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Research article

Bioecological characteristics of mangrove snail in Langsa mangrove forest, Aceh, Indonesia: Diversity and community structure

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Abstract

The most crucial aspect of managing an ecosystem or habitat is knowledge about accompanying biota, such as snails. The research on mangrove snails in Langsa mangrove forest area was conducted in November 2021 with the goal of evaluating species diversity, density, ecological index, distribution, and their link to surrounding environmental conditions. Snail data was obtained via quadrat transects, with observation stations established using purposive sampling. The snail diversity was found to be five species from four families, with the highest density found in *N. planospira* (03.13 ind/m^2). The diversity index was low (H' ≤ 2.0), dominance was moderate (0.5 < C ≤ 0.75), and uniformity tended to be balanced (0.5 < E ≤ 0.75). The distribution pattern is clustered (Iδ > 1), with *C. cingulata* being abundant (83.33%), and *C. capucinus* being frequently found (50.00%), *N. planospira*only found occasionally (36.11%), and *L. scabra* and *T. telescopium* are relatively uncommon (11.11% and 0.56%, respectively), with a link to environmental variables indicating that *T. telescopium* prefers fine mud substrates. Meanwhile, *C. cingulata, C. capucinus, L. scabra,* and *N. planospira*live in habitats with fine mud substrates that are more solid than *T. telescopium*'s habitats.

Keywords: Mangrove, gastropod, diversity, density, ecological index, distribution, forest management unit

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Introduction

Snails or commonly known as gastropods are one of the most diverse animals (Appeltans et al., 2012; Puillandre et al., 2012; Modica et al., 2014; Zapata et al., 2014; Uribe et al., 2019; Cunha & Giribet, 2019; Johnson et al., 2019; Ran et al., 2020) and are abundant in the ocean and are successful colonial animals in both terrestrial and freshwater environments (Loker, 2010; Salinas & Kisailus, 2013; Zapata et al., 2014; Cunha & Giribet, 2019). Snails have the longest fossil record (Fryda et al., 2008) and are among the most diverse organisms on the planet (Puillandre et al., 2012; Modica et al., 2014). Bieler (1992) stated that snails make up approximately 80% of all molluscs (Uribe et al., 2019). They are classified into seven lineages: Patellogastropoda, Cocculiniformia, Neomphalina, Vetigastropoda, Neritmorpha, Caenogastropoda, and Heterobranchia. According to Fryda et al. (2008) and Ran et al. (2020), snails have a variety of morphologies (shells), including colour, shape, and size.

The wide range of physical characteristics exhibited by snails is a result of natural selection adapting to different ecological situations (Johnson et al., 2019). In addition, snails serve as a significant source of animal protein for both other organisms and humans, and they possess considerable economic value (Echem, 2017). Consequently, they play a crucial role in the economies of numerous countries worldwide (Keegan et al., 2003; Cob et al., 2009; Ran et al., 2020). Particularly noticeable examples of economically valuable snail species include *Haliotis* spp., *Glossaulax* spp., *Strombus* spp., and *Rapana* spp. (Leiva & Castilla, 2002; Culha et al., 2009; Li et al., 2014). According to Kanazawa (2001), Zhukova (2007), Ozogul et al. (2008), Zarai et al. (2011), snails are rich in nutritious components such as fatty acids, amino acids, and sterols.

Snails are a prominent component of the mangrove ecosystem (Morgan & Hailstone, 1986; Pribadi et al., 2009; Jeeva et al., 2018), which is characterized by diverse plant species (Suratissa & Rathnayake, 2017) and is primarily found in tropical (Gaut, 2018; Alongi, 2018; Schaduw, 2019) and subtropical regions (Maiti & Chowdhury, 2013; Polania et al., 2015; Alongi, 2018) between 5° North Latitude and 5° South Latitude (Giri *et al.,* 2011). Mangroves are known for their high species diversity in marine environments, particularly along beaches and river estuaries affected by sea tides (Gaut, 2018; Schaduw, 2019).

Mangroves are frequently present in lagoon regions and alongside river banks (Maiti & Chowdhury, 2013), as well as in delta areas where the water flow carries sediment (Schaduw, 2019). Haryani (2013) states that coastal mangroves have numerous economic benefits and functions. These include providing materials for construction such as building wood, firewood, plywood, and telephone poles. Mangroves also serve as a source of fishing poles, docks, railway sleepers, wood for furniture and handicrafts, and house roofs. Additionally, they offer tannin, medicinal ingredients, sugar, alcohol, acetic acid, animal protein, honey, carbohydrates, and dyes (Eddy et al., 2015).The mangrove ecosystem offers physical protection against storms and coastal flooding by reducing the strength of waves and acting as a barrier against wind exposure (Spalding et al., 2014; Marois & Mitsch, 2015; Sandilyan & Kathiresan, 2015). Additionally, mangroves provide a range of benefits to support human well-being, such as livelihoods, income, food security, health services, poverty reduction, and social sustainability (UNEP, 2014). In addition, mangroves serve as important habitats for a variety of aquatic organisms, including fish, shrimp, shellfish, birds, and gastropods or snails. They provide essential functions such as feeding, spawning, and acting as nursery grounds for these species (Kuenzer et al., 2011; Schaduw, 2019).

The Aceh Region III Forest Management Unit (KPH) is a Technical Implementation Unit (UPTD) of the Environmental and Forestry Service in Aceh Province. It was established under Aceh Governor Regulation Number 46 of 2018 and it is in Langsa City. The KPH's jurisdiction covers the Watershed Group (DAS). Krueng Jambo Aye, Krueng Peureulak, and Krueng Tamiang have been categorized as UPTD Class A (DLHK Aceh, 2022). PPRI (2021) defines KPH as a forest management area that operates in accordance with the primary function and purpose of the forest, ensuring efficient, effective, and sustainable management. KPH is further categorized into conservation KPH, protected KPH, and production KPH. The study conducted by Zurbaet al. (2017) reveals that the KPH Region III Aceh, Langsa City is predominantly occupied by mangrove vegetation, with an estimated extent of around 17000 ha (Husna, 2017). Husna (2017) also reported that the mangrove forest in Langsa City has suffered from degradation. Continued damage is expected to effect the survival of snails and other associated biota. Snails are particularly valuable as bioindicators for assessing the presence of man-made pollutants and for evaluating the actual impact of environmental disturbances on biological components (Fusi et al., 2016). In addition, snails in the mangrove ecosystem have a significant impact on the digging and consumption of mangrove algae (Kristensen et al., 2008; Lee, 2008). The digging activities of snails have a direct effect on the availability of nutrients in the mangrove ecosystem (Berner & Westrich, 1985). Therefore, it is essential to investigate the presence of snails in Langsa mangrove forest. The objective of this study is to assess the species diversity, density, ecological index, distribution, and association of snails with the status of the mangrove ecosystem in KPH Region III Aceh, Langsa City.

