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Diversity of mollusks in the Segara Batu Lumbang mangrove forest, Pemogan Denpasar Bali

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Abstract

Research has been conducted on the diversity and distribution of mollusks from the Gastropod and Bivalvia class along the Segara Batu Lumbang Mangrove Tourism. The study was conducted in February to April 2023. Sampling was carried out in four mangrove forest sites namely in BL1, BL2, BL3 and BL4. In each site, three square plots are placed, so the total number of squares is 12 squares. Each square measuring 1m x 1m. The density of the mollusk species is determined based on the number of individuals per unit area, the diversity of mollusks species is analyzed by the Shanon-Wiener diversity index and the mollusks distribution using the frequency of attendance. The results of the study were found 33 species of mollusks consisting of 25 species from the gastropod class and 8 species from the Bivalvia class. The diversity of mollusks species is included in the medium category and the evenness index including the Very equitable category. This indicates that the condition of mangroves in Segara Batu Lumbang is a good/stable category. Some mollusk species whose density is high enough is *Terebralia palustris* (8.17 individuals/m^2), *Littoraria scabra* (4.67 individuals/m^2), *Littoraria undulata* (2.17 individuals/m^2) and *Anadara antiquata* (2.25 individuals/m^2). Based on the frequency of its distribution/presence, 4 species of gastropod are included in the moderate category (50%≤fi≤ 75%), namely *Littoraria scabra*, *Littoraria undulata*, *Telescopium telescopium*, *Terebralia sulcata* and one species namely *Terebralia palustris* included the category of frequent/absolute (FI>75%). One species from the Bivalvia class is the *Bengalensis polymesoda* of the frequency of its presence including moderate. Mollusks from the gastropod class can be found in roots, stems, leaves of mangrove plants and substrates, while mollusks from the Bivalvia class are generally found in the mangrove habitat substrate.

Keywords: Mangroves; Diversity; Attendance distribution; Mollusks; Gastropods; Bivalvia

1. Introduction

The mangrove area in Indonesia reaches 25 percent of the total mangrove area in the world. In Indonesia, there is a large mangrove forest around the Sunda Basin and is relatively calm and inhabits the mouths of rivers that are on the east coast of Sumatra and the west coast and Kalimantan. On the north coast of Java, these forests have long been eroded by the community's needs for new land clearing. In eastern Indonesia, at shallow sea of Sahul, the mangrove forest which is still maintained is on the southwest coast of Papua, especially around the Bintuni Bay. Mangrove in Papua covers an area of 1.3 million ha., about one third of the area of Indonesian mangroves [9]. In Bali, based on data from the Ministry of Environment and Forestry, the area of mangrove land in Bali Province reaches 2,143.97 hectares, which is distributed in South Bali (Tahura Ngurah Rai) covering 1,373.5 ha, Mangrove Nusa Lembongan covering 202 ha, estuary stretching, which is located in Jembrana Regency Bali has a mangrove forest with an area of 177.09 ha., Gilimanuk Bay covering an area of 265, 92 ha and Buleleng Regency covering 1,291.40 ha. [18].

Mangrove is an ecosystem that provides productive habitats and can support coastal fisheries including mollusks, crabs, shrimp, fish, and other fauna including birds, reptiles, insects and mammals. Mangrove forests have a high diversity of

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biota. The diversity of fauna includes arboreal, terrestrial, semi-executive, mollusks, crustaceans, fish and other aquatic fauna. Mangroves become excellent habitats to support growth and reproduction for the preservation of species in ecosystems. Mangrove is also a habitat for feeding ground, spawning ground and is a nursery ground for various associated marine biota [10, 20].

Segara Batu Lumbang mangrove forest is part of the Tahura Ngurah Rai mangrove forest area, which was developed as a mangrove tourist attraction by the Simbar Segara Pemogan group and the manager of Dalem Luhur temple of Segara Batu Lumbang. Mangrove forests in Segara Batu Lumbang are also one of the tourist attractions based on conservation of the diversity of mangrove fauna flora. Mangrove tourism developed is mangrove tour with canoe or "jukung", fishing tour, voluntourism tourism, and spiritual tourism. In mangrove tourism activities, the diversity of flora fauna is an attraction for tourist, both mangrove plants (rooting types, fruit shapes), mollusks (gastropods and bivalvia), crustaceans, fish and birds. Mangrove tourism facilities in the Batu Lumbang area are canoe, "Jukung", Boat, canoe hall and fishing routes [4, 26].

