International Journal of Science and Research Archive
eISSN: 2582-8185
Cross Ref DOI: 10.30574/ijsra
Journal homepage: https://ijsra.net/

(Research Article)

Diversity of Molluscs Associated with Mangrove Vegetation in the Mangrove Forest Perancak Jembrana Bali

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International Journal of Science and Research Archive, 2025, 16(01), 1042-1058

Publication history: Received on 05 June 2025; revised on 12 July 2025; accepted on 15 July 2025

Article DOI: https://doi.org/10.30574/ijsra.2025.16.1.2112

Abstract

This study aims to analyze the diversity and association of molluscs in the Perancak Jembrana mangrove forest habitat. The study used the square method. A total of 30 squares were carried out in three mangrove forest zones (land zone, middle zone and estuary zone). Species diversity was analyzed using the Shanon-Wiener index. The association of molluscs with mangrove vegetation was analyzed using the 2x2 contingency table method. The use of mangrove vegetation strata was analyzed using Detrended Correspondence Analysis (DCA). The results of the study found 14 species of molluscs from the Gastropoda class which are included in five families and one species from the Bivalvia class. The most dominant mollusc species include *Littorina scabra, Terebralia sulcata, Littoraria carinifera* and *Cerithidea obtusa*. The mollusc diversity index is 2.39, the evenness index is 0.86, this indicates that the condition of the Perancak mangrove forest is in the stable category. Several mollusk species show high association properties with mangrove plant species, namely *Nerita lineata - Rhizophora mucronata*, *Nerita lineata - Sonneratia alba, Cassidula nucleus - Rhizophora mucronata, Cassidula nucleus-Rhizophora mucronata, Littorina scabra-Avicennia lannata, Littorina scabra - Xylocarpus granatum, Littorina* sp.- *Avicennia lannata, Littorina* sp.- *Sesuvium portulacastrum*. Mollusc species that strongly use strata I (substrate) are *Cerithidea cingulata, Nassarius dorsatus, Littorina* sp., *Cassidula aurisfelis,* commonly use strata II (mangrove roots) and strata III (mangrove stems) are *Ostrea edulis*, *Cassidula mustelina*, *Terebralia sulcata, Cerithidea obtusa, Nerita lineata* and molluscs are strongly associated with strata IV (mangrove leaves), namely *Littoraria carinifera, Littorina scabra, Littorina undulata*.

Keywords: Diversity; Molluscs; Gastropods; Species associations; Perancak mangrove

1. Introduction

Mangrove forests have unique flora and fauna diversity and habitat characteristics including substrate type, the presence of sea tides, and fairly high salt content. Flora in mangrove forests have unique characteristics compared to terrestrial flora, including being able to grow in tidal areas, tolerant to fairly high salt levels, able to grow in muddy, sandy and rocky substrate habitats, having unique root characteristics (stilt roots, knee roots, breathing roots, pneumatophor) to adapt to low oxygen levels in mangrove mud. Fauna that interact in mangrove areas also show unique characteristics, including molluscs, crustaceans, fish, birds and some mammals. Molluscs are commonly found in mangrove ecosystems, living on the surface of the substrate or in the substrate or attached to mangrove trees. Most mollusks that live in mangrove ecosystems are members of the Gastropoda and Bivalvia classes. The Gastropoda class is often called the stomach-footed molluscs and has the most members, consisting of shelled snails and non-shelled snails that can live in the sea, fresh water and land. The Bivalvia class is also called Pelecypoda or Lamellibranchiata, consisting of clams, mussels and shells. Members of this class have two shell pieces connected by an elastic hinge called a ligament [6, 20].

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Molluscs that live in mangrove ecosystems are greatly influenced by changes that occur in the ecosystem, because the nature of mollusks that tend to live permanently causes mollusks to accept every environmental change or change from within the mangrove forest, for example changes in the function of mangrove forests into residential areas or the use of the forest for aquaculture activities, mining or other activities. Mangrove molluscs as part of the mangrove forest ecosystem have a fairly important role that directly or indirectly supports the ecological function of the mangrove forest. The food chain and nutrient cycle also involve mangrove molluscs as primary consumers and decomposers. Mollusc shells containing calcium carbonate also play a role in the carbon cycle that occurs in mangrove forests. In turn, the mangrove ecosystem plays an important role in the survival of various fauna, namely crustaceans, fish, reptiles, avivauna and also for molluscs (gastropods, bivalves) themselves [11].

The coastal mangrove forest area of Perancak Village, Jembrana, which covers an area of around 177.09 hectares, has a diversity of fauna typical of mangrove forests, namely molluscs, crustaceans, fish, reptiles, birds and true mangrove plants and associated mangroves [7, 8, 9, 24]. However, there has been no report on the diversity, association and habitat use by molluscs with mangrove vegetation in the Perancak mangrove ecotourism area. Considering the role of molluscs in mangrove forests in the balance of the food chain, nutrient cycles and can also be an ecological indicator of the condition of mangrove forests, research on the diversity of molluscs and their association with mangrove vegetation is important to do. Thus, the purpose of this study was to analyze the diversity, association and use of mangrove vegetation strata by molluscs in the Perancak mangrove forest.

