Journal of Tropical Resources and Sustainable Science
Website : http://journal.umk.edu.my/index.php/jtrss/
eISSN : 2462-2389
Vol: SI Issue 1, 2025, 225-231
DOI: https://doi.org/10.47253/jtrss.v13i3.2007

RESEARCH ARTICLE

Species richness and composition of small mammal assemblage in Sedim River Forest Eco Park

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ARTICLE HISTORY
Received : xx
Accepted : xx
Online : xx

KEYWORDS
Rodent,
diversity,
guild,
lowland forest,
nature-based tourism

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ABSTRACT

Small mammals are essential components of tropical rainforest ecosystems and hold potential to support biodiversity-based ecotourism through engaging wildlife encounters. This study assessed species richness, composition, and beta diversity of small mammals in Sedim River Forest Eco Park, Peninsular Malaysia as well as their guild-specific detection pattern. Systematic sampling was conducted within a 400 m × 200 m plot using 100 collapsible cage traps, three harp traps, and 10 mist nets over five sampling sessions, each comprising five consecutive nights. Opportunistic observations were also carried out. A total of 26 species from 10 families were recorded. Live trapping captured 113 individuals representing 18 species, with *Hipposideros larvatus* being the most common. Direct observation yielded six individuals of six distinct arboreal species, with no overlap between methods, highlighting the complementary value of both methods. Diversity indices across sessions ranged from 0 to 2.53 (Shannon–Weiner), 0 to 0.9021 (Simpson), and 0.628 to 1.0 (evenness), with peak diversity during Session 3. A significant association was found between the sampling method and ecological guild ($\chi^2 = 45.61$, df = 2, $p < 0.001$). Beta diversity analysis using the Bray-Curtis Similarity Index revealed that the small mammal community in Gunung Inas FR (where Sedim River Forest Eco Park is located) was more similar to Padang Chong FR (43.2%) than Ulu Muda FR (29.3%), supported by a shared species count of 12. These findings demonstrate the importance of multi-method sampling and highlight the potential of diverse small mammal communities as valuable assets in low-impact ecotourism and conservation planning.

1. INTRODUCTION

Tropical rainforests are among the most ecologically complex and biologically rich ecosystems on Earth (Gallery, 2014). The ecosystem supports high species diversity, including small mammals that play vital roles in forest dynamics. These mammals contribute to seed dispersal, pollination, and insect control, and form a critical component of food webs as both predators and prey (Lacher et al., 2019; Čepelka & Dokulilová, 2025). Despite their ecological importance, small mammals are often overlooked in conservation assessments and land-use planning (Ruppert et al., 2015), partly due to their cryptic behaviour and limited public appeal compared to larger mammals.

This gap in representation highlights a broader issue in conservation planning, particularly in regions where ecological zoning is primarily based on physical features rather than biological ones. In Malaysia, the classification of sensitive natural areas is guided by the Environmentally Sensitive Areas (ESA) framework, which is part of the National Physical Plan (NPP). This framework categorizes permanent forest reserves into three levels of sensitivity to guide development and conservation priorities (PLANMalaysia, 2017). These levels are typically delineated using physical criteria such as slope gradient, elevation and risk of hazard. However, the increasing recognition of the need to protect functional biodiversity has led to growing support for integrating biological attributes, such as species diversity, abundance, and ecological roles, into ESA classifications to strengthen their ecological relevance and long-term effectiveness (Shahfiz et al., 2021).

Sedim River Forest Eco Park, located within the Gunung Inas Forest Reserve, is renowned for its canopy walkway and natural attractions. The area is designated as ESA Level II, which is moderately sensitive and permits controlled, low-impact development, including activities such as nature-based tourism (PLANMalaysia, 2021). Despite its recreational value, the biological composition of its small mammal community remains poorly documented. Biodiversity assessments in such areas are essential not only to establish ecological baselines but also to provide scientific justification for ESA zoning and conservation planning. Furthermore, identifying which species occur, their ecological functions and their visibility to visitors can inform the development of biodiversity-based tourism (Aihara et al., 2016), an approach that aligns both conservation and sustainable use within protected landscapes.

