

CURRENT STATUS OF BAT DIVERSITY AND CONSERVATION IN UNIVERSITI PUTRA MALAYSIA AND ITS FOREST RESERVES

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Abstract: Universiti Putra Malaysia consists of three main areas, namely Serdang main campus in Selangor (UPMSC), Bintulu campus in Sarawak (UPMKB) and the UPM forest in Ayer Hitam Forest Reserve (AHFR) in Puchong, Selangor, which are all managed by the university. This article compiles available information regarding bats in UPM besides updating the available list of bat species from published and unpublished papers, and recent sampling using harp traps and mist nets. A total of 36 bat species were reported in UPM (12 species in UPMSC, 20 species in UPMKB and 21 species in AHFR). These bats were from seven families: Emballonuridae (three species), Hipposideridae (four species), Megadermatidae (one species), Nycteridae (one species), Pteropodidae (13 species), Rhinolophidae (two species) and Vespertilionidae (12 species). With regards to the conservation status, one species (*Hypsugo macrotis*) is categorised as ‘Data Deficient’, five species (*Dyacopterus spadiceus*, *Kerivoula intermedia*, *K. minuta*, *Nycteris tragata*, and *Rhinolophus sedulus*) as ‘Near Threatened’ and one species (*Megaerops albicollis*) categorised as ‘Vulnerable’ on the IUCN Red List of Threatened Species. The list of bat species provided, including those with conservation importance, can serve as a reference for campus management practices on its environmental activities especially in enhancing biodiversity value within the campus area.

Keywords: Chiroptera, checklist, urban, Sarawak, Ayer Hitam Forest Reserve.

Introduction

Bats (Order: Chiroptera) are fascinating mammals that hold an important place in our ecology. It represents about 50% of mammal species in tropical forests and 20% in the world (Lim *et al.*, 2017). Chiroptera is the second largest order among mammals with more than 1,400 species from 21 extant families have been described worldwide (Simmons & Cirranello, 2020). Bats can be divided into two suborders: Yinpterochiroptera (represented by seven families) and Yangochiroptera (represented by 14 families) (Springer, 2013). Globally, forested areas are the primary habitat that support the highest diversity of bat species (Russo *et al.*, 2016). Bats are also among the most diverse mammals’ group available in urban areas (van

der Ree & McCarthy, 2005; Jung & Kalko, 2011). According to Francis (2019), Phillipps and Phillipps (2018) and Senawi and Norhayati (2021), there are about 143 species of bats found in Malaysia, representing 10% of the world’s bats population. Recently, 113 bat species have been recorded in Peninsular Malaysia (eg: Khan *et al.*, 2008; Lim *et al.*, 2014; Francis, 2018; William-Dee, 2019) and 94 have been found in Malaysian Borneo (eg: Khan *et al.*, 2007; Benda 2010; Phillipps & Phillips, 2018; Khan *et al.*, 2019; Mohd-Azlan *et al.*, 2019; Senawi *et al.*, 2020; Senawi & Norhayati, 2021).

Universiti Putra Malaysia is one of the largest green campuses (Aris *et al.*, 2018) in Malaysia. The uniqueness of UPM is that the campus consists of the main campus in Serdang

Selangor in Peninsular Malaysia, and the Bintulu campus in Sarawak (UPMKB) on the island of Borneo. Apart from that, UPM has its own forest reserve, namely AHFR in Puchong, Selangor, and Nirwana Forest in UPMKB. Both forests are experimental and field stations for educational activities. Having a combination of various environments within the campuses, UPM preserves its green areas amid surrounding development that supports teaching and learning as well as research activities in the campuses. The green areas of UPM are important habitats for wildlife, including bats. Studies on bat communities in UPM have been carried out since 1999 by Jambari *et al.* focusing mainly on AHFR. Later, surveys were carried out, and were documented in either published or unpublished reports.

This paper aims to compile information on the diversity of bat species found throughout the three zones of UPM: UPMSC, UPMKB and AHFR from 1999 to 2020. It is hoped that this list will be useful especially to UPM, other scientific communities, government agencies, and non-governmental organizations to further support conservation strategies of bats.

Materials and Methods

The checklist of UPM bats presented here is based on data from published and unpublished reports, as well as current sampling data. Published data are those available through peer-reviewed articles and short communications published in scientific journals and books. In contrast, unpublished data are based on diploma, bachelor and master's degree project reports (theses), abstracts and proceedings of conferences. Current sampling data refers to the latest studies conducted between 2019 and 2020 at UPM's Serdang Campus. Throughout this article, the following acronyms will be used in the text: Universiti Putra Malaysia Serdang Campus (UPMSC), Universiti Putra Malaysia Bintulu Sarawak Campus (UPMKB) and Ayer Hitam Forest Reserve (AHFR).

Study Areas

Universiti Putra Malaysia comprises of the main campus in Serdang, Selangor, a branch campus in Bintulu, Sarawak and a forest reserve in Puchong, Selangor. The main campus is located at 2° 59' 12.99" N to 2° 59' 48.18" N and longitudes 101° 42' 22.33" E to 101° 42' 42.77" 42.77" E. UPMSC covers an area of 1245.056 ha, with approximately 45.8% covered with natural and ornamental vegetation, 51.2% is covered by agricultural crops, farms and grasslands habitat (Ideris, 2016) and the rest (3%) are built up areas.

Universiti Putra Malaysia Bintulu Sarawak Campus (UPMKB) is one of the few green lungs still left in the Bintulu township (Norfahiah *et al.*, 2012) situated 13 kilometers from the town (3° 12' 31" N, 113° 05' 52" E), and is surrounded by an environment rich in flora and fauna, affirming UPM's mission to further explore the fields of agriculture and bioresources. The campus covers an area of 715.16 ha, with most areas (299.0 ha or 42%) covered with greenery. A total of 37.3 ha has been assigned to the Tropical Rainforest Ecosystem Rehabilitation Project in Sarawak (Planted Forest), 25.5 ha planted with yemane; *Gmelina arborea* and acacia; *Acacia mangium*, 51.0 ha planted with oil palm; *Elaeis guineensis*, 25.0 ha planted with rubber trees; *Hevea brasiliensis*, 60.0 ha are reserved education forest (Nirwana Forest) and 100.2 ha consists of other fragmented secondary forests. Meanwhile, the rest of the area (416.16 ha) consists of existing and future development areas (Ong *et al.*, 2008).

