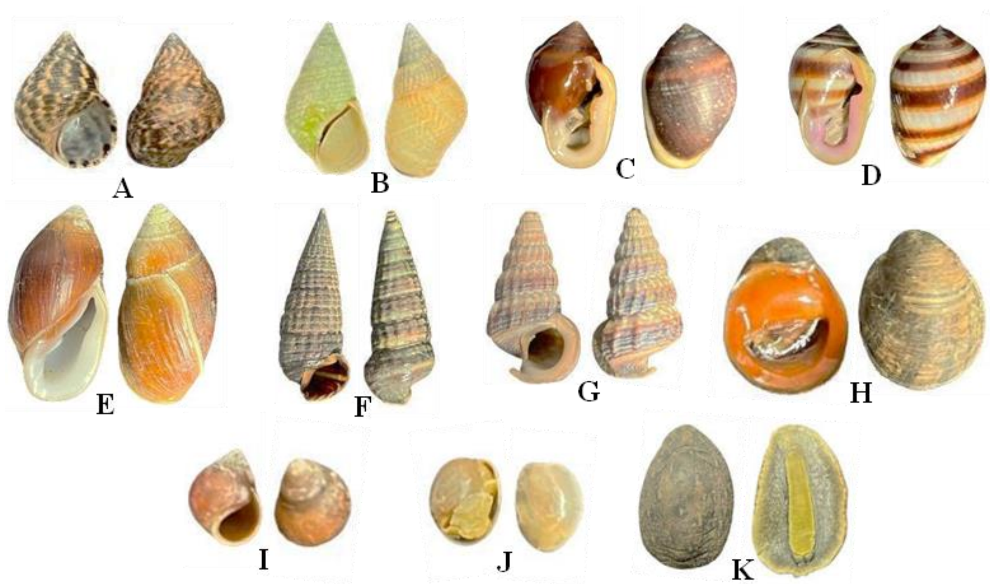

Fig. 3. Composition of gastropods from mangrove area of Sungai Bakau Kecil Village (A) *Littoraria scabra* (B) *L. melanostoma* (C) *Cassidula aurisfelis* (D) *C. nucleus* (E) *Ellobium aurisjudae* (F) *Pirenella cingulata* (G) *Cerithidea obtusa* (H) *Neritona labiosa* (I) *Sphaerassiminea miniata* (J) *Haloa crocata* (K) *Platevindex coriaceus*

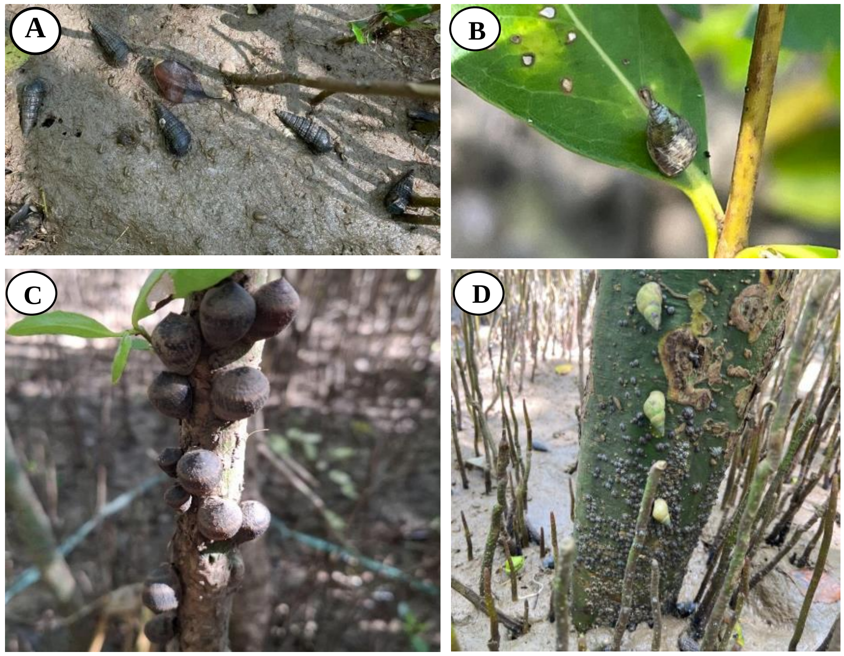

Fig. 4. Behavioral patterns of various gastropod species in the mangrove area of Sungai Bakau Kecil Village as epifauna and treefauna (A) *Pirenella cingulata*, (B) *Littoraria scabra*, (C) *Cassidula aurisfelis*, and (D) *Littoraria melanostoma*