Ecotourism, when designed with a minimal ecological footprint, offers an effective platform for conservation education, community engagement and alternative livelihoods (Kumar et al., 2023). While small mammals are not always the most visible encountered by visitors, they remain a valuable component of nature-based tourism. Many species, such as diurnal and arboreal squirrels (Sciuridae) and tree shrews (Tupaiidae), are suitable for wildlife observation through guided walks and educational programs. Even less conspicuous or nocturnal species contribute to the ecological richness of a site and can be featured in interpretive materials, biodiversity talks, or citizen science initiatives. Therefore, documenting both the composition and richness of small mammals provides a foundation for developing ecotourism activities that are informative, engaging and aligned with conservation objectives.

This study aims to evaluate the diversity and composition of small mammals in Sedim River Eco Park. Specifically, to document (i) the richness and abundance of small mammals, (ii) guild-specific detection patterns to assess their complementarity and (iii) beta diversity patterns in comparison with nearby forest reserves to evaluate species turnover across the landscape.

2. MATERIALS AND METHODS

2.1. Study area

Sedim River Forest Eco Park (N 5.4071˚, E 100.66146˚) is located within the Gunung Inas Forest Reserve, a lowland dipterocarp forest ecosystem in Kedah, Peninsular Malaysia (Figure 1). The area is located approximately 30 km northeast of the town of Kulim and is part of a large permanent forest reserve covering approximately 36,979 hectares. The landscape is characterized by pristine evergreen vegetation, a dense forest canopy and a fast-flowing river system that supports high biodiversity. A prominent feature of the eco park is the Tree Top Walk, a 925 meters long canopy walkway elevated up to 26 meters above the forest floor, making it one of the longest of its kind globally. This structure offers panoramic views of the surrounding forest, providing unique opportunities for observing arboreal wildlife and making the park a popular destination for nature enthusiasts and ecotourists.

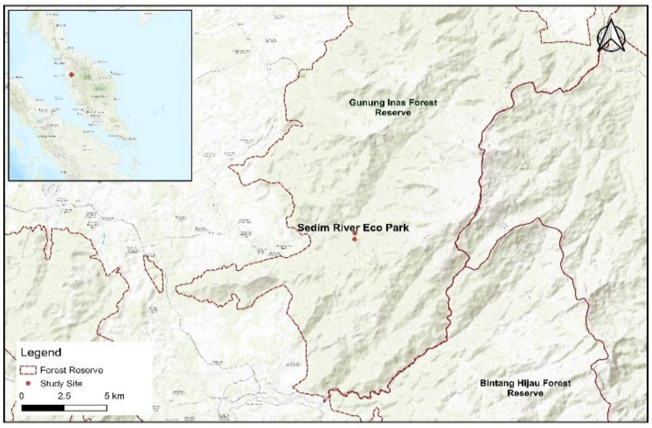

Figure 1: Location map of Sedim River Forest Eco Park, situated within the Gunung Inas Forest Reserve in Kedah, Peninsular Malaysia.

2.2. Live trapping of small mammals

Five sampling sessions were conducted between July and October 2022. Each session consisted of five consecutive nights and employed a standardized sampling protocol using consistent subplots, trap types, quantities and arrangements throughout the study period. Small mammals were surveyed using a combination of trapping methods targeting both volant and non-volant species. Non-volant species were captured using collapsible cage traps, while volant mammals were sampled using harp traps and mist nets. Four subplots (50 meters x 50 meters each) were established within a larger 400 meters x 200 meters main plot, situated at an elevation exceeding 300 meters above sea level.

Within each subplot, 25 collapsible cage traps (42 cm x 16 cm x 16 cm) were deployed along five 50 meters line transects, with traps spaced at 10 meters intervals. All traps were baited with oil palm fruits, a standardized bait widely used in small mammal surveys in Malaysia (Khalib et al., 2018; Abdullah et al., 2021; Harris Nasir et al., 2023), selected for their strong scent, as well as for their durability and cost-effectiveness compared to other baits. Simultaneously, three harp traps and ten mist nets were strategically positioned along potential flyways to capture insectivorous and frugivorous bats. To minimize stress and disturbance, all traps were checked twice daily, in the morning and evening.

