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Research Article

# Mollusk Diversity in Percut Sei Tuan Silvofishery Ponds, North Sumatra, Indonesia

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## Abstract

Silvofishery is a system that combines mangrove and fishery to protect mangrove ecosystems and restore their functions, one of which is as a habitat for macrozoobenthos. Investigate the mollusks and mangrove density. Mollusk sampling was carried out on sub-plots measuring 1 x 1 m² in the mangrove vegetation transect, and mangrove density was measured by counting the number of trees directly on all of the mangrove species at two silvofishery ponds. A total of 16 species of mollusks were found at the observation site, consisting of gastropods and bivalves. The density of mollusks in July was 20 ind/m2 in pond I, while it recorded 9 ind/m2 in pond II. In October, after pond II rehabilitation, the density was inversely proportional to July, and the highest density was found in pond I at 10 ind/m2, while pond II measured 9 ind/m2. After rehabilitation, the index value H' decreased in pond I and pond II from 2.82 and 2.98 to 2.52 and 2.68, respectively. The mangrove density was 887 ind/ha in pond I and 686 ind/ha in pond II. The substrate in both ponds was clay. Nitrate concentration values in the substrate in both ponds ranged from 0.27% to 0.29%, phosphate recorded a percentage of 0.07–0.09%, and C-organic ranged from 3.00% to 5.72%. The water's physicochemical parameters and the type and content of the substrate were still suitable for mollusk life.

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## 1. Introduction

The mangrove ecosystem management efforts to restore its function as a buffer for land and sea ecosystems is called silvofishery, this silvofishery system has been widely applied to aquaculture activities in various coastal areas of Indonesia. Silvofishery is a type of integrated brackish water aquaculture and mangrove tree farming (Hastuti and Budihastuti, 2016; Basyuni *et al*., 2018; Musa *et al*., 2020). Silvofishery involves the protection of the mangrove area by creating a channel-shaped pond that prosper for the mangrove ecosystem as well as for fishery, to obtain ecological and economic benefits, bringing in additional income from fish (Basyuni *et al*., 2018, 2019; Perwitasari *et al*., 2020). Due to their position between land and sea, coastal areas become an attraction for human activities; unfortunately, the coastal system has a longstanding history of exploitation and mismanagement (Calvã o *et al*., 2013) which will indirectly affect the life of mollusks. For example, encroachment and logging for human needs such as firewood and construction pose an issue in this regard (Reboredo and Pais, 2014).

The construction of dams, the huge increase in coastal displacement, and the gradual conversion of open bay areas into closed lagoons are factors that cause erosion processes resulting in the displacement of shorelines (Martins *et al*., 2013; Dias *et al*., 2013). The main pressure comes from urbanization and other developments in all areas, including forestry and fisheries, especially where communities depend on mangroves for their livelihoods (Dale *et al*., 2014; Basyuni *et al*., 2022). Therefore, mangrove ecosystem areas are needed to maintain and conserve the life of macrozoobenthos, which are present in silvofishery ponds in Tanjung Rejo Village, Percut Sei Tuan District. There are two ponds adjacent to this location, however, these ponds are in a damaged condition because they have been neglected for a long time (Balke *et al*., 2021). The ponds and natural conditions of mangroves in this location have an impact on organisms that live there, including the mollusk phylum macrozoobenthos. Neves *et al*. (2012) found that mollusks are one of the macrozoobenthos groups that are commonly found in mangrove areas. Classes of mollusk that live in association with mangrove are bivalves and gastropods. Gastropods can survive in various environmental conditions, including disturbed mangrove forest conditions and high pressure (Zakaria and Rajpar, 2015; Pradisty *et al*., 2022) and they adapt to extreme temperatures and salinity; however, texture and sediment composition affect gastropods. The main factors that affect the distribution and diversity of marine biota include mangrove vegetation as mangroves absorb accumulated organic matter; moreover, gastropods are less developed in mangrove forests that are dominated by sandy substrate with poor feeding conditions (Ariyanto *et al*., 2018). Overall, gastropods are highly abundant and distributed in the mangrove ecosystem and have slow movement characteristics (Kabir *et al*., 2014). Mangrove forests in Indonesia have a fairly high abundance of mollusk species; recently, Basyuni *et al*. (2022) reported 75 gastropod species, 15 bivalves, and 35 crustaceans. Previous research conducted by Hasibuan *et al*. (2021) found seven species of mollusks (gastropods) with a total of 25.56 ind/m$^2$ in the Percut Sei Tuan mangrove forest. The number of gastropod species found in Indonesian mangroves is much higher than in other coastal areas in Southeast Asian countries (Basyuni *et al*., 2022).

