



(RESEARCH ARTICLE)



## Mollusks diversity to support mangrove tourism attractions in the mangrove forest of Nusa Lembongan, Bali, Indonesia

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### Abstract

Research on the diversity of molluscs has been carried out in the mangrove forest of Nusa Lembongan. The purpose of this study was to determine the species of mollusks that interact in the mangrove habitat, to support a scientific interpretation of the existence of mollusks in the mangrove forest of Nusa Lembongan. The research was conducted in seven mangrove forest sites, from April to June 2022 using the quadratic method. At each research site determined five sampling squares. Identification of mollusk species based on morphological characters (shape, size, shell texture and shell color). The abundance of each species was calculated based on the number of individuals per unit area ( $m^2$ ). The diversity of molluscs was calculated using the Shanon-Wiener diversity index. The results showed that 24 species were found in the mangrove forest of Nusa Lembongan, 19 species from the gastropod class and 5 species from the bivalves class. Several species that were quite dominant were the mangrove periwinkle *Littoria scabra*, with a density of 28.4 individuals/ $5 m^2$ , sulcate swamp *Terebralia sulcata*, a density of 10.2 individuals/ $5m^2$ , mud creeper *Cerithidea obtusa*, with a density of 7.2 individuals/ $5m^2$ . The diversity of mollusks species in the mangrove area of Nusa Lembongan is included in the moderate category with a diversity index of 2.79 and an evenness index of 0.88. Based on the diversity index, it shows that the condition of mangroves in Nusa Lembongan is still relatively good or steady. The diversity of mollusks, the abundance of each species, the unique characteristics of each species, and the presence of mollusks in the substrate or mangrove vegetation are scientific interpretations and attractive attractions for eco-friendly mangrove tours.

**Keywords:** Mollusk diversity; Abundance; Mangrove Forest; Mollusk interpretation; Tourist attractions

### 1. Introduction

Nusa Lembongan's mangrove forest is designated as a forestry land register (RTK: Register Tanah Kehutanan) area, namely RTK 22. stipulated by the Minister of Forestry with letter number: SK.172/Menhut-II/2014 dated 3 February 2014 covering an area of 202.00 Ha. with a function as a Protected Forest (HL). As a protected forest, this mangrove forest area can be used for ecotourism purposes. The principle of utilizing mangroves for ecotourism is to utilize without changing the landscape and still maintain the diversity of flora, fauna and ecosystems [6, 21, 22]. This mangrove forest has been utilized by the community for eco-friendly mangrove tour activities. Several tourism organizations that have developed a mangrove tour program in Lembongan village include the Bali Tours Club, the Sari Segara Jungutbatu ecotourism group, Travelfish.org, the Tangjung Sanghyang tour group. In this activity, traveling tourists explore the mangrove forest by using canoes, canoes, jukung, some also follow the trail. Throughout the tour, tourists are accompanied by local guides to enjoy the beauty of the expanse of mangrove forests and recognize the diversity of mangrove flora and fauna.

Data on the diversity of mangrove plants, crustaceans and birds in the mangrove ecosystem of Nusa Lembongan is available. The species of mangrove plants include *Rhizophora* spp., *Bruguiera* sp., *Ceriops* spp., *Avicennia* sp., *Sonneratia*

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sp. (true mangrove) and also found several associated plants including sea bracelet *Sesuvium portulacastrum*, glasswort *Salicornia* sp., hibiscus *Hibiscus sinensis*, crown flower *Calotrophis gigantea*, sea puzzle *Cyperus rotundus*, tropical almond *Terminalia cattapa* [5]. Found 32 species of birds belonging to 26 families. Several bird species have quite high populations namely sooty headed bulbul *Pycnonotus aurigaster*, spotted dove *Spilopelia chinensis*, linchi swiftlets *Collocalia linchi*, king fisher *Todiramphus chloris*, olive-backed sunbird *Nectarinia jugularis* and pacific swallow *Hirundo tahitica* [2]. However, the diversity of mollusks in this area is not yet available. The diversity of mollusks also characterizes the condition of mangroves and is an attraction for ecotourism activities.

