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* (0.313 ind/m²). 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

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, Neritimorpha, 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 Haliothis 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 5º North Latitude and 5º 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. These line transects were then divided into plots for further analysis. A plot measuring 10 x 10 meters is divided into four smaller plots. Subsequently, within each 10 x 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 x 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: $H' \leq 2.0$ (low diversity), $2.0 < H' \leq 3.0$ (medium diversity), and $H' \geq 3.0$ (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: $0 < C \leq 0.5$ (low dominance), $0.5 < C \leq 0.75$ (medium dominance), and $0.75 < C \leq 1$ (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 $0 < E \leq 0.5$ indicates a depressed state, $0.5 < E \leq 0.75$ indicates a somewhat balanced state, and $0.75 < E \leq 1$ 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 Cerithidea cingulata 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/m²) and the lowest density observed in *C. capucinus* (00.04 ind/m²) (Figure 2). Figure 2 indicates that Station I had the largest density of snails, with a density of 02.77 ind/m² 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/m² 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/m²), whereas the highest concentrations of *L. scabra, C. capucinus, C. cingulata*, and *T. telescopium* were recorded at Station I (01.88 ind/m², 00.08 ind/m², 03.92 ind/m², and 00.20 ind/m²).

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-
tions II and I (C = 0.59 and C = 0.35) 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 = 0.73), while Stations II and III had values of E = 0.64 and E = 0.26, 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 = 0.82 < 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 = 0.37 > 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 = 0.51 > 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. planospira* snails are rarely observed.
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 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

![Morihsita index](https://doi.org/10.29103/joms.v1i1.15792)

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

**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.

<table>
<thead>
<tr>
<th>Family</th>
<th>Species</th>
<th>Geography distribution*</th>
<th>Vertical distribution**</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Frequency</td>
<td>Relative Frequency (%)</td>
<td>Category</td>
</tr>
<tr>
<td>Potamididae</td>
<td>C. cingulata</td>
<td>00.83</td>
<td>83.33</td>
</tr>
<tr>
<td>Muricidae</td>
<td>C. capucinus</td>
<td>00.50</td>
<td>50.00</td>
</tr>
<tr>
<td>Littorinida</td>
<td>L. scabra</td>
<td>00.11</td>
<td>11.11</td>
</tr>
<tr>
<td>Neritidae</td>
<td>N. planospira</td>
<td>00.36</td>
<td>36.11</td>
</tr>
<tr>
<td>Potamididae</td>
<td>T. telescopium</td>
<td>00.06</td>
<td>05.56</td>
</tr>
</tbody>
</table>
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 occasion-
ally 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**


The relationship between the level of knowledge and science process skills of Langsa City High School students regarding mangroves, solving mangrove forest ecosystem problems.