Bivalve mollusks provide water quality benefits through their ability to filter particles and have the potential to improve water clarity and quality in mangrove forests (Kreeger *et al*., 2018). The role of gastropods in the mangrove ecosystem is no less important than bivalves, namely playing a role in the food chain or food web as decomposers (Kho *et al*., 2020) or as a source of protein for other biota (Manullang *et al*., 2018), as bioindicators of health or changes in mangrove ecology (Yolanda *et al*., 2015), shells of dead gastropods can also be used by other biota such as hermit crabs (Trivedi *et al*., 2013). Therefore, it is important to study the presence of mollusk species in silvofishery ponds and compare mollusk diversity in natural ponds (without rehabilitation) and in ponds that are being rehabilitated. This information is important for the sustainable management of the mangrove ecosystem in ponds as a habitat for macrozoobenthos, particularly mollusks. Hence, it is essential to study the diversity of vegetation and macrozoobenthos communities and identify the environmental variables that best describe forest management conditions associated with macrozoobenthic community assemblages. The results are expected to indicate that community assemblages, rather than the macrozoobenthic diversity index, are associated with management conditions. The insignificant difference between natural mangroves and naturally regenerated mangroves indicates that the macrozoobenthos community can be used as an indicator of restoration and as a basis for empowering monitoring and community-based activities for adaptive management practices to improve restoration outcomes (Basyuni *et al*., 2021). Therefore, the present study aims to investigate mollusks and mangrove density collected *in situ* at two locations, collecting data before and after the rehabilitation of silvofishery ponds in the mangrove area of Tanjung Rejo Village, Percut Sei Tuan District, North Sumatra, Indonesia.

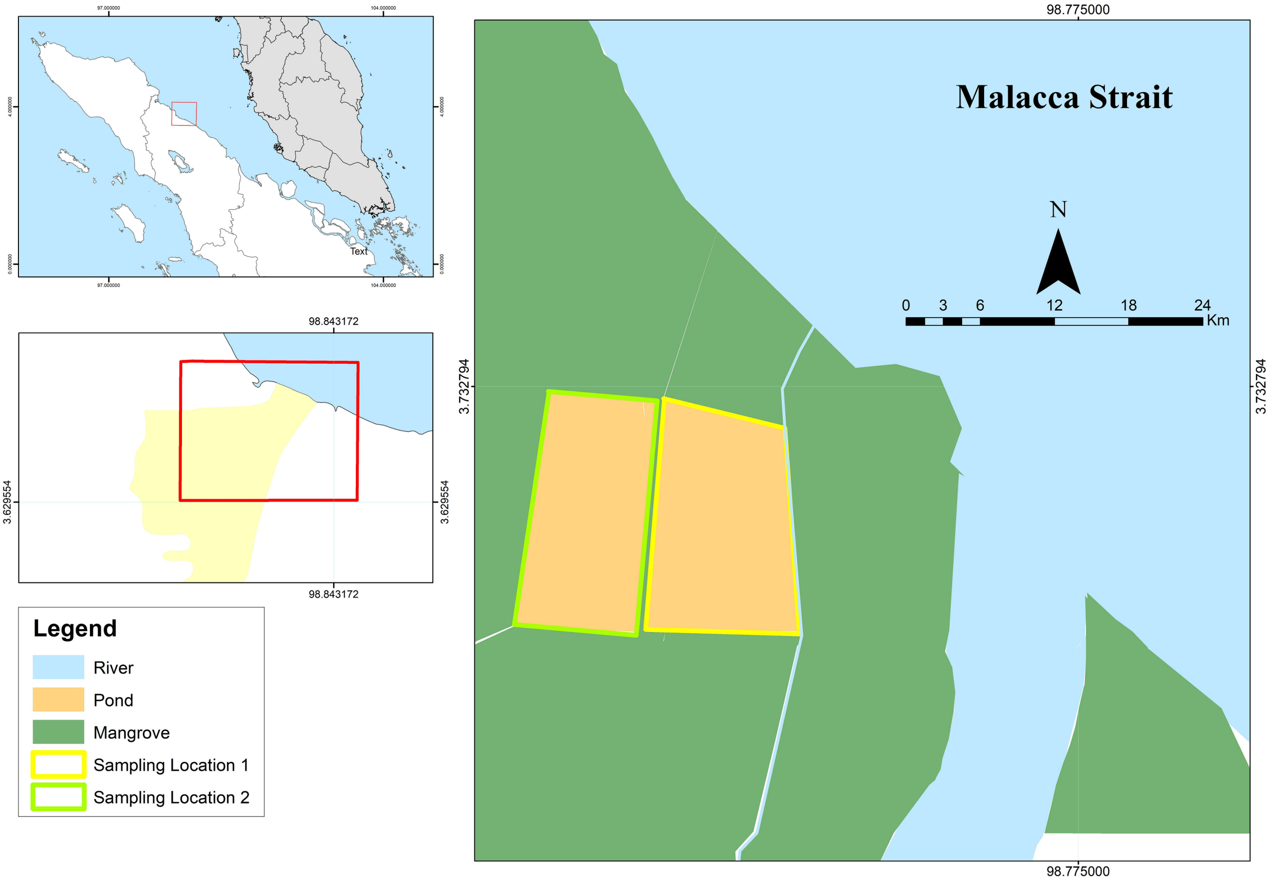



**Figure 1.** Map of silvofishery ponds research locations in Tanjung Rejo Village, Percut Seti Tuann District, North Sumatra. Pond I (3°43’48”N- 98°46’24”E) and pond II (3°43’59” N- 98°46’22”E).


**Figure 2.** Condition of two silvofishery ponds

## 2. Materials and Methods

### *2.1 Study Area*

This research was conducted in July (before rehabilitation) and October 2021 (after rehabilitation) at a silvofishery pond of the mangrove area in Tanjung Rejo Village, Percut Sei Tuan District, North Sumatra, Indonesia (Figure 1). Data concerning mollusks and mangrove density were collected *in situ* at two locations before and after rehabilitation (Figure 2). Mollusk identification was carried out at the Aquatic Environment Laboratory, Universitas Sumatera Utara. The substrate and its organic matter content were analyzed at the Socfin Indonesia laboratory.

