INTL J BONOROWO WETLANDS
Volume 12, Number 1, June 2022
Pages: 1-11

P-ISSN: 2775-8052
E-ISSN: 2775-8044
DOI: 10.13057/bonorowo/w120101

Structure and composition of molluscs (bivalves and gastropods) in the mangrove ecosystem of Pacitan District, East Java, Indonesia

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Manuscript received: 27 December 2021. Revision accepted: 14 February 2022.

Abstract. *Wiraatmaja MF, Hasanah R, Dwirani NM, Pratiwi AS, Riani FE, Hasnaningtyas S, Nugroho GD, Setyawan AD. 2022. Structure and composition molluscs (bivalves and gastropods) in the mangrove ecosystem of Pacitan District, East Java, Indonesia. Intl J Bonorowo Wetlands 12: 1-11.* The mangrove ecosystem is a habitat for several species of molluscs. Therefore, mollusc's existence has an important role in the sustainability of the mangrove ecosystem. This research was conducted to determine the structure and composition of molluscs (gastropods and bivalves) in the mangrove ecosystem of Pacitan, East Java, Indonesia. The mollusc sampling was carried out at three mangrove ecosystems: Teleng Ria, Grindulu, and Siwil. Each sampling research location made a plot of 10 x 10 m. Then, the collected individual and mollusk species were analyzed using the Shanon-Weiner biodiversity index, species density, Margalef species richness index, evenness index, and Simpson dominance index. The molluscs found were 25 species, consisting of 17 gastropod species with 13 families. The gastropod families with the most species are Littorinidae (3), Ellobidae (2), and Potamididae (2). Meanwhile, there are eight species of bivalves consisting of five families. Then, Mytilidae (2), Ostreidae (2), and Veneridae (2) are the families with the most number of species in bivalves. The total molluscs obtained had a density of 36.9 individuals/100 m^2. The mollusc biodiversity index was 2.14 (medium), mollusc species richness reached 4.1 (medium), the evenness of species in this research reached 0.66 (quite even), and the species dominance index was recorded at 0.34 (low), which means that there are no dominant species in the research location. Then, each research location has a different species and density species of molluscs. That is caused by differences in the type of substrate (such as sandy, muddy, or rocky) and abiotic factors found in the research location (such as temperature, pH, and salinity).

Keywords: Bivalves, gastropods, mangrove ecosystem, mollusc diversity, Pacitan

INTRODUCTION

Indonesia has the largest island group in the world, with a very wide sea. It has 17,508 islands and a coastline of 81,000 km^2, the second-longest in the world after Canada (Wiryawan et al. 1999). Based on this, Indonesia has one of the largest and highest biodiversity in the world. Moreover, it has many diverse coastal ecosystems, such as coral reefs, extensive seagrass beds, and mangrove forests. However, not all coastal areas are covered with mangroves, and this is due to several requirements or environmental factors that control the formation of these forests, such as coastal physiography and climate.

Mangrove ecosystems are ecosystems located in coastal areas, and this area is affected by the tides of seawater so that the bottom is always flooded. Therefore, mangrove ecosystems have very important benefits in supporting living things from a physical, ecological, and economic perspective (Li et al. 2015; Alvareza and Leilani 2020). The benefits of mangrove ecosystems for humans are disaster mitigation, such as wave absorbers, and coastal protection from abrasion, tidal waves, and tsunami; this is because they are located on the border and close to the sea (Harahab and Setiawan 2017). In addition to its benefits in preventing natural disasters, another benefit of the mangrove ecosystem is as a natural tourist attraction because it is a cool place even though it is on the beach (Rahmila and Halim 2018).

In addition to its benefits for humans, the mangrove ecosystem can also function as a good habitat for various species of animals, especially animals that live in water. For example, mangrove ecosystems can be natural places for breeding and foraging fish, crabs, shrimp, and other organisms (Igulu et al. 2014; Shing et al. 2014; Vermeiren et al. 2015; Onyena and Sam 2020; Irwansyah et al. al. 2021).

In addition to the animals mentioned above, the mangrove ecosystem is also a habitat for molluscs.

Molluscs are the second-largest invertebrate group in the world, most of which members live in water (Saputra et al. 2020). Molluscs have the two largest members of the class, namely bivalves, and gastropods (Irma and Sofyatuddin 2012; Marshall et al. 2015). Both have different body shapes and shell sizes. This shell modification has the function of helping to distinguish the two classes (Dolorosa and Gallon 2014). Gastropods have a single-threaded shell characteristic, while bivalves have two dorsally interlocked shells (Nur'aini 2012). Gastropod habitats are found on various sand-mud slopes, and this is because gastropods are infauna animals, which give a striking reaction to the size of the texture of the seafloor, while bivalves have different characteristics way of life from gastropods (Dibyowati 2009). The way of life of bivalves is digging, immersing, and gluing themselves using an adherent device to the substrate (Ulmaula et al. 2016).