Mollusks is one of the dominant and important fauna groups in mangrove ecosystems. Mollusks live on the surface of the substrate or inside the substrate or attach to the mangrove tree. The mollusks distribution in mangrove forests is influenced by several factors, namely substrate and depth types, mangrove plant species, salinity, temperature, pH, oxygen, and nutrient availability. Mollusks are important keystone ecosystems, to help arrange a basic waters because the nutrient content in the mollusk shell stranded on the coast can become into nutrients for the coast and inhibits abrasion and provides habitat for the hermit crabs and other microorganisms, protection from predators for microorganisms living in it, and food for a variety of other taxa such as cuttlefish bone which is a food for the Aves group. Most mollusks that live in mangrove ecosystems are members of the gastropod and bivalvia class. The gastropod class is often called a legged mollusks in the stomach and has the most members, consisting of snails that can live in the sea, fresh water and land. Bivalvia class is also called *Pelecypoda* or *Lamellibranchiata*, consisting of clam, "kijing" and mussels. Members of this class have two shells connected by ligaments, namely an elastic hinge [1, 11, 15].

Some mollusk diversity studies in mangrove forests in Bali have been carried out, including Ginantra et al. (2020) [3] found 27 Species Mollusks in the coastal mangrove forest of the Pejarakan Buleleng, Pratiwi et al. (2022) [19] found as many as 12 species in mangrove Kampoeng Kepiting Tuban Badung Bali, and Suartini et al. (2013) [25] found as many as 17 species of mollusks at the Ngurah Rai Mangrove Information Center, Bali. Research on Mollusks species in the mangrove forest of the Segara Batu Pemogan tourist area has not been carried out, so this research is important to do. So the purpose of this study is to determine the diversity and distribution of mollusks along the Segara Batu Pemogan Denpasar mangrove tourism path. The results of this study are expected to be one of the references in mangrove forest conservation.

2. Material and methods

2.1. Study sites and periods

This research was conducted in the Segara Batu Lumbang Mangrove Forest Tourism, which is located in Pemogan Village, Denpasar, Bali Province. Geographically it is located at 8^0 43 '44 02 "S and 115^o 11' 46 07" E, with a height of about 0 to 2.5 meters above sea level (masl.) (Figure 1). Research in the field was conducted in January-April 2023.

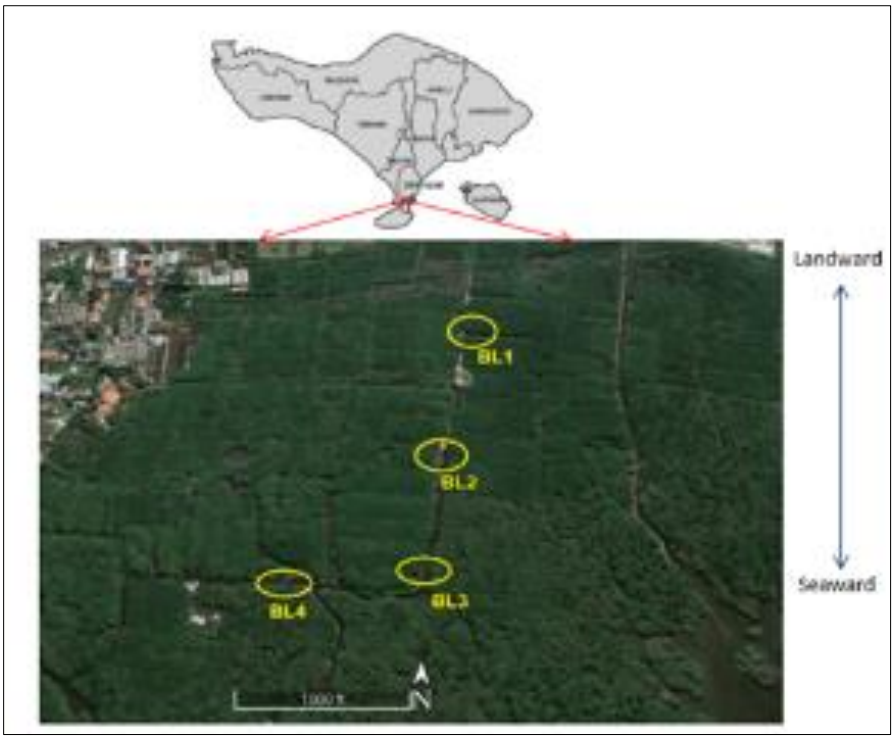


Figure 1 Map of research location in the Mangrove Tourism area Segara Luhur Batu Lumbang. (Source: Google Maps Pro 2023)