Captured individuals were carefully removed and temporarily placed in cloth bags for handling. Species identification was based on standard external morphological characteristics, including measurements of head-body length (HB), hindfoot (HF) and forearm length (FA), as outlined in Francis (2019). Most individuals were marked with ear tags or forearm tags by experienced personnel to facilitate future recapture and tracking while minimizing stress. Up to three individuals per species were collected as voucher specimens and deposited in the Zoological Collection of Forest Research Institute Malaysia (FRIM). Muscle tissue samples were extracted and preserved in absolute ethanol for subsequent molecular analyses. All procedures adhered to the animal ethics requirements of the Department of Wildlife and National Parks Peninsular Malaysia (PERHILITAN) and the Wildlife Conservation Act 2010 (Act 716).

2.3. Opportunistic observations of small mammals

In addition to standardized trapping protocol, opportunistic observations of small mammals were recorded throughout the study period. These incidental sightings occurred during daily field activities, such as trap checks, trail walks, and movement between plots, and were not confined to fixed transects or observation points. When possible, species were identified on sight using field guides and photographs were taken with DSLR cameras to support identification. Although non-systematic, these opportunistic records provided valuable supplementary data on species presence and habitat use, particularly for taxa that may evade conventional traps or are more readily observed in natural behaviour.

2.4. Data analysis

Data analyses were conducted using both PAST (Version 4.03) and RStudio (Version 2024.12.1). In PAST, we calculated standard Alpha diversity metrics including Shannon-Wiener Index (*H'*), Simpson's Index (1 – D), evenness (*E*) and Margalef Index (D) for each sampling session to assess temporal changes in community composition. The resulting index values were exported to R, where box plots were generated with the ggplot2 package to visualize variation across sessions. To examine the relationship between sampling method and ecological guild, species counts were aggregated into a 3 × 2 contingency table and analyzed using a Chi-square test in R. Statistical significance was evaluated at $\alpha = 0.05$.

Beta diversity analysis was conducted to assess the compositional similarity of small mammal communities among three forest reserves: Gunung Inas Forest Reserve (FR), Padang Chong FR and Ulu Muda FR. These sites were selected based on ecological and geographical considerations. Additionally, Padang Chong FR is connected to Gunung Inas FR via the Bintang Hijau FR and Belukar Semang FR. At the same time, the southern boundary of Ulu Muda FR adjoins the northern extent of Gunung Inas FR, forming a continuous forested landscape. Small mammal data from Padang Chong FR and Ulu Muda FR were obtained through secondary data collection from published sources (Saarani et al., 2021; Zam Beri et al., 2023; Ruzman et al., 2024). Using the Bray-Curtis Similarity Index based on species abundance data, an Unweighted Pair Group Method with Arithmetic Mean (UPGMA) dendrogram was constructed, alongside a Venn diagram illustrating species presence-absence across the sites.

3. RESULT AND DISCUSSION

3.1 Small mammal compositions

Table 1 shows that a total of 119 individuals of small mammals were recorded throughout the sampling period, based on a cumulative effort of 2,500 trapping nights using collapsible cage traps, 75 trapping nights using harp traps, and 250 trapping nights using mist nets. These captures represented 24 species of small mammals, consisting of 11 volant and 13 non-volant species. The volant species belonged to three families: Hipposideridae, Pteropodidae, and Rhinolophidae. Meanwhile, the non-volant group included species from families Muridae, Sciuridae, Soricidae, Tupaiidae and Viverridae.

The highest species richness was recorded in the families Muridae, Rhinolophidae and Sciuridae, each comprising five distinct species. This was followed by the family Hipposideridae, which included four species. Only one species was recorded for families Soricidae, Tupaiidae and Viverridae. Of the 24 species documented, 2 species, namely *Maxomys rajah* and *Maxomys whiteheadi*, are classified as Vulnerable (VU). Three species, *Rhinolophus trifoliatus*, *Ratufa bicolor* and *Ratufa affinis* are listed as Near Threatened (NT). The remaining species are classified as Least Concern according to the International Union for Conservation of Nature Red List of Threatened Species (IUCN, 2025). The conservation status of *Rhinolophus refulgens* remains unassessed.

