DIVERSITY OF BATS IN THREE SELECTED FOREST TYPES IN SELANGOR AND KUALA LUMPUR

NURSYEREEN BINTI MOHD NASIR

INSTITUTE OF BIOLOGICAL SCIENCES
FACULTY OF SCIENCE
UNIVERSITY OF MALAYA
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ABSTRACT

Bats have been occupying variety of habitat that can sustain their population. Many bat species play important roles in tropical forest. Through this study, we explored the diversity of bats in various habitats; primary forest, secondary forest and urban forest. The aims of this study are to determine species composition of bats in three different habitat types; primary forest, secondary forest and urban forest, to study the population distribution, species diversity, species richness, species evenness and abundance of bats, and to compare the capture rate of bats using two different capture methods which are mist nets and harp traps. This study was done at the primary and secondary forest of Ulu Gombak Forest Reserve and urban forest in Universiti Malaya Botanical Garden from February 2012 until April 2014. The sampling were done for 3 nights using 10 mist nets and 4 harp traps which were set up across strategic flyways; near fruiting trees and forest gaps. These mist nets and harp traps were left open overnight and checked in one hour interval until 2330 and were closed during the day. This study resulted in the capture of 1226 individuals representing 46 species. Throughout this study, a total of 396 individuals of bats from 33 species were recorded in primary forest, 608 individuals of bats from 31 species were recorded in secondary forest and 222 individuals of bats from 11 species were recorded in urban forest. Primary forest (Shannon-Wiener,H’ = 2.516) has higher diversity of bats compared to secondary forest (Shannon-Wiener,H’ = 2.476) and urban forest (Shannon-Wiener,H’ = 1.527). However, the urban forest has higher evenness index calculated (E = 0.4184) compared to primary forest (E = 0.3994) and secondary forest (E = 0.3718). Species richness in secondary forest is the highest (D_{mn} = 1.616) followed by primary forest (D_{mn} = 1.257) and urban forest (D_{mn} = 0.7383). This study showed that primary forest is more diversified compared to other habitats although more individuals were recorded in secondary forest. ANOVA showed a significant difference between the three habitat types but using JACCARD coefficient dendogram, the diversity of bats in primary forest and urban forest are almost similar. The total capture rate for mist nets recorded in this study (0.39 bats per night per net) is lower that the total capture rate for harp traps (0.56 bats per night per net) showing the effectiness of harp trap in sampling insectivorous bats as well as frugivorous bats.

Keywords: primary forest, secondary forest, urban forest, bats.

KEPELBAGAIAN KELAWAR DI TIGA HUTAN TERPILIH DI SELANGOR DAN KUALA LUMPUR

ABSTRAK

Kelawar telah menduduki pelbagai habitat yang boleh menampung populasinya. Banyak spesies kelawar memainkan peranan penting dalam hutan hujan tropika. Melalui kajian ini, taburan kelawar di hutan dara, hutan sekunder dan hutan bandar telah dikaji. Tujuan kajian ini adalah untuk menentukan komposisi kelawar di tiga habitat berlainan; hutan primer, hutan sekunder dan hutan bandar, mengkaji taburan kelawar, kepelbagaian, kekayaan spesies, kesamarataan dan komposisi kelawar, dan membandingkan kadar tangkapan kelawar menggunakan dua kaedah penangkapan berlainan, jaring kabut dan perangkap harp. Kajian ini dijalankan di hutan primer dan sekunder di Hutan Simpan Ulu Gombak dan hutan bandar di Taman Botani Universiti Malaya daripada Februari 2012 sehingga April 2014. Kajian dijalankan selama 3 hari menggunakan 10 jaring kabut dan 4 perangkap harp yang diletakkan di laluan strategik, berdekatan pokok buah dan jurang hutan. Jaring kabut dan perangkap harp dibuka semalaman dan diperiksa dalam selang sejam sehingga 11.30 malam dan ditutup pada waktu siang. Kajian ini menunjukkan tangkapan 1226 individu mewakili 46 spesies. Sepanjang kajian, 396 individu daripada 33 spesies direkodkan di hutan primer, 608 individu daripada 31 spesies direkodkan di hutan sekunder dan 222 individu daripada 11 spesies direkodkan di hutan bandar.Hutan primer (Shannon-Wiener,H' = 2.516) mempunyai kepelbagaian spesies yang lebih tinggi daripada hutan sekunder (Shannon-Wiener,H' = 2.476) dan hutan bandar (Shannon-Wiener, H' = 1.527). Walaubagaimanapun, hutan bandar mempunyai indeks kesamarataan yang lebih tinggi (E = 0.4184) berbanding hutan primer (E = 0.3994) dan hutan sekunder (E = 0.3718). Kekayaan spesies di hutan sekunder adalah tertinggi (D_{mn} = 1.616) diikuti oleh hutan primer (D_{mn} = 1.257) dan hutan bandar (D_{mn} = 0.7383). Kajian ini menunjukkan kepelbagaian hutan primer adalah lebih tinggi berbanding habitat lain walaupun lebih individu direkodkan di hutan sekunder. ANOVA menunujukkan perbezaan signifikasi antara ketiga-tiga jenis hutan tetapi berdasarkan dendogram koefisien JACCARD, diversiti kelawar di hutan primer dan hutan bandar adalah hampir sama. Jumlah kadar tangkapan kelawar menggunakan jaring kabut (0.39 kelawar per malam per jaring) adalah lebih rendah daripada kadar tangkapan kelawar menggunakan perangkap harp (0.56 kelawar per malam per jaring) di semua vegetasi menunjukkan keberkesanan perangkap harp dalam menyampel kelawar serangga dan juga kelawar buah.

Kata kunci: hutan primer, hutan sekunder, hutan bandar, kelawar.

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LIST OF SYMBOLS AND ABBREVIATIONS

E	East
g	gram
m	metre
mm	millimetre
N	North
ANOVA	Analysis of Variance
IUCN	International Union for Conservation of Nature
UG	Ulu Gombak
UM	University of Malaya
spp.	species

LIST OF APPENDICES

CHAPTER 1: INTRODUCTION

1.1 Background of research

Tropical forest landscape has changes rapidly due to human activities (Fukuda *et al.,* 2009). Existing forest becoming fragmented with increasing development is causing habitat loss and decreasing food resources for bats (Azlan, 2000). Bats occupy variety of habitats including primary forest, secondary forest, mangrove, cultivated areas, orchards, gardens and urban areas (Francis, 2008; Boon & Corlett, 1989; Tan *et al*; 1998). The difference in forest profile in which logging causes the forest canopy level to be lowered compared to a primary forest can have effect on the abundance of bats where there are high chances of netting bats at ground level (Zubaid, 1993; Francis, 1994). Ulu Gombak has high species richness of bats reported as 50 species at single locality (Heller & Volleth, 1995).

The Southeast Asian forests, dominated by mast-fruiting dipterocarps are the oldest rainforests on Earth with biological richness and biodiversity equal of the Amazon and African rainforests. Yet, the rainforests are disappearing rapidly and has a few remaining primary forest (Sodhi & Brook, 2006). Francis (2008) listed over 470 species of land mammals in Southeast Asia. In Peninsular Malaysia, there are 205 species of land mammals comprising 32 families and 11 groups (Khan, 1992). Stevens (1968) documented preferred habitat among these Malaysian mammals, 53% are confined to primary forest, 25% live in primary and tall secondary forest, 12% live in primary and secondary forest or can subsist in cultivate area, and 10% live in cultivated or urban area. Malaysia is a critical country for international bat conservation with over 125 species accounting for over 10% of the world's bat fauna and 40% of the Malaysian mammals (Kingston *et al.,* 2006). Unfortunately, over a quarter or 34 species of Malaysian bats are listed by IUCN as going into extinction, primarily due to habitat loss and hunting.

Francis *et al.* (2010) stated that bats are important indicators of the state of ecological communities and bat survey is often used for conservation planning. In Southeast Asia, the bat communities have been greatly underestimated (Kingston *et al.,* 2003a). The real number of bat species is at least twice of that which is currently recognized (Francis *et al.*, 2010).

Habitat loss and logging has threatened bat diversity. Anthropogenic disturbances can cause species loss and extinction of many bat taxa (Kingston, 2010). Lowland forest is valuable to the logging industry because it is rich in dipterocarp species. When an area has been logged, it requires long periods of time to recover (Sodhi *et al.,* 2004). The effects of habitat disruption may reduce diversity of bats because of changes as edge effects alter the forest microclimate and population of the insects. Edge effects lower humidity and increase light, temperature, wind disturbance and desiccation. These physical alterations lead to a decreasing insects' population due to reductions in plant reproductive success (Didham *et al.,* 1996).

Fragmented forest may influence habitat use by foraging bats due to its effects in flight, prey and roost abundance. According to Kingston *et al*. (2003b), insectivorous bats used different foraging strategy depending on whether they are in highly cluttered space, small clearings like over small streams and open spaces above the forest. Bats did not prefer highly cluttered vegetation because it affects the efficiency of flight. Some species may roost in highly cluttered area but feed in a less cluttered vegetation. Some bats that avoid open area to avoid predators or high winds may interfere with flight or prey capture (Patriquin & Barclay, 2003).

Russo *et al*. (2010) stated that diversity of bats in an area is dependent on the foraging area, availability of roosting and food resources. Bats can access resources that is widely scattered in the environment because they are able to commute between forest patches and utilize matrix habitat for several kilometers in one night. However, some species of bats (*Kerivoula papillosa, Hipposideros ridleyi, Rhinolophus sedulus* and *Rhinolophus trifoliatus)* have a limited foraging range due to energetically expensive flight that is not suitable for long distance (Struebig *et al.,* 2008). Forest bats are strictly dependent on the forest structure for foraging and roosting but some bats that can be found in other types of vegetation are influenced by the size of wing, type of maneuverability, roosting sites and also foraging type (Patriquin & Barclay, 2003).

Bat species play an important role in our ecosystem. At least 31 Malaysian plant species rely on Old World fruit bats (Megachiroptera) to pollinate them including durian, petai, mango, banana, guava, jackfruit and papaya (Kingston *et al.,* 2006). According to Struebig *et al.* (2010), Old World fruit bats exhibit dispersal capabilities and generalist feeding habit. *Eonycteris spleae,* a long-tongued fruit bat that is widely distributed in Southeast Asia has been recorded to consume the pollen grains of durian as large part of its diet (Carter, 1984). The Microchiroptera play an important role as biological control agent on insects' population in forests and agriculture (Zubaid *et al*., 2004). Every night, insectivorous bats eat at least half of its body weight which is equivalent to 600-mosquito-sized insects in an hour and large colonies can consume over 2000 tonnes of insects per year (Kingston *et al.,* 2006).

1.2 Research objectives

1. To determine species compositions of bats in three different habitats types; primary forest, secondary forest and urban forest.

2. To study the population distribution, species diversity, species richness, species evenness and abundance of bats in the three different habitat types.

3. To compare the capture rate of bats using two different capture methods which are mist nets and harp traps.

CHAPTER 2: LITERATURE REVIEW

2.1 The distribution of bats

Tropical region of the world are relatively rich in numbers and species of mammals, compared to the temperate and arctic areas (Fleming, 1979). Small mammals are define as comprising members of the taxonomic orders Marsupilia, Insectivora, Chiroptera, Rodentia and Lagomorpha (Fleming, 1979). Bernard *et al.* (2009) define small mammal as mammals with weight less than 5 kilogram. Small mammals are divided into two categories; the volant and non-volant small mammals (Francis, 2008). Bats belonging to the group of small mammals that can fly are categorized as volant small mammals. Bats are not to be confused with birds since bats have feathers, teeth and give birth to live young (Francis, 2008).

In Malaysia, there are at least over 125 species of bats accounting for over 10% of the world's bat fauna (Kingston *et al*., 2006). Kingston *et al.* (2006) noted that forty percent of Malaysian mammals are bats and in the rainforest ecosystem, they comprise of over half of all mammal species. Bats of Southeast Asia are classified into 9 family based on morphological characteristics; forearm, tail, ears, nose and noseleaf. At genus level, species were identified according to fur colour and structure of teeth (Kingston *et al.,* 2006; Francis, 2008). *Cynopterus brachyotis* Forest and *Cynopterus brachyotis* Sunda have different genetic composition but hard to differentiate morphologically. *C. brachyotis* Sunda has longer forearm and muzzle and a yellowish collar compares to *C. brachyotis* Forest (Kingston *et al*., 2006; Campbell *et al*., 2007).

