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Red berry snail *Sphaerassiminea miniata* (Gastropoda: Mollusca) and its potential as a bioindicator of environmental health in mangrove ecosystem of Pomalaa, Kolaka District, Indonesia

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Abstract. *Purnama MF, Prayitno SB, Muskananfola MR, Suryanti. 2024. Red berry snail* Sphaerassiminea miniata *(Gastropoda: Mollusca) and its potential as a bioindicator of environmental health in mangrove ecosystem of Pomalaa, Kolaka District, Indonesia. Biodiversitas 25: 2330-2339. Sphaerassiminea miniata* Habe 1942 has a high sensitivity to environmental changes in mangrove forest areas. Its existence can be confirmed when the overall condition of the mangrove ecosystem is in good condition. The aim of this research is to analyze the density and distribution of the *S. miniata* gastropod population in relation to the density status of mangroves in the reference site area and overburden exposure areas. This research adopted a purposive sampling method for determining research stations, a simple random sampling technique for placing stations or distributing sampling points (sub-stations), and a hand-picking method for technical sampling of *S. miniata* in the field. The results showed that the mangrove density at each station was very dense (3,700-6,000 trees/ha), the population density of *S. miniata* ranged from 8.67-38.33 ind./m^2, and the distribution pattern of *S. miniata* at each station was clumped with a Morishita index (Id) value range of 1.28-1.34. *Sphaerassiminea miniata* was found at all stations in the reference site area (Totobo mangrove ecosystem). No individual was found in the area with overburden exposure (Dawi-Dawi mangrove ecosystem). Changes in the environmental tone in the Dawi-Dawi mangrove ecosystem, especially the substrate area through the input of sediment waste (overburden), which has been going on for a long time and continuously (until now), directly degrades the living space of the *S. miniata* population on the ground floor (benthos) of the waters. The vulnerability of this species to environmental changes makes it a limiting factor in the quality of habitat health in mangrove ecosystems (Bioindicators).

Keywords: Bioindicators, conservation, mangrove ecosystem, *S. miniata*, sensitive gastropod, sustainable management

INTRODUCTION

The massive impact of anthropogenic activities on land and sea has encouraged the development of the concept of biological indicators to study and determine the health status of the aquatic environment (Norris and Thoms 1999; Dziock et al. 2006; Masykur et al. 2018). Bioindicators are environmental assessment tools based on flora or fauna. one effective aquatic bioindicator is the gastropod class of mollusks (Gitarama et al. 2016; Islamy and Hasan 2020; Chukaeva and Petrov 2023; Fitria et al. 2023; Isroni et al. 2023; Menon et al. 2023; Saleky et al. 2023).

Anthropogenic activities like mining and household tasks in coastal areas can lead to pollution, resulting in changes in water quality (Masykur et al. 2018; Islamy and Hasan 2020). A decrease in water quality simultaneously has an impact on reducing the structure of the gastropod community (Rosdatina et al. 2019; Chukaeva and Petrov 2023; Mukhtorova et al. 2023), not only decreasing the existence of gastropods (macrozoobenthos) in their ecological niche but also can resulting in the loss of species classified as sensitive (Timm et al. 2001; Chakrabarty and Das 2006; Rosdatina et al. 2019) One of the coastal ecosystems that is greatly influenced by various anthropogenic activities is the mangrove ecosystem.

Mangrove forests are brackish swamp ecosystems in tropical areas that ecologically support global biodiversity (German and Castilla 2002; Polania et al. 2015; Ahmad et al. 2018; Hasan et al. 2023) and the gastropod community is the largest group (fauna) of taxa that make up the mangrove ecosystem (Suratissa and Rathnayake 2017). Gastropod community is strongly influenced by the condition of mangrove vegetation (Klussmann-Kolb et al. 2008; Strong et al. 2008; Haszprunar and Wanninger 2012; Pawar 2012; Suresh et al. 2012; Webb 2012; dos Santos Longo et al. 2014; Arbi 2015; Marshall et al. 2015; Voronezhskaya and Croll 2016; Salmo et al. 2017). According to Bosire et al. (2004), the presence of gastropods can indicate the status of a mangrove ecosystem and be used as an indicator of mangrove change due to various factors (El-Sorogy et al. 2013; Zvonareva et al. 2015; Syahrial 2018; Anggraini et al. 2021; Syahrial et al. 2021).

The mangrove gastropod community is divided into tolerant and sensitive species based on their adaptability to changes in the aquatic environment (Timm et al. 2001;

Chakrabarty and Das 2006). Tolerant gastropods have wide movement capabilities in mangrove forest areas (Chukaeva and Petrov 2023; Menon et al. 2023; Wahyudi et al. 2015; Campbell et al. 2008; Barus 2004) and generally measure >10 mm with a hard shell structure composed of $CaCO_3$ (Arbi 2014; Nontji 2007; Dharma 1998). Meanwhile, Sensitive species, approximately 1 mm in size, are greatly affected by specific ecological conditions and vulnerable to changes in the mangrove area.