Situated in Puchong Selangor, Ayer Hitam Forest Reserve (AHFR) (3° 00' 28" N, 101° 38' 34" E) covers an area of 1,248 ha. In 1996, Selangor's state government granted Universiti Putra Malaysia a lease to use the forest reserve for educational and research purposes (Faridah-Hanum, 1999) in forestry, wood science, as well as park and recreation management. AHFR is an important tropical lowland forest located in Selangor, Malaysia. It is the only forested area

left in the Klang Valley besides the 10.6 ha of Bukit Nenas Forest Reserve that is threatened by rapid development.

Bat Surveys

Bat surveys (Figure 1) in UPM have been carried out at UPMSC from 2019 to 2020, which include the campus zone, faculties, institutes and colleges. Bat research in UPMKB was conducted between 2004 and 2010 by diploma, undergraduate and masters students to fulfill their project requirements (unpublished reports: Haziri & Aijam Myustaqeen, 2004; Mazliawati & Mc. Eddy, 2006; Mohd Zabidi & Siti Hawa, 2007; Aminulhisham & Nurul Mardhiah, 2008; Mohd Hazlan & Nurul Aidah, 2008; Edy Izzady & Abu Rahman, 2008; Syed Ahmad Hazman & Fatin Nazwa, 2008; Mohd Firdaus & Mohd Farhan, 2008; Ritauddin & Aminah, 2008; Norisah & Hafizzuddin, 2008; Farah Awatif & Nor Afiedatul Akmal,

2009; Muhammad Hafizzuddin & Sonetha, 2009; Murni & Juliana, 2009; Mohd. Hafis & Norasilah, 2009; Mohamad Syafig & Siti Sarah, 2010; Sasidhran & Siti Nurfatim, 2010; Azema *et al.*, 2009; and Ain Suriani *et al.*, 2010). The study sites in UPMKB covered the campus zone, Planted Forest, Forestry Park and the reserve forest (Nirwana Forest). The campus zone comprises agricultural land, oil palm and rubber plantations, animal farm, mechanization workshops, administration and academic buildings, botanical park, as well as the Biopark and a waterfall area. As reported in the Annual Report UPM-Mitsubishi Forest Rehabilitation Project (Anon, 2019), the 3.4 ha planted forest area is planted with more than 352,694 indigenous forest trees from 127 species on five planting sites, with more than 100 research plots. The Nirwana Forest is a secondary forest that is mostly dominated by species from the family Dipterocarpaceae. Meanwhile, the forest park

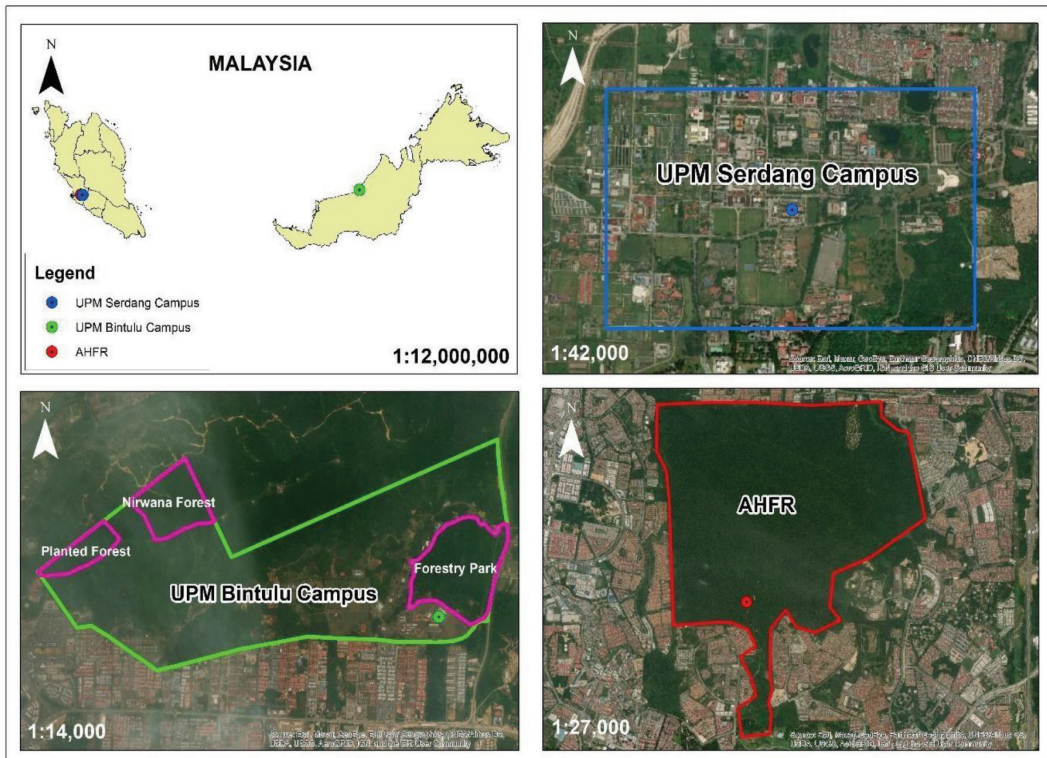


Figure 1: Maps indicating the locations and areas of UPM Serdang Campus (UPMSC), UPM Bintulu Sarawak Campus (UPMKB) and Ayer Hitam Forest Reserve (AHFR)

consists of about 40 ha of lowland secondary forest. The forest park typically has less tree diversity due to logging. Openings created in the forest canopy allow sunlight to reach the forest floor, causing the area to be dominated by pioneer species, like ferns and *Macaranga gigantea*. Finally, bat surveys in the AHFR area began in 1999 to 2017 (Jambari *et al.*, 1999; Mohd. Azlan *et al.*, 2000; Ahmad Juffiry *et al.*, 2015; Marina *et al.*, 2017). The area covered compartments 12, 13, 14 and 15 with different habitat points and landscapes such as river or stream, forest gaps, mid slopes and ridgetops. This lowland Dipterocarp forest covers a huge diversity in flora and fauna, including mammals, avians, reptiles, amphibians, fish and insects (Paiman & Amat, 2007).

