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Tropical gastropod density and diversity in the mangrove forest of Totobo Village, Southeast Sulawesi, Indonesia

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Abstract. *Purnama MF, Prayitno SB, Muskananfola MR, Suryanti. 2024. Tropical gastropod density and diversity in the mangrove forest of Totobo Village, Southeast Sulawesi, Indonesia. Biodiversitas 25: 1663-1675.* The mangrove ecosystem of Totobo Village, Kolaka District, Southeast Sulawesi, Indonesia is a habitat for various species of edible and economically important gastropods. This research aims to determine mangrove gastropods' density and ecological index (diversity). This research was carried out from June to September 2023 in the mangrove ecosystem of Totobo. This research adopts purposive sampling and systematic random sampling techniques to determine stations and place the distribution of sampling points (sub-stations). The gastropod sample collection was done using the handpicking method or manually. More than 34 species of gastropods (14 families and 24 genera) were found in the mangrove ecosystem of Totobo. The diversity index (H' = 3.07) of gastropods in the Totobo mangrove ecosystem is directly proportional to the species richness value (R = 4.43), which is in the high category. The evenness index is in the medium category (E = 0.89), and the dominance index (C) has a value of 0.01, meaning no dominance of a particular species. The condition described is a representation of a system of homeostasis or environmental balance that is currently being maintained. This directly impacts the optimal biological activity (physiology) of the gastropod community and other aquatic organisms in the mangrove ecosystem (estuary) of Totobo Village.

Keywords: Ecological index, gastropods, homeostasis, mangrove

INTRODUCTION

The mangrove ecosystem is located in the intertidal zone, which stores a wealth of aquatic germplasm, one of which is the gastropod community (Nybakken and Bertness 2005; Rotaquio and Gallego 2021; Retnaningdyah et al. 2022; Chen et al. 2023; Chen et al. 2024). Gastropods are the largest class (80%) of the mollusk phylum (Strong et al. 2008; Bouchet et al. 2011; Albert et al. 2022), and 100,000 living species have been identified and are found in marine, freshwater, and terrestrial environments (Khatun et al. 2023; Caril et al. 2023; Ruppert et al. 2004; Davis et al. 2015). Moreover, 61 species of them live in association with the mangrove ecosystem as a habitat for a living (rearing ground), spawning, and foraging for their survival (Pramudji 2001; Nontji 2007; Isnaningsih and Patria 2018; Aditya and Nugraha 2020; Ravinesh et al. 2021; Cannicci et al. 2021; Meijer et al. 2021; Mansingh et al. 2021; Zamprogno et al. 2023).

Mangrove gastropods play an important role in maintaining ecosystem balance, including in the food chain as herbivores, fungivores, carnivores, omnivores, scavengers, and detritivores (Rusnaningsih 2012; Alongi 2009; Pramudji 2001). Gastropods also play a role in controlling biodiversity in the intertidal zone, including controlling the growth of macroalgae and epiphytes (Duarte et al. 2020; Astiti et al. 2021) through their grazing activity and accelerating the process of litter decomposition carried out by microorganisms by tearing and reducing newly fallen litter (Pramudji 2001; Rusnaningsih 2012; Silaen 2013; Picardal and Dolorosa 2014; Zamprogno et al. 2023). Gastropods in the mangrove ecosystem also have economic value. Some Gastropods can be used as food ingredients, such as *Terebralia palustris*, *Telescopium telescopium*, and *Cerithidea obtusa* (Pramudji 2001; Rusnaningsih 2012; Checon et al. 2023; D'Souza and Shenoy 2023).

One of the mangrove areas that has a high diversity and richness of gastropod species is the mangrove ecosystem in Totobo Village, Southeast Sulawesi, Indonesia. The coast of Totobo is covered with mangrove vegetation of the species Bakau (*Rhyzopora* spp.), Pidada (*Sonneratia* spp.), and Api-Api (*Avicenia* spp.). Among the three species of mangroves, the population of mangrove trees tends to dominate, characterized by the formation of mangrove forests up to the estuary area. The density of mangroves on the coast of Totobo Village is relatively dense, supported by a mangrove root system that is interconnected with each other. The dense root structure of the shoots forms root gaps where the snails attach and camouflage themselves from predators (Pramudji 2001; Ravinesh et al. 2021; Cannicci et al. 2021; Meijer et al. 2021; Mansingh et al. 2021). Apart from that, the surfaces of roots and stems covered with epiphytes, as well as leaves containing salts

(minerals), are used by the gastropod community as grazing areas and living space for several minority species, especially the genus *Littorina* and *Ellobium* (Zvonareva et al. 2015; Ramos et al. 2021). Meanwhile, the majority of other gastropods occupy the bottom area of the water (benthic zone) (Jacquot et al. 2023; Thivaiou et al. 2023; Triwiyanto et al. 2015; Hickman et al. 2008; Cappenberg et al. 2006).

The mangrove area of Totobo Village is the only area not affected by overburden waste in Pomalaa Sub-district (existing nickel mining), Southeast Sulawesi, Indonesia. The development of this area is focused on a green open area and community economy, where there are environmentally based tourism activities (ecotourism), such as mangrove tracking and community aquaculture centers (fish farming) with vanname shrimp and milkfish as commodities. These conditions make the mangrove ecosystem of Totobo Village even more protected because these two activities are protected by local regulations, which require farmer-fishermen and residents to preserve mangrove forests.