Methods

The study was conducted in November 2021 at KPH Region III Aceh, Langsa City (Langsa mangrove forest). It involved three observation stations: Station I located at coordinates 04º31'32” N and 98º01'00” E, which is a conservation area with a fine mud substrate; Station II located at coordinates 04º30 '12" N and 98º00'26" E, adjacent to residential areas with a fine and slightly hardened mud substrate; and Station III located at coordinates 04º30'39" N and 98º00'33" E, adjacent to community ponds with a fine mud substrate and slightly hardened (Figure 1).

Sampling procedure

Data on snails in the KPH Region III Aceh of Langsa area was obtained using a purposive sampling method. This involved drawing three line transects, each 40 meters long, at each observation station perpendicular to the coastline. Theseline transects were then divided into plots for further analysis. A plot measuring 10 × 10 meters is divided into four smaller plots. Subsequently, within each 10 × 10 m plot, five smaller subplots measuring 1 x 1 m were established in certain locations (top left, top right, middle, bottom left, and bottom right) (Ernanto et al., 2010). Consequently, the total number of subplots amounted to 180. Snails in the subplot, which has dimensions of 1 × 1 m, are manually collected by hand. This includes snails found on the surface of the substrate as well as those attached to mangrove trees, such as their roots, stems, and leaves. Subsequently, the acquired snails are placed inside a polyethylene plastic bag and subjected to treatment using a 70% alcohol solution.

The snail density in Langsa mangrove forest was determined using the Odum (1996) equation and subsequently compared with Tuan (2000) to establish the density threshold. The ecological index of snails in Langsa mangrove forest was assessed using the Shannon-Weaver diversity index. The criteria for categorizing diversity were as follows: H' ≤ 2.0 (low diversity), 2.0 < H' ≤ 3.0 (medium diversity), and H' ≥ 3.0 (high diversity) (Setyobudiandy et al., 2009). Additionally, the dominance of snails was analyzed using the Simpson dominance index. The criteria for categorizing dominance were as follows: 0 < C ≤ 0.5 (low dominance), 0.5 < C ≤ 0.75 (medium dominance), and 0.75 < C ≤ 1 (high dominance) (Setyobudiandy et al., 2009). The Shannon-Weaver uniformity index is employed to assess the uniformity of the snails. This index categorizes the community into three states based on the value of 0 < E ≤ 0.5 indicates a depressed state, 0.5 < E ≤ 0.75 indicates a somewhat balanced state, and 0.75 < E ≤ 1 indicates a balanced state (Setyobudiandy et al., 2009). In addition, the distribution of snails in Langsa mangrove forest was analyzed using the Morisita index (Morisita, 1959) to determine the distribution pattern. The geographic distribution category was based on Sreelekshmi et al. (2020), and the vertical distribution was grouped according to Phintrakoon et al. (2008).

Data analysis

The density of snails in Langsa mangrove forest was assessed using multivariate Principal Component Analysis (PCA) statistics in the PAST 3 program (Hammer et al., 2001) and SPSS v24. Additionally, the relationship between snails and the condition of the mangrove ecosystem was determined based on similarities in composition. The snails were examined using multivariate cluster statistics based on the Bray - Curtis similarity index in the Primer v7 program, both within observation stations and across different species.

Results

Species diversity

In Langsa mangrove forest, there were 5 species of mangrove snails belonging to 4 families. These families include *Cerithideacingulata* and *Telescopium telescopium* from the Potamididae family, *Chicoreus capucinus* from the Muricidae family, *Littorina scabra* from the Littorinidae family, and *Nerita planospira* from the Neritidae family (Table 1). The species *C. cingulata, L. scabra,* and *N. planospira* were present at every observation point. Meanwhile, the species *C. capucinus*was

