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# The Effect of Domestic Waste on Mollusca Diversity and Their Role in the Ecosystem of the Mangrove Area in Tarakan, North Kalimantan

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## ABSTRACT

Mangroves are vital ecosystems for biodiversity, but are increasingly threatened by pollution, especially domestic waste. This study focuses on the impact of domestic pollution on the diversity of Mollusca on Tarakan Island, North Kalimantan. Although several studies have examined molluscan diversity, there is a lack of analysis of the direct impact of pollution on these species. The method used was belt transects to measure species diversity, dominance and distribution of Mollusca in 4 habitats. The results were conducted in four mangrove habitats, and 36 species of Mollusca, 32 species of gastropods, and four species of Bivalvia were identified. The results showed that habitat 1, with the lowest level of pollution, had the most stable community index, while the habitat with the highest level of pollution showed a significant decline based on the community index. These findings confirm the importance of protecting mangrove ecosystems to maintain Bivalvia diversity and provide a basis for better environmental management policies. This research also opens opportunities for further studies on the interaction between pollution and biodiversity in mangrove ecosystems.

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## INTRODUCTION

Mangroves are complex and diverse ecosystems found on tropical and subtropical coasts around the world (Contreras et al., 2018; Kruitwagen et al., 2010). Mangrove vegetation has morphologically and physiologically adapted to the dynamical and physical properties of coastal environments (Ong & Gong, 2013). Mangroves are vital in coastal ecosystems because they provide habitat, food (Kumari et al., 2020), spawning grounds (Rasmeemasmuang & Sasaki, 2015), and protection from predatory animals (Raghunathan et al., 2018) for numerous aquatic fauna's species, including molluscan. Molluscan hold a vital role in the mangrove ecology. They serve various ecological services such as water filters, herbivores, predators, and detritivores as well.

Despite having a vital role in the surrounding ecosystem, the sustainability of the Mangrove forests is facing various threats under anthropogenic pressure from urbanization, construction projects, garbage dumping, ship operations, and shrimp ponds (Afonso et al., 2021; Guerra-García et al., 2021; Jacquot et al., 2023; Kesavan et al., 2021) Climate change-induced uncertainty in natural cycles and environmental processes (Fanous et al., 2023) and human activities as well, are the major variables ascending coastal vulnerability (Gayo, 2022; Sohaib et al., 2023; Sudhir et al., 2022). The coastal vulnerability also intensifies the rate and number of endangered species in the mangrove environment (Come et al., 2023).

Mangrove pollution is a common problem for populous island areas due to domestic waste.

However, the pollution did not yet gain particular attention before it reached a certain threshold level (Aloy et al., 2011) or when the effect could directly be felt by the surroundings. Most of the people settled in the coastal area have a typical mindset that mangrove areas could be waste dumps where they can throw anything in the areas. However, in recent decades, people have realized that mangrove areas have only limited capacity to absorb waste. However, mangrove areas should not be used as a disposal dump because it could also directly affect the marine flora and fauna. Not only are facing domestic waste, but mangrove ecosystems are also threatened by over-exploitation for timber, land reclamation, dredging, and climate change (Flipkens et al., 2024; Outa et al., 2024). The increase of human population and activities as well, including in the coastal area have intensified the rate of biodiversity extinction by 1,000–10,000 times the rate of natural extinction (Lahbib et al., 2022).

Even minor changes to flora and fauna can greatly impact biodiversity, leading to local extinctions. This deterioration also affects mollusks residing in mangrove habitats (Bürkli & Wilson, 2017; Verones et al., 2022). Molluscans are an extremely diversified and extensive class of invertebrate organisms (López-Alonso et al., 2022). Researchers have identified approximately 85,000 species, comprising 52,525 sea molluscans, 24,000 terrestrial mollusks, and 7,000 freshwater species (Chapman, 2009). Furthermore, mollusks have substantial ecological and economic importance as food and cosmetic substances (Boissery et al., 2022; Duke & Larkum, 2019).