Field Method

The current survey was conducted in UPMSC from December 2019 to October 2020. Permission to conduct field research on bats was approved by the Department of Wildlife and National Parks (DWNP) Peninsular Malaysia (**JPHL&TN (IP): 100-34/1.24 Jld 16 (20)**) and UPMIACUC (Institutional Animal Care and Use Committee) (**UPM/IACUC/AUP-R040/2020**). Bats were captured using mist nets, harp traps and hand nets (modified butterfly net). Three different environments were identified for the bat survey, namely i) foraging area ii) building roosting sites and iii) vegetation roosting sites.

For foraging areas, bats were captured by setting up four to eight mist nets (14 x 5 m with 2.5 mm mesh size and 9 x 4 m with 3.0 mm mesh size) which were placed 0.5 m above ground (Shafie *et al.*, 2011) and set at potential flight corridors or edge of remnants, near ponds, shelters or food sources. Mist nets supported by two aluminum poles were left open for about 12 hours (18:00h to 6:00h) and monitored at one-hour intervals. Nets were set for a period of two consecutive nights in each study area. Two- or four-bank harp traps (Francis, 1989; Jayaraj *et al.*, 2011; Mohd-Hanif *et al.*, 2015;

Yoh *et al.*, 2020) were also deployed randomly for two consecutive nights per area based on the possibility of the bats roosting and anticipated flight paths.

For building roosting sites, all possible buildings around UPM were visited during the sampling period (Fagan *et al.*, 2018). A standard inspection protocol was implemented in order to identify buildings that are actively used by bats. Direct observations of bats roosting were based on the presence of fresh guano, urine staining and feeding remains or rejected fruit pellets (Collins, 2016; Fagan *et al.*, 2018). The surveys were conducted during the day from the exterior to the interior of the man-made structures, progressing from the ground floor to the higher floors. After the roosting sites were located, sampling of bats was conducted by setting up mist nets to cover possible routes that might be used by the bats to escape, and a modified hand-net (Tan *et al.*, 1998) was used to directly capture the bats in any area inside the building.

All trees (ornamental and native) suspected of being used by any bat species were inspected and surveyed in the evening for vegetation roosting sites. All possible roosting sites were identified, and bats were captured by encircling the roost trees with mist nets (Digana *et al.*, 2011) and shaping the mist nets into triangles. The triangle shape requires a long mist net (14 x 3 meters with 4 mm mesh size) and using three poles (6 meters long each) to set up. For trees with more than six meters in height, a triangle lift was used, where the mist nets were set up at a triangle shape frame, and the frame was elevated until the roosting level. This triangle lift requires three long mist nets (14 x 3 meters with 4 mm mesh size), three aluminum telescopic poles (6 meters each), three pulleys, three hauling ropes (nylon braided), three vertical anchor ropes (nylon braided), three diagonal anchor ropes (nylon braided), ten to twelve slider pins and three to four closing cords. The setting up was conducted in the morning of the sampling day, and nets were open from 18:00h to 24:00h.

Species Identification

Standard external measurements of the captured bat (forearm length (mm), body length (mm) and tail (mm)) were taken using electronic digital vernier calipers and body weight (g) was recorded using a Pesola spring balance (100 and 1,000g). In addition, other population data i.e. age (adult or juvenile), sex and reproductive status were also recorded (Ibrahim *et al.*, 2013). Identification of species were made based on taxonomy key of bats for Peninsular Malaysia (Kingston *et al.* 2009), Medway (1983), Francis (2019), while those in Borneo were identified based on Payne *et al.* (1985), Borissenko and Kruskop (2003), Shazali *et al.* (2016), and Phillips and Phillips (2018). The “dental formula” as described by Francis (2019) was used in the identification of unidentified species based on the standard procedure. Voucher specimens were wet-preserved in 70% ethanol and housed at the Biology Department, Faculty of Science, UPM Serdang and the Department of Forestry Science, Faculty of Agricultural Science and Forestry, UPMKB. All other bats were released at the point of capture within 12 hours of capture. The conservation status of the bat species was confirmed against the IUCN (2020), PERHILITAN (2017), Wildlife Conservation Act (2010), and Wildlife Protection Ordinance (1998) lists for their conservation status.

Results and Discussion

Sources of valid records supporting the existence of bat species in the respective areas in UPM are presented in Table 1. Data collected throughout the study period, from 2004 to 2020, recorded 36 bat species (consisting of seven families: Emballonuridae (three species), Hipposideridae (four species), Megadermatidae (one species), Nycteridae (one species), Pteropodidae (13 species), Rhinolophidae (two species) and Vespertilionidae (12 species) (Table 1; Figure 2). This list represents approximately 26% of the total bat species recorded in Malaysia. From this record, 13 species were fruit bats, accounting for 36% of bat species recorded in UPM, with five

species captured in both UPMSC and AHFR, while 10 species were found in UPMKB. On the other hand, 23 species (66%) were found to be insect bats, with seven, 10 and 16 species recorded in UPMSC, UPMKB and AHFR respectively.

Cynopterus brachyotis, *Eonycteris spelaea* and *Myotis muricola* were the most common species recorded and found to be distributed in all three localities (UPMSC/UPMKB/AHFR). Some bat species were reported only in two localities: *Scotophilus kuhlii* (one species; UPMSC/AHFR); *Cynopterus horsfieldii* (one species; UPMSC/UPMKB); *Hipposideros cervinus*, *Megaderma spasma*, *Penthetor lucasi*, *Rhinolophus sedulus*, *R. trifolius* and *Kerivoula papillosa* (six species, UPMKB/AHFR). Species recorded in a single locality were *Saccolaimus saccolaimus*, *Taphozous longimanus*, *T. melanopogon*, *Rousettus amplexicaudatus*, *R. leschenaultii* and *Hypsugo macrotis* (six species; UPMSC); *Hipposideros diadema*, *Balionycteris maculata*, *C. sphinx*, *Dyacopterus spadiceus*, *Macroglossus minimus*, *Megaerops albicollis*, *K. minuta*, *Murina suilla*, and *Pipistrellus* sp. (11 species; UPMKB); and *Hipposideros bicolor*, *H. larvatus*, *Nycteris tragata*, *Balionycteris seimundi*, *Megaerops ecaudatus*, *K. intermedia*, *P. javanicus*, *Tylonycteris fulvida* and *T. malayana* (nine species; AHFR).