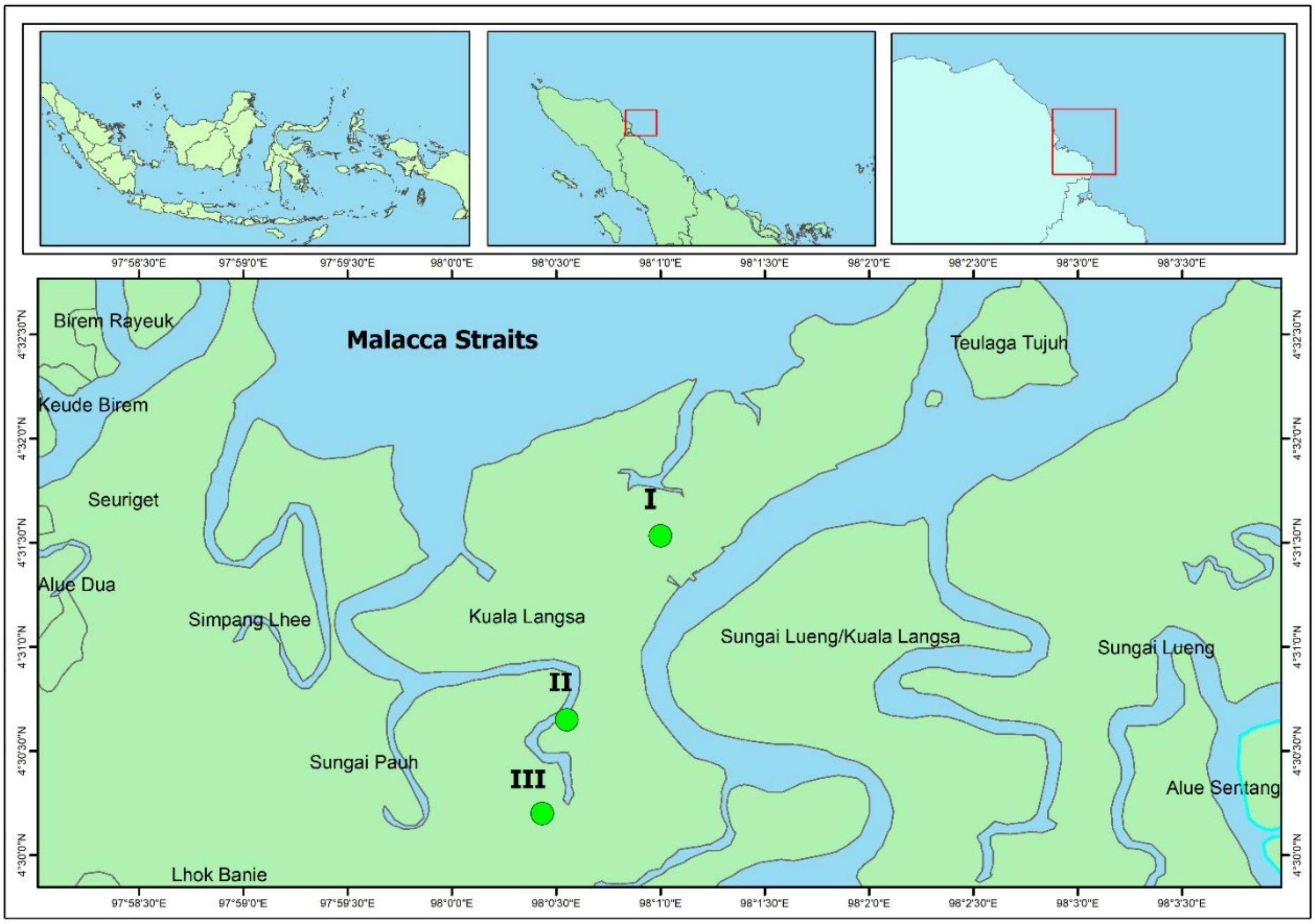

Figure 1. Map of sampling locations.

discovered at Stations I and II, but the species *T. telescopium* was exclusively found at Station I.

Density

The snail density in Langsa mangrove forest exhibited different values, with the maximum overall density observed in the snail species *N. planospira* (03.13 ind/m^2) and the lowest density observed in *C. capucinus* (00.04 ind/m^2) (Figure 2). Figure 2 indicates that Station I had the largest density of snails, with a density of 02.77 ind/m^{2}or 49% of the total. This station also had five different species of snails, with a total of 498 individuals observed. On the other hand, Station II had the lowest density of snails, with a density of 01.29 ind/m^2 or 23% of the total. This station had three different species of snails, with a total of 233 individuals observed. Additionally, Figure 2 indicates that the greatest concentration of *N. planospira* was observed at Station III (04.30 ind/m^2), whereas the highest concentrations of *L. scabra, C. capucinus, C. cingulata,* and *T. telescopium* were recorded at Station I (01.88 ind/m^2, 00.08 ind/m^2, 03.92 ind/m^2, and 00.20 ind/m^2).

The PCA analysis of snail density in Langsa mangrove forest reveals that the first variable has an eigenvalue of 4.13, whereas the second variable has an eigenvalue of 0.87 (Table 2). A single eigenvalue bigger than one (1) was exclusively observed in the first variable (4.13), which had a data diversity of 82.53%. This suggests the presence of only one new component. Nevertheless, the data diversity of 82.53% indicates variations in the density of each snail, either due to a dominant density in a specific location or a dominant density throughout all observation stations. The loading values for each snail in Table 2 demonstrate that *T. telescopium*, *L. scabra*, and *C. cingulata* snails could distinguish density in Langsa mangrove forest. *T. telescopium* snails dominate at Station I with a loading value of 0.4919, while *L. scabra* and *C. cingulata* dominate at all observation stations with loading values of 0.4889 and 0.4862, respectively.

Ecology index

The ecological index of snails in Langsa mangrove forest indicates a low level of snail diversity, with tend to be balanced uniformity and high dominance (Table 3). The Shannon Weaver index reveals that the highest diversity is observed at Station I (H' = 01.70), followed by Stations II and III (H' = 01.01 and H' = 00.51). Moreover, the dominance index revealed that Station III had the highest value (C = 00.84), followed by Sta-

Table 1. Snail diversity in Langsa mangrove forest. + = found; - = not found

Family	Species	Station		
		I	II	III
Potamididae	*Cerithideacingulata*	+	+	+
Muricidae	*Chicoreus capucinus*	+	-	+
Littorinidae	*Littorina scabra*	+	+	+
Neritidae	*Nerita planospira*	+	+	+
Potamididae	*Telescopium telescopium*	+	-	-

Table 2. Explanation of total variance, component matrix, and loadings of snail density in Langsa mangrove forest in PCA analysis.

Component	Initial Eigenvalues			Extraction sums of squared loadings		
	Total	% of Variance	Cumulative (%)	Total	% of Variance	Cumulative (%)
Total variance explained						
1	4.126	82.53	82.53	4.126	82.53	82.53
2	0.874	17.48	100.00	-	-	-

Snails species	*Component matrix*		*Loadings*	
	PC 1	PC 2	PC 1	PC 2
Telescopium telescopium	0.999	-	0.4919	-
Littorina scabra	0.993	-	0.4889	-
Cerithideacingulata	0.988	-	0.4862	-
Nerita planospira	-0.766	-	-0.3769	-
Chicoreus capucinus	0.762	-	0.3750	-