In Pomalaa waters, the *Sphaerassiminea miniata*, also known as the red-berry snail, is a sensitive mangrove gastropod species (Singh and Jahid 2021; Awang et al. 2020). It feeds on detritus and algae found on the mud substrate (Lim et al. 2001; Yulianda et al. 2020). The dependence of *S. miniata* on the natural conditions of the ecological space on the ground floor of the mangrove ecosystem is very high. The slightest change greatly affects the dynamics of this snail population. Its relatively small size limits its space, makes it vulnerable to predation, and makes it easily disturbed by anthropogenic factors.

The Pomalaa Coast has faced pollution from nickel industry activities, causing ecological disturbances for gastropods in the mangrove ecosystems. High-density gastropods are found in Totobo waters, while none are found in the Dawi-Dawi mangrove area due to sedimentation from nickel mining activities upstream (Hamzah 2009; Zubayr 2009; Hamzah et al. 2015; Purnama et al. 2024). The disappearance of *S. miniata* in the Dawi-Dawi mangrove ecosystem shows significant environmental pressure due to human activities, degrading crucial habitat for *S. miniata*. Therefore, research on *S. miniata* as a bioindicator in the Pomalaa mangrove ecosystem is crucial, as it has never been studied in Southeast Sulawesi or Indonesia in general.

MATERIALS AND METHODS

Sampling kit

The tools and materials used in this research are relatively simple and adapted to the research object's living habits, in this case, the *S. miniata* snail. These gastropods are epifauna benthic organisms in low tide conditions and immerse their bodies in mud substrates (infauna) during high tide conditions. This type of small-sized mangrove gastropod (±1 mm) is straightforward to find at low tide, where the population tends to group or cluster on the surface of the substrate with a red morphological hue, like berries. Carelessness in the data collection process can make these gastropods vulnerable to being stepped on by feet and can directly reduce their presence in nature. Some materials and equipment for sampling *S. miniata* are a quadrat transect (1 m^2), small hand scoop (D= ±100 mm), small plastic bottle (V= ±50 mL), bayonet tweezers and distilled water to clean the sample before putting it in the sample bottle.

Time and location

This research was carried out in July 2023-March 2024, taking place in the mangrove tourist area of Totobo Village (S 04°08'49,2" and E 121°37'03,4") and the mangrove ecosystem of Dawi-Dawi Village (S 04°10'00,0" and E 121°36'34,7") (as a comparison of areas contaminated by overburden from nickel mining activities), Pomalaa Sub-district, Kolaka District, Southeast Sulawesi Province, Indonesia (Figure 1).