Bivalves and gastropods have many important values in human life because they can be used as food. In addition, the presence of molluscs, such as bivalves and gastropods, in an ecosystem can be used as a reference to assess the ecological quality of the ecosystem or as a bioindicator of environmental health (El-Sorogy et al. 2013; Sharma et al. 2013). If there are bivalves and gastropods with various species, the quality of the environment and water is still sustainable. In addition, the important role of bivalves and gastropods concerning biotic components in the mangrove ecosystem, apart from being detritus, plays a role in the process of litter decomposition and neutralizes organic matter that is herbivores and detrivores. That plays an important role in the food chain for ecosystem stability because it can support the life of other higher trophic animals (Pawar 2012; Suresh 2012; Irma and Sofyatuddin 2012). The existence and distribution of bivalves and gastropods are strongly influenced by pressure and changes from abiotic and biotic factors, such as environmental conditions, food sources, predation, competition, vegetation, and human activities (Akhrianti et al. 2014). Geographically, bivalves and gastropods are widely distributed on all continents except Antarctica, but patterns of diversity and distribution differ across regions: some areas represent high mollusc diversity (Neubauer et al. 2015), whereas others are faunistically poor, for example, Greenland (Vinarski et al. 2017).

Pacitan District, East Java, Indonesia, has a sustainable mangrove ecosystem with white sand and muddy and rocky substrate as a habitat for several species of mangrove plants and animal organisms (Irwansyah et al. 2021). The research about mangrove trees species in the Pacitan mangrove ecosystem is dominated by *Rhizophora mucronata, R. stylosa, Avicennia alba, Sonneratia alba, Nypa fruticans, A. marina* (Setyawan et al. 2002; Sholiqin et al. 2021). The mangrove vegetation creates habitat and provides suitable food for various living fauna. However, until now, the existence of molluscs, especially bivalves, and gastropods, both in terms of diversity and ecological aspects in the Pacitan mangrove ecosystem, has not been widely carried out by researchers. Whereas knowing the existence of molluscs in an ecosystem can potentially meet human economic needs, become a regulator of mangrove ecosystems, and other benefits for humans and nature.

The limited information about molluscs in Pacitan encourages researchers to determine the structure and composition of molluscs (bivalves and gastropods) in the Pacitan mangrove ecosystem. Furthermore, the information obtained from knowing the diversity of molluscs in this area is expected to be useful for planning the management of the coastal area of Pacitan District and extracting the potential of molluscs in the mangrove ecosystem of Pacitan District, East Java, Indonesia.

MATERIALS AND METHODS

Study site

The sampling was carried out on November 2021 and is located on the mangrove ecosystem of Pacitan District, East Java, Indonesia. Pacitan District is at coordinates between 7º55'-8º17'S and 110º55'-111º25'E. In 2021, according to Badan Pusat Statistik Kabupaten Pacitan (2021), the air temperature was 26-29°C, the average humidity was 23-27.5%, the number of rainy days is 179 days with rainfall 841 mm^3. Mangrove areas in Pacitan District are generally not polluted, and the land has the potential to grow mangrove plants (Dinas Kelautan dan Perikanan Kabupaten Pacitan 2014). The sampling consisted of three locations close to the beach: Teleng Ria, Grindulu, and Siwil. Teleng Ria and Grindulu in Pacitan Sub-district and Siwil in Ngadirojo Sub-district, Pacitan District, East Java, Indonesia (Figure 1).

Teleng Ria. The location research is at coordinates 08º13'19.63"S and 111º04'28.82" E. The vegetation mangrove trees of *A. alba* dominate this location. It has sandy and muddy soil characteristics because it is a riverbank area that leads directly to Teleng Ria Beach (Figure 2A). This location is also at the mouth of the river but not too close to Teleng Ria Beach and is a fishing pier and residential area.

Grindulu. This location is near Grindulu Beach at coordinates 08º13'55.75" S and 111º06'21.42"E. Grindulu is a mangrove conservation area still under development. It is evident from the number of mangrove plant seeds planted. Later this area will become ecotourism Watu Mejo Park and a mangrove nursery center in East Java. This location is a sandy and muddy area dominated by vegetation mangrove trees of *R. stylosa* (Figure 2B).

Siwil. The third location in this research is a river estuary close to Siwil Beach (08°15'37.4"S and 111°17'00.1"E) dominated by the vegetation mangrove tree of *S. alba.* This location is a tidal area with sandy, muddy, and rocky substrate (Figure 2C). According to Sholiqin et al. (2021), this location is intended for mangrove restoration after hit a big flood at the end of 2017. Also, it intended prevention for the flood season. This location's estimated area of mangrove trees is the smallest compared to Teleng Ria and Grindulu.