The relatively dense condition of mangroves is thought to be directly proportional to the density and diversity of the gastropod community that inhabits them (Pramudji 2001; Ravinesh et al. 2021; Cannicci et al. 2021; Zamprogno et al. 2023). Therefore, this research aims to determine the density and ecological index (diversity) of mangrove gastropods in Totobo Village. Research regarding the density and diversity of gastropods in the mangrove ecosystem of the village is important, considering that the database of mangrove gastropod taxa (species) in Kolaka District, especially in Totobo Village is not available. Furthermore, empirical research has never been done on the ecological index of gastropods in the mangrove ecosystem with minimal disturbance (reference site) in Totobo Village, Southeast Sulawesi.

MATERIALS AND METHODS

This research was carried out from July to September 2023 in the mangrove ecosystem of Totobo Village, Pomalaa Sub-district, Kolaka District, Southeast Sulawesi, Indonesia. The mangrove area chosen to carry out this study is not affected by sediment/mud (overburden) of nickel mining activities. Several estuaries in Totobo Village do not have connections with upstream areas where nickel is mined, so the mangrove and coastal areas generally do not experience disturbance from overburden waste. The sampling locations in this study specifically have relatively similar ecological characteristics, both in terms of vegetation type and mangrove density, as well as substrate characteristics (visually). Hence, the 9 research stations are part of repetitions to cover the entire mangrove area of Totobo Village and comprehensively as an inseparable part of efforts to obtain direct information regarding the diversity of gastropods in Totobo mangroves. The distance between each station ranges from 100-200 m (Figures 1 and 2).

Data collection on gastropod community ecological indices was carried out comprehensively by increasing the number of station locations and repeat area units (sub-stations) for exploration activities. This is intended to increase opportunities to obtain diverse gastropod taxa in the mangrove ecosystem of Totobo Village. The purposive and systematic random sampling methods were used to select sampling stations and sub-stations. Meanwhile, the technical collection is done manually using hands, called handpicking. Gastropod community structure observations were carried out simultaneously with mangrove data collection (Species and Density Aspects).

Figure 1. Research locations in several mangrove areas of Totobo Village, Kolaka District, Southeast Sulawesi, Indonesia

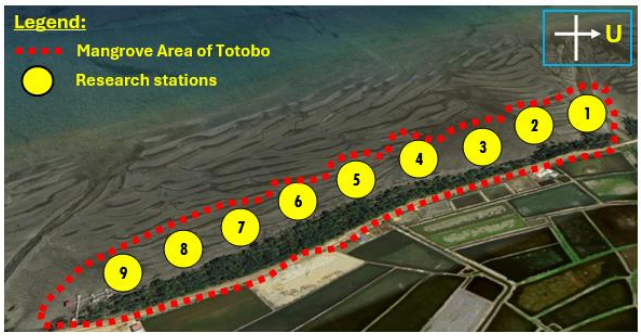

Figure 2. Distribution of stations at the research location (Source: Google Earth 2024)

Technically, the two data were collected using a quadrat transect measuring 10 m^2 for tree-type mangroves, 5 m^2 for sapling-type mangroves, and 1 m^2 for seedling-type mangroves and for observing samples of the gastropod community. The quadrat transects, or quadrat plots used, were placed at each station in 7-10 plots to represent each station area and easily estimate mangrove vegetation density, diversity, and gastropod population density. The gastropod samples observed in this study were individual living gastropods; this was done to strengthen the justification for the relationship between mangrove density and gastropod diversity and density. Taxa (species) were identified in the gastropod samples obtained using the Worms identification key "World Register of Marine Species" (https://www.marinespecies.org), Molluscabase (https://www.molluscabase.org) and Collection of Worldwide Seashells (Collection of worldwide seashells (idscaro.net)), as well as several trusted journals and textbooks, including Dharma (1992), Dharma (1998), Dharma (2005); Cappenberg et al. (2006); Arbi (2014); Dolorosa and Gallon (2014).

Data analysis

Mangrove density

Mangrove density is analyzed by referring to the formula according to Bengen (2003):

$$Density = \frac{Number\ of\ Individuals}{Sample\ Plot\ Area}$$

The standard criteria for mangrove damage are based on Minister of Environment Decree No. 201 of 2004, presented in Table 1.

Table 1. Standard criteria for mangrove damage based on Minister of Environment Decree No. 201 of 2004

Degradation class density criteria		Mangrove coverage (%)	Mangrove density level (trees/ha)
No degradation	Dense	>75	>1500
	Moderate	>50-<75	>1000-<1500
Degradation	Rare	<50	<1000

Gastropod density

Gastropod density was analyzed using the formula according to Khouw (2016), with the following formula:

$$Density = \frac{Number\ of\ individuals\ of\ species\ i}{Total\ number\ of\ observation\ plots}$$

Gastropod density

Analysis of the diversity of gastropod species using the Shannon-Weaner diversity index (Odum 1993) formula:

$$H' = -\sum_{i-1}^{s}\left[\left(\frac{ni}{N}\right) x\ Ln\ \left(\frac{ni}{N}\right)\right]$$

Where: H': diversity index, Ni: number of individuals of the ith species, N: total number of individuals

The Diversity Index criteria are divided into 3 (Wilhm 1975):

H'<1.0 : Low species diversity
1.0<H'<3 : Medium species diversity
H'>3 : High species diversity

Gastropod evenness

The Gastropod Evenness Index was analyzed using the formula according to Odum (1993), namely:

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

Where: E: evenness index, H': diversity index, S: number of species

The criteria for Evenness Index value are as follows:

E<0.31 : low level of species evenness
0.31>E>1 : medium level of evenness
E>1 : high level of species evenness

Species richness

The species richness index (Margalef index) is analyzed based on the formula according to Ludwig and Reynolds (1988), namely:

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

Where: S: number of species, N: number of individuals

The criteria for the Margalef Type Wealth Index value are as follows:

D<2.5 : low level of species richness
2.5> D> 4 : medium level of richness
D > 4 : high level of wealth type

Dominance

The Dominance Index is calculated using the formulation according to Odum (1993), namely:

$$C = \Sigma\left(\frac{ni}{N}\right)^2$$

Where: ni: number of individuals I, N: total number of individuals of all species

The dominance index criteria consist of the following: 0<C<0.5 = no type dominates; 0.5<C<1 = there is a dominant type.

