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DIVERSITY OF NON-VOLANT SMALL MAMMALS IN PULAU TINGGI, JOHOR, MALAYSIA

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Abstract: A non-volant small mammal survey was conducted at Pulau Tinggi between July and September 2019. This study aimed to provide baseline data for non-volant small mammals in Pulau Tinggi by setting 55 cage traps and 20 pitfalls for 44 trapping nights. A total of 20 individuals of non-volant small mammals were documented, representing five species from three families: Soricidae, Sciuridae and Muridae. The Rajah spiny rat (*Maxomys rajah*) and the Red spiny rat (*Maxomys surifer*) were the most abundant species (n=6) of non-volant small mammals in Pulau Tinggi. The Malayan field rat (*Rattus tiomanicus*) was the least species (n=1). The Malayan shrew (*Crocidura malayana*) is the only shrew recorded on the island. The analysis of similarities between our study site and other Malaysian islands reveals that Pulau Tinggi shares more similarities with Pulau Pangkor and Pulau Perhentian than Pulau Tioman. The small mammal richness on Pulau Tinggi is relatively low compared to other islands, most likely due to the study site's limited coverage and time constraints. Long-term monitoring is required to determine the true diversity of species and distribution of small mammals on Pulau Tinggi.

Keywords: Non-volant small mammals, diversity, Pulau Tinggi, island biogeography, South China Sea.

Introduction

Pulau Tinggi is about 32 km from Mersing on the mainland. It covers an area of 152418 hectares, one of the largest islands in Johor state (Omar *et al.,* 2011). The island consists of two villages, which are Kg. Pasir Panjang and Kg. Tg. Balang. The villages are surrounded by primary and secondary forests, hills, caves, mangrove areas and marine ecosystems. Pulau Tinggi has the highest peak at 625 m above sea level (Escobar *et al.,* 2003). In 1994, it was gazetted as a Marine Park under the Fisheries Act 1985. The Pulau Tinggi Marine Park comprises 13 islands including Pulau Harimau, Pulau Mensirip, Pulau Goal, Pulau Besar, Pulau Tengah, Pulau Hujong, Pulau Rawa, Pulau Tinggi, Pulau Mentinggi, Pulau Sibu, Pulau Sibu Hujung, Pulau Pemanggil and Pulau Aur (Department of Marine Park Malaysia).

Over the last 20 years, many ecological studies on non-volant small mammals in Malaysia have been conducted in various habitats to document the diversity, distribution, behaviour and observation of new records (Shukor, 2001; 2007; Turner *et al.,* 2003; Tamblyn *et al.,* 2005; Bernard *et al.*, 2009; Md-Tamrin *et al.*, 2010; Adrus *et al.*, 2011; Tingga *et al.*, 2012; Lit *et al.*, 2012; Jayaraj *et al.*, 2012; 2019; Rahim *et al.*, 2016; Shazali *et al.*, 2016; Mohd-Taib *et al.*, 2019; William-Dee *et al.*, 2019). These studies also include documentation of small non-volant mammals in the island habitat. Diversity studies on non-volant small mammals took place on the islands of Malaysia, including Pulau Tioman (21 species) (Lim *et al.*, 1999), Pulau Perhentian (12 species) (Turner *et al.*, 2003; Tamblyn *et al.,* 2005; Rahim *et al.*, 2016), Pulau Langkawi (19 species) (Medway, 1986; Shukor *et al.,* 2007; Lit

et al., 2012) and Pulau Pangkor (nine species) (Shafiz *et al.*, 2012; Jayaraj *et al.,* 2019; Mohd-Taib *et al.,* 2019).

Although many studies on biodiversity have been done in Pulau Tinggi (Azman *et al.,* 2008; Lim *et al.,* 2012; Chew *et al.,* 2014; Tan *et al.,* 2018; Shuaib *et al.,* 2018), no information on non-volant small mammals is available for the island. Therefore, this survey aimed to provide baseline data on non-volant small mammals of Pulau Tinggi. The findings were compared to similar studies done on other islands of Malaysia.

Materials and Methods

The field sampling was conducted at Pulau Tinggi (2° 18' N, 104° 07' E) from 12th July to 8th August and from 20th August to 4th September 2019 (Figure 1). The study area was divided into five sites: Site A, Site B, Site C, Site D and Site E (Figure 2). Site A was within the resort area, including a herb garden, orchard, mini zoo and chalet. Site B was at the Kampung Tanjung Balang comprised of a banana orchard, peat swamp and bushes. Site C and D were along the primary and secondary forest trails, respectively. Site E was at the grassland area situated near the forest edge.