2.2. Mollusk sampling

Mollusk samples were taken in 4 mangrove forest sites, namely on the BL1, BL2, BL3 and BL4 sites. In each site, 3 square plots were taken, so that the total number of squares was 12 quadratic plots. Each square measuring 1 m x 1 m. In each of the predetermined squares, the substrate is dug up to a depth of 20 cm. Sampling is done at low tide. Representatives of the mollusk species found in the plot are taken and put in a sample bottle. The sample in the bottle was preserved with alcohol (70%), then identified in the laboratory of Animal Taxonomy Laboratories, Biology Study Program, Faculty of Mathematics and Natural Sciences, Udayana University.

2.3. Identification of mollusks species

All specimens are photographed and identified. Mollusca identification based on morphological character (shape, size, texture of shells and shell colors), identification refers to Htwe & Naung (2019), Ginting et al. (2017), Merly et al. (2022a), Nursalwa and Marshall (2014), Ramanibai & Govindan (2018), Tan & Clements (2008) [2, 5, 12, 14, 21, 28].

2.4. Determine the distribution and abundance of mollusks.

In each quadratic of each species of mollusks found the number of individuals is calculated. The distribution of species is determined based on the presence and abundance of each species in each sampling plot. The abundance of each species is calculated based on the number of individuals per unit area (m^2). The presence of mollusks in mangrove habitat is recorded (in mud, attached to the roots, in leaf or in mangrove stems). Mangrove plants in the research site are also identified based on the morphology of mangrove plants namely roots, leaves, flowers, and fruit with reference to the book Identification of Kitamura et al. (1997) [10].

2.5. Data analysis

The diversity of mollusks is calculated by the Shanon-Wiener Diversity Index (H), which H =-∑ [Ni/N x ln Ni/N), which is Ni= the important value of the i-species and N= total important value of all species. The important value is determined from 2 parameters, namely: relative density (Kr) = (Ni/∑N) x 100%, which is Ni = density of the i-species, ∑N= total density of all species mollusks and relative frequency (FR)= (fi/∑f) x 100%, fi = frequency of the presence of the i-species, ∑f = total frequency of all species. Important value of each species (Ni) = Kr + Fr. The evenness index (E) = H/*LnS*, H = diversity index, S = number of species [23].

The frequency of mollusk species distribution is determined by the formula fi (%) = (fi.p/n.p) x100, which fi.p is the number of plots of a species present, n.p is the total number of plot sampling. The category of attendance frequency value is as follows; fi <25% category is very rare, 25%≤fi <50% is a rare category, 50% ≤ fi ≤ 75% included moderate categories and fi> 75% frequent/absolute categories [11].

3. Results and discussion

3.1. Mollusk diversity

A total of 33 species of mollusks from the Gastropod and Bivalvia class were found in the Segara Batu Lumbang Mangrove area (Figure 2 and Figure 3). From the Gastropod class 25 species were found included in 11 families and from Bivalvia as many as 8 species included in 6 families (Table 1). The results showed that Gastropod species from the Potamididae, Muricidae, Neritidae and Littorinidae family are more dominant than the other 7 families, while the Bivalvia class is dominated by the Arcidae family. This result is almost similar to the diversity of mollusks in the southern coastal mangrove of East Lombok and the Malaysian Sarawak mangrove [8,16], that the mollusks species of the Potamididae family, Niritidae are quite dominant. But a little different for the family Muricidae and Littorinidae are less dominant in the mangrove habitat compared to the Segara Batu Lumbang Mangrove. Species from the Family Littorinidae and Potamididae are also quite dominant in the Kampoeng Kepiting mangrove of Tuban Badung Bali and in mangrove forest Sutera Village Sukadana District Kayong Utara Regency [19, 27] and Gastropods from the Potamididae, Muricidae, Niritidae and Littorinidae family are also quite dominant in the coastal mangrove of Pejarakan Buleleng [3]. Species from the Family Arcidae (Bivalvia) are also dominant in Mangrove Pejarakan Buleleng Bali [3] and in coastal of Tanjungbalai, North Sumatera [5].

