JIP
Jurnal Ilmiah PLATAX
Universitas Sam Ratulangi
Terakreditasi Ristekdikti No: 28/E/KPT/2019
ISSN : 2302-3589 (Online)
E_mail : jip_platax@unsrat.ac.id

Gastropod Diversity and Density in Selected Mangrove Ecosystems of Maluku, Indonesia

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Manuscript received: 19 April. 2026. Revision accepted: 27 June 2026

Abstract. Gastropods play essential ecological roles in mangrove ecosystems by supporting nutrient cycling, organic matter decomposition, and food-web dynamics. Their sensitivity to environmental change makes them reliable bioindicators for evaluating ecosystem health and habitat quality. This study assessed the diversity, density, and community structure of gastropods in selected mangrove ecosystems of Maluku Province, Indonesia. Surveys were conducted from August to October 2024 using purposive sampling at five mangrove sites: Leahari, Waai, and Poka on Ambon Island, and Kairatu and Tihulale on Seram Island. Seawater temperature, salinity, pH, and dissolved oxygen were measured in situ, while gastropod specimens were identified at the Marine Research Center Laboratory, National Research and Innovation Agency (BRIN), Ambon. Environmental conditions ranged from 27.5–29.5°C, 30.5–32.5‰ salinity, pH 7.57–8.85, and dissolved oxygen of 10.60–10.85 mg L^{-1}. A total of 45 gastropod species were recorded. Community structure varied among sites, with Waai showing moderate species diversity and *Littorina scabra* exhibiting the highest density at Leahari. Species richness was generally low, whereas evenness was highest at Waai and moderate dominance occurred at Leahari and Kairatu. Overall, the low ecological index values indicate that mangrove gastropod communities remain vulnerable to environmental disturbance.

Keywords: *Abundance, density, diversity, Gastropods, mangrove ecosystem*

INTRODUCTION

The mangrove ecosystem is a carbon-absorbing area supporting fauna and flora, with unique life (Waleed et al. 2024; Come et al. 2023), which play an important role in regulating the Earth's climate (Tasneem & Ahsan 2024; Sidik et al. 2023). This ecosystem is a coastal forest found in river estuaries as well as lagoons in tropical and subtropical areas (Khan et al. 2024; Szafranski & Granek 2023). Serving as ecological system, the mangrove ecosystem significantly contributes to the availability of organic detritus and is an important source of energy for biota that inhabit the surrounding aquatic environment (Arceo-Carranza et al. 2021; Carugati et al. 2018). In addition, it can function as an important nutrient provider for the surrounding waters (Anu et al. 2024; Saifullah et al. 2016), serving as habitat for wildlife species such as fish, crustaceans, primates, reptiles, and birds (Nugraha et al. 2024; Sari et al. 2022). Many marine species also use the area for breeding, egg-laying, hatching, and nurseries because of the ability to thrive in special environments (Arceo-Carranza et al. 2021).

The mangrove ecosystem is one of the habitats for gastropods (Ernawati et al. 2024) and is important for maintaining the diversity of gastropod populations (Purnama et al. 2024b). Gastropods are marine organisms that can be found in various aquatic environments, including shallow coastal zones, sandy substrates, coral reefs, and the deep-sea ecosystem (Laheng et al. 2023). This biota also represents a highly diverse group among non-fish aquatic biological resources (Tetiwar et al. 2024). Gastropods in the mangrove ecosystem play a role in the decomposition process, namely by chopping leaves into smaller pieces, which are then continued by microorganisms (Laraswati et al. 2020). The existence of mangrove forests is also threatened by various natural factors, human activities, and even a combination of both (Saoum & Sarkar 2024). The degradation of this ecosystem still occurs a lot in coastal areas, therefore it is necessary to carry out sustainable mangrove management (Hidayah et al. 2024) hence mangrove forests should be preserved (Cahyaningsih et al. 2022). Studies related to the distribution of gastropods in mangrove ecosystems in Maluku and other marine waters have been widely reported. Islamy and Hasan (2020) found 10 families of Gastropoda consisting of

Assimineidae, Cerithiidae, Ellobiidae, Littorinidae, Muricidae, Neritidae, Olividae, Planaxidae, Potamididae, and Trochidae with 15 genera, namely Assiminea, Clypeomorus, Cerithium, Rhinoclavis, Laemodonta, Littorarina, Tenguella, Semiricinula, Nerita, Clithon, Oliva, Planaxis, Pirenella, Telescopium, and Monodonta on the South Coast of Pamekasan, Madura Island, East Java, Indonesia. Additionally, 11 species were found in the Ngurah Rai Forest Park in Bali, Indonesia, namely Assiminea brevicula, Littoraria articulata, Terebralia palustris, Nerita balteata, Cerithidea cingulata, Vittoida turrita, Cerithidea quadrata, Vittoida variegata, Latirus polygonus, Telescopium telescopium, and Littoraria scabra (Imamsyah et al., 2020). In the mangrove area on the east coast of Aceh Province, Indonesia, 13 species were found from the families Potamididae, Neritidae, Ellobiidae, Littorinidae, Pleuroceridae, Naticidae, Turritellidae, Conidae, Ficidae, Melongenidae, Strombidae, Cassidae, and Muricidae (Mawardi et al. 2023). A total of 34 types of gastropods (14 families and 24 genera) were found in the Totobo (Purnama et al. 2024b). In Ambon Island, namely Tawiri Beach, 7 families and 10 species were found, while in Tanjung Tiram, 3 families and 5 species were identified (Simatupang et al. 2025).

Based on the significant benefits, the existence of gastropods in a coastal water area is unique. For example, Maluku Province, with an extensive water and the mangrove ecosystem, has various islands, including Ambon and Seram, which serve as habitat for gastropods. Other important mangrove areas include Leahari Village, Waai Village, Poka Village in Ambon, and Kairatu and Tihulale Villages in Seram. These five areas were selected for their representative recreational conditions, the collection of marine biota by the community for consumption, and their geographic location. Poka Village is located in Inner Ambon Bay (IAB) waters. Mangroves in IAB are in a highly protected environment with hydrodynamic conditions dominated by tides (Setyawan 2024). Meanwhile, mangrove ecosystems in several locations are in open waters and directly connected to the Banda Sea, namely the waters of Waai (Tuahatu et al. 2016); the waters of Leahari (Radjab et al. 2023); and the waters of Seram Island, including Kairatu and Tihulale (Titaley et al. 2024). Studies in the last 10 years have revealed the diversity of gastropods in the waters of Maluku province, including the coastal waters of Hallong (Supusepa et al. 2023), the waters of Oma (Haumahu et al. 2023), the waters of Marsegu Island (Bula et al. 2017), the waters of Passo and Latuhalat villages (Rumahlatu & Leiwakabessy 2017), and the waters of Nusalaut (Islami 2015). However, there has not been a comprehensive analysis of the diversity and density of gastropods living in the mangrove ecosystem in these five places simultaneously even though the analysis of gastropods in the mangrove ecosystem is critical because it plays a role as a bioindicator of environmental quality (Ray et al. 2025), as well as an alternative source of animal protein for coastal communities (Satheesh et al. 2025). However, excessive and continuous harvesting of gastropods in coastal water may lead to population decline and potential local extinction. Therefore, this study aimed to examine diversity and density of gastropods in the mangrove ecosystem in Maluku province, Indonesia.

