

Diversity of Land Snail and Slug of Gunung Gading National Park, Sarawak

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Received: 23 December 2024

Accepted: 18 December 2025

Published: 30 June 2026

ABSTRACT

Gunung Gading was officially gazetted as a national park in 1994. Since then, many studies have been conducted to record the diversity of various plants and animals in this area yet the study of terrestrial molluscs remains poorly documented. Therefore, with similar objectives, the first survey was conducted on the diversity of land snails and slugs of Gunung Gading National Park. A survey was conducted from 7th to 11th May 2023 to determine the diversity of land snails and slugs in the vicinity of Gunung Gading. As a result, a total of 540 individuals comprising 20 species of land snails and one species of slug from 19 genera and 10 families have been collected. The study found that the family Cyclophoridae is the most diverse land snail species with a total of six species with 72.59% relative abundance, while the family Helicarionidae and Vallonidae are considered as the least diverse family of land snail with both families comprises of two species with 0.19% relative abundance, respectively. *Cyclophorus perdix borneensis* is found as the most abundant species with approximately 48.89% of the total number of individuals found. Ecological indices were analysed, comprising species richness (Margalef's index) = 3.02, diversity index (Shannon-Wiener's index; H') = 1.878, dominance index (Simpson's index) = 0.7257 and evenness index = 0.327. Based on these diversity indices, it indicates that the area has moderate diversity considering it is a non-karst area. Gunung Gading National Park also exhibits a unique ecological dynamic due to its higher species richness but less balanced distribution. These findings provide baseline data for terrestrial molluscs in GGNP as well as contribute to understanding community composition in non-karst tropical forests and highlight the importance of land snails and slugs in biodiversity and conservation assessments.

Keywords: Diversity, Gunung Gading National Park, inventory, land snails, non-karst area

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INTRODUCTION

Gunung Gading National Park (GGNP) is located near the small town of Lundu and approximately 100 km (62 miles) to the southwest of Kuching, the capital city of Sarawak. It covers an area of about 4,196 hectares. The Park was established in 1983 and officially gazetted as a national park in 1994 with the aim of establishing a conservation area for the protection of endangered plant species i.e., *Rafflesia*, the world's largest flower (Sarawak Government Gazette, 1998; Bukhori *et al.*, 2020). Gunung Gading National Park encompasses a variety of habitats such as lowland mixed dipterocarp, heath, alluvial, submontane, and highland mixed dipterocarp forest (Bukhori *et al.*, 2020). These diverse habitats can support a wide range of organisms

adapted to different ecological niches (Bukhori *et al.*, 2020) supported by studies that have recorded the presence of 38 species of understory birds (Arif & Mohd-Azlan, 2014), 36 species of bats (Mohd-Ridwan *et al.*, 2018) and 19 species of amphibians fauna (Das *et al.*, 2017).

While GGNP is renowned for its diverse flora and fauna, including a plethora of bird, mammal, and plant species documented by researchers (Das & Haas, 2005; Arif & Mohd-Azlan, 2014; Jailan *et al.*, 2018; Mohd-Ridwan *et al.*, 2018; Bukhori *et al.*, 2020), the biodiversity of the invertebrate remains lacking and a significant gap in our understanding of the land snail diversity specifically, is not known. Land snails

are important to ecosystems due to their ability to serve as effective bioindicators (Watters *et al.*, 2005; Nunes & Santos, 2012). They also constitute a vital element of forest ecosystems as they actively contribute to nutrient recycling (Graveland *et al.*, 1994; Dunk *et al.*, 2004). Moreover, evidence from Sarma *et al.* (2007) highlights that land snails also play a role in pollination although this case is exceptional and very rare. Besides, Mathew (2024) has also stated that the presence and abundance of land snails can significantly influence processes such as habitat modification, biodiversity and their ability to alter soil structure, plant composition and nutrient availability. For this reason, lands snails serve as valuable model system in ecological studies (Gümüş, 2010).

To contextualise the significance of studying land snails in GGNP, it is critical to situate this research within the broader body work on land snail species in non-karst habitats throughout Sarawak. To date, the documentation of land snail species in non-karst areas in Sarawak has been carried out at several areas, including Mount Penrissen (Schilthuizen, 2017), Lanjak-Entimau Wildlife Sanctuary (Liew & Huang, 2011), Gunung Santubong National Park (Marzuki *et al.*, 2019) and in Bako National Park (Khalik & Marzuki, 2023). Over the last two decades, only four studies have been conducted in non-karst areas. Given these records, study related to the diversity of land snails in non-karst areas is scarce. Considering GGNP as an important non-karst environment for protection of various organisms, it provides a necessity to study the land snail species that may be endemic or otherwise important for conservation in the area.

Therefore, this study is conducted to provide the biodiversity and the checklist of land snail and slug species present within the vicinity of GGNP. The diversity and abundance of the species were assessed in this area in an attempt to understand the biodiversity of land snails and

slugs in non-karst areas. This study emphasised the importance of broadening the scope of land snail research to include a wider range of environments, thereby improving our understanding of the ecology and distribution of the gastropods across Sarawak.

MATERIALS AND METHODS

Study Area

A survey was conducted for a total of five days from 7th to 11th May 2023 at Gunung Gading National Park (GGNP) (1°41'26"N, 109°50'45"E) (Figure 1) located in Sarawak, Malaysia. The park consists of primary vegetation featuring mixed dipterocarp and gradually replaced by lower montane forest near the summit (Das *et al.*, 2017). This includes four prominent mountain peaks that are Gunung Gading, Gunung Perigi, Gunung Sebuloh, and Gunung Lundu (Bukhori *et al.*, 2020).

Sampling Strategy and Data Collection

The fieldwork was conducted by a team of 10 people and 30 minutes is spent on each plot. Altogether, 20 plots were covered across various habitats within GGNP to ensure comprehensive coverage of the area (Figure 2A–D). Each plot measuring approximately 20 × 20 (400 m²) was pre-determined prior to sampling within the national park area. The sampling duration took thirty minutes where living snails and empty shells were actively searched at each plot. This process involved by looking carefully through the leaf litter, under the logs and rocks as well as on the vegetation for the presence of land snails and empty shell. The top soils and leaf litter were also collected mainly targeting empty shells or soil-dwelling snails. The land snail and shell are later extracted *via* floatation technique. For the extraction of land snails in floatation method, the method was carried out by following the protocol by Vermeulen and Whitten (1998).

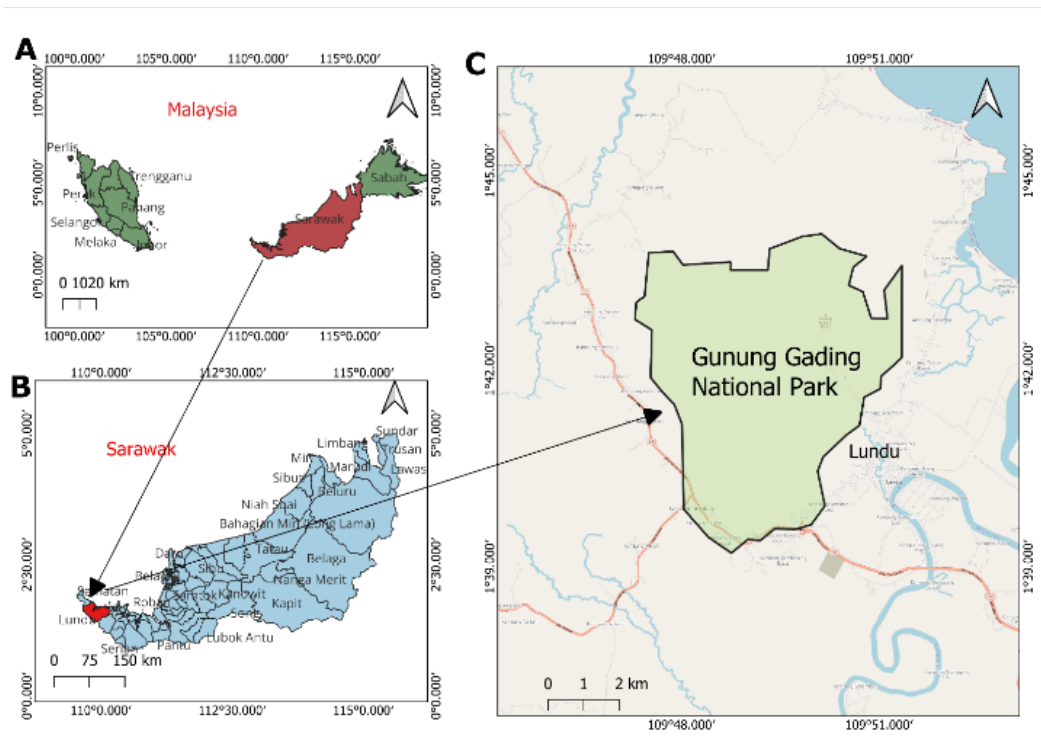


Figure 1. The map of the locality of Gunung Gading National Park in the district of Lundu, Sarawak. (A) The map of Malaysia with the state of Sarawak is indicated by the brown colour. (B) The map of Lundu, shaded with the red colour. (C) The map showing the sampling site of our study at Gunung Gading National Park