Table 1 Diversity of mollusks in the Segara Batu Lumbang mangrove forest

No	Species	Family	Density (ind/m^2)	Important value
Gastropoda				
1	*Cerithidea obtusa*	Potamididae	0.25	3.27
2	*Telescopium telescopium*	Potamididae	0.42	6.21
3	*Terebralia palustris*	Potamididae	8.17	43.11
4	*Terebralia sulcata*	Potamididae	1.33	10.91
5	*Chicoreus capucinus*	Muricidae	0.42	3.91
6	*Indothais* sp.	Muricidae	0.25	3.27
7	*Tylothais virgata*	Muricidae	0.08	1.47
8	*Conus betulinus*	Conicidae	0.08	1.47
9	*Cypraea annulus*	Cypraeidae	0.25	3.27
10	*Cypraea boivinii*	Cypraeidae	0.42	5.06
11	*Eunaticina papilla*	Naticidae	0.33	3.59
12	*Natica vitellus*	Naticidae	0.42	5.06
13	*Hemifusus ternatanus*	Melongenidae	0.25	3.27
14	*Pugilina cochlidium*	Melongenidae	0.08	1.47
15	*Littoraria scabra*	Littorinidae	4.67	27.26
16	*Littoraria undulata*	Littorinidae	2.17	15.28
17	*Littoraria carinifera*	Littorinidae	1.00	7.32
18	*Oliva oliva*	Olividae	0.17	1.79
19	*Nerita balteata*	Neritidae	0.17	1.79

20	*Nerita planospira*	Neritidae	0.25	2.12
21	*Nerita plicata*	Neritidae	0.17	2.94
22	*Strombus marginatus*	Strombidae	0.17	2.94
23	*Strombus* sp.	Strombidae	0.08	1.47
24	*Trochus radiatus*	Trochidae	0.08	1.47
25	*Umbonium vestiarium*	Trochidae	0.08	1.47
Bivalvia				
26	*Anadara antiquata*	Arcidae	2.25	14.46
27	*Anadara corrugata*	Arcidae	0.58	6.86
28	*Anadara granosa*	Arcidae	0.25	3.27
29	*Decatopecten radula*	Pectynidae	0.08	1.47
30	*Gafrarium tumidum*	Veneridae	0.08	1.47
31	*Pinctada margaritifera*	Pteriidae	0.08	1.47
32	*Polimesoda bemgalemsis*	Corbiculidae	0.42	6.21
33	*Tellina cancellata*	Tellinidae	0.33	3.59
Diversity Index, H = 2.93				
Evenness index, E = 0.84				

Some species of mollusks are quite dominant found in Segara Batu Lumbang Mangrove, namely *Terebralia Palustris* (Important value 43.11), *Littoraria scabra* (Important Value 27.26), *Littoraria undulata* (important value 15.28), *Anadara antiquata* (important value 14.46). The density of these species respectively is 8.17 individuals /m^2, 4.67 individuals /m^2, 2.17 individuals /m^2, and 2.25 individuals/m^2. *Terebralia palustris* was also found dominant in several mangrove forests, including in the coastal mangrove of Pejarakan Buleleng [3], in Mangrove Payun Beach, Meraoke [13], and in the Mangrove Forest of the Sidangoli Islands, North Maluku [6].

