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Gastropods on Marine Debris at Mangrove Ecosystem

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Abstract. *The mangrove ecosystem is one of the accumulation areas for various marine debris including plastic and also the habitat for gastropods. This condition allows direct contact between gastropods and debris which can be an entranceway for contamination in biota. This study aimed to know the species of gastropods in the marine debris in the Bulaksetra mangrove ecosystem in Pangandaran. The method used was stratified random sampling with a transect line of 100 m. Gastropods and debris in the 1 m x 1 m square in the 10 m x 10 m plot were collected, identified, counted, and determined in composition. There were 22 types of marine debris in the Bulaksetra mangrove ecosystem which were dominated by plastic. 16 species of gastropods were found in the area around the debris and 15 species were found attached to the debris. Gastropods can be found on the top, middle, or bottom surfaces of plastic waste. Faunus ater and Terebralia palustris dominate in the surrounding area and the debris. Treefauna gastropods utilize stuck debris to move from one part to another part of the tree. Plastic waste has become part of the mangrove habitat and there are interactions with gastropods that use it as a living medium.*

Keywords: *diversity, Faunus ater, gastropods, marine debris, plastic*

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INTRODUCTION

Marine debris, especially plastic, has become a global issue that can be found in various areas, ecosystems and harm marine biotas such as fish, turtles, marine mammals, and seabirds (Thiel et al., 2018; Duncan et al., 2021; Thiele et al., 2021; Kanhai et al., 2022; Zantis et al., 2021). The size of marine debris varies from micro to mega (Kroon et al., 2018; Manullang, 2019). Marine debris accumulation is clearly seen in various coastal areas. On the beach, marine debris creates a dirty impression and negatively impacts tourism (Ashuri & Kustiasih, 2020; Galgani et al., 2019). Marine debris is recorded as a part of fishermen's catches, disturbing coral reefs, and has been found in the digestive

tract of fish and aquatic biota (Nash, 1992; Kaladharan et al., 2020; Wongnutpranont et al., 2021). Most of the marine debris comes from land and enters the sea through the river (Jambeck et al., 2015). While the others come from direct disposal into the sea or coastal areas which then enter the waters. With various reported impacts, efforts to clean up debris in coastal areas, especially beaches, have been carried out by multiple parties (Nazriati et al., 2020; Husain & Saleh, 2022).

The mangrove ecosystem is an area that also affected by marine debris (Yin et al., 2020; Yoswaty et al., 2021). The location of the mangrove ecosystem in the estuary area can be exposed various marine debris from several directions, such as from land that enters rivers, oceans by tides, or through direct disposal (Fajriah et al., 2019; Nau & Sombo, 2020). Marine debris in this area can be found on the substrate and stuck in the root or other parts of the mangrove. Unlike the beach area, there have not been many efforts or movements to clean up debris in the mangrove, so this area has the potential to continue accumulating marine debris (Rahim et al., 2020). On the other hand, the mangrove ecosystem is a habitat for various biota and has ecological functions as a feeding ground, nursery ground, spawning ground, and abrasion barrier (Maulida et al., 2019). Macrozoobenthos, including gastropods, live in sediments and some attached to trees (Abubakar et al., 2022; Armansyah et al., 2022). Several macrozoobenthos biotas have been reported to colonize the existing marine debris in the mangrove ecosystems (Riascos et al., 2019).

Such other macrozoobenthos, gastropods live in sediments and some are attached to mangrove trees (Abubakar et al., 2022; Armansyah et al., 2022). These gastropods search for food on the substrate by eating fallen leaves and other organic material (Raw et al., 2017). In the other hand, microplastic contamination has been identified in sediments from mangrove areas (Pradit et al., 2022). This interaction can be one of the factors that allow the discovery of microplastic contamination in the gastropods (De-La-torre et al., 2020; Weber et al., 2021; Zaki et al., 2021). Gastropods have also been found living and attached to marine debris. This condition becomes a serious problem considering that people use se eral species of gastropods as foodstuff.