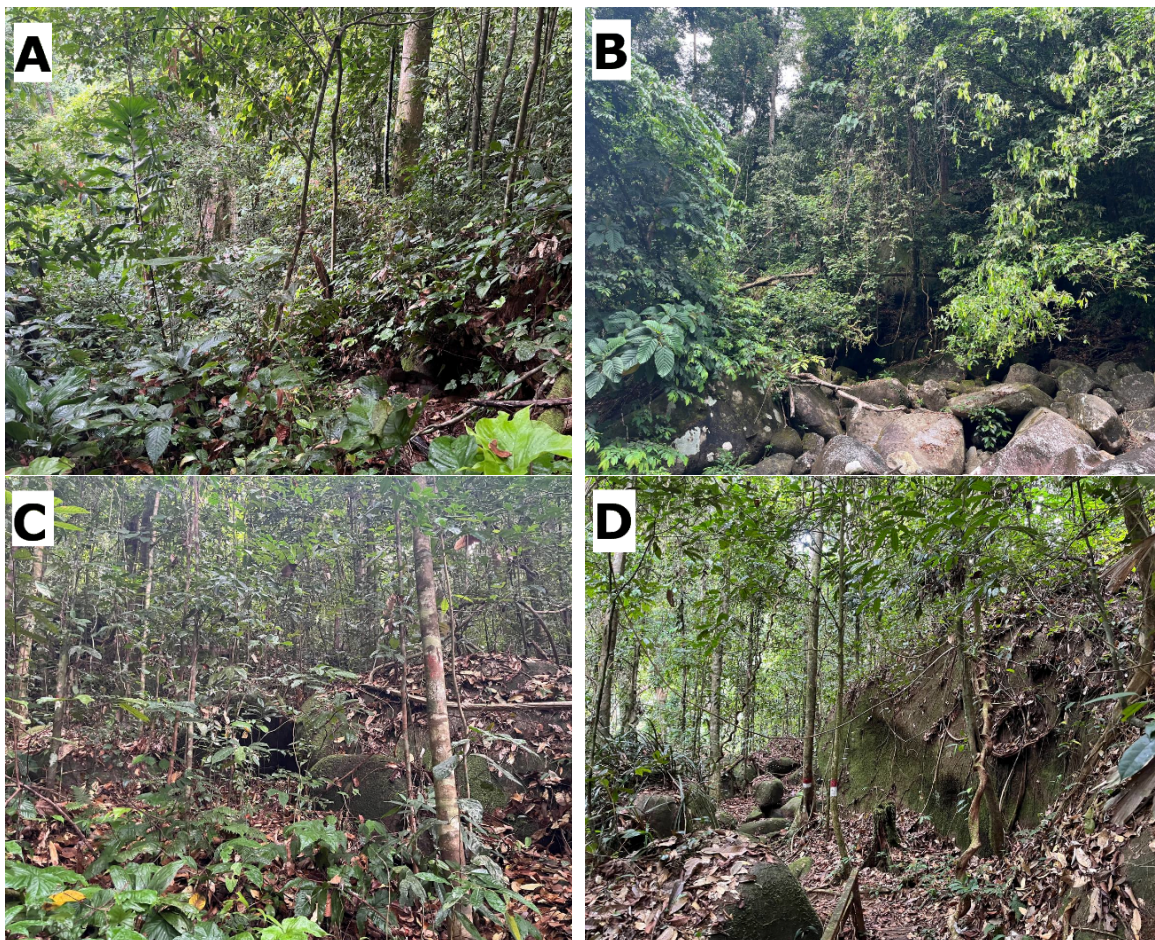


Figure 2. Examples of areas surrounding Gunung Gading National Park where sampling plots were designated

Species Identification, Storage and Imaging

Living specimens were retrieved during the collection process and were preserved in sample vials (2 ml or 10 ml, depending on the size of the shell) filled with 70% ethanol. Meanwhile, empty shells underwent cleaning and drying before being stored. Then, the samples were sorted and identified based on their diagnostic morphological characters and available literature (Marzuki *et al.*, 2021; Vermeulen & Liew, 2022; Lee *et al.*, 2024). Finally, all materials are deposited in the UNIMAS Zoological Museum. A representative for each of the species was chosen for the imaging process. The samples were photographed using a modified Nikon DSLR. The taken images were scaled by using Adobe Photoshop 24.1 and edited in GIMP 2.10.36. Species were photographed in four different views: apertural, side, umbilical and apical views.

Species Abundance and Species Diversity

The species abundance was determined by using statistical software RStudio (Posit Team, 2023) with R version 3.3.0. This involved calculating the relative species abundance in percentage, which was achieved by dividing the number of individuals of each species by the total number of individuals recorded, and then converting the resulting quotient into a percentage (refer to formula, Eq. (1) below). This method allowed

for a comprehensive assessment of the relative abundance of each species within the study area.

$$\text{Relative abundance (\%)} = \frac{I_{si}}{\sum N_{si}} \times 100 \quad \text{Eq. (1)}$$

Note:

I_{si} = Number of individuals of species i

$\sum N_{si}$ = Total number of individuals in sample i

Diversity indices were calculated using PAST v.4.17 software (Hammer *et al.*, 2001). These indices include Margalef's species richness index (Clifford & Stephenson, 1975), Simpson's dominance index (Krebs, 1994), Shannon-Wiener diversity index (Shannon & Weaver, 1963), and the evenness index. For Margalef's index, it measures the number of species with that of sample size and simply can be used to estimate the species richness. As for the diversity of land snail species, it was determined using Shannon-Wiener index. As the value of this index increases, the diversity of the species in that certain area increases and typically Shannon-Wiener index has a maximum number of 5. In contrast, Simpson's index focuses more on relative abundance as compared to Shannon-Wiener index and the higher the value of Simpson's index, this indicates high dominance or low biodiversity of land snail's species in that area. Species evenness was also calculated to determine the commonness or rarity of the land snail species as this index measures the distribution of the species across the community. The formulas used for each index are detailed in Table 1.

Table 1. The formula for ecological indices

Diversity Index	Formula
Margalef's index	$D = \frac{S-1}{\ln(N)}$
Simpson's index	$D = \sum \left(\frac{n_i}{N} \right)^2$
Shannon-Wiener's index	$H' = - \sum (p_i \ln p_i)$
Evenness index	$J = \frac{H'}{\ln(S)}$

This combination of indices allows for a comprehensive assessment of the land snail community in GGNP. To have better understanding of the community structure in GGNP, these indices are compared with secondary data from Gunung Penrissen (Schilthuizen, 2017), Gunung Santubong

National Park (Marzuki *et al.*, 2019), and Bako National Park (Khalik & Marzuki, 2023).

RESULTS

A total of 20 land snails species representing 19 genera and 10 families were obtained from a

survey at Gunung Gading National Park (GGNP) (Table 2). Based on this study, 12 species of land snails are only recorded in GGNP and not found at other three localities namely Gunung Penrissen, Gunung Santubong National Park and Bako National Park. The species include *Tanychlamys sanctijohni*, *Microcystina*

physotrochus, *Amphidromus* cf. *angulatus*, *Leptopoma undatum*, *Opisthophorus euryomphalus*, *Kaliella angulata*, *Philalanka kusana*, *Everettia minuta*, *Helicarion dyakanum*, *Coptocheilus doriae*, *Tylotoechus hosei* and *Anaglyphula sauroderma*.

Table 2. The checklist of land snail species found at Gunung Gading National Park with their number of individuals and the relative abundance (%) of each species

Family/Species	Number of individuals	Relative species abundance (%)
Ariophantidae		
<i>Hemiplecta densa</i>	21	3.9
<i>Damayantia carinata</i>	2	4.0
<i>Tanychlamys sanctijohni</i>	3	6.0
<i>Microcystina physotrochus</i>	2	4.0
<i>Vitrinula glutinosa</i>	2	4.0
Camaenidae		
<i>Amphidromus</i> cf. <i>angulatus</i>	62	11.5
Cyclophoridae		
<i>Cyclophorus perdix borneensis</i>	264	48.9
<i>Leptopoma undatum</i>	30	5.6
<i>Leptopoma sericatum</i>	26	4.8
<i>Opisthophorus euryomphalus</i>	64	11.9
<i>Lagocheilus barbatus</i>	8	1.5
Chronidae		
<i>Kaliella angulata</i>	4	7.0
<i>Exrhysota brookei</i>	2	4.0
Charopidae		
<i>Philalanka kusana</i>	17	3.2
Dyakiidae		
<i>Everettia minuta</i>	2	4.0
Helicarionidae		
<i>Helicarion dyakanum</i>	1	2.0
Trochomorphidae		
<i>Geotrochus bicolor</i>	9	1.7
Pupinidae		
<i>Coptocheilus doriae</i>	6	1.1
<i>Tylotoechus hosei</i>	1	2.0
Assimineidae		
<i>Anaglyphula sauroderma</i>	14	2.6

The families of Ariophantidae and Cyclophoridae were identified as the speciose with a total of five species were recorded. However, the family Cyclophoridae has the highest relative abundance with a percentage of 72.7%. The family Chronidae and Pupinidae were each represented by two recorded species, indicating a notable yet relatively lower presence compared to other families. Furthermore, *Cyclophorus perdix borneensis* (Cyclophoridae) recorded as the most abundant species within the studied population (48.9%), indicating its prominent ecological presence. Notably, the checklist also includes the semi-slug

Damayantia carinata, which is known for its distinct features.

