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Research Article

EXISTING CONDITIONS OF GASTROPOD COMMUNITIES IN AREAS AFFECTED BY OVERBURDEN NICKEL MINING IN THE MANGROVE ECOSYSTEM OF DAWI-DAWI, SOUTHEAST SULAWESI

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ARTICLE HIGLIGHTS

- Nickel mining activities significantly impacted the ecological integrity of the Pomalaa coastal area in Southeast Sulawesi, particularly in the mangrove ecosystem.
- The exposure of overburden waste in the mangrove ecosystem has led to the loss of important gastropod species and a decline in population of surviving species
- The low population of gastropod species in nickel mining impact areas indicates extensive environmental damage caused by these activities.

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ABSTRACT

Gastropod resources in the Dawi-Dawi mangrove ecosystem, Southeast Sulawesi are greatly influenced by the input of overburden wastewater from nickel mining activities. This condition has been going on for the last 2 decades and has degraded the habitat and structure of the gastropod community. The upstream connectivity associated with the existing nickel mining area and the Dawi-Dawi River estuary mean that the mangrove ecosystem in this area is continuously affected by overburden runoff. This research was carried out in June-August 2023 in the mangrove ecosystem of Dawi-Dawi Village, Southeast Sulawesi Province. This research aimed to determine the existing condition of mangrove gastropods affected by overburden. This research began by conducting initial observations in the field, to identify mangrove ecosystems affected by overburden. Research stations were determined using a purposive sampling technique and sampling of gastropods was carried out by using a simple random sampling method. The ecological index of mangrove gastropod community affected by overburden showed a tendency for a medium diversity index (H' = 1.81), low species richness (R = 1.42), high evenness index (E = 1.12), and no dominance of certain species (C = 0.19). The gastropod species found were of typical types that made up the mangrove fauna, namely *Terebralia sulcata*, *Terebralia palustris*, *Faunus ater*, *Telescopium telescopium*, *Hebra nigra*, and several taxa of climbing *Littoraria snails* which were found in the roots, stems and leaves of mangroves. The abundance of gastropods obtained was also very low, namely around 0-12 ind./m^2. At some points (rarely) schools of small snails of the type *T. sulcata* (5-21 ind./m^2) were sometimes found. This research showed that overburden waste eliminates or reduces the diversity and richness of gastropod species in the mangrove ecosystem of Dawi-Dawi.

Keywords:
ecological index, gastropods, nickel mining, overburden

INTRODUCTION

Community structure is a concept that examines the arrangement or composition of various species and their abundance in a community (Dibyanti 2023; Hanny 2023; Anggie 2022; Daulima 2021; Montesinos-Navaro *et al.* 2018; Hidayani 2015). Three approaches are generally used to describe community structure, namely 1) species diversity, 2) species interactions, and 3) functional interactions (Jennifer 2023; Hikmatul 2023; Ashari 2023; Schowalter 1996). Community structure can be studied through the composition, size, and diversity of species which are closely related to habitat conditions. Changes in habitat will affect community structure because changes in habitat will affect the species level as the smallest component that makes up the population in the community. One of the organisms that make up the basic aquatic ecosystem is mollusks, such as gastropods and other benthic biota (Amin *et al.* 2023; Aryanti *et al.* 2023; Hasanah *et al.* 2023; Mustofa *et al.* 2023; Yulianto *et al.* 2023; Lestari *et al.* 2021; Kinasih *et al.* 2018; Putro 2017; Mushthofa *et al.* 2014; Nugroho *et al.* 2012).

Gastropod community in the mangrove ecosystem of Dawi-Dawi Village, Southeast Sulawesi is strongly influenced by the input of overburden waste or reddish-orange sediment originating from nickel mining activities, both on a temporal and spatial scale. Overburden waste is carried by river flows that are directly connected to the upstream area where nickel mining is located and trapped in the mangrove ecosystem of Dawi-Dawi, Pomalaa, Indonesia (Hamzah *et al.* 2015; Hamzah 2009; Zubayr 2009).