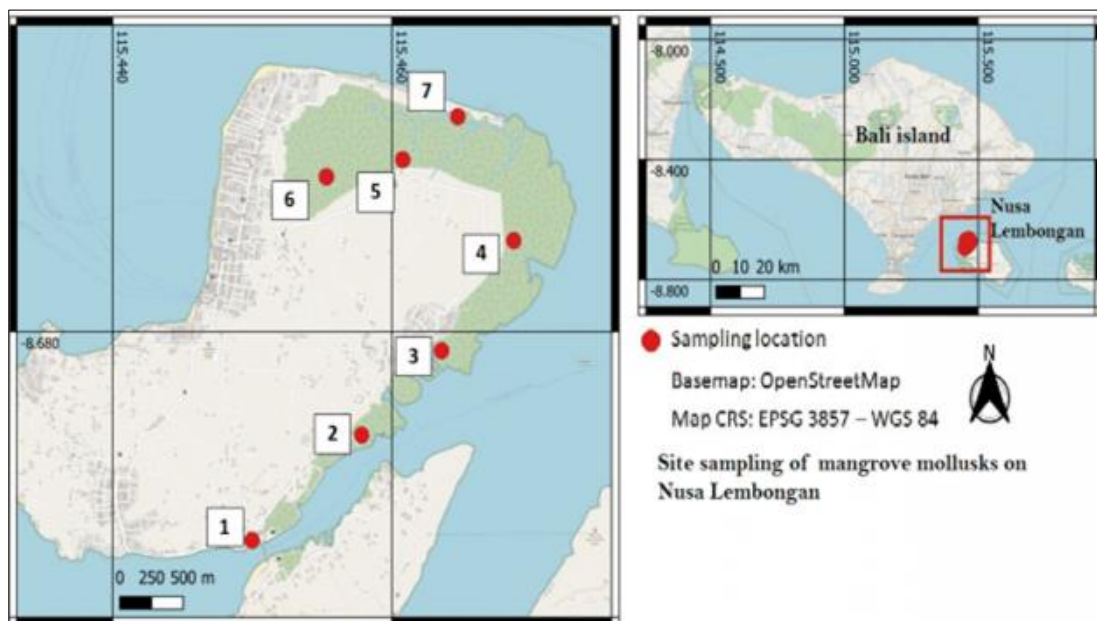
Mollusks are one of the dominant and important fauna groups in the mangrove ecosystem. Mollusks live on the surface of the substrate and in the substrate, attached to mangrove trees and some are in the stem tissue as parasites (wood-borers). Mollusks that live in mangrove ecosystems are members of the Gastropods and Bivalve classes. Gastropods are stomach-legged mollusks and have the most diverse members, including shelled and non-shelled snails that can live in sea, fresh water and land. Bivalvia is also called Pelecypoda or Lamellibranchiata, consisting of clams and mussels. Members of this class have two shell pieces connected by elastic hinges called ligaments [3, 5, 17].

The mollusks that live in the mangrove ecosystem are greatly affected by the changes that occur in the ecosystem, because the nature of the mollusks whose lives tend to be sedentary causes the mollusks to accept any changes in the environment or changes within the mangrove forest, for example changing the function of the mangrove forest into a residential area or the use of the forest for aquaculture, mining or other activities. Mangrove mollusks as part of the mangrove forest ecosystem have an important role which directly or indirectly supports the ecological function of mangrove forests. Food chains and nutrient cycles also involve mangrove molluscs as first consumers and as decomposers. Mollusk shells containing calcium carbonate also play a role in the carbon cycle that occurs in mangrove forests [7].

Information regarding the species of mollusks present, description of the characteristics of their shells, their populations and their presence in the substrate or in vegetation is important for interpretation. This is because, in educational tourism or mangrove tours, the interpretation of the existence of fauna, especially mollusks and the introduction of the diversity of mollusks that interact with mangrove ecosystems are part of the principles of eco-friendly tourism and become an attraction for ecotourism activities. Thus, the purpose of this study was to determine the species of molluscs that interact in the mangrove habitat, to support a scientific interpretation of the presence of mollusks in the mangrove forest of Nusa Lembongan.

## 2. Material and methods

### 2.1. Research site and periods



**Figure 1** Map of research location

The research was conducted in April-June 2022, field surveys were carried out six times in three months. The research was conducted in the mangrove ecosystem area of Nusa Lembongan, Klungkung Regency. Geographically it is located at coordinates 80 40' 05.02 S; 110 28' 06.19" E. Sampling was carried out at seven sites, with the distance between one site and another being 500 m-700 m (Figure 1).

## 2.2. Methods

- **Sampling and identification of mollusks.** Fauna analysis was carried out in 35 squared plots. Each square measures 1m x 1m. Laying the squares vertically follows the mangrove zonation (from near the sea to towards the land), 5 plots for each site (Figure 1). In each square, specimens of mollusks and crustaceans were taken. In each predetermined square, the substrate is excavated to a depth of 20 cm. Sampling was carried out at low tide. Fauna found in the plot was taken and put in a sample bottle. Samples in bottles were preserved with alcohol (70%), then identified in the laboratory. All specimens were photographed and identified. Identification of mollusks based on morphological characters (shape, size, shell texture and shell color), identification refers to Perry & Larsen (2004), Tan & Clements (2008), Nursalwa & Marshall (2014) [15, 18, 27].
- **Determining the abundance of Mollusks.** In each squared plot of each species of molluscs found, the number of individuals was counted. The abundance of each species was calculated based on the number of individuals per unit area (m<sup>2</sup>). The presence of mollusks and crustaceans in the mangrove habitat was recorded (in the mud, attached to the roots, on the leaves, stalks or on the mangrove stems).