### *2.2 Procedures*

Mollusk sampling was carried out in sub-plots measuring 1 x 1 m² located within the mangrove vegetation transect. The epifauna mollusks were directly sampled by hand, while infauna mollusks were taken using a shovel by digging the substrate at a depth of about 10 cm. The excavated substrate sample was then filtered to separate the mollusks from the substrate using a 1 x 1 mm mesh sieve. The obtained mollusk sample was then put into a sample bag, labeled, and identified. An alcohol solution was added as a preservative. The mangrove density was measured by counting the number of the mangrove trees in each pond.

Water quality measurements for physical and chemical parameters, which included water temperature, salinity, pH, and DO (dissolved oxygen), were carried out directly in the field starting at 08.00 – 10.00 AM (*in situ*). While the chemical parameters of the substrate, which included nitrate (NO3), phosphate (PO4), and C-organic, were measured using plastic samples (plastic bags) by taking the samples, putting them in a cool box, and then taking them to the laboratory for *ex situ* testing analysis.

### *2.3 Data Analysis*

#### *2.3.1 Mollusks density, diversity index, evenness index, and dominance index*

The density of mollusks can be expressed as the number of individuals found per unit area using the Hasibuan *et al.* (2021)'s formula as follows:

$$D = Ni / A \quad (1)$$

Information:

D: Species density (individual/m$^2$)
Ni: Number of individuals in the plot (individuals)
A: Transect area (m$^2$)

The diversity index (H') of the species is calculated according to Shannon-Winner's formula as follows:

$$H' = -\sum (ni/N) \times \ln (ni/N) \quad (2)$$

Information:

H': Diversity index
ni: Number of individuals per species (individuals)
N: Number of individuals of all types (Individuals)

The diversity index (H') consists of several criteria:H' > 3.0 indicates very high diversity.

H' of 1.6–3.0 shows high diversity.
H' of 1.0–1.5 indicates moderate diversity.
H' < 1 indicates low diversity.

Evenness Index or Uniformity Index (E) is a calculation that shows the level of uniformity of a community. The value of Evenness index is calculated using the following formula by Hasibuan *et al.* (2021):

$$E = H' / (H' maks) = H' / (In S) \quad (3)$$

Information:

E : Evenness index (E)
S : Number of species
H' : Shannon-Wiener's diversity index
ln : Natural logarithm

The value of uniformity in the population ranges from 0-1 with the following criteria:

E > 0.6 : High uniformity
0.4 < E< 0.6 : Medium uniformity
E < 0.4 : Low uniformity

Dominance index is used to provide an information about the dominant mollusk species in the community. This index is calculated using the following formula by Hasibuan *et al.* (2021):

$$D = \sum (pi)^2 \quad (4)$$

Information:

D: Dominance index
Pi : ni/N
ni : Number of individuals
N : Total number of individuals

The criteria of Dominance Index

D value close to 0: no dominant species
D value close to 1: there is a dominant species

*2.3.2 Mangrove density*

Mangrove density is the number of individual trees per unit area. The value of species density and relative density is calculated using the following formula (Hasibuan *et al*., 2021):

$$D = Ni / A \times 10{,}000 \quad (5)$$

Information:

D: Species density (individual/$m^2$)
Ni: Number of individuals (individuals)
A: Sample area (ha)

*2.3.3 Analysis of the relationship between mangrove density and mollusk density*

Statistical analysis of the relationship between mangrove density and mollusk density was applied to the R programming language to create data analysis scripts and visualization (Araújo and Shideler, 2019).

## 3. Results and Discussion

### *3.1 Results*

*3.1.1 Mollusk Relative Density and Diversity*

The research conducted in all ponds reported 15 species of mollusks from the Gastropod class and one species from the Bivalvia class (Figure 3). The results demonstrated that the value of relative density and the number of species found were higher in pond I and II before the rehabilitation of the mangroves (Table 1). Furthermore, before mangrove rehabilitation, a few species were found in certain locations, for instance, *Natica tigrine* was only found in pond I. On the other hand, *Cassiudula aurisfelis Cerithidea alata*, *Dostia violacea*, *Ellobium* sp., *Littoraria melanostoma*, and *Melampus fasciatus* were found in the ponds before rehabilitation but disappeared from both ponds after mangrove rehabilitation.

The gastropods that were always present in every sampling were the *Cassidula nucleus, Cerithidea obtusa*, *Littoraria intermedia*, *Littoraria scabra*, *Melampus castaneus*, *Nerita baltaeta,* and *Telescopium telescopium*, while the gastropods found only after rehabilitation came from the Bivalvia class, namely the *Glauconome virens.*

*3.1.2 Mollusks Density, Diversity Index, Evenness Index, and Dominance Before and After Rehabil- itation*

Before rehabilitation, both silvofishery ponds displayed different densities and diversity index values. The density values before rehabilitation in pond I and II were 20 ind/$m^2$ and 9 ind/$m^2$, respectively, and these values decreased after rehabilitation to 10 ind/$m^2$ and 9 ind/$m^2$, respectively (Table 2).

