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Checklist of mangrove snails (Gastropoda: Mollusca) on the coast of Lamongan District, East Java, Indonesia

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Abstract. *Isroni W, Sari PDW, Sari LA, Daniel K, South J, Islamy RA, Wirabuana PYAP, Hasan V. 2023. Checklist of mangrove snails (Gastropoda: Mollusca) on the coast of Lamongan District, East Java, Indonesia. Biodiversitas 24: 1676-1685.* Mangroves are crucial transition zone ecosystems providing sheltered nursery zones and abundant marine and terrestrial biota resources. Mangrove snails (Gastropoda: Mollusca) are ecologically important ecosystem engineers, trophic links for higher predators, and a source of human food and livelihoods. Mangrove snails are also ideal bioindicators to monitor environmental pollution. A strong baseline understanding of current richness and distribution is therefore important. Thus, this study provides data on the species composition of mangrove snails on the north coast of Lamongan District, East Java, Indonesia. Sampling was conducted during low tide at four stations from September to November 2022 using square transects. Ten families consisted of Cerithiidae, Cypraeidae, Fasciolariidae, Muricidae, Naticadae, Neritidae, Plaxidae, Potamididae, Trochidae, and Turbinidae comprising 20 genera and 24 species. The most dominant family found is Muricidae, with six genera and eight species. Most mangrove snails were found in rocky, sandy substrates, around trees, and mangrove roots. Gastropods observed in this study were alive and dead (i.e., empty shells). We suspect that there is still much-hidden diversity of Gastropoda in this region. Therefore, we suggest that future work addresses differences in microhabitat and snail morphology with quantitative and semi-quantitative methods to understand distribution drivers and ecological roles better.

Keywords: Diversity, ecosystem, estuary, intertidal zone, invertebrate, macrozoobenthos, shellfish

INTRODUCTION

Gastropods are a class in the phylum Molluscs, the biggest class of Mollusca comprising 80% of this phylum and thus is the second most diverse animal phylum occurring in all major environments except the aerospace (Strong et al. 2008; Islany and Hasan 2020). Physical factors influence the distribution of organisms, and ecological communities vary widely through time and space (Gizachew 2022). The name gastropod is derived from the Greek word *gaster*, which means stomach, and *podos*, which means foot. Thus Gastropods are shelled animals that "walk" on their stomachs. Gastropod shells are hugely diverse and vary considerably in shape, color, and pattern, although most are spiral with chiral symmetry (Harminto 2003; Kadim et al. 2022). Shell morphology is a plastic and adaptive trait, with size and shape relating to anti-predator defense and habitat (Signor 1993; Bourdeau 2010; Hasibuan et al. 2021). Most Gastropods are benthic and epifaunal species that occupy a broad range of habitats, including tidal areas, mangroves, seagrass beds, coral reefs, and rocky reefs (Santhanam 2019; Ogi et al. 2022; Sari et al. 2022). This behavioral adaptation of Gastropods constitutes a fundamental evolutionary advantage when facing a fluctuating environment (Rimadiyani et al. 2019; Susintowati et al. 2019). High gastropod species richness is related to primary productivity rates as most gastropods are herbivorous, although some are predatory (Pribadi et al. 2009). Thus, niche diversification drives a high species richness community (Béguinot 2021; Rahman et al. 2021). Gastropods are ecosystem engineers and keystone species; losing certain species may cause ecological phase shifts. For example, reducing herbivory may lead to algal smothering (Ratnaningdyah et al. 2022; Tebiary et al. 2022). Gastropods are tolerant to some environmental perturbation, but certain taxa are sensitive to disturbance (Marwoto and Isnaningsih 2014). Ubiquity in the environment and these traits make mollusks ideal bioindicators in aquatic ecosystems (Baderan et al. 2019; Sujarta et al. 2022).

Mangrove forests consist of tropical plant communities dominated by tree species that grow and develop in the tidal zone of muddy beaches (Isroni et al. 2019; Hasan et al. 2022a). Mangrove ecosystems confer beneficial ecosystem services by economically providing timber products, food, tourism, and desalinating nearby land for crop cultivation (Hasan et al. 2019a; Freiss et al. 2020; Hasan et al. 2021; Nugroho et al. 2022). Mangrove forests are also critical for storm and flood defense in coastal regions, protecting against tidal forces, erosion, and strong winds (Hilmi et al. 2022; Utama et al. 2022). Unfortunately, economic factors and a lack of public understanding of mangrove forests' importance have led to over-exploitation and degradation (Chatarina et al. 2011; Nugroho et al. 2022; Palupi et al. 2022; Sari et al. 2022).