## 2.3. Data analysis

Mollusks diversity was calculated by the Shanon-Wiener diversity index (H), which is  $H = -\sum [ni/N \times \ln ni/N]$ , where  $ni$  = the importance value of the  $i$ th species and  $N$  = the total importance value of all species. The significant value is determined from two parameters, namely relative density (Dr) and relative frequency (Fr). Evenness index (E) =  $H/\ln S$ ,  $H$  = diversity index,  $S$  = number of species. Evenness index range,  $E = 0-1$ ;  $E$  is close to 0, meaning that the distribution of individuals between species is uneven/a certain species is dominant,  $E$  is close to 1, meaning that the distribution of individuals between species is even [26]. For the application of mollusk diversity for scientific interpretation of mangrove tour tourists, a handbook was prepared. The handbook displays three main sections, namely: information on the coastal mangrove area of Nusa Lembongan, the characteristics of each type of mollusk accompanied by color photographs and the distribution of mollusk species on the mangrove site

## 3. Results and discussion

### 3.1. Mollusks diversity

A total of 24 species of molluscs were found, consisting of 19 species from the Gastropod class and 5 species from the Bivalvia class. The dominant mollusks are from the gastropod class. Several species that are quite dominant from the gastropod class include *Littoria scabra* (Mangrove periwinkle snail) density of 5.68 individuals/m<sup>2</sup>, *Cerithidea obtusa* (sea snail/mud creeper) density of 1.44 individuals/m<sup>2</sup>, *Terebralia sulcata* (sea slug /sulcate swamp cerith) density of 2.04 individuals/m<sup>2</sup>. Class bivalvia found 5 species with important values that are quite evenly distributed with one another. Detailed data on mollusk diversity are presented in Table 1. Several researchers have also reported the diversity of mollusk species in mangrove forests in Bali, which consists of gastropods and bivalves. Ginantra et al. (2020) [4] reported 27 species of mollusks consisting of 19 species from the gastropod class and 7 species from the Bivalvia class and 1 species from the Polyplacophora class) in the coastal mangroves of Pejarakan Buleleng; Pratiwi et al. (2022) [19] reported 12 species from the gastropod class and 1 species from the Bivalvia class in the Kampoeng Kepiting Tuban Badung Mangrove; and Kusuma et al. (2023) [12] reported 25 species from the gastropod class and 8 species from the bivalves class in the Segara Batu Lumbang Pemogan mangroves, Denpasar.

**Table 1** Mollusks species diversity in the mangroves of Nusa Lembongan

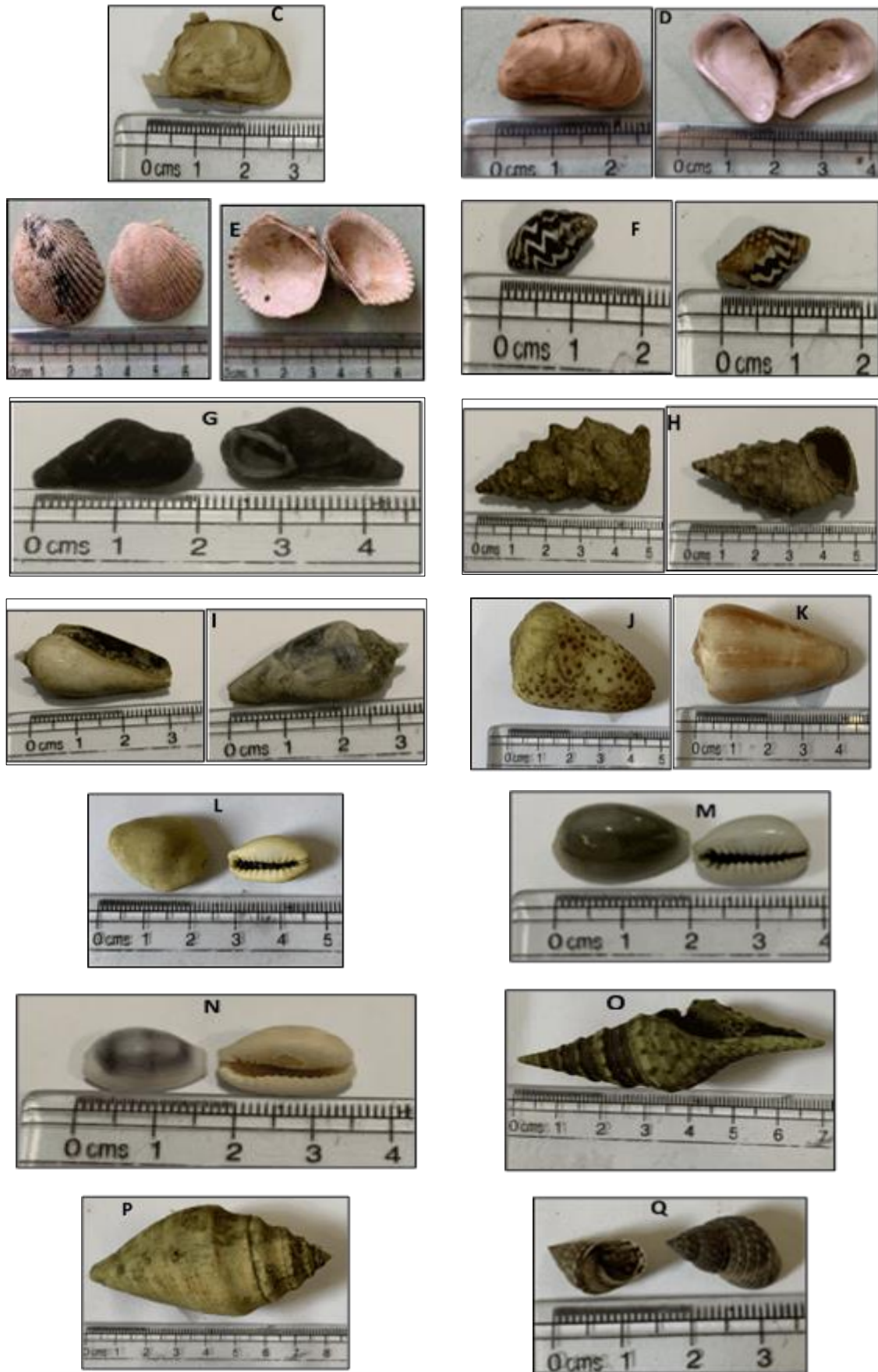
No	Family	Species	Common name	Density (ind./5 m <sup>2</sup> )	Important value
<b>Class: Bivalvia</b>					
1	Arcidae	<i>Anadara antiquata</i>	Shellfish	1.40	4.52
2	Arcidae	<i>Anadara granosa</i>	blood cokle	1.40	3.72
3	Ostreidae	<i>Crassostrea rhizophorae</i>	The mangrove oyster	2.00	4.88