METHODS

Description of the study sites

This study was conducted in five areas, namely the mangrove ecosystem in Leahari, Waai, Poka - Ambon Island, Kairatu and Tihulale villages - Seram Island (Figure 1). The experiment was carried out in August-October 2024, and the determination of the data collection area was conducted by purposive sampling based on the presence of gastropods in the mangrove ecosystem.

Gastropod Collection

Sampling was conducted at five locations from five different villages. The research locations were selected based on the representativeness of two locations on Seram Island and

three on Ambon Island. Gastropod sampling used the plot transect method. In the mangrove ecosystem, 10 transects were established, each containing five 2x2 m plots, for 50 plots per observation area. During the east monsoon season, sampling was conducted during low tide from July to August 2024. The placement of plot was adjusted to the base area of 1 individual mangrove tree, with the study plots comprising a total of 25 trees. Furthermore, measurement of environmental physicochemical parameters, including temperature, salinity, pH, and DO of sea water, was carried out in-situ at each observation station.



Figure 1. Map of the study area showing the sampling areas (Leahari, Waai, Poka - Ambon Island, and Kairatu, Tihulale - Seram Island)

Identification of Gastropods

Samples obtained at each plot were then placed in ethylene plastic bags and labeled, followed by being placed in an ice box and taken to the laboratory. Each sample found was photographed with a digital camera and then identified for morphological characteristics, including shell color and shape. Based on these morphological characteristics, samples were identified using references from several sources, including Leiwakabessy (1999), and Dharma (1989). Meanwhile, taxon determination in the classification used WoRMS (2024).

Parameter Analysis

Diversity index (H') of gastropods was determined using the Shannon-Wiener index (Odum 1993) as follows.

$$H' = -\sum Pi\ lnPi$$

$$Pi = \frac{ni}{N}$$

where:
H': Diversity index
Pi: Proportion of the number of individuals of the i-th species (ni) to the total number of individuals (N)
ni: Number of individuals of the i-th species N: Total number of individuals of all species

Criteria for determining diversity (H'):
H'<3.32 : Low species diversity
3.32<H'< 9.97: Medium species diversity H'>9.97 : High species diversity

The species richness value (R) of gastropods was determined using the following formula.

$$R = \frac{(S-1)}{Ln\ M}$$

where:
R : Richness
S : Total number of species (n1, n2, n3...)
N : Number of individuals of each species

Criteria:
R<3.5 = Richness is low
R=3.5-5.0 = Richness is moderate R>5.0 = Richness is high

The evenness value was obtained by using the following formula:

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

where:
E : Evenness
H': Diversity index
S : Total number of species (n1, n2, n3...)

Criteria:
0<Es 0.4 = Low evenness,
stressed community 0.4<Es 0.6 = Medium evenness,
stable community 0.6<Es 1.0 = High evenness, stable community

The Simpson Dominance Index (C) value was determined by the formula: $D = \Sigma\ (ni/N)^2$ (Odum 1993).
Criteria:
0 < C < 0.5 = no species dominates
0.5 < C < 1 = there is a species that dominates

The absolute density of the i-th species (D) was obtained by calculating the number of individuals of a species per area observed. The calculation of density of gastropods can be calculated using density formula (Krebs 1989).

$$Absolute\ density/D = \frac{The\ number\ of\ individuals\ of\ each\ species}{The\ number\ of\ individuals\ of\ all\ species}$$

$$Relative\ density/RD = \frac{The\ number\ of\ individuals\ of\ each\ species}{The\ number\ of\ individuals\ of\ all\ species}\ x\ 100$$

Criteria:
Score 0 = No density
Score 1-10 = Less density
Score 11-20 = High/very high density

To calculate the Frequency of occurrence (F) and Relative Frequency of occurrence (FR), the formula used is as follows:

$$Frequency/F = \frac{The\ number\ of\ plots\ occupied\ by\ a\ species}{Total\ number\ of\ plots}$$

$$Relative\ \frac{Frequency}{RF} = \frac{Frequency\ of\ occurrences\ a\ species}{Total\ number\ of\ occurrences}\ x\ 100$$

With the criteria of frequency of occurrence:
F = 0 -25% : Very rare occurrence
F = 25-50% : Rare occurrence
F = 50-75% : Moderate occurrence

F > 75% : Frequent/absolute occurrence
Species Important Value (SIV) using the Formula:
SIV = Relative Density (RD) + Relative Frequency (RF)

Data Analysis

Gastropod data were analyzed quantitatively using species density, relative density, Shannon-Wiener diversity index (H'), evenness index (E), Simpson dominance index (C), and Margalef species richness index (R).

RESULTS AND DISCUSSION

Result

Physical and Chemical Factors of the Environment

Sampling was conducted in five distinct areas, accompanied by in-situ measurements of key physico-chemical parameters, including dissolved oxygen (DO), salinity, pH, and temperature (Table 1).

Table 1. Physico-chemical Parameter of the Environment in the Study Area

Mangrove area	DO (Mg/L) Average±SD	Salinity (‰) Average±SD	pH Average±SD	Temperature (°C) Average±SD
Leahari	10.60±0.141	32.5±0.707	8.85±0.071	28.5±0.707
Waai	10.65±0.071	32.5±0.707	7.57±0.035	29.5±0.707
Poka	10.55±0.071	31.5±0.707	8.85±0.071	28.5±0.707
Kairatu	10.85±0.071	32.5±0.707	8.15±0.071	27.5±0.707
Tihulale	10.75±0.071	30.5±0.707	8.25±0.071	28.5±0.707

The analysis of physico-chemical parameters in the mangrove ecosystems indicated that dissolved oxygen (DO) levels were 10.55 ± 0.071 mg/L in Poka Village and 10.85 ± 0.071 mg/L in Kairatu Village, both within the acceptable range for seawater quality. Salinity levels were lowest in Tihulale Village at 30.5 ± 0.707‰, while higher values of 32.5 ± 0.707‰ were recorded in Leahari, Waai, and Kairatu Villages, aligning with standard seawater quality thresholds. The lowest pH value was recorded in Waai (7.575 ± 0.035), whereas the highest was in Leahari Village (8.85 ± 0.071); pH levels in Leahari and Poka Villages remained within the normal range for seawater. Temperature measurements ranged from 27.5 ± 0.707 °C in Kairatu to 29.5 ± 0.707 °C in Waai Village, also falling within the standard seawater temperature range.

Types of Gastropods Found in the Mangrove Ecosystem of Leahari, Waai, Poka, Kairatu and Tihulale Villages.

The mangrove ecosystem can change due to high surrounding activity, causing an inventory of gastropods to be necessary. This inventory was carried out to determine the environmental status in all villages (Table 2 and Figure 2). The results showed that the total species found in the five village locations were 45 species grouped into 30 genera, 21 families and 7 orders.

Based on the results, the types of gastropods found in the mangrove ecosystem in 5 study areas consisted of 13 species in Leahari, 23 at Waai, 19 in Poka, 13 in Kairatu, and 12 in Tihulale Village.

