TROPICAL LIFE SCIENCES RESEARCH

Comparative Distribution of Small Mammals Diversity in Protected and Non-Protected Area of Peninsular Malaysia

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DOI: https://doi.org/10.21315/tlsr2019.30.2.10

Highlights

- An individual of *Bandicota indica* was recorded at Wang Kelian SP and is the first record for this site. This finding of this species in a primary forest shows the extension of its range.
- A single individual of *Crocidura monticola* and *Suncus etruscus* were caught at Ulu Gombak FR. The record of these two forest species indicates that Ulu Gombak FR, which is close to populated area, still holds quality habitat. The two shrew species were commonly found in forests with little or no disturbance.
- Listed as Vulnerable by IUCN Red List, *Murina aenea* was recorded at Sungkai WCC, highlighting the importance of the conservation centre as roosting site and eliminates the threat of habitat loss.

Tropical Life Sciences Research, 30(2), 131–147, 2019

Comparative Distribution of Small Mammals Diversity in Protected and Non-Protected Area of Peninsular Malaysia

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Published date: 18 July 2019
To cite this article: Julius William-Dee, Faisal Ali Anwarali Khan, Qhairil Rosli, Muhd Amsyari Morni, Isham Azhar, Lee Sim Lim, Roberta Chaya Tawie Tingga and Mohd Ridwan Abdul Rahman. (2019). Comparative distribution of small mammals diversity in protected and non-protected area of Peninsular Malaysia. *Tropical Life Sciences Research* 30(2): 131–147. https://doi.org/10.21315/tlsr2019.30.2.10
To link to this article: https://doi.org/10.21315/tlsr2019.30.2.10

Abstrak: Pembangunan yang semakin pesat di Malaysia telah meningkatkan bilangan aktiviti antropogenik, sekaligus menyebabkan kemerosotan alam sekitar. Ini menunjukkan bahawa perlunya inventori hidupan liar dan sumber alam sekitar dijalankan di dalam kawasan hutan yang sedia ada, untuk mempromosikan peningkatan yang seimbang dalam pelan pemuliharaan dan pengurusan yang sedia ada, terutamanya untuk haiwan yang terancam seperti spesies mamalia kecil. Kajian mamalia kecil telah dijalankan di Tasik Bera, Hutan Simpan Ulu Gombak, Pusat Konservasi Hidupan Liar Sungkai, Pulau Pinang, dan Taman Negeri Wang Kelian. *Harp trap, mist net, cage trap* dan *pitfall trap* telah dipasang untuk kajian. Spesies *Rhinolophus affinis* (N = 61) merupakan spesies yang paling banyak ditangkap, diikuti dengan *R. Lepidus* (N = 27). Manakala untuk mamalia kecil tidak terbang, species *Leopoldamys sabanus* merupakan spesies paling banyak (N = 33) diikuti dengan *Maxomys rajah* (N = 25) dan *Tupaia glis* (N = 22). Dua spesies cencurut, *Suncus etruscus* dan *Crocidura monticola* masing-masing telah ditangkap dengan jumlah satu individu bagi setiap satu spesies. Hutan Simpan Ulu Gombak merekodkan kepelbagaian spesies yang paling tinggi (*H'* = 2.754), manakala Pulau Pinang merekodkan nilai yang paling rendah (*H'* = 2.245). Senarai mamalia kecil yang telah direkodkan melalui kajian ini merupakan maklumat yang signifikan bagi tujuan pemantauan dan konservasi biodiversiti.

Kata kunci: Antropogenik, Cencurut, Inventori, Kelawar, Tikus

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Abstract: Rapid urbanisation in Malaysia has led to an increase in anthropogenic activities, inducing degradation of the natural environment. This advocates the necessity of wildlife and resource inventories be conducted at available forested areas, promoting steady improvement in the existing conservation and management plans, especially for threatened taxa such as the small mammals. Small mammals surveys was conducted at Tasik Bera, Ulu Gombak Forest Reserve, Sungkai Wildlife Conservation Centre, Penang Island, and Wang Kelian State Park. Harp traps, mist-nets, cage traps and pitfall traps were set during the surveys. *Rhinolophus affinis* was the most abundant (N = 61) volant small mammal, followed by *Rhinolophus lepidus* (N = 27). Meanwhile, the most abundant non-volant small mammal are *Leopoldamys sabanus* (N = 33), followed by *Maxomys rajah* (N = 25), and *Tupaia glis* (N = 22). Two species of shrews, *Suncus etruscus* and *Crocidura monticola* were caught as singletons. The results indicated that Ulu Gombak Forest Reserve has the highest species diversity (*H'* = 2.754), whereas Penang Island recorded the lowest (*H'* = 2.245). The species lists of small mammals generated from the survey will be significant for various stakeholders' conservation and monitoring plans.

