

Composition of Small Mammals between Disturbed and Undisturbed Areas of Peat Swamp Forest in Ayer Hitam Utara Forest Reserve in Johor

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Abstract

Ayer Hitam Utara Forest Reserve (AHUFR) is the largest remaining peat swamp forest in Johor. Studies on small mammals are still limited given lots of research being done in AHUFR. This study aimed to make a checklist of small mammals and compare their composition between disturbed and undisturbed areas of AHUFR for a total of 12 sampling days. Sampling involved 24 cage traps and 4 mist nets across two sampling sites in each disturbed and undisturbed areas. Four species were recorded: *Tupaia glis* (Common Treeshrew), *Leopoldamys sabanus* (Long-tailed Giant Rat), *Maxomys rajah* (Rajah Spiny Rat), and *Rhinolophus trifolius* (Trefoil Horseshoe Bat). While both areas recorded three species, the undisturbed area had a higher abundance (11 individuals) compared to the disturbed area (seven individuals). The disturbed area exhibited a higher Shannon-Weiner index ($H' = 0.9557$) and evenness ($E = 0.8699$) and a T-test (T-test = 0.674; p-value > 0.05) indicated no statistically significant difference between the areas. The findings can provide baseline data for future research and conservation efforts.

1. Introduction

Peat swamps, located inland near coastal mangroves and river floodplains, are characterized by their peat substrate, which releases organic acids and tannins, resulting in low water pH levels of 3.6 to 5.9 [1]. In the world's wetlands, peat swamp forests are essential because they act as a link connecting land and water. They are transitional areas where water movement, nutrient cycle, and sun radiation combine to create a special ecosystem with its own soils, plants, and hydrology. Energy production, forestry and fishery products, flood control, water supply, and groundwater recharge are only a few benefits of peat swamp forests [2].

Peat swamp forests form in waterlogged areas where organic material accumulates over millennia at a rate of 0.5 to 2 millimetres annually. Acting like sponges, they retain moisture and develop dome-shaped structures that can rise above flood levels. Peat layers often exceed 4 meters in depth, with some reaching up to 20 meters [3]. There are very few peat swamp forests with both disturbed and undisturbed areas. Disturbed areas show high human activity, such as tree removal, logging, burning, and reduced plant cover, while undisturbed areas have dense vegetation, canopy cover, and minimal disturbance, with no signs of human activity [4].

Small mammals are those mammals that weighing less than 5 kg, are categorized as non-volant that cannot fly such as rodents, shrews, and volant those that can fly like bats [5]. Rodentia (rodents) and Chiroptera (bats) make up over 60% of all mammal species [6], with Chiroptera being the second most diverse order [7]. In peat

swamp forest Malaysia, Pounsins' research (2018) recorded 60 individuals of chiropterans, four species from two families, in the Setiu Wetland Beach Ridges Interspersed with Swales (BRIS) forest [8]. Additionally, previous research found seven species of non-volant small mammals from two families in Ulu Sebuyau National Park [9] and a total of 21 small mammal individuals from four distinct families captured in the Kuala Langat North Forest Reserve (KLNFR) [10]. Small mammals like rodents, shrews, and bats are crucial for ecosystem balance. Rodents and shrews help with pollination and seed dispersal, serving as bio-indicators of ecosystem health, while bats contribute to pollination and control insect populations [11, 12].

Ayer Hitam Utara Forest Reserve (AHUFR) is the study site for this research. It has a peat swamp ecosystem located in Muar District, Johor. A lot of research has been done but there are few or no small mammal-related studies in AHUFR. Thus, this research aims to make a checklist of small mammals and compare the composition of small mammals between disturbed and undisturbed areas in AHUFR to provide baseline data for future research and conservation efforts.

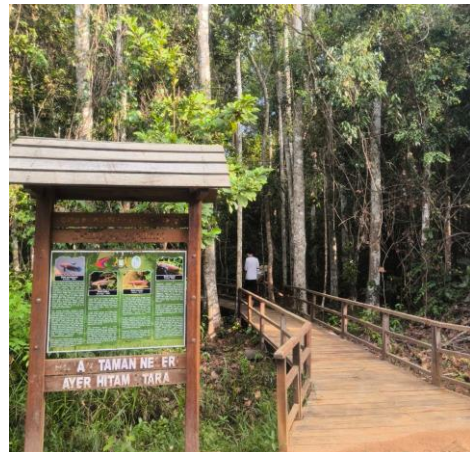
2. Research Methodology

2.1 Study Site

Ayer Hitam Utara Forest Reserve (AHUFR) is located in Muar district of Johor, Peninsular Malaysia, at coordinates $1^{\circ} 52'$ North and $103^{\circ} 11'$ East. It is the state's largest forest reserve, with 3,797 hectares, and the only peat swamp forest still remaining. This peat swamp ecosystem, situated at an elevation of 11 meters, represents a critical ecological resource for Johor [13, 14, 15]. The study was conducted at two sampling sites in disturbed and undisturbed areas within the peat swamp forest at AHUFR (Fig. 1, Fig. 2), with the site coordinates provided in Table 1. Disturbed areas are more publicly accessible [16], such as trails constructed for visitors, whereas undisturbed areas are less accessible.