Gastropods are benthic organisms that walk with their legs on the ground floor of the mangrove ecosystem so that almost all their biological activities are carried out on the bottom substrate (Harminto 2003; Chukaeva & Petrov 2023; Menon *et al.* 2023; Campbell *et al.* 2008). The "substrate" parameter is one of the key variables for the survival of the gastropod community in the mangrove ecosystem (Litaay *et al.* 2023; Mustofa *et al.* 2023; Yuanike 2023). Disturbances that occur in the substrate directly have implications for the destruction of their natural habitat and can slowly cause the death of individual gastropods (Magfirah *et al.* 2014). This condition has occurred in the Dawi-Dawi mangrove ecosystem since 5 decades ago (1968) or half of century ago until now (2023). Overburden waste is the waste rock in the form of mud/acid rock drainage which contains low mineral content (Hamzah *et al.* 2015; Hamzah 2009; Zubayr 2009).

Long and continuous exposure times cause the thickness of the overburden sediment to increase range from 10-30 cm, so that overburden exposure in the Dawi-Dawi mangrove ecosystem systemically degrades the living habitat and causes a drastic reduction in the abundance and taxa of the gastropod community. Empirical research on the structure of gastropod communities in overburden exposure areas in Southeast Sulawesi is not yet available, even in Indonesia generally. Therefore, research regarding the existing conditions of gastropod communities in mangrove ecosystems affected by overburden is very important, considering that scientific information regarding gastropod taxa that can survive in environments exposed to overburden waste is not yet available. Apart from that, this research has never been carried out on the coast of Dawi-Dawi Village, Southeast Sulawesi. This research aimed to determine the existing condition of mangrove gastropods affected by overburden.

MATERIALS AND METHODS

Time and Location of Research

This research began with preliminary research activities in the field for one month. Preliminary research takes the form of direct observation or survey at the research location to obtain initial information regarding research stations and gastropods. This observation activity helps researchers determine research station points and facilitates the process of determining them. In addition, the distribution of the gastropod community at the research location is specifically known, making it easier to collect samples when the research is carried out. This research was carried out in the period of July-September 2023, taking place in the mangrove ecosystem of Dawi-Dawi Village, Pomalaa District, Kolaka Regency, Southeast Sulawesi Province. Research stations were spread across mangrove areas exposed to overburden, consisting of 5 sampling points with 3 substations at each station. Repetition in this research was focused on the spatial distribution to strengthen the justification for concluding the condition of the gastropod community exposed to overburden in the Dawi-Dawi mangrove ecosystem.

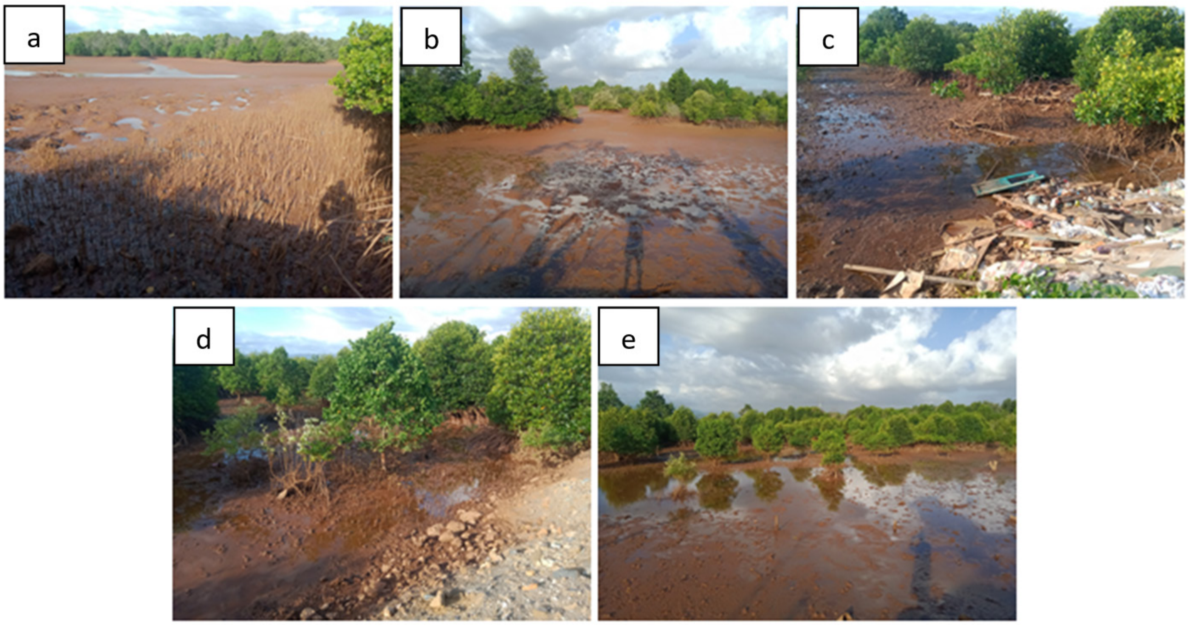

Figure 1 Research locations with overburden exposure in the Dawi-Dawi mangrove ecosystem

