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RESEARCH ARTICLE

Inventory of Non-Volant Small Mammals in the Mixed-land Use Habitats at Pusat Penyelidikan Pertanian Tun Razak, Jerantut, Pahang.

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Abstract The extensive use of land for agriculture has significantly influenced the distribution and diversity of wild species, including small mammals. From 22nd February to 17th March 2023, an inventory was conducted to identify the diversity and bait preferences of non-volant small mammals across three localities which are oil palm, orchard and forest area at Pusat Penyelidikan Pertanian Tun Razak (PPPTR), Jerantut, Pahang. A total of 105 individuals representing three families and six species of the orders Rodentia and Scandentia were trapped and identified. Out of this, four species from 26 individuals were caught in the oil palm area, six species from 36 individuals in the orchard, and five species from 43 individuals in the forest area. *Rattus tiomanicus* was the most abundant species recorded at PPPTR. The Shannon-Wiener Index was calculated and compared, showing that the forest area (H = 1.391) had a greater diversity value than the oil palm (H = 1.293) and orchard (H = 1.367). Simpson's Diversity Index also revealed that the forest area (0.7258) had a higher index value than the oil palm (0.7012) and orchard (0.6852), indicating that the forest area has better habitat suitability for small mammals. The analysis of bait preferences revealed that non-volant small mammals at PPPTR showed a strong preference for oil palm loose fruit, followed by bananas, likely due to dietary habits and food availability in the area. In conclusion, this inventory provides fundamental data on non-volant small mammal diversity in the mixed-land use habitats at PPPTR and offers valuable insights for small mammals' conservation and agricultural pest management strategies.

Keywords: Oil palm, orchard, forest, species diversity, bait preferences.

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Introduction

According to Munian *et al.* [32], any mammal weighing less than 5 kg is classified as a small mammal. Among these, small mammals are further categorized into volant species, which can fly, and non-volant species, which cannot fly [18]. Non-volant small mammals are some of the most prevalent in various ecosystems, playing crucial ecological roles such as seed dispersers, which aid in forest regeneration and the maintenance of biodiversity [4]. Certain species, particularly omnivorous rodents and squirrels, contribute significantly to biocontrol by preying on insects, thereby helping to regulate pest populations [28]. These small mammals are also key components of the diets of many predatory species, including wild cats, civets, birds, and snakes, forming essential links in food webs [31].

However, not all small mammals are beneficial in agricultural contexts. Species like *Rattus argentiventer* and *Rattus tiomanicus* have been identified as significant pests, particularly in oil palm plantations, where their presence can lead to substantial economic losses due to crop damage and increased management costs [29]. The economic implications are notable, as pest control measures often require significant investment and can lead to increased use of chemical interventions [13]. Conversely, maintaining a diverse and balanced small mammal community can naturally mitigate pest populations, promoting more sustainable agricultural practices [7].

Pusat Penyelidikan Pertanian Tun Razak (PPPTR), located in Jerantut, Pahang, is a unique residential and agricultural area surrounded by oil palm and multi-crop plantations, forest patches and recreational areas. This diverse landscape has been selected as the study site due to the significant influence of agricultural expansion on local biodiversity, particularly on small mammal populations. These habitats are essential for many small mammal species, providing critical resources such as food, shelter and breeding grounds. However, the impact of habitat modification on species diversity and ecosystems health within PPPTR remains largely unstudied, making this investigation the first comprehensive assessment of non-volant small mammal diversity in the area. Thus, this study aims to inventory the diversity of non-volant small mammals within this mixed-use landscape. It seeks to provide practices that balance agricultural productivity with wildlife conservation, ultimately contributing to the long-term sustainability of the region's agricultural landscape.

Materials and Methods

Study Site

The study site is located at Pusat Penyelidikan Pertanian Tun Razak (PPPTR), Jerantut, Pahang (3°53'02.3"N, 102°31'53.1"E). This site is recognized as a Research and Development Centre (R&D) for agriculture, managed by FGV Holdings Berhad. The area of complex covers approximately 2,379 hectares, consists of oil palm plantation, multicrops, forest and residential area. Each locality offers unique characteristics. The oil palm plantation spans approximately 1627 hectares, dominated by mature oil palm trees manages intensively for agricultural production. Adjacent to this, the orchard covers about 227 hectares, featuring a diverse of fruit trees such as durian (*Durio zibethinus*), banana (*Musa paradisiaca*), rambutan (*Nephelium lappaceum*) and mangosteen (*Garcinia mangostana*). This orchard contributes to the local economy and provides seasonal resources for wildlife. Meanwhile, the forested area covers more than 50 hectares within PPPTR. This area is characterized by secondary dipterocarp forest, providing essential ecological functions and diverse habitats. The study focused on exploaring differences in small mammal species diversity across these three distinct localities within PPPTR which are the oil palm plantation, orchard and forest areas (Figure 1).