In terms of abundance, *Leopoldamys sabanus*, *Maxomys whiteheadi* and *Maxomys rajah* were among the most frequently captured non-volant species. Among the volant species, *Hipposideros larvatus* was the most recorded. Notably, only one individual was captured for each of the following nine species namely *Hipposideros atrox, Rhinolophus lepidus*, *Callosciurus notatus*, *Ratufa bicolor*, *Ratufa affinis*, *Sundasciurus lowii*, *Sundasciurus tenuis*, *Crocidura malayana* and *Arctogalidia trivirgata*. For non-volant arboreal species, this may be attributed to the placement of collapsible traps on the forest floor, which limits the detection of canopy dwelling small mammals (Haysom et al., 2021; McCleery et al., 2022). Similarly, for bat species represented by a single individual, limited detection may be related to species-specific flight behaviour, such as high canopy foraging or the use of open space flyways reducing the likelihood of contact with traps or mist nets deployed.

Table 1: Small mammal species recorded in Gunung Inas Forest Reserve (GIFR), Padang Chong Forest Reserve (PCFR), and Ulu Muda Forest Reserve (UMFR), including IUCN conservation status, detection method (live-trapping [LT] and observation [Obs]), and total number of individuals (*n*) recorded in GIFR. Abundance values represent the presence of species in PCFR and UMFR. IUCN = IUCN Red List of Threatened Species; LC = Least Concern; VU = Vulnerable; NT = Near Threatened; NE = Not Evaluated; LT = Live-trapping method; Obs = Observation method.

Family	Species	IUCN	GIFR [a]			PCFR [b, c]	UMFR [d]
			LT	Obs	*n*		
Hipposideridae	*Hipposideros atrox*	LC	1	0	1	0	0
	Hipposideros bicolor	LC	6	0	6	1	0
	Hipposideros cervinus	LC	2	0	2	0	0
	Hipposideros larvatus	LC	20	0	20	3	0
	Hipposideros diadema	LC	0	0	0	3	0
Muridae	*Leopoldamys sabanus*	LC	17	0	17	25	4
	Maxomys rajah	VU	14	0	14	5	2
	Maxomys surifer	LC	2	0	2	0	11
	Maxomys whiteheadi	VU	16	0	16	19	13
	Niviventer cremoriventer	LC	2	0	2	3	2
	Niviventer fulvescens	LC	0	0	0	0	2
	Sundamys muelleri	LC	0	0	0	1	7
	Chiropodomys gliroides	LC	0	0	0	0	1
	Rattus tiomanicus	LC	0	0	0	0	2
Pteropodidae	*Chironax melanocephlus*	LC	8	0	8	2	0
	Cynopterus brachyotis	LC	2	0	2	20	0
	Cynopterus horsefieldii	LC	0	0	0	1	0
	Balionycteris seimundi	LC	0	0	0	4	0
	Macroglossus sobrinus	LC	0	0	0	1	0
Rhinolophidae	*Rhinolophus affinis*	LC	7	0	7	10	0
	Rhinolophus lepidus	LC	1	0	1	0	0
	Rhinolophus pusillus	LC	2	0	2	2	0
	Rhinolophus refulgens	NE	6	0	6	0	0
	Rhinolophus trifoliatus	NT	3	0	3	5	0
	Rhinolophus luctus	LC	0	0	0	1	0
	Rhinolophus stheno	LC	0	0	0	1	0
Vespertilionidae	*Hesperoptenus blanford*	LC	0	0	0	1	0
	Pipistrellus tenuis	LC	0	0	0	5	0
	Kerivoula papillosa	LC	0	0	0	15	0
	Kerivoula hardwickii	LC	0	0	0	7	0
	Kerivoula minuta	NT	0	0	0	1	0
	Murina suilla	LC	0	0	0	10	0
	Murina peninsularis	NE	0	0	0	1	0
	Tylonycteris fulvida	NE	0	0	0	6	0
	Tylonycteris malayana	NE	0	0	0	1	0
	Myotis muricola	LC	0	0	0	1	0
Sciuridae	*Callosciurus notatus*	LC	0	1	1	7	0
	Callosciurus caniceps	LC	0	0	0	2	0
	Rhinosciurus laticaudatus	NT	0	0	0	2	0
	Ratufa affinis	NT	0	1	1	0	0
	Ratufa bicolor	NT	0	1	1	0	0
	Sundasciurus lowii	LC	0	1	1	2	0
	Sundasciurus tenuis	LC	0	1	1	0	0
Soricidae	*Crocidura malayana*	LC	1	0	1	0	0
Tupaiidae	*Tupaia glis*	LC	3	0	3	0	1
Viverridae	*Arctogalidia trivirgata*	LC	0	1	1	0	0
Total number of individuals			113	6	119	168	45
Total number of species			18	6	24	32	10