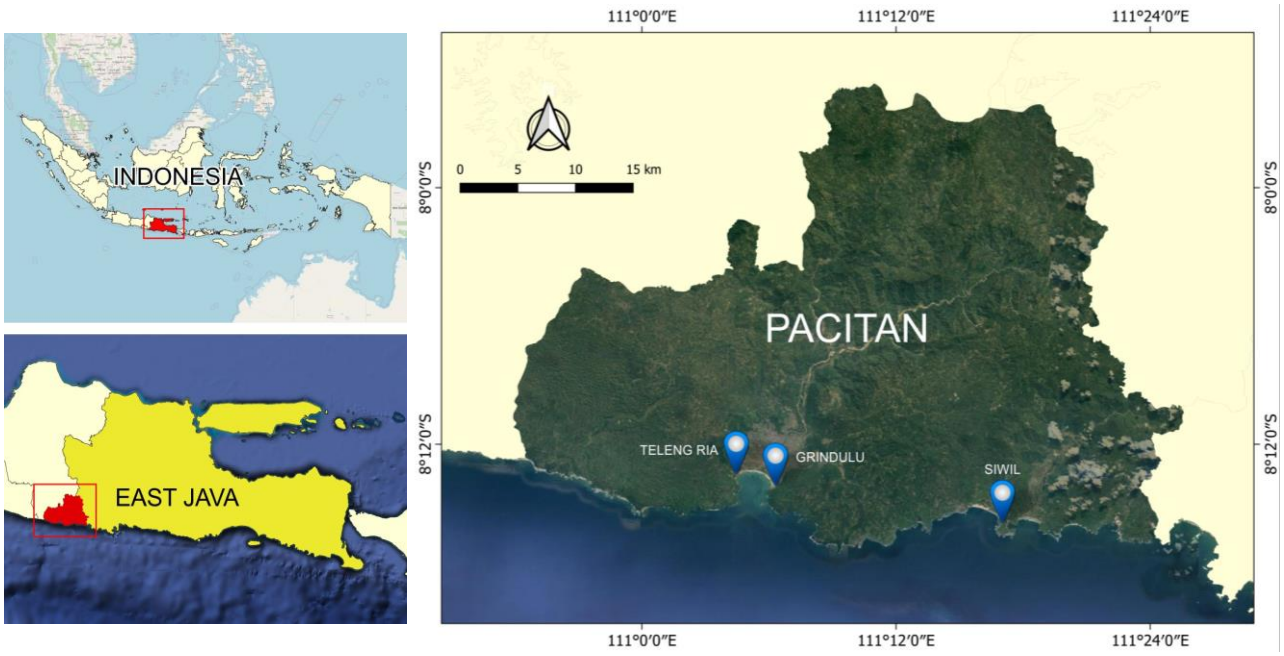

Figure 1. The sampling area in the mangrove ecosystem of Pacitan District, East Java, Indonesia (Location 1: Teleng Ria; location 2: Grindulu; location 3: Siwil)

A **B** **C**

Figure 2. Condition of each mangrove ecosystem of Pacitan District, East Java, Indonesia: A. Teleng Ria; B. Grindulu; C. Siwil

Sampling molluscs

Sampling was conducted by making transect 10 x 10 m^2 plots in each location research. This method is a modified method of the published journal by Islamy and Hasan (2020). The plot selection was based on the condition of the substrate, i.e., sandy, muddy, rocky, etc. The mollusc specimens in the plots were collected by handpicking on the surface of the substrate, and the arboreal was collected from mangrove trees like stems, roots, and leaves, following Kantharajan et al. (2017). After that, the species and number of mollusc in each plot were counted and recorded. Then, abiotic factors measured, including temperature (air, water, and soil), pH (water and soil), and water salinity, were recorded. The dominant species of mangrove trees were also recorded in each location research.

Identification molluscs

The samples that had been collected from the research location were preserved using 70% alcohol, then identified using literature studies by Irma and Sofyatuddin (2012), Dolorosa and Gallon (2014), Kementerian Kelautan dan Perikanan Indonesia (2014), Baderan et al. (2019), and Islamy and Hasan (2020). The species identification process is carried out at the Laboratory of Animal Taxonomy, Faculty of Mathematics and Natural Sciences, Universitas Sebelas Maret, Surakarta, Indonesia. Identification of molluscs was carried out by observing morphological characteristics such as shell shape, shell color, and shell pattern. Once identified, the sample was photographed using a digital camera and stored in a sample bottle.