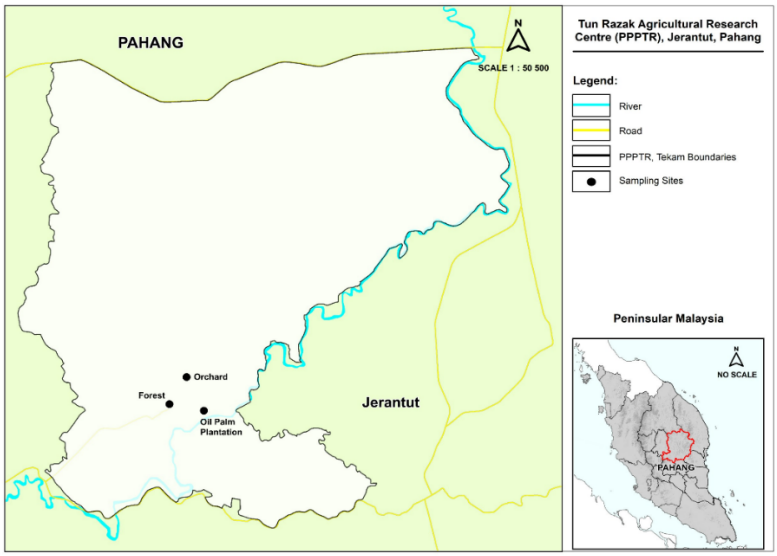

Figure 1. An inventory of non-volant small mammals was conducted at PPPTR, located in Jerantut, Pahang. Three localities were selected to compare their diversity: the oil palm plantation, orchard, and forest area

Field Sampling

The inventory was conducted from 22nd February to 17th March 2023 at PPPTR. A total of 75 traps were used for this study, with 25 cages placed at each of the three localities: the oil palm plantation, orchard and forest area. Baits such as oil palm loose fruit, bananas, salted fish, and sweet potatoes were placed inside the cage traps to attract the non-volant small mammals. The sampling design employed in this study involved the use of random trapping in each habitat. The traps were placed near the fallen logs, tree trunks and close to vegetation or other structural features that provide shelter and food resources. The traps were left overnight and checked every morning to collect any trapped small mammals and rebait the empty ones. For this inventory, a capture-release method was used after the samples had been recorded and measured. The body measurements which included the tail (T), head-to-body length (HB), ear length (E) and hindfoot (HF) were recorded following the standard measurement. The animals were further examined to identify their age (juveniles or adults) and sex (male or female). The external body measurements were taken with a ruler and vernier callipers and the weight was recorded as well by using a weighing scale [1]. All collected samples were identified by referring to Francis [16]. Apart from trapping, observations were made daily, where each trap location was surveyed for signs of small mammal activity. Field sampling occurred about 3 weeks (18 nights) at each locality ensuring that each locality received equal sampling effort across the study period.

Statistical Analysis

Descriptive statistics of the samples were calculated using Minitab 21. Paleontological Statistics (PAST) software was used to analyse the diversity index of the non-volant small mammals in the oil palm plantation, orchard, and forest areas [20]. The diversity indices, including Simpson's Index (1-D), Shannon-Wiener Index (H'), and Evenness (eH/S), were calculated and compared between the three localities. These diversity indices are crucial for evaluating the biodiversity of these non-volant small mammals in the area and understanding ecological relationships between these three habitats – oil palm plantation, orchard and forest areas. Rarefaction curves can be used to measure the total species richness of populations at sampling sites [2]. This approach provides a broad view of community diversity. A rarefaction curve was also constructed using PAST, while the species accumulation curve and an interval plot of consumption rates against bait types were constructed using Excel. The analysis of bait preferences of non-volant small mammals at PPPTR has been included in this study.