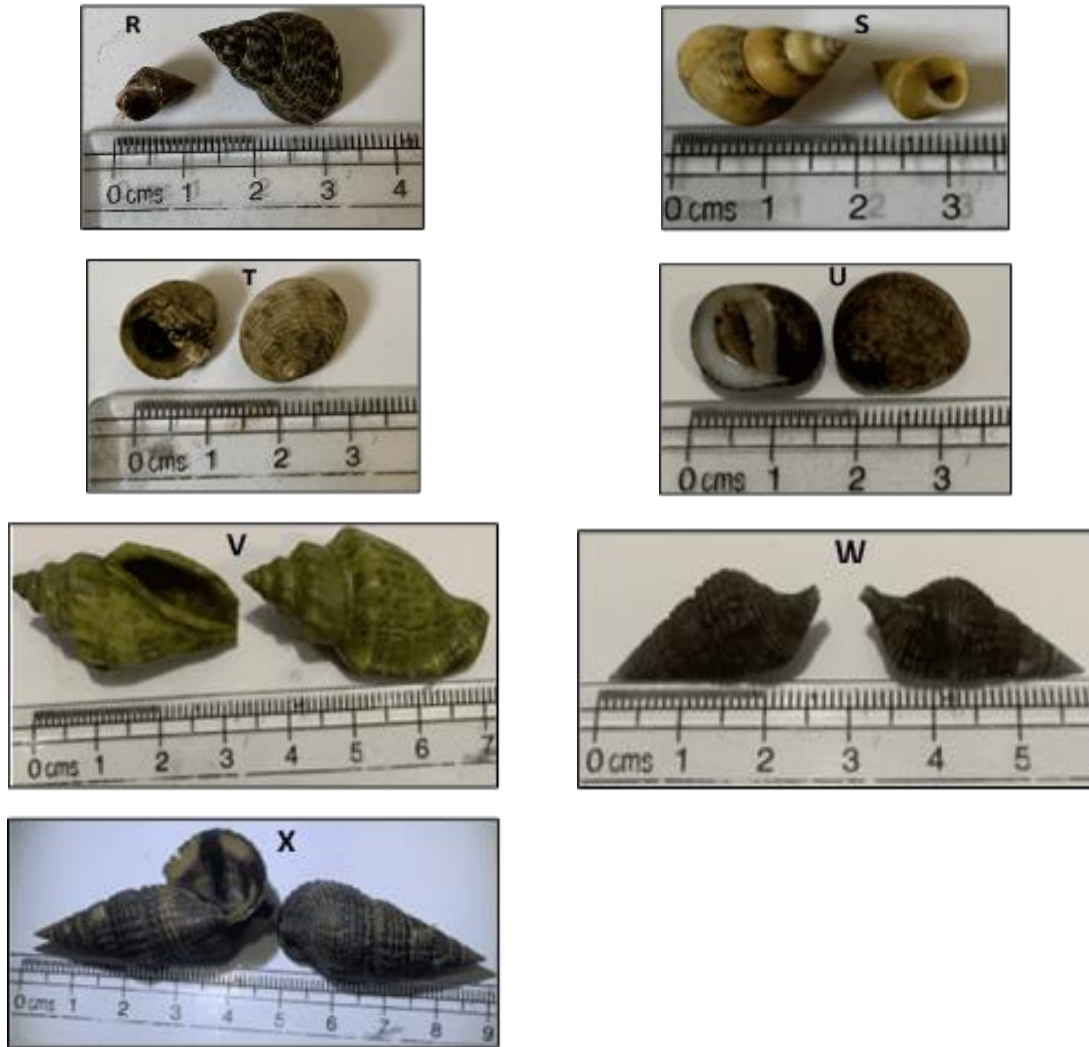
4	Mytilidae	<i>Modiolus micropterus</i>	horse mussel	3.00	6.99
5	Veneridae	<i>Gafrarium tumidum</i>	kerek clam	1.25	2.01
Class Gastropoda					
6	Assiminaeidae	<i>Assiminaea</i> sp.	sea snail	1.80	3.28
7	Portaminidae	<i>Cerithidea obtusa</i>	mud creeper	7.20	10.70
8	Cerithiidae	<i>Clypeomorus pellucida</i>	Pellucid clitus	1.60	4.19
9	Conidae	<i>Conus asiaticus</i>	cone snail	1.60	2.29
10	Conidae	<i>Conus betulinus</i>	Betulline cone	1.20	3.71
11	Conidae	<i>Conus virgo</i>	cone snail	1.60	2.29
12	Cypraeidae	<i>Cypraea boivinii</i>	cowries	2.00	6.07
13	Cypraeidae	<i>Cypraea caputserpentis</i>	snakehead cowry	0.40	1.18
14	Cypraeidae	<i>Cypraea</i> sp.	snakehead cowry	1.00	3.35
15	Melonginidae	<i>Hemifusus ternatanus</i>	ternate false fusus	1.00	2.54
16	Muricidae	<i>Indothais gradata</i>	rock snail/murex snails	1.80	3.28
17	Littorinidae	<i>Littorina carinifera</i>	periwinkles	3.2	10.22
18	Littorinidae	<i>Littoria scabra</i>	mangrove periwinkle	28.40	36.78
19	Littorinidae	<i>Littoria undulata</i>	mangrove periwinkle	1.00	2.54
20	Neritidae	<i>Nerita plicata</i>	nerites	1.00	2.54
21	Neritidae	<i>Nerita planospira</i>	Siput laut nerita	2.22	3.65
22	Melonginidae	<i>Pugilina conchidium</i>	spiral melongena	1.00	2.54
23	Portaminidae	<i>Terebralia palustris</i>	mangrove whelk	3.00	5.20
24	Portaminidae	<i>Terebralia sulcata</i>	sulcate swamp cerith	10.20	15.90