Figure 2 Research stations in the estuary of Dawi-Dawi Village, Pomalaa

Source: Google Earth (2024)

Figure 1 (a-e) are several mangrove areas affected by overburden in Dawi-Dawi Village, Pomalaa. These five areas are the only mangrove areas in Dawi-Dawi Village exposed to acid mine sludge waste (overburden), which is the main reason for determining them as research locations. The research locations were located at the mouth of the Dawi-Dawi River and were also the locations for sampling the gastropod community or stations in this study, i.e., (a) Station 1 was located to the north of the Dawi-Dawi River estuary which was dominated by pidada vegetation (*Sonneratia* spp.); (b) Station 2 was to the south of the Dawi-Dawi River estuary which was overgrown by mangrove vegetation (*Rhizophora* spp.), pidada (*Sonneratia* spp.), and api-api (*Avicennia* spp.); (c) Station 3 was to the west of the Dawi-Dawi Estuary which was dominated by mangrove vegetation (*Rhizophora* spp.); Stations 4 (d) and 5 (e) were located to the east of the Dawi-Dawi estuary, which was 100-150 m from each other; stations 4 and 5 were also dominated by mangrove and pidada vegetation.

Sampling Method

Sampling locations were determined by using a purposive sampling technique or deliberately based on the criteria "exposure to overburden waste" in the mangrove ecosystem of Dawi-Dawi Village. The placement of substations or distribution of sampling points for the gastropod community used the simple random sampling method. Meanwhile, the technique for collecting gastropod samples at each station adopted the handpicking technique. Generally, mangrove gastropods are benthic epifauna, so the collection process is very easy, just use your gloved hands. During the mangrove data collection, observations were made on the community structure of gastropods. The data were collected using quadrat transects of different sizes. For tree-type mangroves, a 10 m^2 quadrat was used, for sapling-type mangroves a 5 m^2 quadrat was used, and for seedling-type mangroves as well as for observing samples of the gastropod community, a 1 m^2 quadrat was used. Seven to ten quadrat plots were placed at each station to represent the station area, to make it easier to estimate the density and diversity of mangrove vegetation and the density of the gastropod population. The gastropod samples observed in this study were individual gastropods in living conditions. This was done to strengthen the justification for the relationship between mangrove density and gastropod diversity and density. The focus of observing gastropod samples in the mangrove ecosystem is centered on two areas, namely (1) the benthic substrate and (2) mangrove trees, specifically the roots, stems, and leaves of the mangrove where climber periwinkle gastropod dwelling. These types of climbing snails are dominated by *Littoraria* sp.

Data Analysis

Gastropod community data obtained from sampling results were analyzed using the following ecological index formulations:

1) The abundance of gastropods was analyzed using the formulation of Yasman (1998):

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

where:

A = abundance (ind./m^2)

xi = number of individuals (ind.)

ni = sample plot (m^2)

2) Analysis of the diversity of gastropod species using the Shannon-Wiener diversity index (Odum 1993), with the formula:

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

where:

H' = Diversity index

Ni = Number of individuals of each species

N = Total number of individuals

According to Wilhm (1975) the Diversity Index criteria are divided into 3 categories, namely:

$H' < 1.0$ = Low species diversity

$1.0 < H' < 3$ = Medium species diversity

$H' > 3$ = High species diversity

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

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

where:

E = Evenness index

H' = Diversity index

S = Number of species

The criteria for the species Evenness Index value are as follows:

$E < 0.31$ = Low level of species evenness

$0.31 > E > 1$ = Medium level of species evenness

$E > 1$ = High level of species evenness

4) The species richness index (Margalef Index) was analyzed based on the formula formulation according to Ludwig and Reynolds (1988):