2. Density of mangrove gastropods

During field sampling, a total of 14,004 individuals of mangrove gastropods were discovered, distributed across five sampling stations (Table 3). The gastropod's distribution varied among species and stations, with station II showing the highest total number (3,307 individuals), while the lowest number was observed at station I (1,885 individuals). Among the identified species, *P. cingulata* was dominant in the study area, exhibiting the highest number with a total of 6,762 individuals. This species was recorded at all stations, with the highest number found at station IV, accounting for 1,921 individuals, and the lowest at station I reaching 949 individuals. Apart from that, *L. melanostoma* was the second most abundant species totaling 2,966 individuals, found mostly at station IV (818 individuals) and station II (740 individuals). Similarly, *S. miniata* was present in significant numbers (2,546 individuals), with the highest abundance at station II (1,017 individuals). Meanwhile, other species exhibited lower concentration, with 788 individuals of *L. scabra* and 631 individuals of *C. nucleus*. Some species were found in relatively small numbers including *C. aurisfelis*, *E. aurisjudae*, *C. obtusa*, *N. labiosa*, *H. crocata*, and *P. coriaceus*, ranging from 7 to 209 individuals. Notably, the least abundant species were *H. crocata* and *P. coriaceus* with only 13 and 7 individuals recorded, respectively.

Across all sampling stations, there was a variation of the mangrove gastropod's density and relative density in Sungai Bakau Kecil Village, indicating differences in species distribution and abundance. Station II showed the highest total density (73.49 ind/m²), while station III exhibited the lowest value (40.53 ind/m²). Among the identified species, *P. cingulata* exhibited the highest density, where 16.17 ind/m² (39.90% relative density) was observed at station III and 32.02 ind/m² (61.18% relative density) at station IV. This species was dominant in the gastropod community and contributed significantly to the overall density at each station. A considerable presence was also showed by *S. miniata*, particularly at station II, where it had a density of 22.6 ind/m², accounting for 30.75% of the total gastropod community at that station. Similarly, *L. melanostoma* was another abundant species, with its highest density at station II (16.44 ind/m²) and relative density reaching 26.05% at station IV. Conversely, species such as *H. crocata*, *C. aurisfelis*, *E. aurisjudae*, and *P. coriaceus* were found in relatively low densities across the stations. *H. crocata* was only recorded at station II and III, while *C. aurisfelis* had a density below 1 ind/m² across all stations.

Table 3. Density of mangrove gastropods from mangrove area of Sungai Bakau Kecil Village, Mempawah Regency

Species	Station I			Station II			Station III			Station IV			Station V		
	Σ (ind)	K (ind/m²)	KR (%)	Σ (ind)	K (ind/m²)	KR (%)	Σ (ind)	K (ind/m²)	KR (%)	Σ (ind)	K (ind/m²)	KR (%)	Σ (ind)	K (ind/m²)	KR (%)
L. scabra	76	2,53	4,03	257	5,71	7,77	241	3,21	7,93	60	1,00	1,91	154	3,42	5,85
L. melanostoma	301	10,03	15,96	740	16,44	22,38	608	8,11	20,00	818	13,63	26,05	499	11,09	18,96
N. labiosa	9	3,77	5,99	0	0,87	1,18	1	0,71	1,74	24	0,02	0,03	17	0,07	0,11
C. aurisfelis	89	0,30	0,48	0	0	0	62	0,01	0,03	294	0,40	0,76	186	0,38	0,65
C. nucleus	0	2,97	4,72	2	0	0	6	0,83	2,04	6	4,90	9,36	1	4,13	7,07
E. aurisjudae	949	0	0	1239	0,04	0,06	1213	0,08	0,20	1921	0,10	0,19	1440	0,02	0,04
P. cingulata	1	31,63	50,32	2	27,53	37,47	8	16,17	39,90	4	32,02	61,18	1	32,00	54,71
C. obtusa	113	0,03	0,05	39	0,04	0,06	53	0,11	0,26	1	0,07	0,13	3	0,02	0,04
S. miniata	343	11,43	18,19	1017	22,6	30,75	845	11,27	27,80	12	0,20	0,38	329	7,31	12,50
H. crocata	0	0	0	10	0,22	0,30	3	0,04	0,10	0	0	0	0	0	0
P. coriaceus	4	0,13	0,21	1	0,02	0,03	0	0	0	1	0	0	1	0,02	0,04
TOTAL	**1885**	**62,83**	**100**	**3307**	**73,49**	**100**	**3040**	**40,53**	**100**	**3141**	**52,35**	**100**	**2631**	**58,47**	**100**