Terebrallia palustris

Littoraria scabra

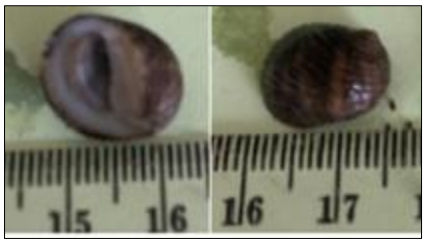
Littoraria undulata

Littoraria carinifera

Chicoreus capucinus

Trochus radiatus

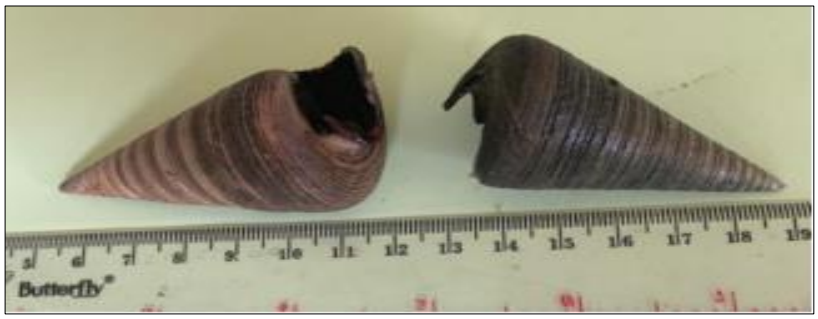
Nerita planospira



Nerita plicata

Nerita balteata

Terebralia sulcata



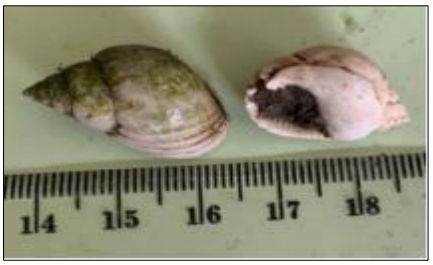
Telescopium telescopium

Hemifusus ternatanus

Cerithidea obtusa

Tylothais virgata

Umbonim vestiarium



Natica vitellus

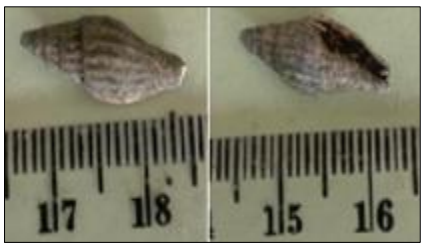
Strumbus marginatus

Cypraea boivinii

Eunaticina papilla

Cypraea annulus

Oliva oliva



Strombus sp.

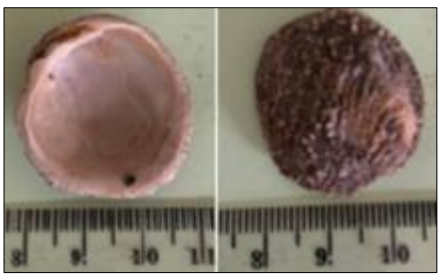
Indothais sp.

Conus betulinus

Pugilina cochlidium

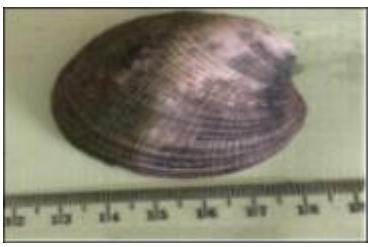
Figure 2 Species of Gastropod class in Segara Batu Lumbang mangrove forest, Pemogan

Polimesoda bengalensis

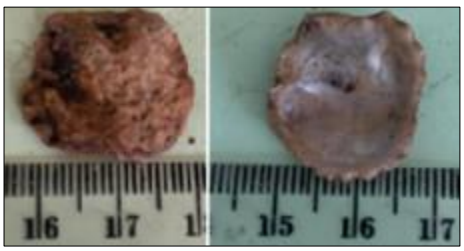


Anadara granosa

Anadara corrugata

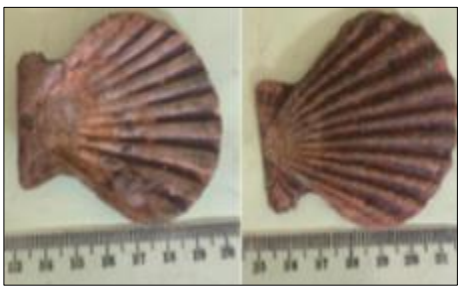


Tellina cancellata



Pinctada margaritifera

Anadara antiquata



Decatopecten radula

Gafrarium tumidum

Figure 3 Species of Bivalvia class in Segara Batu Lumbang mangrove forest, Pemogan

The diversity of mollusks species in Segara Batu Lumbang Mangrove is a medium category, with a diversity index (Shannon-Wiener) of 2.93 and a high or very equitable index of 0.84. The values of the evenness that are close to 1 also

means that of all species found (33 species of mollusks) there are no one or several species that dominate absolutely. Indications based on the diversity index and evenness index this can be a pointing that the condition of mangroves in the Segara Batu Lumbang Pemogan area of Denpasar Bali, belongs to the good/steady or stable category. Some researchers also reported a stable relationship of mangrove conditions based on the diversity of mollusks species. Ginantra et al. (2020) [3] reported that the condition of mangroves on the coast of Pejarakan Buleleng; Pratiwi et al. (2022) [19] in Mangrove Kampoeng Crab Tuban Badung Bali; Rahcman and Arianti (2020) [20] in the Coastal Mangrove Forest Teluk Uma Karimun Regency; and Putra et al. (2021) [16] in the South Coastal Mangrove East Lombok.