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

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 species richness

$D > 4$ = High level of species richness

5) The Dominance Index was calculated using the formulation according to Odum (1993):

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

where:

ni = Number of individuals i

N = Total number of individuals of all species

The dominance index criteria consist of:

0 < C < 0.5 = No type dominates

0.5 < C < 1 = There is a dominant type

RESULTS AND DISCUSSION

Ecologically, the mangrove ecosystem is valued as a sediment trap. This ecological function is beneficial from an environmental perspective in a broad sense. However, it may harm aquatic organisms that inhabit the bottom of the waters if the trapped waste sediment from industrial activities for example contaminated with nickel. River flows carrying sediment with waste materials from nickel mining activities in upstream areas can directly cover the mangrove ecosystem's ground floor. On the other hand, the mangrove substrate becomes a living space and feeding ground area for benthic organisms, one of which is the gastropod community. These conditions impact changes in the ecological niche and structure of the gastropod community. The impact is proven in this study by the research results in the Dawi-Dawi mangrove ecosystem in the Pomalaa district. The results showed a decrease in the diversity (medium) and species richness (low) of gastropods in areas affected by overburden.

The number of gastropod species found inhabiting the Dawi-Dawi mangrove were only seven species (*Telescopium telescopium*, *Terebralia sulcata*, *Terebralia palustris*, *Faunus ater*, *Herba nigra*, *Littoraria scabra*, and *Littoraria melanostoma*), Meanwhile, in areas not affected by overburden (reference site), the number of species was much higher, namely 34 species.

In contrast, in the reference site area or areas with minimal disturbance, it was found to be ± 30 species. The low richness of gastropod species in the Dawi-Dawi mangrove ecosystem has implications for high species uniformity (E = 1.12). If this condition continues, a tendency for dominance by certain species may exist, although this has not happened (C = 0.19). The results of the gastropod ecological index analysis in the Dawi-Dawi mangrove ecosystem, Pomalaa, are presented in **Table 1.**

The gastropod ecological index analysis reveals that ecological pressure or an environmental imbalance has disrupted the homeostasis system in the Dawi-Dawi mangrove ecosystem (Table 1). The community's expression of its environment's quality is evident in the gastropod community structure, where diversity metrics, specifically species richness, indicate low indices. The Dawi-Dawi mangrove ecosystem exhibits a low number of gastropod taxa (species), directly influencing the ecological index. The diversity of gastropods in this ecosystem fell into the medium category with a tendency for low index values (H' = 1.81), while the richness was in the low category (R = 1.42).

The impact of low species richness in the Dawi-Dawi mangrove ecosystem is further manifested in the high gastropod uniformity index (E = 1.12). This condition raises concerns about the potential domination by certain species in the future, even though it is not observed currently; the trend is moving in that direction (C = 0.19) (Table 1).

Table 1 Gastropod ecological index in the existing nickel mining area in Dawi-Dawi Village, Pomalaa-Southeast Sulawesi

No.	Ecological Index	Value	Category
1	Diversity (H')	1.81	Medium
2	Species richness (R)	1.42	Low
3	Evenness (E)	1.12	High
4	Dominance (C)	0.19	No one type dominates

These ecological components serve as benchmarks for evaluating environmental quality or the health condition of an aquatic ecosystem. Overburden waste pollution in the Dawi-Dawi mangrove ecosystem not only alters the color of the substrate and water to reddish-brown in the mangrove area but also induces systemic changes in the life of aquatic organisms. This impact is visibly reflected in the structural composition of the gastropod community in the Dawi-Dawi mangrove landscape. This observed condition aligns with the findings of Sinapoy *et al.* (2020) regarding the diversity index (H') of gastropods in a mangrove ecosystem in the former nickel mining area in Tokowuta Village, Lasolo. The diversity index was found to be in the low category (H' = 1.36). The evenness index (E) indicated evenness with an unstable community at 0.70, while the dominance index, categorized as moderate in 0.35. The gastropod species diversity index in this area was classified as low, with moderately polluted water quality. This is attributed to the accumulation of chemicals from nickel mining, transported by water and settling in sediment (overburden).