The diversity of mollusk species in the mangrove area of Nusa Lembongan is included in the medium/moderate category with a diversity index of 2.67 and an evenness index of 0.86, which means that the individual composition of each species is fairly even. Based on the diversity index and evenness index it can be said that the condition of the mangroves in this area is still relatively good/steady. The diversity of mollusks in the mangrove ecosystem can indicate the condition of the mangroves, which was also carried out in the Kolaka mangrove forest, South Sulawesi by Hasidu et al. (2020) [7]. Each species of mollusk exhibits varying shell morphological characteristics, both in terms of shape, size, color, shell pattern and aperture (Figure 2).









(A: *Anadara antiquata* ; B: *Anadara granosa* ; C: *Crassostrea rhizophorae* ; D: *Modiolus micropterus* ; E: *Gafrarium tumidum* ; F: *Assiminaea* sp.; G: *Cerithidea obtusa* ; H: *Clypeomorus pellucida* ; I: *Conus asiaticus*; J: *Conus betulinus* ; K: *Conus virgo*; L: *Cypraea boivini*; M: *Cypraea caputserpentis*; N: *Cypraea* sp.; O: *Hemifusus ternatanus* ; P: *Indothais gradata* ; Q: *Littorina carinifera* ; R: *Littoria scabra* ; S: *Littoria undulata* ; T: *Nerita plicata* ; U: *Nerita planospira* ; V: *Pugilina conchlidium* ; W: *Terebralia palustris* ; X: *Terebralia sulcata* )

**Figure 2** Species of mollusks in the mangroves of Nusa Lembongan

### 3.2. Interaction of mollusks with mangrove habitat

Mollusks of the class Bivalvia are found mainly in the front/oceanic and middle zones, Bivalvia live in muddy or sandy substrates. Habitat characteristics for bivalve life according to the type of habitat in the front zone and the sea. Thus it can be concluded that a high type of mud substrate can increase the abundance of bivalves because the type of mud substrate is highly favored by bivalve organisms. Pakaya et al. (2017) [16], stated that differences in substrate texture can cause different types of molluscs that live on the substrate. The high abundance of bivalves is related to the high organic matter content of the substrate and the type of substrate containing silt and also stated that bivalves are biota that commonly occupy mangrove habitat types with muddy substrates.

Species from the bivalve class are mostly found in mangrove habitat substrates, whether in mud, sand, rocks or gravel. Only one species was found attached to mangrove roots (*Rhizophora* sp.), namely *Crassostrea rhizophorae*. Most of the gastropods class are also found in the substrate of mangrove habitat, but there are three species associated with mangrove plant species, namely *Littorina carinifera*, *Littoria scabra* and *Littoria undulata*. Some of these species stick or move on the leaves, on the roots or on the stems of the mangrove plants *Rhizophora apiculata*, *Rhizophora stylosa*, *Rhizophora mucronata* and *Sonneratia alba*. Detailed data on mollusk encounters in mangrove habitat are presented in Table 2.