Data analysis

Data on the number of species and the number of individuals of each species that have been collected will be analyzed using the density formula, Shanon-Weiner diversity index (H'), Margalef species richness index (R), Evenness index (E) and Simpson dominance index (D) which will be described as follows:

Density

$$Density\ (K) = \frac{number\ of\ individuals}{plot\ area}$$

Shanon-Weiner diversity index (H')

H' = – Σpi x ln pi

Where:
H' : Diversity index of Shannon-Wiener
Pi : Number of individuals of the *i* species divided by the total number of individuals

Evenness index (E)

$$E = \frac{H'}{\ln (S)}$$

Where:
E : Evenness index
H' : Shanon-Weiner diversity index
S : Total number of species found

Simpson dominance index (D)

$$D = \sum_1^s \frac{n_i (n_i - 1)}{N(N-1)}$$

Where:
D : Dominance index
n_i : Number of individuals of the *i* species
N : Total number of individuals

Margalef species richness index (R)

$$R = \frac{s-1}{\ln(N)}$$

Where:
R : Richness index
S : Total number of species found
N : Total number of individuals found

RESULTS AND DISCUSSION

Molluscs at the research location

A total of 25 mollusc species were recorded from three research locations, namely Teleng Ria, Grindulu, and Siwil (Table 1, Figure 3). Gastropods are represented by 17 species (Figure 3A-3Q) with 13 families, namely Achatinidae, Ampullariidae, Batillariidae, Cypraeidae, Ellobiidae, Littorinidae, Naticidae, Neritidae, Lottidae, Pachychilidae, Partulidae, Patellidae, and Potamididae. Meanwhile, eight species of bivalves were recorded (Figure 3R-3Y) from five families: Arcidae, Myidae, Mytilidae, Ostreidae, and Veneridae. In gastropods, the most common families in terms of the number of species are Littorinidae (3), Ellobidae (2), and Potamididae (2), and the others are only one species (Table 1). Members of the family Littorinidae are arboreal and are found attached to the roots, trunks, or leaves of mangrove trees (see Figure 4). Then, Mytilidae (2), Ostreidae (2), and Veneridae (2) are the dominant families among bivalves (Table 1). Of the 17 species, 13 are terrestrial gastropods; *Achatina fulica* (Bowdich, 1822) *Pomacea canaliculata* (Lamarck, 1822); *Batillaria zonalis* (Bruguière, 1792); *Ellobium aurisjudae* (Linnaeus, 1758); *Pythia scarabaeus* (Linnaeus, 1758); *Littoraria angulifera* (Lamarck, 1822); *Littoraria scabra* (Linnaeus, 1758); *Littoraria* sp.; *Neritina turrita* (Gmelin, 1791); *Faunus ater* (Linnaeus, 1758); *Partula* sp.; *Pyrenella cingulata* (Gmelin, 1791); and *Terebralia sulcata* (Born, 1778). Then the other four species are marine gastropods; *Cypraea annulus* (Linnaeus, 1758), *Patelloida* sp., *Patella* sp., and *Polinices* sp. While in bivalves, eight species were found; *Anadara granosa* (Linnaeus, 1758); *Mya* sp.; *Mytilus* sp.; *Perna viridis* (Linnaeus, 1758); *Crassostrea gigas* (Thunberg, 1793); *Ostrea* sp.; *Meretrix* sp.; and *Paphia* sp.

The density of molluscs in the research location

The total density of molluscs found at the three research locations was 36.9 individuals/100 m^2 (ind/100 m^2). Each species density value in each location, such as Teleng Ria with 11.4 ind/100 m^2, Grindulu with 1.6 ind/100 m^2, and the highest in Siwil with 23.9 ind/100 m^2. The species *F. ater* was the species with the most individuals in Teleng Ria with 3.1 ind/100 m^2, while *A. granosa* was the species with the most individuals in Grindulu with 0.8 ind/100 m^2, then with a value of 16.2 ind/100 m^2 by species *P. scarabaeus*, thus making this species the most abundant individual found in Siwil. That makes *P. scarabaeus* the species with the most individuals in this research. Meanwhile, the lowest species number ind/100 m^2 with a value of 0.1 ind/100 m^2 were *Paphia* sp., *B. zonalis*, *E. aurisjudae*, *Polinices* sp., and *T. sulcata*. The density of a species shows the number of individual species with a certain unit area. Table 1 provides detailed information regarding this.

Ecological index in the research location

Shanon-Weiner diversity index (H'). Teleng Ria has the highest diversity index value in this research, 2.02. Meanwhile, Siwil has a diversity index value of 1.2 and is followed by Grindulu as the lowest diversity index value in this research, with 1.04 (Figure 5). According to Krebs (1989), the criteria for the diversity index are; H'<1.5, then the species diversity is low; 1.5 <H'<3.5 means that the species diversity is moderate; and H'>3.5, then the species diversity is high. So in this research, Teleng Ria has a moderate diversity index category, followed by Siwil and Grindulu, whose diversity index category is low. However, if three locations are combined, the value reaches 2.14, categorized as moderate. The diversity index (H') describes the state of the population of organisms mathematically to make it easier to analyze the number of individuals of each species in a community.