The relative abundance of each family is shown in Figure 3. A highly skewed distribution, with Cyclophoridae having a dominant peak in abundance while the other nine families have substantially lower values, contribute only a small fraction to the overall composition. Despite their low abundance, these less common families still enhance the diversity of the community. This pattern, where a few families are dominant and most are relatively rare, is typical of natural ecological systems.

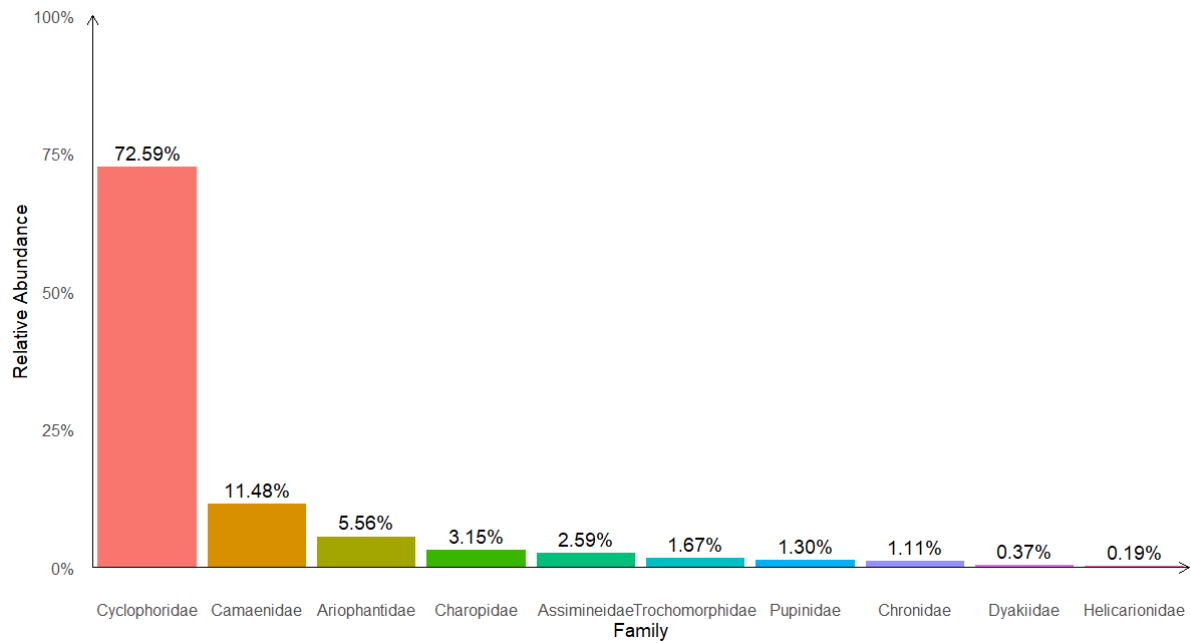


Figure 3. Bar graph of relative abundance of land snails' families in Gunung Gading National Park

A summary of diversity indices of land snails at GGNP in comparison with Gunung Penrissen, Gunung Santubong National Park and Bako National Park (Table 3). The results show that GGNP boasts a high species abundance with a total of 540 individuals from 20 species of land snails and slug with a Shannon–Wiener diversity index of 1.878 indicating moderate diversity. However, the species evenness is rather low at a value of 0.327, indicating a few dominant species. In contrast, Gunung Penrissen exhibits greater species evenness (0.8719) and diversity

(Shannon-Wiener index of 3.082) with its 25 species and 85 individuals. Gunung Gading National Park's diversity metrics show moderate diversity with a Simpson's score of 0.7257 and a Shannon-Wiener index of 1.878. In comparison with other parks such as Bako National Park which exhibits the highest evenness (0.98), GGNP stands out for having a more diverse range of species but a less equal distribution. This distinctive community structure in GGNP reflects a unique ecological dynamic within the area.

Table 3. Ecological indices of Gunung Gading National Park, Gunung Penrissen, Gunung Santubong National Park and Bako National Park

	No. of species	No. of individuals	Species evenness	Margalef's index	Shannon-Wiener index	Simpson's index	Reference
Gunung Gading National Park	20	540	0.327	3.02	1.878	0.7257	Current study
Gunung Penrissen	25	85	0.8719	5.402	3.082	0.9479	Schilthuisen (2017)
Gunung Santubong National Park	9	46	0.6514	2.09	1.769	0.7594	Marzuki <i>et al.</i> (2019)
Bako National Park	12	31	0.98	3.203	2.465	0.9097	Khalik & Marzuki (2023)

Checklist

Family Cyclophoridae Gray, 1847

Genus *Cyclophorus* Montfort, 1810

Cyclophorus perdis borneensis (Metcalf, 1852) (Figure 4A)

Type locality. “Borneo”.

Materials examined.

MZU.MOL.23.451, MZU.MOL.23.453, MZU.MOL.23.454, MZU.MOL.23.456, MZU.MOL.23.458, MZU.MOL.23.459, MZU.MOL.23.460, MZU.MOL.23.510, MZU.MOL.23.512, MZU.MOL.23.552.

Distribution in Sarawak. Widely distributed in western side of Sarawak from Kuching, Samarahan, Serian, Mukah, Kapit as well as the northern part of Sarawak in Miri (Marzuki *et al.*, 2021; Vermeulen & Liew, 2022). Can also be found in Peninsular Malaysia (Morgan, 1885; Stoliczka, 1872).

Species identification. The shell of this species is typically white to pale yellowish-brown, occasionally albino. It often displays a zig-zag pattern of dark brown with white spots below the suture and at the periphery. There are no thin, continuous spiral lines, but one wide or two narrower bands of darker brown below the periphery. The umbilical region is white with fewer brown markings. The spire is low and conical (Vermeulen, 1999). A crucial characteristic of the species is the straightness and slight inward curve of the inner part of the peristome along the umbilical margin, accompanied by a somewhat extended basal portion (Rost, 1886). This species was also identified by referring to species descriptions by Marzuki *et al.* (2021).

Genus *Leptopoma* L. Pfeiffer, 1847

Leptopoma undatum (Metcalf, 1852) (Figure 4B)

Type locality. “Borneo”

Materials examined.

MZU.MOL.23.467, MZU.MOL.23.480, MZU.MOL.23.482, MZU.MOL.23.488, MZU.MOL.23.494, MZU.MOL.23.502, MZU.MOL.23.509, MZU.MOL.23.522, MZU.MOL.23.525, MZU.MOL.23.528, MZU.MOL.23.529, MZU.MOL.23.539, MZU.MOL.23.540, MZU.MOL.23.574, MZU.MOL.23.576, MZU.MOL.23.580, MZU.MOL.23.581, MZU.MOL.23.584, MZU.MOL.23.586.

Distribution. Can be found in the Kuching, Serian and Miri divisions in Sarawak (Marzuki

et al., 2021). Endemic to Borneo. Widespread in the northern part of Borneo, in Sabah (Phung *et al.*, 2017).

Species identification. Can be easily distinguished due to its uniformly white shell, which is transparent when its young and becomes opaque as it ages. Its unique shell shape features less pronounced curves in its spirals and a distinct sharp ridge on the final whorl (Phung *et al.*, 2017).

Leptopoma sericatum L. Pfeiffer, 1852

(Figure 4C)

Type locality. “Borneo”

Material examined.

MZU.MOL.23.469, MZU.MOL.23.473, MZU.MOL.23.476, MZU.MOL.23.501, MZU.MOL.23.521, MZU.MOL.23.523, MZU.MOL.23.531, MZU.MOL.23.533, MZU.MOL.23.575, MZU.MOL.23.577, MZU.MOL.23.582, MZU.MOL.23.583, MZU.MOL.23.585.

Distribution Widely distributed in the western side of Sarawak. Endemic to Borneo (Marzuki *et al.*, 2021).

Species identification. *Leptopoma atricapillum*, *L. sericatum*, and *L. pellucidum*, share a close resemblance in shell shape and exhibit colour pattern variations. However, *L. atricapillum* and *L. sericatum* stand out due to their distinct and pronounced spiral ridges on the shell surface, with *L. atricapillum* having more prominent ridges compared to *L. sericatum*. In contrast, the spiral ridges of *L. pellucidum* are less defined (Phung *et al.*, 2017).