Sampling Method and Species Identification

This survey used 55 cage traps and 20 pitfall traps along the trail. The traps were on the forest floor, approximately ten metres away from each trap. The traps had been baited with bananas, pineapples and dried fish. Pitfall traps were buried and their rim was adjusted according to the same ground level (William-Dee *et al.,* 2019). All traps were checked twice a day at 0800 hours and 1700 hours. The trapping effort was calculated by the total number of traps multiplied by the number of sampling days (Md. Tamrin *et al.,* 2010). The identification of individuals captured was done based on descriptions by Francis *et al.* (2008) and Phillips and Phillips (2016). Morphological measurements such as total length, tail length (T), head and body length, and hindfoot length (HF) were taken using a digital vernier calliper and weighted using the Pesola spring balance (Tingga *et al.,* 2012). Selected voucher specimens were euthanised using chloroform and underwent skinning procedures. The liver and muscle tissues were excised and stored in

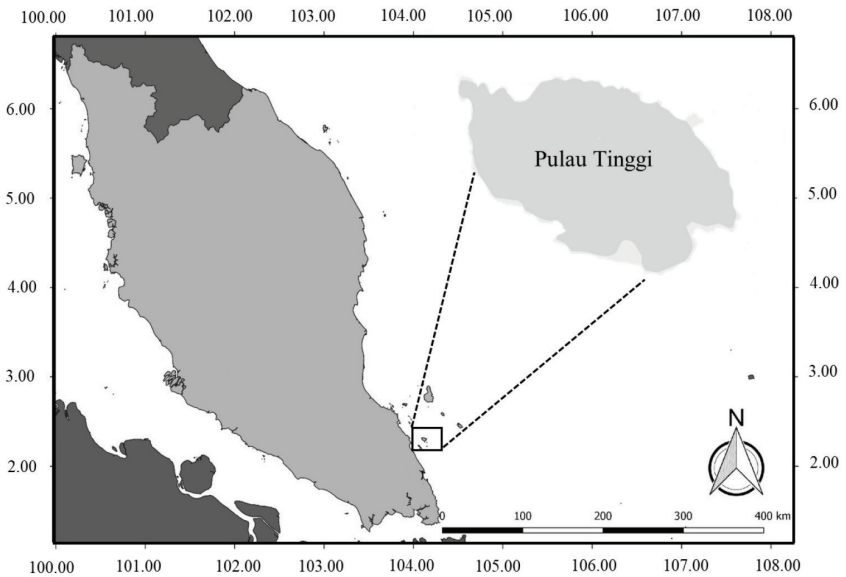

Figure 1: Map showing the location of Pulau Tinggi in Peninsular Malaysia

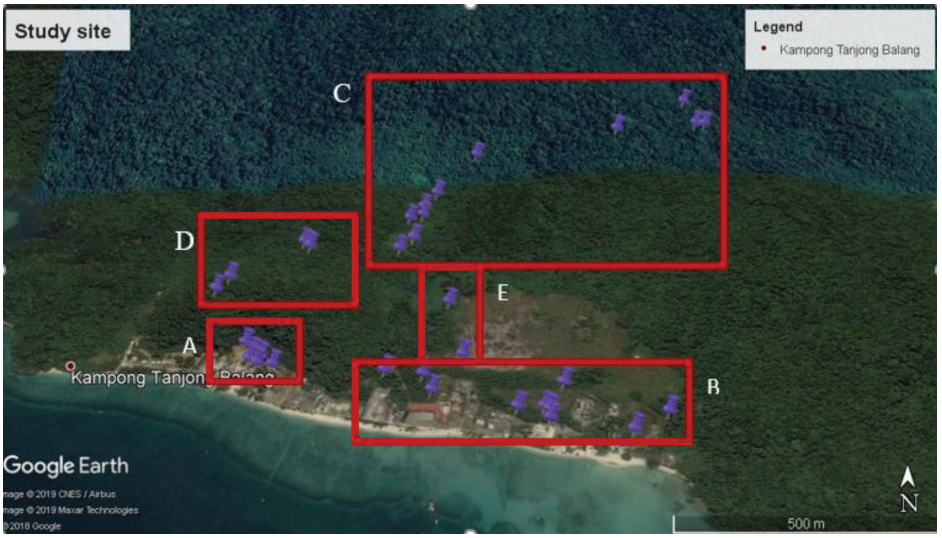

Figure 2: The mapping of the study site in Pulau Tinggi (Google Earth Pro, 2019)

75% ethanol. The samples were then deposited at the Universiti Tun Hussein Onn Malaysia (UTHM) zoological museum.