The mangrove ecosystem on the north coast of Lamongan District plays a vital role for the surrounding community in the tourism, capture fisheries, and aquaculture sectors. In the food chain, epifauna gastropods utilize epiphytic biomass in seagrass leaves. Meanwhile, infauna gastropods are components that utilize litter on the surface of the sediment. Many types of mangrove gastropods have important economic value. The local people of the Lamongan District use it as a source of animal protein for daily consumption and as a snack, while the shells are used as ornamental souvenirs typically of Lamongan (Novinta and Adharini 2022). However, the mangrove ecosystem in the northern coastal Lamongan District is experiencing significant natural and anthropogenic changes. According to a survey conducted by Nurkumala and Sukma (2022) in Labuhan Village, Lamongan District, East Java, the cause of the reduction in mangrove plants is the result of land conversion for fish and shrimp ponds (50%), coastal erosion (27%), and logging (23%). Therefore, along with the decreasing area of healthy mangrove forests, there is a concern that the combined stressors may result in ecological disturbance across the ecosystem, including mangrove snails, which may result in currently unpredictable trophic cascades and phase shifts. Therefore, recording the species present in a location is very important, and it is imperative to understand the aquatic species richness, relative abundance, and diversity of mangrove snails, considering that worldwide gastropod diversity has begun to decrease drastically (Pramono et al. 2021; Sujarta et al. 2022). Unfortunately, research on mangrove snails on the North coast of Lamongan District is scarce. This study aims to provide information on the species composition of mangrove snails on the North coast of Lamongan District, East Java, Indonesia.

MATERIALS AND METHODS

Study area

The determination of observation stations is based on differences in environmental conditions, with a distance between station locations is about 500 m. A complete description of each sampling station is shown in Figure 1 and Table 1.

Sampling and identification of mangrove snails

Sampling was conducted during low tide at four stations (Figure 1) monthly for three months, from September to November 2022, using the square transect method at locations where accessible sampling was possible. Location determination in this method was conducted deliberately at locations considered appropriate to the natural habitat of mangrove snails (Gerami et al. 2016; Pototan et al. 2021; Tebiary et al. 2022). Individual snails per m^2 were determined each month at each station. All samples of mangrove snails were put into a sample box and immediately preserved in 96% alcohol (Hasan et al. 2019b; Hasan et al. 2023). For longer preservation, all specimens were transferred to 10% formalin (Serdiati et al. 2021; Hasan et al. 2022b). Identification of mangrove snails was carried out by observing morphological characteristics such as shell shape, shell width, shell length, shell color, apex, whorl, whorl body, siphonal canal, spire, suture, aperture, and columella. Once identified, the sample was measured using a caliper, photographed using a digital camera, and stored in the collection bottle. Furthermore, using this previous data, all samples were identified following the morphological characteristics in published references, including Abbot and Dance (2000); Tapilatu and Pelasula (2012); Arbi (2014); Dolorosa and Gallon (2014); Reid (2014); Baharuddin and Marshall (2015); Reid and Ozawa (2016); Islamy and Hasan (2020).

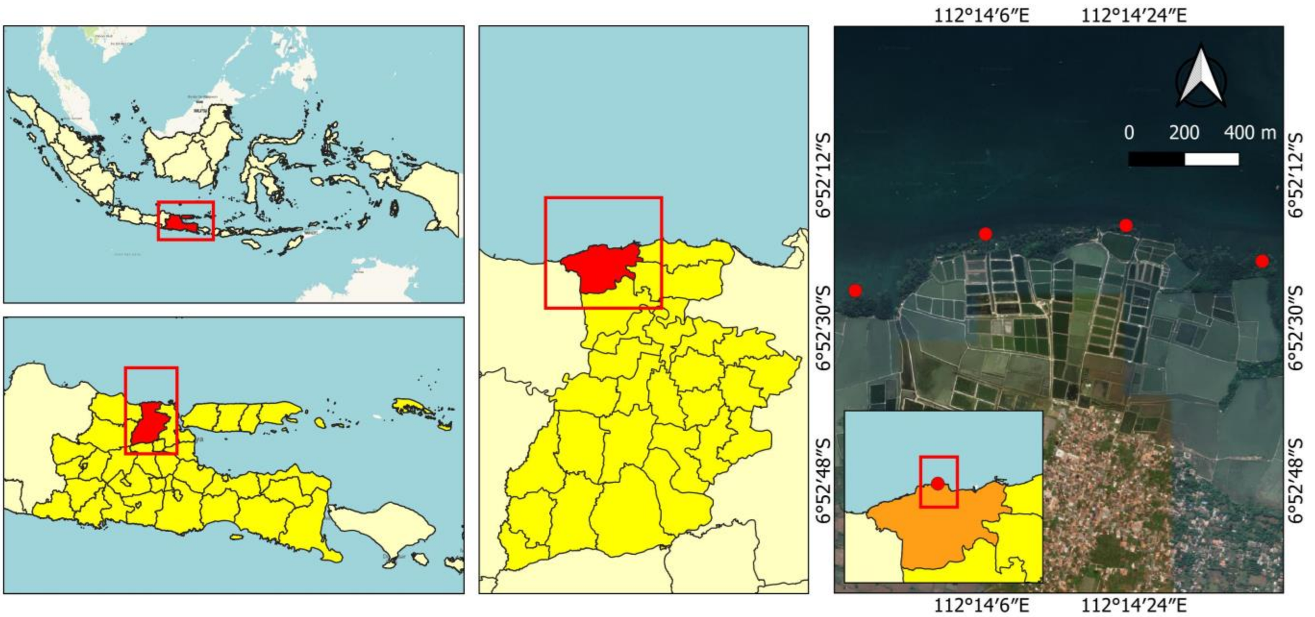

Figure 1. Collecting site of mangrove snails in coast of Lamongan District, East Java, Indonesia

