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DISCUSSION

5.1 Comparative diversity and abundance of small mammals between forest and oil palm habitat.

5.1.1 Non-volant small mammals

The result of this study indicated that forested habitats support more species of non-volant small mammals compared to oil palm plantation. Of 10 800 trapping nights, a total of 22 species of non-volant small mammals were successfully captured. Twenty-one species were found in forest while five species of non-volant small mammals were recorded in oil palm plantation. Previous study in Borneo had recorded 11 species of non-volant small mammals in forest habitat and only four species of non-volant small mammals were caught in the oil palm plantation (Bernard *et al.*, 2009). Other study also indicated that species richness and diversity of non-volant small mammals were significantly higher in unlogged than logged forests (27 verses 17 species respectively) Wells *et al*. (2007). Therefore, increase complexity in vegetation structure would increase the abundance and richness of small mammals species (Maisonneuve & Rioux, 2001).

Various estimators showed that both forest habitats and oil palm plantation were under sampled (less than 90% of richness estimator). This could be due to the type of the sampling technique used in this study. In this study, traps were predominantly placed on the forest floor, thus not targeting the arboreal species. There were several other methods used to record non-volant small mammals such as direct observation and pit-fall traps which would enhance trapping success. Thus using multiple sampling techniques will enhance the probability of recording more species of non-volant small mammals. The low percentage of richness estimators also could be due to lack of trapping effort (Mohd Azlan *et al*., 2005).

More members of family Muridae were recorded in this study due to its largest extant. This is the largest mammalian family, comprising more than two-thirds of all rodent species. Its members survive in a wide range of habitats form; forest to grassland to mountain ranges. Similar to previous study (Bernard *et al*., 2009), this study also recorded higher number of non-volant small mammals species in forested habitats than oil palm plantation. Therefore, most small mammals species are preferring forested area as their habitat. More individuals of non-volant small mammals are recorded in oil palm plantation due to domination of *Rattus tiomanicus*. Rats are also known to have high adaptability towards their surrounding and have high reproduction rate. These adaptations ensure better survival of *Rattus tiomanicus* and explain why it was abundantly found in oil palm plantations. This species serve as major pest in oil palm plantation. Piles of old fronds and structure of palm crown have attracted the rats to builds its nest and rest on the ground (Francis, 2008).

Common species such as *Rattus tiomanicus, Rattus exulans*, *Maxomys surifer* and *Tupaia glis* were recorded in both forested habitat and oil palm plantation. These species were known to inhabit secondary forest, disturbed area, forest adjacent garden and also plantation (Francis, 2008). These common species are habitat generalist, therefore were less affected by any changes in habitat condition (Bernard *et al*., 2009). Generalist species usually have low sensitivity to habitat changes and have high adaptation which allows them to survive in a wide range of conditions.

Most of the squirrels captured in this study were recorded in forested habitats. Squirrels have high diversity in the Malaysian tropical rain forests. A total of 14 diurnal and 11 nocturnal species of squirrels were recorded in Peninsular Malaysia alone

(Medway, 1983). Members of family Sciuridae are mostly arboreal, therefore they respond negatively to habitat alteration. Tree diversity in the forested habitats provides good resources of food and offer structural heterogeneity favoured by squirrel. Some arboreal rats and squirrel do not prefer altered habitat due to the reduce of canopy space and altered tree composition (Saiful *et al*., 2001; Yasuda *et al*., 2003; Wells *et al*., 2004). Thus, absences of these characteristics in the oil palm plantation prohibit the use of the habitat by arboreal species. *Calloscirus caniceps* was recorded in the oil palm plantation. Earlier study reported that this diurnal species can be found in a wide range of forest types such as plantations, cultivated areas and gardens (Francis, 2008).

Echinosorex gymnurus commonly known as Moon rat was also recorded in this study (forested habitats). This prefers swampy forests or areas nearby streams as habitat (Medway, 1983; Francis, 2008). This species was recorded in the forest habitat of the study area as recorded earlier by Wells *et al*. (2007). Their feeds mainly terrestrial invertebrates such as earthworms and arthropods (Francis, 2008) which was commonly found in wet area near streams might be an important feeding site for the species.