Evenness index (E). The evenness index determines the evenness of each species in each community encountered. According to Pielou (1977), if the results show a value of 0.00-0.25, it means that the evenness index is uneven; if the result shows a value of 0.26-0.50, it means that the evenness index is less evenly distributed; if the results show a value of 0.51-0.75, it means that evenness index is relatively even; if the result shows a value of 0.76-0.95, it

means that the evenness index is almost evenly; then if the result shows a value of 0.96-1.00, it means that the evenness index is evenly distributed. The total evenness index of the three locations shows a value of 0.66 which means quite even. In contrast to the total results of the research locations, Teleng Ria has a value of 0.81 and Grindulu of 0.95, so it is categorized almost evenly. The lowest evenness index value is in the Siwil, which shows a value of 0.45, so it is categorized as less evenly distributed (Figure 5).

Simpson dominance index (D). The species dominance index values from highest to lowest were Teleng Ria, Grindulu, and then Siwil, with each value being 0.47, 0.36, and 0.21. At the same time, the overall value of all locations is 0.34. Simpson's dominance index is a parameter that states the level of centralized dominance (mastery) of a species in a community. Suppose the results show a value of 0<C<0.5, it means that the species dominance is low; if the result shows a value of 0.5<C<0.75, it means that the species dominance is moderate; if the results show a value of 0.75-1.00, it means that species dominance is high (Odum 1971). Therefore, based on Odum's (1971) explanation, all the results of this research were categorized as low, meaning there were no dominant species in each location (Figure 5).

Margalef species richness index (R). Species richness is the number of species in a certain area. Species richness index combined with individual abundance/density values for each unit. The highest species richness index value was obtained at the research location of Teleng Ria with a value of 2.38, followed by Siwil at 2.19, and the lowest was Grindulu, which was 0.96. According to Magurran (1998), if the results show a value of R>5, it means that species richness is high; if the result shows a value of 3.5<H<5, it means that the species richness is moderate; if the results show a value of H<3.5, it means that species richness is low. Therefore, the three research locations have the same low species richness category. However, in the total calculation of all locations, the value reached 4.1, which can be categorized as medium species richness.

For more details on the comparison of all the results of the ecological index in each research location, see Figure 5.

Environmental (abiotic) factors in the research location

The suitable environmental conditions for molluscs' life will help them play an important role in the mangrove ecosystem. In this research, the parameters of temperature (air, water, and soil), pH (water and soil), and salinity were measured (Table 2). Measurements of all temperatures at the three sampling locations ranged from 28-33°C. The highest temperature was recorded at Siwil. Then, all pH at the three locations ranged from 6-8, with the lowest value (close to acid) being Teleng Ria. The results of temperature and pH measurements at research locations tend to vary. Then, Teleng Ria and Siwil have the same salinity, 5 ppt, while in Grindulu, it is 10 ppt. In general, the three research locations are not too close to the sea so that the salinity value of the water is not too salty.

Table 1. List and density of molluscan species recorded in the mangrove ecosystem of Pacitan District, East Java, Indonesia

Class	Family	Species	Density (ind/100 m^2) in each location			Total
			Teleng Ria	Grindulu	Siwil	
Bivalves	Arcidae	*Anadara granosa* (Linnaeus, 1758)	-	0.8	-	0.8
	Myidae	*Mya* sp.	-	-	3.5	3.5
	Mytilidae	*Mytilus* sp.	-	0.4	-	0.4
		Perna viridis (Linnaeus, 1758)	-	-	0.4	0.4
	Ostreidae	*Crassostrea gigas* (Thunberg, 1793)	2,6	-	-	2.6
		Ostrea sp.	0.2	-	-	0.2
	Veneridae	*Meretrix* sp.	0.2	-	-	0.2
		Paphia sp.	-	-	0.1	0.1
Gastropoda	Achatinidae	*Achatina fulica* (Bowdich, 1822)	0.2	-	0.1	0.3
	Ampullariidae	*Pomacea canaliculata* (Lamarck, 1822)	2	0.4	-	2.4
	Batillariidae	*Batillaria zonalis* (Bruguière, 1792)	0.1	-	-	0.1
	Cypraeidae	*Cypraea annulus* (Linnaeus, 1758)*	-	-	1.1	1.1
	Ellobiidae	*Ellobium aurisjudae* (Linnaeus, 1758)	-	-	0.1	0.1
		Pythia scarabaeus (Linnaeus, 1758)	-	-	16.2	16.2
	Littorinidae	*Littoraria angulifera* (Lamarck, 1822)	0.4	-	-	0.4
		Littoraria scabra (Linnaeus, 1758)	-	-	0.2	0.2
		Littoraria sp.	0.8	-	1	1.8
	Lottiidae	*Patelloida* sp.*	-	-	0.5	0.5
	Naticidae	*Polinices* sp. *	-	-	0.1	0.1
	Neritidae	*Neritina turrita* (Gmelin, 1791)	1.1	-	-	1.1
	Pachychilidae	*Faunus ater* (Linnaeus, 1758)	3.1	-	-	3.1
	Partulidae	*Partula* sp.	0.5	-	-	0.5
	Potamididae	*Pirenella cingulata* (Gmelin, 1791)	0.2	-	-	0.2
		Terebralia sulcata (Born, 1778)	-	-	0.1	0.1
	Patellidae	*Patella* sp.*	-	-	0.5	0.5
Total			11.4	1.6	23.9	36.9