Table 1. Coordinates, substrate, type of mangrove vegetation, and description of the sampling station

Station	Coordinates	Substrate	Vegetation	Site description
1	6°52'25.6"S 112°13'51.1"E	Sandy mud	*Sonneratia*	Station 1 is located in a mangrove area dominated by *Sonneratia* species. Near unused ponds, so there is minimal cultivation activity. The substrate in this area is sandy-mud. Mangrove density is still rare, and the mangrove category is the level of seedlings, saplings, poles, and trees. When high tide, the location is flooded, while at low tide is not inundated. This location is far from settlements, and no water inlet from the mainland except for unused pond ditches.
2	6°52'18.9"S 112°14'06.5"E	Muddy sand	*Sonneratia, Avicennia, Rhizophora, Bruguiera*	Station 2 is in a mangrove area of *Sonneratia*, *Avicennia*, *Rhizophora*, and *Bruguiera*. Near the grouper fish pond area, it is full of cultivation activities. The substrate in this area is muddy sand. However, mangrove density is relatively dense; the mangrove category is the level of seedlings, saplings, poles, and trees. When high tide, the location is flooded, while at low tide is not inundated. This location is far from settlements. There is a water inlet channel from the mainland, namely the pond ditch, which drains the waste water from the aquaculture ponds every time.
3	6°52'17.9"S 112°14'23.1"E	Muddy sand	*Sonneratia*	Station 3 is located in a mangrove area dominated by *Sonneratia* species near seaweed cultivation. The substrate in this area is sandy mud. Mangrove density is classified as medium, and the mangrove category is the pole and tree level. At high tide, the location is flooded, while at low tide is slightly inundated. This location is far from settlements, and there is no water inlet from the mainland.
4	6°52'22.1"S 112°14'39.2"E	Sandy mud	*Sonneratia, Avicennia*	Station 4 is located in a mangrove area dominated by *Sonneratia* and *Avicenni*a species. Its estuary and fishing port area. The substrate in this area is sand-mud. Mangrove density is classified as dense, but the mangrove category found is only at the pole and tree level. This location is always inundated with 30-100 cm depth water.

Analysis data

Sampling efficiency was assessed using a rarefaction curve for each month's sampling iteration, plotted against sample size (i.e., individuals detected). Diversity indices were calculated to compare between sites as a baseline reference for future work. Species Richness (Sprich) is derived as the number of species in a community. Shannon-Weiner Index of Diversity (Shannon 1948) was calculated for each station, aggregating the data from each month as replicates. This index describes the entropy of a given community.

$$(H) = \sum_{i=1}^{S} p_i \ln p_i$$

Where, H is the Shannon diversity index, which has no bounded upper value; S is the total number of species in the community; P_i is the proportion of S comprised of the *i*th species. Shannon's evenness (eqn 2) was calculated from the results of eqn 1.

$$E_H = H/H_{max} = lnS$$

Where, E_H is Shannon's evenness; H is Shannon's diversity index; and H_{max} is the natural log of total species detected in the basin.

E_H is bounded between zero and one, where one represents complete evenness. A Kruskal-Wallis's test was used to identify differences in diversity indices between Stations. A Dunn test with Holm-Bonferroni corrections was applied post hoc to determine between-level differences. All statistical analyses were performed within the R software environment version 4.0.2 and the package "vegan" (Oksanen et al. 2019; R Core Team 2020).

RESULTS AND DISCUSSION

Mangrove snails found at the study site

The rarefaction curves indicate an efficient sampling procedure as all curves plateau (Figure 2). This study found 10 families (Table 2) consisting of Turbinidae Muricidae, Cerithiidae, Trochidae, Planaxidae, Fasciolariidae, Cypraeidae, Prodotiidae, Naticidae, Neritidae, and Potamididae with consist of 20 genera, i.e., *Cerithium*, *Clypeomorus*, *Mauritia*, *Fasciolaria*, *Claremontiella*, *Cytharomorula*, *Muricopsis*, *Orania*, *Rapana*, *Reishia*, *Natica*, *Nerita*, *Planaxis*, *Telescopium*, *Trochus*, *Monodonta*, *Astralium*, *Bolma*, *Lunella*, and *Turbo* with consist of 24 species, i.e., *Cerithium echinatum*, *Clypeomorus clypeomorus*, *Clypeomorus petrosa*, *Clypeomorus moniliferus*, *Mauritia arabica*, *Fasciolaria lignaria*, *Claremontiella nodulosa*, *Cytharomorula manusuduirauti*, *Muricopsis omanensis*, *Muricopsis matildeae*, *Muricopsis chiarae*, *Orania xuthedra*, *Rapana venosa*, *Reishia clavigera*, *Natica tigrine*, *Nerita lineata*, *Planaxis sulcatus*, *Telescopium telescopium*, *Trochus maculatus*, *Monodonta confusa*, *Astralium rhodostomum*, *Bolma rugosa*, *Lunella cinerea*, and *Turbo argyrostoma*.