Previous studies on bat diversity in various habitat; primary forest, secondary forest, agricultural plantation, oil palm and orchard has contributed to the references for this study. Azlan (2000) stated that the diversity of bat species in forest reserve appears to be relatively low in comparison to that of primary forest in the peninsula. An assessment of the diversity of bats at two contrasting habitat, the secondary forest and oil palm plantation shows no significance difference in species richness (Shafie, 2011). Francis (1994) studied the abundance of fruit bats at subcanopy level and ground level which resulted in higher species diversity in the subcanopy level. Zubaid (1993) noted that primary forest harbor high diversity of bats compared to disturbed forest. A study by Fukuda *et al.* (2009) shows high diversity of bats in primary forest and that the capture rate of bats was lower in oil palm than in primary forest, secondary forest and orchards due to low abundance of prey and capture rate success. Nakagawa *et al.* (2006), investigate the effects of various forest uses on small mammal communities in Sarawak, by comparing six forest types; fragmented primeval forest, abandoned fallow at three development stages (new, young, and old), rubber plantation and primary forest. They have suggested that among various habitat types, only new fallow has severe effects on small mammal communities.

Bats often choose habitat with lots of food sources, roosting site, less threats, social organization and a suitable physical environment (Hodgkison *et al.*, 2004a; Campbell *et al.*, 2006; Kunz *et al.*, 2011). Most species of bats are capable of adapting to various environments because it is dependant to the food availability in the habitat (Campbell *et al.,* 2006). Microchiroptera bats such as *Hipposideros cervinus, H. larvatus* dan *Rhinolophus affinis* often lives in a large community up to 1000 individuals in a cave (Kingston *et al.,* 2006). At night, this bats forage for food in a group using echolocation. Bats that have larger wing tend to fly further than smaller bats that forage close to the roost (Kunz *et al.,* 2011).

Rhinolophus affinis, R. stheno and *R. lepidus* lives in a large colonies. *R. affinis* have make limestone cave as a habitat (Kingston *et al.*, 2006). Caves are the most permanent habitat because it provides shelter to species such as *Rhinolophus affinis, R. stheno* and *R. lepidus* (Kunz, 1982). Megachiroptera can adapt to roosting on branches and leaves. The leaves of trees are formed into tent (Campbell *et al.,* 2006). The species of bats that roost on trees are *Cynopterus brachyotis, C. horsefieldi* and *Balionycteris maculata*. In a study in Taman Negara Perlis and Taiping, *C. brachyotis* that were found in primary, secondary forest and agricultural land often used *Arenga obtusifolia* (Palmae), *Macaranga gigantea* (Euphorbiaceae) and *Orania sylvicola* (Palmae) as roosting site (Campbell *et al.,* 2006). *B. maculata* was only found in primary forest or secondary forest (Hodgkison & Kunz, 2006; Kingston *et al.,* 2006). This roost site is usually temporary depending on the surrounding area. This type of roosting site has always supported one individual or a small group (Mickleburgh *et al.,* 1992). Struebig *et al.* (2010) stated that fragmented forest being large or small can still support diversity of bats in different numbers. Bats that roost on trees or leaves are more vulnerable to threats compared to bats that live in caves (Struebig *et al.,* 2010). The foraging behaviors of Chiroptera are ordained by its colony sizes (Bonaccorso *et al.,* 2002). Bonaccorso *et al.* (2002) stated that the lesser bare-backed bats (*Dobsonia minor)* that forage in primary and secondary forest and in abandoned gardens are solitary and roost in foliage of understory and subcanopy trees in lowland rainforest. Bats species that are solitary, particularly in tropical forests, often roost within their foraging area and incur minimal time and energy costs for commuting than bats species with larger colony sizes (Bonaccorso *et al.,* 2002).

Fruits that is available all year long in Malaysia such as *Pterandra echinata, Ficus globosa* and *Ficus scortechinii* are major food sources for *Balionycteris maculata, Cynopterus* *brachyotis* and *Chironax melanocephalus* (Hodgkison *et al*., 2004b). *Ficus* has been a major food preference of frugivorous bat. Agoramoorthy and Hsu (2005) in the study of Indian fruit bat, *Latidens salimalii* indicate that this species feed on at least three species of figs such as *Ficus dadotii, F. macrocarpa,* and *F. racemosa* including other plants such as *Eleocarpus oblongus, Diospyros ovaliflora* and *Prunus ceylanicus*. A study by Stier *et al.* (2005) in lowland dipterocarp forest throughout the Phillipines, noted that figs appear to be dietary staples for *Aceredon jubatus* and *Pteropus vampyrus lanensis.* According to August (1981) in the study on *Artibeus jamaicensis*, the foraging activity of bats correlated with fruit condition. The finding indicates that more bats were foraging at a tree that contained ripe fruits than a tree containing unripe fruits. The availability of food in different habitat influenced how bats forage through the area. Bats that uses echolocation often chooses open area and forest edge as well as narrow area (Schnitzler *et al.,* 2003; Norberg & Rayner, 1987). In a narrow and constricted area, bats feed on insects, fruits and flowers while in an open area, bats feed on aerial insects (Kunz *et al*., 2011; Denzinger & Schnitzler, 2013). Hazebroek and Morshidi (2000) noted Microchiroptera are known to use two common techniques to catch and hunt their prey by dodging through undergrowth or gleaning off the surface of water, leaves, foliage and ground. In addition, Fenton (1982) found that there are two styles of catching prey by insectivorous bats, through response from far distances for one attempt and another strategy by response from near ranges for several attempts. Species in the family Vespertilionidae and Emballuronidae likes to forage at forest edge and they use combined sounds while hunting prey (Denzinger & Schnitzler, 2013). Michrochiroptera mostly feed on insects by using echolocation to detect their prey (Kalko, 1995; Altringham, 1996). According to Richardson (1985), some Microchiroptera species also feed on small vertebrates like small mammals and reptiles and also birds. Species such as *Nycticeius humeralis, Myotis septentrionalis*, *Eptesicus fuscus* and *Myotis sodalist* consumed insects from order Coleoptera, Lepidoptera and Hymneptora (Whitaker Jr, 2004). Since bats are nocturnal, the day-flying insects are not a major component of their diet (Kunz, 1982; Parsons & Jones, 2000). According to Borror *et al.* (1981), Dermaptera, Thysanura, Hymenoptera and Orthoptera are some of the orders of insects that are active at night. There are a few insects such as mantids, lacewing and moths that have the ability to detect the echolocation calls of insectivorous bats and generate escape responses (Altringham, 1996; Fenton, 1982). Consequently, most of the insectivorous bats had overcome this insect ability by adjusting the frequency of echolocation, added flight speeds and try to mimic the prey sound (Fenton, 1982).Variation in food foraging can lessen the competition for available sources among bats.

Bats in Kuala Krau Forest Reserve have been extensively sampled. Among the studies are differential use of vertical space by bats (Francis, 1994; Hodgkison *et al.,* 2004a), diversity of bats (Kingston *et al*., 2003a; Kingston *et al*., 2006; Francis, 2008) and the diets of frugivorous bats (Hodgkison *et al.*, 2004a; Hodgkison *et al.,* 2004b). A study by Shafie *et al.* (2011) recorded 13 species of bats. *Cynopterus brachyotis* and *Macroglossus minimus* was caught in abundance in secondary forest. *Cynopterus brachyotis* and *C. horsfieldi* was also captured in oil palm plantation. Inventory of species of bats in Peninsular Malaysia has also been done in Taman Diraja Belum, Perak in which 18 species of bats were recorded (Shukor *et al.,* 2006). Shafiz *et al.* (2011) recorded 22 species of bats at Gunung Mandi Angin. A study in Hutan Simpan Temenggor using harp trap recorded 20 species of insectivorous bats (Joann *et al.,* 2011).

Diversity of bats was also studied extensively in Sabah and Sarawak. 33 species of bats were recorded in Banjaran Tinggi Crocker National Park (Tuen *et al.,* 2002), Taman Negara Bukit Lambir recorded 25 species of bats (Fukuda *et al.,* 2009), Wiantoro *et al.* (2009)

recorded 5 species of bats in Gunung Murut, four species of bats were recorded in Gunung Silam, Sarawak (Ketol *et al.,* 2009) and 45 species of bats at 8 localities in Sarawak (Jayaraj *et al.,* 2011). These studies inventorised species of bats and also looking at diversity and composition of species at different habitat types.

2.2 Techniques used for capturing bats

There are many techniques that can be used to sample bats such as mist-net (Hodgkison *et al.,* 2004b; Kingston *et al.,* 2006), harp trap (Kingston *et al.,* 2006), Tunnel trap (Sedlock *et al.,* 2008) and radiotelemetry (Flaquer *et al.,* 2007). The used of various techniques are for the purpose of effectively sampling bats in the area. Generally, harp trap are very effective to catch insectivorous bats and may also catch frugivorous bats mist net are suitable to catch frugivorous bats (Francis, 1989). The location for setting up trap is important as there are species of bats that fly at canopy level, under canopy level and fly low at the surface of water (Mckenzie *et al.,* 1995). The success rate of capturing bats also depends on time interval because bats activity is different for each species and sexes (Presley *et al.,* 2009). Tan *et al.* (1999) stated that *C. brachyotis* first become active shortly after sunset to check the condition of the food and its location and will only start feeding when it confirms that the territory is secure. Adult females of *Pteropus poliocephalus* emerged earlier due to their higher foraging needs as indicated by their body condition. Young emerged later because they were likely to be more at risk of predation (Welbergen, 2006). Trapping outside the time interval can reduce the effectiveness of sampling and composition of bats captured might be reduced. The uneffectiveness of catching bats such as insectivorous species may be because of the ability to locate mist net using echolocation and escaping by torning off the net using the teeth (Francis, 1989).

2.3 Forests in Malaysia and how the changes affected bats

Malaysia is rich in flora and fauna with an optimal temperature and high average annual rainfall. Whitmore (1990) stated that forest trees usually flowers at the same time. Trees from family Dipterocarpaceae will flower two times a year. Trees that flowers and produce fruit all year round are *Pternandra echinata* (Melastomataceae), *Ficus globosa* (Moraceae), *Ficus scortechin* (Moraceae) and *Nauclea officinalis* (Rubiaceae) which are food sources for many animals including bats (Hodgkison *et al.,* 2004b). Flower that is pollinated by bats usually blooms at night, with thicker nectar, sour smell and the colour is unattractive. The flower that is pollinated by bats are *Parkia speciosa* and *Pseudo bombax* (Whitmore, 1990).

Until 2006, 44% from 14.39 million hectare of forest in Malaysia has been gazetted as Forest Reserve that is being managed by Pengurusan Hutan Mapan (Rahim et al., 2011). Forest Reseve is divided into two which are productive forest (11.18 million hectare) and protected forest (3.21 million hectare) (Rahim *et al.,* 2011). Protected forest ensures the diversity of species in the forest, protecting water resources and richness of soil. Productive forest provides woods such as Kelat (*Syzygium* sp.), Meranti (*Shorea* sp.) and Nyatoh (*Payena* sp.) for wood-based product (Rahim *et al.,* 2011; Samsudin *et al.*, 2010).

Protected forest includes virgin forest, forest reserve, forest for research and education, forest for wild animal protection, forest for flood mitigation and water reservoir. Bamboo trees found in protected forest and logged forest are buluh betong (*Dendrocalamus asper*) while buluh akar (*Schizostachyum grande*) grows in abundance in disturbed forest (Whitmore, 1990; Yong, 1994). Bamboo and rattan usually grows in disturbed forest. Several species of bats rely on bamboo trees as roosting site for example *Tylonycteris robustula* and *Glischropus tylopus* (Kingston *et al.*, 2006). *Cynopterus brachyotis* have also been found perching on rattan (*Calamus* spp.) (Campbell *et al.,* 2006).