**Table 2** Presence of Mollusks species at the research site

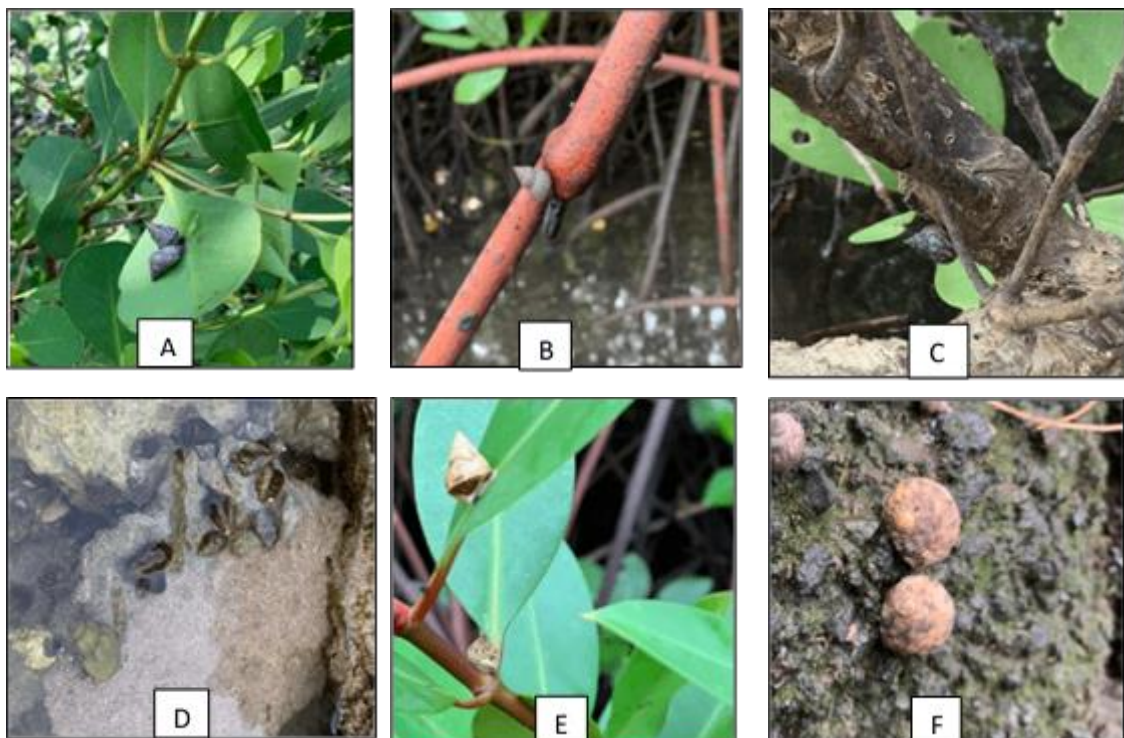
No	Species (conservation status)	Common name	Density (ind./5 m <sup>2</sup> ) on site							Species encounters in mangrove habitat
			1	2	3	4	5	6	7	
1	<i>Anadara antiquata</i>	Shellfish	-	-	1	1.5	-	3.75	-	In rocky sand, sandy silt
2	<i>Anadara granosa</i>	blood cokle	-	1	-	-	-	3.75	-	In sandy mud.
3	<i>Crassostrea rhizophorae</i>	The mangrove oyster	-	3	5	-	-	2.5	-	Some were found attached to the roots of <i>Rhizophora apiculata</i> and some in sandy mud
4	<i>Modiolus micropterus</i>	horse mussel	-	3	5	-	-	8.75	2.5	In sandy silt substrates, in rocky sands
5	<i>Gafrarium tumidum</i>	kerek clam	-	0.8	0.5	-	-	-	-	In sandy mud
6	<i>Assiminaea</i> sp.	sea snail	3.5	-	-	-	-	-	-	Clinging to the rocks
7	<i>Cerithidea obtusa</i>	mud creeper	57.5	-	-	3.5	-	-	-	In the rocks, in the gravel sand, in the gritty mudr
8	<i>Clypeomorus pellucida</i>	Pellucid clitus	-	-	-	-	-	1.1	1.4	In the mud
9	<i>Conus asiaticus</i> (LC)	cone snail	-	-	-	1.5	-	-	-	In sandy mud
10	<i>Conus betulinus</i>	Betulline cone	1.3	1.4	-	-	-	-	-	In sandy mud
11	<i>Conus virgo</i> (LC)	cone snail	3.5	-	-	7.5	-	-	-	In sandy mud
12	<i>Cypraea boivinii</i>	cowries	3.5	1	5	5	-	-	-	On pebbly sand, muddy sand
13	<i>Cypraea caputserpentis</i>	snakehead cowry	-	2.0	-	-	-	-	-	On pebbly sand
14	<i>Cypraea</i> sp.	snakehead cowry	2	-	-	1	-	-	-	On pebbly sand
15	<i>Hemifusus ternatanus</i>	ternate false fusus	-	-	1	-	-	-	-	On rocky sand
16	<i>Indothais gradata</i>	rock snail/murex snails	5	-	-	-	-	-	-	On the rocks, pebbly sand
17	<i>Littorina carinifera</i>	periwinkles	-	13	21	-	-	-	7.5	Attaches to leaves, twigs, roots of the mangrove species <i>Rhizophora apiculata</i> , <i>Sonneratia alba</i>
18	<i>Littoria scabra</i>	mangrove periwinkle	-	55	10	45	-	12.5	48.7	Attaches to leaves, twigs, leaf buds, roots of mangrove species <i>Rhizophora apiculata</i> , <i>Rhizophora stylosa</i> , <i>Rhizophora mucronata</i> and <i>Sonneratia alba</i> .