Data Analysis

The richness of the species was calculated by the total number of species caught and the relative abundance was estimated by the total number of individuals per species divided by the total number of individuals. The Shannon-Wiener Diversity Index (H') has been used to estimate species diversity in Pulau Tinggi, which is sensitive to changes in the abundance of rare species in the community (Solow, 1993). The Shannon index has been calculated using PAST software (Hammer *et al.,* 2001). The phenogram was generated to compare the species richness of non-volant small mammals documented in four islands of the Peninsula of Malaysia. The absence and presence matrices of the species recorded in all the locations served as the basis for comparisons for the cluster analysis (Tingga *et al.,* 2012). The selected sites include Pulau Perhentian (Turner *et al.,* 2003; Tamblyn *et al.*, 2005; Rahim *et al.,* 2016; Baki *et al.*, 2021), Pulau Tioman (Lim *et al.,* 1999) and Pulau Pangkor (Shafiz *et al.,* 2012; Jayaraj *et al.,* 2019; Mohd-Taib *et al.,* 2019). A Venn diagram was produced to determine the shared and unique non-volant small mammal species for comparison among other islands.

Result and Discussion

This survey captures 20 individuals of non-volant small mammals, representing five species from three families: Soricidae, Sciuridae and Muridae (Table 1). The most abundant species of non-volant small mammals were the Rajah spiny rat (*Maxomys rajah*) and the Red spiny rat (*Maxomys surifer*), each with six individuals. It was followed by Malayan shrew (*Crocidura malayana*) and Plantain squirrel (*Callosciurus notatus*) with four and three individuals, respectively. The Malayan field rat (*Rattus tiomanicus*) was recorded as singleton.

Comparison with Other Malaysia Islands

The study's findings were compared to those of three other Malaysian islands: Pulau Perhentian, Pulau Tioman and Pulau Pangkor. There are 29 species of non-volant small mammals found on those islands (Table 2). Pulau Tioman has the greatest diversity of non-volant small mammals (21 species), followed by Pulau Perhentian (14 species), Pulau Pangkor (nine species) and

Table 1: Taxonomic composition of non-volant small mammals in Pulau Tinggi

No.	Family Species	N	Relative Abundance (%)	IUCN 2022	DWNP 2017
	Soricidae				
1	*Crocidura malayana*	4	20	LC	DD
	Sciuridae				
2	*Callosciurus notatus*	3	15	LC	LC
	Muridae				
3	*Maxomys rajah*	6	30	VU	LC
4	*Maxomys surifer*	6	30	LC	LC
5	*Rattus tiomanicus*	1	5	LC	LC
	Total individual	20	100		
	Shannon-Weiner (H')	1.48			
	Total species	5			

LC=Least Concern, VU=Vulnerable, DD=Data Deficient

Table 2: Taxonomic comparison of non-volant small mammals' diversity between Pulau Tinggi with other islands

No.	Family Species	This Study	Pulau Perhentian [a,b,c,d]	Pulau Tioman[e]	Pulau Pangkor [f,g,h]
	Erinaceidae				
1.	*Hylomys suillus*	-	-	+	-
	Soricidae				
2.	*Crocidura malayana*	+	+	-	-
3.	*Crocidura negligen*	-	-	+	-
	Tupaiidae				
4.	*Tupaia glis*	-	+	+	+
	Cynocephalidae				
5.	*Galeopterus variegatus*	-	+	+	+
	Lorisidae				
6.	*Nycticebus coucang*	-	-	+	+
	Viverridae				
7.	*Paradoxurus hermaphroditus*	-	-	+	-
	Tragulidae				
8.	*Tragulus napu*	-	-	+	-
	Sciuridae				
9.	*Ratufa bicolour*	-	-	+	-
10.	*Callosciurus notatus*	+	+	+	+
11.	*Callosciurus nigrovittatus*	-	-	+	-
12.	*Sundasciurus tenuis*	-	-	+	-