Tragically, more than quarters (34 species) of Malaysian bats are red-listed by the IUCN as being at some risk of extinction while many other small mammal species are declining (Shafie, 2011). Anthropogenic disturbance; deforestation, conversion to agricultural land and association with resident human population has become major threat to this small mammal community (Bruner *et al.*, 2001). It is very important to know how this disturbance can affect the forest and, in turn, different biological communities living within it (Shafie, 2011). Facing this reality, wildlife biologists are working to understand the effect of forest conversion on threatened species and how coexistence of human and wildlife can be manage (Sedlock, 2008).

Anthropogenic disturbance is often present within officially protected areas. According to Sodhi and Brook (2006), disturbances in the natural habitat can cause habitat loss or habitat modification and fragmentation. Habitat fragmentation is defined as the discontinuity, resulting from the spatial distribution of resources and conditions present in an area at a given scale that affects occupancy, reproduction, or survival in a particular species (Franklin *et al.,* 2002). The effect of habitat fragmentation on small mammals as studied by Charles and Ang (2010) were reduction in the species richness and diversity in relation to size fragment, the disappearance of species with large home ranges and specific habitat requirements, invasion of generalists or opportunists into the fragments from degraded habitats, absence of predators, a possible reduction in the activity space of generalists in fragment, erosion in the trophic structure of the small mammal community, changes in the small mammal abundance in relation to fragment size and dominance of one species over other co-occurring species in an isolated fragment.

Changes of structure and arrangement of forest can influence the distribution of bat communities by affecting roosting and foraging habitat (Yates & Muzika, 2006). A study by Syakirah *et al*. (2000) stated that selective logging is not expected to reduce food availability or the number of nesting site drastically although many studies proven that logging activities affected species richness, abundance and composition. Fruit bats exhibit dispersal capabilities and generalist feeding habits that support their persistence in disturbed landscape (Meijaard *et al*., 2005). Likewise, insectivorous species that forage in forest edge and tree fall gaps (Vespertilionidae) or the open spaces above and outside forest (*Taphozous* spp.) may be readily adapted to exploit disturbed habitat (Kingston *et al*., 2003a; Meijaard *et al*., 2005). Although some species are able to make use of new habitats, most remain dependant on their neighboring patches of forest and cannot survive without them. Nevertheless, the tolerance level of species towards the disturbance actually depends on the varying abilities of species to thrive in disturbed habitat (Shafie, 2011). Logging and forest conversion to plantation shows pattern of decreasing in species richness and species abundance thus, caused changes in bat community structure (Danielsen & Heegard, 1995; Shafie *et al.*, 2011).

CHAPTER 3: METHODOLOGY

3.1 Study Sites

The study was carried out at two sites in Ulu Gombak Forest Reserve in Selangor representing the primary and secondary forest, and Universiti Malaya Rimba Ilmu Botanical Garden in Kuala Lumpur that represent urban forest (Figure 3.1). These study sites were selected as they differed in forest structure.

3.1.1 Urban Forest of Universiti Malaya

The urban forest is a botanical garden located in the campus of Universiti Malaya in Kuala Lumpur (3°8’ N, 101°40’ E). The garden was established in 1974 and planted with diversity of plants in need to conserve and study flora in Malaysia (Wong, 1997). The collections were labeled to provide names and information of plants to visitors. Species of plants that can be found are medicinal plants such as *Orthosiphon aristatus* and *Catharanthus roseus* (Wong, 1997). The Palms and the Citrus and Citroid Collection are the main collections of the botanical garden. Various other plant species including ferns, bamboos, fruiting-tree and timber were also planted. Most species of plants in the garden are indigenous to the region but there are also plants from other continents in the collection.

3.1.2 Primary forest of Ulu Gombak Forest Reserve

The primary forest (3° 19.191’ N, 101° 44.512’ E) is an intact forest of Ulu Gombak Forest Reserve. It is located along side the east-coast highway. More species that form the canopy and emergent layers can be seen. The variations in canopy height were much larger than in regenerating forest due to intermittently occurring gap formation between trees. Many towering tree of the family Dipterocarpaceae (*Shorea* spp. and *Dipterocarpus* spp.) and *Ficus* sp. are present in this area. Bamboo and small shrubs also present in some area within this study site.

3.1.3 Secondary forest of Ulu Gombak Forest Reserve

The secondary forest (3° 20.033’ N, 101° 46.347’ E) is a regenerated forest after been logged approximately 30 years ago. Tree heights in the forest vary and there are many bamboo trees as a result of disturbance. Other vegetation in this area is rattan, pandan, small palm trees, *Macaranga* spp. and aggregation of medium sized trees. Canopy heights in this area were much lower than in the primary forest due to the fact that the trees growth immediately after logging and the canopy gap is uniform. The forest floor is dense with shrub vegetation covering the ground while some patch area is open area which no trees present.

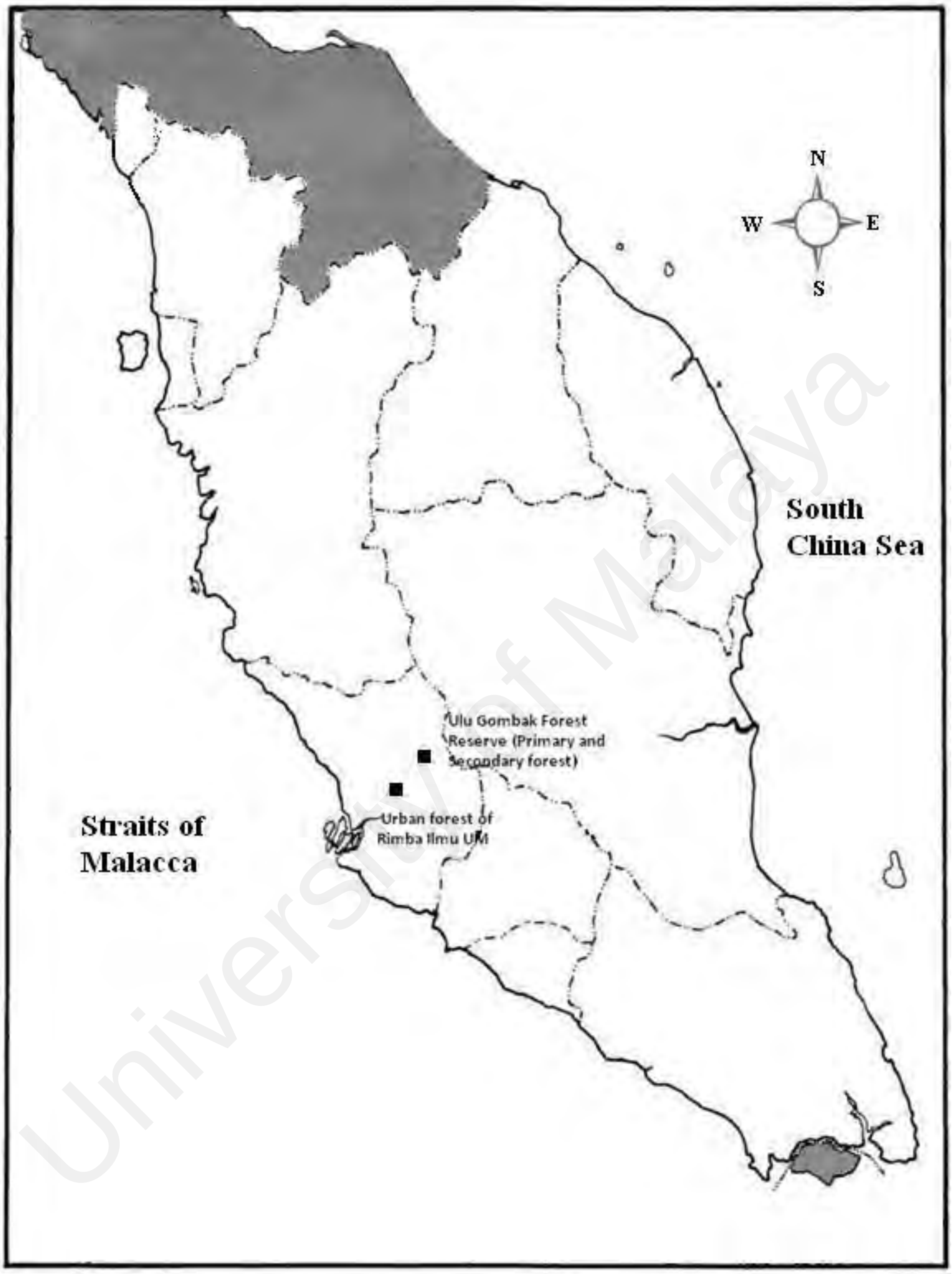

Figure 3.1: The map of Peninsular Malaysia showing three sampling localities; the primary forest, secondary forest of Ulu Gombak Forest Reserve, Selangor, and urban forest at Universiti Malaya Rimba Ilmu Botanical Garden, Kuala Lumpur

3.2 Field Methods

The samplings were done every three months at three different forest types alternately between February 2012 until April 2014 (Table 3.1). Two common methods that were used to capture bats are mist netting and harp trapping. Direct observation method is not used since it is unsuitable to study bats which are nocturnal without proper gear or equipment. Mist netting and harp trapping are more useful since it facilitate identification process.

Table 3.1: Frequency of visits for each forest types

Forest type	Dates of visit
Primary forest	8-11Feb 2012; 16-19 May 2012; 4-7 Sept 2012; 7-10 Jan 2013; 23-26 Apr 2013; 19-22 Aug 2013; 10-13 Nov 2013; 10-13 Feb 2014
Secondary forest	4-7 Mar 2012; 22-25 June 2012; 2-5 Oct 2012; 5-8 Feb 2013; 15-18 May 2013; 2-5 Sept 2013; 12-15 Dec 2013, 20-23 Mar 2014
Urban forest	12-15 Apr 2012; 11-14 July 2012; 4-7 Nov 2012; 12-15 Mar 2013; 3-6 June 2013; 20-23 Oct 2013; 4-7 Jan 2014, 5-8 Apr 2014

Mist nets that were used in this study are made up of nylon and has dimension of 2.5m high, 12m long and 38mm mesh size. Poles and ropes were used to erect the mist nets. Four-bank harp trap is made up of aluminum rectangular frame which has a canvas bag attached to it for holding trapped bats (Francis, 1989). It has vertical line across it with the sewed nylon. The setup of harp trap was supported by surrounding small trees. The mist nets (placed at ground level) and harp traps were selectively installed within narrow path. They were placed in the area that was potentially used as flyways, well established trail, or in small clearing area, near roosting site, and near to river or any water sources.

During each visit, 10 mist nets and 4 four-bank harp traps were set up for a period of three nights. These mist nets and harp traps were left open overnight and the nets were closed during the day. Mist nets and harp traps were opened at 1830 hours, and checked at 1930 hour, 2030 hour, 2130 hour, 2230 hour and 2330 hour and before closing after the last check at 0630 hour. More frequent visit was done in the event where capture rate was high. Regular monitoring is not needed if the capture rate is low since it can increase disturbance and may affect capture rate (Barlow, 1999).

There are three factors that influence the choice of capture methods (mist nets and harp traps). The first one is due to existence of inter-specific variation in relative susceptibility to harp traps or mist nets. Francis (1989) explained that the Microchiroptera is able to echolocate, thus able to detect the mist nets before hitting them compare to Megachiroptera that used vision for navigation. The dentitions types of Microchiropteran and Megachiropteran are the second factor in selecting the capture methods. Study done by Laval and Fitch (1977) proved that, Microchiropteran teeth have sharp cutting edges which enable them to chew the nets while Megachiropteran teeth have rounded and pointed crown which is not effective at cutting nets. Body size of the bats influenced the rate of trapping success. Aldridge (1987) pointed that large sized bats have higher wing loadings and cannot turn as sharply to avoid mist nets.

3.3 Bats Identification

All trapped bats were extracted from nets and traps and were temporarily kept inside cloth bags. Individuals captured were marked by wing punctuation to avoid double counting during the visit. Bats were then identified up to species level using the information from field guide following Francis (2008) and Kingston *et al.* (2006). The standard morphological measurements were recorded and picture of bats were taken for correct identification and future reference. Vernier caliper (measure in mm), steel ruler and spring scales (measure weight ranges up to 100 g) were used in measuring the external morphological characters. Morphological characters that were measured are ear length (E), forearm length (FA), tibia length (TB), tail length (l), weight (g) and sex (male/female). Sex of the bats can be identified by the presence of nipples for female and prominent penis for males. All the morphological measurements were recorded in a data sheet and all bats were released at the site of capture after processing.