3. Biological index of mangrove gastropods

The biological indices such as diversity (H'), evenness (E), and dominance (C) of mangrove gastropods in Sungai Bakau Kecil Village varied across all sampling stations, indicating differences in species distribution and ecological balance (Table 3). These indices provide information on the overall stability and condition of mangrove ecosystems. Additionally, analyzing these indices helps monitor ecological equilibrium, identify potential environmental changes, and recognize the significance of gastropods as indicators of ecosystem health.

Tabel 4. Biological index of mangrove gastropods from Sungai Bakau Kecil Village

Biological Index	Station				
	I	II	III	IV	V
H'	1.43	1.35	1.43	1.03	1.31
E	0.65	0.61	0.60	0.47	0.57
C	0.32	0.29	0.28	0.45	0.36

The diversity index (H') of mangrove gastropods ranged from 1.03 at station IV to 1.43 at stations I and III. According to diversity level criteria **(Odum, 1993)**, all stations exhibited moderate species diversity, except for station IV that showed a less diverse gastropod community. This value is similar to the findings of **Atnasari *et al*. (2020)** in mangrove area of Bakau Besar Laut Village, where gastropods had low to moderate levels of diversity. In other mangrove areas of Mempawah Regency, **Herviory *et al*. (2019)** showed slightly different results, where gastropods were found with moderate to high levels of diversity.

The value of evenness index (E) also varied between 0.47 at station IV and 0.65 at station I, representing low to moderate category. The low evenness value indicates that certain species were highly dominant, leading to an uneven species distribution, whereas the moderate evenness category demonstrates a more balanced distribution of individuals among species. The findings of the evenness index in this study are slightly lower than **Atnasari *et al*. (2020)**, who found gastropods with moderate to high levels of uniformity across all sampling stations.

The variation was also seen in the dominance index (C) which ranged from 0.28 at station III to 0.45 at station IV. The high value of the dominance index at station IV indicates that there was a particular species that dominates the community, and this phenomenon was parallel with the lower diversity and evenness. Meanwhile, the lowest dominance index observed at station III indicates a more balanced species composition and community structure. In overall, the dominance index value of this study is similar to the results of **Atnasari *et al*. (2020)**, except that they discovered gastropods with high dominance at stations I and III.

