4

RESULTS

This study was focusing on the species richness and composition of small mammal species in the different types of habitats. The data from the Kota Gelanggi 5 and Lepar Utara 11 were pooled together according to the characteristic of habitats.

4.1 Oil palm plantation and forest habitat

4.1.1 Non-volant small mammals

Captures

A total of 1125 individuals belonged to 22 species of non-volant small mammals were successfully captured in both habitats. The captures consisted of three orders; Rodentia, Scandentia and Insectivora. Two families; Muridae and Sciuridae are classified under order Rodentia, while family Tupaiidae and Erinaceidae are respectively classified under order Scandentia and Insectivora. Almost half of the species caught in this study belonged to the family Muridae. Order Tupaiidae and Erinaceidae were represented by only one species each; *Tupaia glis* and *Echinosorex gymnurus* respectively (Figure 4.1-2). Members of family Muridae showed higher percentage in terms of abundance which consisted of 86% from the total individuals captured. On contrary family Erinaceidae had the lowest number of individuas captured (Figure 4.1-2).

The trapping success based on all capture events was 10.42% for overall of 10800 trapping efforts (Appendix C). There is a significant difference between trapping success showed in oil palm and forest habitats; 608 individuals were recorded in the oil palm while 517 mammals were captured in the forest (Mann-Whitney *U* test, W = 435.5 df = 1, $P < 0.05$). Even though oil palm plantation habitat shows the highest success in captures (608 individuals), it is only represented by five species of non-volant small mammals. While, 517 individuals captured in forested habitat represented 21 species of non-volant small mammals (Figure 4.1-1).

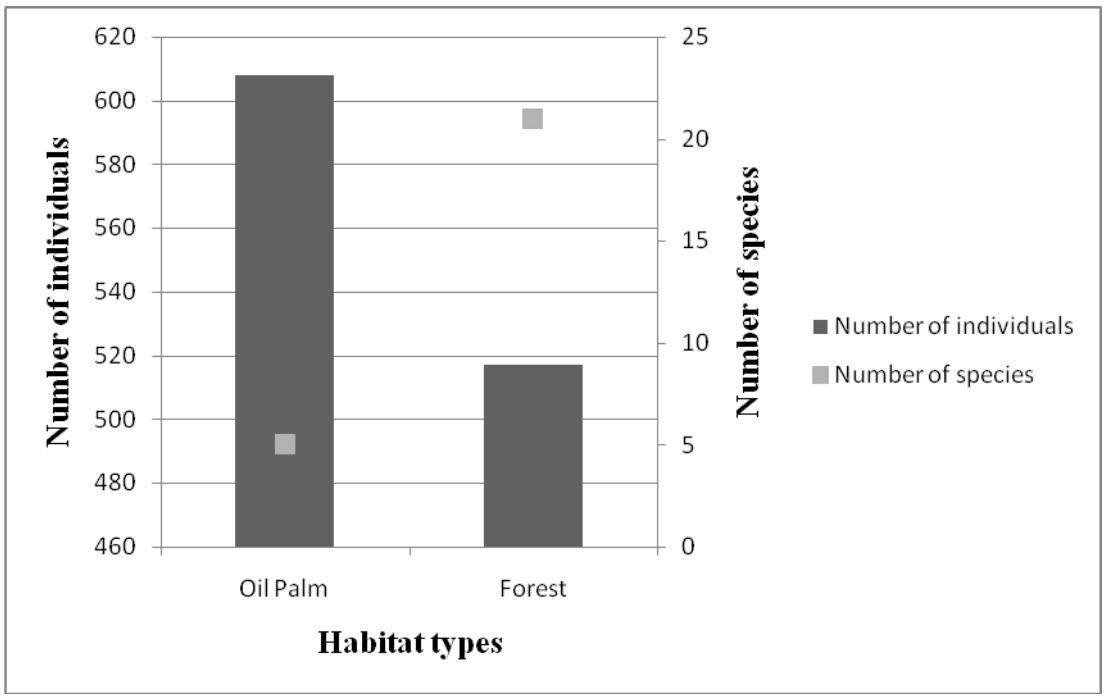


Figure 4.1-1: **The abundance of non-volant small mammals and number of species caught in forested area and oil palm plantation habitats.**

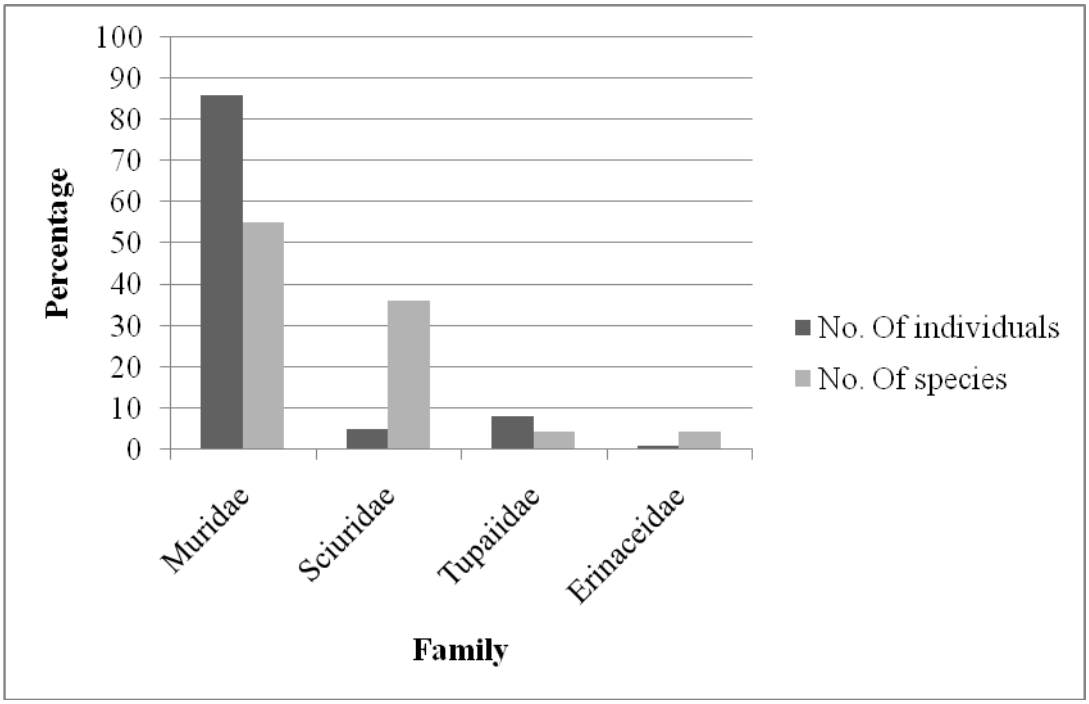


Figure 4.1-2: **Family composition of non-volant small mammals based on number of species and number of individuals by family caught in forested habitat and oil palm plantation.**

Species richness estimator and species accumulation curve.

Highest species number was recorded in forest habitat (21 species) and the lowest was found in oil palm plantation (five species). Sampling efficiency was lowest in oil palm plantation habitat in all estimators with 66.76% (Table 4.1-1). Species rarefaction curve rates were much higher in the forest habitat compared to the oil palm plantation (Figure 4.1-3).

Species composition and relative abundance.

Rattus tiomanicus shows highest species relative abundance in both habitat types. In oil palm plantation only five species of non-volant small mammals recorded and majority of capture are *Rattus tiomanicus* (98.68%). In the forest habitat, *Rattus tiomanicus, Maxomys rajah* and *Tupaia glis* were species that showed the high relative abundance with 18.18%, 17.79%, and 16.44% respectively. *Rattus tiomanicus, Rattus exulans, Maxomys surifer* and *Tupaia glis* were species that present at both habitats, while *Calloscirus caniceps* was only found in the oil palm plantation area (Appendix C). One species that have been listed as Endangered (EN) under the Red List of Mammals for Peninsular Malaysia *Berylmys bowersi* was recorded in the forest habitat during this study (Appendix A). In addition, three species that were listed as Vulnerable (VU) under IUCN Red List Status were only recorded in the forested habitat, these are *Maxomys rajah, Maxomys whiteheadi* and *Niviventer cremoriventer* (Appendix A). The relative abundance for all species in each habitat types is shown in Figure 4.1-4.

Species diversity and similarity index

The forest habitat shows higher Shannon-Weiner index with (2.36) and higher evenness with (0.78) compared to other habitat types (Table 4.1-2). The Mann-Whitney U test shows that there was significant difference between habitat ($W = 435.5$, $df = 1$, $P < 0.05$). Although oil palm plantation recorded higher number of individuals captured, the evenness was very low because presence of dominant species. Similarity of species between the two sites using Jaccard's coefficient of similarity index and oil palm and forest was clustered at 18%.

Table 4.1-1: **Species number of the different species estimators for the non-volant small mammals in forested area and oil palm plantation. Percentage of estimated species over captured is given in the parentheses.**

		Estimators					
Habitat types	**Captured**	**Chao 2 Mean**	**Jack 1 Mean**	**Jack 2 Mean**	**Bootstrap Mean**	**MMMeans (1 run)**	**Mean of estimators**
Forested area	21	24.15 (*86.96*)	25.72 (*81.65*)	28.49 (*73.71*)	23.09 (*90.95*)	22.54 (*93.17*)	24.8 (*84.68*)
Oil palm plantation	5	7.83 (*63.86*)	7.83 (*63.86*)	10.5 (*47.62*)	6.08 (*82.24*)	5.22 (*95.79*)	7.49 (*66.76*)

Table 4.1-2: Indices values of Shannon-Wiener (H) and Pielou's Eveness for non-volant small mammals inhabiting forested area and oil palm plantation.

	Oil palm plantation	**Forested habitat**
Total captured	608	517
Number of species	5	21
Shannon–Wiener (H)	0.08	2.36
Pielou's Evenness (J)	0.05	0.78

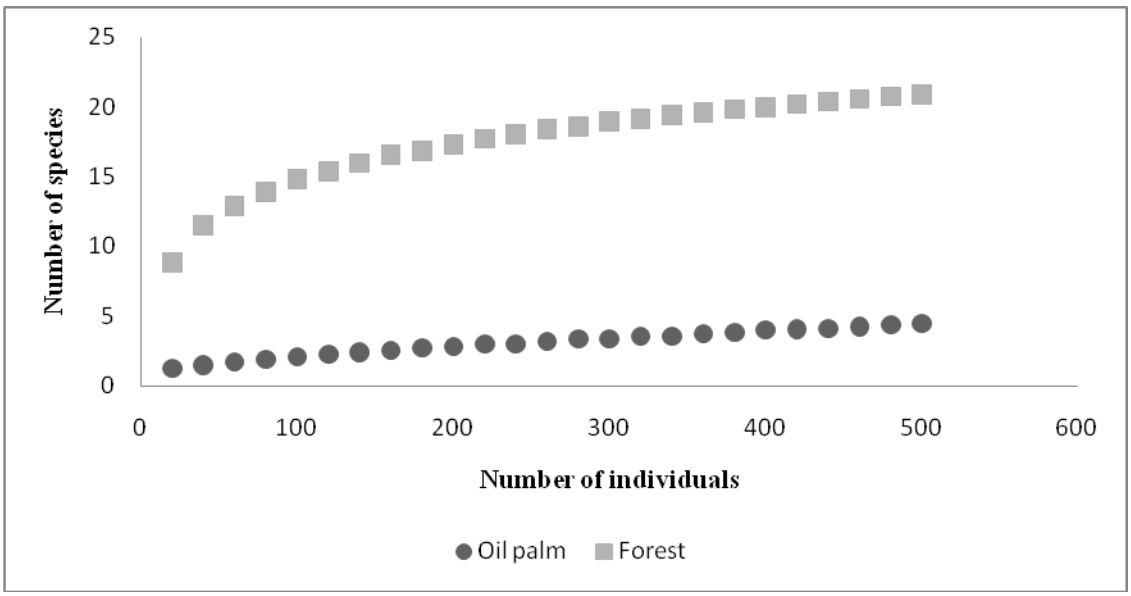
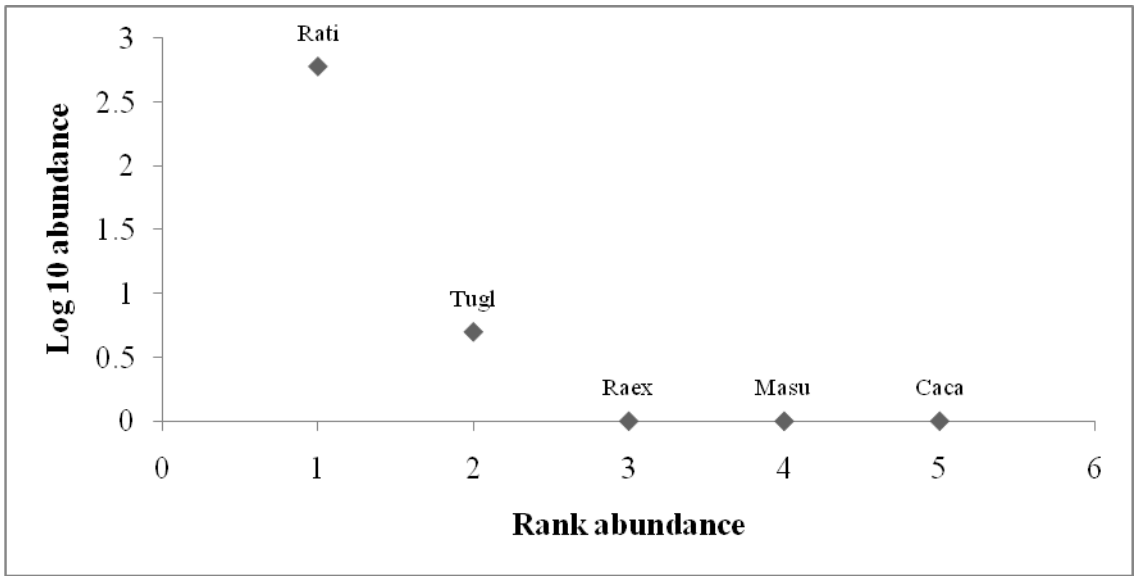