2. Materials And Methods

2.1. Periods and Place of Research

The research will be conducted in April-August 2024, field surveys were conducted 6 times in 3 months. The research was conducted in the Perancak Jembrana mangrove ecosystem area. Sampling was carried out on 30 plots in three mangrove forest zones (land zone, middle zone and estuary zone), with a distance between one site and another of 100 m, the coordinate points (GPS) of each location were recorded (Figure 1).

2.2. Method

- **Mollusc sampling**. Mollusc sampling was carried out in 30 squares, with each square measuring 1 m x 1 m. The sample squares were placed in three mangrove zones, namely the land zone, middle zone and estuary zone (Figure 1). In each of the designated squares, mollusc specimens were collected, excavations were carried out to a depth of 15 cm for mollusc specimens below the substrate surface. Molluscs found in the plot were taken and put in sample bottles and preserved with alcohol (70%), then identified at the Animal Taxonomy Laboratory of the Biology Study Program, Faculty of Mathematics and Natural Sciences, Udayana University. Vegetation and substrate type measurements were also carried out at each site.
- I**dentification of mollusc species.** All mollusc specimens were photographed and identified. Identification of molluscs was based on morphological characteristics (shape, size, shell texture and shell color), identification refers to Nursalwa and Marshall (2014) and Tan and Clements (2008) [19, 25].
- **Determining the abundance of Molluscs**. In each square plot, each species of molluscs found was counted for the number of individuals. The abundance of each type was calculated based on the number of individuals per unit area (M^2). The presence of molluscs in the mangrove habitat was recorded (in the mud, attached to the roots, or on the mangrove trunk).

(Map source : google earth, image © 2025, Airbus)

Figure 1 Map of research location

2.3. Data Analysis

The diversity of molluscs is calculated using the Shannon-Wiener diversity index (H), where H = -∑[ni/N x Ln ni/N), where ni= the importance value of the i-th species and N=the total importance value of all species. The importance value is determined from 2 parameters, namely: Relative density (Kr) =(Ni/∑N) x 100%; where Ni = the density of the I-th species, ∑N = the total density of all species. Relative frequency (Fr) = (Fi/∑F) x 100%, where Fi = the frequency of presence of the I-th species, ∑F = the total frequency of all species. The importance value of each species (ni) = Kr + Fr. Evenness index (E) = H/lnS, H= diversity index, S = number of species. The criteria for the Shannon-Wiener diversity index are: if H < 1: low diversity index, 1 ≤H ≤ 3: medium diversity category and diversity index H > 3: high diversity [5, 23].

The association of molluscs with mangrove vegetation was analyzed using the 2x2 contingency table method (Table 1),

Table 1 2x2 contingency table

Species A	**Species B**			
		Present	**Absent**	**Amount**
	Present	A	B	*M*=a+b
	Absent	C	D	*N*=c+d
	Amount	*r*=a+c	*s*=b+d	N=a+b+c+d

Which, a = number of squares containing species A and species B, b = number of squares containing species A only, c = number of squares containing species B only, d = number of squares containing no species A and species B, N = Number of a, b, c and d. Furthermore, to determine the nature of the association, the following formula is used: E(a) = (a + b) (a + c)/ N, Based on this formula, the association is a positive association if the value of a> E(a) means that the pair of species occurs together more often than expected, and a negative association if the value of a < E(a) means that the pair of species occurs together less often than expected. The value of the association between malapari and other species is calculated using the Ochiai Index (IO), with the following formula: $IO = \frac{a}{\sqrt{a+b}.\sqrt{a+c}}$, The range of association index categories between species is if the IO value is between 1-0.75 including very high association, the IO value of 0.74-0.49 is high, 0.48-0.23 is low and IO <0.23 is very low [17]. Analysis of the association of habitat stratification use (substrate, roots, stems and leaves/branches) by molluscs was carried out using the DCA (Detrended Correspondence Analysis) test with SPPS version 24.

3. Results and Discussion

3.1. Diversity of Molluscs

There are 15 species of molluscs in the Perancak mangrove forest, consisting of 14 species from the gastropoda class, which belong to 5 families and 1 species from the Bivalvia class. The families that are quite dominant are Potamididae and Littorinidae (Table 2). Of the 15 species found, several species are quite dominant, namely *Littorina scabra*, *Terebralia sulcata, Littoraria carinifera* and *Cerithidea obtusa*. From the Bivalvia members, only one species was recorded, namely *Ostrea edulis*. The diversity of mollusc species in the Perancak mangrove area is included in the medium category with a diversity index (H) of 2.39 (where 1≤H≤3: medium category) and a species evenness index of 0.86, which means that the species composition is quite even. Based on the diversity index, it can be said that the condition of the mangroves in this area is still relatively good/stable. Hasidu *et al*. (2020) [10], reported that the diversity of molluscs in the Kolaka mangrove ecosystem, South Sulawesi, is generally categorized as medium. Hulopi *et al.* (2022) [12], also reported that the diversity of molluscs in the Baguala Ambon mangrove ecosystem is categorized as medium.