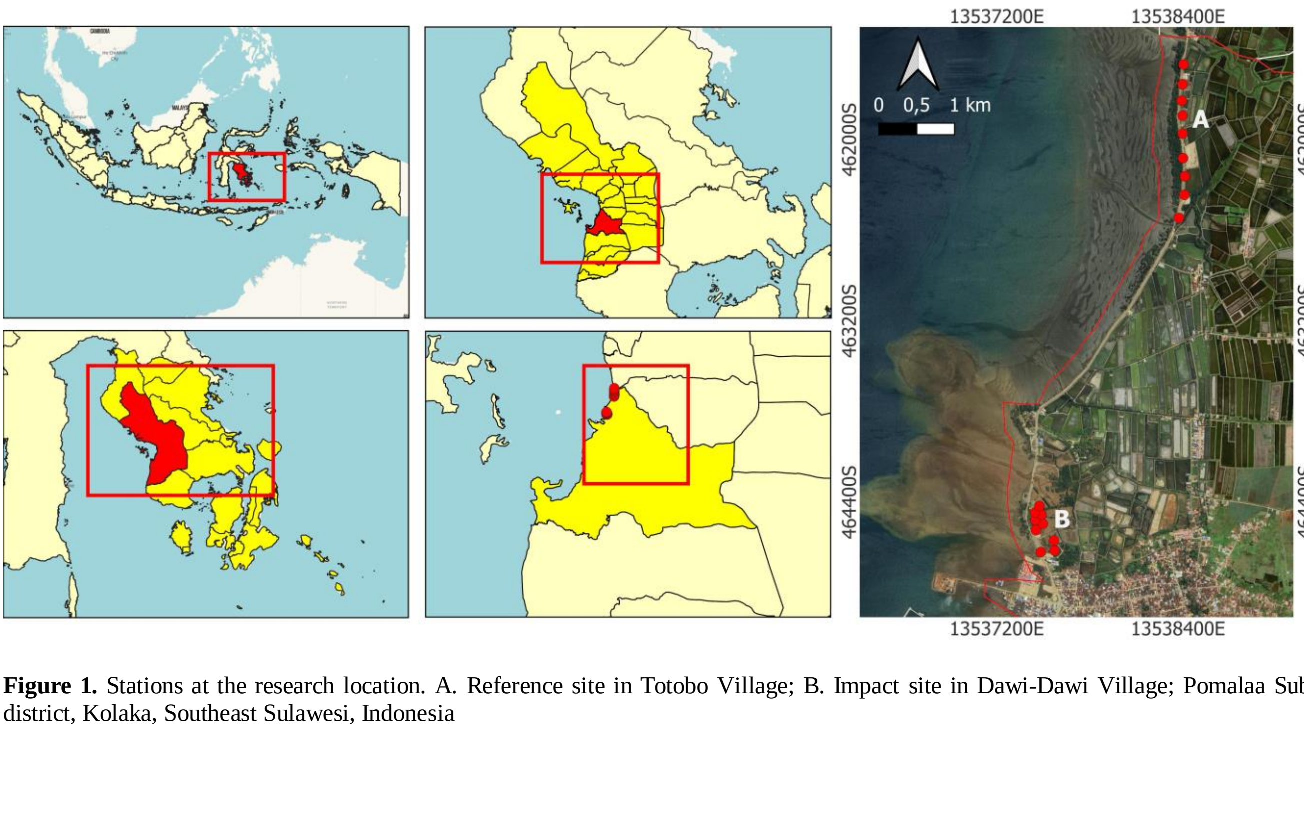

Figure 1. Stations at the research location. A. Reference site in Totobo Village; B. Impact site in Dawi-Dawi Village; Pomalaa Sub-district, Kolaka, Southeast Sulawesi, Indonesia

Figure 2. *Sphaerassiminea miniata* in A. Reference site and; B. Impact site (overburden area)

The two locations were chosen because administratively, they border each other and have very different environmental conditions. Dawi-Dawi mangrove ecosystem is exposed to disturbance or input of sediment waste (overburden) from nickel mining activities, while Totobo mangrove is not. The weight of overburdened waste is indicated by changes in the color of the substrate and water (reddish-brown) as well as the stems, roots and leaves of mangrove trees (bottom) (Figure 1).

Description of the problem or scientific reason for the research

The *S. miniata* snail is classified as a gastropod that is sensitive to disturbances that occur in the mangrove ecosystem, especially in the substrate area (ground floor) and changes in the density of mangrove vegetation (Figure 2.A). In Pomalaa, this species is only found in mangrove areas with medium to very dense density. In areas with exposure to overburden pollutants or acid mine sediment (reddish-brown) waste from nickel mining activities, this type was not found at all, even in conditions of very dense mangrove density (Figure 2.B). The high sensitivity to environmental changes in mangrove areas is the empirical basis for the potential of *S. miniata* as a bioindicator of environmental damage or health, especially in mangrove ecosystems. Considering the importance of the existence of mangroves for their associated biota as well as the ecological, social, and economic benefits of this coastal forest community for the sustainability of life in coastal areas and humans as resource utilization subjects, it is very important to reveal scientific information regarding the bioecology of the gastropod species *S. miniata* in mangrove areas, especially in efforts to develop it as a biological indicator of environmental health quality in the mangrove ecosystem.

Data collection methods

This research is field-based research or exploratory research with a quantitative approach whose output is very dependent on the natural conditions themselves. The mangrove ecosystem, as the habitat of *S. miniata*, is the only target research locus because this type of gastropod is only found living in association with mangrove forests, so a purposive sampling technique was used as a method to determine the location for this research. Meanwhile, the method used for placing stations and sub-stations or distributing sampling points at the research location is the simple random sampling technique. The aim of applying this simple random sampling technique is to ensure a wider sampling area coverage and the possibility of obtaining a larger sample of *S. miniata*. Furthermore, considering the very small dimensions of *S. miniata*, gastropod samples were collected at each station using hand-picking techniques or manually using hand tools using a hand scoop and bayonet tweezers. This gastropod from the Assimineidae family is very easy to find when the waters are at low tide because it is on the ground floor (water substrate) as a benthic epifauna organism, so it is enough to collect it by hand, without involving the use of special fishing equipment. However, high precision and accuracy are required in the process of exploring this biota. Its small size makes it very vulnerable to being stepped on and killed. The exploration process for *S. miniata* in the Pomalaa mangrove ecosystem was carried out when the water conditions were receding. Data collection activities are carried out every week (2-3/week) to ensure that all sampling points are sampled and represent the entire mangrove area at the reference site and the overburden exposure area.