Various reports tend to examine aspects of gastropod diversity in areas exposed to marine debris. However, there is still limited information about the species of gastropods that directly interact with marine debris in the mangrove ecosystem. This study aimed to conduct an inventory of the gastropods species that are in contact with or attached to the marine debris in the mangrove ecosystem so that it can be determined which species are potentially affected or adapt to the presence of marine debris. This research contributes information on the composition of marine debris in the Bulaksetra mangrove ecosystem, gastropod species exposed to marine debris, gastropod species around the marine debris cover and forms of interaction between gastropods and marine debris.

MATERIALS AND METHODS

This research was conducted in March 2022 using an exploratory survey method in the Bulaksetra mangrove area, Pangandaran. A sampling of marine debris and gastropods was carried out by stratified random sampling at 2 stations. The sampling method used was a modification technique used by (Aditya & Nugraha, 2020). A 100 m line transect was laid out with 5 plots of 10m x 10m inside. In each plot, 5 plots of 1m x 1m quadrate were

placed. The marine debris found at 1m x 1m quadrate was collected, cleaned from sediment, dried, determined by the type, counted, and weighted. Gastropods present on the sediment surface, around the debris, and attached to the debris in the 1m x 1m quadrate were collected by hand picking, identified, and counted in the number. Identification of gastropod species refers to the identification guide by (Dharma, 2005). Measurements of the length, width, and weight of the shell were carried out on gastropods attached to the marine debris. The dimensions of the shell were measured using a digital vernier caliper Taffware SH20 and weighing with a Taffware Digipounds 0.01g scale.

The marine debris found was determined by its composition expressed as a percentage (%), density (pieces/m2), and weight (g/m2) (Prajanti et al., 2020). The same thing was also applied to the gastropod community where the total composition is expressed as a percentage (%) while the abundance of gastropods in the area around the marine debris is expressed as the number of individuals in a unit area (individuals/m2). The density of gastropods found attached to marine debris was expressed in the number of individuals per number of marine debris per type (individual/piece of marine debris). Gastropod species found around or attached to marine debris were described for their characteristics. The diversity of gastropods in the area around and attached to marine debris was analyzed using the following ecological indices:

Shannon-Wiener diversity index (H') (Shannon, 1948)= $-\sum Pi \ln Pi$ 1

Dominance index (C) (Odum & Barret, 2005) = $\sum Pi^2$ 2

Evenness index (E) (Hill, 1973) = H'/LnS 3

Desription

Pi = number of species to-i (ni)/ total number of all species (N)

S = number of species

RESULTS AND DISCUSSION

In the Bulaksetra mangrove area, 22 types of 6 categories of marine debris were found in various positions and conditions, where most of them lying around the surface of the substrate while the others were covered by sediment or stuck in parts of mangroves tree (Figure 1A). The plastics and rubber categories dominated in numbers (90.37%) followed by cloth and its derivatives (5.35%) (Figure 1B). By weight composition, the plastic and rubber category occupies a proportion of 46.55%, while cloth and its derivatives are 28.48%. Glass,wood and their derivatives have weight proportions of 13.74% and 10.38% respectively. The most common type of marine debris is plastic fragments followed by plastic packaging, styrofoam, cloth/clothing, and ropes (Figure 1C). The density of marine debris in the Bulaksetra mangrove area is 3.74 pieces/m2 and 24.53 g/m2.

In addition to the beach, the mangrove ecosystem becomes the potential coastal area for marine debris accumulation and these conditions are disliked by the community (Toisuta et al., 2019; Faizal et al., 2021). The presence of marine debris in the mangrove has been reported from various locations including ecotourism areas (Hastuti et al., 2014; Silmarita et al., 2019; Salestin et al., 2021). As with other studies, plastic and rubber debris are dominant in number and weight in the Bulaksetra mangrove ecosystem (Paulus et al., 2020; Yoswaty et al., 2021). Most of the waste is related to human activities such as food packaging, while the rest is clothing materials, part of fishing equipment, and some building materials. The presence of marine