Table 2 Diversity of Mollusc species in the Perancak mangrove

No	Species	Family	Ind./m²	Distribution frequency (%)	Importance Value
	Gastropoda				
1	*Cassidula aurisfelis*	Ellobiidae	0.08	16.67	2.56
2	*Cassidula mustelina*	Ellobiidae	0.25	4.17	5.79
3	*Cassidula nucleus*	Ellobiidae	0.79	8.33	13.94
4	*Cerithidea cingulata*	Potamididae	0.29	16.67	4.24
5	*Cerithidea obtusa*	Potamididae	0.75	4.17	17.38
6	*Telescopium telescopium*	Potamididae	0.21	12.50	5.46
7	*Terebralia sulcata*	Potamididae	2.08	8.33	31.92
8	*Terebralia triangularis*	Potamididae	0.13	33.33	2.90
9	*Littoraria carinifera*	Littorinidae	1.79	25.00	22.02
10	*Littorina scabra*	Littorinidae	2.42	16.67	42.16
11	*Littorina* sp.	Littorinidae	0.75	50.00	7.94
12	*Littorina undulata*	Littorinidae	0.67	4.17	12.93
13	*Nassarius dorsatus*	Nassariidae	0.08	16.67	2.56
14	*Nerita lineata*	Neritidae	0.33	4.17	10.24
	Bivalvia				
15	*Ostrea edulis*	Ostreidae	1.75	4.17	17.91
H = 2.39; E= 0.86					

Molluscs in the Perancak mangrove ecosystem, most of the molluscs found are from the gastropod class compared to bivalves. This condition is common in several mangrove forest ecosystems in Indonesia. Ginantra and Sundra (2023) [9], reported 19 species of molluscs from the Gastropoda class and 5 species from the Bivalvia class in the Nusa Lembongan mangrove; Rahardjanto *et al*. (2020) [21], recorded 11 species from the gastropod class and two species from the Bivalvia class in the Trenggalek mangrove forest; Kusuma *et al.* (2023) [16], reported 25 species of the gastropod class and eight species in the Batu Lumbang Tahura Ngurah Rai Bali mangrove forest; Ginantra *et al*. (2020) [7], found 19 species of the Gastropoda class and 7 species of Bivalvia in the Pejarakan Buleleng Bali Mangrove Forest and Kaharudin & Wahidin (2020) [15], recorded 14 species of gastropods and 3 species of Bivalvia in the Kendari Bay Mangrove, Sulawesi and Insani *et al.* (2024) [13], reported in the Central Lombok mangrove forest also found a richer diversity of species from the gastropod group.

The diversity of molluscs is important for the balance of the mangrove ecosystem in the Perancak mangrove forest, because molluscs act as consumers, especially litter eaters on the mangrove forest floor which indirectly act as decomposers. Hotchkiss and Hall, (2010) [11], stated that mangrove molluscs are biotic components in the mangrove forest ecosystem that are important in the food chain and nutrient cycle. As primary consumers and decomposers, molluscs play a role in the nutrient cycle of mangrove forests. Mollusc shells containing calcium carbonate also play a role in the carbon cycle that occurs in mangrove forests.

3.2. Association of Molluscs with Mangrove Vegetation

There are 11 species of mangrove plants associated with 15 species of molluscs in the Perancak mangrove sampling area. Thus, 154 species pairs (molluscs-mangroves) were produced with association strengths ranging from very low to very high (Table 3). The association of molluscs with mangrove plants can be based on the presence of molluscs on the substrate, roots, stems and leaves of mangrove plants where both species were found together in a sampling plot. Several species of mangrove molluscs show positive association (Ea) and high association strength (IO) with each other, namely *Nerita lineata - Rhizophora mucronata, Nerita lineata-Sonneratia alba, Cassidula nucleus-Rhizophora mucronata, Cassidula nucleus - Rhizophora mucronata, Littorina scabra - Avicennia lannata, Littorina scabra - Xylocarpus granatum, Littorina sp.-Avicennia lannata, Littorina* sp.- *Sesuvium portulacastrum.*

This positive and high association in several molluscs with mangrove plants is due to the high presence of molluscs on the mangrove plant site either on the roots, stems, leaves or substrate of the mangrove habitat. Several species of molluscs are often found attached to the leaves of mangrove plants *Rhizophora mucronata, Rhizophora apiculata, Avicennia lannata, Sonneratia alba, Xylocarpus granatum* namely *Littorina scabra, Cassidula nucleus, Nerita lineata*. Several species of molluscs are often found attached to the roots and stems of mangroves *Rhizophora mucronata, Avicennia lannata, Avicennia marina* namely *Cassidula nucleus*, *Littorina scabra, Littorina* sp. (Figure 3). One species of molluscs showed a positive association and high to very high association strength namely *Ostrea edulis-Sonneratia alba and Ostrea edulis-Rhizophora apiculata. Ostrea edulis* is a mangrove clam that is only found attached to the roots of the mangrove plants *Rhizophora apiculata* and *Sonneratia alba*.