Figure 4.1-3: Rarefaction curve of non-volant small mammals in forested area and oil palm plantation.

a)



b)

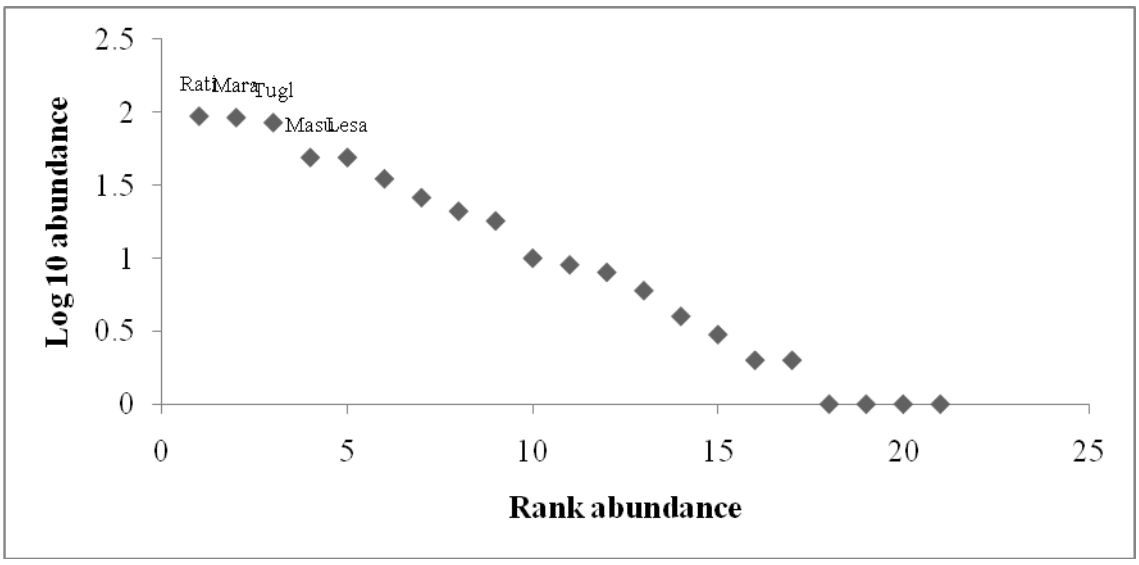


Figure 4.1-4: **Species rank abundance of non-volant small mammals at two habitat types, a) Oil palm plantation, and b) Forested habitat. Species code: Rati – *Rattus tiomanicus*; Raex – *Rattus exulans*; Mara – *Maxomys rajah*; Masu – *Maxomys surifer*; Lesa – *Leopaldamys sabanus*; Tugl – *Tupaia glis*; Caca – *Callosciurus caniceps*.**

4.1.2 Volant small mammals

Capture

A total of 526 individuals belonged to 36 species of volant small mammals were successfully captured in both habitats. All captures can be classified into five families, i.e; Pteropodidae, Rhinolophidae, Hipposideridae, Vespertilionidae, and Megadermatidae. Family Vespertilionidae showed largest number of species, consists of 40% of captured species. On contrary, family Megadermatidae was represented by a single species only, i.e *Megaderma spasma* (Figure 4.1-6). In term of abundance, family Vespertilionide and Pteropodidae have high percentage which consists of 31% and 30% of all individuals captured (Figure 4.1-6).

A total of 24.35% of trapping success was recorded for overall of 4320 trapping effort (Appendix D). Trapping success showed significant difference between oil palm and forest habitats (Man-Whitney *U* test, W = 867.5, df = 1, p-value < 0.05). Forested habitats show highest number of individuals and species captured with 312 individuals and 31 species of volant small mammals recorded. On the other hand, 214 individuals of volant small mammals that belonged to 21 species were recorded in oil palm habitat (Figure 4.1-5).

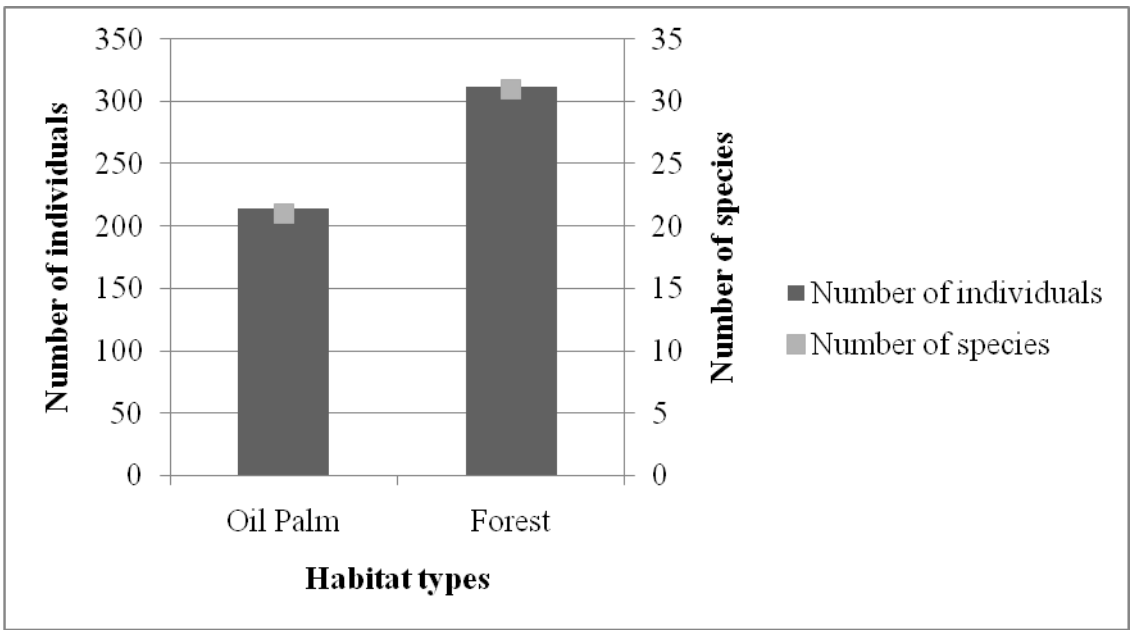


Figure 4.1-5: **The abundance and number of species of volant small mammals recorded from forested and oil palm plantation habitats.**

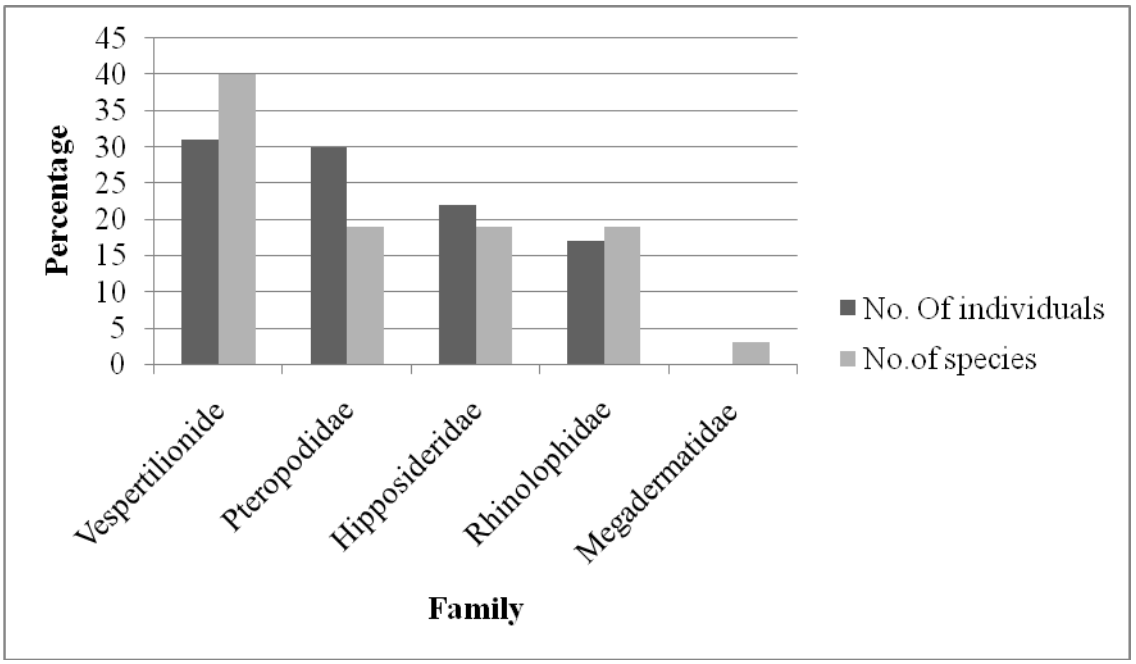


Figure 4.1-6: **Family composition of volant small mammals based on number of species and number of individuals by family caught in forested habitat and oil palm plantation**.

Species richness estimator and species rarefaction curve.

For a comparison of sampling efficiency of the two habitats, the species richness estimator of the community was calculated. Sampling efficiency (captured species over estimated species) was generally higher in the forested habitats than in oil palm plantation (Table 4.1-3). Higher species number was recorded in forested habitats (31 species) and less species was found in oil palm plantation (21 species). Species rarefaction curve rate was much higher in the forested habitats compared to the oil palm plantation (Figure 4.1-7).

Species and composition relative abundance.

In the oil palm plantation habitat, two species of frugivorous bats, *Cynopterus horsfieldi* and *Cynopterus branchyotis* were abundantly recorded with 29.91% and 25.70% respectively (Figure 4.1-8). While in forested habitats, *Hipposiderous bicolour* (12.82%) and *Rhinolophus trifoliatus* (11.22%) showed highest relative abundance (Figure 4.1-10). *Rousettus amplexicaudatus*, *Eonycteris spelaea*, *Macroglossus sobrinus*, *Scotophilus kuhlii* and *Myotis ridleyi* were recorded only in oil palm plantation habitat. Family Megadermatidae is represented by only one species which is *Megaderma spasma.* This species was recorded only in forested habitats (Appendix B). The relative abundance for all species in each habitat types was shown in Figure 5. Three species have been classified as Vulnerable (VU) under the Red List of Mammals for Peninsular Malaysia. These species include *Hesperoptenus blanfordi* which was recorded in both habitats, *Kerivoula intermedia* and *Phoniscus atrox* which were recorded only in forested habitat (Appendix B). IUCN Red List classified another two recorded species *Hipposideros ridleyi* and *Murina aenea* as Vulnerable (VU). These species were captured in forested habitat (Appendix B). Family Pteropodidae family

had the highest number of represented species recorded in oil palm plantation while family Vespertilionidae had highest species representative recorded in forested habitat (Appendix B).

Species diversity and similarity

The forested habitats show higher Shannon-Weiner index with 2.92 and highest evenness with 0.85 while, oil palm plantation recorded 2.17 for Shannon-Weiner index and 0.71 for the Pielou's Evenness index (Table 4.1-4). A similarity by Jaccard's coefficient of similarity shown that species similarity between oil palm and forested habitats was clustered at 46%.

Table 4.1-3: **Species number of the different species estimators for the volant small mammals in forested area and oil palm plantation. Percentage of estimated species to captured species are given in parentheses.**

		Estimator					
Habitat types	**Captured**	**Chao 2 Mean**	**Jack 1 Mean**	**Jack 2 Mean**	**Bootstrap Mean**	**MMMeans (1 run)**	**Mean of estimators**
Forested area	31	46.58 (*66.55*)	42.33 (*73.23*)	50.49 (*61.40*)	35.78 (*86.64*)	36.53 (*84.86*)	42.34 (*73.22*)
Oil palm plantation	21	35.17 (*59.71*)	30.44 (*68.99*)	37.66 (*55.76*)	25.01 (*83.97*)	27.87 (*75.35*)	31.23 (*67.24*)

Table 4.1-4: **Indices values of Shannon-Wiener (H) and Pielou's Eveness for volant small mammals inhabiting forested area and oil palm plantation.**

	Oil palm	**Forest**
Total captured	214	312
Number of species	21	31
Shannon–Wiener (H)	2.17	2.92
Pielou's Evenness (J)	0.71	0.85