Note: -: not found, *: marine gastropods

Table 2. Environmental (abiotic) factors in the mangrove ecosystem of Pacitan District, East Java, Indonesia

Location of research	Temperature ºC			pH		Salinity (ppt)
	Air	Water	Soil	Water	Soil	
Teleng Ria	33	32.6	33	7.6	6	5
Grindulu	32	32.5	33	8	7	10
Siwil	32	28.2	31	7.6	6.1	5

Figure 3. Checklist molluscs in the coastal of Pacitan District, East Java, Indonesia: A. *Achatina fulica* (80 mm), B. *Pomacea canaliculata* (50 mm), C. *Pirenella cingulata* (15 mm), D. *Faunus ater* (15 mm), E. *Batillaria zonalis* (13 mm), F. *Neritina turrita* (19 mm), G. *Littoraria angulifera* (21 mm), H. *Polinices* sp. (37 mm), I. *Pythia scarabaeus* (18 mm), J. *Terebralia sulcata* (22 mm), K. *Littoraria* sp. (15 mm), L. *Partula* sp. (10 mm), M. *Littoraria scabra* (29 mm), N. *Ellobium aurisjudae* (34 mm), O. *Patelloida* sp. (15 mm), P. *Patella* sp. (16 mm), Q. *Cypraea annulus* (20 mm), R. *Anadara granosa* (20 mm), S. *Ostrea* sp. (64 mm), T. *Crassostrea gigas* (89 mm), U. *Mya* sp. (46 mm), V. *Mytilus* sp. (25 mm), W. *Perna viridis* (24 mm), X. *Paphia* sp. (59 mm), Y. *Meretrix* sp. (55 mm)

Figure 4. *Littoraria scabra* (Gastropod) clinging to the leaves of the *Sonneratia alba* tree

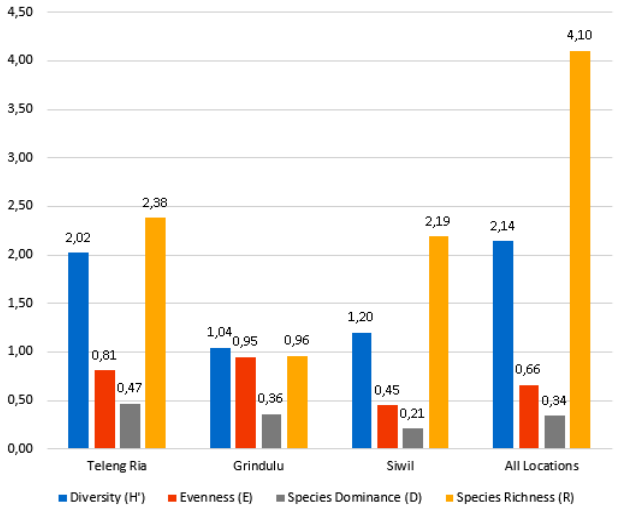

Figure 5. Comparison of ecological index values at each research location

Discussion

Mollusc studies elsewhere also found that the species diversity of gastropods was higher than bivalves. For example, 202 species of gastropods were found in France, Europe, while 39 species of bivalves (Bichain et al. 2019). Then in the Americas, precisely in the Strait of Magellan, Chile, Aldea et al. (2020) reviewed 134 research articles on the diversity of molluscs (gastropods and bivalves) in the area and managed to collect data on 173 gastropod species and 107 bivalves species. Then on the African continent, Morocco to be precise, 26 gastropods and ten bivalves were found (Irikov and Gerdzhikov 2013). In the Australian continent, Murphy (2015) identified 142 species comprising 34 bivalves (24 families) and 108 gastropods (51 families). Finally, some countries in Asia, such as the Philippines, found up to 50 gastropods and 15 bivalves (Dolorosa and Gallon 2014), while in India, 46 gastropods and 14 bivalves were found by Kantharajan et al. (2017). Meanwhile, in another area in Indonesia, Baderan et al. (2019) also found 21 species of gastropods and three species of bivalves. The higher diversity of gastropods compared to bivalves in mangrove ecosystems is due to the ability of gastropods to tolerate better environmental changes and harsh conditions in these ecosystems (Dolorosa and Gallon 2014).

This research revealed that mollusc families, such as Potamididae, Littorinidae, Ellobiidae, and Neritidae, have a high abundance of individuals and are commonly found in mangrove ecosystems near mangrove trees (Table 1). According to Walthew (2012), Baderan et al. (2017), and Yadav et al. (2019), the family mentioned previously can dominate in the mangrove ecosystem because it likes to live in areas affected by tides and muddy areas with mangrove trees vegetation. Meanwhile, the distribution of the abundance of bivalves is generally limited to a very narrow zone of the low tide boundary due to the need for feeding and larval life. Very few species, such as *A. granosa*, *C. gigas*, *Mytilus* sp., *Mya* sp., *Ostrea* sp., and *P. viridis*, can adapt well to the spray zone and changes in environmental conditions in intertidal mangrove areas (Rangan 2010; Khade and Mane 2012; Kabir et al. 2014; Kementerian Kelautan dan Perikanan Indonesia 2014; Samson and Kasale 2020). Therefore, that species was the dominant bivalve found in this research locations (Table 1).