Most molluscs showed low and very low associations with certain mangrove plant species (Table 3). This shows that most mollusc species are more associated with mangrove plant diversity than with specific associations with certain mangrove plants. The high variation of mangrove plants, both in terms of root structure, stems, leaves and litter produced, certainly provides varied resources for the diversity of mollusc species. Insani *et al.* (2024) [13], also found that molluscs were more associated with mangrove plant diversity in the Central Lombok mangrove ecosystem. Bayudana *et al.* (2022) and Takandare and Papilaya (2018) [2, 26], reported that the abundance of macrozoobenthos (including Gastropoda) was strongly associated with the density and diversity of mangrove vegetation in the Seribu Islands mangrove ecosystem and in the coastal Central Maluku. Al-Khayat *et al.* (2021) [1], also reported that the diversity of smoothfish was greatly influenced by the diversity of substrate types and mangrove vegetation in the Khor Qatar mangrove habitat.

Table 3 Association of molluscs with mangrove plants in the Perancak mangrove

No	Species pair (Molluscs-Mangrove plant)	The number of species plots present together (a)	Properties of association E(a)	Association categories (*)	Ochiai association index (IO)	Power of association
1	*Nerita lineata-Rhizophora mucronata*	4	2.67	positive	0.50	High
2	*Nerita lineata-Rhizophora apiculata*	1	0.50	positif	0.29	Low
3	*Nerita lineata-Avicennia marina*	1	1.17	negative	0.19	Very low
4	*Nerita lineata-Avicennia lannata*	2	0.83	positif	0.45	low
5	*Nerita lineata-Bruguiera gymnorhiza*	0	0.83	negative	0.00	very low
6	*Nerita lineata-Excoecaria agallocha*	1	0.50	positive	0.29	low
7	*Nerita lineata-Sonneratia alba*	2	0.67	positive	0.50	high
8	*Nerita lineata-Ceriops decandra*	0	0.17	negative	0.00	very low
9	*Nerita lineata-Xylocarpus granatum*	0	0.50	negative	0.00	very low
10	*Nerita lineata-Sesuvium portulacastrum*	0	0.17	negative	0.00	very low
11	*Nerita lineata-Clerodendrum inerme*	0	0.17	negative	0.00	very low
12	*Cassidula aurisfelis-Rhizophora mucronata*	1	0.67	negative	0.25	low
13	*Cassidula aurisfelis-Rhizophora apiculata*	0	0.13	negative	0.00	very low
14	*Cassidula aurisfelis-Avicennia marina*	0	0.29	negative	0.00	very low
15	*Cassidula aurisfelis-Avicennia lannata*	0	0.21	negative	0.00	very low
16	*Cassidula aurisfelis-Bruguiera gymnorhiza*	0	0.21	negative	0.00	very low
17	*Cassidula aurisfelis-Excoecaria agallocha*	0	0.13	negative	0.00	very low
18	*Cassidula aurisfelis-Sonneratia alba*	0	0.08	negative	0.00	very low
19	*Cassidula aurisfelis-Ceriops decandra*	0	0.04	negative	0.00	very low
20	*Cassidula aurisfelis-Xylocarpus granatum*	0	0.13	negative	0.00	very low

21	*Cassidula aurisfelis-Sesuvium portulacastrum*	0	0.04	negative	0.00	very low
22	*Cassidula aurisfelis-Clerodendrum inerme*	0	0.04	negative	0.00	very low
23	*Cassidula nucleus-Rhizophora mucronata*	4	2.67	positive	0.50	high
24	*Cassidula nucleus-Rhizophora apiculata*	1	0.50	positive	0.29	low
25	*Cassidula nucleus-Avicennia marina*	0	1.17	negative	0.00	very low
26	*Cassidula nucleus-Avicennia lannata*	0	0.67	negative	0.00	very low
27	*Cassidula aurisfelis-Bruguiera gymnorhiza*	0	0.83	negative	0.00	very low
28	*Cassidula nucleus-Excoecaria agallocha*	1	0.50	positive	0.29	low
29	*Cassidula nucleus-Sonneratia alba*	1	0.67	positive	0.25	low
30	*Cassidula nucleus-Ceriops decandra*	0	0.17	negative	0.00	very low
31	*Cassidula nucleus-Xylocarpus granatum*	0	0.50	negative	0.00	very low
32	*Cassidula nucleus-Sesuvium portulacastrum*	0	0.33	negative	0.00	very low
33	*Cassidula nucleus-Clerodendrum inerme*	0	0.17	negative	0.00	very low
34	*Cerithidea cingulata-Rhizophora mucronata*	1	0.67	positive	0.25	low
35	*Cerithidea cingulata-Rhizophora apiculata*	0	0.13	negative	0.00	very low
36	*Cerithidea cingulata-Avicennia marina*	1	0.29	positive	0.38	low
37	*Cerithidea cingulata-Avicennia lannata*	0	0.17	negative	0.00	very low
38	*Cerithidea cingulata-Bruguiera gymnorhiza*	1	0.21	positive	0.45	low
39	*Cerithidea cingulata-Excoecaria agallocha*	0	0.13	negative	0.00	very low
40	*Cerithidea cingulata-Sonneratia alba*	0	0.17	negative	0.00	very low
41	*Cerithidea cingulata-Ceriops decandra*	0	0.04	negative	0.00	very low
42	*Cerithidea cingulata-Xylocarpus granatum*	0	0.13	negative	0.00	very low
43	*Cerithidea cingulata-Sesuvium portulacastrum*	0	0.08	negative	0.00	very low