Results

A total of 105 individuals from two orders which are Rodentia and Scandentia, were captured from this inventory in PPPTR (Table 1). Two families that have been identified from the order Rodentia are Muridae and Sciuridae, while the order Scandentia consists of the family Tupaiidae. Six species of non-volant small mammals were recorded from PPPTR (Figure 2). The total number of trap-nights across all localities was 1,350 (calculated as 75 traps x 18 nights). The trapping success rate was calculated for each locality and the overall trapping success for the study was 7.26%.

At the oil palm plantation, 26 individuals were captured, resulting in a trapping success of 1.93%. In the orchard, 35 individuals were captured with a trapping success of 2.59%. The forest area yielded 37 individuals, with a trapping success of 2.74%. The most abundant species captured overall was *Rattus tiomanicus* (n=39) and the least species captured was *Ratufa bicolor* (n=1). According to localities, *Rattus argentiventer* was the most abundant species captured in oil palm (n=11), whereas *Rattus tiomanicus* was the most abundant species in orchard (n=17) and forest area (n=15). Based on the IUCN Red List status, all species captured were listed as Least Concern (LC) except for *Ratufa bicolor*, which is listed as Near Threatened (NT).

Table 1. List of non-volant small mammal's species collected from three localities in PPPTR

Order	Family	Species	Oil Palm	Orchard	Forest	Total individuals	IUCN Status (2016)
Rodentia	Muridae	*Rattus tiomanicus*	7	17	15	39	LC
		Rattus rattus diardii	4	2	7	13	LC
		Rattus argentiventer	11	8	14	33	LC
		Rattus exulans	0	1	1	2	LC
	Sciuridae	*Ratufa bicolor*	0	1	0	1	NT
Scandentia	Tupaiidae	*Tupaia glis*	4	7	6	17	LC
		TOTAL	26	36	43	105	

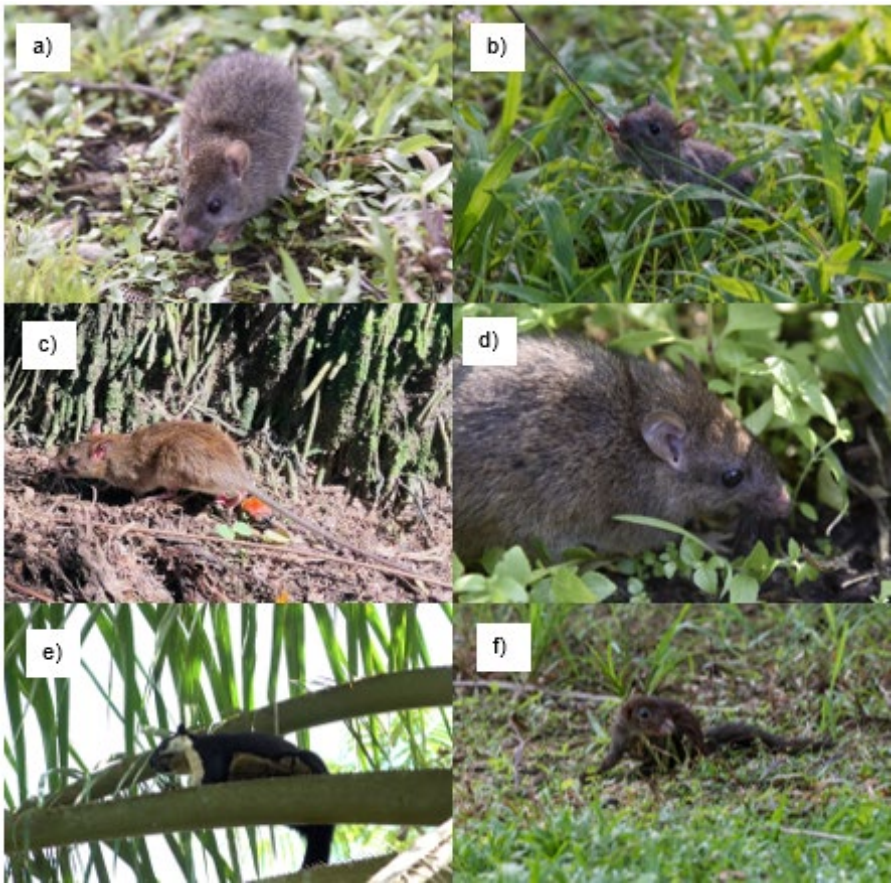

Figure 2. Six species of non-volant small mammals have been identified from PPPTR: a) *Rattus tiomanicus*, b) *Rattus rattus diardii,* c) *Rattus argentiventer,* d) *Rattus exulans,* e) *Ratufa bicolor* and f) *Tupaia glis*

The diversity indices of non-volant small mammals in PPPTR were calculated using PAST software (Table 2). Based on Table 2, the value of Simpson's Index is highest in the forest area (0.7258), indicating greater species diversity in this habitat compared to the oil palm plantation (0.7012) and orchard area (0.6852). The Shannon-Wiener Index also shows a similar pattern. The forest area has the highest index value (1.391), followed by the orchard (1.367) and the oil palm plantation (1.293).