A low diversity index value indicates low species richness, and there tends to be only one or a few species that have an abundant number of individuals. This condition causes this area to have low species diversity, the distribution of the number of individuals of each species is low, and the stability of the community is low due to the waters being polluted by nickel metal levels in the waters and sediments. According to Rachmawaty (2011), species diversity in an area is influenced by several factors, namely polluted substrate, availability of food sources, inter- and intra-species competition, disturbances, and conditions of the surrounding environment so that species that have high tolerance will increase while those that having low tolerance will further decrease. The types of gastropods affected by overburden in the Dawi-Dawi, Pomalaa mangrove area are also relatively the same as the gastropods found during research in the mangrove forest area of the former nickel mining area in Tokowuta Village, Lasolo, consisting of 7 species, namely *Terebralia sulcata*, *Cerithidea cingulata*, *Cerithidea quadrata*, *Nerita lineata*, *Littoraria scabra*, *Littoraria melanostoma* and *Telescopium telescopium* (Sinapoy *et al*. 2020).

The dominance index value obtained in this area was 0.35. This value is similar to the gastropod dominance index in the Dawi-Dawi mangrove ecosystem (C = 0.19), both in the low category. This value showed that in general, there are no dominant gastropods. The absence of dominant gastropod species in this area is thought to be due to the relatively small number obtained due to the decreasing quality of the aquatic environment, which is no longer suitable for gastropod species to live, except for species that have a high tolerance range for changes in environmental conditions. Kharisma *et al*. (2012) stated that the dominance index determines the type of gastropod that dominates a community and the influence of environmental quality on an individual's community. The results of another study which also had the same conditions, namely by Supratman *et al.* (2018), stated that the results of the analysis of the gastropod diversity index in all research locations were categorized as small diversity because the diversity index value was < 2 (Odum 1993).

The low diversity index at this location was caused by the extreme environmental conditions, such that certain species dominate the gastropods. The high dominance of a species will affect the low diversity of gastropods at the research location. The high dominance of a species can be caused by several factors, such as polluted habitat conditions so that only species that are tolerant of pollution can live in that habitat or the availability of abundant food sources for certain species so that other species cannot compete. Likewise, according to Arbi *et al.* (2019) and Cappenberg (2006), high and low species diversity index values can be caused by several factors, namely the number of species obtained, the presence of species that dominate other species, substrate conditions, and ecosystem conditions as habitat for gastropods. Ecosystem or environmental conditions are good if they show low Diversity Index (H') and Dominance Index (C) values. The abundance of gastropod species in the Dawi-Dawi, Pomalaa mangrove ecosystem is presented in **Figure 3.**

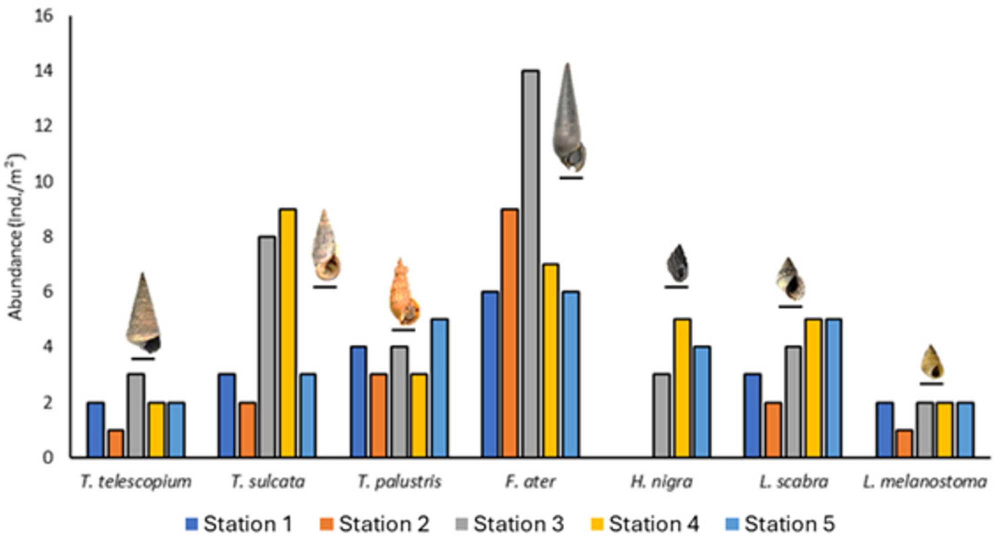

Figure 3 Average abundance of gastropod species in areas affected by overburden in the Dawi-Dawi mangrove ecosystem, Pomalaa