Pteropodidae

Among the 13 species of fruit bats recorded, *Cynopterus brachyotis* and *Eonycteris spelaea* were the most common species captured and recorded in all localities. *Cynopterus brachyotis* was described as a common bat that can occupy a variety of habitats, including disturbed areas, orchards and plantations (Jayaraj *et al.*, 2013; Khan *et al.*, 2019; Mikail *et al.*, 2017; Lim *et al.*, 2019; Francis, 2019) indicating a relatively high ecological plasticity of the bat species (Benda, 2010). In UPMSC, it was observed to either roost singly or in small groups under leaves of trees and palms.

Eonycteris spelaea is an important and most effective pollinator of many forest trees and commercial plant species, such as *Durio* spp. and *Parkia* spp. (Bumrungsri *et al.*, 2008; 2009). It can always be found roosting in large colonies in caves, and forages in canopies of primary forest, gardens, mangroves and disturbed areas (Kingston *et al.*, 2009; Acharya *et al.*, 2015; Phillips & Phillips, 2018). All records in UPM show that this species was successfully captured using mist nets set up near fruiting or flowering trees. This species can travel as far as 38 km to forage and feed on at least 31 species of plants (Bumrungsri *et al.*, 2013).

The current survey recorded *Cynopterus sphinx* was captured in UPMKB campus zone

and reserve forest (Planted Forest, Nirwana Forest and Forestry Park) (Mazliawati & Mc. Eddy, 2006; Aminrullisham & Nurul Mardhiah, 2008; Mohd Firdaus & Mohd Farhan, 2008; Eddy Izzady & Abu Rahman, 2008; Azema *et al.*, 2009). Compared to *C. brachyotis*, *C. sphinx* is larger with forearm length recorded between 65 and 69 mm. However, this species is rarely found in Borneo (Phillipps & Phillipps, 2018). Payne and Francis (2007) reported only one record from Borneo, in Central Kalimantan province. Other researchers, Kitchener and Maharadatunkamsi (1991) reported a male specimen from Gunung Kinabalu and Benda (2010) recorded the species in Sapulut, Sabah.

Table 1: List of bat species documented in Universiti Putra Malaysia

Family/Species/ Common Name	Total Species at UPMSC	UPMKB	Total Species at UPMKB	AHFR	Total Species at AHFR	IUCN Status 2020	PER- HILITAN 2017	WCA 2010	WLPO 1998
EMBALLONURIDAE									
<i>Saccolaimus saccolaimus</i> (Temminck, 1838) Bare-rumped Sheathail Bat	Current Study (2019-2020) + (1)	Unpublished Reports, 2004-2010 Azema <i>et al.</i> 2009	Ain Suriani <i>et al.</i> 2010	Jambari <i>et al.</i> 1999 Mohd. Azlan <i>et al.</i> 2000 Ahmad Jufriy <i>et al.</i> 2015	Marina Current Study (2019-2020)	LC	LC	NP	NP
<i>Taphozous longimanus</i> Hardwicke, 1825 Long-winged Tomb Bat	+ (2)					LC	DD	NP	NP
<i>Taphozous melanopogon</i> Temminck, 1841 Black-bearded Tomb Bat	+ (1)					LC	LC	NP	NP
HIPPOSIDERIDAE									
<i>Hipposideros bicolor</i> (Temminck, 1834) Bicolored Roundleaf Bat						LC	LC	NP	NP
<i>Hipposideros cervinus</i> (Gould, 1863) Fawn Roundleaf Bat						LC	LC	NP	PA
<i>Hipposideros diadema</i> E. Geoffroy, 1813 Diadem Roundleaf Bat						LC	LC	NP	PA
<i>Hipposideros larvatus</i> (Horsfield, 1823) Intermediate Roundleaf Bat						LC	LC	NP	NP

to be continued

Continued Table 1: List of bat species documented in Universiti Putra Malaysia

MEGADERMATIDAE													
<i>Megaderma spasma</i> (Linnaeus, 1758) Lesser False Vampire	+	+	+	+	+	+	+	+	+	LC	LC	NP	PA
NYCTERIDAE													
<i>Nycteris tragata</i> (K. Andersen, 1912) Malayan Slit-faced Bat										NT	LC	NP	
PTEROPODIDAE													
<i>Balionycteris maculata</i> (Thomas, 1893) Spotted-winged Fruit Bat	+	+	+	+	+	+	+	+	+	LC	LC	NP	PA
<i>Balionycteris seimundi</i> (Kloss, 1921) Malayan Spotted-winged Fruit Bat									+	LC	LC	NP	
<i>Cynopterus brachyotis</i> (Müller, 1838) Short-nosed Fruit Bat	+	+	+	+	+	+	+	+	+	LC	LC	NP	PA
<i>Cynopterus horsfieldii</i> (Gray, 1843) Horsfield's Fruit Bat	+	+	+	+	+	+	+	+	+	LC	LC	NP	PA
<i>Cynopterus sphinx</i> (Vahl, 1797) Greater Short-nosed Fruit Bat	+	+	+	+	+	+	+	+	+	LC	LC	NP	PA
<i>Dyacopterus spadiceus</i> (Thomas, 1890) Dayak Fruit Bat										NT	NT	NP	PA
<i>Eonycteris spelaea</i> (Dobson, 1871) Cave Nectar Bat	+	+	+	+	+	+	+	+	+	LC	NT	NP	PA