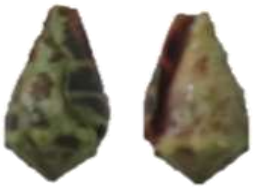
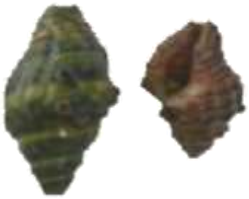
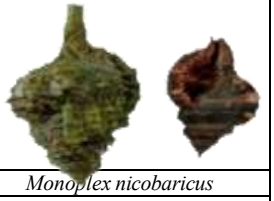
Number of Gastropods Individuals at Each Study Area

Based on the results, in Leahari Village, there are 13 species with a total of 1078 individuals, 22 species with 667 individuals in Waai, 19 species comprising 409 individuals in Poka, 13 species consisting of 6695 individuals in Kairatu, and 11 species with 528 individuals in Tihulale Village (Table 4).

Table 2. Gastropods found at the Study Area

Order	Family	Genus	Species	Leahari	Waai	Poka	Kairatu	Tihulale
Trochida	Angariidae	Angaria	*Angaria delphinus*	-	-	✓	-	✓
	Calliostomatidae	Calliostoma	*Calliostoma laugieri*	-	-	-	✓	-
	Turbinidae	Turbo	*Turbo bruneus*	-	✓	-	-	✓
		Lunella	*Lunella cinerea*	✓	-	✓	-	✓
	Trochidae	Monodonta	*Monodonta labio*	-	-	✓	-	-
Ellobiida	Ellobiidae	Cassidula	*Cassidula aurisfelis*	-	-	-	✓	-
		Ellobium	*Ellobium aurisjudae*	-	-	✓	-	-
Littorinimorpha	Cassidae	Cassis	*Cassis semigranosa*	-	✓	-	-	✓
	Cypraeidae	Cypraea	*Cypraea clandestina*	-	-	✓	-	-
		Erronea	*Erronea caurica*	-	✓	-	-	-
	Littorinidae	Littorina	*Littorina scabra*	✓	✓	✓	✓	✓
			Littorina melanostoma	✓	✓	✓	✓	-
	Cymatiidae	Monoplex	*Monoplex nicobaricus*	-	✓	✓	-	-
	Strombidae	Strombus	*Strombus labiatus*	-	-	✓	-	-
Neogastropoda	Muricidae	Chicoreus	*Chicoreus torrefactus*	-	-	-	✓	-
		Drupella	*Drupella margariticoa*	-	-	-	✓	-
		Indothais	*Indothais gradata*	-	✓	-	-	-
		Morula	*Morula margariticola*	✓	✓	-	-	-
			Morula granulata	-	✓	-	-	-
		Reishia	*Reishia bitubercularis*	-	-	✓	-	✓
	Conidae	Conus	*Conus glaucus*	-	-	-	✓	-
			Conus distans	-	✓	-	-	✓
			Conus coronatus	-	✓	-	-	✓
	Mitridae	Mitra	*Mitra paupercula*	-	-	-	-	✓
	Nassariidae	Nassarius	*Nassarius pullus*	-	✓	✓	✓	-
			Nassarius niger	-	-	✓	-	-
			Nassarius leptospira	-	✓	✓	-	-
			Nassarius graphiterus	-	-	✓	-	-
	Pseudomelatomidae	Ptychobela	*Ptychobela nodulose*	-	✓	-	-	-
	Melongenidae	Volegalea	*Volegalea cochlidium*	✓	✓	-	-	-
Caenogastropoda	Cerithiidae	Clypeomorus	*Clypeomorus batillariaeformis*	-	✓	✓	-	✓
	Pachychilidae	Faunus	*Faunus ater*	-	✓	-	✓	-
	Potamididae	Terebralia	*Terebralia palustris*	✓	✓	✓	✓	-
			Terebralia sulcata	✓	✓	✓	-	-
		Telescopium	*Telescopium telescopium*	-	-	-	✓	-
	Turritellidae	Turritella	*Turritella attenuata*	-	✓	-	-	-
Cycloneritida	Neritidae	Nerita	*Nerita variegata*	-	✓	-	✓	-
			Nerita polita	✓	✓	-	-	-
			Nerita grossa	✓	-	-	-	-
			Nerita patula	✓	-	-	-	-
			Nerita balteata	✓	-	-	-	-
			Nerita planospira	✓	-	-	✓	-
			Nerita chamaeleon	✓	-	✓	-	-
			Nerita ocellata	-	-	-	-	✓
			Clithon corona	-	-	✓	-	-
Total Species				**13**	**22**	**19**	**13**	**11**

Table 3. Types of Gastropods found at the study area

			
Angaria delphinus	*Cassidula aurisfelis*	*Cassis semigronosa*	*Chicoreus torrefactus*
			
Clithon corona	*Clypeomorus batillariaeformis*	*Cypraea clandestine*	*Conus glaucus*
			
Conus distans	*Conus coronatus*	*Calliostoma laugieri*	*Drupella margariticola*
			
Ellobium aurisjudae	*Erronea caurica*	*Faunus ater*	*Indothais gradata*
			
Littorina scabra	*Littorina melanostoma*	*Lunella cinerea*	*Mitra paupercula*
			
Morula margariticola	*Morula granulata*	*Monodonta labio*	*Monoplex nicobaricus*
			

Nassarius pullus	*Nassarius niger*	*Nassarius leptospira*	*Nassarius graphiterus*
			
Nerita variegata	*Nerita polita*	*Nerita grossa*	*Nerita patula*
			
Nerita balteata	*Nerita planospira*	*Nerita chamaeleon*	*Nerita ocellata*
			
Ptychobela nodulosa	*Reishia bitubercularis*	*Strombus labiatus*	*Terebralia palustris*
			
Terebralia sulcata	*Telescopium telescopium*	*Turbo bruneus*	*Turritella attenuata*
			
	Volegalea cochlidium		

Table 4. Number of individuals of each type of gastropod

No	Species	Leahari	Waai	Poka	Kairatu	Tihulale
1	*Angaria delphinus*	0	0	2	0	**3**
2	*Calliostoma laugieri*	0	0	0	1	**0**
3	*Turbo bruneus*	0	2	0	0	**3**
4	*Lunella cinerea*	8	0	3	0	**5**
5	*Monodonta labio*	0	0	2	0	**0**
6	*Clithon corona*	0	0	3	0	**0**
7	*Cassidula aurisfelis*	0	0	0	91	**0**
8	*Ellobium aurisjudae*	0	0	1	0	**0**
9	*Cassis semigranosa*	0	6	0	0	**9**
10	*Cypraea clandestina*	0	0	1	0	**0**
11	*Erronea caurica*	0	1	0	0	**0**
12	*Littorina scabra*	898	125	38	18	**46**
13	*Littorina melanostoma*	45	22	14	28	**0**
14	*Monoplex nicobaricus*	0	3	2	0	**0**
15	*Strombus labiatus*	0	0	1	0	**0**