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debris in mangrove areas can be sourced from water, either river flows or tides, but can also come from direct disposal (Kahar et al., 2020; Loliwu et al., 2021). Some types of plastic debris such as bottles and styrofoam with lightweight will float by water at high, move places, and then will lie back at low tide. Styrofoam, plastic bottles, shoes, and slippers were also found stuck or trapped between Rhizophora roots. When it has been stuck or trapped in a tight Rhizophora root, the debris will tend to be restrained and difficult to move. Marine debris in the form of fabrics, clothes, and diapers over time tends to be trapped in sediment so that it becomes heavy, difficult to be carried away by water, and lying on the substrate. Meanwhile, the rope is often found wrapped around the roots or other parts of the mangrove (Purba et al., 2017). Mangrove areas can have a role in catching large-sized marine debris (Li et al., 2021). The more complex and dense mangrove vegetation can also increase its ability to trap marine debris either from land, rivers, or the sea (Martin et al., 2019; Luo et al., 2021). On the other hand, an increase in marine debris amount will be correlated with lower abundance of gastropods (Djohar et al., 2020).

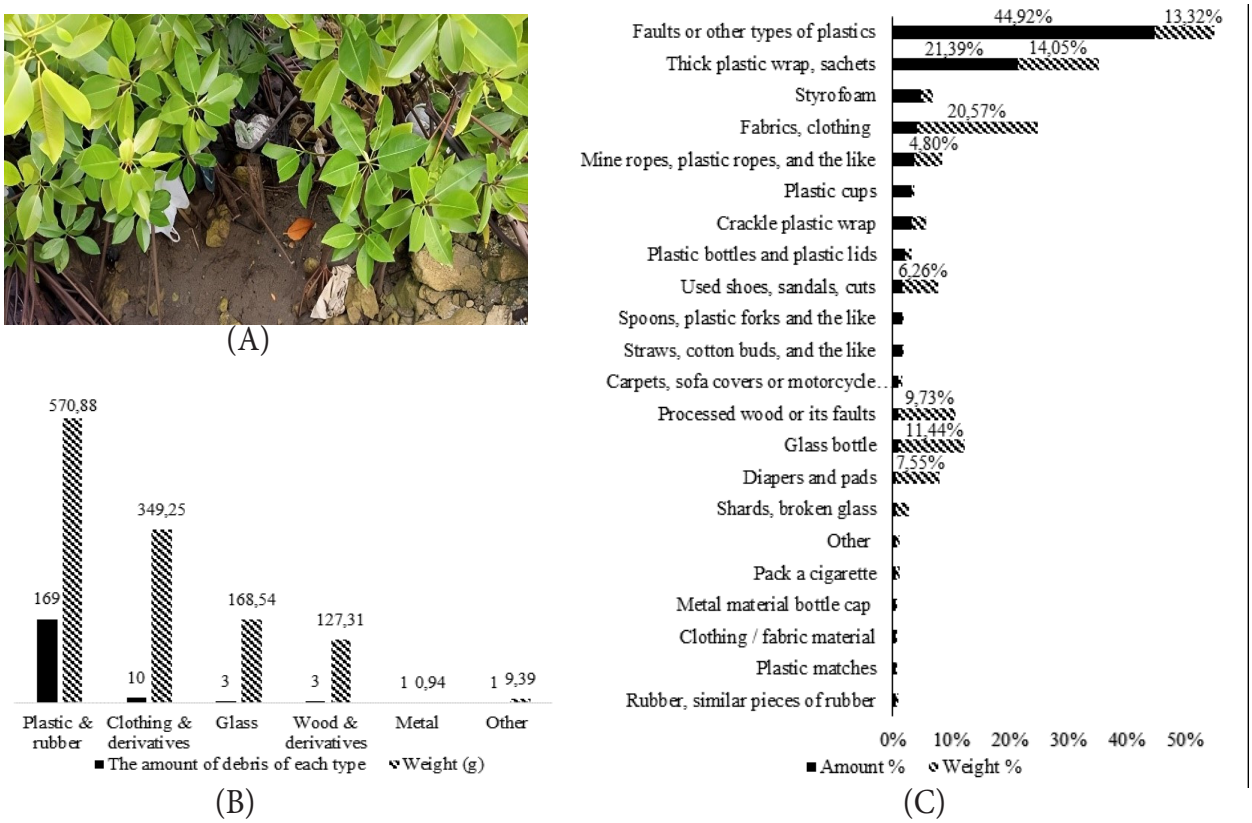
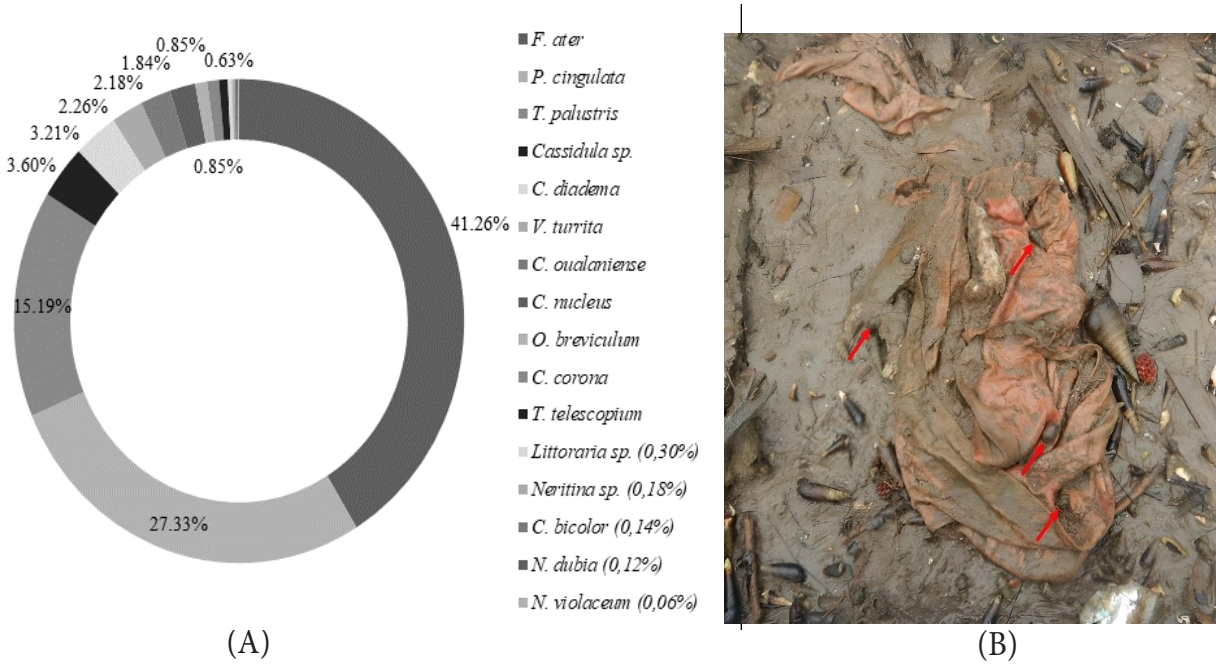


Figure 1. (A) Marine debris at the Bulaksetra mangrove area; (B) The amount and weight of marine debris by category; (C) The composition of marine debris types in the Bulaksetra.

The Bulaksetra mangrove area with marine debris at the same time is also a habitat for various gastropod species. Previously, the Bulaksetra mangrove ecosystem was reported to be a habitat for 12 species of macrozoobenthos and included 9 species of gastropods (Krisnafi et al., 2021). These gastropod species live on substrates and are potentially exposed to marine debris with the discovery of microplastics in sediments (Daulima et al.,

2021; Maghsodian et al., 2022). In this research, at least 16 species of gastropods from 6 families were found in the area around the marine debris cover (Figure 2A). In addition to epifauna, some treefauna such as Littoraria and Cassidula are also found around areas with marine debris. The gastropod density around the area with marine debris was 99.02 ind/m2. Besides being found around marine debris, gastropods are also found attached to the debris (Figure 2B).