DISCUSSION

The species composition of mangrove gastropods in this study is relatively similar to the findings of previous research conducted in mangrove ecosystems. They also recorded a dominance of the families Ellobiidae, Littorinidae, and Potamididae in the mangrove area of Mempawah Regency **(Herviory *et al*., 2019; Maura *et al*., 2021; Fitra *et al*., 2023)**. The relatively high species diversity of these families is consistent with studies by **Purnama *et al*. (2024)**, which highlight the adaptability to various microhabitats within mangrove environments. Family *Ellobiidae* with the high species diversity in this study aligns with the findings of **Hilmi *et al*. (2022)** from the north coast of Jakarta, who discovered seven species, including *Cassidula* and *Ellobium*. In the mangrove ecosystem of Sungai Bakau Kecil Village, the presence of a diverse *Ellobiidae* assemblage is likely influenced by the mud-clay substrate. This substrate characteristic provides a favorable habitat. It has been documented that many gastropod species prefer mud-clay substrates **(Imamsyah *et al*., 2020; Hilmi *et al*., 2022)**. This preference is due to their fine texture, high organic matter content, and capacity to retain nutrients **(Gireeshkumar *et al*., 2020; Adey, 2024)**, which supports detritus-based food chains. Furthermore, Ellobiidae has been confirmed as native to mangrove ecosystems, exhibiting a wide distribution and an ability to thrive on muddy substrates, as well as on mangrove trees **(Belhiouani *et al*., 2019; Purnama *et al*., 2022)**. The considerable species diversity within the Littorinidae family recorded in this study is consistent with the findings of **Simanulang *et al*. (2024)** in mangrove ecosystems on the coast of Nusa Lembongan and Perancak. The Littorinidae family includes over 200 species, and the majority of these species are highly specialized for living on mangrove vegetation **(Reid *et al*., 2012)**, especially on trunks and leaves of mature *Rhizophora*. Research demonstrated that Littorinidae species, for example *L. melanostoma* rapidly adapt to mangrove reforestation, frequently establishing dominance in the initial phases of vegetation recovery **(Chen *et al*., 2017)**. Meanwhile, the diversity of species within the Potamididae family observed in this study corresponds with the findings of **Mawardi *et al*. (2023)** on the east coast of Aceh Province. Potamididae, for instance, is the original inhabitant and exclusively associated with mangrove vegetation, showcasing adaptations that allow them to exploit this niche effectively **(Arbi *et al*., 2022)**.

The morphological and morphometric variations observed among species highlight their different adaptive strategies within the mangrove ecosystem. Shell shape, size, and others morphological characteristics cause gastropods to have different habitat preferences, mobility, and resistance to stressful environmental factors. Species like *L. scabra* and *L. melanostoma* exhibit turbinate shells with well-developed apertures **(Islamy & Hasan, 2020)**, facilitating their arboreal lifestyle by allowing strong attachment to mangrove tree **(Chen *et al*., 2023)**. In contrast, *P. cingulata* and *C. obtusa* possess more robust and elongated or conical shells **(Islamy & Hasan, 2020)**, which provide stability in sediment environments, reducing the risk of displacement by tidal currents. In this study, *L. scabra* are found with shell lengths ranging between 1.2 and 1.5cm. The shell coloration varies from yellowish-brown to light brown, coming with distinct dark brown bands that form a contrasting striped pattern along the shell. *L. melanostoma* has an average shell length of 2.2cm. The outer shell color was yellow-brown coloration, while the underside ranges from white to pale brown. These differences in color and markings help gastropods camouflage **(Gordy, 2023)**, allowing the species to blend seamlessly with the textured surfaces of mangrove trunks and leaves, thereby offering protection from predators.

Cassidula aurisfelis and *C. nucleus* have nearly the same shell shape and color, which are smooth, oval-shaped, and brown shell. The difference is a prominent white band encircling the outer surface of the shell which is present in *C. nucleus*. By knowing their shell size, these gastropods are relatively small with an average shell length of 2.3cm and width of 1.8cm. These gastropods exhibit an average shell length of 2.3cm and a width of 1.8cm, reflecting their relatively small yet distinct morphological features. Mangrove forests, especillay *Rhizophora*, become stable microhabitats that provide shelter and food sources, and both species are often found attached to the roots and stems. Previous studies have documented that the genus *Cassidula* is a native component of mangrove ecosystems, often found as a permanent resident **(Saleky & Merly, 2021; Yuliawati *et al*., 2021)**. *E. aurisjudae* possesses a thick, elongated, oval shell with a blunt apex, providing it with a robust structure well-suited to its habitat. The shell surface is adorned with fine, shiny lines, which may aid in camouflage or protection against environmental stressors. This species exhibits a shell length ranging from 3.8 to 4.8cm and a width between 0.9 and 1.5cm, making it relatively larger than many other mangrove-associated gastropods. *E. aurisjudae* is commonly found both on the substrate surface and attached to dead mangrove trees, utilizing these areas as shelter and feeding grounds. The genus *Ellobium* has been recognized as a native inhabitant of mangrove ecosystems **(Yuliawati *et al*., 2021; Harzhauser *et al*., 2023)**, with its distribution closely tied to tidal influence.