RESULTS AND DISCUSSION

Results

Mangrove density in Totobo Village is in the very good category. It is relatively the same between stations, namely "very dense (>1,500 trees/ha)," based on the standard criteria of the Ministerial Decree. LH. No. 201 of 2004. The very dense condition of the mangroves provides a supporting capacity for the life of gastropod communities and other aquatic organisms on the Totobo coast. The results of the analysis of mangrove density at each station in the mangrove ecosystem of Totobo Village, are presented in Table 2.

The mangrove ecosystem of Totobo Village, is an optimal habitat for the gastropod community. The very dense condition of mangroves (3-9 trees/10m^2) directly forms the ecological space and relief on the ground floor (substrate) as a living niche, source, and place to find food (feeding ground) for the gastropod community. This condition, simultaneously with the community structure (ecological index) of gastropods in the Totobo mangrove, which has high diversity and species richness values, indicates good environmental quality and an ecological integrity system fully functioning well. The results of the gastropod ecological index analysis in the Totobo mangrove ecosystem are presented in Table 3.

The results of the analysis of gastropod population density at the reference site (Totobo Village) are presented in Figure 3.

Table 2. Mangrove density in Totobo Village, Kolaka District, Southeast Sulawesi, Indonesia

Research Station	Mangrove density (trees/ha)	Category
Stasion 1	7,333.33	Dense
Stasion 2	7,000	Dense
Stasion 3	5,666.67	Dense
Stasion 4	7,666.67	Dense
Stasion 5	7,000	Dense
Stasion 6	7,666.67	Dense
Stasion 7	4,333.33	Dense
Stasion 8	4,000	Dense
Stasion 9	7,666.67	Dense

Table 3. Ecological index of gastropods at each station in the mangrove ecosystem of Totobo Village, Kolaka District, Southeast Sulawesi, Indonesia

Research station	Ecological Index	Grade	Category	Ecological index ranking between stations
Station 1	Diversity index (H')	2.43	Medium	**3rd**
	Species richness index (R)	3.75	Medium	
	Evenness index (E)	0.81	Medium	
	Dominance Index (C)	0.13	No type dominates	
Station 2	Diversity index (H')	3.01	High	**1st**
	Species richness index (R)	6.33	High	
	Evenness index (E)	0.86	Medium	
	Dominance Index (C)	0.08	No type dominates	
Station 3	Diversity index (H')	3.09	High	**1st**
	Species richness index (R)	5.71	High	
	Evenness index (E)	0.92	Medium	
	Dominance Index (C)	0.06	No type dominates	
Station 4	Diversity index (H')	1.96	Medium	**2nd**
	Species richness index (R)	4.31	High	
	Evenness index (E)	0.63	Medium	
	Dominance Index (C)	0.31	No type dominates	
Station 5	Diversity index (H')	2.88	Medium	**2nd**
	Species richness index (R)	5.75	High	
	Evenness index (E)	0.85	Medium	
	Dominance Index (C)	0.10	No type dominates	
Station 6	Diversity index (H')	3.14	High	**1st**
	Species richness index (R)	6.28	High	
	Evenness index (E)	0.90	Medium	
	Dominance Index (C)	0.07	No type dominates	
Station 7	Diversity index (H')	3.00	Medium	**2nd**
	Species richness index (R)	5.41	High	
	Evenness index (E)	0.93	Medium	
	Dominance Index (C)	0.06	No type dominates	
Station 8	Diversity index (H')	3.30	High	**1st**
	Species richness index (R)	6.09	High	
	Evenness index (E)	0.98	Medium	
	Dominance Index (C)	0.04	No type dominates	
Station 9	Diversity index (H')	2.91	Medium	**2nd**
	Species richness index (R)	5.46	High	
	Evenness index (E)	0.88	Medium	
	Dominance Index (C)	0.08	No type dominates	

A total of 34 species (14 families and 24 genera) of gastropods were found in the mangrove ecosystem of Totobo Village (Table 4), and there may still be species that have not been caught in exploration efforts in this mangrove area. Several genera of mangrove gastropods have identical morphological characteristics, so accuracy is needed in determining the species. *Faunus ater* has the largest number of individuals and density (10-112 Ind./m^2). Apart from that, the dense mangrove vegetation in Totobo Village indirectly provides a supporting capacity for the life of gastropods (indicators) of the *Sphaerassiminea miniata* type. These mangrove health indicator gastropods were found in very dense numbers (± 21-87 ind./m^2) and were spread throughout the ground floor of the Totobo mangrove ecosystem. The small morphological characteristics (± 5 mm) and red body color are characteristic of this indicator species. The following is the appearance of sumpil (*F. ater*) in its habitat with very high densities (Figure 4).