A total of 24 species were found in station 1 (*C. echinatum, C. clypeomorus, C. petrosa, C. moniliferus, M. arabica, F. lignaria, C. nodulosa, C. manusuduirauti, M. omanensis, M. matildeae, M. chiarae, O. xuthedra, R. venosa, R. clavigera, N. tigrine, P. sulcatus, T.*

telescopium, Monodonta confuse, A. rhodostomum, B. rugosa, L. cinerea, and *T. argyrostoma*). A total of 21 species were found in station 2 (*C. echinatum, C. clypeomorus, C. petrosa, C. moniliferus, M. arabica, F. lignaria, C. nodulosa, C. manusuduirauti, M. omanensis, M. matildeae, M. chiarae, R. venosa, Natica tigrina, N. lineata, P. sulcatus, T. telescopium, T. maculatus, M. confusa, A. rhodostomum, L. cinerea, dan T. argyrostoma*). Total of 20 species were found in station 3 (*C. echinatum, C. clypeomorus, C. petrosa, C. moniliferus, M. arabica, F. lignaria, C. nodulosa, C. manusuduirauti, M. omanensis, M. matildeae, M. chiarae, O. xuthedra, R. venosa, R. clavigera, P. sulcatus, T. telescopium, M. confusa, A. rhodostomum, B. rugosa,* and *T. argyrostoma)*. Overall, 21 species were found in station 4 *(C. echinatum, C. clypeomorus, C. petrosa, C. moniliferus, F. lignaria, C. nodulosa, C. manusuduirauti, M. omanensis, M. matildeae, M. chiarae, O. xuthedra, R. venosa, R. clavigera, Natica tigrina, N. lineata, P. sulcatus, T. telescopium, T. maculatus, M. confusa, L. cinerea,* and *T. argyrostoma).*

Station 3 had the highest density of mangrove snails (Table 3). The highest Sprich of mangrove snails was at Station 1 in November (24 species) and the lowest in Station 3 in October (20 species). Moreover, there was no difference in Sprich between stations (X^2: 3.42, df: 3, p-value = 0.33). Similarly, there was no difference in H (X^2: 6.69, df: 3, p-value = 0.08). On the contrary, there was a significant difference in EH (X^2: 9.6, df: 3, p-value < 0.05) (Table 4; Figure 3) where Station 4 had significantly higher EH than Station 2 (z: 2.83; $p < 0.05$; Figure 3).

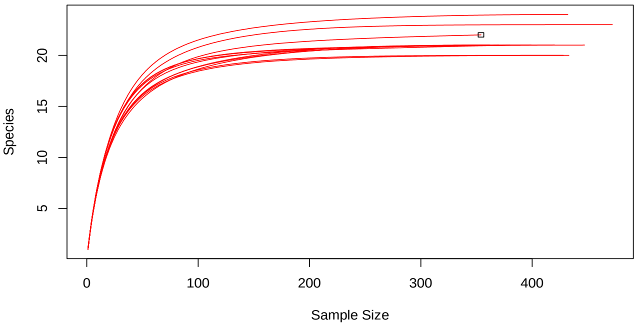

Figure 2. Rarefaction curves of sampling efficiency, where each line indicates monthly sampling iteration

Table 2. Species of mangrove snails across all stations

Family	Genera	Species	Station 1	Station 2	Station 3	Station 4
Cerithiidae	*Cerithium*	*Cerithium echinatum*	+	+	+	+
	Clypeomorus	*Clypeomorus clypeomorus*	+	+	+	+
		Clypeomorus petrosa	+	+	+	+
		Clypeomorus moniliferus	+	+	+	+
Cypraeidae	*Mauritia*	*Mauritia arabica*	+	+	+	-
Fasciolariidae	*Fasciolaria*	*Fasciolaria lignaria*	+	+	+	+
Muricidae	*Claremontiella*	*Claremontiella nodulosa*	+	+	+	+
	Cytharomorula	*Cytharomorula manusuduirauti*	+	+	+	+
	Muricopsis	*Muricopsis omanensis*	+	+	+	+
		Muricopsis matildeae	+	+	+	+
		Muricopsis chiarae	+	+	+	+
	Orania	*Orania xuthedra*	+	-	+	+
	Rapana	*Rapana venosa*	+	+	+	+
	Reishia	*Reishia clavigera*	+	-	+	+
Naticidae	*Natica*	*Natica tigrine*	+	+	-	+
Neritidae	*Nerita*	*Nerita lineata*	+	+	-	+
Planaxidae	*Planaxis*	*Planaxis sulcatus*	+	+	+	+
Potamididae	*Telescopium*	*Telescopium telescopium*	+	+	+	+
Trochidae	*Trochus*	*Trochus maculatus*	+	+	-	+
	Monodonta	*Monodonta confusa*	+	+	+	+
Turbinidae	*Astralium*	*Astralium rhodostomum*	+	-	+	-
	Bolma	*Bolma rugosa*	+	+	+	-
	Lunella	*Lunella cinerea*	+	+	-	+
	Turbo	*Turbo argyrostoma*	+	+	+	+