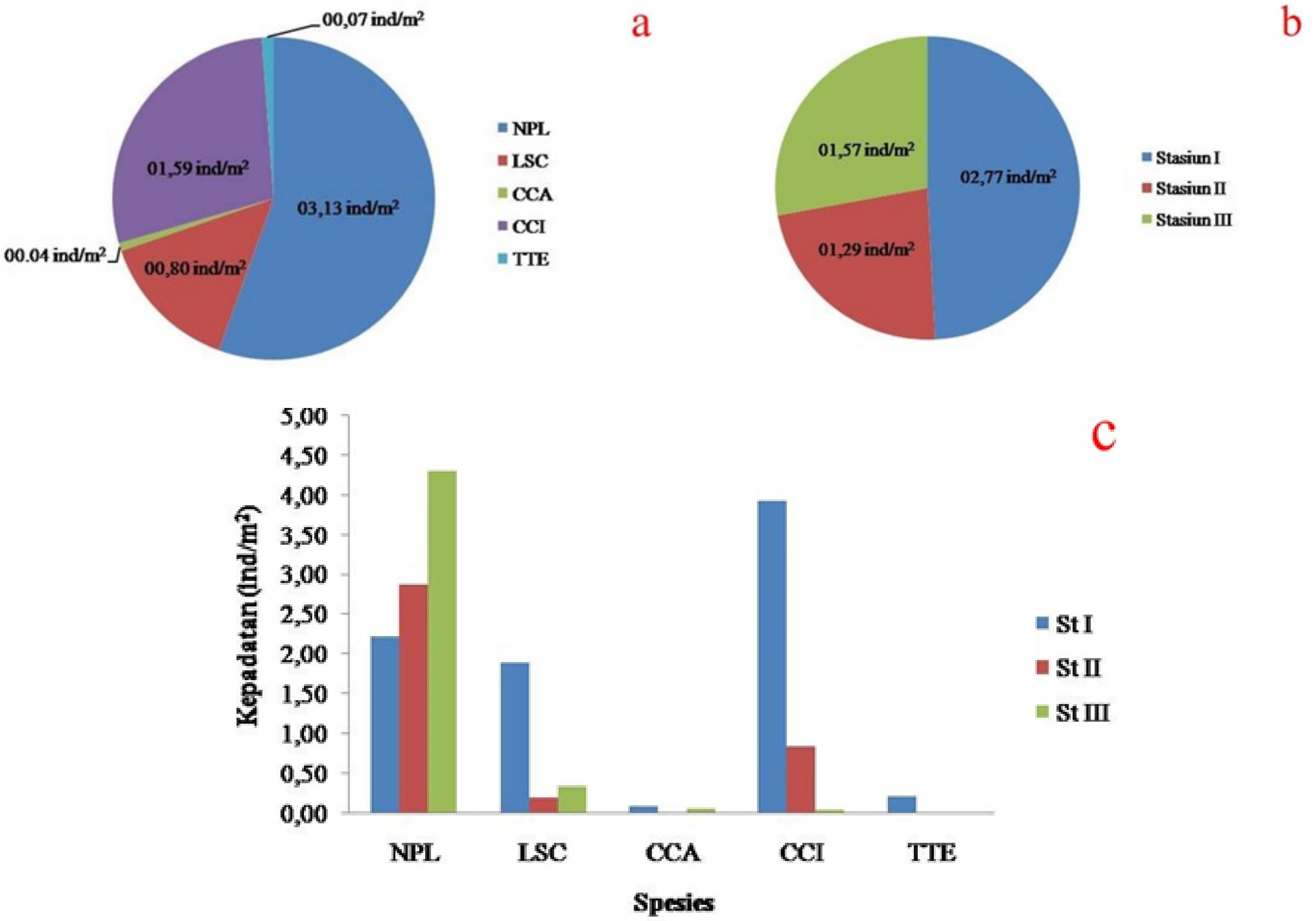

Figure 2. Snail density in Langsa mangrove forest; a = interspecies; b = between stations; c = species between stations; NPL = *Nerita planospira*; LSC = *Littorina scabra*; CCA = *Chicoreus capucinus*; CCI = *Cerithidea cingulata*; TTE = *Telescopium telescopium*.

tions II and I (C = 00.59 and C = 00.35) in Langsa mangrove forest. Additionally, the uniformity or evenness index of snails in the same area yielded a value the highest value observed at Station I (E = 00.73), while Stations II and III had values of E = 00.64 and E = 00.26, respectively.

Distribution

The analysis of snail distribution in Langsa mangrove forest, reveals a grouping pattern (Figure 3) based on the Morisita index. The overall distribution exhibits low diversity and moderate dominance and evenness (Table 3). However, variations in the distribution pattern were observed at each individual station. Station I exhibited a uniform distribution pattern (Iδ = 00.82 < 1) with low diversity and dominance. However, it had the highest number of snail species and individuals compared to other observation stations (5 species and 498 individuals). Station II, on the other hand, displayed a clustered distribution pattern (Iδ = 02.37 > 1) with relatively low diversity and moderate dominance (3 species in 233 individuals). Similarly, Station III had a grouped distribution pattern like Station II (Iδ = 02.51 > 1) with low diversity but high dominance (4 species in 283 individuals).

In addition, the geographic distribution of snails in Langsa mangrove forest indicates that *C. cingulata* snails are highly abundant, *C. capucinus* snails are commonly found, *N. plano-*

Table 3. Ecological index of snails in Langsa mangrove forest.

Station	Ecology index					
	H'	Criteria	C	Criteria	E	Criteria
I	01.70	Low	00.35	Low	00.73	Tend to be balanced
II	01.01	Low	00.59	Moderate	00.64	Tend to be balanced
III	00.51	Low	00.84	High	00.26	Stressed
Average	01.07	Low	00.59	Moderate	00.54	Tend to be balanced

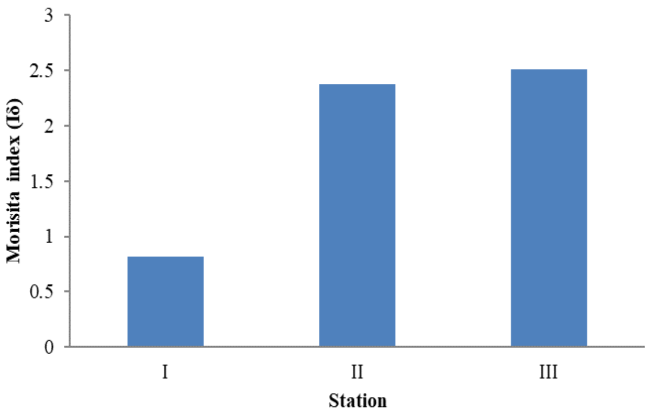

Figure 3. The distribution pattern of snails in Langsa mangrove forest is based on the Morisita index.

spira snails are only occasionally found, and *L. scabra* and *T. telescopium* snails are classified as rarely found (Table 4). In addition, the vertical distribution of snails in Langsa mangrove forest reveals that the *L. scabra* snail is categorized as an arboreal (A) snail, meaning it resides by climbing on the roots, stems, and canopy of the mangrove forest. On the other hand, the *C. cingulata* snail, *C. capucinus*, *N. planospira*, and *T. telescopium* are classified as epifaunal (E) snails, which means they inhabit the substrate of the mangrove forest in Langsa mangrove forest (Table 4).

The Relationship between snails and mangrove ecosystem conditions

The cluster analysis results, using the Bray-Curtis similarity measure, of the snail composition between observation stations and snail species in Langsa mangrove forest reveal two distinct groups (Figure 4). The first group comprises only Station I, which represents the core zone area of the KPH Region III Aceh Langsa City (conservation). The dominant substrate in this area is fine soil/mud, and the snail species associated with this habitat is *T. telescopium*. Station II and III comprise the second group of snails, which thrive in mangrove forests near fishponds and residential areas. The primary type of soil in this habitat is soft soil/mud, which is slightly more compact than the soil in Station I. The snails found in this habitat include *C. cingulata*, *C. capucinus*, *L. scabra*, and *N. planospira*.