(a)

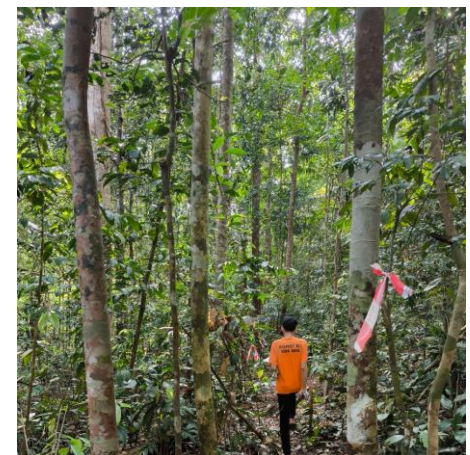


(b)

Fig. 1 (a) Site 1; (b) Site 2 identified as disturbed areas



(a)



(b)

Fig. 2 (a) Site 1; (b) Site 2 identified as undisturbed areas

Table 1 Coordinates and date visit for each site

Coordinate and date visit	Disturbed area	Undisturbed area
Site 1	2° 03' 02.49" N 102° 49' 38.43" E 1 to 3 November 2024	2° 03' 04.05" N 102° 49' 37.45" E 7 to 9 November 2024
Site 2	2° 03' 17.45" N 102° 49' 44.66" E 4 to 6 November 2024	2° 03' 08.69" N 102° 49' 40.43" E 14 to 16 November 2024

2.2 Sampling method

Two sampling sites were set up in each disturbed and undisturbed area. A total of 24 cage traps and four mist nets were used, with each site equipped with 12 cage traps baited with bananas along a 600 m transect line and two mist nets for volant small mammals. Traps were checked every two hours during the day and left overnight, while mist nets were checked the following morning. Sampling occurred over 12 days, with three days at each site. Captured small mammals were temporarily placed in cloth bags [5], morphological traits, sex, reproductive status, and species identification were recorded and small mammals were released with nail polish markings to prevent recapture.

2.3 Data analysis

The analysis assessed species richness, evenness, and abundance, along with comparing composition of small mammals between disturbed and undisturbed areas. Relative abundance was calculated as the proportion of individuals of a species to the total individuals [17]. Species diversity was measured using the Shannon-Wiener Diversity Index (H'), with diversity categorized as low ($H' < 1.5$), moderate ($1.5 \leq H' \leq 3.5$), or high ($H' > 3.5$), by using the formula [18]:

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

Evenness (E) was determined using the Shannon-Wiener equitability index, by using the formula [19, 20]:

$$E = \frac{H'}{\ln(S)} \quad (2)$$

Both indices were verified using PAST 4.03 software. A T-test compared small mammal composition between areas, and SPSS software was used for further statistical analysis of species and individual counts.

3. Result and Discussion

3.1 Result

3.1.1 Checklist of Small Mammals in Disturbed and Undisturbed Areas

Four species of small mammals from four genera representing three families were captured in both areas (Table 2). The non-volant group included three species: the Common Treeshrew (*Tupaia glis*) and Long-tailed Giant Rat (*Leopoldamys sabanus*) from the family Tupaiidae, both classified as Least Concern (LC), and the Rajah Spiny Rat (*Maxomys rajah*) from the family Muridae, classified as Vulnerable (VU). The volant group featured one species, the Trefoil Horseshoe Bat (*Rhinolophus trifoliatius*) from the family Rhinolophidae, listed as Near Threatened (NT) (IUCN, 2024). The small mammals were shown in Fig. 3 and Fig. 4.