Similarly, the diversity index (H') in pond I and II was 2.82 and 2.98, respectively, and these values decreased to 2.52 and 2.68 after rehabilitation, respectively (Table 2). The overall diversity index value before and after rehabilitation was classified as a high diversity category. The value of the evenness index (E) in pond I and II before rehabilitation was 0.72 and 0.83, respectively, however, after rehabilitation, the value increased to 0.84 in pond I and 0.83 in pond II. The evenness index in all ponds before and after rehabilitation indicated a large degree of evenness in the population. The value of the dominance index (C) in both ponds before rehabilitation was 0.23 and 0.16, then after rehabilitation, it measured 0.20 and 0.17. The level of dominance in both ponds before and after rehabilitation was classified as low dominance.

*3.1.3 Mangrove Density in Silvofishery Pond Before and After Mangrove Rehabilitation*

The results of mangrove planting/rehabilitation showed that there was a slight increase in mangrove density in pond II around 144 ind/ha. The density value of mangroves in pond I was the same, thus remaining within the rare category with less than 1000 ind/ha before and after rehabilitation (Figure 4). Mangrove planting was only carried out in pond II, after which the density value in pond II increased from 687 ind/ha to 831 ind/ha. However, this increase was not large because the period between planting and density measurement was only three months, so it remained in the rare category.

*3.1.4 Relationship between Mangrove Density, Mol-lusk Density, and Diversity*

The relationship between mangrove density, mollusk density, and diversity in silvofishery ponds in Tanjung Rejo Village, Percut Sei Tuan District was analyzed using a simple linear regression equation (Figure 5 and Figure 6).

The equation $y = 0.0294x - 12.129$ highlighted a negative relationship, meaning that every increase in the X variable would result in a decrease in the Y variable, assuming other factors remained and did not change (Figure 5). The coefficient of determination ($R^2$)

**Table 1.** Relative abundance (%) of mollusks found in ponds before and after mangrove rehabilitation in silvofishery ponds in Tanjung Rejo Village, Percut Sei Tuan District

| No. | Class | Species | Before | | After | |
|---|---|---|---|---|---|---|
| | | | Pond I | Pond II | Pond I | Pond II |
| 1 | Gastropods | *Cassidula aurisfelis* | 8.9 | 27.2 | - | - |
| 2 | | *Cassidula nucleus* | 7.2 | 19.8 | 11.8 | 15 |
| 3 | | *Cerithidea alata* | 10.6 | 3.7 | - | - |
| 4 | | *Cerithidea obtusa* | 7.8 | 16 | 25.8 | 23.8 |
| 5 | | *Cerithidea quoyii* | 1.1 | 1.2 | - | 1.3 |
| 6 | | *Dostia violacea* | 1.1 | 1.2 | - | - |
| 7 | | *Ellobium sp.* | 0.6 | 2.5 | - | - |
| 8 | | *Littoraria intermedia* | 2.2 | 1.2 | 7.5 | 6.3 |
| 9 | | *Littoraria melanostoma* | 2.8 | 4.9 | - | - |
| 10 | | *Littoraria scabra* | 5.6 | 7.4 | 8.6 | 13.8 |
| 11 | | *Melampus castaneus* | 2.2 | - | 1.1 | 1.3 |
| 12 | | *Melampus fasciatus* | 0.6 | - | - | - |
| 13 | | *Natica tigrina* | 0.6 | - | - | - |
| 14 | | *Nerita baltaeta* | 4.4 | 6.2 | 15.1 | 15 |
| 15 | | *Telescopium telescopium* | 44.4 | 8.6 | 29 | 22.5 |
| 16 | Bivalves | *Glauconome virens* | - | - | 1.1 | 1.3 |

**Table 2.** Density, diversity index, evenness, and mollusk dominance before and after rehabilitation

| Index | Before | | After | |
|---|---|---|---|---|
| | Pond I | Pond II | Pond I | Pond II |
| Density (D) | 20 | 9 | 10.3 | 8.88 |
| Diversity (H’) | 2.82 | 2.98 | 2.52 | 2.68 |
| Evenness (E) | 0.72 | 0.83 | 0.84 | 0.84 |
| Dominance (C) | 0.23 | 0.16 | 0.2 | 0.17 |

**Table 3.** Water parameters are shown as the mean ± SD (n = 3) in the silvofishery ponds in Tanjung Rejo Village, Percut Sei Tuan District

| Water Parameters | July | | October | |
|---|---|---|---|---|
| | Pond I | Pond II | Pond I | Pond II |
| Water Temperature (°C) | 33.16 ± 0.32 | 32.16 ± 1.79 | 31.43 ± 0.2 | 31.76 ± 1.46 |
| Salinity (ppt) | 30.66 ± 1.52 | 28.66 ± 2.3 | 31.77 ± 1.25 | 28.66 ± 1.52 |
| pH | 6.10 ± 0.17 | 6.00 ± 0.00 | 6.30 ± 0.26 | 6.00 ± 0.00 |
| DO / Dissolve Oxygen (mg/L) | 4.96 ± 0.4 | 4.96 ± 0.75 | 5.46 ± 0.61 | 5.33 ± 0.72 |

obtained is 0.2708, indicating that the mangrove density after planting affects the density of mollusks in the study area by 27% and the remaining 63% is influenced by other variables such as human activities and physicochemical parameters of the water and substrate. The correlation coefficient (r) obtained is 0.52, indicating a moderate relationship between the two variables.