to be continued

Continued Table 1 : List of bat species documented in Universiti Putra Malaysia

<i>Kerivoula intermedia</i> Hill and Francis, 1984	+	+	+	+	+	NT	NP
Small Woolly Bat							
<i>Kerivoula minuta</i> Miller, 1898	+	+			NT	NP	PA
Least Woolly Bat							
<i>Kerivoula papillosa</i> (Temminck, 1840)	+	+	+		LC	LC	PA
Papillose Woolly Bat							
<i>Murina suilla</i> Temminck, 1840	+	+			LC	LC	PA
Brown Tube-nosed Bat							
<i>Myotis muricola</i> (Gray, 1846)	+	+	+		LC	LC	PA
Wall-roosting Mouse-eared Bat							
<i>Pipistrellus javanicus</i> (Gray, 1838)	+	+	+		LC	DD	NP
Javan Pipistrelle							
<i>Pipistrellus</i> sp.							
<i>Scotophilus kuhlii</i> Leach, 1821	+	+			LC	LC	PA
Asiatic Lesser Yellow House Bat							
<i>Tylonycteris fulvida</i> (Peters, 1872)	+	+	+		LC	LC	NP
Lesser Bamboo Bat							
<i>Tylonycteris malayana</i> Chasen, 1940	+	+	+		LC	LC	NP
Greater Bamboo Bat							
Total Species	12	16	16	8	20	10	6
Total Families	3				5		6

Note: '+' = recorded; IUCN 2020 - The IUCN Red List of Threatened Species; RLMPM 2017- Red List of Mammals for Peninsular Malaysia 2017; WCA - Wildlife Conservation Act 2010; WLPO - Sarawak Wild Life Protection Ordinance 1998; LC- Least Concern; V-Vulnerable; DD-Data Deficient; NI-Near Threatened; NP-Not Protected; PA-Protected Animal; the value in brackets for the current study is the number of individuals.



Figure 2: Bat species recorded in UPM. 1- *Saccolaimus saccolaimus* © Ahmad Badrul Amin, A. R.; 2- *Taphozous melanopogon* © Marina, M.T.; 3- *Taphozous longimanus* © Nur Farrazuin, J.; 4- *Hipposideros bicolor* © Senawi, J.; 5- *Hipposideros cervinus* © Nor Afiedatul, A.; 6- *Hipposideros diadema* © Juliana, N.; 7- *Hipposideros larvatus* © Senawi, J.; 8- *Megaderma spasma* © Nor Afiedatul, A.; 9- *Nycteris tragata* © Senawi, J.; 10- *Aethelops aequalis* © Mohd Firdaus, K.; 11- *Balionycteris maculata* © Mohd. Hafis, N.; 12- *Balionycteris seimundi* © Senawi, J.; 13- *Cynopterus brachyotis* © Marina, M.T.; 14- *Dyacopterus spadiceus* © Senawi, J.; 15- *Eonycteris spelaea* © Ahmad Badrul Amin, A. R.; 16- *Megaerops ecaudatus* © Senawi, J.; 17- *Megaerops albicollis* © Azema, I.; 18- *Penthetor lucasi* © Muhamad Syafiq, C. S.; 19- *Rousettus amplexicaudatus* © Ahmad Badrul Amin, A. R.; 20- *Rousettus leschenaultii* © Nur Farrazuin, J.; 21- *Rhinolophus sedulus* © Farah Awatif, K.; 22- *Rhinolophus trifolius* © Murni, S.; 23- *Glischropus tylopus* © Marina, M.T.; 24- *Hypsugo macrotis* © Nur Farrazuin, J.; 25- *Kerivoula intermedia* © Senawi, J.; 26- *Kerivoula minuta* © Mohd Firdaus, K.; 27- *Kerivoula papillosa* © Mohd Firdaus, K.; 28- *Murina suilla* © Azema, I.; 29- *Myotis muricola* © Ritauddin, A. R.; 30- *Pipistrellus* sp. © Mohd. Hazlan, A.R.; 31- *Scotophilus kuhlii* © Ahmad Badrul Amin, A. R.; 32- *Tylonycteris fulvida* © Senawi, J.; and 33- *Tylonycteris malayana* © Noraini Che, A. N.

Ain Suriani *et al.* (2010) recorded a single individual of the Dayak fruit bat (*Dyacopterus spadiceus*) in the oil palm plantation of UPMKB. A single individual of this species was also captured at Gunung Mulu by Shazali *et al.* (2016). Phillipps and Phillipps (2018) reported the species in the lowland area of Sarawak, and sometimes found it in the upper canopy while feeding on fruiting figs. The species is rarely caught in the understorey traps, except when they come down to drink or feed on lower fruit trees (Mohd-Ridwan *et al.*, 2018). This species is listed as a near threatened species under the IUCN (IUCN, 2020) due to the decline of lowland rainforests.

Two individuals of the white collared fruit bat (*Megaerops albicollis*) (one male adult and one male juvenile) were captured using a 4-shelf mist net in 2009 at the Nirwana Forest of UPMKB. The findings have been published in the 3rd Regional Conference on Natural Resources in the Tropics (NRTrops3) in Kuching, Sarawak, in 2009 (Azema *et al.*, 2009). Shazali *et al.* (2016) reported on a single individual of the same species caught using high-net trap in Gunung Mulu National Park in Sarawak. It is noted that the first record of the species was in Tasek Merimbun in Brunei during a field study conducted in 1983-84 (Haji Idris, 2012; Payne, 1985; Philips & Phillips, 2018). According to Matthew *et al.* (2006), this species is categorised as a below canopy frugivore. Therefore, the species may only be sampled at ground level if they commute to roost or forage in the understorey. At Krau Wildlife Reserve, Pahang, this species is known to forage at the canopy level (Kingston *et al.*, 2006). *Megaerops albicollis* is listed as vulnerable due to the shrinking lowland rainforest area (Francis, 2019) and categorised as rare by Phillipps and Phillipps (2018).

Two species of *Rousettus* have been recorded in UPMSC, which were captured near a mango tree at Kolej Sepuluh, along a pond at Ladang Humprey, and few foraging areas at Bukit Ekspo, Faculty of Forestry and Environment and Faculty of Biotechnology. Previously, *R. leschenaultii* has only been

recorded in Wang Kelian State Park in Perlis (Jayaraj *et al.*, 2013) and Batu Caves in Selangor (Moseley *et al.*, 2012). This data adds to the current distributional record of *R. leschenaultii* in Peninsular Malaysia.