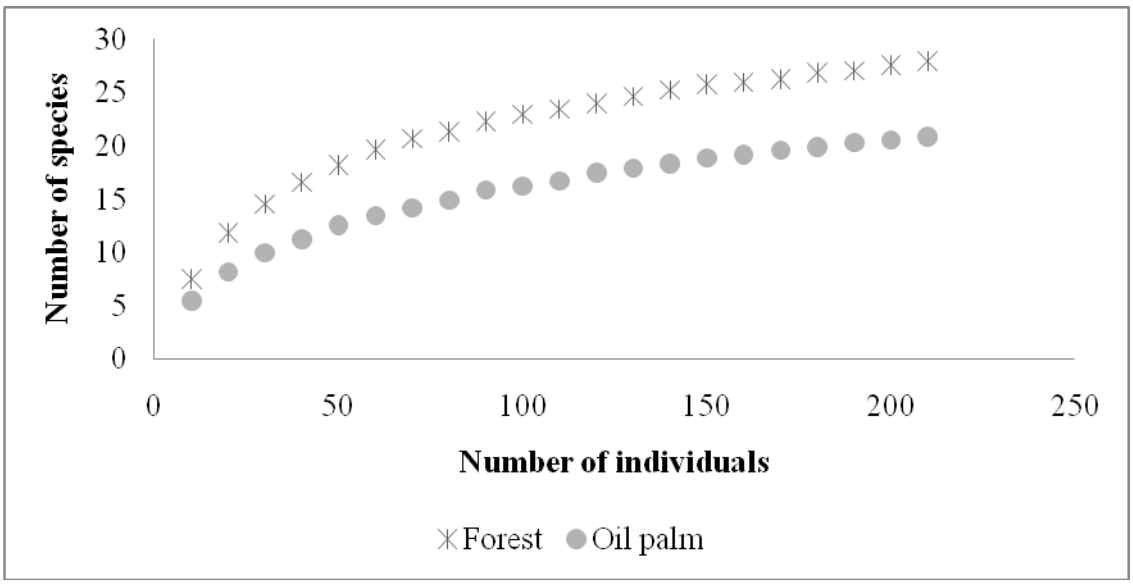
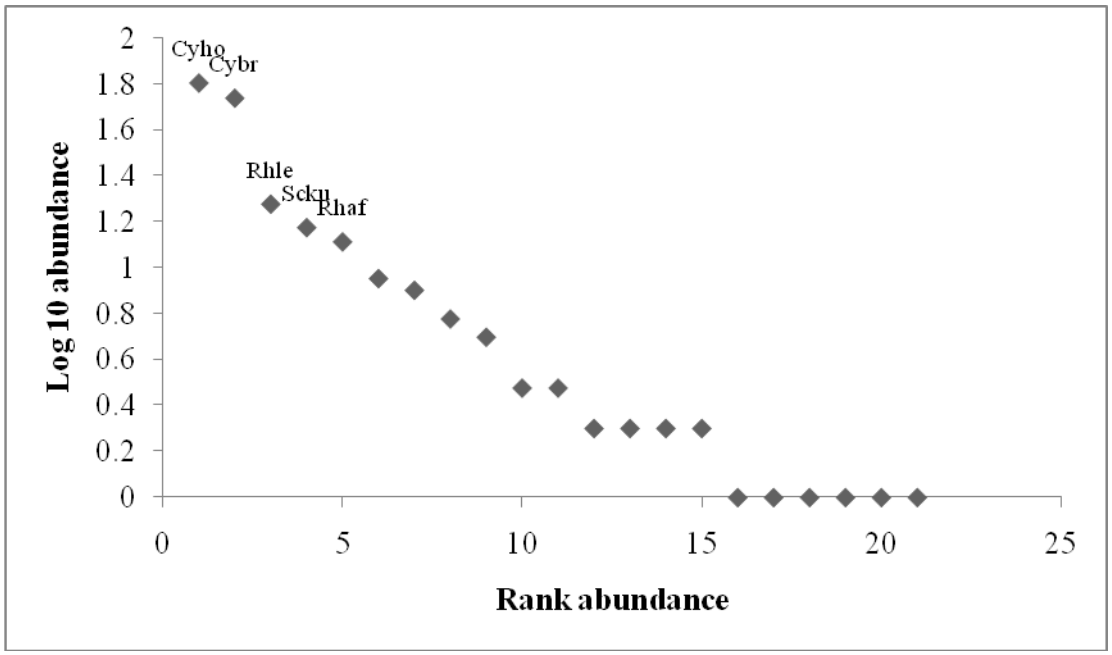


Figure 4.1-7: Rarefaction curve of volant small mammals in forested area and oil palm plantation.

a)



b)

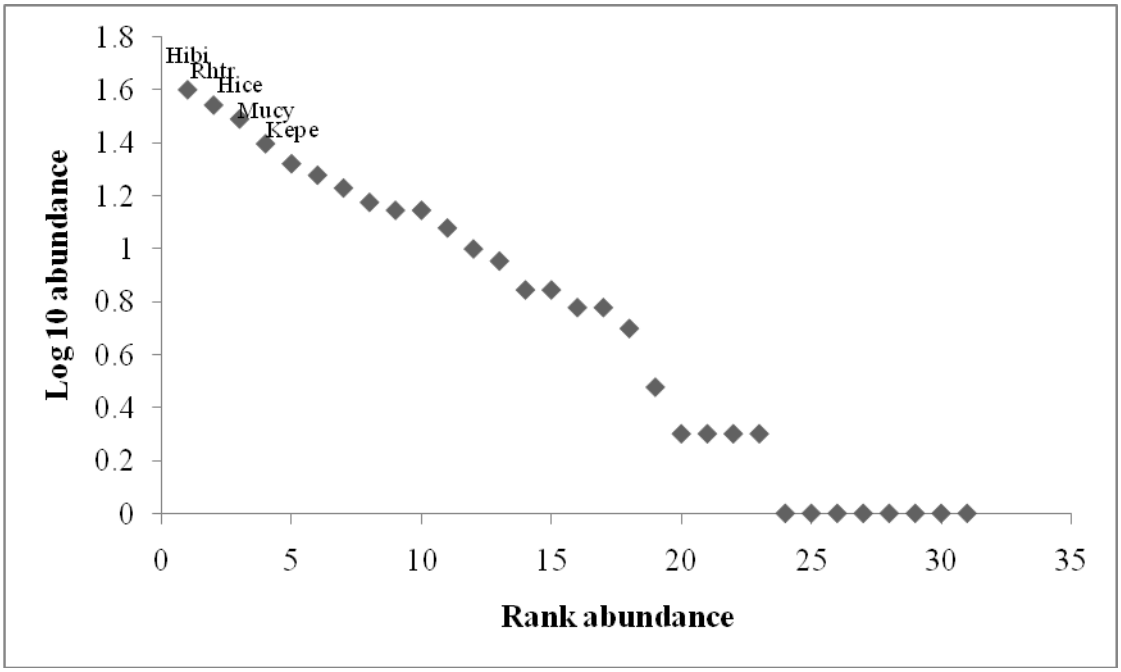


Figure 4.1-8: **Species rank abundance of volant small mammals at two habitat types, (a) Oil palm plantation, and b) Forest habitat. Species code: Cyho – *Cynopterus horsfieldi*; Cybr – *Cynopterus brachyotis*; Rhle – *Rhinolophus lepidus*; Rhaf – *Rhinolophus affinis*; Rhtr – *Rhinolophus trifoliatus*; Hibi – *Hipposideros bicolor*; Hice – *Hipposideros cervinus*; Mucy – *Murina cylotic*; Kepe – *Kerivoula pellucida*; Scku – *Scotophilus kuhlii*.**

4.2 Effect of forest edge distance on species composition of small mammals.

4.2.1 Non-volant small mammals

Capture

A total of 517 individuals of non-volant small mammals which belonged to 21 species were successfully captured across all three types of habitats. All captures can be grouped into three order; Rodentia, Insectivora, and Scandentia. Majority of captured species belonged to family Muridae (57%) followed by family Sciuridae (33%) (Figure 4.2-2). More than half of the total individuals captured belonged to family Muridae (70%) (Figure 4.2-2). Order Scandentia and Insectivora were only represented by a single representative each; *Tupaia glis* and *Echinosorex gymnurus* were also recorded.

The capture success was determined in the percentage of the number of captures and the number of trap nights. A total of 28.73% of capture success was recorded of the 517 captures for overall of 5400 trap nights across all three sites (Appendix C). Trapping success varies significantly between habitats (Kruskal-Wallis, $\chi^2 = 8.6849$, p-value < 0.05). The percentage of trapping success was the highest in the adjacent forest compared to intermediate and interior forest with 15.39%, 10.17%, and 3.17% respectively (Appendix C). Highest number of individuals and species were captured in adjacent forest while lowest capture of species and individuals were recorded in interior forest with 57 individuals and 10 species only (Figure 4.2-1).

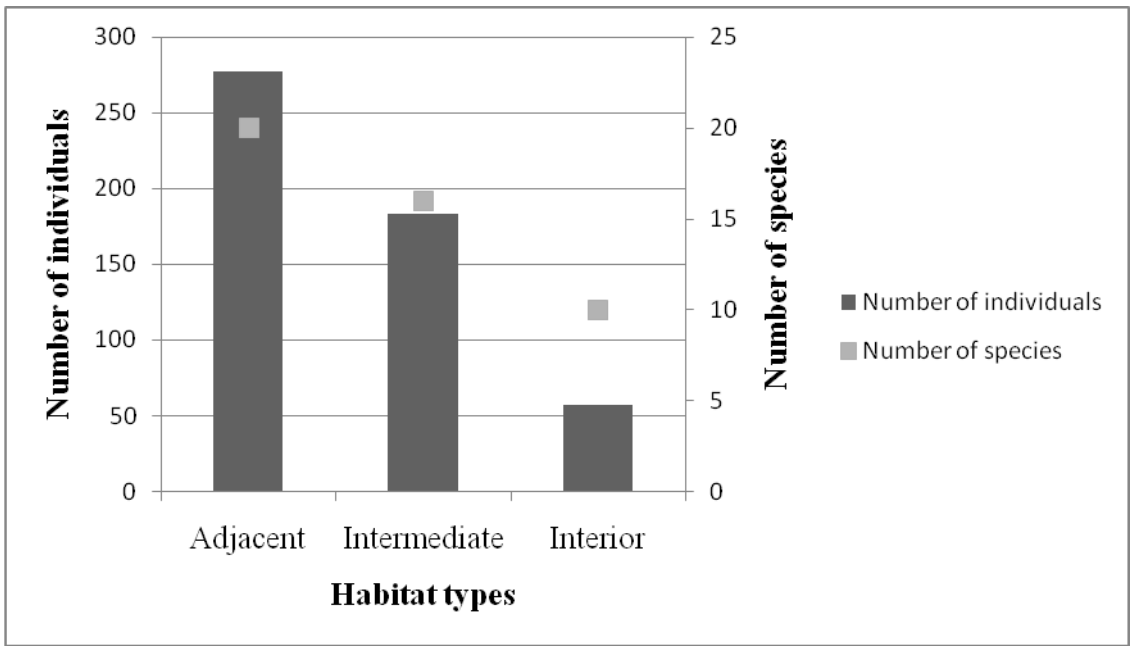


Figure 4.2-1: **The abundance and diversity of non-volant small mammals species captured in adjacent, intermediate and interior forests.**

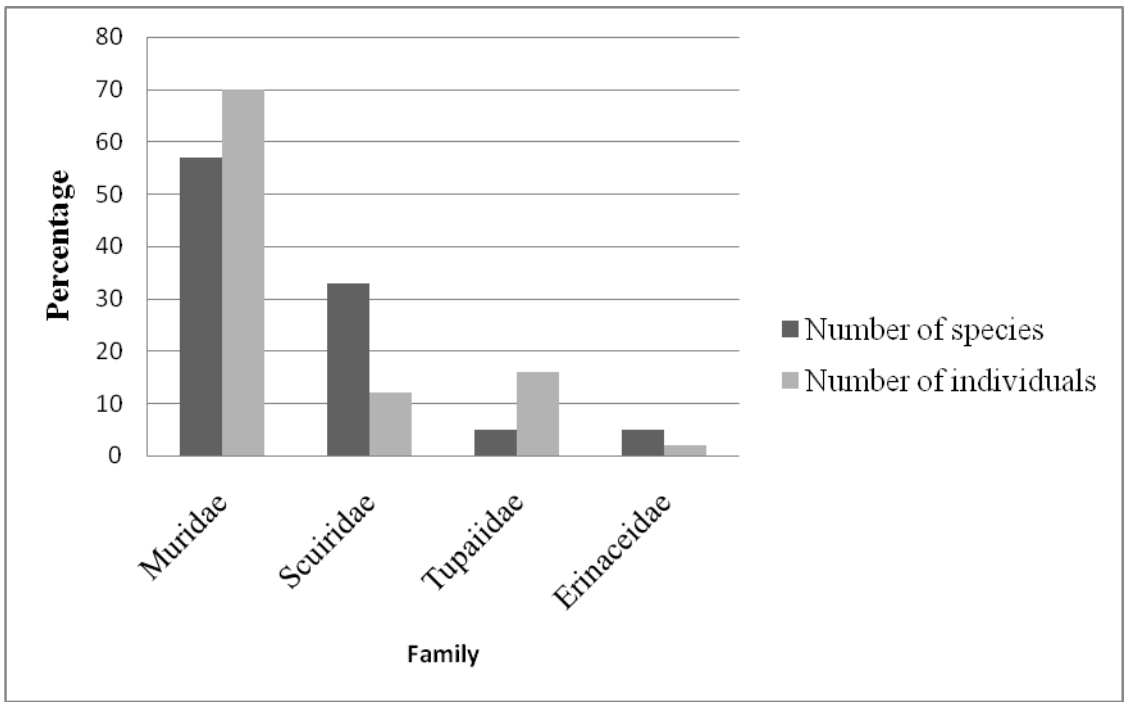


Figure 4.2-2: **Family composition of non-volant small mammals based on number of species and number of individuals by family caught in adjacent, intermediate and interior forests.**

Species richness estimators and species rarefaction curve.

Highest species number was obtained from adjacent forest (20 species) while and the lowest was was recorded from interior forest habitat (10 species). Sampling efficiency was generally higher in the interior forest than in adjacent and intermediate forests habitats (Table 4.2-1). The lowest percentage value of mean sampling efficiency was recorded in intermediate forest, at 77.59% (Table 4.2-1). The rarefaction curve indicated that more species should be recorded in the adjacent forest than intermediate and interior forest habitats (Figure 4.2-3).

Species relative abundance and composition

Tupaia glis and *Maxomys rajah* shows high species relative abundance in adjacent forest habitat with 26.43% and 22.91% respectively (Figure 4.2-4). In the intermediate forest habitat, *Rattus tiomanicus* and *Maxomys rajah* show higher relative abundance with 28.96% and 16.94% (Figure 4.2-5). *Maxomys surifer* and *Maxomys rajah* also show the higher relative abundance in the interior forest habitat with 31.58% and 15.79% respectively (Figure 4.2-4). There were nine species of non-volant small mammals present in all study plots. These are *Rattus tiomanicus*, *Rattus muelleri*, *Maxomys surifer*, *Maxomys rajah*, *Maxomys whiteheadi*, *Leopaldamys sabanus*, *Niviventer cremoriventer*, *Calloscirus notatus* and *Tupaia glis*. On contrary, *Pithecheir parvus*, *Mus musculus*, *Chiropodomys gliroides* and *Sundascirus hippurus* were recorded only in the adjacent habitat. While *Berylmys bowersi* was recorded only in the intermediate forest habitat and was listed as Endangered (EN) under the Red List of Mammals for Peninsular Malaysia (Appendix A). Another three species of rats are listed as Vulnerable (VU) under IUCN Red List.