Table 2. Diversity indices of non-volant small mammals in three localities in PPPTR

Diversity Index	Oil Palm	Orchard	Forest
Simpson (1-D)	0.7012	0.6852	0.7258
Shannon-Wiener (H)	1.293	1.367	1.391
Evenness ($e^{H/S}$)	0.9111	0.6537	0.8034

Based on Figure 3, the rarefaction curve of non-volant small mammals from three localities – orchard (blue curve), forest area (green curve) and oil palm plantation (red curve). The oil palm area has reached an asymptote, while both the orchard and forest areas have not. The overlapping of the curves for oil palm and orchard at the point of the ninth individual captured indicates that both sites had the same species richness at that sampling point.

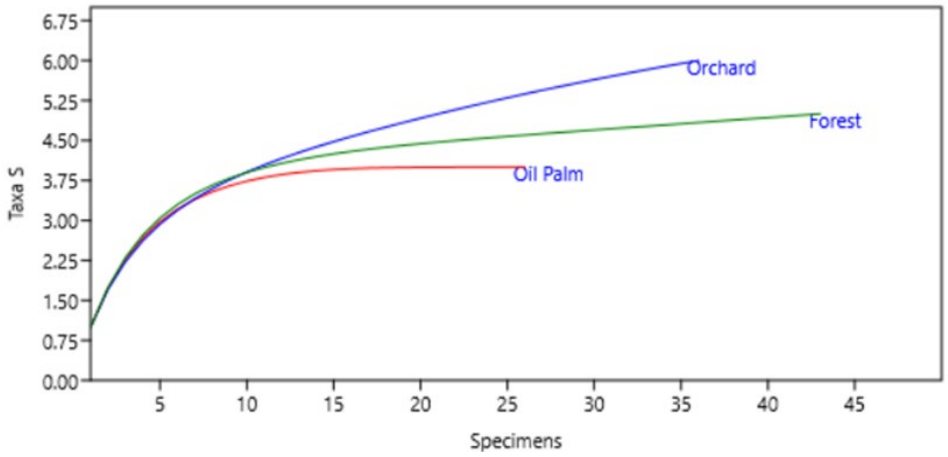

Figure 3. The rarefaction curve of non-volant small mammals captured from three localities – oil palm plantation, orchard and forest area in PPPTR

Figure 4 illustrates the species accumulation curves for three localities in PPPTR – oil palm plantation (red curve), orchard (blue curve), and forest areas (green curve). The species accumulation curves show the cumulative number of species captured relative to sampling effort (abundance). The orchard exhibits the highest species richness with the curve still gradually rising. The forest area also shows high species richness but levels off sooner, implying a saturation point at fewer individuals. In contrast, the oil palm plantation has the lowest species richness, with a clear levelling off at a low number of species.