Keywords: Anthropogenic, Rodents, Inventories, Bats, Shrew

INTRODUCTION

Malaysia is one of the biodiversity hotspots in the tropical region of Southeast Asia, with a high multitude of faunal diversification. This is specifically important for small mammals that weigh less than 10 kg, which vastly contributes to their expanded home range. The diversity of mammals within the Malaysian territory is quite significant with at least 440 species of mammals recorded (Department of Wildlife and National Parks [DWNP] 2016), from which 15% (66 species) of it are endemic to Malaysia (Payne *et al*. 1985; Francis 2008).

There are at least seven new mammalian species discovered in Malaysia since the year 2000, signifying the prevailing faunal diversification in this region. Moreover, numerous species were discovered either through morphological or molecular analysis or the results of further exploration. These include *Rhinolophus chiewkweeae* from Johor (Yoshiyuki & Lim 2005), *Kerivoula krauensis* from Pahang (Francis *et al*. 2007), *Neofelis diardi diardi* from Sarawak (Wilting *et al*. 2007), *Neofelis diardi borneensis* from Sabah (Wilting *et al*. 2007), *Nycticebus spp.* from Borneo (see Munds *et al*. 2013), *Rhinolophus francisi* from Sabah (Soisook *et al*. 2015) and *Rhinolophus luctoides* (Volleth *et al*. 2015). These findings highlight the importance of wildlife inventories in providing useful information to uncover underrepresented diversity and to improve management plans.

The presence of various types of habitats plays a major role in the richness of Malaysia's diversity (Ashton 1969; Baillie *et al*. 1987; Debski *et al*. 2002). Authorities in Malaysia have identified the significance of preserving the natural environment as a part of protecting specific areas and their contents (wildlife and resources). In response to this, a total of 5,611,614 ha of the forest area has been gazetted (2.9 million ha in Peninsular Malaysia; 837,553.80 ha in Sarawak;

1,874,061.54 ha in Sabah) (Sarawak Forestry Corporation 2006; Sabah Forestry Department 2016; DWNP 2016). Peninsular Malaysia specifically has about 25% and 14% of lowland and hill dipterocarp forest, respectively, classified as totally protected area; most of the unprotected areas have been converted into human settlements, agriculture plots and industrial parks (DWNP 2016). Numerous researchers have little or no interest in non-protected areas due to the general assumption that anthropogenic activities and the loss of natural habitats influenced the carrying capacity, hence diminishing the biodiversity of affected areas. Consequently, the distribution and diversity of faunal species in non-protected areas are often overlooked, hindering the understanding of urban species and the potential for new discoveries. Regardless of the mentioned consequences, there are species that thrive in such environment as pests (e.g. *Suncus murinus, Rattus* spp.). Their adaptations to man-made structure and highly modified environment promotes their survival, which is a potential constituent that permits diversification, denoting that such areas are too, pivotal for scientific discoveries.

Intensive urbanisation and the increase in anthropogenic activities have been sourced out as great concern towards biodiversity conservation (Sodhi *et al*. 2010). This underlines the need of inventories data to aid authorities in improving their present conservation and management plans. Information provided in this manuscript corroborate the significance of such information by providing species composition and distribution of volant and non-volant small mammals in various areas with contrasting habitats in Peninsular Malaysia.

MATERIALS AND METHODS

Study Areas

The study areas were classified into three categories, namely urban, suburban and forested. The categorisation of sites was done based on the frequency of human activities in the surrounding areas, distance to human settlement or activities, types of forest, and the status of the forest (protected or non-protected). The urban area is defined as an area with the most number of human activities, lowest distance to human settlement, and is not protected or totally protected area. Suburban area is defined as an area with a moderate or limited number of human activities, the average distance to human settlement and is not a protected or totally protected area. The forested area is defined as an area with the least or zero number of human activities, highest distance to human settlement, and is protected or totally protected area.

Surveys were carried out at different time of the year at five distinct localities (Fig. 1, Table 1). The following are details on the survey, including a brief description of each sampling site.