Genus *Opisthoporus* Benson, 1851

Opisthoporus euryomphalus (L. Pfeiffer, 1857) (Figure 4D)

Type locality. “Borneo”.

Materials examined.

MZU.MOL.23.479, MZU.MOL.23.489, MZU.MOL.23.503.

Distribution. Can be found in the division of Kuching. Endemic to Borneo (Marzuki *et al.*, 2021).

Species identification. It can be differentiated from *O. biciliatus* due to its smaller shell size and the absence of a hairy outer layer known as the periostracum (Marzuki *et al.*, 2021).

Genus *Lagocheilus* A. A. Gould, 1859

Lagocheilus barbatus (L. Pfeiffer, 1855) (Figure 4E)

Type locality. “Borneo, Sarawak”.

Materials examined.

MZU.MOL.23.93, MZU.MOL.23.94,
MZU.MOL.23.95, MZU.MOL.23.96,
MZU.MOL.23.97, MZU.MOL.23.98,
MZU.MOL.23.99.

Distribution. Various dispersed localities span from the limestone hills in the western part to the central part of Sarawak. Endemic to Borneo (Marzuki *et al.*, 2021).

Species identification. It distinguishes itself from *other Lagocheilus* species in Borneo through these features: a relatively flat, medium-sized shell with a broad umbilicus, a last whorl with a pronounced keel along its edge, and the presence of long, delicate, feather-like hairs that can be easily shed along the first ridge of the shell's periphery and underneath it (Marzuki *et al.*, 2021).

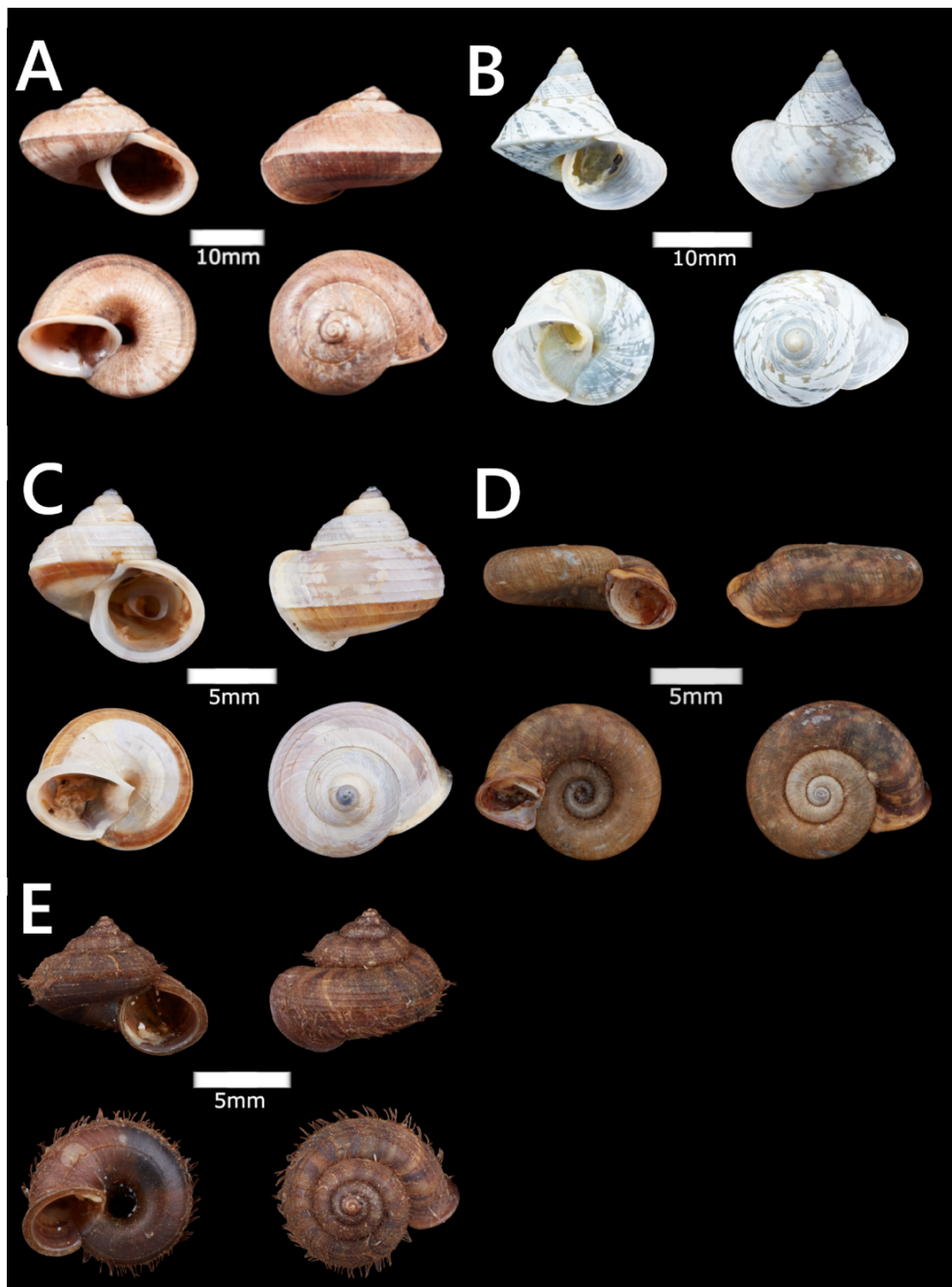


Figure 4. (A) *Cyclophorus perdix borneensis* (Metcalf, 1852) MZU.MOL.23.552. (B) *Leptopoma undatum* (Metcalf, 1851) MZU.MOL.23.480. (C) *Leptopoma sericatum* (Pfeiffer, 1851) MZU.MOL.23.469. (D) *Opisthoporus euryomphalus* (Pfeiffer, 1856) MZU.MOL.23.489. (E) *Lagocheilus barbatus* (Pfeiffer, 1855) MZU.MOL.23.99

Family Pupinidae L Pfeiffer, 1853**Genus *Coptocheilus* A. Gould, 1862*****Coptocheilus doriae* (Issel, 1874) (Figure 5A)****Type locality.** “Sarawak”**Materials examined.**

MZU.MOL.23.465, MZU.MOL.23.471,

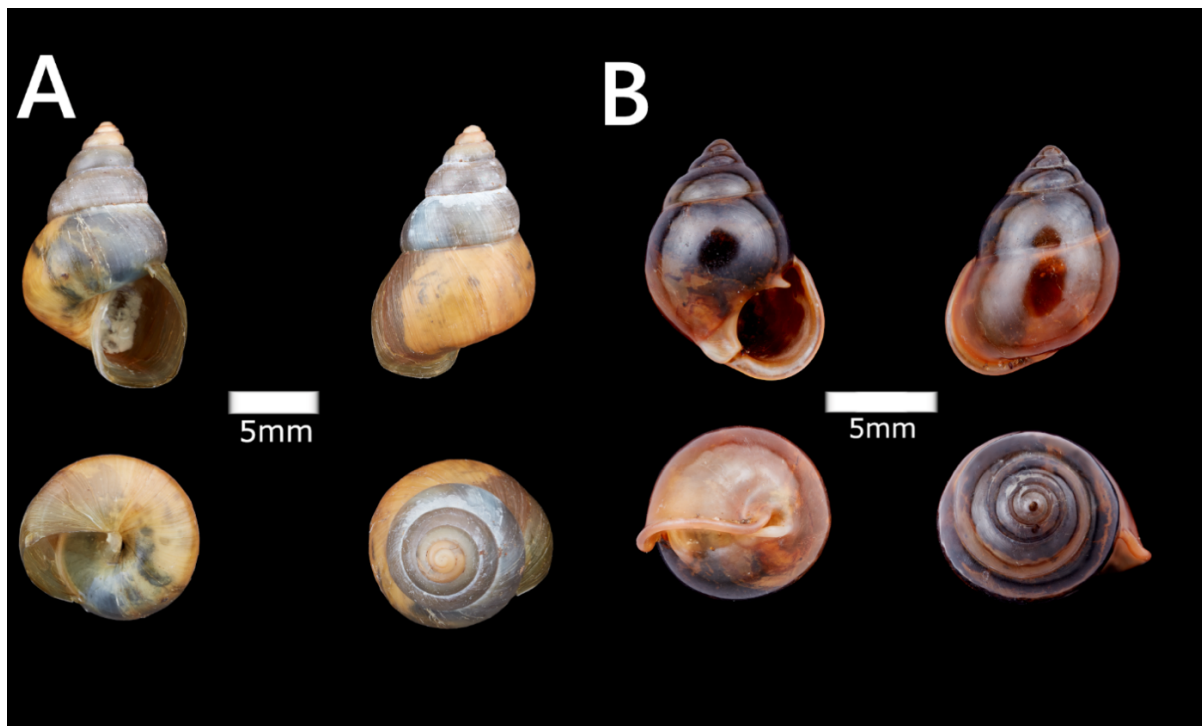
MZU.MOL.23.570.