16	*Chicoreus torrefactus*	0	0	0	2	**0**
17	*Drupella margariticola*	0	0	0	7	**0**
18	*Indothais gradata*	0	3	0	0	**0**
19	*Morula margariticola*	20	144	0	0	**0**
20	*Morula granulata*	0	22	0	0	**0**
21	*Reishia bitubercularis*	0	0	19	0	**265**
22	*Conus glaucus*	0	0	0	2	**0**
23	*Conus distans*	0	2	0	0	**1**
24	*Conus coronatus*	0	1	0	0	**1**
25	*Mitra paupercula*	0	0	0	0	**2**
26	*Nassarius pullus*	0	9	1	1	**0**
27	*Nassarius niger*	0	0	55	0	**0**
28	*Nassarius leptospira*	0	5	3	0	**0**
29	*Nassarius graphiterus*	0	0	4	0	**0**
30	*Ptychobela nodulosa*	0	6	0	0	**0**
31	*Volegalea cochlidium*	1	1	0	0	**0**
32	*Clypeomorus batillariaeformis*	0	150	182	0	**184**
33	*Faunus ater*	0	77	0	5567	**0**
34	*Terebralia palustris*	4	37	19	809	**0**
35	*Terebralia sulcata*	60	38	47	0	**0**
36	*Telescopium telescopium*	0	0	0	150	**0**
37	*Turritella attenuata*	0	3	0	0	**0**
38	*Nerita variegata*	0	3	0	9	**0**
39	*Nerita polita*	6	7	0	0	**0**
40	*Nerita grossa*	11	0	0	0	**0**
41	*Nerita patula*	6	0	0	0	**0**
42	*Nerita balteata*	6	0	0	0	**0**
43	*Nerita planospira*	6	0	0	10	**0**
44	*Nerita chamaeleon*	7	0	12	0	**0**
45	*Nerita ocellata*	0	0	0	0	**9**
	Total	**1078**	**667**	**409**	**6695**	**528**

Based on the results (Table 4), three species of gastropods were identified in the mangrove ecosystem of the study area, namely Faunus ater, Littorina scabra, and Terebralia palustris. F. ater is the highest abudance species with 5567 individuals found in Kairatu Village, followed by 898 of L. scabra in Leahari and 809 of T. palustris Kairatu. These 3 species are commonly found in mangrove habitats, with some attaching to the stems and leaves, while others inhabit the sediment and substrate surrounding mangrove trees.

Diversity, Richness, Evenness and Dominance of Gastropods

Diversity determines the variation and variability of life on earth (Kishore et al. 2023). In organisms, diversity occurs because of various factors such as morphology, i.e. texture, color, size, number, and shape, which are biological characteristics to show the structure of the community (van den Berg et al. 2020). To determine the biological characteristics of gastropods in the mangrove ecosystem at the study area, diversity, richness, evenness, and dominance indices were calculated. The dominance of species in the community correlated to the adaptability of a species in a habitat (Mawardi et al. 2023). Based on the results, the calculation of diversity, richness, evenness, and dominance of gastropods in the mangrove ecosystem in the coastal waters of Leahari, Waai, Poka, Kairatu, and Tihulale villages is shown in Table 5.

As presented in Table 5, Waai Village exhibited the highest gastropod diversity with a Shannon-Wiener index value of 2.16, corresponding to medium medium diversity classification. The richness indeks was 3.22 (low criteria), while the evenness value reached 0.70, indicationghigh evenness and suggesting a stable community structure. The highest dominance indeks (0.70), classified as medium was observed in Leahari and Kairatu Villages. In contras, Kairatu also exhibited the lowest diversity (0.62), richness (1.36), and evenness

(0,24), all within the low classification/criteria range. Furthermore, the lowest dominance value (0.15), classified as low, was recorded in Waai Village.

Table 5. Diversity, richness, evenness, and dominance of gastropods in the study area

Study area	Diversity (H')	Richness (R)	Evenness (E)	Dominance (C)
Leahari	0.77	1.72	0.30	0.70
Waai	2.16	3.22	0.70	0.15
Poka	1.81	2.88	0.61	0.23
Kairatu	0.62	1.36	0.24	0.70
Tihulale	1.31	1.58	0.54	0.34

Density, Frequency of Occurrence and Importance of Gastropods

Density values reflect the ecological tolerance of species, with higher densities generally indicating greater adaptability to environmental conditions (Purnama et al. 2024b; Miranda et al. 2011). Species with the highest relative density are are considered more capable of adapting to their surroundings, while those with lower relative densities may have limited adaptive capacity (Nursyahra & Meriko 2016). The importance index of a species in a community is a parameter for determining the level of role of the species in its community (Ismail et al. 2017). Therefore, higher species importance value (SIV) of a species corresponds to greater control over the community and vice versa (Arief & Mijiarto 2024; Muslih et al. 2022; Rawana et al. 2022). Density, frequency of occurrence, and SIV of gastropods in the mangrove ecosystem of Negeri Leahari, Ambon Island, are presented in Table 6.

Table 6. Density, frequency of occurrence, and importance value index of gastropods in Leahari Village, Ambon Island

Species	Number	Plot	D	RD	F	RF	SIV
Littorina scabra	898	25	1.382	83.380	1	28.664	112.044
Littorina melanostoma	45	16	0.069	4.178	0.64	18.345	22.523
Terebralia sulcata	60	14	0.092	5.571	0.609	17.448	23.019
Nerita polita	6	4	0.009	0.557	0.16	4.586	5.143
Nerita grossa	11	2	0.017	1.021	0.08	2.293	3.314
Nerita planospira	5	3	0.008	0.464	0.12	3.440	3.904
Nerita patula	6	3	0.009	0.557	0.12	3.440	3.997
Nerita balteata	6	4	0.009	0.557	0.16	4.586	5.143
Nerita chamaeleon	7	2	0.011	0.650	0.08	2.293	2.943
Lunella cinerea	8	3	0.012	0.743	0.12	3.440	4.182
Morulla margariticola	20	6	0.031	1.857	0.24	6.879	8.736
Terebralia palustris	4	3	0.006	0.371	0.12	3.440	3.811
Volegalea cochlidium	1	1	0.002	0.093	0.04	1.147	1.239
Total	**1071**		**1.657**	**100**	**3.489**	**100**	**200**

(Note: D: Density, RD: Relative density, F: Frequency, RF: Relative frequency, SIV: Species importance value).

Based on the results of data analysis (Table 5), the absolute density of gastropods in the Leahari mangrove ecosystem was 1.657 individuals/m^2, predominantly consisting of *Littorina scabra* with a density of 1.382 individuals/m^2, a frequency of occurrence at 1.0, and a Species Importance Value (SIV) of 112.044. In contrast, *Volegalea cochlidium* exhibited the lowest density at 0.002 individuals/m^2, a frequency of occurrence of 0.04, and an SIV of 1.239.