Sumpil snails (*F. ater*) in the Totobo mangrove area are abundant in almost all species and ecological habitat characteristics. Still, the highest density of this species is found in areas influenced by estuary salinity and pond inlet/outlet areas (Figure 4). The sumpil snail is a type of gastropod with euryhaline properties. Its tolerance and adaptability to salinity are quite high so that this snail can survive in the diverse habitat characteristics of the Totobo mangrove ecosystem. Apart from *F. ater*, several other gastropods have unique living habits in the Totobo mangrove ecosystem; these include living attached to mangrove roots, stems and leaves, and dead wood in the mangrove ecosystem (Figure 5).

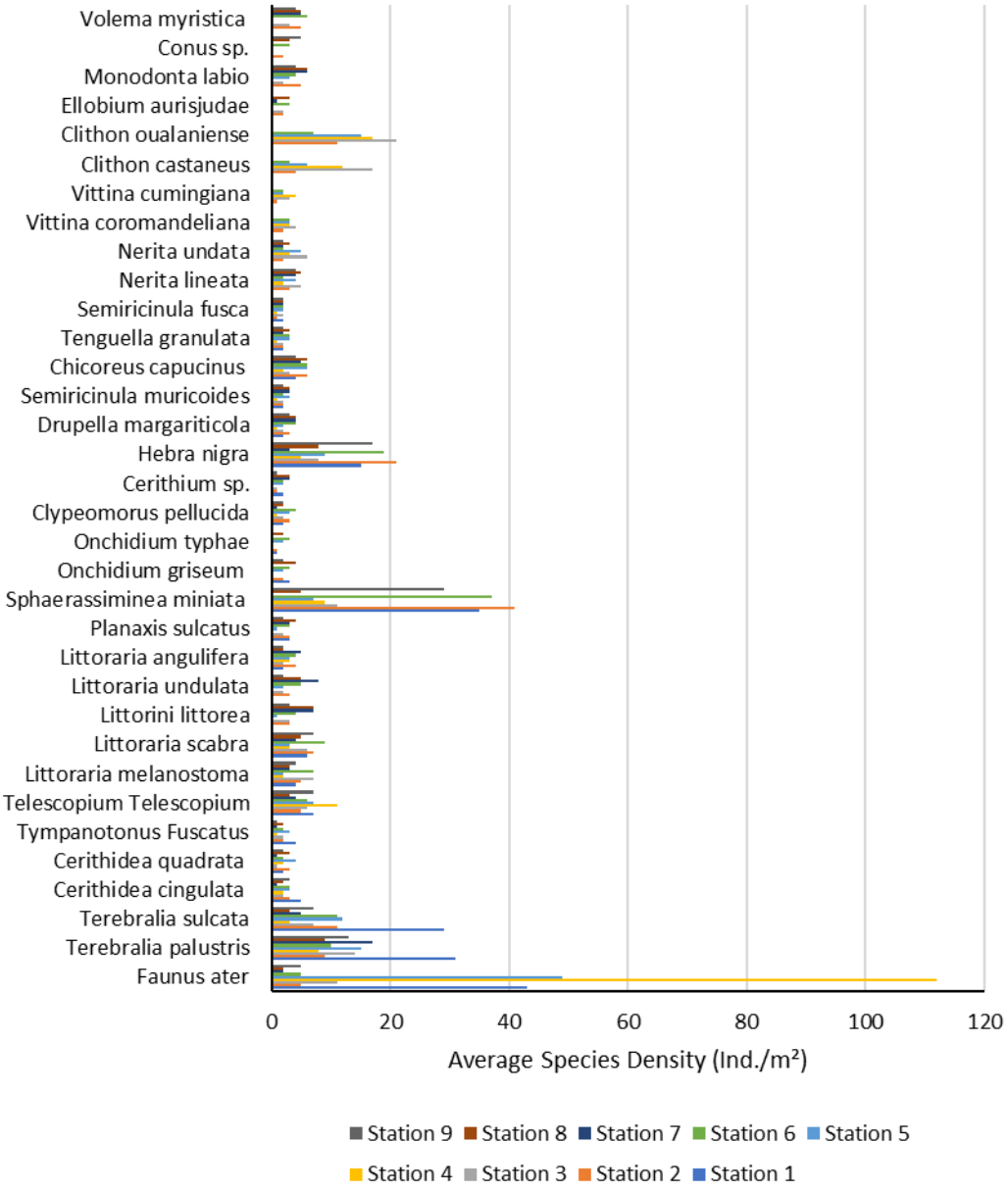

Figure 3. The average density of gastropod communities at each station

Figure 4. Appearance of hundreds of living sumpil (*Faunus ater*) in the mangrove area of Totobo Village. A. *F. ater* in the mangrove area (estuary flow), B. *F. ater* in the inlet/outlet area of community aquaculture