44	*Cerithidea cingulata-Clerodendrum inerme*	0	0.04	negative	0.00	very low
45	*Cerithidea obtusa-Rhizophora mucronata*	4	4.00	positive	0.41	low
46	*Cerithidea obtusa-Rhizophora apiculata*	1	0.75	positive	0.24	low
47	*Cerithidea obtusa-Avicennia marina*	3	1.75	positive	0.46	low
48	*Cerithidea obtusa-Avicennia lannata*	2	1.25	positive	0.37	low
49	*Cerithidea obtusa-Bruguiera gymnorhiza*	0	1.25	negative	0.00	very low
50	*Cerithidea obtusa-Excoecaria agallocha*	1	0.75	positive	0.24	low
51	*Cerithidea obtusa-Sonneratia alba*	2	1.00	positive	0.41	low
52	*Cerithidea obtusa-Ceriops decandra*	0	0.25	negative	0.00	very low
53	*Cerithidea obtusa-Xylocarpus granatum*	0	0.75	negative	0.00	very low
54	*Cerithidea obtusa-Sesuvium portulacastrum*	0	0.50	negative	0.00	very low
55	*Cerithidea obtusa-Clerodendrum inerme*	0	0.25	negative	0.00	very low
56	*Littoraria carinifera-Rhizophora mucronata*	3	2.67	positive	0.38	low
57	*Littoraria carinifera-Rhizophora apiculata*	1	0.50	positive	0.29	low
58	*Littoraria carinifera-Avicennia marina*	1	1.17	negative	0.19	very low
59	*Littoraria carinifera-Avicennia lannata*	1	0.83	positive	0.22	low
60	*Littoraria carinifera-Bruguiera gymnorhiza*	0	0.83	negative	0.00	very low
61	*Littoraria carinifera-Excoecaria agallocha*	1	0.50	positive	0.29	low
62	*Littoraria carinifera-Sonneratia alba*	1	0.67	positive	0.25	low
63	*Littoraria carinifera-Ceriops decandra*	0	0.17	negative	0.00	very low
64	*Littoraria carinifera-Xylocarpus granatum*	0	0.50	negative	0.00	very low
65	*Littoraria carinifera-Sesuvium portulacastrum*	0	0.33	negative	0.00	very low
66	*Littoraria carinifera-Clerodendrum inerme*	0	0.17	negative	0.00	very low

67	*Littorina scabra-Rhizophora mucronata*	6	8.00	negative	0.43	low
68	*Littorina scabra-Rhizophora apiculata*	1	1.50	negative	0.17	very t low
69	*Littorina scabra-Avicennia marina*	2	3.50	negative	0.22	very low
70	*Littorina scabra-Avicennia lannata*	4	2.50	positive	0.52	high
71	*Littorina scabra-Bruguiera gymnorhiza*	3	2.50	positive	0.39	low
72	*Littorina scabra-Excoecaria agallocha*	1	1.50	negative	0.17	very low
73	*Littorina scabra-Sonneratia alba*	1	2.00	negative	0.14	very low
74	*Littorina scabra-Ceriops decandra*	1	0.50	positive	0.29	low
75	*Littorina scabra-Xylocarpus granatum*	3	1.50	positive	0.50	high
76	*Littorina scabra-Sesuvium portulacastrum*	2	1.00	positive	0.41	low
77	*Littorina scabra-Clerodendrum inerme*	1	0.50	positive	0.29	low
78	*Littorina* sp.-*Rhizophora mucronata*	1	0.67	positive	0.25	low
79	*Littorina sp.-Rhizophora apiculata*	0	0.13	negative	0.00	very low
80	*Littorina sp.-Avicennia marina*	0	0.29	negative	0.00	very low
81	*Littorina sp.-Avicennia lannata*	1	0.17	positive	0.50	high
82	*Littorina sp.-Bruguiera gymnorhiza*	0	0.21	negative	0.00	very low
83	*Littorina sp.-Excoecaria agallocha*	0	0.13	negative	0.00	very low
84	*Littorina sp.-Sonneratia alba*	0	0.17	negative	0.00	very low
85	*Littorina* sp.-*Ceriops decandra*	0	0.04	negative	0.00	very low
86	*Littorina* sp.-*Xylocarpus granatum*	0	0.13	negative	0.00	very low
87	*Littorina sp.-Sesuvium portulacastrum*	1	0.08	positive	0.71	high
88	*Littorina sp.-Clerodendrum inerme*	0	0.04	negative	0.00	very low
89	*Littorina undulata-Rhizophora mucronata*	2	2.67	negative	0.25	low