Characteristics of the habitat structure obviously differed between forest and oil palm plantation. Forest habitat had denser tree with higher species richness compare to oil palm plantation. Complexity of the vegetation structure will increase the abundance and richness of small mammals (Maisonneuve & Rioux, 2001).

5.1.2 Volant small mammals.

Forest habitat recorded higher species richness of volant small mammal species with 31 species compared to 21 species in oil palm plantation. Forest habitat also recorded higher species abundance compared to oil palm plantation. Nur Juliani *et al*. (2011) reported the oil palm plantation had a greater volant small mammals abundance compare to forest habitat but low in species richness.

Both habitat types (forest and oil palm plantation) were under sampled as shown by various estimators. This is because both habitats recorded less than 90% of richness estimator. This could be due to lack of trapping effort or inappropriate sampling technique. This study focus more on under storey bats because harp trapping and mist netting were only capable of sampling under storey animals. The techniques therefore, unable to catch bats that fly at the forest canopy level such as *Pteropus vampyrus*. The species accumulation curve does not reach an asymptote due to lack of sampling effort (Anwarali Khan *et al*., 2008) as the longer a survey is conducted the more species will be detected (Preston, 1948). Harp trapping is less effective in the open areas like oil palm plantations. The positioning of harp traps across forest trails is much more effective as sampling is more concentrated in bats flyway. Bat species in the oil palm plantation are probably under sample because an insectivorous bat is known to avoid mist nets (Larsen *et al*., 2007).

In this study, family Pteropodidae was found abundant in the oil palm plantation. Out of seven species recorded, six species were found in the oil palm plantation. These species feed mainly on nectar and fruits and commonly found roosting under the large leaves such as palm leaves (Kingston *et al*., 2006). *Cynopterus horsefieldi* and *Cynopterus brachyotis* were found in both habitats in the forest and oil palm plantation. These two species recorded more than half of the captured individuals in the oil palm plantation habitat. Heidemann & Heaney (1989) reported that *Cynopterus horsefieldi* and *Cynopterus brachyotis* successfully utilised oil palm habitat. These species were commonly known in disturbed area (Francis, 2008) because of its highly adapted to the environment. These species occurs in almost all habitat types including dipterocarp forest, garden, mangroves and agriculture area (Francis, 2008). The availability of roosting site contributes to this occurrence. *Cynopterus horsefieldi* commonly roosts in a modified banana leaf while *Cynopterus brachyotis* roosts were discovered in anthropogenic habitat (Campbell *et al*., 2006).

The forest habitat was dominated by Rhinolophidae, Hipposideridae and Vespertilionidae families. *Hipposideros bicolour* has the highest percentage of species recorded in forest habitat with 12.82% of total individual caught in forest. This species usually forage in a large group (Kingston *et al*., 2006) and roosting in large colonies mainly in caves or tunnels (Francis, 2008). More individuals were captured probably because of the traps were coincidentally placed in their flight path.

Apart of *Hipposideros bicolour*, *Rhinolophus trifoliatus* was the second most abundant bat species recorded in the forest habitat. *Hipposideros bicolour* and *Rhinolophus trifoliatus* was abundantly recorded in the forested habitat because they roost under the palm leaves and small tree (Kingston *et al*., 2006) or in cave (Medway, 1983). This species was found roosting individually and hunt for a flying insects under the canopy (Kingston *et al*., 2006). *Rhinolophus trifoliatus* was commonly used as a forest indicator because this species was known as forest specialist. However, this species was also recorded in the oil palm plantation although not so abundant. This may be because the species used oil palm tree leaves as their roosting sites.

Scotophilus kuhlii is the only species that was recorded in the oil palm plantation. This species often found associated with human habitation. It was found in the human structure like house rooftop (Francis, 2008) or abandoned building. It was also reported roosting in crowns of palm trees and prey for insects (Kingston *et al*., 2006). The existence of human settlements of farm workers near the oil palm plantation provides good roosting sites for the species. The oil palm frond and epiphytic plants in the oil palm plantation also provide shelter for the species.