19	<i>Littoraria undulata</i> (LC)	mangroveperiwinkle	-	-	2	-	-	-	-	Attaches to leaves, leaf buds, stems, mangrove species <i>Rhizophora apiculata</i> , <i>Rhizophora mucronata</i> and <i>Sonneratia alba</i>
20	<i>Nerita plicata</i>	nerites	-	-	2	-	-	-	-	In the mud
21	<i>Nerita planospira</i>	Nerita mangrove snail	6.5	-	-	-	-	-	8.8	On the sand, muddy sand
22	<i>Pugilina conchlidium</i>	spiral melongena	-	-	-	-	-	-	1.3	The sand is a bit muddy
23	<i>Terebralia palustris</i> (DD)	the giant mangrove whelk	-	7	8	-	-	-	-	In sandy silt, in rocky sand
24	<i>Terebralia sulcata</i>	sulcate swamp cerith	31.5	14	15	3.5	6.3	-	-	Clinging to rocks, rocky sand, sandy mud

Scarcity: LC: Least Concern, DD :data deficient, refers to the IUCN Red List, 2022 version

### 3.3. Diversity of Mollusks in mangrove ecosystems as an ecotourism attraction

Existence of mollusks, activity of mollusks, use of habitat by mollusks, distribution of their abundance in mangrove habitat are attractions in mangrove tourism. Information about the species found, their status whether protected or not, rare or common, is important information in ecotourism activities. Activities and use of habitat by observed molluscs and crustaceans, be it clinging to mangrove roots, clinging to mangrove stems or roots, clinging to rocks, walking on sand, walking and making holes in mud, looking for food, walking on mud flats are attractions interesting for mangrove fauna observation activities (Figure 3).



(A: *Littoraria scabra* attached to mangrove leaves *Sonneratia* sp.; B: *Littorina carinifera* attached to mangrove roots *Rhizophora apiculata* ; C: *Littoraria scabra* attached to *Sonneratia alba* stems. ; D: *Cerithidea obtusa* on rocks; E: *Littoraria undulata* attached to mangrove leaves *Sonneratia alba*; F: *Nerita plicata* clings to rocks)