These are *Maxomys rajah*, *Maxomys surifer* and *Niviventer cremoriventer*. Only one species of non-volant small mammals recorded in this study is listed as Near Threatened (NT) under IUCN Red List. This is *Rhinosciurus laticaudatus* which was recorded in adjacent and intermediate forest habitats (Appendix A).

Species diversity index and similarity.

The calculated diversity index shows that non-volant small mammals species in adjacent habitat are more divers compared to intermediate and interior habitats (Table 4.2-2). However, non-volant small mammals species in interior habitat are more evenly distributed compared to other forest habitats (Table 4.2-2). The Jaccard's Coefficient of similarity also indicated that adjacent and intermediate habitats have similar species which was clustered at 71%.

Table 4.2-1: **Species number of the different species estimators for the non-volant small mammals in adjacent, intermediate and interior forests. Percentage of estimated species to captured species are given in parentheses.**

		Estimators					
Habitat types	**Captured**	**Chao 2 Mean**	**Jack 1 Mean**	**Jack 2 Mean**	**Bootstrap Mean**	**MMMeans (1 run)**	**Mean of estimators**
Adjacent	20	25.83 (*77.43*)	25.83 (*77.43*)	29.43 (*67.96*)	22.54 (*88.73*)	23.1 (*86.58*)	25.35 (*78.90*)
Intermediate	16	20.17 (*79.33*)	21 (*76.19*)	23.93 (*66.86*)	18.21 (*87.86*)	19.8 (*80.81*)	20.62 (*77.59*)
Interior	10	10.17 (*98.33*)	11.67 (*85.69*)	10.87 (*92.00*)	11.07 (*90.33*)	15.34 (*65.19*)	11.82 (*84.60*)

Table 4.2-2: **Indices values of Shannon-Weiner (H) and Pielou's Evenness for non-volant small mammals in adjacent, intermediate and interior forests**.

	Adjacent	**Intermediate**	**Interior**
Total captured	277	183	57
Number of species	20	16	10
Shannon–Wiener (H)	2.32	2.22	2.01
Pielou's Evenness (J)	0.77	0.80	0.87

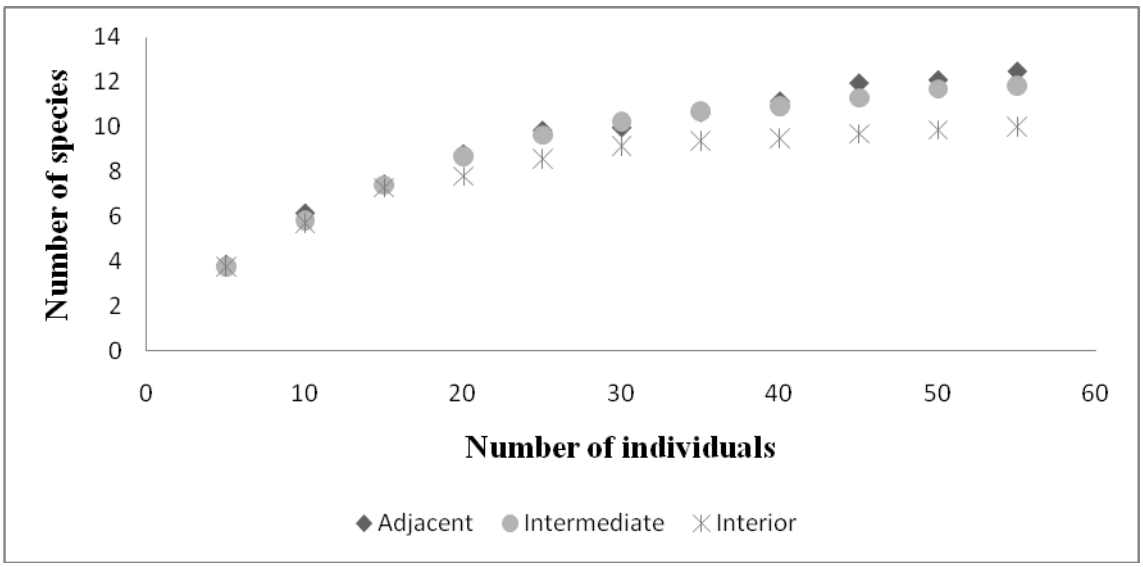
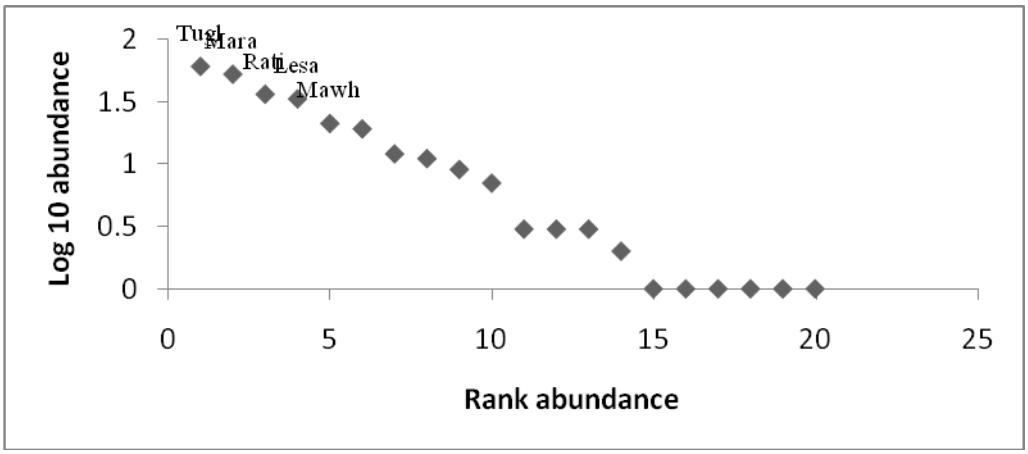


Figure 4.2-3: **Rarefied species-accumulation curves representing the average number of non-volant small mammal species for a given number of captured individuals in adjacent, intermediate and interior forests.**

a)



b)

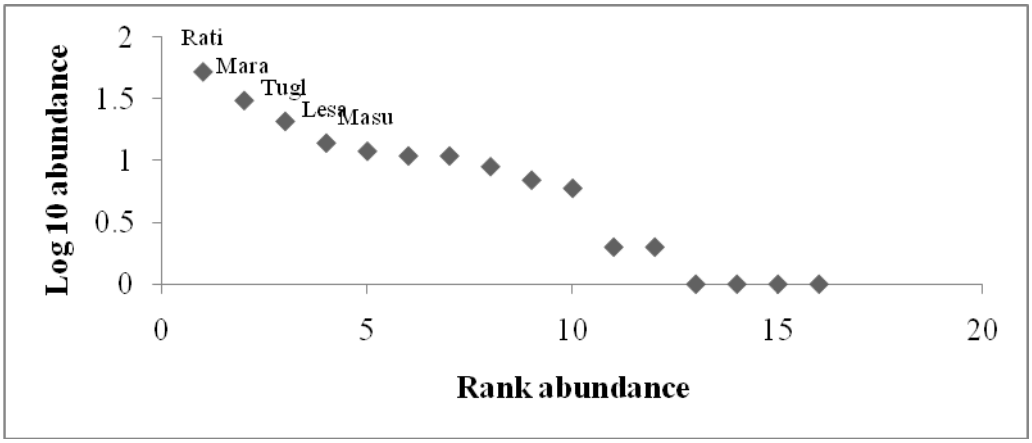


Figure 4.2-4: Species rank abundance of non-volant small mammals in three different distances from forest edge, (a) Adjacent (b) Intermediate (c) Interior. Species code: Rati – *Rattus tiomanicus*; Ramu – *Rattus muelleri*; Mara – *Maxomys rajah*; Masu – *Maxomys surifer*; Mawh – *Maxomys whitehedi*; Lesa – *Leopaldamys sabanus*; Nicr – *Niviventer cremoriventer*; Tugl – *Tupaia glis*.

Figure 4.2-4, continued.

c)

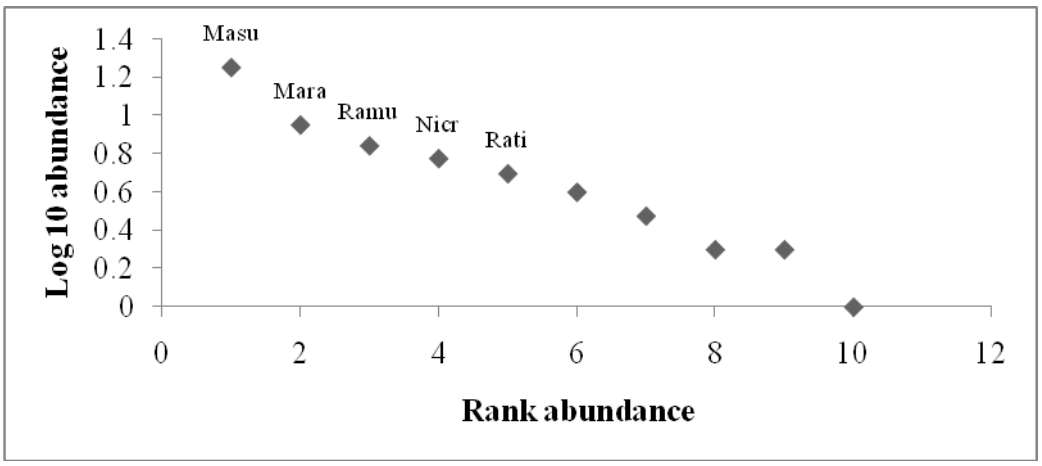


Figure 4.2-4: **Species rank abundance of non-volant small mammals in three different distances from forest edge, (a) Adjacent (b) Intermediate (c) Interior. Rati – *Rattus tiomanicus*; Ramu – *Rattus muelleri*; Mara – *Maxomys rajah*; Masu – *Maxomys surifer*; Mawh – *Maxomys whitehedi*; Lesa – *Leopaldamys sabanus*; Nicr – *Niviventer cremoriventer*; Tugl – *Tupaia glis*.**

4.2.2 Volant small mammals

Capture

A total of 312 bats comprising of 31 species were successfully captured across all three habitats. All captures can be classified into five families; Pteropodidae, Rhinolophidae, Hipposideridae, Vespertilionidae, and Megadermatidae. Family Vespertilionidae shows the highest percentage in term of number of species caught (42%) while Megadermatidae recorded the lowest percentage of number species caught (3%) at all habitat types (Figure 4.2-6). Members of family Vespertilionidae and Hipposideridae dominated sampling areas, contributed 44% and 31% of the total individuals captured (Figure 4.2-6). The total number of Megachiroptera caught in these sites were 24 individuals.

The capture success was determined in the percentage of the number of captures and the number of trap nights. A total of 43.33% of capture success was recorded for 2160 trapping nights across all three sites (Appendix D). Trapping success showed no significant different between these habitats (Kruskal-Wallis, $\chi^2 = 2.8737$, df = 2, p-value > 0.05). The percentage of capture success was the highest in the intermediate forest habitat compared to adjacent and interior forest (19.58%, 13.33%, and 10.42% respectively) (Appendix D). Intermediate forest habitat had the highest number of individuals and species captured while interior habitat had the lowest number of individuals and species captured (Figure 4.2-5).