Several countries around the world commonly encounter plastic waste, a major pollutant (Supriatna et al., 2023; Vorsatz et al., 2021). On the coastline, plastic waste is common, originating from either domestic waste or shipments from other locations transported during high tide. Moreover, Tarakan generates plastic waste by cultivating seaweed using plastic bottles. People discard these unused bottles, causing pollution in the coastal regions. Plastic is a major problem for island areas because it will be very difficult to process due to limited land and resources (Choudhary et al., 2024). This will result in a significant amount of plastic going unprocessed, ultimately finding its way into the mangrove area. Plastic in the mangrove area not only creates aesthetic issues but also poses numerous environmental challenges to the sustainability of the ecosystem. Tanin can cause the death of fauna in the mangrove area due to blockage of the digestive tract and decreased reproductive performance (Abdel Gawad, 2018; van Bijsterveldt et al., 2021). Plastic debris in coastal areas harms and kills many mangrove species, according to ample evidence (Mendes et al., 2023). Moreover, other anthropogenic activities already threaten many of these species. Research on molluscan on Tarakan Island (Ibrahim & Nugroho, 2020; Nugroho & Putri, 2024; Salim et al., 2019; Taqwa et al., 2017; Toding Bua, 2017) provides an overview of the diversity of molluscan, but there is a gap in terms of the effects of pollution by domestic waste.

Therefore, to overcome the negative problems caused by pollution, it is necessary to strengthen environmental protection policies. In addition, public awareness about not throwing garbage in mangrove areas can reduce pollution levels. Previously, researchers have made efforts to explore the impact of domestic waste problems in mangrove areas (Campos et al., 2023; Fajriaty et al., 2024; Selvaraj & Portilla-Cabrera, 2024). However, only a few have analyzed the direct impact on fauna, in this case molluscan. Therefore, this study aims to analyze the impact of domestic pollution in the mangrove area on the diversity of Mollusca on Tarakan Island. Figure 2 depicts the mangrove area of Tarakan Island; this reflects the pollution level and the community's apathy towards the mangrove area's protection.

## MATERIALS AND METHODS

### Study Area and Data Collection

The coordinates of Kalimantan's northernmost point are 117°30'50"-117°40'12" E and 3°14'23"-3°26'37" N. Four nearby areas form the island's mangrove forests: Mamburungan (MB) at N 3°16'25", E 118° 36'45", Tanjung Batu (TB) at N 4°14'27", E 113°38'53", Juwata (JW) at N 2°26'21", E 117.34'33", and Amal Beach (PA) at N 5°15'33", E 117°39'13".

In addition, we also wanted to see the differences in characteristics in each habitat polluted by waste, such as muddy and sandy (Habitat 1), sandy, rocky, and muddy substrates (Habitat 2); mangrove and sandy (Habitat 3); and rocky and coral (Habitat 4) on the coast of Tarakan Island, North Kalimantan.

The study on the diversity and distribution of fauna in the mangrove area of Tarakan Island was conducted from May to July 2024. The belt transect method was used to study of species richness and its association with mangroves (Anderson &

Pospahala, 1970; Manly & Alberto, 2015). A stratified random sampling design was used to place belt transects in mangrove areas. Sampling locations are shown in Figure 3, consisting of four belt transects with a fixed width of 5 m and length of 300 m placed in each habitat type. Visual observations were made to increase species richness in the selected habitat types and observe domestic sewage's impact. Sampling was done at low tide. The four habitats experienced similar tidal influences; however, the impact of inland water intrusion was not the same in all habitats. Visual data determined the availability and interactions between molluscan and domestic sewage.

The species of molluscan found in the four habitats were identified and confirmed using several methods, such as the Dharma (2005), Hubber (2010), and the website www.marinespecies.org. All empty molluscan shells collected were separated into genus based on external morphologic characteristics. Empty and live shells were collected and preserved at the Basic Laboratory of the University of Borneo, Tarakan, but live shells were preserved in 70% alcohol as type specimens for future research activities.