90	*Littorina undulata-Rhizophora apiculata*	0	0.50	negative	0.00	very low
91	*Littorina undulata-Avicennia marina*	2	1.33	positive	0.35	low
92	*Littorina undulata-Avicennia lannata*	1	0.50	positive	0.29	low
93	*Littorina undulata-Bruguiera gymnorhiza*	1	0.83	positive	0.22	very low
94	*Littorina undulata-Excoecaria agallocha*	0	0.50	negative	0.00	very low
95	*Littorina undulata-Sonneratia alba*	0	0.67	negative	0.00	very low
96	*Littorina undulata-Ceriops decandra*	0	0.17	negative	0.00	very low
97	*Littorina undulata-Xylocarpus granatum*	0	0.50	negative	0.00	very low
98	*Littorina undulata-Sesuvium portulacastrum*	1	0.33	positive	0.35	low
99	*Littorina undulata-Clerodendrum inerme*	0	0.17	negative	0.00	low
100	*Nassarius dorsatus-Rhizophora mucronata*	1	0.67	positive	0.25	low
101	*Nassarius dorsatus-Rhizophora apiculata*	0	0.13	negative	0.00	very low
102	*Nassarius dorsatus-Avicennia marina*	0	0.29	negative	0.00	very low
103	*Nassarius dorsatus-Avicennia lannata*	0	0.21	negative	0.00	very low
104	*Nassarius dorsatus-Bruguiera gymnorhiza*	0	0.21	negative	0.00	very low
105	*Nassarius dorsatus-Excoecaria agallocha*	0	0.13	negative	0.00	very low
106	*Nassarius dorsatus-Sonneratia alba*	0	0.13	negative	0.00	very low
107	*Nassarius dorsatus-Ceriops decandra*	0	0.04	negative	0.00	very low
108	*Nassarius dorsatus-Xylocarpus granatum*	0	0.13	negative	0.00	very low
109	*Nassarius dorsatus-Sesuvium portulacastrum*	0	0.08	negative	0.00	very low
110	*Nassarius dorsatus-Clerodendrum inerme*	0	0.04	negative	0.00	very low
111	*Telescopium telescopium-Rhizophora mucronata*	2	1.33	positive	0.35	low
112	*Telescopium telescopium-Rhizophora apiculata*	0	0.25	negative	0.00	very low

113	*Telescopium telescopium-Avicennia marina*	0	0.58	negative	0.00	very low
114	*Telescopium telescopium-Avicennia lannata*	0	0.42	negative	0.00	very low
115	*Telescopium telescopium-Bruguiera gymnorhiza*	0	0.42	negative	0.00	very low
116	*Telescopium telescopium-Excoecaria agallocha*	1	0.33	positive	0.35	low
117	*Telescopium telescopium-Sonneratia alba*	0	0.25	negative	0.00	very low
118	*Telescopium telescopium-Ceriops decandra*	0	0.08	negative	0.00	very low
119	*Telescopium telescopium-Xylocarpus granatum*	0	0.25	negative	0.00	very low
120	*Telescopium telescopium-Sesuvium portulacastrum*	0	0.17	negative	0.00	very low
121	*Telescopium telescopium-Clerodendrum inerme*	0	0.08	negative	0.00	very low
122	*Terebralia sulcata-Rhizophora mucronata*	4	5.33	negative	0.35	low
123	*Terebralia sulcata-Rhizophora apiculata*	1	1.00	positive	0.20	very low
124	*Terebralia sulcata-Avicennia marina*	3	2.33	positive	0.40	low
125	*Terebralia sulcata-Avicennia lannata*	0	1.67	negative	0.00	very low
126	*Terebralia sulcata-Bruguiera gymnorhiza*	1	1.67	negative	0.16	very low
127	*Terebralia sulcata-Excoecaria agallocha*	2	1.00	positive	0.41	low
128	*Terebralia sulcata-Sonneratia alba*	1	1.33	negative	0.18	very low
129	*Terebralia sulcata-Ceriops decandra*	0	0.33	negative	0.00	very low
130	*Terebralia sulcata-Xylocarpus granatum*	1	1.00	positive	0.20	very low
131	*Terebralia sulcata-Sesuvium portulacastrum*	0	0.67	negative	0.00	very low
132	*Terebralia sulcata-Clerodendrum inerme*	0	0.33	negative	0.00	very low
133	*Terebralia triangularis-Rhizophora mucronata*	1	0.67	positive	0.25	low
134	*Terebralia triangularis-Rhizophora apiculata*	0	0.13	negative	0.00	very low
135	*Terebralia triangularis-Avicennia marina*	0	0.29	negative	0.00	very low