Distribution. Can only be found in the area of Lundu district.**Species identification.** This species was identified by using original descriptions by Issel (1874) with these characteristics: The shell is solid, chestnut-coloured, and adorned with irregular oblique stripes. It has a turreted spire with 8 convex whorls and a nearly vertical, chestnut-coloured aperture. The peristome is whitish-dirty, highly developed, reflected, and double, with a slight suture visible at the upper part. The operculum is circular and thin with regular concentric ribs. It can be distinguished

from similar species by its thickness, solidity, darker colour, less translucence, and a more extensive whitish peristome with a wide interruption in the outer margin (Issel, 1874).

Genus *Pupina* Vignard, 1829***Tylotoechus hosei* (Godwin-Austen, 1889) (Figure 5B)****Type locality.** “Busan Hills, Borneo”

[= Jambusan Hills, Bau, Sarawak].

Material examined. MZU.MOL.23.569.**Distribution.** Can be found at the area of Kuching and Miri divisions in Sarawak (Marzuki *et al.*, 2021). It is also widely distributed in Sabah (Vermeulen & Liew, 2022).**Species identification.** This species can be differentiated from other Bornean *Pupina* species as it has a bigger high spire dark brown shell with a wide notch along the suture margin (Marzuki *et al.*, 2021).**Figure 5.** (A) *Coptocheilus doriae* (Issel, 1874) MZU.MOL.23.465. (B) *Tylotoechus hosei* (Godwin-Austen, 1889) MZU.MOL.23.569

Family Camaenidae Pilsbry, 1895**Genus *Amphidromus* Albers, 1850*****Amphidromus* cf. *angulatus* (Fulton, 1896) (Figure 6A)****Type locality.** “Sarawak”.**Materials examined.**

MZU.MOL.23.462, MZU.MOL.23.463,
 MZU.MOL.23.466, MZU.MOL.23.470,
 MZU.MOL.23.478, MZU.MOL.23.483,
 MZU.MOL.23.485, MZU.MOL.23.487,
 MZU.MOL.23.492, MZU.MOL.23.495,
 MZU.MOL.23.499, MZU.MOL.23.500,
 MZU.MOL.23.505, MZU.MOL.23.507,
 MZU.MOL.23.513, MZU.MOL.23.514,
 MZU.MOL.23.519, MZU.MOL.23.532,
 MZU.MOL.23.535, MZU.MOL.23.537,
 MZU.MOL.23.542, MZU.MOL.23.545.

Distribution. Endemic to Borneo. Can be found in limestone hills in Kuching, Bau, Serian, Padawan and Miri division in Sarawak (Marzuki *et al.*, 2021).

Species identification. This species shares similarities with *Amphidromus thalassochromus* (Vermeulen & Junau, 2007) and *A. coeruleus* in terms of shell shape and colour pattern on the shell surface. However, it distinguishes itself from *A. thalassochromus* by possessing a rounded last whorl at the periphery and differs from *A. coeruleus* by exhibiting a somewhat

stout shell with a shortened spire (Marzuki *et al.*, 2021). The species was identified based on original descriptions by Fulton (1896) that states the shell is sinistral and ovate-conic, with a thin structure and angular shape at the periphery and it is also obliquely striated and nearly covered umbilicus.

Family Assimineidae H. Adams & A. Adams, 1856**Genus *Anaglyphula* B. Rensch, 1932*****Anaglyphula sauroderma* Vermeulen, T.-S. Liew & Schilthuizen, 2012 (Figure 6B)****Type locality.** “Malaysia, Sabah, Tawau Province, Batu Baturong ca. 50 km W.S.W. of Lahad Datu”.**Materials examined.**

MZU.MOL.23.564, MZU.MOL.23.566.

Distribution. Endemic to Borneo. Distributed in Kuching division, Sarawak. (Marzuki *et al.*, 2021)

Species identification. *Anaglyphula sauroderma* exhibits the same irregular cancellate sculpture with shallow pits as *A. cancellata* B Rensch, 1932 (from Indonesia, Flores). It can be identified with a spire that is more elongated (distinctly taller than wide) and whorls that are uniformly rounded (Vermeulen & Liew, 2022).

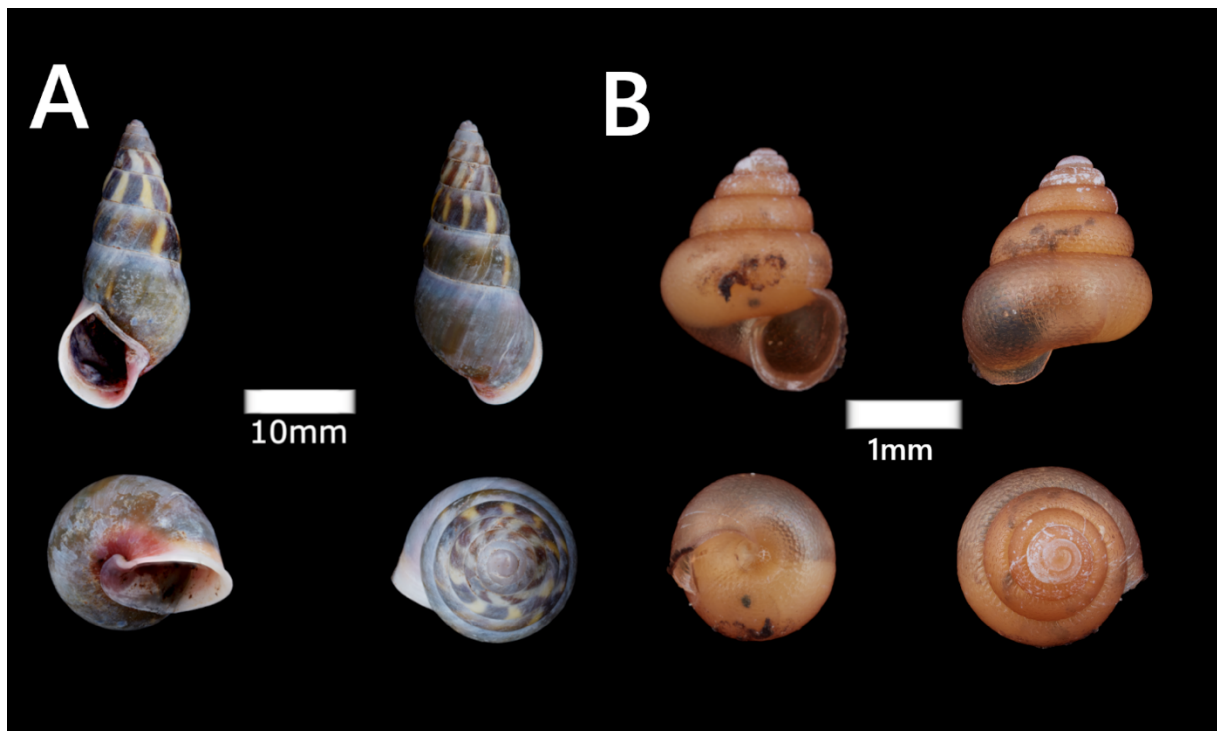


Figure 6. (A) *Amphidromus* cf. *angulatus* (Fulton, 1896) (Family Camaenidae) MZU.MOL.23. (B) *Anaglyphula sauroderma* Vermeulen, (Liew & Schilthuizen, 2012) (Family Assimineidae) MZU.MOL.23.566

Family Ariophantidae Godwin-Austen, 1883**Genus *Damayantia* Issel, 1874*****Damayantia carinata* Collinge, 1901**

Type locality. “Kuching, Mt. Penrissen, and Mt. Santubong, N.W. Borneo”.

Materials examined.

MZU.MOL.23.551, MZU.MOL.23.579.

Distribution. Dispersed localities in Kuching and Sibu divisions in Sarawak. Endemic to Sarawak. (Marzuki *et al.*, 2021)

Species identification. This semi-slug has a flattened shell marked with spiral grooves and features a plain, circular opening (Godwin-Austen, 1903).

Genus *Hemiplecta* Albers, 1850***Hemiplecta densa* (A. Adams & Reeve, 1850) (Figure 7A)**

Type locality. “Philippine Islands”.

Materials examined.

MZU.MOL.23.450, MZU.MOL.23.452, MZU.MOL.23.457, MZU.MOL.23.472, MZU.MOL.23.486, MZU.MOL.23.498, MZU.MOL.23.511, MZU.MOL.23.517, MZU.MOL.23.527, MZU.MOL.23.546, MZU.MOL.23.549, MZU.MOL.23.588.

Distribution. Widely distributed in Sarawak from Kuching, Serian to Samarahan Divisions (Marzuki *et al.*, 2021). Can be found in both West and East Kalimantan Provinces, as well as in Sumatra, and the Philippines (Adams & Reeve, 1850; Mousson, 1857; Smith, 1895).