Abiotic data were measured using several parameters such as water quality, including temperature, dissolved oxygen, and salinity. A total of 9 sites were tested for water quality using an

(Habitat 1) (Habitat 2) (Habitat 3) (Habitat 4)

**Figure 1.** Habitat type for Mollusca observation, muddy and sandy (Habitat 1) sandy, rocky, and muddy (Habitat 2); mangrove and sandy (Habitat 3); and rocky and coral substrates (Habitat 4)

**Figure 2.** Condition of domestic waste


**Figure 3.** Mollusca sampling locations and parameter measurement

instantaneous water quality meter. Testing of these parameters was conducted at low tide from July 12 to July 15 as an initial test of water quality. In addition, diversity was measured using the (Shannon & Weaver, 1949), dominance using (Simpson, 1949), and distribution pattern using the standardized (Morisita, 1959).

## RESULTS AND DISCUSSION

The coastal area of Tarakan Island recorded a total of 36 species of molluscan. A total of 32 Gastropod species dominates the coastal area of Tarakan Island. Table 1 lists up to 4 species of bivalves. The total number of species in each area of Tarakan Island ranges from 20 to 34 species. Based on the research results, it shows that most gastropod families include Cerithiidae (463 individuals), Littorinidae (415 individuals), Nassariidae (123 individuals), Neritidae (322 individuals), Potamididae (163 individuals), and after that, Veneridae (117 individual) and Placunidae (25 individuals) are the dominant families of bivalves. The Littorinidae family comprises arboreal members that inhabit roots, leaves, and mangrove bark.

The diversity of gastropods was higher than that of bivalves in mangrove areas due to gastropods' better tolerance to the harshness of the mangrove environment (Nugroho & Putri, 2024). Additionally, there are many examples of changes in morphology (Gutierrez, 1988), behavior (Chapperon et al., 2017; Iacarella & Helmuth, 2011; Reid, 1985; Tanaka & Maia, 2006; Waki, 2017), and physiology (Leung et al., 2020; Stickle et al., 2015) that can happen at different stages of a living thing's life. The results of the research conducted support the statement above in Figure 4.

According to observations made during the period, molluscan diversity in Habitat 1 (Figure 5) is extremely high compared to the other three habitats. The highest species found in this habitat is *C. coralium* (363 individuals), and the second highest is *P. alata* (114 individuals). Molluscans play an important role in human food structure, especially for people living in mangrove areas. The molluscan distribution in an area can illustrate that the food chain in the ecosystem is healthy (Bürkli & Wilson, 2017; Come et al., 2023; Verones et al., 2022). The observation of 19 gastropod families revealed two abundant families, Potamididae and Neritidae, each with five species, primarily found in rocky, muddy, and coral substrate habitats. We recorded the Potamididae family as the second largest, with 4 species, and found it in the same habitat (Figure 6).

The distribution of food sources and substrates observed in Habitat 1 drives the molluscan distribution. On the other hand, very little domestic waste, in the form of plastic waste, drives the distribution of gastropods in Habitat 1. In this habitat, we recorded several bird species (White-faced Stork and Reef Stork), which are closely related to the trophic structure. These birds are usually associated with the food chain in an area; if there are birds living, then the ecosystem is running well.