3.4 Data Analysis

Analysis were done to determine the species richness, evenness, abundance and significant differences between the three sites. Shannon-Wiener (H) was used to determine thespecies diversity. Shannon-Weiner Equitability was used to calculate the evenness (E) in the community. Species richness (R) was calculated using Menhinick's Richness index. Relative abundance index was used to determine the ratio of species number to individuals captured and species dominance. An ANOVA test was used to compare mean of bats captured in the three habitat types. If the p-value is below than 0.05, there is statistically significant difference between the three sites while if the p-value is more than 0.05 it shows no significant difference. All statistical analyses were analyzed using PAST software (Paleontological statistic).

Species accumulation curve was plotted for the three forest types to illustrate the completeness of sampling efficiency. The first-order Jacknife method was used to estimate projected species richness at increasing levels of sampling effort. The number of species is estimated using Chao, ACE and Jacknife. According to Smith and Pontius (2006), Jacknife estimate are based on the number of unique species presented in each observation. The analysis can give estimate of species richness that estimate the number of species obtains if the sampling is continued. If the curve is flat, it shows that the sampling has reach asymptotes and can be stopped. Estimate S Version 9.1.0 was used to plot the species accumulation curve.

Dendogram is constructed using Jaccards coefficients to show the degree of similarity between three sites. This analysis is done using PCORD version 6.0 software. The name of species used in the PCORD software will use the code as in Table 3.2.

Table 3.2: Code used in dendogram for species name

Species	Code
Balionycteris maculata	*Balio*
Cynopterus brachyotis	*Cynop 1*
Cynopteros horsfieldi	*Cynop 2*
Chironax melanocephalus	*Chiro*
Emballunora monticola	*Emballu*
Eonycteris spleae	*Eonyc*
Glischropus tylopus	*Glischro*
Hipposideros bicolor	*Hippo 1*
Hipposideros cervinus	*Hippo 2*
Hipposideros cineraceus	*Hippo 3*
Hipposideros diadema	*Hippo 4*
Hipposideros doriae	*Hippo 5*
Hipposideros galleritus	*Hippo 6*
Hipposideros larvatus	*Hippo 7*
Kerivoula harhdwickii	*Keri 1*
Kerivoula intermedia	*Keri 2*
Kerivoula minuta	*Keri 3*
Kerivoula papillosa	*Keri 4*
Kerivoula pellucida	*Keri 5*
Macroglossus minimus	*Macro 1*
Macroglossus sobrinus	*Macro 2*
Megaderma lyra	*Mega 1*
Megaderma spasma	*Mega 2*
Megaerops ecaudatus	*Megae*
Murina aenea	*Murina 1*
Murina suilla	*Murina 2*
Murina cyclotis	*Murina 3*
Myotis ater	*Myo 1*
Myotis muricola	*Myo 2*
Myotis ridleyi	*Myo 3*
Myotis rosseti	*Myo 4*
Nycteris tragata	*Nycteris*
Penthetor lucasi	*Penthe*
Philetor brachypterus	*Phile*
Pipistrellus tenuis	*Pipis*
Rhinolophus acuminatus	*Rhino 1*
Rhinolophus affinis	*Rhino 2*
Rhinolophus lepidus	*Rhino 3*
Rhinolophus luctus	*Rhino 4*
Rhinolophus sedulus	*Rhino 5*
Rhinolophus stheno	*Rhino 6*
Rhinolophus trifoliatus	*Rhino 7*
Scotophilus kuhlii	*Scoto*
Taphazous longimanus	*Tapha*
Tylonycteris pachypus	*Tylo 1*
Tylonycteris robustula	*Tylo 2*

CHAPTER 4: RESULTS

4.1 Species Accounts

The samplings have resulted in the capture of 1226 individuals representing 46 species. Throughout this study, a total of 396 individuals of bats from 33 species were recorded in primary forest, 608 individuals of bats from 31 species were recorded in secondary forest and 222 individuals of bats from 11 species were recorded in urban park (see Appendix A)

4.1.1 The highest and lowest family of bats captured in the three types of habitat

From the seven families recorded in the three habitat types, family Vespertilionidae recorded the highest number of species in the secondary forest with 13 species (95 individuals). Family Vespertilionidae also recorded the highest number of species in primary forest with 9 species composing of 49 individuals.

Pteropodidae has the highest number of individuals in the secondary forest with 305 individuals from 8 species. *Cynopterus brachyotis* contributed to the most number of bats captured from family Pteropodidae in all three habitat types.

Family Hipposideridae showed the highest species captured (7 species) in primary forest with 182 individuals. For Family Rhinolophidae, only 6 species were recorded at primary and secondary forest respectively with 35 individuals found in primary forest and 37 individuals recorded in secondary forest. Nycteridae is the lowest family of bats capture with only four individuals in a primary forest. The family

Emballuronidae has a low number of species captured with only two species at primary forest while family Megadermatidae also recorded all two species in the family at primary forest.

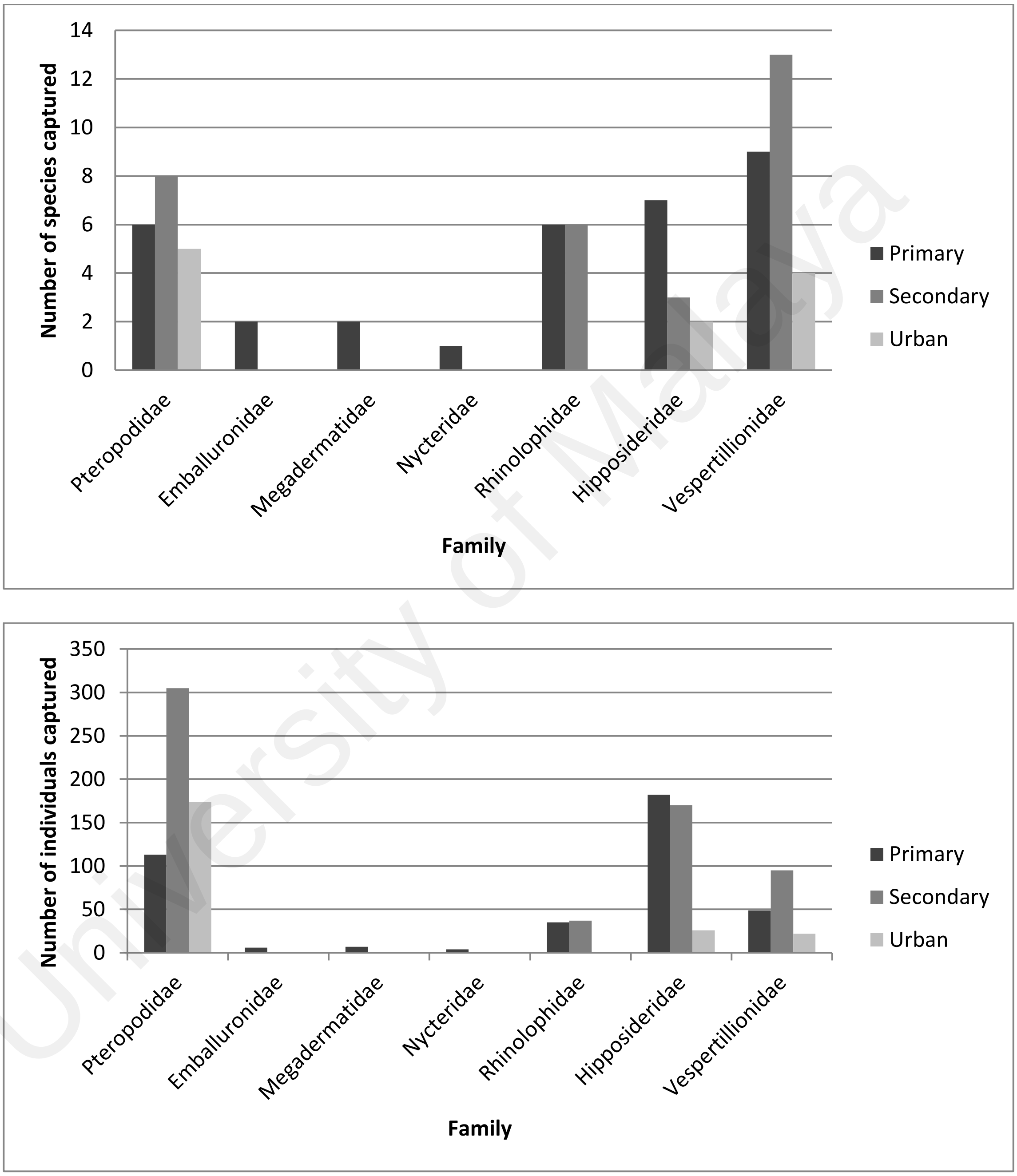

Figure 4.1: Number of species and individuals captured according to family in the three types of habitat

4.2 Species diversity in the primary, secondary and urban forest

4.2.1 Relative abundance of families in the three types of habitat

Seven families of bats were recorded in this study. Of all the families, Pteropodidae has recorded a high relative abundance in all the three habitat types. Pteropodidae accounted for 29.86% in primary forest, 50.23% in secondary forest and 78% in urban forest. In primary forest, Hipposideridae family was the highest family capture with 46.47%. *Hipposideros cervinus* was the representative of the family Hipposideridae that were most captured. Secondary forest and urban forest also showed high capture of the Hipposideridae family compared to other families. Rhinolophidae family was only captured in the primary and secondary forest with 8.94% and 5.92% respectively. Family Emballuronidae (1.53%) and Megadermatidae (1.79%) were only present in the primary forest. The Nycteridae family was only present in primary forest with 1.02% and secondary forest with 0.16%.

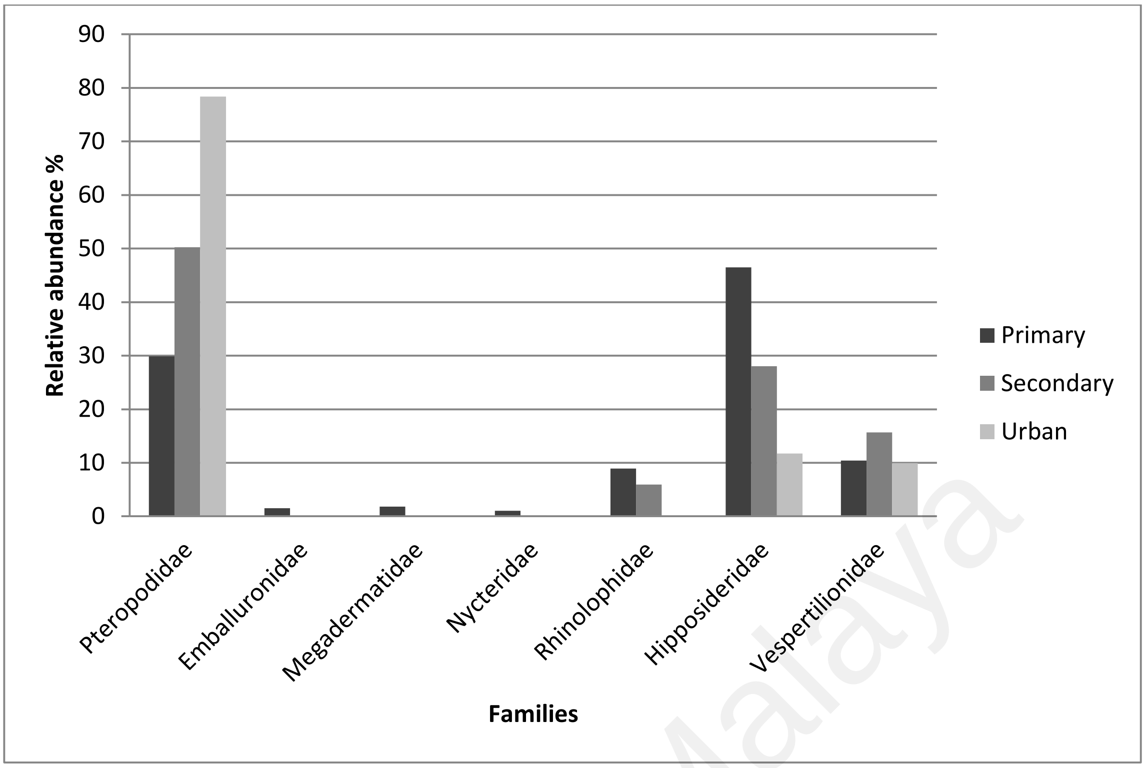

Figure 4.2: Relative abundance of families in the three types of habitat

4.2.2 Relative abundance of species in the three types of habitat

Cynopterus brachyotis shows the highest species relative abundance in the two habitat types; secondary forest and urban forest, whereas *Hipposideos cervinus* was the most dominant species in the primary forest. In the primary forest, *Hipposideros cervinus* and *Cynopterus brachyotis* were the two species that showed the highest relative abundance with 32.4% and 21.94% respectively. *Cynopterus brachyotis* (27.14%) and *Hipposideros cervinus* (16.61%) were also dominant in the secondary forest. Although more than 100 individuals of *Hipposideros cervinus* were captured respectively in primary and secondary forest, only 17 individuals of *H. cervinus* were captured in urban forest. In urban forest, *Cynopterus brachyotis* showed the highest relative abundance with 59.91% followed by *Cynopterus horsfieldi* with 9.46%. *Hipposideros larvatus, Hipposideros diadema, Hipposideros galleritus* and *Hipposideros doriae* were only found in the primary forest. *Macroglossus sobrinus* and *Macroglossus minimus* were only found in the secondary forest and urban forest. *Scotophilus kuhlii* was only found in the urban forest. There were several species that were represented by only one individual in one habitat type, but was represented by more than one individuals in another habitat types. For example only one individual of *Chironax melanocephalus* was recorded in the primary forest but 19 individuals were recorded in the secondary forest.