Tasik Bera, Pahang

Tasik Bera, Pahang (Tasik Bera: 3°02.50'N; 102°39.25'E) (35 metres above sea level) consists of alluvial riparian swamp system from which 90% of the area is covered with swamp forest. It is the first internationally recognised Ramsar Site in Malaysia, situated at the southwest of Pahang. Tasik Bera is also famous as one of the tourist attraction spots in Pahang and is a protected area. Traps were set adjacent to the lake and swamp forest.

Universiti of Malaya Field Studies Centre, Ulu Gombak Forest Reserve, Selangor

Universiti of Malaya Field Studies Centre, Ulu Gombak Forest Reserve, Selangor (Ulu Gombak FR: 3°19'33.24''N; 101°45'16.92''E) (325 metres above sea level) is located on 120 hectares of secondary lowland evergreen forest (Omar *et al*. 2013) and primary forest, with Sungai Gombak flowing through the site. The study centre is managed by Universiti Malaya and is exclusive only to researchers with permission from the university. Trapping was conducted here along steep dipterocarp forest hill next to Sungai Gombak.

Sungkai Wildlife Conservation Centre, Perak

Sungkai Wildlife Conservation Centre, Perak (Sungkai WCC: 3°59'56.236''N; 101°18'419''E) (40 metres above sea level) was set up in 1971 and is situated in the western part of Perak. The reserve consists of primarily dipterocarp forest, this reserve, however, was subjected to selective logging in most of the area (Kamil *et al*. 2001). The main focus of this centre is to protect and breed Sambar deer (*Rusa unicolor*). This site is located about 15 km from Sungkai town and is a tourist attraction as well as a protected area.

Bukit Jambul, Moon Gate Recreational Park, Youth Park, Pulau Pinang

Bukit Jambul (5°24'51.005''N; 100°19'43.532''E), Moon Gate Recreational Park (5°24'53.716''N; 100°19'47.14''E) and Youth Park (5°25'16.256''N; 100°20'27.981''E) in Pulau Pinang are among the sites that are heavily visited by the public. Bukit Jambul has an altitude of 241 metres above sea level, Moon Gate Recreational Park (298 metres a.s.l), and Youth Park (204 metres a.s.l), which makes all of the sites a good hiking trail for the locals. Generally all sites (Pulau Pinang) are lowland dipterocarp forest and also recreational park which are accessible to the public. Trapping was done in a fragmented secondary forest surrounded by housing and urban landscape. All of the sites are not protected area.

Wang Kelian State Park

Wang Kelian State Park (Wang Kelian SP: 6°41'39.563"N; 100°11'28.575"E) (230 metres above sea level) is located at the northwest of Perlis within the Nakawan Range. It is established as the first protected area in the northern most Peninsular Malaysia. Among the main features of this park is the Wang Burma Cave I and II. It is a semi-deciduous forest and the only protected area in Peninsular with such vegetation type.