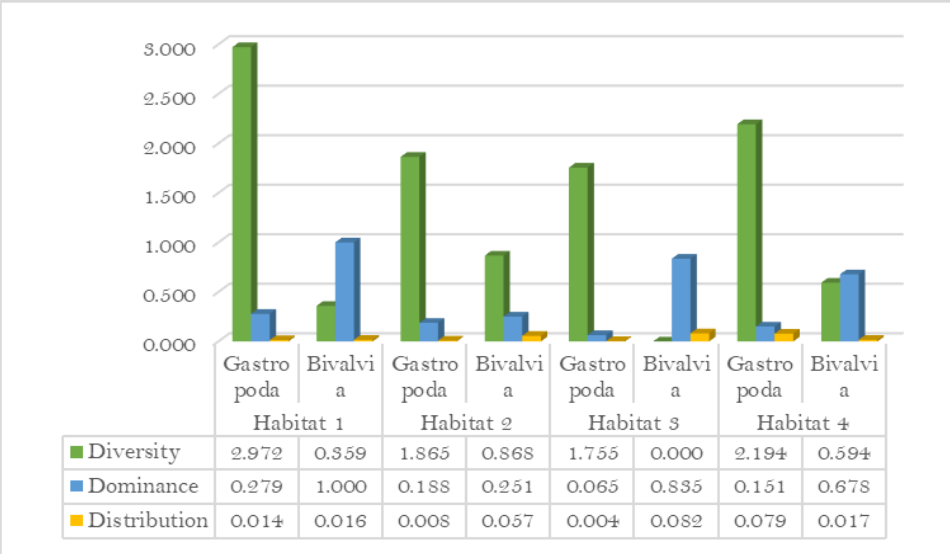


**Figure 4.** Comparison of gastropod and bivalve community indices in several habitats

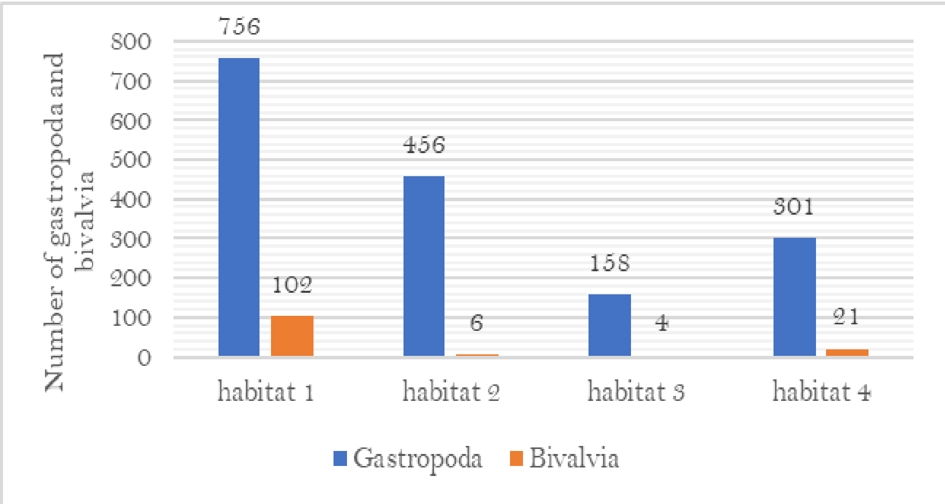


**Figure 5**. Distribution of molluscan in four different habitats

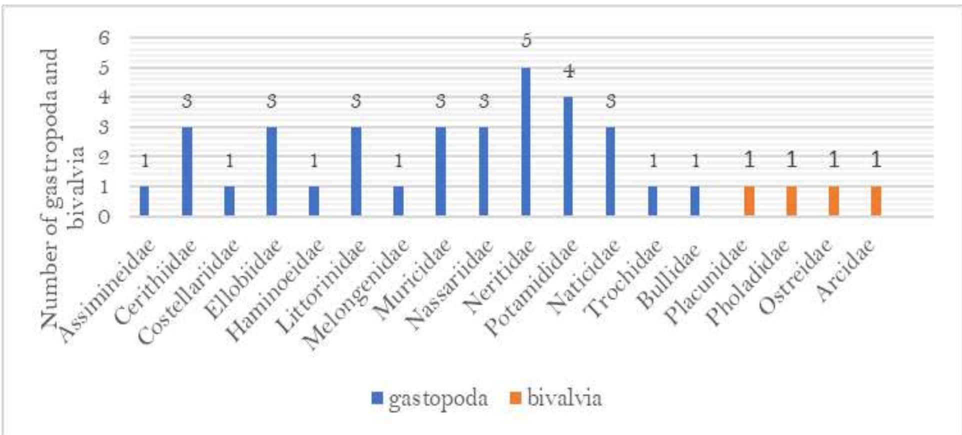


**Figure 6**. Species diversity in different families of gastropods and bivalves in the study area

**Table 1.** Diversity of molluscan in four habitats on Tarakan Island

| Num | Family | Species | Habitat 1 | Habitat 2 | Habitat 3 | Habitat 4 |
|---|---|---|---|---|---|---|
| | **Gastropoda** | | | | | |
| 1 | Assimineidae | *Optediceros breviculum* | 90 | - | 1 | 1 |
| 2 | Cerithiidae | *Cerithium coralium* | 363 | - | 10 | 3 |
| 3 | Cerithiidae | *Clypeomorus pellucida* | 3 | 1 | 3 | 2 |
| 4 | Cerithiidae | *Clypeomorus pellucida* | 57 | - | 19 | 2 |
| 5 | Costellariidae | *Vexillum alvinobalani* | - | 3 | 11 | - |
| 6 | Ellobiidae | *Cassidula triparietalis* | 6 | - | - | - |
| 7 | Ellobiidae | *Melampus nuxcastaneus* | 15 | - | - | 4 |
| 8 | Ellobiidae | *Pythia plicata* | 1 | - | 1 | - |
| 9 | Littorinidae | *Littoraria filosa* | 18 | 126 | 5 | 51 |
| 10 | Littorinidae | *Littoraria conica* | 6 | 69 | - | 36 |
| 11 | Littorinidae | *Littoraria articulata* | 4 | 31 | 2 | 67 |
| 12 | Melongenidae | *Volema myristica* | - | - | 2 | - |
| 13 | Muricidae | *Chicoreus capucinus* | 50 | - | 19 | 1 |
| 14 | Muricidae | *Cymia carinifera* | 5 | - | - | 1 |