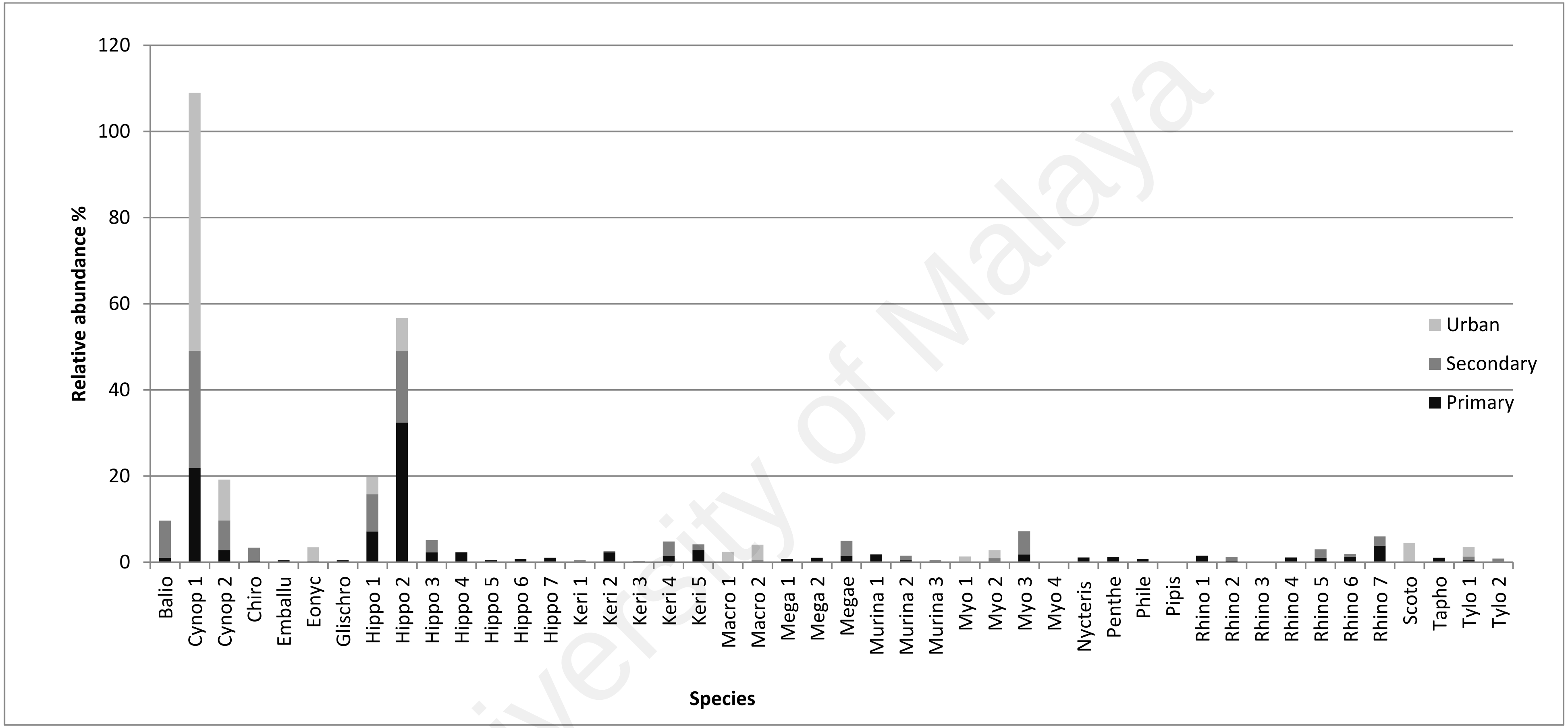

Figure 4.3: Relative abundance of species in the three types of habitat

4.2.3 Species accumulation curve

During each sampling visit, species accumulation curve showed there was an increase of species captured in each habitat (Figure 4.4). The result is very close to CHAO estimator where it estimates 33 species for primary forest, 34 species for secondary forest and 11 species for urban forest. Jackknife estimator estimated that there are probably 40 species in the primary forest, 38 species in secondary forest and 12 species in urban forest.

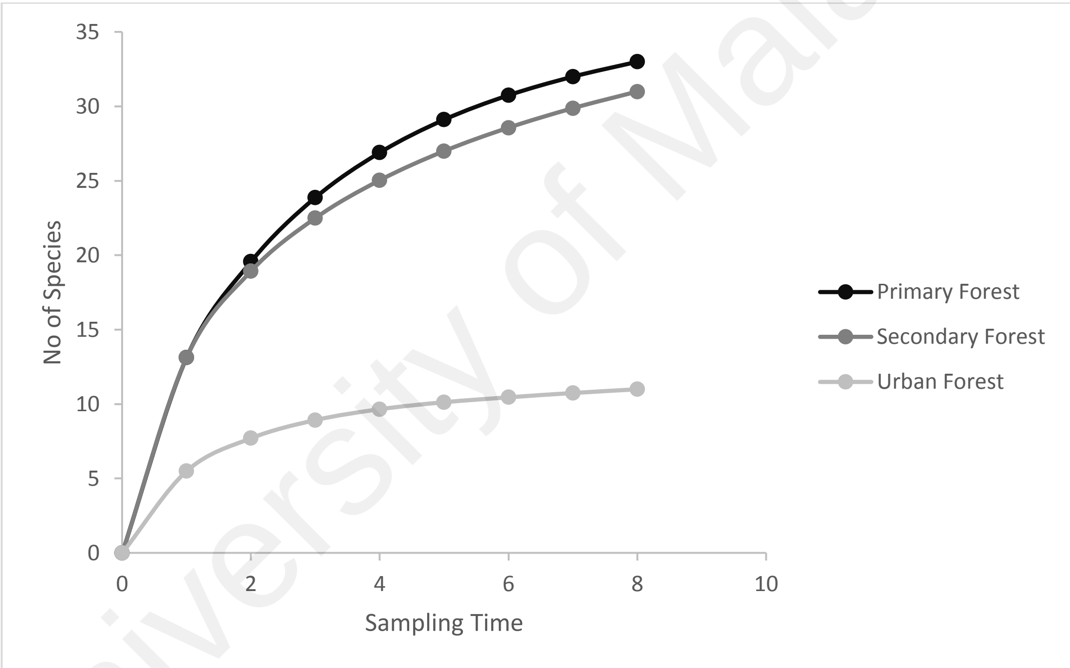

Figure 4.4: Species accumulation curves indicating the cumulative number of species encountered relative to sampling time

4.2.4 Comparison between the three types of habitat

The species diversity index calculated shows that the primary forest (Shannon-Wiener,H' = 2.516) has higher diversity of bats compared to secondary forest (Shannon-Wiener,H' = 2.476) and urban forest (Shannon-Wiener,H' = 1.527). However, the urban forest has higher evenness index calculated (E = 0.4184) compared to primary forest (E = 0.3994) and secondary forest (E = 0.3718). Species richness in secondary forest is the highest (D_{mn} = 1.616) followed by primary forest (D_{mn} = 1.257) and urban forest (D_{mn} = 0.7383).

Jaccard coefficient dendogram shows that primary forest and urban forest have the most species similarity (Figure 4.5). Based on the two-way dendogram, species were grouped into 5 groups from the three habitat. ANOVA test showed that there was a significant difference in the diversity of bats captured in all three habitat types (F = 1.385, p = 0.02539).

Table 4.1: Diversity, richess and evenness for the three types of habitat

	Primary forest	Secondary forest	Urban forest
Number of species **S**	33	31	11
Number of individual **N**	396	608	222
Menhinicks's Index	1.257	1.616	0.7383
Shannon's Diversity Index **H**	2.516	2.476	1.527
Shannon's Equitability $\mathbf{E_H}$	0.3994	0.3718	0.4184

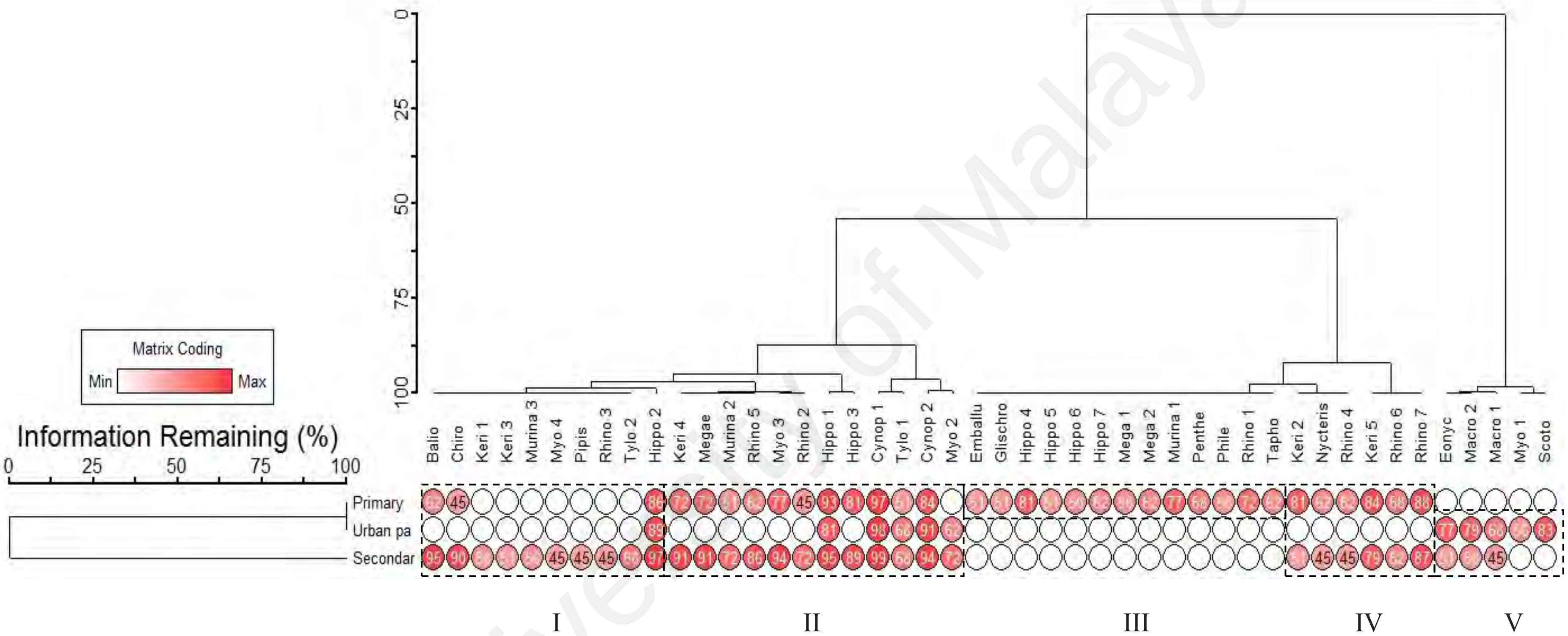

Figure 4.5: Dendogram of two-way cluster of bat species based on present matrix data generated by PC-Ord 6

4.3 Capture rate of bats using two different methods in the three habitat types

The total trapping effort using mist nets were 2880 hours and for the harp traps were 1152 hours. Capture rate using mist nets in primary forest was 0.04, secondary forest was 0.10 and for urban forest was 0.06. Capture rate using harp traps show high values which was 0.25 in primary forest, 0.27 in secondary forest and 0.04 in urban foret. Capture rates using harp traps were higher comprising of 650 individuals as compared to capture rates for mist nets which comprised of 576 individuals.