Discussion

The presence of snails *C. cingulata, L. scabra,* and *N. planospira* in Langsa mangrove forest suggests that these three species have a broad range of tolerance. Conversely, the presence of snails *C. capucinus* and *T. telescopium* indicates that these two species have a very narrow tolerance. The scarcity of *L. scabra* and *T. telescopium* snails in Langsa mangrove forest can be attributed to the infrequent monitoring of their natural or preferred habitats, particularly the mangrove forests where *L. scabra* snails typically reside and grow. Positioned near the ocean or situated in estuaries or riverbanks, these organisms are affixed to the stems, roots, and leaves of mangroves. The substrate they inhabit consists of fine mud that retains an adequate amount of standing water.The *T. telescopium* snail exhibits a strong preference for fine muddy mangrove bottoms that have an ample amount of standing water (Kurniawati et al., 2014). Typically, this snail is found in areas covered by mangroves of *Avicennia* sp., *Sonneratia* sp., and/or *Rhizophora* sp. *C. cingulata*, a snail species indigenous to the mangrove ecosystem, exhibits a remarkable capacity to withstand environmental fluctuations, hence enabling its robust survival and reproductive success (Maura et al., 2021). Conversely, *T. telescopium* snails exhibit a strong preference for locations near human waste disposal sites due to the abundant availability of food in these places (Harahap et al., 2022).

The ecological index of snails in Langsa mangrove forest has a relatively low level of variety, accompanied by a balanced level of uniformity and a high level of dominance. This indicates that the environment is predominantly controlled by a single species. Zakaria et al. (2018) asserted that the Shannon-Weaver diversity index is commonly employed to elucidate the characteristics of ecological communities. According to Jin & Tang (1996), a higher value of the Shannon-Weaver index corresponds to more species variety. In addition, Molinari (1989) asserted that the uniformity index is employed to measure the evenness of species distribution within a community, while the dominance index is utilized to indicate the prevalence of a certain species inside the community. A high

Table 4. Distribution of snails in Langsa mangrove forest. * = Sreelekshmi et al., (2020);**Phintrakoonet al., (2008); E = *Epifaunal*; A = *Arboreal*; + = Group members; - = Not group members.

Family	Species	Geography distribution*			Vertical distribution**	
		Frequency	Relative Frequency (%)	Category	E	A
Potamididae	*C. cingulata*	00.83	83.33	Abundant	+	-
Muricidae	*C. capucinus*	00.50	50.00	Common	+	-
Littorinidae	*L. scabra*	00.11	11.11	Rare	-	+
Neritidae	*N. planospira*	00.36	36.11	Rare	+	-
Potamididae	*T. telescopium*	00.06	05.56	Rare	+	-

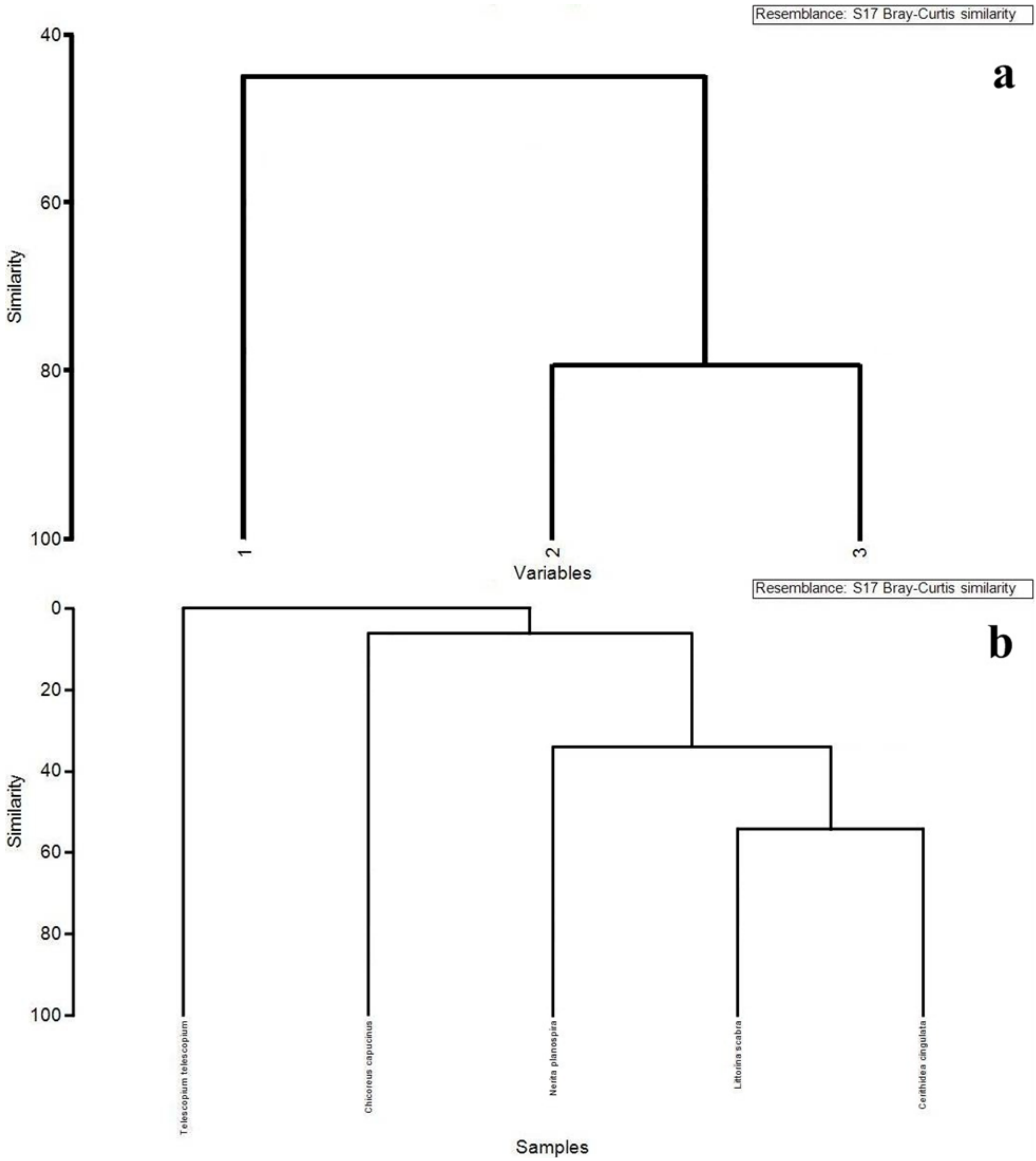

Figure 4. Grouping the composition of snails found in Langsa mangrove forest; a (top) = based on observation station; b (bottom) = based on species found

dominance index value implies that a species has exerted control over a territory or area, while a low dominance index value suggests the absence of species control over the territory or region.