(A) (B)

Figure 2. (A) The composition of gastropods in the area around the marine debris cover; (B) gastopods on the marine debris (red arrow) and the area around the marine debris cover in the Bulaksetra mangrove area.

The largest proportion of gastropods in the area around the debris cover was filled by *Faunus ater*, *Pirenella Cingulata* and *Terebralia palustris* (83.78%), while the rest were filled by 13 other species. These three gastropod species are commonly found in the mangrove area of Pangandaran or Segara Anakan (Pribadi et al., 2009; Nurfajrin & Rosada, 2018; Sugiarto et al., 2021). *F. ater* from small to adult size (5.30 mm to 55.77 mm in length) can be found in the area around the debris. *F. ater* is the dominant species and is widespread in Bulaksetra where the density can reach 153.63 individuals/m2 and fill 64.04% of the community (Krisnafi et al., 2021). The density of *F. ater* around the debris can reach 40.86 individuals/m2. *F. ater* are herbivores that feed on detritus and organic matter from the substrate (Agustina et al., 2017). Like some other areas, *F. ater* in Bulaksetra was taken by people for consumption (Saenab et al., 2014). *P. cingulata* is an obligate deposit feeder that is commonly found in estuary areas and is often considered a pest because of its large population (Solanki et al., 2017). The largest gastropod species found around marine debris are *T. palustris* and *Telescopium telescopium*. *T. palustris* is often found in groups consuming mangrove leaves that have just fallen on the substrate (Raw et al., 2017). The substrate in Bulaksetra which is a mixture of mud and sand meets the criteria as a gastropod habitat (Nurfajrin & Rosada, 2018; Waran et al., 2020). The presence of mixed mangrove vegetation in Bulaksetra become an ideal habitat for treefauna gastropods although some report

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says that there are no significant differences between mangrove canopy cover and the abundance of Mollusca (Hakim et al., 2021; Kusmana & Ningrum, 2016; Tinambunan et al., 2021). Polluted mangrove areas can have lower diversity and abundance of gastropods (Suratissa & Rathnayake, 2017).

15 species of gastropods were found attached to 16 types of marine debris in the Bulasksetra mangrove area. *F. ater* was the most common species found attached to marine debris (Figure 3A). Plastic fragments/other types of plastic, thick plastic packaging/sachets, and fabrics/clothing were marine debris with the highest number of gastropod species (Figure 3B).