Pirenella cingulata has a blackish-brown shell with a conical shape and a sharply pointed apex. These characteristics help to protect themselves from predator attacks and environmental stress. The shell length ranges from 3.1 to 3.4cm and width between 0.9 and 1.1cm. This species is mostly found on the surface of muddy substrates **(Solanki *et al*., 2017)**, where it plays a crucial role in nutrient cycling by feeding on detritus and organic matter. **Reid and Ozawa (2016)**, reported *P. cingulata* as a native species in mangrove ecosystems. In addition, this species is recognized as an opportunistic organism, which is able to adapt quickly to environmental changes and fluctuations in habitat conditions. Its ability to thrive in disturbed environments is largely attributed to its high reproductive rate, allowing rapid population growth and persistence even in areas experiencing ecological stress **(Zvonareva & Kantor, 2016; Solanki *et al*., 2017)**. These characteristics make *P. cingulata* a dominant species in many mangrove regions, where they can sometimes reach bloom conditions due to limited natural predators and competitors.

Cerithidea obtusa has a solid, cone-shaped shell with a blunt apex. The shell is brown, with lengths ranging from 3.2 to 4.2cm and widths between 1.8 and 2.1cm. This morphological characteristic helps *C. obtusa* survive in harsh environmental conditions. In the study area, this species was commonly found on muddy substrates or attached to the mangrove roots and stems, especially *Rhizophora* and *Bruguiera*, indicating a preference for these mangroves types. **Yap *et al*. (2023)** in their research reported that *C.*

obtusa is a native species in mangrove habitats. As a native species, *C. obtusa* has a high level of adaptation to dynamic environmental conditions, occupying a variety of microhabitats both as benthic and arboreal organisms. They are also able to use a variety of food types present in the environment. Furthermore, the species' widespread distribution and persistence in mangrove environments highlight its resilience to tidal influences.

N. labiosa has a thick, strong, and solid shell surface, with an oval or round shape, and low spire. It measures about 1.3-1.6cm in length with an average width of 0.9cm. The shell has an oval-shaped aperture with a smooth, silvery, or white color inside. The color scheme varies from brown to black, often dotted with zigzag patterns or darker spots. In general, this species is reported to be a visitor species, only temporarily present in mangrove habitats for foraging, breeding or shelter, but their primary habitat is located elsewhere. **Purnama *et al*. (2022)** stated that in general, gastropods of the Neritidae family tend to occupy stream habitats with rock substrates or lotic zones, which provide optimal environmental conditions for their survival.

Sphaerassiminea miniata is a small gastropod species with an average shell length of 0.7cm and a width of 0.4cm. This species is commonly known as the "red berry snail" because of its reddish-brown shell, with a smooth surface. This species is frequently grouped with high density on the surface of the substrate, even partially buried by mangrove leaf litter. Its preference for these habitats suggests that it plays a role in the decomposition process, contributing to nutrient cycling within the mangrove ecosystem. According to **Purnama *et al*. (2024b)**, *S. miniata* is a native species that mainly found in mangrove vegetation with good condition, where its abundance ranges from 8.67 to 38.33 ind/m^2. This species exhibits a clustered distribution pattern, where this behavior may serve as a survival strategy and provide protection against predators. Its presence in high densities within healthy mangrove ecosystems highlights its ecological importance. Furthermore, *S. miniata* serves as a crucial bioindicator of environmental health, as its population dynamics can reflect changes in habitat quality, pollution levels, and overall ecosystem stability.

Haloa crocata is a is quite tiny gastropod species, with an average shell length of 0.9cm and a width of 0.6cm. They have a thin, fragile, smooth, and transparent shell, with an oval shape that widened at the center and a concave apex. *H. crocata* is typically found on muddy substrates, where it may contribute to nutrient cycling by grazing on microalgae and detritus. Meanwhile, *P. coriaceus* encountered had a flattened and elongated body with a rough skin texture. Its coloration varies from dark brown and gray to black, often exhibiting spotted patterns that provide camouflage against mangrove roots and decaying wood. The species has an average length of 2.1cm and a width of 1.8cm, with its dorsal surface protected by a thick mantle that offers protection against predators. In the study area, *P. coriaceus* was frequently observed attached to the roots and stems of *Rhizophora* and *Avicennia* mangroves, as well as on decomposing wood.