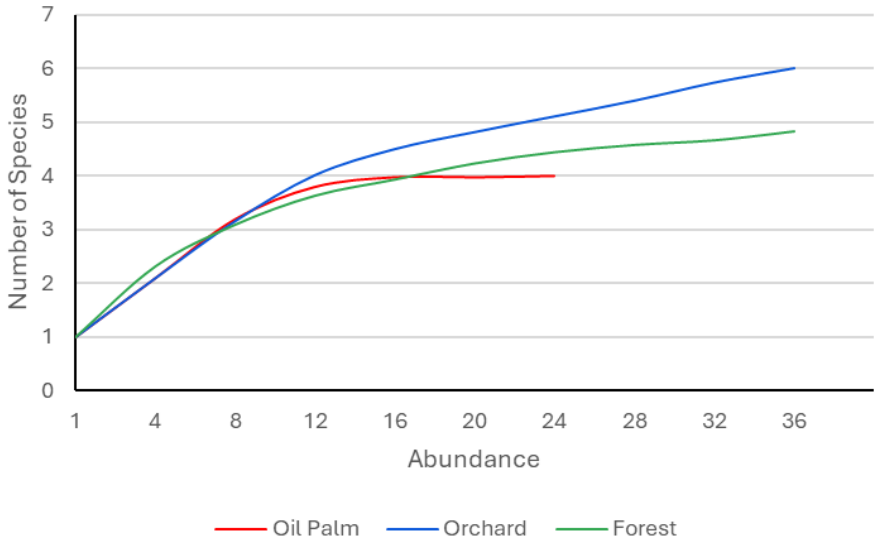

Figure 4. The species accumulation curve for three localities in PPPTR

A bar graph of consumption rate versus bait type was constructed using Excel (Figure 5). Four types of baits were used in this inventory: banana, oil palm loose fruit, salted fish, and sweet potato. The results show that most non-volant small mammals at PPPTR, prefer oil palm loose fruit over the other baits.

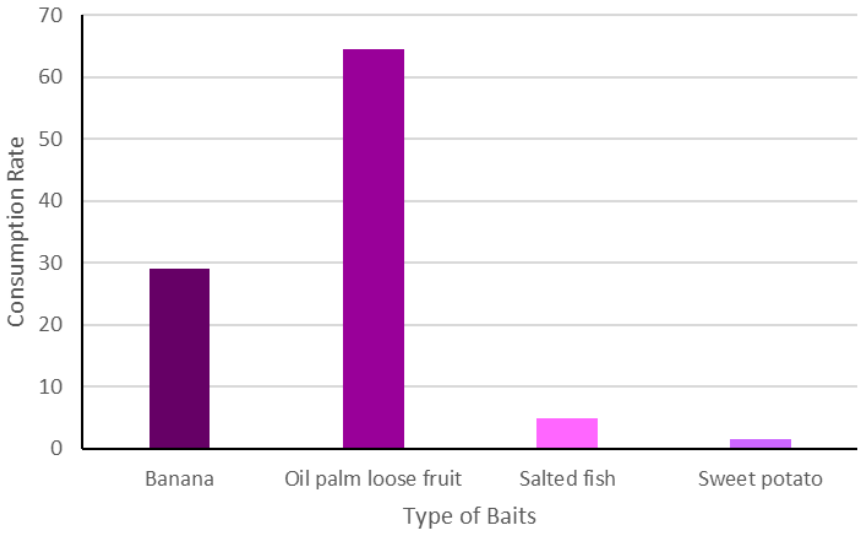

Figure 5. Comparison in baits preferences of the non-volant small mammals in PPPTR

Discussion

The species distribution across different habitats underscores the adaptability and habitat preferences of these mammals in response to environmental changes brought about by agricultural practices [12]. In this study, Rodentia and Scandentia were captured at three distinct habitats which are oil palm plantation, orchard and forest area. Out of the small mammals captured, *Rattus tiomanicus* was likely to be the most dominant species, adapting and thriving across these habitat types [39, 35, 29]. This rat species' adaptability to both agricultural and semi-natural environments emphasize its ecological flexibility, which may have implications for both conservation and pest management. On the other hand, *Ratufa bicolor* which was captured at the very least may have vulnerability towards human-modified landscapes. This species has been frequently observed jumping from one tree to another at PPPTR. Due to its Near Threatened (NT) status, further information is required to ensure its long-term survival in this area [22, 27].

On the other hand, the high abundance of *Rattus argentiventer* in the oil palm plantation is consistent with its known role as a major agricultural pest, particularly in Southeast Asia [39, 29]. This species' ability to exploit monoculture environments like oil palm plantations could lead to significant economic impacts due to crop damage [8]. Therefore, the high population of *Rattus argentiventer* in the oil palm area indicates the need for integrated pest management strategies that consider the species' ecology and its interactions with the agricultural landscape [11, 37].

The analysis of diversity indices provides a detailed understanding of the biodiversity of non-volant small mammals in PPPTR across three distinct habitats which are the oil palm plantation, orchard, and forest areas. The forest area provides a more heterogeneous environment, supporting a wider variety of species [23, 17, 15]. The forest area not only supports a higher number of species, but it also explains that this area would be the most preferred location for terrestrial species to thrive [10, 15]. This is likely due to the forest's natural structure, which offers varied microhabitats and food sources, supporting both generalist and specialist species [38]. The slightly lower diversity in the oil palm and orchard areas could be attributed to the monoculture nature of these agricultural landscapes, which often supports fewer species due to limited habitat complexity and interspecific competition [25, 12].