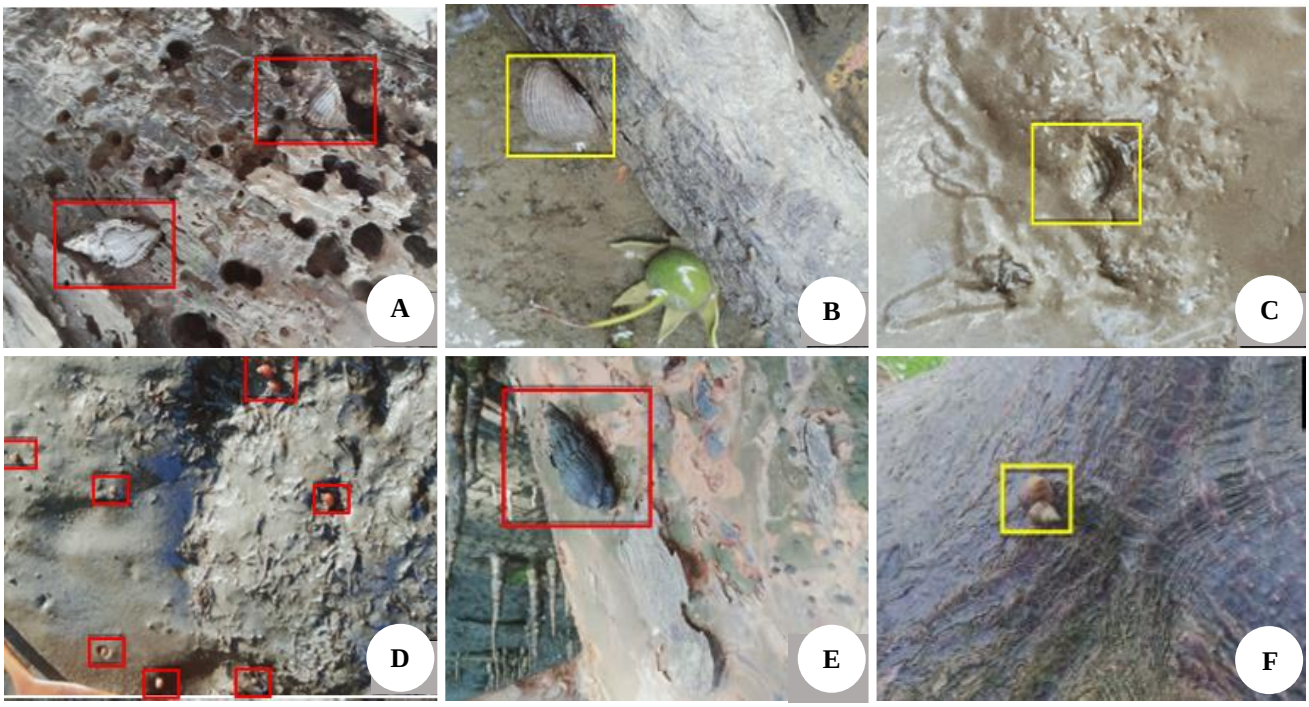

Figure 5. Habitual action of several species of gastropods in the mangrove area of Totobo Village, Kolaka District, Southeast Sulawesi, Indonesia. A. Murex (*Chicoreus capucinus*), B. *Nerita undata*, C. *Herba nigra*, D. *Sphaerassiminea miniata*, E. *Terebralia sulcata*, F. *Littoraria scabra*

Discussion

The mangrove ecosystem is a typical tropical coastal vegetation community dominated by several species of distinctive trees or bushes that can grow and develop in tidal areas and have muddy substrates (Bengen 2002; Lestari et al. 2021; Madjid and Ahmad 2022). The mangrove ecosystem has abundant wealth in terms of flora and fauna (Crocetta et al. 2020). Mangrove forests have the most important ecological value as feeding grounds, spawning grounds, and nursery grounds for fish, shrimp, shellfish, and gastropods (De La Morinière et al. 2002; Nybakken and Bertness 2005; Nagelkerken et al. 2008; Muslimin et al. 2021). The strong roots of mangrove trees that rise above the ground help reduce the impact of erosion from waves and tsunamis (Yuliawati et al. 2021).

One of the fauna groups that is a biotic component and dominates in mangrove areas is the gastropods. The abundance and distribution of gastropods in mangrove areas are influenced by environmental conditions, including changes that occur in the function of mangrove forest areas, such as a decrease in the density of mangrove vegetation cover due to excessive use of mangrove trees and conversion of mangrove areas into areas for fish cultivation and other development functions (Kabir et al. 2014; Siwi et al. 2017; Salmo et al. 2019; Japa et al. 2021; Kottè-Mapoko et al. 2021; Jacquot et al. 2023; Cheng et al. 2023; Hamli et al. 2023; Diadhiou et al. 2023).

Table 4. Species of gastropods found at each station in the mangrove ecosystem of Totobo Village, Kolaka District, Southeast Sulawesi, Indonesia