Conclusions

In Langsa mangrove forest area, a study identified a total of 5 species of mangrove snails from 4 different families. The most abundant species, *T. telescopium*, was found predominantly at Station I, while *L. scabra* and *C. cingulata* dominated at all observation stations. The overall diversity of snails in the area was relatively low, with a high level of uniformity and dominance. As a result, the distribution pattern of snails appeared to be clustered. In terms of geographical distribution, the snail species *C. cingulata* is considered abundant, *C. capucinus* is frequently found, *N. planospira* is only occasionally found, and *L. scabra* and *T. telescopium* are rarely found. Additionally, *L. scabra* is arboreal, while *C. cingulata, C. capucinus, N. planospira*, and *T. telescopium* are epifaunal. In addition, *T. telescopium* snails are found in habitats characterized by fine mud substrates. Similarly, *C. cingulata, C. capucinus, L. scabra,* and *N. planospira* are also associated with habitats with fine mud substrates, although they are more compact *T. telescopium* environments.

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Authorship contribution

NAM: Conceptualization, methodology, investigation, resources, sample processing and analysis, data curation, formal analysis, visualization, writing - original draft preparation, writing - review and editing. **EE**: Methodology, writing - review and editing, supervision. **SS:** Conceptualization, methodology, formal analysis, writing - original draft preparation, writing - review and editing, supervision. **FWH:** writing - review and editing. **RE:** writing - review and editing. **WOBB:** writing - review and editing. **YL:** writing - review and editing. All authors gave final approval for publication and agreed to be held accountable for the work performed therein.

Data availability

Datasets generated during and/or analysed throughout the present study are available from the corresponding author upon reasonable request.

Conflict of interest

On behalf of all authors, the corresponding author states that there are no conflicts of interest.

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References

Alongi, D. M. (2015). The impact of climate change on mangrove forests. *Current Climate Change Reports*. *1*(1): 30-39.

Alongi, D. M. (2018). Impact of global change on nutrient dynamics in mangrove forests. *Forests*. *9*(10): 1-13.

Appeltans, W., Ahyong, S. T., Anderson, G., Angel, M. V., Artois, T., Bailly, N., Bamber, R., Barber, A., Bartsch, I., Berta, A., Błazewicz-Paszkowycz, M., Bock, P., Boxshall, G., Boyko, C. B., Brandao, S. N., Bray, R. A., Bruce, N. L., Cairns, S. D., Chan, T., Cheng, L., Collins, A. G., Cribb, T., Curini-Galletti, M., Dahdouh-Guebas, F., Davie, P. J. F., Dawson, M. N., De Clerck, O., Decock, W., De Grave, S., de Voogd, N. J., Domning, D. P., Emig, C. C., Erseus, C., Eschmeyer, W., Fauchald, K., Fautin, D. G., Feist, S. W., Fransen, C. H. J. M., Furuya, H., Garcia-Alvarez, O., Gerken, S., Gibson, D., Gittenberger, A., Gofas, S., Gomez -Daglio, L., Gordon, D. P., Guiry, M. D., Hernandez, F., Hoeksema, B. W., Hopcroft, R. R., Jaume, D., Kirk, P., Koedam, N., Koenemann, S., Kolb, J. B., Kristensen, R. M., Kroh, A., Lambert, G., Lazarus, D. B., Lemaitre, R., Longshaw, M., Lowry, J., Macpherson, E., Madin, L. P., Mah, C., Mapstone, G., McLaughlin, P. A., Mees, J., Meland, K., Messing, C. G., Mills, C. E., Molodtsova, T. N., Mooi, R., Neuhaus, B., Ng, P. K. L., Nielsen, C.,Norenburg, J., Opresko, D. M., Osawa, M., Paulay, G., Perrin, W., Pilger, J. F., Poore, G. C. B., Pugh, P., Read, G. B., Reimer, J. D., Rius, M., Rocha, R. M., Saiz-Salinas, J. I., Scarabino, V., Schierwater, B., Schmidt-Rhaesa, A., Schnabel, K. E., Schotte, M., Schuchert, P., Schwabe, E., Segers, H., Self-Sullivan, C., Shenkar, N., Siegel, V., Sterrer, W., Stohr, S., Swalla, B., Tasker, M. L., Thuesen, E. V., Timm, T., Todaro, M. A.,Turon, X., Tyler, S., Uetz, P., van der Land, J., Vanhoorne, B., van Ofwegen, L. P., van Soest, R. W. M., Vanaverbeke, J., Walker-Smith, G., Walter, T. C., Warren, A., Williams, G. C., Wilson, S. P., & Costello, M. J. (2012). The magnitude of global marine species diversity. *Current Biology*. *22*(23): 2189-2202.

Berner, R. A., & Westrich, J. T. (1985). Bioturbation and the early diagenesis of carbon and sulfur. *American Journal of Science*. *285*(3): 193-206.

Bieler, R. (1992). Gastropod phylogeny and systematic. *Annual Review of Ecology and Systematics*. 23: 311-338.

Cob, Z. C., Arshad, A., Bujang, J. S., & Ghaffar, M. A. (2009). Age, growth, mortalty and population structure of *Strombus canarium* (Gastropoda: Strombidae): Variations in male and female sub-populations. *Applied Sciences*. *9* (18): 3287-3297.

Culha, M., Bat, L., Dogan, A., & Dagli, E. (2009). Ecology and distribution of the veined rapa whelk *Rapana venosa* (Valenciennes, 1846) in Sinop Peninsula (Southern Central Black Sea), Turkey. *Animal and Veterinary Advances*. *8*(1): 51-58.

Cunha, T. J., & Giribet, G. (2019). A congruent topology for deep gastropod relationships. *Proceedings of the Royal Society B – Biological Sciences*. *286*: 20182776. https://doi.org/10.1098/rspb.2018.2776.

Dharma, B. (1988). *Indonesian Snails and Shells (Indonesian Shells).* Jakarta, Indonesia.