Table 3. Mean±SE of mangrove snail density at each station aggregated over the three-month sampling period (individual snails per m^2)

Station	Mean±SE ind/m^2
1	19.13±1.23
2	18.83±0.57
3	22.21±0.69
4	20.78±0.97

Table 4. Mean±SE of diversity indices Sprich (species richness), H (Shannon diversity), and EH (Shannon's Evenness) of mangrove snails for each sampling station aggregated over the three-month sampling period as replicates

Station	Sprich	H	EH
1	22.33±0.88	2.73±0.04	0.88±0.004
2	21.00±0.00	2.67±0.007	0.87±0.002
3	21.00±1.00	2.72±0.03	0.89±0.002
4	21.00±0.00	2.78±0.006	0.91±0.002

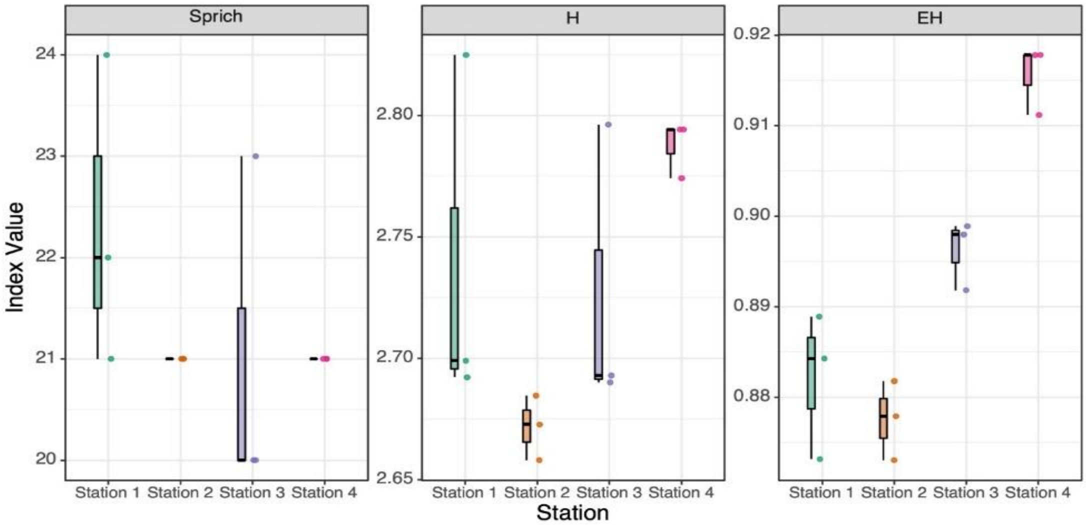

Figure 3. Diversity index values of mangrove snails in each sampling station, where Sprich is species richness, H is Shannon diversity, and EH is Shannon evenness. Boxplots indicate median and 25-75% quartiles, whiskers indicate the 5-95% range and points indicate raw data

The checklist

Family of Cerithiidae

Cerithium echinatum (Figure 4.A). This conch has an elongated, multilevel shell consisting of 11 circular petals. The shell length reaches 25.82 mm, and the width is up to 9.42 mm (Sun and Zhang 2014). The protoconch and sharp edges of the shell are usually worn away. The early teleoconch is elongated, formed by two spiral threads that gradually form a ridge on the shell. Mature teleoconch petals are formed with three distinct primary beaded spiral cords. The beads line up parallel to the helix on the axial ribs. The body loop comprises six or seven spiral cords and three posterior beads. The collumella is sunken with moderate callus and a columellar lip. The anterior siphonal canal is short, comprehensive, and slightly curved. The anal canal is clearly visible, flanked by the parietal columella callus and distinct teeth. The outer lip margin is thickened, with the denticles extending inwards and the posterior sinuses widening. The shell is black to light gray, sometimes showing white stripes. The outer lip is occasionally white, while the operculum is light brown and thin, like an eccentric corneus and ovate. This study found *C. echinatum* in the mud under mangrove trees. Generally, this genus can be found on mud flats in the intertidal zone from mid to low tide and under coastal estuary mangrove trees (Zvonareva and Kantor 2016; Islamy and Hasan 2020). Furthermore, the development in the planktonic phase occurs at 10 to 12 days (Ozawa et al. 2015).

Clypeomorus clypeomorus (Figure 4.B), *C. petrosa* (Figure 4.C), and *C. moniliferus* (Figure 4.D). This snail is an epifaunal species that could live include: intertidal zone, estuaries, around mangrove plants, on muddy or sandy substrates between *Avicennia pneumatophores*, and is herbivorous (Soekendarsih 2019). This study found the snail *Clypeomorus* sp. in *Sonneratia* and *Avicennia* mangrove habitats. These animals live as deposit feeders in areas with high deposit content. This animal food consists of microalgae, fibrous algae, vascular plants, and diatoms, detritus in mangrove habitat (Houbrick 1992).