Megaderma spasma was the only member of Megadermatidae, recorded in the study area. This species was found in forested habitat but absence from oil palm plantation. This species was primarily a forest inhabitant (Kingston *et al*., 2006) but also roosting in the caves. *Megaderma spasma* diet usually consists of large insects but also eat small vertebrates such as frogs and lizards (Francis, 2008).

Species from the family Vespertilionidae dominated the forest habitat because there are known as a tree/foliage roosting species. *Tylonycteris robustula* and *Glischropus tylopus* for example are generally known as a bamboo bats, therefore were only recorded in the forest habitat. These species frequently roosts in the bamboo stems or dead or damage bamboo in the forested area (Kingston *et al*., 2006).

The study showed that forest habitat have more volant small mammals species than oil palm plantation. Forested area has more volant small mammals because it has more complex habitat due to variety of plant species compare to oil palm plantation. This had resulted, forest habitat provide better roosting site and more food resources for volant small mammals. Species richness of bats in the study area was positively correlated with three species richness (Harvey *et al*., 2006) and availability of food resources (Hodgkison *et al*., 2004).

Three bat species; *Kerivoula intermedia*, *Phoniscus atrox* and *Hesperoptenus blanfordi* were classified as Vulnerable (VU) by The Red List Mammals for Peninsular Malaysia. Revising of the species conservation status is important for conservation management and strategies as well as to protect their habitat.

5.2 Comparative diversity and abundance of small mammals of adjacent, intermediate and interior forests.

5.2.1 Non-volant small mammals.

The transformation of natural habitat to croplands represents one of the greatest threats to global biodiversity (Sala, 2000). The vegetation structure is important factors to determine the non-volant small mammal distributions, diversity and species richness. Habitat variables such as tree sizes, climbers, tree connection and forest gaps were related with habitat utilisation by some small mammals (Bernard *et al*., 2009). Tekam Forest Reserve is a secondary forest, it had been logged approximately 20 years ago, thus logging activities have change the vegetation structure as the forest was dominated by *Macaranga* sp., *Melastoma* sp., and family of palms (Calamoideae) known as rattan. Habitat edges can have both positive and negative impacts on wildlife. Edge effects have different consequences for different species (Figueiredo & Fernandez 2004; Santos-Filho *et al*., 2008). Pardini (2004) found significantly richer small mammal community in edge habitats in comparison with the interior of mature forest and conclude that arboreal species are more affected by edge effects.

In this study, a total of 21 species of non-volant small mammals were recorded in all three plots. The species was dominated by family Muridae with 70% of total individuals captured. The species number appeared to be higher in the adjacent forest (20 species) compared to intermediate forest (16 species) and interior forest (10 species). This study proved that non-volant have tendency to inhabit forest edge habitat than forest interior. Different habitat associations among small mammals species possibly reflected differential resources requirements (Fitzherbert *et al*., 2006). Habitat with high structural diversity and vegetation complexity can provides a ranges of microhabitats for small mammals, and this will indirectly influence species richness (Yasuda *et al*., 2003). Other factors such as availability of food resources and protection from the predators, are also important criteria for habitats to support non-volant small mammals.

The species richness for adjacent forest was higher compared to the other two plots (intermediate and interior) with Shannon-Wiener, H'= 2.32. More individuals and species were recorded in adjacent forest, which reflect the abundance of food resource than intermediate and interior forests. *Pithecheir parvus*, *Mus musculus*, *Chiropodomys gliroides* and *Sundascirus hippurus* were species that were only recorded in adjacent forest. As most terrestrial small mammals nest in fallen trees or hollows under dead trees (Medway 1983), the abundance of large fallen logs in the study sites provide sites for foraging, resting, hiding and nesting. Increases of herbaceous vegetation cause increase abundant of arthropods and fruits. This may lead to increase in non-volant small mammals densities in the disturbed area (Malcom & Ray, 2000; Lambert *et al*., 2004) than unlogged forest.