This behavior may suggest a preference for stable substrates, where it can feed on biofilms, algae, and organic matter. Several previous studies have documented the presence of *P. coriaceus* in Indonesian mangrove habitats, confirming its status as a native species **(Goulding *et al*., 2018; Goulding *et al*., 2021)**.

The existence of gastropods as epifauna or treefauna may serve as an adaptation of morphology and physiology in the environment. One of their key adaptive features is the secretion of mucus from specialized glands **(Greistorfer *et al*., 2023)**, which helped them attach to a variety of surfaces, including muddy substrates and the bark of mangrove trees. This study revealed distinct habitat preferences among various gastropod species within the mangrove ecosystem. *L. scabra* was frequently observed on the upper sections of the trees, including branches and leaves, whereas *L. melanostoma* primarily inhabited the mid-trunk region and roots, and *P. coriaceus* was more commonly found near the base and roots of the mangrove trees. Such behavior patterns likely as an adaptive response to environmental factors such as tidal fluctuations, predation pressure, and food availability. Gastropods living in mangrove trees seek higher elevations to avoid predation from crabs and fish, as well as escape inundation at high tide. **Kesaulya and Robinson (2021)** reported that *L. scabra* exhibits a daily vertical migration as an adaptive strategy to avoid submersion during high tide. This behavior allows the species for maintaining an optimal positioning within the mangrove habitat. Additionally, their distribution is closely linked to food availability and food preferences. Treefauna gastropods rely on biofilm layers, lichens, and residual organic material **(Stafford & Davies, 2005; Asplund *et al*., 2018)** that accumulate on mangrove roots, trunks, and leaves. Meanwhile, *N. labiosa*, *S. miniata*, and *H. crocata* were exclusively found on the substrate surface, suggesting their preference for soft substrate enriched with organic matter. Organic matter plays a crucial role in sustaining epifaunal gastropods by providing a continuous food source. These gastropods primarily feed on detritus, periphyton algae, and decomposed organic matter that accumulates from mangrove litter, contributing to nutrient recycling within the ecosystem **(Lombardo & Cooke, 2002; Lv *et al*., 2022)**. Interestingly, some other gastropod species, including *C. aurisfelis*, *C. nucleus*, *E. aurisjudae*, *P. cingulata*, and *C. obtusa* demonstrated a broader ecological range, occupying both arboreal and benthic habitats, indicating their ability to exploit multiple microhabitats within the mangrove ecosystem. This broad range may also indicate physiological adaptations that allow them to tolerate varying levels of salinity, submersion durations, and competition with other gastropod species.

The abundance of mangrove gastropods in this study is consistent with the results by **Syahrial *et al*. (2023)** and **Sandaruwan *et al*. (2024)** where *P. cingulata* is the most commonly found species. The high density of *P. cingulata* observed in the study area can be attributed to its dominance within the ecosystem. Hundreds to thousands of individuals were recorded on the substrate surface, highlighting its ability to thrive in mangrove environments. This finding aligns with **Pribadi *et al*. (2009)**, who stated that gastropods from the genera *Cerithidea* and *Pirenella* exhibit broad distributions within mangrove ecosystems and are often found in high densities. *Pirenella* is well adapted to thrive in extreme environmental conditions, including brackish estuaries, hypersaline lagoons, and inland lakes **(Islamy & Hasan, 2020)**. Additionally, *P. cingulata* has been identified as a nuisance gastropod or pest in mangrove forests due to the absence of natural predators and competitors, leading to excessive population growth and even population blooms **(Zvonareva & Kantor, 2016)**. The species' high reproductive capacity **(Solanki *et al*., 2017)** further contributes to its abundance, allowing for rapid population expansion. Furthermore, its relatively short life cycle facilitates continuous reproduction and sustains its dominance in mangrove habitats.