Family of Cypraeidae

Mauritia arabica (Figure 4.E). The *M. arabica* snail has an oval shell and a strong, slippery structure. The size of the shell is 3.5 cm long, 2.1 cm high, and 2.9 cm wide. The shell has no rotation, and the mouth of the shell has 23 serrated teeth. The shell has no operculum and a proboscis with a siphon 0.3 cm long. The siphonal canal is short, measuring 0.1 cm, and is shaped like a sticking out at the anterior part of the mouth of the shell. The shell leg was 4.1 cm long, and no byssus was found. These shells are usually found on the coast, especially attached to rocks or seagrasses in areas always submerged in seawater, even at low tide (Fajeriadi et al. 2019). These living animals have a mantle covered with fine white "fur," siphons, and black tentacles (Huang et al. 2008).

Family of Fasciolariidae

Fasciolaria lignaria (Figure 4.F). *Fasciolaria lignaria* snails often have huge shells, with the largest sizes reaching 275 and 278 mm. The shell is usually quite flat, with the protoconch having a well-defined or faint axial riblet at the circumferential end of the shell. Teleoconch streaks usually consist of spiral fibers that are faint to invisible. If there is an axial streak, you will see a weak rib streak at the beginning of the whorl teleoconch. The surface of the shell shows intact or interrupted spiral strokes, the inner side is smooth, and the inlet folds are more prominent than the columellar folds (Snyder et al. 2012).

Figure 4... Mangrove snails on the North Coast of Lamongan, East Java. A. *C. echinatum* (35 mm); B. *C. clypeomorus* (21 mm); C. *C. petrosa* (26 mm); D. *C. moniliferus* (33 mm); E. *M. arabica* (57 mm); F. *F. lignaria* (39 mm); G. *C. nodulosa* (30 mm); H. *C. manusuduirauti* (29 mm); I. *M. omanensis* (24 mm); J. *M. matildeae* (27 mm); K. *M. chiarae* (29 mm); L. *O. xuthedra* (24 mm); M. *R. venosa* (36 mm); N. *R. clavigera* (35 mm); O. *Natica tigrina* (24 mm); P. *N. lineata* (14 mm); Q. *P. sulcatus* (20 mm); R. *T. telescopium* (71 mm); S. *T. maculatus* (44 mm); T. *M. confusa* (11 mm); U. *A. rhodostomum* (24 mm); V. *B. rugosa* (13 mm); W. *L. cinerea* (21 mm); X. *T. argyrostoma* (46 mm)

Family of Muricidae

Claremontiella nodulosa (Figure 4.G). *Claremontiella* shell is broad with a high crest consisting of seven or eight axial ribs, rounded and nodular, traversed by a subsutural spiral lying beneath the suture and five main subsutural spirals on the convex portion of the teleoconch whorl, with secondary and tertiary sutures. The narrow aperture is a smooth columellar lip, low apical denticles, and low parietal teeth at the adapical end. Short siphonal canals are 12-14% of the total shell length (Houart et al. 2019).

Cytharomorula manusuduirauti (Figure 4.H). The shell of *C. manusuduirauti* has a high apex, is elongated, ovate, and nodose, and rarely exceeds 25 mm in length at maturity. The axial streak of the final whorl teleoconch consists of 7-9 narrowly spaced, low, sharp, or weakly spaced lines with rounded edges. The oval aperture is a columellar lip that is weakly concave, smooth, or apically weakly folded, body almost wholly attached to the shell. The anal indentation is wide and deep. While the outer lip is strongly elongated denticles inside. The siphonal duct is short and wide open ventrally. The radula is three-dimensional in teeth with a rachidian in the form of a long, moderately broad, centered central crest, small, narrow lateral denticles, moderately long, wide lateral cusp, and strong marginal folds (Houart et al. 2019).

Muricopsis omanensis (Figure 4.I). *Muricopsis matildeae* (Figure 4.J). *Muricopsis chiarae* (Figure 4.K). *Muricopsis* sp. snail shell is oval, nodose, and can reach a length of 37 mm at maturity. The aperture is ovate and slightly angular. The columellar lip is smooth, broad, and erect in shape with a less pronounced anal indentation. The outer lip is wrinkled irregularly, and the inside is smooth. The body whorl comprises six to seven low and two to four long stripes. The long carinal bones are followed by shorter ones and are sometimes invisible. The spiral stroke consists of many squamous threads of various sizes. Circular spiral strokes on the shell consist of six to eight lines. The siphonal canal is quite short, slightly bent backward, barely visible without outlines, and shows a series of long straight open projections (Houart 1986).

Orania xuthedra (Figure 4.L). The *O. xuthedra* snail has a shell with a tall spire, wide elongated, ovate, nodose, and when it reaches adulthood, it does not or rarely exceed 20 mm in shell length. The axial stroke of the last teleoconch is a wide, tall, and rounded circle. Spiral strokes are quite tall and wide in the primary connection line, the secondary line is narrow, and there are few connections. Columellar lip weakly sunken, smooth, or with abapically weak folds. Outer shell lip with narrow and elongated denticles inside. The radula of this type has a three-dimensional rachidian tooth with long, narrow, prominent central cusp, very small and narrow lateral denticles, lateral cusp, and marginal folds that are faintly visible. The outer lip is crescent-shaped laterally, with a wide base (Houart et al. 2019).