Data analysis

A number of data obtained in the field, such as mangrove density (trees/ha), *S. miniata* density (ind./m^2), and distribution patterns of gastropods, were then analyzed using several formulations below:

Density

Mangrove density in the reference site area (Totobo Village) was analyzed by referring to the formula according to Bengen (2003), with the following formula:

$$Mangrove\ density\ (K) = \frac{number\ of\ individuals}{sample\ plot\ area}$$

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<coverage<75	1000<level<1500
Degradation	Rare	< 50	< 1000

The standard criteria for mangrove damage refer to the Minister of Environment Decree No. 201 of 2004, which is presented in Table 1.

The density of *S. miniata* gastropods was analyzed using the formula according to Khouw (2016), with the following formula:

$$Density = \frac{number\ of\ individuals}{total\ number\ of\ observation\ plots}$$

The distribution pattern of the *S. miniata* species was calculated using the Morisita Dispersion Index (Krebs 1989; Rani 2003). The formulation of the Morisita dispersion index is described using the formula.

Calculating Morishita Index (ID)

$$\mathrm{ID} = n\left\{\frac{\Sigma xi^2 - \Sigma xi}{(\Sigma xi)^2 - \Sigma xi}\right\}$$

Where:
ID = Morisita Dispersion Index
n = Total number of sampling units/plots
Σxi = The number of individuals contained in n plots
Σxi^2 = Square of the number of individuals per plot

The criteria for species distribution patterns are as follows:
ID=0 = Random distribution pattern (R)
ID>0 = The distribution pattern is clumped (C)
ID<0 = Uniform distribution pattern (U)

Calculating Mu and Mc

The distribution pattern is shown through Mu and Mc calculations as follows:

$$Mu = N\frac{X^2 0{,}975 - n + \sum xi}{(\sum xi) - 1}$$

$$Mc = N\frac{X^2 0{,}025 - n + \sum xi}{(\sum xi) - 1}$$

Where:
Mu = Morishita index for uniform distribution patterns
$X^2_{0,975}$ = Table Chi-square value with n-1 degrees of freedom with 97.5% confidence interval
Mc = Morishita Index for clustered distribution patterns
$X^2_{0,975}$ = Table Chi-square value with n-1 degrees of freedom with a confidence interval of 2.5%

Calculating the standard Morishita degrees (Ip)

$$Ip = 0{,}5+0{,}5\ \frac{id - Mc}{N - Mc} : \text{if } Id \geq Mc > 1$$

$$Ip = 0{,}5\ \frac{id - Mc}{N - Mc} : \text{if } Mc > Id \geq 1$$

$$Ip = -0{,}5\ \frac{id - Mc}{N - Mc} : \text{if } 1 > Id > Mu$$

$$Ip = -0{,}5+0{,}5\ \frac{id - Mc}{N - Mc} : \text{if } Id > Mu > Id$$

There are 4 formulas for calculating Ip: (i) The first condition, if value id>1, dan id> atau = Mc, then use formula 1; (ii) The second condition, if value id>1, dan id<Mc, then use formula 2: (iii) The third condition, if value id<1, dan id>Mu, then use formula 3; (iv) The fourth condition, if value id<1, dan id<Mc, then use formula 4

If Ip<0 then the distribution pattern is uniform
If Ip=0 then the distribution pattern is random
If Ip>0 then the distribution pattern is clumped

RESULTS AND DISCUSSION

In general, the Totobo Village mangrove ecosystem (reference site) has a very dense mangrove density (>1500 trees/ha) (Table 2). The Totobo area is one of the tourist sites in the coastal area of Kolaka District, where the mangrove forest area is being developed as an ecotourism destination (tracking mangrove) so that the preservation of mangrove vegetation in Totobo Village is protected by local regulations. Apart from that, the majority of local people also work as catch fishermen (small scale who use marine products in coastal areas), cultivators of vaname shrimp (*Litopenaeus vannamei* Boone 1931), and milkfish (*Chanos chanos* Forsskål 1775) in the community farming area of Totobo Village, Pomalaa. This livelihood, which is very dependent on the condition of the quality of the mangrove forest, directly requires indigenous fishermen and pond activists to always maintain the sustainability of mangrove forests by planting mangrove seeds around the pond area, especially in the inlet and outlet areas (biological filter). Mangrove vegetation (*Rhyzophora* spp.) is the largest or dominant tree population found in the Totobo mangrove ecosystem. The dense root system (stilt-roots) indirectly forms a good ecological niche for gastropod communities and other benthic biota. Apart from mangrove trees, there are several other types, such as *pidada* (*Sonneratia* spp.) and *api-api* (*Avicennia* spp.). These three types of mangroves form a unity of vegetation that supports the life of aquatic organisms in the Totobo mangroves, one of which is the population of the *S. miniata* which is classified as sensitive to environmental changes in the mangrove ecosystem.

As a benthic organism, *S. miniata* has a habitat preference for mud substrates that are protected by the root system and canopy of mangrove vegetation. The dense density of mangroves supports their distribution on the bottom of the waters. The abundance of these small gastropods in the Totobo mangrove ecosystem cannot be separated from the relatively well-maintained condition of the mangroves and the absence of disturbance or ecological pressure due to nickel mining activities. The following are details of the results of mangrove density analysis at each research station in the Totobo mangrove ecosystem (Table 2).