3.2. The mollusks distribution along the Segara Batu Lumbang mangrove path.

The results of the study were found that the species of Bivalvia classes were more limited compared to the gastropod class, Bivalvia more limited in mangrove zones near the sea, namely on the BL3 and BL4 sites, in the stone substrate or slightly muddy sand or rocky mud, while the species of the gastropod class was more evenly distributed on sites BL1, BL2, BL3 and BL4. Laheng et al. (2021) [11] states that the distribution of mollusks in mangrove forests is influenced by several factors, namely substrate and depth types, mangrove plant species, salinity, temperature, pH, oxygen, and nutrient availability. The presence of Bivalvia is also closely related to the habit of obtaining food, namely by filtering (filter feeders) materials that are suspended in sea water, so that Bivalvia is more suitable to live in the mangrove zone that tides does not get to dry and in the current/movement of water more often, namely in the zone of mangrove forests near the sea.

The number of gastropod species was more than the number species of Bivalvia in the Segara Batu Lumbang mangrove ecosystem. The composition of gastropod species is much higher at 80.6% compared to Bivalvia which is 19.4% (Table 2). Some researchers also reported that the diversity of species from the gastropod class in the mangrove ecosystem was higher than the Bivalvia class [16, 20, 24, 29]. Furthermore, Samsi et al. (2018) [24] states that gastropods are found more abundant than bivalvia, because Bivalvia is permanent and less able to move actively, so this class has more limited tolerance than gastropods. Mollusks from the Gastropod class the food habits are more varied, there are grazing on the leaves, root layer, bark layer and some are the habit of eating feeder filters or detritus feeders.

Table 2 Distribution of mollusks in each site of the Segara Batu Lumbang mangrove forest

No	Species	Fi (%)	The important value of the species on the site sampling			
			BL1	BL2	BL3	BL4
Gastropoda = 80.6%						
1	*Cerithidea obtusa*	16.67			11.82	
2	*Chicoreus capucinus*	16.67	13.74	9.10		
3	*Conus betulinus*	8.33			5.09	
4	*Cypraea annulus*	16.67			11.82	
5	*Cypraea boivinii*	25.00			13.45	3.82
6	*Eunaticina papilla*	16.67				9.24
7	*Hemifusus ternatanus*	16.67			11.82	
8	*Indothais* sp.	16.67				8.44
9	*Littoraria scabra*	66.67	26.12	31.93	23.29	33.69
10	*Littoraria undulata*	50.00	11.04		13.45	24.96
11	*Littorina carinifera*	25.00		28.01		7.00
12	*Natica vitellus*	25.00				13.06
13	*Nerita balteata*	8.33		11.06		

14	*Nerita planospira*	8.33	12.39			
15	*Nerita plicata*	16.67		9.10		3.82
16	*Oliva oliva*	8.33				4.62
17	*Pugilina cochlidium*	8.33				3.82
18	*Strombus marginatus*	16.67			5.09	3.82
19	*Strombus* sp.	8.33			5.09	
20	*Telescopium telescopium*	50.00	11.04	9.10	5.09	3.82
21	*Terebralia palustris*	83.33	96.61	47.62	29.85	20.20
22	*Terebralia sulcata*	58.33	9.68	44.96	8.37	
23	*Trochus radiatus*	8.33	9.68			
24	*Tylothais virgata*	8.33			5.09	
25	*Umbonium vestiarium*				5.09	
Bivalvia = 19.4%						
26	*Anadara antiquata*	41.67			16.90	24.31
27	*Anadara corrugata*	33.33			5.09	13.85
28	*Anadara granosa*	16.67				8.44
29	*Decatopecten radula*	8.33				3.82
30	*Gafrarium tumidum*	8.33			5.09	
31	*Pinctada margaritifera*	8.33				3.82
32	*Polimesoda bengalensis*	33.33	9.68	9.10	5.09	5.41
33	*Tellina cancellata*	16.67			13.45	
The number of species			9	9	19	19
Substrate type			Slightly rocky mud, sandy	Mud is quite deep	Muddy coral Muddy stones	Rocky mud
True Mangrove species			*Rhizophora mucronata* *Bruguiera gymnorhiza* *Xylocarpus granatum*	*Rhizophora mucronata* *Sonneratia alba* *Xylocarpus granatum*	*Sonneratia alba* *Rhizophora apiculata* *Xylocarpus granatum* *Rhizophora mucronata* *Xylocarpus granatum*	*Rhizophora apiculata* *Rhizophora mucronata* *Avicennia marina* *Lumnitzera racemosa* *Excoecaria agalocca*