[a] Current study; [b] Zam Beri et al., 2023; [c] Ruzman et al., 2024; [d] Saarani et al., 2021

Capture efficiency varied across the three sampling methods. Harp traps demonstrated the highest efficiency, capturing individuals at a rate of 64%. Mist nets followed with an efficiency of 4%, while collapsible cage traps had the lowest efficiency at 2.2%. The lower overall capture rate documented in this study (4%) compared to previously reported rates of 6% in comparable tropical forest habitats (Munian et al., 2020; Fauzi et al., 2024) may reflect methodological and environmental constraints. Apart from the ground-level placement of collapsible cage traps, which are likely limiting the detection of arboreal species, the frequent rainfall during specific sampling periods may have inhibited small mammal activity and compromised trap efficacy (Richard et al., 2022). In addition, a study by Oosthuizen et al. (2025) reported that decreased activity of small mammals under increased lunar visibility could be a contributing factor to lower capture rate, which may be overlooked in studies related to small mammals in tropical forest.

3.2 Species diversity of small mammals

Diversity index analyses revealed apparent variation in small mammal assemblages across the five sampling sessions. Session 1 recorded the lowest value across all indices. The absence of species diversity and richness in this session is likely due to trap shyness, a neophobic behaviour in which small mammals avoid unfamiliar objects such as traps, especially during the initial phase of exposure (Stryjek et al., 2019). This behaviour is well-documented among small terrestrial mammals, particularly rodents and shrews and is often intensified by habitat disturbances and human scent during trap deployment (Travaini et al., 2013; Johnstone et al., 2024). As individuals habituated to the traps and bait, capture rates improved in subsequent sessions (Barnett, 2018).

Session 2 showed a marked increase in diversity, with a Shannon-Wiener Index of 2.368, a Simpson's Index of 0.872, an evenness of 0.628, and a Margalef Index of 3.833. This pattern continued into Session 3 (carried out in late August to early September) as shown in Figure 2, which recorded the highest overall diversity across the study period (Shannon–Weiner = 2.530, Simpson = 0.9021, evenness = 0.7387 and Margalef = 4.030), indicating a well-balanced and species-rich community. This situation was consistent with the known fruiting season in our tropical rainforest. During this period, the increased availability of fruit likely increased food resources, stimulating activity and possibly the reproductive rate of small mammals at the study site (Nakagawa et al., 2007). Session 4 exhibited moderate diversity, suggesting a relatively even species distribution despite lower richness. Similarly, Session 5 showed slightly lower diversity. Notably, evenness remained consistently high across sessions, often approaching 1, indicating that when multiple species were present, they were captured in relatively equal proportions. The temporal trends observed in this study underscore the importance of multi-session sampling to account for behavioural biases and environmental variability.