The very dense mangrove density (3,700-6,000 trees/ha) at the 9 research stations (Table 2) is simultaneous with the results of the population density analysis of *S. miniata*, which has the same tendency or trend as the condition of the mangroves in Totobo Village, Pomalaa (Figure 3). The highest density of *S. miniata* was obtained at station 2 (38.33 ind./m^2) and the lowest at station 5 (8.67 ind./m^2). Meanwhile, other stations fluctuate in a fairly high range (12.67-32.33 ind./m^2) following the condition of mangrove density. As in Figure 4, *S. miniata* is usually found in clusters or groups. The appearance of these gastropods is very clear when the water conditions recede, where they can be seen emerging from the mud substrate (infauna) and crawling on the surface of the substrate (epifauna) when the substrate conditions in the mangrove ecosystem are exposed to air. The results of the analysis of gastropod density at each station in the Totobo mangrove ecosystem (reference site) are presented in Figure 3.

The overall distribution pattern of *S. miniata* in the Totobo mangrove ecosystem is in the clumped category (Table 3); this can be seen from the Morishita index value, which is in the range of 1.28-1.34 or Id>0. The distribution pattern analysis results obtained are in line with the conditions of this gastropod population in nature (Figure 5), where they are always found in groups. The clustered distribution pattern of *S. miniata* is also closely related to the nature of its population, which has a habitual action in colonies. *S. miniata* in the Totobo mangrove ecosystem has never been found moving individually (solitarily).

In the reference site area, *S. miniata* occupies the entire bottom floor of the waters with high density and is evenly distributed in colonies with a certain number (±20-50 ind./m^2). The population of *S. miniata* can be seen clearly when the mangrove waters are at low tide. Meanwhile, in the area impacted by nickel mining activities, the habitat of *S. miniata* is experiencing degradation, which makes it unable to adapt to these conditions; this was due to the very high intensity of overburden waste sedimentation in the impact area. This condition can be seen from the color of the water, which is reddish brown all the time. Currently, overburden waste has covered the natural substrate base of the impact area with a thickness of ±30-45 cm. This causes many systemic changes in the mangrove area of the impact zone, including a massive decline in the structure of the gastropod community and their habitat.

The status of the presence of *S. miniata* at each station at the reference site (Totobo Village mangrove ecosystem) and the affected area (Dawi-Dawi Village mangrove ecosystem) overburden sediment waste is presented in Table 4. The presence of *S. miniata* in the mangrove ecosystem of Totobo Village, Pomalaa, is greatly influenced by the input of overburden waste originating from nickel mining activities (impact area). Based on observations at 9 research stations (stations 10-18), not a single individual *S. miniata* snail was found (Figure 6). The small body size of *S. miniata* (morphology) and its very limited movement makes it unable to avoid the continuous input of overburdened waste from the last 2 decades until now. One of the main causes of the loss of the existence of *S. miniata* in the mangrove ecosystem of Totobo Village is because of its clumped distribution. This condition allows the *S. miniata* population to be more quickly exposed to overburdened waste because it is spread in clumped in areas that are easily accessible by sedimentation activities.

Table 2. Mangrove vegetation density at each station in Totobo Village, Pomalaa (reference site)

Research station	Mangrove density (tree/m^2)	Mangrove density (tree/ha)	Criteria
Station 1	0.57	5,700	Dense
Station 2	0.6	6,000	Dense
Station 3	0.4	4,000	Dense
Station 4	0.37	3,700	Dense
Station 5	0.37	3,700	Dense
Station 6	0.57	5,700	Dense
Station 7	0.43	4,300	Dense
Station 8	0.37	3,700	Dense
Station 9	0.53	5,300	Dense

Table 3. Distribution pattern of *S. miniata* at each station

Research station	Morishita Index (Id)	Category (distribution)
Station 1	1.34	Clumped
Station 2	1.32	Clumped
Station 3	1.31	Clumped
Station 4	1.29	Clumped
Station 5	1.28	Clumped
Station 6	1.33	Clumped
Station 7	1.32	Clumped
Station 8	1.28	Clumped
Station 9	1.31	Clumped