				Xylocarpus granatum
Mangrove association species	*Thespesia populnea* *Casuarina equsetifolia* *Clerodendrum inerme* *Sesuvium portulacastrum*	*Thespesia populnea*		

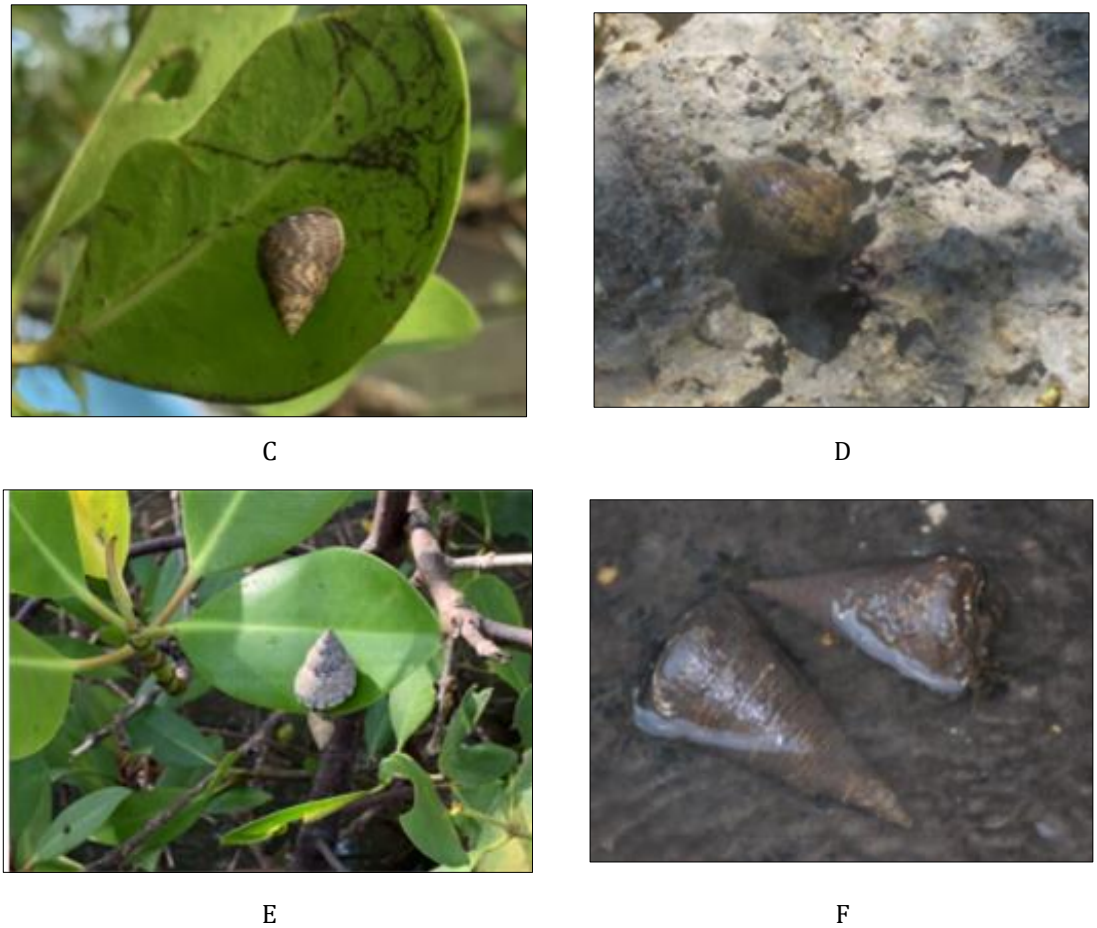
Some species of mollusk are found evenly distributed in all zoning and frequency of distribution including moderate categories (50%≤ fi ≤75%) and frequent/absolute (fi >75%) in Segara Batu Lumbang mangrove, including *Telescopium telescopium*, *Terebralia sulcata* and *Terebralia palustris*, The three of them are from Gastropoda, Family Potamididae. *Terebralia palustri*s and *Telescopium telescopium* (Figure 4) is generally found in mangrove forest substrates, both in mud substrates, sandy/rocky mud or in muddy sand substrates. Rahmawati et al. (2015) [22] states that gastropods from the genus of *Terebralia* are high gastropods to mangrove environmental conditions, especially salinity and substrate type. Hasan et al. (2020) [6] also reported that the species of the Potamididae family are always present in every mangrove forest zone (front, middle, or back zone) with the highest species composition in the back zone of the mangrove forest in the Sidangoli islands.