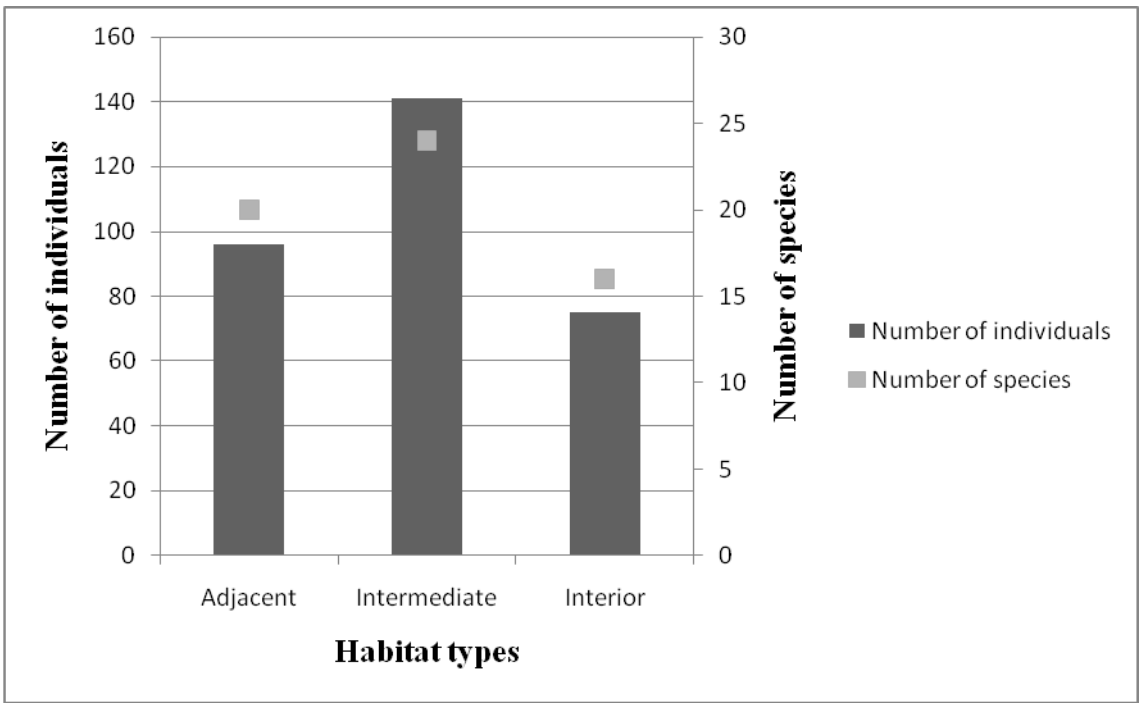


Figure 4.2-5: **The abundance and diversity of volant small mammals species captured in adjacent, intermediate and interior forests.**

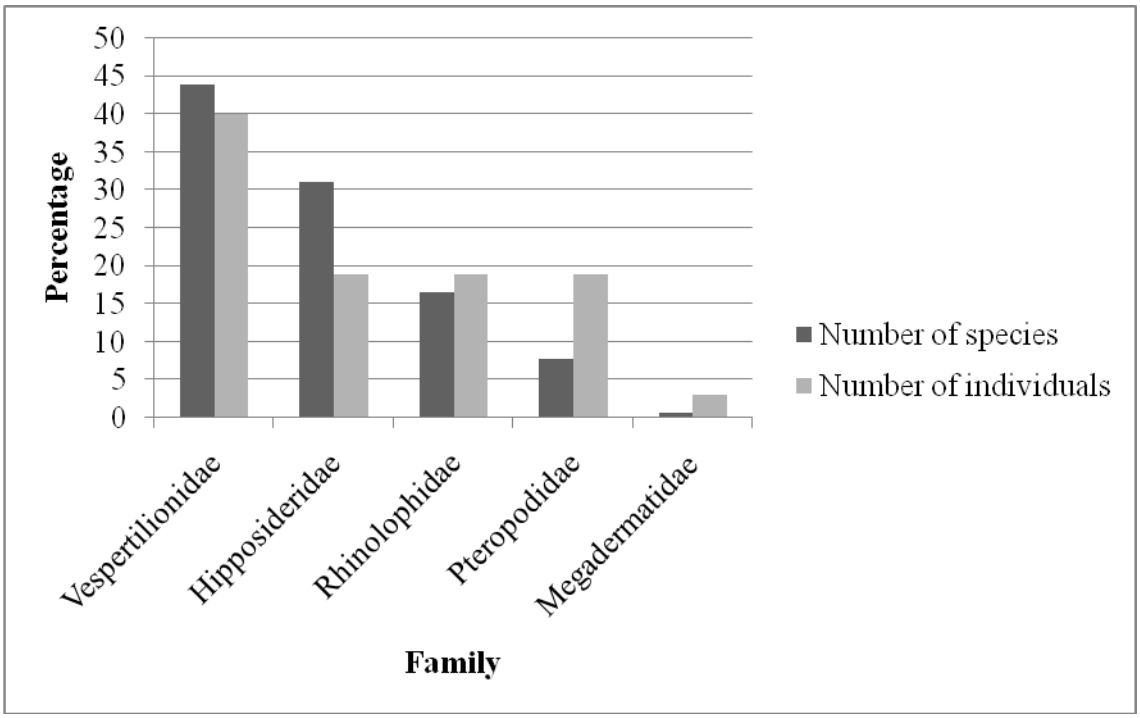


Figure 4.2-6: **Family composition of volant small mammals based on number of species and number of individuals by family caught at adjacent, intermediate and interior forests.**

Species richness estimators and species rarefaction curve.

Highest species number was recorded in the intermediate forest habitat (24 species) and lowest species richness was seen in the interior forest habitat (16 species). Sampling efficiency was higher in the interior forest habitat, but lowest in adjacent forest habitat (Table 4.2-3). Rarefaction curves indicated that more species recorded from intermediate forest habitat than adjacent and interior forest habitats (Figure 4.2-7).

Species relative abundance and composition

Hipposideros cervinus and *Kerivoula hardwickii* shows high species relative abundance in adjacent forest with 12.50% and 10.42% (Figure 4.2-8). *Hipposideros bicolour* and *Rhinolophus trifoliatus* are abundantly recorded in intermediate forest habitat (18.44% and 14.18% respectively) (Figure 4.2-10). *Kerivoula minuta* dominated interior forest habitat with 17.33% of species relative abundance (Figure 4.2-8). Eleven species of bats were recorded in all habitats type while four species (*Rhinolophus acuminatus*, *Rhinolophus stheno*, *Murina aenea* and *Tylonycteris robustula*) were captured only in adjacent forested area (Appendix B). Three bat species were recorded only in interior forested habitat. These are *Rhinolophus lepidus*, *Hipposideros galeritus* and *Pipistrellus tenuis.* Three species (*Kerivoula intermedia*, *Phoniscus atrox* and *Hesperoptenus blanfordi*) have been listed as a Vulnerable (VU) under Red List of Mammals for Peninsular Malaysia (Appendix B). Only one species (*Hipposideros ridleyi*) is recognise as Vulnerable (VU) by IUCN Red List Status but four species are listed as Near threatened (NT). These are *Kerivoula minuta, Kerivoula pellucida, Kerivoula intermedia* and *Rhinolophus sedulus* (Appendix B).

Species diversity and similarity

Even though intermediate forest recorded highest number of individuals and species captured with 141 individuals and 24 species, adjacent forest had the highest species diversity index (Shannon-Wiener = 2.74) compared with intermediate and interior forest habitat (Table 4.2-4). Adjacent and interior forest shared the same value of evenness (Table 4.2-4). When comparing the similarity of species composition using Jaccard's Coefficient similarity index, adjacent forest and interior forest had similar species composition and was clustered at 79%.

Table 4.2-3: **Species number of the different species estimators for the volant small mammals in adjacent, intermediate and interior forests. Percentage of estimated species to captured species are given in parentheses.**

		Estimators					
Habitat types	**Captured**	**Chao 2 Mean**	**Jack 1 Mean**	**Jack 2 Mean**	**Bootstrap Mean**	**MMMeans (1 run)**	**Mean of estimators**
Adjacent	20	29.38 (*68.07*)	28.33 (*70.60*)	33.4 (*59.88*)	23.66 (*84.53*)	31.14 (*64.23*)	29.18 (*68.54*)
Intermediate	24	33.17 (*72.35*)	34 (*70.59*)	39.33 (*61.02*)	28.51 (*84.18*)	37.77 (*63.54*)	34.56 (*69.44*)
Interior	16	18.08 (*88.50*)	20.17 (*79.33*)	21.9 (*73.06*)	18.02 (*88.79*)	23.25 (*68.82*)	20.28 (*78.90*)

Table 4.2-4: **Indices values of Shannon-Weiner (H) and Pielou's Evenness for volant small mammals in adjacent, intermediate and interior forests.**

	Adjacent	**Intermediate**	**Interior**
Total captured	96	141	75
Number of species	20	24	16
Shannon–Wiener (H)	2.74	2.71	2.53
Pielou's Evenness (J)	0.91	0.85	0.91

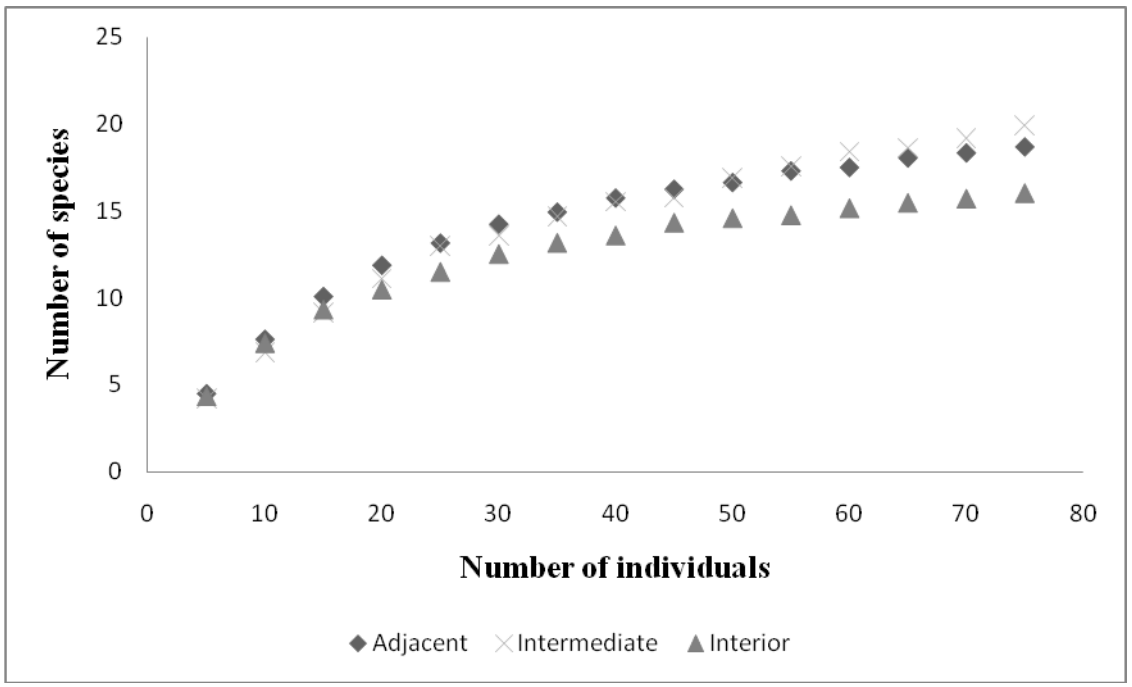
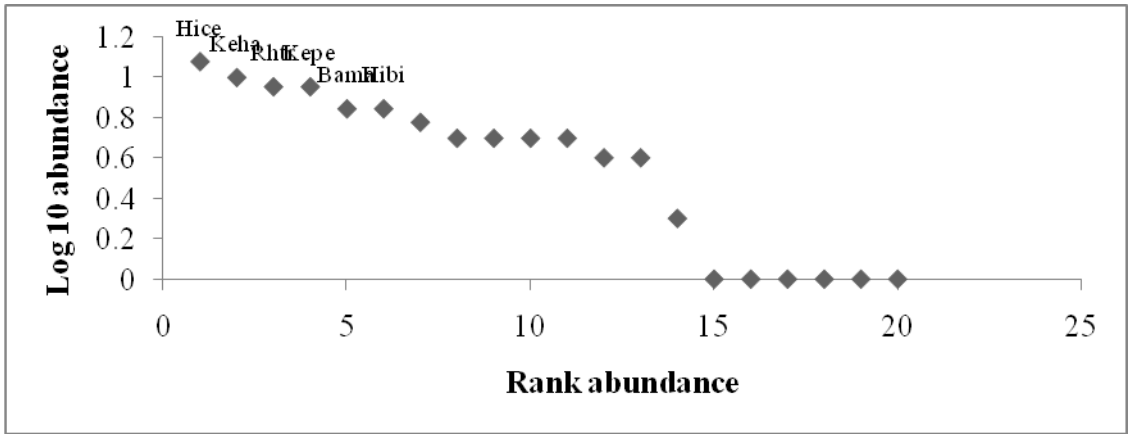


Figure 4.2-7: **Rarefied species-accumulation curves representing the average number of volant small mammal species for a given number of captured individuals in adjacent, intermediate and interior forests.**

a)



b)

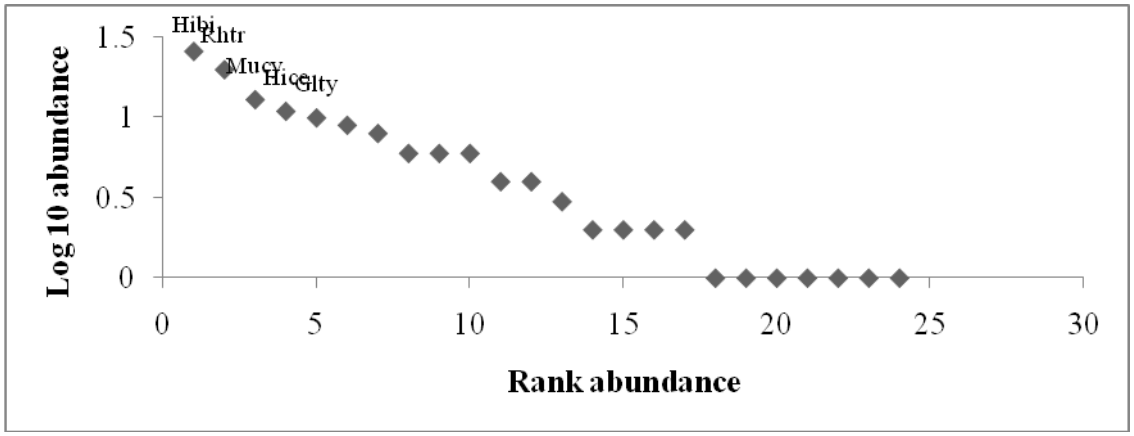


Figure 4.2-8: **Species rank abundance of volant small mammals in three different distances from forest edge (a) Adjacent (b) Intermediate (c) Interior. Species code: Bama – *Balionycteris maculata*; Glty – *Glischropus tylopus*; Hice – *Hipposideros cervinus*; Hibi – *Hipposideros bicolor*; Hidi – *Hipposideros diadema*; Keha – *Kerivoula hardwickii*; Kepe – *Kerivoula pellucida*; Kemi – *Kerivoula minuta*; Mucy – *Murina cylotic*; Rhtr – *Rhinolophus trifoliatus*.**

Figure 4.5-8, **continued.**

c)