The other six fruit bat species (*Balionycteris seimundi*, *B. maculata*, *Cynopterus horsfieldii*, *Macroglossus minimus*, *Megaerops ecaudatus*, and *Penthetor lucasi*) are commonly and widely distributed throughout Peninsular Malaysia (Medway, 1983; Matthew *et al.*, 2006; Jayaraj *et al.*, 2013; Lim *et al.*, 2019) and Borneo (Payne *et al.*, 1985; Andrew *et al.*, 2002; Benda, 2010; Struebig *et al.*, 2012; Phillipps & Phillipps, 2018; Khan *et al.*, 2019).

Emballonuridae

Three species of Emballonuridae were recorded only in UPMSC. Bare-rumped sheath-tail bat (*Saccolaimus saccolaimus*) was caught in UPMSC near the guest-housing area. This bat has been found in houses, hollow trees and rock crevices, and forages high above the ground (Francis, 2019). A single black-bearded tomb bat (*Taphozous melanopogon*) was accidentally caught at UPM's Main Hall building attic, trapped in a mist net which was set up as a bat control measure in the building. The species has been reported to roost in buildings in urban areas (Kingston *et al.*, 2009). Other than that, two male long-winged tomb bats (*T. longimanus*) were captured in palm trees (*Livistona chinensis*) at a college residential area and faculty site. *Taphozous longimanus* has been reported to roost in buildings, caves, tree hollows, crowns of palm trees and among rocks (Francis, 2019; Lim *et al.*, 2017). For identification purposes, *T. longimanus* possesses a glandular pouch under the chin and metacarpal pouch, while *S. saccolaimus* and *T. melanopogon* possess either a glandular pouch or a metacarpal pouch, respectively (Francis, 2019). According to Krutzsch (2000), glandular pouch or glandular scent organ found on some emballonurids is a secondary sexual characteristic commonly found in males. It is used to mark territory, as a defense mechanism and for breeding purposes.

Hipposideridae

Four species namely *Hipposideros bicolor*, *H. cervinus*, *H. diadema* and *H. larvatus* were recorded (see Table 1). *Hipposideros bicolor* and *H. larvatus* were recorded by Mohd. Azlan *et al.* (2000) and Shaidin *et al.* (2015). These bats were captured in AHFR in a low number of individuals. Higher number of captures has been reported in other lowland mixed dipterocarp tropical rainforests across Peninsular Malaysia (Lim *et al.*, 2019; Jayaraj *et al.*, 2013). *Hipposideros cervinus* was captured at UPMKB's Planted Forest (Farah Awatif & Nor Afiedatul Akmal, 2009) and Campus Zone (fruit orchard) (Mazliawati & Mc. Eddy, 2006) area. In AHFR, this species was captured using both harp traps and mist nets (Mohd. Azlan *et al.*, 2000; Marina *et al.*, 2017). Meanwhile, one *H. diadema* was captured at the Planted Forest in UPMKB (Mohd Hazlan & Nurul Aidah, 2008) and four *H. larvatus* were recorded only at AHFR (Ahmad Juffiry *et al.*, 2015). Although these four species are known to roost in large colonies, such as in limestone caves (Kingston *et al.*, 2009), *H. cervinus* being a dominant cave-roosting species (Struebig *et al.*, 2012), was the most recorded species in both UPMKB and AHFR.

Megadermatidae

Lesser false vampire (*Megaderma spasma*) was the only species recorded under this family. This species was first recorded with only one individual captured in 2009 at the Planted Forest and fruit orchard in UPMKB (Farah Awatif & Nor Afidatul Akmal, 2009; Azema *et al.*, 2009; Ain Suriani *et al.*, 2010) and at AHFR in 2015 (Ahmad Juffiry *et al.*, 2015) respectively. In Peninsular Malaysia, they roost in a small group in caves, tunnels or hollow trees (Kingston *et al.*, 2009) while Lim *et al.* (2019) reported two individuals captured in the lowland tropical forests with rock boulders or within limestone areas.

Nycteridae

One individual of the Malayan slit-faced bat (*Nycteris tragata*) was captured at AHFR (Ahmad Juffiry *et al.*, 2015). Coastal or low-disturbance inland forests caves or rock boulders are suitable areas for this species (Lim *et al.*, 2019). The bat species is primarily a forest species (Kingston *et al.*, 2009) and is classified as near threatened as the population is depleting (IUCN, 2020).

Rhinolophidae

Two bats species, Lesser wooly horseshoe bat (*Rhinolophus sedulus*) and Trefoil horseshoe bat (*R. trifolius*) were both recorded in the Planted Forest and the Nirwana Forest of UPMKB and AHFR (Norisah & Hafizuddin, 2007; Syed Ahmad Hazman & Fatin Najwa, 2008; Mohd Hazlan & Nurul Aidah, 2008; Farah Awatif & Nor Afiedatul Akmal, 2009; Azema *et al.*, 2009; Jambari *et al.*, 1999; Mohd. Azlan *et al.*, 2000; Ahmad Juffiry *et al.*, 2015; Marina *et al.*, 2017). According to Matthew *et al.* (2006), *R. sedulus* is a narrow space insectivore and is categorised as near threatened due to a reduction in the lowland rainforests (Francis, 2019). The capture of the species in the Planted Forest of UPMKB may be related to trees that are planted closely together in the area. *Rhinolophus trifolius* is often caught in the understorey of the primary forest where it sometimes roosts under large leaves (Shirley *et al.*, 2005). Other studies reported finding the species near established paths in the forest or forest gaps caused by fallen trees (Shazali *et al.*, 2016; Khan *et al.*, 2019).

Vespertilionidae

A total of 12 species were recorded, indicating the species' ability to adapt to different habitats in several localities. Newly recorded in AHFR in 2020, the common thick-thumbed bat (*Glischropus tylopus*) was caught in a mist net near bamboo plants in Compartment 15. This species was found roosting in small groups in bamboo stems or dead or damaged bamboo (Kofron, 1994; Lim *et al.*, 2019).