Other species that exhibited high density values in the study area included *S. miniata* and *L. melanostoma*. The presence and significant abundance of *S. miniata* in mangrove ecosystems have been widely documented in previous studies. **Yugovic *et al*. (2024)** reported that *S. miniata* exhibited the highest density (1.20–5.40 ind/m²) among gastropod species in the mangrove area of Sungai Bakau Kecil Village, West Kalimantan. Furthermore, **Purnama *et al*. (2024a,b)** observed that *S. miniata* was exclusively found in healthy mangrove ecosystems, with densities ranging from 8.67–38.33 ind/m² in Pomala and 21–87 ind/m² in Totobo Village. Specifically, the species was absent in areas affected by nickel mining activities in Southeast Sulawesi, which reinforces its sensitivity to environmental disturbances. As a species highly responsive to habitat changes **(Awang *et al*., 2020; Singh & Jahid, 2021)**, *S. miniata* flourish under optimal environmental conditions that support their growth and population stability. Its strong sensitivity to habitat alterations makes it a potential bioindicator for assessing environmental health and detecting ecological degradation. The high abundance of *S. miniata* in the mangrove ecosystem of Sungai Bakau Kecil Village indicates that the study area is still in relatively good condition, capable of supporting a diverse range of aquatic biota including gastropods.

In this study, the Shannon-Wiener diversity index (H’) indicate moderate species diversity within the mangrove ecosystem. A moderate category reflects a balanced yet dynamic community, where species richness and evenness are maintained but not at peak levels. Stations I and III, with the highest diversity values, suggest relatively stable environmental conditions that provide sufficient resources to support a wider range of gastropod species. In contrast, the lowest diversity observed at station IV may be attributed to habitat disturbances that favor only a few tolerant species. The presence of moderate diversity across stations implies that the mangrove ecosystem remains ecologically well-functioning, although potential stressors may be affecting species composition and distribution. Given that diversity indices are crucial indicators of ecosystem health, these findings highlight the importance of continuous ecological monitoring and conservation strategies to ensure the long-term stability of gastropod populations and the overall integrity of the mangrove ecosystem.

The variation in the evenness index (E) and dominance index (C) across sampling stations highlights differences in species distribution and ecological balance within the gastropod community. The low evenness value at station IV suggests an uneven species distribution, where a few species dominate while others are present in much lower numbers. This pattern is further supported by the higher dominance index at the same station, indicating that a particular species outcompetes others, leading to reduced biodiversity. The dominance of certain species may be influenced by environmental stressors, such as habitat disturbances, pollution, or variations in substrate type, which create conditions that favor only a few tolerant species. The presence of plastic waste at station IV, as observed during field sampling, may contribute to these ecological imbalances by altering the habitat and limiting resources for certain gastropod species. In contrast, station III exhibited the lowest dominance index and a moderate evenness value, indicating a more balanced species composition where no single species overwhelmingly dominates. This suggests a relatively stable and well-functioning mangrove habitat in this location, providing suitable conditions that support a diverse gastropod community. Similarly, station I recorded the highest evenness value, signifying a more equitable distribution of individuals among species, which is a characteristic of a healthy ecosystem.

These findings emphasize the importance of maintaining habitat quality in mangrove ecosystems to support species diversity and ecological balance. Stations with higher dominance and lower evenness may indicate early signs of environmental degradation, thus requiring ongoing monitoring and conservation efforts. Understanding species distribution patterns through evenness and dominance indices provides valuable insights into ecosystem stability and helps formulate strategies for habitat protection and restoration.

CONCLUSION

This study recorded eleven gastropod species from seven families, representing both epifaunal and tree-faunal groups in the mangrove habitat. Species distribution and abundance varied, with some species dominating the community while others were less frequent. *P. cingulata*, *L. melanostoma*, and *S. miniata* were the most abundant species, widely distributed across the study area, whereas *H. crocata* and *P. coriaceus* had the lowest count. These findings underscore the ecological diversity of mangrove gastropods and highlight the importance of habitat conditions in shaping species distribution. The moderate species diversity and varying evenness and dominance indices across stations indicate that the mangrove ecosystem retains ecologically well-functioning, though certain stressors, such as habitat disturbances and pollution, may be influencing gastropod distribution. Overall, the findings highlight the importance of gastropods as ecological indicators in mangrove ecosystems. Variations in their diversity and distribution reflect environmental conditions, making them valuable for monitoring habitat health. Conservation efforts should focus on mitigating habitat degradation, particularly in areas with lower diversity, to maintain the ecological integrity of mangrove ecosystems.

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