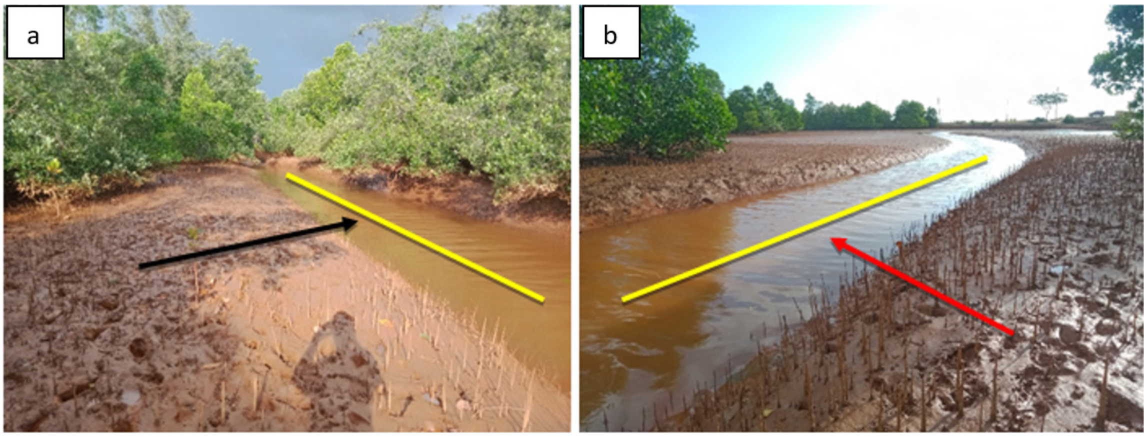

Figure 4 River flow carrying overburden sediment (receding conditions) which empties into the Dawi-Dawi mangrove area, Pomalaa. The area where overburden waste is trapped is to the east (a) and west (b) of the mangrove area

The gastropod types ***F. ater*** (6-14 ind./m^2) and ***T. sulcata*** (2-9 ind./m^2) have an average abundance far exceeding other species in the Dawi-Dawi mangrove ecosystem. The average abundance with the lowest value was found in the climber snail, ***L. melanostoma*** (1-2 ind./m^2). The image below shows the actual condition of the area affected by overburdened waste in the Dawi-Dawi mangrove ecosystem and the gastropod community living in it (**Figs. 4** & **5**).

Dawi-Dawi waters, Pomalaa receives overburden waste input from nickel mining activities in upstream areas with connectivity (flow) with estuary or mangrove areas. This condition has been going on for the last ± 2 decades, resulting in many changes to the life of aquatic organisms in the Dawi-Dawi mangrove ecosystem (Hamzah ***et al.*** 2015). Among the many macrozoobenthos organisms affected by overburden waste, the gastropod community is a typical aquatic biota of the bottom of the waters (benthos), which has experienced a decline in population density (**Fig. 3**) and its taxa. This decline happens because the ground floor of the mangrove ecosystem, which is the living and feeding ground for various types of gastropods, has been covered by overburdened sediment waste. In other words, the ecological niche which is rich in organic material and is needed by the gastropod community for its survival is directly degraded and lost due to input of overburden waste which continues to occur until now. Only seven types of gastropods were found in the Dawi-Dawi mangrove ecosystem, which has a very low average density (2-5 ind./m^2).