Family	Species	Research station								
		I	II	III	IV	V	VI	VII	VIII	IX
Pachychilidae	*Faunus ater*	43	5	11	112	49	5	2	2	5
Potamididae	*Terebralia palustris*	31	9	14	8	15	10	17	9	13
Potamididae	*Terebralia sulcata*	29	11	7	3	12	11	5	3	7
Potamididae	*Cerithidea cingulata*	5	3	2	2	3	3	1	2	3
Potamididae	*Cerithidea quadrata*	2	3	1	2	4	2	1	3	2
Potamididae	*Tympanotonus fuscatus*	4	2	2	1	3	2	1	2	1
Potamididae	*Telescopium Telescopium*	7	5	6	11	7	6	4	3	7
Littorinidae	*Littoraria melanostoma*	4	5	7	2	2	7	3	3	4
Littorinidae	*Littoraria scabra*	6	7	6	3	3	9	4	5	7
Littorinidae	*Littorini littorea*	0	3	3	0	1	4	7	7	3
Littorinidae	*Littoraria undulata*	0	3	2	0	2	5	8	5	2
Littorinidae	*Littoraria angulifera*	2	4	2	3	3	4	5	2	2
Planaxidae	*Planaxis sulcatus*	3	3	2	0	1	3	3	4	2
Assimineidae	*Sphaerassiminea miniata*	35	41	11	9	7	37	0	5	29
Onchididae	*Onchidium griseum*	3	2	0	0	2	3	0	4	2
Onchididae	*Onchidium typhae*	1	1	0	0	2	3	0	2	0
Cerithiidae	*Clypeomorus pellucida*	2	3	2	1	3	4	1	2	2
Cerithiidae	*Cerithium* sp.	2	1	1	0	2	2	3	3	1
Nassariidae	*Hebra nigra*	15	21	8	5	9	19	3	8	17
Muricidae	*Drupella margariticola*	2	3	2	1	2	4	4	4	3
Muricidae	*Semiricinula muricoides*	2	2	2	1	3	2	3	3	2
Muricidae	*Chicoreus capucinus*	4	6	3	2	6	6	5	6	4
Muricidae	*Tenguella granulata*	2	2	2	1	3	3	2	3	2
Muricidae	*Semiricinula fusca*	2	1	2	1	2	2	2	2	2
Neritidae	*Nerita lineata*	0	3	5	2	4	2	4	5	4
Neritidae	*Nerita undata*	0	2	6	3	5	2	2	3	2
Neritidae	*Vittina coromandeliana*	0	2	4	3	3	3	0	0	0
Neritidae	*Vittina cumingiana*	0	1	3	4	2	2	0	0	0
Neritidae	*Clithon castaneus*	0	4	17	12	6	3	0	0	0
Neritidae	*Clithon oualaniense*	0	11	21	17	15	7	0	0	0
Ellobidae	*Ellobium aurisjudae*	0	2	2	0	0	3	1	3	0
Trochidae	*Monodonta labio*	0	5	2	0	3	4	6	6	4
Conidae	*Conus* sp.	0	2	0	0	0	3	0	3	5
Melongenidae	*Volema myristica*	0	5	3	0	0	6	5	5	4
Average number of gastropods per station		206	183	161	209	184	191	102	117	141

Mangrove forests contribute to organic detritus as a food source for biota that live in the surrounding waters. Microorganisms such as bacteria will break down fallen leaves through a decomposition process and gastropods can consume the results of this decomposition by absorbing the organic material contained in the substrate (Sirante 2011). The reduction in gastropod numbers will reduce the decomposition process in mangrove forests (Baderan et al. 2019). According to Fadhilah et al. (2013), gastropods in mangrove forests play an important role in the food chain's structure, namely in decomposing litter and mineralizing organic matter. In other words, gastropods chop leaves into small pieces, which will continue the decomposition process by gastropod microorganisms relatively stay in their habitat because of their movement limitations (Susiana 2015). From an economic perspective, gastropods have important value because their shells can be used for various highly valuable decorations, such as in the *Cypraea*, *Murex*, and *Trochus* species. Also, gastropods can be used as food ingredients with high sales value, such as Cymbiola. In other words, the high diversity and density of each gastropod species in the mangrove ecosystem directly becomes a source of income for local fishermen (Uspar et al. 2021).

The range of mangrove density at the 9 research stations was 4,000-7,666.67 trees/ha (Table 2). This condition makes the Totobo mangrove area an optimal ecological space for the life of the gastropod community. Therefore, 34 species of gastropods have been identified living in the Totobo mangrove ecosystem; this may continue to increase because there are several species with the same taxa (families) but have different morphological identities and meristic characteristics, such as the Muricidae, Potamididae, and Neritidae families. These three families of gastropods have quite high species diversity, especially Neritidae, with varied color patterns but small dominant size dimensions (±1 mm), making it difficult to identify.

The epifauna, infauna, and tree fauna gastropod groups in the Totobo mangrove ecosystem can be found easily, including *H. nigra*, *T. telescopium*, *L. scabra*, *L. melanostoma*, and *T. sulcata* (Figures 3-5). In addition, the

species classified as sensitive to disturbances in mangrove areas, such as *Sphaerassiminea miniata*, were found to inhabit the Totobo mangrove ecosystem in high abundance (± 21-87 ind./m^2) (Figure 5.D). Likewise, other species relatively tolerant to water quality changes in mangrove areas also tend to have high populations and abundances (Figures 4 and 5). This condition is a factual illustration of the environmental quality and ecological integrity of the Totobo mangrove, which is stable and suitable for the gastropod community. In other words, the dense condition of the mangrove ecosystem is an absolute requirement for the high gastropod diversity and species richness in the Totobo mangrove ecosystem. Similar to the results of research by Ashari et al. (2024) in the Mangunharjo mangrove ecosystem, Semarang City, dense mangroves at several points in the research location have the potential to have high organic material content due to a lot of litter from fallen leaves and twigs, while in areas of land, conversion tends to contain relatively lower organic matter. Isman et al. (2018) stated that litter originating from fallen leaves and mangrove twigs would decompose and increase sediment organic matter. According to Supriharyono et al. (2019), benthic animals are closely related to the availability of organic material in the substrate because they are the main food source. This statement is in line with Suwondo et al. (2006), Maria (2020), Mansingh et al. (2021), Bravo et al. (2021), and Hau et al. (2021), who stated that the condition of the mangrove ecosystem largely determines the presence of gastropods. Suppose there is a diversity condition and a small number of gastropod individuals in a mangrove ecosystem; that indicates the mangrove ecosystem is certainly disturbed, and vice versa (Imamsyah et al. 2020). According to Zvonareva et al. (2015), Salim et al. (2020), Yadav et al. (2019), Keerthana et al. (2023), and Degamon et al. (2023), mangrove density can influence the abundance of gastropods and is also influenced by sediment, organic material, and the sunlight availability. This is in line with the opinion of Tarida et al. (2018), which states that the density of mangroves contains organic material to provide abundant food for these animals; the existence and abundance of gastropods are largely determined by the presence of mangrove vegetation and litter production in the Dompak coastal area. Most gastropods use the mangrove ecosystem as a habitat and process for gastropod activities.