Jaccard Similarity index showed that non-volant small mammals in adjacent forest was more similar with intermediate forest compare to interior forest. This is because these two habitats shared 15 similar species of non-volant small mammals. The trapping effort at each plot was standardized to reduce bias. The species richness estimators result indicated that most plots are well sampled. Preston (1948) noted that the longer a survey is conducted the more species were detected.

Common species of omnivorous murids and tupaiids (i.e; *Rattus tiomanicus, Maxomys rajah, Maxomys surifer, Leopaldamys sabanus* and *Tupaia glis*) were recorded in all plots. This result is consistent with previous studies on non-volant small mammals by Zubaid & Khairul (1997). Yasuda *et al*. (2003) and Wells *et al*. (2007).

Out of 21 species of non-volant small mammals, nine species were found in all study plots (Table 4.2-1). These generalist species have low sensitivity to habitat changes, therefore were less affected (Bernard *et al*., 2009; Rhim & Lee, 2007).

In this study, a total of 85 individuals of *Tupaia glis* was recorded in all three study plots. This species showed significant preference for adjacent forest ($\chi^2 = 16.91$, $p < 0.05$). *Tupaia glis* which was recorded in all forested habitats generally active during day time and commonly associated with secondary forest, gardens and plantations (Francis, 2008). Previous study in Peninsular Malaysia indicated that number of treeshrews was increased instantly after logging (John, 1997). The increase of insects and larvae in rooting wood after logging process provide food sources for treeshrew.

Leopaldamys sabanus was found in all study plots. This species adapted well with disturbed habitats, although it was previously confined to forest interiors and avoiding disturbed forest (Medway, 1983; Bernard *et al*., 2009). Wells *et al*. (2008) reported *Leopaldamys sabanus* has large movement distance thus it needs large home range to move within forest.

Rattus tiomanicus is a medium sized rat. The species was captured in all forest habitats and it is unaffected by distances to the forest edge. Similar conclusion was recorded by Yasuda *et al*. (2003). This species is known as pest (Wood & Fee, 2003) and was found in all areas. Such an invasion may cause unfavourable, including negative effect especially on forest species of small mammals. These findings suggest that the forest edge can keep more species of non-volant small mammals and play important role as a preference habitat for some small mammals.

Berylmys bowersi also known as Bowers rat is a large sized rat which have smooth fur and colour varying from dark grey to bright brownish. This species mostly active during night and dig extensive burrow systems, commonly found in primary forest (Francis, 2008). In this study, this species was recorded in the intermediate forest once. This species was listed as endangered (EN) by Red List Status of Mammals for Peninsular Malaysia (DWNP, 2010).

5.2.2 Volant small mammals.

Generally, small mammals are more abundance at the forest edge. This may due to greater complexity of vegetation and the availability of two or more habitat types. Edge habitat provides more food and cover compare to single habitat type (Yoakum & Dasmann, 1969). The result shows that the bats abundance did not increase as distance from the forest edge increases. Intermediate forest had a highest number of bat captures and species recorded while interior forest recorded the lowest number of species and individual recorded. This may be due to other factor beside distance from the forest edges that are affecting distribution of bats abundance.

According to estimators, all study sites (adjacent, intermediate and interior) are under sampled because they have less than 90% of richness estimators. Estimators had estimated a relatively high number of species for adjacent and intermediate forest habitats, since these areas have highly diverse with rare species, this species may not be detected as often as other species. This may be due to lack of trapping effort (Mohd. Azlan *et al*., 2005) or due to sampling technique (Kingston *et al*., 2000).

Intermediate forest located approximately 2 kilometres from the forest edge has recorded 141 individuals comprised of 24 species of bats. *Hipposideros bicolor* was found dominated this habitat representing 18.44% of the total population. Thabah *et al*. (2006) discovered that this species is highly versatile and can either roost under the boulders or rock crevices within the forest or in caves. This species can be found in wide variety of forests (Struebig *et al*., 2009) due to their high adaptability. Kingston *et al*. (2006) reported that this species always roosting together in a large colony. High abundance of this species may be due to traps were coincidentally placed in their foraging pathway.