13.	*Lariscus insignis*	-	-	+	-
14.	*Rhinosciurus laticaudatus*	-	-	+	-
15.	*Petaurista petaurista*	-	-	+	-
16.	*Iomys horsfieldii*	-	-	+	-
	Muridae				
17.	*Rattus rattus*	-	+	-	+
18.	*Rattus tanezumi*	-	+	-	-
19.	*Rattus tiomanicus*	+	+	+	+
20.	*Rattus argentiventer*	-	+	-	-
21.	*Rattus exulans*	-	-	+	-
22.	*Sundamys muelleri*	-	+	-	-
23.	*Sundamys annandalei*	-	+	-	-
24.	*Niviventer cremoriventer*	-	-	+	-
25.	*Leopoldamys sabanus*	-	-	+	+
26.	*Maxomys rajah*	+	+	-	+
27.	*Maxomys surifer*	+	+	+	+
28.	*Maxomys whiteheadi*	-	+	-	-
	Hystericidae				
29.	*Atherurus macrourus*	-	-	+	-
	No. of family	3	5	10	5
	No. of species	5	14	21	9

[a]Rahim *et al.,* 2016, [b]Tamblyn *et al.,* 2005, [c]Turner *et al.,* 2003, [d]Baqi *et al.,* 2021, [e]Lim *et al.,* 1999, [f]Shafiz *et al.,* 2012, [g]Jayaraj *et al.,* 2019, [f]Mohd-Taib *et al.,* 2019, + = present, - = absent

Pulau Tinggi (five species). These islands shared three species of small mammals: *C. notatus*, *R. tiomanicus* and *M. surifer* (Figure 3).

Meanwhile, 13 and five species are unique to Pulau Tioman and Pulau Perhentian, respectively. The phenogram (Figure 4) shows the comparison of four sites in cluster analysis resulted in two groups. Pulau Tinggi clustered with Pulau Pangkor as the islands have close relationships in species richness, followed by Pulau Perhentian. However, the distance between Pulau Tinggi and Pulau Tioman is close compared to other islands. The two islands show a distant relationship in terms of species richness. According to island biogeography theory, an organism's richness depends on the size and remoteness of the island (MacArthur & Wilson, 2016). The size of the island affects its biological diversity since larger islands have a wider choice of habitats, forcing species to diversify to fill existing niches (MacArthur & Wilson, 2016). This theory is supported by the

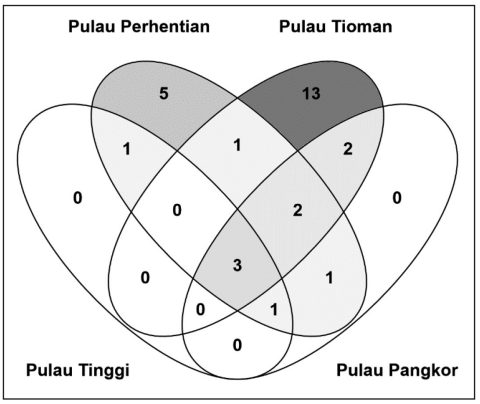

Figure 3: The Venn diagram illustrates the number of shared and unique non-volant small mammals across other Malaysia's islands

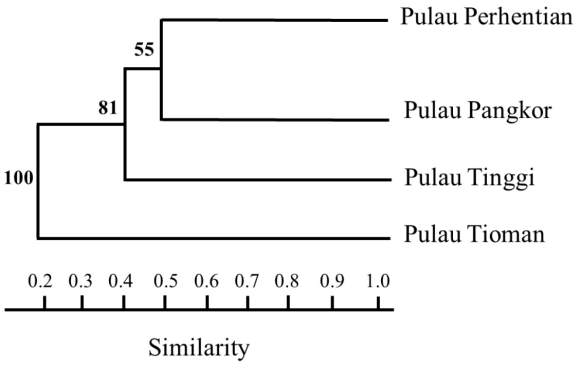

Figure 4: Phenogram of the comparison between Pulau Tinggi with other islands of Peninsular Malaysia

richness of small mammal species on Tioman Island (138km^2), which is nearly ten times the size of Pulau Perhentian (15.35km^2), Pulau Pangkor (18km^2) and Pulau Tinggi (14.85km^2).