| 15 | Muricidae | *Indothais javanica* | 4 | - | 4 | 1 |
| 16 | Nassariidae | *Nassarius fuscus* | - | 6 | 4 | - |
| 17 | Nassariidae | *Nassarius pullus* | - | 2 | 6 | - |
| 18 | Nassariidae | *Nassarius sordidus* | - | 9 | 3 | 8 |
| 19 | Neritidae | *Clithon oualaniens* | - | - | 3 | - |
| 20 | Neritidae | *Nerita balteata* | - | 84 | 2 | 57 |
| 21 | Neritidae | *Neritina cornucopia* | - | - | 3 | - |
| 22 | Neritidae | *Nerita histrio* | - | 99 | 5 | 43 |
| 23 | Neritidae | *Nerita chamaeleon* | - | 22 | - | 4 |
| 24 | Potamididae | *Cerithidea obtusa* | - | - | 16 | 1 |
| 25 | Potamididae | *Cerithidea anticipata* | 4 | - | 5 | 5 |
| 26 | Potamididae | *Pirenella incisa* | 114 | - | 8 | 2 |
| 27 | Potamididae | *Telescopium telescopium* | 2 | - | 4 | 2 |
| 28 | Naticidae | *Paratectonatica tigrina* | - | 3 | 5 | 1 |
| 29 | Naticidae | *Neverita didyma* | 3 | - | 3 | 1 |
| 30 | Naticidae | *Polinices mammilla* | - | 1 | 5 | 1 |
| 31 | Trochidae | *Umbonium vestiarium* | - | - | 9 | 5 |
| 32 | Bullidae | *Bulla striata* | 11 | - | - | 2 |
| | **Number of gastropod species** | | **756** | **456** | **158** | **301** |
| | **Bivalvia** | | | | | |
| a | Placunidae | *Placuna ephippium* | 4 | - | - | 17 |
| c | Veneridae | *Meretrix lamarckii* | 93 | 4 | - | 1 |
| d | Ostreidae | *Saccostrea cuccullata* | - | 1 | - | 3 |
| e | Arcidae | *Vepricardium sinense* | 5 | 1 | 4 | - |
| | **Number of bivalvia species** | | **102** | **6** | **4** | **21** |