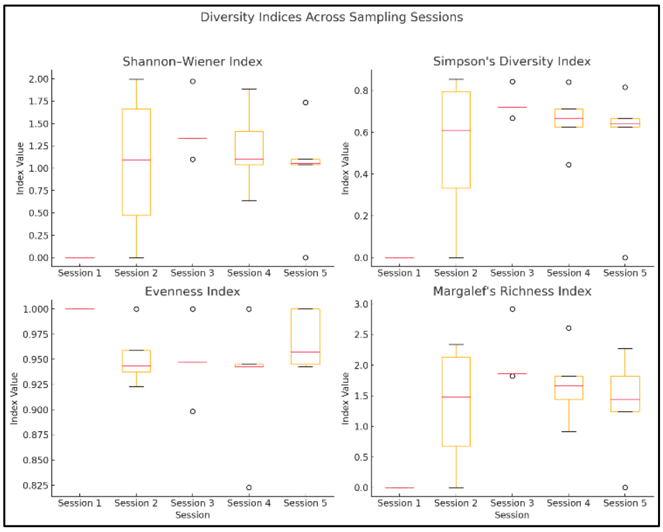

Figure 2: Boxplots of diversity indices for small mammal assemblages across five sampling sessions in Sedim River Forest Eco Park.

3.3 Guild-specific Detection Patterns

A total of 58 volant bats, 52 non-volant terrestrial mammals, and nine non-volant arboreal mammals were recorded. Live-trapping accounted for all individuals of bats and terrestrial mammals, whereas direct observation recorded six of the nine arboreal individuals. A Chi-square test confirmed a strong association between sampling method and guild ($\chi^2 = 45.61$, df = 2, $p < 0.001$), demonstrating that live-trapping is more effective for nocturnal and ground-dwelling mammals, while visual surveys preferentially detect diurnal, tree-dwelling species.

This pattern highlights the complementary strengths of our survey techniques. Live-trapping effectively captures cryptic and nocturnal species (e.g., insectivorous and frugivorous bats, ground-dwelling rodents). In contrast, visual surveys are essential for recording diurnal, arboreal species (e.g., squirrels and civets) that would otherwise be overlooked. Such high diversity of small mammals in the study area provides an opportunity to explore potential economic revenue through various nature-based activities. Integrating biodiversity inventory with species-specific detectability enables Sedim River Forest Eco Park to develop comprehensive ecotourism offerings.

Daytime canopy tours could highlight arboreal species such as *Callosciurus notatus* and *Ratufa bicolor*, while nocturnal excursions, known as "night walks," would feature nocturnal terrestrial fauna. Organizing such activities with a focus on mammal diversity will provide a 24-hour eco-tourism perspective, allowing the visitors to experience different types of engagement and contribute to tourism revenue.

This dual-mode approach enhances ecological monitoring, which will assist park managers and relevant authorities to establish baseline databases for long-term monitoring. Ultimately, such efforts will contribute to more specific key habitats or microhabitats rich with species diversity, leading to more targeted protection measures and minimal disturbance during development of trails or lodges.

3.4 Beta diversity and community similarity

The beta diversity analysis revealed notable differences in small mammal assemblages across Gunung Inas FR, Padang Chong FR and Ulu Muda FR, despite all three being situated within the same lowland forest ecosystem. The Bray-Curtis Similarity Index indicated that Gunung Inas FR shared greater similarity with Padang Chong FR (43.2%) compared to Ulu Muda FR (29.3%). In comparison, Padang Chong FR and Ulu Muda FR had the lowest similarity (20.7%) (Figure 3). This pattern likely reflects underlying differences in landscape connectivity, habitat continuity and possibly historical disturbance regimes. The relatively higher similarity between Gunung Inas FR and Padang Chong FR may be attributed to their indirect connectivity via Bintang Hijau FR and Belukar Semang FR, facilitating gene flow and species dispersal across the landscape (Garrido-Garduño et al., 2016).

In contrast, Ulu Muda, one of Malaysia's most extensive remaining tracts of continuous lowland rainforest, serves as a vital water catchment area for the Muda, Pedu, and Ahning reservoirs (Rajoo et al., 2021). Its ecological importance and relative inaccessibility have helped reduce human disturbances creating conditions favorable for maintaining distinct small mammal communities. This distinctiveness may be influenced by localised environmental gradients, forest structure and hydrological stability.

The Venn diagram highlights the differences and overlaps in small mammal species across the three forest reserves (Figure 4). Of the 46 species recorded, Gunung Inas FR and Padang Chong FR shared the highest number of species, with eight species, while only five species were common to all three sites. At the same time, a considerable number of species were unique to each forest, nine species in Gunung Inas FR, 18 species in Padang Chong FR and three species in Ulu Muda FR. These patterns suggest a more substantial community similarity between these two sites. This pattern can be attributed not only to their closer geographic proximity and forest connectivity but also to the difference in sampling scope.