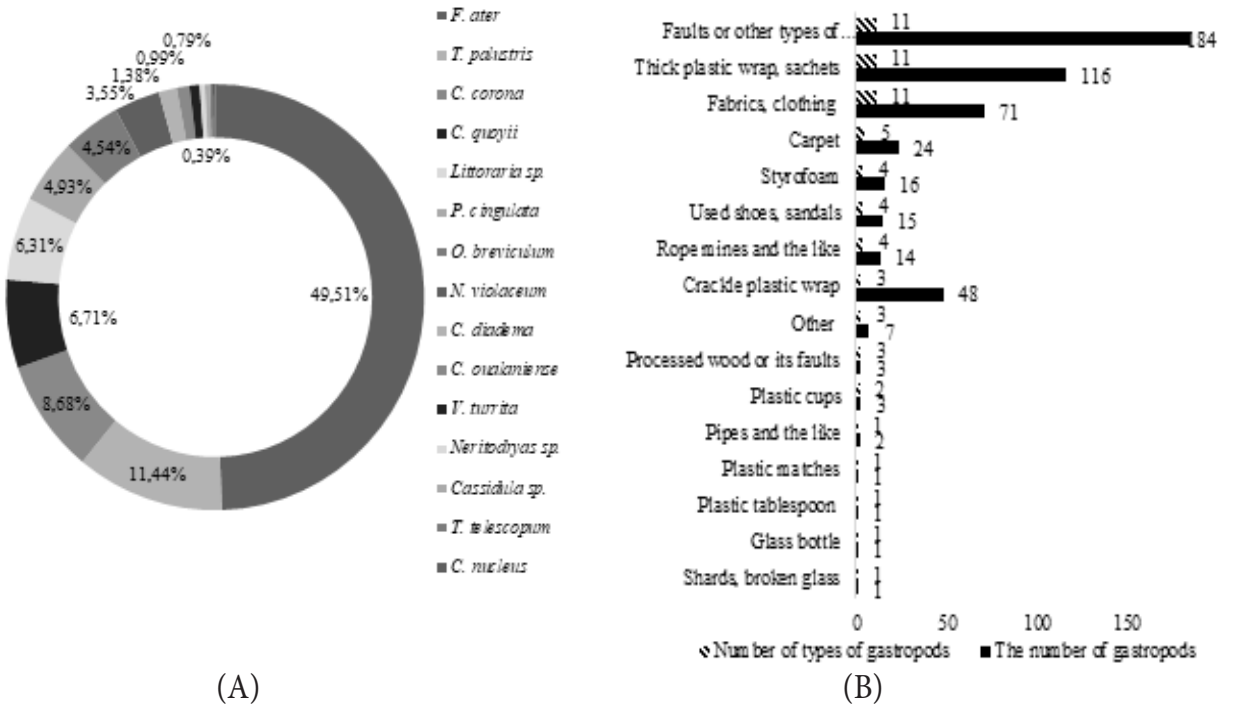

Figure 3. (A) The composition of gastropods attached to the debris; (B) The number of species and number of gastropods attached to waste in the Bulaksetra mangrove ecosystem.

Plastic waste has been reported to be a colonization medium for microorganisms and an attachment surface for microalgae and Cirripedia (Gallo et al., 2018; Minchin, 1996; Wright et al., 2020). Gastropods are mostly found attached and live on wet surfaces or submerged marine debris. However, gastropods are not always found on the upper surface of debris, some are also found covered by debris or in the inner part of the debris. (Figures 4A and 4B). All *O. breviculum* was obtained from the upper surface of the marine debris. *T. palustris* can be found consuming mangrove leaves with plastic debris underneath. *F. ater* and *Neripteron violaceum* were the species that can be found in all three positions. Some treefauna can be found in stuck marine debris in roots or other parts of mangrove trees (Figure 4C). Treefauna such as Littoraria, Cassidula and *Cerithidea quoyii* can be found in exposed marine debris. Gastropods use marine debris as a medium to move from one part to another part of the mangrove tree.

Plastic debris such as fragments, pack-

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(A) (B) (C)

Figure 3. (A) *T. palustris* covered in plastic waste; (B) *V. turrita* and *T. palustris* on the surface of fabric debris; (C) *Littoraria* sp. above styrofoam debris

Table 1. Distribution of gastropod species on marine debris in the Bulaksetra mangrove ecosystem.

Gastropods Species	Amount of Marine Debris Type	Highest Density of Gastropods (Individual /Type of Marine Debris)	Marine Debris with The Highest Density of Gastropods	Gastropod Weight (g)	
				Largest	Smallest
Faunus ater	8	58	Plastic fragment	3.86	0.01
Littoraria sp.	8	6	Styrofoam; carpet	0.07	0.01
Neripteron violaceum	8	2	Plastic fragment	0.22	0.01
Terebralia palustris	7	27	Fabric	34.64	0.97
Cerithidea quoyii	7	6	Sandals	1.75	0.01
Clithon corona	5	15	Plastic fragment	0.23	0.01
Optediceros breviculum	4	7	Plastic packaging	0.01	0.01
Coronula diadema	4	4	Plastic fragment	0.17	0.01
Pirenella cingulata	3	8	Fabric	0.73	0.25
Clithon oualaniense	3	2	Fabric; plastic fragment	0.35	0.01
Vittina turrita	4	1	Glass bottles; sachets; building materials; plastic fragment	3.12	0.08
Neritodryas sp.	2	1	Foam	0.36	0.04

aging, and fabric become marine debris with the highest number of gastropod species followed by carpets, styrofoam shoes/sandals, and ropes. Different from plastic debris, styrofoam is known to be a source of harmful additive compounds for marine life with an unknown impact on gastropods (Jang et al., 2016; Weber et al., 2021). On one piece of plastic debris (packaging or fragment) there are up to 5 species of gastropods (*F. ater*, C. quoyii, Littoraria, N. violaceum, and O. breviculum). The densest gastropod that can be found on one piece of plastic debris was 77 individuals/pieces of marine debris. Small-