136	*Terebralia triangularis-Avicennia lannata*	0	0.21	negative	0.00	very low
137	*Terebralia triangularis-Bruguiera gymnorhiza*	0	0.21	negative	0.00	very low
138	*Terebralia triangularis-Excoecaria agallocha*	0	0.13	negative	0.00	very low
139	*Terebralia triangularis-Sonneratia alba*	0	0.13	negative	0.00	very low
140	*Terebralia triangularis-Ceriops decandra*	0	0.04	negative	0.00	very low
141	*Terebralia triangularis-Xylocarpus granatum*	0	0.13	negative	0.00	very low
142	*Terebralia triangularis-Sesuvium portulacastrum*	0	0.08	negative	0.00	very low
143	*Terebralia triangularis-Clerodendrum inerme*	0	0.04	negative	0.00	very low
144	*Ostrea edulis-Rhizophora mucronata*	2	1.33	positive	0.35	low
145	*Ostrea edulis-Rhizophora apiculata*	2	0.25	positive	0.82	sangat high
146	*Ostrea edulis-Avicennia marina*	1	0.58	positive	0.27	low
147	*Ostrea edulis-Avicennia lannata*	1	0.42	positive	0.32	low
148	*Ostrea edulis-Bruguiera gymnorhiza*	0	0.33	negative	0.00	very low
149	*Ostrea edulis-Excoecaria agallocha*	0	0.25	negative	0.00	very low
150	*Ostrea edulis-Sonneratia alba*	2	0.33	positive	0.71	high
151	*Ostrea edulis-Ceriops decandra*	0	0.08	negative	0.00	very low
152	*Ostrea edulis-Xylocarpus granatum*	0	0.25	negative	0.00	very low
153	*Ostrea edulis-Sesuvium portulacastrum*	0	0.17	negative	0.00	very low
154	*Ostrea edulis-Clerodendrum inerme*	0	0.08	negative	0.00	very low

(*) positive association if the value of a > E(a); negative association if the value of a < E(a)

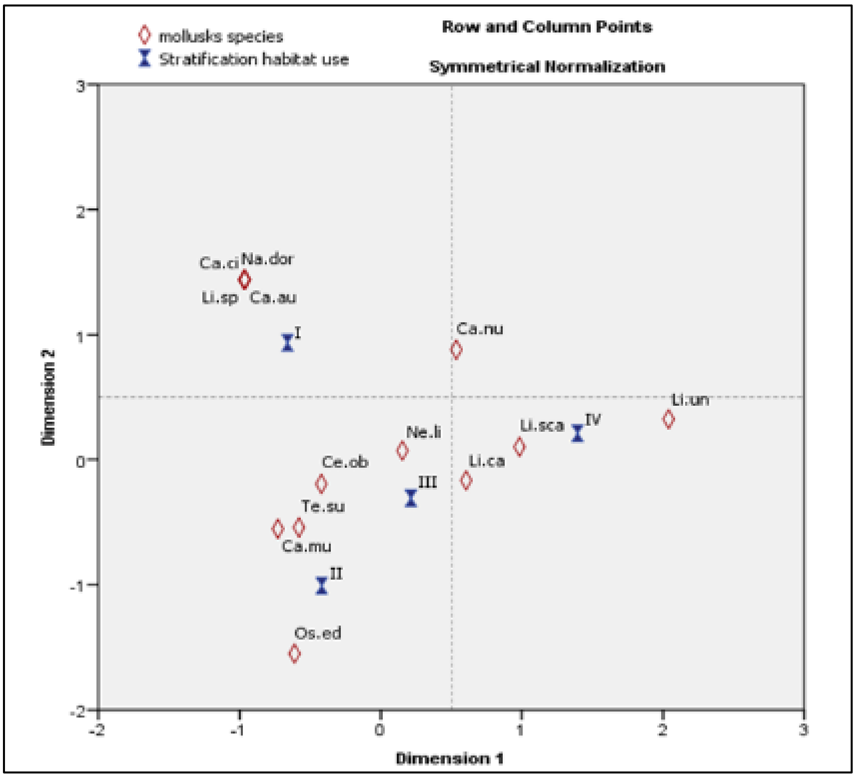

Figure 2 DCA analysis of vegetation strata use by molluscs in Perancak Jembrana mangrove forest

(Habitat stratification; I: Substrate, II: Roots, III: Stem, IV: Branches and leaves). (Mollusc species ; Ca.au: *Cassidula aurisfelis*, Ca.mu: *Cassidula mustelina*, Ca.nu: *Cassidula nucleus*, Ca.ci: *Cerithidea cingulata*, Ce.ob: *Cerithidea obtusa*, Li.ca: *Littoraria carinifera*; Li. sca: *Littorina scabra*, Li.sp: *Littorina* sp., Li.un: *Littorina undulata*, Na.dor: *Nassarius dorsatus*, Ne.li: *Nerita lineata*, Os.ed: *Ostrea edulis*, Te.te: *Telescopium telescopium*, Te.su: *Terebralia sulcata*, Te.tri: *Terebralia triangularis)*