Specifically, species data for Ulu Muda FR was limited to small non-volant mammals, as no records of volant species were available from the secondary sources used. This sampling gap likely contributed to the lower species count and reduced similarity with the other sites. The absence of volant species data makes comparisons with Gunung Inas FR and Padang Chong FR less comprehensive and may underrepresent the true diversity of Ulu Muda FR. Despite this limitation, the results demonstrate that each site supports a distinct assemblage of small mammals.

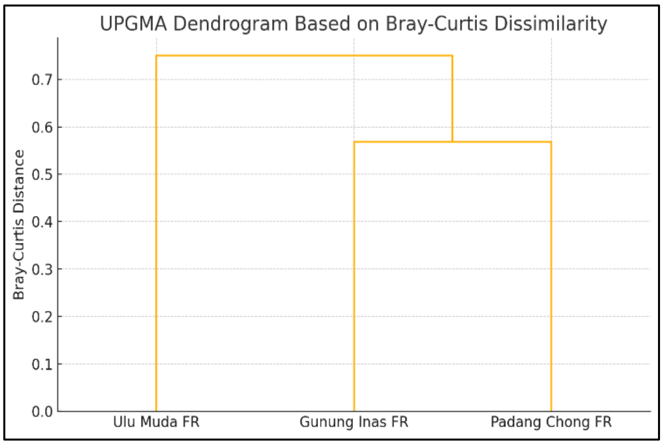

Figure 3: UPGMA dendrogram of small mammal assemblages based on Bray-Curtis Similarity Index across three forest reserves (Gunung Inas FR, Padang Chong FR, and Ulu Muda FR).

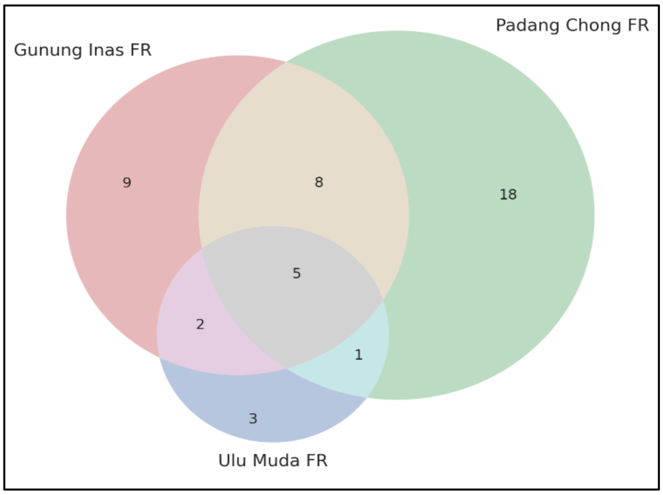

Figure 4: Venn diagram showing the overlap of small mammal species presence among Gunung Inas FR, Padang Chong FR, and Ulu Muda FR.

4. CONCLUSION

This study recorded 26 small mammal species across ten families in the Sedim River Forest Eco Park, using both live trapping and direct observation, with no species overlapping between the two methods. Diversity indices varied temporally, and detection patterns differed across ecological guilds, highlighting the need for multi-method, multi-session sampling. Beta diversity analysis revealed greater species similarity between the Gunung Inas and Padang Chong Forest Reserves, indicating habitat connectivity. These findings underscore the small mammal ecological significance and highlight the value of incorporating into biodiversity-focused eco-tourism initiatives that promote wildlife appreciation and sustainable forest management.

ACKNOWLEDGEMENT

This research was funded, and equipment was acquired through Project RMk-12 P23085100210003. We acknowledge the Department of Wildlife and National Parks (DWNP), Peninsular Malaysia, for issuing research permits (B-00298-15-22) and the Forestry Department of Peninsular Malaysia for granting permissions for field sampling. We would also like to extend our appreciation to the Division Director of the Forest Biodiversity Division, FRIM, and the Project Leader of RMk-12, as well as all the support staff of the Zoology Branch, for their contributions to this research.

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