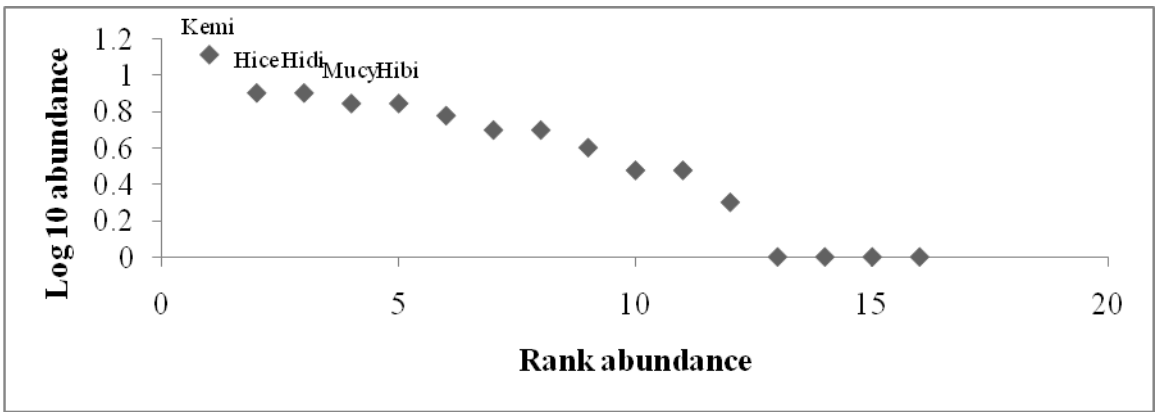


Figure 4.2-8: **Species rank abundance of volant small mammals in three different distances from forest edge (a) Adjacent (b) Intermediate (c) Interior. Species code: Bama – *Balionycteris maculata*; Glty – *Glischropus tylopus*; Hice – *Hipposideros cervinus*; Hibi – *Hipposideros bicolor*; Hidi – *Hipposideros diadema*; Keha – *Kerivoula hardwickii*; Kepe – *Kerivoula pellucida*; Kemi – *Kerivoula minuta*; Mucy – *Murina cylotic*; Rhtr – *Rhinolophus trifoliatus*.**

4.3 Effect of oil palm ages on small mammals assemblages.

4.3.1 Non-volant small mammals

Capture

A total of 608 individuals which belonged to five species of non-volant small mammals were successfully captured from all sites. The captures consisted of two orders; Rodentia, and Scandentia. Only one species of squirrel from family Sciuridae, which is *Callosciurus caniceps* was recorded. Most captured species belong to family Muridae (Figure 4.3-1), consist of three species; *Rattus tiomanicus*, *Rattus exulans* and *Maxomys surifer*. *Tupaia glis* from order Scandentia was recorded in this study.

A total of 33.78% of capture success was recorded of the 608 captures for overall of 5400 trap nights across all three sites. Trapping success between habitat is not significantly different (Kruskal-Wallis, $\chi^2 = 0.2663$, df = 2, p-value = 0.8753). Higher capture success was recorded in old oil palm plantation than in the young and matured oil palm plantations area (13%, 11.78%, and 9% respectively) (Appendix C). Only two species; *Rattus tiomanicus* and *Tupaia glis* that have been successfully captured in young oil palm plantation. However, more species of non-volant small mammals was recorded from mature and old oil palm plantations (Figure 4.3-2).

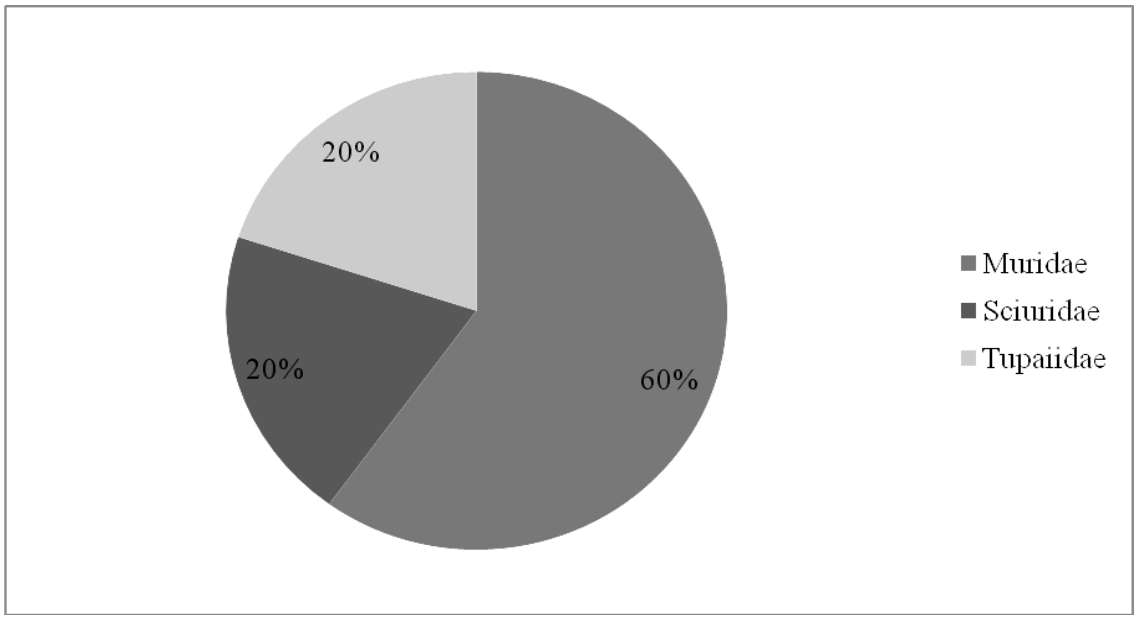


Figure 4.3-1: **Overall family composition of non-volant small mammal family based on number of species by family in the oil palm plantation.**

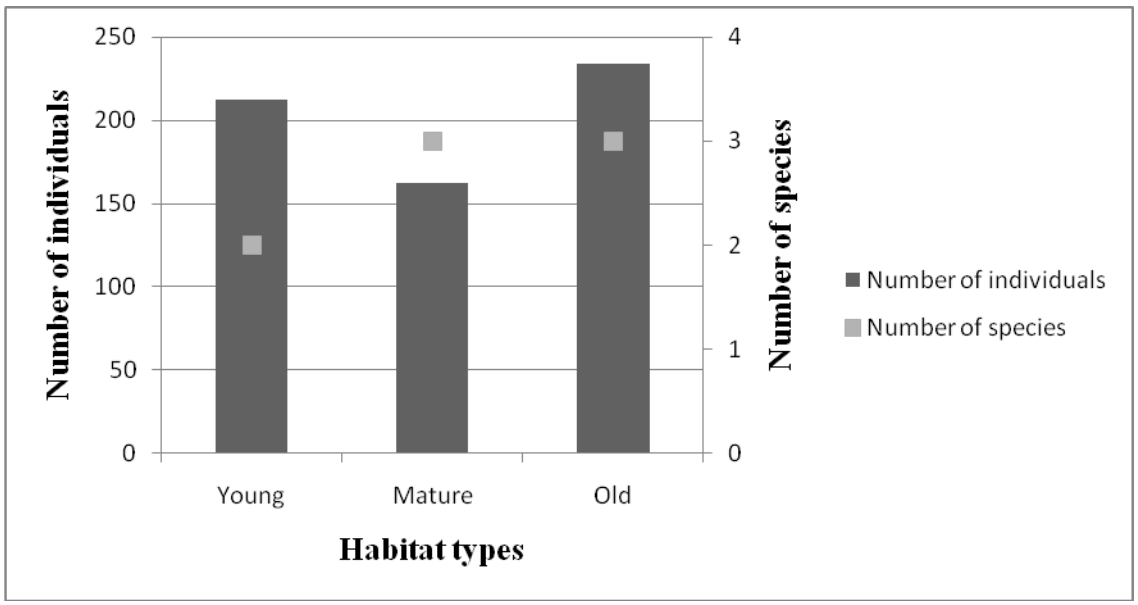


Figure 4.3-2: **The abundance and species of non-volant small mammals caught in three different ages of oil palm plantation.**

Species richness estimators and species rarefaction curve.

Mature and old oil palm plantations recorded highest number of species (three species) while young oil palm plantation only recorded two species of non-volant small mammals. Sampling efficiency in old oil palm plantation also lower than young and mature oil palm plantations (Table 4.3-1). Species rarefaction curve estimated more species should be discovered from mature and old oil palm plantations (Figure 4.3-3).

Species relative abundance and composition

Rattus tiomanicus shows highest species relative abundance in all three habitats, representing more than 90% of captures (Figure 4.3-4). On contrary, *Callosciurus caniceps* was only recorded in mature oil palm plantation, while *Maxomys surifer* and *Rattus exulans* were only recorded in old oil palm plantation (Appendix A). All species were recorded in the oil palm plantation habitat are listed as least concern (LC) by the Red List of Mammals for Peninsular Malaysia and IUCN Red List (Appendix A).

Species diversity and similarity index.

More species were captured in mature oil palm plantation than young and old oil palm plantations. Non-volant small mammals in young oil palm plantation also are less evenly distributed than other habitats. On contrary, the Jaccard's Coefficient of similarity showed young and matured oil palm plantations have more similar species composition and were clustered at 67%.

Table 4.3-1: **Species number of the different species estimators for the non-volant small mammals in three different ages of oil palm plantation. Percentage of estimated species to captured species are given parentheses.**

		Estimators					
Habitat types	**Captured**	**Chao 2 Mean**	**Jack 1 Mean**	**Jack 2 Mean**	**Bootstrap Mean**	**MMMeans (1 run)**	**Mean estimators**
Young	2	2 (*100*)	2.83 (*70.67*)	3.5 (*57.14*)	2.33 (*85.84*)	2.12 (*94.34*)	2.56 (*78.13*)
Mature	3	3 (*100*)	3.83 (*78.33*)	4.5 (*66.67*)	3.35 (*89.55*)	3.45 (*86.96*)	3.63 (*82.64*)
Old	3	3.83 (*78.33*)	4.67 (*64.24*)	6 (*50*)	3.67 (*81.74*)	3.61 (*83.10*)	4.37 (*68.65*)

Table 4.3-2: **Indices values of Shannon-Weiner (H) and Pielou's index of non-volant small mammals in three different ages of oil palm plantation.**

	Young Oil Palm	**Matured Oil Palm**	**Old Oil Palm**
Total captured	212	162	234
Number of species	2	3	3
Shannon–Wiener (H)	0.03	0.15	0.06
Pielou's Evenness (J)	0.04	0.14	0.05

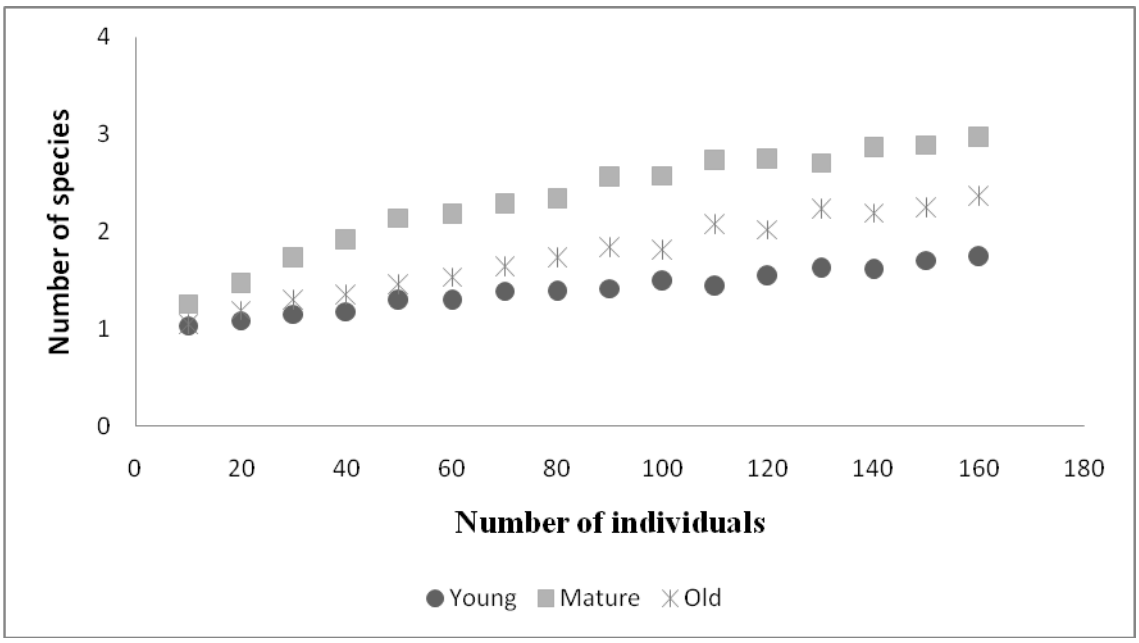
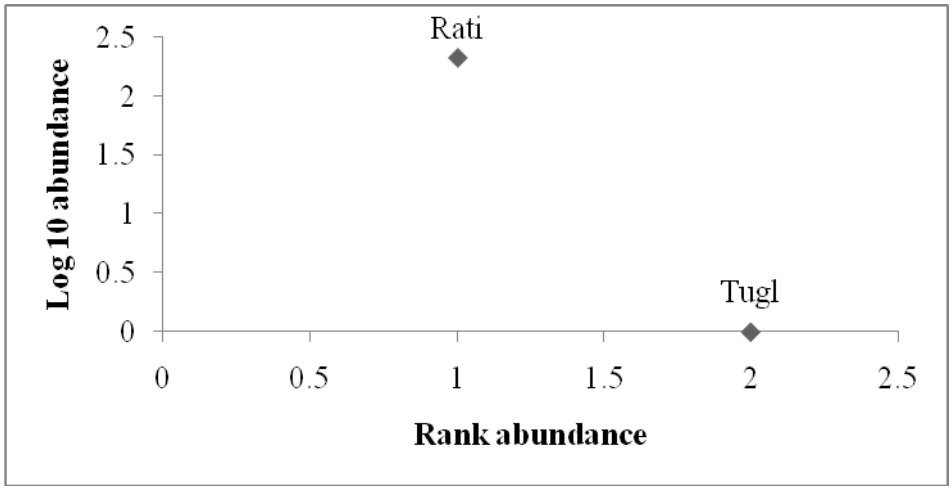