Similar to the result of the previous regression analysis, the result of a simple regression analysis of the relationship between variable X (mangrove density) and Y (mollusk diversity) also showed a non-unidirectional relationship with the equation y = -0.0016x + 4.0409 (Figure 6). The value of the coefficient of determination ($R^2$) was 0.572, indicating that mangrove density after planting leads to a decrease in mollusk diversity by 57%, and the other 43% is influenced by other variables such as human activities and the physical-chemical parameters of the waters and substrates. The correlation coefficient (r) obtained was 0.75, indicating a strong relationship between the two variables.

#### *3.1.5 Water parameters*

Water temperature ranged from 32 to 33°C in pond I (July), in contrast, no change was observed in October (31°C) in both ponds. Similarly, salinity and pH parameters displayed a consistent data before and after rehabilitation. Interestingly, DO increased after rehabilitation from 4.96 mg/L to 5.33–5.46 mg/L three months after the plantation (Table 3).

**Table 4.** Analysis of substrate represented as the mean ± SD (n = 3) in the silvofishery ponds in Tanjung Rejo Village, Percut Sei Tuan District

| Parameters | Pond | |
|---|---|---|
| | I | II |
| Type of substrate | Clay | Clay |
| Nitrate (%) | 0.29 ± 0.03 | 0.27 ± 0.02 |
| Phosphate (%) | 0.08 ± 0.01 | 0.07 ± 0.01 |
| C-organic (%) | 4.11 ± 0.69 | 4.04 ± 0.91 |

#### *3.1.6 Substrate Analysis*

The results of the analysis of the basic substrate type in each silvofishery pond showed that the substrate type in pond I and II were varied. Pond I and II had a type of clay substrate. The nitrate content in the ponds was varied with the highest average of nitrate content was recorded in pond I and the lowest was in pond II. The value of phosphate content in pond I also displayed a higher average value compared to pond II. The highest average organic C content in the substrate was also found in pond I, while the lowest average was found in pond II (Table 4).

### *3.2 Discussion*

This study found 16 types of mollusks consisting of 15 species from the Gastropod class and one species from the Bivalvia class in the silvofishery ponds (Figure 1). Relative density and species of mollusks were found to be higher in both ponds before mangrove rehabilitation (Table 1).

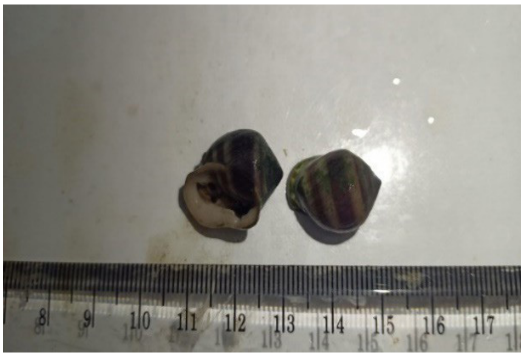
The gastropods that were always found in each sampling were *Cassidula nucleus*, *Cerithidea obtusa*, *Littoraria intermedia*, *Littoraria scabra*, *Melampus castaneus*, *Nerita baltaeta*, and *Telescopium telescopium.* These species are indeed native biota of mangrove habitat and can survive in various environmental conditions despite the disturbances during mangrove planting. According to Baderan *et al.* (2019), each mollusk biota has a wide range of adaptations to environmental factors. More types of mollusks were found in pond I influenced by the condition of the pond, which was closer to the sea and with dense mangrove vegetation. Conversely, the floodgates and the condition of the mangrove vegetation were more damaged in pond II.

Furthermore, before mangrove rehabilitation, a few species were found in certain locations, for instance, *Natica tigrine* was only found in pond I. On the other hand, *Cassiudula aurisfelis Cerithidea alata*, *Dostia violacea*, *Ellobium* sp., *Littoraria melanostoma*, and *Melampus fasciatus* were found in the ponds before rehabilitation but disappeared from both ponds after mangrove rehabilitation. Kottè-Mapoko *et al.* (2021) stated that human activities in mangrove forests in particular can impact mollusk diversity. Hence, it is suspected that the mangrove rehabilitation activities cause some of these species to no longer be found in the two ponds after being rehabilitated.

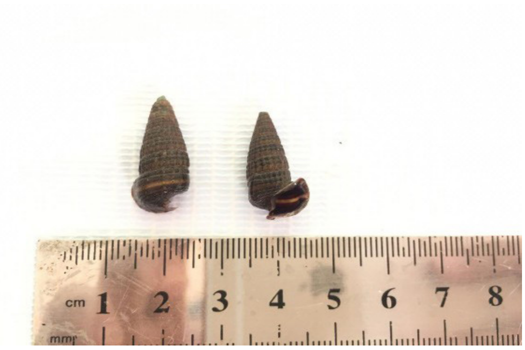
*Glauconome virens* is the only species of the class of bivalves found after rehabilitation. Before rehabilitation, the ponds were abandoned with damaged mangrove vegetation and floodgates, particularly in pond II, thus preventing water from entering the pond. After repairing the floodgates, the seawater was able to flow into the pond again, thus allowing mollusks from the Bivalvia class, namely *Glauconome virens*, to enter and flourish. According to Zakaria and Rajpar (2015), the tide is a factor that affects the density of a species of bivalves. This is supported by Balke *et al.* (2015) who reported that strong tides can affect biota in an area because these biotas can be carried away by currents and waves at high tide.