Littoraria scabra and *Littoraria undulata* species were also found evenly distributed in four Segara Batu Lumbang mangrove forest sites, the distribution frequency was a moderate category (50%≤ fi ≤75%). This gastopod species generally moves actively in mangrove plants both in the leaves, stems, and roots of the *Rhizophora apiculata* mangrove plant, *R. mucronata, Sonneratia alba*, *Xylocarpus granatum* (Figure 4). Putra et al. (2021) [16] and Idris et al. (2018) [7] states that a broad distribution in *Littorina* spp. because this species is able to survive only by splashes of tidal water, so that its existence is not threatened even in drought conditions. In addition, *Littorina* spp. has a shell with a low peak so that the movement is more stable. In general, mollusk shells with low peaks will produce more stable movements, and can adapt very well when moving upside down or when on the vertical surface of rocks or vegetation. This motion activity is thought to be associated with efforts to avoid inundation of tidal water, predators, and to find food.

Terebralia sulcata is also a species that attracts its attention in the Segara Batu Lumbang mangrove forest. This species is often found in the pencil-like root or conical root (pneumatophor) of the *Sonneratia alba* mangrove plants, especially on the BL2 site, while in the BL1 and BL3 site more found in mud substrates and flooded substrates. Suartini et al. (2013) [25] also found that the *Terebralia sulcata* species were more in the roots of mangroves at the Mangrove Information Center (MIC) Tahura Ngurah Rai. The existence of this species in the roots of mangroves is related to its eating habits, which eats the part of the root layer which is an organic substance using its radula. Putri & Patria (2018) [17] stated that *Terebralia* spp. the food is an organic substance of mangrove plants and also plays an important role in the litter decomposition in the mangrove forest. Thus, the role of mangrove vegetation for mollusks is to provide food sources, as well as a shelter from enemies or from high tides.

A

B



C D

E F

(A: *Littoraria undulata* at the stilt root of the *Rhizophora apiculata* mangrove plant; B:*Littoraria undulata* stick to the stem of the *Rhizophora apiculata* mangrove plant ; C: *Littoraria carinifera* in the leaves of the *Sonneratia alba* mangrove plant; D: *Nerita planospira* on the rocks; E : *Littoraria scabra* stick to the leaves of the *Sonneratia alba* mangrove plant; F: *Telescopium telescopium* in rocky mud slightly submerged in water.

Figure 4 The presence of several gastopods in the mangrove habitat

4. Conclusion

In the Segara Batu Lumbang Mangrove Forest found 33 species of mollusks consisting of 25 species from the Gastropod class and 8 species from the Bivalvia class. The diversity of mollusks species is included in the medium category and the evenness index including the high category. Some dominant mollusk species found are *Terebralia palustris*, *Littoraria scabra*, *Littoraria undulata* and *Anadara antiquata*. Based on the frequency of distribution,five species from class Gastropod are included in the moderate and frequent/absolute category in the Segara Batu Lumbang mangrove, *Telescopium telescopium*, *Terebralia sulcata*, *Terebralia palustris*, *Littoraria scabra*, *Littoraria undulata* and one species from the Bivalvia class of the presence of the frequency including moderate is *Polymesoda bengalensis.*

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

The implementation of the research and writing of the manuscript is the result of the collaboration of all the authors

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