[DLHK] Environment and Forestry Service of Aceh Province. (2022). UPTD – KPH Region III. Accessed at https://dlhk.acehprov.go.id/profil/kph-region-iii/ on 03 February 2022 at 09.40 WIB.

Echem, R. T. (2017). Morphometric relations of gastropod species: *Nerita albicilla* and *Patella nigra*. *World News of Natural Sciences*. *7*: 30-36.

Eddy, S., Mulyana, A., Ridho, M. R., & Iskandar, I. (2015). The impact of anthropogenic activities on mangrove forest degradation in Indonesia. *Environment and Development*. *1*(3): 240-254.

Ernanto, R., Agustriani, F., & Aryawati, R. (2010). Gastropod community structure in the mangrove ecosystem at the estuary of the Batang Ogan Komering Ilir River, South Sumatra. *Maspari*. *1*: 73-78.

Fryda, J., Nutzel, A., & Wagner, P. (2008). Paleozoic Gastropoda. *In:* Ponder, W.F., Lindberg, D. R. (Eds.), Phylogeny and evolution of the mollusca. University of California Press. Berkeley. pp 238-270.

Fusi, M., Beone, G. M., Suciu, N. A., Sacchi, A., Trevisan, M., Capri, E., Daffonchio, D., Din, N., Dahdouh-Guebas, F., & Cannicci, S. (2016). Ecological status and sources of anthropogenic contaminants in mangroves of the Wouri River Estuary (Cameroon). *Marine Pollution Bulletin*. *109* (2): 723-733.

Gaut, B. S. (2018). A convergent outcome: Small genomes in mangroves. *New Phytologist*. *217*(1): 5-7.

Giri, C., Ochieng, E., Tieszen, L. L., Zhu, Z., Singh, A., Loveland, T., Masek, J., & Duke, N. (2011). Status and distribution of mangrove forests of the world using earth observation satellite data. *Global Ecology and Biogeography*. *20*(1): 154-159.

Hammer, O., Harper, D. A. T., & Ryan, P. D. (2001). PAST: Paleontological statistic software package for education and data analysis. *Paleontologica Electronica*. *4*(1): 1-9.

Harahap, I. M., Syahrial, Erniati, Erlangga, Imanullah, & Ezraneti, R. (2022). *Telescopium telescopium* (Linnaeus, 1758) gastropods in the mangrove forest of Cut Mamplam Village, Aceh Province, Indonesia. *Jurnal Kelautan Tropis*. *25*(2):156-168.

Haryani, N. S. (2013). Analysis of changes in mangrove forests using Landsat imagery. *Widya*. *1*(1): 72-77.

Husna, A. (2017). The relationship between the level of knowledge and science process skills of Langsa City High School students regarding mangroves, solving mangrove forest ecosystem problems. *Tabularasa PPS Unimed*. *14* (1): 79-92.

Jeeva, C., Mohan, P. M., Sabith, K. K. D. B., Ubare, V. V., Muruganantham, M., & Kumari, R. K. (2018). Distribution of gastropods in the intertidal environment of South, Middle and North Andaman Islands, India. *Marine Science*. *8*: 173-195.

Jin, X., & Teng, Q. (1996). Changes in fish species diversity and dominant species composition in the Yellow Sea. *Fisheries Research*. *26*(3-4): 337-352.

Johnson, A. B., Fogela, N. S., & Lambert, J. D. (2019). Growth and morphogenesis of the gastropod shell. *Proceedings of The National Academy of Sciences*. *116*(14): 6878-6883.

Kanazawa, A. (2001). Sterols in marine invertebrates. *Fisheries Science*. *67*: 997-1007.

Keegan, W. F., Portell, R. W., & Slapcinsky, J. (2003). Changes in invertebrate taxa at two pre-Columbian sites in Southwestern Jamaica, AD 800–1500. *Archaeological Science*. *30*: 1607-1617.

Kristensen, E., Bouillon, S., Dittmar, T., & Marchand, C. (2008). Organic carbon dynamics in mangrove ecosystems: A review. *Aquatic Botany*. *89*(2): 201-219.

Kuenzer, C., Bluemel, A., Gebhardt, S., Quoc, T.V., & Dech, S. (2011). Remote sensing of mangrove ecosystems: A review. *Remote Sensing*. *3*: 878-928.

Kurniawati, A., Bengen, D. G., & Madduppa, H. (2014). Characteristics of *Telescopium telescopium* in the mangrove ecosystem in Segara Anakan, Cilacap Regency, Central Java. *Bonorowo Wetlands*. *4*(2): 71-81.

Lee, S. Y. (2008). Mangrove macrobenthos: Assemblages, services and linkages. *Sea Research*. *59*(1-2): 16-29.

Leiva, G. E., & Castilla, J. C. (2002). A review of the world marine gastropod fishery: Evolution of catches, management and the Chilean experience. *Reviews in Fish Biology and Fisheries*. *11*: 283-300.

Li, X., Zhao, L., Zhang, Q., Xiong, Q., & Jiang, C. (2014). Purification, characterization, and bioactivity of polysaccharides from *Glossaulax didyma*. *Carbohydrate Polymers*. 102: 912-919.

Loker, E. S. (2010). Gastropod immunobiology. *Advances in Experimental Medicine and Biology*. *708*: 17-43.

Maiti, S. K., & Chowdhury, A. (2013). Effects of anthropogenic pollution on mangrove biodiversity: A review. *Environmental Protection*. *4*(12): 1428-1434.

Marois, D. E., & Mitsch, W. J. (2015). Coastal protection from tsunamis and cyclones provided by mangrove wetlands – A review. *International Journal of Biodiversity Science, Ecosystem Services and Management*. *11*(1): 71-83.

Maura, G., Aritonang, A. B., & Helena, S. (2021). Composition and distribution pattern of gastropods on the Bakau Besar Laut Village, The District of Sungai Pinyuh, Mempawah Regency. *Laut Khatulistiwa*. *4*(2): 6-11.

Modica, M. V., Puillandre, N., Castelin, M., Zhang, Y., & Holford, M. (2014). A good compromise: Rapid and robust species proxies for inventorying biodiversity hotspots using the Terebridae (Gastropoda: Conoidea). *PLos One*. 9: e102160.

Molinari, J. (1989). A calibrated index for the measurement of evenness. *Oikos*. *56*: 319-326.

Morgan, G. J., & Hailstone, T. S. (1986). Distribution of gastropods in a mangrove habitat in South-East Queensland. *The Malacological Society of Australia*. *7*(3-4): 131-140.