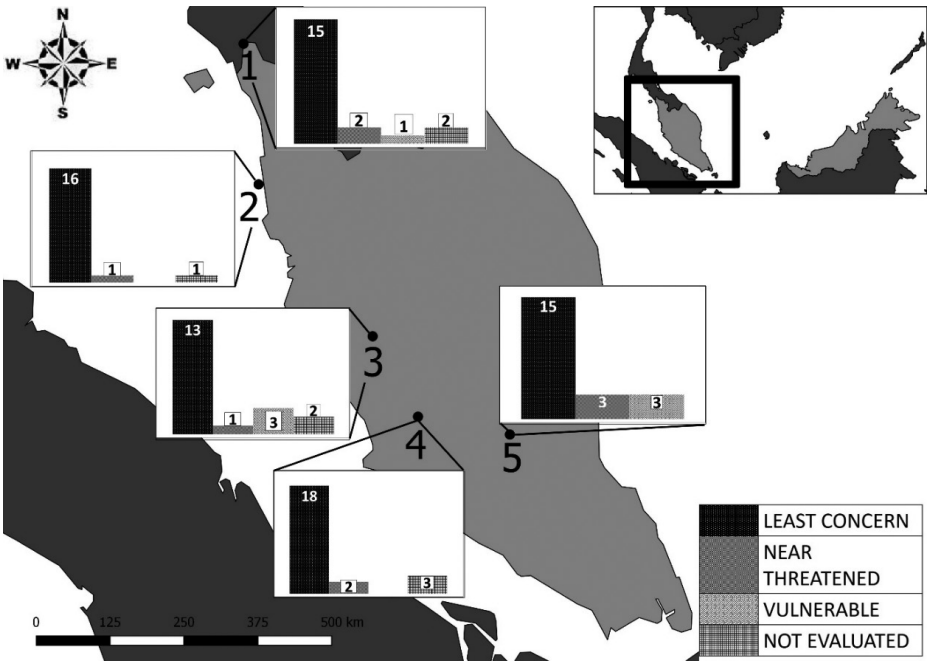

Figure 1: Location of study site (1 = Wang Kelian State Park; 2 = Penang Island; 3 = Sungkai Wildlife Conservation Centre; 4 = Ulu Gombak Forest Reserve; 5 = Tasik Bera). The bar graphs represent the number of species listed in the IUCN categories in each site.

Table 1: Sampling site in Peninsular Malaysia and survey period between May 2014 to January 2015.

Location	Degree of Urbanisation	Date
Tasik Bera, Pahang	Forested	8 –14 May 2014
Ulu Gombak Forest Reserve	Suburban	30 May–4 June 2014, 12–17 January 2015
Sungkai Wildlife Conservation Centre	Suburban	5 –11 June 2014
Pulau Pinang	Urban	27 December 2014 – 2 January 2015
Wang Kelian State Park	Forested	2–10 January 2015

Volant Small Mammals Sampling

An average of three to 10 mist-nets and four four-bank harp traps were set at various potential flyways for bats per survey night. Mist-nets and harp traps were checked every 15 min from 1830 h to 2100 h and for every subsequent hour thereafter. Species identification was done following Payne *et al*. (1985) and Francis (2008). Echolocations of bats were taken using EM3+ Echometer bat detector and analysed using Kaleidoscope software (Wildlife Acoustics). External body measurements were taken using callipers and weighed using Pesola spring balance. Measurements taken include forearm (FA), ear (E), tibia (TB), hind foot (HF), tail ventral (TV), total length (TL), and weight (WT).

Non-volant Small Mammals Sampling

One hundred cage traps and 60 pitfall traps with a distance of ten metres and five metres apart respectively were used to capture non-volant small mammals such as rodents, treeshrews and shrews. Cage traps baited with banana were set along the trails with distances ranging from 100 to 500 metres. Fifty pitfall traps were buried in the ground with its opening adjusted to the same level as the ground. Cage traps and pitfall traps were checked twice daily, in the morning and evening. All samples collected were identified based on Payne *et al.* (1985) and Francis, (2008). External body measurements were taken using callipers and weighed using Pesola spring balance. Measurements taken were ear (E), hind foot (HF), tail ventral (TV), head body (HB), and weight (WT).

Statistical Analyses

Different levels of disturbance or anthropogenic activities may have different effects on animal diversity. Species diversity index (Shannon-Wiener) is used to calculate the species richness of each selected localities. Indices for each locality were used to compare the diversity of each site. The species diversity index, Shannon-Wiener index (*H'*) and Evenness was calculated using Paleontological Statistics (PAST) software. Shannon-Wiener index shows both richness and abundance. It quantified the species richness and the number of individuals for each species within each community. Species evenness showed the gap in numbers between the species in the environment. *t*-test was used to compare the diversity indices between sites. Rarefaction analysis was calculated using R software. The rarefaction curves were used to calculate the species richness for a given number of individual samples.

RESULTS

Surveys at the five localities have successfully recorded a total of 50 species representing 11 families, from which 17 species were non-volant small mammals and 33 species were bats (Table 1). Overall, there were 295 individuals of captured bats from seven families, which include Pteropodidae (5 species), Nycteridae (1 species), Megadermatidae (1 species), Hipposideridae (8 species), Rhinolophidae (7 species), Emballonuridae (1 species), and Vespertilionidae (10 species). The vespertilionids were the most diverse family with 10 species recorded from three genera (*Kerivoula*, *Murina*, and *Tylonycteris*). Meanwhile, *Rhinolophus affinis* was the most abundant species with 61 individuals, from which 87% of them were captured from Penang Island. Five species were recorded as singletons, namely *Nycteris tragata, Megaderma spasma, Rhinolophus sedulus, Emballonura monticola,* and *Murina aenea* (Table 2).