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sized *F. ater* can reach density of 58 individuals/ pieces of plastic debris. Other species found in quite large quantities on one piece of marine debris are *T. palustris* (27 individuals/ pieces of debris), *C. corona* (15 individuals/ pieces of debris) and *P. cingulata* (8 individuals/pieces of debris). The plastic debris attached by *F. ater*, *Clithon*, *P. cingulata*, *O. breviculum*, and *N. violaceum* was in wet or submerged conditions and was often covered by sediment.

Fabric debris covered with sediment became a living medium for epifauna (*F. ater*, *P. cingulata*, *T. palustris*, *C. oualaninense*, *C. corona*, *T. Telescopium*) to several treefauna such as *C. quoyii* and *Cassidula*. In fabric debris, gastropods tend to be found more on the upper surface of the debris. In one piece of fabric or clothing debris can be found up to 6 types of gastropods (*F. ater*, T. palustris, *P. cingulata*, *C. oualaniense* and *C. corona*). The largest density of gastropods found in one piece of fabric debris was 43 individuals/ pieces of debris. Gastropods were also found attached to the glass and organic debris.

Table 2. Indices of diversity, dominance and uniformity of gastropod communities in debris and the area around the waste cover.

Gastropod	Number of Gastropods Species	H'	C	E
Attached on the marine debris	15	1.78	0.28	0.66
In the area around the marine debris cover	16	1.64	0.27	0.59

With the most similar species composition, the ecological index values for gastropods in the area around the marine debris cover or in direct contact with the debris are in the same moderate category. Meanwhile, the dominance and evenness indices values are low and moderate (Table 2). This shows that most gastropod species in the mangrove area have the potential for direct contact with marine debris.

Direct contact of gastropods with inorganic marine debris, especially plastic, opens the potential for contamination of biota. Microplastics are reported to have been found in *T. palustris*, *T. telescopium*, *Cheritidea*, and *Littoraria* sp. (Fitri & Patria, 2019; Patria et al., 2020; Putri & Patria, 2021; Siahaan & Patria, 2021). Plastic can cause death in marine life because it causes disturbances in the gastrointestinal tract and decreased reproductive ability (Suratissa & Rathnayake, 2017). Some species such as *T. palustris* and *T. Telescopium* are known to be consumable, so there is a possibility of microplastic transfer when consuming it (Harahap et al., 2022; Merly et al., 2022).

CONCLUSION

Plastic and fabric are marine debris categories that can serve as mediums for gastropod attachment in the mangrove ecosystem. Most of the gastropod species present in the surrounding area of marine debris can also be found in direct contact with or attached to the debris. Direct contact with marine debris occurs not only for epifauna but also for treefauna gastropods. The value of the diversity index of gastropods attached to the marine debris and those around the debris are in the same category, which is moderate. Knowing that some gastropod species are exposed to and affected by marine debris indicates that marine debris pollution in mangrove areas requires management of its sustainability as a habitat. Although cleaning up the marine

debris in mangrove areas is quite difficult to do, this needs to be done with the potential for contamination to the gastropods and the food chain through direct contact. Several gastropods exposed to marine debris are known to be consumption species that are eaten by the surrounding community, so further studies are needed for the potential of microplastic contamination concerning food safety.

AUTHOR CONTRIBUTION

N.R.P. designed the research, supervised all the process, collecting data, analysed the data and wrote the manuscript; R.A.K. collecting data and wrote the manuscript; P.M.D. collecting data and analysed the data; MA wrote and editing the manuscript. N.R.P. is the major contributor of this article.

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CONFLICT OF INTEREST

We declare that we have no conflict of interest either regarding the order of the authors, research, and research funding.

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