Rarefaction curves provide a way to visualize species richness pattern across sites, even when sample sizes are standardized, enabling meaningful comparisons of species accumulation between the different habitat studied [6, 2]. In this study, the rarefaction curves reveal distinct patterns of species accumulation across the oil palm plantation, orchard, and forest areas, highlighting differences in species richness and community composition among these habitats. The oil palm plantation and forest area have reached the asymptote (plateau) as the number of active sampling days is enough to cover these two areas, but the orchard has not reached the asymptote yet. A short period of sample collection may cause any miss in certain species that come seasonally [5]. Therefore, it is suggested that the sampling period be extended until the asymptote is reached through continuous sampling efforts.

Species accumulation curves are essential for visualizing how species richness increases with additional sampling effort. This pattern can reveal whether the sampling effort was sufficient to capture the diversity within each locality or if further sampling might yield additional species [19]. The rapid asymptote in the oil palm plantation's curve highlights the impact of habitat simplification on species richness indicates that additional sampling in the oil palm area is unlikely to capture other recorded species due to monoculture plantations [13]. Meanwhile, the more gradual curves for the orchard and forest areas suggest these areas harbour more diverse communities that benefit from richer habitat structures [34]. These findings emphasize the importance of preserving and managing diverse habitats within agricultural landscapes to maintain and enhance biodiversity [3, 9, 37].

The oil palm loose fruit is the highest type of bait preferred by the non-volant small mammals in PPPTR while the sweet potato is the least preferred one. Mohd-Taib and Ishak [30] found that different small mammal communities have considerably different preferences for bait. It is anticipated that palm kernel will be the small mammals' primary food source due to their diets and habitat, particularly if they live on or nearby an oil palm plantation. Verde and D'Elía [6] suggested that animals choose their food based on accessibility and rarely change their diet unless they are undergoing adaptations. Since the oil palm, orchard, and forest are located close to each other, species from the orchard and forest also had access to oil palm loose fruit as a food resource. In contrast, sweet potato was the least preferred option, likely because the small mammals were not accustomed to this new diet introduced during the sampling period.

While this study provides valuable insights into the diversity and habitat associations of non-volant small mammals in PPPTR, there are some caveats to consider. The study's duration, though effective for a preliminary inventory, was relatively short, potentially limiting the full capture of seasonal variations in species composition and bait preferences. Additionally, trap placement and bait types were selected to attract a broad range of species, yet certain species may have specific habitat or dietary preferences that were not fully captured under this approach [14, 24]. For future research, we could expand on this study by conducting sampling over multiple seasons to capture potential temporal shifts in small mammal communities. Incorporating additional bait types, adjusted for specific preferences, and applying methods such as camera traps could increase detection rates of rare or elusive species [26, 33]. Exploring how habitat fragmentation, land use, and resource availability influence small mammal population dynamics would provide a more comprehensive understanding of how these mammals interact with the land-use landscape [21].

Conclusions

In summary, this study provides an overview of the non-volant small mammals at PPPTR, where a total of 105 individuals from two orders, three families and six species were identified in the oil palm plantation, orchard and forest areas. *Rattus tiomanicus* was the most common species across all habitats, reflecting its adaptability to agricultural landscapes. The dominated *Rattus tiomanicus* and *Rattus argentiventer* population in the oil palm area indicates their adaptiveness in the oil palm plantation. Meanwhile, the rare capture of *Ratufa bicolor*, raises concerns about its vulnerability in fragmented environments. The diversity indices indicate that the forest area supports the highest species diversity, suggesting it offers a more complex and stable habitat compared to the oil palm and orchard areas, which are likely limited by their monoculture nature. Rarefaction and species accumulation curves further highlight that the oil palm plantation has a lower species richness, while the orchard and forest areas are more diverse, suggesting that extended sampling might reveal additional species in these areas. The bait preference analysis shows a strong preference for oil palm loose fruit among the small mammals, likely due to its abundance and familiarity, while sweet potato was the least favoured, indicating that unfamiliar food sources may not be effective. This study highlights the importance of preserving diverse habitats, such as forested areas within agricultural landscapes, to maintain and enhance the biodiversity of small mammal species.

Conflicts of Interest

The author(s) declare(s) that there is no conflict of interest regarding the publication of this paper.

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