Figure 4.3-3: **Rarefied species-accumulation curves representing the average number of species for a given number of captured individuals of non-volant small mammal for three different ages of oil palm plantation.**

a)



b)

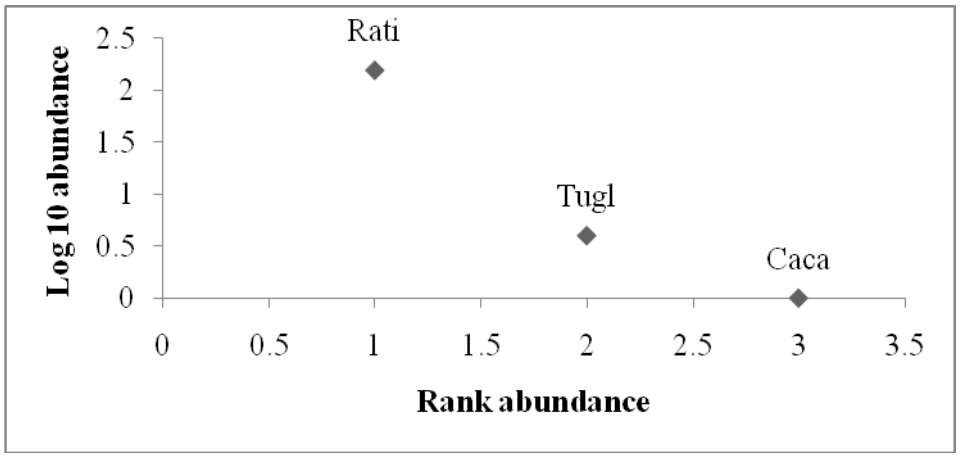


Figure 4.3-4: **Species rank abundance of non-volant small mammals in various ages of oil palm plantations, (a) Young (b) Mature (c) Old. Species code: Caca – *Calloscirus caniceps*; Masu – *Maxomys surifer*; Rati – *Rattus tiomanicus*; Raex – *Rattus exulans*; Tugl – *Tupaia glis*.**

Figure 4.3-4, continued.

c)

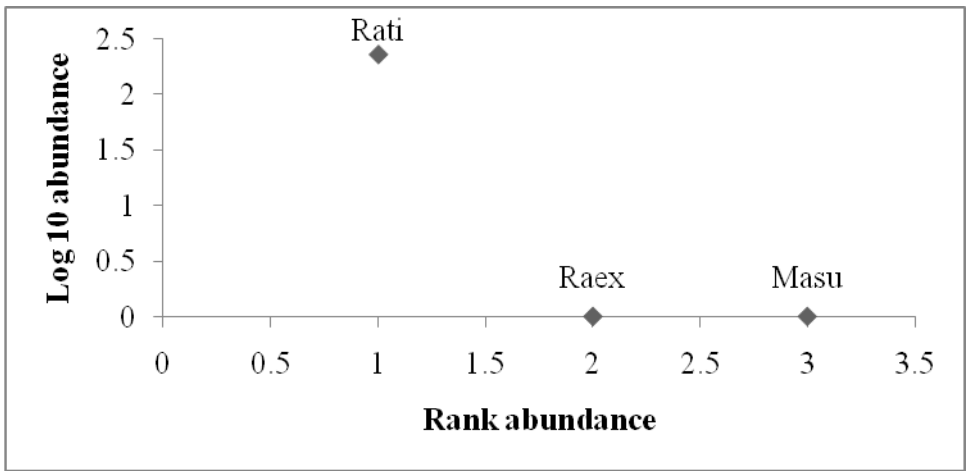


Figure 4.3-4: **Species rank abundance of non-volant small mammals in various ages of oil palm plantations, (a) Young (b) Mature (c) Old. Species code: Caca – *Calloscirus caniceps*; Masu – *Maxomys surifer*; Rati – *Rattus tiomanicus*; Raex – *Rattus exulans*; Tugl – *Tupaia glis*.**

4.3.2 Volant small mammals

Capture

A total of 214 individuals of volant small mammals that belonged to 21 species were successfully captured in all sites. The captures consisted of four families; Pteropodidae, Rhinolophidae, Hipposideridae, and Vespertilionidae. Family Vespertilionidae showed highest number of species, consists of seven species of bats (33%) (Figure 4.3-6). Family Pteropodidae showed highest number of individuals (63% of all captured) (Figure 4.3-6), represented by six species; *Cynopterus brachyotis*, *Cynopterus horsfieldi*, *Rousettus amplexicaudatus*, *Balionycteris maculata*, *Eonycteris spelaea* and *Macroglossus sobrinus*.

A total of 29.73% of trapping success was recorded of the 214 captured for overall of 2160 trap nights. Even though the percentage of capture success was highest in the young oil palm plantation compared to matured and old oil palm plantation area (Appendix D), the statistical analysis show no significant different in terms of trapping success (Kruskal-Wallis, $\chi^2 = 1.8436$, df = 2, p-value > 0.05). Although old oil palm plantation recorded the lowest number of individuals captured, it had the highest number of species (Figure 4.3-5).

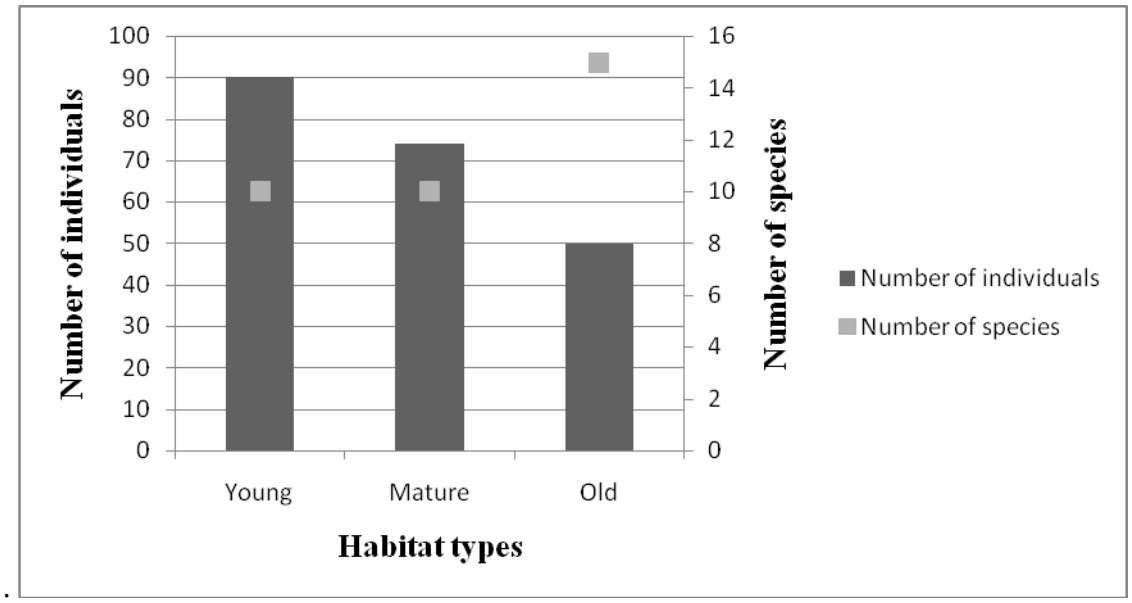


Figure 4.3-5: **The abundance and number of species of volant small mammals caught in three different ages of oil palm plantation.**

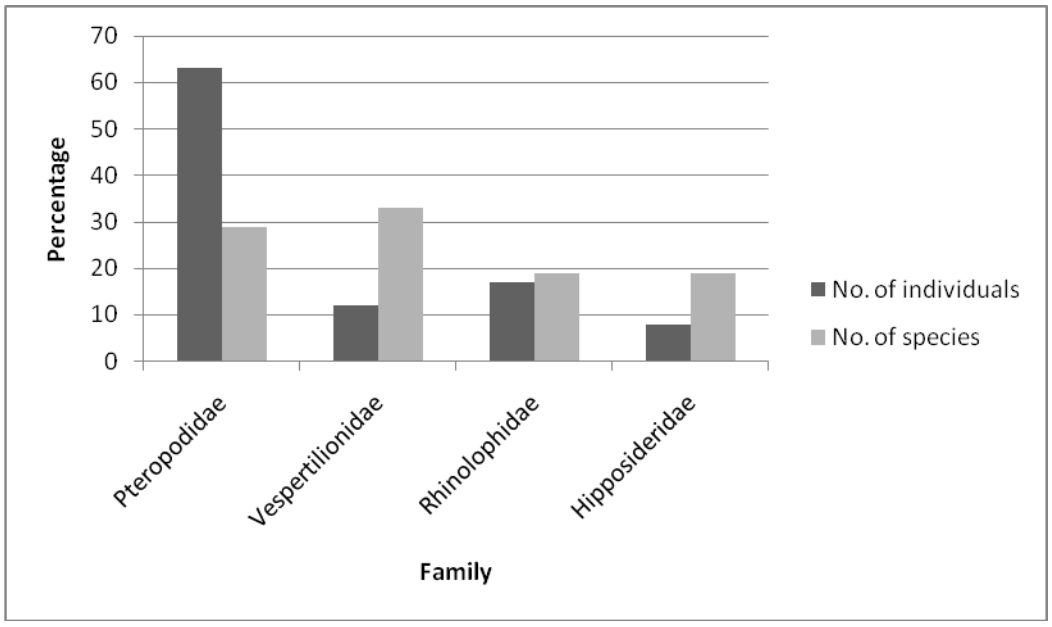


Figure 4.3-6: **Family composition of volant small mammals based on number of species and number of individuals by family caught at young, mature and old oil palm plantation.**

Species richness estimators and species rarefaction curve.

Old oil palm plantation recorded highest number of species (15 species) while both young and mature oil palm plantation recorded similar number of species (10 species). The lowest value of percentage of mean sampling efficiency was recorded in old oil palm plantation with 59.61% (Table 4.3-4). Species rarefaction curve estimate more species should be recorded in old oil palm plantation than young and mature oil palm plantations (Figure 4.3-7).

Species relative abundance and composition

Cynopterus horsfieldi shows highest species relative abundance in young oil palm plantation (Figure 4.3-8), while *Cynopterus brachyotis* was the most dominant species in matured and old oil palm plantations (Figure 4.3-8). Five species present in all ages of oil palm plantation. These are *Cynopterus brachyotis*, *Cynopterus horsfieldi*, *Rhinolophus affinis*, *Hipposideros cervinus* and *Scotophilus kuhlii*. On contrary, *Pipistrellus tenuis* was found only in matured oil palm plantation area, while *Macroglossus sobrinus*, *Hipposideros bicolour* and *Hipposideros larvatus* were found only in young oil palm plantation habitat (Appendix B). One species, *Hesperoptenus blanfordi* which is Vulnerable (VU) according Red List of Mammals for Peninsular Malaysia was recorded in old oil palm plantation (Appendix B). Two recorded species, *Kerivoula minuta* and *Myotis ridleyi* are listed as Near threatened (NT) under IUCN Red List Status (Appendix B).

Species diversity index

Old oil palm plantation area has more species of volant small mammals than other habitats. Volant small mammals in this habitat are also more evenly distributed. Result also indicated that young oil palm plantation habitat not only has least species of volant small mammals but the species also was not evenly distributed (Table 4.3-5). The community of volant small mammals in young oil palm plantation is closely resemble mature oil palm plantation and it was clustered at 58% of Jaccard's Coefficient similarity index.

Table 4.3-4: **Species number of the different species estimators for the volant small mammals in three different ages of oil palm plantation. Percentage of estimated species to captured species are given parentheses.**

		Estimators					
Habitat types	**Captured**	**Chao 2 Mean**	**Jack 1 Mean**	**Jack 2 Mean**	**Bootstrap Mean**	**MMMeans (1 run)**	**Mean estimators**
Young	10	11.25 (*88.89*)	13.33 (*75.02*)	14.4 (*69.44*)	11.62 (*86.06*)	15.21 (*65.75*)	13.16 (*75.98*)
Mature	10	16.25 (*61.54*)	15 (*66.67*)	18.47 (*54.14*)	12.11 (*82.58*)	14.52 (*68.87*)	15.27 (*65.49*)
Old	15	22.5 (*66.67*)	23.33 (*64.29*)	27.87 (*53.82*)	18.7 (*80.21*)	33.42 (*44.88*)	25.16 (*59.61*)

Table 4.3-5: **Indices values of Shannon-Weiner (H) and Pielou's index of volant small mammals in three different ages of oil palm plantation.**

	Young Oil Palm	**Matured Oil Palm**	**Old Oil Palm**
Total captured	90	74	50
Number of species	10	10	15
Shannon–Wiener (H)	1.60	1.72	2.31
Pielou's Evenness (J)	0.70	0.78	0.85