This study found that L. scabra exhibited the highest abundance, likely due to its strong habitat preference for mangrove ecosystems. The species commonly inhabits area near mangrove roots, stems, and leaves, and lives with seawater splashes during high tide (Imakulata & Tokan 2018). Tidal fluctuations influence the ecological interactions of the Littorina genus with other intertidal mollusks, such as Mytilus edulis, and also affect morphological traits such as shell aperture size and shell height (Ganguly et al. 2020). The mating time of L. scabra depends on moisture levels in the habitat and the moon cycle, which regulates tidal rhythms. Low densities were recorded in Nerita, Lunella, Morulla, Terebralia, and Volegalea. These reduce populations are likely due to interspecific competition for food and habitat space.

According to Mustapha et al. (2021), species in the Nerita genus are particularly culnerable to habitat degradation caused bymangroves destruction, water pollution, climate change, and anthropogenic pressure. Table 7 present the density, frequency of occurrence, and Species Importance value (SIV) of gastropods in the mangrove ecosystem of Waai Village, Ambon Island.

Table 7. Density of frequency of occurrence and species importance value of gastropods in Waai Village, Ambon Island

Species	Number	Plot	D	RD	F	RF	SIV
Faunus ater	77	17	0.385	11.544	0.68	12.319	23.863
Clypeomorus battilariaeformis	150	19	0.75	22.489	0.76	13.768	36.257
Littorina scabra	125	19	0.625	18.741	0.76	13.768	32.509
Littorina melanostoma	22	5	0.11	3.298	0.2	3.623	6.922
Terebralia sulcata	38	7	0.19	5.697	0.28	5.072	10.770
Morulla margariticola	144	19	0.72	21.589	0.76	13.768	35.357
Ptychobela nodulosa	6	3	0.03	0.900	0.12	2.174	3.073
Erronea caurica	1	1	0.005	0.150	0.04	0.725	0.875
Nassarius pullus	9	5	0.045	1.349	0.2	3.623	4.973
Nerita polita	7	5	0.035	1.049	0.2	3.623	4.673
Conus coronatus	1	1	0.005	0.150	0.04	0.725	0.875
Nerita variegata	3	2	0.015	0.450	0.08	1.449	1.899
Terebralia palustris	37	9	0.185	5.547	0.36	6.522	12.069
Indothais gradata	3	2	0.015	0.450	0.08	1.449	1.899
Turritella attenuate	3	2	0.015	0.450	0.08	1.449	1.899
Monoplex nicobaricus	3	2	0.015	0.450	0.08	1.449	1.899
Turbo bruneus	2	1	0.01	0.300	0.04	0.725	1.024
Nassarius leptospira	5	5	0.025	0.750	0.2	3.623	4.373
Volegalea cochlidium	1	1	0.005	0.150	0.04	0.725	0.875
Cassis semigranosa	6	5	0.03	0.900	0.2	3.623	4.523
Conus distans	2	2	0.01	0.300	0.08	1.449	1.749
Morula granulata	22	6	0.11	3.298	0.24	4.348	7.646
Total	**667**		**3.335**	**100**	**5.52**	**100**	**200**

(Note: D: Density, RD: Relative density, F: frequency, RF: Relative frequency, SIV: Species importance value).

Based on the data analysis (Table 6), the absolute density of gastropods in the mangrove ecosystem of Waai Village was 3.335 individuals/m2. The highest species density was recorded for Clypeomorus battilaeriformis, with a density of 0.75 individuals/m2, a frequency of occurrence of 0.76, and a SIV of 36.257. In contrast, Volegalea cochlidium exhibited the lowest density at 0.005 individuals/m2, with frequency of 0.04, and a SIV of 0.875.

The high density of gastropods are associated with their tolerance to environmental stress and the availability of food in seagrass beds, such as algae and detritus. Conversely, low-density levels can be caused by specific and different adaptation abilities in gastropods. Key environmental paramenters, including temperature, salinity, substrate type, and organic content, significantly influence gastropod distribution and abundance. The density, frequency of occurrence, and SIV of gastropods in the mangrove ecosystem of Poka village, Ambon Island, are shown in Table 8.

As shown in Table 8, the absolute density of gastropods in the mangrove ecosystem of Poka village was 1.697 individuals/m2. The highest species density was recorded for Clypeomorus battilaeriformis, with a value of 0.607 individuals/m2, the frequency of occurrance at 1.0, and a SIV of 58.896. The lowest species density was observed for Strombus labiatus, Ellobium aurisjudae, Nasarius pulus, and Cypraea clandestine, with a density of 0.003 individuals/m2, the frequency of 0.04, and the SIV of 1.122.

Table 8. Density, frequency of occurrence, and species importance value of gastropods in Poka Village, Ambon Island

Species	Number	Plot	D	RD	F	RF	SIV
Terebralia sulcata	47	16	0.157	9.234	0.64	14.809	24.043
Nassarius niger	155	18	0.517	30.452	0.72	16.660	47.112
Littorina scabra	38	6	0.127	7.466	0.24	5.553	13.019
Monodonta labio	2	2	0.007	0.393	0.08	1.851	2.244
Strombus labiatus	1	1	0.003	0.196	0.04	0.926	1.122
Nerita chamaeleon	12	7	0.04	2.358	0.28	6.479	8.837
Clithon corona	3	2	0.01	0.589	0.08	1.851	2.441
Nassarius leptospira	3	3	0.01	0.589	0.12	2.777	3.366
Monoplex nicobaricus	2	2	0.007	0.393	0.08	1.851	2.244
Reishia bitubercularis	19	5	0.063	3.733	0.2	4.628	8.361
Ellobium aurisjudae	1	1	0.003	0.196	0.04	0.926	1.122
Lunella cinerea	3	2	0.01	0.589	0.08	1.851	2.441
Nassarius pullus	1	1	0.003	0.196	0.04	0.926	1.122
Terebralia palustris	19	6	0.063	3.733	0.24	5.553	9.286
Nassarius graphiterus	4	3	0.013	0.786	0.12	2.777	3.563
Littorina melanostoma	14	6	0.047	2.750	0.24	5.553	8.304
Cypraea clandestina	1	1	0.003	0.196	0.04	0.926	1.122
Angaria delphinus	2	1	0.007	0.393	0.042	0.964	1.357
Clypeomorus batillariaeformis	182	25	0.607	35.756	1	23.139	58.896
Total	**509**		**1.697**	**100**	**4.322**	**100**	**200**

(Note: D: Density, RD: Relative density, F: frequency, RF: Relative frequency, SIV: Species importance value)

Poka village is a productive area with a fairly large seagrass meadow, serving as a potential habitat for marine organisms. The intertidal area of Poka village generally has muddy and sandy substrates, which contribute to a high diversity of organisms, i.e. benthic fauna. Rumpeniak et al. (2019) reported several gastropod species closely an associated with seagrass ecosystems, including Polinices mammilla, Natica vitellusi, Strombus labiatus, Strombus urceus, Bursa tuberosissima, Liotina peronii, Conus coronatus, Conus moriculatus, Nassarius pullus, and Nassarius limnaeiformis. These associations reflect both tolerance capabilities of gastropods and reciprocal relationships between seagrass and gastropods. Unlike other study sites, the genus Nassarius is often found in the waters of Poka Village. This finding is supported by a study by Haumahu et al. (2023), who reported that Nassaridae had a high abundance on sandy substrates in the intertidal area of Ambon Island. The density, frequency of occurrence, and SIV of gastropods in the mangrove ecosystem of Kairatu Village, Seram Island can be seen in Table 9.