This research recorded the eating habits of molluscans throughout the food chain (Kumari et al., 2020; Raghunathan et al., 2018). Most molluscans are tropically homogeneous (Golding et al., 2007). Among these molluscans are carnivores and non-carnivores, representing trophic levels 2 and 3 in the natural environment. Humans consume several species of molluscans included in the observations, particularly those from the Potamididae family. In addition, we observed *C. obtusa*, which had rotted around the gastropods, leading us to suspect that the crabs had preyed on the molluscan. This observation indicates that the habitat of molluscan significantly influences their trophic status. The Potamididae and Neritidae families are the most dominant in Area 1 (Figure 4), showing high adaptability. Furthermore, the measurements of abiotic parameters indicate that habitat 1 is suitable and appropriate for molluscan Table 2.

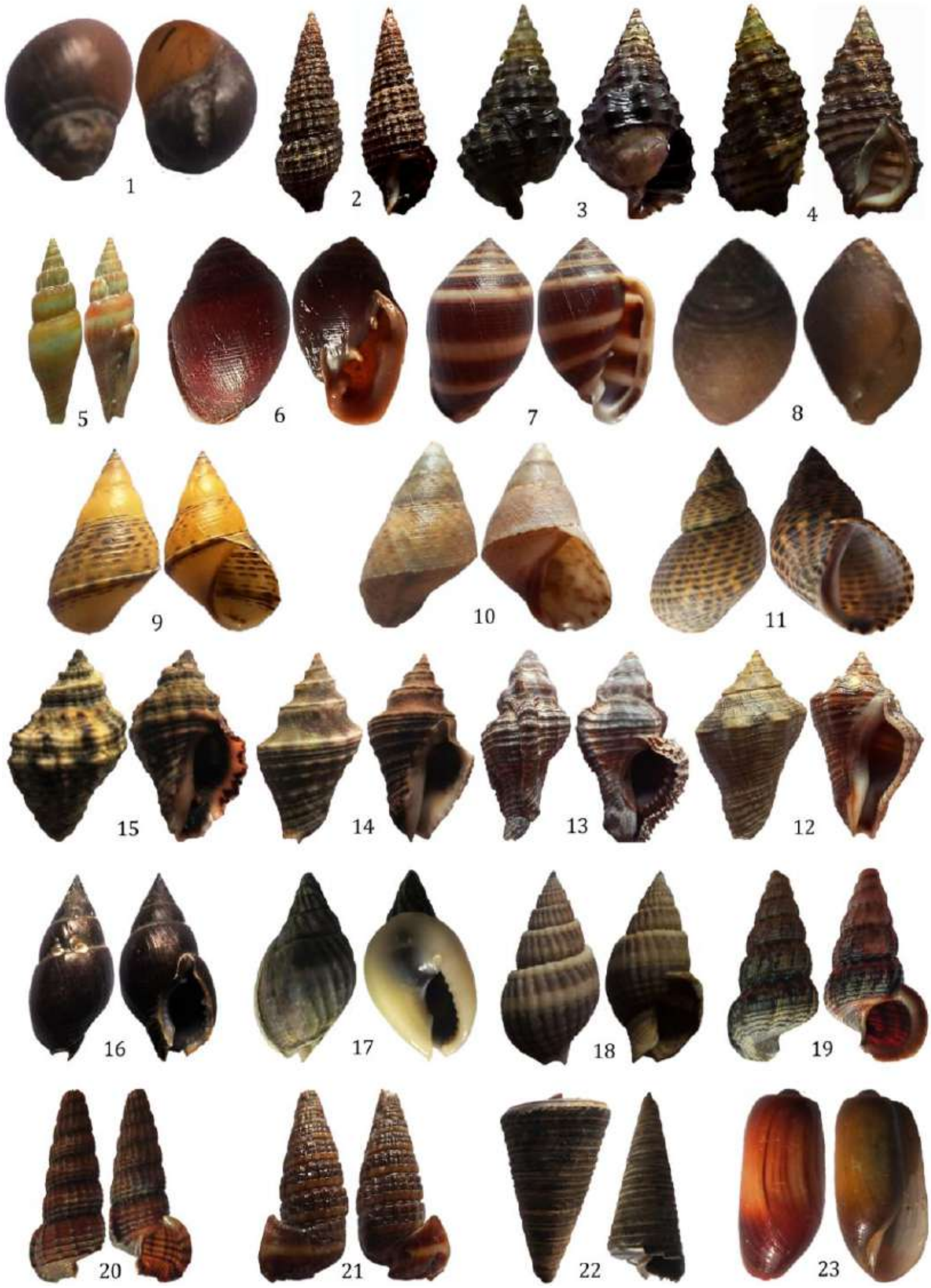


**Figure** 7. Gastropoda collected from the mangrove ecosystem of Tarakan. 1. *O. breviculum*, 2. *C. coralium*, 3. *C. pellucida*, 4. *C. pellucida*, 5. *V. alvinobalani*, 6. *C. triparietalis*, 7. *M. nuxcastaneus*, 8. *P. plicata*, 9. *L. filose*, 10. *L. conica*, 11. *L. articulata*, 12. *V. myristica*, 13. *C. capucinus*, 14. *C. carinifera* , 15. *I. javanica* , 16. *N. olivaceus*, 17. *N. pullus*, 18. *N. stolatus*, 19. *C. obtuse*, 20. *C. quoyii*, 21. *P. incisa*, 22. *T. telescopium*, 23. *B. striata*

**Table 2.** Abiotic parameter measurement

| Parameters | Sampling Location | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
| Do | 7.2 | 7 | 10.5 | 7 | 8.2 | 7.3 | 5.8 | 6.4 | 10.7 |
| Temperature | 31.19 | 31.9 | 30.3 | 30.5 | 28.3 | 28 | 28.7 | 30 | 30 |
| TDs | 6500 | 6560 | 5640 | 6680 | 1080 | 1070 | 1640 | 6640 | 6630 |
| Salinity | 30 | 35 | 36 | 35 | 33 | 30 | 32 | 28 | 33 |