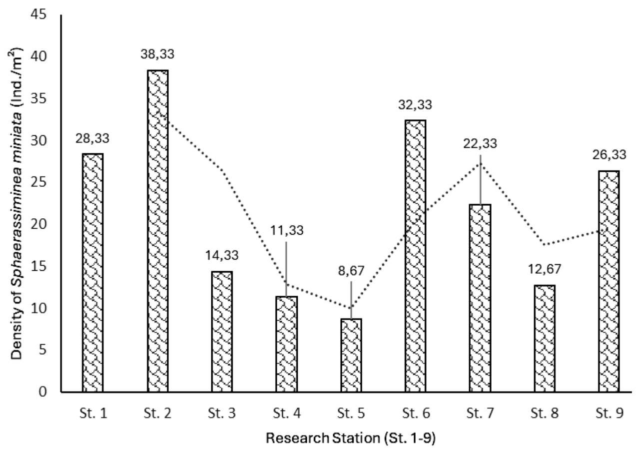

Figure 3. Average density of *S. miniata* in the reference site area

Figure 4. Condition of the mangrove ecosystem where *S. miniata* is found

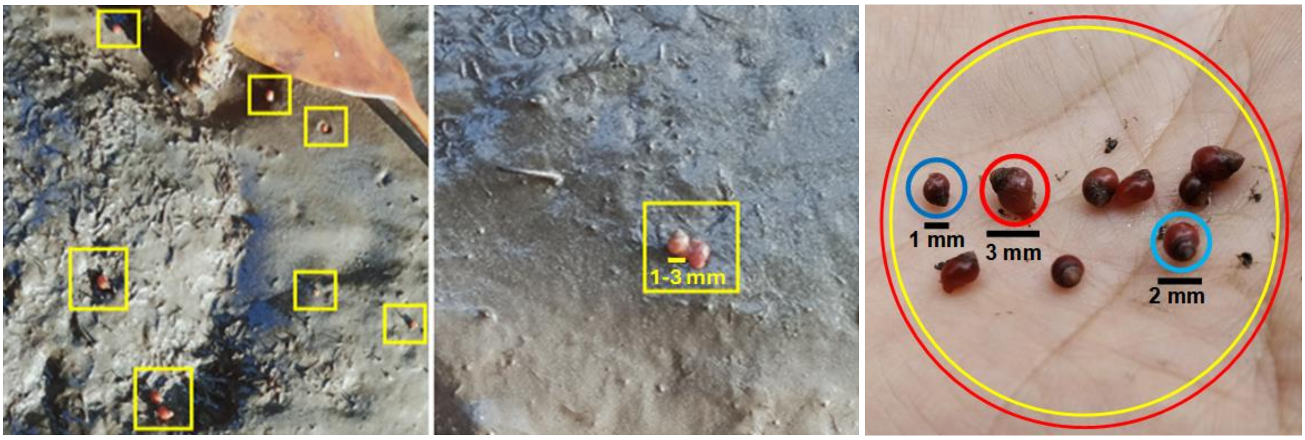

Figure 5. Appearance of *S. miniata* during low tides

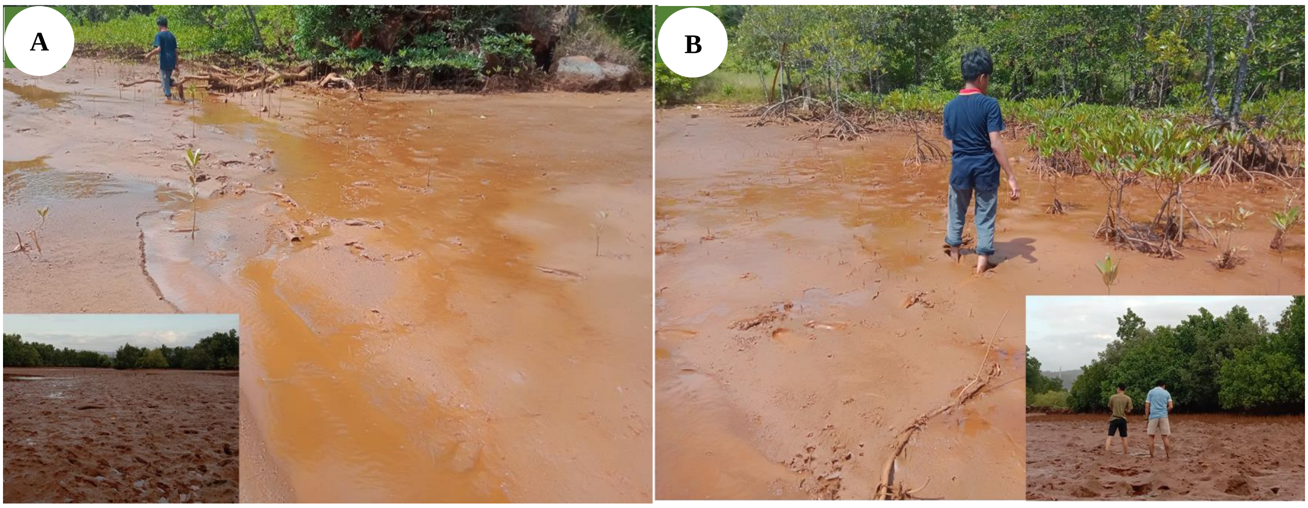

Figure 6. The mangrove area in Dawi-Dawi Village is affected by overburdened waste (A and B). No *S. miniata* was found at 9 observation stations (St. 10-18) in the impact area (Some of the images above are representative of areas affected by overburden)