Table 9. Density, frequency of occurrence, and species importance value of gastropods in Kairatu Village, Seram Island

Species	Number	Plot	D	RD	F	RF	SIV
Faunus ater	5567	25	13.918	83.152	1	21.552	104.703
Terebralia palustris	809	25	2.023	12.084	1	21.552	33.635
Telescopium telescopium	150	18	0.375	2.240	0.72	15.517	17.758
Cassidula aurisfelis	91	16	0.228	1.359	0.64	13.793	15.152
Nerita planospira	10	3	0.025	0.149	0.12	2.586	2.736
Nerita variegata	9	4	0.023	0.134	0.16	3.448	3.583
Drupella margariticola	7	5	0.018	0.105	0.2	4.310	4.415
Chicoreus torrefactus	2	2	0.005	0.030	0.08	1.724	1.754
Conus glaucus	2	2	0.005	0.030	0.08	1.724	1.754
Littorina scabra	18	6	0.045	0.269	0.24	5.172	5.441
Littorina melanostoma	28	8	0.070	0.418	0.32	6.897	7.315
Nassarius pullus	1	1	0.003	0.015	0.04	0.862	0.877
Calliostoma laugieri	1	1	0.003	0.015	0.04	0.862	0.877
Total	**6695**		**16.738**	**100**	**4.64**	**100**	**200**

Based on the data analysis (Table 9), the absolute density of gastropods in the mangrove

ecosystem of Kairatu Village is 16.738 individuals/m2. The highest species density was observed for Faunus ater, with a value of 13.918 individuals/m2, the frequency of occurrence of 1.0, and the SIV was 104.703. The lowest species densities were recorded for Nasarius pulus, Calliostoma laugieri, each with a density of 0.003 individuals/m2, the frequency of 0.04, and the SIV was 0.877.

The coastal zone of Kairatu Village is characterized by sandy and muddy substrates, providing favorable conditions for gastropod growth and reproduction. In this area, Faunus ater, and Terebralia palustris were found in high abundance, while Telescopium telescopium and Cassidula aurisfelis were present in moderate numbers. F. ater is usually found on fine sandy, silt, and clay substrates, which are one of the main factors influencing its spatial distribution (Udayantha & Munasinghe 2009). Additionally, rainfall intensity may influence water temperature and physico-chemical conditions, contributing to the increasedabundance of F. ater. According to Sulphayrin et al. (2020), F. ater thrives in low salinity environments andi s commonly observed crawling on mangrove stems and roots. The ecological importance of F. ater also extends to local communities, as the species serves as protein-rich food source with high nutritional value. The density, frequency of occurrence, and SIV of gastropods in the mangrove ecosystem of Tihulale Village can be seen in Table 10.

Table 10. Density, frequency of occurrence, and species importance value of gastropods in Tihulale Village, Seram Island

Species	Number	Plot	D	RD	F	RF	SIV
Littorina scabra	46	7	0.153	8.829	0.28	9.211	18.040
Lunella cinerea	5	3	0.017	0.959	0.12	3.947	4.907
Reishia bitubercularis	265	25	0.883	50.863	1	32.895	83.758
Mitra paupercula	2	2	0.007	0.383	0.08	2.632	3.015
Conus coronatus	1	1	0.003	0.191	0.04	1.316	1.508
Conus distans	1	1	0.003	0.191	0.04	1.316	1.508
Turbo bruneus	3	3	0.01	0.575	0.12	3.947	4.523
Clypeomorus batillariaeformis	184	25	0.613	35.316	1	32.895	68.211
Angaria delphinus	1	2	0.003	0.191	0.08	2.632	2.824
Cassis semigronosa	4	4	0.013	0.767	0.16	5.263	6.031
Nerita ocellata	9	3	0.03	1.727	0.12	3.947	5.675
Total	**521**		**1.737**	**100**	**3.04**	**100**	**200**

(Note: D: Density, RD: Relative density, F: frequency, RF: Relative frequency, SIV: Species importance value)

Based on the data analysis (Table 10), the absolute density of gastropods in the mangrove ecosystem of Tihulale Village was 1.737 individuals/m2. The highest species density was recorded for Reisha bitubercularis, with a value of 0.883 individuals/m2, the frequency of occurrence was 1.0, and the SIV was 83.758. The lowest species densities were observed for Conus coronatus, Conus distans, each with a density of 0.003 individuals/m2, the frequency of 0.04, and the SIV was 1.508.

Discussion

Physical and Chemical Factors of the Environment

Seawater Quality Standards are the limits or levels of living organisms (biological), substances (chemical), energy, or components (physical) that exist including pollutant elements tolerated in seawater. According to the Decree of the Indonesian Minister of Environment No. 51 of 2004 concerning Seawater Quality Standards in the mangrove ecosystem, the acceptable range are as follows: temperature between 28-32oC, pH 7-8.5, salinity 33-34 ‰, and DO level > 5-6 mg/L (equivalent to > 80-90% saturation) (Ministry of Environment and Forestry, 2004).

These physico-chemical parameters significantly influence marine organisms by affecting seawater fertility, metabolic processes, reproductive success, respiration,

osmoregulation, and the diffusion balance within the aquatic environment. A previous study conducted by Munandar et al. (2022) demonstrated that salinity affected the survival rate of gastropods, including shell growth, hemolymph cell fragility, and glucose levels in Turbo chrysostomus. Salinity is also affected the population density, distribution, and body size Melampus coffeus (Maia & Coutinho 2016). Additionally, vertical and horizontal gradients in the environment also influence gastropod life cycles and behavior (Imamsyah et al. 2020). In this study, gastropod sampling was conducted on the coastal area with salinity level ranging from 31-33‰, which fall below the standard value defined by the Seawater Quality Standards. The decrease in salinity levels may be attribute to a higher influx of freshwater, lower temperature, lack of evaporation, and high rainfall levels (Vandarwala et al. 2020). Coastal areas distant from river estuaries exhibited more stable salinity levels, whereas estuarine zones were more susceptible to fluctuations due to freshwater inflow and land-derived pollutants. In addition, elevated salinity levels can reduce dissolved oxygen concentrations in seawater, thereby potentially affecting the physiology and survival of gastropods (Fitriadi et al. 2023). Dissolved oxygen (DO) is a critical parameter for most aquatic organisms, as it plays a central role in metabolic process. DO levels in mangrove ecosystems can be influenced by temperature, atmospheric pressure, microbial activity, season, salinity, and water depth (Wintah et al. 2021). Fluctuations in DO concentrations can impact the behavior, body size, and thermal tolerance of gastropods. Low DO levels can induce hypoxia or decreased oxygen levels in the tissue which is harmful to gastropods (Koopman et al. 2016). Hypoxic conditions can cause behavioral changes to become abnormal such as gastropods appearing more often on the surface of the water to breathe atmospheric oxigen (Marshall & McQuai 2020). Prolonged hypoxia can impair physiological function, reproductive capacity, and metabolic processes of gastropods, particularly in species such as Nassarius festivus species (Cheung et al. 2008). Furthermore, McClain and Rex (2001) reported that higher the DO in combination with depth of aquatic waters, affects the body size of gastropods, notably in Benthomangelia antonia species. Additionally, gastropods are often found in the mangrove ecosystem, with distribution influenced by DO levels (Retnaningdyah et al. 2022).