The association of habitat strata use by molluscs is presented in Figure 2 (DCA analysis). Molluscs use roots, stems and leaves for eating, resting and sheltering. From the results of the association, it appears that the mollusc species that strongly use strata I (substrate) are *Cerithidea cingulata, Nassarius dorsatus, Littorina* sp., *Cassidula aurisfelis*. Wahida *et al*. (2024) [27], reported that *Cerithidea cingulata* is commonly found in mangrove substrates in the West Lombok mangrove forest. Mollusc species that commonly use strata II (mangrove roots) and strata III (mangrove stems) are *Ostrea edulis*, *Cassidula mustelina*, *Terebralia sulcata, Cerithidea obtusa, Nerita lineata*. These species in some individuals were observed in the roots and also in the mangrove stems. Kusuma *et al.* (2023) [16], reported that gastropods of the *Terebralia sulcata* species generally attach to mangrove roots in the Simbar Segara Tahura Ngurah Rai mangrove forest, Bali. Three species of molluscs are strongly associated with strata IV (mangrove leaves and branches), namely *Littoraria carinifera, Littorina scabra, Littorina undulata*. Siahaan *et al*. (2022) [22], also found that *L. scabra* widely uses the leaves and stems of mangroves in the mangrove ecosystem on Padaidori Island, Biak Numfor Regency, Papua. Darmi *et al.* (2017) [4], also reported that *Littorina* sp. gastropods were often found attached to mangrove leaves in the Kuala Baru Sambas mangrove forest.

	
Littorina undulata	*Littorina scabra*
	
Ostrea edulis	*Terebralia sulcata*
	
Cerithidea cingulata	*Telescopium telescopium*

Figure 3 Several species of molluscs in mangrove substrate and vegetation

Figure 3 shows several species of molluscs that use substrates, roots, stems, leaves/branches for feeding, resting and sheltering. Some species that are commonly found on the substrate for feeding activities are *Cerithidea cingulata* and *Telescopium telescopium*. *Ostrea edulis* (bivalvia) attaches to the mangrove roots of the *Rhizophora apiculata* species in the estuary zone which is almost always inundated. The species that attaches to the mangrove trunk is *Terebralia sulcata.* Two species of gastropods, namely *Littorina undulata* and *Littorina scabra*, commonly carry out feeding activities on the leaves and twigs of mangrove plants (*Sonneratia alba*).

Molluscs from the class Gastropoda (mangrove snails) have a structure called an odontophore at the anterior end of their digestive tract (mouth part), this organ supports a wide ribbon-like section topped with "teeth" (denticles) called a radula. This radula is used to scrape, cut, or tear food. The radula is used for eating, muscles push the radula out of the mouth, spread it, then slide it over the supporting odontophore, carrying particles or pieces of food and dirt into the esophagus. Parts of the mangrove plant, namely bark or roots, leaves and litter become organic sources (food) for

Gastropoda. This process will produce organic material which is then reused by mangrove trees as a source of nutrition. This process will stimulate the existence and biodiversity of molluscs, both bivalves and gastropods. This process is important in the nutrient cycle and helps accelerate the decomposition of organic matter, acting as decomposers in the mangrove ecosystem [3, 18].

4. Conclusion

The results of the study found 14 species of molluscs from the Gastropoda class which are included in five families and one species from the Bivalvia class. The dominant mollusc species include *Littorina scabra, Terebralia sulcata, Littoraria carinifera and Cerithidea obtusa*. The mollusc diversity index is 2.39, the evenness index is 0.86, this indicates that the condition of the Perancak mangrove forest is in the stable category.

Several species of molluscs show high association with mangrove plant species, namely *Nerita lineata - Rhizophora mucronata, Nerita lineata - Sonneratia alba, Cassidula nucleus - Rhizophora mucronata, Cassidula nucleus - Rhizophora mucronata*, *Littorina scabra - Avicennia lannata*, *Littorina scabra - Xylocarpus granatum*, *Littorina sp.- Avicennia lannata*, *Littorina* sp.-*Sesuvium portulacastrum*.

Molluscs are associated with mangroves in four strata, namely substrate, roots, stems and leaves of mangrove vegetation. Mollusc species that strongly use strata I (substrate) are *Cerithidea cingulata, Nassarius dorsatus, Littorina* sp., *Cassidula aurisfelis*. Mollusc species that commonly use strata II (mangrove roots) and strata III (mangrove stems) are *Ostrea edulis*, *Cassidula mustelina*, *Terebralia sulcata, Cerithidea obtusa, Nerita lineata*. Three species of molluscs are strongly associated with strata IV (mangrove leaves and branches), namely *Littoraria carinifera, Littorina scabra, Littorina undulata*.

Compliance with ethical standards

Acknowledgments

We would like to thank the Head of the Institute for Research and Community Service and the Dean of the Faculty of Mathematics and Natural Sciences, Udayana University for funding the research through the 2024 Study Program Excellence Research scheme. Thank you to the Biology students of Udayana University, namely Rivan Hadinata Surya, I Made Widi Angga Suputra and I Komang Adi Pradipta for their assistance in research and sample collection in the field.

Disclosure of conflict of interest

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

Author's declaration

All authors are responsible for research planning, research implementation and writing of publication articles.

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