Table 4. Status of the presence of *S. miniata* at each station at the reference site and areas affected by overburden in Pomalaa, Southeast Sulawesi, Indonesia

Research Station	Presence of *S. miniata*	Description (status)	Location category
Station 1	+	Exist	Reference site
Station 2	+	Exist	
Station 3	+	Exist	
Station 4	+	Exist	
Station 5	+	Exist	
Station 6	+	Exist	
Station 7	+	Exist	
Station 8	+	Exist	
Station 9	+	Exist	
Station 10	-	Not exist	Impact site
Station 11	-	Not exist	
Station 12	-	Not exist	
Station 13	-	Not exist	
Station 14	-	Not exist	
Station 15	-	Not exist	
Station 16	-	Not exist	
Station 17	-	Not exist	
Station 18	-	Not exist	

Discussion

Sphaerassiminea miniata is a type of gastropod that belongs to the order Littorinimorpha and family Assimineidae (Mollusca: Gastropoda). This type has a typical shell without any significant variations. *Sphaerassiminea miniata* is easily recognized by its size, color and behavior as a Gastropod. Morphologically, this type takes the general shell shape of the Assiminiidae family. The specimen is approximately 4mm in size, with a round, bright red or brownish red outer shell. It displays a jerky movement on the mangrove floor due to its thin, smooth, spherical shell and delicate operculum. Quite often found in mangrove areas with mud or sandy mud substrates. *S. miniata* is a sensitive group of gastropods found in the Totobo mangrove ecosystem. Its existence is very dependent on the quality of the substrate it occupies (Figure 4). This is proven by the abundance of *S. miniata* in the reference site area and not a single individual was found in the mangrove area exposed to overburden or acid mine sediment waste (Table 4).

On the other hand, a dense canopy structure (vegetation cover), dense root system, and mangrove density (Figure 1) are vital components that support the existence of these gastropods. However, these conditions must be balanced by the quality of the substrate or water floor which remains natural and distant from environmental pressure. In this case, the environmental pressure is derived from nickel mining activities, occured in Dawi-Dawi mangrove ecosystem, where no red berry snail population was found. Dawi-Dawi mangrove is considered as medium to very dense category, but its substrate is covered by overburden sediment waste that has been accumulating for a long time and continues to this day. In addition, the very small size of this snail (±1 mm) makes it very easy to be swept away or carried away with sediment or buried in piles of overburden and die. Environmental disturbance causes significant decrease of *S. miniata* population and eliminates its ecological function in the Pomalaa mangrove ecosystem. This sensitivity to changes in environmental quality makes *S. miniata* naturally act as a limiting factor between good condition of mangrove ecosystems and the disturbed or polluted ones by various anthropogenic activities originating from terrestrial areas. This statement is in line with the research results of Rahmadhani and Martuti (2023) that Semarang mangrove ecosystem is one of the coastal areas in Indonesia, which has a high level of vulnerability, danger, and risk of disasters and is under pressure from heavy and massive anthropogenic activities (Sudarsono 2011; Wibawa 2007; Martuti et al. 2019; Safitri et al. 2019). This condition encourages indigenous communities to make efforts to protect biota species in the Semarang coastal area through ecotourism activities (counseling and awareness) (Martuti et al. 2018). As stated by Basyuni et al. (2016), ecotourism can improve ecosystem management in coastal areas and can maintain mangrove ecotourism objects while still paying attention to the carrying capacity of the area.