Cynopterus brachyotis and *Cynopterus horsfieldi* were recorded in intermediate and interior forests. These species were known to present in anthropogenic habitat (Francis, 2008) and dominate the oil palm plantation (Heidemann & Heaney, 1989).

Roosting sites play important factor for the bats occurrence and different species may have different requirements for roosting sites. Greater bamboo bat (*Tylonycteris robustula*) was always being associated with bamboo especially in forested areas. It is commonly found in lowland forest and sometimes found roosting together with *Glischropus tylopus* (Kingston *et al*., 2006). Greater bamboo bat was only recorded in adjacent and intermediate forests, this may have been due to an abundance of bamboo groves in the sites.

Six out of ten species of subfamily Kerivoulinae in Peninsular Malaysia were recorded in this study. These species were present in almost all study plots (adjacent, intermediate and interior forest). Species of Kerivoula are known as interior forest-dwelling bat that usually forage in cluttered environments (Kingston *et al*., 2003). *Kerivoula papillosa* inhabits forest of various altitudes (Joann *et al*., 2011) and always roosting in the tree hollow. This species have a small home range, therefore recapture rates are high (Kingston *et al*., 2006). Struebig *et al*. (2009) indicates that high abundance of group of tree/foliage roosting species show that the site is less disturbed.

The abundance of insects plays an important role in affecting foraging behaviour of insectivorous bats. These types of bats usually choose their foraging sites according to the availability of insects (Morris *et al*., 2010). The abundance of prey (insect) in the forests can also be influenced by vegetation density. In some cases, insect's abundance in harvested areas is similar to that observed prior to the harvest (Grindal & Brigham, 1999). While in other cases, insects are more abundant in the areas with greater tree density than in harvested areas (Grindal 1996; Burford *et al*., 1999). Adjacent forest with high disturbance level had recorded highest Shannon-Wiener Index compare to other plot. The disturbance may provide opportunities for certain bat species as this may influence the distribution and abundance of insects which indirectly provide more food for bats.

Forest structure play importance factor that influence the composition of bats species. Bats usually avoid areas with high clutter and prefer areas with less clutter (Humes *et al*., 1999; Erikson & West, 2003). Small bats such as *Myotis* spp. are more manoeuvrability, therefore were less affected by tree density. While large bat preferred a clear cut and avoided intact space and these were correlated with size and wing morphology (Patriquin & Barclay, 2003). *Megaerops ecaudatus* for instance is primarily a forest inhabitant from the lowland and hill to montane forests (Kingston *et al*., 2006). This species was only recorded in intermediate forest.

Some species that were listed as vulnerable (VU) in the Red List Mammals of Peninsular Malaysia were found within the study plots. *Kerivoula intermedia* and *Phoniscus atrox* were recorded only in an adjacent and intermediate forests while *Hesperoptenus blanfordi* was only recorded in intermediate forest. The habitat ecology and factors that limit the distribution of these species remain unknown.

5.3 Comparative diversity and abundance of small mammals of different ages of oil palm plantation.

5.3.1 Non-volant small mammals.

Oil palm, *Elaeis guinensis* is global importance. Malaysia and Indonesia is the largest producers with approximately covers over 14.5 million hectares and this cultivation is rapidly expanding in areas such as Nigeria and Columbia (FAO, 2014). In this study, a total of five species of non-volant small mammals were recorded in all three difference ages of oil palm plantation. The number of species recorded was very low compared to forested area. Bernard *et al*. (2009) and Scott *et al*. (2004) was also recorded low number of species in the oil palm plantation in Sabah and Sumatra.

Rattus tiomanicus, *Rattus exulans*, *Maxomys surifer, Callosciurus caniceps* and *Tupaia glis* were the only species recorded in the oil palm plantation during this study. Common species might be able to survive in the agriculture habitat such as oil palm plantation. The non-volant small mammals with specialized feeding habits that depend on specific resources seem to be most affected with the habitat alteration. Species that present in various ages of oil palm plantation are mainly habitat generalist. The species composition of non-volant small mammals in young, mature and old oil palm plantation was almost similar. There are only four species of non-volant small mammals in the young and mature oil palm plantation in Sabah (Bernard *et al*. 2009).