A total of 110 individuals of rodents were captured in this survey, representing 14 species from two families. The most abundant species of non-volant small mammal was *Leopoldamys sabanus* with 33 individuals, followed by *Maxomys rajah* with 25 individuals. *Tupaia glis* (N = 22) was the only species recorded under the Order Scandentia. Two species of shrews, *Suncus etruscus* and *Crocidura monticola* were both captured from Ulu Gombak FR (Table 3). The most diverse site was Ulu Gombak FR with 23 species recorded, with the highest value of Shannon index (*H*' = 2.754), followed by Tasik Bera with 21 species (*H*' = 2.423) (Table 4). *Kerivoula pellucida, Hipposideros atrox,* and *R. affinis* were recorded from four out of the five sites. All sites except for Wang Kelian State Park and Penang Island have achieved asymptote (Fig. 2).

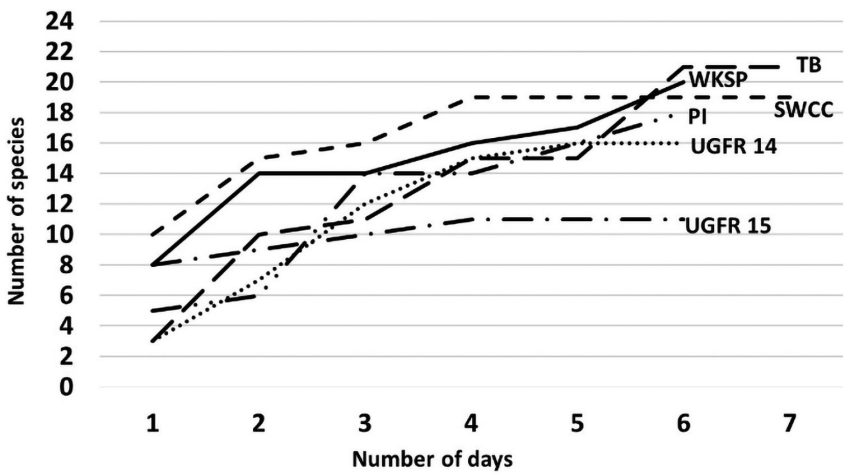

Figure 2: Cumulative graph on number of species caught at selected sites. TB = Tasik Bera, WKSP = Wang Kelian State Park, SWCC = Sungkai Wildlife Conservation Centre, UGFR 14 = Ulu Gombak Forest Reserve (sampling conducted on 2014), UGFR 15 = Ulu Gombak Forest Reserve (sampling conducted on 2015).

Table 2: Species list of bats recorded in Peninsular Malaysia.

Family	Species	Tasik Bera	Ulu Gombak Forest Reserve	Sungkai	Penang Island	Wang Kelian State Park	IUCN status
Pteropodidae	*Balionycteris maculata*	1	4	3			Least concern
	Cynopterus brachyotis	1	1	1	10	8	Least concern
	Cynopterus horsfieldii		3		7		Least concern
	Eonycteris spelaea				7		Least concern
	Megaerops ecaudatus		2			4	Least concern
Nycteridae	*Nycteris tragata*				1		Near threatened
Megadermatidae	*Megaderma spasma*				1		Least concern
Hipposideridae	*Hipposideros armiger*				5	4	Least concern
	Hipposideros atrox		2	1	14	5	Not evaluated
	Hipposideros bicolor			5			Least concern
	Hipposideros cervinus	1	10	5			Least concern
	Hipposideros cineraceus		2				Least concern
	Hipposideros diadema			1		4	Least concern
	Hipposideros larvatus					3	Least concern
	Hipposideros ridleyii	25					Vulnerable
Rhinolophidae	*Rhinolophus affinis*	1		1	53	6	Least concern
	Rhinolophus coelophylus					2	Not evaluated
	Rhinolophus lepidus			6	19	2	Least concern
	Rhinolophus luctus	1		2			Least concern
	Rhinolophus sedulus		1				Near threatened
	Rhinolophus stheno				1		Least concern
	Rhinolophus trifoliatus	4	1	6			Least concern

(*Continued on next page*)

Table 2 (*Continued*)