Increasing public knowledge and awareness of preserving the coastal environment is a very important aspect, considering that damage to coastal areas is largely caused by destructive human behavior. The conditions above also influence the presence of several mangrove gastropods, especially the *S. miniata* type. This type is only found at station III because this station is directly connected to the sea so muddy water flows can be found leading to the sea at low tide. *Sphaerassiminea miniata* is often found in groups and covered by litter on the bottom substrate of waters because of its small size and epifauna nature. This species is often found inhabiting mangrove forests and likes areas with mud or sandy mud substrates that are rich in detritus. Adi et al. (2013) stated that *S. miniata* is a species that lives in groups and moves freely on sandy mud and mud substrates. Furthermore, Maghfiroh et al. (2023) reported that a comparison of the relative abundance values of Gastropoda in the Kawang and Kili-kili mangrove estuary areas showed that the highest abundance was dominated by *Melanoides riquetii* Grateloup 1840, *S. miniata*, *Nerita undata* Linnaeus 1758, *Littorina scabra* Linnaeus 1758, *Cerithidea cingulata* Gmelin 1791, *Nerita planospira* Anton 1838. The highest relative abundance index in the Kili-kili mangrove estuary area, Muncar sub-district at all stations is the species *S. miniata*, *N. planospira*, *C. cingulata*, *N. undata*, *L. scabra*, and *Nassarius olivaceus* Bruguière 1789. Meanwhile, the smallest relative abundance was found in the species *Cassidula nucleus* Gmelin 1791, *Nerita balteata* Reeve 1855, *Murex trapa* Röding 1798, and *Littorina carinifera* Menke 1830. The high abundance of *S. miniata* in the Kili-kili mangrove estuary area, Muncar sub-district, is because this mangrove area is still relatively natural and has good mangrove density and no pollution activities. A study by Hookham et al. (2014) found that *S. miniata* had the highest density on the surface of the mangrove mud on Langkawi Island and the Merbok River in Malaysia. Syahrial et al. (2023) reported that the presence of *S. miniata* gastropods in the mangrove ecosystem of Banda Aceh City after 18 years of the tsunami and 16 years of coastal rehabilitation was only found at two observation stations (station II (total 751 individuals from 7 species) and station III (total 1023 individuals. of 5 species)). Overall, the gastropods found consisted of 8 families, 8 genera, 10 species, and 6945 individuals. The most commonly found species was *C. cingulata* (5,400 ind.), followed by *Cassidula aurisfelis* Bruguière 1789 (525 ind.), *C. nucleus* (413 ind.), and *L. scabra* (216 ind.).

The minimal presence of *S. miniata* is closely related to the condition of the mangroves themselves, where the mangrove forests in Banda Aceh City are the result of rehabilitation activities due to the natural disaster of the tsunami, which has experienced internal succession in their habitat, so that the species used to be different from after the rehabilitation activities were carried out. Prolonged ecological pressure leads to certain species dominating in response to complex environmental changes. This results in the dominance of *C. cingulata* on the ground floor of the Banda Aceh mangrove ecosystem.

This statement is in line with Pribadi et al. (2009) that Cerithidea is a genus of gastropods whose members are widely distributed in mangrove forests, so their densities are often found to be high. Similar to Zvonareva and Kantor (2016), that *C. cingulata* is very abundantly found in mangrove ecosystem areas.

In addition, Zvonareva and Kantor (2016) stated that *C. cingulata* is considered a nuisance snail or pest, this is because there are very few predators and competitors in nature, so its population is high and can bloom (explode). Solanki et al. (2017) added that the explosion or blooming of *C. cingulata* in an area can also be caused by its very fast growth. The same condition occurs in other rehabilitated mangrove ecosystems, as reported by Chen et al. (2007) in the Jiulongjiang rehabilitated mangrove area, China found 8 species of mangrove gastropods and when compared with the results of this study, the results of the mangrove gastropod species found by Chen et al. (2007) is classified as fewer (8 species) than this study (10 species). Similarly, the results of the study by Syahrial et al. (2019) in the rehabilitation mangrove area of the Seribu Islands, Indonesia, namely that there are fewer species (3 species) when compared to this study (10 species), while the results of the study by Zvonareva et al. (2015) in the rehabilitation mangrove area Central Vietnam found more mangrove gastropod species (53 species) than the results of this study (10 species). Sugiarto et al. (2021) stated that the Segara Anakan mangrove forest functions as a spawning ground, nursery ground, and feeding ground for various types of animals such as fish (Zvonareva et al. 2015), crustaceans (Ahmed et al. 2018) and macrobenthos (Ariyanto et al. 2018). Apart from that, the roots of mangroves and mud substrates are very good for protecting mollusks, crustaceans, and several types of fish from strong water currents and attacks by predatory animals. Gastropods are one of the classes in the mollusk phylum that are most often found in mangrove forests (Lazzeri et al. 2014).

Most gastropods live in bottom sediments as filter feeders and deposit feeders, and some types are herbivores that eat fallen leaves or algae that live on plant bark and are predators (Puryono and Suryanti 2019). Segara Anakan is currently experiencing great pressure, namely the high rate of sedimentation from the land and illegal logging, which can destroy mangrove forests. The area of the Segara Anakan mangrove is 6,716 ha (Purwanto et al. 2014). Sedimentation in Segara Anakan mainly comes from the Citanduy, Cibeureum, and Cikonde rivers and a small part comes from coastal sedimentation. The decline in water productivity can indirectly affect the condition of the biota that live in mangrove forest areas, such as fish and macrobenthos. Gastropods, as one of the macrobenthos in the mangrove ecosystem in Segara Anakan, are expected to be affected by these conditions. Environmental pressure in the Segara seedling mangrove is simultaneous, with the average abundance of *S. miniata* being 0.818 ind./m^2. This abundance is very low compared to previous research results (Hookham et al. 2014; Maghfiroh et al. 2023; Syahrial et al. 2023). This condition strengthens the role of *S. miniata* as a biological indicator of stressed mangrove ecosystems in the region.

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