Table 2 List of small mammals captured in both areas

Group	Family	Genus	Scientific name	Common name	IUCN status
Non-volant	Tupaiidae	Tupaia	<i>Tupaia glis</i>	Common Treeshrew	LC
	Muridae	Leopoldamys	<i>Leopoldamys sabanus</i>	Long-tailed Giant Rat	LC

		Maxomys	<i>Maxomys rajah</i>	Rajah Spiny Rat	VU
Volant	Rhinolophidae	Rhinolophus	<i>Rhinolophus trifolius</i>	Trefoil Horseshoe Bat	NT

* LC=Least Concern; NT=Near Threatened; VU=Vulnerable



Fig. 3 (a) Common Treeshrew (*Tupaia glis*); (b) Long-tailed Giant Rat (*Leopoldamys sabanus*)



Fig. 4 (c) Rajah Spiny Rat (*Maxomys rajah*); (d) Trefoil Horseshoe Bat (*Rhinolophus trifolius*)

3.1.2 Species Distribution and Abundance of Small Mammals

Table 3 highlights the distribution and abundance of 18 small mammals captured in disturbed (seven individuals) and undisturbed (11 individuals) areas. *Tupaia glis* was the most abundant species, accounting for 72.2% (13 individuals), with more observed in the undisturbed area (nine individuals) than in the disturbed area (four individuals). Out of the 13 individuals caught, nine were male, but not all could be sexed because some escaped after nail polish was applied and before their sex could be determined, and they were never recaptured [20]. *Leopoldamys sabanus* was found only in the disturbed area (two males individuals, 11.1%), while *Maxomys rajah* was equally distributed across both areas (one individual each, total accounting for 11.1%), all male. The volant species *Rhinolophus trifolius* was exclusively found in the undisturbed area, represented by one male (5.6%).

Table 3 Species distribution and abundance of small mammals across both areas

Species	Study areas		Number of individuals (n)	Relative abundance (%)	Sex (Male/Female)
	Disturbed area	Undisturbed area			
<i>Tupaia glis</i>	4	9	13	72.2	9/0
<i>Leopoldamys sabanus</i>	2	0	2	11.1	2/0
<i>Maxomys rajah</i>	1	1	2	11.1	2/0
<i>Rhinolophus trifolius</i>	0	1	1	5.6	1/0
Total of individuals (N)	7	11	18	100	14/0

3.1.3 Comparison of the Composition of Small Mammals Between Both Areas

Both disturbed and undisturbed areas showed equal species richness (three species each), but the undisturbed area had more individuals (11 individuals) than the disturbed area (seven individuals). Despite this, the disturbed area exhibited higher diversity ($H' = 0.9557$) and evenness ($E = 0.8699$) compared to the undisturbed area ($H' = 0.6002$, $E = 0.5463$), where *Tupaia glis* was dominant. The T-test results ($t = -0.442$, $p = 0.674$) indicated no statistically significant difference between the two areas (Table 4 and Table 5).

Table 4 Species richness, Shannon-Wiener Index and Evenness in both areas

	Disturbed area	Undisturbed area
Species richness	3	3
Total of individuals (N)	7	11
Shannon-Wiener Index (H')	0.9557	0.6002
Shannon-Wiener equitability index (E)	0.8699	0.5463

Table 5 Descriptive statistics of T-test

Study site	N	Mean	Standard Deviation	Standard Error of the Mean
Disturbed area	4	1.7500	1.7078	0.8539
Undisturbed area	4	2.7500	4.1933	2.0966

3.1.4 Mean Body Measurement of small mammals

The average body measurements for both non-volant and volant small mammals are presented in Table 6. All measurements were recorded in millimetres.

Table 6 Mean body measurement of non-volant and volant small mammals

Non-volant species	Tail length	Hind foot length	Forearm length	Ear size	Body length
<i>Tupaia glis</i>	176.1 N = 9	45.0 N = 8	58.1 N = 8	18.8 N = 8	189.4 N = 8
<i>Leopoldamys sabanus</i>	210.0 N = 2	37.5 N = 2	42.5 N = 2	20.0 N = 2	190.0 N = 2
<i>Maxomys rajah</i>	140.0 N = 2	35.0 N = 2	37.5 N = 2	25.0 N = 2	152.5 N = 2
Volant Species	Wingspan	Hind foot length	Forearm length	Ear size	Tail length
<i>Rhinolophus trifolius</i>	300.0 N = 1	30.0 N = 1	50.0 N = 1	20.0 N = 1	25.0 N = 1

3.2 Discussion

The three recorded non-volant species belonged to two families, Tupaiidae and Muridae. *Tupaia glis*, the sole representative of the family Tupaiidae, was more abundant in the undisturbed area (nine individuals) compared to the disturbed area (four individuals). This species prefers lowland forests and is mainly ground-active [21, 22] rather than peat swamp habitats. It is typically found near human settlements, plantations, orchards, secondary woods, and dipterocarp forests [23], with the lowland forest likely contributing to its higher abundance in undisturbed areas. Two species from the family Muridae, *Leopoldamys sabanus* and *Maxomys rajah*, were identified. Previous studies have shown higher capture rates for *Leopoldamys sabanus* in Meranti and hill Dipterocarp forests, with capture rates four times higher than *Tupaia glis* in the Pasoh Forest Reserve [24]. Similarly, *Leopoldamys sabanus* has been predominantly found in primary mixed-dipterocarp forests [25]. However, this study recorded only two individuals of *Leopoldamys sabanus*, possibly due to the prevalence of peat swamps and lowland forests in the study area [20].