Family	Species	Tasik Bera	Ulu Gombak Forest Reserve	Sungkai	Penang Island	Wang Kelian State Park	IUCN status
Emballonuridae	*Emballonura monticola*		1				Least concern
Vespertilionidae	*Kerivoula hardwickii*	1	1		1	1	Least concern
	Kerivoula intermedia	2					Near threatened
	Kerivoula minuta	1				1	Near threatened
	Kerivoula papillosa	1	1	1		1	Least concern
	Kerivoula pellucida	3	1	4		2	Near threatened
	Murina aenea			1			Vulnerable
	Murina peninsularis		1	3			Not evaluated
	Murina suilla			5		2	Least concern
	Tylonycteris pachypus		4				Least concern
	Tylonycteris robustula		10				Least concern

Table 3: Species list of non-volant small mammals recorded in Peninsular Malaysia

Family	Subfamily	Species	Tasik Bera	Ulu Gombak Forest Reserve	Sungkai	Penang Island	Wang Kelian State Park	IUCN status
Rodentia	Muridae	*Bandicota indica*					1	Least concern
		Chiropodamys gliroides		1				Not evaluated
		Leopoldamys sabanus	7	3	3	4	16	Least concern
		Maxomys rajah	8				17	Vulnerable
		Maxomys surifer	3			8	9	Least concern
		Maxomys whiteheadi	5		2			Vulnerable
		Niviventer cremoriventer			1			Vulnerable
		Rattus exulans	1					Least concern
		Rattus rattus				3		Least concern
		Rattus tiomanicus	4			2		Least concern
		Sundamys muelleri		1	1	3		Least concern
	Sciuridae	*Callosciurus caniceps*	1					Least concern
		Callosciurus notatus	2	1		1		Least concern
		Lariscus insignis					2	Least concern
Scadentia	Tupaiidae	*Tupaia glis*	1	3		10	8	Least concern
Insectivora	Soricidae	*Suncus etruscus*		1				Least concern
		Crocidura monticola		1				Least concern

Table 4: Shannon Index and species evenness of small mammals.

	Tasik Bera	Ulu Gombak Forest Reserve	Sungkai Wildlife Conservation Centre	Penang Island	Wang Kelian State Park
Shannon index	2.423	2.754	2.723	2.245	2.634
Evennes	0.5369	0.6829	0.8017	0.5246	0.6962

DISCUSSION

The surveys has recorded 50 species, where 66% of the total species recorded were bats. The diversity index and evenness for Ulu Gombak FR (suburban area), Sungkai WCC (suburban area), and Wang Kelian SP (totally protected) were much higher compared to Tasik Bera (totally protected) and Penang Island (disturbed area). Interestingly, the highest number of individual caught was from Penang Island (N = 150), but it has the lowest diversity index and evenness (despite sampling at different sites). Most of the species recorded were cosmopolitan species, which may explain their tolerance toward heavily modified landscape, enabling the establishment of substantial colonies sustained by the available resources.

Volant Mammal Diversity

There were 33 species of bats recorded in this survey, with *R. affinis* (N = 61) as the most abundant species followed by *R. lepidus* (N = 27). Penang Island also recorded the highest number of bats individual (N = 119), revealing wide diversity with 12 species from six families. Ulu Gombak FR has the highest species richness with 16 species, followed by Sungkai WCC (15 species) and Wang Kelian SP (14 species). These three sites are protected areas, thus are expected to have higher species richness.

Cynopterus brachyotis was common throughout this survey where it was caught in all of the five sites. This species can be found in habitats ranging from secondary forest to gardens (Mohd-Azlan *et al*. 2010; Corbet & Hill 1992). Its diet mainly consists of fruits, flowers, and leaf fractions which enables them to be found abundant across the region (Csorba *et al*. 2008). *Rhinolophus coelophyllus*, a species known to be widely distributed in Thailand (Ith *et al*. 2011), was caught in this study at Wang Kelian SP. This species can be found ranging from northern Myanmar to northern Malaysia, but scarcely recorded in Malaysia (Kedah and Langkawi) (Ith *et al*. 2011), and was not recorded in other sites for this study. Penang Island recorded the highest number of *R. affinis* (N = 53) which is known to forage in forest understorey, man-made habitats, agriculture area, and secondary forest (Kingsada *et al*. 2011). Insects are abundant in understorey and agriculture area due to high nutrient availability (Karolewski *et al*. 2013), thus providing suitable foraging area and roosting sites for *R. affinis* which is also known to roost in large colonies (Kingsada *et al*., 2011).