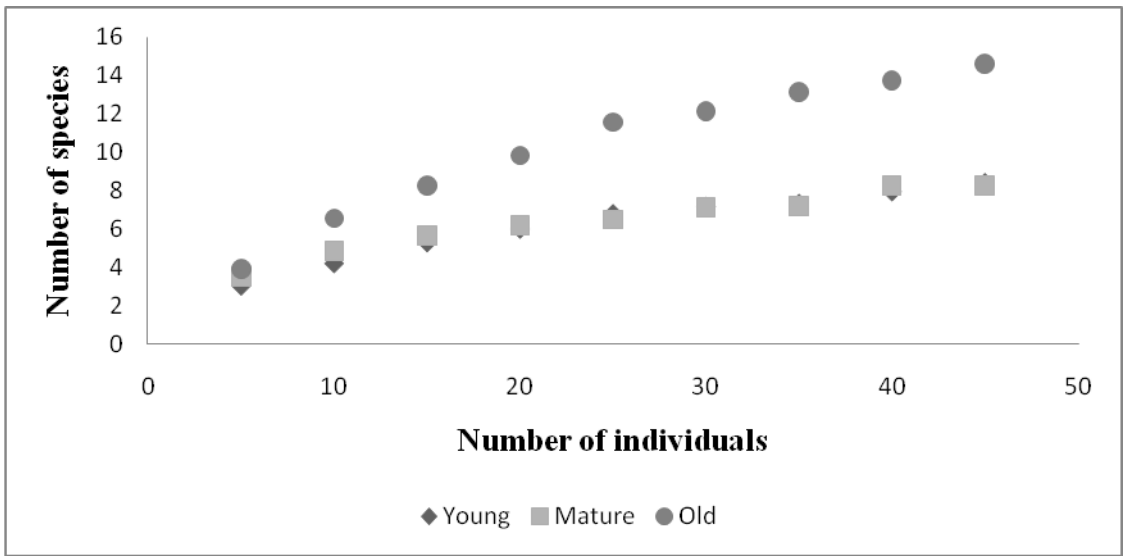
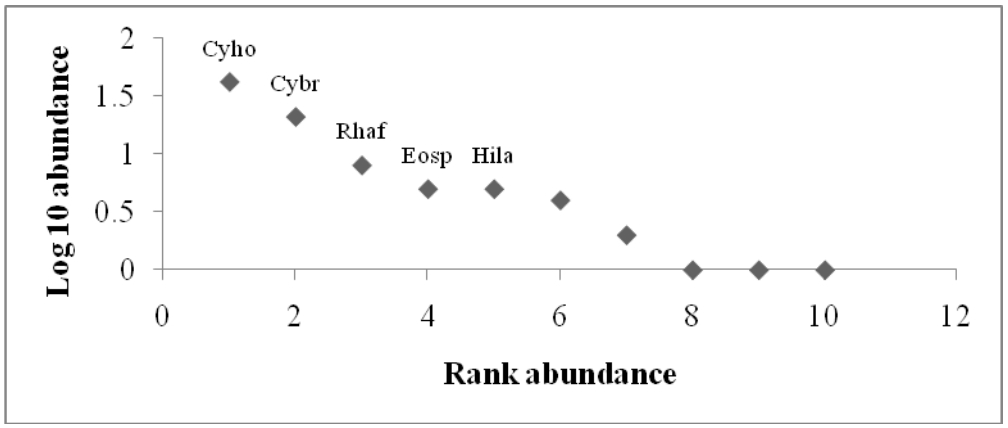


Figure 4.3-7: **Rarefied species-accumulation curves representing the average number of species for a given number of captured individuals of volant small mammal for three different ages of oil palm plantation.**

a)



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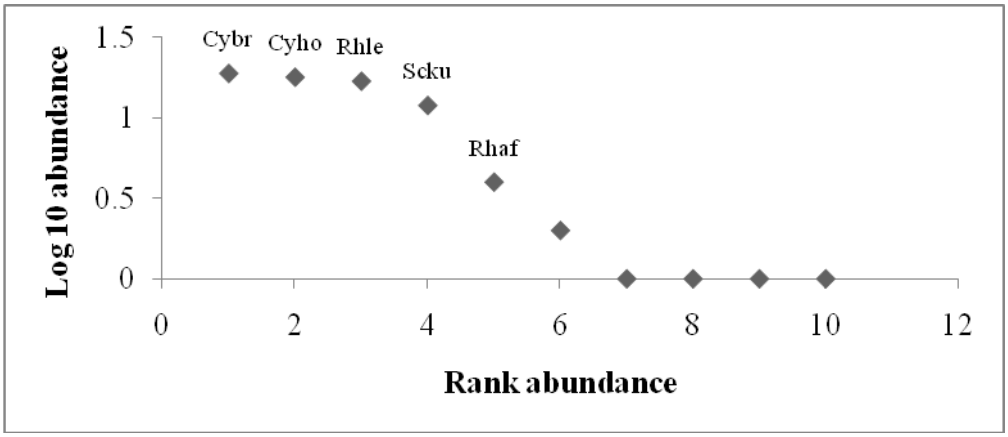

Figure 4.3-8: **Species rank abundance of volant small mammals in various ages of oil palm plantations, (a) Young (b) Mature (c) Old. Species code: Bama – *Balionycteris maculata*; Cyho – *Cynopterus horsfieldi*; Cybr – *Cynopterus brachyotis*; Eosp – *Eonycteris spelaea*; Hila – *Hipposideros larvatus*; Hice – *Hipposideros cervinus* Kemi – *Kerivoula minuta*; Mucy – *Murina cylotic*; Musu – *Murina suilla*; Myri – *Myotis ridleyi*; Rhaf – *Rhinolophus affinis*; Rhle – *Rhinolophus lepidus*; Rhac – *Rhinolophus acuminatus*; Scku – *Scotophilus kuhlii*.**

Figure 4.3-8, continued.

c)

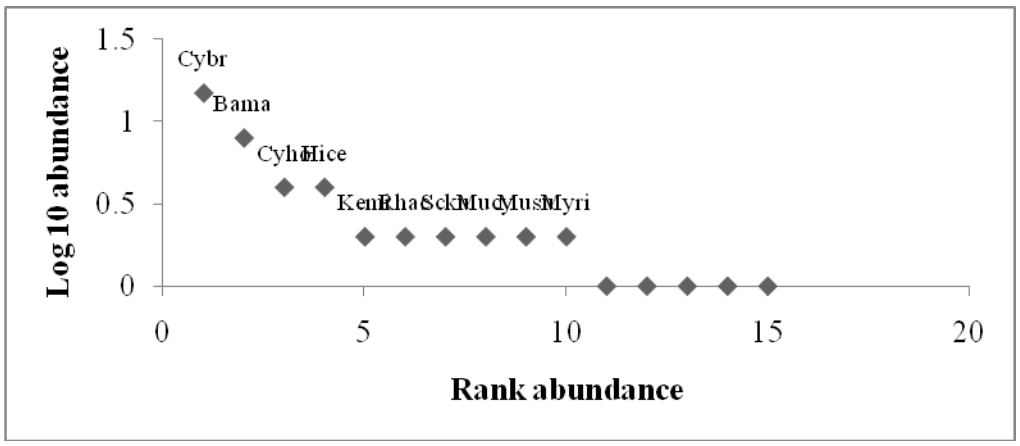

Figure 4.3-8: **Species rank abundance of volant small mammals in various ages of oil palm plantations, (a) Young (b) Mature (c) Old. Species code: Bama – *Balionycteris maculata*; Cyho – *Cynopterus horsfieldi*; Cybr – *Cynopterus brachyotis*; Eosp – *Eonycteris spelaea*; Hila – *Hipposideros larvatus*; Hice – *Hipposideros cervinus* Kemi – *Kerivoula minuta*; Mucy – *Murina cylotic*; Musu – *Murina suilla*; Myri – *Myotis ridleyi*; Rhaf – *Rhinolophus affinis*; Rhle – *Rhinolophus lepidus*; Rhac – *Rhinolophus acuminatus*; Scku – *Scotophilus kuhlii*.**

4.4 Similarity in non-volant small mammal species assemblages between habitat types.

The result of cluster analysis based on species compositions show that the intermediate forest formed different clusters. The non-volant small mammal species composition in interior forest was generally more similar to the mature and old oil palm plantation than in adjacent forest.

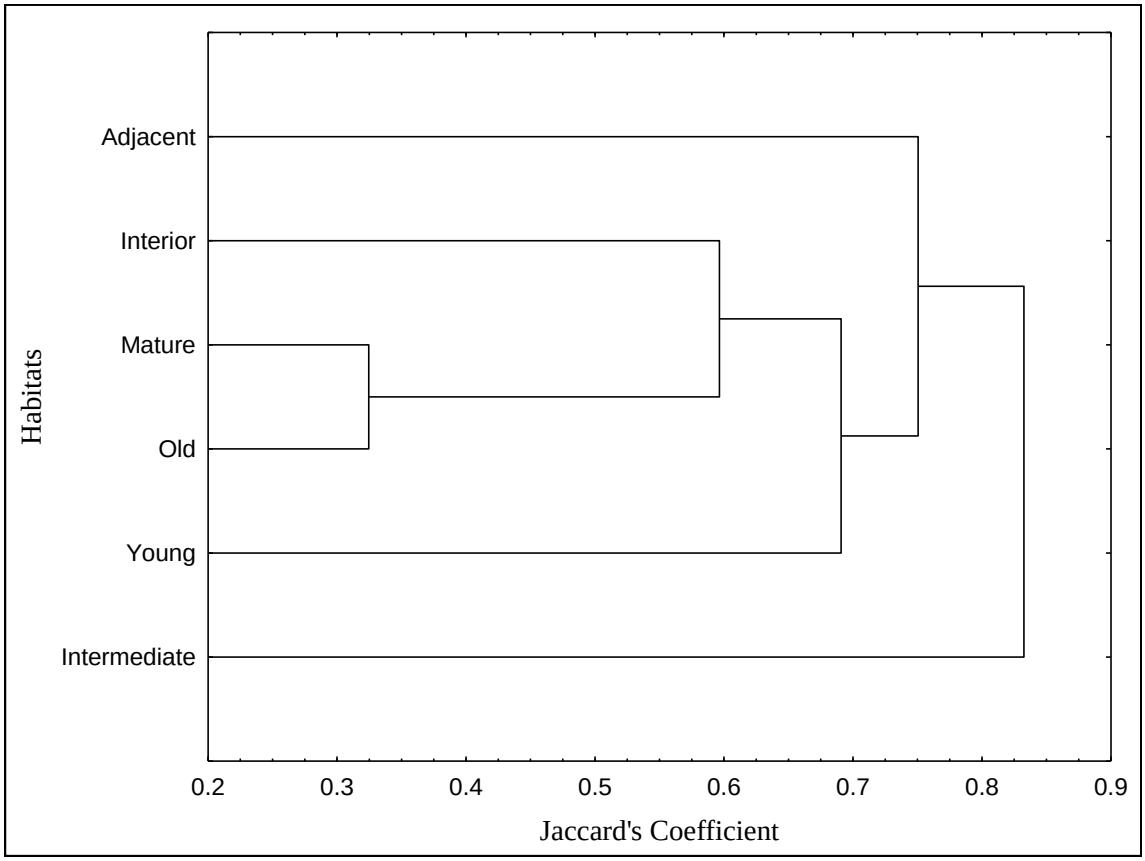

Figure 4.4: **Dendrogram based on Jaccard's Coefficient similarities of non-volant small mammal species assemblages present at each habitat types.**

4.5 Similarity in volant small mammal species assemblages between habitat types.

Cluster analysis showed that the similarity of volant small mammal species can be divided into two sub groups, as shown in Figure 4.5. The first subgroup consists of adjacent forest, interior forest, young oil palm plantation and old oil palm plantations. Interestingly, volant small mammal assemblages were more similar between the intermediate forest and mature oil palm plantation.

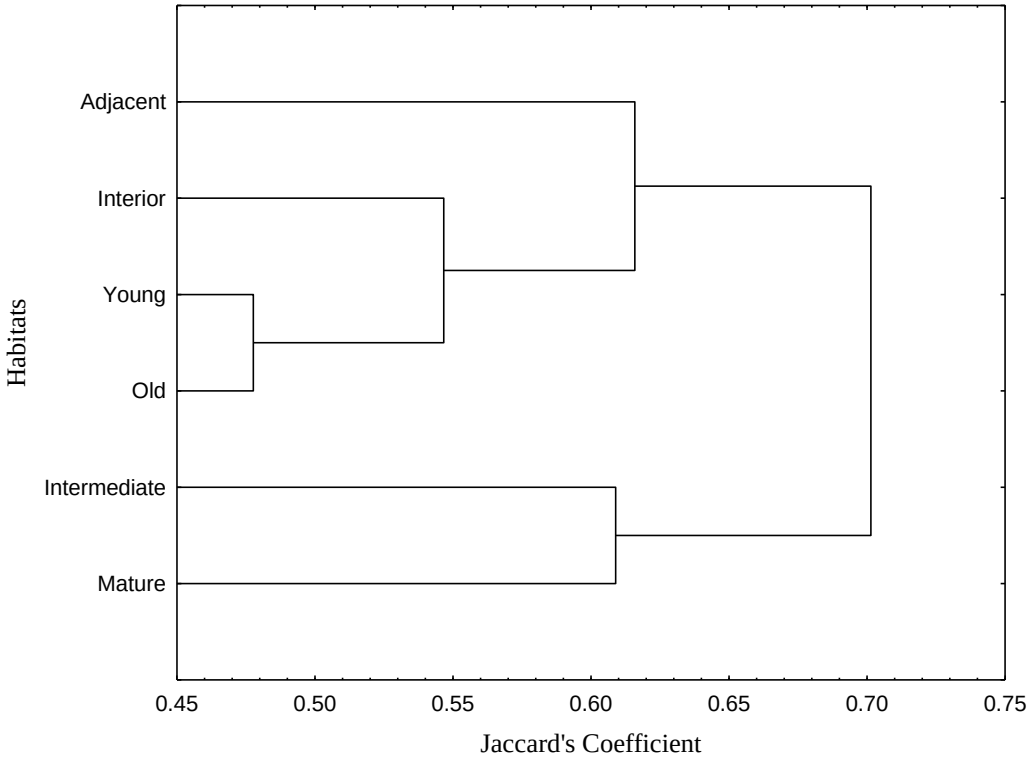

Figure 4.5: **Dendrogram based on Jaccard's Coefficient similarities of volant small mammal species assemblages present at each habitat types.**