Rapana venosa (Figure 4.M). The shell of *R. venosa* is round with a large body whorl, a deep umbilicus, and a low conical spire of the shell. Spiral strokes do not look uniform. The columellar lip is wide, smooth, and slightly concave. Large shell opening, oval in shape, and slightly widened with a thin outer lip. Small elongated serrated teeth along the outer edge of the shell lip. The siphonal tract is broad, wide open, and has a series of scales. The outer color of the shell is brownish-gray with an irregular pattern of spots that tend to form interrupted patterns along the shell lines. Inside the aperture is orange. The maximum size of an adult shell is 18 cm (Santhanam 2019).

Reishia clavigera (Figure 4.N). The *R. clavigera* Snail (Murex Snail) has a dark gray shell with blunt protrusions on the surface of the shell. The end of the shell is slightly tapered and jagged. Spiral stripes and teeth thicken towards the outer lip of the shell and have a large siphonal canal as the aperture (Cossignani and Ardovini 2004).

Family of Naticidae

Natica tigrina (Figure 4.O). The shell of the *Natica tigrina* snail is medium in size and white in color-a grayish white on the underside and orange-yellow on the top. Many brownish-red oval spots on the shell's upper side are arranged in radial rows. The coat and legs are brownish with light-colored spots. The maximum shell size at maturity reaches 2.5-5.6 cm (Santhanam 2019).

Family of Neritidae

Nerita lineata (Figure 4.P). The *N. lineata* snail is round and finely grooved with a fairly sharp outer shell lip. There are thin brown spiral ribs with a white base color. This snail has an operculum made of lime attached to the leg. This structure seals the snail's body when pulled inside the shell, thus protecting the snail from predators. When it reaches adulthood, its shell can grow to 1.2 to 3.4 cm (Santhanam 2019).

Family of Planaxidae

Planaxis sulcatus (Figure 4.Q). The shell of the *P. sulcatus* snail is conical in shape with a clearly visible square spiral line-wide shell opening with a white and sometimes dark purple inner surface. The operculum is thin and dark. The outer surface of the shell is blackish with white or yellowish spots. The body is pale, and the legs are tiny with pale underparts and dark mottled patterns above. Female snails are generally larger than males. The shell size when entering adulthood varies between 1 to 3.5 cm (Santhanam 2019).

Family of Potamididae

Telescopium telescopium (Figure 4.R). These snails have large, thick, and elongated conical shells. The tip of the shell is usually blunt due to abrasion. The circular base of the shell is flat, with a diameter of 30% of the total length of the shell. The shell aperture is a slanted square. The apertural lips are tortuous but not widened and thickened. While their columella is thick and twisted brown, and the operculum is small and circular. The body of this snail is grayish-black with a long proboscis and gray-white legs. The snout is large and long, with a pair of tentacles on the head. The tentacles narrowed sharply at the ends. It has three eyes on the edge of its coat and a pair of eyes on the tentacles. The siphonal duct is thick, and its inner rim has one or two orange-pigmented spots. The shell is dark brown at the base and lighter at the apex. This snail can stay out of water for a long time. The maximum shell size in adult snails is 15 cm (Santhanam 2019).

Family of Trochidae

Trochus maculatus (Figure 4.S). *Trochus* snails have a thick, rather dense shell and a high spire. The spire has an almost straight line. The top of the shell is generally blunted from erosion and is orange. There are seven planulae-shaped circles and sometimes a depression in the middle of the shell. The whorl body has sharply angled edges. Protrusions of beads on each circle with uneven sizes surround the surface of the shell. The base of the shell is circle strokes. Lirae are slightly coarse-textured granulosa with wide slits, surrounded by twisting lirula or striae on the shell. Columella oblique has a firm coating on top and almost smooth edges with blunt teeth. The umbilical canal is funnel-shaped and relatively wide, with a rib in the middle. The shell color is yellowish and has dark red radiating lines encircling the shell. The base of the shell is white or pink with red spots. The aperture, columella, and umbilical areas are pearly white. Adult snail on their shells is usually covered with algae with sizes varying from 1.7 to 4.0 cm (Santhanam 2019).

Monodonta confusa (Figure 4.T). Most of the shells of *M. confusa* are patterned to resemble cobblestone paths. The shell surface of this snail is solid with a grainy, rough surface. The circle of the body widens, and the second circle from the back is rather flat. The aperture has a nacreous interior. There is a single tooth-shaped structure at the shell's opening, which is white and smooth. The operculum is made of thin yellow chitin with concentric rings. The flexible operculum allows the snail to retract its body into the shell, protecting it from predators. The body is pale in color, and long tentacles border the mantle's edges. Large, pale legs are on the underside and mottled with green above. A pair of long tentacles are visible on the head. Shell color varies from dark reddish-brown to pale brown, with a cream or pinkish spiral band. The maximum length of the shell when entering adulthood is between 1.5 and 4.5 cm (Santhanam 2019).