Morisita, M. (1959). Measuring of dispersion of individuals and analysis of the distributional patterns. *Memories of The Faculty of Science Kyushu University Series E (Biology)*. *2* (4): 215 – 235.

Odum, E. P. (1996). *Fundamentals of ecology*. Gadjah Mada University Press. Yogyakarta, Indonesia.

Ozogul, Y., Duysak, O., Ozogul, F., Ozkutuk, A. S., & Tureli, C. (2008). Seasonal effects in the nutritional quality of the body structural tissue of cephalopods. *Food Chemistry*. *108*: 847-852.

Phintrakoon, C., Wells, F. E., & Chitramvong, Y. (2008). Distribution of molluscs in mangroves at six sites in the Upper Gulf of Thailand. *The Raffles Bulletin of Zoology*. Supplement no. *18*: 247-257.

Polania, J., Urrego, L. E., & Agudelo, C. M. (2015). Recent advances in understanding Colombian mangroves. *Acta Oecologica*. *63*: 82-90.

[PPRI] Republic of Indonesia Government Regulations. (2021). Republic of Indonesia Government Regulation Number 23 of 2021 concerning forestry implementation. Jakarta, Indonesia.

Pribadi, R., Hartati, R., & Suryono, C. A. (2009). Species composition and distribution of gastropods in the Segara Anakan Cilacap mangrove forest area. *Marine Science*. *14*(2): 102-111.

Puillandre, N., Modica, M. V., Zhang, Y., Sirovich, L., Boisselier, M.C., Cruaud, C., Holford, M., & Samadi, S. (2012). Large-scale species delimitation method for hyperdiverse groups. *Molecular Ecology*. *21*: 2671-2691.

Ran, K., Lia, Q., Qi, L., Li, W., & Kong, L. (2020). DNA barcoding for identification of marine gastropod species from Hainan Island, China. *Fisheries Research*. *225*: 105504.

Salinas, C., & Kisailus, D. (2013). Fracture mitigation strategies in gastropod shells. *JOM: The Journal of The Minerals, Metals and Materials Society*. *65*(4): 473-480.

Sandilyan, S., & Kathiresan, K. (2015). Mangroves as bioshield: An undisputable fact. *Ocean and Coastal*. *103*: 94-96.

Schaduw, J. N. W. (2019). Community structure and percentage of mangrove canopy cover Salawati Island, Raja Ampat Islands Regency, West Papua Province. *Indonesian Geography Magazine*. *33*(1): 26-34.

Setyobudiandi, I., Sulistiono, Yulianda, F., Kusmana, C., Hariyadi, S., Damar, A., Sembiring, A., & Bahtiar. (2009). *Sampling and analysis of fisheries and marine data: Application of sampling methods in coastal and marine areas*. Faculty of Fisheries and Marine Sciences, Bogor Agricultural Institute. Bogor, Indonesia.

[SIPPa] Planning and Budgeting Information System. (2022). RPI2-JM Job Creation Sector Langsa City 2015 – 2019: Chapter IV Profile of Langsa City. Visited at https://sippa.buatkarya.pu.go.id/sippa_online/ws_file/document/rpi2jm/DOCRPIJM_147901132604_BAB_IV_PROFIL_KOTA_pdf.pdf. February 3, 2022 at 21.16 WIB.

Spalding, M. D., Ruffo, S., Lacambra, C., Meliane, I., Hale, L. Z., Shepard, C. C., & Beck, M. W. (2014). The role of ecosystems in coastal protection: Adapting to climate change and coastal hazards. *Ocean and Coastal Management*. *90*: 50 – 57.

Sreelekshmi, S., Nandan, S. B., Kaimal, S. V., Radhakrishnan, C. K., & Suresh, V. R. (2020). Mangrove species diversity, stand structure and zonation pattern in relation to environmental factors — A case study at Sundarban delta, east coast of India. *Regional Studies in Marine Science*. 35: 101111. https://doi.org/10.1016/j.rsma.2020.101111.

Suratissa, D. M., & Rathnayake, U. S. (2017). Effect of pollution on diversity of marine gastropods and its role in trophic structure at Nasese Shore, Suva, Fiji Islands. *Asia – Pacific Biodiversity*. 10(2): 192-198.

Tuan, V. S. (2000). Status and solution for farming and management of the clam *Meretrix lyrata* at Go Cong Dong, Tien Gang Province. *Vietnam Phuket Marine Biological Center Special Publication*. *21*(1): 167-170.

[UNEP] United Nations Environment Programme. (2014). The Importance Of Mangroves To People: A call to action. van Bochove, J., Sullivan, E., & Nakamura, T. (Eds). United Nations Environment Programme World Conservation Monitoring Centre, Cambridge.128 pp.

Uribe, J. E., Irisarri, I., Templado, J., & Zardoya, R. (2019). New patellogastropod mitogenomes help counteracting long-branch attraction in the deep phylogeny of gastropod mollusks. *Molecular Phylogenetics and Evolution*. *133*: 12-23.

Zakaria, R. M., Sofawi, A. B., Joharee, N. A., & Pauzi, A. Z. (2018). Stand structure and biomass estimation in the Klang Islands Mangrove Forest, Peninsular Malaysia. *En-*

vironmental Earth Sciences. *77*(486). https://doi.org/10.1007/s12665-018-7636-7.

Zapata, F., Wilson, N. G., Howison, M., Andrade, S. C. S., Jorger, K. M., Schrodl, M., Goetz, F. E., Giribet, G., & Dunn, C. W. (2014). Phylogenomic analyses of deep gastropod relationships reject Orthogastropoda. *Proceedings of The Royal Society B – Biological Sciences*. 281: 20141739. https://doi.org/10.1098/rspb.2014.1739.

Zarai, Z., Frikha, F., Balti, R., Miled, N., Gargouria, Y., & Mejdoub, H. (2011). Nutrient composition of the marine snail *(Hexaplex trunculus)* from the Tunisian Mediterranean coasts. *Science of Food and Agriculture*. *91*: 1265-1270.

Zhukova, N. V. (2007). Lipid classes and fatty acid composition of the tropical nudibranch mollusks *Chromodoris* sp. and *Phyllidia coelestis*. *Lipids*. *42*: 1169-1175.

Zurba, N., Effendi, H., & Yonvitner. (2017). Management of the potential of the mangrove ecosystem in Kuala Langsa, Aceh. *Tropical Marine Science and Technology*. *9*(1): 281-300.