Among species recorded, non has a high conservation value. These species are common and habitat generalist. Therefore it was less affected by changes of habitat compared to specialist species (Rhim & Lee 2007; Bernard *et al*., 2009). Common species with flexible diets cope well with the wide range of resources and have greater tolerance to resources availability.

Rats have high adaptability and also a fast reproducing animal (Francis, 2008). This species cause a serious damage to the plantation because they feed on developing brunch and fallen fruits (Wood & Fee, 2003). This study showed *Rattus tiomanicus* dominated oil palm plantation with 98% of the total captured. Wood & Fee (2003) estimated the population of *Rattus tiomanicus* in oil palm plantation in Malaysia was between 100 to 600 individuals per hectare and it has become a major pest in oil palm plantation area. This species making their nest and rest either on the ground, normally in the piles of old fronds that were cut from palms and on the palm or on the palm crowns. High number of *Rattus tiomanicus* individuals was recorded in old oil palm plantation compared to young and mature oil palm plantations. This is because old oil palm plantation provides more shelter and microhabitat for this species to survive. Abundance of epiphytes plant on the tree trunks and oil palm fronds stacked in between of oil palm tree row also offer a good nesting sites for *Rattus tiomanicus* (Buckle *et al*., 1997). This species also occupied a subterranean burrow which was self constructed or left by other animals (Francis, 2008).

Tupaia glis was recorded in young and mature oil palm plantations is omnivorous species. It consumed wide variety of food such as fruits, insects and other arthropods (Francis, 2008; Mariana *et al*., 2010). This species is well adapted in disturbed area and commonly found in the forests, gardens and plantation area. Young oil palm plantation ground areas are covered by creepers and this offer a good microhabitat for *Tupaia glis*. On the other hand, *Maxomys surifer* was only recorded in old oil palm plantation, probably searching for fallen ripped oil palm fruit.

Impact of converting the forested area to oil palm plantation was greater for non-volant small mammals. The reason for this loss of biodiversity are generally because reduction of complexity of the landscape. The complexity of tropical rain forest with heterogeneous habitat provides abundance of food resources, shelter and microhabitats thus will affect the abundance of non-volant small mammals species (Wilcove & Koh, 2010; Yasuda *et al*., 2003). Meanwhile, oil palm plantation is a monocultures habitat which have a uniform tree age structure and bare undergrowth compared to forest habitat that had larger, denser trees, with higher species richness (Koh & Wilcove, 2007).

During the trapping session, the predator such as phyton, cobra, monitor lizard and barn owl were observed in the study area. Shine *et al*., (1999) reported that the number of pythons and cobras increased with the number of their main prey especially rodents in oil palm plantation. These predators are important to control rat population in the oil palm plantation because they act as biological control agent. White Throated Kingfisher (*Halcyon coromanda*) was also observed having a small rat as their food (personal observation).

5.3.2 Volant small mammals.

Oil palm plantations were reputed as harsh upon biodiversity, diminishing richness of several groups such as beetles, butterflies and birds (Chung *et al*., 2000; Koh, 2008). A total of 21 species of bats were recorded in various ages of oil palm plantation during this study. Species from the family Pteropodidae shows the highest number of individuals with 63% of total individual captured in these areas. Although old oil palm plantation recorded lowest number of individual captured, it has a highest number of species recorded. This study suggests no significant different in volant small mammals population between oil palm ages.

The estimators postulated that all oil palm plantations were under sampled since all sites recorded less than 90% of richness. Oil palm plantation has open environments that do not have any narrow flyways suitable for placing harp traps. Although some bats species prefer the open and less clustered environment for their foraging activities, it also present difficulty in capturing them. Thus, there are limited place to set the harp trap because there are no pathways. Harp trapping is less effective in open areas in oil palm plantations as it covers only a small area. As a result, less bat were trapped in this area, presenting false information about bat community.