**Figure 3** Several gastropod encounters in the mangrove ecosystem of Nusa Lembongan

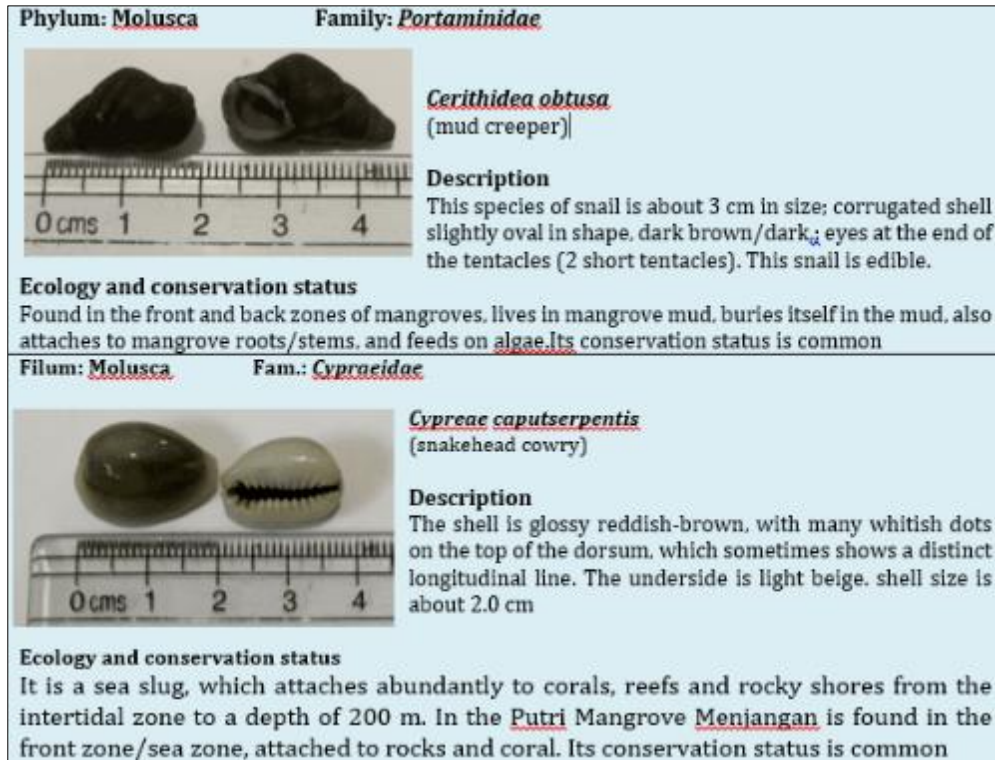


Observation of mollusks began with field activities, namely observing the fauna directly in the Mangrove area. Mangrove fauna observation tour guides should have good competence (knowledge, skills, and behavior) so that they are able to interpret and explain thoroughly the fauna of mangrove forest habitats properly. To assist ecotourism guides in observing fauna so that they can interpret it properly, it is necessary to develop a handbook on the presence of mollusks. Observation of the typical fauna of mangrove forests (especially mollusks) and mangrove vegetation directly in mangrove habitat by tourists is an interesting activity, can provide real examples of the diversity of living things in ecosystems and provide education about the interdependence of living things in ecosystems. The activity of observing fauna by mangrove tour tourists on Nusa Lembongan can be done by walking through the gaps between the mangrove plants, via wooden bridges, using canoes, and traditional bouts. Figure 4 shows some tourist activities on a mangrove tour at Mangrove Nusa Lembongan.



**Figure 4** Mangrove tour activities in the Nusa Lembongan Mangrove Forest

The handbook displays photos, morphological characteristics, ecology, status of existence (Figure 5). This information is important for both beginners and experienced observers. The information in this handbook is also important to add insight and knowledge to ecotourists about the existence of mollusks. In the following, several species of mollusks in the mangrove ecosystem show interesting attractions. There are species that are attached to corals, on rocks, and there are clinging to mangrove stems or roots, clinging to rocks, and walking on sand. Information regarding the conservation status of the mollusk species is also interesting material to interpret in guiding ecotourists on mangrove tours. In the Lembongan mangroves there are four species included in the rare category based on the IUCN Redlist [10], three species with Least Concern (LC) status, namely *Conus asiaticus*, *Conus virgo*, *Littoraria undulata* and one species with Data Deficient (DD) status, namely *Terebralia palustris*.



**Figure 5** Example of the contents of the Mollusk Handbook in the Nusa Lembongan mangrove ecosystem

The use of mangroves for environmentally friendly tourism activities (ecotourism) plays an important role in preserving mangrove ecosystems and providing economic value to the local community Duangjai et al. (2014) [1] stated that eco-friendly tourism activities in mangrove areas in Satun Province, Thailand can provide a sustainable source of income for local communities and raise awareness about the importance of environmental services and the benefits of mangrove ecosystems for communities around the forest. Rahmila & Halim (2018) [21]; Sari et al. (2015) [23] stated that the feasibility of mangrove areas for eco-friendly tourism (ecotourism), in addition to the diversity of mangroves, is a characteristic of mangrove habitat (tidal, mud). Accessibility and diversity of fauna (molluscs, crustaceans, insects, reptiles, birds, fish and mammals). The diversity and activity of mollusks is one of the supporting factors for the preservation of mangrove forests for ecotourism activities.

The sustainability of mangrove areas and the ecotourism business is highly dependent on the diversity of living things (including the diversity of mangrove plants, molluscs, crustaceans and birds), so it is important to reduce the loss of biodiversity. Stakeholders and policy makers need to integrate biodiversity and management area considerations for sustainable tourism purposes. Contributions from local communities around the mangrove forests for the development of tourism mangrove tours are very important [8, 9, 11, 13, 14, 20, 24, 25]. In the mangrove forest of Nusa Lembongan, local community fishermen groups (“Sari Segara” fishermen group) have managed mangroves for mangrove tours. This mangrove tour was developed by combining mangrove biodiversity conservation and tourism business.

#### 4. Conclusion

From the research results it can be concluded that there were 24 types of Molluscs, consisting of 19 species from the Gastropod class and 5 species from the Bivalvia class. In the mollusks phylum there are 3 species that are quite dominant, namely *Littoria scabra*, *Terebralia sulcata* and *Cerithidea obtusa*. The diversity of mollusk species in the mangrove area of Nusa Lembongan is included in the moderate/moderate category, which indicates that the condition of the mangroves is in the good/steady category. The existence of mollusks, their encounter activities are important and interesting for mangrove tourism attractions in the mangrove forest of Nusa Lembongan.

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## Compliance with ethical standards

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### *Disclosure of conflict of interest*

We declare that there is no conflict of interest in this research and article.

### *Author's declaration*

We declare that the research process, data analysis and writing of this article was the result of collaboration between the two authors

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