Non-volant Mammal Diversity

Leopoldamys sabanus was the most abundant species throughout the sampling where 16 individuals of this species were caught in a single site at Wang Kelian SP. An individual of *Bandicota indica* was recorded at Wang Kelian SP and is the first record for this site. This species was introduced to the northern part of Peninsular Malaysia (Kedah and Perlis) and is widely distributed in southern Asia (Musser & Carleton 2005). *Bandicota indica* can be found in the paddy field, gardens, and villages (Sridhara & Srihari 1983). Thus, the finding of this species in a primary forest shows the extension of its range. Comparison between sites showed that Tasik Bera has the highest number of species for non-volant small mammals (N = 9). As Malaysia's largest natural lake, Tasik Bera provides food and water source to various faunas. A single individual of *Crocidura monticola* and *S. etruscus* were caught at Ulu Gombak FR. Records of these two forest species at Ulu Gombak FR which is close to Malaysia's most populated city (Kuala Lumpur), indicate that this reserve, although fragmented, still holds quality habitat. Forest-dwelling shrews such as *C. monticola* and *S. etruscus* are found in forests with little or no disturbance (Payne *et al*. 1985). Presence of clear river and isolated from human activities may preserve the quality of the natural habitat and able to support the forest species observed here.

Small Mammal Species Diversity Between Surveyed Sites

Of the 10 paired *t*-test analysis performed between sites, there were significant differences in small mammal diversity for Ulu Gombak FR vs Penang Island, Sungkai WCC vs Penang Island, and Penang Island vs Sungkai WCC. Contrasting vegetation and intensities of anthropogenic activities found at each site may explain the observed variations. Sites at Penang Island can be categorised as disturbed area because it is accessible to public as it is a recreational park and tourist attraction. Our sampling sites at Penang Island were also close to the main road and exposed to disturbance caused by human activities. Penang Island also recorded the lowest diversity index and species evenness (Refer to Table 4). Tasik Bera has the highest species richness with 21 species. It is speculated that its status as a protected area and the presence of natural freshwater enables it to support large diversity from the surrounding area. Rarefaction analysis showed that Ulu Gombak FR has the highest diversity with high number of species but low number of individuals caught.

There are several factors that lead to the small mammal species list recorded in this survey such as the presence of freshwater ecosystem, roosting sites availability, and abundance of foraging areas. Bamboo trees can be found abundant in Ulu Gombak FR, and these trees act as roosting site for bamboo bat. Ten individuals of *Tyloncyteris robustula* and four individuals of *T. pachypus* were recorded in Ulu Gombak FR. These bat species are known to roost inside bamboo trees (Phillipps & Phillipps 2016). Animal-plant interaction between bamboo bats and bamboo trees exists with the trees providing roosting site

to the bats and the bats consume the insects that may be harmful to the trees (Medway & Marshall 1972). A large number of *H. ridleyii* were caught in Tasik Bera. This forest-dependent species is mostly threatened by habitat loss (IUCN 2017) and availability of the roosting site and freshwater can boost its population in the area. Most of the sites visited recorded *Leopoldamys sabanus, Maxomys rajah,* and *M. surifer*. These species are known to demonstrate scatter-hoarding behaviour (Yasuda *et al*. 2000). Food hoarding behaviour allows terrestrial rodents to optimise its foraging activities, as well as to increase the chances of survival during food insufficiency (Yasuda *et al*. 2000). This behaviour also benefits the plants by dispersion of seed (Howe *et al*. 1985 & Vander Wall 1990). Thus, these species acting as seed dispersal agents are important in the extension of forest area and maintaining the quality of the forest. The semi-deciduous forest of Wang Kelian SP holds unique species of mammals, namely *B. indica* and *R. coelophyllus* which can only be found in the northern part of this country (Jayaraj *et al*. 2013). Urban and fragmented secondary forest in Penang Island still able to hold a high number of species diversity, with *R. affinis* caught as the most abundant. The ability of this species to adapt and strive in an urban area enables it to maintain high population and receive no major threats (IUCN 2017). Unlike *R. affinis, N. tragata* which was recorded in Penang Island is threatened by habitat degradation. Findings of this species in area with high anthropogenic activities indicate that *N. tragata* may prefer small fragmented forest. In Sungkai WCC, *M. aenea*, listed as Vulnerable by IUCN Red List, was recorded. This species is dependent towards lowland forest and threats such as habitat degradation and fragmentation may reduce the population of *M. aenea* (IUCN 2017). The conservation centre provides roost site and eliminates the threat of habitat loss of the bats species.