1.*Cassidula aurisfelis*

2. *Cassidula nucleus*



3.*Cerithidea alata*



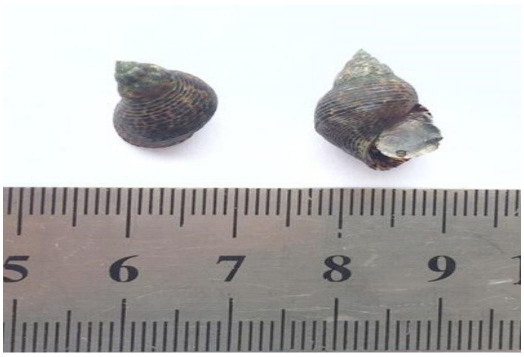

4. *Cerithidea obtuse*


5.*Cerithidea quoyii*

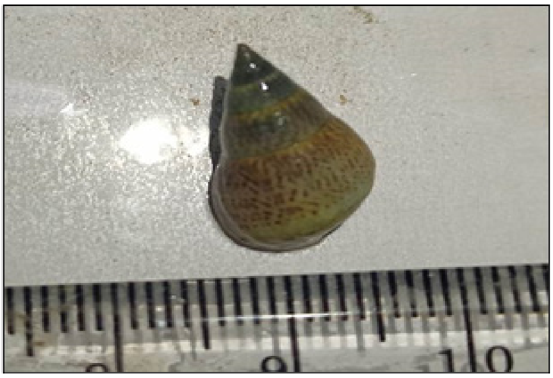
6. *Dostia violacea*

7. *Ellobium* sp.

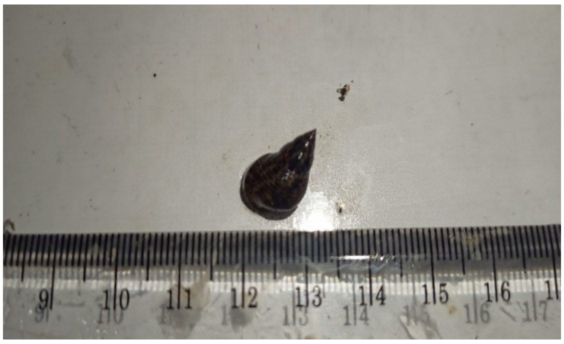
8. *Littoraria intermedia*



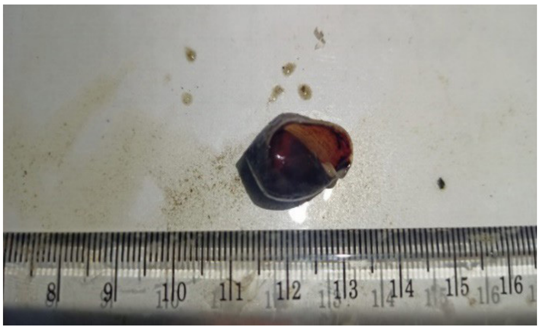
9. *Littoraria melanostoma*



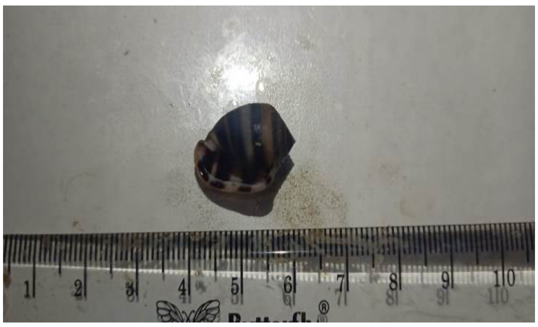
10. *Littoraria scabra*



11.*Melampus castaneus*

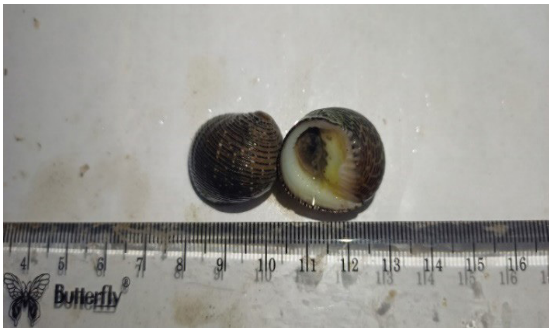


12. *Melampus fasciatus*



13. *Natica tigrine*

14. *Nerita baltaeta*




15. *Telescopium telescopium*

16. *Glauconome virens*

**Figure 3.** Mollusks sampled in the field.

A decrease in the density values in each pond was observed after mangrove rehabilitation was carried out only in pond II (Table 2). The density values before rehabilitation in pond I and II were 20 ind/m$^2$ and 9 ind/m$^2$, respectively, however, these values decreased after rehabilitation to 10.3 ind/m$^2$ and 8.88 ind/m$^2$, respectively. This decrease is presumably due to the rehabilitation activities that cause the mollusk biota to feel disturbed and forced them to move habitats. According to Calvã o *et al.* (2013), human activities can influence the individuals and mollusk community in a habitat.