The oil palm plantations has no of importance value for biodiversity conservation, but it may contribute to the abundance of few taxa (Donald, 2004). In this study, some individual of megachiropteran was high. This habitat was dominated by *Cynopterus horsfieldi* and *Cynopterus brachyotis* (>50% of all individuals captured). Heidemann & Heany (1989) and Nur Juliani *et al*. (2011) also reported these two species had dominated oil palm plantation very well. High capture and dominance of *Cynopterus brachyotis* in agricultural land have been reported in other studies (Abdullah *et al*., 1997 ; Hall *et al*., 2004). Abdullah *et al*. (1997) recorded a very high capture rate of *Cynopterus brachyotis* in Cocos and banana plantations in Indonesia, where *Cynopterus brachyotis* accounted for 93% of total captures. The high capture rate of *Cynopterus brachyotis* and *Cynopterus horsfieldi* in the oil palm plantations may indicate that these species used this area as shelter and roosting site. As suggested by Fukuda *et al*. (2009), megachiropterans that were frequently captured in orchards and oil palm plantations indicate that agricultural plants are their primary food resources. According to Phua & Corlett (1989), *Cynopterus brachyotis* usually attracted to fruits with red, green black, purple, yellow, and white in colour.

Old oil palm plantation has high species richness (H'=2.31) and evenness (J=0.85) compared to young and matured oil palm plantations. Therefore, old oil palm plantation offers more suitable habitat for bats. In natural habitat, bats diversity is maintained by several factors including food resources (Hodgkison *et al*., 2004), roosting sites (Zubaid, 1993) and heterogeneity of forest structure (Hodgkison *et al*., 2004). Old oil palm fronds provide a good roosting site and shelter for the volant small mammals in the oil palm plantations. The downward angled of oil palm fronds created a natural roof-shaped shelter, providing protection from direct sunlight, rain and wind. In addition, the epiphytic fern was also abundance in the old oil palm plantation and this also provides roosting sites for several bats species in the oil palm plantations. Other than roosting sites, the prevalence of epiphytic fern also benefit for arthropods group, indirectly offer the food resources for volant small mammals in the oil palm plantations. Koh (2008) discovered that prevalence of epiphytic fern in oil palm plantation would increase bird species richness.

The capture of insectivorous bats was low in the oil palm plantation habitat. Fukuda *et al*. (2009) reported capture rate of microchiropterans was notably lower in oil palm plantations. This may be because of the low abundance of prey insects. This was supported by Chung *et al*. (2000) which reported low beetle abundance and diversity in oil palm plantations compared to logged and primary forests in Sabah, Malaysia. In this study*, Rhinolophus trifoliatus* was recorded in the old oil palm plantation. This species was commonly used as a forest indicator because it is known as forest specialist. Present of this species in the oil palm plantation may be due to old oil palm plantation located adjacent to the forest habitat or the bat may fly into the oil palm plantation while foraging. Surprisingly *Myotis ridleyi*, the species which commonly found in the primary forest or caves (Medway, 1983) was also recorded in the oil palm plantation.

Several species of family Hipposideridae were recorded in oil palm habitat. *Hippisideros cervinus* for instance was present in young, mature and old oil palm plantations. Members of family Hipposideridae are highly versatile since, they can roost in various types of habitats. Thabah *et al*. (2006) discovered that this can roost under the boulder or rock crevices within the forest and also in the caves. Because of this ability, they are usually found in most forests (Struebig *et al*., 2009). Less cluttered vegetation in the oil palm plantation allow bats to maneuver easily for foraging. Patriquin & Barclay (2003) reported smaller species of bats were less affected by clutter habitat compare to larger bats.

High similarity suggests that mature and young oil palm plantations are sharing more similar bats composition compare to old oil palm plantation. The presence of epiphytic fern added more habitat complexity in the old oil palm plantation, thus encourage more bats compare to young and mature oil palm plantations. This finding suggests that vegetation characteristics are affecting oil palm plantations in harbouring more species of bats.

This study concludes that bat abundance and diversity was not significantly different between young, mature and old oil palm plantations. The development of better management practice in oil palm plantation would increase the species richness of biodiversity in the oil palm plantation.