Table 4.2: Capture rate of bats using mist net and harp trap in primary forest

Family	Scientific name	Individuals captured in primary forest	
		Mist net	Harp trap
Pteropodidae	*Balionycteris maculata*	2	2
	Cynopterus brachyotis	84	2
	Cynopterus horsfieldi	11	0
	Chironax melanocephalus	0	1
	Eonycteris spleae	0	0
	Macroglossus minimus	0	0
	Macroglossus sobrinus	0	0
	Megaerops ecaudatus	6	0
	Penthetor lucasi	5	0
Emballuronidae	*Emballunora monticola*	0	2
	Taphozus longimanus	0	4
Megadermatidae	*Megaderma lyra*	0	3
	Megaderma spasma	0	4
Nycteridae	*Nycteris tragata*	0	4
Rhinolophidae	*Rhinolophus acuminatus*	0	6
	Rhinolophus affinis	0	1
	Rhinolophus Lepidus	0	0
	Rhinolophus luctus	0	4
	Rhinolophus sedulus	0	4
	Rhinolophus stheno	0	5
	Rhinolophus trifoliatus	0	15
Hipposideridae	*Hipposideros bicolor*	0	28
	Hipposideros cervinus	0	127
	Hipposideros cineraceus	0	9
	Hipposideros diadema	0	9
	Hipposideros doriae	0	2
	Hipposideros galleritus	0	3
	Hipposideros larvatus	0	4

Table 4.2, continued.

Vespertilionidae	*Glischropus tylopus*	0	2
	Kerivoula hardwickii	0	0
	Kerivoula intermedia	0	9
	Kerivoula minuta	0	0
	Kerivoula papillosa	0	6
	Kerivoula pellucida	0	11
	Murina aenea	0	7
	Murina suilla	0	2
	Murina cyclotis	0	0
	Myotis ater	0	0
	Myotis muricola	0	0
	Myotis ridleyi	0	7
	Myotis rosseti	0	0
	Pipistrellus tenuis	0	0
	Philetor brachypterus	0	3
	Scotophilus kuhlii	0	0
	Tylonycteris pachypus	0	2
	Tylonycteris robustula	0	0
	Total records	108	288
	No of species	5	30
	No of families	1	7
	Trapping effort	2880	1152
	Capture rate	0.04	0.25

Table 4.3: Capture rate of bats using mist net and harp trap in secondary forest

Family	**Scientific name**	**Individuals captured in secondary forest**	
		Mist net	**Harp trap**
Pteropodidae	*Balionycteris maculata*	48	4
	Cynopterus brachyotis	163	2
	Cynopterus horsfieldi	40	2
	Chironax melanocephalus	19	0
	Eonycteris spleae	2	0
	Macroglossus minimus	0	1
	Macroglossus sobrinus	3	0
	Megaerops ecaudatus	21	0
	Penthetor lucasi	0	0
Emballuronidae	*Emballunora monticola*	0	0
	Taphozus longimanus	0	0
Megadermatidae	*Megaderma lyra*	0	0
	Megaderma spasma	0	0
Nycteridae	*Nycteris tragata*	0	1

Table 4.3, continued.

Rhinolophidae	*Rhinolophus acuminatus*	0	0
	Rhinolophus affinis	1	5
	Rhinolophus lepidus	0	1
	Rhinolophus luctus	0	1
	Rhinolophus sedulus	1	11
	Rhinolophus stheno	0	4
	Rhinolophus trifoliatus	0	13
Hipposideridae	*Hipposideros bicolor*	0	52
	Hipposideros cervinus	0	101
	Hipposideros cineraceus	0	17
	Hipposideros diadema	0	0
	Hipposideros doriae	0	0
	Hipposideros galleritus	0	0
	Hipposideros larvatus	0	0
Vespertilionidae	*Glischropus tylopus*	0	0
	Kerivoula hardwickii	0	3
	Kerivoula intermedia	0	2
	Kerivoula minuta	0	2
	Kerivoula papillosa	0	20
	Kerivoula pellucida	0	8
	Murina aenea	0	0
	Murina suilla	0	6
	Murina cyclotis	0	3
	Myotis ater	0	0
	Myotis muricola	0	6
	Myotis ridleyi	0	33
	Myotis rosseti	0	1
	Pipistrellus tenuis	0	1
	Philetor brachypterus	0	0
	Scotophilus kuhlii	0	0
	Tylonycteris pachypus	0	5
	Tylonycteris robustula	0	5
	Total records	294	314
	No of species	8	27
	No of families	2	5
	Trapping effort	2880	1152
	Capture rate	0.10	0.27

Table 4.4: Capture rate of bats using mist net and harp trap in urban forest

Family	Scientific name	Individuals captured in urban forest	
		Mist net	Harp trap
Pteropodidae	*Balionycteris maculata*	0	0
	Cynopterus brachyotis	133	0
	Cynopterus horsfieldi	21	0
	Chironax melanocephalus	0	0
	Eonycteris spleae	7	0
	Macroglossus minimus	5	0
	Macroglossus sobrinus	8	0
	Megaerops ecaudatus	0	0
	Penthetor lucasi	0	0
Emballuronidae	*Emballunora monticola*	0	0
	Taphozus longimanus	0	0
Megadermatidae	*Megaderma lyra*	0	0
	Megaderma spasma	0	0
Nycteridae	*Nycteris tragata*	0	0
Rhinolophidae	*Rhinolophus acuminatus*	0	0
	Rhinolophus affinis	0	0
	Rhinolophus lepidus	0	0
	Rhinolophus luctus	0	0
	Rhinolophus sedulus	0	0
	Rhinolophus stheno	0	0
	Rhinolophus trifoliatus	0	0
Hipposideridae	*Hipposideros bicolor*	0	9
	Hipposideros cervinus	0	17
	Hipposideros cineraceus	0	0
	Hipposideros diadema	0	0
	Hipposideros doriae	0	0
	Hipposideros galleritus	0	0
	Hipposideros larvatus	0	0
Vespertilionidae	*Glischropus tylopus*	0	0
	Kerivoula hardwickii	0	0
	Kerivoula intermedia	0	0
	Kerivoula minuta	0	0
	Kerivoula papillosa	0	0
	Kerivoula pellucida	0	0
	Murina aenea	0	0
	Murina suilla	0	0
	Murina cyclotis	0	0
	Myotis ater	0	3
	Myotis muricola	0	4
	Myotis ridleyi	0	0
	Myotis rosseti	0	0
	Pipistrellus tenuis	0	0
	Philetor brachypterus	0	0
	Scotophilus kuhlii	0	10

Table 4.4, continued.

	Tylonycteris pachypus	0	5
	Tylonycteris robustula	0	0
	Total records	174	48
	No of species	5	6
	No of families	1	2
	Trapping effort	2880	1152
	Capture rate	0.06	0.04

CHAPTER 5: DISCUSSION

5.1 Species accounts

This study has recorded 46 species of bats in three habitat types in Peninsular Malaysia. Seven families of bats were recorded in this study which is Pteropodidae, Emballonuridae, Nycteridae, Megadermatidae, Rhinolophidae, Hipposideridae, and Vespertilionidae. The two most represented family throughout this study were the Vespertilionidae (18 species) and Pteropodidae (9 species). Family Vespertilionidae shows species dominance because this family are comprised of 5 subfamilies with over 20 species in Malaysia (Kingston *et al.,* 2006). In this study, *Myotis ridleyi* were the most caught species (33 individuals) in family Vespertilionidae. This species have been known to occur in lowland rainforest, foraging in understory thus were easily caught in traps put up at ground-level. For family Pteropodidae, 52% of species in the family were recorded. In my opinion, Family Pteropodidae has variations in term of food preferences including fruits, tree leaves and also nectar. The most caught species in this family is *Cynopterus brachyotis* which are abundantly caught in each visits because of its being highly adaptable to changes in habitat (e.g. logging, open area for agriculture and human habitation).

5.1.1 The highest and lowest family of bats captured in the three types of habitat

The highest number of species in primary forest and secondary forest were from the Family Vespertilionidae with 9 species and 13 species respectively. Family Vespertilionidae comprises of four subfamily which are Murininae, Vespertilionidae, Kerivoulinae and Miniopterinae (Kingston *et al.,* 2006). A high chances of catching many species from the family Vespertilionidae is because this family is the most diverse and widespread family of bats. Despite recording the highest number of species, the individuals captured which is 49 individuals in primary forest and 95 individuals in secondary forest are lower than Family Pteropodidae and Family Hipposideridae.

The highest number of species in urban forest is from the Family Pteropodidae with 5 species. Family Pteropodidae recorded the highest species in urban forest due to the presence of abundant fruit trees in the vicinity such as durian, jack fruit, guava and citrus plantation. *Cynopterus brachyotis* have been the most caught species for family Pteropodidae in urban forest. *C. brachyotis* can be found in many habitats including primary forest, secondary forest, agricultural landscape, orchard, mangrove and disturbed habitat (Mickleburgh *et al.*, 1992; Ketol *et al.*, 2009; Struebig *et al.*, 2010).

Family Vespertilionidae recorded the second highest species in urban forest. For example, *Tylonycteris pachypus* was captured due to the abundance of bamboo groves in the vicinity. These bat roosts in small groups in the internodes of live bamboo stem (Payne, 1985). *Scotophilus kuhlii* was also recorded in urban forest. This species were found roosting under house roofs, in palm tree leaves and in hollow tree and forages for aerial insects in open areas, around towns and over forests (Payne, 1985). A small building in the vicinity could have become a roosting site for this species.

Family Hipposideridae is the second highest family in primary forest recorded 7 species with 182 individuals. The high number of species for family Hipposideridae marks that the habitat has abundance of insects. Insectivorous bats that live in a large colony consume about 2000 tones of insects a year (Kingston *et al.*, 2003b; Tingga *et al.*, 2012).

Family Nycteridae is the family with the lowest species in which were only caught in primary forestand secondary forest. This is because the family comprises of only one species which is *Nycteris tragata*. Thus, Family Nycteridae shows 100% of species captured. Family Megadermatidae also shows 100% of species captured which comprises of all 2 species. Both *Megaderma lyra* and *Megaderma spasma* were caught in primary forest with 3 and 4 individuals respectively. *Megaderma spasma* is a species that inhabit the forest while *Megaderma lyra* prefers abandon building, mines and tunnel as habitat (Csorba *et al.*, 2008a). In this study, *Megaderma lyra* was also found in primary forest due to the forest situated close to a mining area. Small number of individuals was recorded for *Megaderma spasma* because it lives in a very small colony of 2 to 5 individuals or 3 to 30 individuals depending on the size of area (Kingston, *et al.*, 2006; Csorba, *et al.*, 2008b).

5.2 Species diversity in the primary, secondary and urban forest

5.2.1 Relative abundance of families in the three types of habitat

The diversity of Hipposideridae was the highest in primary forest. Zubaid (1988) and Azlan *et al.* (2000) reported that insectivorous bats are more specialized in their feeding behaviour, thus more seriously affected by changes of habitats. Insect diversity is strongly related to plant diversity (Murdoch *et al*., 1972; Azlan *et al*., 2000). It was reported that a landscape with a complex vegetation attracts more species of insects for example, Coleoptera and Hymenoptera. Forest fragmentation did not only influence the abundance and diversity of insects, but also modifies higher-order interactions between insects and other organisms, both directly and indirectly (Didham *et al*., 1996).