Importance of Protected Area in Malaysia

Gazetting a forest as a protected area is one of the *in situ* conservation strategies with the goals of reducing habitat loss and ensuring the sustainability of species within it (Wilcox 1984). The objective of a protected area is to conserve and protect the species it is hosting, using legal means such as passing an ordinance, act, or enactment to ensure the effectiveness of the area (DWNP 2016). There are needs to protect and conserve these biological and genetic resources, which can be achieved by establishing the forests as protected areas, where human disturbances are restricted by law. Evolution of genetic resources can be continued in this area without the unwanted disturbances and thus maintaining ecosystem function. Processes such as soil regeneration, pollination, and nutrient cycling, which are essential in a healthy ecosystem should be maintained to conserve individual species (Altieri 1999). Protected area has proven to be an effective tool in conserving species where findings recorded high animal diversity within it (e.g. Mount Kinabalu [Shukor 2001]; Bako [Khan *et al*. 2007]; Kuala Atok [Tingga *et al*. 2012]). Similar observations were recorded in this study at Wang Kelian SP, Ulu Gombak FR, and Tasik Bera with high diversity of volant and non-volant mammals.

Approximately three millions ha of land have been gazetted as protected area in Sarawak and Sabah, equivalent to that gazetted in Peninsular Malaysia (DWNP 2016; Forest Department Sarawak 2017; Sabah Forestry Corporation 2017). Local authorities in Malaysia realised the importance of designating forests as protected area which is meant for sustainable forest management. This could boost the animal species diversity in those protected area. The results of massive efforts that were portrayed through recent findings of endemic and rare species in national parks and protected area throughout Malaysia were published (Lading 2006; Tingga *et al*. 2012; Jayaraj *et al*. 2013; Pounsin *et al*. 2016). The finding of rare species in the protected area as observed in the current study further highlights the relevance of establishing a new protected area in Malaysia.

IUCN Status

Based on the assessment by International Union for Conservation of Nature (IUCN), species recorded in this study are listed as Least Concern (LC), Near Threatened (NT), Vulnerable (VU), or Not Evaluated (NE). Thirty-six species are listed as LC, five species each in the NT and V, and four species in the NE category. *Maxomys rajah* is listed as VU (IUCN 2016), and 17 individuals of this species were caught in Wang Kelian SP. This emphasises the importance of protected area as an effective tool in conserving rare species. *Murina aenea* is also listed as VU (IUCN 2008), was caught as singleton in Sungkai WCC. This species is locally rare and may roosts in small group. Deforestation and logging are the main threat to *M. aenea* (Hutson *et al*. 2008). *Hipposideros ridleyi* recorded in Tasik Bera is also listed as VU (Hutson *et al*. 2008). Similar to *M. aenea, H. ridleyi* is a forest-dependent species that can roost in a small group up to 15 individuals. Both of these species are predicted to decline in the future given their dependency on lowland forest that is rapidly converted into agriculture land or human settlement.

CONCLUSIONS

Our study showed that protected area harbour high diversity compared to non-protected area. Nevertheless, non-protected area appears to also hold an important role in providing habitat for species that are highly adaptable. Given that some of these non-protected areas are established as nature park, proper authorisation is important to ensure the park is managed appropriately as they still function as an ecosystem. In brief, the local biodiversity is sustained by the interactions between plants and the animals with the environment. The value of the ecosystem services provided by these interactions are immeasurable and will vastly influence the survival of the habitat and its content.

ACKNOWLEDGEMENTS

I would like to extend my gratitude to Faculty of Resource Science and Technology, Universiti Malaysia Sarawak (UNIMAS) for the permission to conduct the study and help with the logistics and transportation. My gratitude also to the Ministry of Higher Education for providing the research grants: RACE/g(2)/1107/2013(15), NRGS/1087/2013(01) and NRGS/1088/2013(02). Thanks to the Department of Wildlife and National Park for granting us the research permit JPHL&TN(IP):100-34/1.24(12). I am extremely grateful to my colleagues from Faisal Ali Anwarali Khan's lab, Nursyafiqah Shazali, Nur Mukminah Naharuddin, Rafik Murni, Nurshilawati Abdul Latip, Nurul Farah Diyana Ahmad Tahir, and Sultana Parveen Habeebur Rahman for the endless support and help in data recording and also in the preparation of this paper.

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