Another critical environmental factor known to affect the growth, behavior, and survival of gastropods is temperature. High temperature has a negative impact on the physiological processes, causing decreased long-term responses related to survival (Falkenberg et al. 2021). However, Dong et al. (2018) reported that Nerita spp. and N. albicilla exhibit high thermal tolerance of approximately 50°C and caused harmful effects, namely damage to enzymatic activity. Increasing temperature above the tolerance limit of gastropods could also cause loss of adaptation ability and increased mortality (Shaikh et al. 2022). Leung et al. (2019) showed that high temperature affected the respiration rate in several gastropods such as N. atramentosa, Austrocochlea concamerata, and A. constricta. Moreover, thermal stress can stimulate an increase in total antioxidant capacity as a defense mechanism agains oxidative damage, which has been linked to accelerated spawing in some gastropods (Teixeira et al. 2012).

Nonetheless, high temperatures may also impair locomotion (Prayudi et al. 2024), and vulnerability to predation (Hayford et al. 2021). Physiochemical factors such as pH affect the life of gastropods in the mangrove ecosystem. Based on previous studies, low pH levels could cause damage to gastropods, such as thinner shells, surface defects/abnormalities, reduced shell density, erosion, rounded shape, and increased mortality (Chatzinikolaou et al. 2016). These detrimental effects are largely attribute to reduced availability of carbonate which is essntial for shell structure composition (Chatzinikolaou et al. 2021). Furthermore, decreased pH has been shown to disrupt gastropods metabolism, which affected body homeostasis, physiological processes, and their development (Viotti et al. 2019).

This study recorded salinity at Leahari, Waai, and Kairatu as the highest compared to Poka and Tihulale. Keerthana et al. (2023) reported that high salinity can increase gastropod diversity, while Yadava et al. (2019) found the highest diversity at low salinity. Thus, salinity and pH act as limiting factors gastropods that fail to adapt will experience population declines and even disappear from an area (Kenconojati et al. 2024). Rumahlatu and Leiwakabessy (2017) also correlated salinity, temperature, pH, and dissolved oxygen (DO) levels with gastropod diversity in Passo and Latuhalat. Bhuyain et al. (2020) added that a pH range of 7–8 is tolerable, while extreme pH levels cause shell thinning and detrimental increases in metabolism. However, some species can adapt to high pH and oxygen levels (Gümüş et al., 2022). Regarding temperature, Hu et al. (2021) reported optimal gastropod activity at 23–27°C and decreased above 30°C. Interestingly, Waai Beach, with the highest temperature (~29.5°C), showed high diversity, while Poka, with the lowest temperature (~27°C), had the lowest diversity. This finding aligns with Mawardi et al. (2023), who noted gastropod tolerance in East Aceh mangrove forests at 27–30°C without a direct positive correlation to diversity.

Types of Gastropods Found in the Mangrove Ecosystem of Leahari, Waai, Poka, Kairatu and Tihulale Villages

Generally, the mangrove ecosystem is a habitat for mollusk groups such as gastropods, which play an important role in nutrient recycling, litter decomposition, and energy transfer (Baharuddin & Satyanarayana 2024). The presence of organic matter, including detritus and decomposing leaves, supports gastropod populations by providing both a food source and suitable microhabitats for reproduction and shelter (Keerthana et al. 2023; Galgani et al. 2023). Due to their short life cycles, ecological sensitivity, and widespread distribution, gastropods play a vital role in maintaining mangrove ecosystem health and are often used as bioindicators (Awang et al. 2022). For instance, a study by Krupnova et al. (2018) showed some species like Contectiana listeri, Lymnaea stagnalis, and Bithynia tentaculate were used to monitor pollution from metals in aquatic environment.

The condition of the mangrove ecosystem has a significant influence on the existence of gastropods. Density and diversity of gastropods are directly proportional to density of the mangrove ecosystem (Purnama et al. 2024a). Low mangrove density can lead to increased sunlight penetration, resulting in elevated water temperatures; conversely, dense mangrove cover contributes to shading and temperature regulation (Imamsyah et al. 2020). In this study, the highest number of gastropods species was found in Waai, followed by Poka, Kairatu, Leahari, and Tihulale villages. The abundance of gastropods in the five study areas was influenced by combination of biotic factors (e.g., life cycle, predators, and food availability), abiotic factors (temperature, salinity, pH, dissolved oxygen, sediment composition) and environmental changes, including changes in mangrove vegetation, water quality, anthropogenic waste, human activities, hydrological and physiographic factors (Bae & Park 2020; Belhiouani et al. 2019).

Number of Gastropods Individuals at Each Study Area

A previous study by Wiraatmaja et al. (2022) stated that the distribution of Faunus ater has been influenced by substrate types (e.g., sand, mud, rocks) as well as temperature, pH, and salinity. Another study Udayantha and Munasinghe (2009) reported that those substrate did not affect the distribution of F. ater, T. palustris, and L. scabra, which are found in large numbers in mangrove and brackish places. The reason of this condition is due to their ability to live in mangrove area and competitive advantages for food and space (Dewiyanti et al. 2021). Some species get more food and space, then become dominant and persistent populations (Mainwaring & Hartley, 2019). T. palustris was found at multiple study locations and is considered a characteristic species of mangrove ecosystems (Samsi et al. 2020). It feeds on

mangrove leafs litter during high tide and plays a crucial ecological role in litter decomposition and nutrient cycling (Müller García & Nebelsick 2024).

The presence of T. palustris and L. scabra is associated with the good environmental condition and serves as an indicator of ecosystem health (Shah & Mohan, 2020; Syahrial et al. 2021). High number of L. scabra may be attributes to its ability to utilize mangrove leaf detritus efficiency, supporting its role in the trophic structure of mangrove ecosystems (Imakulata & Tokan, 2018).

Diversity, Richness, Evenness and Dominance of Gastropods

Diversity, richness, evenness, and dominance of gastropods are influenced by various factors such as environment condition, land use, and human activities (Wahida et al. 2024). A study conducted by Afwanudin et al. (2019) reported that gastropods diversity was influenced by the substrate type, with muddy substrates typically associated with lower oxygen availability compared to sandy substrates. However, muddy substrates are often rich in organic matter, which promotes mangrove growth and provides an abundant nutrient supply for gastropods (Kusuma et al. 2024). Key environmental factors that significantly influencing diversity, richness, evenness, and dominance of gastropods are water temperature, pH, salinity, and DO (Sujarta et al. 2022; Rumahlatu & Leiwakabessy 2017). In addition, high water temperatures can enhance the decomposition process of organic matters by gastropods, conversely, water temperatures that are too low may cause cellular stress and organ damage (Bula et al. 2017). Another factor is the of predators in the mangrove environment that affect the presence of gastropods. Previous analysis conducted by Li et al. (2020) by observing the predatory gastropod Reishia clavigera as well as its prey Amphibalanus amphitrite and Brachidontes variabilis have found that low pH can affect the response between prey and predator which will change their interaction process, thereby affecting the population dynamics of both species.