Maxomys rajah, a common forest rat, is widely distributed across Southeast Asia, including Peninsular Thailand, Malaysia, Sumatra, Borneo, and nearby islands [26, 27]. It thrives in peat swamp forests, primary and secondary lowland forests up to 1100 meters in elevation, and occasionally in plantations near forested areas [27]. This study confirmed that *Maxomys rajah* occupies diverse habitats, including peat swamps and lowland

forests in both disturbed and undisturbed areas. *Rhinolophus trifoliatus*, an insectivorous bat, is typically found in lowland forests such as primary, secondary, and mangrove forests but struggles to survive in disturbed environments like plantations or farmland. It uses echolocation to detect flying insects while perched before catching its prey [28]. In this study, it was the only volant species recorded and is considered naturally rare in AHUFR, showing low population density.

To enhance bat capture rates, it is advised to use at least three mist net stations nightly and relocate the nets daily, as bats quickly adapt to net placements, reducing effectiveness [29]. Additionally, longer sampling periods of at least five nights, preferably a week, are recommended to improve data reliability [29]. Weather variations, including rainfall, wind, and temperature, also influence small mammal activity and catchability [30, 31]. The study recorded a male-biased sex composition, with 14 males and no females. This imbalance may result from sampling bias, behavioural differences, or ecological factors. Females, being more trap-shy, often stay near the nest while pregnant or nursing, reducing their likelihood of capture [20, 32, 33]. Additionally, the skewed ratio could result from the short study duration and small sample size [20].

KLNFR in Selangor, primarily composed of peat swamp and lowland dipterocarp forests, shares similar vegetation with AHUFR [10, 34]. However, KLNFR exhibited higher species richness, recording eight species compared to AHUFR's four species. This difference is likely due to KLNFR's more extensive sampling, which involved 50 cage traps, 10 mist nets, and two harp traps over five days, whereas AHUFR used only 24 cage traps and four mist nets over 12 days [10].

The T-test in this study revealed no statistically significant difference in small mammal composition between disturbed and undisturbed areas, as the p-value exceeded 0.05. This lack of significance may result from poorly defined boundaries between the disturbed and undisturbed areas. Generally, undisturbed areas with denser and more diverse vegetation support greater species richness, whereas disturbed areas, impacted by human activities such as deforestation and construction, exhibit lower tree density and increased light exposure due to open spaces [35].

4. Conclusion

This research successfully met its objectives by creating a checklist of small mammals and comparing their composition between disturbed and undisturbed areas in AHUFR. Four species were recorded: *Tupaia glis*, *Leopoldamys sabanus*, *Maxomys rajah*, and *Rhinolophus trifoliatus*. The undisturbed areas had a higher abundance (11 individuals) compared to disturbed areas (seven individuals), with *Tupaia glis* being most abundant. However, the disturbed areas had a higher Shannon-Wiener diversity index, reflecting a more even species distribution. Despite these findings, the T-test showed no statistically significant difference in small mammal composition between the two areas. This study provided baseline data on small mammals in AHUFR, marking a critical first step in understanding peat swamp biodiversity and aiding conservation efforts.

The research faced limitations, including unpredictable weather, environmental obstacles like fallen trees, and disturbances from monkeys damaging equipment and altering mammal behaviour. The closure of the planned study site and deep swamp areas also limited the scope and accuracy of the study. These challenges emphasized the need for flexibility in ecological research. Future studies should extend the sampling period to at least one year with repeated sampling to improve data accuracy, increase trap numbers, and explore alternative trapping methods like harp and camera traps. Using varied bait types beyond bananas could also improve species diversity and capture rates.

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Conflict of Interest

The author confirms that there are no conflicts of interest regarding the publication of the paper.

Author Contribution

The authors confirm contributions to the paper as follows: study conception and design: Sim Sin Rou; data collection: Sim Sin Rou; analysis and interpretation of results: Sim Sin Rou, Arney Sapaat; draft manuscript preparation: Sim Sin Rou, Arney Sapaat. All authors reviewed the results and approved the final version of the manuscript.

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