Family of Turbinidae

Astralium rhodostomum (Figure 4.U). *Astralium* snails have a flat shell at the bottom, shaped like a wheel, and slightly tapered at the top. Six circles are evenly distributed on top, doubled, and the folds are rather uneven and irregular. The shell's rim is carinated spinose, with 12 protruding spines on the body-whorl. The whorl body descends towards the aperture. Concentrically convex bases are more or less densely squamose in shape. The outer lyre is generally prominent and subspinose, sometimes giving the shell margins a bicarinate appearance. The aperture is oval, highly slanted, and white, with a fine pearl texture. While the operculum is small, calcareous, and semicircular with a smooth, shiny surface-a pale body with black lines and long tentacles with fine black lines. The shell is usually covered in algae so that the snail can camouflage well over rocks. The color of the shell is greenish or brownish gray when adults, the maximum size can reach 6 cm (Santhanam 2019).

Bolma rugosa (Figure 4.V). The *B. rugosa* snail's shell has a dense, conical structure. The suture is the canaliculus bounded below by a series of curved tubercles running throughout the shell. There are six to seven circles in the form of oblique flat striations. The upper circle is carinate and tuberculate, or spinose, found on the shell's surface. The descending shell circles are rounded or bicarinata and spiral: slanted aperture, transverse oval, and curved columella portion of fine pearly white. The operculum is a short oval and brown inside with four whorls. The outer shell is orange and spirals in shape. The size of the adult snail shell varies from 2.5 to 8.0 cm (Santhanam 2019).

Lunella cinerea (Figure 4.W). The *L. cinerea* snail has a dense, turbine-shaped shell that is depressed. A series of irregular spiral nodules and grains cover the shell. The spire is depressed and dome-shaped with eroded edges and is reddish. The shell has four to five whorls, with the last being large. The aperture is large, round, and colorful inside. The columella is uniformly wide, and the shell base is connected. The operculum is flat, greenish, and golden, with five to six whorls and a subcentral nucleus. The outside is convex, greenish, and has a grainy texture all over the shell. The color of the shell varies from brown to reddish and will turn white in individuals covered with lime deposits. At an adult age, this snail shell can grow to a maximum size of 4 cm (Santhanam 2019).

Turbo argyrostoma (Figure 4.X). The shell of this snail is quite large, thick, heavy, and Conca-shaped with the same length or slightly larger than the width. The spire is well-developed and pointed. Whorls are convex with a rounded, slightly flattened outline below a well-defined tide. Smooth textured shell surface. The aperture is ovate and elongated, half the shell's total length. The outer lip of the shell is thin and smooth on the inside. The columella is smooth without the umbilicus. The operculum is nearly circular, with a subcentral nucleus and a convex shape, and has a smooth, shiny texture with a bluish-green color in the center and brownish edges. The shell's exterior varies in color and pattern with brown, red, orange, or greenish tones and is decorated with dark spiral bands of thin, chevron-shaped, pale axial stripes. The aperture is silvery-white on the inside and is often tinged with yellow, orange, or greenish around the edges, especially around the edge of the inner shell lip. The maximum shell length in adulthood is 8.5 cm (Santhanam 2019).

Discussion

The high diversity and community evenness of mangrove snail species, which was relatively consistent across all sampling stations, indicates that the area's natural primary productivity mangrove ecosystem remains (Hasibuan et al. 2021; Kadim et al. 2022). Comparisons of mollusk species richness with other regional fauna or other Indonesian islands are difficult to evaluate because of data deficits in the area. Surveying mangrove snails was challenging due to accessibility and risks related to the habitat. Considering this, despite the high richness detected in a small area and the good sampling efficiency, we suspect many species that were not detected due to inaccessibility in the mangrove habitat (Islamy and Hasan 2020). Survey efficiency could be improved in the future by incorporating molecular methods alongside traditional taxonomic surveys such as the present study (Borges et al. 2016; Moles et al. 2021).

This study found ten families (Table 2) consisting of Cerithiidae, Cypraeidae, Fasciolariidae, Muricidae, Naticadae, Neritidae, Plaxidae, Potamididae, Trochidae, and Turbinidae. Most mangrove snails are found in rocky, sandy substrates and around trees and mangrove roots (Islamy and Hasan 2020). Accordingly, gastropods in this study were found alive and dead, primarily on mangrove structures.

Gastropods are animals that have the potential to be able to monitor species stability and also the environment; they can also be bioindicators of ecosystem changes (Theofilius et al. 2021; Retnaningdyah et al. 2023). Given the community species richness similarity between the stations, regular monitoring may detect changes in the community composition of key species more sensitive to environmental change (Islamy and Hasan 2020). Furthermore, there may be environmental differences between the stations that are not recorded during this study due to being a taxonomical endeavor, which explains the distributional differences. Moreover, there is very little ecological data on mangrove snails in Indonesia besides their use as heavy metal biomonitors (e.g., Yap and Cheng 2013; Manurung et al. 2017; Hewindati et al. 2022). Thus, further study is needed to characterize the micro-habitat preferences of mangrove snails in Indonesia to make meaningful inferences. Also, genetic analysis of gastropods, especially mangrove snails, is necessary to find out variations at the molecular level (Schneibs et al. 2022).

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