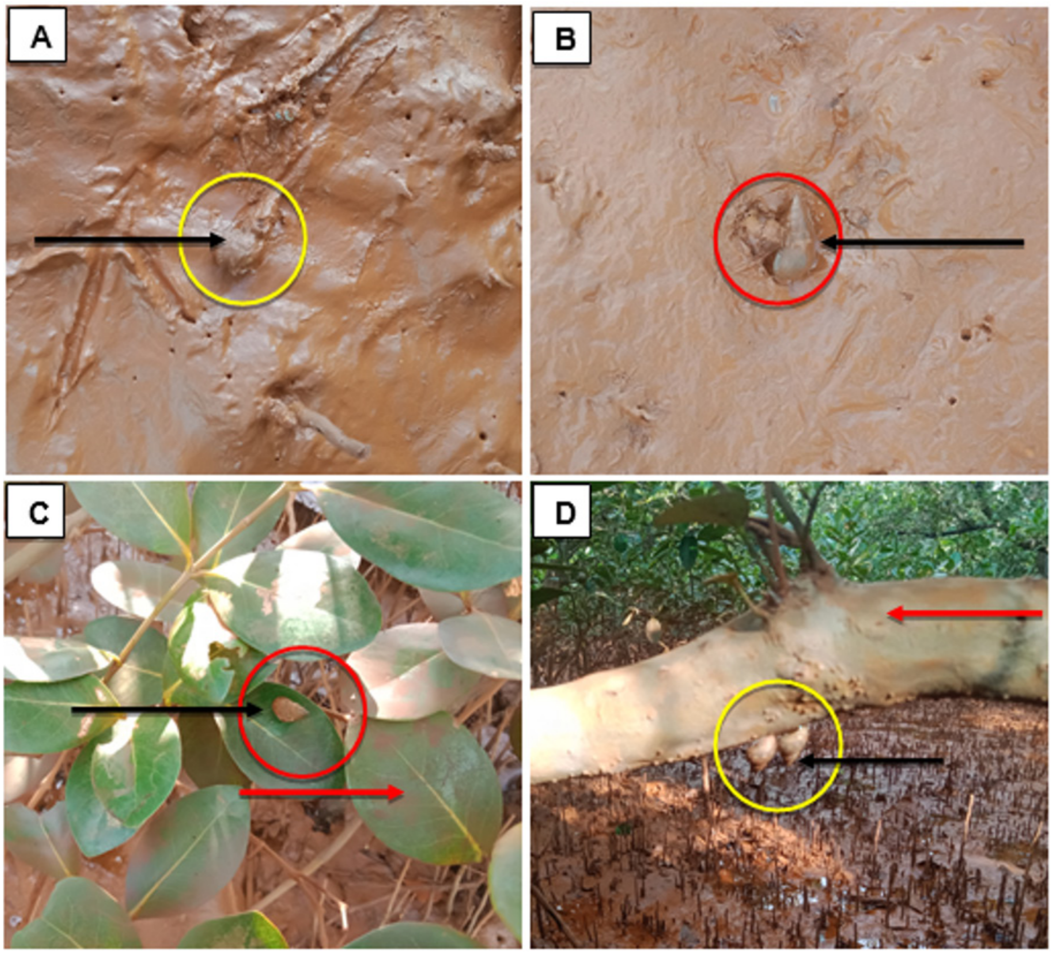

Figure 5 Existing condition of the gastropod community in the area affected by overburden waste in the Dawi-Dawi mangrove ecosystem, Pomalaa

Notes: *Terebralia sulcata* gastropods covered in overburden mud (A, B), and the leaves, stems and climbing gastropods of the *Littoraria scabra* species are exposed to overburden waste during high tide conditions, and visible at low tide on the reddish brown surface of the leaves, stems and shells of *L. scabra* (C, D).

Several types found in a large abundance, namely *F. ater* (6-14 ind./m^2) and *T. sulcata* (2-9 ind./m^2), are typical types of mangroves that have high resistance to changes in the quality of the aquatic environment. in mangrove areas, as well as other species such as *H. nigra*, *L. scabra*, *L. melanostoma*, *T. Telescopium* and *T. palustris* (Kurniawati *et al.* 2022; Arbi *et al.* 2019; Sarong *et al.* 2017; Sarong *et al.* 2015; Arbi 2014; Ayunda 2011; Wells 2003). Furthermore, Rachmawaty (2011) stated that species diversity in an area is influenced by several factors, namely polluted substrate, availability of food sources, inter- and intra-species competition, disturbances, and conditions of the surrounding environment so that species with high tolerance will increase. In comparison, those with low tolerance will decrease further. Rachmawaty's (2011) explanation above is very appropriate to the condition of the Dawi-Dawi mangrove ecosystem, which is polluted by overburdened sediment waste, and the impact is to eliminate feeding ground areas and other ecological spaces for the biological needs of the gastropod community. Arbi *et al.* (2019) emphasized that changes in the function of mangrove areas are the main factor that can threaten the stability of their flora and fauna, including the gastropod communities associated with mangrove areas.