In the secondary forest, Pteropodidae was recorded as the family that is the most diverse. Pteropodidae bats are keystone species for forest regeneration visiting at least 141 plant species including a number of commercially important plants (*Durio* sp.*,* *Ceiba* sp. and *Parkia* sp.) for nectar or pollen (Fujita & Tuttle, 1991; Marshall, 1985). In this study, the existence of roost or perch site provided by *Macaranga* sp., palm (*Orania sylvicola*), and rattan (*Calamus* sp.) used by fruit bats in a small colony increases the success of capturing Pteropodidae bats. Bats are considered to play important roles in maintaining forest diversity (Bonaccorso & Gush, 1987).

The urban forest has a very high diversity of Pteropodidae bats. The urban forest which was planted with many fruit trees may have been an adequate food resources for most frugivorous bats. Palm vicinity in the urban forest has contributed as roosting sites for bats. Hipposideridae recorded the second highest diversity in urban forest although only 2 species were caught from this family. The high diversity for *Hipposideros bicolor* and *Hipposideros cervinus* proven that these two species are from a large colonies in the vicinity.

5.2.2 Relative abundance of species in the three types of habitat

Cynopterus brachyotis was the most species caught in the secondary and urban forest and was also highly captured in the primary forest. *Cynopterus brachyotis* can be found in various habitat including the primary forest, secondary forest, agricultural land, orchard, and disturbed habitat (Struebig *et al.,* 2010). Fruit bats are among the species that are most tolerant of human disturbance (Evelyn, 2003). According to Fukuda *et al.* (2009), *Cynopterus brachyotis* was capable of maneuvering between vegetation types. The ability of this species to enter wide variety of areas contributes to their ecological roles as seed dispersers. Boon and Corlett (1989) suggest that tree architecture and fruit morphology affected the presence of *Cynopterus brachyotis.* As it may be true, *Cynopterus brachyotis* have been known as a generalist species thus was commonly captured.

Cynopterus horsfieldi were present in all forest types but are captured the most in urban forest. *C. horfieldi* roost in caves, rock shelters and in between leaves (Campbell & Kunz, 2006; Campbell *et al*., 2006). Hodgkison *et al.* (2004a) stated that this species forages at all height below the canopy, utilizing both synchronously and synchronously fruiting trees. The wide range of diets on fruits explains the presence of this species in urban forest. From observation in the field, *C. horsfieldi* was always captured in small numbers during each sampling time suggesting that it roost in small colonies.

Balionycteris maculata was abundance in the secondary forest. *B. maculata* is primarily a forest species, found from lowland to hill and occasionally montane forest (Tingga *et al.,* 2012). This species roost in the cavities in the root masses of epiphytic plant species, active arboreal nest of the ants, abandoned arboreal termites nest and the hollow base of a large detached branch (Hodgkison *et al.,* 2003b). Secondary forest in the study provides a suitable habitat for this species because of the presence of logs and branches remnants from logging activities many years ago.

Hipposideros cervinus was captured extensively in the primary and secondary forest. Since this species usually roost in large colonies (Francis, 2008), relatively high numbers of individual were captured during sampling. According to Payne *et al*. (1985), this species has been noted to feed in the forest understory, increasing the chance of being caught by the understory harp traps. This species's presence does not necessarily connote population stability, given that they were also found in disturbed forest (Sedlock *et al.,* 2008). The high captured rate of this species shown that it emerges from a huge colony recorded up to 1000 individuals for a single colony (Kingston *et al*., 2006). This species usually emerges in a group to prey for insects and the high relative abundance of this species shows that the area receives abundance of insects. According to Kingston (2006), *Hipposideros cervinus* can be found in primary forest, feed under the canopy with *H. bicolor*. This can explains the abundance of *H. bicolor* in both primary and secondary forest.

Macroglossus spp. was captured in secondary forest and urban forest but none in the primary forest. *Macroglossus minimus* is an important pollinator of mangroves (*Sonneratia*) and native bananas (*Musa*) (Payne *et al*., 1985, Bonaccorso & McNab, 1997). Winkelmann (2003) noted that *M. sobrinus* is abundant in inland forest and considered a banana specialist. In this study, some *Macroglossus* spp. has been observed to make occasional return flights to locate variable food resources, in garden and secondary forest. The long snout that they possessed has been adapted for their feeding behavior to feed nectar and the pollen of banana flowers and other fruits (Francis, 2008).

Philetor brachypterus recorded three individuals in the primary forest. According to Francis (2008), this species is usually found near intact forest. This species is not immediately at risk but has declined due to loss of forest. The presence of this species in primary forest suggested that this species depend on pristine forest and are sensitive to disturbance or landscape changes.

Nycteris tragata were present at both primary and secondary forest. This species largely roost in mature rainforest and hunt insects by passive listening for prey (Francis, 2008) suggesting it has restricted movement. *Murina aenae* were only captured in primary forest. Many forest-interior insectivorous species are likely to be restricted to forest, and some of these species (e.g. *Murina aenea, M. rozendaali, Phoniscus jagorii*), have mostly been recorded in undisturbed habitat.

5.2.3 Species accumulation curve

Throughout the sampling, species accumulation curve shows an increase of new found species in all three types of habitat. The percentage of success sampling of the number of species estimated in primary and urban forest based on CHAO estimator is 100%. CHAO had estimated 3 more new found species in secondary forest if more sampling were done. Although Jacknife estimator estimates an increase of a lot more species, but 82.5% and 89.5% of the number of estimates have been successfully sample for primary forest and secondary forest respectively.

5.2.4 Comparison between the three types of habitat

Shannon-Wiener's index shows that the species richness and species diversity of bat were higher in primary forest than in secondary forest and urban forest. The species richness and diversity of bats were always higher in natural forest (Danielsen & Heegaard, 1995). High species diversity shows the complexity of habitat and a low level of disturbances in the habitat (Molles, 2005). However, this study showed that the evenness of bats in urban park was higher compared to primary and secondary forest. This was probably because the abundance of each species was more evenly distributed and the difference of abundance between each species was low compared to primary and secondary forest (Shafie, 2011). ANOVA test showed that there was a significant difference in the three types of habitat. Jaccard coefficient and Sorenson index shows that the composition of species present in primary forest and urban forest are almost the same.This could be due to factors such as forest gap in which vegetation in urban forest are far apart from each other and also the presents of many fruit trees that provide food sources all year long. A two-way cluster dendogram grouped the species into five groups (I, II, III, IV and V) (see Figure 4.5). Group III shows the species that were only found in the primary forest in this study thus having 100% probability of similarity. The species are *Emballunora monticola, Glischropus tylopus, Hipposideros diadema, Hipposideros doriae, Hipposideros galleritus, Hipposideros larvatus, Megaderma lyra, Megaderma spasma, Murina aenea, Penthetor lucasi, Philetor brachypterus* and *Taphozus longimanus*. Group II which consist of species captured in almost all three types of habitat shows 50% probability of similarity. Group IV which consists of species captured in primary and secondary forest also shows 50% of probability similarity. Species that were shown presents in all three habitats were species that are highly adaptable and can exploits sources such as roosting sites and food.

Diversity in primary forest shows that all bat family captured in this study was present in the habitat. High species diversity in primary forest consisted of insectivorous bats from the family Hipposideridae, Rhinolophidae, Vespertilionidae. *Murina aenea* which is only captured in primary forest is categorized as vulnerable in the IUCN Redlist. Bats from family Vespertilionidae and Emballuronidae forage in open area and the edge of forest (Denzinger & Schnitlzer, 2013). The primary forest in this study has more open area than the secondary forest which is denser. Open area facilitates movement of bats during foraging as bats quickly taken their preys during flight. During sampling, many insectivorous bats were captured around the forest edge as nets were deployed in the surrounding area due to early observations of bats flying around the open areas. Morris *et al.* (2010) noted that bat activity patterns were strongly related to forest edge. This is because forest edge function similarly to natural forest gaps because it provides more foraging opportunities for bats. Insectivorous bats prefer to forage or commute along the forest edge. Bats that commute along forest edge are more readily to exploit disturbed habitat. The environmental conditions make forest edge habitats appealing to bats (Hogberg *et al.,* 2002). Since the forest are located along the road, forest edge play important role in the foraging of bats.

The high abundance of species such as *Hipposideros cervinus, Hipposideros bicolor, Cynopterus brachyotis, Cynopterus horsfieldi* and *Balionycteris maculata* contributes to the species richness in the secondary forest. Hipposideridae was abundance in the study may be because of the existence of caves in the study area. There are only small caves/cervices presents in the study site which functioned as rooting sites for insectivorous bats with small colonies. Roosting site for bats were not found but from observations, we could see bats emerging from the caves during dusk. Caves support food sources, roosting sites and safety encouraging the breeding of the species (Henderson & Broders, 2008). A close distance of food sources and roosting site cause the species to gather at the same area (Hein *et al.*, 2009). The presence of bats is highly affected by food sources. The drastic increase in food sources can cause the habitat to be the hotspot for bats (Hodgkison *et al.*, 2004b). The presence of *Cynopterus brachyotis, C. horsfieldi* and *Balionycteris maculata* help in structuring plant communities as it plays important role in pollinating and seed dispersal. *B. maculata* and *C. brachyotis* feed on a wide range of food resources or known as permanent "big bang" food resources while *C. horsfieldi* is exclusively related with temporary "big bang" food resources (Hodgkison *et al*., 2004). *C. brachyotis* is a common species in disturbed areas and it has wide distribution habitats; dipterocarp forest, montane forest, mangrove, orchards, strand vegetation, oil palm plantations and open areas (Francis, 2008).

Secondary forest shows higher species richness compared to primary forest and urban forest. Some species take advantage of the changes of the forest because the logging effect may increase in feeding opportunity (Clarke *et al.,* 2005). Moreover, changes in forest are not pronounced to all bats. In the study, as the secondary forest is a regenerative forest of more than 30 years, it has becoming more stable to support diversities of bats.We can see vegetations as in the natural forest such as ficus and durian trees which are the food sources for frugivorous bats. Kerivoulinae recorded five species in secondary forest which is denser with understory vegetation compared to primary forest. Dense vegetation that was created in a complex environment can impede the flight of some bats species and limit their locomotion (Kalko *et al.,* 1996). However, Schmieder *et al.* (2012) reported that Kerivoulinae, Hipposideridae, Rhinolophidae and Murininae have better echolocation calls to track and approach their prey in dense rainforest understory. Specializations of wing morphology and ability to echolocate in clutter environments are characteristic of the species that forage in dense vegetation. Thus making these taxa capable to forage in dense clutter of the forest understorey (Kingston *et al.,* 2003b). The presence of indicator species that roost in bamboos; *Tylonycteris pachypus* and *T. robustula* proved that the vegetation has massive bamboo trees and is a secondary forest. Russo *et al.* (2010) noted that species richness respond to availability of roosting sites (tree cavity and foliage roosting).

The urban forest shows a high evenness of bats although the individuals captured for each species is low. 5 species of Megachiroptera and 6 species of Microchiroptera were captured. Frugivorous bats feed on fruits, leaves and nectar of forest tree and this made a wider food selection (Corlett, 2004; Nelson *et al.*, 2005). Other than forest tree, fruit trees were also the main diet of frugivorous bat. The presence of fruit trees such as rambutan (*Nephelium lappaceum*) and jambu (*Psidium guajava*) promotes abundance of *Cynopterus brachyotis* (Liat, 1970). The main diet of *C. brachyotis* and *C. horsfieldi* is *Ficus* sp. but the presence of seasonal species such as *Artocarpus maingayi*, *Palaquium obovatum* and *Payena maingayi* attracted the presence of frugivorous bats (Tan *et al.*, 1998). Various niche in the urban habitat have promotes the captures of species such as *Scotophilus kuhlii* which often roost under building roofs and *Myotis muricola* in a furled central leaves of banana plants (Francis, 2008).

Forest changes caused by logging activities have increased the feeding opportunities for some species (Brosset *et al.*, 1996). Clarke *et al.* (2005) found that there is no evidence that forest changes had affected species richness of bats. The density of prey or prey types may shift in the regenerating area. Habitat fragments act as corridors to maximize habitat area that promote connectivity among large core areas of forest (Struebig *et al.*, 2010). In the early succession, disturbed forest is dominated by keystone and late-seral vegetation such as *Macaranga, Mallotus, Callicarpa* and *Melastoma* (Appanah, 1990). These vegetations attract insects such as grasshopper (Orthoptera), bee (Hymenoptera) and butterfly (Lepidoptera) to visit the vegetation (Appanah, 1990). The abundance of insects attracts insectivorous bats to the habitat.