Several studies have also reported similar results regarding gastropod diversity in Indonesia. Isroni et al. (2023) study in Lamongan Regency, East Java's mangrove forests found 24 species belonging to 10 families with high and consistent gastropod diversity and evenness. Sujarta et al. (2022) also reported a moderate gastropod diversity index with low dominance on the coast of Liki Island, Papua. Hilmi et al. (2022) reported that mangrove forests on the north coast of Jakarta have a richness of 13 gastropod species in 8 genera and 6 families. Gastropod diversity studies obtained from various regions in Indonesia can support coastal ecosystem conservation efforts and form the basis for sustainable use of marine resources, thus providing direct benefits to coastal communities. However, gastropods in the waters of Maluku Province are starting to be threatened by community activities. Haumahu et al. (2024) explained waste disposal activities. Natan et al. (2023) reported on the community's marine biota harvesting, also known as bameti, of several gastropod species. This analysis of gastropod diversity on Seram and Ambon Islands is expected to provide insight and guidance for local communities in wisely managing marine gastropod populations while encouraging their participation in conservation efforts and mitigating environmental impacts.

Density, Frequency of Occurrence and Importance of Gastropods

Leahari village has a variety of substrates, such as sandy, coral, muddy, and predominantly rocky substrates. Suitable substrate conditions leads to enhance the presence of gastropods in the area (Natan et al. 2023), supporting growth and development, alongside the availability of adequate food or nutritional sources. The structural complexity of tropical islands habitats contributes to increased species richness and population density. High gastropods density is also influenced by the presence of natural shelters such as the mangrove ecosystem. A study by Wintah et al. (2021) reported that optimal environmental conditions, such as water

pH value (6.92-7.93), DO (4.13-6.65 mg/L), substrate type (dust, clay, and sand), and phosphorus concentration (0.25-0.33%) could affect density of gastropods.

The intertidal zone of Waai Village is characterized by sandy and muddy substrates, creating optimal condition for seagrass growth. Gastropods are one of the animals that can associate closely with seagrass ecosystems, playing an important ecological role in these habitats. They contribure to the food chain in seagrass beds by feeding on detritus, seagrass leaf litter, and organic matter deposited on the substrate (Batuwael & Rumahlatu 2019). Density of gastropods is highly dependent on seagrass ecosystem, which provides protection, food sources, habitat, and sediment deposition, beneficial for various organisms (Fajeri et al. 2020). The types of gastropods can vary in seagrass beds depending on distribution patterns. A previous study conducted by Vian et al. (2022) reported that gastropods in the seagrass beds of Gazumbo Island were dominated by Cerithiidae (72.9%), followed by Litiopidae (12.7%), and Nassariidae (5.7%).

Along the coast of Tihulale Village, R. bitubercularis exhibited a high frequency of presence and plays an important ecological role in the microbenthic community as a predator. In addition, this species has been identified as a protential bioindicator for assessing environmental changes, particularly in coastal zones contaminated with heavy metals (Kusuma et al. 2024). Generally, R. bitubercularis can be found in rock crevices, which prevents exposure to strong waves and maintains body temperature to survive the moist conditions during dry or low (Baharuddin et al. 2018). A study by Proum et al. (2017) found that low gastropods density may be attribute to unfavorable environmental condition. The degree of acidity (pH) can change the behavior of gastropods, such as isolation and migration, causing a reduction in nutrient, energy absorption, and leading to decrease in their presence frequency

CONCLUSIONS AND RECOMMENDATION

Conclusion

Gastropods found in five mangrove ecosystems (Leahari, Waai, Poka - Ambon Island, Kairatu and Tihulale villages - Seram Island) amounted to 45 species grouped into 30 genera, 21 families, and 7 orders. In Leahari Village, there are 13 species with a total of 1078 individuals, 22 species with 667 individuals in Waai, 19 species with 409 individuals in Poka, 13 species with 6695 individuals in Kairatu, and 11 species with 528 individuals in Tihulale Village. The presence of gastropods in the mangrove ecosystem is influenced by the physical-chemical parameters of the environment, where the levels of dissolved oxygen (DO), salinity, pH, and temperature in the mangrove ecosystem are within the acceptable range for gastropod life. In addition, the diversity, richness, uniformity, and dominance of gastropods in each study area vary between locations and are influenced by various factors such as environmental conditions, land use, and human activities. Gastropod diversity was observed in Waai Village with moderate criteria, with low richness and high evenness. Moderate dominance indexes were observed in Leahari and Kairatu Villages. Kairatu Village also showed low diversity, richness, and evenness, while the lowest dominance value was recorded in Waai Village. On the other hand, gastropod density in each study area varied between locations and was influenced by various substrates, such as sand, coral, mud, and rocks. The results of sampling in the five study areas, showed the highest to lowest species densities in order, namely Faunus ater (13,918 individuals/m2) in Kairatu Village, Littorina scabra (1,382 individuals/m2) in Leahari Village, Reisha bitubercularis (0,883 individuals/m2) in Tihulale Village, Clypeomorus battilariaeformis (0.75 individuals/m2) in Waai Village, and Clypeomorus battilariaeformis (0,607 individuals/m2) in Poka Village. This study highlights the importance of gastropod diversity and density in ecosystem functions and services, as well as human well-being. This

study suggests that conservation and encouraging ecosystem management are needed to prevent the extinction of gastropods.

Recommendation

The following are some recommendations for further research related to the Diversity and Density of Gastropods in Selected Mangrove Ecosystems in Maluku, Indonesia: The Effect of Seasonal Variation on Gastropod Diversity and Density. Examining how seasonal changes (rainy and dry seasons) affect the species composition and density of gastropods in mangrove ecosystems. The Impact of Human Activities on Gastropods in Mangroves. Analyzing the effects of anthropogenic pressures such as pollution, coastal development, or mangrove logging on gastropod diversity and populations. Comparison of Gastropod Diversity between Degraded and Protected Mangroves. Conducting a comparative study to examine differences in species diversity and density of gastropods in degraded and pristine or protected mangrove areas. The Relationship of Gastropods with Physical and Chemical Environmental Parameters of Mangroves. Examining the correlation between environmental factors such as salinity, pH, water temperature, and soil substrate with gastropod distribution and density. The Role of Gastropods in the Food Web and the Function of the Mangrove Ecosystem. Investigating the ecological position of gastropods as part of the food chain and their contribution to nutrient cycling in the ecosystem. mangrove, Genetic and Phylogenetic Identification of Gastropods in Maluku Mangroves and Conducting molecular analysis to identify gastropod species that are difficult to distinguish morphologically and to understand their evolutionary relationships and also the Potential Utilization of Gastropods as Bioindicators of Mangrove Environmental Quality whether gastropods can be used as biological indicators in assessing the condition and health of mangrove ecosystems.

ACKNOWLEDGEMENTS

The authors express their sincere gratitude to the leadership of Pattimura University, particularly the Institute for Research and Community Service, for funding this study with contract number: 1058/UN13/SK/2024.

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