In the current study in UPMSC, we added a new location for the distribution of the big-eared pipistrelle (*Hypsugo macrotis*) for Malaysia, which is listed under the Data Deficient category. This species was spotted inhabiting the tight-top end corners of the roofing (range of 1 to 14 individual/s) and behind a blue pin-up bulletin board (4 individuals) at the Centre of Foundation Studies for Agricultural Science in UPMSC. Other locations where the species was spotted in UPMSC are the Faculty of Science, Faculty of Modern Language and Communication, Faculty of Forestry and Environment, and Faculty of Engineering. Six individuals of the species were captured at their roosting tree (*Livistona chinensis*) living together with *Scotophilus kuhlii*, but at a different side of the dry palm fronds. This species was first recorded in Selangor by Medway (1978) and then by Francis and Hill (1986). In 2016, Lim *et al.* reported finding this species at a school in the center of Seremban city.

Small woolly bat (*Kerivoula intermedia*) was recorded in both UPMKB (Planted Forest and Nirwana Forest) (Norisah & Hafizuddin, 2007) and AHFR (Mohd. Azlan *et al.*, 2000), while the least woolly bat (*K. minuta*), which is Borneo's smallest bat (Phillipps & Phillipps, 2018), was recorded only in Nirwana Forest of UPMKB (Syed Ahmad Hazman & Fatin Nazwa, 2008). The small woolly bat inhabits the understorey of tall lowland forests, and has been reported in low abundance by Christine *et al.* (2013) in six forest reserves in Peninsular Malaysia. Meanwhile, the least woolly bat prefers the understorey of lowland rainforest (Francis, 2019) and have been found at Mount Penrisen in Sarawak by Jayaraj *et al.* (2006). Previous studies indicated that *K. intermedia* is distributed widely throughout Borneo (Payne and Francis 1985) while *K. minuta* is rare (Jayaraj *et al.*, 2006). Both species are listed as Near Threatened conservation status (IUCN, 2020). The papillose woolly bat (*K. papillosa*) was found in both forested areas of UPMKB (Planted Forest and Nirwana Forest) (Mohd Zabidi & Siti Hawa, 2007; Mohd. Hazlan & Nurul Aidah, 2008; Syed Ahmad & Fatin Nazwa,

2008) and AHFR (Mohd. Azlan *et al.*, 2000). The papillose woolly bat prefers to forage in the understorey of lowland rainforests and roosts in small holes of living trees, and sometimes found inside bamboo cavities (Francis, 2019). Forest specialists from the genus *Kerivoula* mainly forage in dense vegetation (Mohd-Ridwan *et al.*, 2018).

The brown tube-nosed bat (*Murina suilla*) was recorded in the Planted Forest of UPMKB (Mohd Zabidi & Siti Hawa, 2007; Azema *et al.*, 2009) and this species is a common bat found in forested areas throughout Borneo (Phillipps & Phillipps, 2018). *Murina* is among the rare species of vespertilionids, but has been recorded throughout Southeast Asia (Medway, 1983; Tingga *et al.*, 2012).

The Asian whiskered myotis (*Myotis muricola*) was captured in UPMKB Campus Zone (Ritauddin & Aminah, 2008) and in Compartment 15 of AHFR (Mohd. Azlan *et al.*, 2000 & Marina *et al.*, 2017). It has been captured using mist nets near bamboo plots (Jayaraj *et al.*, 2012), in open areas, heath forest, peat swamps, streams and rivers near a forest, and agricultural plots (Francis, 2008; 2019). In UPMSC, a single bat was found roosting in young rolled-up banana leaves at the staff housing area and nearby Serumpun College. In Singapore, similar findings on *M. muricola* roosting has been reported by Baker (2017), where the species was found in furred young leaves of ornamental banana plants in a garden of a concrete apartment building complex in a suburban area. They found three and eight bats in two different tubular leaves. Happold and Happold (1990) discussed that furred banana leaves provide suitable roosting conditions for banana bats as: (i) the leaves are available perennially, (ii) the humid microclimate within the furred leaves due to plant transpiration limits dehydration during the day and (iii) intraspecific competition for suitable leaves is limited.

Only two Javan pipistrelle (*Pipistrellus javanicus*) individuals were captured using the harp traps in AHFR (Mohd. Azlan *et al.*, 2000) and four individuals were captured using a mist

net set up under the clay-tiled roof at the gazebo of Kolej Kedua, UPMSC. This species has been recorded in a wide variety of habitats, including mangroves, lowland and hill forests, towns and rubber plantations, and in tree ferns, fallen logs and caves (Kingston *et al.*, 2006; Francis, 2019). In Peninsular Malaysia, the species has also been reported in Perak and Pulau Pinang (Medway, 1969); Pahang (Kingston *et al.*, 2009; Hill, 1967); and Kedah (Norsham *et al.*, 1999). Only one individual of *Pipistrellus* sp. was captured at the Planted Forest of UPMKB (Mohd. Hazlan & Nurul Aidah, 2008) but identification up to the species level was not done.

Asiatic lesser yellow house bat (*Scotophilus kuhlii*) was the second highest capture recorded at UPMSC. This bat was trapped in mist nets set up at foraging area or roosting trees, and found roosting either as a big colony in palm trees (*Livistona chinensis*) or roosting together with other species, such as *Cynopterus brachyotis* or

Hypsugo macrotis. A single individual of this species was captured in AHFR by Mohd. Azlan *et al.* (2000). The bats are known to inhabit a wide variety of habitats, including forested and urban areas (Jayaraj *et al.*, 2016; Francis, 2019; Lim *et al.*, 2019) and can be found roosting in large colonies in the roofs of houses, old and abandoned buildings, and in the crowns of palm trees in gardens (Kingston *et al.*, 2009; Nuratiqah *et al.*, 2017).

On the other hand, two species of *Tylonycteris* bat, both lesser bamboo bat (*Tylonycteris fulvida*, formerly known *T. pachypus*) and greater bamboo bat (*T. malayana*, formerly *T. robustula*) were captured in AHFR (Mohd. Azlan *et al.*, 2000). These bats prefer using bamboo internodes as roosting sites (Francis, 2019; Tingga *et al.*, 2020) and depend on bamboo stands for survival. These species are now threatened by deforestation (Tingga *et al.*, 2020).