Species identification. The species was identified on original descriptions by Adams and Reeve (1850) as well as referring to Marzuki *et al.* (2021). *Hemiplecta densa* and *H. humphreysiana* (Lea, 1841) have comparable shells and might eventually be considered the same species. Typically, the former tends to have a more defined angular edge on the last whorl and is slightly more tightly coiled (Vermeulen & Liew, 2022).

Genus *Tanychlamys* Gray, 1847***Tanychlamys sanctijohni* (Godwin-Austen, 1891) (Figure 7B)**

Type locality “Busan Hills, Borneo”

Materials examined.

MZU.MOL.23.571, MZU.MOL.23.573

Distribution. Can be found in western Sarawak in the area of Bau and Serian-Padawan limestone hills to the northern of Sarawak in the area on Niah district (Nasir *et al.*, 2024).

Species identification. It can be differentiated from other Bornean *Tanychlamys* species by possessing a tiny, reddish-brown shell with one spiral groove that are evenly spaced (Marzuki *et al.*, 2021).

Genus *Microcystina* Mörch, 1872***Microcystina physotrochus* Vermeulen, T.-S. Liew & Schilthuizen, 2015 (Figure 7C)**

Type locality. “Malaysia, Sabah, Sandakan Province, Kinabatangan Valley, Batu Keruak 2, near Sukau”

Material examined. MZU.MOL.23.554.

Distribution. Endemic to Borneo. Can be found in Kuching, Bau, Serian, Padawan, Bintulu and Miri divisions in Sarawak (Marzuki *et al.*, 2021; Vermeulen & Liew, 2022).

Species identification. It can be identified by its small, thin shell that is somewhat translucent and brown. It has a glossy surface and varies in shape from slightly inflated and lens-like to depressed and egg-shaped. The spire, or top part, is moderately raised with either rounded or flatter sides, culminating in a rounded apex. It can also be determined with its relatively inflated shell (Vermeulen & Liew, 2022).

Genus *Vitrinula* Gray, 1857***Vitrinula glutinosa* (Metcalf, 1852) (Figure 7D)**

Type locality “Borneo”

Materials examined.

MZU.MOL.23.536. MZU.MOL.23.572

Distribution Endemic to Borneo. Can be found in various localities in Sarawak as it is present in Kuching, Mukah, Kapit, Sibu and Miri divisions (Marzuki *et al.*, 2021). It also can be found in the area of Bau and Serian-Padawan limestone hills (Nasir *et al.*, 2024).

Species identification. The specimen of *Vitrinula glutinosa* illustrated in Figure 15 appears to be a juvenile, as indicated by its small size and underdeveloped shell features. No adult specimen was available during the study, which limits the certainty of the identification. However, the preliminary identification was made in consultation with a taxonomic expert and based on its morphological traits in its colour and spire form, with pale to dark brown being the most common variations (Marzuki *et al.*, 2021). Further confirmation would require examination of a mature specimen.

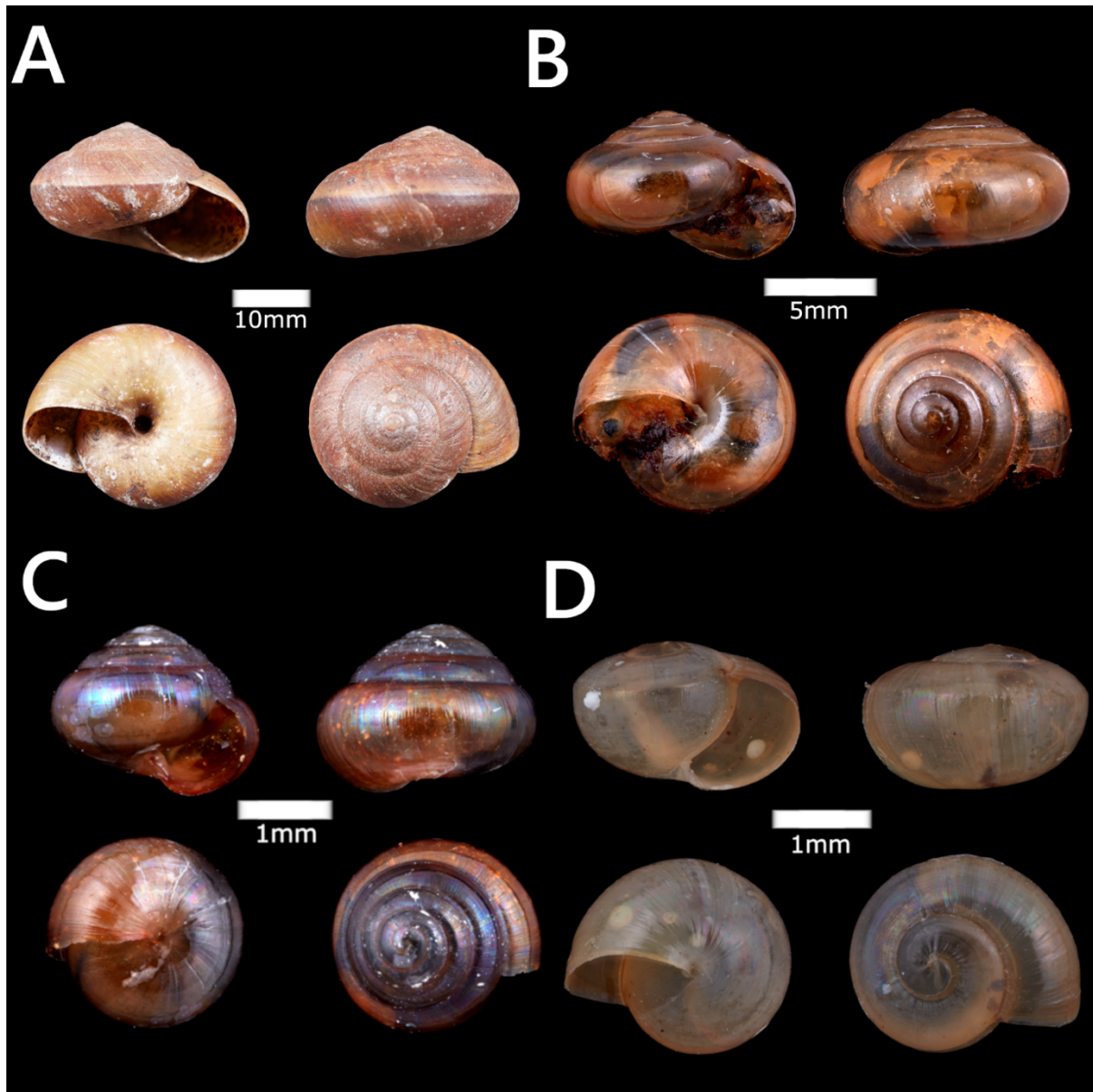


Figure 7. (A) *Hemiplecta densa* (A. Adams & Reeve, 1850) MZU.MOL.23.457. (B) *Tanychlamys sanctijohni* (Godwin-Austen, 1891) MZU.MOL.23.571. (C) *Microcystina physotrochus* (Vermeulen, Liew & Schilthuizen, 2015) MZU.MOL.23.554 D) *Vitrinula glutinosa* (Metcalf, 1852) MZU.MOL.23.572

Family Chronidae Thiele, 1931

Genus *Kaliella* W.T. Blanford, 1863

***Kaliella angulata* (Issel, 1874) (Figure 8A)**

Type locality. “Borneo”

Materials examined.

MZU.MOL.23.567, MZU.MOL.23.559.