Similar to the opinion of Oostdijk et al. (2018), mangroves are the most important ecosystem for coastal protection, carbon absorption, and storage, and mangrove ecosystems provide habitat for various marine species. Martuti (2013) stated that the Tugurejo Mangrove Forest area is an ecotourism or natural tourism area that has a high diversity of gastropods because the condition of the mangroves is good and supported by several vegetations, including *Rhizophora mucronata*, *Avicennia marina*, *Excoecaria aghalloca*, *Brugueira cylindrical*, and *Xylocarpus mocullensis*. This is supported by research by Supriadi et al. (2018), which states that mangrove vegetation largely determines the presence and abundance of gastropods. In line with this, Dewi et al. (2017), Kantharajan et al. (2017), Velasco et al. (2018), Zvonareva et al. (2020), Singh and Jahid (2021), Ebadzadeh et al. (2023) also said that an increase would follow an increase in mangrove forest density in the diversity of gastropod species.

Other research also found the same thing, such as Taqwa (2010) reporting that the mangrove forest in Tarakan City is the Mangrove and Proboscis Monkey Conservation Area. Tarakan City Mangrove and Proboscis Monkey Conservation Area is an ecotourism or natural tourism area in the middle of the city and has several mangrove vegetation such as *Avicennia* sp., *Rhizophora* sp., *Bruguiera* sp., *Sonneratia alba*, and *Nypa fruticans* and has a diverse gastropod community high one. Haryoardyantoro et al. (2013) stated that most gastropods have a clustered distribution pattern, presumably because the mangrove forest area has optimum environmental conditions for the survival of gastropods. Dewi et al. (2017) state that an increase will follow an increase in mangrove forest density in the diversity of gastropod species. Another condition that causes the Totobo Village mangrove forest to have a high diversity and richness of gastropod species is that it is in direct contact with coastal areas without any clear boundaries, apart from the mangrove vegetation itself. These conditions allow the distribution of food sources (nutrients) to be abundant at the bottom due to the tidal and trapping of organic material in the mangrove ecosystem (Figure 5). This is confirmed by the statement of Ambeng et al. (2023). The high-density value at stations 1-9 is thought to be because this location is close to the coastal area, which allows for a more abundant distribution of nutrients compared to other stations. Apart from that, the aspect of mangrove density is also very primary in supporting the density of gastropods at each station. Even though several stations have higher densities, such as stations 1, 4, and 6, they have values that are not much different from other stations. This is simultaneous with the condition of mangrove density at each station which is categorized as dense (Table 2). This is in line with research conducted by Saleky et al. (2019) regarding the distribution of gastropods on the north coast of Manokwari, which states that the presence of gastropods is abundant in the intertidal zone that borders the land because it is related to the abundant availability of food in the intertidal zone near the land due to the crashing waves bring litter or other food materials to that. According to Fitriana (2006), the diversity index is a condition that describes stability, productivity, and pressure on the ecosystem. Low species diversity indicates low productivity as an indication of heavy pressure and an unstable ecosystem. This is to the statement by Ernawati et al. (2019) that low species diversity is caused by environmental pressure, which always changes over time, and the influence of human activities. Mangroves are an ecosystem in the intertidal area with strong interactions between marine, brackish, river, and terrestrial waters. This interaction makes the mangrove ecosystem have high biodiversity in the form of flora and fauna (Martuti 2013).

Figure 6. The mangrove ecosystem and the Totobo beach, Kolaka District, Southeast Sulawesi, Indonesia intersect each other

Moreover, 34 species of gastropods from 14 families and 23 genera in the Totobo mangrove ecosystem form a stable and balanced ecological system. This can be seen from the composition of the gastropod ecological index in the Totobo mangrove ecosystem (Table 3), which shows habitat quality with optimal ecological integrity. In general, the ecological index value is in the good condition and high category. Gastropod diversity is in the high category (H' = 3.01-3,30), as are species richness (R = 4.43-6,33), medium evenness index (E = 0.63-0,98). There is no dominance of certain species (C = 0.04-0,31). The relatively even representation of individuals of each species in the community and the high density of mangrove vegetation (Figure 6) is the basis for forming balanced habitat conditions and living niches (homeostasis) in the Totobo mangrove ecosystem.

Handayani (2006) said that a community is said to have high diversity if the community is composed of many species of almost the same abundance. On the other hand, if the community is structured with few species, the species diversity will be low. The balance of distribution of a species in a community can be determined from the uniformity index (Brower et al. 1998). According to Sirait et al. (2018), the uniformity index value will be inversely proportional to the diversity index value. If the diversity index value is high, the uniformity value tends to be low so that you will find several species of relatively abundant gastropods compared to other species. Other research shows varied results regarding the number of gastropod species and the condition of the mangrove vegetation. Some of them are reported by Hasanah et al. (2023) that the gastropods found in the Gerupuk coastal mangrove area of Central Lombok consist of 14 species covering 7 families.