Table 2: Number of individuals for each bat species from the current study

Family	Species	Individuals Captured	Relative Abundance (%)
Emballonuridae	<i>Saccolaimus saccolaimus</i>	1	0.09
	<i>Taphozous longimanus</i>	2	0.18
	<i>Taphozous melanopogon</i>	1	0.09
Pteropodidae	<i>Cynopterus brachyotis</i>	729	64.97
	<i>Cynopterus horsfieldii</i>	1	0.09
	<i>Eonycteris spelaea</i>	44	3.92
	<i>Rousettus amplexicaudatus</i>	86	7.66
	<i>Rousettus leschenaultii</i>	28	2.50
Vespertilionidae	<i>Hypsugo macrotis</i>	36	3.21
	<i>Myotis muricola</i>	3	0.27
	<i>Pipistrellus javanicus</i>	5	0.45
	<i>Scotophilus kuhlii</i>	186	16.58
Total Individuals		1122	100
Number of Species		12	
Number of Families		3	
Diversity, H'		1.174	
Evenness, J'		0.473	

A total of 1,122 bat individuals comprising 12 species from three families have been recorded in UPMSC. The most abundant bat species in this survey was *C. brachyotis* (n = 729, 64.97%) followed by *Scotophilus kuhlii* (n = 186, 16.58%) and *R. amplexicaudatus* (n = 86, 7.66%). Three species were captured as singletons: *S. saccolaimus*, *Taphozous melanopogon* and *C. horsfieldii*. The diversity index, H' for bats in UPMSC was 1.174 but it was not evenly distributed ($J' = 0.473$). However, in terms of species diversity, UPMSC has a low number of species compared to UPMKB and AHFR (Table 2).

In Universiti Malaysia Terengganu (UMT), formerly known as Kolej Universiti Sains dan Teknologi Malaysia (KUSTEM), species diversity seems to be lower than UPMSC, and it has been reported that UMT has four species from two families (Widad & Wong, 2013). Three species were frugivorous bats from the family Pteropodidae, which are *Cynopterus brachyotis*, *C. horsfieldii*, and *Eonycteris major*, while the one insectivorous species was from the family Vespertilionidae, which is *Kerivoula papillosa* (Widad & Wong, 2013). They reported three fruit bat species (*C. brachyotis*, *C. horsfieldii* and *Eonycteris major*) and one insect bat species, (*K. papillosa*) were captured, with *C. brachyotis* being the highest capture, similar to what was reported in UPMSC. Various sampling techniques and locations surveyed, especially possible roosting trees and buildings, contributed to 12 bats species recorded in UPMSC.

A total of 20 bat species were recorded in UPMKB (Azema et al., 2009 & Ain Suriani et al., 2010) representing 21% of a total 94 species of bats recorded in Borneo. Among the three capture areas, Azema et al. (2009) reported the Planted Forest showed a higher number of bat species than the Nirwana Forest and Forestry Park. Flowering and fruiting trees are the food sources that attract animals to the Planted Forest. The Nirwana Forest recorded the second highest bat species after the Planted Forest. The close

distance between the Nirwana Forest and Planted Forest probably influenced the number of bat species captured. The Forestry Park recorded the lowest number of species caught. Fewer big trees in the Forestry Park probably affected the availability of the bats' food source and roosting site (Marina et al., 2017). Studies by Gaisler et al. (1998) and Lesinski et al. (2000) found that tree cover positively influenced the overall pattern of species richness of bat communities. Castro-Luna et al. (2007) stated that certain bat species select specific succession stages. This selection is positively or negatively correlated with the canopy cover and floristic composition of the vegetation stand. Martínez-Ferreira et al. (2020) reported that although several bat species can find resources in the secondary forests, they continue to depend on the resources available in old growth forests, which favor great diversity and abundance for bats.

When compared to UPMSC and UPMKB, the diversity of insectivorous bat species recorded in AHFR is higher, with 16 species recorded and one new species currently added to the list of bats in AHFR. However, Mohd. Azlan et al. (2000) previously reported that the diversity of bats species in AHFR appeared to be relatively low in comparison to other forest reserves in Peninsular Malaysia: Krau Wildlife Reserve, Pahang (32 species, Zubaid, 1993; 69 species, Kingston et al., 2009); Temengor Forest Reserve, Perak (41 species, Ratnam et al., 1995); and Ulu Gombak Forest Reserve, Pahang (57 species, Sing et al., 2013). The species diversity at AHFR is comparable to that reported in Bangi Forest Reserve (13 species, Zubaid, 1993); Fraser Hill Forest Reserve (16 species, Mohd-Hanif et al., 2015) and Endau-Kota Tinggi Forest Reserve (17 species, Mohd-Hanif et al., 2015) or slightly better to Endau-Kluang Forest Reserve (9 species, Mohd-Hanif et al., 2015), Sungai Dusun Forest Reserve (10 species, Mohd-Hanif et al., 2015), Tasek Bera Forest Reserve (10 species, Mohd-Hanif et al., 2015), and Lata Bujang Forest Reserve (11 species, Mohd-Hanif et al., 2015).

Conclusion

Availability of different habitats (including forested, agricultural, and urban areas) has greatly contributed to UPM's ability in accommodating different species of bats. This paper records 36 bat species in UPM and its forest reserves revealing common species and several relatively rare forms, such as *Cynopterus sphinx*, *Dyacopterus spadiceus*, *Megaerops albicollis*, *Rhinolophus sedulus*, *Nycteris tragata*, *Hypsugo macrotis*, *Kerivoula intermedia*, and *K. minuta*. Consistent and continuous monitoring and surveys should be implemented in all three localities of UPM to update and record species diversity and distribution of bats for future tracking. Future monitoring of species, particularly those listed as Vulnerable, Near Threatened and Data Deficient should be conducted persistently. Scale enhancement of habitats or landscapes must be introduced to increase bats diversity and prioritizing protection of suitable habitats within the vicinity of bats' roosting sites can be a good practice for the management and conservation of bat diversity.

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