Among the molluscs found in this research, the following species have the potential to be cultivated for food: such, *Meretrix* sp., *A. granosa*, *P. canaliculata*, *P. viridis*, *F. ater*, and *Ostrea* sp. (Lok et al. 2011; Khade and Mane 2012; Sawant and Mohite 2013; Shan et al. 2013; Wang et al. 2013; Pritchard et al. 2015; Soon and Ransangan 2016; Agustina et al. 2019). Therefore, exploring the cultivation potential of this species can help provide a stable source of economic income among local residents. First *P. scarabaeus*, the highest abundance in this research, and most other members of Ellobiidae were considered pollution indicators in mangrove ecosystems (Satheeshkumar and Khan 2012; Dissanayake and Chandrasekara 2014; Kantharajan et al. 2017). Next, *N. turrita* has a familiar shell used for aquarium ornaments because of its unique color (Hristov 2020). Finally, *Achatina fulica*, *P. canaliculata*, and *P. cingulata* are invasive animal species because they become a pest to agricultural land and pond (Karraker and Didgeon 2014; Goldyn et al. 2017; Solanki et al. 2017).

Family Littorinidae has the most species in this research (Table 1). There are three species, including *L. angulifera*, *L. scabra*, and *Littoraria* sp. The Littorinidae family is a facultative gastropod because many individuals and species are found inside and outside the mangrove ecosystem (Susanti et al. 2021). Khade and Mane (2012) and Marshall et al. (2015) suggested that *Littoraria* lives on mangrove trees' trunks, branches, roots, and leaves. Several factors, such as the function of an area as a shelter for molluscs and the species of vegetation mangrove trees, determine the distribution of species. In addition, *P. scarabaeus* and *Partula* sp. are also a gastropod that lives on parts of

mangrove trees to breed and find food (Hopper and Smith 1992; O'Rorke et al. 2016; Sischo and Hadfield 2017). This species is very abundant in this research location and lives in mangrove trees, such as A. alba and *S. alba*.

The stability of the mollusc community can be described with analysis of the values of diversity index (H'), evenness (E), dominance (D), and species richness (R). The results of the Shannon-Wiener diversity index in each location showed different values (Figure 5). The mollusc diversity index in Teleng Ria was higher (2.02) than in Siwil (1.2) and Grindulu (1.04). The mollusc diversity index value in Teleng Ria is moderate compared to Siwil and Grindulu, which are low. The same thing happened with Teleng Ria, the diversity index value in general from three locations research is 2.14 (medium). Diversity includes two main things: variations in the number of species and the number of individuals of each species in an area. At each location, the abundance of each species varied in number because several species were much larger than other species, resulting in a low diversity of an ecosystem (Table 1). Suppose the number of species and the variation in the number of individuals of each species is relatively low. In that case, it means an imbalance in the ecosystem caused by disturbance or pressure. Research with a moderate value diversity index was also found by Hasidu et al. (2020) in the mangrove ecosystems of Kolaka District, Southeast Sulawesi, Indonesia, and Yadev et al. (2019) in mangrove ecosystems of Paradeep, east coast of India. Furthermore, Baderan et al. (2019) explain that the moderate diversity index is enough to describe the complexity of the ecosystem.

Teleng Ria has a value of 0.81 and Grindulu of 0.95, so the evenness index is categorized almost evenly. At the same time, Siwil shows the lowest evenness value in this research with 0.45, so it is categorized as less even. Meanwhile, the total evenness index for three locations shows a value of 0.66 which means quite even (Figure 5). The evenness index value is close to 1, indicating the number of individuals each species is almost the same and the stability of the ecosystem. On the other hand, if the evenness index is close to 0, it means a certain species predominate in the ecosystem (Asadi et al. 2018; Baderan et al. 2019; Hasidu et al. 2020).

The dominance index value obtained from each research location is between 0.21-0.47 (Figure 5). The dominance value is used to determine whether certain species dominate an ecosystem. Based on this, the dominance index obtained is mostly close to the value 0, meaning no particular species dominate in the community (Odum and Barrett 2005). Furthermore, the value of the evenness index with the dominance index in this research shows inversely proportional results. The evenness index value is close to 1, and the dominance index is close to 0 (zero). That indicates that the evenness of species is evenly distributed in an ecosystem, and no dominant species exist.