The diversity index value (H') before rehabilitation in pond I and II were 2.82 and 2.98, respectively. After the rehabilitation of pond II, the index value in each pond decreased to 2.52 and 2.68 but remained in the high diversity category. Mangrove rehabilitation activities are thought to reduce the diversity index (Table 1). Jombodin *et al.* (2021) explained that benthic organisms such as mollusks have slow mobility or even stationary/session, so their existence can be directly in- fluenced by anthropogenic activities. In this study, the small ponds were directly affected by the mangrove rehabilitation activities carried out last July. Additionally, repairing the floodgates caused seawater entering the pond to fluctuate more, and some biota could not survive in such conditions. Hence, the inundation in the pond is an indication of the cause of the decrease in density and the value of the diversity index in both ponds after rehabilitation.

The increase in the evenness and dominance index in both ponds before and after rehabilitation was not large, and the overall value indicated the stable condition of the mollusk community. The low dominance value indicated that there are no dominant species in both ponds. It means that the individuals for each species are evenly distributed, and there is no tendency to be dominated by certain species. Thus, pond repair and rehabilitation activities do not cause significant disturbance, instead, they can lead the number of existing species to become more even. During the study, several types of mangroves were identified within the two ponds: *Avicennia marina*, *Bruguiera gymnorihiza*, *Excoeceria agallaocha*, and *Rhizopora stylosa*. The type of mangrove used in the rehabilitation activities in pond II is *Avicennia marina* mangrove. The mangrove density in the two ponds was classified as damaged with rare mangrove conditions following the standard criteria for mangrove density established by the Decree of the Minister of the Environment No. 51 of 2004. Both ponds were abandoned and suspected to be damaged due to abrasion, waves, and other natural phenomena. Thus, the ponds were rehabilitated, especially pond II, which was in a very damaged condition. According to Dale *et al.* (2014), rehabilitation is an activity or effort that involves the restoration and creation of habitats by changing damaged systems to become more stable. This rehabilitation activity is expected to improve the condition of mangrove vegetation in ponds.

After carrying out mangrove rehabilitation activities in pond II last July, the number of mangroves that managed to survive a 2000 seedling categories was around 48 individuals, thus, increasing the value of mangrove density in October after repair activities were carried out in the pond II from 687 ind/ha to 831 ind/ha. This finding aligns with Eddy *et al.* (2016) who highlighted that the success of mangrove forest rehabilitation can be noted from the increase in the density of mangrove vegetation. However, the planting activity, which was conducted three months ago has not been able to fully restore the mangrove vegetation.

The results of the simple linear regression analysis of the relationship between mangrove density and mollusk density obtained the equation y = 0.0294x - 12.129, demonstrating a negative relationship, and the coefficient of determination ($R^2$) was 0.2708, indicating that mangrove density after rehabilitation has an impact on decreasing the density of mollusks by 27% at the study site (Figure 5). This could mean that the mangrove ecosystem has not fully settled and is still in a transitional state. This is thought to have occurred because the mollusk sampling period after rehabilitation was not sufficient to restore the pond ecosystem, one of the causes of significant changes in the gastropod assemblage, mainly due to changes in water quality and seasons (Kabir *et al*., 2014; Ariyanto *et al*., 2018).

Similarly, the relationship between mangrove density and mollusk diversity showed a negative relationship with the equation y = -0.0016x + 4.040. The coefficient of determination ($R^2$) obtained was 0.572, meaning that mangrove density after planting leads to a decrease in mollusk diversity by 57% (Figure 6). The correlation coefficient (r) obtained was 0.75, indicating a strong relationship between the two variables. According to previous reports that mangrove trees require more than five years to get to a diameter of 3–6 cm in the category of saplings and trees (Sharma, 2018; Basyuni *et al*., 2021; Hasibuan *et al*., 2021; Rumondang *et al*., 2021). Once destroyed, a mangrove forest takes up to 15 years or more to re-vegetate compared to rain forests that take five years to re-grow. Thus, the period after rehabilitation from July to October at pond I and II was insufficient to restore the damaged ponds and increase the density of mollusks. According to Basyuni *et al.* (2021), the composition of mollusks in the mangrove ecosystem