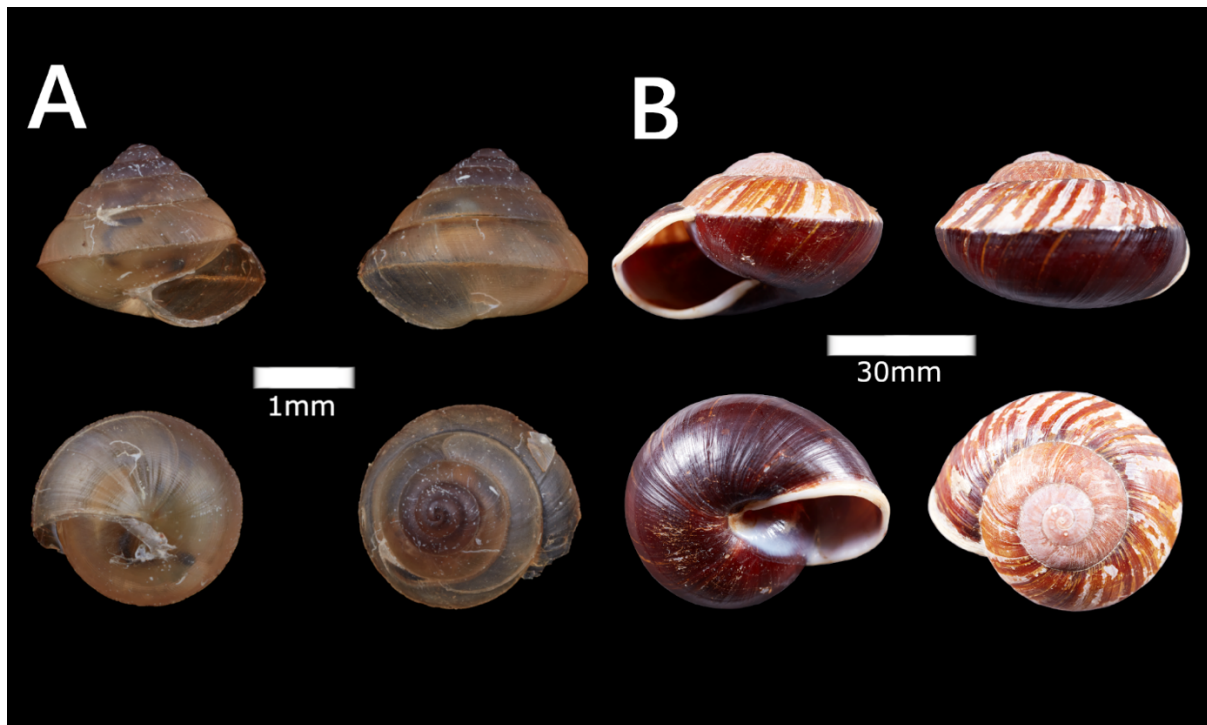
Distribution. This species is present in Lundu district. Can also be found in the area of North Borneo and at Sabah.

Species identification. Based on descriptions by Godwin-Austen (1891), this species can be identified by looking at this features: pyramid-shaped shell with a raised fine ridge on the edge of the last coil, small hole and a crisscross pattern

with fine oblique lines intersecting with regular spiral lines, the shell is usually in dark-brown colour, tall spire and slightly rounded sides conical and blunt tip, a noticeable groove between the whorls, commonly six rounded whorls, has long and oval opening with a thin edge. In this study, the species is placed under the genus *Kaliella*, following the most recent regional treatment or for consistency with similar taxonomic references (Vermeulen, T.-S. Liew & Schilthuizen, 2015). This placement is provisional and subject to future revision, pending further morphological or molecular data to clarify its systematic position.

Genus *Exrhysota* H. B. Baker, 1941***Exrhysota brookei* (A. Adams & Reeve, 1848) (Figure 8B)****Type locality.** “Mountains of Borneo”.**Materials examined.**

MZU.MOL.23.455. MZU.MOL.23.534.

Distribution. Widely distributed in Borneo. Can be found from western to northern of Sarawak. Endemic to Borneo (Marzuki *et al.*, 2021).**Species identification.** It is the largest native land snail species that can be found in Borneo(Marzuki *et al.*, 2021). It was initially included in the genus *Bertia* due to its resemblance to other species with similar shell forms (Sutcharit *et al.*, 2019). Based on its reproductive anatomy, (Godwin-Austen, 1891; Laidlaw, 1932), Baker (1941) reclassified *Bertia* within the Trochomorphidae family. Furthermore, Baker introduced a new subgenus under *Bertia*, named *Exrhysota*, wherein *Helix brookei* was placed.**Figure 8.** (A) *Kaliella angulata* (Issel, 1874) MZU.MOL.23.567. (B) *Exrhysota brookei* (A. Adams & Reeve, 1848) MZU.MOL.23.455.**Family Charopidae Hutton, 1884****Genus *Philalanka* Godwin-Austen, 1898*****Philalanka kusana* (Aldrich, 1889) (Figure 9A)****Type locality.** “Kusan and Penggiron districts in South-eastern Borneo”.**Materials examined.**

MZU.MOL.23.560, MZU.MOL.23.561, MZU.MOL.23.563, MZU.MOL.23.565.

Distribution. Widely distributed in Borneo. Can be found in various localities in western to northern of Sarawak. Present in West Malaysia to Papua (Marzuki *et al.*, 2021; Vermeulen & Liew, 2022).**Species identification.** The shell sculpture comprises of fine transverse striations, with two to three pronounced spiral ridges interspersed. These spiral markings gradually diminish as theyapproach the umbilical region (Sow-Yan, 2022). *Philalanka carinifera* (Stoliczka, 1873) which is native to Peninsular Malaysia, shares a similar shape with *P. kusana*, with the former being notably smaller in size (Vermeulen & Liew, 2022).**Family Dyakiidae Gude & B. B. Woodward, 1921****Genus *Dyakia* Godwin-Austen, 1891*****Everettia minuta* Marzuki, T.-S. Liew & Mohd-Azlan, 2021 (Figure 9B)****Type locality.** “Sarawak”**Material examined.** MZU.MOL.23.484.**Distribution.** Can be found in various localities in Bau and Serian-Padawan limestone hills (Marzuki *et al.*, 2021).

Species identification. The species was identified by referring to original revision by Marzuki *et al.* (2021). The species can be distinguished by other similar species like *Everettia jucunda* (Pfeiffer, 1863), *E. banguueyensis* (Smith, 1895) and *E. jucundior* (Liew, Schilthuizen & Vermeulen, 2009) by comparing the shell size. This species has a smaller shell size compared to other *Everettia* species found in Sarawak (Marzuki *et al.*, 2021).

Family Helicarionidae Bourguignat, 1877

Genus Helicarion Férussac, 1821

***Helicarion dyakanum* (Godwin-Austen, 1891) (Figure 9C)**

Type locality. “Busan Hills, Borneo” [= Jambusan Hills, Bau, Sarawak].

Material examined. MZU.MOL.23.592.

Distribution. Widely spread in Sarawak. Endemic to Borneo (Marzuki *et al.*, 2021; Vermeulen & Liew 2022).

Species identification. The species was identified by using original descriptions by Godwin-Austen (1891) and species description by Vermeulen and Liew (2022): small, thin, translucent shell with a slightly silky surface. The shape is inflated lenticular with a moderately elevated spire. Whorls are moderately convex. Spiral grooves near the suture, becoming finer and more closely spaced towards the base. Umbilical areas may have slightly coarser striae. The aperture is broadly crescent shaped with a curved basal peristome. Umbilicus partially covered by the widened columellar side of the peristome. Dimensions: Height up to 7.9 mm, width up to 10.0 mm.

Family Trochomorphidae Möllendorff, 1890

Genus Geotrochus H. Adams & A. Adams, 1855

***Geotrochus bicolor* (E. von Martens, 1864) (Figure 9D)**

Type locality. “Im mittleren Sumatra” [= Central Sumatra].

Materials examined.

MZU.MOL.23.468, MZU.MOL.23.477, MZU.MOL.23.491, MZU.MOL.23.497, MZU.MOL.23.504, MZU.MOL.23.515, MZU.MOL.23.526, MZU.MOL.23.543.

Distribution. Widely distributed in Borneo (Marzuki *et al.*, 2021). This species is also present in Sumatra to Lesser Sunda (Vermeulen & Whitten, 1998).

Species identification. Martens (1867) and Benthem-Jutting (1952) both emphasised the shell shape that are moderately umbilicated, depressingly conical, and low conical with its colouration pattern of chestnut with white regions and in some samples yellow or light brown with a spiral band of chestnut. It is also finely striated, has strong radial growth lines on the upper surface and has many spiral lines on the base. Solem (1964) provides additional details on colour banding, surface ornamentation, and keel sharpness. The species was identified by referring to original description by Martens (1864) as well as descriptions by Marzuki *et al.* (2021).

Family Geotrochidae Schileyko, 2002

Genus Geotrochus van Hasselt, 1823

***Geotrochus cf. conicoides* (Metcalf, 1852) (Figure 9E)**

Type locality. “Borneo”.

Material examined. ME0007137

Distribution. Can be found in Lundu, Kuching, Serian and Miri divisions in Sarawak. This species is also present in West Coast and Tawau divisions in Sabah (Marzuki *et al.*, 2021). It is widely distributed but rare in Sabah. It is present in Pulau Tiga Park, W Coast Islands and Tawau hills (Vermeulen & Liew, 2022). It can also be found in Sumatra (Benthem-Jutting, 1959).

Species identification. The species was identified by referring to original revision by Marzuki *et al.* (2021) and Vermeulen and Liew, 2022. Based on descriptions by Vermeulen and Liew (2022) this species can be identified by its characteristics such as its relatively thin and medium-sized shell with pale to dark brown colour. It has a conical shaped spire with nearly flat to slightly concave sides with its apex protrudes slightly. The final whorl is sharply angular, featuring a prominent peripheral ridge, while the surface shows faint radial growth lines and fine, closely spaced spiral threads near the periphery.