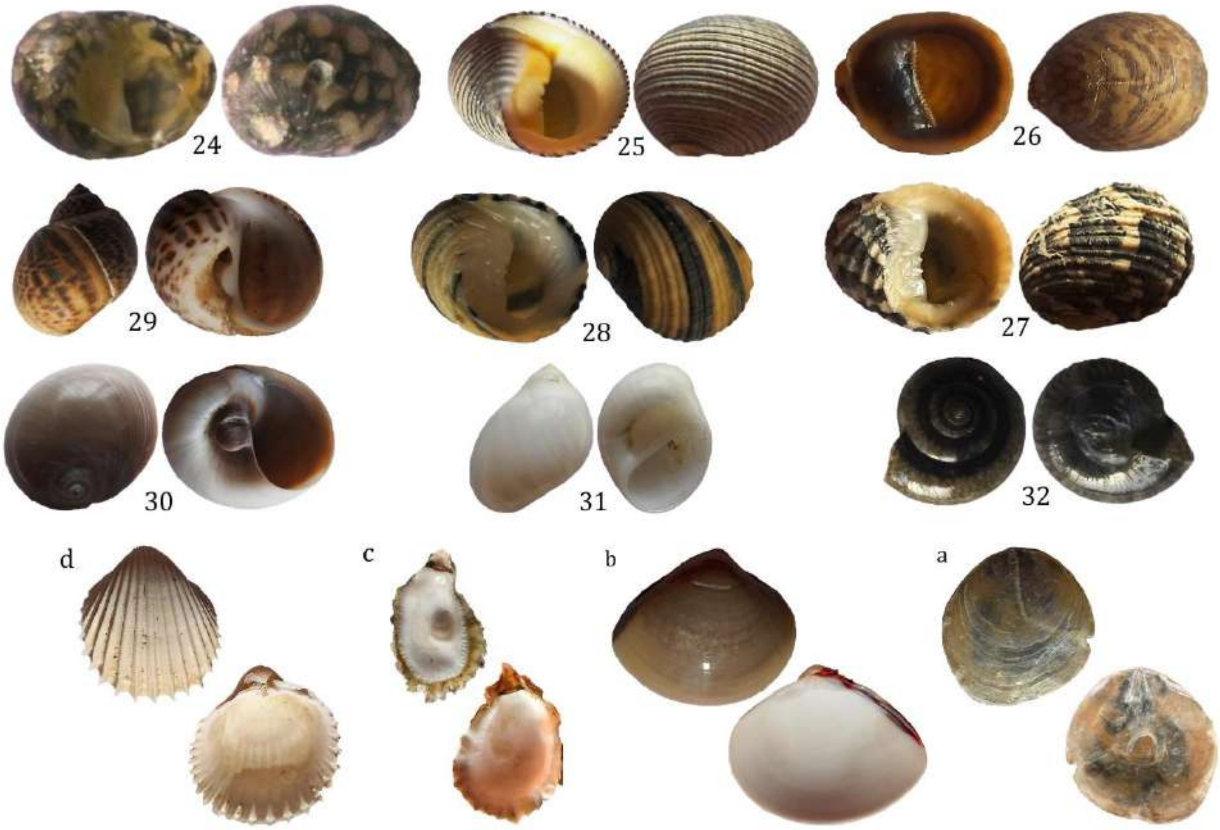


**Figure 8**. Gastropoda and Bivalvia were collected from the mangrove ecosystem of Tarakan. 24. *C. oualaniens*, 25. *N. balteata*, 26. *N. cornucopia*, 27. *N. histrio*, 28. *N. chamaeleon*, 29. *P. tigrine*, 30. *N. didyma*. 31. *P. mammilla*, 32. *U. vestiarium*, a. *P. ephippium*, b. *M. lamarckii*, c. *S. cuccullata*, d. *V. sinense.*

Environmental factors play an important role in the survival of molluscan (Alongi, 2002; Contreras et al., 2018; Ong & Gong, 2013). Habitat 1, with its muddy characteristics, provides strong support, making it an ideal habitat for the two families. *Pythia plicata* is the least observed species; this poses a threat to the trophic level. The loss of one species will impact the ongoing food chain. Habitats 3 and 4 have a low distribution and dominance of molluscan; this is thought to be due to several chemical pollutions caused by domestic waste, factory activities, and coal loading and unloading. Several researchers have studied organotin biocide pollution and its effects on molluscans (Guan et al., 2018; Ramo´n & Amor, 2001). This study identifies the importance of expanded water quality analysis on Tarakan Island. The high DO content (National Standard 5.2 to 6.8 mg/L) is very good for the life of aquatic creatures (Suratissa & Rathnayake, 2017).

Furthermore, the density of mudskippers was significantly higher in Habitats 3 and 4, suggesting that tidal effects have contaminated freshwater in these habitats. In addition, they can live in polluted water, where most other fish cannot live (Al-Behbehani et al., 2010). This could be an indication of the habitat's pollution status. On the other hand, Molluscans are a good model for detecting marine pollution because they reflect different pollution variations in their physiological systems (Primost et al., 2016). (Primost et al., 2016). Further research in Nuevo Bay, Argentina, found interesting results on shell shape as an indicator of pollution (Lindberg & Ponder, 2001; Siddique et al., 2024).

## CONCLUSION

This study identified 36 molluscan species in the Tarakan Island area, with 32 gastropods and four bivalve's species. The results indicated that habitats with low pollution levels (habitat 1) had higher gastropod community compared to more polluted habitats, where gastropod community indices were significantly lower. Domestic pollution, especially plastic waste, negatively impacts the Mollusca community in the mangrove ecosystem. These results offer fresh perspectives on how domestic pollution affects the molluscan community an aspect previously disregarded in previous studies. Further research is needed to investigate the long-term effects of pollution on Mollusca species and mangrove ecosystems and to understand the interactions between Mollusca species and other environmental factors, including climate change and human activities.

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