Figures 4 and **5** above show the massive impact of overburden waste in the Dawi-Dawi mangrove area, where not only is the entire substrate area covered by overburden waste, but the surface of the leaves and trunks of mangrove trees is also covered by reddish-orange dust. The gastropod community that lives inside is affected, where the surface of the shell and operculum is covered by overburdened sediment waste, making it even more difficult for gastropod movement when moving (**Fig. 5**). The impact on the gastropod community is because, during high tide, the leaves and lower trunk/twigs

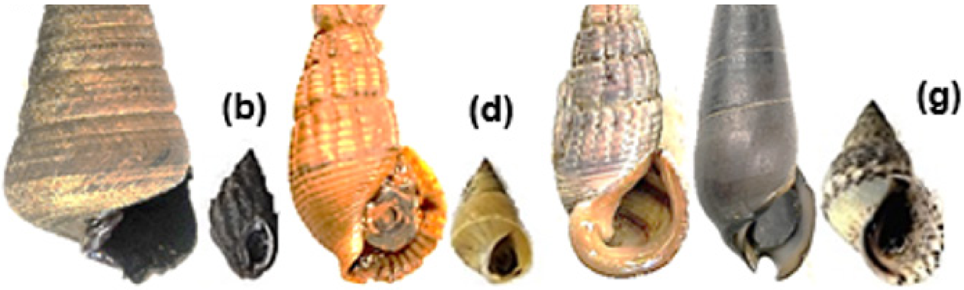

Figure 6 Seven species of gastropods found in the Dawi-Dawi mangrove ecosystem, Pomalaa

Notes: (a) *T. Telescopium*; (b) *H. nigra*; (c) *T. palustris*; (d) *L. melanostoma*; (e) *T. sulcata*; (f) *F. ater*; (g) *L. scabra*.

of mangrove trees are submerged by water, which carries sediment particles (overburden). The types of gastropods found in the Dawi-Dawi mangrove ecosystem are shown in **Figure 6**.

The existing condition of gastropod taxa (species) in the Dawi-Dawi mangrove ecosystem that is affected by overburden is directly related to the unique characteristics of these types of snails as native inhabitants of mangrove habitats and are not facultative or migratory species. This correlation can be seen from the adaptability of these 7 species to changes in water quality or disturbances that occur in their ecological environment. Rangan (2010) stated that the adaptability of a gastropod community to exponential changes in the habitat environment is an indicator or sign that the species can be categorized as native, facultative, and/or visitor species. The group of mangrove gastropods is known as a native species if the individual/ population of gastropods spends its entire life cycle in the mangrove ecosystem. Meanwhile, the facultative group can be found in mangrove areas and beaches, where this type of gastropod species tends to have euryhaline properties. In contrast, the visitor gastropod group is the type of gastropods in marine areas carried to the mangrove forest by current activity and dynamic waves in coastal areas.

Odum (1993) also explained that a species with the highest density indicates that the organism can occupy a larger space and thus develop more. The condition of the gastropod community in the Dawi-Dawi mangrove ecosystem is in line with the results of research by Maturbongs and Elviana (2016), where the *Littorinidae* and *Potamididae* families are the majority groups that dominate mangrove forest areas. The input of overburden waste reduces the number of sensitive mangrove gastropod taxa and slowly and massively reduces the number of individuals of each species in the mangrove ecosystem due to the nature of gastropod communities, which tend to be sessile or have limited movement. Maturbongs and Elviana (2016) stated that the activities around the mangrove ecosystem greatly influence the density of the gastropod community, which affects the survival of gastropods because living gastropods tend to stay settled with limited movement. Gastropods are very sensitive to changes in the water quality in which they live. Changes in the aquatic environment, for example, in river basins, affect the composition and diversity of the population of this class (Odum 1993). According to Fachrul (2007), pristine waters usually have high species diversity and vice versa for poor or polluted waters.

CONCLUSION

The abundance and number of taxa (species) of the gastropod community exposed to overburden waste in the Dawi-Dawi mangrove ecosystem experienced a drastic decrease from their natural conditions (without exposure to overburden). Overburden waste has a negative impact on the structure of the mangrove gastropod community. The diversity index is in the medium category (H' = 1.81), with low species richness (R = 1.42), high evenness (E = 1.12), and no dominance of certain species (C = 0.19).

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