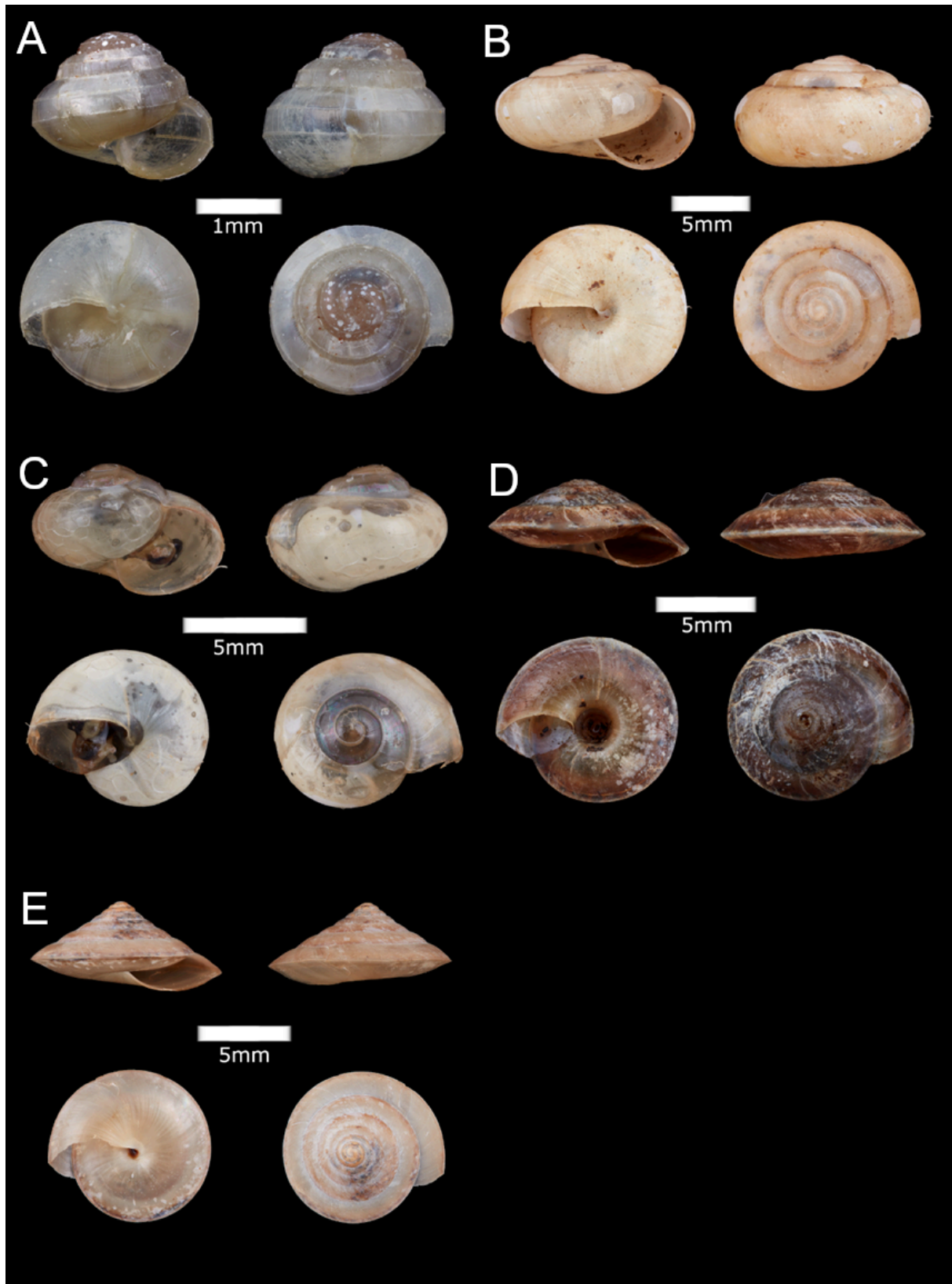


Figure 9. (A) *Philalanka kusana* (Aldrich, 1889) (Family Charopidae) MZU.MOL.23.565 (B) *Everettia minuta* (Marzuki, T.-S. Liew & Mohd-Azlan, 2021) (Family Dyakiidae) MZU.MOL.23.484. (C) *Helicarion dyakanum* (Godwin-Austen, 1891) (Family Helicarionidae) MZU.MOL.23.504. (D) *Geotrochus bicolor* (E. von Martens, 1864) (Family Trochomorphidae) MZU.MOL.23.504 (E) *Geotrochus* cf. *conicoides* (Metcalf, 1852) (Family Geotrochidae) ME0007137

DISCUSSION

The survey conducted within the Gunung Gading National Park (GGNP) revealed that despite it is a non-karst area, supports a significant diversity of land snails. Research conducted in non-karst lowland forests in Malaysia notably recorded less abundant of species compared to a limestone forest (Schilthuizen *et al.*, 2003; Marzuki *et al.*, 2019; Boonmachai *et al.*, 2024). This study in GGNP indicates the common notion of the low diversity of land snail in non-karstic areas may not be always the case, since some species can occur in non-karstic environment, such as *Lagocheilus barbatus* (Marzuki *et al.*, 2021), *Allopeas gracile* (Marzuki *et al.*, 2021; Nurhayati *et al.*, 2023), and *Allopeas clavulinum* (Marzuki *et al.*, 2021; Nurhayati *et al.*, 2023).

From the diversity indices of the four localities, it indicates that GGNP has moderate diversity. In comparison to Gunung Penrissen and Bako National Park, the community of land snails in the area is less evenly scattered and diversified. In addition, the majority of the abundance are low with the exceptions of *Cyclophorus perdix borneensis*, *Pterocyclos tenuilabiatus*, *Amphidromus angulatus*, *Leptopoma undatum*, *Leptopoma sericatum*, *Philalanka kusana* and *Anaglyphula sauroderma* that counts for more than single-digit populations. This pattern is supported by Juříčková *et al.* (2008), indicating that land snails can thrive even in calcium-poor bedrock environments. Study had also found that even in habitats with high acidity, low calcium availability, and poor soil water retention, diverse malacofauna populations can thrive (Schilthuizen, 2006). Based on our results, it could be emphasised that most of the species that are in high abundance are large size and conspicuous. This suggests that there is a possibility of the tiny species being overlooked and the relative abundance of these small species is higher than the recorded data, for example species like *Microcystina* spp. and *Kaliella* spp. The most abundant species identified was *Cyclophorus perdix borneensis*, with an abundance of 264 individuals, contrasting sharply with the observation that all other species exhibited a markedly lower abundance, typically ranging from 1 to 61 individuals. *C. perdix borneensis* can be found widely distributed across limestone and montane forests

throughout the regions of Sarawak and Sabah (Marzuki *et al.*, 2021).

The presence of 12 species that are only can be found in GGNP, indicates their specialized ecological niche within this non-karst environment that supports their survival despite the fact that all of these four localities share this characteristic. Some of the factors that can potentially cause this unique presence of species includes microhabitat variation and specific climate conditions. According to Kemencei *et al.* (2014), land snails are very sensitive towards fine-scale habitat selection and susceptible to minute ecological and changes in microclimatic. Gheoca *et al.* (2021) and Liew *et al.* (2021) had also highlighted that habitat characteristics are proven to influence the species richness and abundance of land snail's species. Although this pattern was documented for other land snail's species, this provides a strong basis to relate the survivability of these species with specific environmental conditions within the vicinity of GGNP.

The survey was conducted over five days in May, a relatively short temporal window. Seasonal variations could impact species activity and visibility, and future studies should consider long-term monitoring. Liew *et al.* (2010) examined land snail assemblages across an elevational gradient on Mount Kinabalu, finding that species richness, abundance, and activity levels varied significantly with elevation. This reflects the changes in climate and habitat conditions over space and time. Additionally, a study on islands off the coast of Sabah (Schilthuizen *et al.*, 2013) showed that both the number of land snail species and the way they were distributed were strongly influenced by specific local environmental conditions such as humidity, vegetation, and shelter availability. These findings highlight how even small changes in habitat features can shape land snail communities, suggesting that microhabitat differences across time and space may also affect species presence in mainland forests like GGNP.

CONCLUSION

In conclusion, the study conducted in GGNP highlights the moderate diversity of land snail species in a non-karst environment. The presence of 12 species found only in GGNP emphasises the ecological uniqueness of the

GGNP. These findings contribute valuable insights into the adaptability of land snails to calcium-poor environments and emphasize the importance of fine-scale habitat characteristics in shaping biodiversity. This study also contributes to a deeper understanding of land snail biodiversity in non-karst areas and emphasizes the importance of preserving diverse habitats to support their specialised niches and ecological roles. Future studies should investigate specific microhabitat variables such as soil pH, moisture levels, canopy cover, and organic matter content to better understand niche preferences among snail species.

ACKNOWLEDGEMENTS

The authors would like to thank Sarawak Forestry Corporation for the permission to conduct research (Permit no.: SFC.810-4/6/1(2023)-129). The authors would also like to thank the park rangers of Gunung Gading National Park for providing invaluable support and assistance during the fieldwork. This research was supported by Biodiversity Research Grant Scheme UNIMAS (UNI/I01/BRG/85910/2023), which provided essential financial resources throughout this research.

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