The abundance of gastropods in the Gerupuk Beach mangrove area is classified as moderate. Several stations have dense mangrove vegetation and fairly stable station conditions. Organic material is very useful as nutrition for basic biota; if the organic material exceeds the limit, then the position of the organic material becomes a pollutant (Amin et al. 2012). The number of gastropod species at the observation location is lower than the number of gastropod species in the mangrove ecosystem of Pelangan village (n = 20 species), Sekotong subdistrict, West Lombok, (Candri et al. 2022), Seger Beach, Central Lombok, 20 species (Parorrongan et al. 2018), and in Mangrove Forest in Sutera Village, Sukadana District, 20 species of gastropods (Rupmana et al. 2021). Several Asian countries, such as India, found 46 gastropods (Kantharajan et al. 2017) and 50 gastropods in the Philippines (Dolorosa and Gallon 2014). Meanwhile, Abdillah et al. (2019) only found 9 species of gastropods in Poton Bako, East Lombok.

Gastropods in the mangrove ecosystem can live as epifauna (on the surface of the substrate), infauna (in the substrate), and tree fauna (attached to the roots, stems, and leaves of the mangrove), while in their distribution, gastropods in the mangrove ecosystem can spread vertically and horizontally (Mujiono 2009). Gastropods can live on the mangrove plants' leaves, stems, and twigs, attach to mangrove roots, or bury themselves in the forest substrate (Nontji 2007). The description of several research findings above includes a linear relationship between the gastropod community and the mangrove ecosystem, where the abundance and diversity of gastropod taxa are largely determined by the condition of the mangrove vegetation (density). Generally, the gastropod community on the ground floor of the Totobo mangrove lives attached to roots, stems, twigs, leaves, and dead and rotting wood (tree fauna). The rest creep and bury themselves in the substrate (epifauna and infauna). Supriadi et al. (2018) stated that the results of observations of gastropods in Dompak waters were that more species of gastropods were found attached to parts of mangrove trees, such as stems, leaves, and roots compared to those found on the mangrove substrate. This is similar to research by Kamalia (2014), several species of gastropods mostly live attached to mangrove stems and leaves and are less tolerant of muddy substrates.

Of the 34 species of gastropods that inhabit the Totobo mangrove ecosystem, several species were found at all research stations. These gastropod species belong to the families Potamididae, Neritidae, and Littorinidae, which are abundant in the Totobo mangrove forest. In addition, its high resistance to water quality makes it able to adapt to various ecological variations in the Totobo mangrove ecosystem. This statement is supported by the research results of Darmi and Yanti (2017) that the Potamididae family is often found because it is a gastropod native to mangroves that uses detritus as a food source. The Neritidae family is often attached to mangrove trunks (tree fauna). Neritidae was found attached to mangrove stems as a form of self-protection to avoid predator attacks and being carried away by waves during high tide. The research results show that gastropod families such as Potamididae and Littorinidae have a high abundance of individuals and are often found in the Gerupuk mangrove ecosystem. This family dominates the mangrove ecosystem because it likes areas affected by tides and muddy areas with mangrove tree vegetation (Yadav et al. 2019). The Potamididae family is the most commonly found species because research was only carried out in the mangrove ecosystem, which is the Potamididae's natural habitat.

The substrate character preferred by this Potamididae group is muddy (Budiman 2009; Göltenboth et al. 2012; Harzhauser et al. 2023; Thivaiou et al. 2023). Even though there are 3 large family groups in the Totobo mangrove ecosystem, there is one species of snail whose density is much greater than all species of gastropods in the Totobo mangrove; even snails from the families Potamididae, Neritidae, and Littorinidae. The gastropod is *Faunus ater* from the Pachychilidae family. *F. ater* occupies almost all research stations in the Totobo Mangrove Area. However, this species of coarse sand substrate is not found in certain areas. *F. ater* tends to be abundant with very high densities in mangrove areas, which are heavily influenced by estuarine flow (runoff), areas of mangrove land conversion (aquaculture), and areas with mangrove vegetation of the Nipa-Nipa, Mangrove, Pidada, and Api-Api species which are has a mud substrate.

The high density of *F. ater* shows that this species inhabits the Totobo mangrove area and can adapt well to its habitat. Apart from that, the high-density value of the *F. ater* species is because this species of gastropod grows in large numbers in mangrove areas (Figure 4). Kurniawati and Wahyuningsih (2022) stated that the high density of *F. ater* is not new; this has happened in several areas, one of which is in the Demang Gedi mangrove ecosystem, Purworejo District. The research results showed that the density of Sumpil Shellfish (*F. ater*) was 491 ind/m² (Station I), 453 ind/m² (Station II), and 318 ind/m² (Station III). This species of gastropod is dominates the community. *F. ater* is an epifauna benthic organism that moves crawling on the bottom of the water. This animal lives in mangrove forests and around river mouths. This area is ideal for this species, which has brackish salinity with the required salinity range between 15-30‰. *F. ater* also forms groups with very high densities in estuary areas dominated by Nipa-Nipa vegetation and at the inlet/outlet of brackish water cultivation activities (aquaculture) (Purnama et al. 2019; Moradi et al. 2021). According to Lok et al. (2011), these sumpil clams almost cover the surface of the sediment. They are generally abundant in fresh waters approaching brackish, namely in estuaries and downstream rivers. *F. ater* occupies muddy sand bottom waters with gravel litter as its habitat. The substrate chosen for living in groups at the bottom of the water is on the surface of the water bottom. Because this litter can become food for *F. ater*, all members of this species' population can survive and gather in habitat areas to form or live in groups. The high diversity and richness of gastropod species and the dense density of mangrove vegetation in the mangrove ecosystem area of Totobo Village, are indications of ecosystem balance (homeostasis) and optimal environmental health.

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