The highest richness index value was obtained at the research location of Teleng Ria with a value of 2.38, followed by Siwil at 2.19, and the lowest was Grindulu, which was 0.96 (Figure 5). However, in the total calculation of all locations, the value reached 4.1, which can be categorized as medium species richness. The species richness index is the simplest measure of biodiversity because it only considers differences in the number of species in a certain area (Magurran 1998). Species richness in an area depends on the health of its habitat or ecosystem. If the habitat or ecosystem can provide food and a breeding ground for a species, the species richness can be high (Aditya et al. 2019).

The numbers of individual and species molluscs in the three research locations have differed. According to Odum and Barrett (2005) and Stagg and Mendelssohn (2012), the type of substrate and mangrove vegetation greatly determines the density and composition of molluscs. The research location in Siwil has the most varied substrate types compared to other locations, such as sandy, rocky, and muddy. Substrate variations play a role in the diversity of mollusc species in Siwil, so in this research, the number of species was the highest compared to Teleng Ria and Grindulu, namely 13 species (Table 1). In contrast to Teleng Ria, the Grindulu and Siwil areas have less mangrove cover (Figure 2). In addition to providing a living habitat for mollusks, mangrove trees are also a source of food and reproduction, especially for terrestrial gastropods. Not surprisingly, coastal areas with mangrove vegetation have a high diversity of terrestrial gastropods. Teleng Ria is where the most terrestrial gastropod species were found nine species (Table 1). Meanwhile, according to Irma and Sofyatuddin (2012), the abundance of marine bivalves does not affect the existing plant vegetation.

Based on the 25 species of molluscs in this research (Table 1), the environmental conditions at the research location were considered optimal for molluscs to survive and reproduce with temperatures between 28-33°C (Table 2). These results are close to temperature measurements in the mangrove area of the Musi River estuary, South Sumatra, Indonesia, which ranges from 28-31.5°C (Hartoni and Agussalim 2013) and in the mangrove area Nusa Lembongan, Bali, Indonesia, which ranges from 27-30°C (Pratiwi and Ernawati 2016). According to Maretta et al. (2019), the optimum temperature for gastropod metabolism ranges from 25-32°C, while bivalves can metabolize optimally at 25-28°C. The differences in temperature characteristics at the research location are influenced by mangrove vegetation cover and measurement time.

The degree of acidity (pH) is important to support the survival of mollusc organisms. That is because pH can affect the type and availability of nutrients and the toxicity of trace elements. The pH conditions at the research location were recorded in 6-8 (Table 2). According to Odum and Barrett (2005), waters and soil with a pH of 6-9 are waters and soils with high fertility because they can encourage the dismantling of organic matter in the waters, and soils into minerals are ideal for mollusc life. Conversely, according to Artiningrum and Anggraini (2019), environmental conditions with a pH below or above the previously mentioned values can interfere with mollusc life.

The salinity level at the research location ranged from 5-10 ppt (Table 2). It is why the marine gastropod and bivalves species that were in low abundance in this

research, such as *Paphia* sp. It is estimated that this newcomer species is carried away by currents from the sea due to the effects of floods that often occur at the research location (Sholiqin et al. 2021). Then, according to Mathius et al. (2018) and Saputra et al. (2020), the optimal salinity to support mollusc life ranged from 28-34 ppt. The evaporation rate influences the difference in salinity in locations and freshwater entry into the sea coast from river flows. These research locations are not too close to the sea, so the fresh water from the river is more than seawater intrusion into the estuary. That causes the salinity value of the water to be not too salty and is categorized as brackish water.

Even so, the results of this research still have a higher diversity of bivalves and gastropods than in other regions in Indonesia. For example, research by Irma and Sofyatuddin (2012) in the mangrove ecosystem of Aceh Besar (14 gastropods and five bivalves), then nine gastropods and two bivalves were found in the Mangrove ecosystem at the Kumbe River Estuary, Merauke by Katukdoan et al. (2018) and Manusawai et al. (2020) with eight gastropods and two bivalves in Kaisu Mangrove Forest of Sarmi Regency, Papua. Information on molluscs diversity in the mangrove ecosystem in Indonesia is not optimal, especially in Pacitan. Therefore, considering mollusc diversity is important to support the conservation effort. Therefore, it needs more research about mollusc diversity in the mangrove ecosystem in Pacitan, East Java, Indonesia.

It can be concluded a total of 25 species were found in this research, with gastropods being more species than bivalves. The gastropods were 17 species and 13 families, while eight species and five families were bivalves. Then, the total molluscs obtained had a density of 36.9 individuals/100 m^2. The mollusc diversity index was 2.14 (medium), mollusc species richness reached 4.1 (medium), the evenness of species in this research reached 0.66 (quite even), and the species dominance index was recorded at 0.34 (low), which means that there are no dominant species in the research location. Then, each research location has a different species and density species of molluscs. That is caused by differences in the type of substrate (such as sandy, muddy, or rocky) and abiotic factors found in the research location (such as temperature, pH, and salinity).

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