Anthropogenic changes to an area can create mosaics of fragmented vegetation, thereby affecting the diversity, abundance and feeding behavior of bats (Fukuda, 2008). According to Levey (1998) and Cueto and de Casenava (1999), mammal's distribution, diversity, species richness and activity were determined by vegetation structure and abiotic factors (temperature, rainfall and humidity). The differences in bat diversity may be due to various other factors including variation in sampling methods, duration of study, types of capture method employed and the suitability of the forest to support a great diversity of bats (Azlan *et al*., 2000). This reflects the complexity of factors that can influence directly or indirectly the distribution and species richness of animal species (Cueto & de Casenava, 1999).

Monadjem (1999) stated that the vegetation structure was the principal determinant of animal species, whereas the abiotic factor was a secondary factor and the effect is negligible. Bats activity was not significantly related to abiotic factor, but significantly related to habitat (Roger *et al*., 2006; Russo *et al.,* 2003). The abiotic factors such as temperature, rainfall and humidity do not fluctuate differently throughout the year in tropical country such as Malaysia (Shafie *et al.,* 2011).

5.3 Capture rate of bats using two different methods in the three habitat types

The total capture rate for mist nets recorded in this study (0.39 bats per night per net) is lower that the total capture rate for harp traps (0.56 bats per night per net) in all vegetations. This can be explained by the species richness each sites harbor. Insectivorous bats shown higher species richness in the three habitat types contributed to the high capture rates in harp trap. Moreover, as mist nets were mostly able to catch only frugivorous bats, harp traps had successfully captured some species of frugivorous bats.

In this study, some frugivorous bats in primary forest and secondary forest were also caught in harp trap. Frugivorous bats that were caught in harp trap in the primary forest are *Balionycteris maculata* with 2 individuals, *Cynopterus brachyotis* with 2 individuals and *Chironax melanocephalus* with one individual. In secondary forest, 4 individual of *B. maculata*, 2 individual of *C. brachyotis*, 2 individual of *C. horsfieldi* and 1 individual of *Macroglossus minimus* were caught in harp trap. Harp trap is especially effective in capturing small bats that weigh less than 30g. However certain species such as hovering and gleaning bats appear to be better at avoiding harp trap than heavy, larger bodied frugivorous bats (Kunz & Kurta, 1988).

In the secondary forest, one individual of *Rhinolophus affinis* and one individual of *R. sedulus* were caught in the mist net. This may be due to bats that fly through familiar area often navigate by special memory and does not listen to their acoustic and visual input (Tuttle, 1974b).

Capture rate using mist net was the highest in urban forest. All frugivorous bats in the urban forest habitat were captured in the mist net. Because insectivorous bats are usually able to detect mist nets, only frugivorous, nectarivorous and gleaner species tend to be sampled in mist net (Bergallo, 2003). One cause of these high capture rates are because of many fruiting trees and the abundance of flowers in the vicinity. Three species of nectarivorous bats; *Eonycteris spleae, Macroglossus sobrinus* and *M.* minimus were captured in urban forest. Three species of cultivated plant (*Durio* sp., *Musa* sp., and *Parkia* sp.) were the primary food sources for *E. spleae* and *M. minimus* (Fukuda, 2009).

Capture rate using harp traps were relatively high in primary and secondary forest. Sedlock (2008) stated that harp traps greatly increased capture rate of largely insectivorous species. Capture rate of harp trap have been quite low in the urban forest. In this study, the urban forest is concepted as a garden so, the distance between vegetations is quite large for harp trap to be effective. Harp trap is very effective when placed across narrow paths or between trees (Payne, 2008) suggesting that a garden-like urban forest is not very suitable for this methods to be employed. Bats usually will avoid areas with high clutter and prefer areas of reduced clutter (Humes *et al.*, 1999). Secondary forest which is a regenerated forest has high clutter of vegetation in which the forest floor is dense with vegetation. Corlett (2004) stated that bats usually search for food in a high clutter vegetation structure and fly away to feeding roost with less clutter area, about 20-200 m from the food source. However, response to structural clutter often varies with species, depending on their body size, wing morphology, and echolocation structure (Chrome & Richards, 1988; Fenton, 1990; Shafie, 2011).

In this study, the use of the combination of mist nets and harp traps enriched the overall species inventory by registering almost all families of bats. Individual's methods (Joann *et al.,* 2011; Flaquer *et al.,* 2007) have been proven to only capture the expected species from some families. It is most efficicent to use a combination of capture methods to sample the Order as a whole.

CHAPTER 6: CONCLUSIONS

6.1 General conclusion

This study has determined that species diversity was higher in primary forest, followed by secondary forest and urban forest. Many species of bats depended solely on the primary forest to fulfill their habitat requirement to survive. Food and roost for many bat species may readily be available in the primary forest. Species abundance was higher in secondary forest compared to primary and urban forest. Secondary forest being a regenerative forest have large constituent of vegetation; from dipterocarp plant to non-dipterocarp. The heterogeneous landscape led to the high assemblage of bats in this area as it became the movement corridor for them. Some species of bats may be adapted to exploit this vegetation for feeding and roost.

Through statistical analysis, we found out that there is a significant difference in the diversity of bats between the three habitat types. From the data, we can see that some species were recorded in one habitat but not the other. It may show that the species is unique to the type of habitat for example *Philetor brachypterus* recorded in primary forest roost only in intact forest.

From this study, we found out that Megachiropteran were abundantly caught in all three types of habitat. This indicated that they were capable of movement between vegetation types. Some species used these sites mainly for feeding. Bats feed on *Ficus* sp. which is the pioneer plant to thrive in hot and dry clearings. Urban forest or botanical garden has abundant and consistent food sources, contributing to the maintenance of nectarivorous bats populations. Megachiropteran may rely on plants in the garden during inter-flowering period. Lowland dipterocarp in the region are known for the supra-annual flowering and fruiting phenologies of many trees.

Although most of the time bats diversity in the primary forest is higher, but factors such as food sources and roosting sites availability in a habitat can promote the breeding of bats. Since the primary forest is located near to the secondary forest and the urban forest is near to the fragmented forest, it encourage the increased of various microhabitat. This can attract more forest bat species to utilize the resources in the secondary forest and help stabilize the diversity in disturbed habitat.

The result has demonstrated that combinations of different capture methods which are mist nets and harp traps are necessary to capture more species of bats. In this study, mist nets were the most appropriate for capturing frugivorous bats and harp traps were the most appropriate for capturing insectivorous bats. Differential capture rate can be resulted by habitat use by bat species, flying mode and also location of where the nets and harp traps were placed.

6.2 Recommendation for future study

This study mainly focused on the distributions of the bats. However, it is recommended to study the diets of bats by pollen examination or fecal analysis to know the actual feeding locations and their movement between vegetation types. It is also wise to sample insects so that we can actually determine the species of insects present in the area and compare them with parts of insects obtain from fecal analysis. Apart from that, the plant communities also need to be critically studied and thus relates them with the distribution of bats.

The application of Geographical Information System (GIS) is very useful to determine habitat suitability for bats. According to Shafie *et al*. (2011), the distance of sampling points (for example secondary forest and oil palm plantation) from (road, rivers, afgricultural area) were determined to identify the most important factors that may influence the habitat suitability using GIS followed by constructing database and developing maps. The results obtained can be used to determine the important factors that influence the distribution of small mammal species with high conservation value.

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Appendix A: Individuals of bats and the relative abundance in the three types of habitat; primary forest, secondary forest and urban forest

No.	Family	Scientific name	Individuals (Relative abundance %)		
			Primary	Secondary	Urban
1	Pteropodidae	*Balionycteris maculata*	4 (1.02)	52 (8.62)	
2		*Cynopterus brachyotis*	86 (21.94)	165 (27.14)	133 (59.91)
3		*Cynopterus horsfieldi*	11 (2.81)	42 (6.91)	21 (9.46)
4		*Chironax melanocephalus*	1 (0.26)	19 (3.13)	
5		*Eonycteris spleae*		2 (0.33)	7 (3.15)
6		*Macroglossus minimus*		1 (0.16)	5 (2.25)
7		*Macroglossus sobrinus*		3 (0.49)	8 (3.60)
8		*Megaerops ecaudatus*	6 (1.53)	21 (3.45)	
9		*Penthetor lucasi*	5 (1.28)		
10	Emballuronidae	*Emballunora monticola*	2 (0.51)		
11		*Taphozus longimanus*	4 (1.02)		
12	Megadermatidae	*Megaderma lyra*	3 (0.77)		
13		*Megaderma spasma*	4 (1.02)		
14	Nycteridae	*Nycteris tragata*	4 (1.02)	1 (0.16)	

Appendix A, continued.

15	Rhinolophidae	*Rhinolophus acuminatus*	6 (1.53)		
16		*Rhinolophus affinis*	1 (0.26)	6 (0.99)	
17		*Rhinolophus lepidus*		1 (0.16)	
18		*Rhinolophus luctus*	4 (1.02)	1 (0.16)	
19		*Rhinolophus sedulus*	4 (1.02)	12 (1.97)	
20		*Rhinolophus stheno*	5 (1.28)	4 (0.66)	
21		*Rhinolophus trifoliatus*	15 (3.83)	13 (2.14)	
22	Hipposideridae	*Hipposideros bicolor*	28 (7.14)	52 (8.62)	9 (4.05)
23		*Hipposideros cervinus*	127 (32.40)	101 (16.61)	17 (7.66)
24		*Hipposideros cineraceus*	9 (2.30)	17 (2.80)	
25		*Hipposideros diadema*	9 (2.30)		
26		*Hipposideros doriae*	2 (0.51)		
27		*Hipposideros galleritus*	3 (0.80)		
28		*Hipposideros larvatus*	4 (1.02)		

Appendix A, continued.

29		*Glischropus tylopus*	2 (0.51)		
30		*Kerivoula hardwickii*		3 (0.49)	
31		*Kerivoula intermedia*	9 (2.30)	2 (0.33)	
32		*Kerivoula minuta*		2 (0.33)	
33		*Kerivoula papillosa*	6 (1.53)	20 (3.29)	
34		*Kerivoula pellucid*	11 (2.81)	8 (1.32)	
35		*Murina aenea*	7 (1.79)		
36		*Murina suilla*	2 (0.51)	6 (0.99)	
37	Vespertilionidae	*Murina cyclotis*		3 (0.49)	
38		*Myotis ater*			3 (1.35)
39		*Myotis muricola*		6 (0.99)	4 (1.80)
40		*Myotis ridleyi*	7 (1.79)	33 (5.43)	
41		*Myotis rosseti*		1 (0.16)	
42		*Pipistrellus tenuis*		1 (0.16)	
43		*Philetor brachypterus*	3 (0.77)		
44		*Scotophilus kuhlii*			10 (4.50)
45		*Tylonycteris pachypus*	2 (0.51)	5 (0.82)	5 (2.25)
46		*Tylonycteris robustula*		5 (0.82)	
		Total records	396 (100)	608 (100)	222 (100)
		No of species	33	31	11
		No of families	7	5	4

Appendix B: List of conferences attended

1) The 17th Biological Sciences Graduate Congress (BSGC)

Venue : Chulalongkorn University, Bangkok, Thailand.

Date : 8-10th December 2012

Hosted by : Faculty of Sciences, Chulalongkorn University, Bangkok.
In Collaboration with Department of Biological Sciences, National University of Singapore and Institute of Biological Sciences University of Malaya, Malaysia.

Session : Oral Presentation

Title : Distribution of bats in various selected habitat in Peninsular Malaysia.

2) Zoological and Ecological Research in Progress

Venue : University of Malaya

Date : 18th December 2012

Hosted by : Zoological and Ecological Research Network

Session : Oral Presentation

Title : Distribution of bats in four selected habitat in Peninsular Malaysia

3) 2nd Zoological and Ecological Research in Progress

Venue : University of Malaya

Date : 27th December 2013

Hosted by : Zoological and Ecological Research Network

Session : Oral Presentation

Title : Variation of bats in selected habitat in Peninsular Malaysia