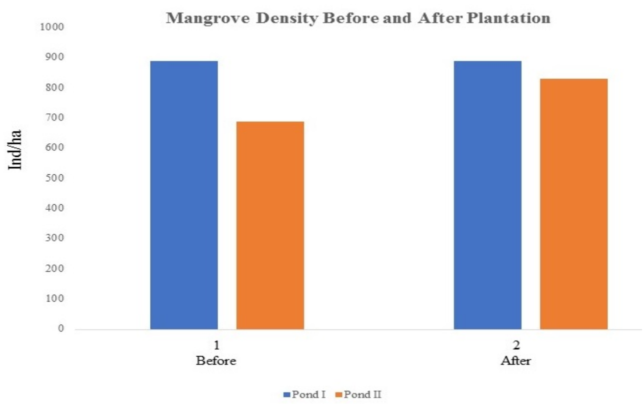



**Figure 4.** Mangrove density in ponds I and II before and after rehabilitation

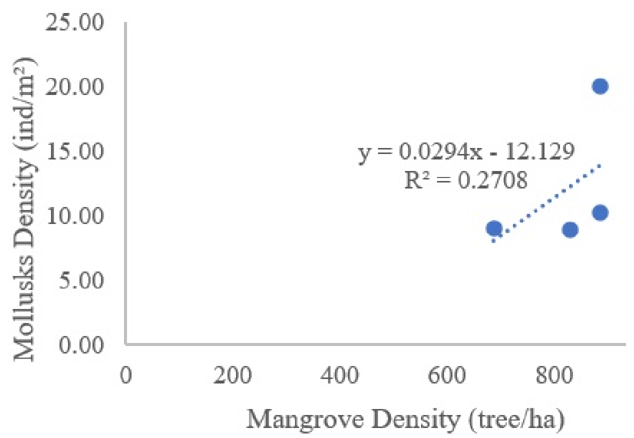



**Figure 5.** Relationship between mangrove density and density of mollusks

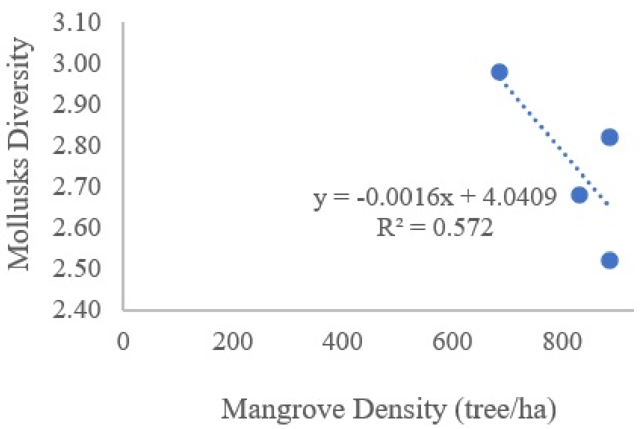



**Figure 6.** Relationship between mangrove density and diversity of mollusks

is strongly influenced by changes that occur in the ecosystem. Hence, the rehabilitation activities that took place in July are thought to have caused changes in the composition of density in the two ponds.

Overall, the findings showed that all ponds were still suitable for mollusk life in the mangrove ecosystem in general. In this regard, the pH value in the mangrove ecosystem was between 6–7 (Hasibuan *et al*., 2021), and the DO range was still suitable for mollusk life. According to Hastuti *et al*. (2019), DO content of 6–6.8 mg/L is a good condition for the development of benthos. At a low tide condition with low DO content, mollusks can adapt to survive in this condition. The temperature in the pond indicated that the waters were still suitable for mollusk life with a temperature range of 31–33.5°C. According to Karniati *et al*. (2019), the ideal temperature for the growth of macrozoobenthos is 26.50°C, and the highest temperature is 34.57°C.

Furthermore, the type of basic substrate is a very important component for the life of benthic organisms. In this study, the results of the substrate analysis showed that the substrate of the two ponds was of the same type, namely clay loam, which is a habitat for mollusks that live on mangrove substrates. Additionally, this type of substrate also causes mollusks that live in ponds to be dominated by gastropods rather than bivalves. Gastropods are abundant organisms with a dominant role in lake and river ecosystems and can thrive if adequate food intake comes from mangrove plants (Pyron and Brown, 2015). The high concentration of nitrate is thought to be due to common occurrence of landslides from mangroves and degradation which occurred in the ponds. This can be shown by the condition of mangrove vegetation in each pond, namely, pond II displayed a more damaged condition than pond I. The content of nitrate and phosphate in the substrate in the mangrove ecosystem is for the growth of mangroves in that location (Supriyantini *et al*., 2017). The source of sediment in the pond area comes from the mangrove vegetation itself in the form of piles of fallen leaves, twigs, and dead organisms in that location. The value of nitrate and phosphate content is not much different from the research by Hasibuan *et al*. (2021) in the Percut Sei Tuan natural forest, which means that the observed location is almost the same as the surrounding location, namely the natural forest.

The low organic C concentration could be due to mangrove litter that has accumulated on the substrate in both ponds, however, it is still suitable for mollusks that live in ponds. Mangrove leaves in brackish water ponds with insufficient water exchange can be dangerous. However, if the water exchange is sufficient, the rotting mangrove leaves can be used as an organic fertilizer that is useful as a food source (Rejeki *et al*., 2019). Research conducted by Agah *et al*. (2013) stated that the organic matter content of the sediment ranged from 4.4% to 10%. Thus, the results of this study demonstrated that the water physicochemical parameters and the type and content of the substrate were still suitable for mollusk's life in the Percut Sei Tuan silvofishery pond.

## 4. Conclusion

In Percut Sei Tuan pond, 16 mollusk species were found with gastropod class consisting of 5 families: Ellobiidae, Littorinidae, Naticidae, Neritidae, and Potamididae, while only one family from the Bivalvia class was noted: Unionidae. The levels of salinity, pH, DO, and temperature in the ponds are still at the tolerance level for mollusk growth. The results of the substrate analysis in this study demonstrated that the substrate for both ponds had the same type of clay, which is a habitat for mollusks.

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## Authors' Contributions

The contribution of each author is as follow, M.B. and A.S.; conceptualized the manuscript. H.H., M.B., R.A., and Y.B.; conducted the methodology. H.H., M.B., I.E.S., and A.S.; validate, formal analyzed, and investigated the data. M.B. and T.K.; provided resources. M.B.; curated the data. H.H. and M.B.; wrote an original draft preparation. M.B., R.A., A.S., T.K., and I.E.S.; reviewed and edited the manuscript. H.H., Y.B.; visualized the data. M.B., I.E.S., and A.S.; supervised the research. M.B.; managed project administration. M.B.; acquired funding research. All authors have read, agreed, discussed, and contributed to the final manuscript.

## Conflict of Interest

The authors declare that there is no conflict ofinterest.

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