Rodents are the most common non-volant small mammals on Pulau Tinggi. All rodent species recorded on Pulau Tinggi were cosmopolitan species that were highly adaptable to modified landscapes such as secondary forests, fruit orchards and housing (William-Dee *et al.*, 2019). The most abundant non-volant small mammals on Pulau Tinggi were *Maxomys rajah* and *Maxomys surifer*. Both species are extremely rare in sympatry (Francis, 2008). However, both species appear to be common and coexist on Peninsular Malaysia's islands (e.g., Pulau Tinggi, Pulau Pangkor and Pulau Perhentian). The IUCN Red List of Threatened Species classified *Maxomys rajah* as vulnerable (Ruedas, 2016) but the DWNP redlist (2017) classified it as least concern suggesting the species is common in Malaysia. Meanwhile, the IUCN (Aplin, 2016a) and DWNP redlist (2017) classify *Maxomys surifer* as the least concern.

Three rodent species, *R. tiomanicus*, *M. surifer* and *C. notatus* can be island generalists because they are on other Malaysian islands (e.g., Pulau Pangkor, Pulau Tioman and Pulau Perhentian). An individual of *R. tiomanicus* was recorded at Pulau Tinggi. Its range includes plantations, grassland, gardens, orchards, scrub and disturbed secondary forests. On Pulau Tioman, *R. tiomanicus* ranges from lowland to hill forests. This species is semi-arboreal; it spends much time in the trees during the day and at night on the ground (Lim, 2015). It is omnivorous and its diet consists primarily of insects, land mollusks, roots and fruits. It has become a major pest in crop habitats (e.g., oil palm), causing significant damage (Lim, 2015). The IUCN (Aplin, 2016b) and DWNP redlist (2017) classified it as the least concern.

The Plaintain squirrel (*C. notatus*) is a common squirrel that lives in various habitats, including secondary forests, mangroves and plantation and semi-urban areas (Francis, 2008; Phillips & Phillips, 2016). In Malaysia, *C. notatus* is classified as a secondary pest of agriculture, making opportunistic visits to crop fields to obtain food (Lim, 2016). Unlike primary pests, which are well-adapted permanent residents of crop habitats, secondary pests cause relatively little damage (Lim, 2016). IUCN (Duckworth, 2016) and DWNP (2017) listed it as the least concern with an increasing population trend. The Malayan shrew (*C. malayana*) is the only shrew species found on Pulau Tinggi. The species is restricted to Peninsular Thailand and Malaysia south of the Isthmus of Kra and several offshore islands (Hutterer, 2005). Previously, it was also reported in Pulau Perhentian (Rahim *et al.*, 2016). This species is terrestrial and has been found in both hill and lowland forests (Francis, 2008). It was globally listed as the least concern (Cassola, 2016). However, it was listed as data deficient at the national level due to a lack of ecological and distribution data (DWNP, 2017).

Like other Malaysian island habitats, biodiversity on Pulau Tinggi is particularly threatened by habitat loss caused by the tourism sector and human settlement development. Development in Pulau Tinggi is currently under control and is restricted to coastal land areas. However, continuous landscape changes in Pulau Tinggi will negatively impact the island's biodiversity in the future, particularly in small mammal diversity. The richness of small mammals in Pulau Tinggi is considerably low compared to other islands in Malaysia. The scarcity of individuals and species suggests that surveys of small mammals in Pulau Tinggi are still insufficient. The reason for this is that the study site is only concentrated in coastal habitats on the island. Long-term monitoring of forest areas in Pulau Tinggi is urgently needed to determine the true diversity of species and the distribution of small mammals on the island. Information on small mammal communities in Pulau Tinggi is important for local authorities in developing management and conservation plans, particularly in identifying and controlling populations of invasive species such as rodents (e.g., *Rattus tiomanicus*) which can cause significant economic and biodiversity losses on the island.

Conclusion

This study successfully provided a preliminary checklist of small non-volant mammals in Pulau Tinggi. A total of five species from three small mammal families have been successfully recorded on the island. The study found that the family Muridae is the dominant group of small mammals in Pulau Tinggi. The richness of small mammal species in Pulau Tinggi was also lower than in other islands in Malaysia (e.g., Pulau Tioman, Pulau Perhentian and Pulau Pangkor). The short sampling period during the study and the small coverage of the study site may explain this variation. Longer studies covering unexplored areas need to be conducted in the future to assess the species richness, distribution and ecology of small mammals on the island.

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